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Recent Developments & Applications in CEASIOM

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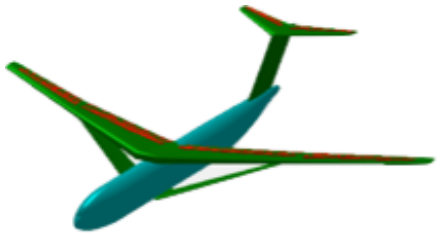
Toulouse, France

Content

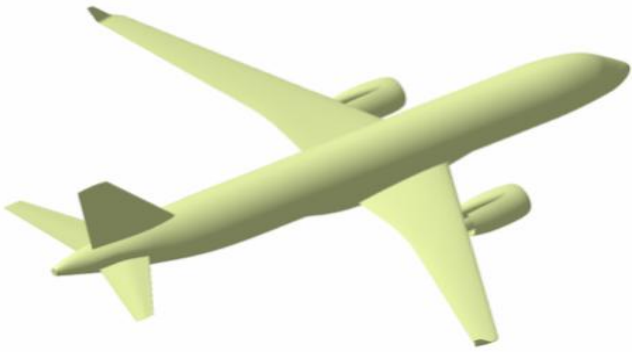
Future release of CEASIOM

- compatibility with CPACS
- improvements over existing methods
- outstanding geometry issues

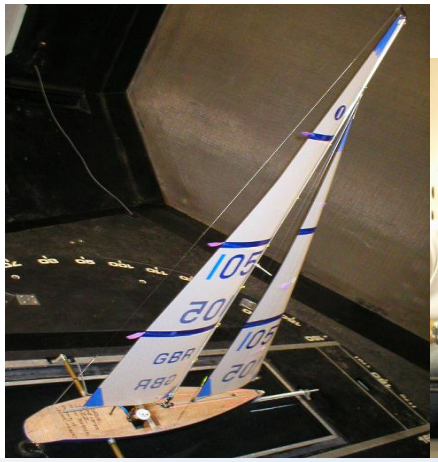


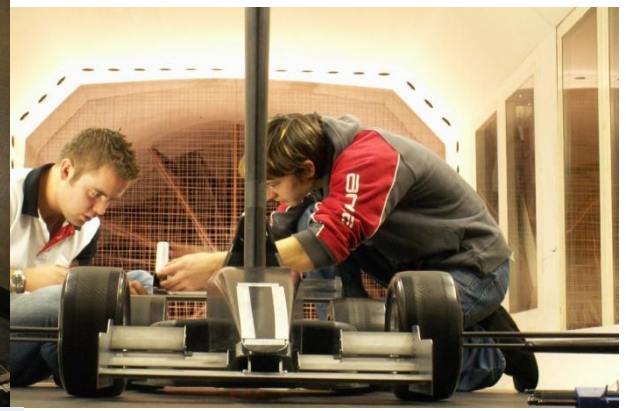
An application

- regional transport jet



Thanks to M. Cristofaro & CEASIOM Team





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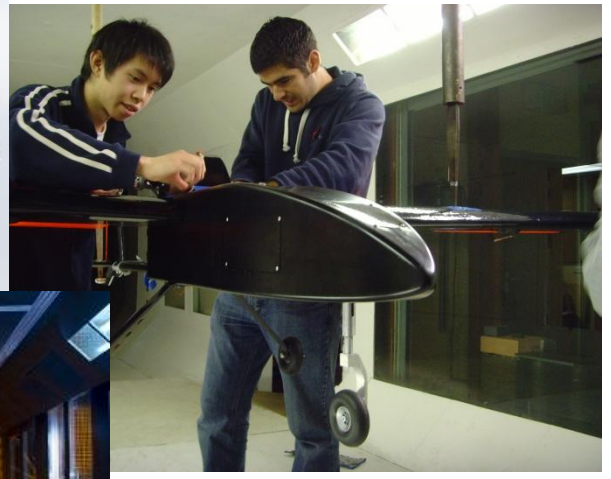
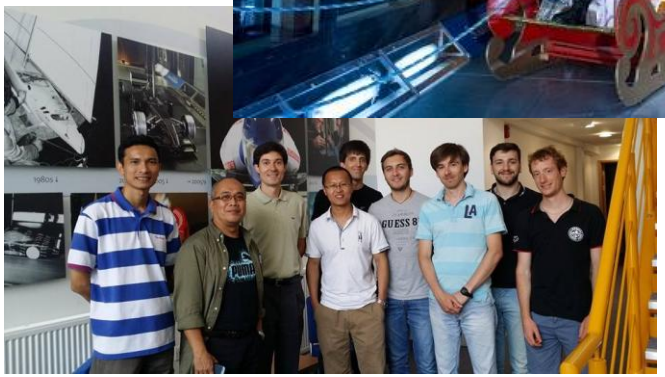


