Glider design process: starting from the beginning

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The research work

- Project supported by the General Secretariat for Research and Technology
- Participants:
  - National Technical University of Athens (NTUA), School of Naval Architecture and Marine Engineering (SNAME)
  - Hellenic Centre for Marine Research (HCMR)
- Objective of the project: acquire knowledge about underwater gliders and their operation, through the development of a new measuring instrument in the form of underwater glider

The design process

- The research work based on the three classic designs of Slocum, Seaglider and Spray gliders.
- Understanding of their functionality, their behavior and their physics, for developing a new vehicle design.
- Motion dynamics
- Vehicle design and Hydrodynamic study
- Design of the optimal glide paths
- Motion control
- Design parameters
- Mechanical design and electrical components

Dynamic Modeling and Equations of Motion

- Dynamic equations of motion
- Derivation of 2d plane model
- The equations are solved for the equilibrium in order to derive steady glide paths were the energy consumption is minimal

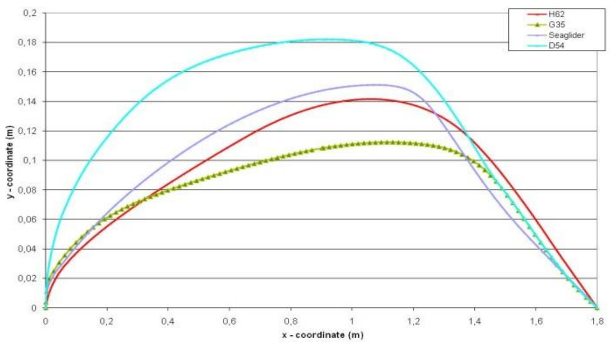
Body shape design and hydrodynamic study

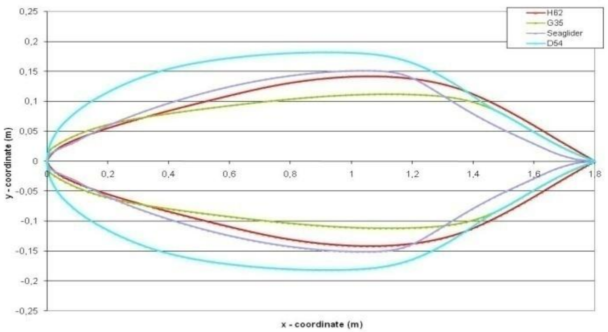
- Hydrodynamic design in order to minimize energy consumption during the oceanographic missions
- Study of the hydrodynamic behavior of the vehicle and its characteristics
- Determination of the induced forces (lift, drag) in order to solve the equations of motion

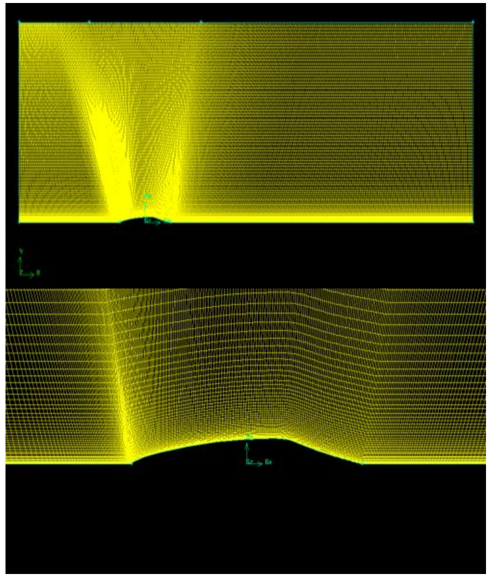
Study of low drag shapes – 2D modeling

2D mesh generation (preprocessor GAMBIT)

