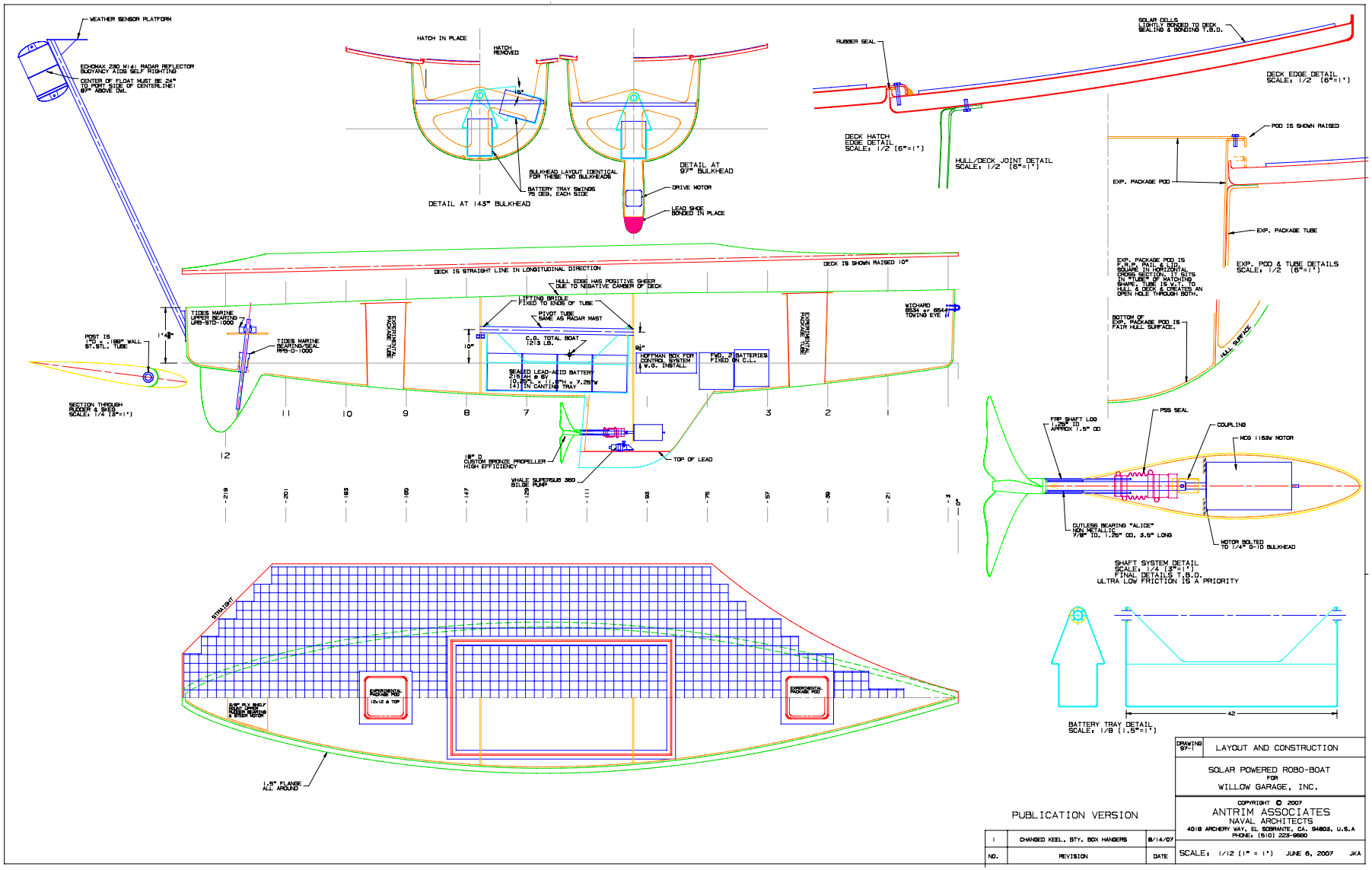
The Overboat



Where did it come from?

