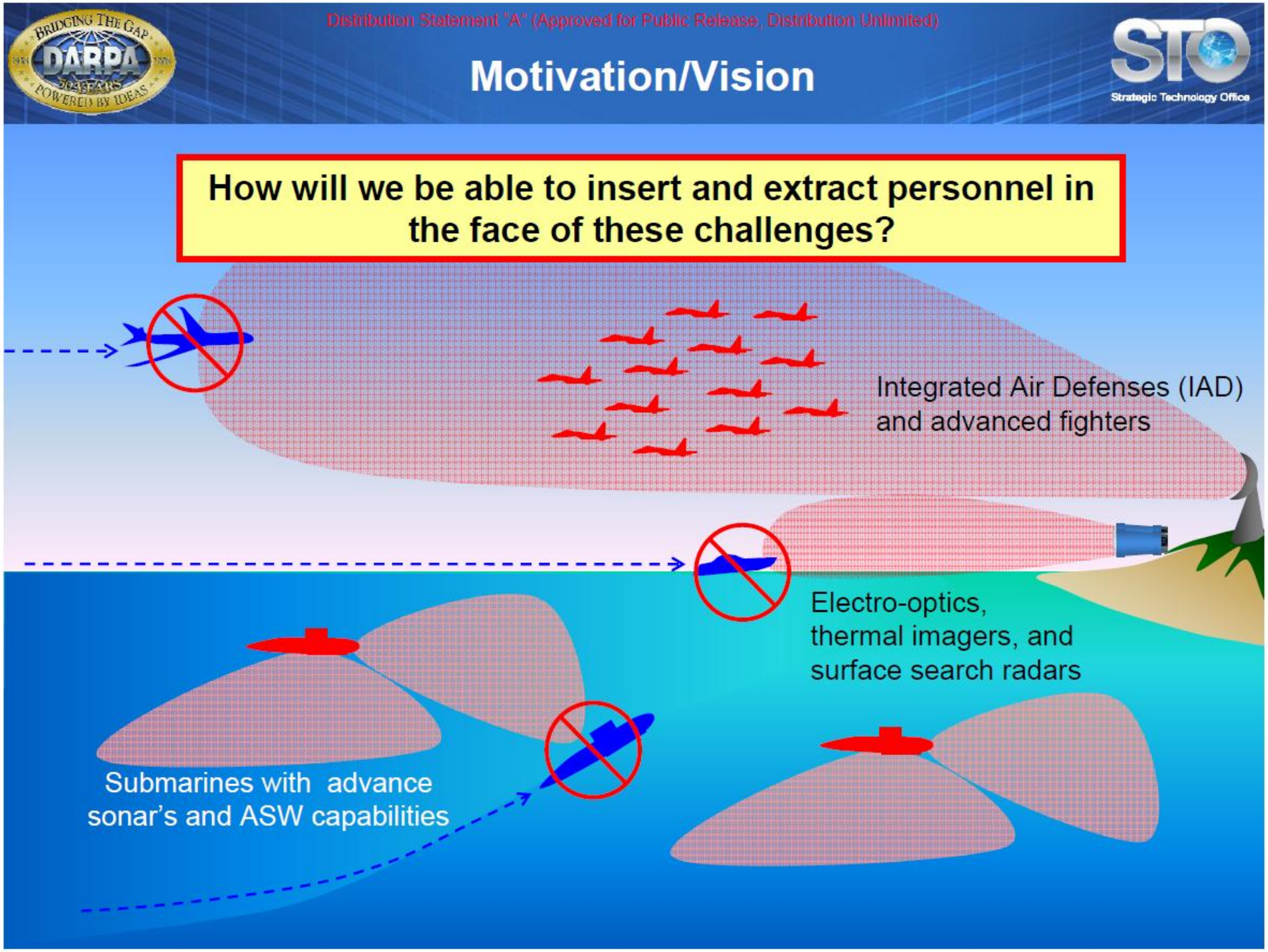
Design Project Plan

DARPA AirNautilus


Distribution Statement "A" (Approved for Public Release, Distribution Unlimited)
Motivation/Vision
How will we be able to insert and extract personnel in the face of these challenges?
Integrated Air Defenses (IAD) and advanced fighters
Electro-optics, thermal imagers, and surface search radars
Submarines with advance sonar's and ASW capabilities
Strategic Technology Office

Statement of Need

- In order to assure that the U.S. maintains its tactical advantage for future coastal insertion missions, DARPA is interested in exploring radical new technologies that can provide a game changing Department of Defense capability for inserting small teams, clandestinely, along coastal locations.

