



# PRELIMINARY DESIGN OF A SUBSCALE FLOATPLANE

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BRAZIL



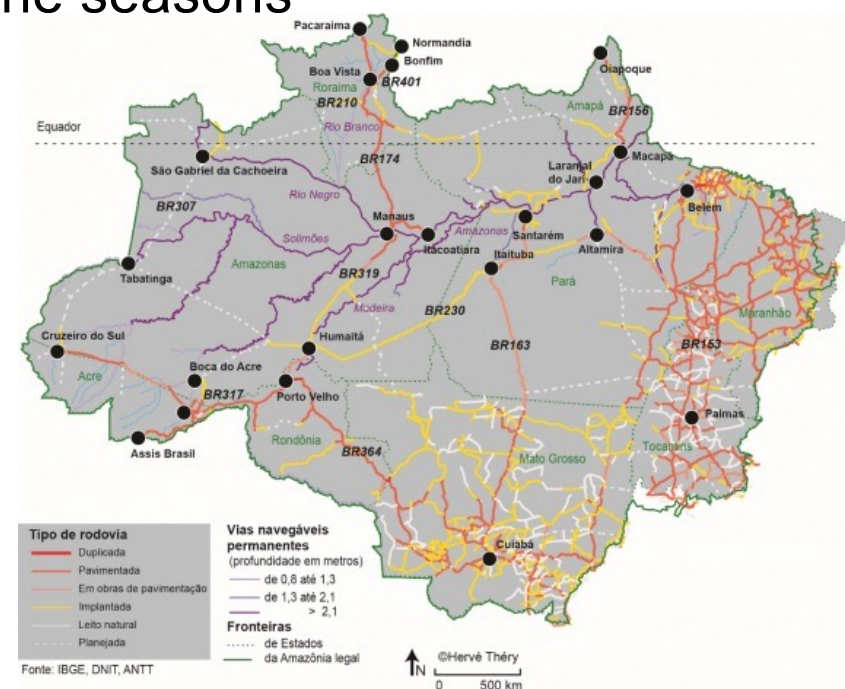


# Summary

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- **Motivation 1: Amazon Region Amphibian**
- **Motivation 2: Modeling Challenges**
- **Generalized Procedure**
- **Some Results**
- **Main Conclusions**

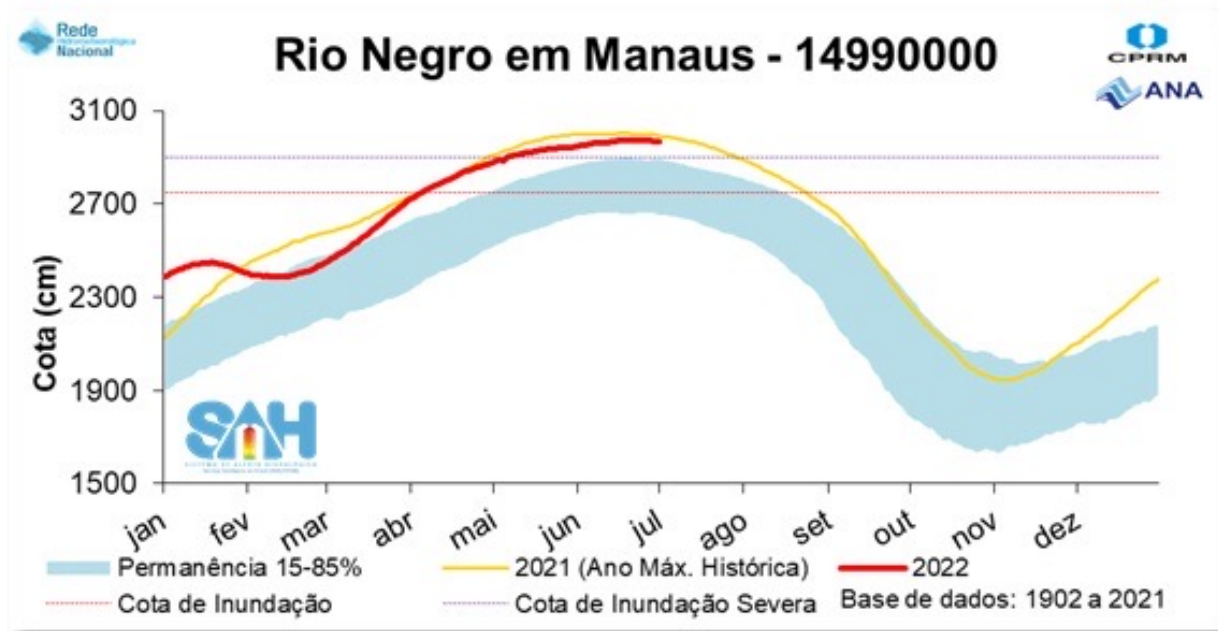
- Roads are not a sustainable: Maintenance and **Environmental issues!**
- Rivers are **THE** “sensible roads” (slow/cargo transport)
- Rivers provide natural and (almost) maintenance free airstrips (fast/emergency/relief transport)
- Important: river levels change with the seasons





# Amphibious ACFT and the Amazon Region UFMG

- Aircraft should have the ability to land in airports
- River levels change continuously





