The Seventh Annual AIAA Southern California Aerospace Systems and Technology (ASAT)

- Robotic CEM™ (Cloud Enhanced Microvehicle) Technology as applied to swarms of micro sea-craft to enhance existing land, sea and space-based surveillance assets

by

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and

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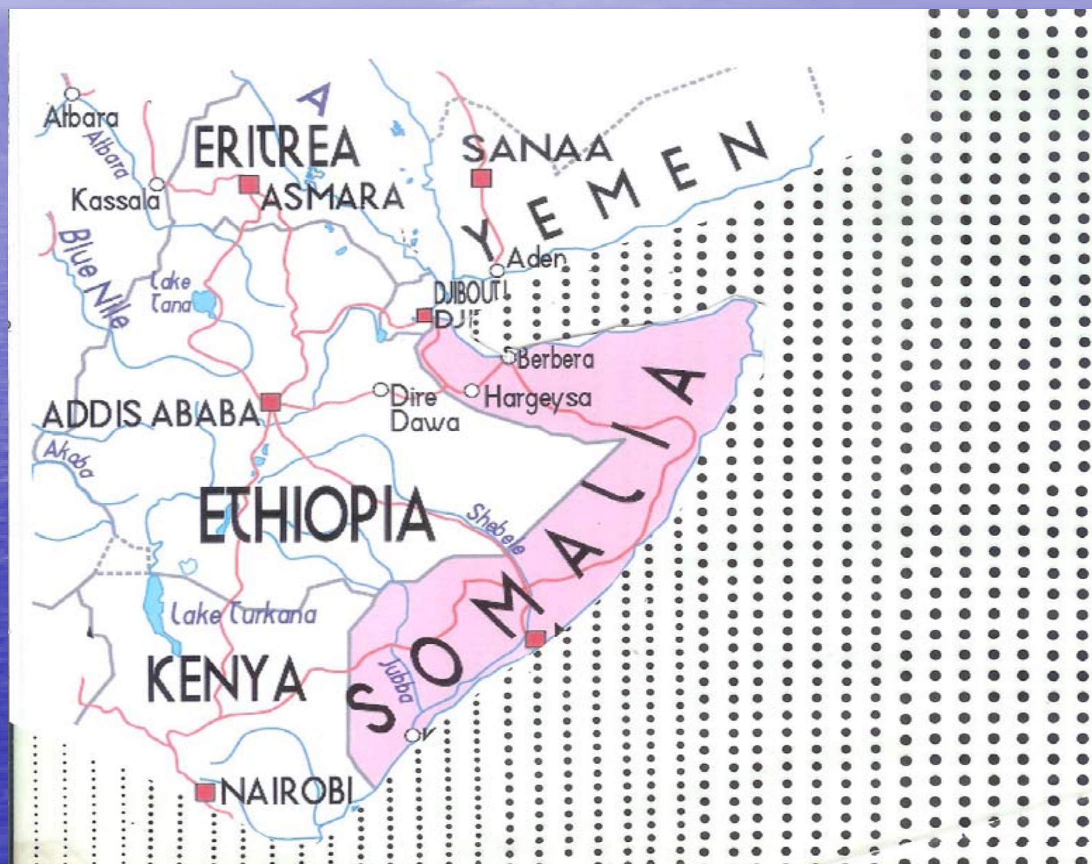
Swarms of Micro-sea-craft



Existing land, sea and space-based surveillance assets

Micro-vehicle Propulsion

There are two propulsion means for the microcraft: electrical (motor) and wind (sail or airfoil):

- shaft power, P_s, is given by

  $P_s = R_t\ U\underline{+/}\varepsilon_p$ W where R_t is the required thrust equal to the drag or resistance of the microcraft (hulls plus keel) in kg moving at speed U_c in ms^{-1} and ε_p is the propeller efficiency typically between 0.35 and 0.65.

