

Designing and testing the world's fastest car, the BLOODHOUND LSR project

Dr Ben Evans @DrBenEvans
UWTSD, Nov 27th 2019



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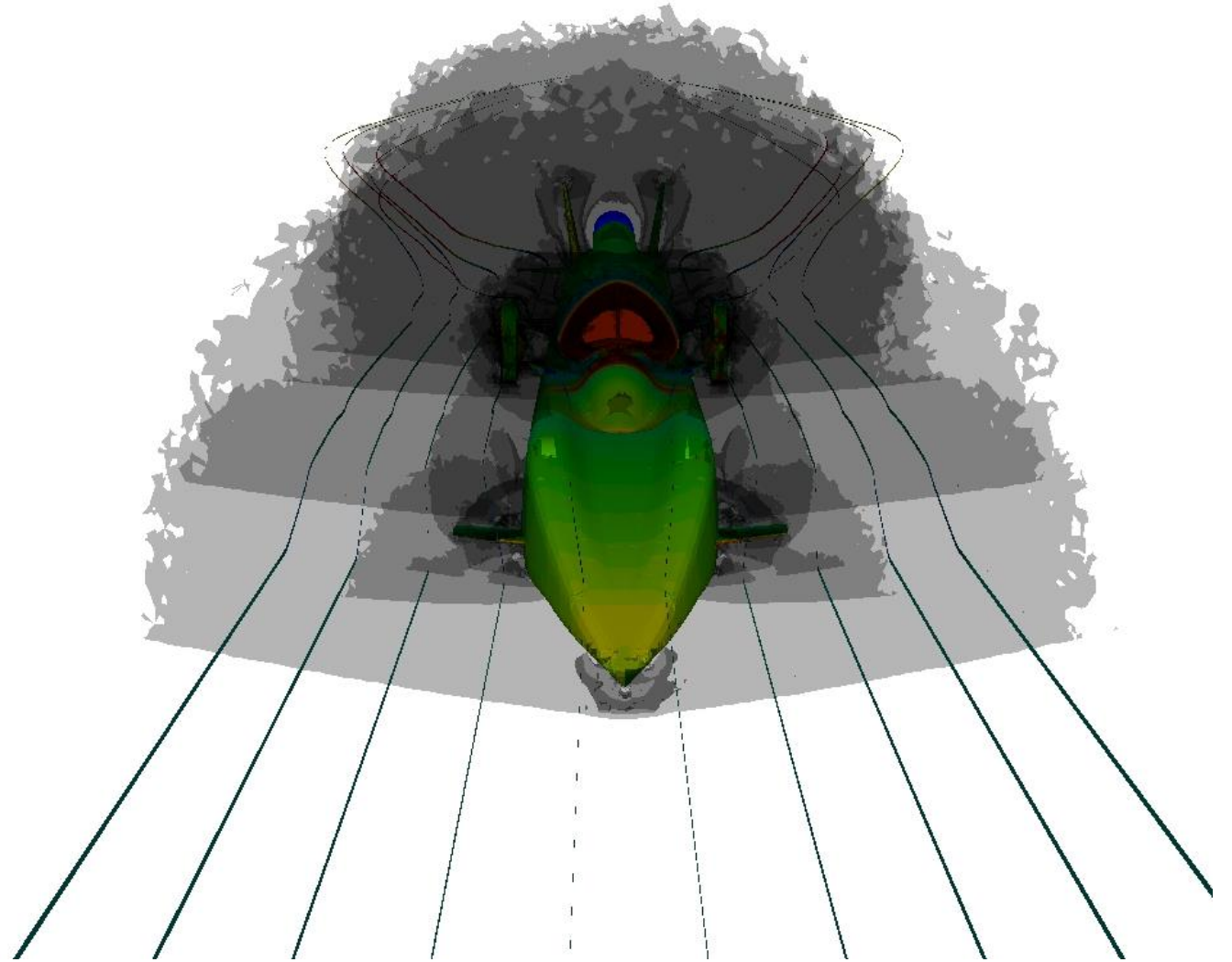
Contents

- Design

- Subsonic to Supersonic
- The CFD process
- BLOODHOUND LSR design
- The role of optimisation in design
- Ongoing research

- Testing

- Aerodynamic performance
- Vehicle Performance



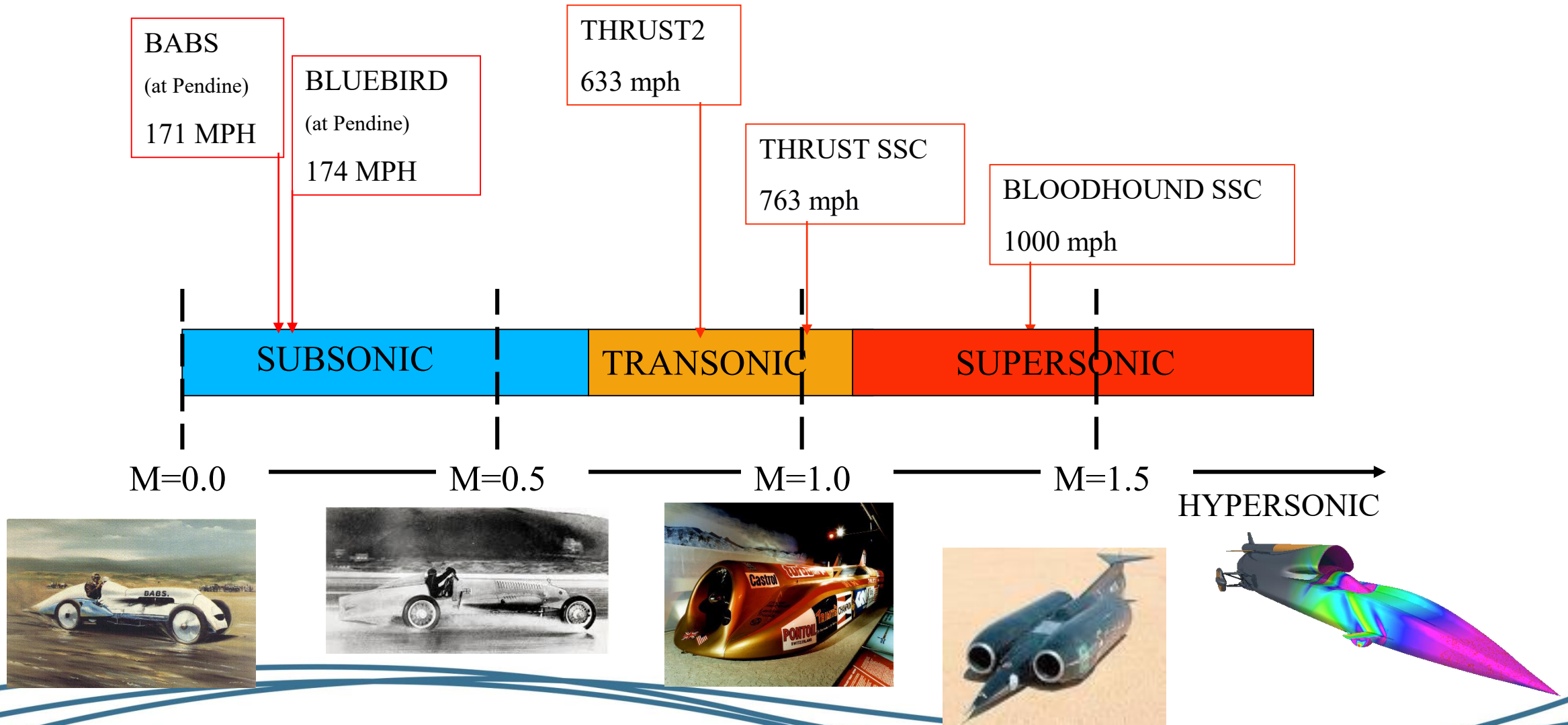
BLOODHOUND LSR – What's it all about?



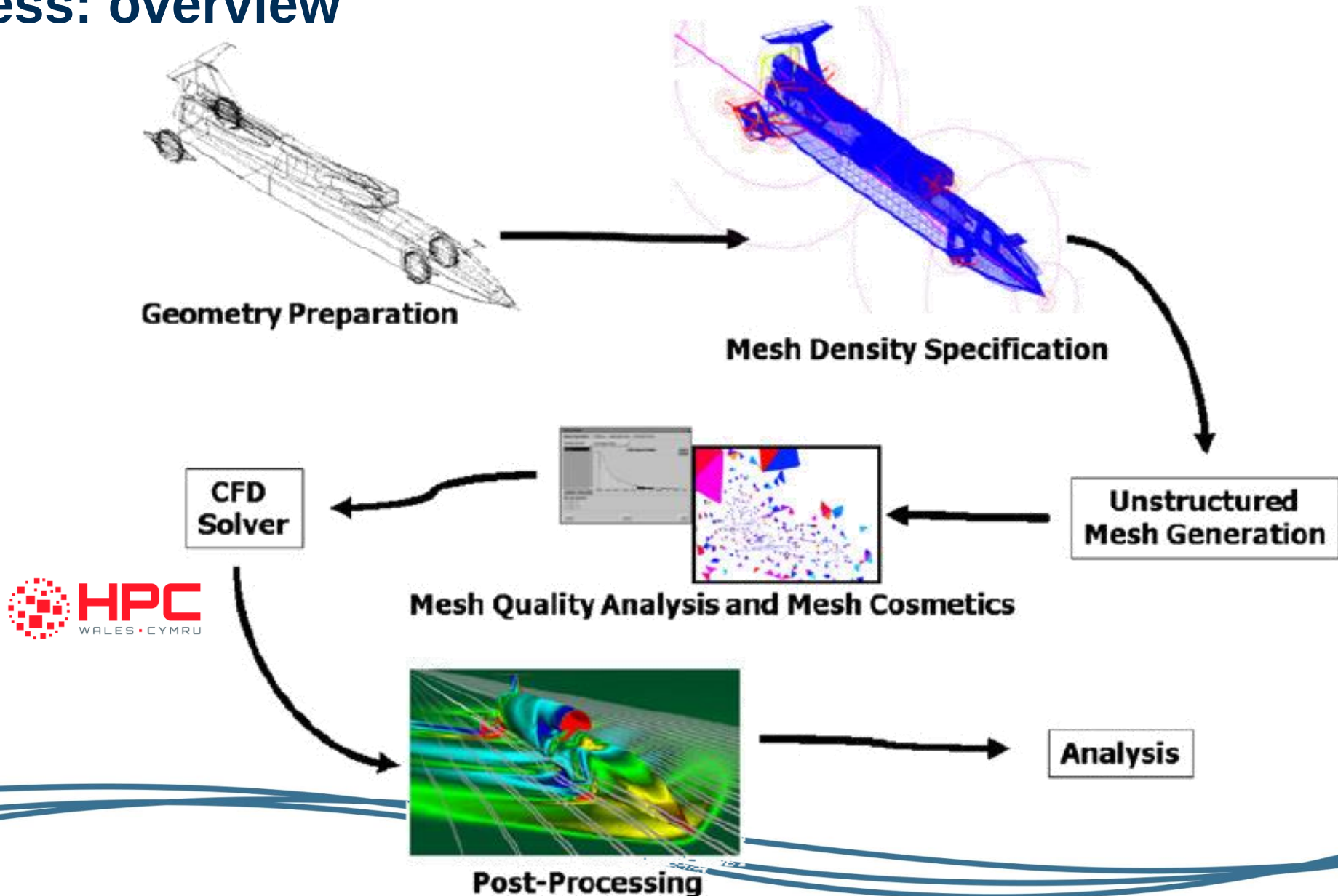
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Subsonic to Supersonic