2nd largest academic facility in the U.K. behind National Facility (12,200 cores)

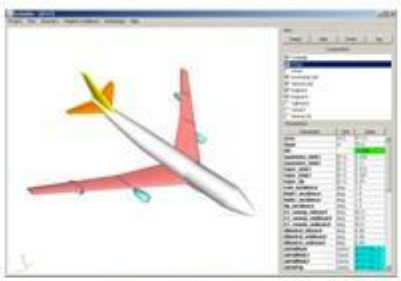
Top 30 in the World

largest academic wind tunnel in the UK

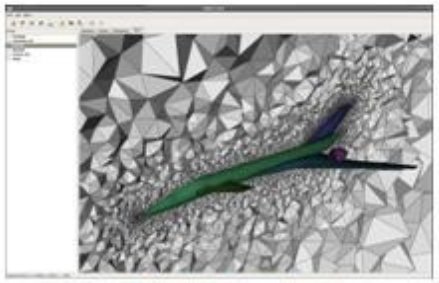
2nd in aerospace eng. in the UK (The Guardian)



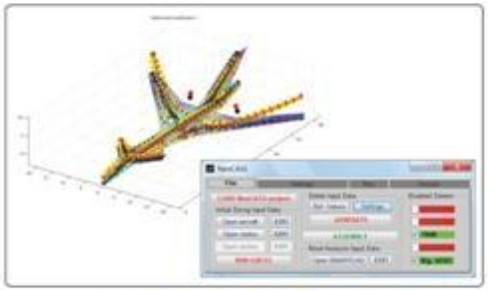
CEASIOM



Aircraft builder

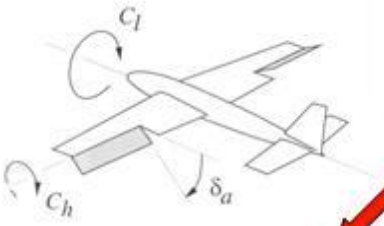


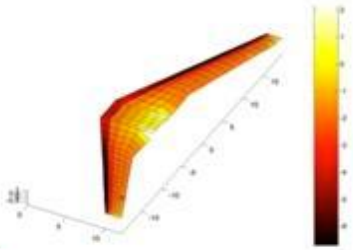
3D mesh generator



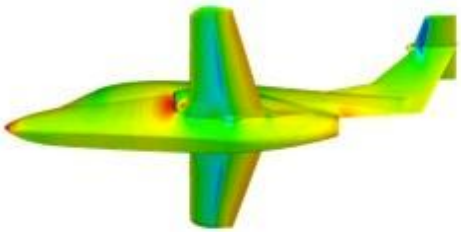
Structural & Aeroelastic modelling

CEASIOM main GUI

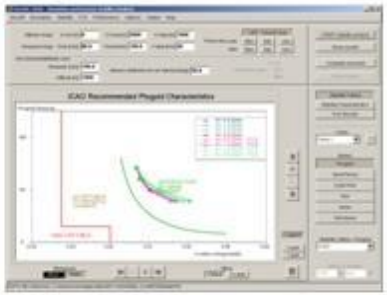




Low to high fidelity (Datcom to Euler) **aerodynamic methods**



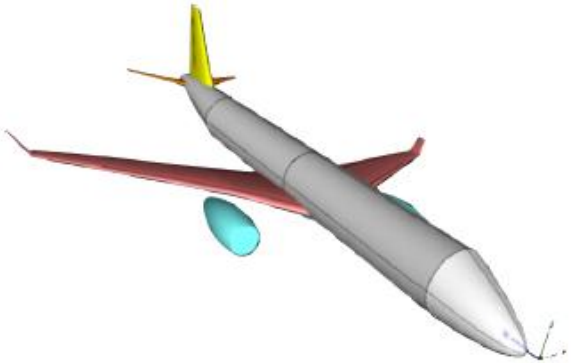
Flight Control System Design Tool-kit and Integrated **Stability & Control** analyzer