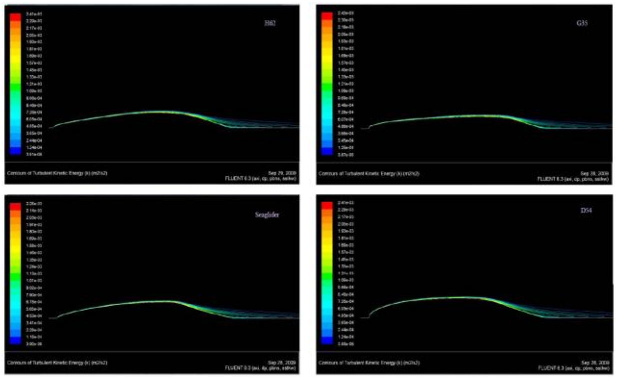
low drag - laminar flow shapes



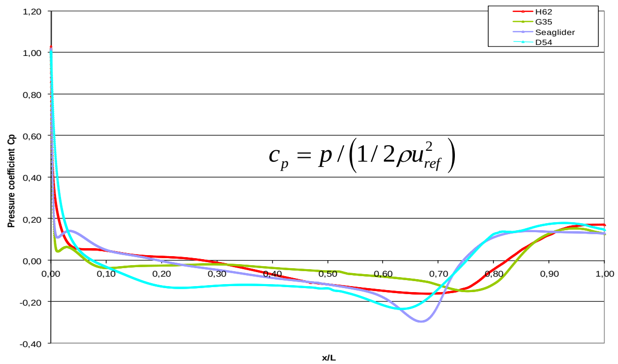




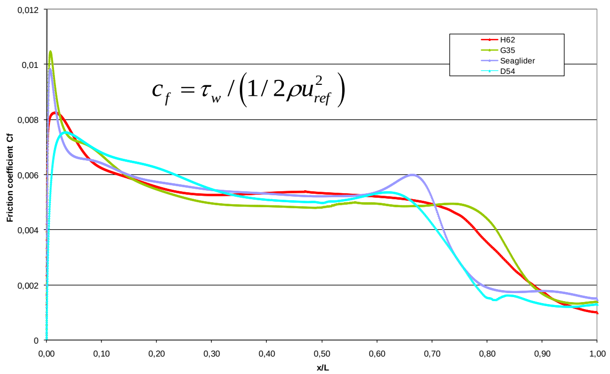
Solution of the flow (CFD solver FLUENT) – turbulent kinetic energy



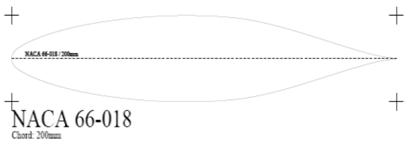
Pressure coefficient along the bodies, Re= $9 \cdot 10^5$

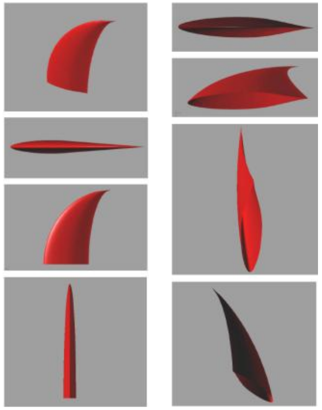


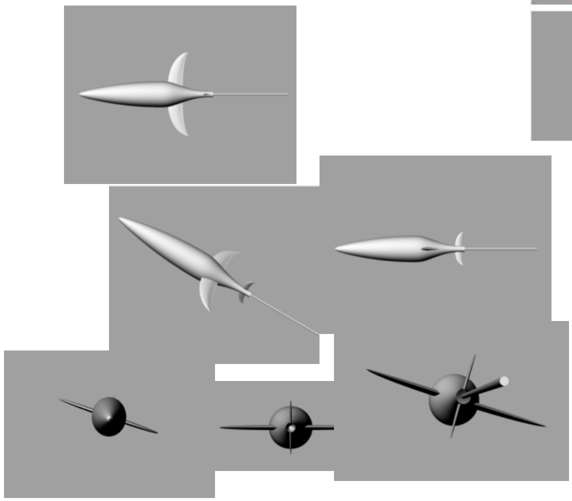
Skin friction coefficient along the bodies, Re= $9 \cdot 10^5$

