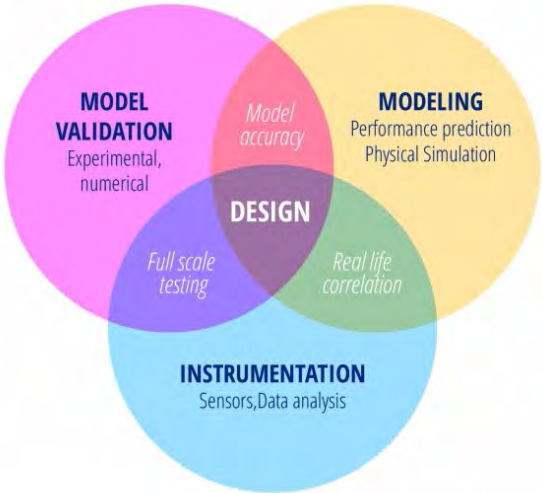
America's Cup and advanced yacht design with CAESES

CAESES Users Meeting 2019

Artemis Racing & Technologies

- **Artemis Racing** is a professional sailing team founded in 2006 by successful businessman and sailor, Torbjörn Törnqvist. The Team competed in the 34th and 35th America's Cup.

- **Artemis Technologies** was established in 2017, as a sister company to Artemis Racing which has over a decade of experience in high-performance yacht racing and America's Cup competition. Utilising world class skills in simulation, lightweight structure engineering, electronics, hydraulics, aerodynamics and hydrodynamics, Artemis Technologies has been developing new green technologies with various maritime applications for the past year and aims to deliver real innovation to its customers through unique solutions and products such as fast racing boats and autonomous sailing vessels.



www.artemistechnologies.co.uk

1. **America’s Cup**
   The race and the boats

2. **Caeses at Artemis**
   How we use it
   Examples

America's Cup

- Oldest trophy in international sport
- Held every ~3-4 years
- Held in the last winner's country i.e. the "defender" (usually…)
- Format of racing: "Match racing": 1 vs 1

Rule	Year	Venue	Defending club	Challenging club
Fleet racing	1851	Isle of Wight	Royal Yacht Squadron	New York Yacht Club
	1870	New York City	New York Yacht Club	Royal Thames Yacht Club
Schooner match	1871	New York City	New York Yacht Club	Royal Harwich Yacht Club
	1876	New York City	New York Yacht Club	Royal Canadian Yacht Club
65 ft sloop	1881	New York City	New York Yacht Club	Bay of Quinte Yacht Club
NYYC 85ft	1885	New York City	New York Yacht Club	Royal Yacht Squadron
	1886	New York City	New York Yacht Club	Royal Northern Yacht Club
	1887	New York City	New York Yacht Club	Royal Clyde Yacht Club
SCYC 85ft	1893	New York City	New York Yacht Club	Royal Yacht Squadron
SCYC 90ft	1895	New York City	New York Yacht Club	Royal Yacht Squadron
	1899	New York City	New York Yacht Club	Royal Ulster Yacht Club
	1901	New York City	New York Yacht Club	Royal Ulster Yacht Club
	1903	New York City	New York Yacht Club	Royal Ulster Yacht Club
Universal 75 ft	1920	New York City	New York Yacht Club	Royal Ulster Yacht Club
Universal J-Class	1930	Newport	New York Yacht Club	Royal Ulster Yacht Club
	1934	Newport	New York Yacht Club	Royal Yacht Squadron
	1937	Newport	New York Yacht Club	Royal Yacht Squadron
	1958	Newport	New York Yacht Club	Royal Yacht Squadron
IYRU 12mR	1962	Newport	New York Yacht Club	Royal Sydney Yacht Squadron
	1964	Newport	New York Yacht Club	Royal Thames Yacht Club
	1967	Newport	New York Yacht Club	Royal Sydney Yacht Squadron
	1970	Newport	New York Yacht Club	Royal Sydney Yacht Squadron
	1974	Newport	New York Yacht Club	Royal Perth Yacht Club
	1977	Newport	New York Yacht Club	Sun City Yacht Club
	1980	Newport	New York Yacht Club	Royal Perth Yacht Club
	1983	Newport	New York Yacht Club	Royal Perth Yacht Club
	1987	Fremantle	Royal Perth Yacht Club	San Diego Yacht Club
DOG match	1988	San Diego	San Diego Yacht Club	Mercury Bay Boating Club
IACC	1992	San Diego	San Diego Yacht Club	Compagnia Della Vela di Venezia
	1995	San Diego	San Diego Yacht Club	Royal New Zealand Yacht Squadron
	2000	Auckland	Royal New Zealand Yacht Squadron	Yacht Club Punta Ala
	2003	Auckland	Royal New Zealand Yacht Squadron	Société Nautique de Genève
	2007	Valencia	Société Nautique de Genève	Royal New Zealand Yacht Squadron
DOG match	2010	Valencia	Société Nautique de Genève	Golden Gate Yacht Club
AC72	2013	San Francisco	Golden Gate Yacht Club	Royal New Zealand Yacht Squadron
AC50	2017	Bermuda	Golden Gate Yacht Club	Royal New Zealand Yacht Squadron
AC75	2021	Auckland	Royal New Zealand Yacht Squadron	

