SHEARWATER

A Homogeneous Platform for Ocean Applications

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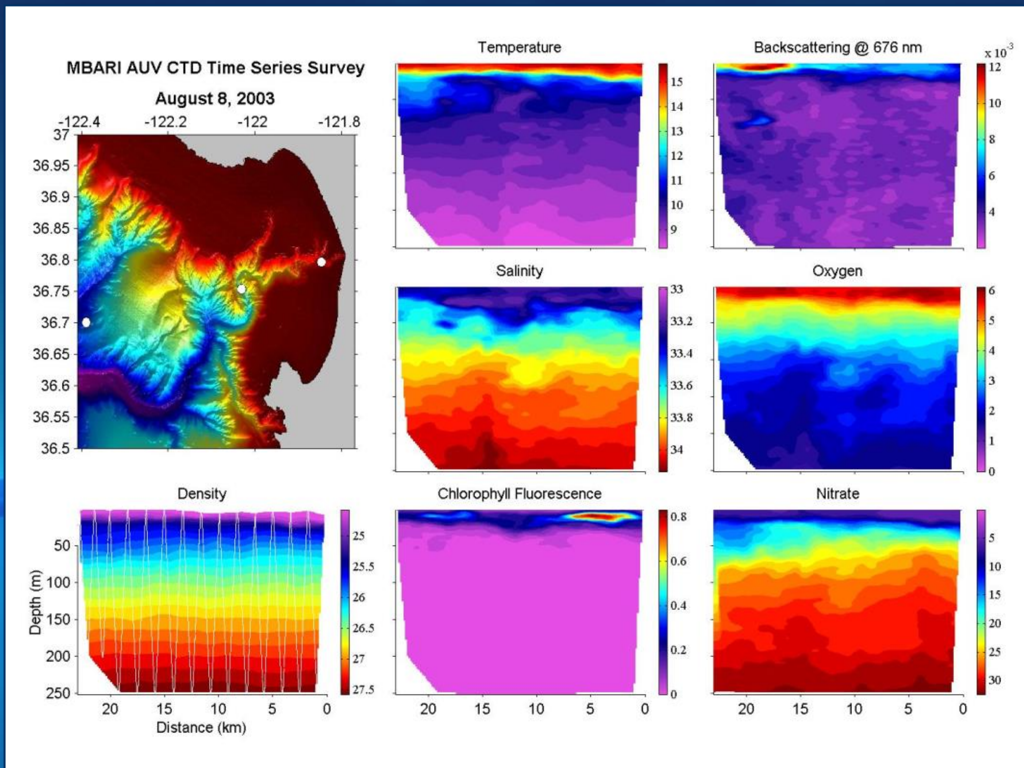
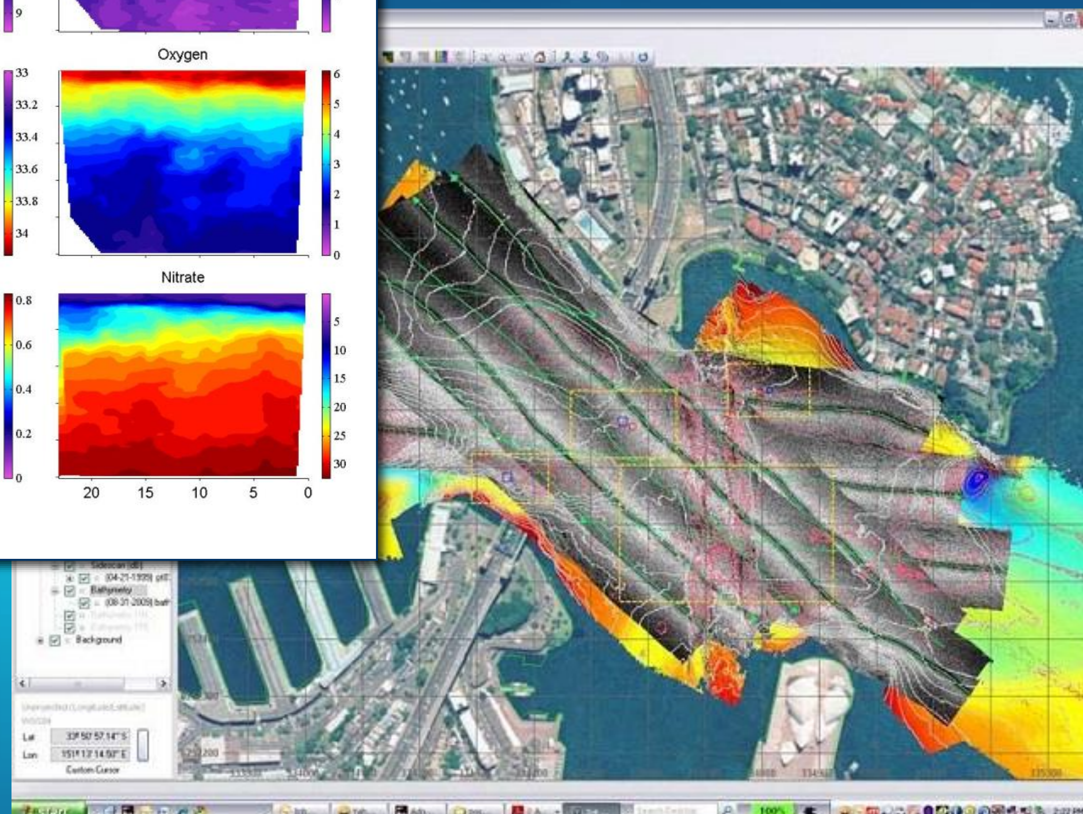
Routine Operations for End Users



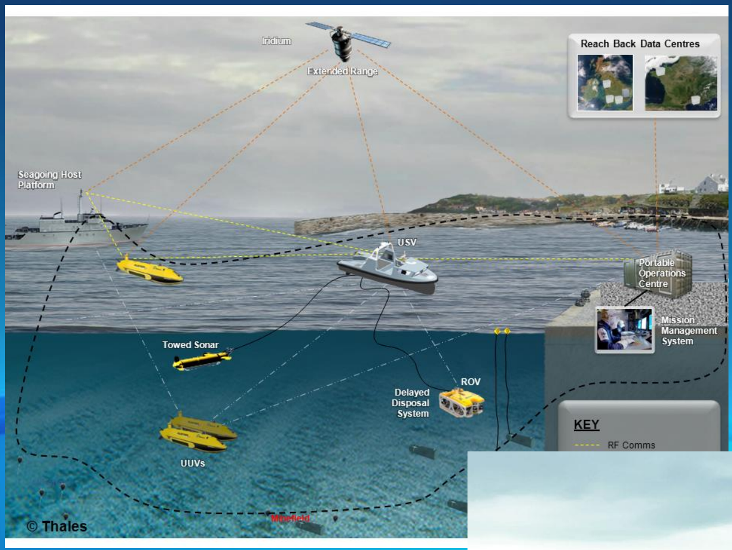


First thing to keep in mind:

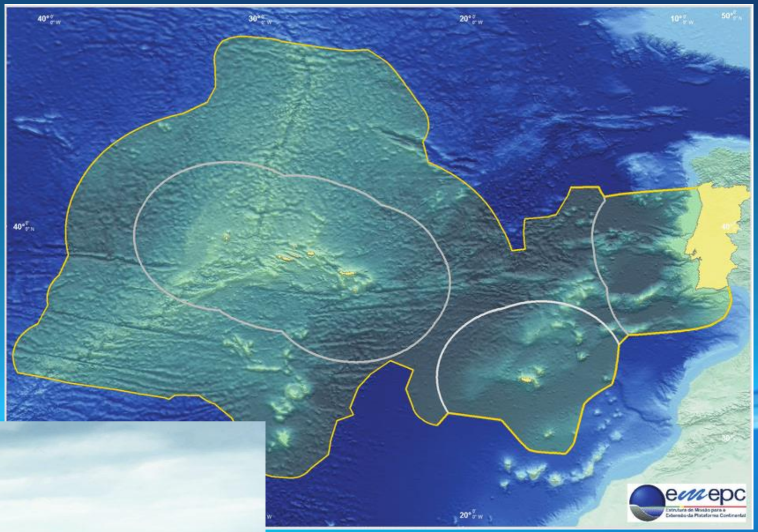
End user desires are for dense data sets to address issues at the lowest cost, not to get a new vehicle