  For the nominal case with $\underline{U_c\ = 3.1}$ ms^{-1} and $R_t = 0.337$ kg, $P_s = 2.1$ W and $P_e = 2.3$ W.

- $U_{wm} = ½ (+2U_c \pm\sqrt{[(2U_c)^2 -4(U_c^2 -2R+/1.33\ \rho_a\ A_s)]}$ ms^{-1}. . For the nominal case let us take As = 0.35 m^2 (0.7m high and 0.5m high square sail or airfoil plan form), $U_c = 3.1$ ms^{-1} and $R_t = 0.337$ kg' we compute $U_{wm} = 4.2$ ms^{-1} (for a plus root) or about an eight-knot minimum wind for a down-wind craft motion.

In More Detail

On a run with the wind aft and the sail(s) or rigid airfoil(s) acting essentially as flat plates, the apparent wind peed, $U_{a'}$, is simply

$U_{a'} = U_w - U_c$ $\quad ms^{-1}$

where U_w is the wind speed. The wind force to overcome drag, $R_{t'}$, is

$R_t = ½\rho_a U_{a'}2 A_s C_D$ $\quad$ kg

where ρ_a is the density of air at sea level at 20^0 C = 1.2 kgm^{-3}, A_s = the area of the sail(s_0 or airfoil(s) and C_D is the drag coefficient = 4/3 = 1.33 according to p. 18 of "Physics of Sailing," by John Kimbell, CRC Press. Thus the minimum wind speed necessary for the microcraft to be on a down-wind run, $U_{wm'}$, is

$$(U_{wm} – U_c)^2 = U_wm^2 - 2 U_{wm}U_c + U_c^2 = 2R_t/1.33 \rho_a A_s$$

Whose quadratic solution is on the preceding slide.

Micro-vehicle Power Generation

Solar Power Generation:

– . For the nominal microcraft A_s = 0.35 m^2, l = 1 m, , B = 0.10 m so that the total area (during doldrums) is 0.55 m^2 and 0.20 m^2 while under aerodynamic propulsion when the sail(s)/airfoil(s) are vertical. Assume that only 20% of this power is available. we have about (10hr/24hr)(15) = 6.4 [cos (φ)/ cos (340^0)] W available in doldrums (for electronics and propulsion) and (6.4)(0.2m^2/0.55m^2) = 2.3[cos (φ)/ cos (340^0)] W available while under sail propulsion for use in the electronics.