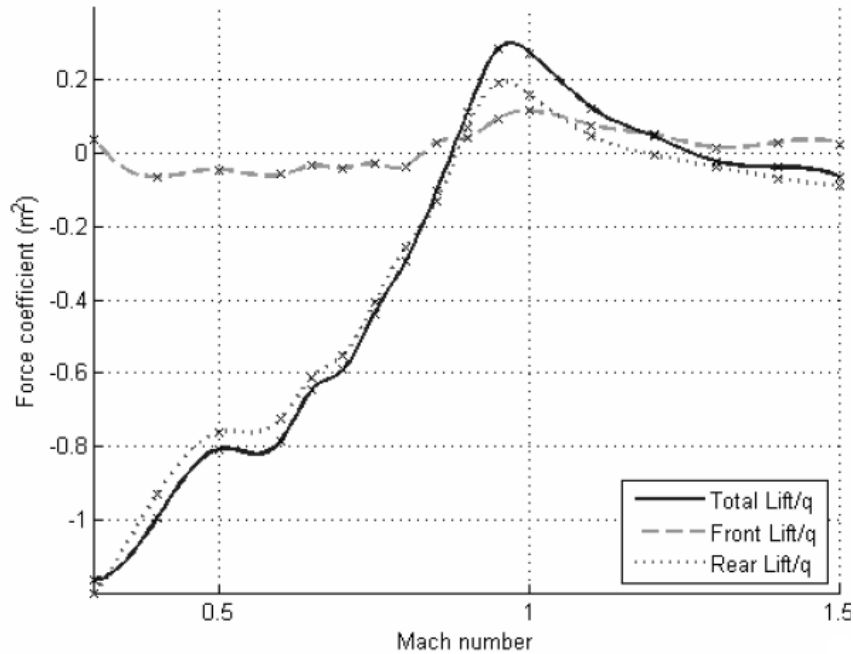


CFD Process: overview

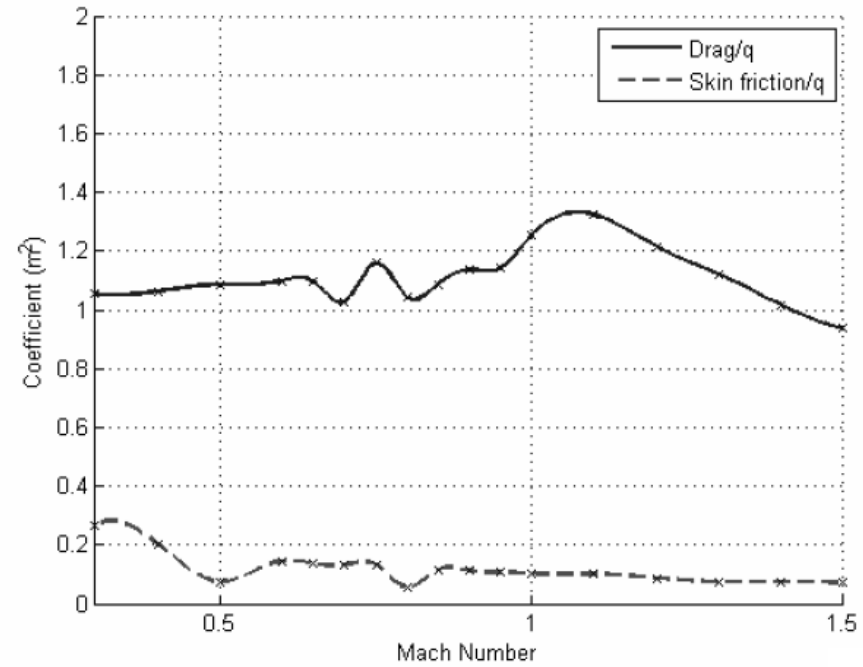


B.J.Evans, O.Hassan, J.W.Jones, K.Morgan, L.Remaki, *Computational Fluid Dynamics Applied to the Aerodynamic Design of a Land-Based Supersonic Vehicle*, Numerical Methods for Partial Differential Equations, Vol 27, 141 – 159, 2011

Force coefficient outputs



config12 lift variation with Mach number (acceleration)

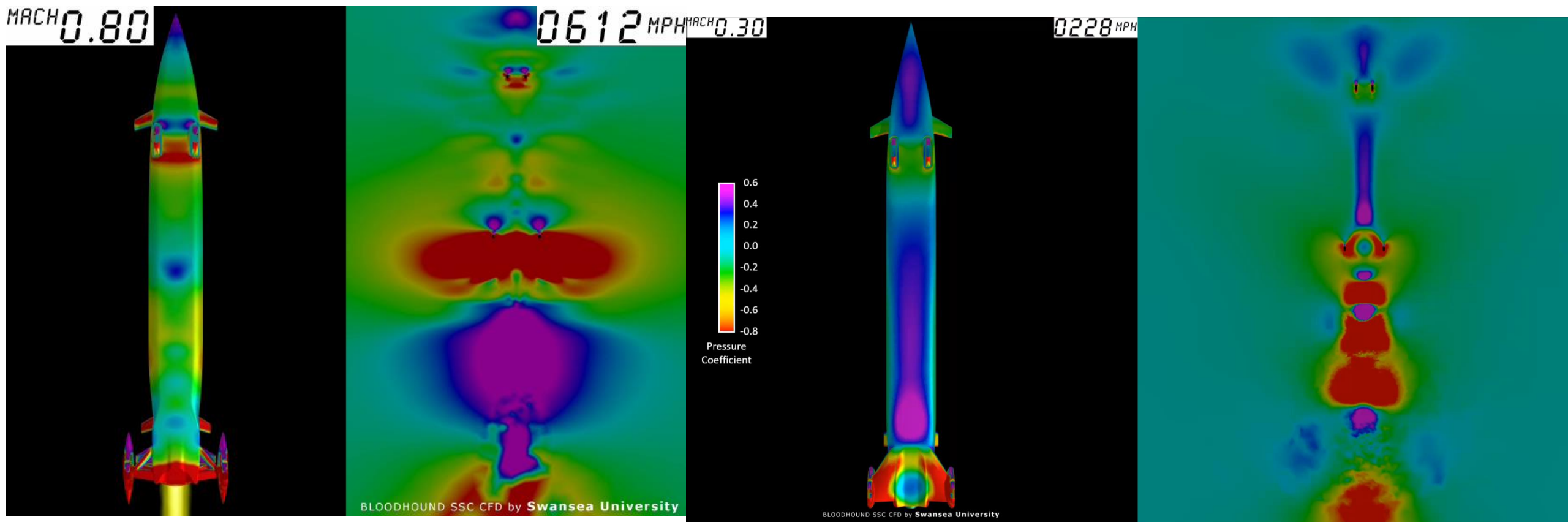


config12 drag variation with Mach number (acceleration)

B. Evans, C. Rose, *Simulating the aerodynamic characteristics of the Land Speed Record vehicle, BLOODHOUND SSC*, **IMechE Journal of Automotive Engineering**, April 2014



