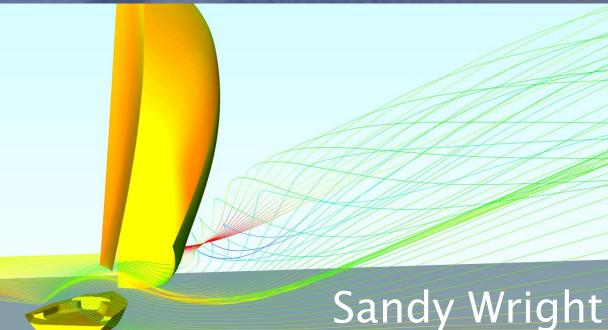
Using CFD in the design environment



Principal Research Engineer Wolfson Unit MTIA



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 10⁷; DNS will require 10²⁰ (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)





NOLOGY AND INDUSTRIAL AERODYNAMICS

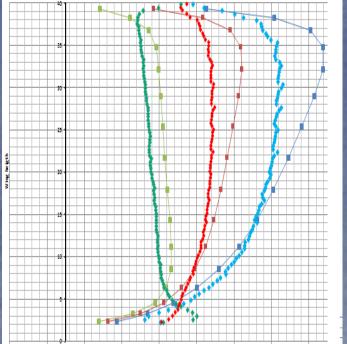
Resources - codes

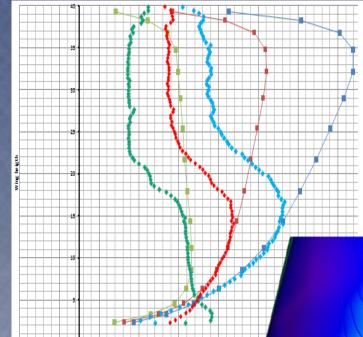
 Fully commercial · Up to date & QA but its going to cost • Black box Personal / in house full control & cheap but effort to keep up • Freeware / open source stronghold in academic community and possibly the long term future





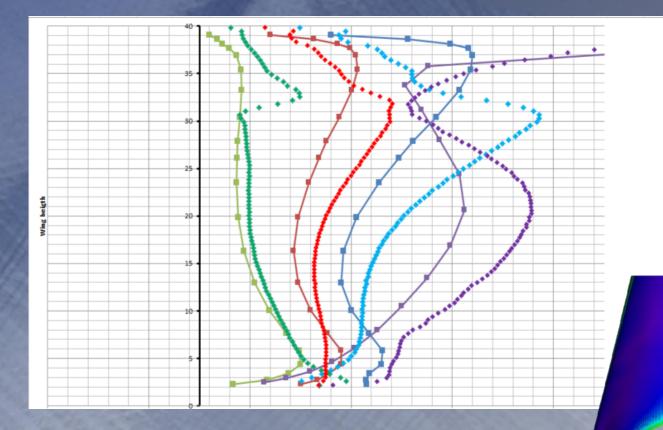
Panel codes – the workhorse Attached flow: little differences Flow 'stalling': larger differences







Panel codes - the workhorse



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So





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



project Casestudy Casestudy title 3sail_A designer Open control file C: \CFD \bubblebath\Casestudies\3sail\sail.vwt Boatspeed 11.92 kts TWS Heel 16.90 deg TWA 125.00 deg AWA 70.77 deg Leeway 1.60 deg TWA 125.00 m Dyn. Head 22.524 Pa Pitch 0.00 Density 1.224 kg/m³ Wind Gradient Sinkage 0.000 Density 1.224 kg/m³ Wind Gradient Genoa_centre Genoa_centre Superative Status Superative Status Superative Status Superative Status Superative Status Geometry control Staysail_centre BlockMesh control SnappyHexMesh control Superative Status Output Output Solver(s) Solver(s) Solver(s)	Bubblebath OpenFOAM pre-	-processor	
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	Output		
	Save control file		Exit

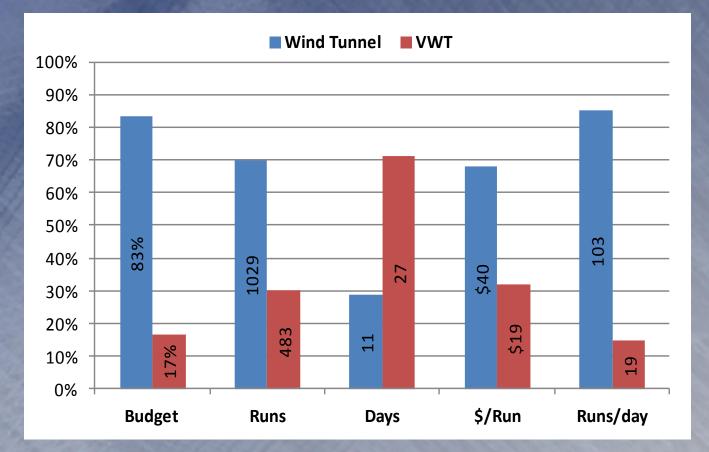


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Aero R&D < 4% of total sail budget = G1 headsail.