Willow Garage

- Menlo Park-based Engineering Research Facility
- Specializes in robotics
- Promotes open-source

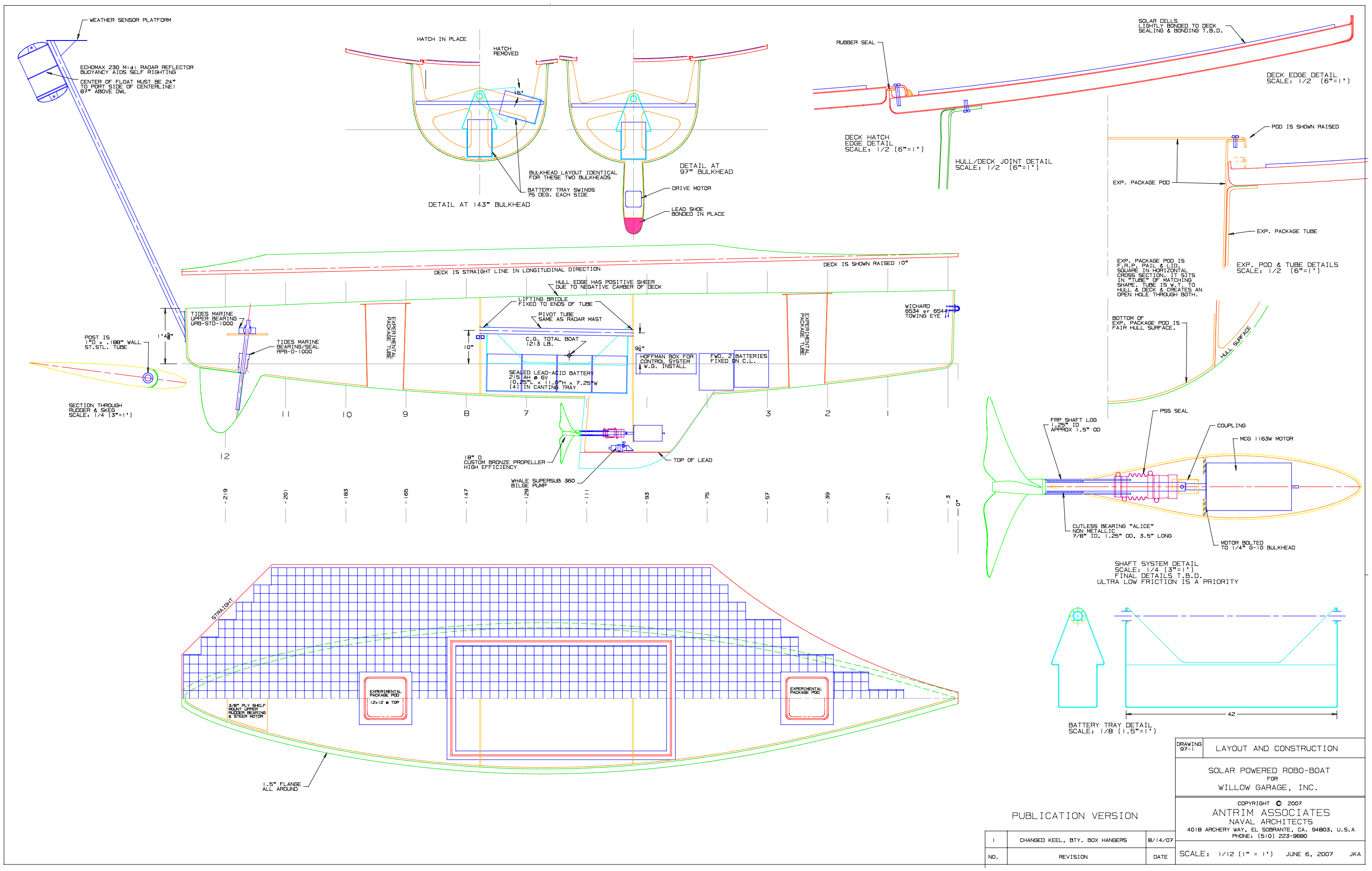
Why is it here?

- Reprioritization
- Test bed for sensors, software
- And because the Overbot was lonely…

What's it look like?