  (ref: DARPA BAA-09-06)


sonicbomb.com

Operating Enviroment

- Sea state five conditions
  - 21-25 knot winds
  - Wave height 8-12 feet
  - Average period 5.5-7 seconds
  - Average wave length 105-157.5 feet
- Submersing one atmosphere (~30 feet) to avoid detection
- Maximum altitude ~17,000 feet
- Tactical approach altitude ~100-200 feet

Requirements

- Carry up to eight personal with equipment
  - ~250 pounds per person = 2,000 pounds

- Carry an additional 2,000 pounds of cargo

- Land on water

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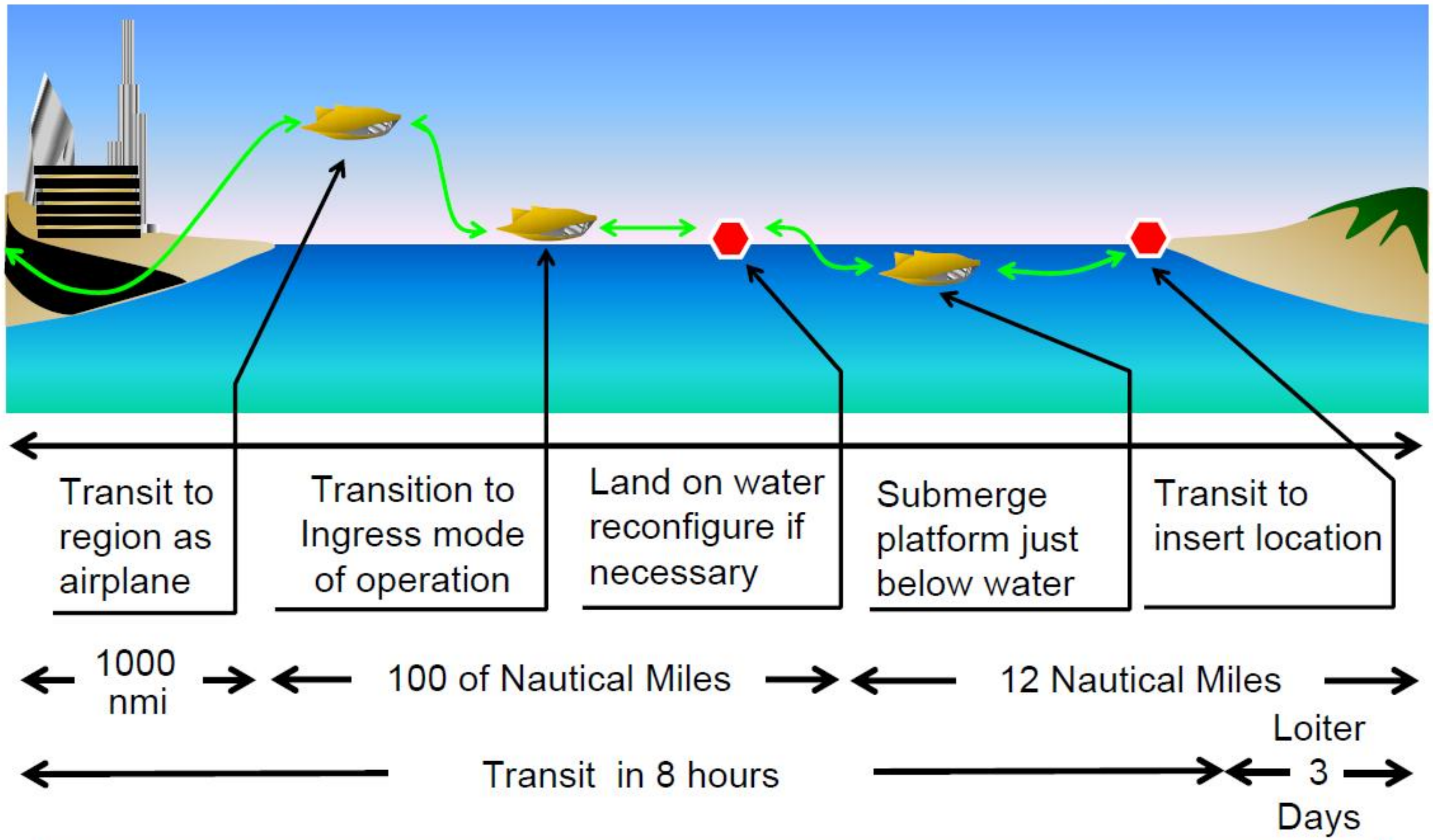
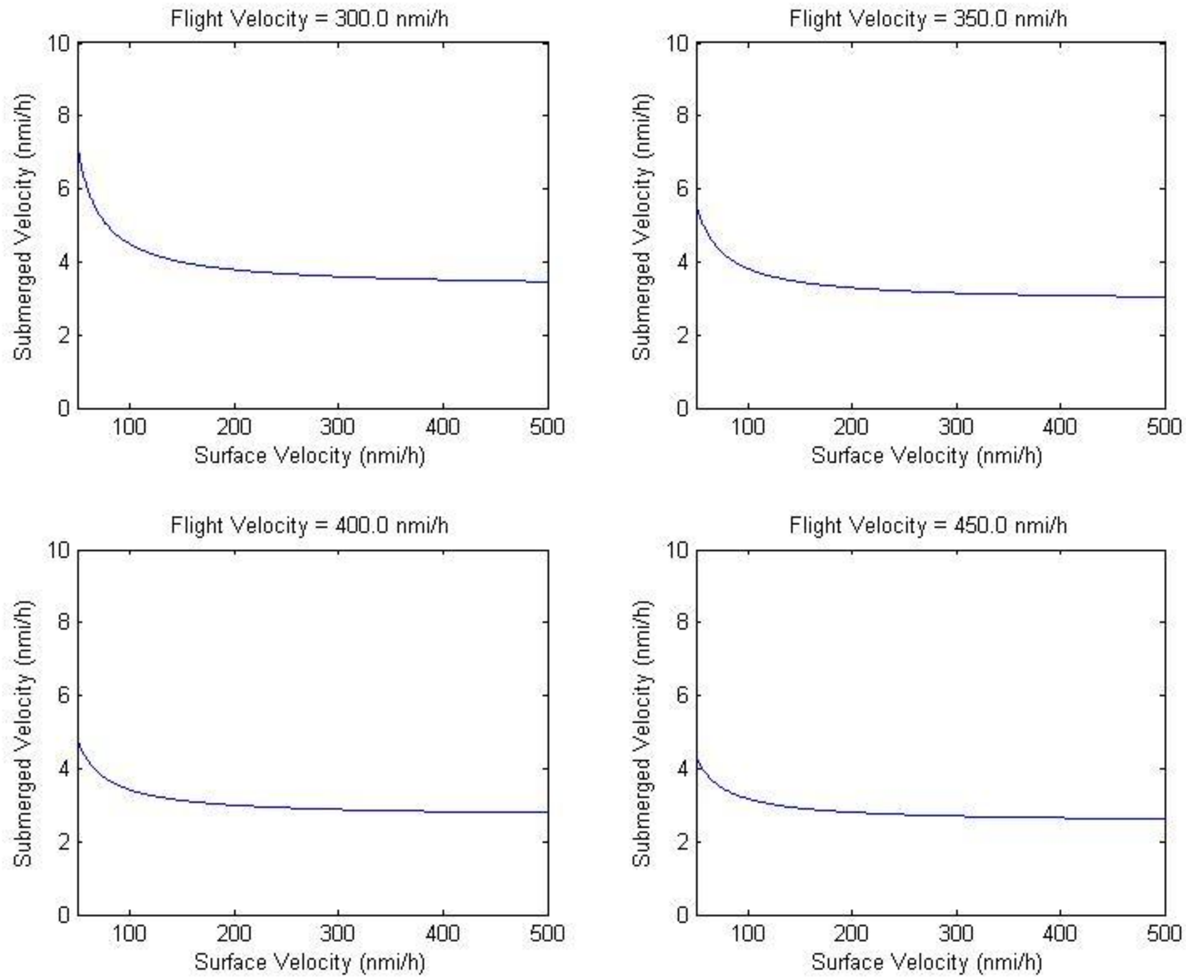
Objective System