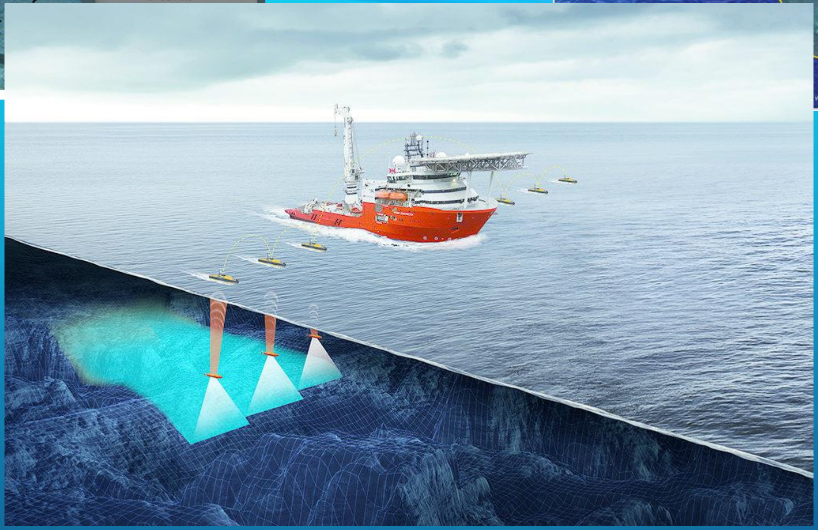
Multi-Vehicle Ops Needs/Drivers

Military



Resource Management and Protection



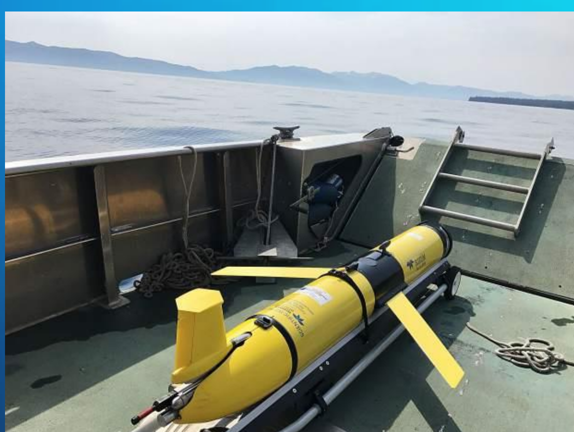


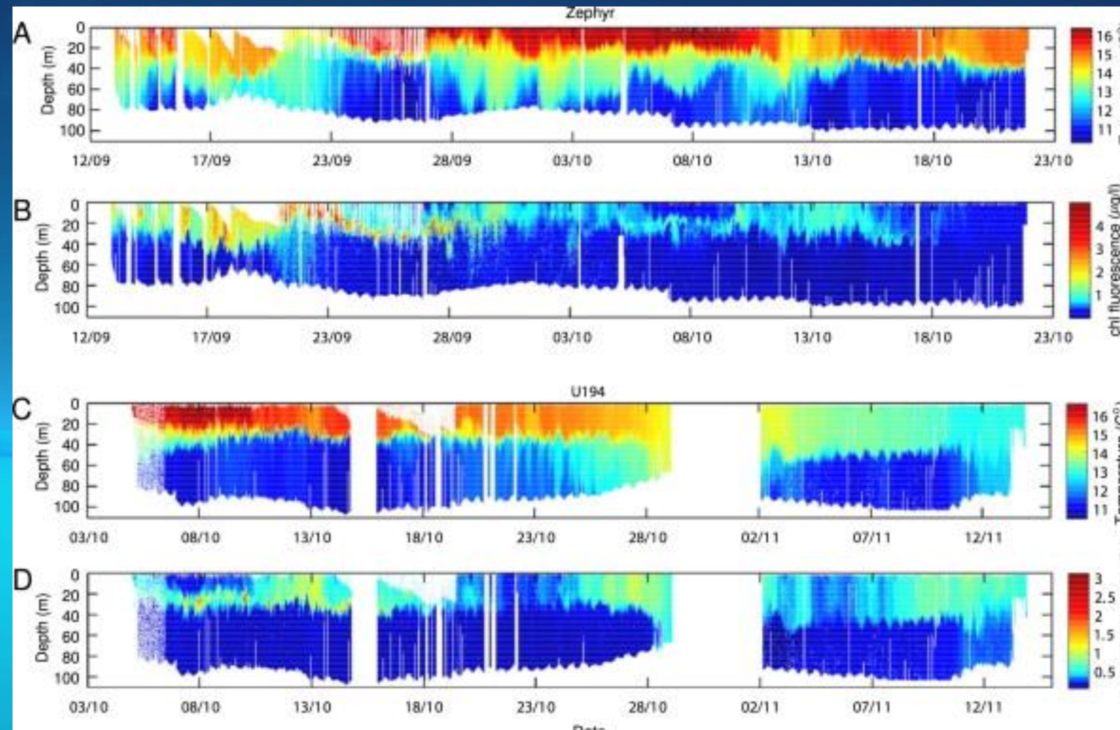
Oil and Gas

Integrated Multiplatform Operations - AOSN

These operations provide extremely dense data sets but are very expensive and are very hard to maintain for any length of time… plus moving assets as conditions change can be difficult

An Idea is Born - Gliders





Ocean Transects - Large Data Sets

But what is it telling me?

SPEED – Getting better Temporal and Spatial Correlatio

How to Improve ~~Gliders~~ Data

Current Status of Autonomy for AUVs

Pro	Con
* Navigation by tracking * Faster deep survey * Multiple platforms	* Ship costs dominate
* Ship free for additional activity	* Navigation an issue
* Episodic response * Rough weather ops * Multiple platforms * Space-time cov.	* Complex * Dock expensive * Deployment and recovery
* No ship! Very few People	* Energy required for transit * Navigation an issue

Range/Speed Relationships

Power consumption:

$$P_T = \frac{1}{2}\frac{\rho\, C_d\, S}{\eta} v^3 + P_h$$

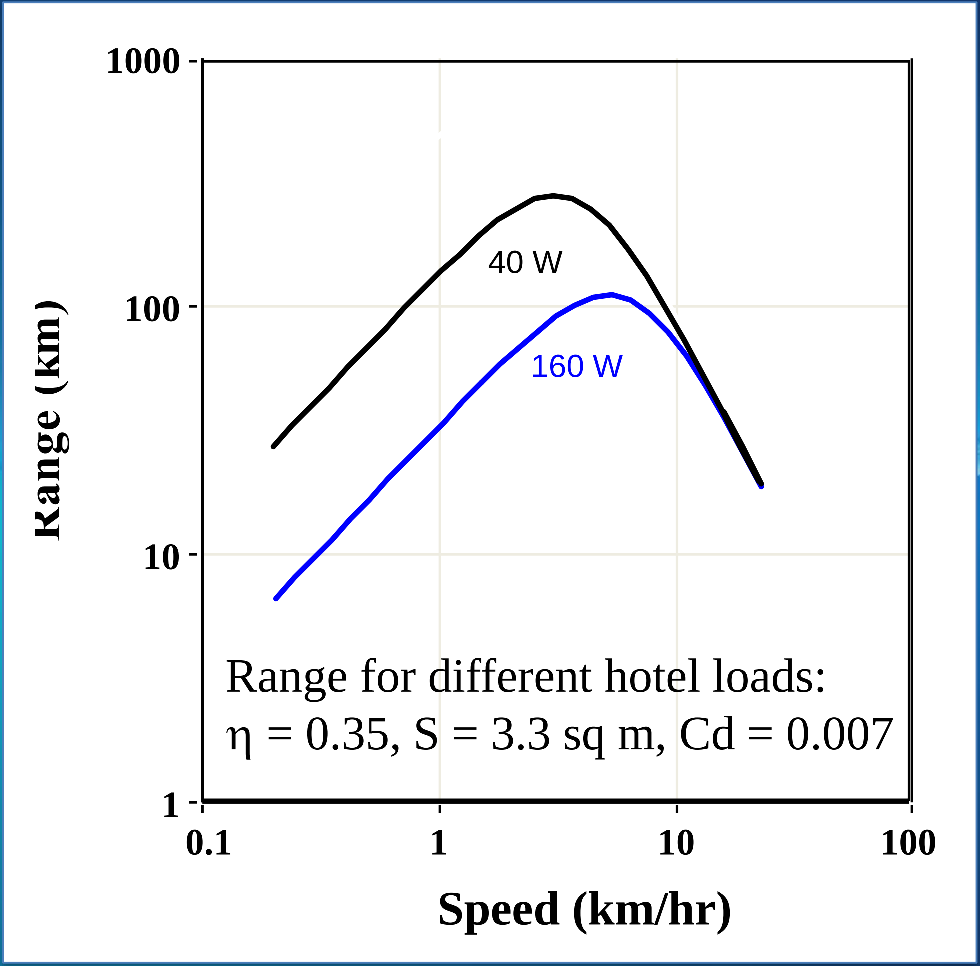
Energy per distance traveled:

$$e = \frac{1}{2}\frac{\rho\, C_d\, S}{\eta} v^2 + \frac{P_h}{v}$$

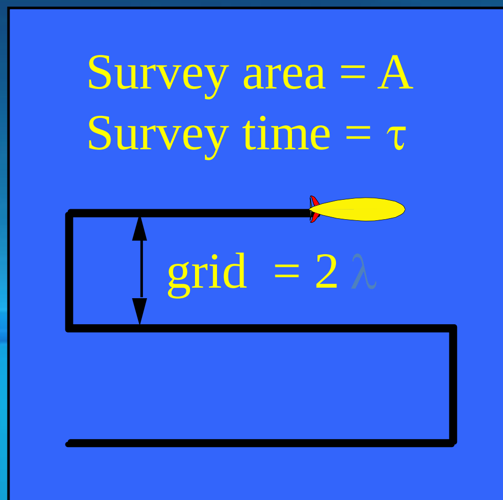
Best speed:

$$v_{opt} = \left(\frac{P_h\, \eta}{\rho\, C_d\, S}\right)^{1/3}$$

$$\textbf{when} \quad P_p = \frac{P_h}{2}$$



The Grid Survey



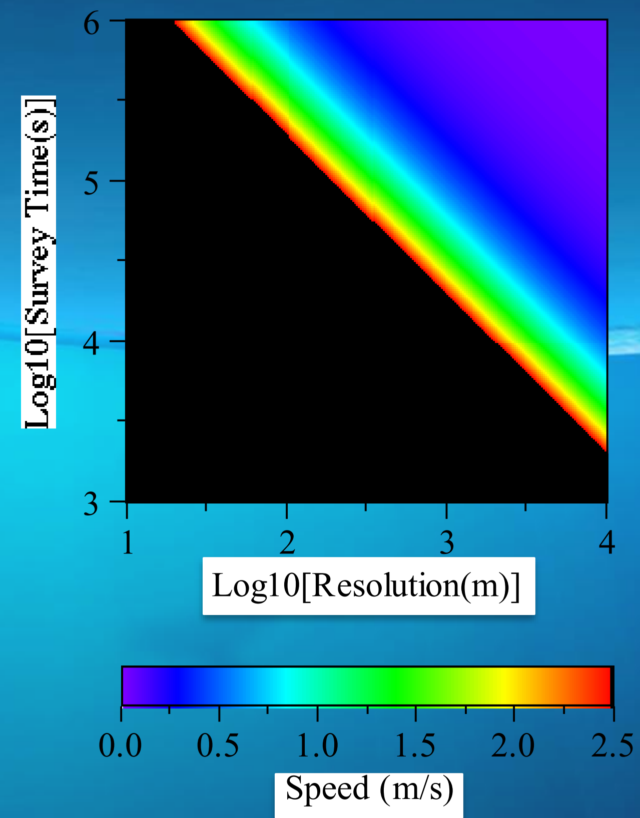
Total Survey Distance

$\mathbf{d = A/2\lambda}$

Required Speed

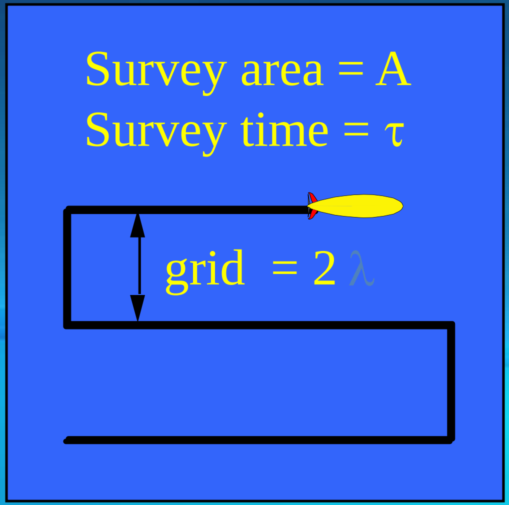
$\mathbf{v = A/2\lambda\tau}$

Example - 100 sq km Area

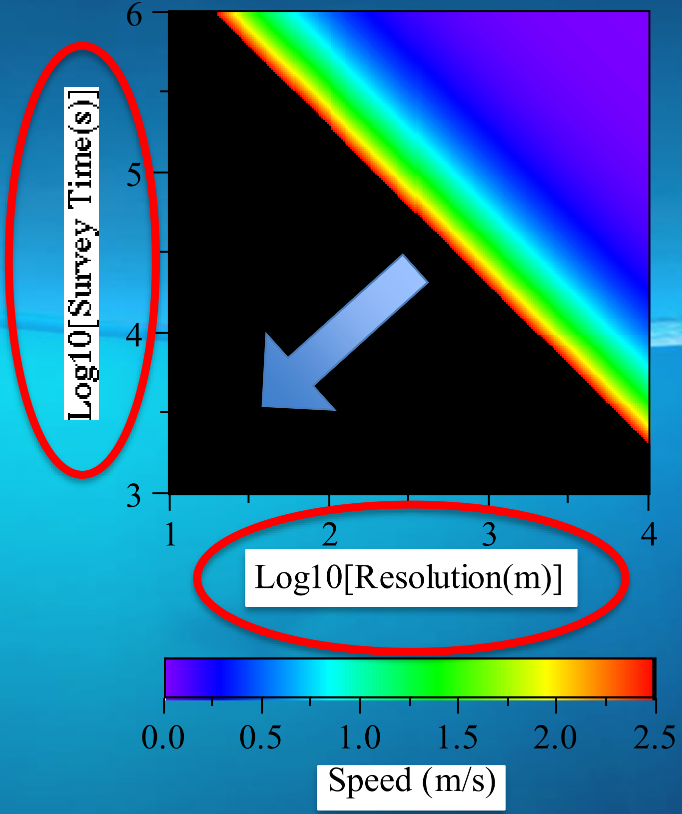


From Bellingham and Wilcox

The Grid Survey - Improved



Example - 100 sq km Area



Total Survey Distance

d = A/2λ

Required Speed

v = A/2λτ

From Bellingham and Wilcox

Survey Envelope

Determining the accessible survey space using an Odyssey IIB

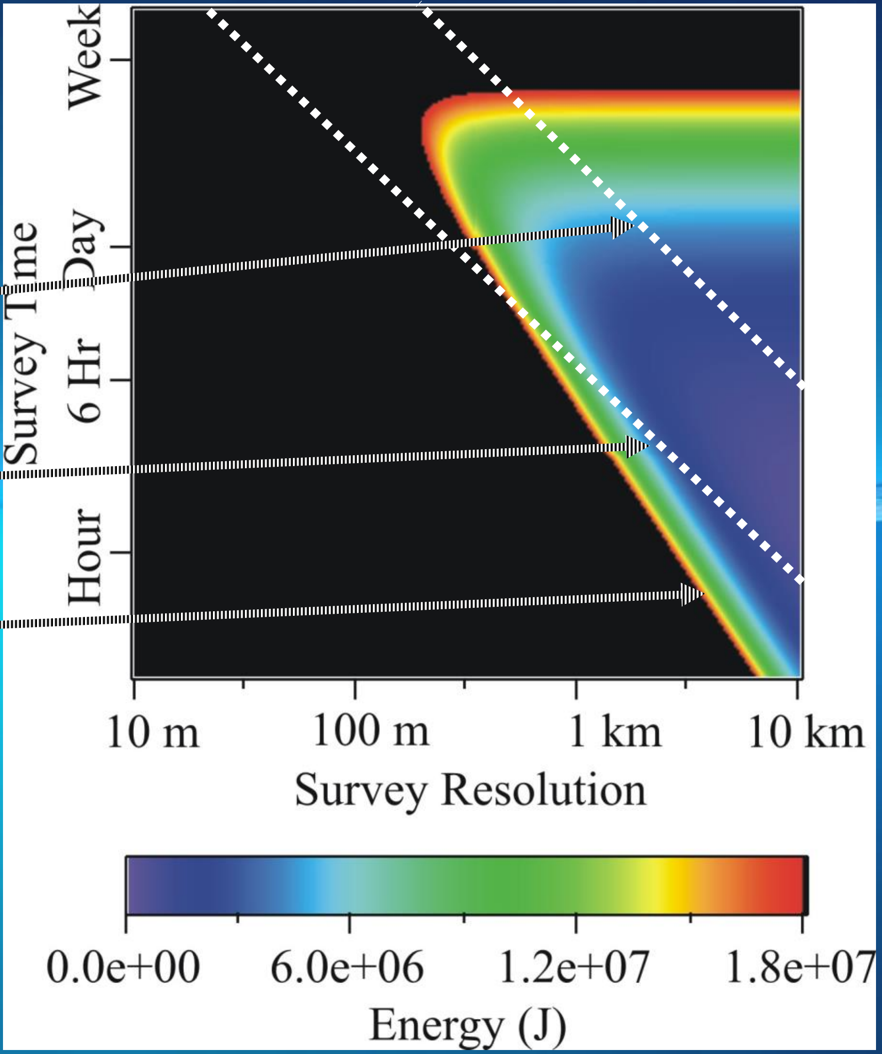
Minimum vehicle velocity

Maximum vehicle velocity

Energy limit of vehicle

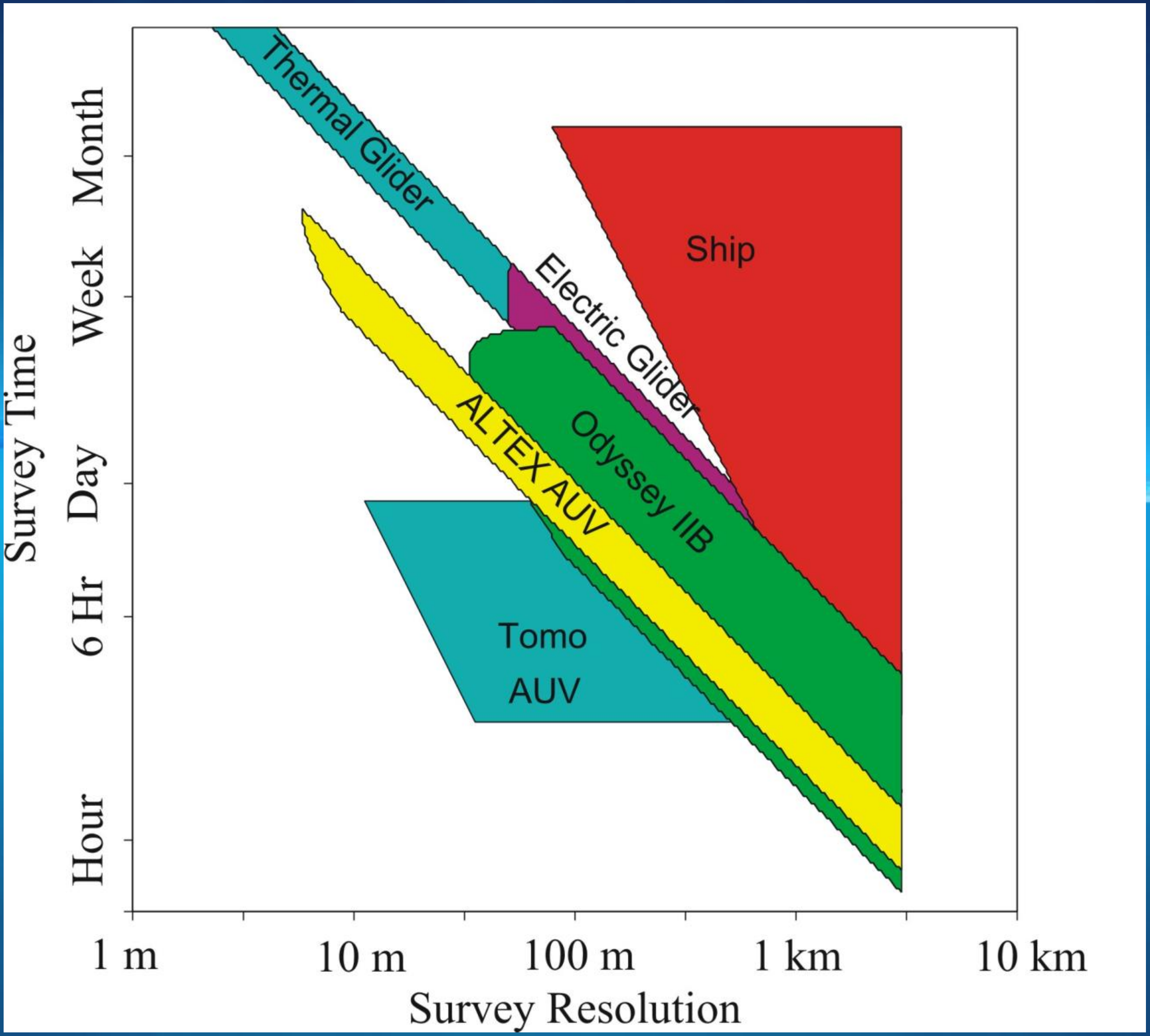
E_{total} = total energy available.

$$(P_{total})\tau = \left(\frac{\rho\, C_d S V^3}{2\eta} + P_h \right) \tau$$



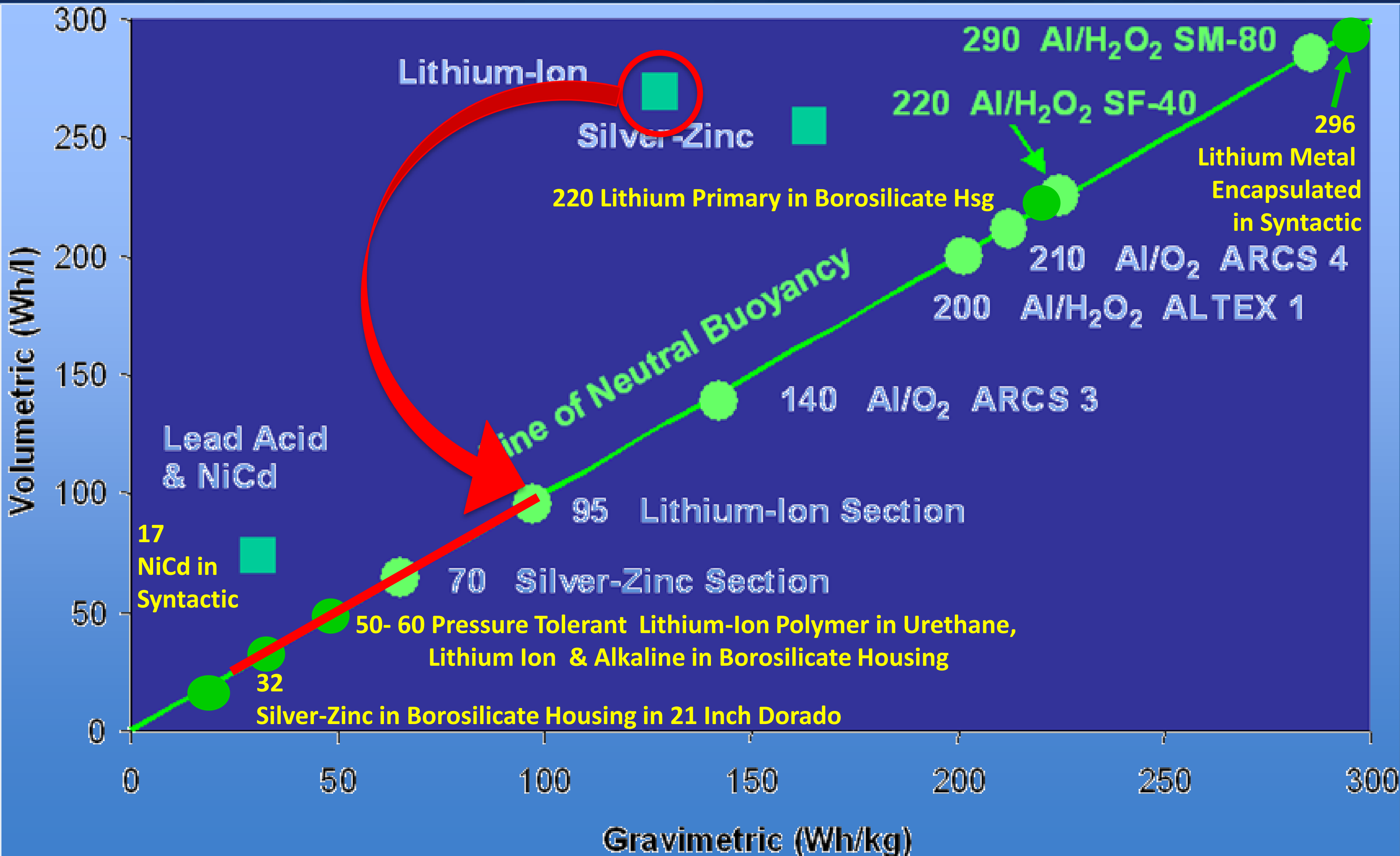
From Bellingham and Wilcox

Comparative Look at Vehicle Options



From Bellingham and Wilcox

Energy Systems - Specific Energy



What About a Hybrid?