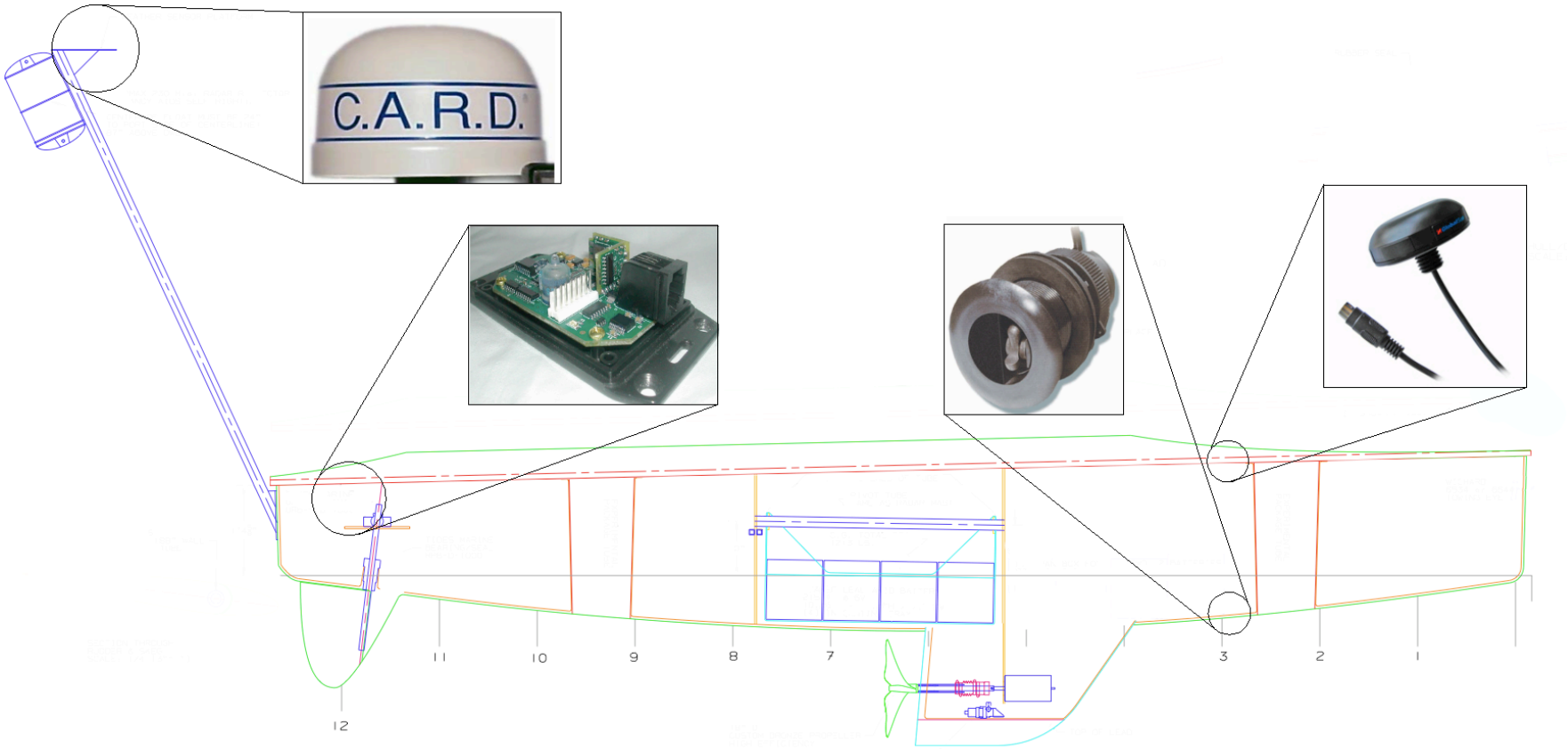
- 13' surface vehicle
- Bright yellow
- 4 motors
- 6 batteries
- 412 PV cells
- Mobile ballast