www.ceasiom.com

Data Format

XML format
- small number of parameters
- low fidelity geometry description



CPACS format
- unlimited number of parameters
- high fidelity geometry description

Compatibility with conceptual design?

- Datcom wrapper

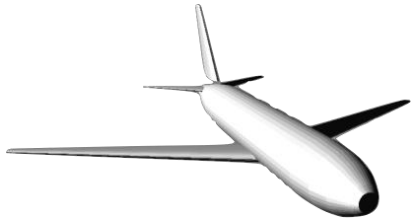
- Exporting aero tables for S&C

Datcom Wrapper

CPACS detailed geometry

Input Wrapper .m

Digital Datcom



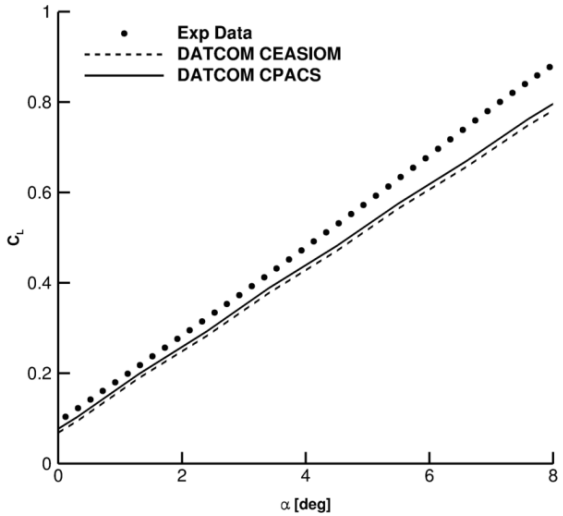
Conceptual geometry, approx. 10s of parameters