America’s Cup - the boats

America

J Class

$$R = \frac{0.18 \cdot L \cdot \sqrt{S}}{\sqrt[3]{D}}$$

1851

1914 ------- 1937

Time

America’s Cup - the boats

Artemis TECHNOLOGIES

“12 - meters”

$$\frac{L + 2d + \sqrt{S} - F}{2.37} \leq 12 \text{ metres}$$

Deed of Gift

IACC

$$\frac{L + 1.25 \times \sqrt{S} - 9.8 \times \sqrt[3]{DSP}}{0.686} \leq 24.000\, metres$$

1958 ----- 1987 | 1988 | 1992 ----- 2017 | Time

America's Cup - the boats

Artemis TECHNOLOGIES

Deed of Gift

AC72

AC50

2010 2013 2017

Artemis Racing at the 36th America's Cup


AMERICASCUP.COM

An America’s Cup team

- ~ 100 people
  - Management
  - Sailors
  - Design (Naval Architecture, Sails, Aero / Hydrodynamic)
  - Engineering (Structural, Mechanical)
  - Building (Composites)
  - Marketing - Legal
  - Support

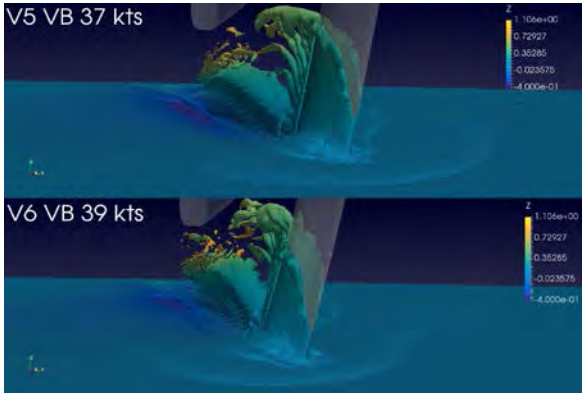
- ~ 100 Millions budget (over 4 years)

CFD - HYDRO

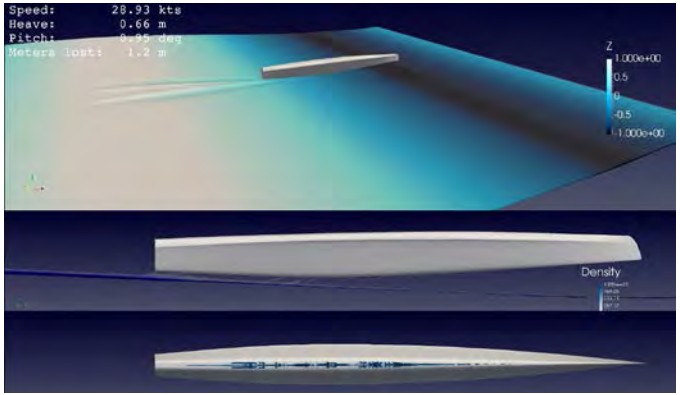
- High fidelity hydro (Ranse):
  - for hull (static and dynamic in waves)
  - appendage design (free surface, cavitation models)

- High fidelity FSI (coupling with FEA)