9700 Wh/l

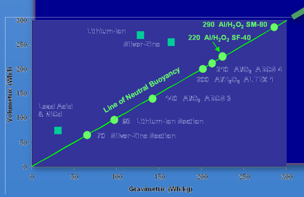
Why Gasoline? 32 times more energy per liter

Wh/l – 9,700 41 times more energy per kg

Wh/kg – 12,200

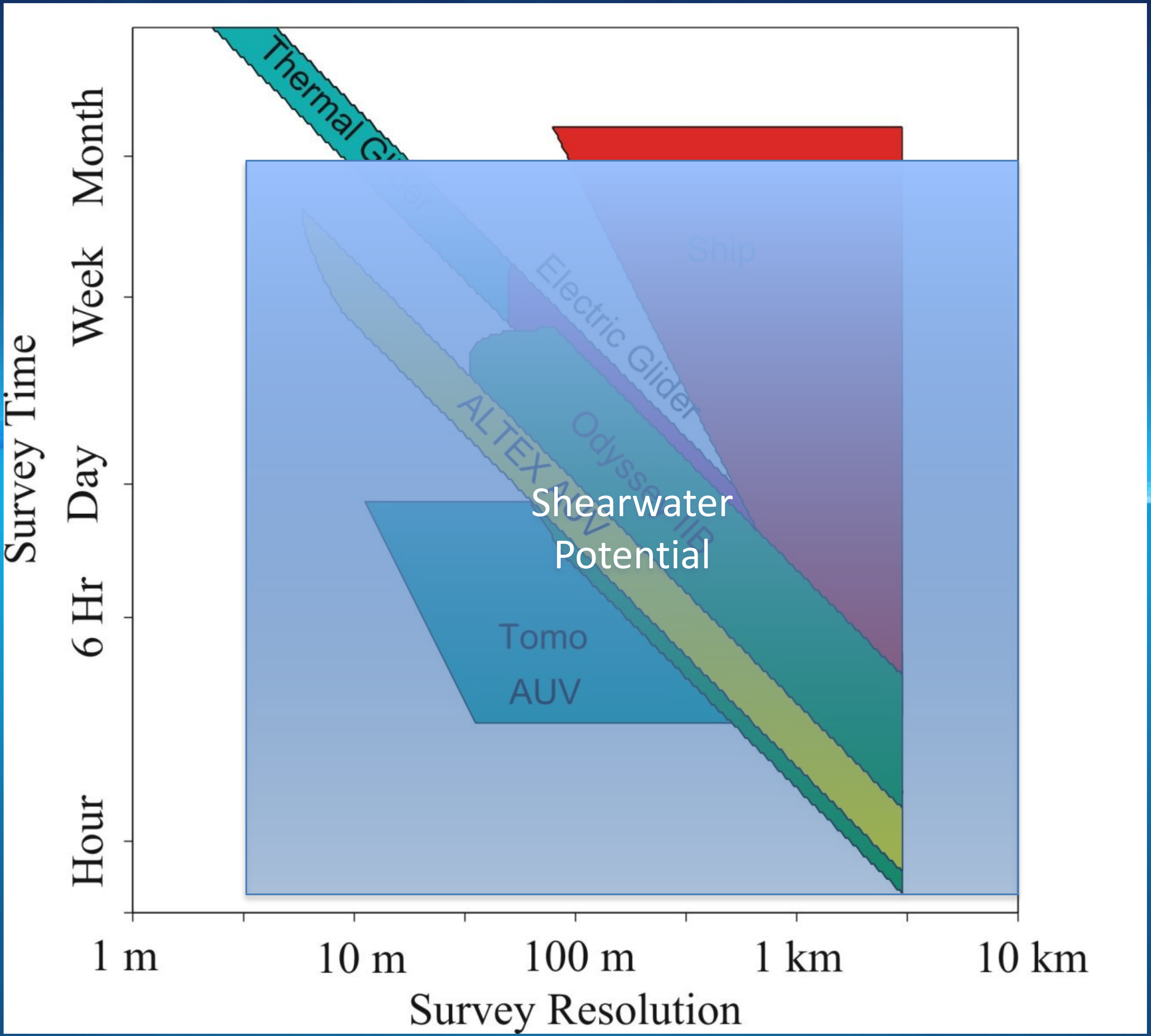
Another thing to keep in mind…

Discussions refer to BATTERIES as zero emission solutions. They are not. They are energy carriers, not energy sources and thus involve losses from the true energy source.



12200 Wh/kg

What A Hybrid Can Offer



From Bellingham and Wilcox

The Dream of Shearwater



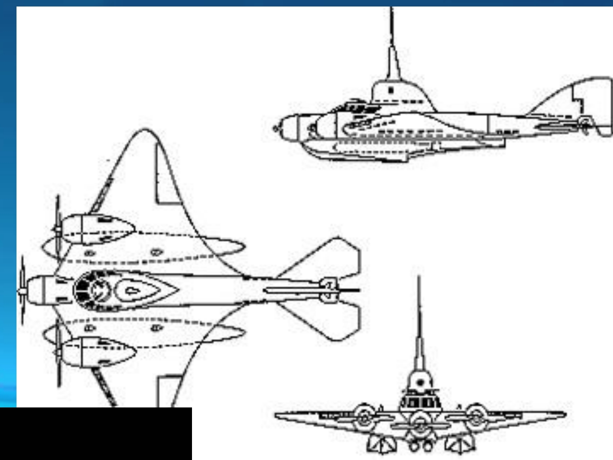
Shearwater – a Self-Deploying Autonomous Ocean Platform

Proof of Concept Mission for Part 2

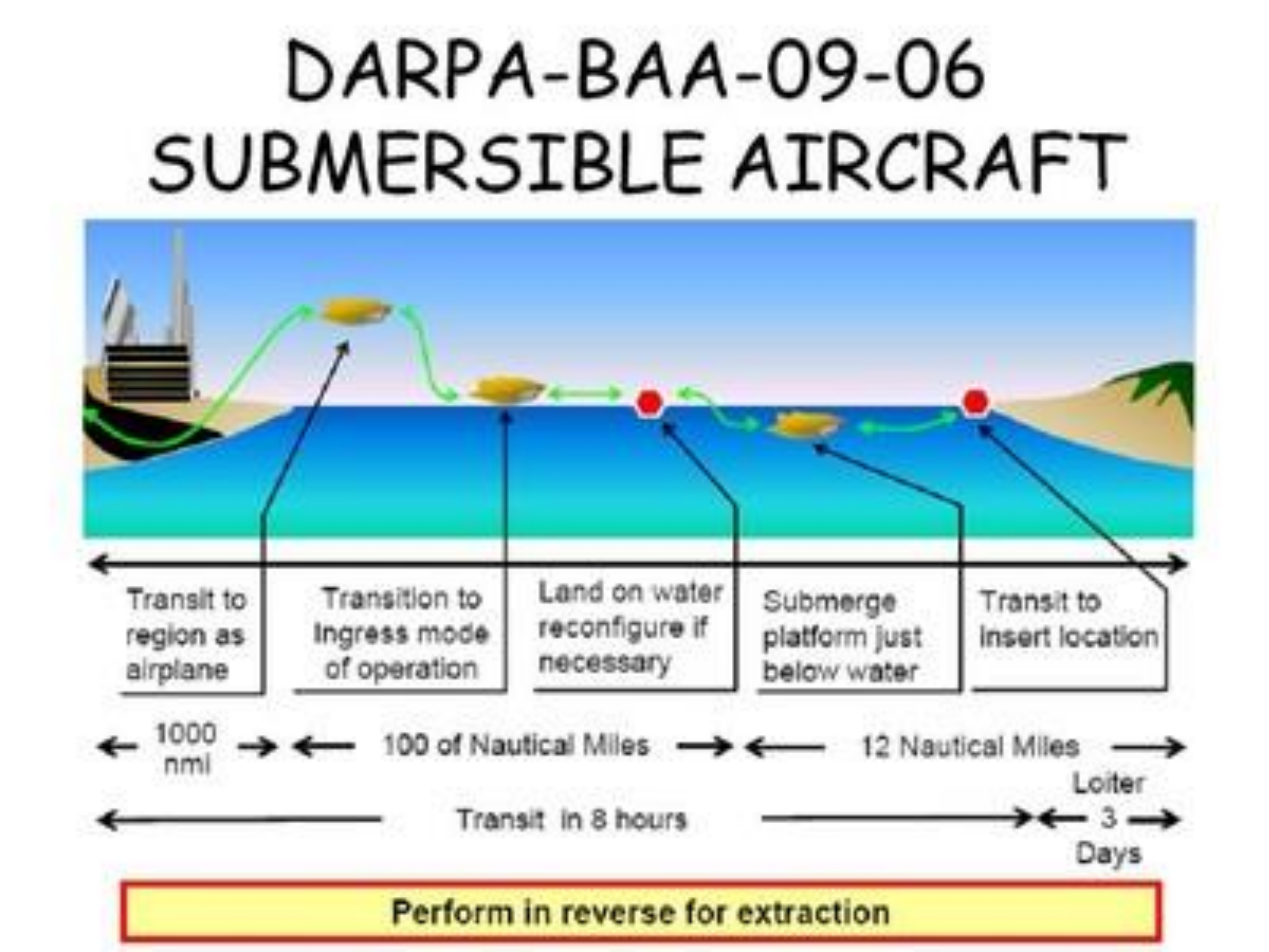
- Oversea flight from just outside the Moss Landing harbor entrance to M1 45m/s (~100mph)
- Land and Preform submerged mission 1.5m/s (3knots) duration of 8hours at 200m depth
- Surface and return home via oversea flight

Concept has been around for over 50 years.