Perform in reverse for extraction

Performance Criteria (1 hr transition)



Performance Criteria

- Similar aircraft:
  - ~1,000 nm range
  - Land on water
- Velocity in the 350–400 knot range (transonic)
- Study existing aircraft to get an initial estimate on aircraft weight and size

Existing Vehicle Study

- Bombardier 415
  - Top mounted turbo-prop
  - Lands on water
  - 1,320 nm range
  - Max takeoff weight from water: 37,850 pounds
  - Top Speed: 194 knots

Existing Vehicle Study

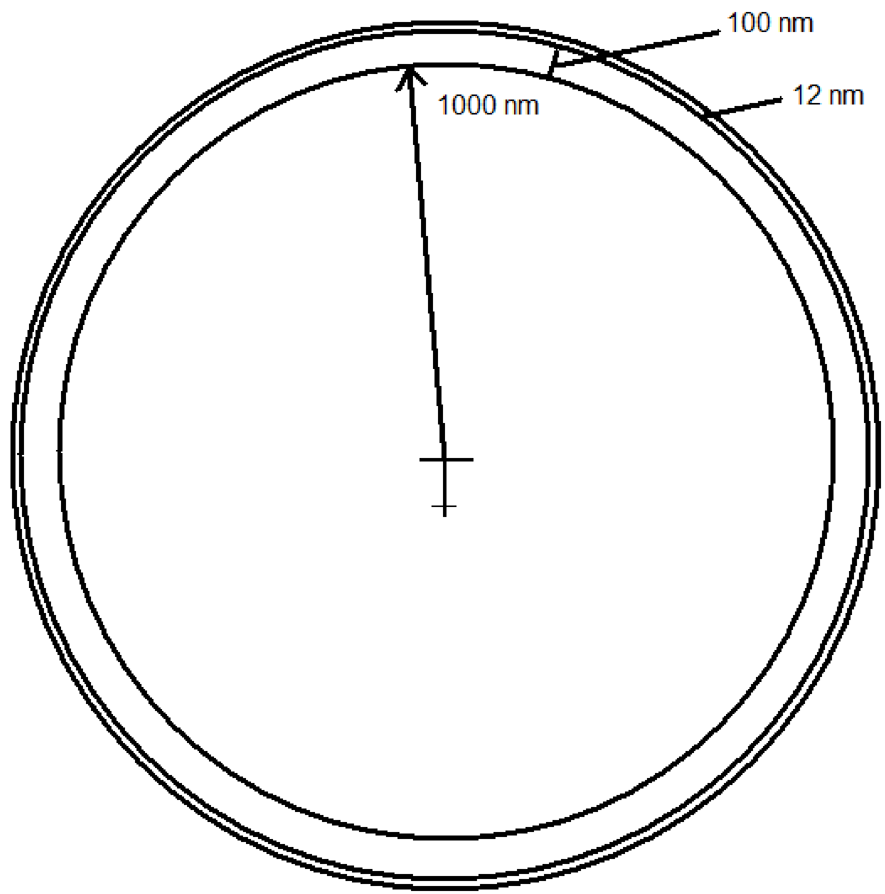
- ERJ 145
  - Dual rear mounted turbofans
  - Similar in size to Bombardier 415
  - 1,630 nm range
  - Max takeoff weight 46,500 pounds from land
  - Top Speed: 450 knots

Aircraft Conclusions

- Aircraft should be in the 40,000 to 50,000 pound range
- Wing loading = 90 $\frac{lb_f}{ft^2}$
- Two-engine configuration

Trade studies

- Will cover the following areas:
  - Flight
  - Submersion
  - Structures
  - Propulsion
  - Power



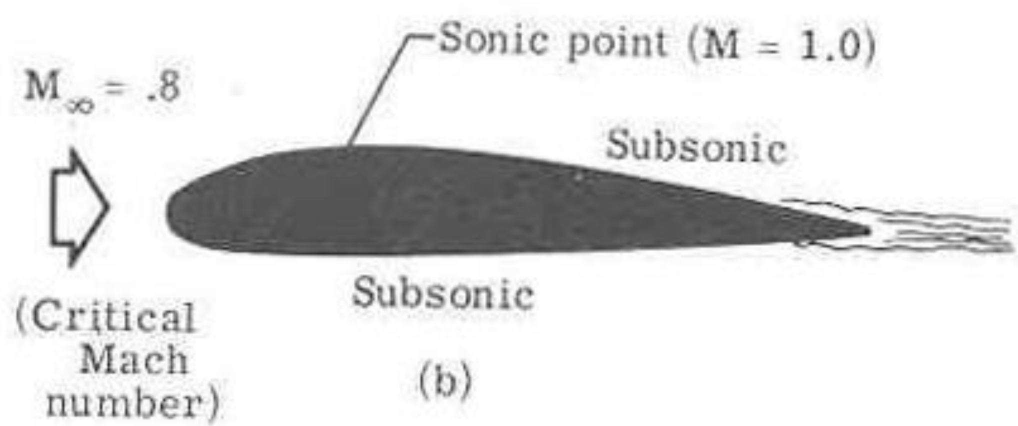
Flight

Requirements

- Velocity in the 350–400 knot range (transonic)
- Water take-off and landing using hydrofoils or body shape
- Stream-lined for a low drag profile

Transonic Velocities

- Swept wings for transonic flight and low profile while submerged
- Super-critical airfoil
- Possibly tailless



Water Take-off and Landing

- Body Landing
- Pontoon/Hydrofoil
- Canard

Submersion

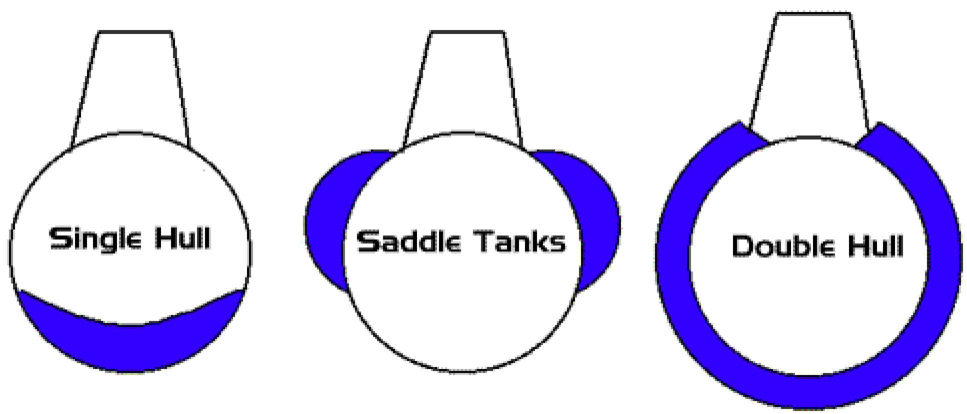
Types of Submersion

- Dynamic Diving
  - Forward force of the object along with dive planes submerses the object into the water
  - Inherently floats (positive buoyancy)
  - Used by most military submarines