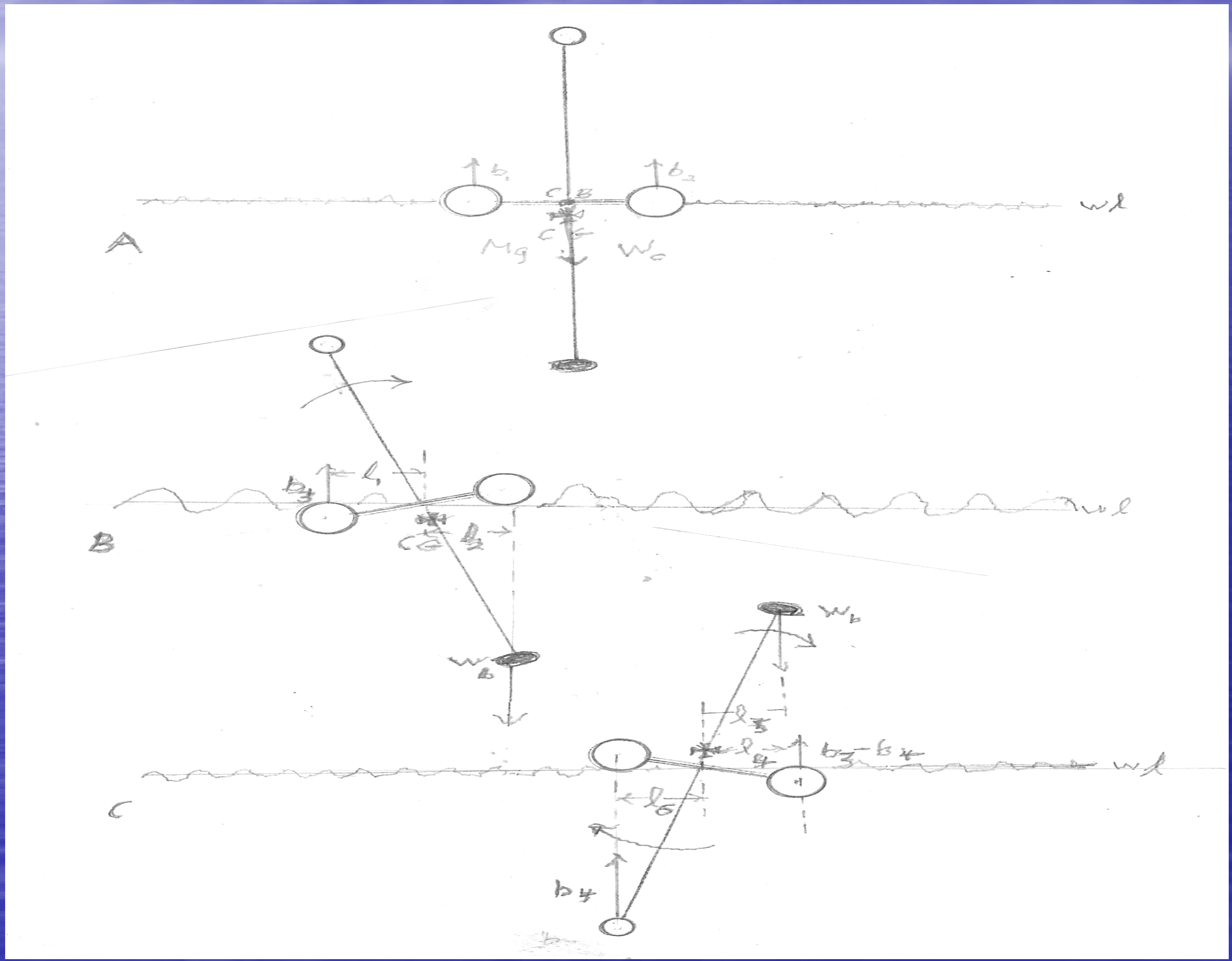
Micro-vehicle Power Generation

Water/Wind Turbine Power Generation:

One example is found at www.ezinarticles.com and at 8 to 9 knots has an output of 9 to 11 amps at 12 V DC. It is far too large for the microcraft, but provides a point of reference. water turbine (assuming a 10:1 reduction in size or a 0.01 reduction in turbine rotor area and a 0.001 reduction in turbine weight) would generate about 0.03 to 0.04 amps or 0.36 to 0.48 watts at hull speed

With regard to wind turbines, they are also commercially available for sailboats and the wind speed is not the hull speed but the apparent wind speed. similar blade area, must be multiplied by the density of air (sea level at 20^0 C) divided by the density of water = 1.204/1026 = 0.00117 in order to compare approximately with the water turbine

Micro-vehicle Self Righting



Micro-vehicle Self Righting

The center of buoyancy, CB, is above the center of gravity, CG, so that the microcraft is stable and will not capsize due to a disturbance. Also it is to be recognized that the buoyancy of the hulls (b_1 and b_2) is equal to the craft's weight or displacement, Mg or W_c. The bulbous, but streamlined, battery compartment at the end of the keel is assumed to have negligible buoyancy but significant weight.

Micro-vehicle Cost

Prior to fabrication of a prototype microcraft it is difficult to estimate fabrication cost for the mass production of a large number of microcraft. A reasonable approach is to determine the actual retail cost per kilogram of commercially available remote-control (R/C) model boats and make estimates based upon a study of these costs. In addition it would be necessary to estimate the cost of the on-board electronics (including cloud computation elements) and the cost of the various sensors.

The following Table exhibits the retail cost and weight of five commercially available R/C model boats.