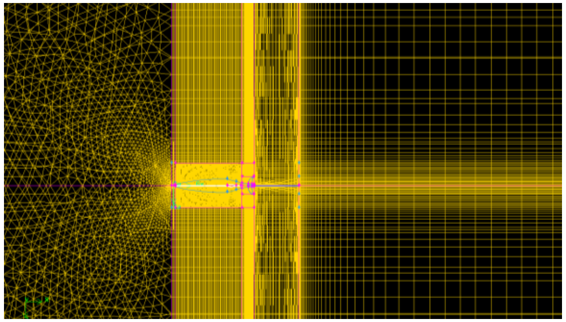


3D modeling

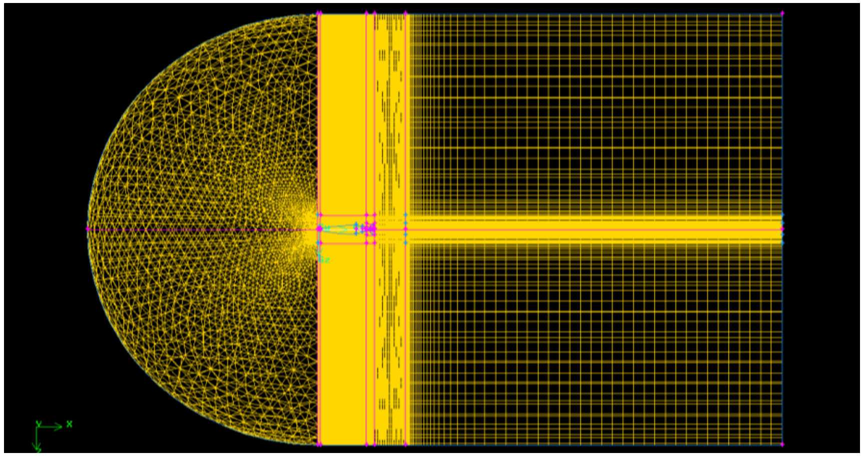


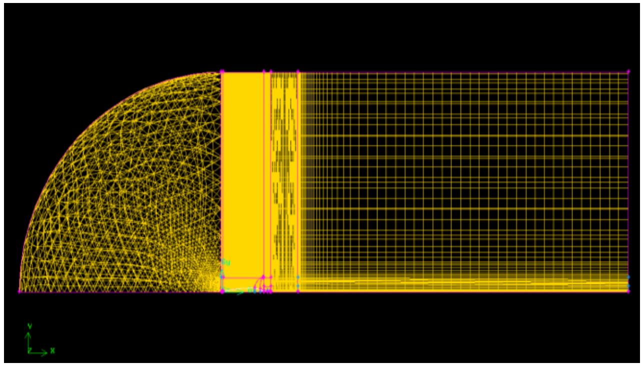


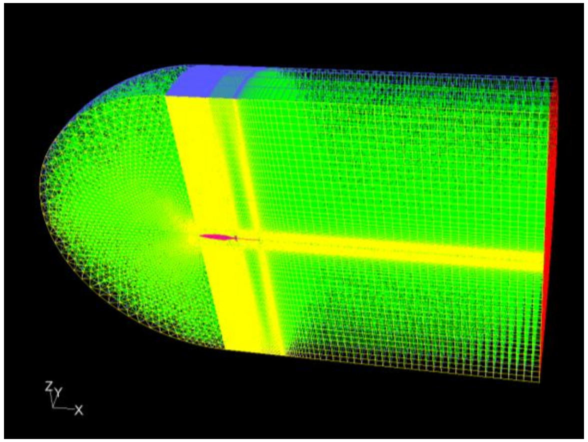


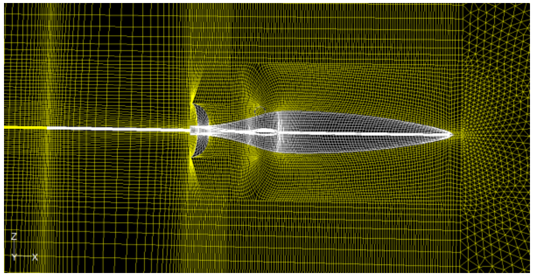