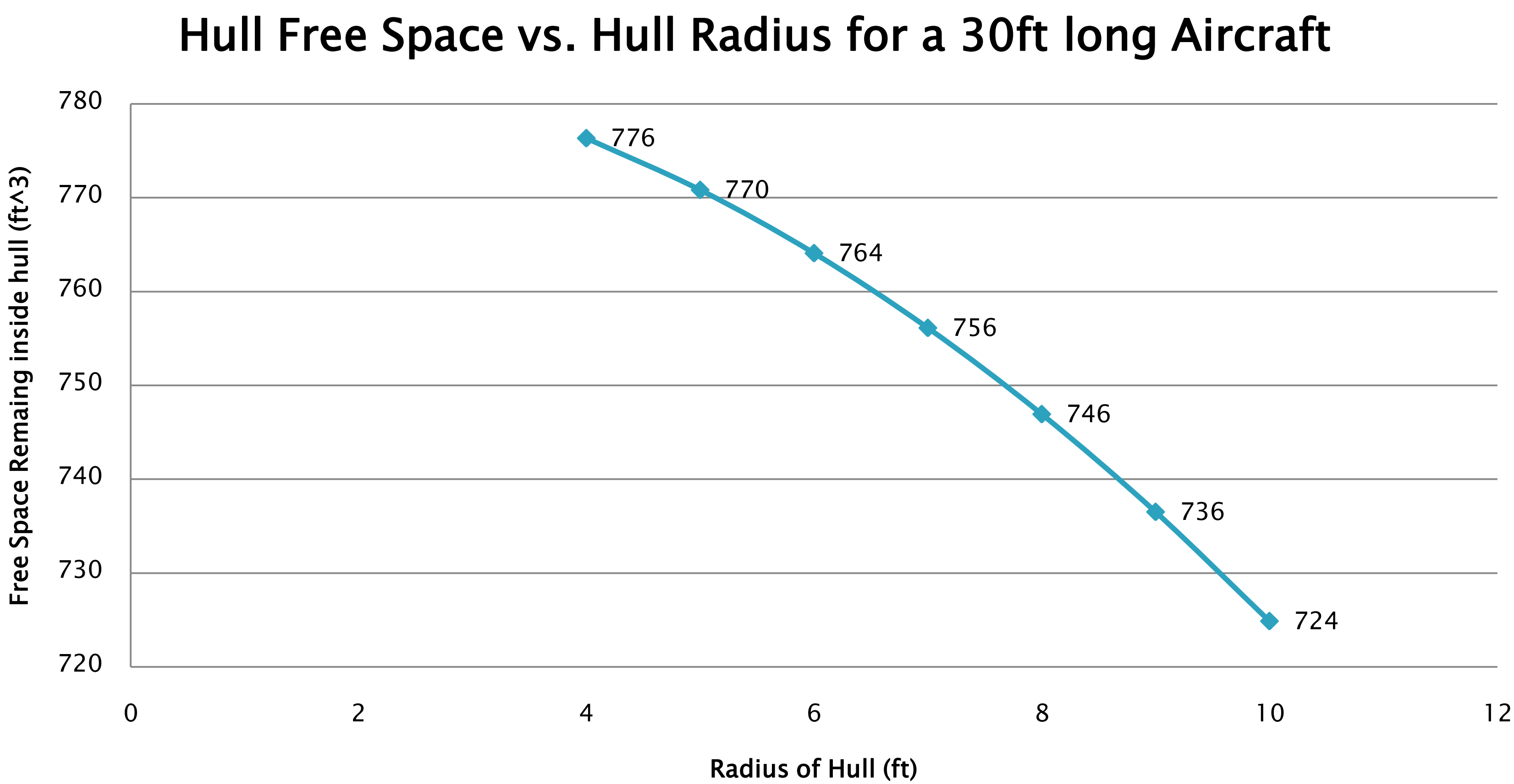
- Static Diving
  - Uses ballast tanks to take in water to change the buoyancy of the object

Static Diving

- Three ways to use ballast tanks
  - Saddle Tanks
  - Single Hull
  - Double Hull

