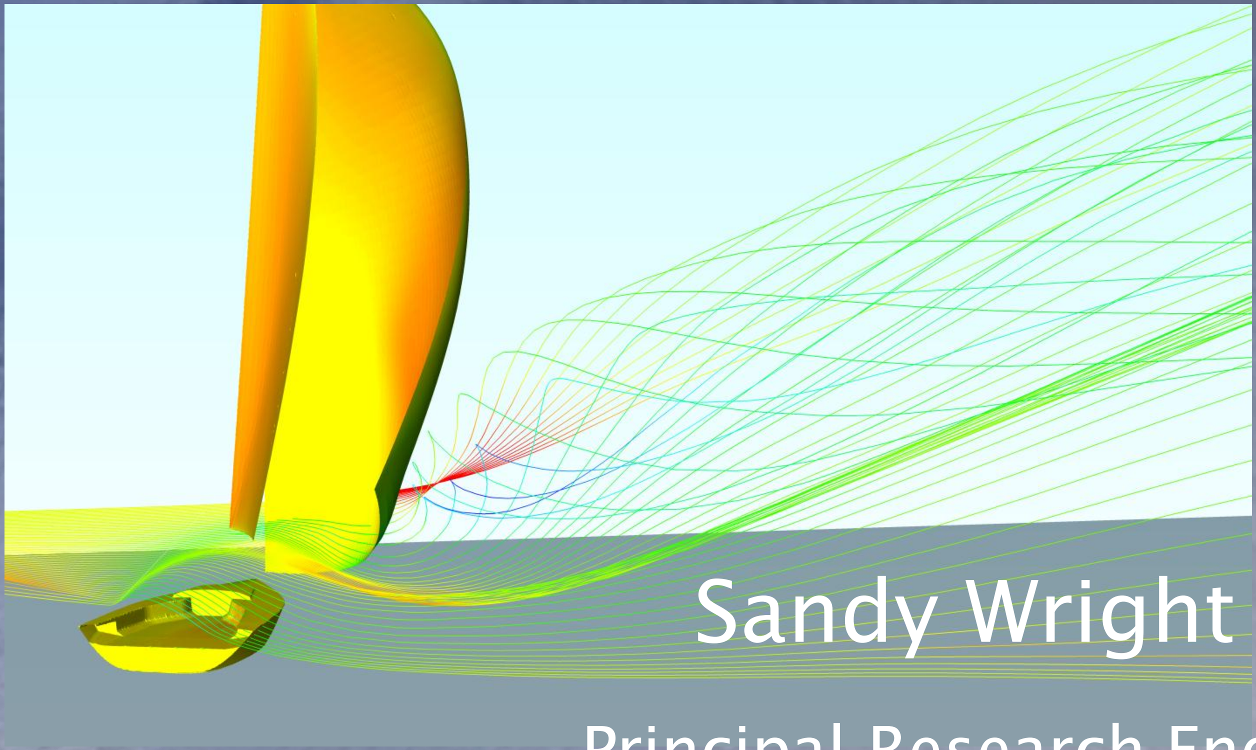
Using CFD in the design environment



Sandy Wright

Principal Research Engineer
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Using CFD in the design environment

- Historical use
- North sails – production run use of CFD
- Track cycling – why CFD is no good
- DES – the future ?
- Resources required

Historical use of CFD

- Origins
  - NASA & Boeing 1960's
  - 1st notable yacht use -Stars & Stripes '87

- Limits of computers
  - Never enough !
  - Current RANS models of a wing are 10^7; DNS will require 10^{20} (approx. 2080 if Moore's Law holds)

Historical use of CFD

- Mathematical models
  - Potential flow (60’s)
  - Euler (early 80’s)
  - RANS (90’s)
  - LES (research since 90’s; design …..)

Modelling approaches

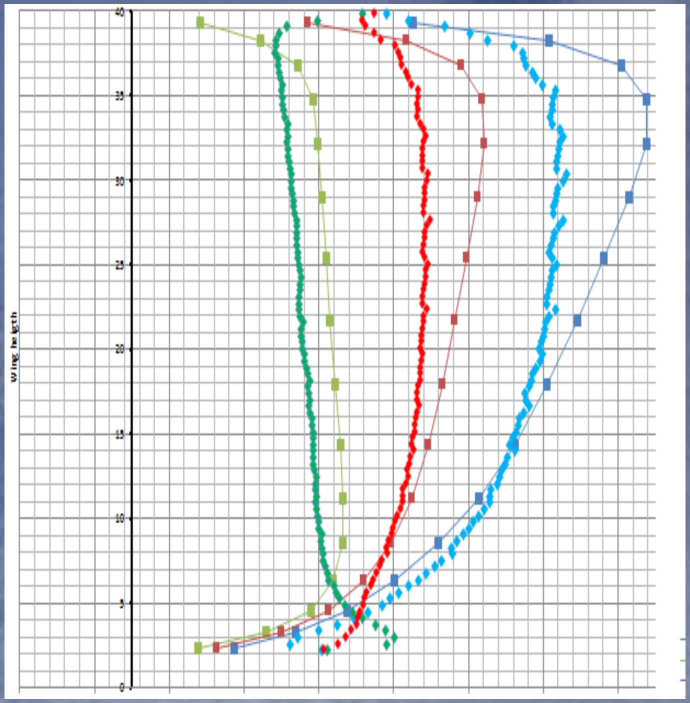
- **Panel codes**
  - potential flow, no viscosity
- **RANS**
  - empirical model to simulate viscosity via Reynolds stress.
- **LES and beyond**
  - Large Eddy Simulation, explicitly solves large eddies, uses models only at sub grid scale (SGS)

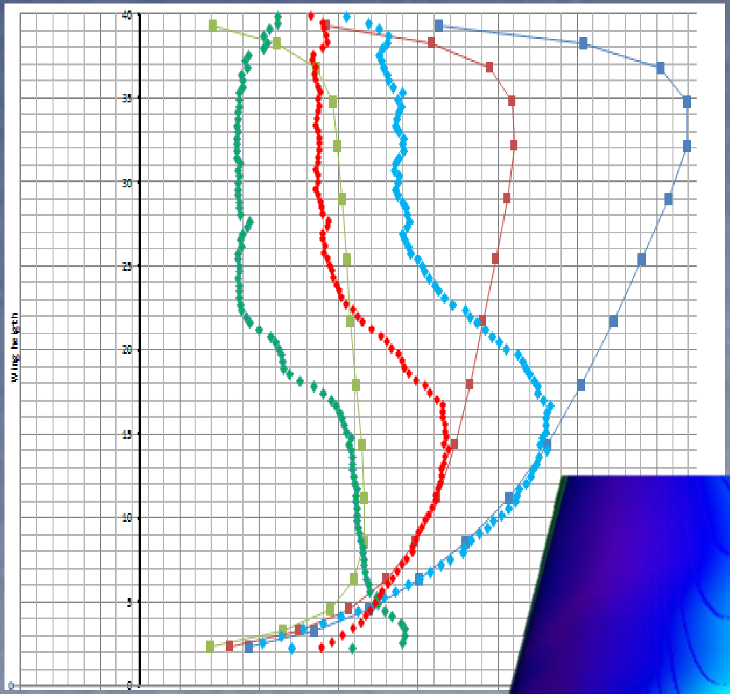
Resources - codes

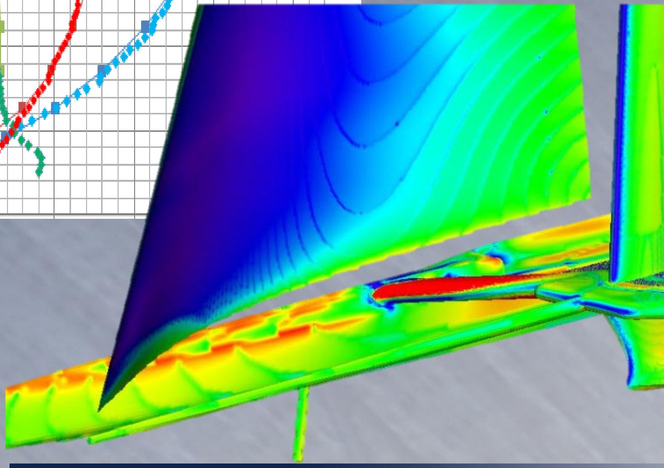
- Fully commercial
  - Up to date & QA but its going to cost
  - Black box
- Personal / in house
  - full control & cheap but effort to keep up
- Freeware / open source
  - stronghold in academic community and possibly the long term future