Internals

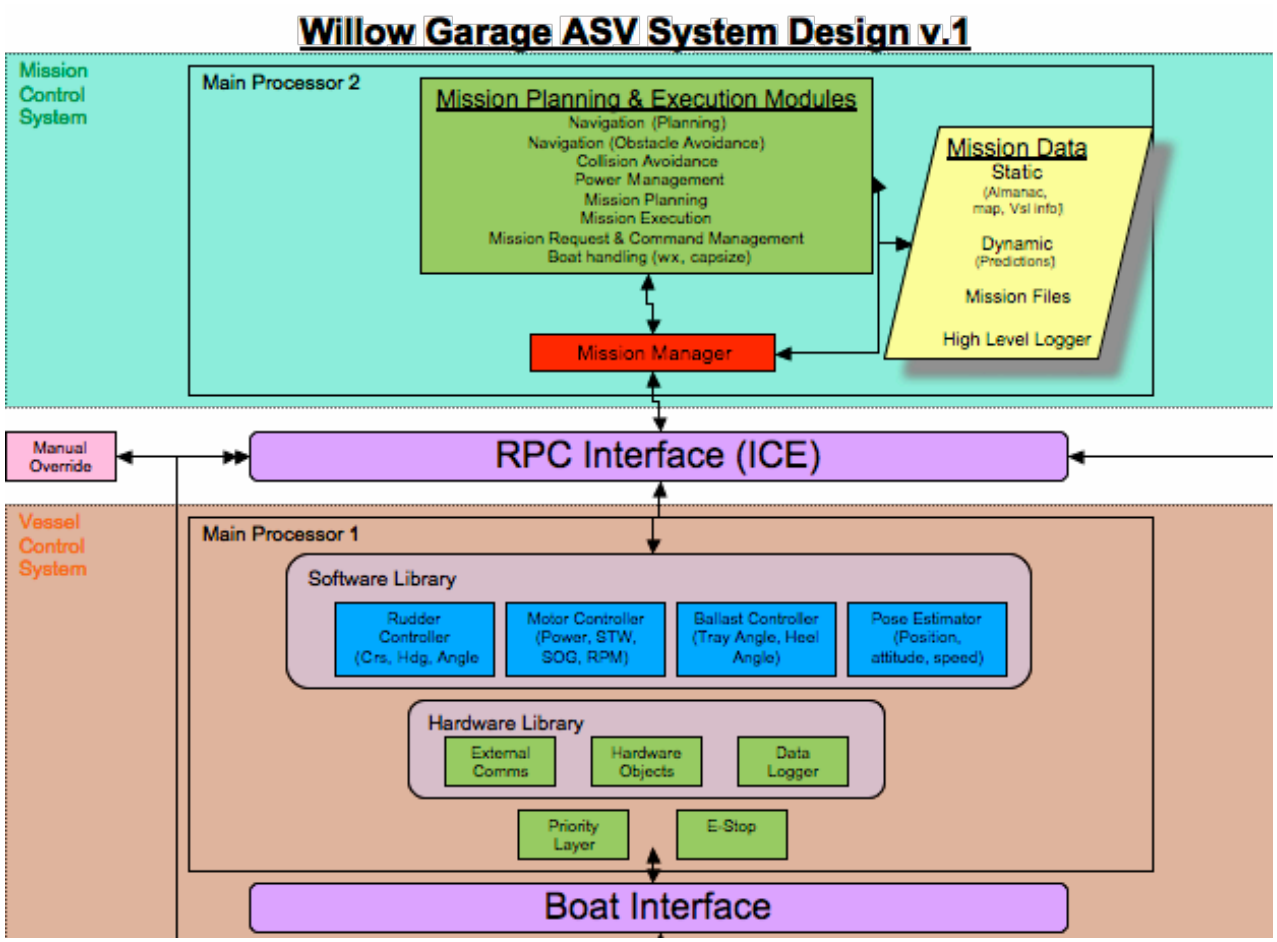


WEATHER SENSOR PLATFORM
ECHOMAX 230 Midi RADAR REFLECTOR
BUOYANCY AIDS SELF RIGHTING
CENTER OF FLOAT MUST BE 24" TO PORT SIDE OF CENTERLINE! 87" ABOVE DWL
HATCH IN PLACE
HATCH REMOVED
15°
BULKHEAD LAYOUT IDENTICAL FOR THESE TWO BULKHEADS
BATTERY TRAY SWINGS 75 DEG. EACH SIDE
DETAIL AT 143" BULKHEAD
DETAIL AT 97" BULKHEAD
DRIVE MOTOR
LEAD SHOE BONDED IN PLACE
DECK IS STRAIGHT LINE IN LONGITUDINAL DIRECTION
HULL EDGE HAS POSITIVE SHEER DUE TO NEGATIVE CAMBER OF DECK
DECK IS SHOWN RAISED 10"
RUBBER SEAL
SOLAR CELLS LIGHTLY BONDED TO DECK SEALING & BONDING T.B.D.
DECK EDGE DETAIL SCALE: 1/2 (6"=1')
DECK HATCH EDGE DETAIL SCALE: 1/2 (6"=1')
HULL/DECK JOINT DETAIL SCALE: 1/2 (6"=1')
POD IS SHOWN RAISED
EXP. PACKAGE POD
EXP. PACKAGE TUBE
EXP. POD & TUBE DETAILS SCALE: 1/2 (6"=1')
HULL SURFACE
PSS SEAL
COUPLING
MCG 1163W MOTOR
FRP SHAFT LOG
SHAFT SYSTEM DETAIL SCALE: 1/4 (3"=1') FINAL DETAILS T.B.D. ULTRA LOW FRICTION IS A PRIORITY
C.G. TOTAL BOAT
SEALED LEAD-ACID BATTERY
TOP OF LEAD
WHALE SUPERSUB 350 BILGE PUMP
SECTION THROUGH RUDDER & SKEG SCALE: 1/4 (3"=1')
STRAIGHT
1.5" FLANGE ALL AROUND
42
BATTERY TRAY DETAIL SCALE: 1/8 (1.5"=1')
DRAWING 97-1
LAYOUT AND CONSTRUCTION
SOLAR POWERED ROBO-BOAT
FOR
WILLOW GARAGE, INC.
COPYRIGHT © 2007
ANTRIM ASSOCIATES
NAVAL ARCHITECTS
4018 ARCHERY WAY, EL SOBRANTE, CA. 94803, U.S.A
PHONE: (510) 223-9680
PUBLICATION VERSION
1 CHANGED KEEL, BTY. BOX HANGERS 8/14/07
NO. REVISION DATE
SCALE: 1/12 (1" = 1') JUNE 6, 2007 JKA