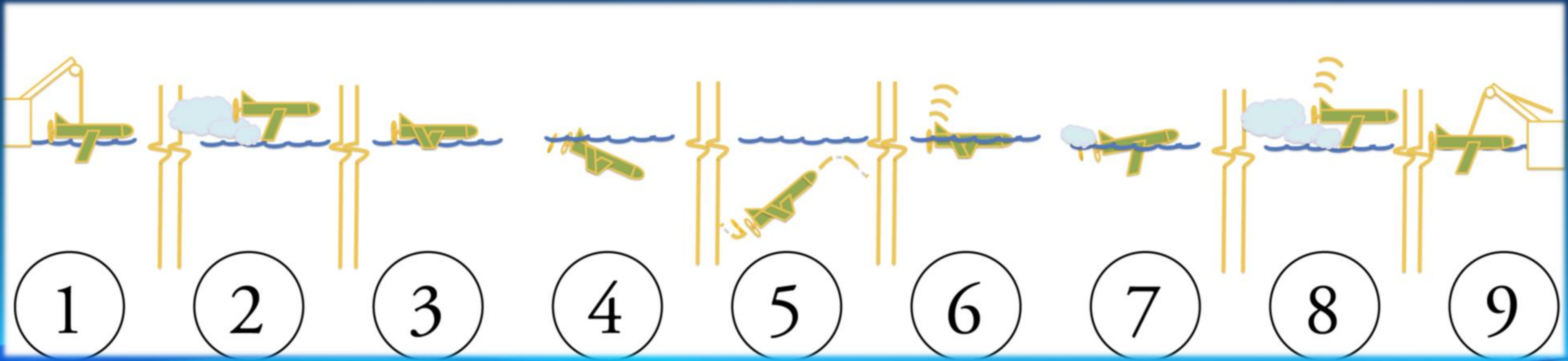
Soviets had plans in WWII



DARPA – Basic Specifications



Concept of Operations



Key point: Each step as outlined has been done… this is an integration exercise

Question: Can we integrate all the necessary functions with current or near term technologies into a single package?

Re Number (flow similarity)

This is critical – it says that the propellers and flow over the body will work in air and water

$$Re = \frac{\rho v L}{\mu} = \frac{vL}{\nu}$$

Air	Water
$L = 2\text{m}$	$L = 2\text{m}$
$v = 45 \text{ m/s}$	$v = 1.5 \text{ m/s}$
$\nu = 13.58 \times 10^{-6} \text{ m}^2/\text{s}$	$\nu = 1.307 \times 10^{-6} \text{ m}^2/\text{s}$
$Re = 6.63 \times 10^6$	$Re = 2.30 \times 10^6$

note: ν is assumed at 10º C at standard atmospheric pressure

Where to start? WIG capable AUV

Wing in Ground Effect (WIG) offers two advantages a bigger payload and less energy to transit, the pelican has demonstrated this

Look around and see what works, nature is a good place to start

Prior Work

The Soviets actually pursued portions of this plan

Can carry 50 % more weight than a similar sized airplane by using ground effect

Uses 50% less fuel to carry the larger load and transits at the same speed as a fuel aircraft

The WIG part has been proven, the efficiency numbers not yet.

Prior Work

The US has also looked at a variety of fast options

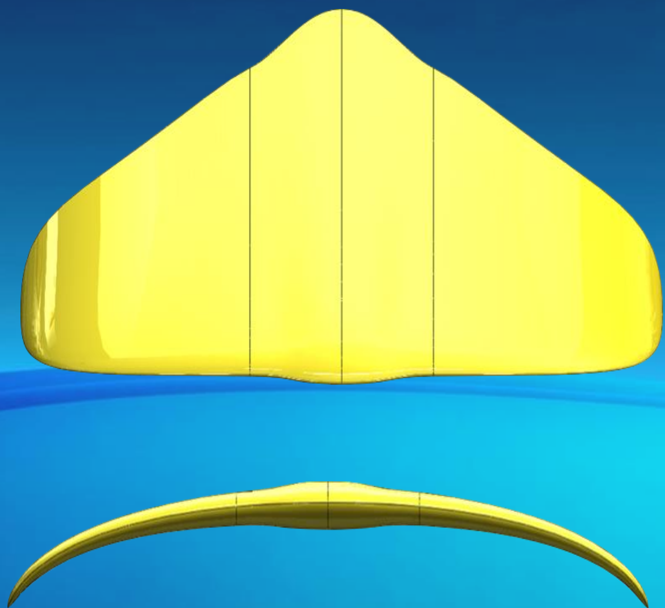
Prior Work

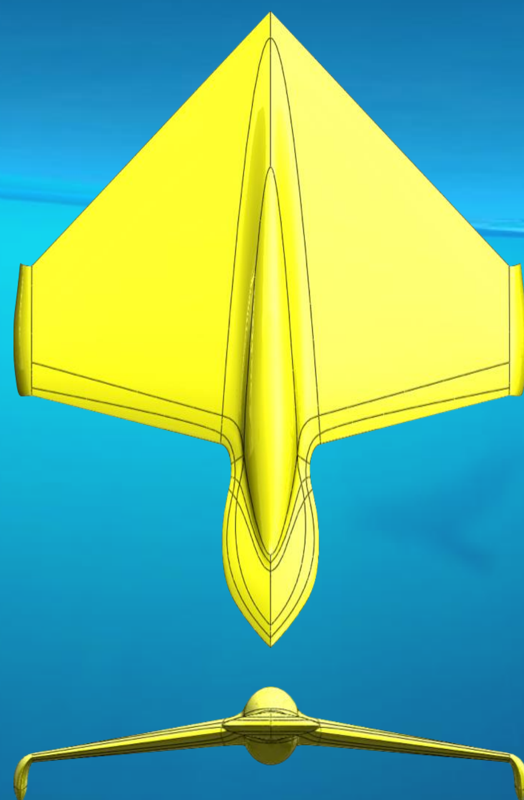
The vehicle will be a compromise there is no doubt,
but the cleanest design to conserve energy is a priority

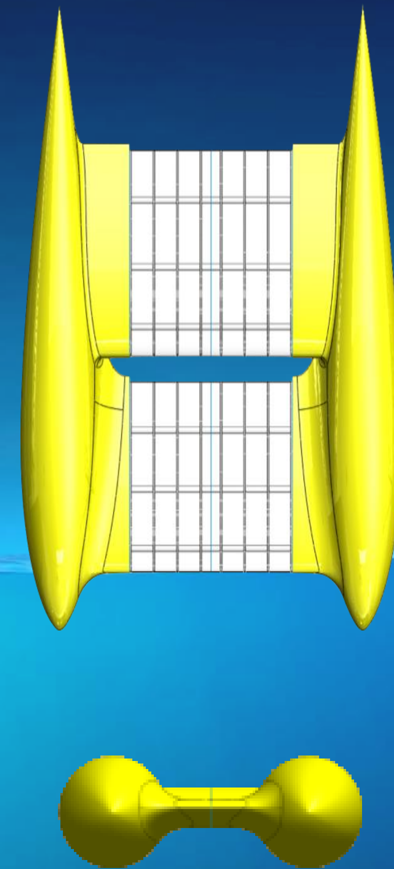
Sleek with the minimum number of surface protrusions
capable of breaking from the ocean surface

Design Studies

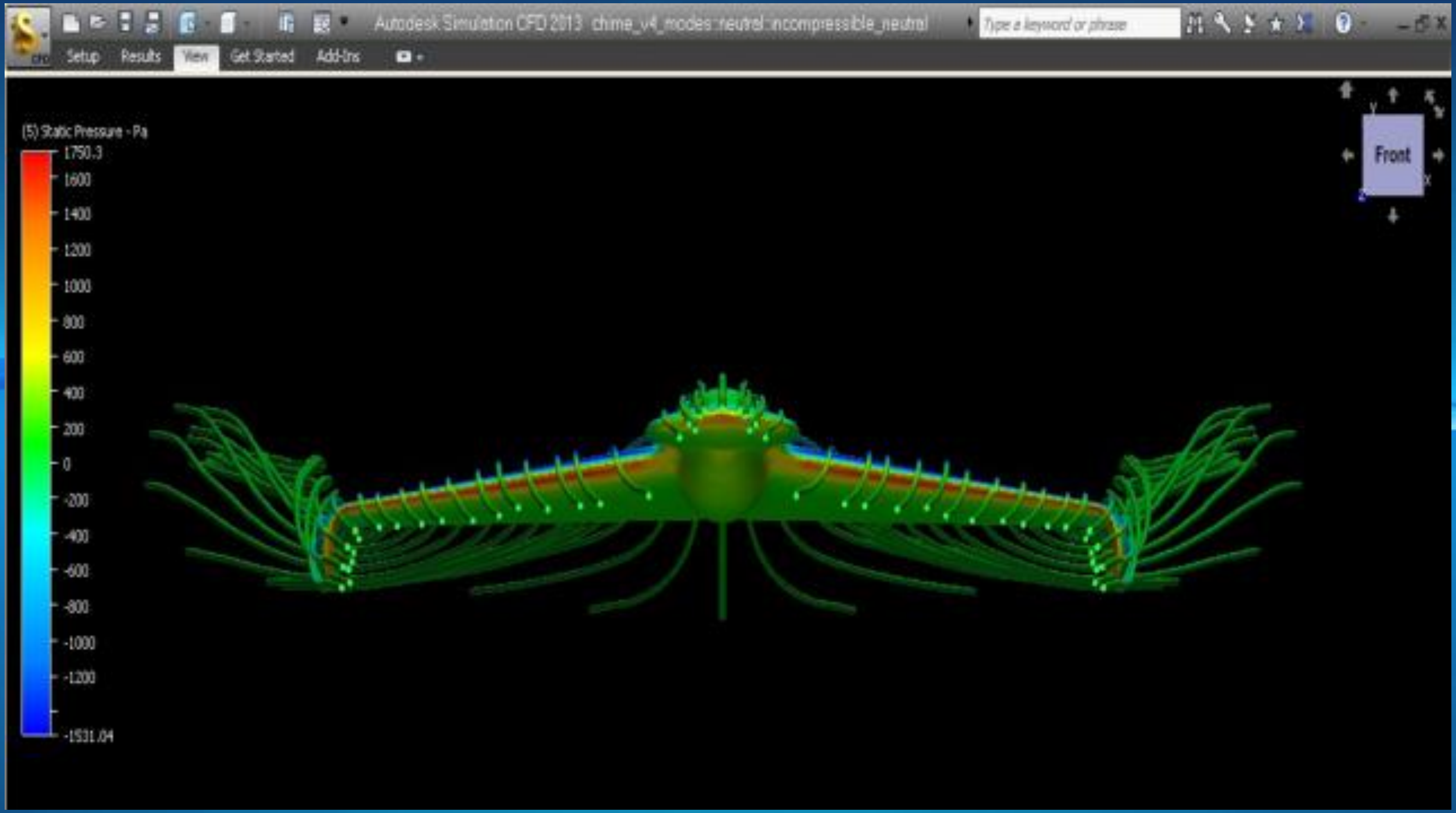
We started looking at various bodies





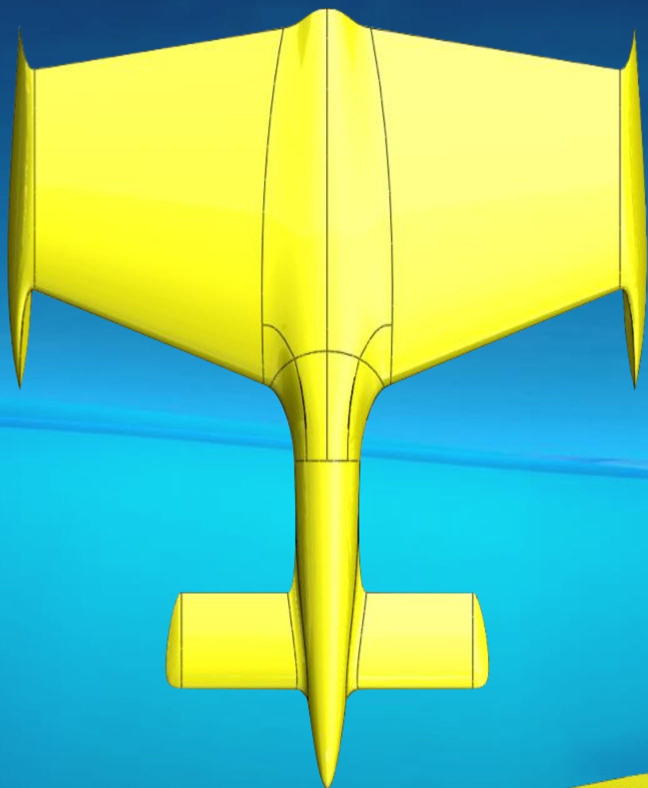


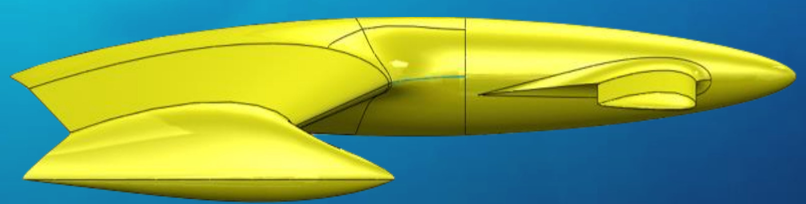
Computational Fluid Dynamics (CFD) Simulations