Panel codes – the workhorse

- Attached flow: little differences
- Flow 'stalling': larger differences







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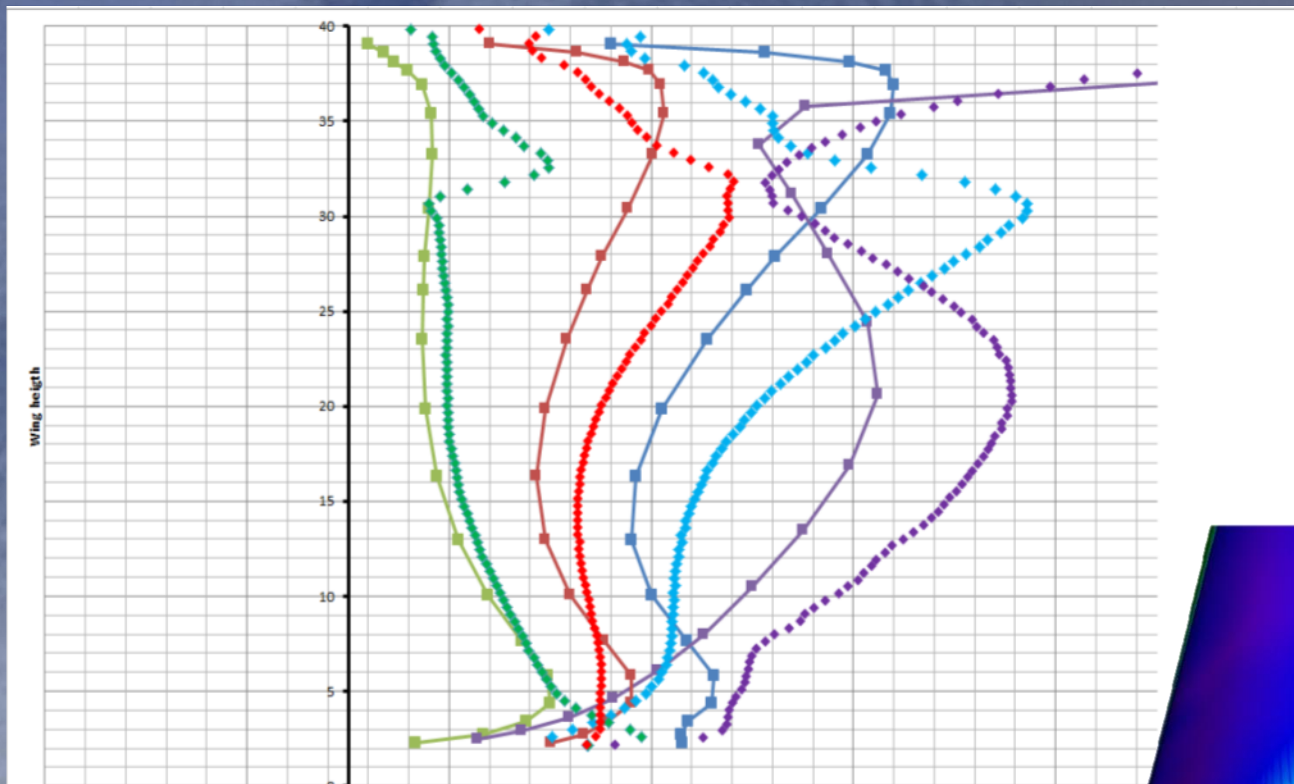
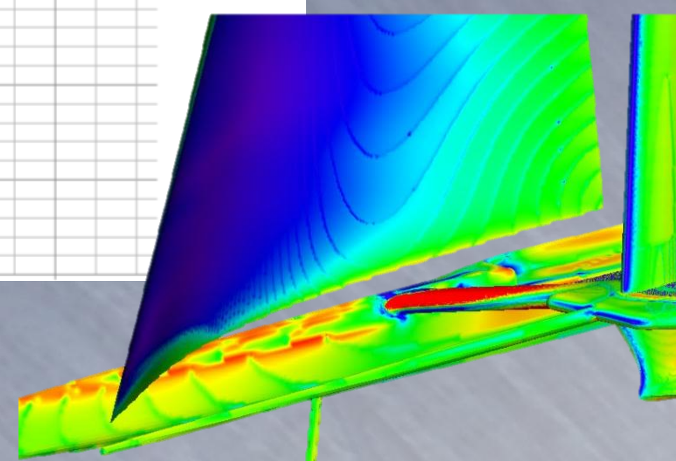
Panel codes – the workhorse





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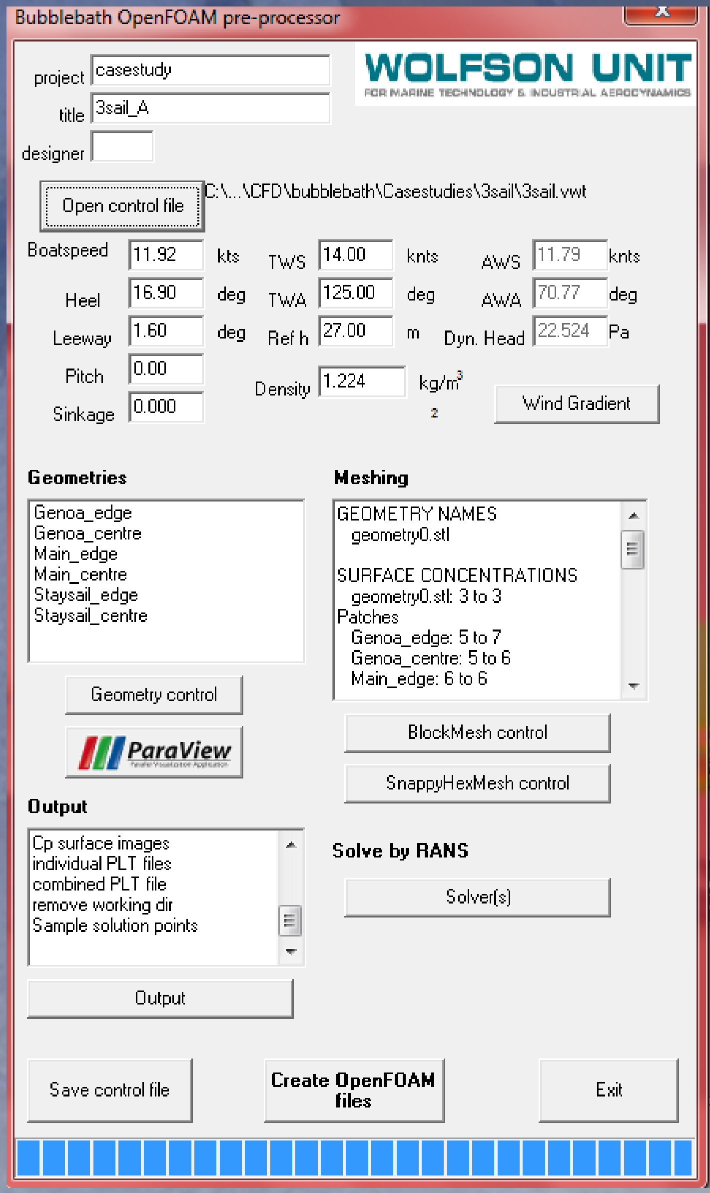
North Sails design tool