BLOODHOUND CFD analysis as a design tool



Model Validation



CFD Model Validation

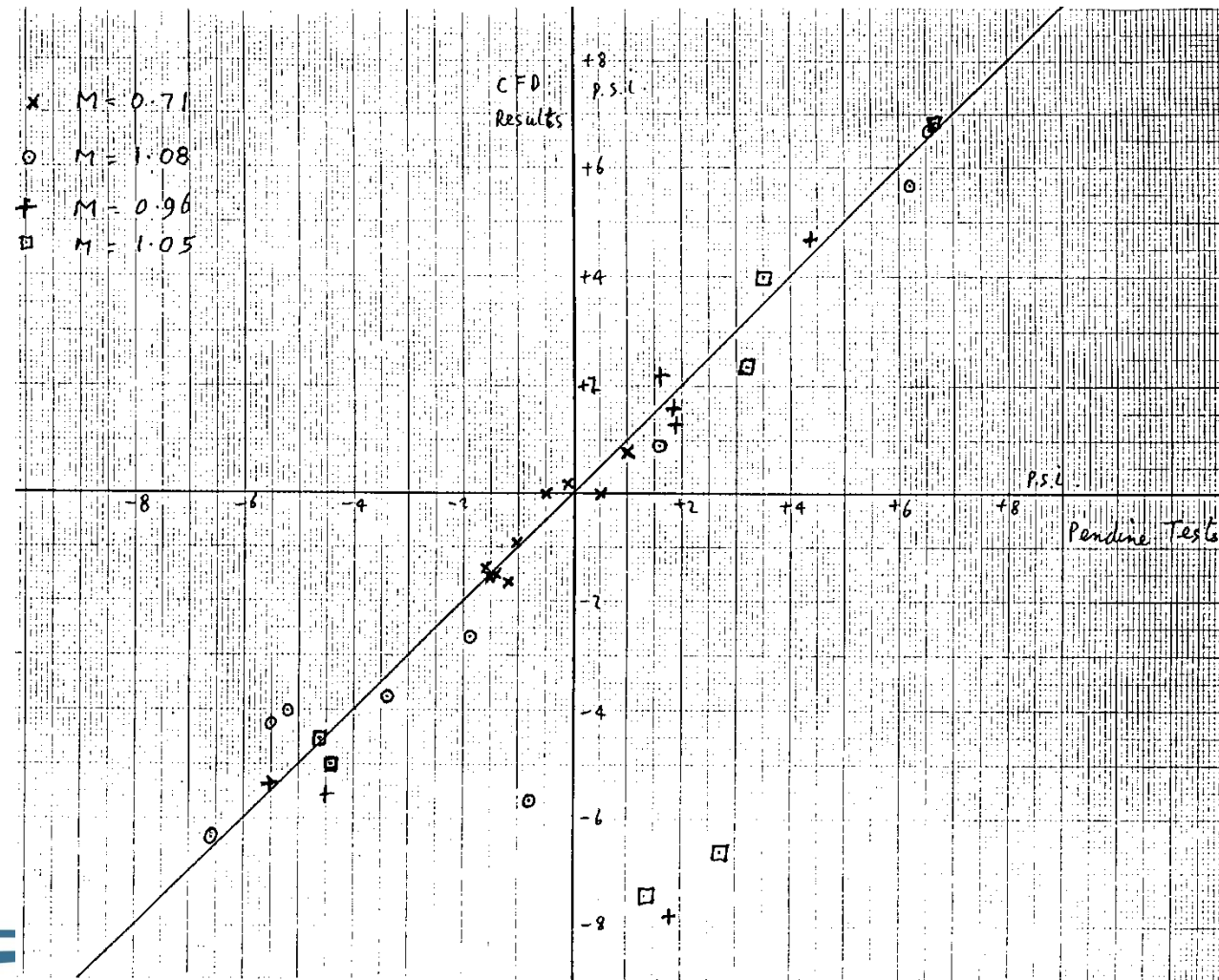
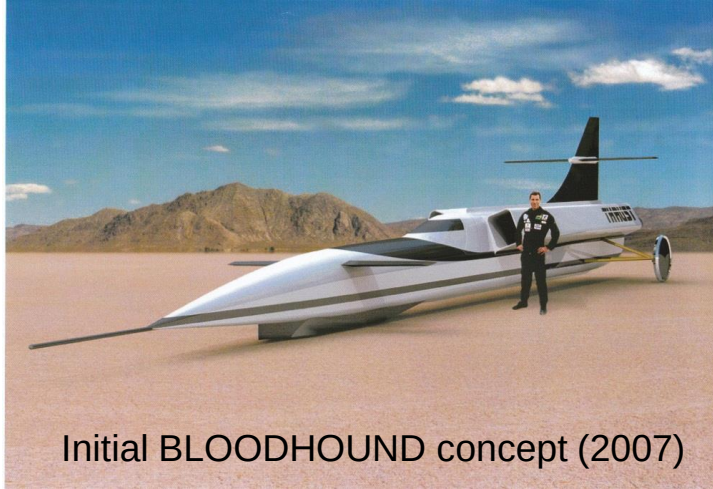


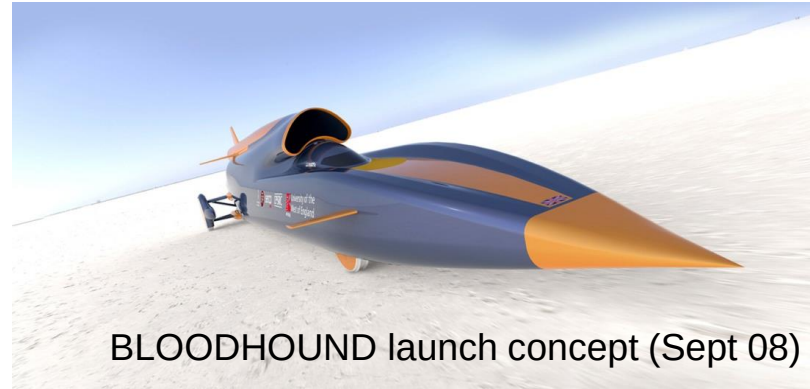
Figure 9.



BLOODHOUND SSC Design Evolution



Initial BLOODHOUND concept (2007)



BLOODHOUND launch concept (Sept 08)



BLOODHOUND final design (Dec 14)



BLOODHOUND high speed testing (Nov 19)

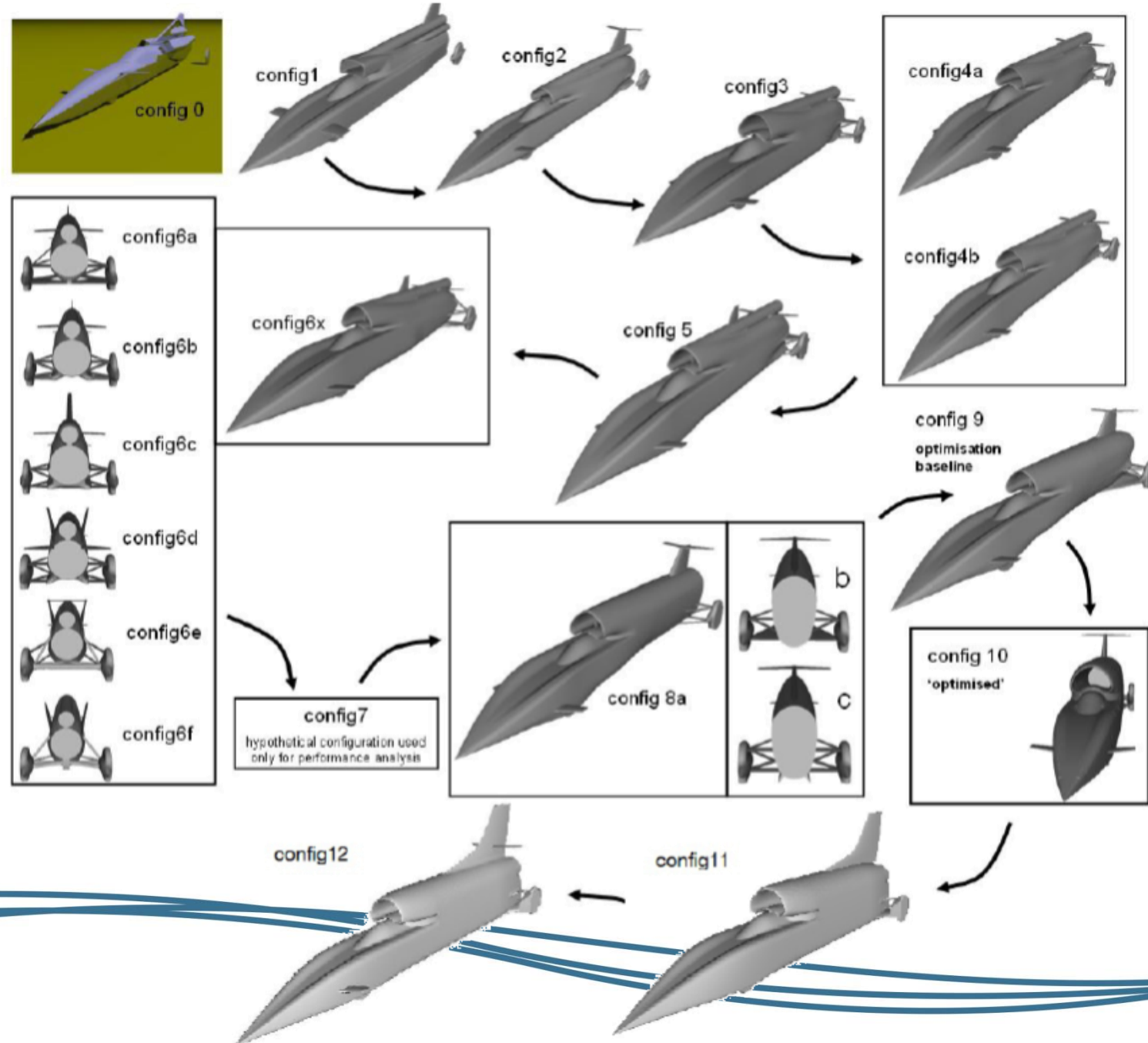


BLOODHOUND low speed testing (Oct 17)



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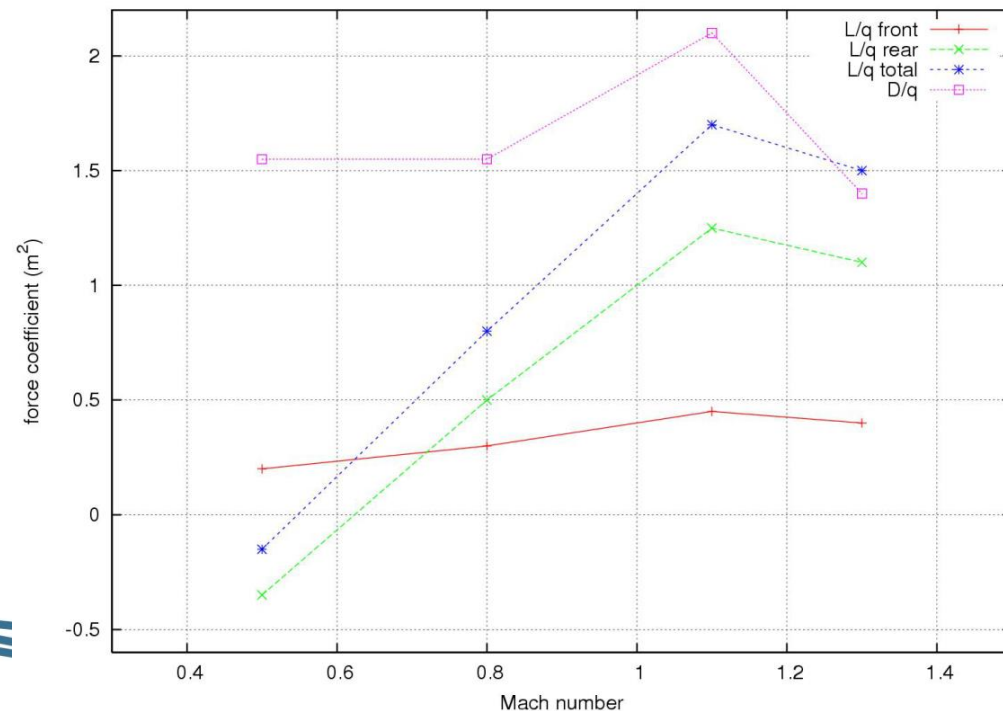