# Advanced configurations? Flying boats?

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# Amazon Region Demands

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- Efficiency yes , BUT WHAT DOES IT MEAN?
- Extremely Harsh Environment, Heavy Currents, Strong Winds
- Submerged Logs and Capybaras present a constant risk
- Steering in heavy currents: a main concern!
- Logistics: a most important issue in remote regions
- Other requirements, common to any type of operation have to be taken into account.
- **Conditions are different from, say, in North America Lakes!**



# Modeling Issues

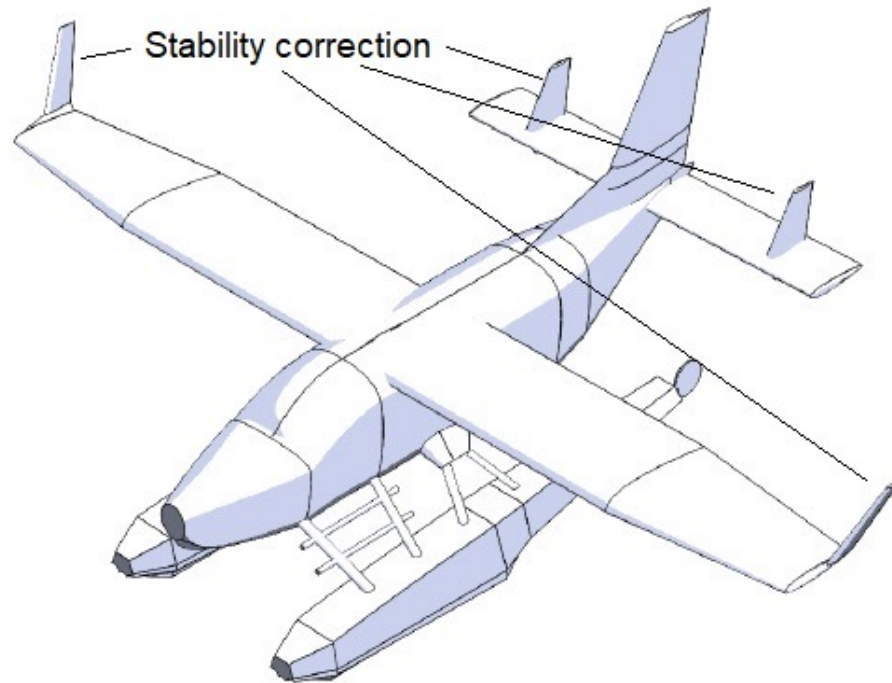
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- Steering in strong water currents
- Flight Stability float associated issues
- Additional stability surfaces
- Small propeller modeling
- Models (includes numerical) still rely on first half of 20th century empirical results (mainly towing tank), hence
- SFT and SWT (Subscale Water Modeling) are promising



# Amazon Region Floatplane

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REFERENCE AIRCRAFT

Parameter	<i>DS</i>	<i>FS</i>
Chord Length, $c$ (m)	0.23	1.71
Wing Area, $S$ (m <sup>2</sup> )	0.49	23.97
Wingspan, $b$ (m)	2.0	14.0
Oswald Efficiency Factor, $e$	0.94	0.93
Mass, $m$ (kg)	15.94	4000
Moment of Inertia, $I_y$ (kg·m <sup>2</sup> )	2.841	33380
Velocity, $u_0$ (m/s)	30.24	80.0
Tail Arm, $l_t$ (m)	0.727	5.089
Aspect Ratio, $AR$	8.16	8.18
Angle of Attack, $\alpha$ (°)	2.000	2.000
Altitude, $h$ (m)	120	3250
Air Density, $\rho$ (kg/m <sup>3</sup> )	1.225	0.886
Dynamic Pressure, $Q$ (Pa)	561.1	2837.1