Design Studies

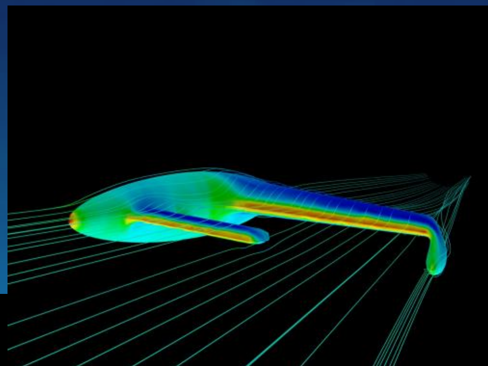
Rear wing on AUV airframe with canards



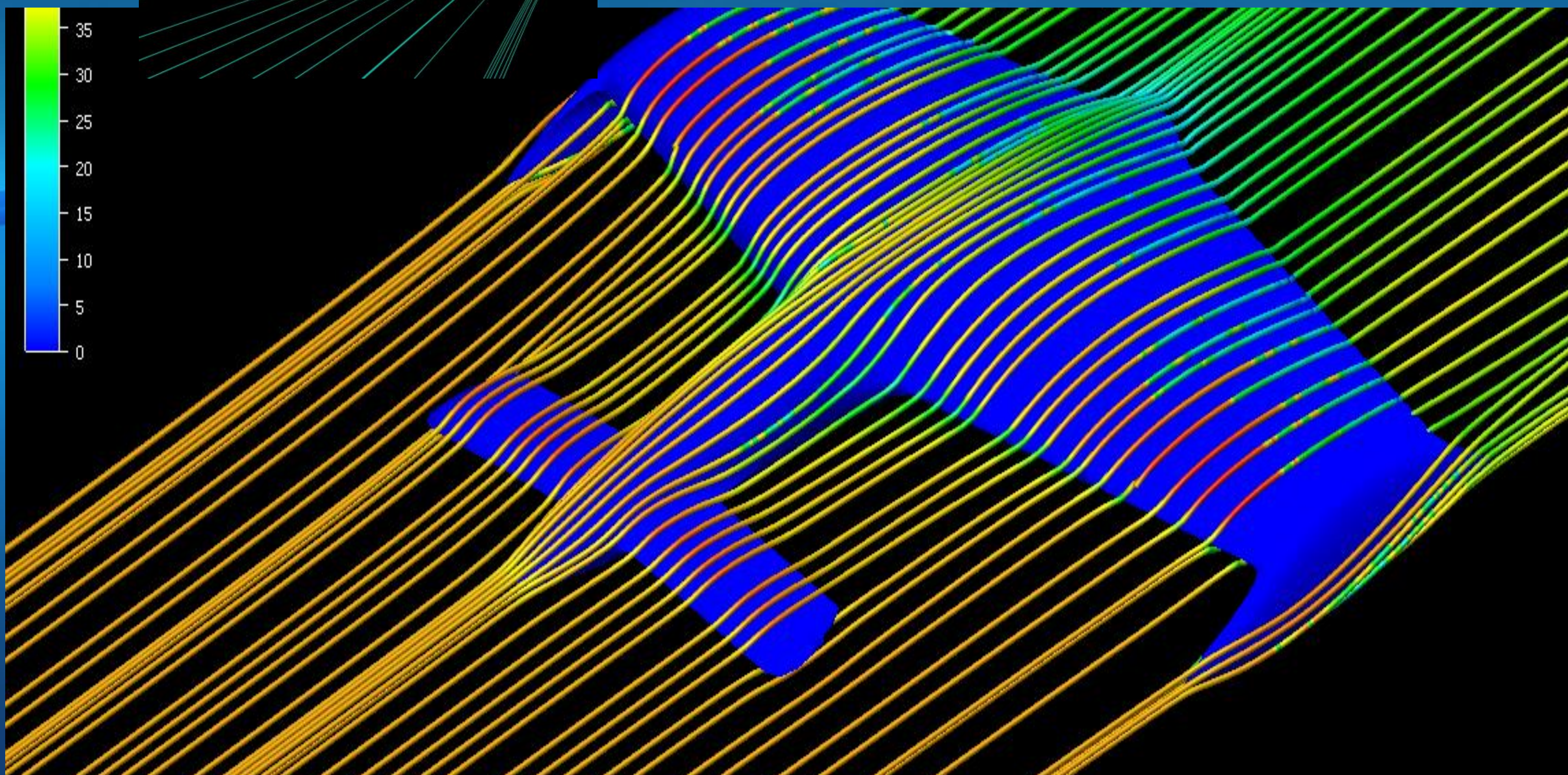


This design offered the best payload options
and in CFD modeling did very well in flight

