Underwater Robotics

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NDIA
June 14, 2005

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Team

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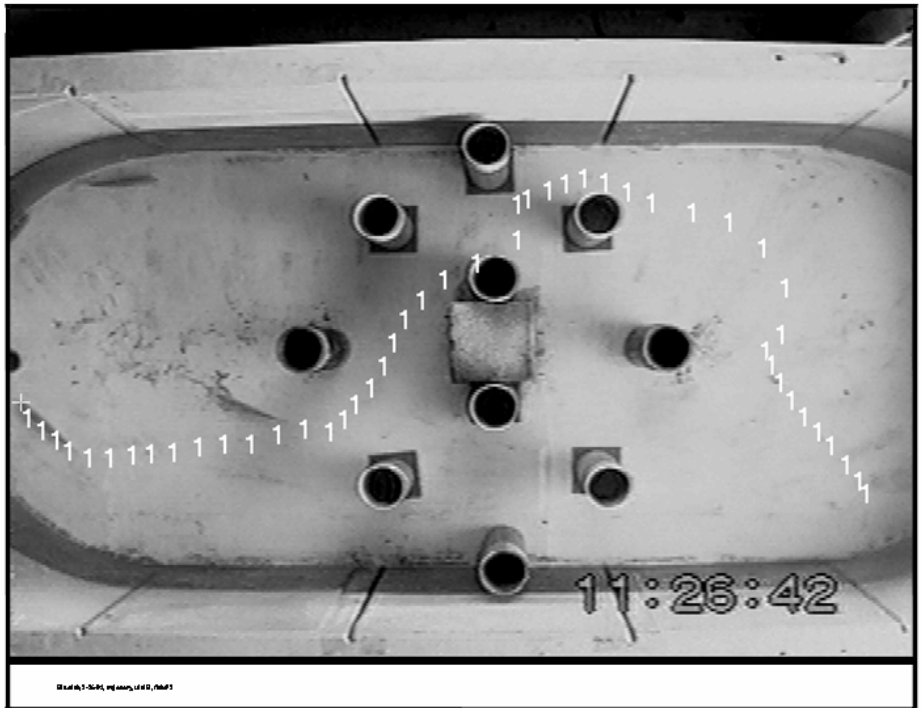
- Mr. Jason Gaudette (Control)
- Mr. Albert Fredette (EE)
- Professor Anuradha Annaswamy (MIT: Theo Control)

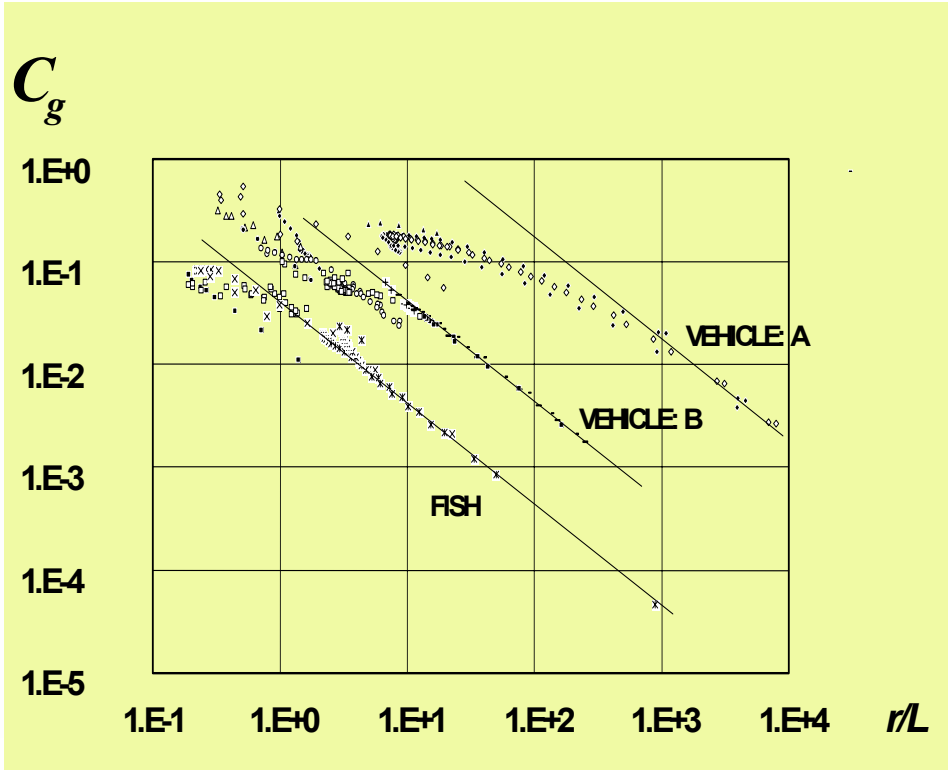
- Dr. David Beal (Hydro)
- Mr. William Nedderman (Design)

- Dr. Stephen Forsythe (Sonar)
- Mr. Thomas Fulton (MARV & Sonar)

- Walter Boober (Noise)