Craft Name	Vender	Weight lbs.	Weight kg	Retail Cost $	$ per kg
"Shadow Breaker" NQD No.757T-4012D	Double Horse	0.7	0.32	32.90	103
CRC Boat	Double Horse	1.5	0.68	79.16	116
Electric Red Catamaran	Kotula's	5.0	2.25	129.99	58
R c Boat Trimaran"Legend Rider"	Dickie Toys	1.0	0.45	26.00	57
Ace Racing Sloop	Dumas Boats	1.45	0.66	37.99	58

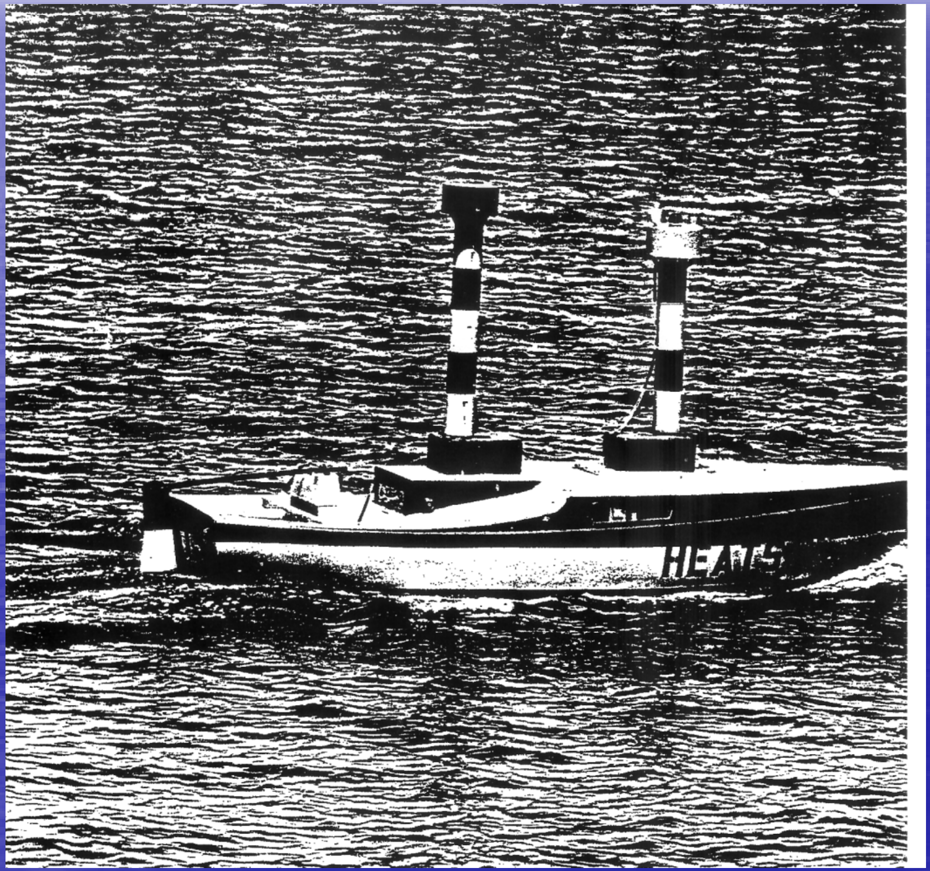
Micro-vehicle Cost

We will take the retail price average of about $75 per kilogram as the upper bound on the retail price for one thousand or more microcraft of the nominal design. Thus the unit price for each 10 kg microcraft would be $750. If mass-production economies were achieved, then the unit price might drop to $300 or less than $100 for lots of several thousand.