3D flow simulation

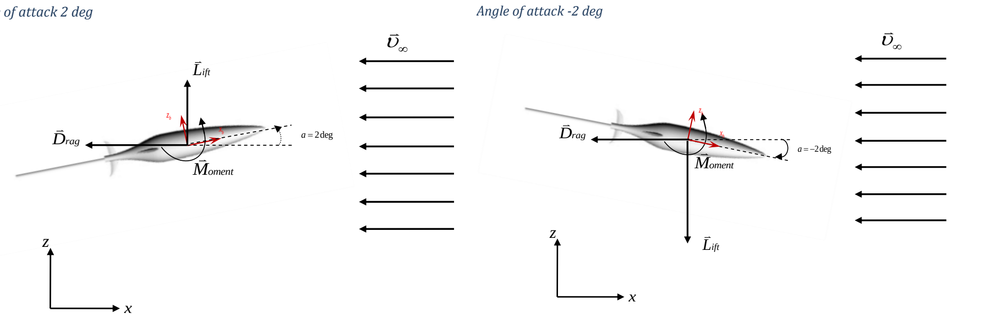




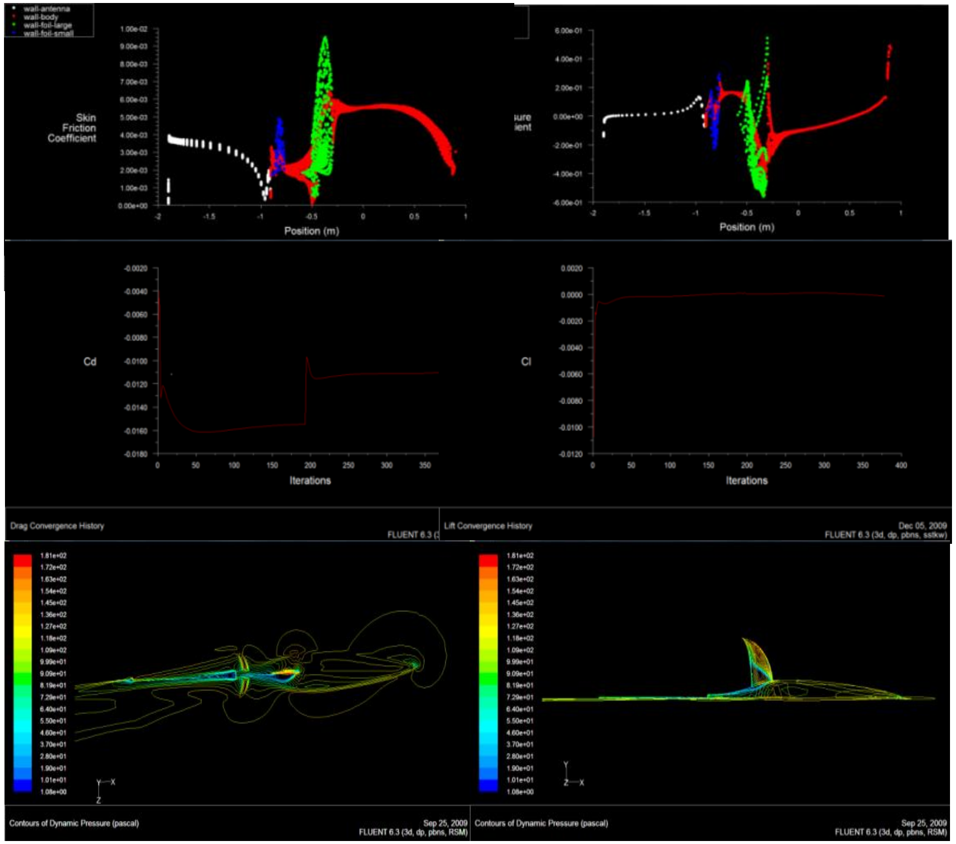


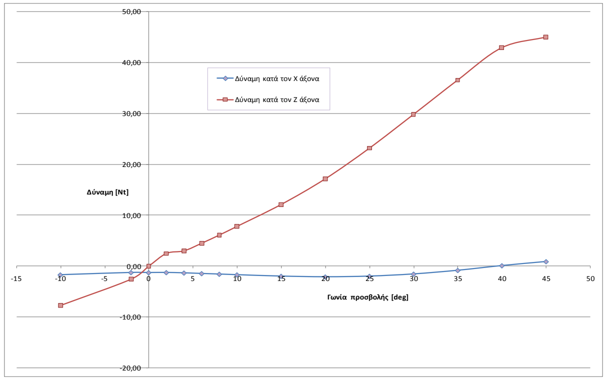


Solution of the steady flow

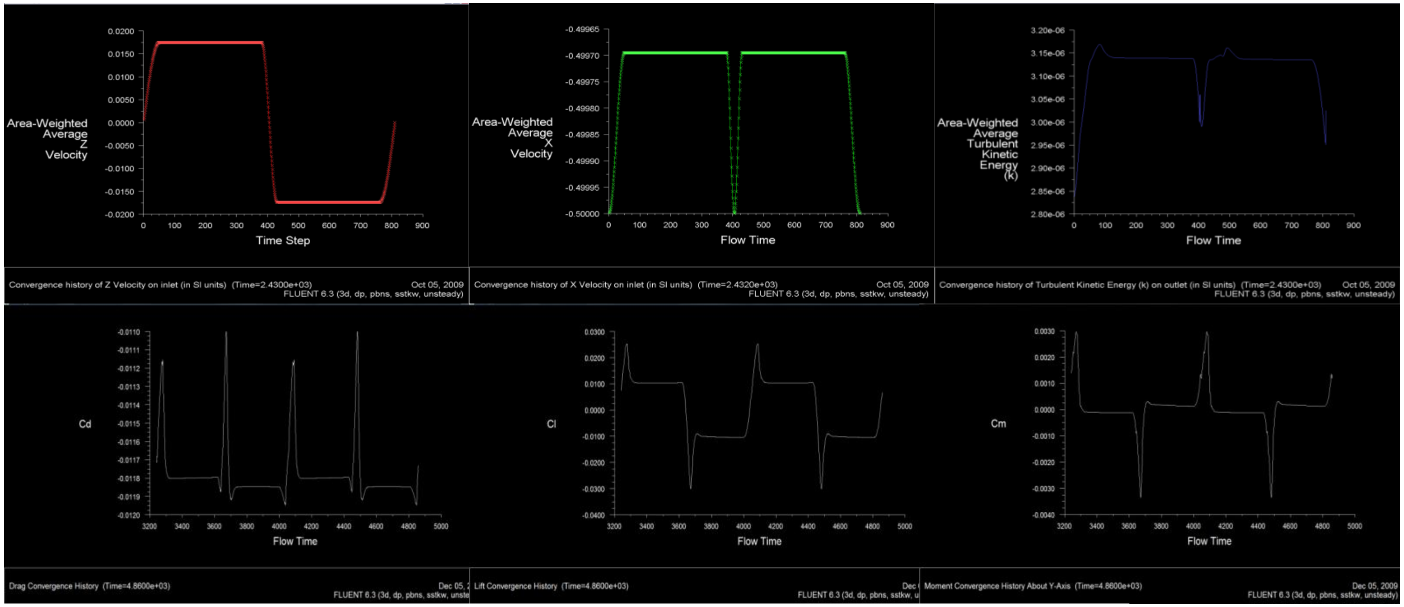


- Attack angles 0 deg, -2 deg (down), 2 deg (up)
- Drag, lift, moment for various attack angles
- Calculations counting in sea currents
- Hydrodynamic effects by the use of wings and antenna mast, changes in drag