Sensors



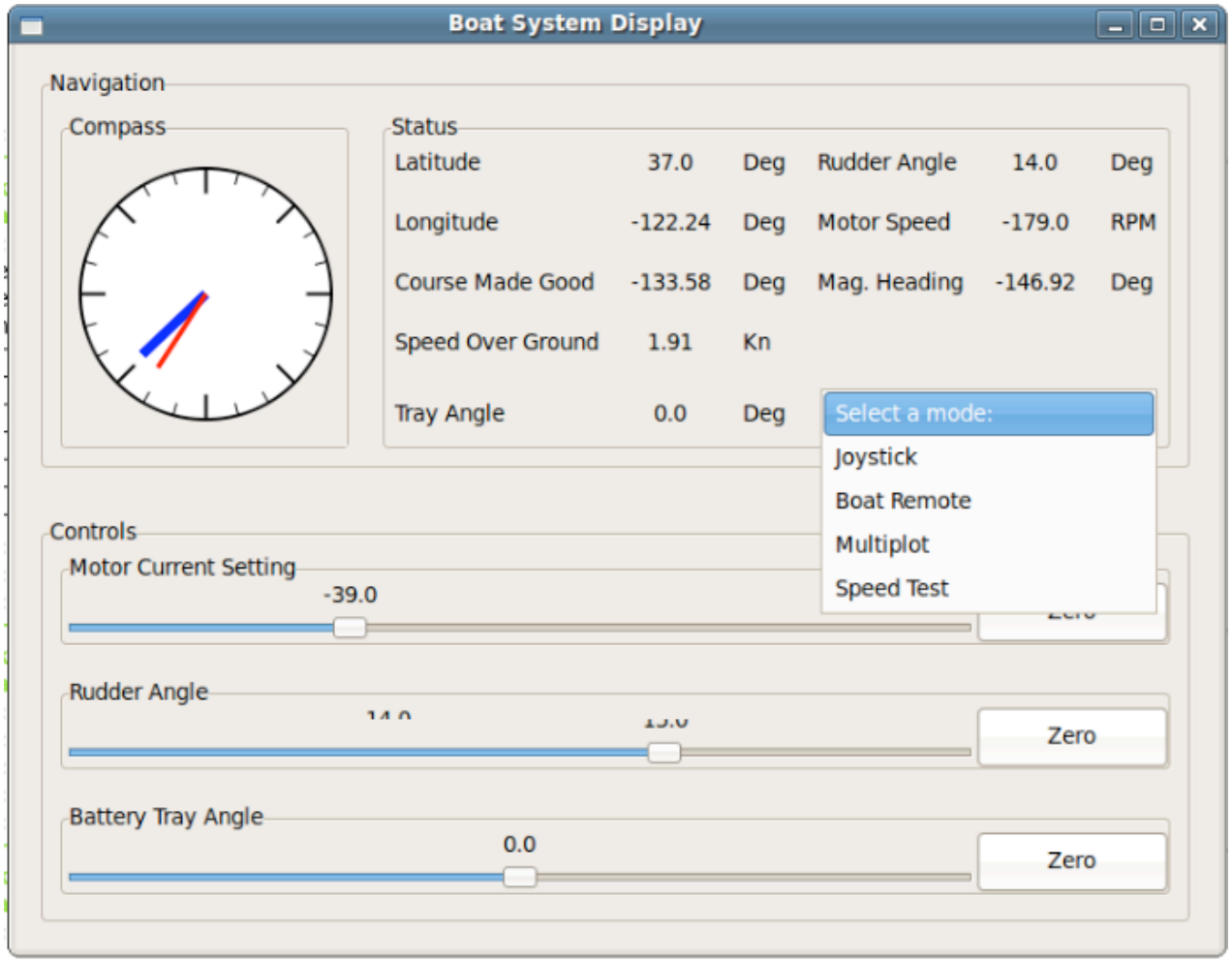
Software


Willow Garage ASV System Design v.1
Mission Control System
Main Processor 2
Mission Planning & Execution Modules
Navigation (Planning)
Navigation (Obstacle Avoidance)
Collision Avoidance
Power Management
Mission Planning
Mission Execution
Mission Request & Command Management
Boat handling (wx, capsize)
Mission Data
Static
(Almanac, map, Vsl info)
Dynamic
(Predictions)
Mission Files
High Level Logger
Mission Manager
Manual Override
RPC Interface (ICE)
Vessel Control System
Main Processor 1
Software Library
Rudder Controller (Crs, Hdg, Angle
Motor Controller (Power, STW, SOG, RPM)
Ballast Controller (Tray Angle, Heel Angle)
Pose Estimator (Position, attitude, speed)
Hardware Library
External Comms
Hardware Objects