DS: Dynamic Scaled

FS: Full-Scale ACFT



## *Why Subscale Flight Testing (SFT) ?*

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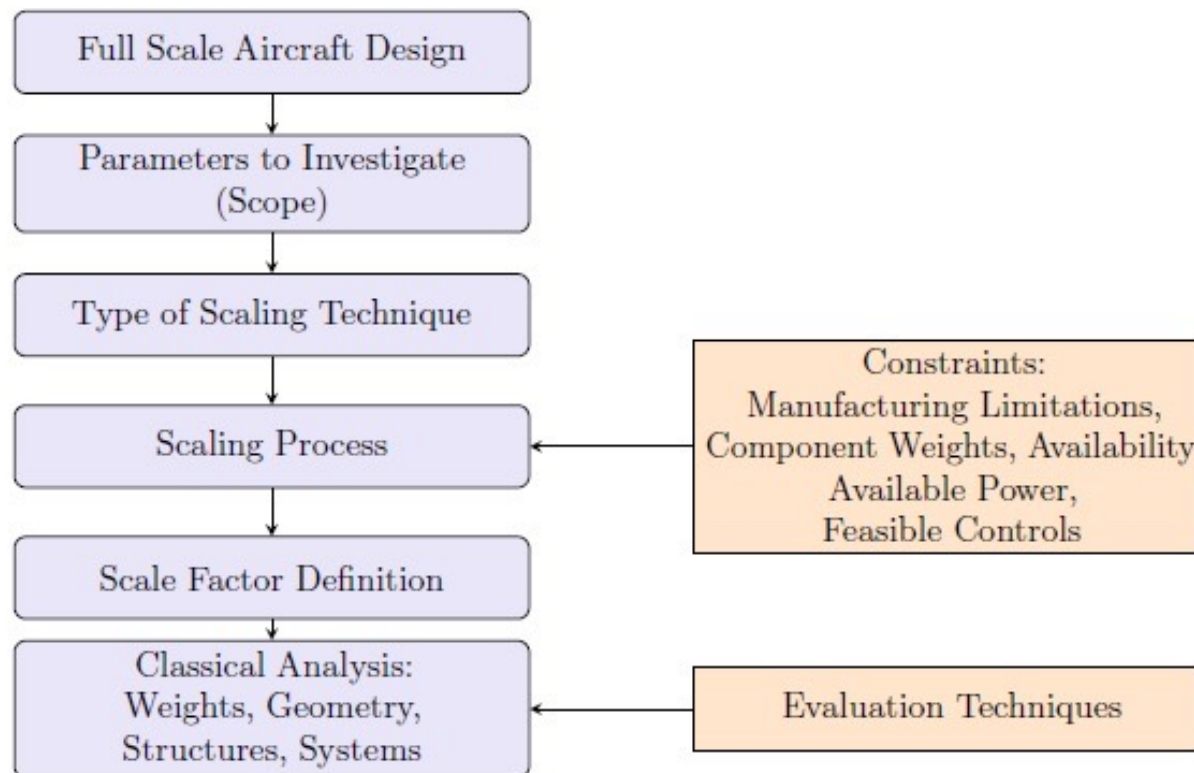
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- The “golden age” of seaplanes occurred during the first half of the 20th century, hence,
- Modeling difficulties restrained the available solutions to empirical modelling.
- Market limitations: Most of the available amphibians operating in remote areas are converted landplanes, based on older projects
- Clear need for improved design tools
- Important: SFT to be used with other techniques



# Amphibious Aircraft SFT

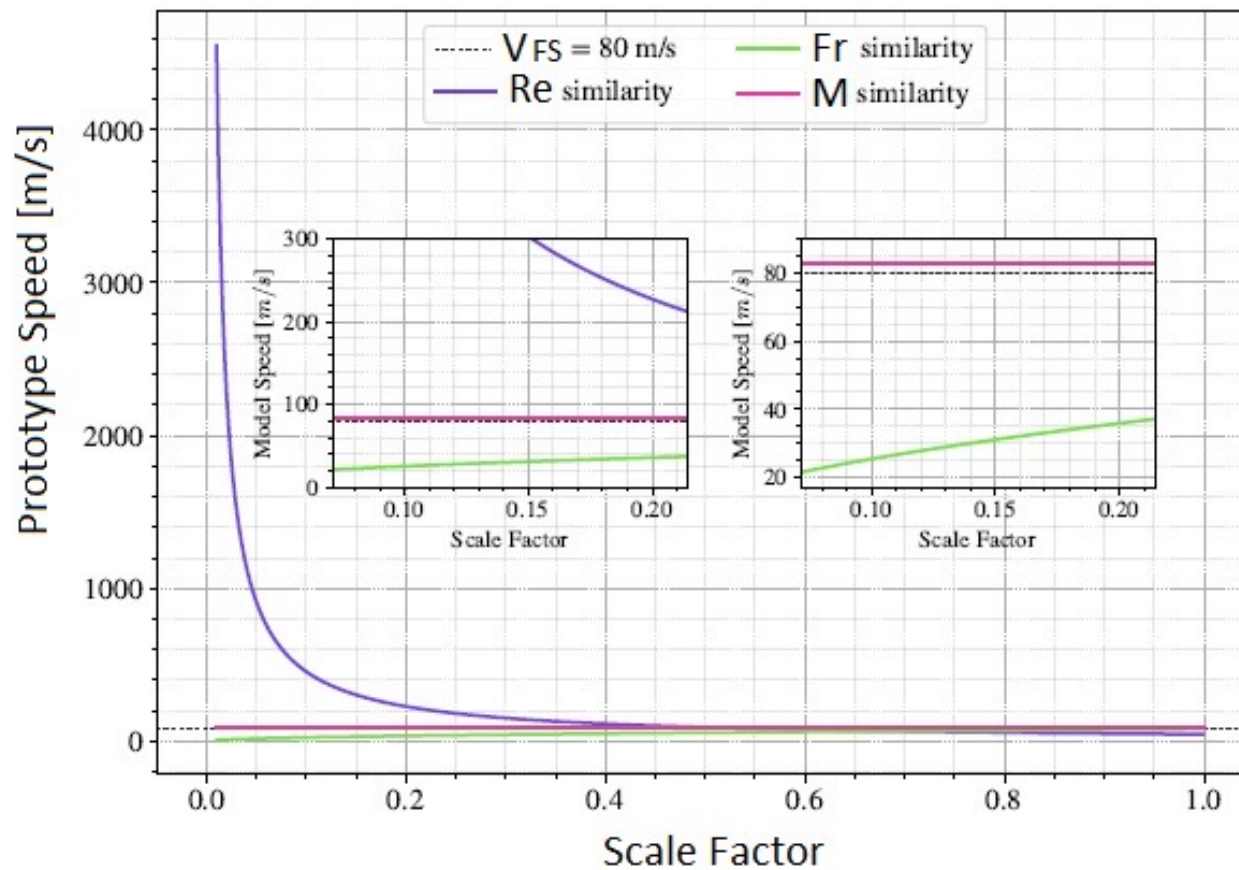
- Dynamic (force/moment) scaling
- Two different environments: Air and Water