- RANS modelling
- Template recipe provided via desktop application
- Designer run, inputting geometry and key physical values (e.g. Boatspeed, Wind speed)
- Utilises Iridis3 supercomputer

North Sails design tool



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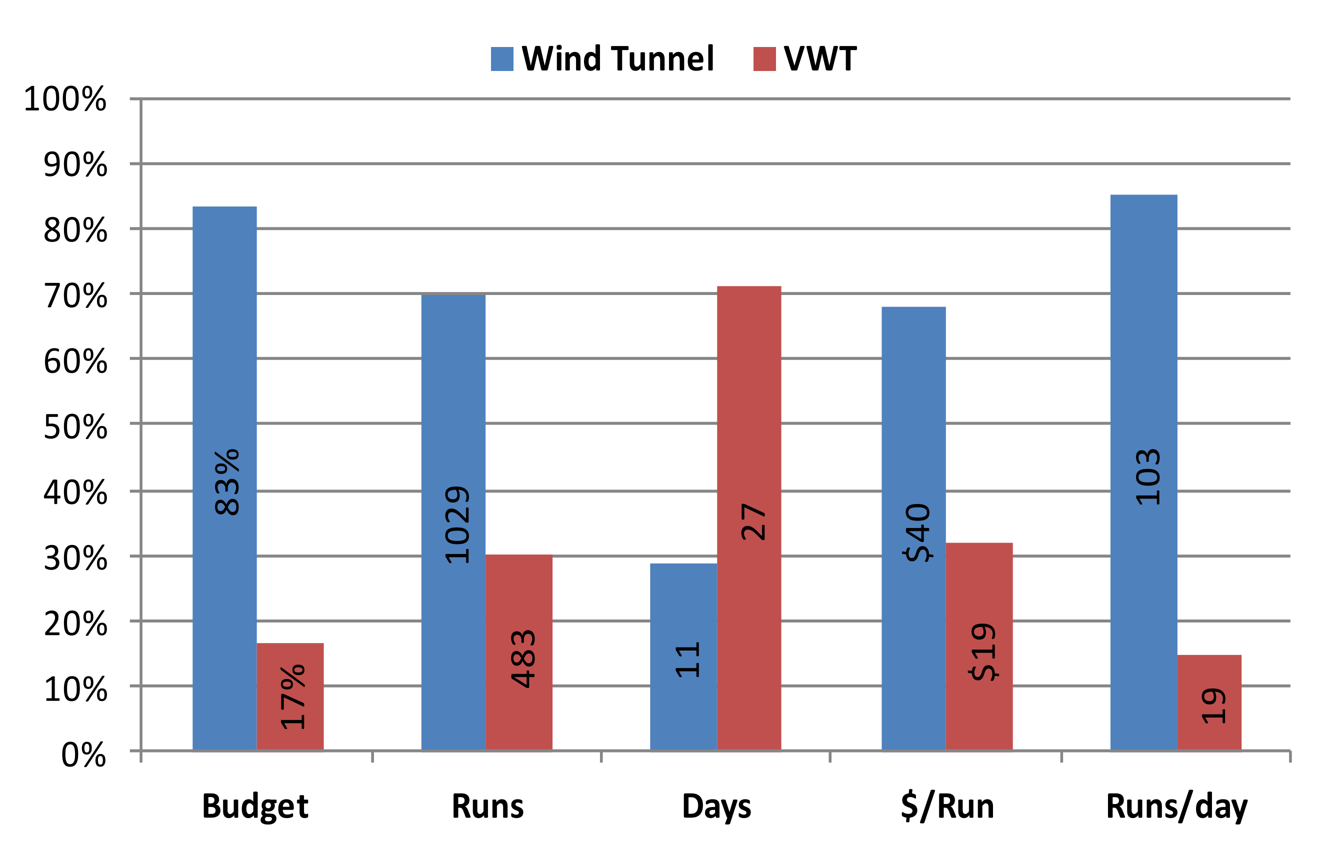
Volvo 70 sail wardrobe

Aero R&D < 4% of total sail budget = G1 headsail.



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Volvo 70 sail wardrobe

Real Wind Tunnel		Virtual Wind Tunnel	
Pro's	**Con's**	**Pro's**	**Con's**
High run rate	Outlier queries.	Cheaper per run	Low run rate
Lots of tests/designs.	Expensive / Run	Worldwide 24/7	Aero Curves N/A
Quick to right area	Travel.	Re-useable	No crew "feel"
Aero curves.	No pressures.	Pressure map	
Crew "feel"	LAX customs...		
Dynamic(ish)			

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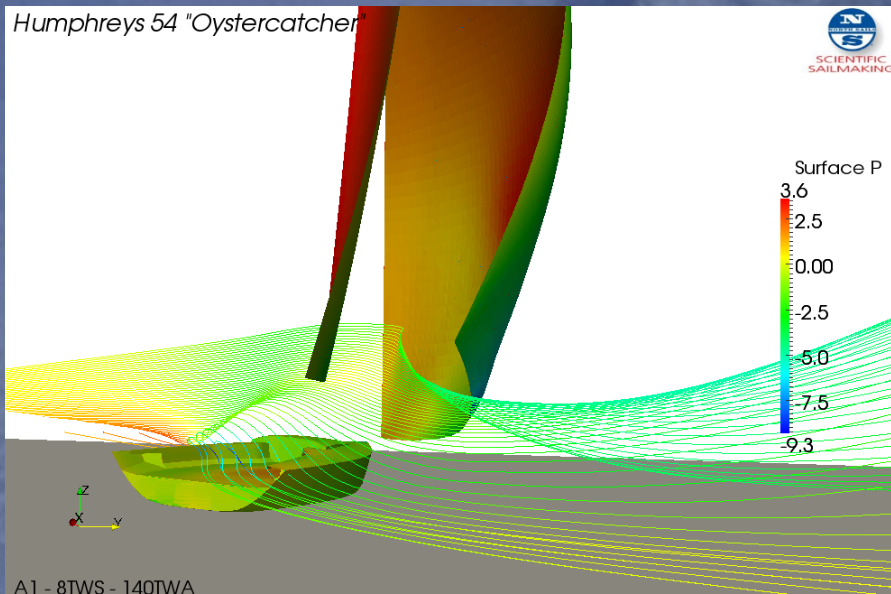
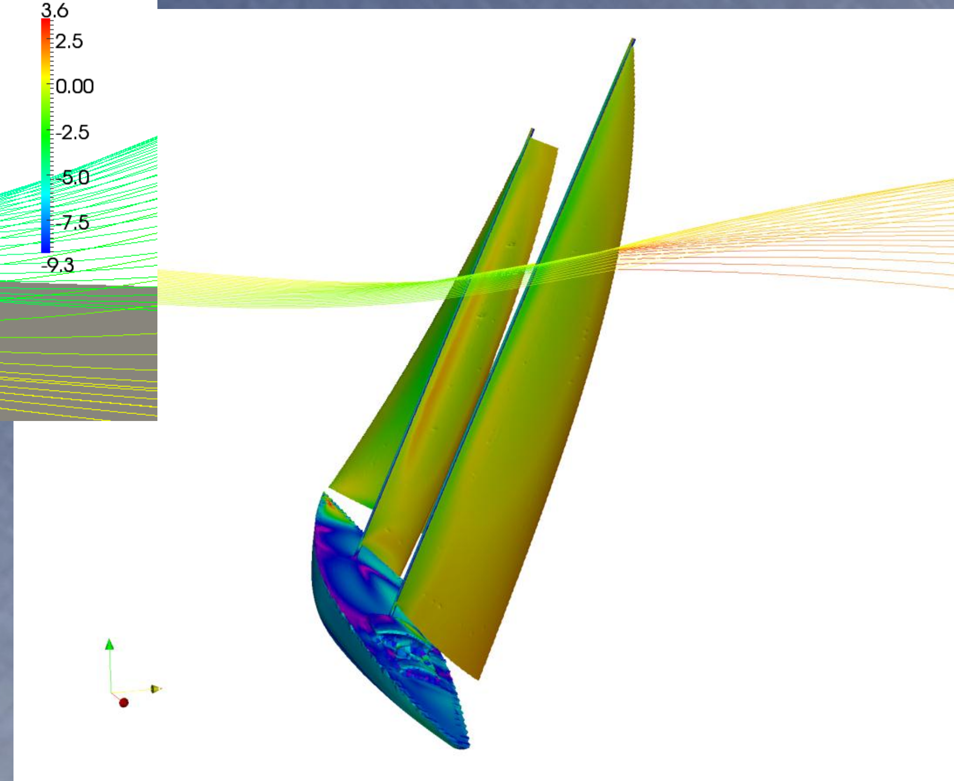
Sail wardrobe development