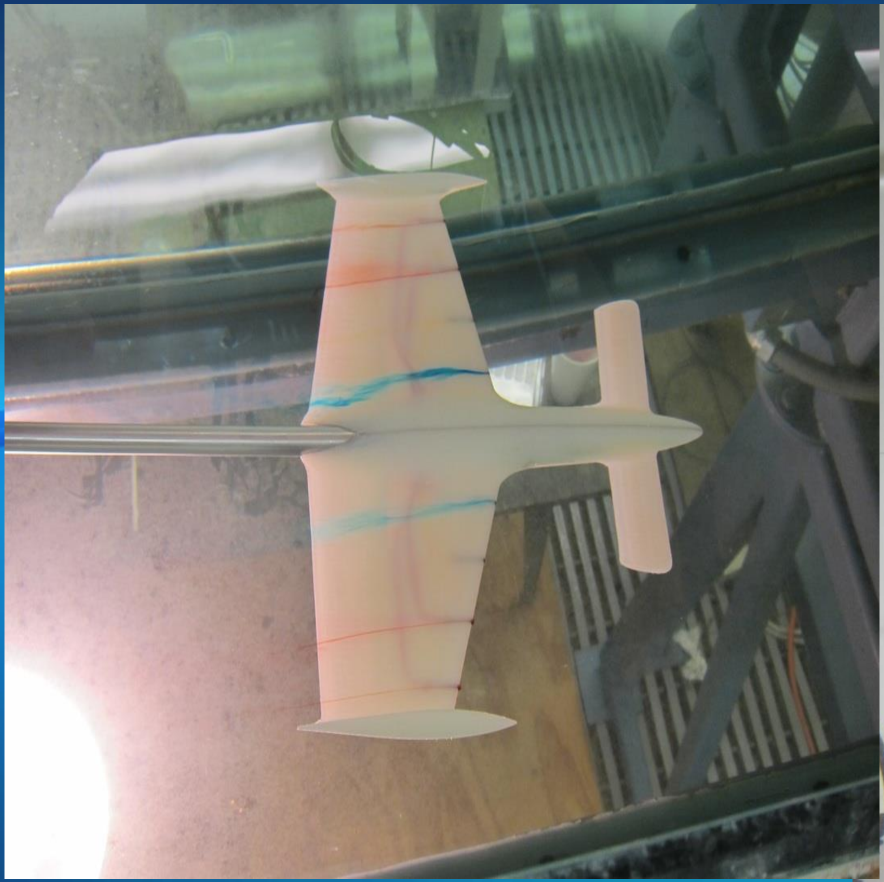
CFD Analysis

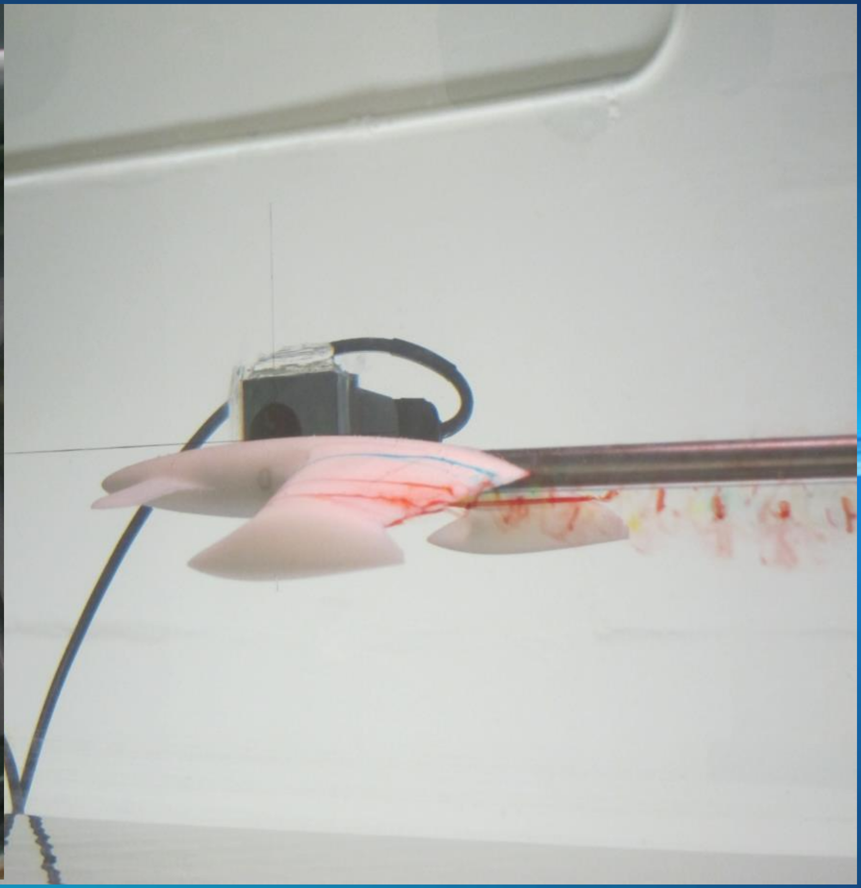


Lift and Flight Stability



Model Testing – NPS, Monterey





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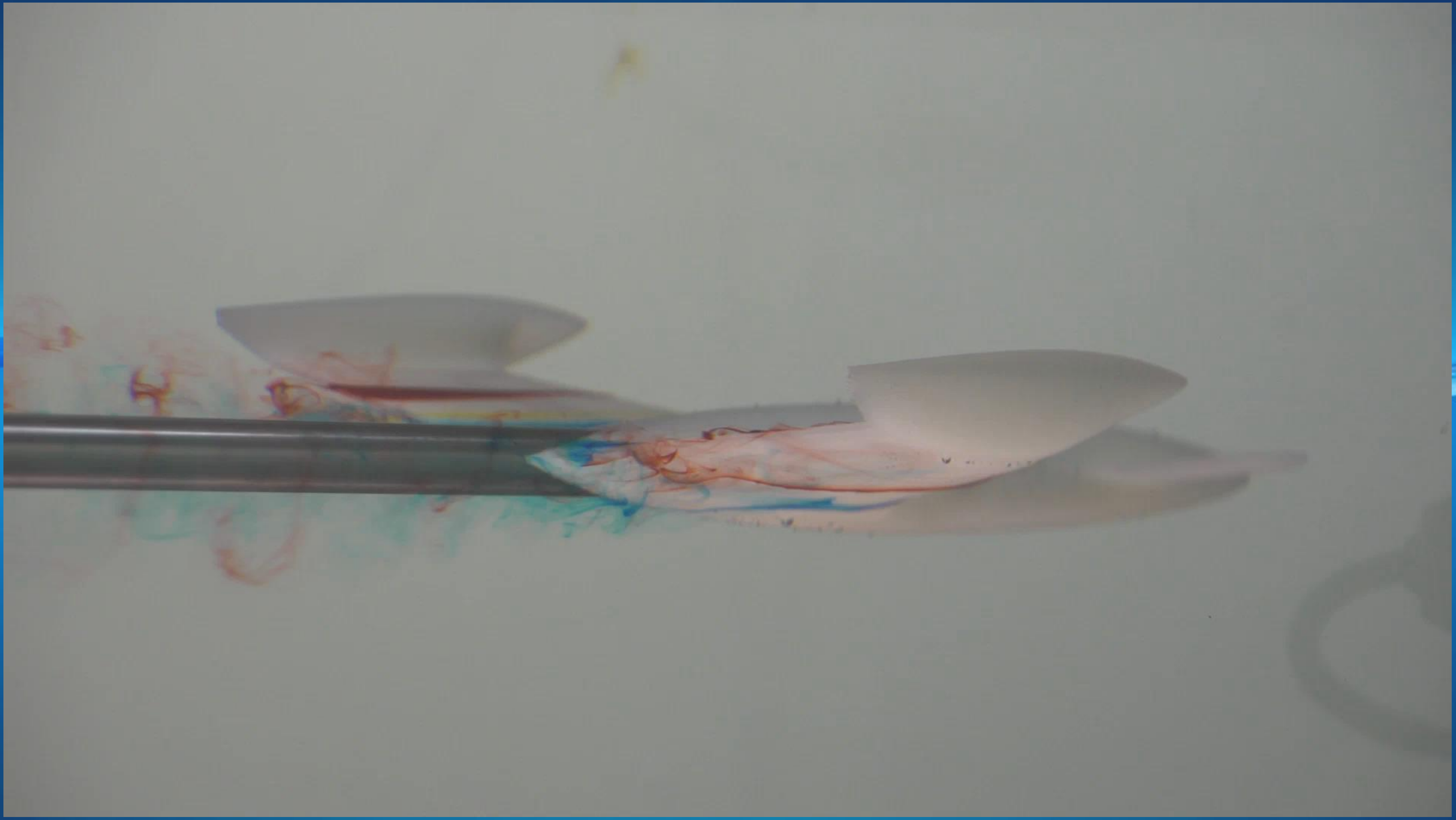


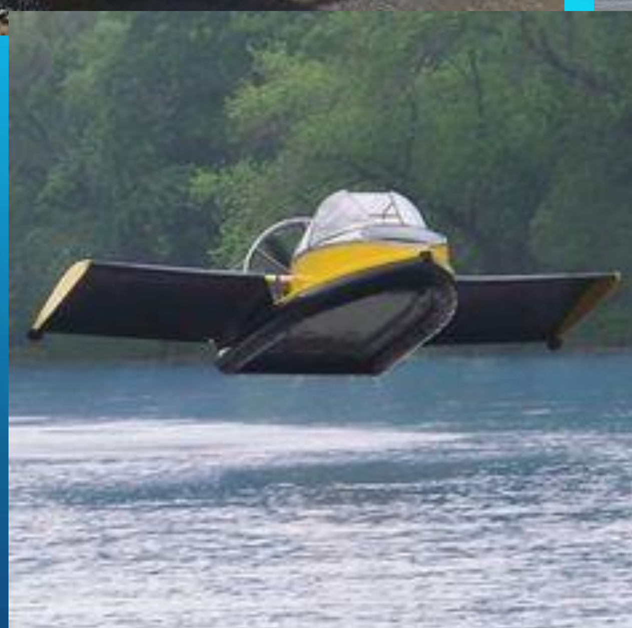
Office of Naval Research

Award: N00014-18-1-2169

Part 1 – Build an RC model of the Shearwater and demonstrate flight, landing on water, submerging and returning to flight

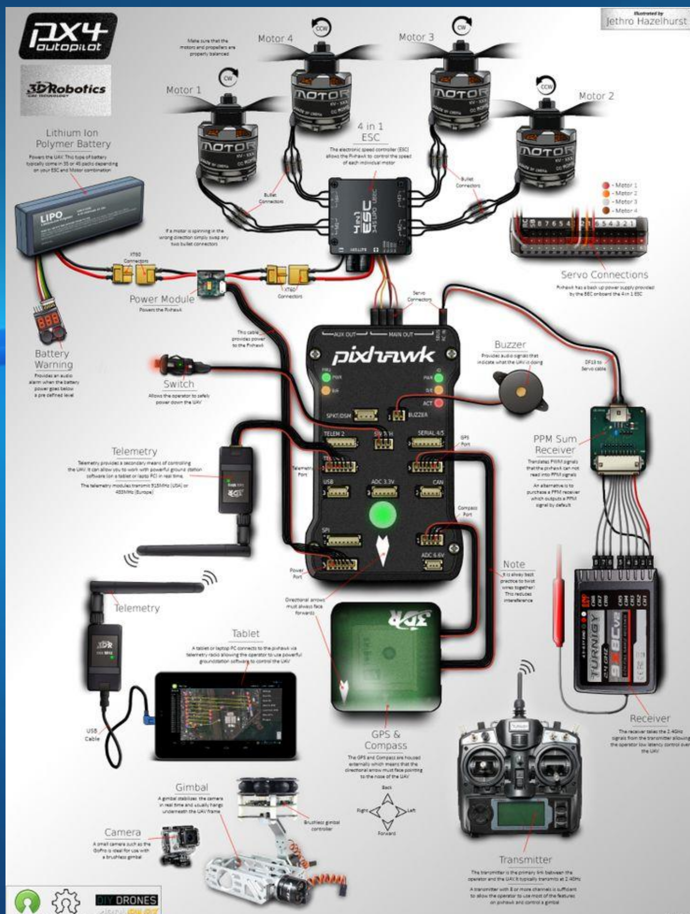
Part 2 – Do the background calculations and detail concepts for structure, energy, payload and endurance

Plans for Deployment and Recovery



Flight is possible over land and over water and we could accommodate taking off from land

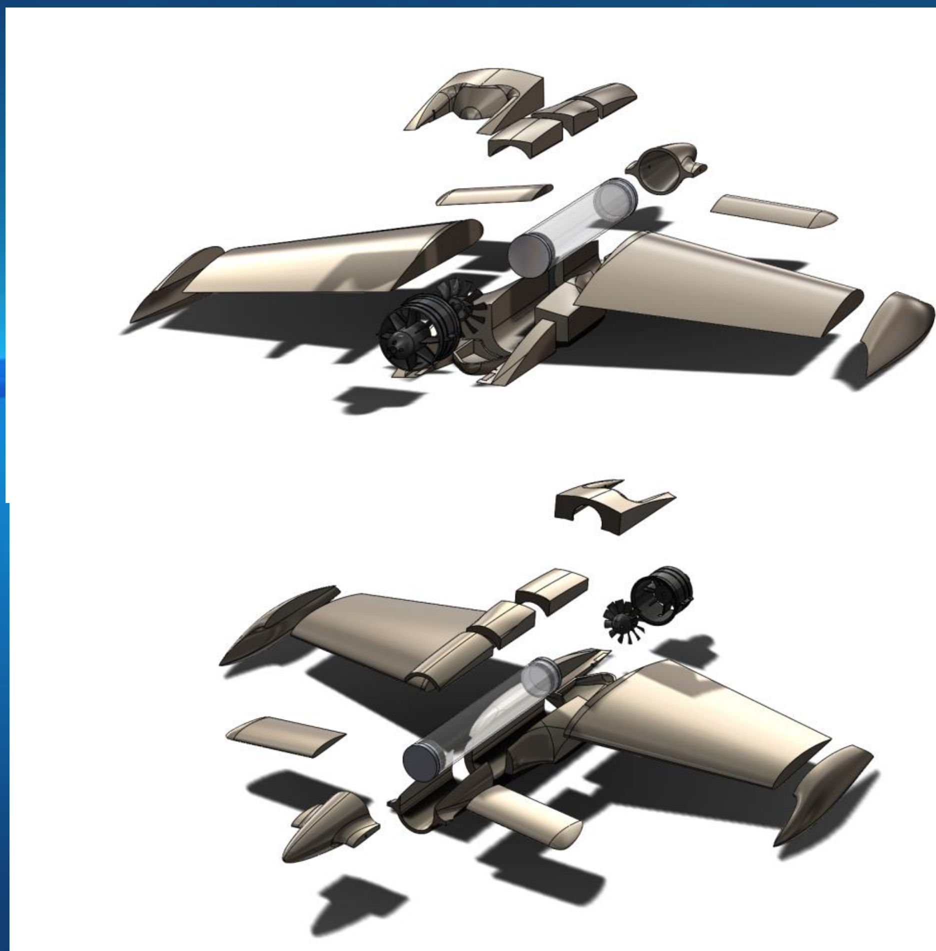
Part 1 – RC Model

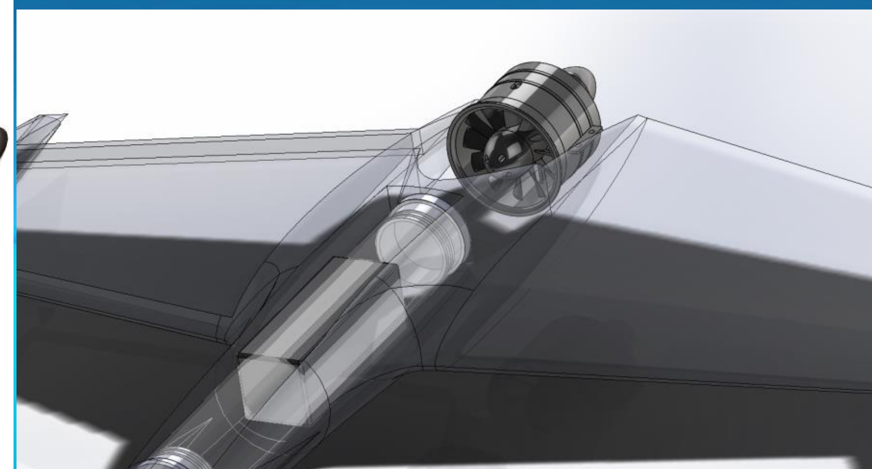


PixHawk based with a Raspberry Pi for autonomous control, brushless DC ducted fan propulsion

