Amphibious High Water Speed
Focus Area Forum

# Advanced Hull Forms/Propulsor Hydrodynamics

# Technology Area

August 27, 2015

Dr. Thomas C. Fu (Hydro IPT-Lead)
ONR Code 33
thomas.fu@navy.mil

Mr. Alan Becnel
NSWCCD

# Agenda

- Operational Environment
- Lessons Learned
- Current State-of-the-Art
- Technology Challenges

# Operational Environment

- Operate in open seas, in salt and fresh water, characterized by a Significant Wave Height (SWH) of up to and including 0.91 meters (3 feet) Objective (middle sea state 3)
- Longer stand-off distances are required to protect ships from shore based threats - higher water speeds required to be effective at longer ranges
- Transit seaward and shoreward in a surf zone characterized by Significant Breaker Height (SBH) of up to and including 1.8 m (6 ft) Objective
- Launch from the well deck of Amphibious ships while the ship is underway at up to 39 kph (21 knots), and in all headings, in seas up to 0.91 meters (3 feet) SWH

Sea conditions based on ACV 1.1 System Specification.
ACV 2.0 may be different when finalized

# EFV Lessons Learned

- Requirement for high water speed has had a significant impact on vehicle cost and complexity
  - Flat bow extension used to add length, lift and provide vehicle trim.
  - Bow foldable to reduce impact to ground mobility & fit on ship
  - Chines wider than vehicle to provide more lift and reduce wetted area of vehicle
  - Transom Flap needed to control vehicle trim through “hump”
  - Flat bottom used to maximize vehicle lift
  - Tracks retracted and covered to reduce drag
    - Retractable suspension – high cost system
- System complexity and harsh operating environment can lead to lower reliability
- Ride quality and motions limited EFV top speed and restricted some headings in Objective seas

# EFV Lessons Learned

## Power Requirement Mismatch

- 2,750 HP needed to get a 78,200 lb vehicle on plane for high water speed operation
- Less than 900 HP needed for land mission
- Vehicle Operation: Land 90%, Water 10%

## Weight Control

- Exotic/expensive materials were required to stay within 78,200 lb limit
- Unable to have ***all*** desired capabilities
- Difficult to maintain sufficient growth margin
  - Reserve buoyancy

# Current State of the Art

- EFV– 25+ knot armored semi-planing vehicle
  - Most amphibious vehicles are displacement vehicles limited to about 6 knots
- Investigations with extending bow and aft hydrofoil show promise for enabling lower drag up to 22 knots

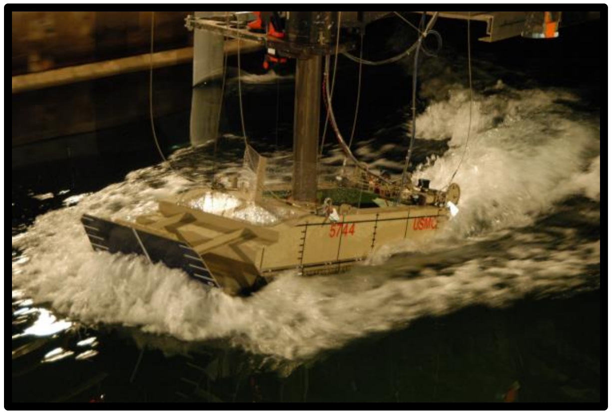
VIDEO

# Technology Challenges

Challenge: Affordably reduce hydrodynamic drag and increase propulsive efficiency while minimizing impact to ACV or host ship capabilities.