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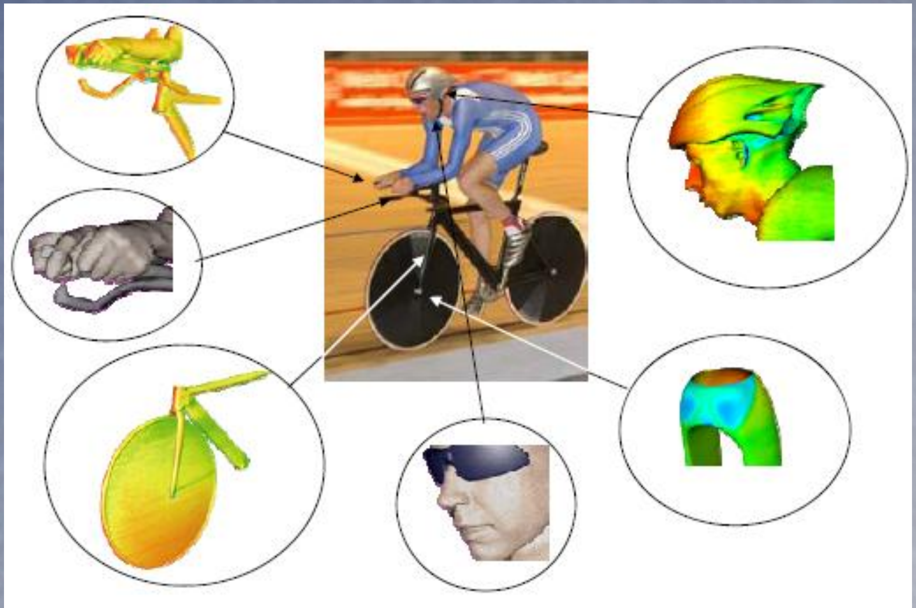
Track cycling

- Beijing 2008
  - Wind tunnel testing (Wolfson)
  - RANS modelling (Totalsim)

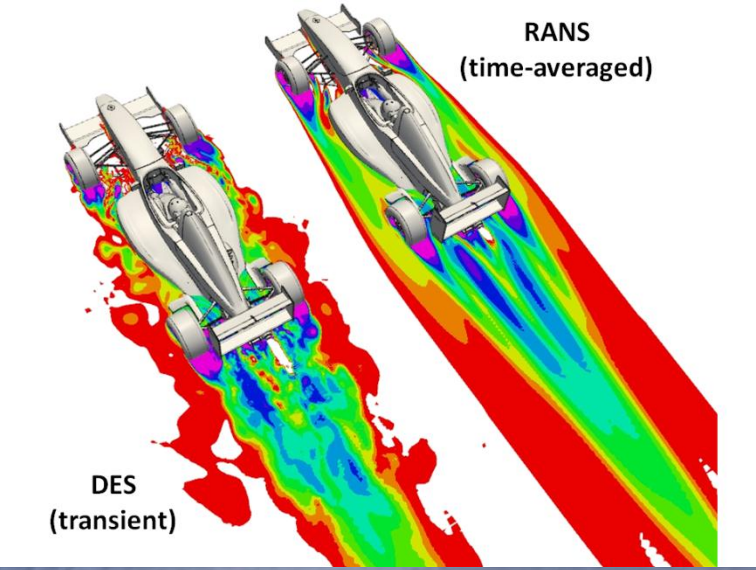


Track cycling

- Beijing 2008
  - RANS modelling did not tally with wind tunnel results
  - Bluff body flow ⇨ large zones of unsteady flow
  - Averaged (R**A**NS) models not adequate
    - Key question/factor is time scale of turbulent motion containing energy compared to changes in the mean flow

What is DES ?

Detached Eddy Simulation

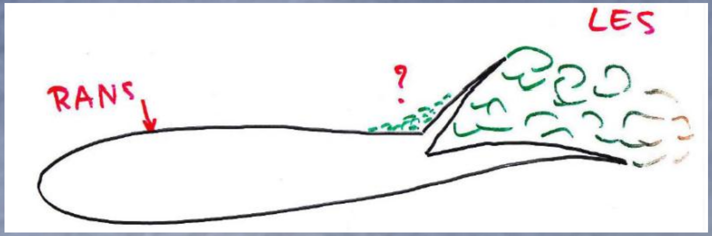


Turbulence model switches to SGS in regions fine enough.

Near wall is RANS

Large Turbulent length scales is LES

i.e. hybrid , 'engineering' solutions



Spalart, "Reflections on RANS modelling", 3rd Symposium on Hybrid RANS -LES Methods, June '12

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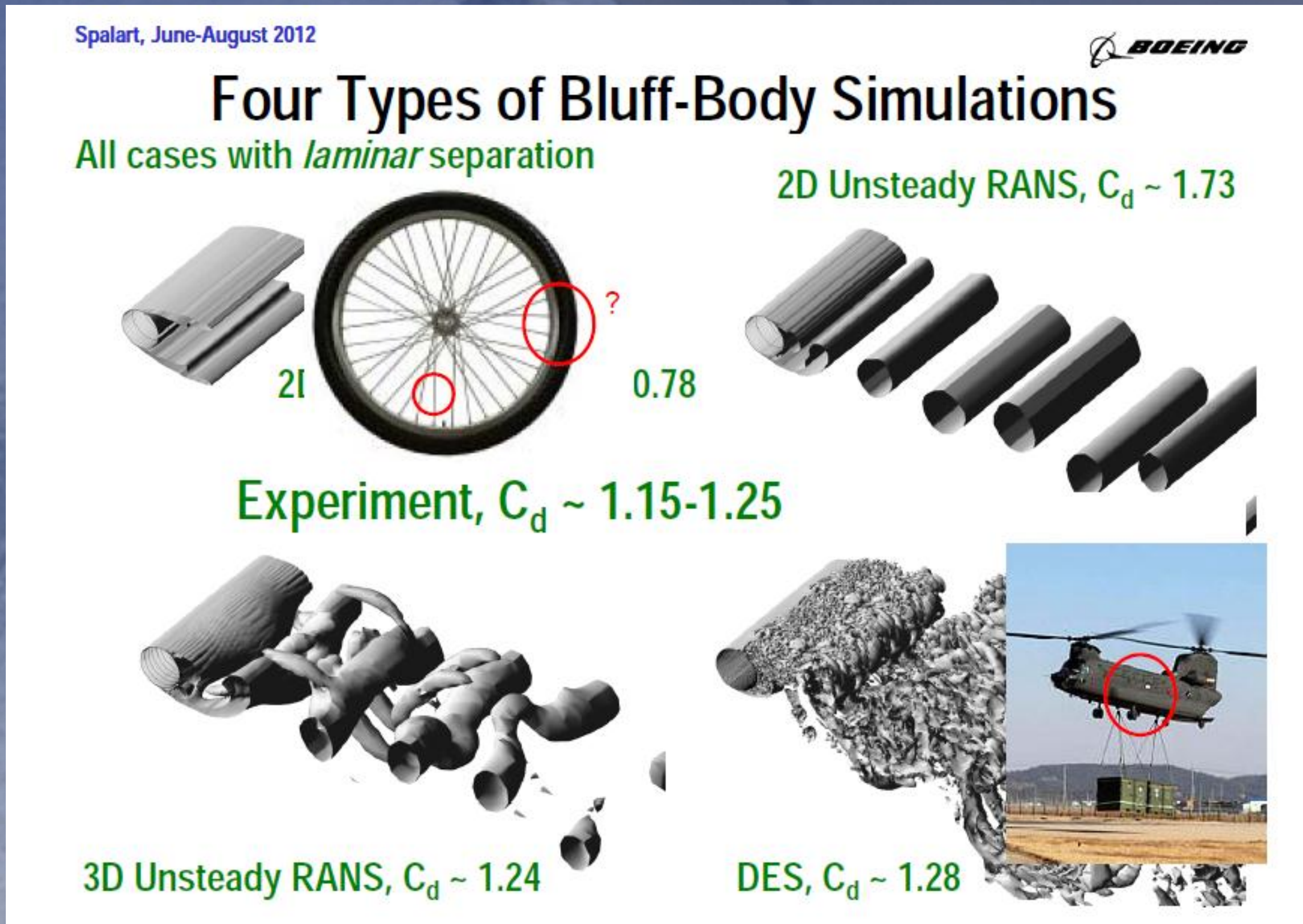
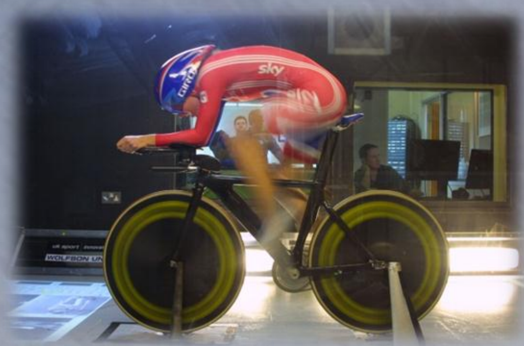
DES – bluff body flows