Design challenge: reducing supersonic lift

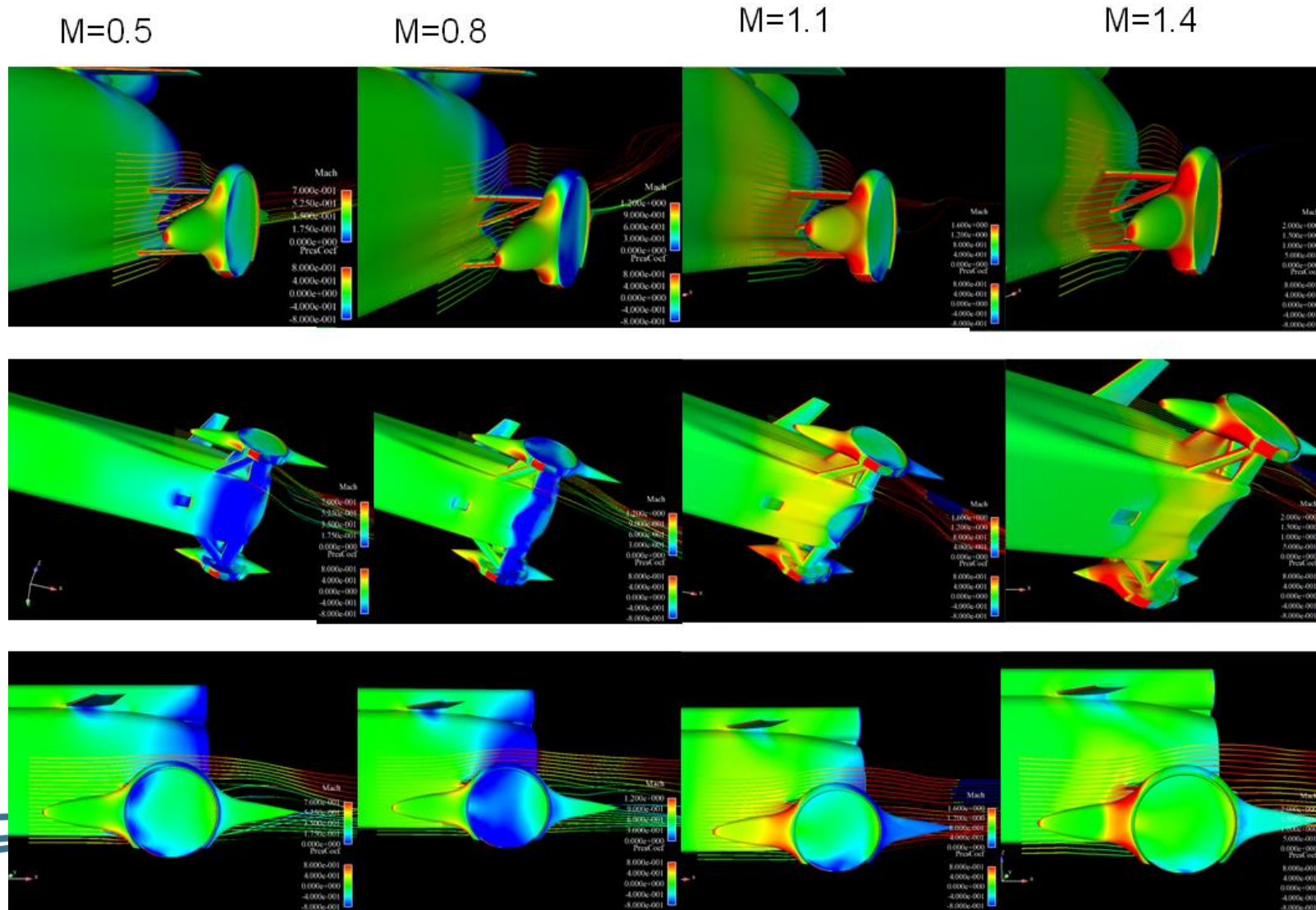
The lift force at Mach = 1.1 in 'config 9' design was 142.6 kN
(lift force coefficient L/q is 1.7 m^2)

The weight of the vehicle without fuel is 63 kN

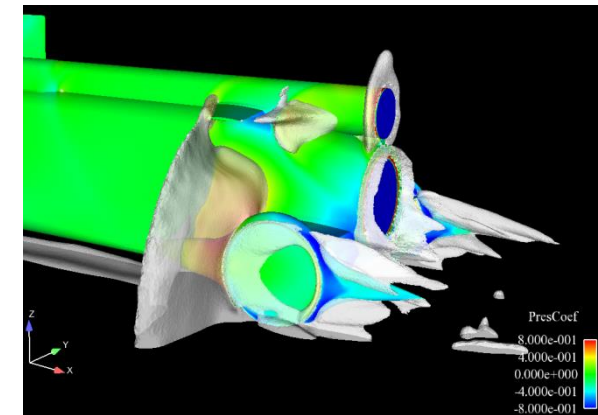
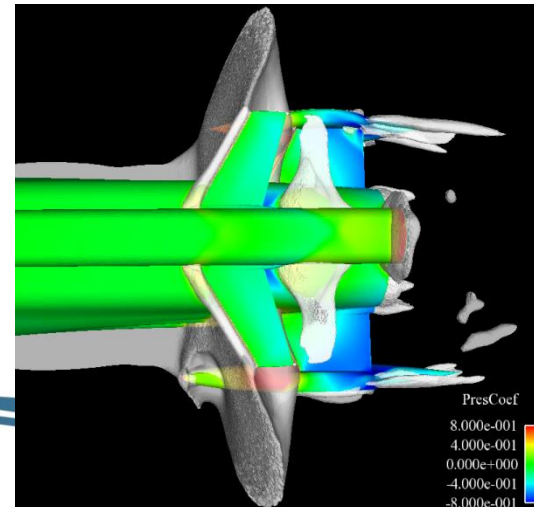
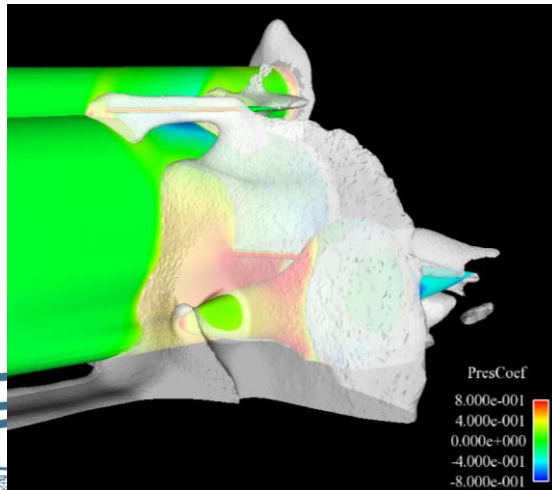
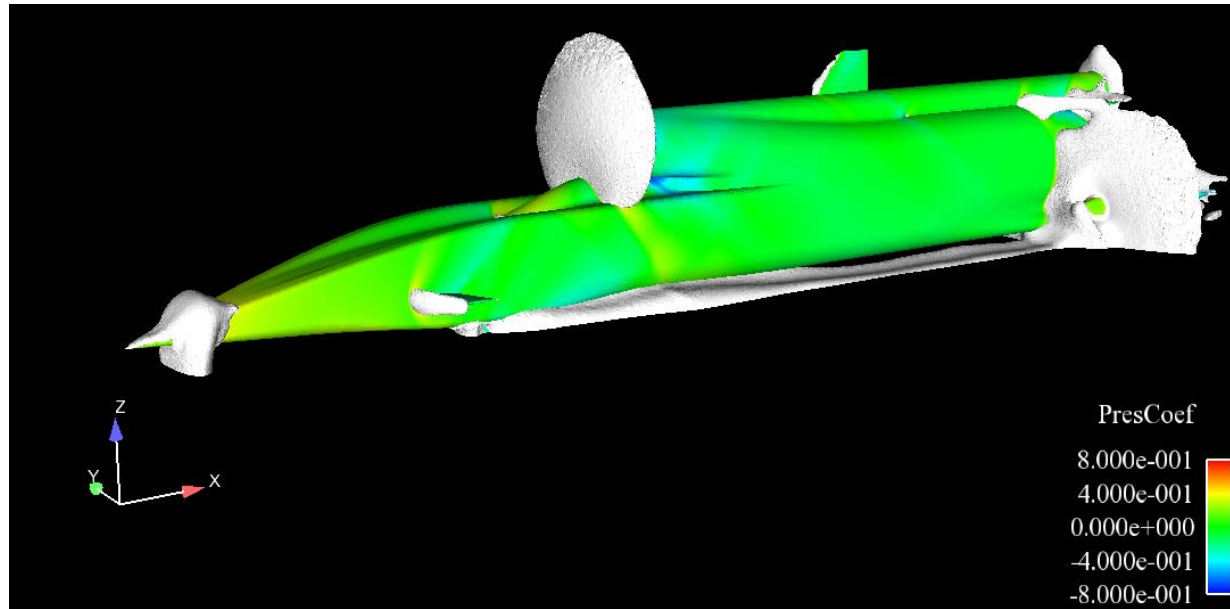
Rear lift force coefficient L/q rear is too large