# Scaling: Water Takeoff

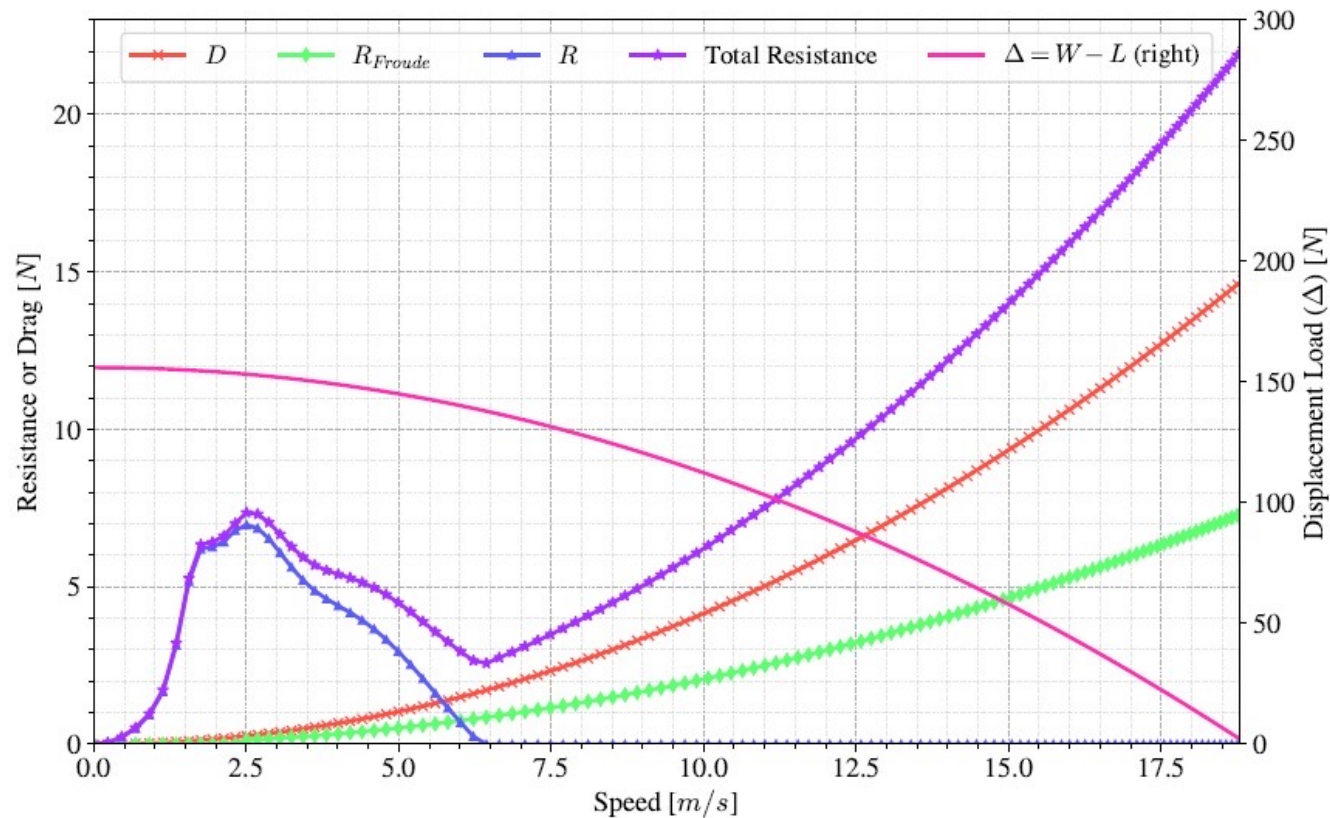
- Froude number prioritize
- Reynolds number corrections