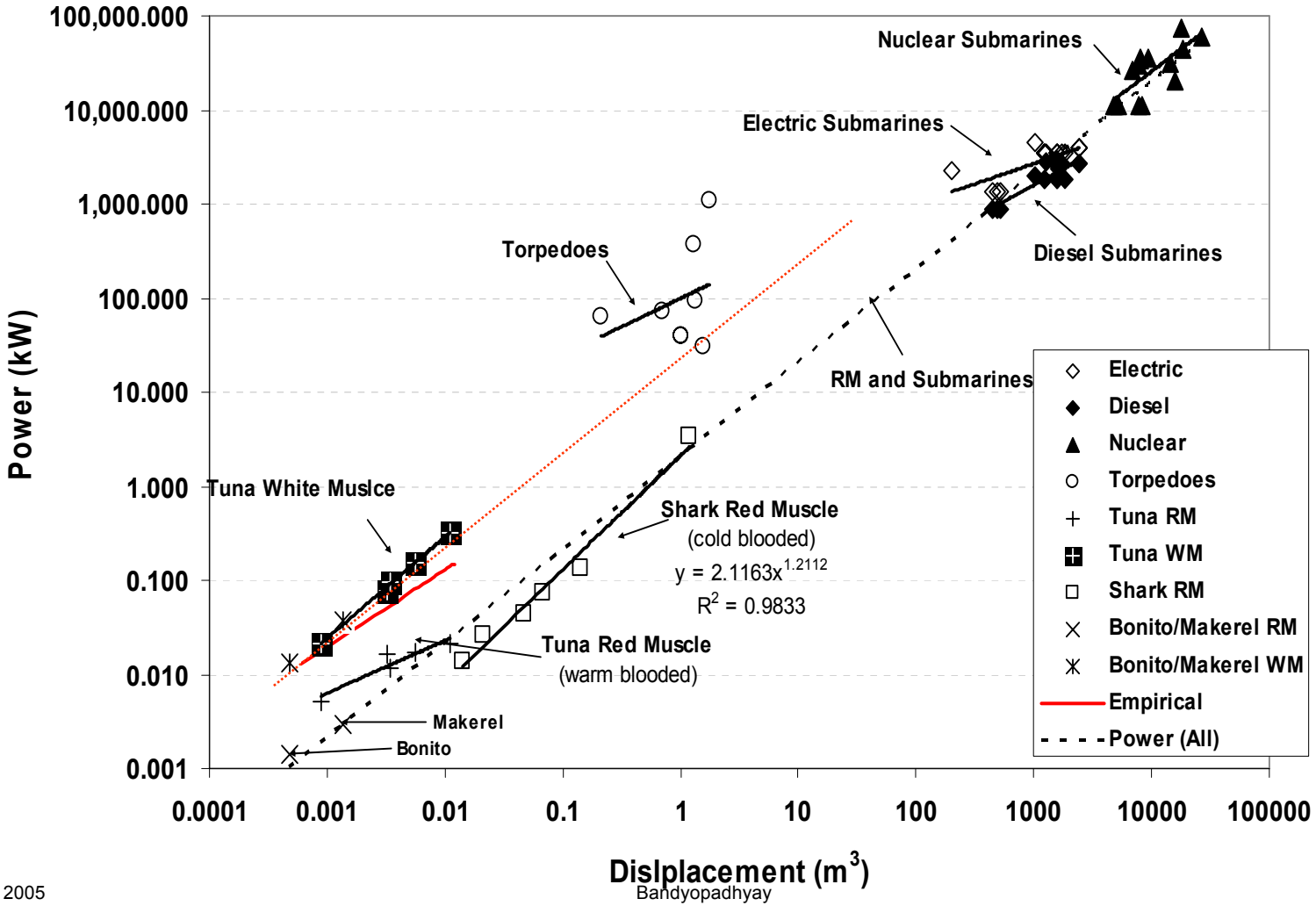
Maneuvering in Nature & in Engineering





- **In turning radius, nature is still ahead of engineering although the gap is narrowing**