Back to … track cycling

- London 2012
- DES modelling
  - Captured trends of wind tunnel much better
  - Still no match for the wind tunnel !
    - Human = continual movement
    - Fabrics = wrinkles, rough & stretching
    - Athlete (i.e. client /end user) trust and buy in





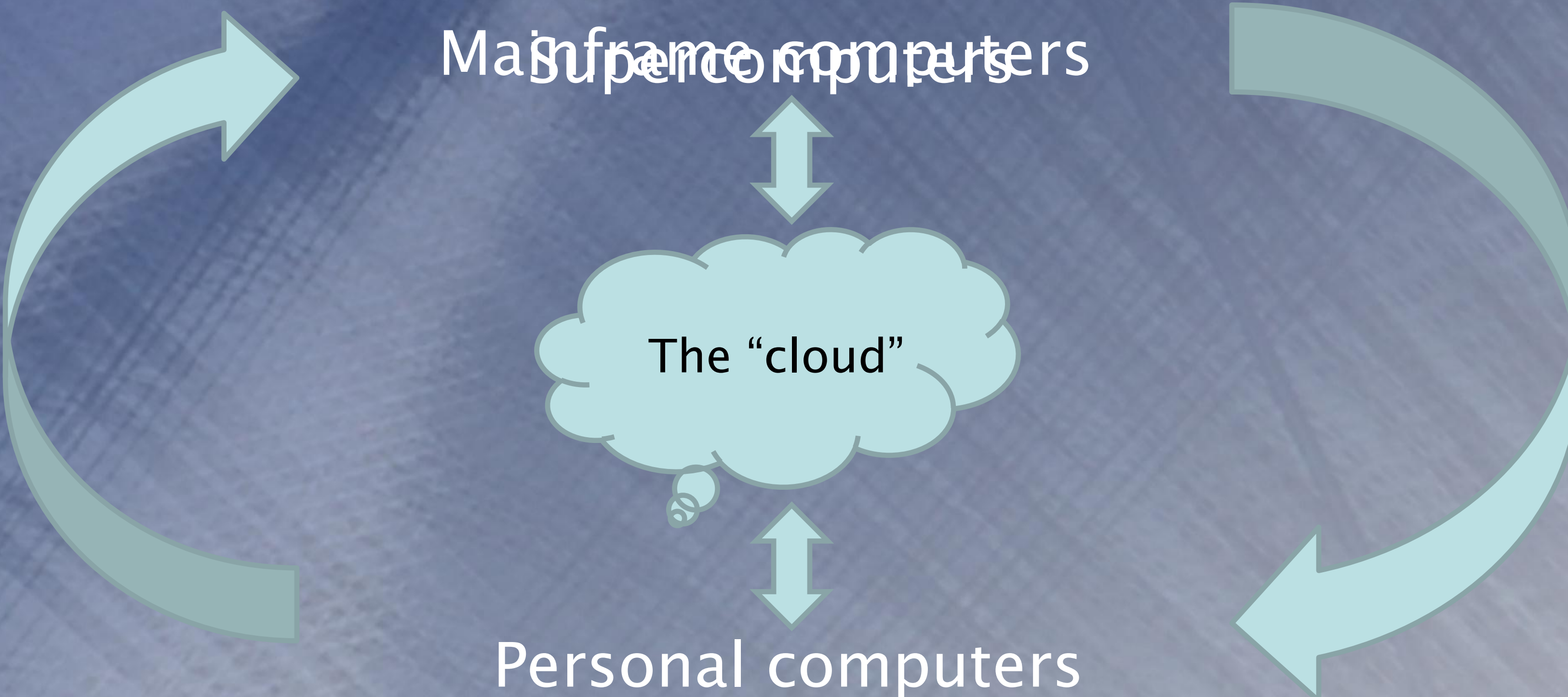
Why not use DES always?

- Code
- People & knowledge base
- Computational resources
  - Resources required
    - 48 processors, ≈48hrs per run (compared to 4-5 hrs for RANS)

Limits of computers

- iPhone = **Faster & more memory than** 1995 Pentium desktop
- Iridis3 (2009)
  - 8000 x 2.27GHz processors
  - 22 GB memory per node
  - 75^{th} in world when launched, 331^{st} in Nov 12 (and that was after an additional 3000 processors added)
- Iridis4 (2013)
  - 12000 CPUs (125%, and faster ….)
  - 32 GB of Memory per node (145%)
  - storage with Parallel File System (385%)
  - A number of nodes with 100's of GB per node