Data Logger
Priority Layer
E-Stop
Boat Interface

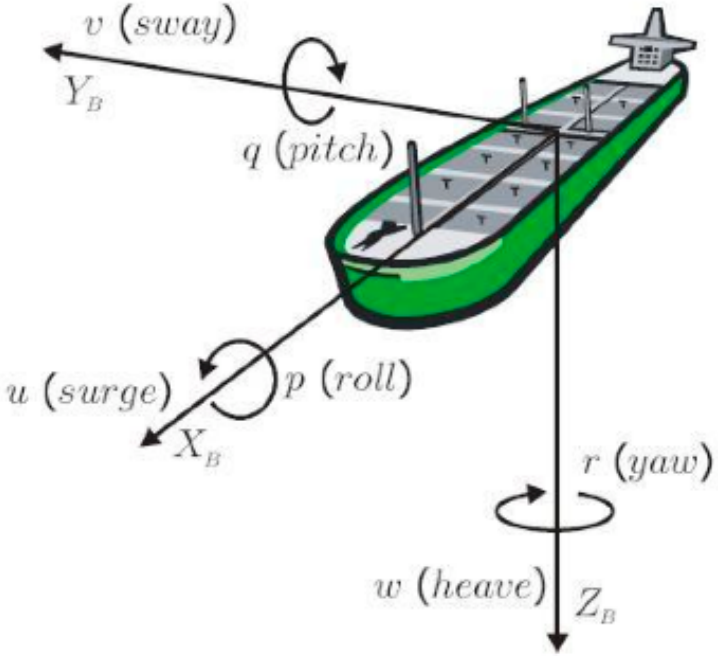
Software

- Complicated to build
- Dual platform (ARM, x86)
- Remote control
- Test programs
- Linux dependent

Remote Control



Terminology



Barauskis and Friis-Hansen. Fast-time Ship Simulator. (2007) pp. 1-8

Simulation

- What we're looking for
  - 4 Degrees of freedom (roll, yaw, surge, sway)
  - External forces (current, wind)
  - Power (drain, gain)
  - Global position
  - Real-world response

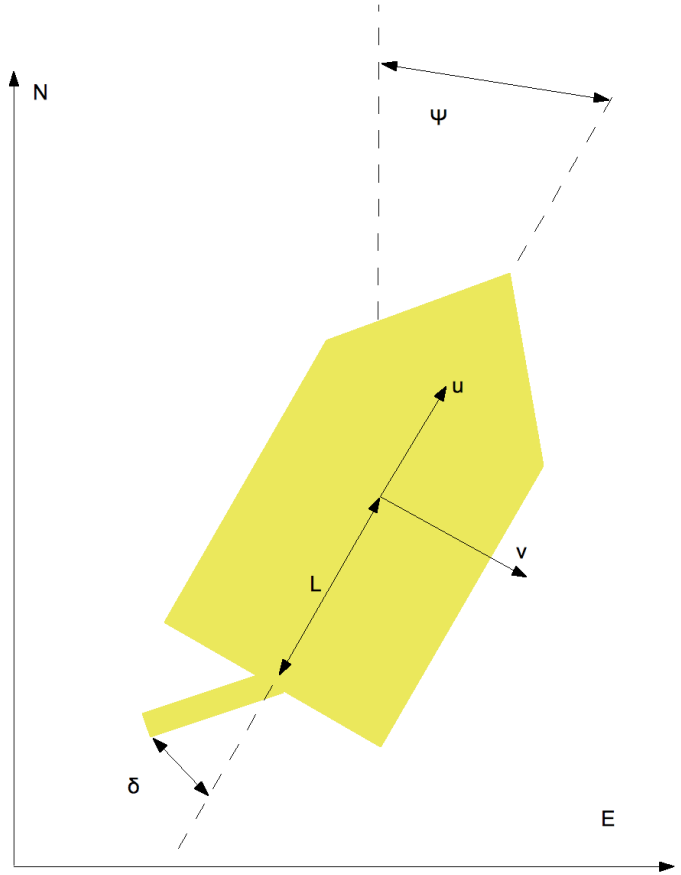
Provided Simulation

- Sun position & power
- Global position
- 4-DOF – inverted bicycle model

$$\dot{n} = u\cos(\Psi) - v\sin(\Psi)$$

$$\dot{e} = u\sin(\Psi) + v\cos(\Psi)$$

$$\dot{\Psi} = \frac{u\tan(\delta)}{L}$$



Outcome

Disadvantages:

- Simple rudder model
- Excludes boat architecture
- Hard to add forces

Advantages:

- Requires few boat parameters
- Easy to implement
- Possibly “good enough”

Autoboat Sim 2.0

- Ties into dsPIC workflow
- Based on 4-DOF model from Fossen 1994
  - Improved rudder model
  - Built around sums of forces and moments
- Requires more boat parameters
  - Need to collect data

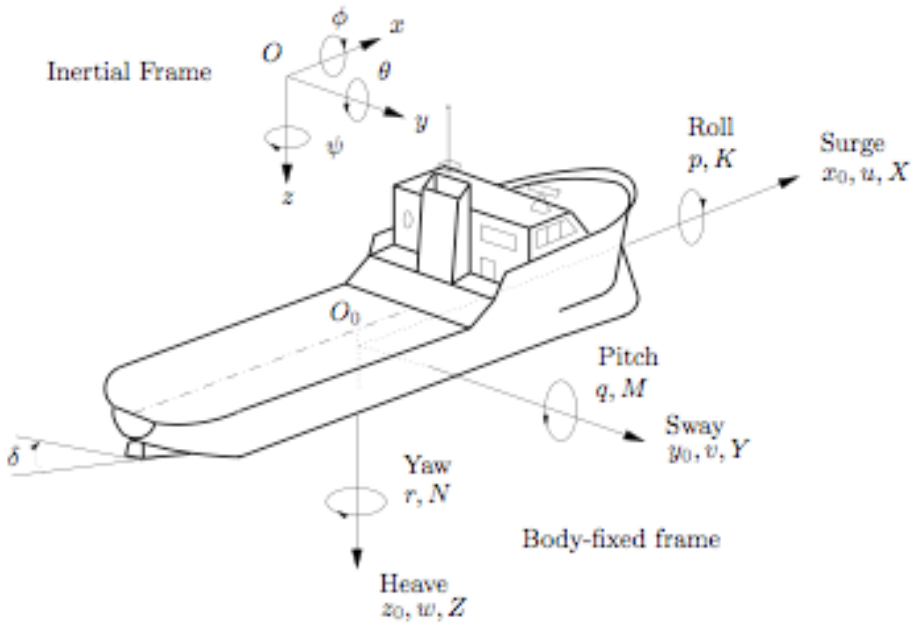
Equations of motion

Forces:
- Hydrodynamic (drag, etc.)
- External
- Propulsion
- Control surfaces

$$\begin{bmatrix} m & 0 & 0 & 0 \\ 0 & m & -mz_G & mx_G \\ 0 & -mz_G & I_{xx} & 0 \\ 0 & mx_G & 0 & I_{zz} \end{bmatrix} \cdot \begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{p} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} X \\ Y \\ K \\ N \end{bmatrix} + \begin{bmatrix} m(vr + x_G r^2 - z_G pr) \\ -mur \\ mz_G ur \\ -mx_G ur \end{bmatrix}$$