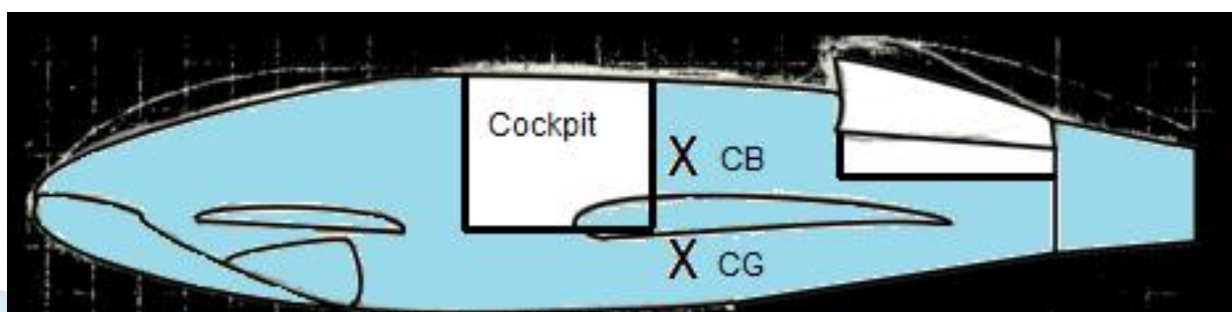


Buoyancy Caclulations



Submersion Design Concept

- Single hull 50,000 pound aircraft
- Four foot radius
- 46,530 pounds of water need to counter act buoyancy force
- Remaining volume is 776 ft^3 which is primarily for the engines and cockpit



Structure

Structure Requirements

- Must meet these requirements:
  - Single platform
  - 3 day loiter period (corrosion)
  - 1 atmosphere water pressure
  - Weight: less than ~ 12,000 lbs
  - Density: ~1,025 kg/m^3 (saltwater)

Material Options

Material	Ultimate Strength (Mpa)	Density (g/cm^3)	Strength/ Density
Steel	760	7.8	97.436
Aluminum	455	2.7	168.519
Titanium	900	4.51	199.557
Composites	5,650	1.75	3,228.571

Corrosion

- Aircraft must be resilient to saltwater corrosion over a period of ~3 days
- Engine must be isolated from salt water
- Motors and electronics must be isolated from saltwater

Corrosion continued..

- Possible materials:
  - Zinc : density: 7.14g/cm^3
  - Aluminium: density: 2.70g/cm^3
  - Stainless Steel: density: $7.48x10^{-8}$g/cm^3
  - Titanium density: 4.59g/cm^3
  - Polyester resin: density: 1.45 g/cm^3

Propulsion

Requirements

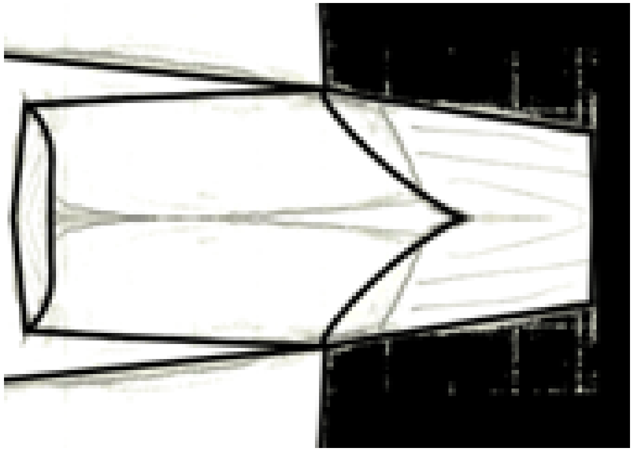
- Looked into completely electric or completely gas for both phases
  - Electric: Technology not there for large scale aircraft
  - Gas: Snorkeling and using props is not covert or efficient

- Going forward with split systems, electric for submerged, engines for flight

- Velocity needed for 1,000 nm leg and velocity needed for submerged make turbo-fans necessary for flight

In Flight

- In-board turbo-fans will decrease aircraft profile
- Single turbo-fan intake easier to seal up for submerged mode
- Rear mounted nozzles could be used for both flight and submerged legs