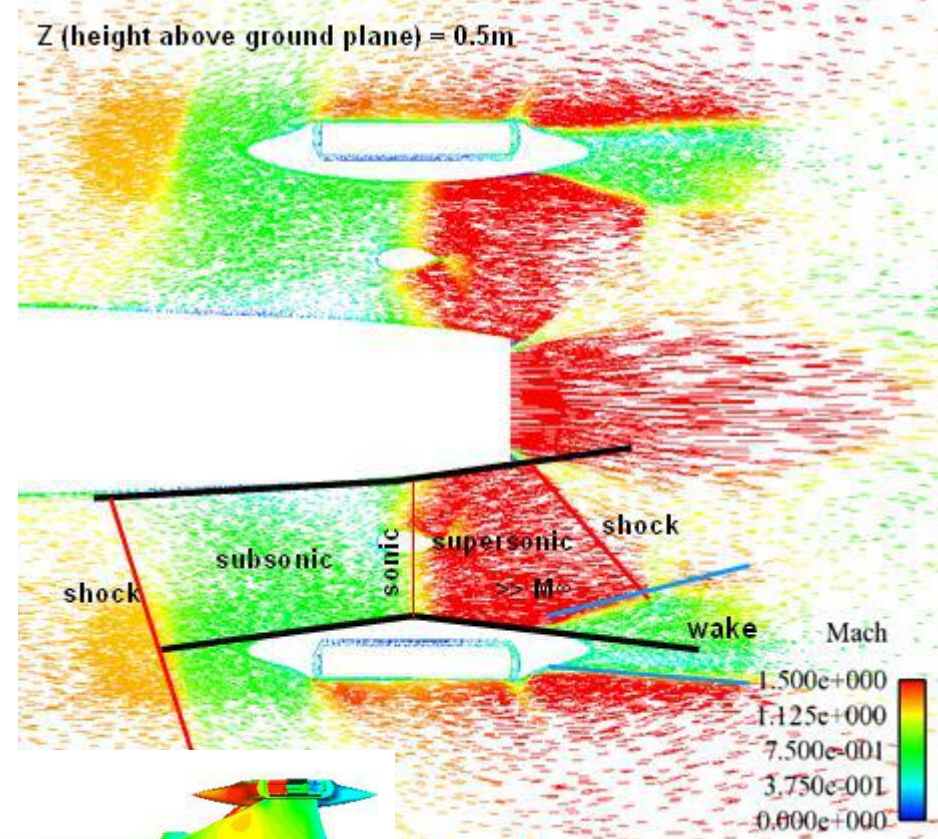
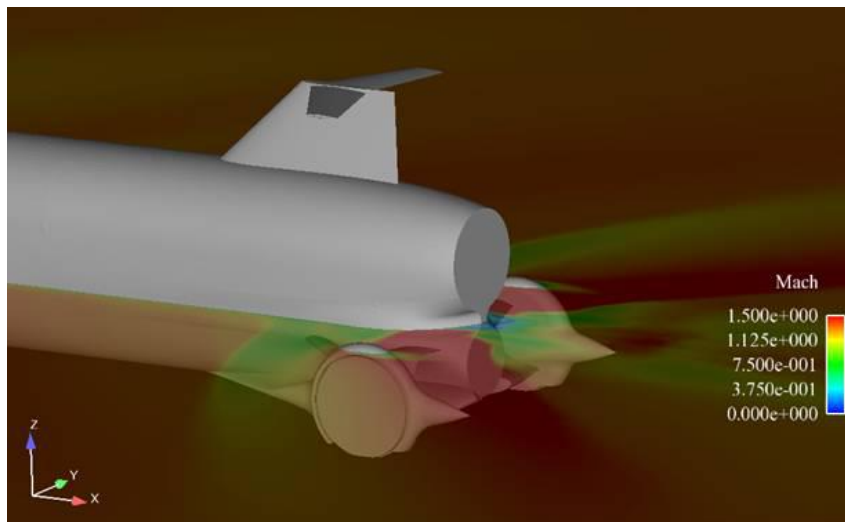
BLOODHOUND config5 – rear supersonic lift



BLOODHOUND config5 – Mach 1 isosurfaces ($M^\infty=1.1$)



The Aerodynamic Cause



$M_{\infty}=1.3$

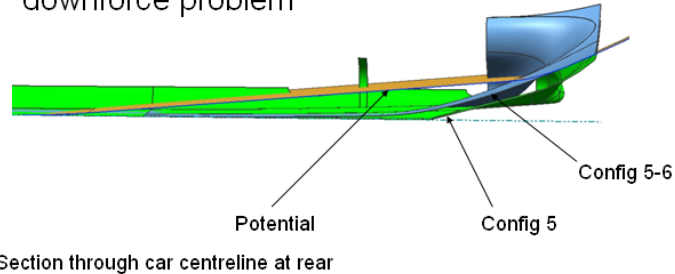
$M_{\infty}=0.5$

PresCoef
8.000e-001
3.500e-001
-1.000e-001
-5.500e-001
-1.000e+000

Potential Solutions.....

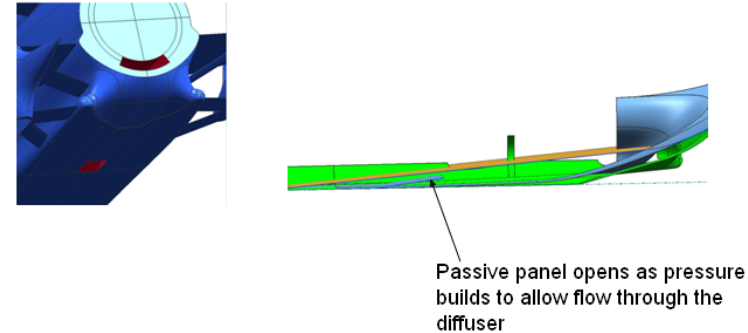
Rear Diffuser

- Raise/angle EJ200 to allow larger rear diffuser
 - Solves high speed lift, creates low speed downforce problem



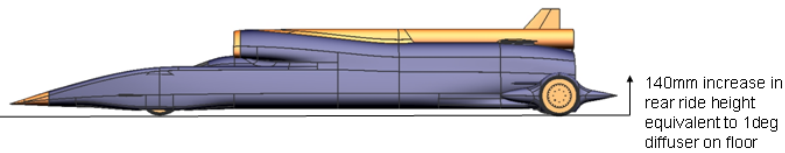
Rear Bleed

- Possibly in conjunction with rear diffuser behind a “false floor”



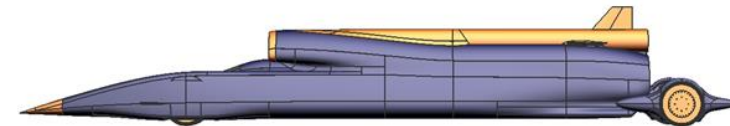
Rake Car

- Angle car floor by raising rear suspension
 - Need to understand how cg position and mass of car vary throughout the run



Move Rear Wheels

- Move wheels rearward by 1m – change to beam rear suspension



config10 – parametric optimisation

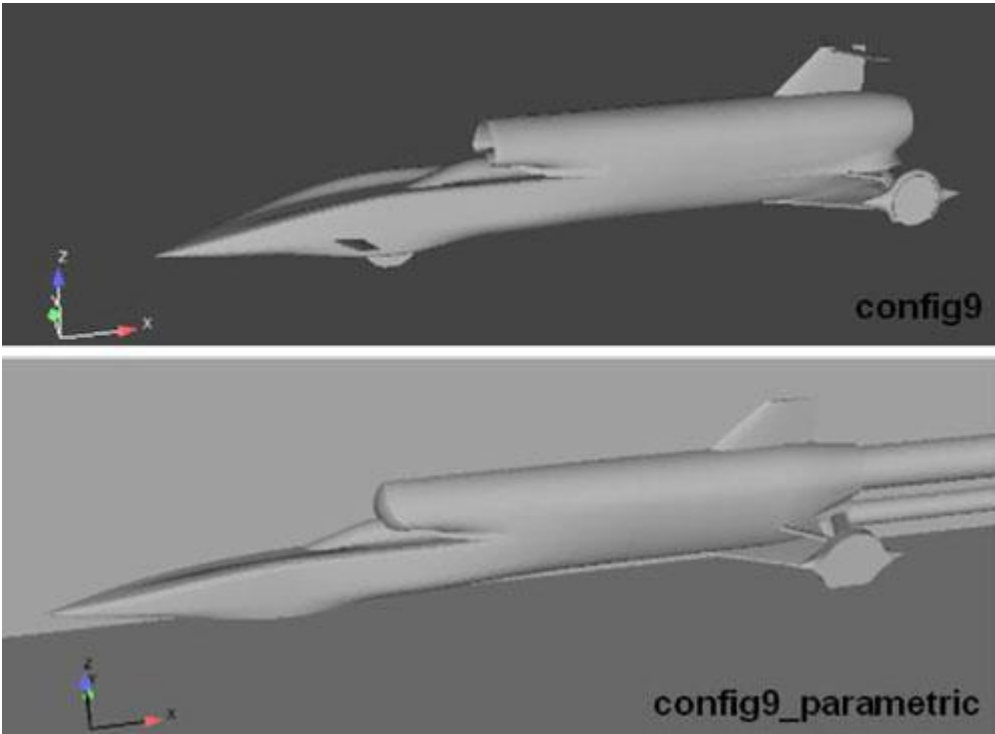


Study parameters:

- delta leading edge sweep angle
- base area
- rear wheel track
- fairing spike length
- fairing spike height
- boat-tail angle
- body-delta angle
- ride height
- delta angle of attack
- delta strut camber
- 'spam' shape
- diffuser
- suspension 'blister'
- delta leading edge 'crank'
- delta – body blend
- fairing radius
- fairing cone diameter
- delta AoA