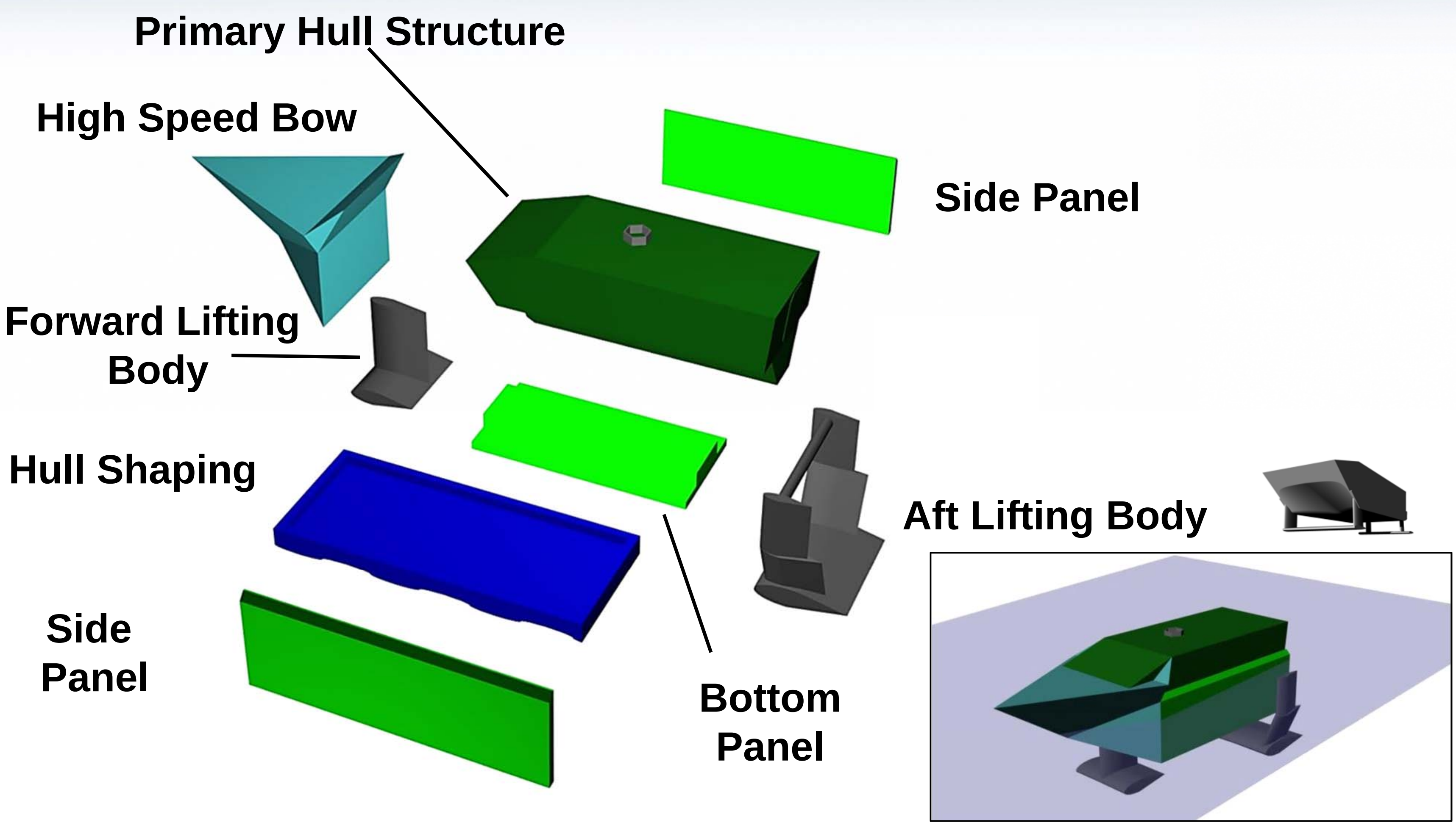
## Hull form

- Innovative hull shapes, hydrofoils, fairings, inflatables and appendages that maximize lift, decrease drag and reduce complexity and have minimal impact (weight, stowage space etc.)
- Ability to fit on and launch from ships, operate through surf zone, on land and return back to ship



# Technology Challenges

Challenge: Affordably reduce hydrodynamic drag and increase propulsive efficiency while minimizing impact to ACV or host ship capabilities.



# Technology Challenges

Challenge: Affordably reduce hydrodynamic drag and increase propulsive efficiency while minimizing impact to ACV or host ship capabilities.