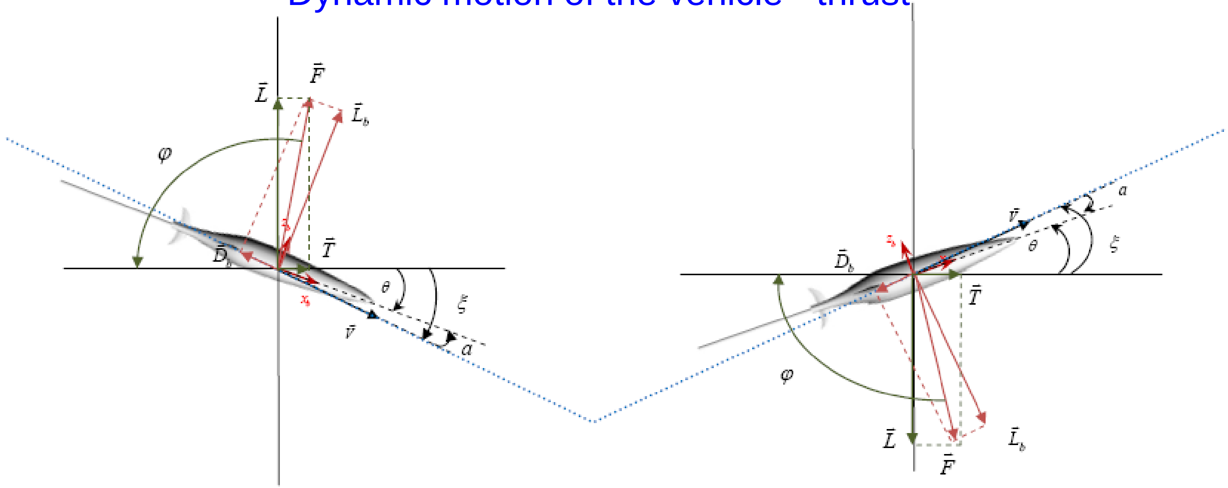


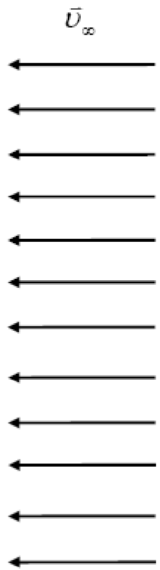


Solution of unsteady flow

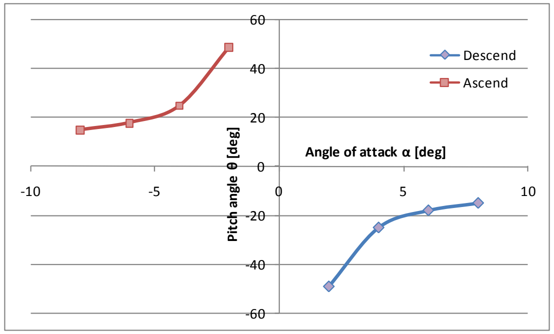


Dynamic motion of the vehicle - thrust



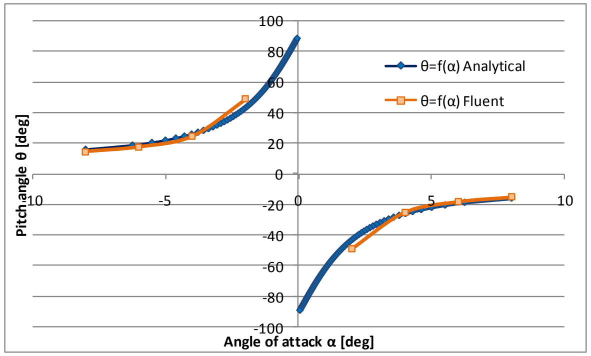


Angles corresponding to steady straight glide paths

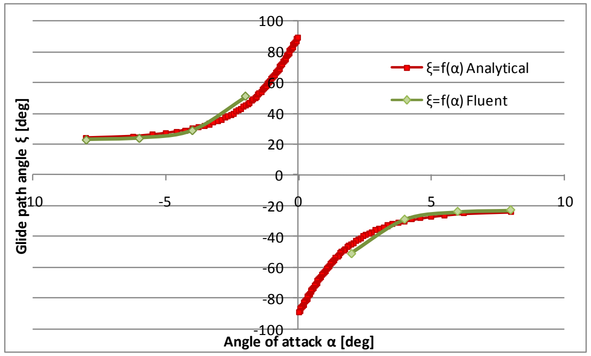


Determination of equilibrium states: glide path angle ξ, pitch angle θ, angle of attack α, variable and movable mass