Parametric CFD Model Analysis

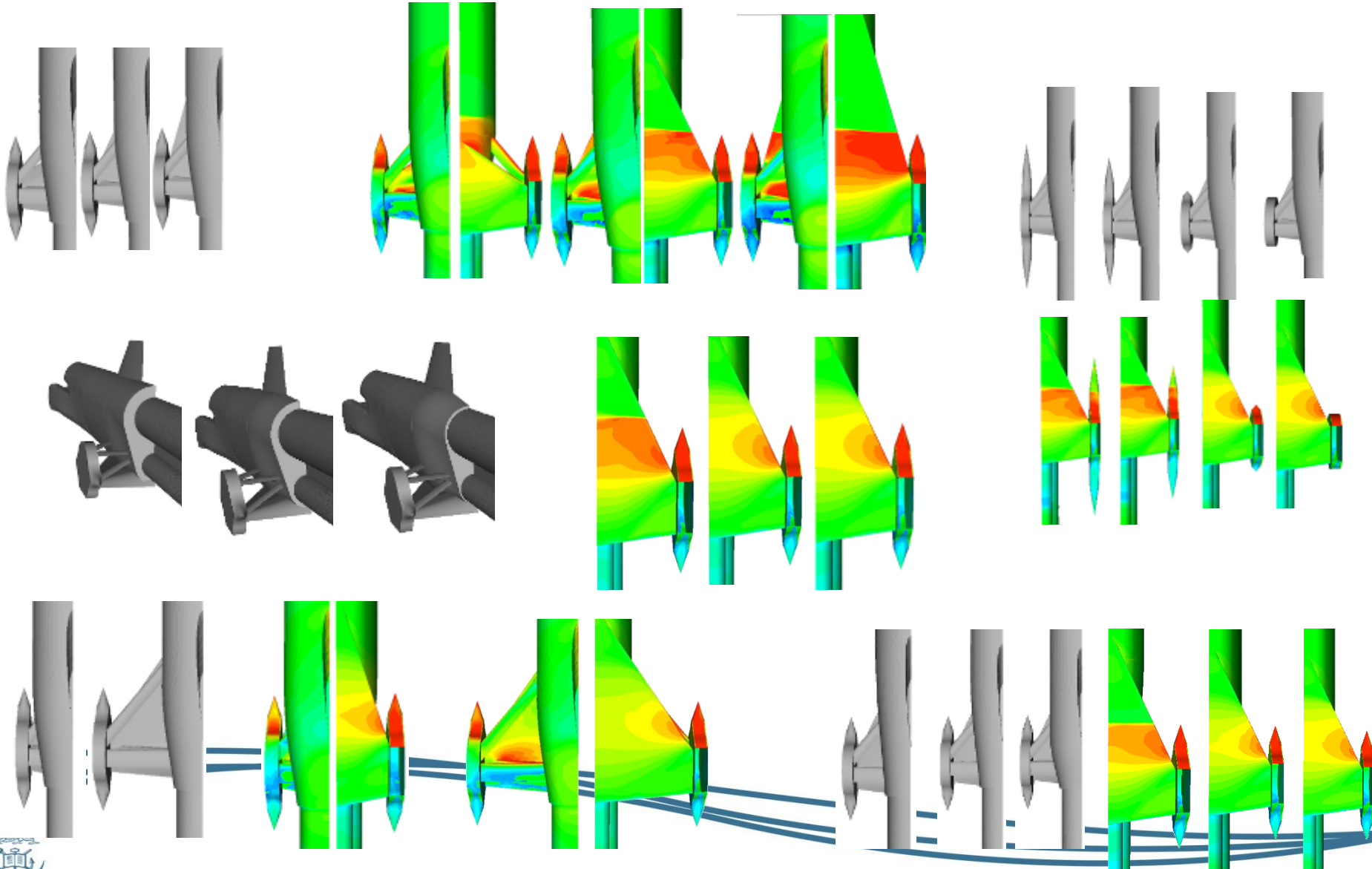


B. Evans et al.

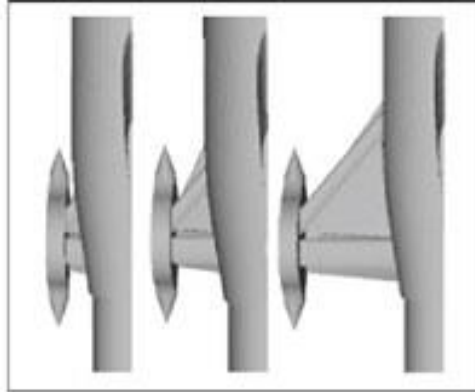
Table 1 Comparison of the config9 full car geometry and parametric model lift and drag results

Model	Mach [∞]	L/q total (m ²)	L/q front (m ²)	L/q rear (m ²)	D/q (m ²)	Drag LoA above ground plane (m)
Config9 - full car	1.3	1.39	0.369	1.021	1.88	0.63
Config9 - parametric	1.3	$0.65 * 2 = 1.3$	$-0.119 * 2 = -0.238$	$0.769 * 2 = 1.54$	$0.93 * 2 = 1.86$	0.77

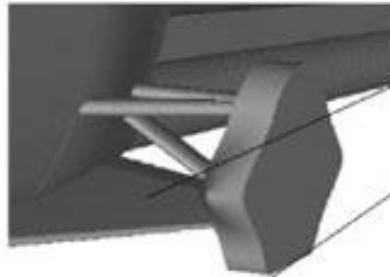
config10 – parametric optimisation



Principle design factors affecting rear supersonic lift



*rear wheel track variation considered



- delta strut leading edge sweep angle (DL)
- delta strut angle of attack (DA)

- base area (C)
- rear wheel track
- fairing spike length
- fairing spike height

- boat-tail angle (R)
- body-delta angle

- ride height
- delta strut camber

- **base shape (S)**

- diffuser
- suspension 'blister'
- delta leading edge 'crank' angle
- delta-body blend
- fairing radius
- fairing cone diameter

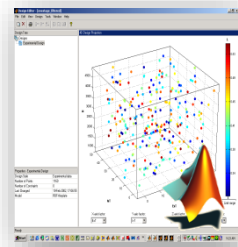


Design Optimisation

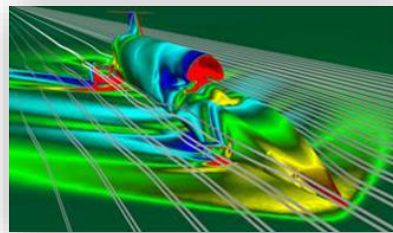
Process of choosing good input parameters settings that optimise a chosen design criteria

Steps involved:

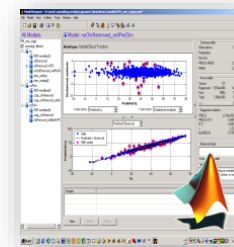
- **Design of Experiments** (choose where to collect data)
- **Data Collection** (run CFD model for chosen settings)
- **Response Surface Modelling** (fit statistical model to data)
- **Optimisation** (find where the statistical model is minimum)



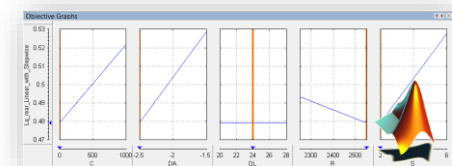
**Design of
Experiment**



**Data
Collection**



**Data
Modelling**



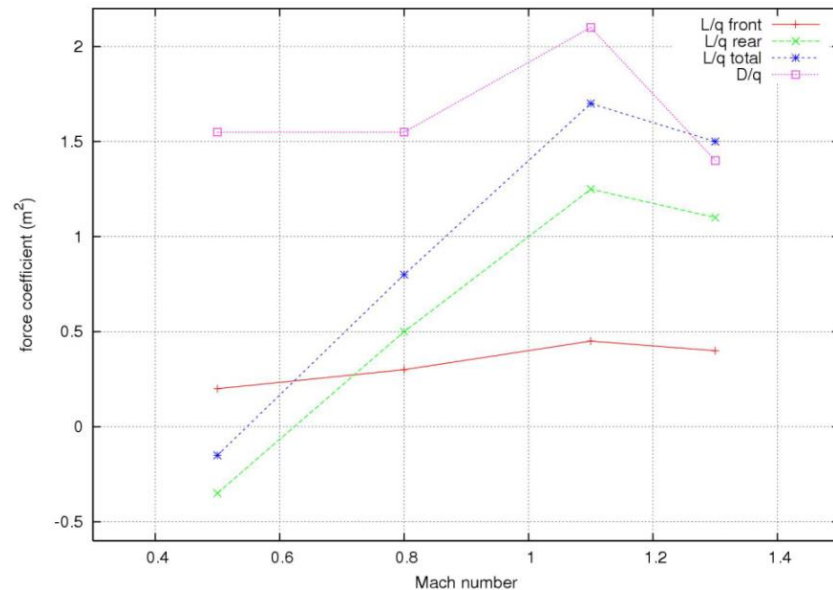
Optimisation



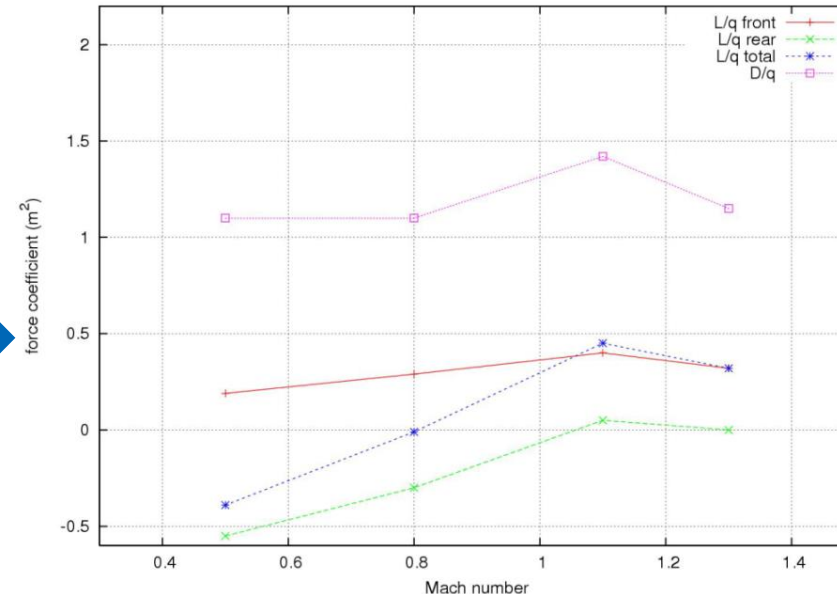
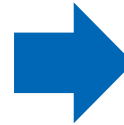
Results - config10

Lift coefficient (L/q), at Mach = 1.1, was reduced from 1.7 m^2 to 0.4 m^2

- This is a reduction in the lift force from 142.6 kN to 33.6 kN
- The weight of the vehicle without fuel is 63 kN