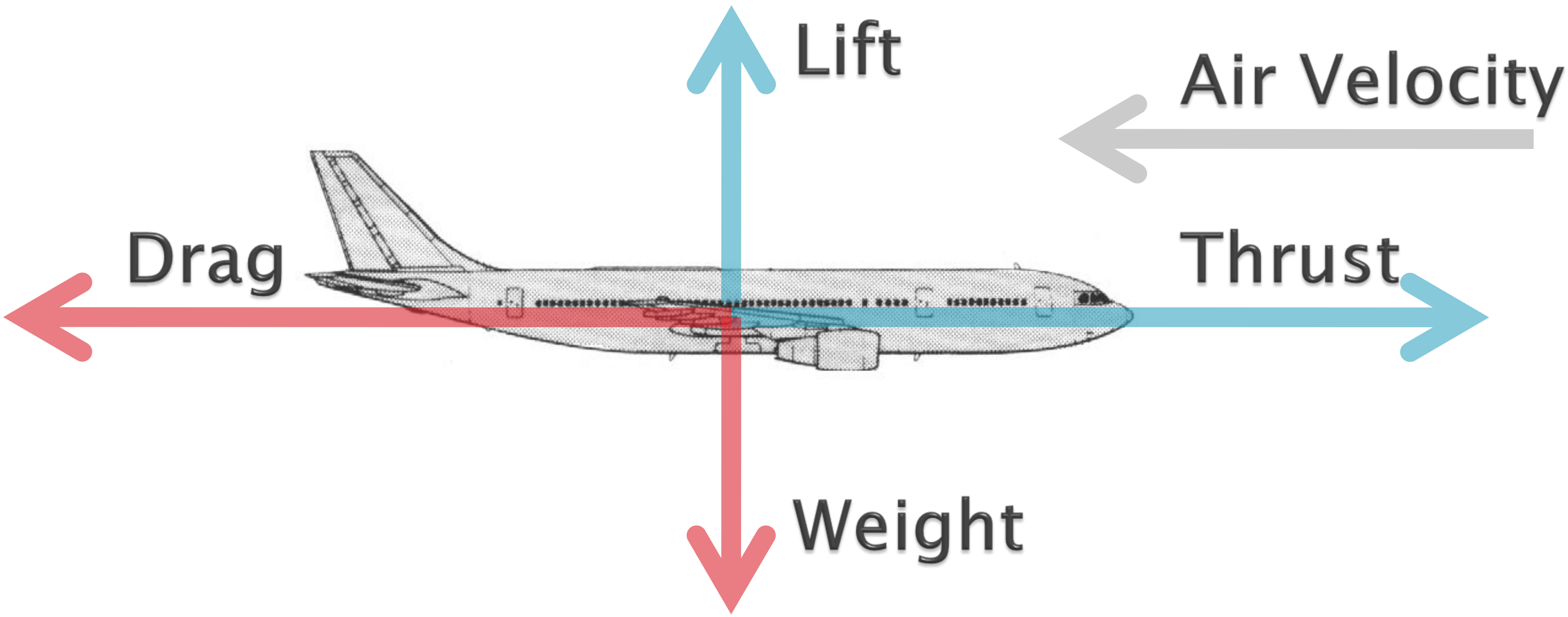


While Submerged

- Electrical motors need enough power to overcome increased drag in water
- Speed underwater will be in the 3-5 knot range
- Method of recharging batteries needed

Power

Design Trade-off study



Power = Drag*Velocity

Power

- Power Requirements
  - Assuming a 50,000 pound aircraft
  - Assuming velocity of 348 knots (ERJ-145 speed)

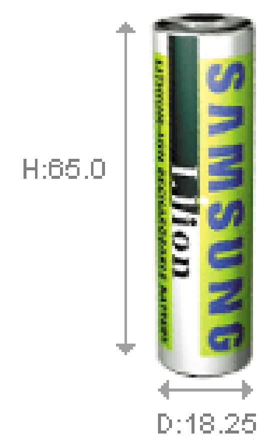
  - Power requirements for flight:12.5 MW
  - Power requirements while submerged: 23.4 kW

  - Energy requirements for flight: 129 GJ
  - Energy requirements while submerged: 2.0 MJ