# Water Take-off simulated results

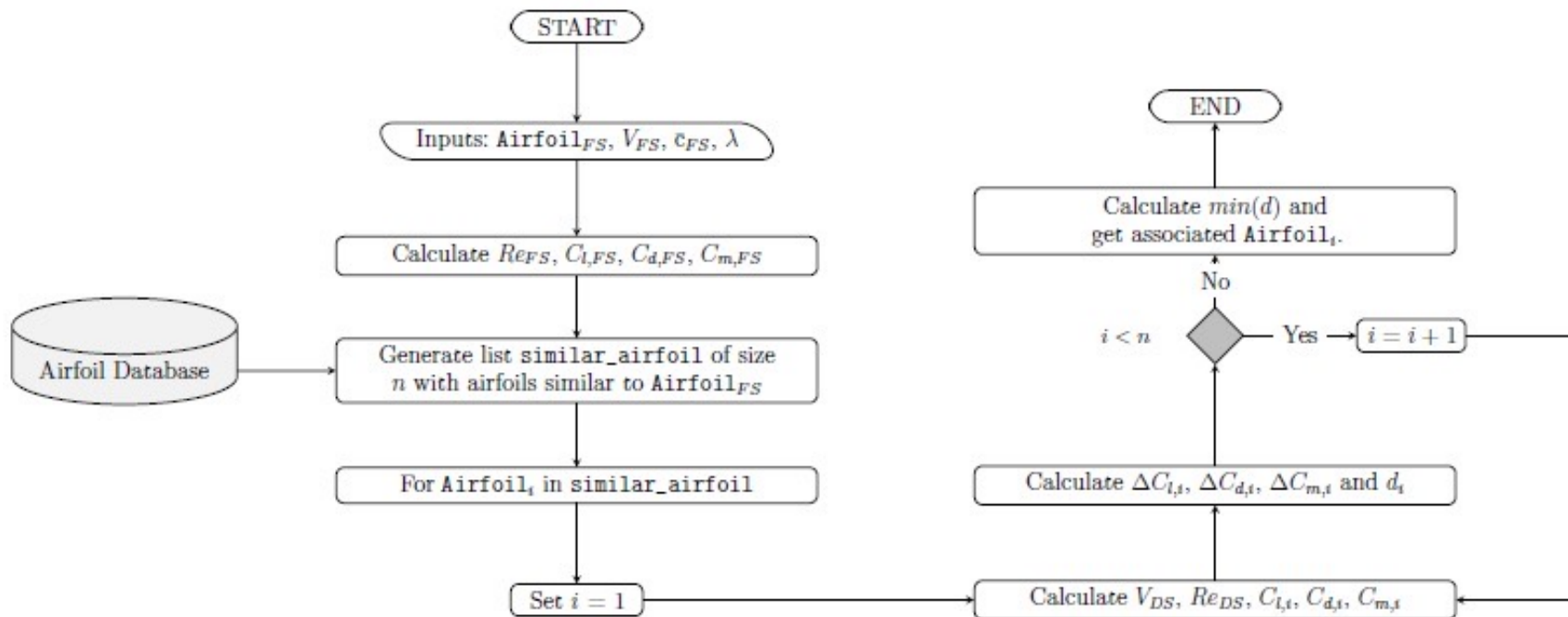
- Unlike conventional land planes, airplane mass has a decisive influence on buoyancy, suction, water boundary layer and other fluid flow effects. Example: 16% in weight increases takeoff 30%





# Aerodynamic Scaling

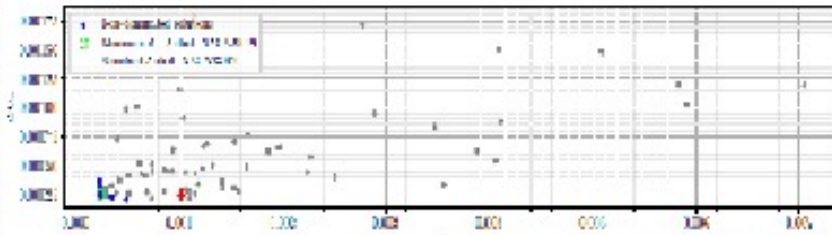
- Simulation to obtain optimized geometry based on force/moment scaling



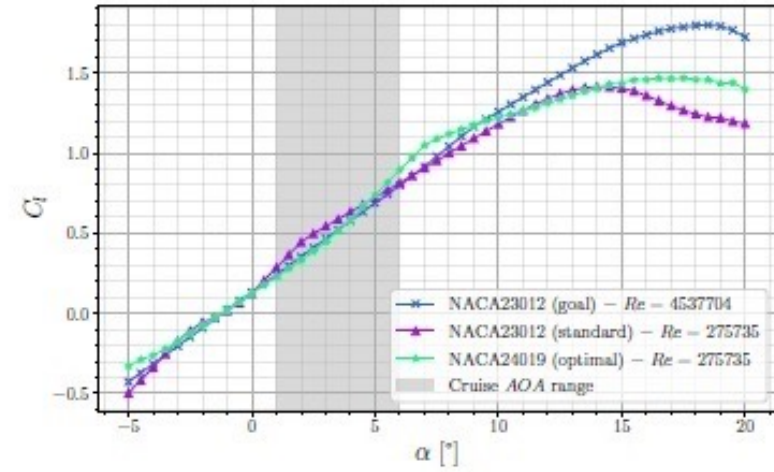
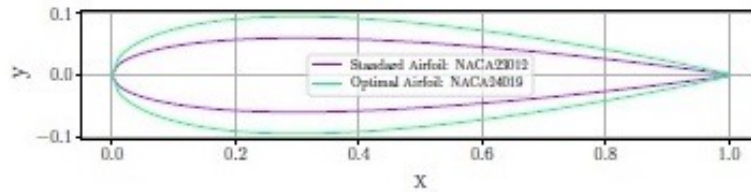