Nature & Man Made

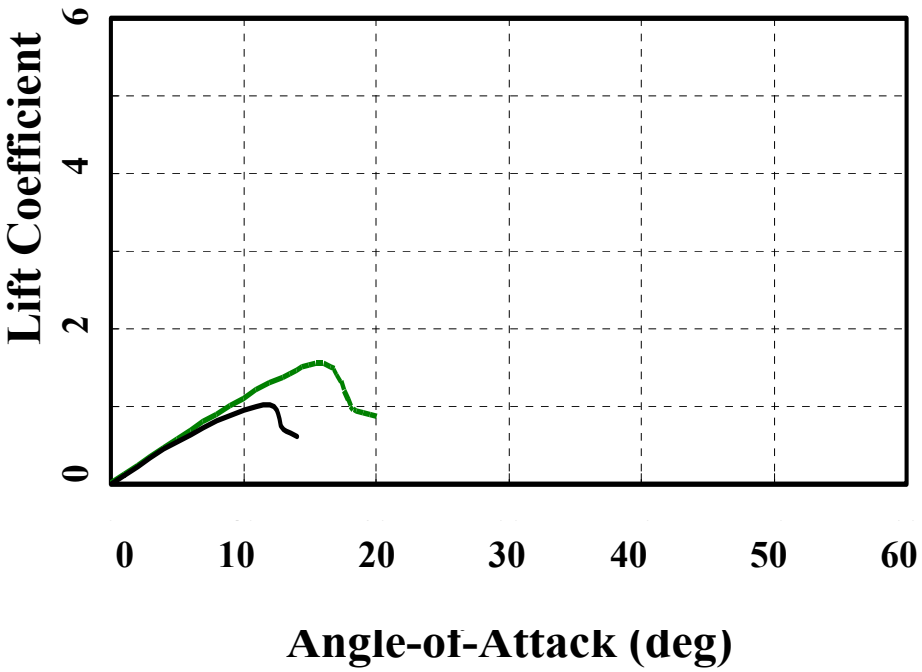


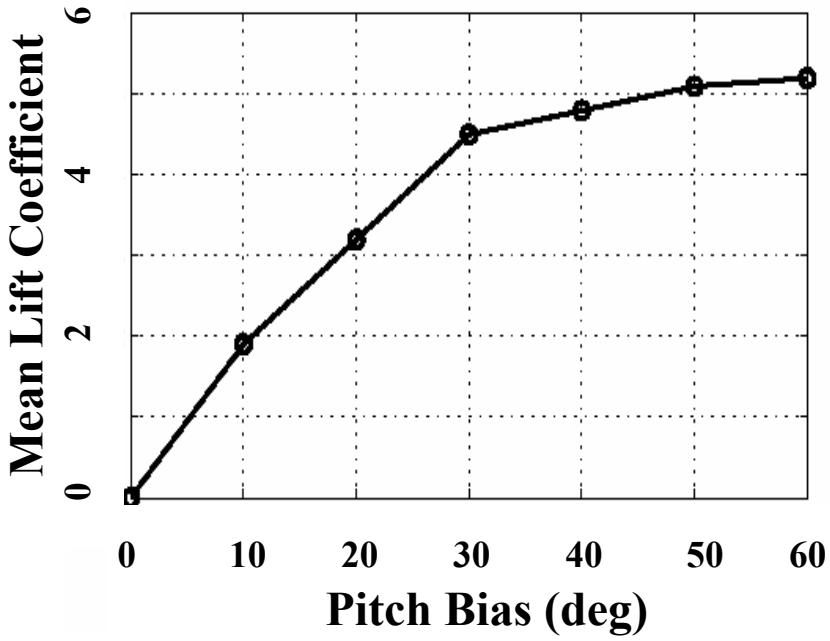
Nature and Man Made

- There is convergence in cruise
- But, Nature is still ahead in Maneuvering

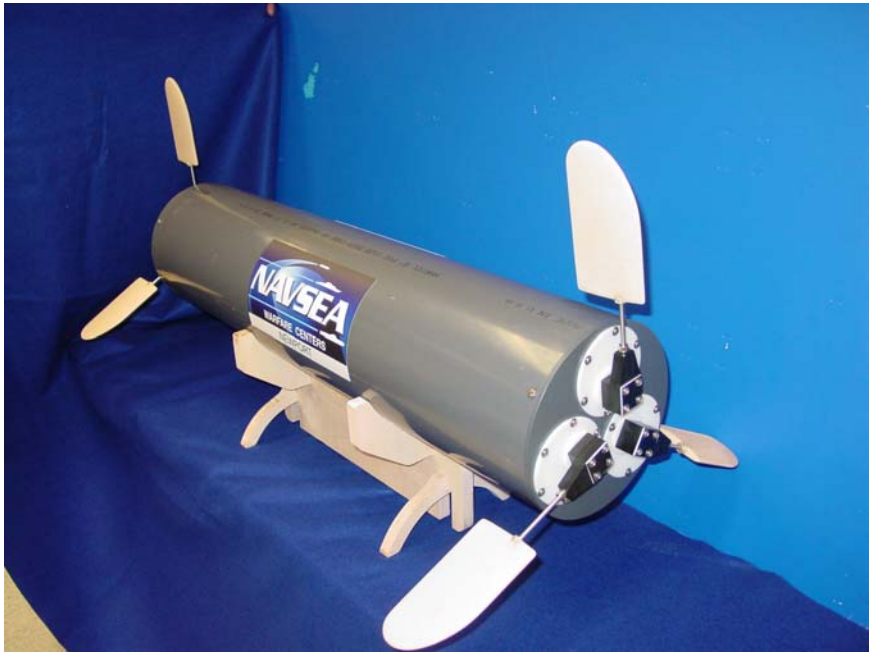
- What science principle is behind nature's superiority that engineering has not implemented?