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Real Win	d Tunnel	Virtual Wind Tunnel			
<u>Pro's</u>	<u>Con's</u>	<u>Pro's</u>	<u>Con's</u>		
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)					

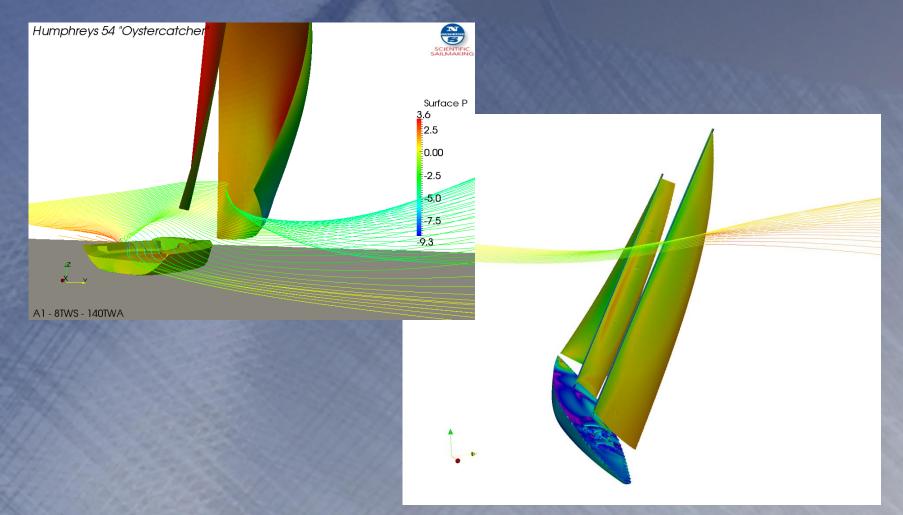






Sail wardrobe development







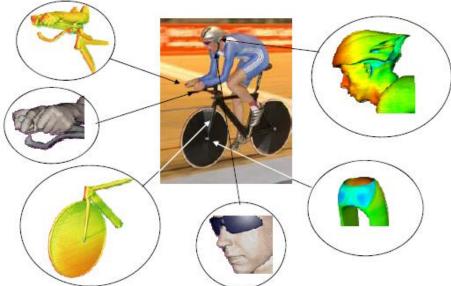


Track cycling

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



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Track cycling

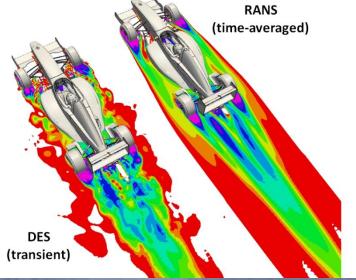
Beijing 2008

- RANS modelling did not tally with wind tunnel results
- Bluff body flow ⇒ large zones of unsteady flow
- Averaged (RANS) models not adequate

 Key question/factor is time scale of turbulent motion containing energy compared to changes in the mean flow

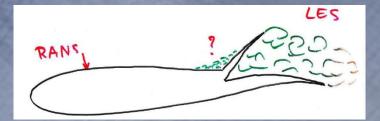


What is DES ? Detached Eddy Simulation



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

Spalart, June-August 2012

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BOEING

Four Types of Bluff-Body Simulations

0.78



2D Unsteady RANS, C_d ~ 1.73



Experiment, C_d ~ 1.15-1.25





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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





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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
- 75th in world when launched, 331st 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

Mainframenters

The "cloud"