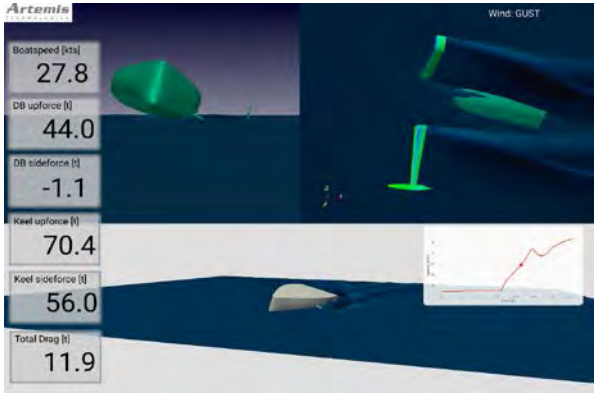
- Unique capabilities for setting up and testing dynamic scenarios (e.g take off, landing, perturbed equilibrium etc.)



2017 Spray on AC50 appendage



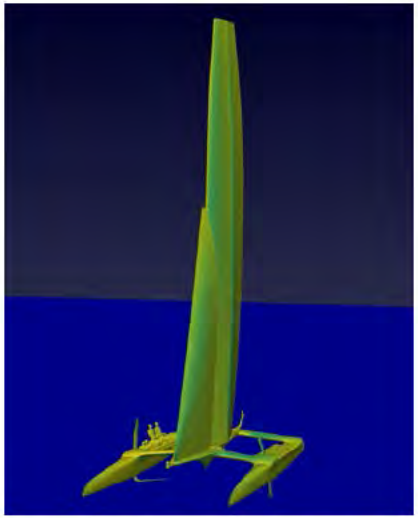
2019 100ft Ultim Trimaran CFD in waves



2018 Open 60' Dynamic take off simulation

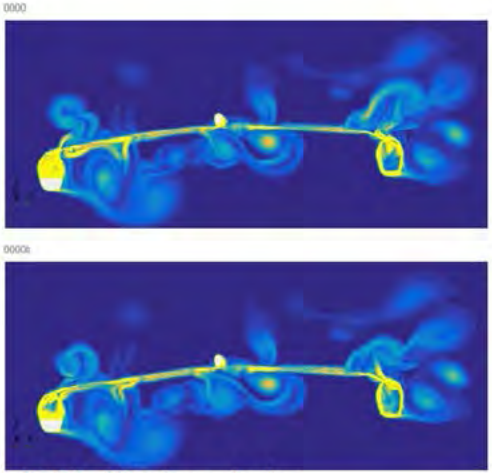
CFD - AERO

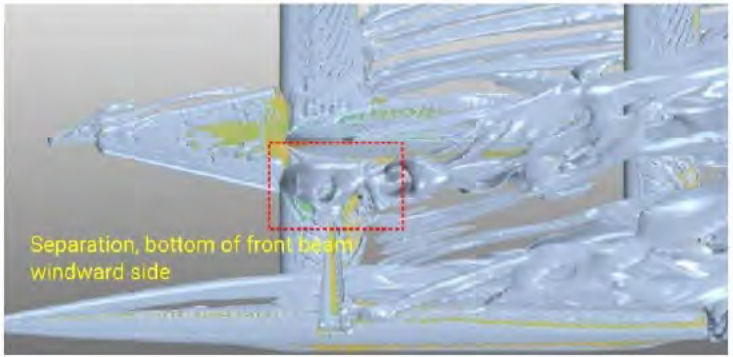
- High fidelity aero (Ranse):
  - sail plan aero and trim optimization
  - platform windage optimization
  - wind sensor upwash calibration



Artemis TECHNOLOGIES

AC50 Beam fairing candidates - Virtual Flow Viz.





AC50 - Windage studies

Caeses at Artemis Racing

- Automated or semi automated workflow, we want to be able to test many variants:
  - Concept stage: to make sure we're testing a fair representation of the idea
  - Optimization stage: to get the last X%

CAD that:

- can run on Linux
- Batch / Scriptable capabilities
- internal optimizer

Examples

1. **Aero workflow**
   Scriptable + Batch + Linux

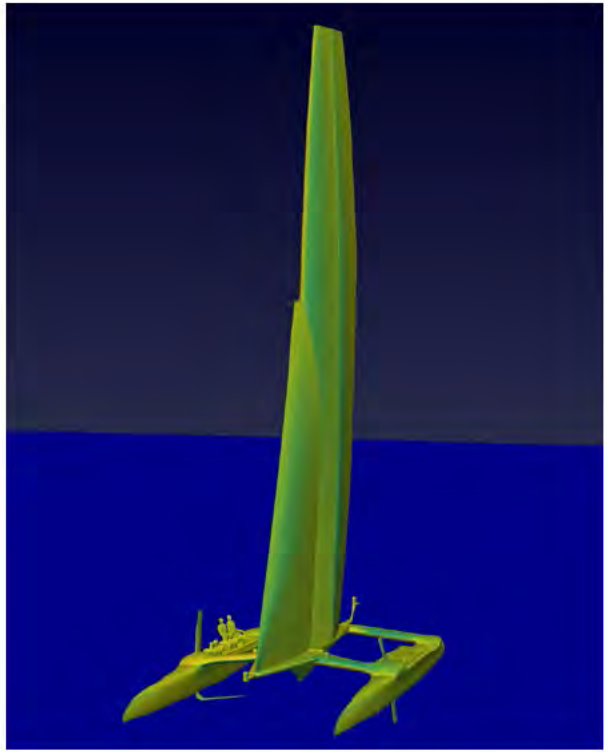
2. **Hull design workflow**
   GUI + Batch + Windows + Linux

3. **2D section design**
   Optimization

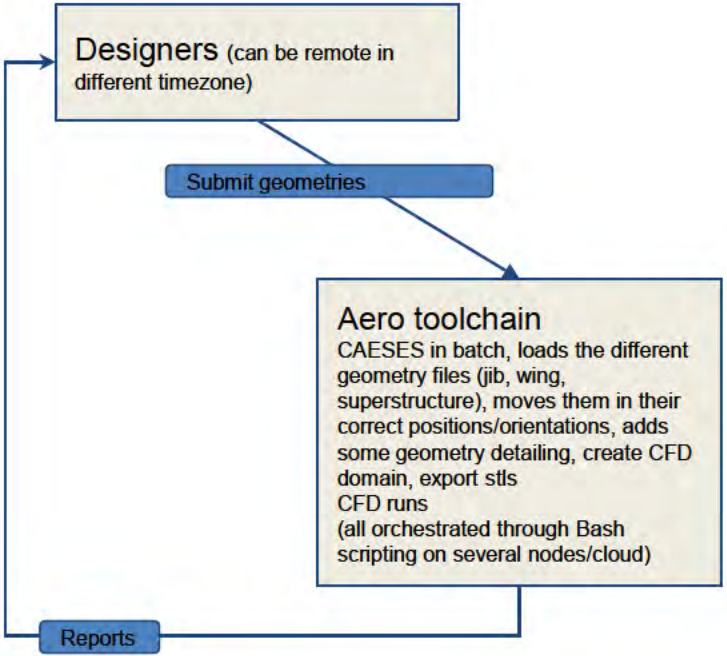
CFD Aero workflow

Artemis TECHNOLOGIES

- AC50s (boats used in the 35th America's Cup) are catamarans with 1 sail (foresail) and a solid wing.
- CFD process involves modelling everything above the water (i.e. in the air).
- The different parts/geometries of the boat are being developed with their own toolchain (e.g. superstructure through Catia + FEA, Sail + Wing through FSI).
- An automatic CFD process was needed to test a large amount of geometries

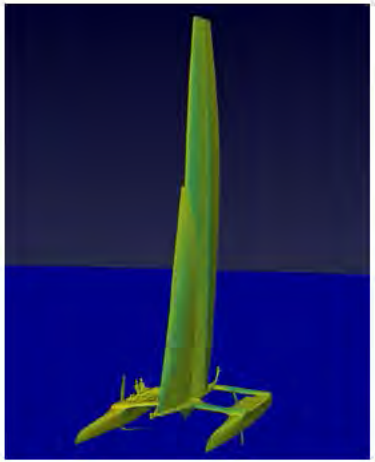


CFD Aero process



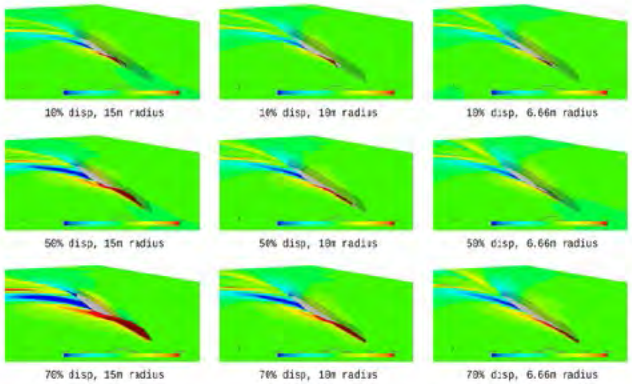
- Key features:
  - Scriptable
  - Runs in Linux
  - Runs in batch
  - Export high quality geometries