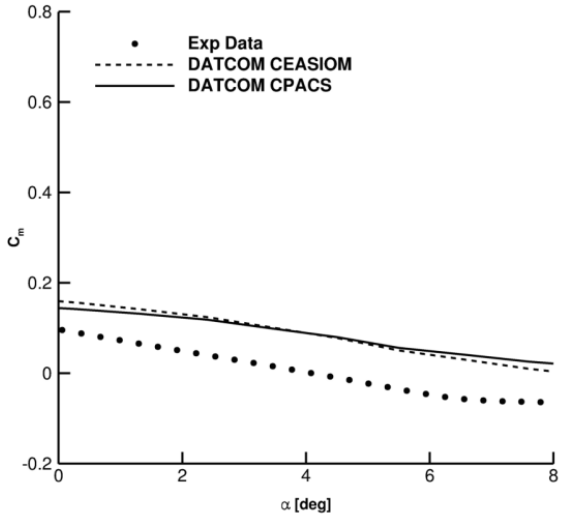
Output Wrapper .m

Aero data

✓ CPACS/DATCOM compatibility solved

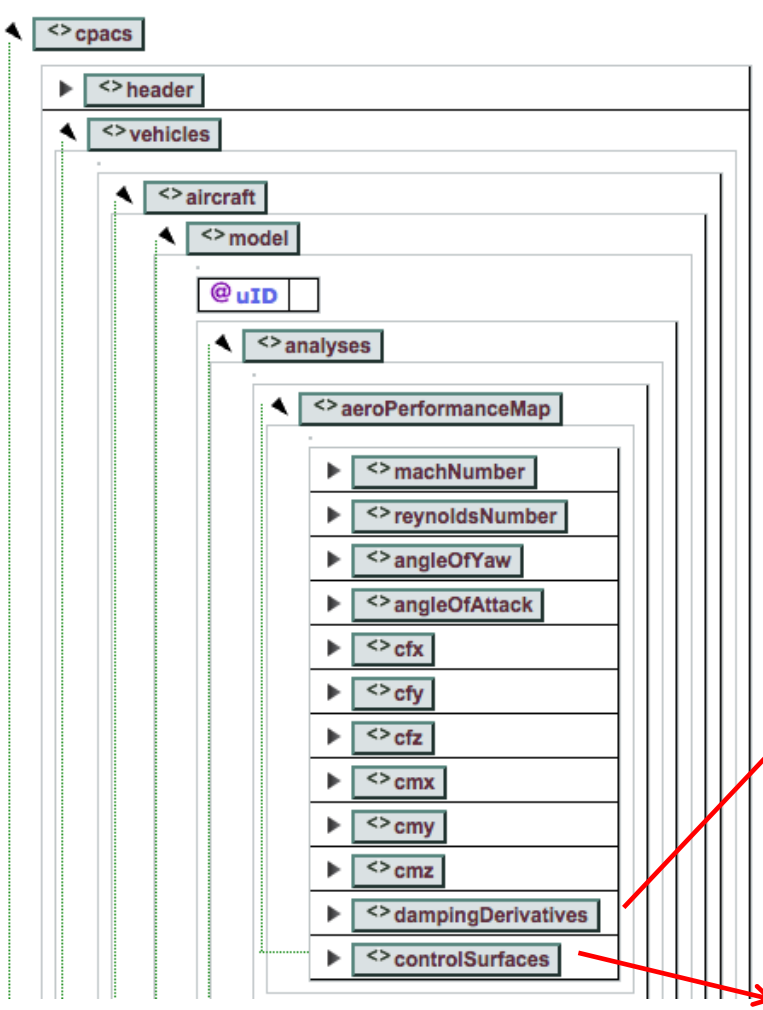
B747-8 validation

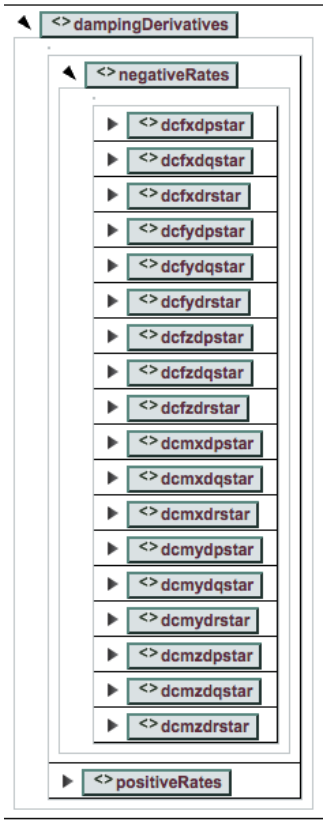




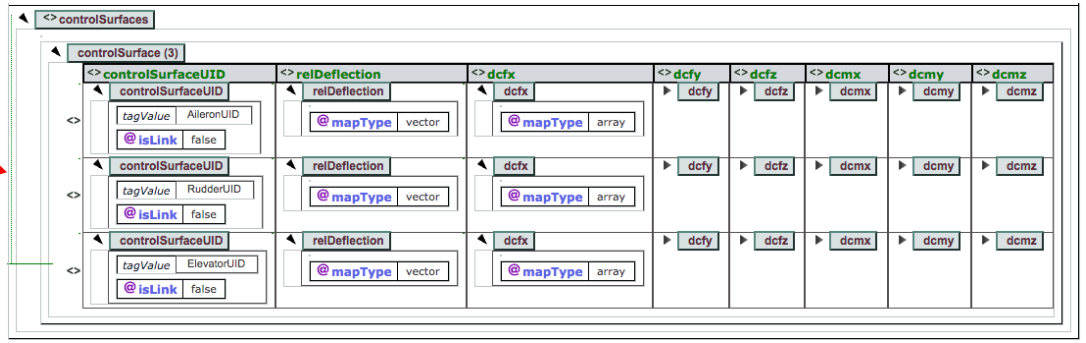
Aero Tables for S&C

Tabulated forces and moments





Dynamic derivatives

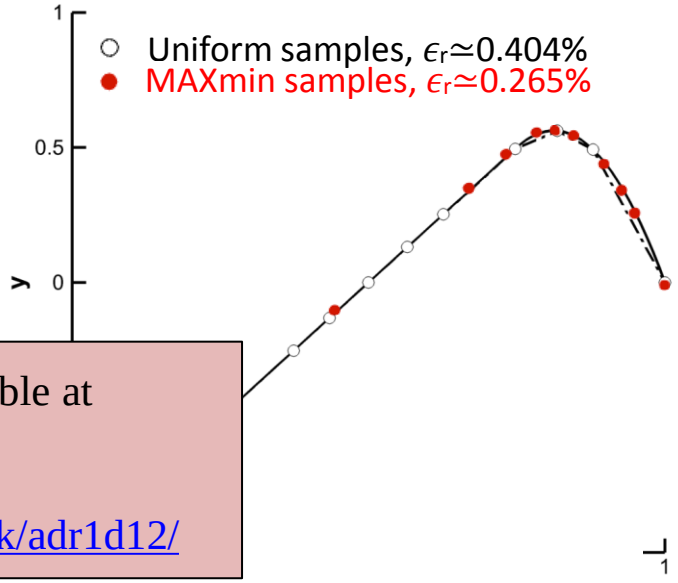


Control increments

Sampling Strategy