Resources - computers



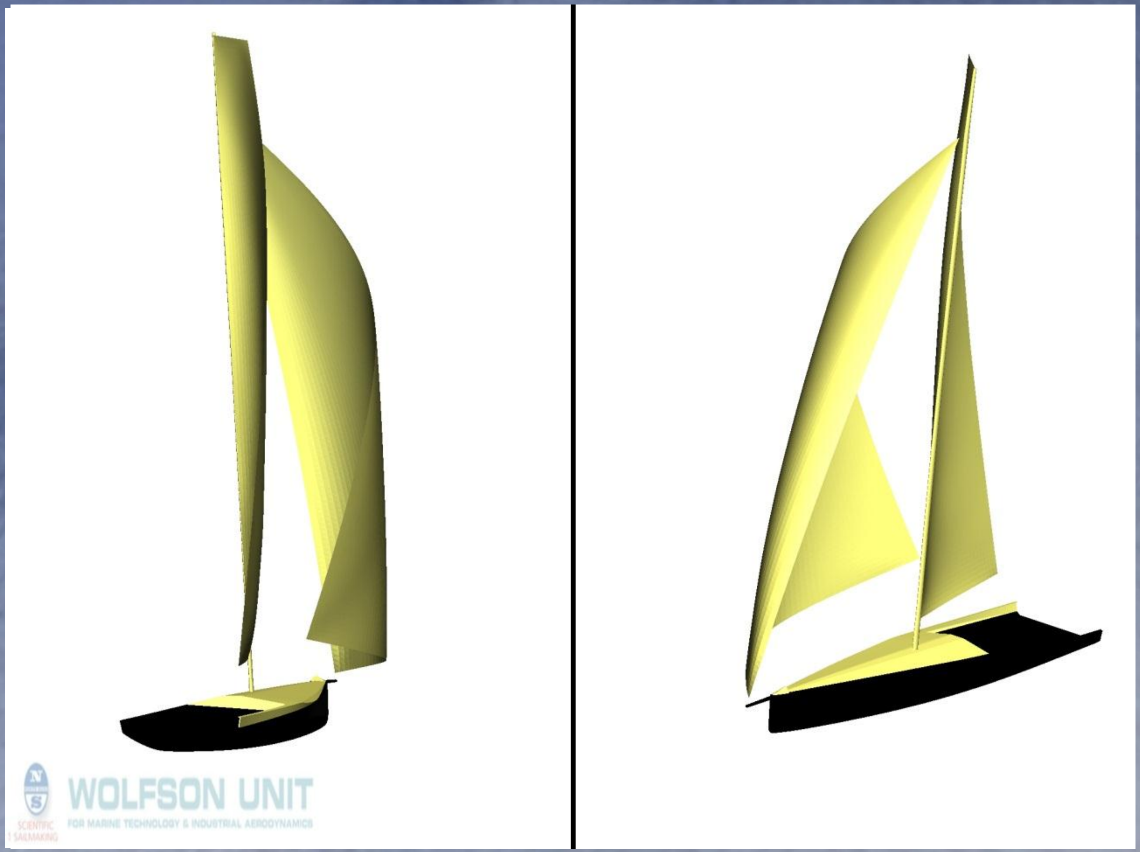
Modelling of offwind sails

- We know panel codes are good enough for non separated flow
- With 'some' separated flow, RANS is more accurate than panel
- Where does RANS start failing, and is DES required ?
  - Modern racing yachts & apparent wind

Modelling of offwind sails

- Case study of Volvo 70 yacht
  - 9 knots TWS, 50 TWA
  - 11 knots TWS, 70 TWA
  - 15 knots TWS, 110 TWA
  - 17 knots TWS, 125 TWA
- And a ‘slower’ 40ft yacht
  - 14 knots TWA, 147 TWA