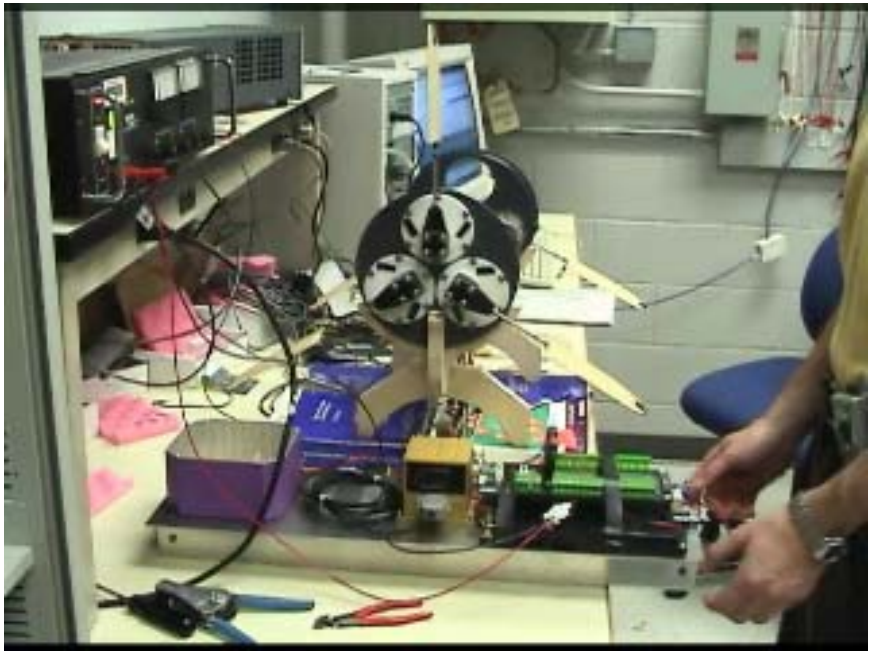
High-Lift Principle



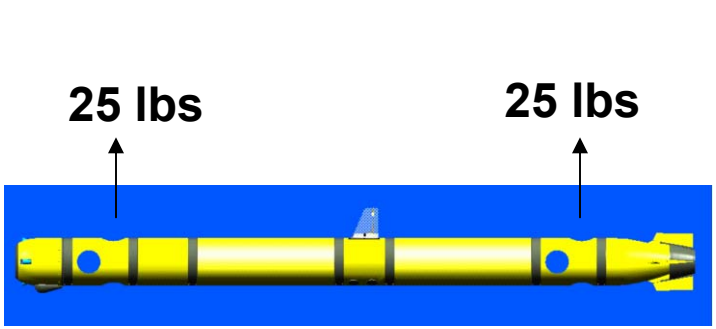


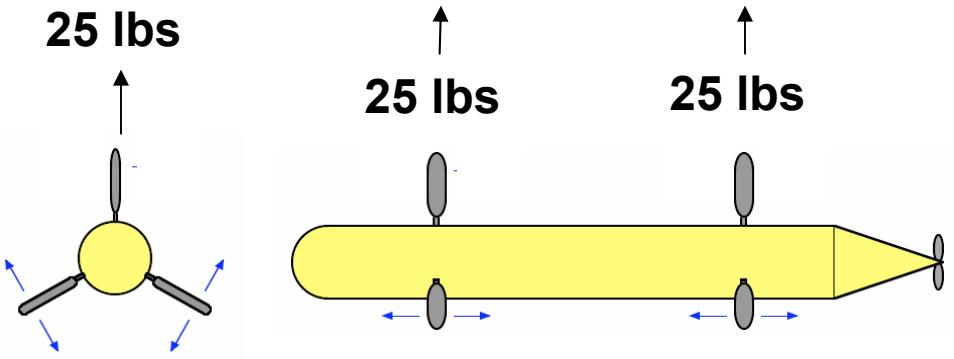
The Proposed Vehicle





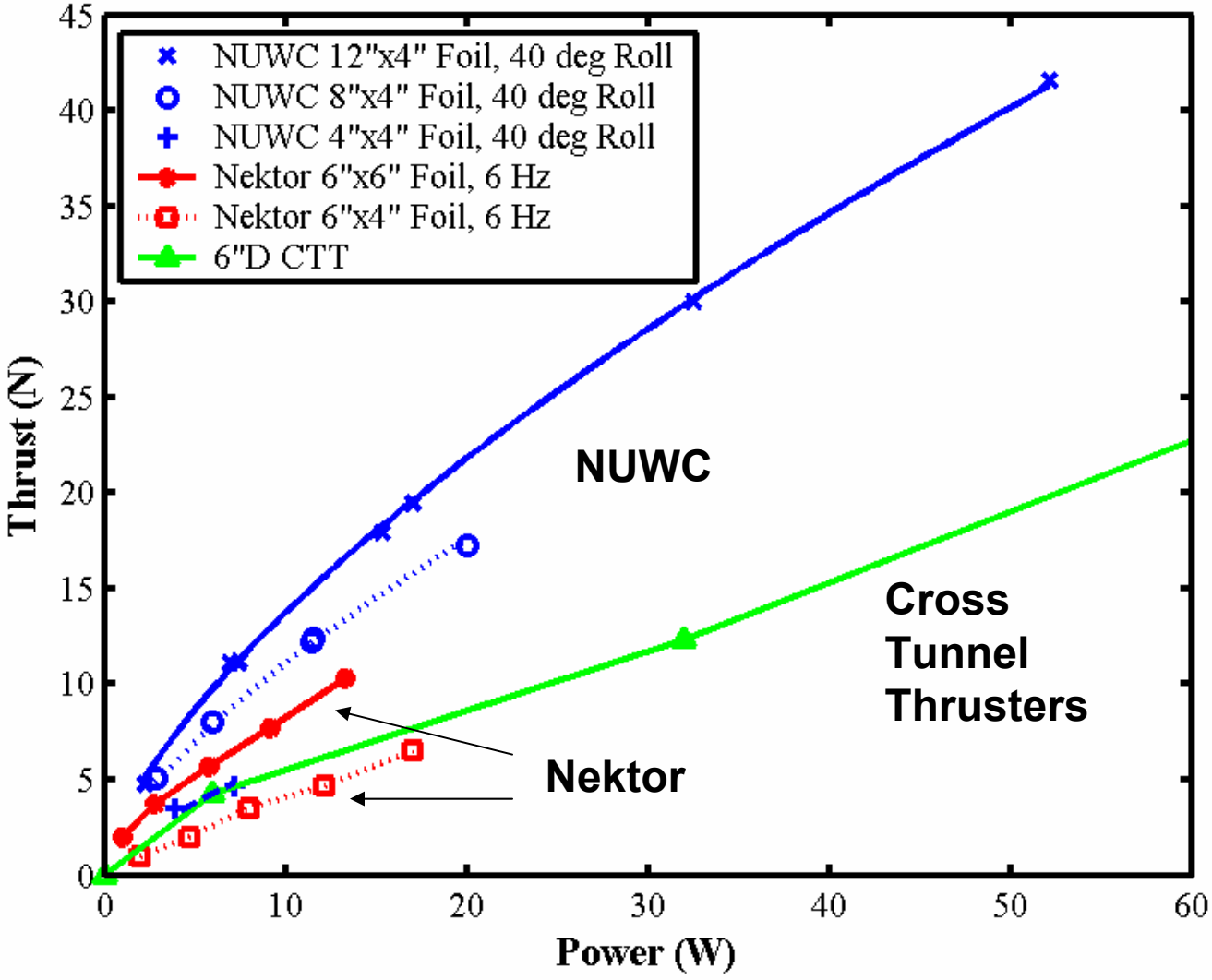
Actuator Power Saving Over Cross Tunnel Thrusters





- **For upward translation, 4 foils do the work of 2 CTT @25lbs each**
  - **Lift-based (12” span): 440W Foils vs. 1078W CTT**
  - **Lift-based (8” span): 540W Foils vs. 1078W CTT**

NUWC Biorobotic Foils Have the Best Power Saving Performance Over CTT & Nektors



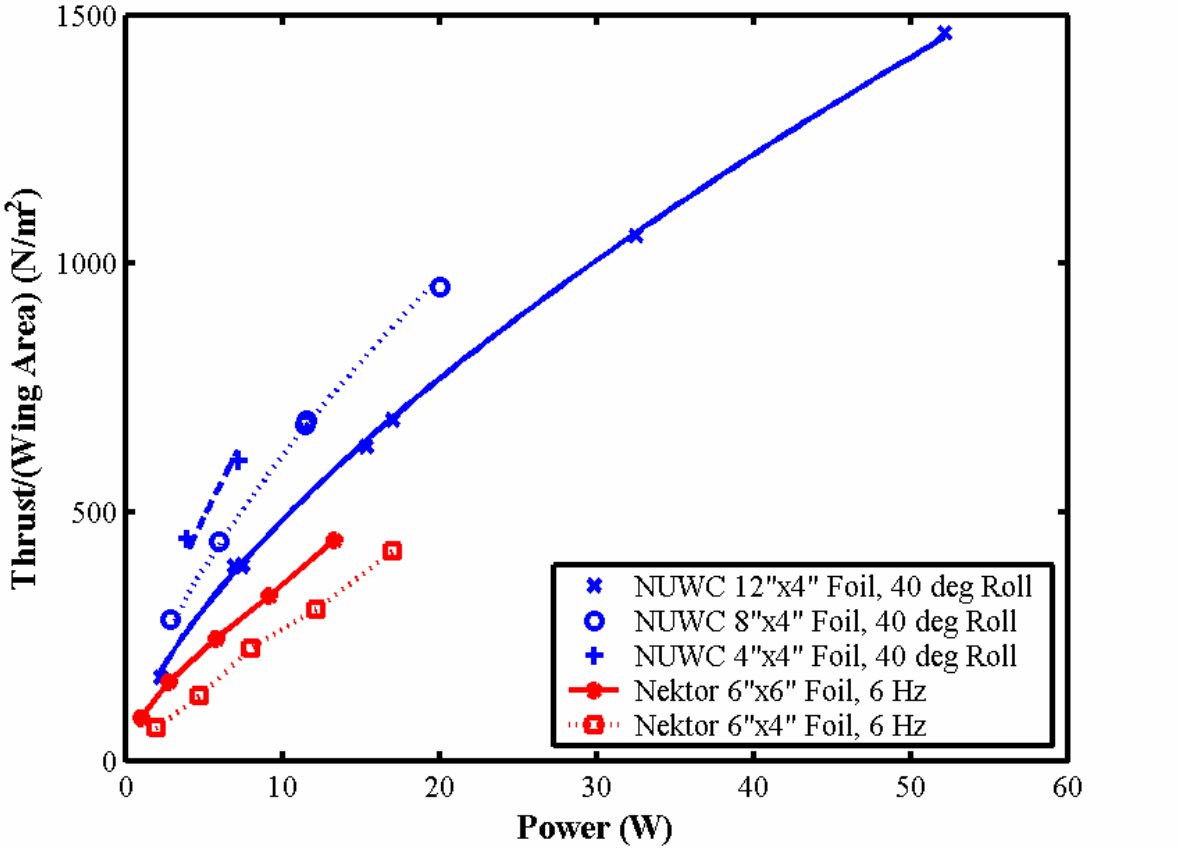
NUWC Foils are more efficient and more scalable over Nektors

Example for 420 N/m^2 Thrust, the hydro power used by 6” x 6” Nektor is:

50% greater compared to NUWC 12” foil

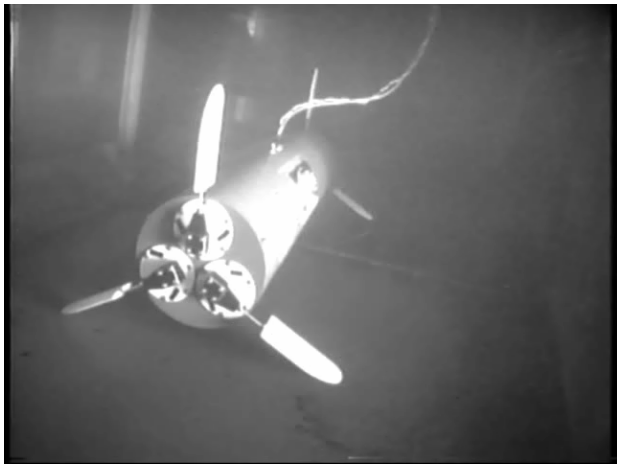
100% greater compared to NUWC 8” foil, and