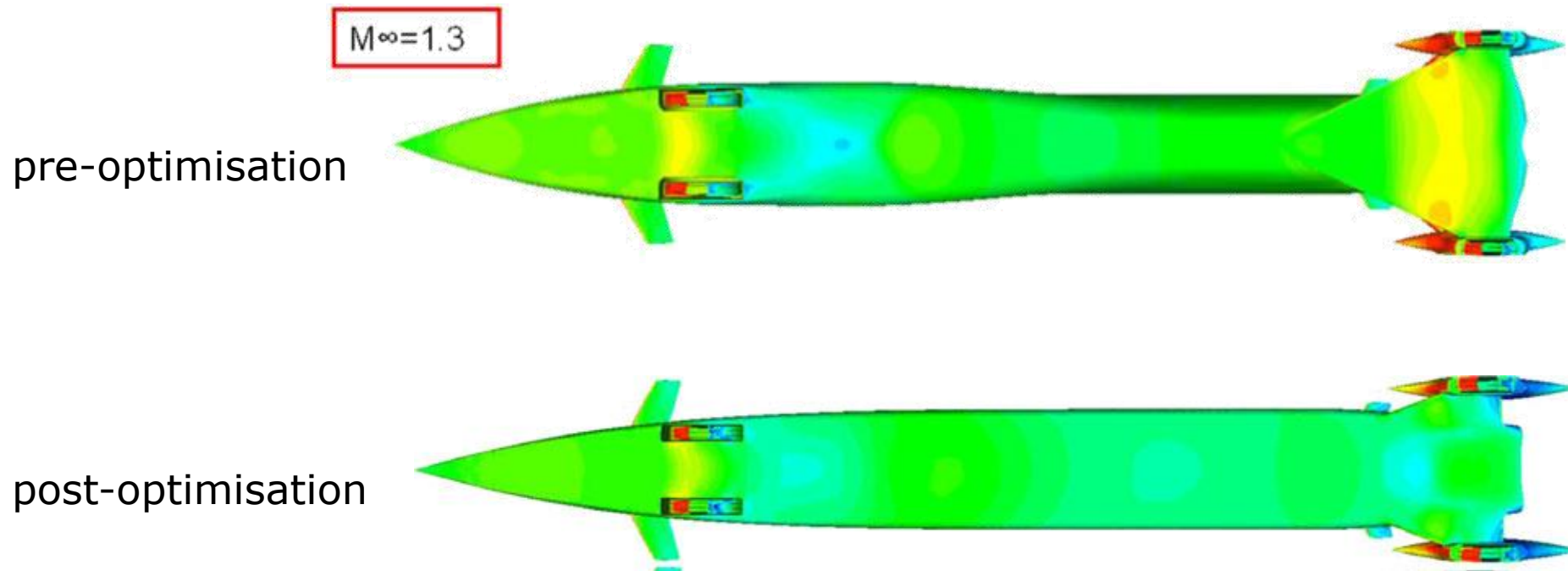
pre-optimisation



post-optimisation



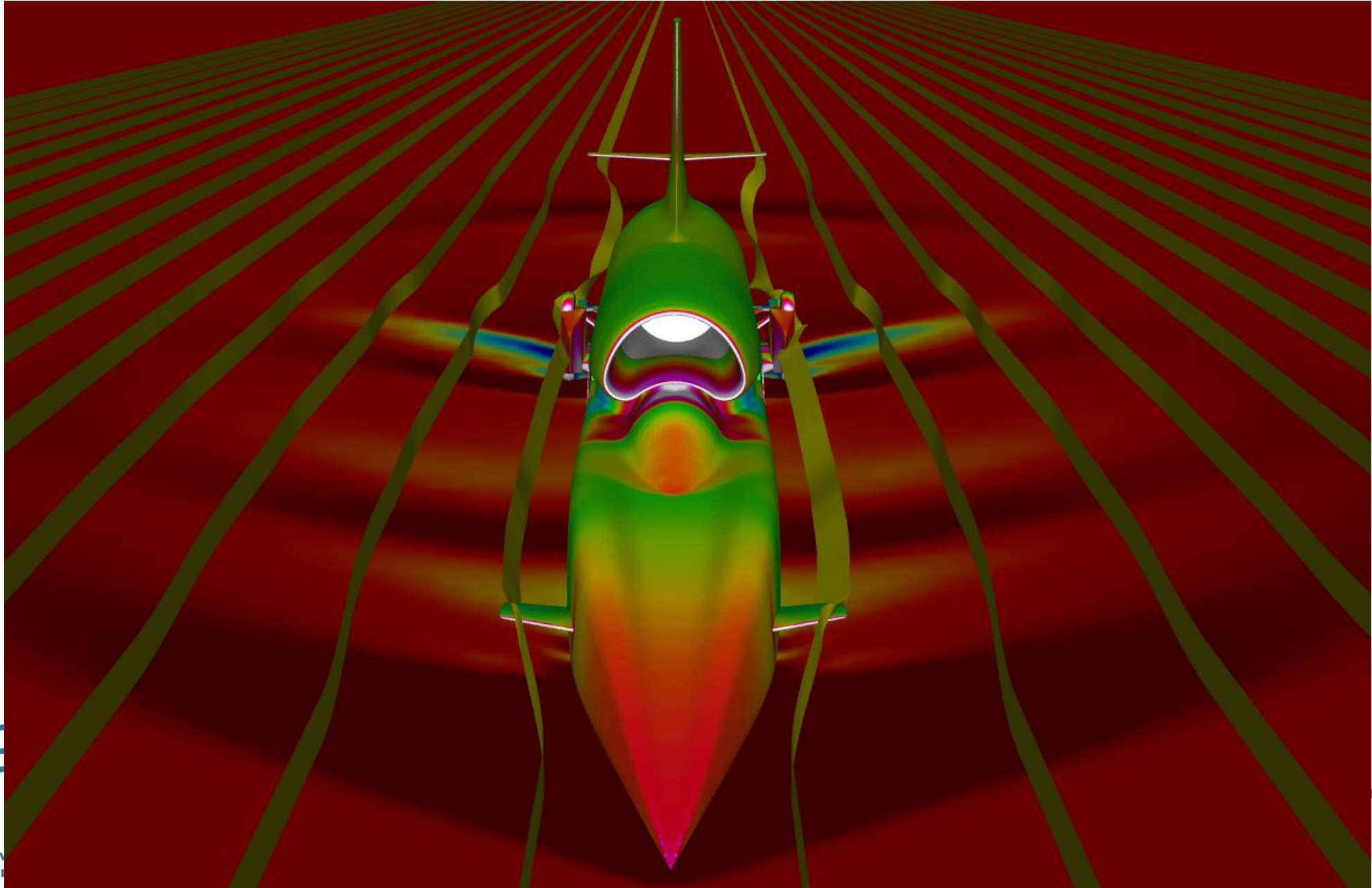
Pre- and post-optimisation



B. Evans, T. Morton, M. Chapman, I. Niven, O.Hassan, K.Morgan, *Design optimization using computational fluid dynamics applied to a land--based supersonic vehicle, the BLOODHOUND SSC*, **Structural and Multidisciplinary Optimization**, Article 826, 2012
DOI: 10.1007/s00158-012-0826-0



Optimised config13



Final (frozen) Aerodynamic Design



CAR BUILD: January 2015 – Spring 2017



TESTING: Low Speed Testing (LST) – Newquay (UK) October 2017



High Speed Testing & The Record Attempt: Hakskeen Pan, South Africa

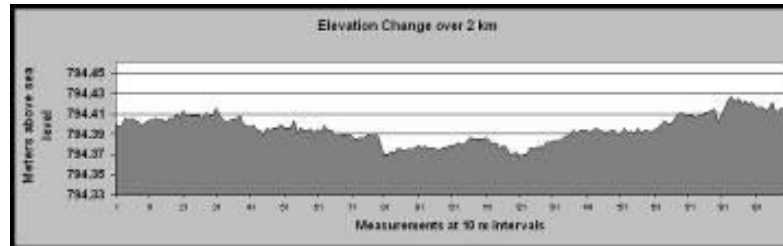
Hakskeen Pan, Northern Cape of South Africa

Alkali playa surface

12 miles (19 Km) of track

very hard and very flat

good access & ideal weather



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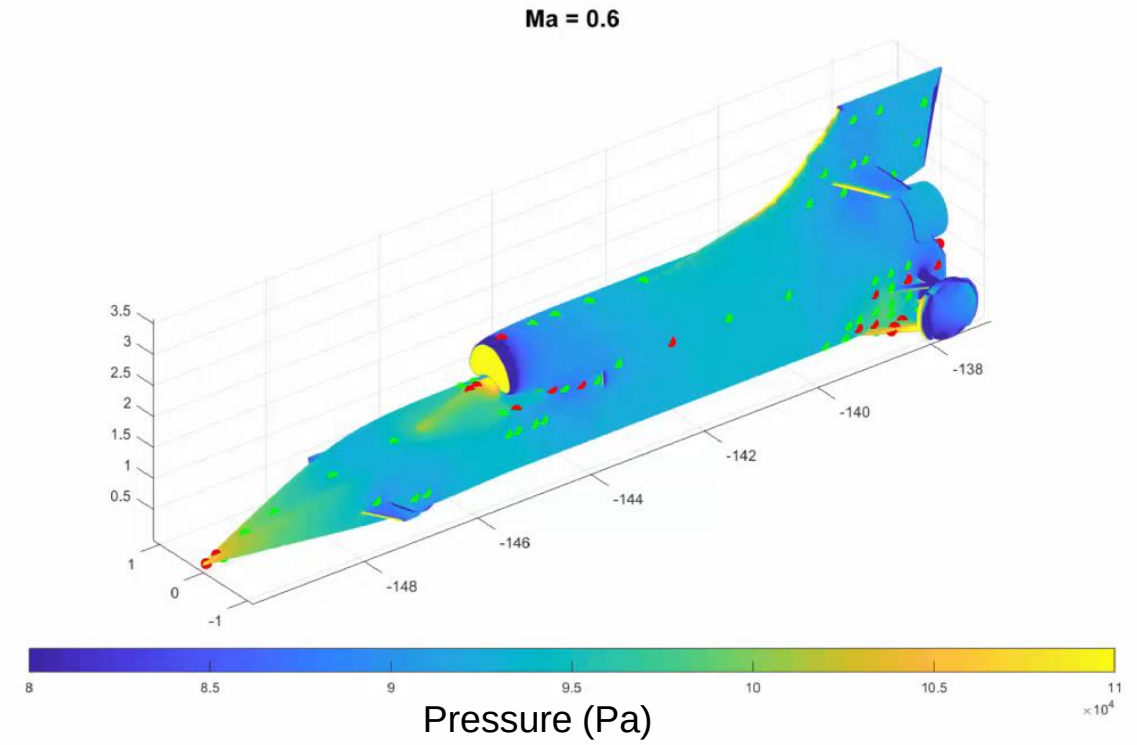
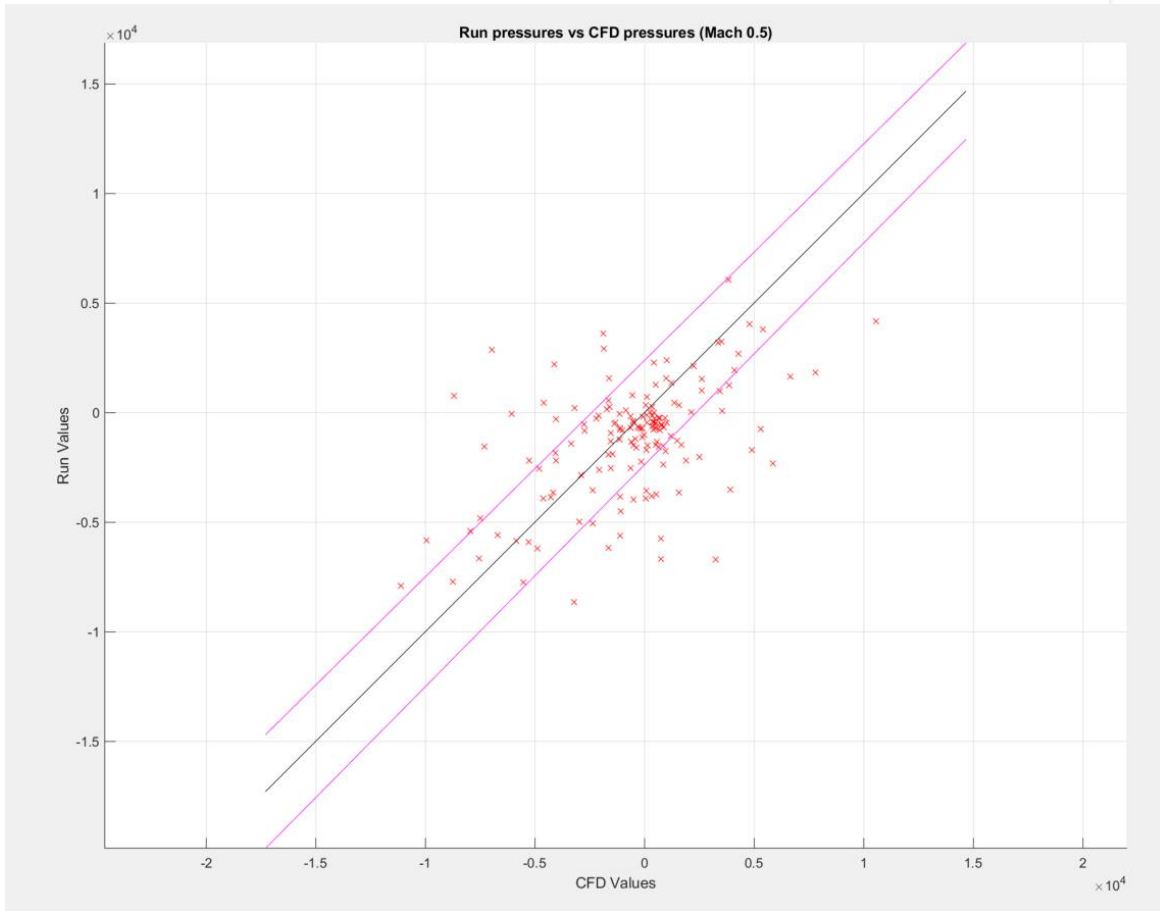
High Speed Testing (HST) 2019 – the highlights