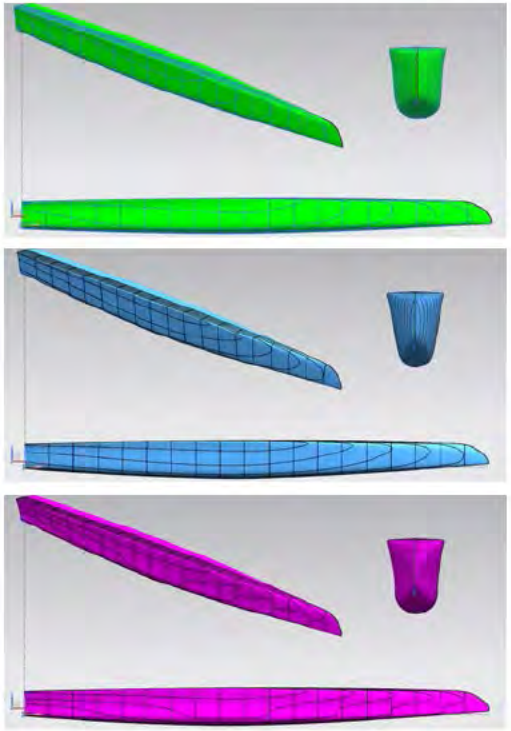
(We also do some “shape deformation” (scripted) through the same process)



Hull design process

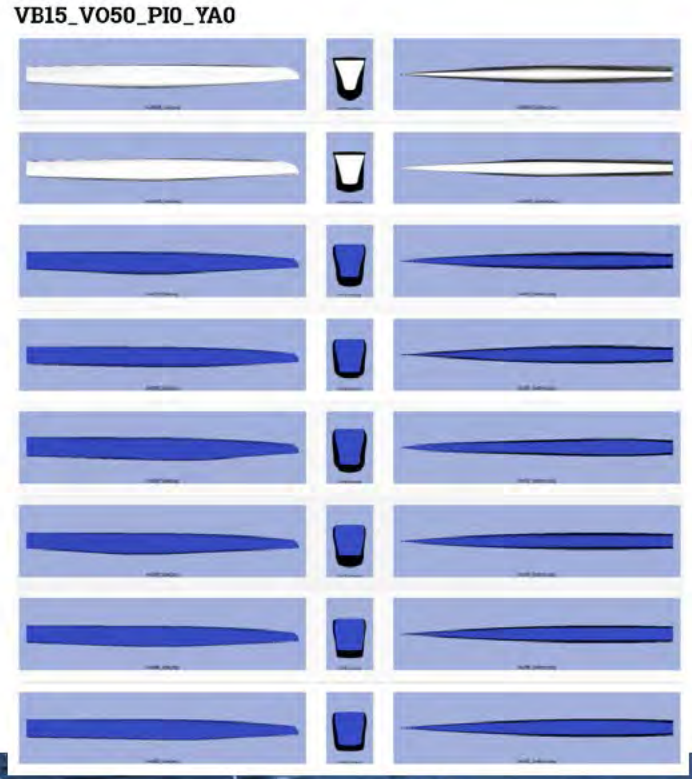
- Process is similar to Aero (automatic CFD + reporting) but geometry is generated in CAESES.
- Hull designers can generally generate 1 shape per day (rule constraints, displacement, lcb, needs to “look” right)
- Design space in terms of geometries is large, range of sailing conditions (low Fn, take-offs, manoeuvring) is huge (leeway, pitch, heave).
  (i.e. pure optimization hasn’t proved that successful (yet))