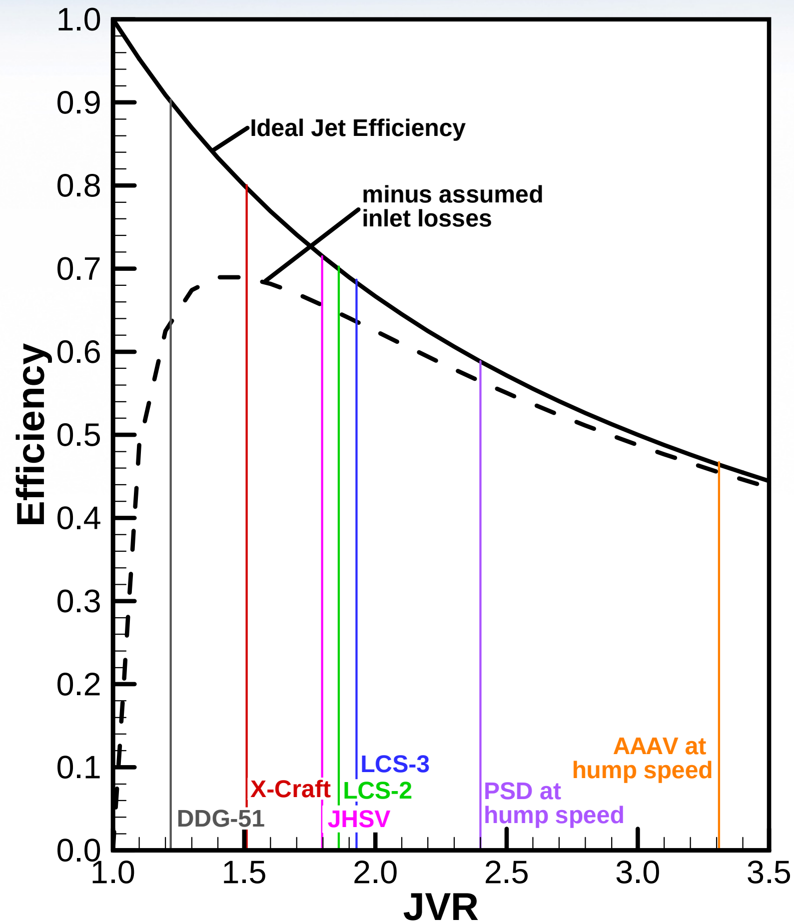
**Propulsor**

- Alternate affordable ways to provide power for the water mission (Only 10% of mission but requires 3X power)
  - External/alternate power & booster technology
- Improved efficiency
- Water jet or other propulsor alternatives
- Propulsor options must be examined with a systems integration approach to ensure they are compatible with the power system without introducing more losses

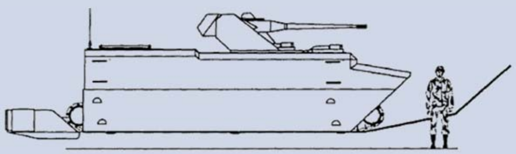
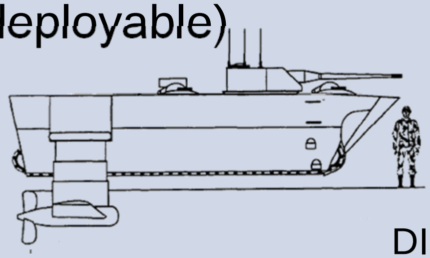
# Technology Challenges

**Importance of Flow Area**

- Jet Velocity Ratio (JVR=Vjet/Vship) sets an upper bound on efficiency
- Since *Thrust* = $\rho Q V_s (JVR-1)$, the flow rate (Q) must be increased to reduce JVR for a given thrust
- To increase the flow rate (without cavitation), the flow area must be increased
- Limited space available within the existing envelope
- Deployable propulsors stow in/on the body and open/expand when needed
- *Need to find space for bigger propulsors*



# Technology Challenges

| Boost Propulsion Type | Pros | Cons |
|---|---|---|
| Waterjet Pumps (internal or deployable)  | • Acceleration<br>• Low speed steering<br>• Minimal exposure of moving parts | • Low speed efficiency<br>• Complex steering hardware |
| Ducted Propellers (deployable)  | • Acceleration<br>• Moving parts protected | • Difficult to stow |
| Open Propellers (deployable)  | • Higher efficiency<br>• Potential folding design for compact stowage | • Acceleration<br>• Exposed moving parts |

# Technology Challenges

- Drag reduction
  - AAAV (EFV) Lessons learned:

*"Minimizing drag is of prime concern since added drag means more thrust is required to achieve desired speed which means more installed horsepower is required which means vehicle weight must increase which means more drag and so on and so on."*



Hoyt, J.G., et al. "Test and Evaluation of the Propulsion System Demonstrator." CRDKNSWC/HD-1452-01, June 1994