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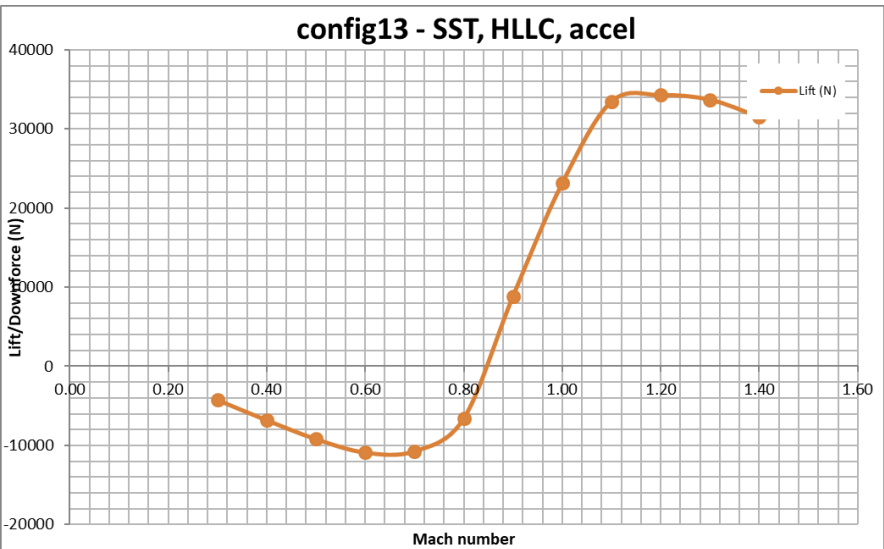
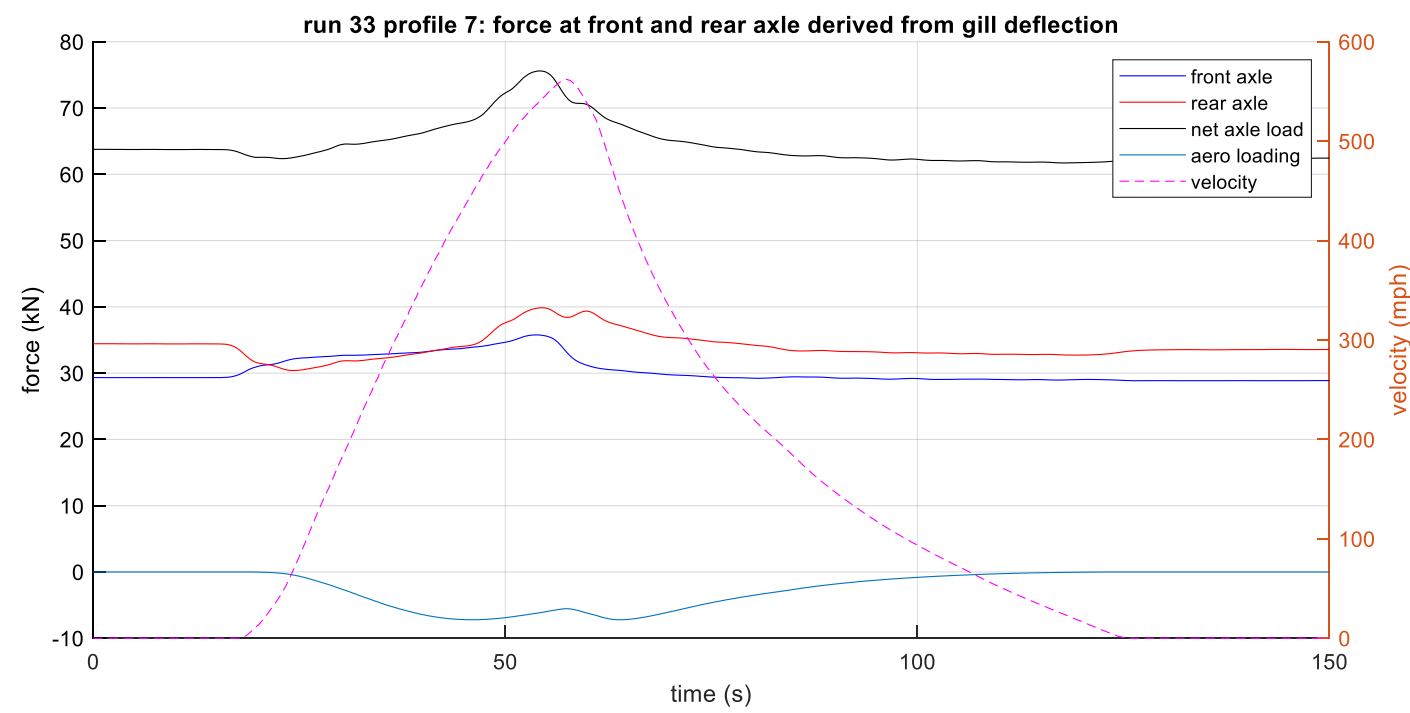
High Speed Testing (HST) 2019 – aerodynamic performance



Run 30 – max speed 580 mph (~Mach 0.6)x

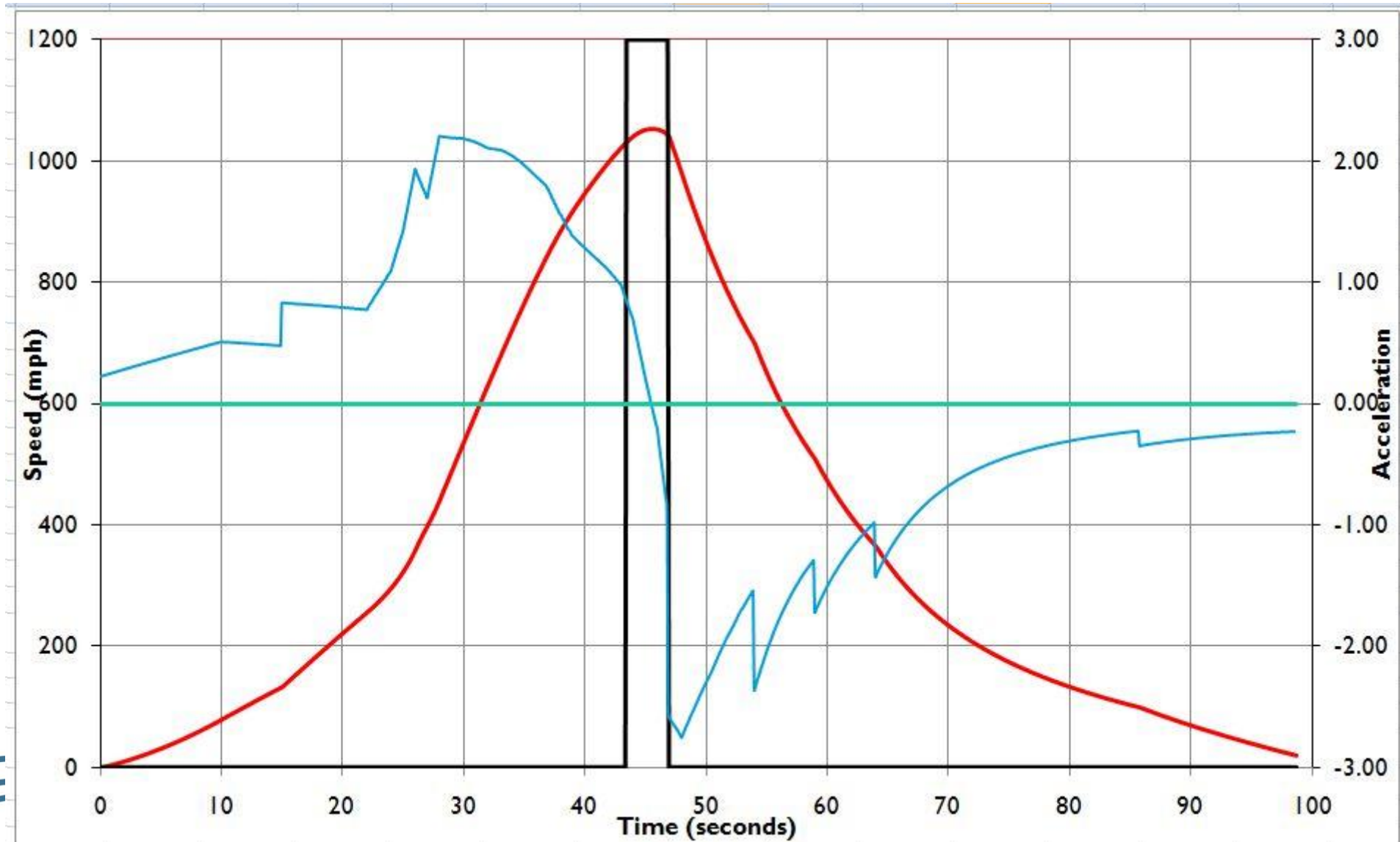


High Speed Testing (HST) 2019 – overall vehicle performance



Run 33 – max speed 562 mph (~Mach 0.6)

The future: a 1,000mph BLOODHOUND run... is it possible?



Thank you for listening...

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www.bloodhoundlslr.com