# Optimized Wing Tip Airfoil

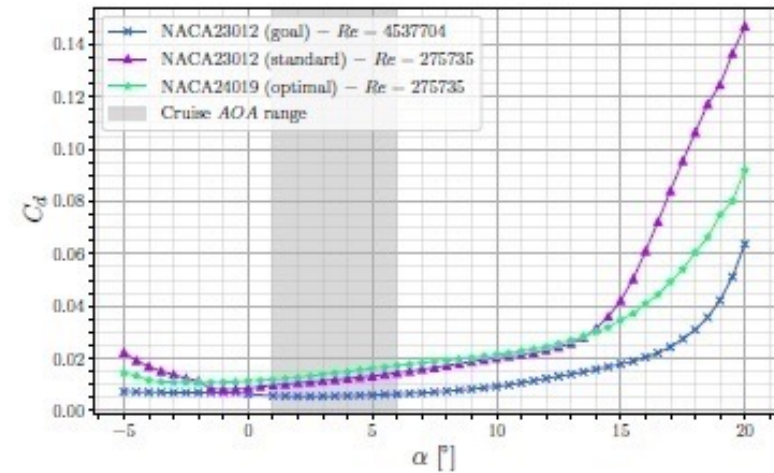
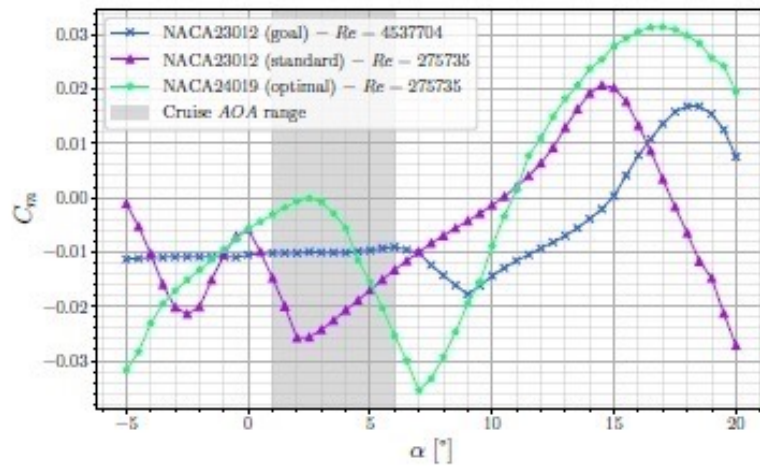
Aero Force Coeff 2



Aero Force Coeff 1

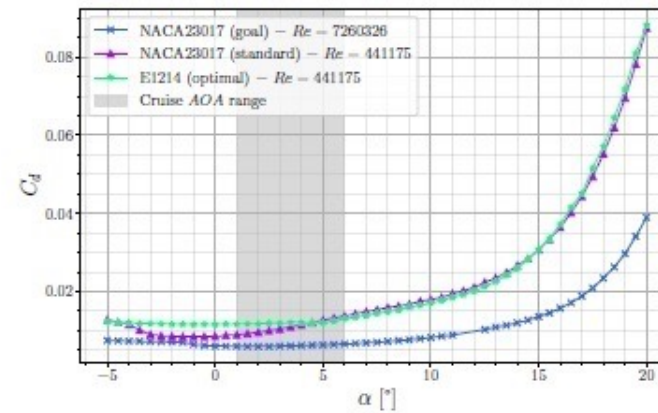
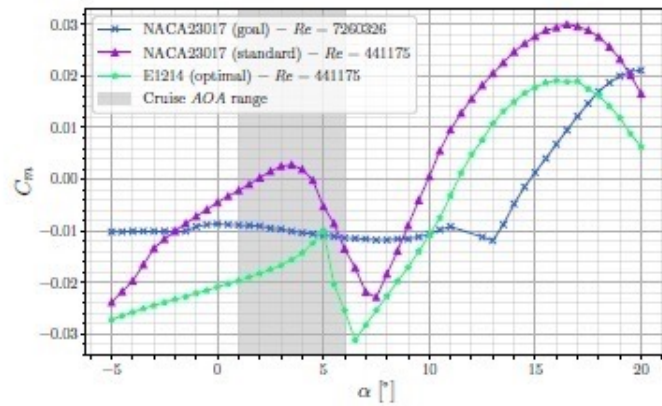
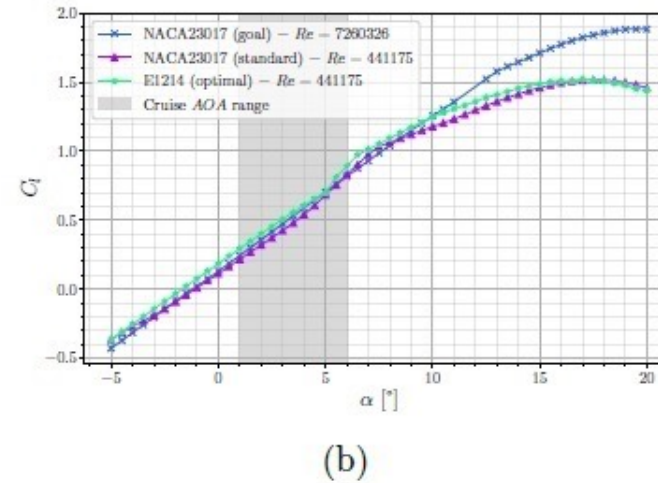
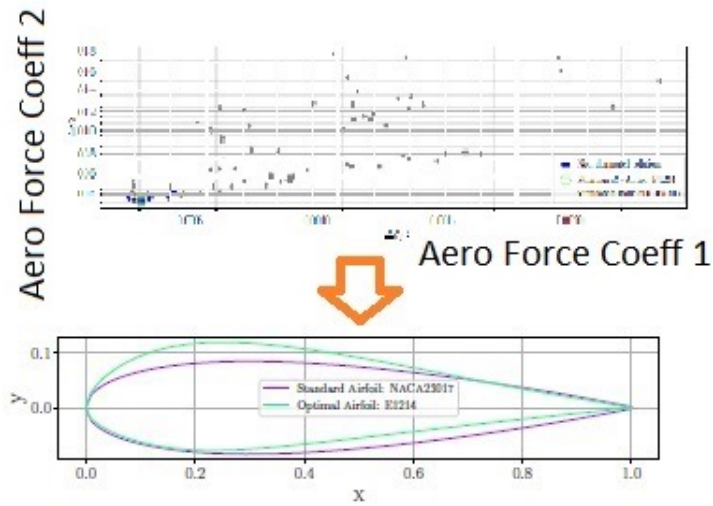