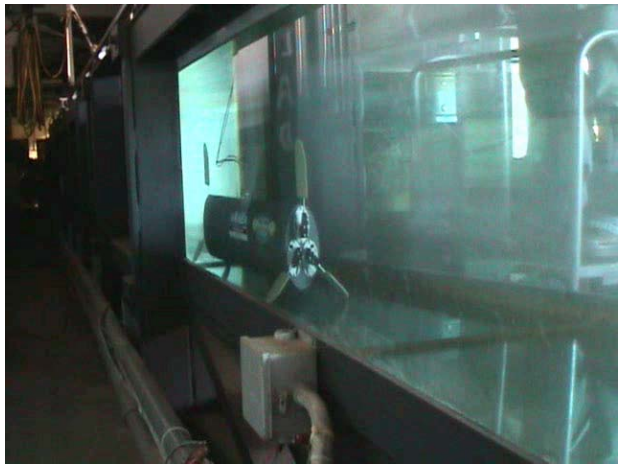
200% greater compared to NUWC 4” foil

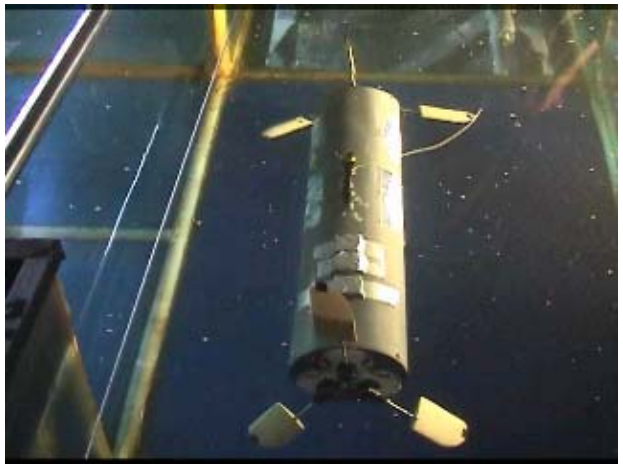


Swimming in Acoustic Test Facility

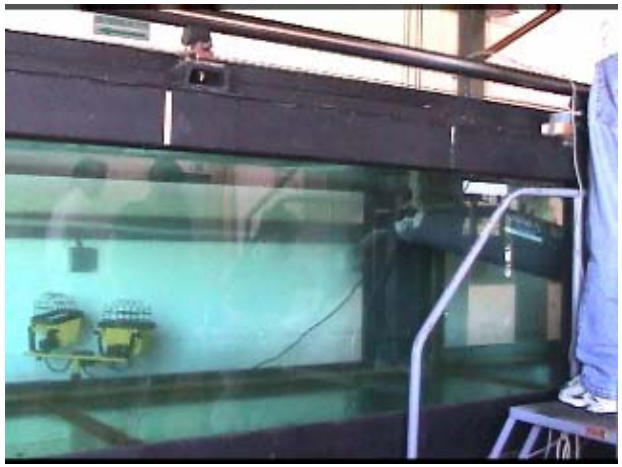
Low Speed Maneuvering

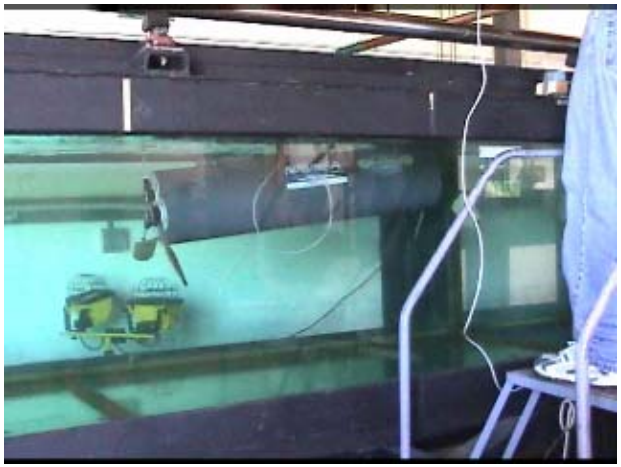




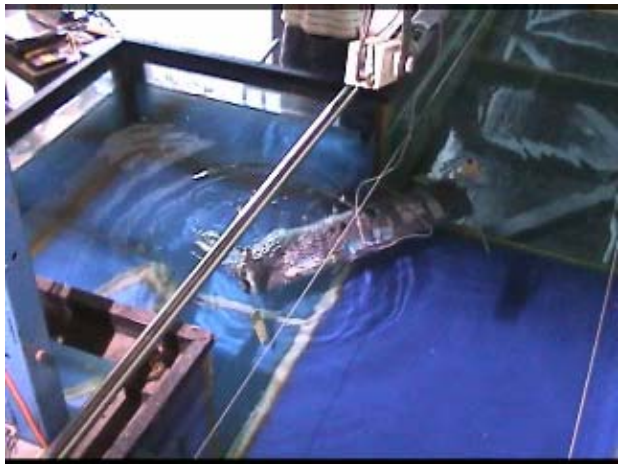


Low Speed Maneuvering





Low Speed Maneuvering



Subneuron: A Robust Orbit Generator

Inferior Olive

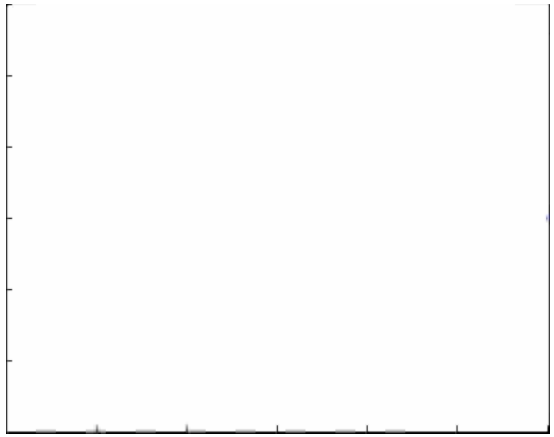
$$\frac{dz}{d\tau} = f(z) - w \qquad \frac{dw}{d\tau} = \varepsilon_{ca}[z - I_{ca} - I_{ext}]$$