Power Storage

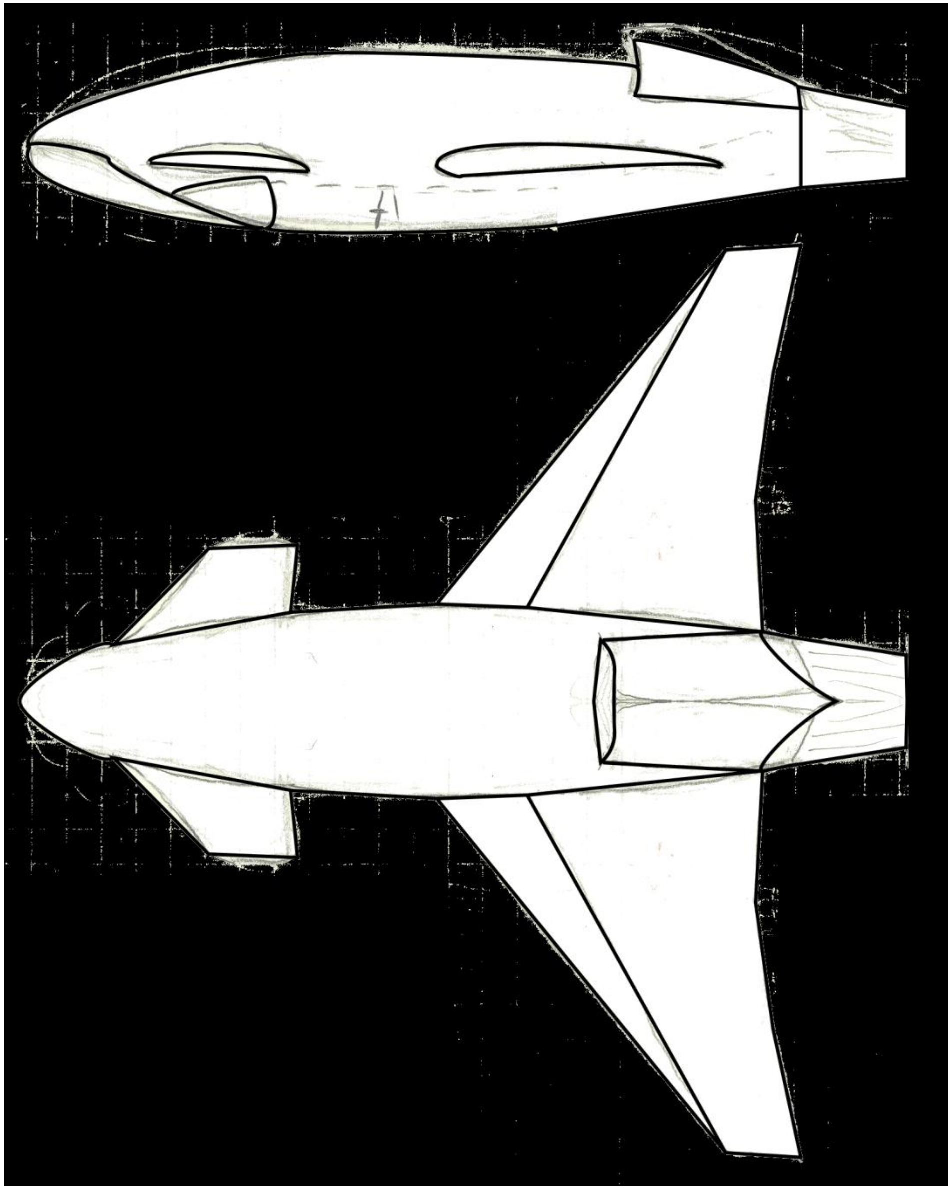
- Using power requirements flight fuel weight can be calculated:
  - 129 GJ/42.8 MJ/kg = 3,014 kg (6,640 pounds)

- The same can be done to calculate battery weight for submerged travel:
  - 50 kW(safety factor added) * 10hr(underwater both ways) = 500,000Wh
  - 3.78V*3Ah(Samsung Li-Ion Cell) = 11.34Wh
  - 500,000Wh/11.34Wh = 44,091 Cells
  - 48g/cell = 2,116kg = 4,664lbs



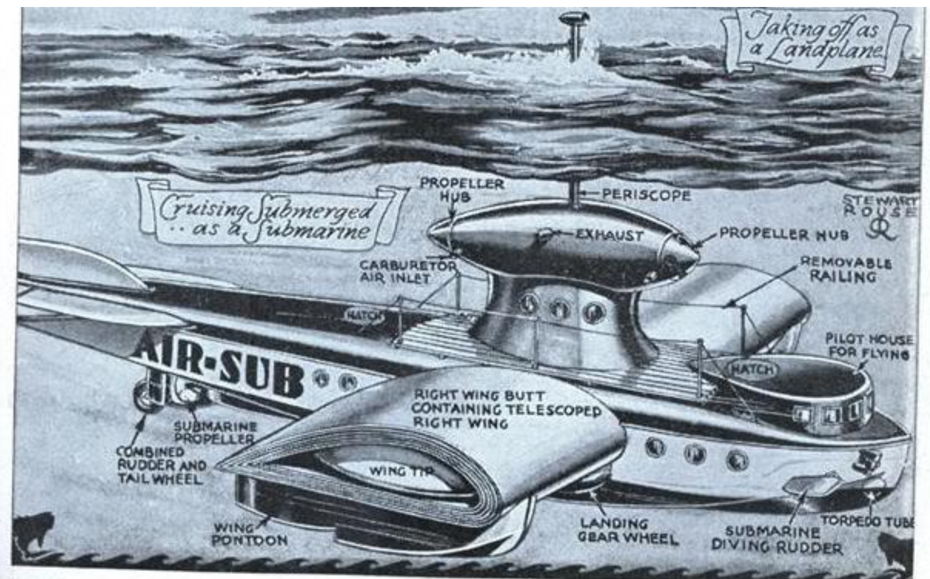
Initial Design Concept

- Rear mounted turbofans
- Dual-motor water propulsion
- Thrust vectored
- Fully electronic cockpit
- Canard for water take-off



In Progress

- Weight/density budget
- Buoyancy and Center of Mass
- Modeling:
  - Wing
  - Propeller
  - Structure
  - Electronics
  - Stability
  - Intakes/Nozzles



Amazing in the daringness of conception, and expected to be far reaching in strategical value from a military standpoint is the remarkable new submarine-amphibion airplane secretly tested by Denmark.

Inventions for September 75