(b)



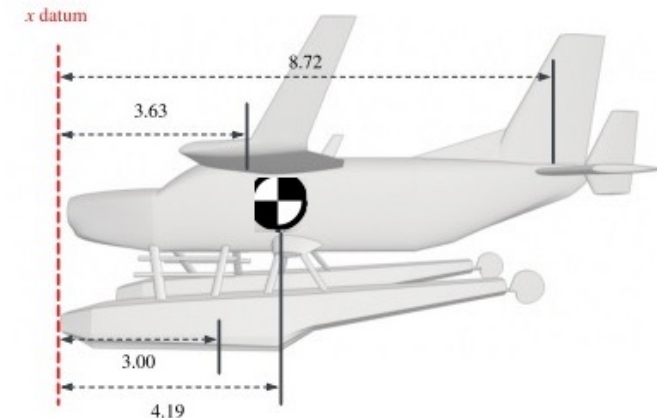
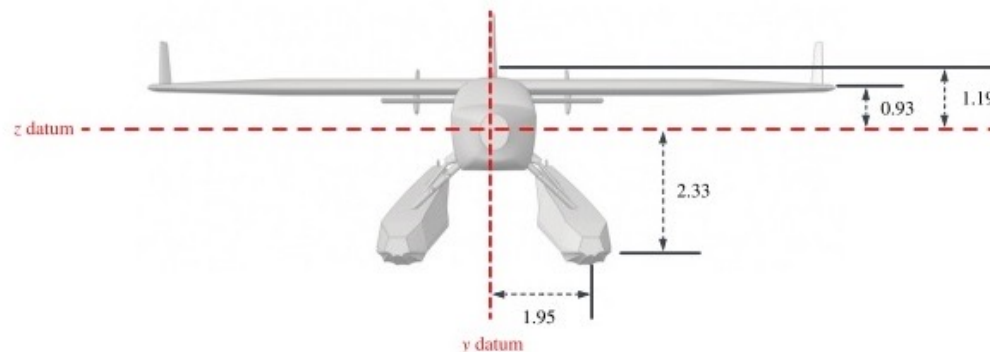


# Optimized Wing Root Airfoil



## Mass / Size Breakdown SFT Prototype

Component	Mass/Size	Remark
BLDC Motor	1.0 kg / (120×70)	1.5 kW <sup>a</sup>
Propeller	30 g / diameter = 100 mm	Propeller
ESC + cables	100 g	
Batteries	2 kg (190×75×65)	Based on 340 Wh/kg <sup>b</sup>
Servos	4×50 g + 2×100 g	Function of required torque
AutoPilot	50 g (50×70) mm	Pixhawk 6 mini
GPS + PWR mod + accelerometers + cables	150 g	
Airframe	2.5 kg	Composite manufacture
Miscellanea	300 g	Wiring, screws, fittings, etc.
<b>Total weight (without ballast)</b>	<b>Approximately 7 kg</b>	Mass can be added depending on test requirements



Correct Inertia for Water may be different!



# Dynamics of Flight Scaling

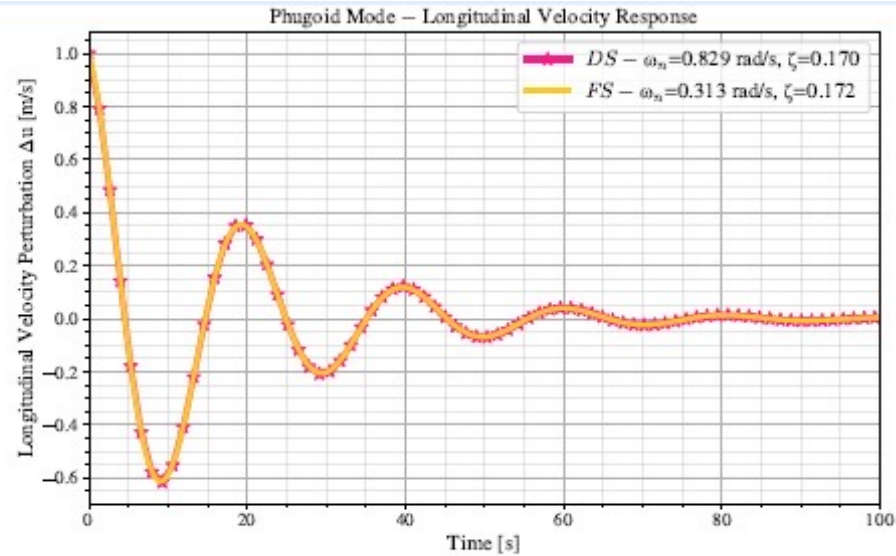
- Generalized equations of Aircraft Motion have to be considered

$$\dot{x} = Ax + B\eta$$

- Dynamics of Flight Derivatives provide a valuable insight
- Correct non dimensional derivatives and non dimensional time!