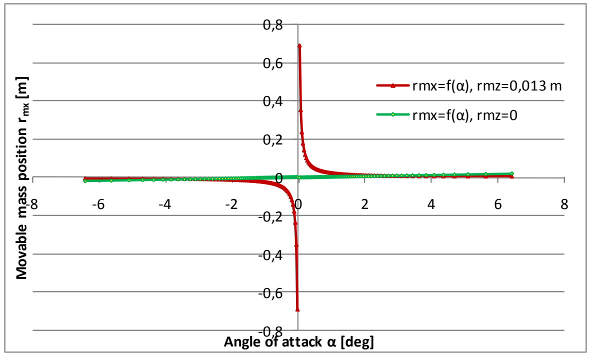
Pitch angle θ



Glide path angle ξ

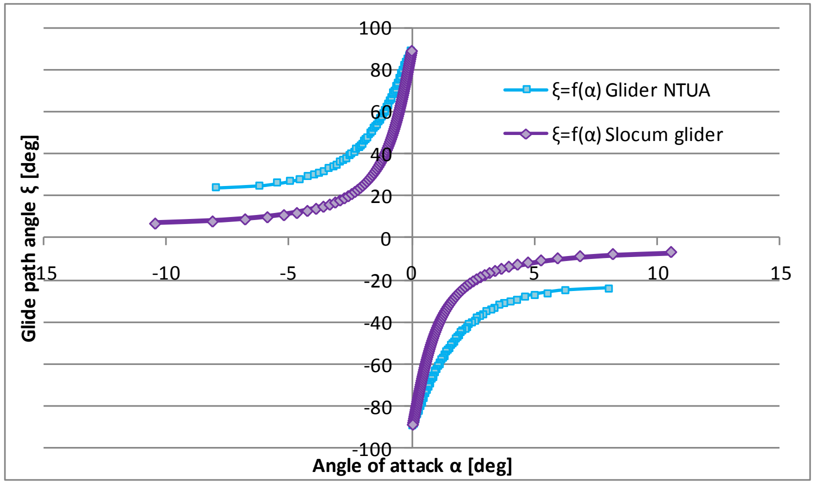


Movable mass position



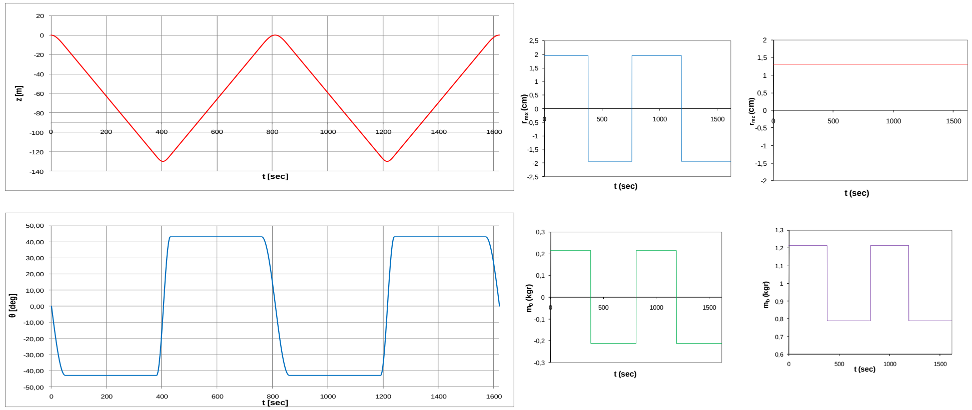
And a comparison

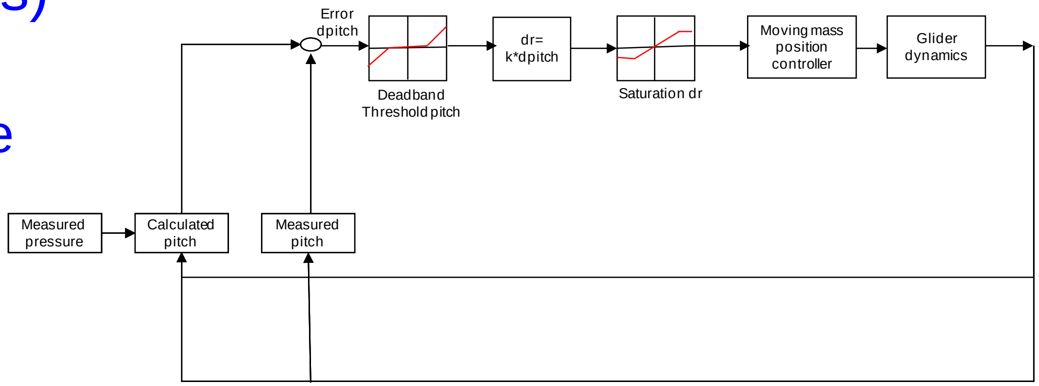
- Slocum electric for littoral use (200 m) $\xi_{eq} \in [6.3°, 90°]$ $\xi_{eq} \in [-90°, -6.3°]$
- NTUA glider $\xi_{eq} \in [24°, 90°]$ $\xi_{eq} \in [-90°, -24°]$



Motion control

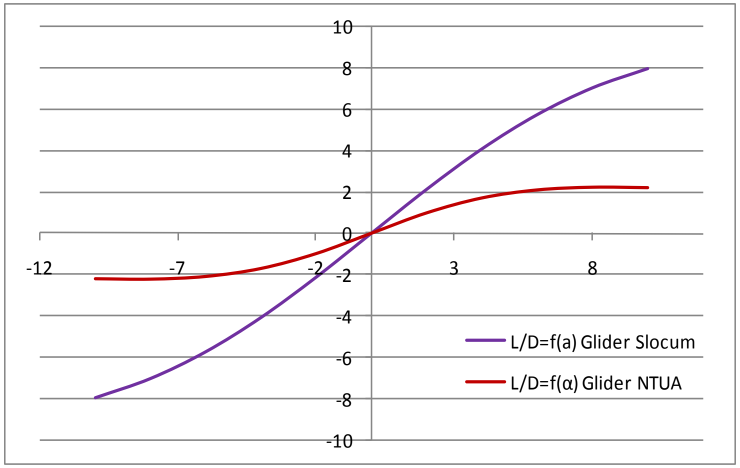
- Accurate navigation for travel and correlation of recorded scientific sampling data to spatial locations
- Study of control systems on operational gliders (linear controllers, PD or PID loops)
  - Design of pitch control algorithm for a typical dive cycle
- Study of a model based control system