Unmanned Test Craft

Under US Navy Contract N 6601-78-C-0375 a 20-ft unmanned seacraft was tested by Transportation Sciences Corporation (TSC). It was called by the Navy an High-Endurance Translocating Subsystem or HEATS. One of it purposes was to drag a hydrophone array for submarine surveillance. The tests, at the Naval Oceans Systems installation in San Diego California, were successful

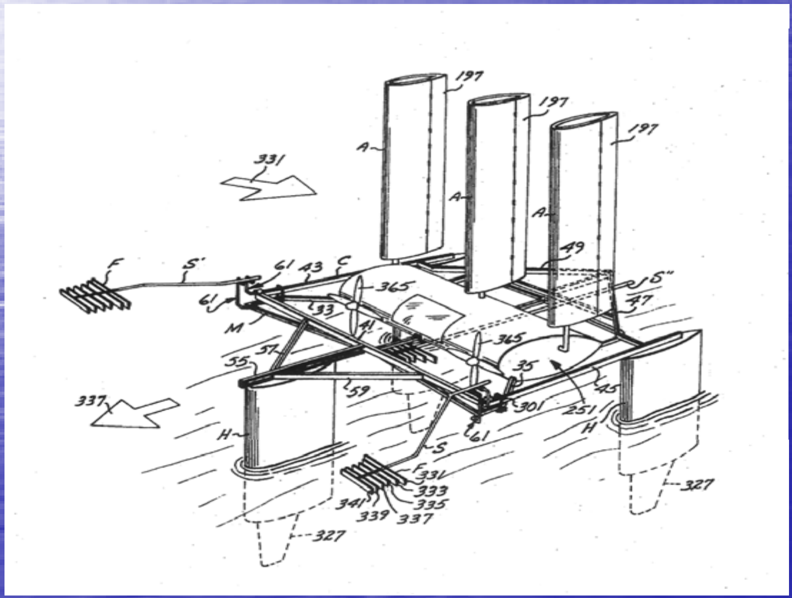
HEATS Underway

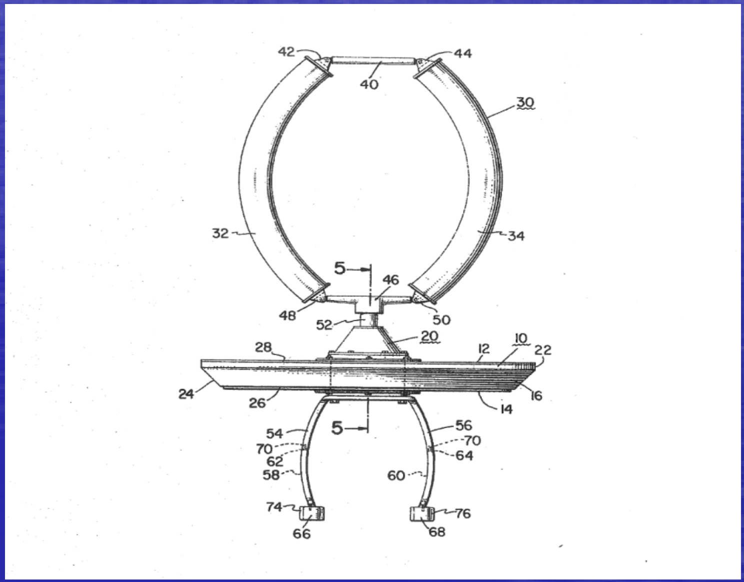


Patented Unmanned Ridged-Airfoil Sail craft

Patent No. 3532067 Filed September 18, 1968
Bonnie and Robert Baker

Patent No. 3556035 Filed January 28, 1969
Ernest Schlieben (RCA Corp.)





Summary

Robotic CEM™ (Cloud Enhanced Microvehicle) Technology as applied to swarms of low cost micro sea-craft. Such swarm include very small unmanned, self-deploying, high endurance, water conveyances forming a distributed surveillance system to detect and track stealthy and non stealthy aeronautical, surface and subsurface entities including UAV, UAS, Submarines, Divers, Surface craft, etc. as well as provide real-time augmentation, enhancement and calibration of existing land, sea and space based surveillance and geophysical assets.

The Future is Unmanned Vehicles

The Future is NOW!