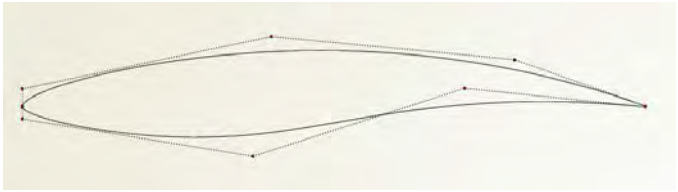


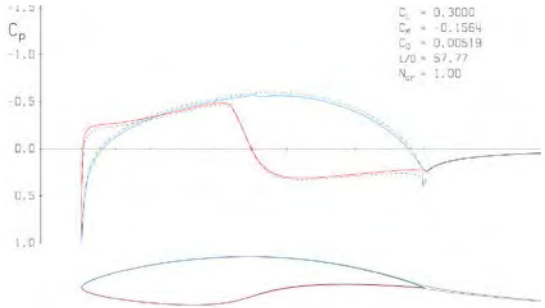
Hull design process

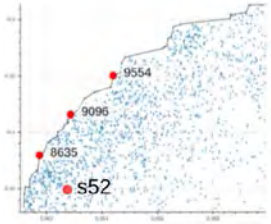
- We increase the amount of shapes by creating variants from the designers shape (e.g. to check sensitivities).
  Semi-optimization process with designer in the loop.
- Some surprising results, lots learnt!
  - Key features:
    - Scriptable, runs in Linux in batch
    - Runs in Windows
    - Nice UI (e.g. dragging points)
    - WebApps?



2D section optimization







Two objective functions (values to be decreased in optimization) taken as:

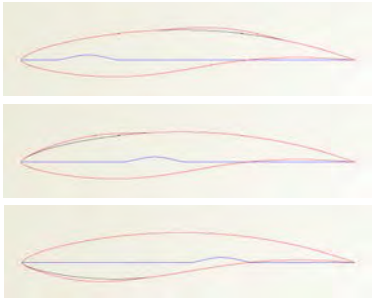
1/ An aggregate value of drag at several lift coefficients

$$F_1 = 0.25\,CD_{CL=0.3} + 2.0CD_{CL=0.4} + 3.0CD_{CL=0.5} + 2.0CD_{CL=0.6} + 0.25CD_{CL=0.65}$$

2/ A minimum coefficient of pressure at CL=0.3 (to increase cavitation speed)

$$F_2 = -MinCP_{CL=0.3}$$

Sensitivity to building tolerance



Bumps scaling here increased for illustration

CAESES at Artemis

Artemis TECHNOLOGIES

Key

Often neglected but also key. Need a good geometry "export" for a good mesh

Not used much in production but useful for initial studies (e.g. 2d optimization)

Key. Both global optimization and more basic design engines.

GEOMETRY MODELING

CAESES® foundation is a powerful and flexible parametric 3D modeler. The main purpose: Robust variable geometry with fewer parameters.

SIMULATION-READY

Create a clean and robust parametric geometry that is ideal for automated meshing and analysis.

CFD AUTOMATION

Integrate, launch and control your simulation runs. Let it be your flexible GUI for process automation incl. 3D post-processing.

OPTIMIZATION

CAESES® offers integrated methods for automated design explorations and shape optimization.

SHAPE DEFORMATION

Optimize imported geometries by using the shape deformation and morphing techniques of CAESES.

POWERFUL SCRIPTING

CAESES® is a command-driven platform that can be fully scripted and customized. Includes batch mode capabilities.

ADJOINT CFD

Accelerate your shape optimization process by mapping the results of an adjoint flow analysis to the geometry parameters.

CUSTOM TEMPLATES

Get your flexible CAESES model in just a few days! Customized to your needs and easy to use. No CAESES expertise required.

Preference towards geometry modeling because of complex constraints. But used in some cases.

Used every day.

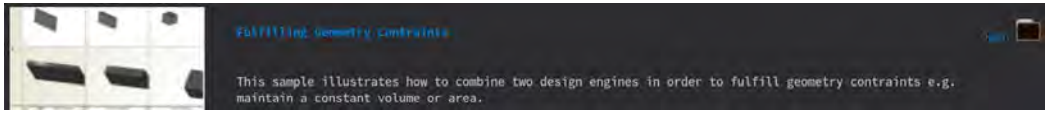
Preference towards geometry modeling because of complex constraints.

Haven't used yet!

Some tips

- Feature Definitions:
  * good way to clean, organize and streamline project
  * customize

- Geometrical equality constraints while optimizing?
  Look at nested design engines to reduce amount of free variables



Questions?