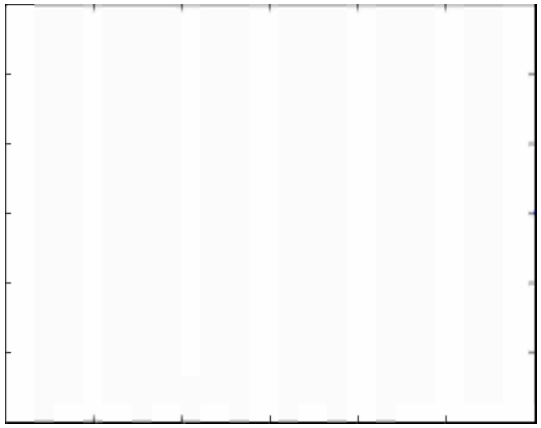
$$\frac{du}{dt} = \frac{1}{\varepsilon_{ca}}[f(u) - v] \qquad \frac{dv}{dt} = u - (z - I_{ca}) - I_{Na}$$

$$x = w - w_0 \qquad \omega = \sqrt{\varepsilon_{ca}}$$

$$\ddot{x} + g(x)\dot{x} + \omega^2 x = 0$$

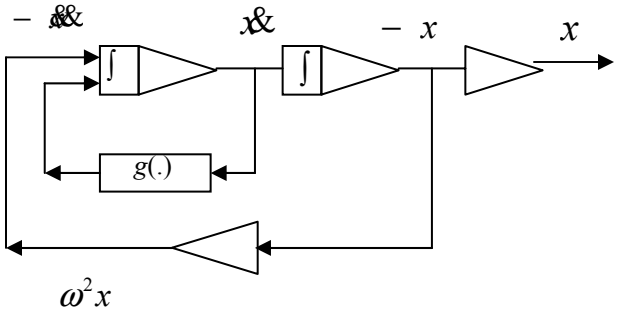
$$g(y) = a_0 + a_1 y + y^2$$

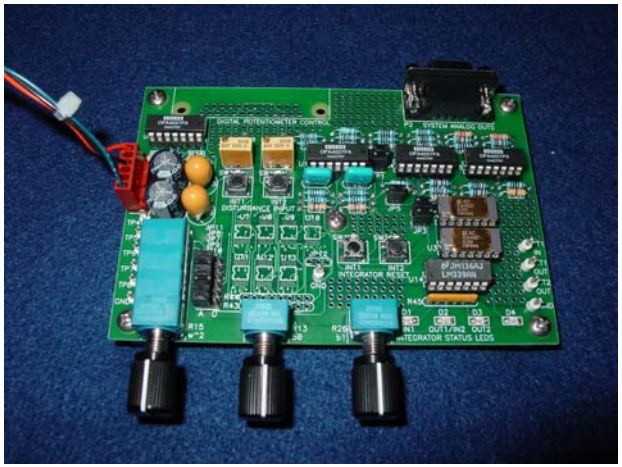




Frequency, amplitude, bias, and general shape can be varied through a_0, a_1 and ω

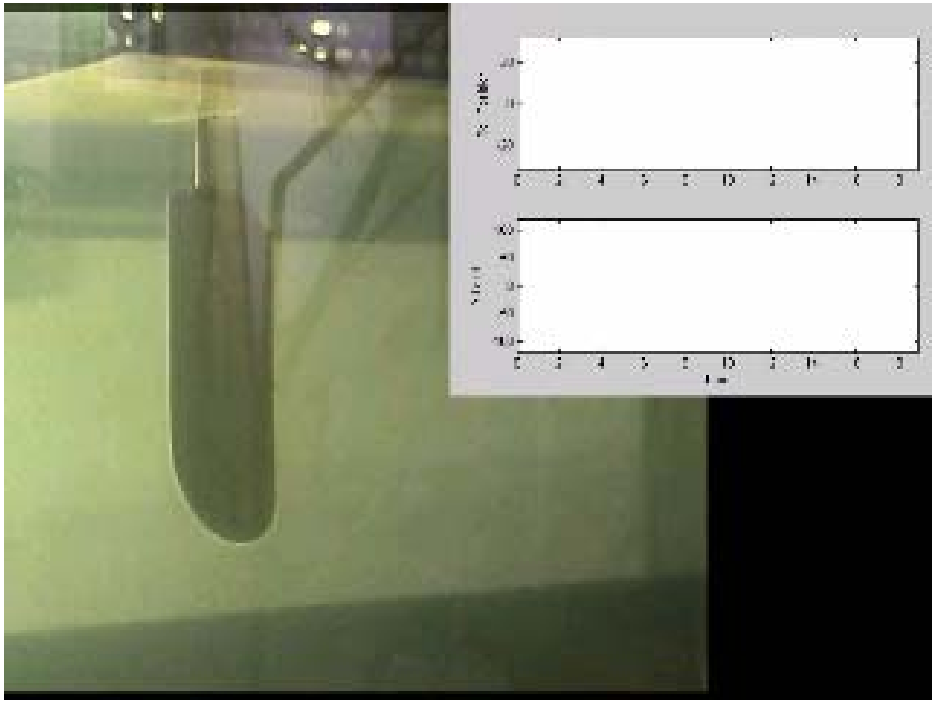
PCB-analog implementation:

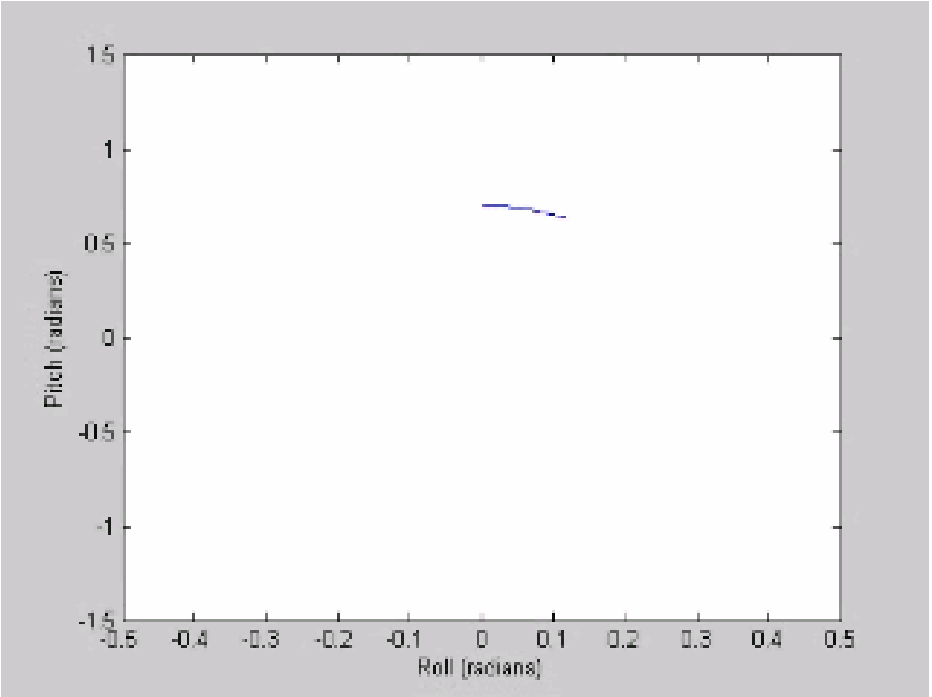




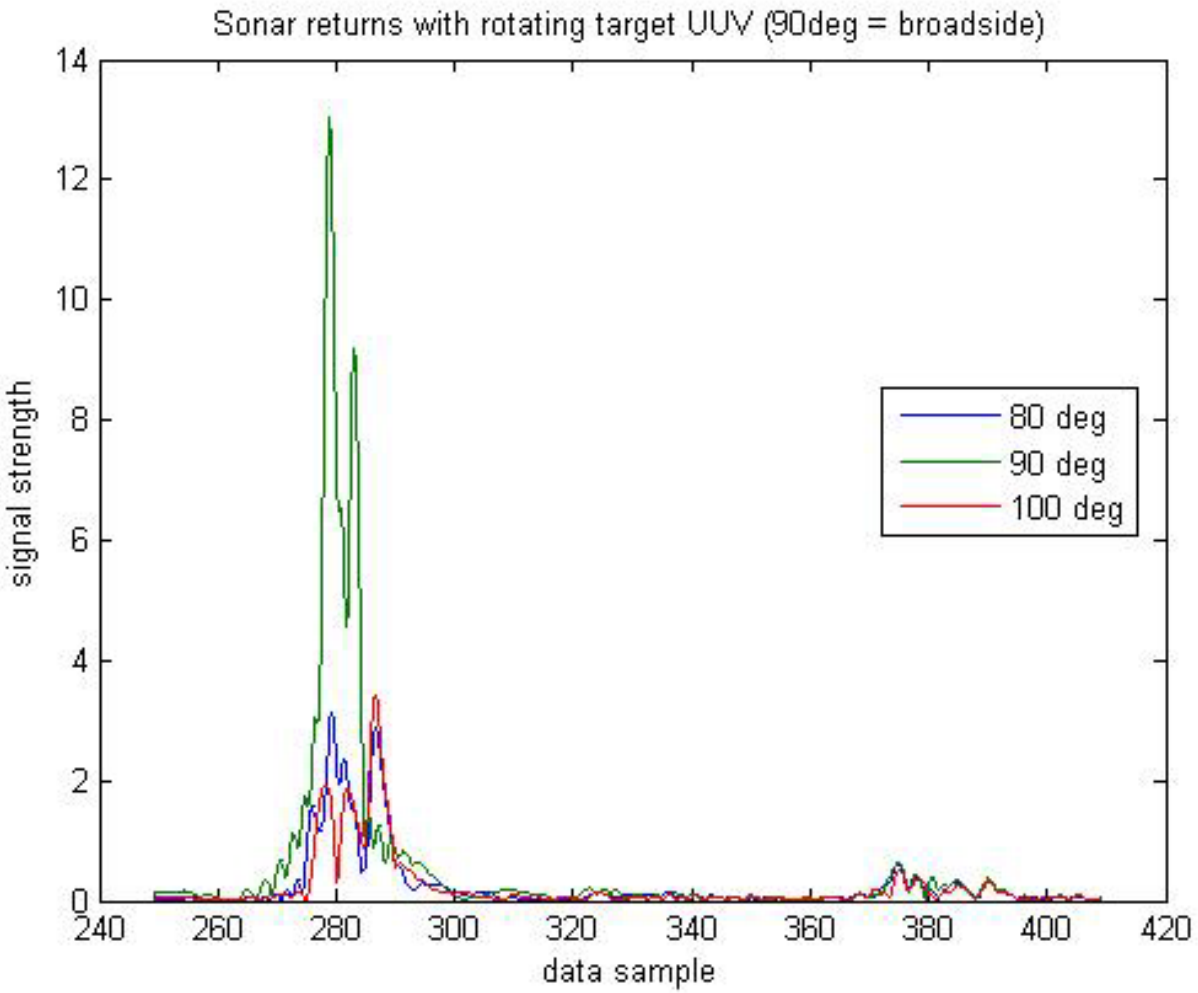
Local Autonomy of Actuators

Roll & Lift



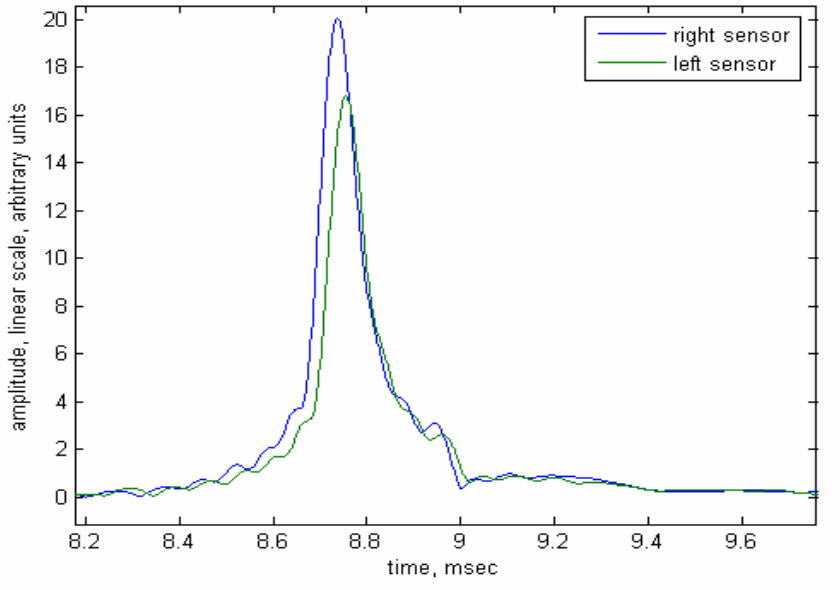


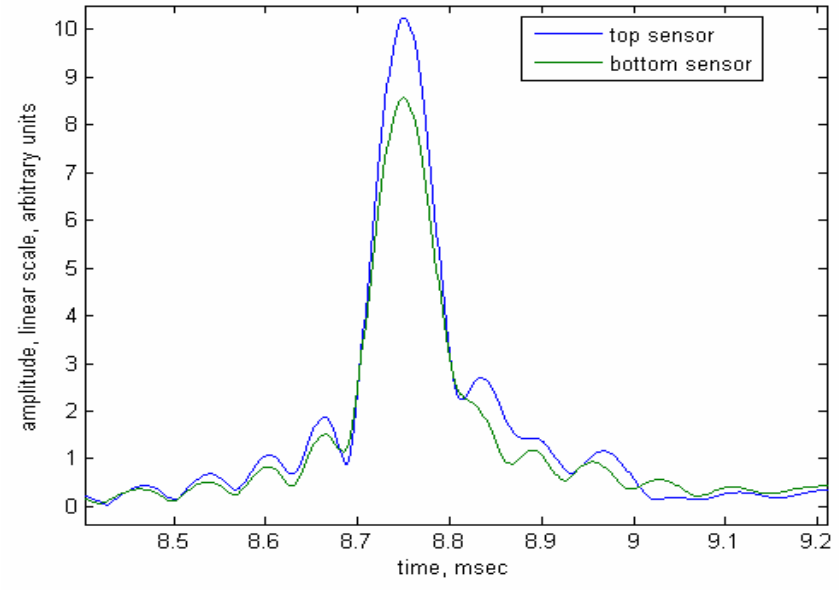
Sonar: x3 Drop in 10 deg Yaw



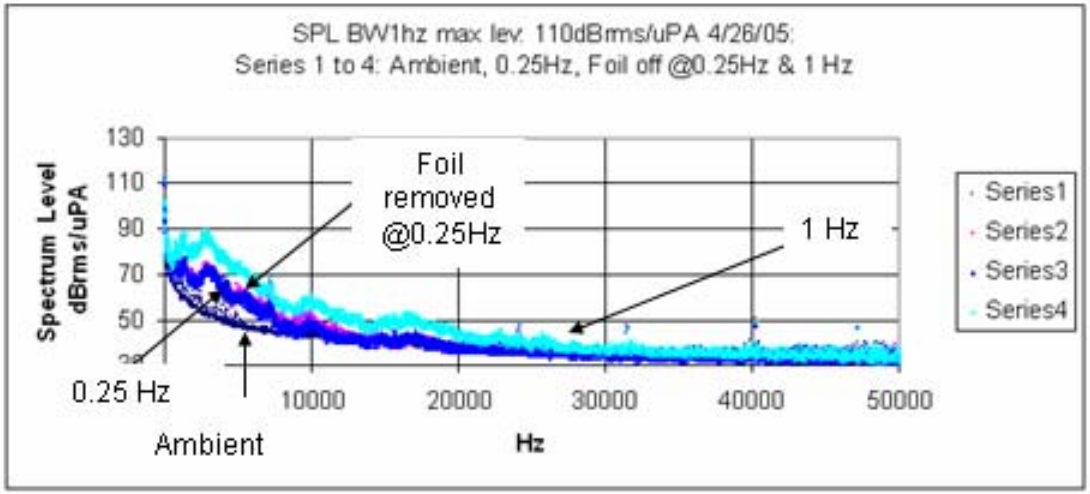
Interaural Arrival Times

Observe different arrival times between left and right ears, but equal arrival times between top and bottom ears