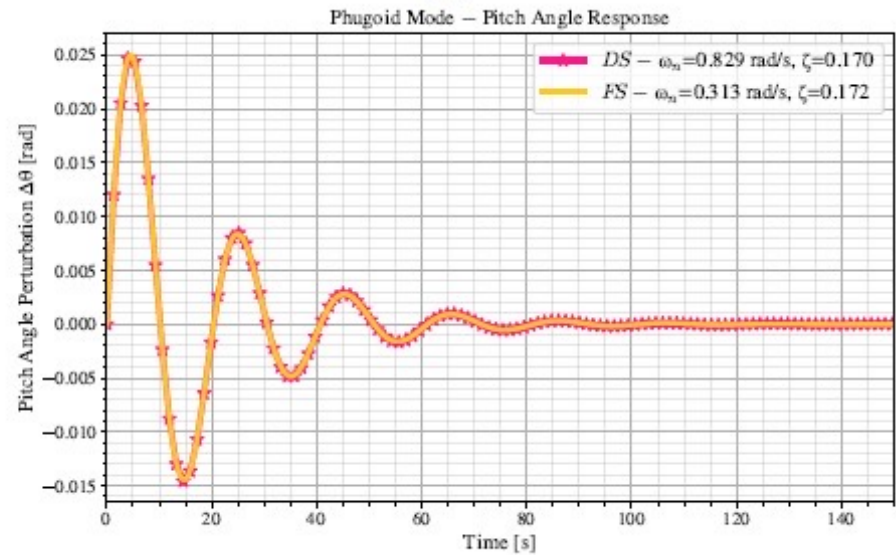
$$\tau = tV/l$$

- However: It is important to consider that in contrast with conventional land planes, airplane mass has a decisive influence on a variety of fluid (water) flow, such as boundary layer behavior, suction forces, water resistance and also vertical buoyancy forces



(a)

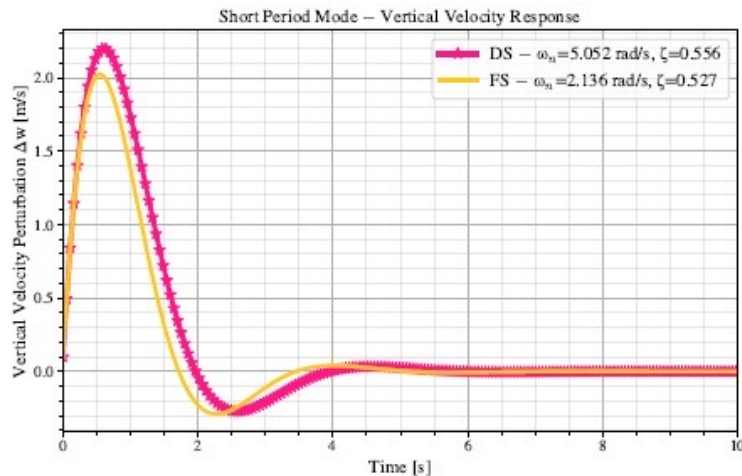
errors < 1%



errors < 2.5%

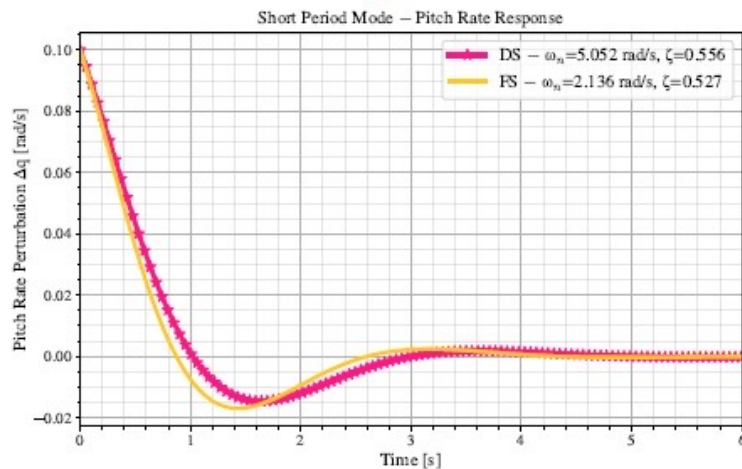


# Short Period Scaling



(a)

errors < 2.5%



(b)



# Propulsion Scaling

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- Small low Reynolds Propeller difficulties, hence:
- Comparative Analysis based on Power to Weight Ratio
- Machine Learning together with Blade Element Analysis under current development at CEA UFMG



# Main Conclusions

- Amazon region floatplane conceptual design motivated present SFT/SWT research
- Floatplane design relies on empirical methodology developed during the first half of the 20th century
- Amphibious aircraft mass complex influence on water flow, hence and unsurprisingly:
  - Amphibious aircraft needs two different domains, subscale water testing (SWT) and subscale flight testing (SFT)
  - Important to observe non-dimensional time when carrying out dynamic response modeling  $\tau = tV/l$
  - The research continues, future work includes reduced scale propellers



# Thank you very much



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