Modelling of offwind sails



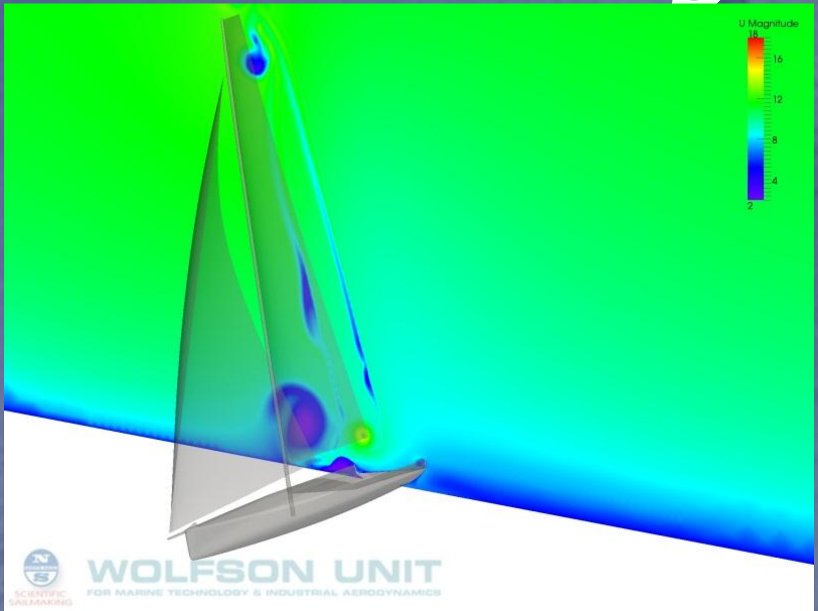
TW :50°
AW: 23°

TW :80°
AW: 32°

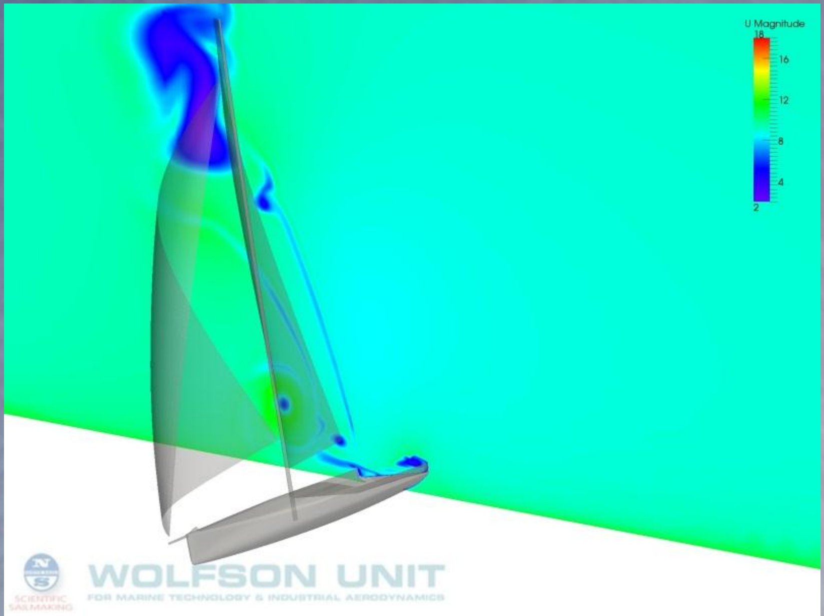
TW :110°
AW: 42°

TW :125°
AW: 50°

Modelling of offwind sails



TW :50°
AW: 23°



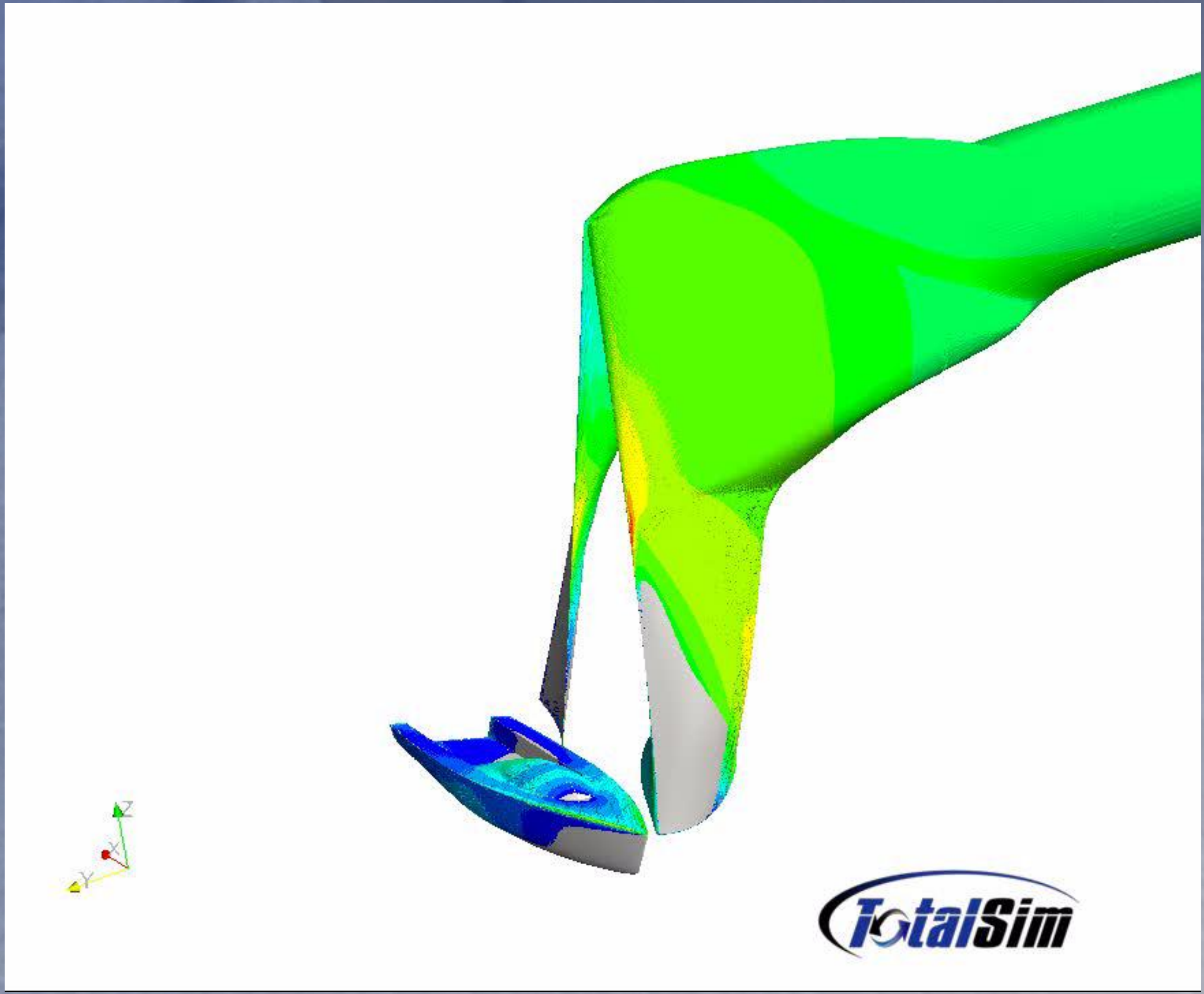
TW :125°
AW: 42°

Modelling of offwind sails

- 125 TWA

Modelling of offwind sails

- 147 TWA



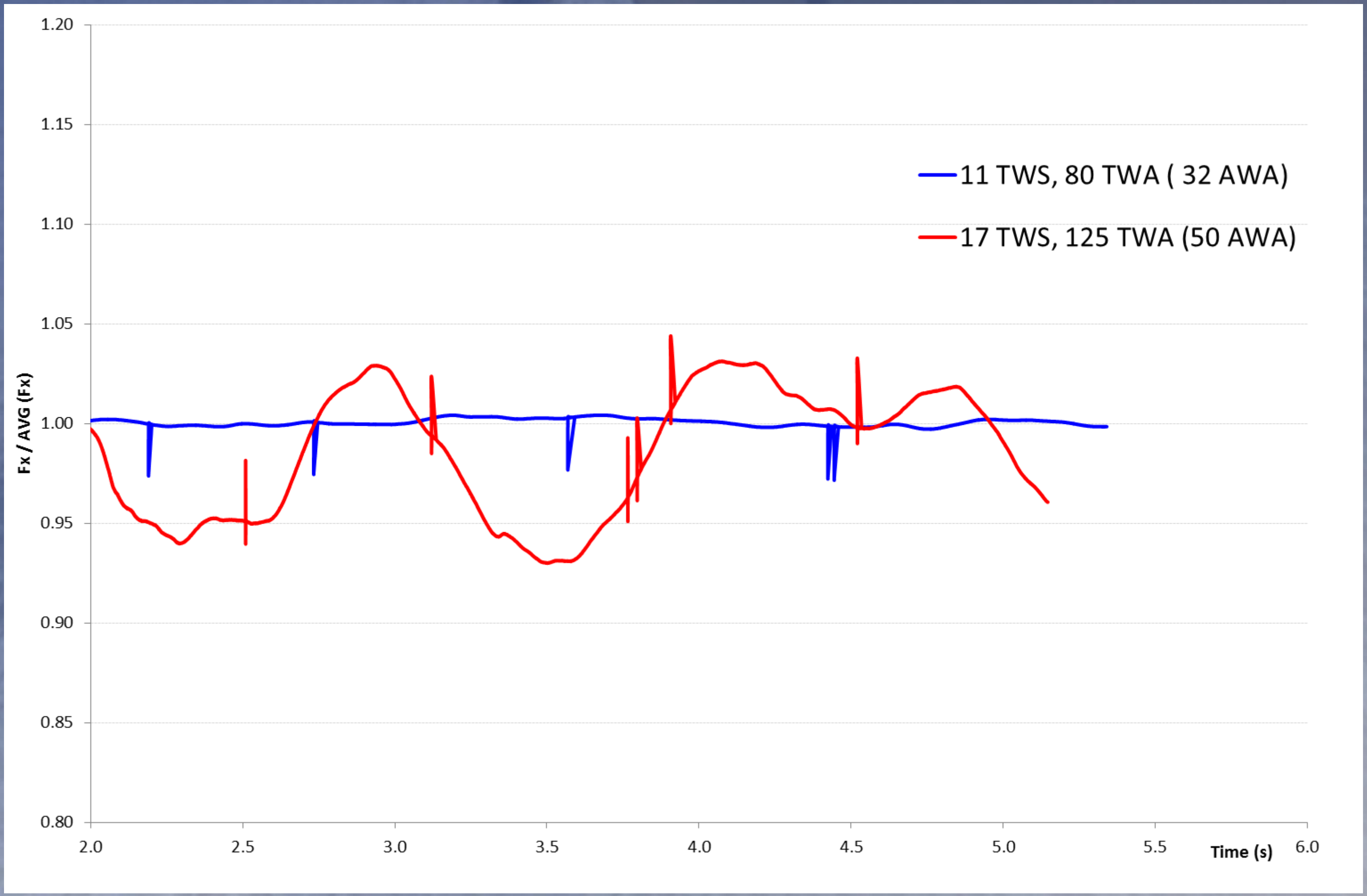
Modelling of offwind sails

- Forces
  - % difference between RANS & DES

TWS	TWA	AWS	AWA	Fx	Fy	Fz
9	**50**	16	**23**	**0%**	**0%**	**1%**
11	**80**	19	**32**	**0%**	**1%**	**1%**
15	**110**	21	**42**	**-3%**	**-1%**	**0%**
17	**125**	18	**50**	**3%**	**0%**	**2%**
14	**147**	8	**90**	**65%**	**31%**	**6%**