Personal computers

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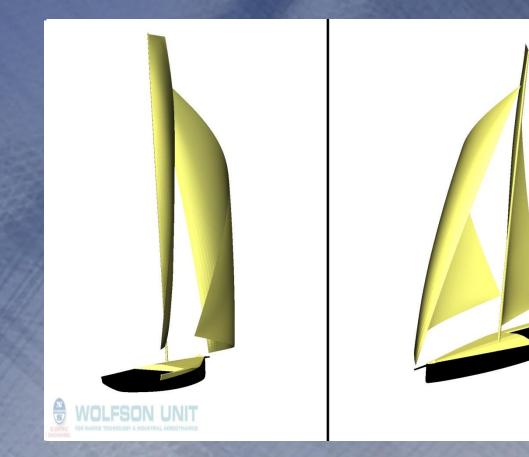
- We know panel codes are good enough for non separated flow
- With 'some' separated flow, RANS is more accurate than panel
- Where does RANS start failing, and is DES required ?
 - Modern racing yachts & apparent wind



· 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







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TW :50° AW: 23° TW :80° AW: 32° TW :110° AW: 42° TW :125° AW: 50°



TW :50° AW: 23°



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TW :125° AW: 42°





• 125 TWA







• 147 TWA

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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%

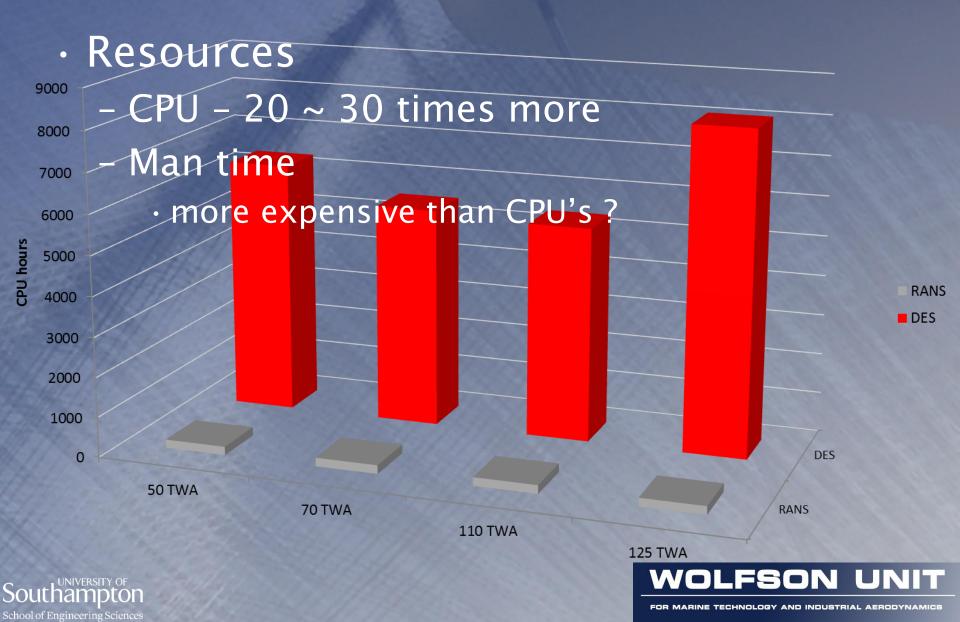






FOR MARINE TECHNOLOGY AND INDUSTRIAL AERODYNAMICS

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DES Modelling

Requirements

6000 CPU hrs @ 5p/hr
£300 per run

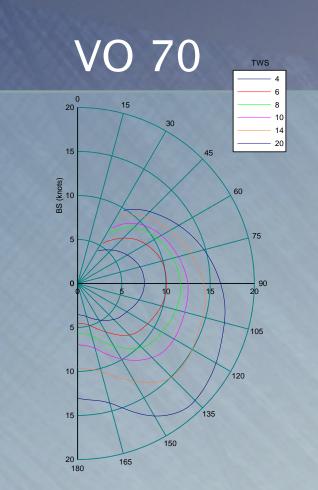
Probably 1 man day per run (meshing, control, post pro)





- VPP analysis
- IMS 40 TWS 20 г (knots) 10 SS

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VPP analysisIMS40

•	V	0	7	0	
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	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	17.4	17.3	19.4	20	20.7	21.5	20.8
40	17.6	17.4	17.8	18.5	19.2	19.7	20.7	21.5	20.7	23.4	25.1
40	17.0	19.6	20	20.1	20.7	21.2	20.7	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
			1.29	L. L. M.	10000	12/2/18					
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

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As a result...

You probably need one of these to accurately model this



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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

- Code
- Computers
- People

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Time

Conclusions

 Resources (software, computational etc.) are available

- Resources are economically viable on any size of project
- Engineering judgement
- Mixed economy
 - Including experimental testing !!





ECHNOLOGY AND INDUSTRIAL AERODYNAMICS

Questions

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