Flight of Early Prototype

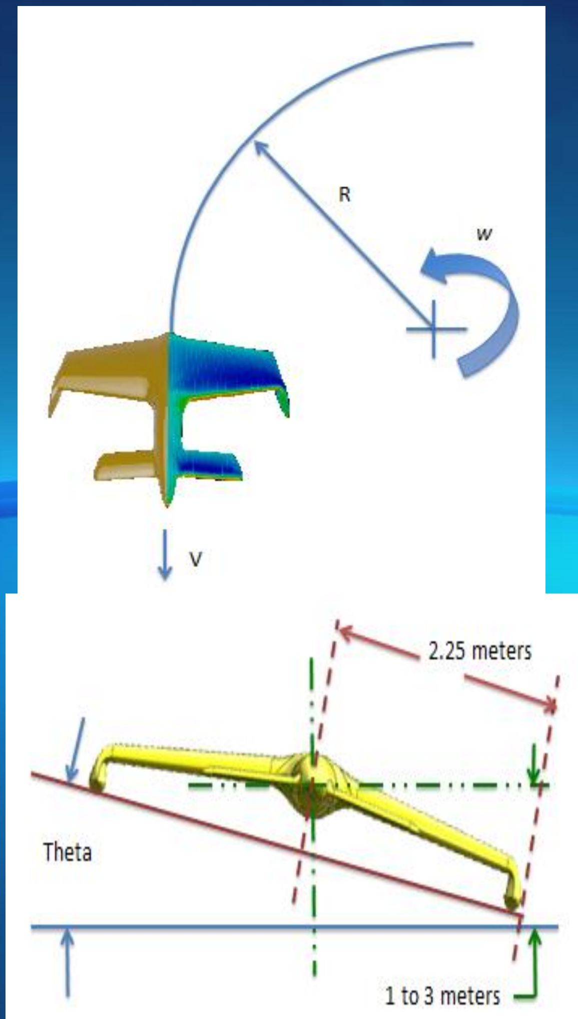
Part 1 – RC Model



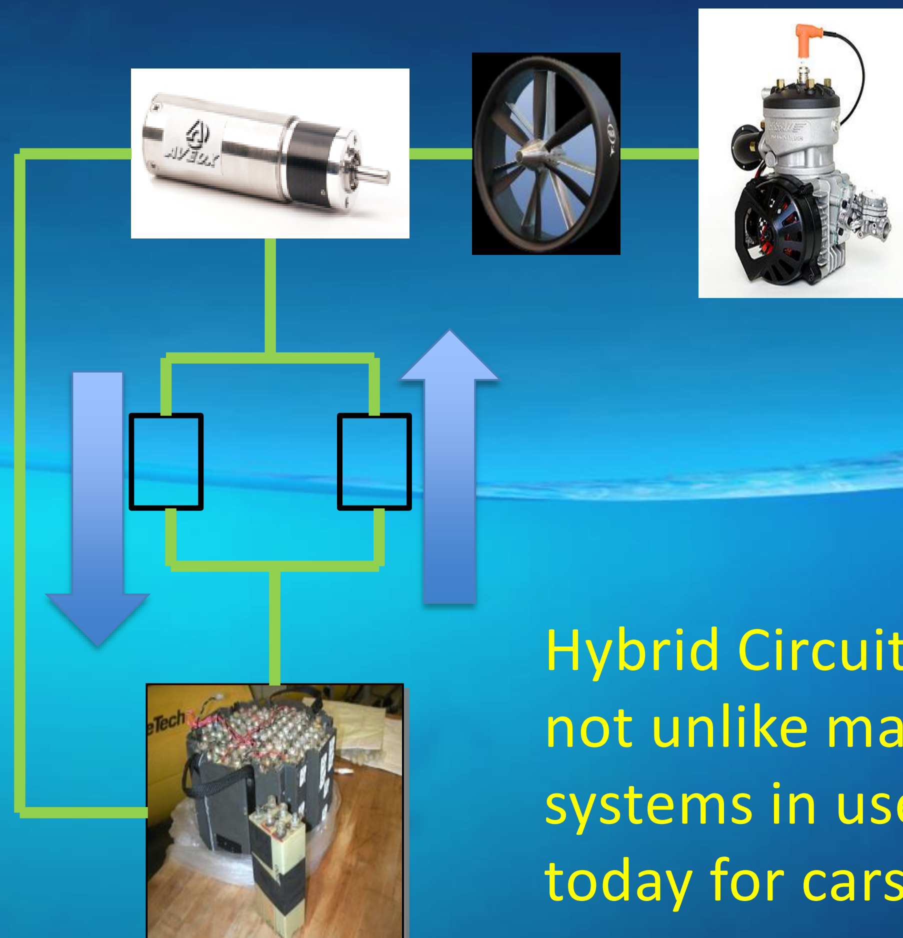


3D Printed Model Ready for Assembly

Part 2 – Performance Calcs



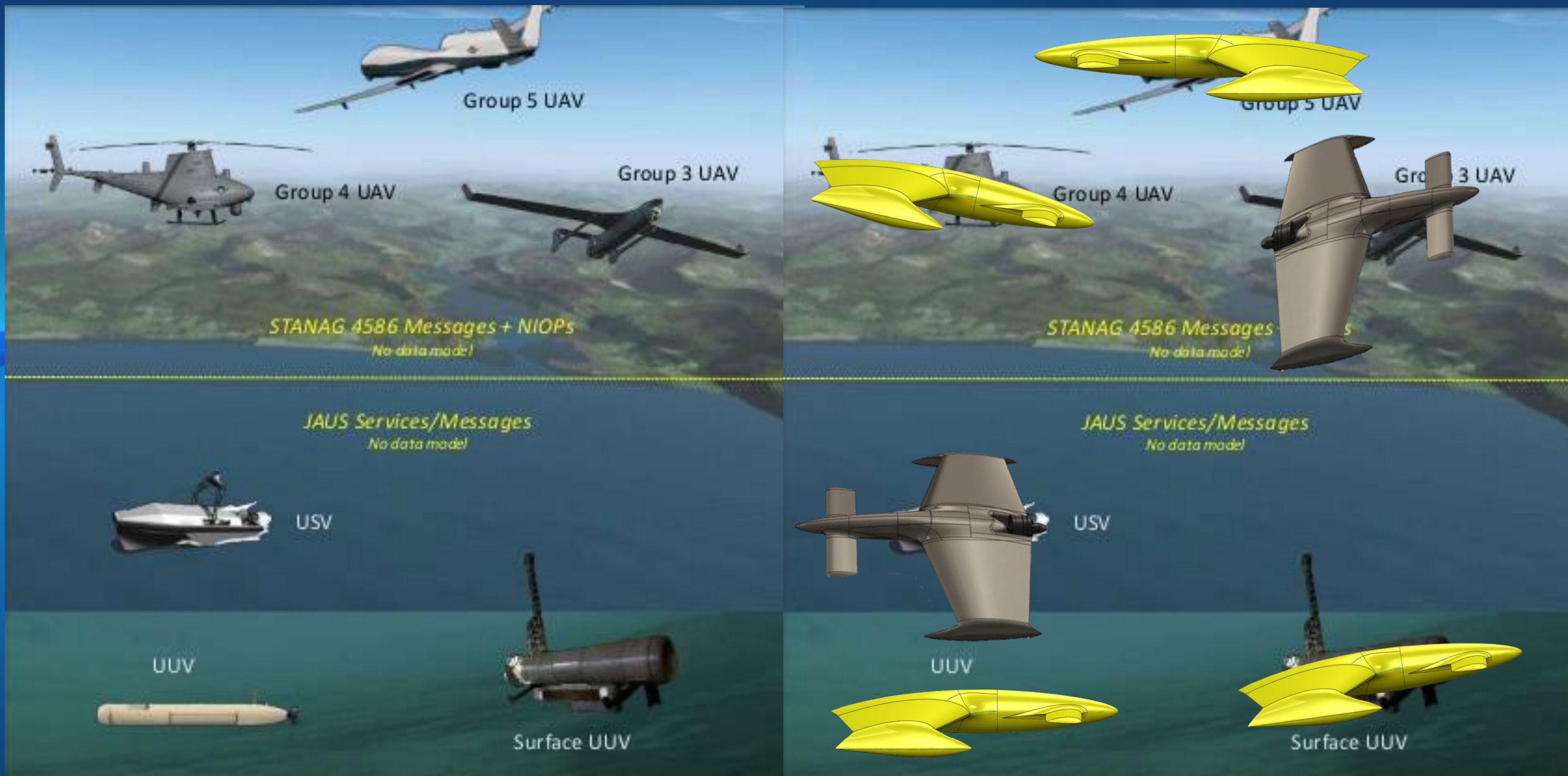
Flight Characterization



Hybrid Circuit, not unlike many systems in use today for cars.

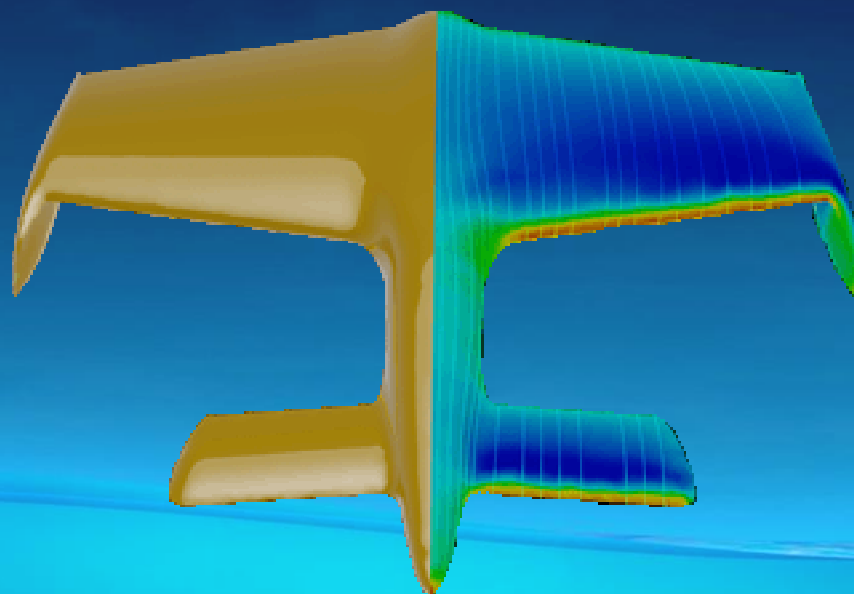
Shifting Assets to Common Platform

Integrated Heterogenous Operations **Integrated Homogeneous Operations**



Shearwater would likely not perform every function but it could do m

Acknowledgements



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Shearwater Team: Justin Tucker, Ben Erwin, Dr. Chris Kitts, Dr. Michael Neumann, Dr. Dan Deitz, and Bailey Hoover

Questions ?

MBARI – Shearwater

A heterogeneous vehicle for Autonomous Marine Observations and Operations