Modelling of offwind sails

•



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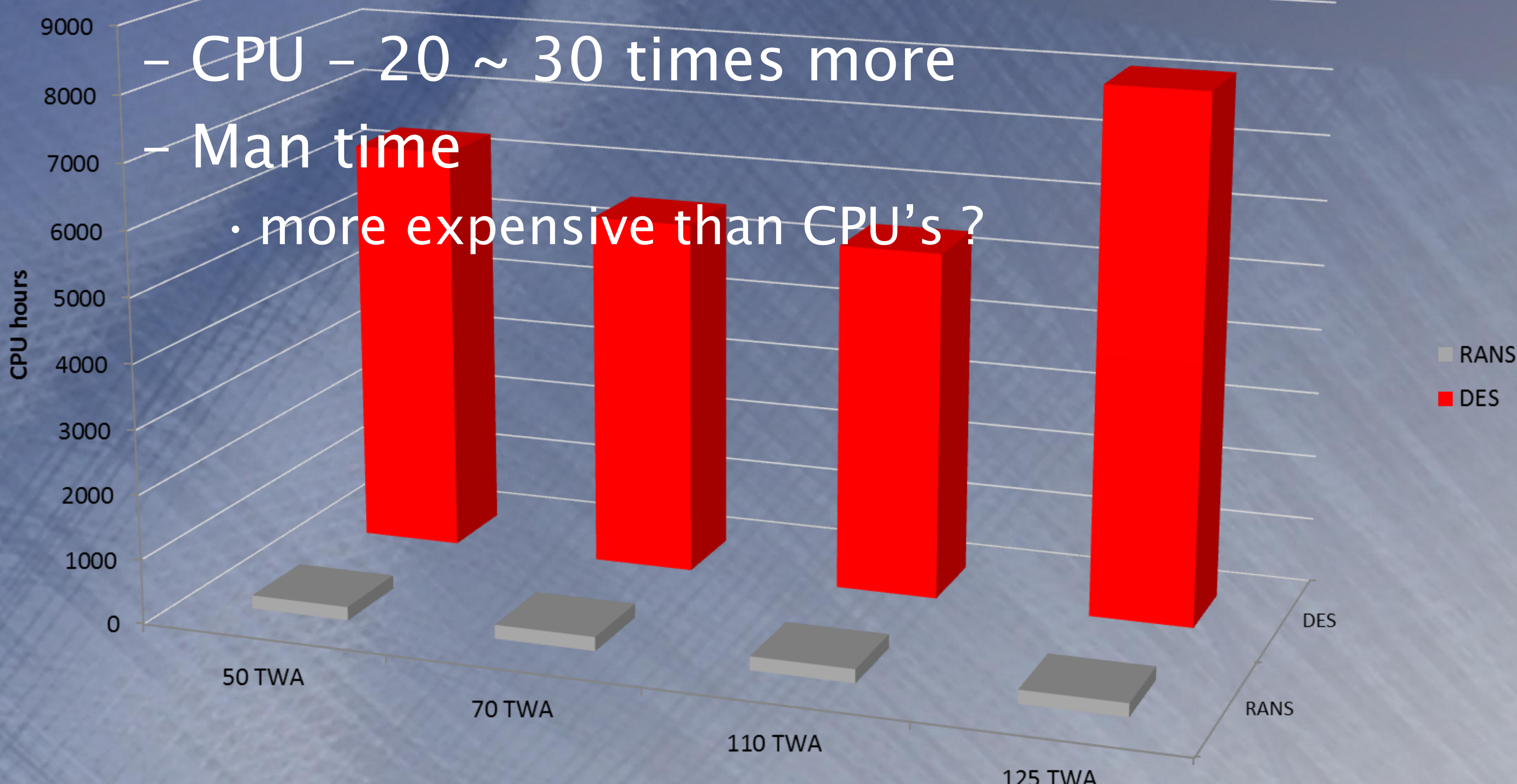
Modelling of offwind sails

- Resources
  - CPU – 20 ~ 30 times more
  - Man time
    - more expensive than CPU's ?



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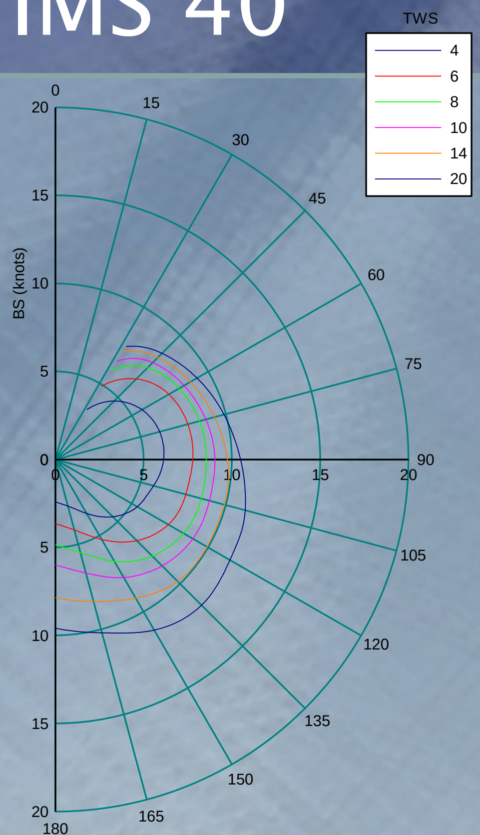
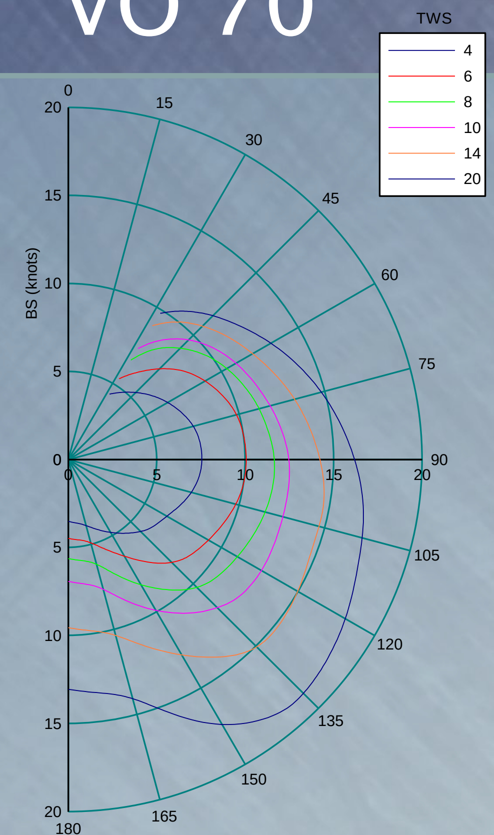
DES Modelling

- Requirements
  - 6000 CPU hrs @ 5p/hr
    - £300 per run
  - Probably 1 man day per run (meshing, control, post pro)

Modelling of offwind sails

- VPP analysis
- IMS 40 VO 70





Modelling of offwind sails

- VPP analysis
  - IMS40
  - VO70

	4	5	6	7	8	9	10	12	14	16	20
32	15.2	16.1	16.7	17	17.4	17.3	18.2	18.5	19	19.6	20.8
36	16.5	17.4	17.8	18.3	18.2	18.4	19.4	20	20.7	21.5	23
40	17.6	18.4	18.8	19	19.2	19.7	20.7	21.5	22.4	23.4	25.1
45	18.9	19.6	20	20.1	20.7	21.2	22.3	23.5	24.7	25.8	27.8
52	20.4	20.9	21.4	21.9	22.6	23.5	24.8	26.3	27.8	29.1	31.6
60	22	22.3	23.1	23.9	25	26.1	27.6	29.5	31.4	33	35.5
70	23.7	24.3	25.4	26.5	27.9	29.3	31.1	33.6	35.5	37.3	40.4
80	25.5	26.5	27.9	29	30.7	32.3	34.3	37.2	39.4	41.5	45
90	27.6	28.8	30	32.1	33.3	35.1	37.4	40.6	43.1	45.5	49.6
100	30.2	31.5	32.9	34.8	37.2	38.4	42	43.7	46.6	49.5	54.1
110	33.8	34.8	36.5	38.6	40.3	42.4	44.5	48.7	51.9	54.8	59.3
120	38.3	38.5	40	42	44.4	46.2	47.7	51.3	55.1	58.4	63.5
135	43.8	45.3	46.3	48.3	50.6	53	55.7	58.8	60.9	64.7	70.6
150	56.9	65.7	70.3	71.4	72.1	74.1	76	81.1	84.4	86	88.3
160	74.4	91.4	100.3	105	107	107.1	107.9	110.3	114	116.8	119
170	111	133.2	140.7	144.2	146	146.8	147	147.5	148.2	149.5	151
180	180	180	180	180	180	180	180	180	180	180	180
Up	18	19.5	20.4	19.8	19.7	20	21.4	21.5	21.5	22	23.3
Dn	49	48	49.3	53.9	55.8	61.1	65.6	68.1	71.1	74.8	80.6

As a result…

- You probably need one of these to accurately model this

As a result…

- But one of these to model this

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Resources - people

- In house v out sourcing
- Expertise in types CFD
- Expertise in application area
- Time is money

Resources

- Pay off

Accuracy

Resources ⟷ Time

- Code
- Computers
- People

Conclusions

- Resources (software, computational etc.) are available
- Resources are economically viable on any size of project
- Engineering judgement
- Mixed economy
  - Including experimental testing !!

Questions

- What is the problem?
- Resources required v available ?
- Select accordingly