Global Reference Frame

- Equations of motion define dynamics in local inertial frame

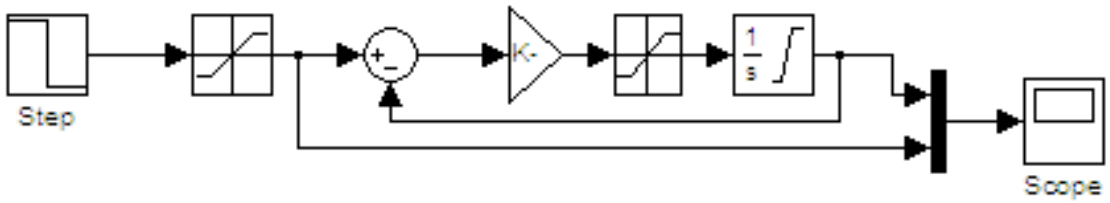


Hydrodynamics

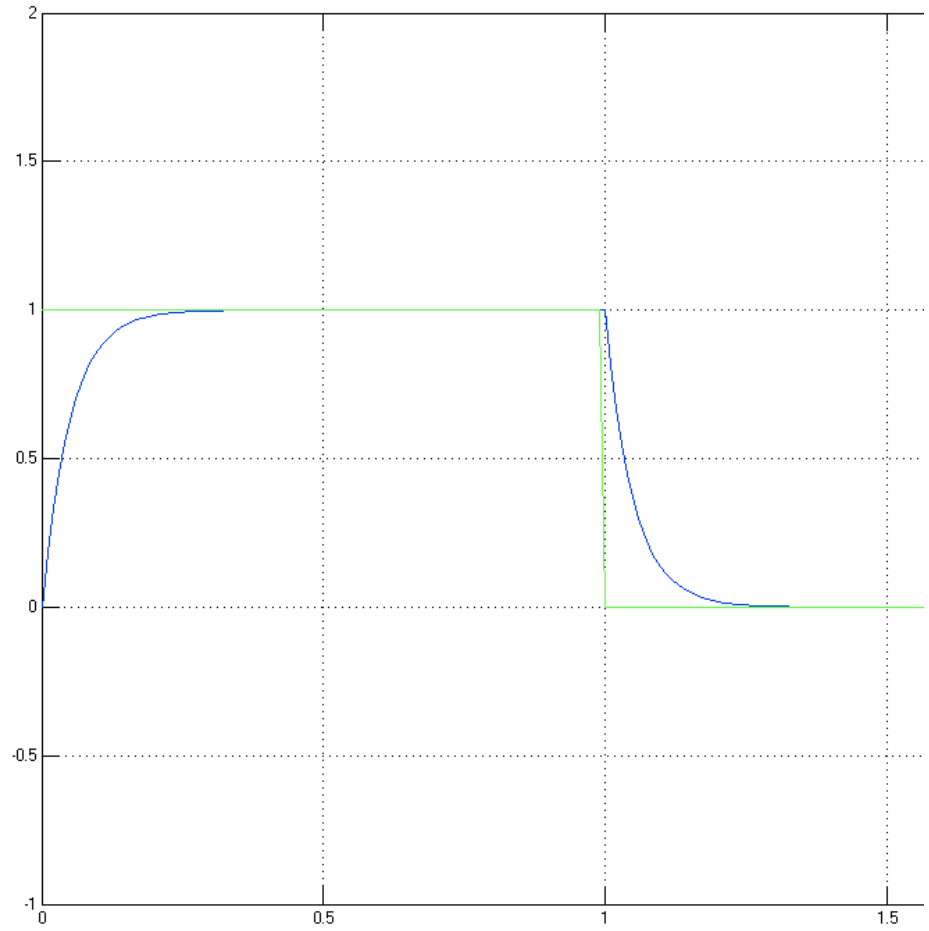
- Dynamics because of air and water
- Multiple origins
  - Motion in an ideal fluid with no circulation
  - Motion in an ideal fluid with circulation
  - Motion in a viscous fluid
  - Gravitational and buoyancy forces

Rudder Lag

- Rudder angle lags desired rudder position
- Simple 1st-order system

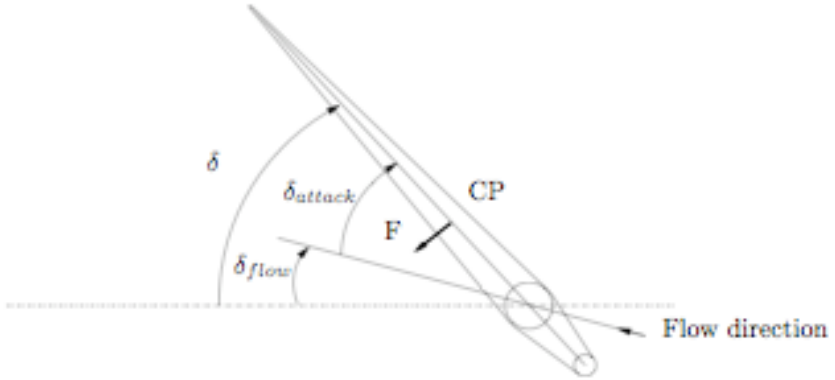


Rudder Response



Rudder Forces

$$F = \begin{cases} \frac{1}{2}\rho C_F A_r V_{av}^2 \sin\left(\frac{\pi}{2}\frac{\delta_{attack}}{\delta_{stall}}\right) \\ \frac{1}{2}\rho C_F A_r V_{av}^2 sign(\delta_{attack}) \end{cases}$$



Current Status

- Building simulations in MATLAB
- Examining existing software
- Documenting current hardware
- Planning for next revision