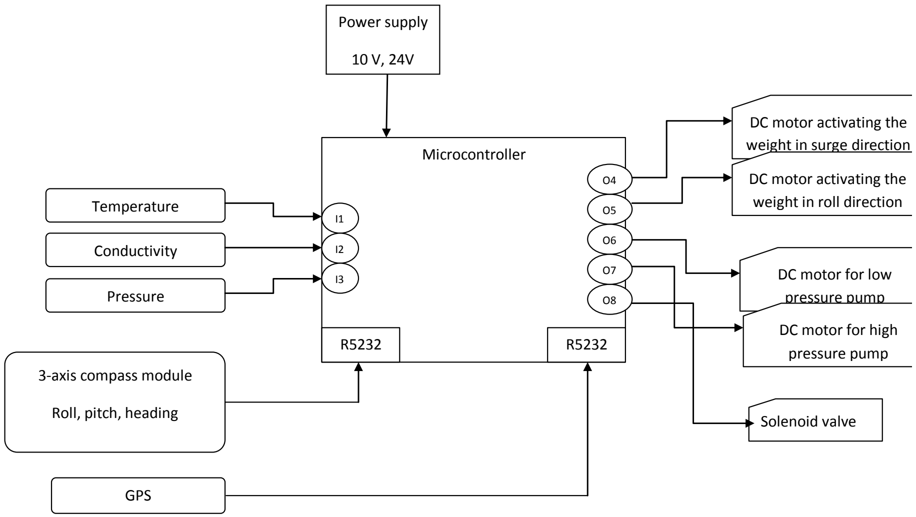
Some conclusions for a preliminary design

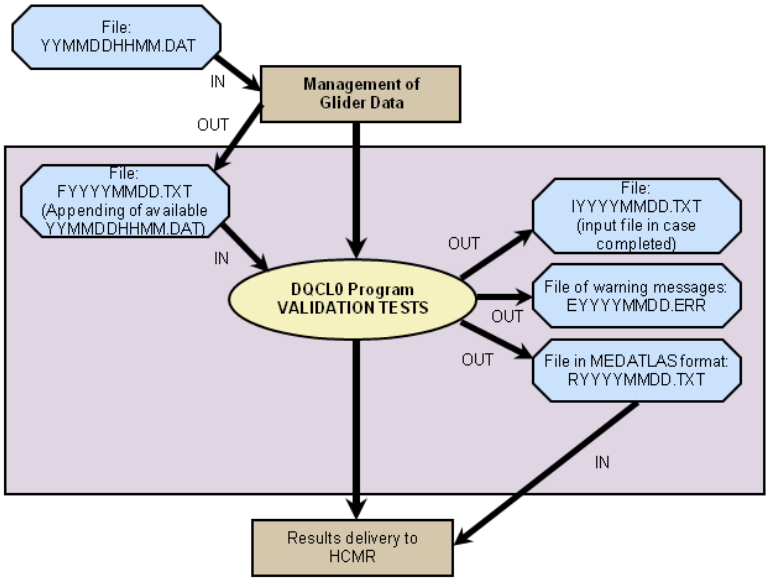
- Mission requirements (range, endurance, speed and payload) will determine power requirements, size of the main components and an initial vehicle geometry
- An initial design may use a glider layout like that of existing oceanographic gliders, with some hydrodynamic improvements
- Desired steady glide performance (glide path angle and speed) will determine vehicle's geometry and ballast system
- Glide path selection will determine the operational lift/drag ratio required in the design.
- Estimation of the size of the body and wings to produce a low or a high lift/drag ratio. Designing an underwater glider for shallow glide path angles would require high lift/drag ratios



Mechanical design and electrical components

- Design of the fairing and the internal hull, choice of the appropriate materials for the fabrication
- VBD (variable buoyancy device), transducer in order to locate and track the vehicle, attitude sensing package
- Battery packs for the power budget and the role of movable mass, microprocessor, navigation receiver, antennas
- Scientific sensors: conductivity – temperature – depth (CTD), fluorometers, dissolved oxygen, photosynthetically active radiation (PAR) and other optical and biochemical sensors
- Satellite data telemetry





The next step – future work

- Development and construction of a new experimental vehicle, for educational and operational use
- Further optimization of the body and wings considering comparisons with existing glider shapes and also parametric hydrodynamic analysis in order to come up with a final shape
- Definition of mission requirements, capabilities of the vehicle for both its functionality and the oceanographic measurements (type of sensors, sampling frequency etc)
- Definition of the technical characteristics of the device
- Optimization and development of the needed software that will control and navigate the vehicle (feedback control systems for efficient gliding)
- Experimental application in sea trials with the purpose of gathering dynamic data for improvement of glider hydrodynamics and performance and consequently efficiency and scientific utility
- Experimental and operational use of existing oceanographic gliders

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Thank you for your attention!