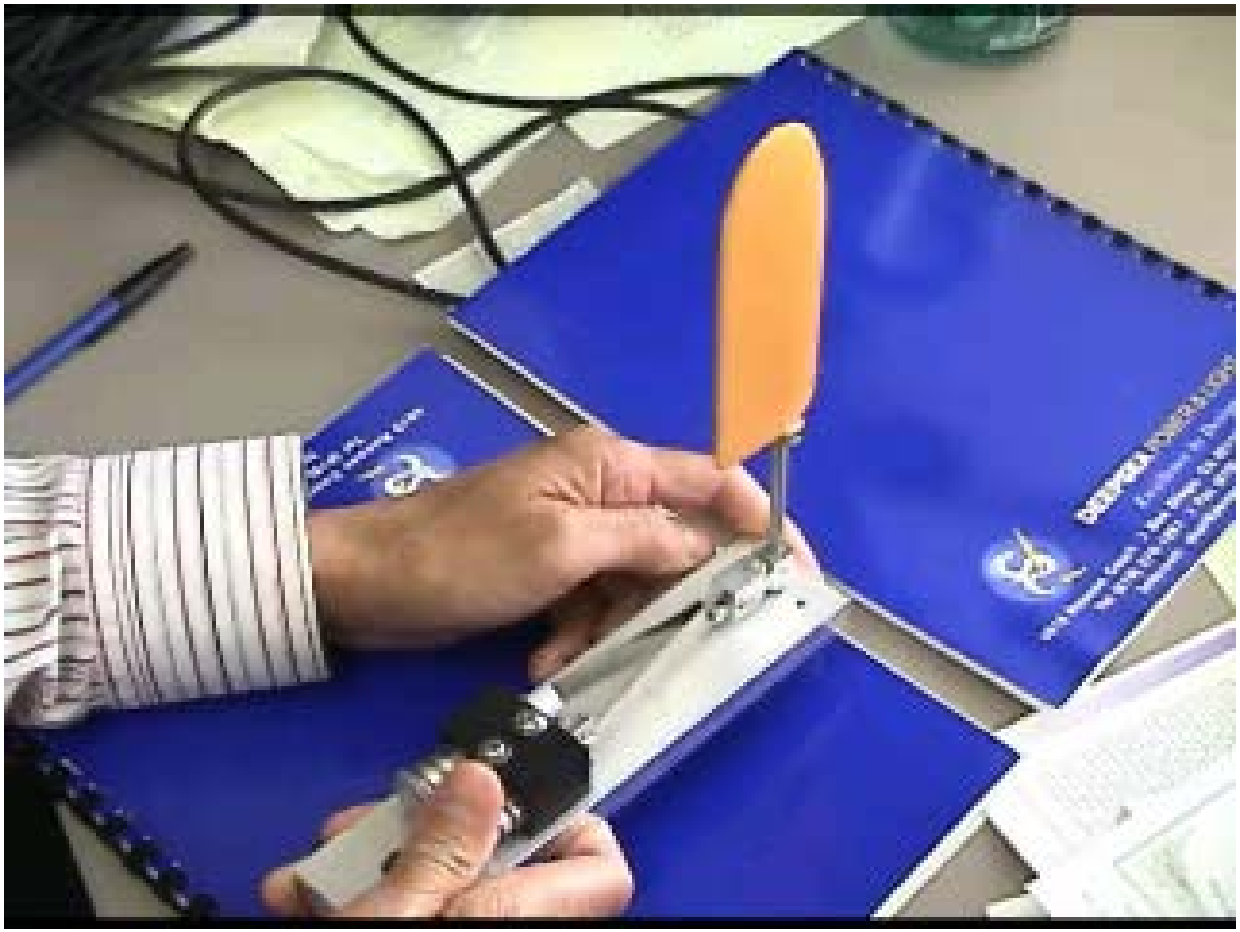




Noise


SPL BW1hz max lev. 110dBrms/uPA 4/26/05:
Series 1 to 4: Ambient, 0.25Hz, Foil off @0.25Hz & 1 Hz
Spectrum Level dBrms/uPA
130
110
90
70
50
Foil removed @0.25Hz
1 Hz
0.25 Hz
Ambient
10000
20000
30000
40000
50000
Hz
Series1
Series2
Series3
Series4

Linear Actuation of Foils



Usefulness

- Hovering
- Power Efficiency
- Station Keeping
- Docking/Recovery
- Stealth