Off-the-shelf methods (prediction error)

- inability to capture local nonlinearities
- large number of samples for convergence



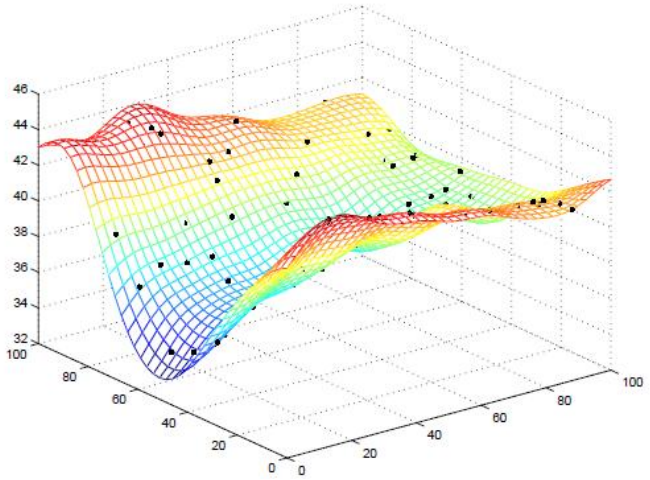
New implemented methods

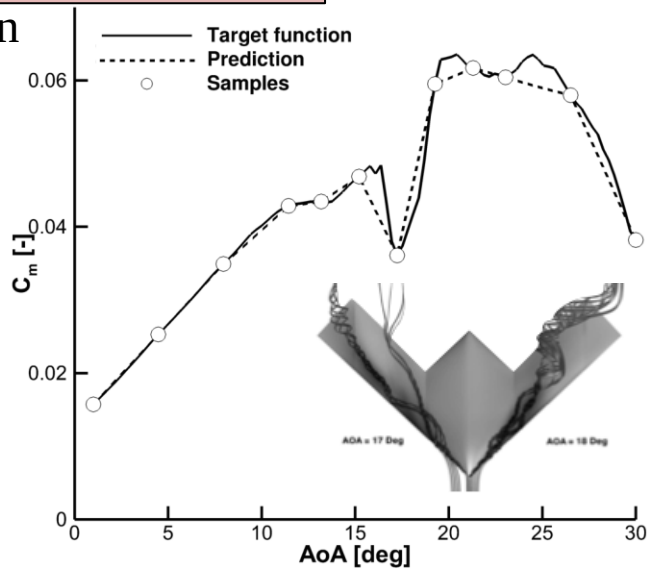
1. local max/min of the funct
2. Hessian matrix of the function prediction estimation

✓ Standalone toolboxes available at

www.ceasiom.com

http://www.personal.soton.ac.uk/adr1d12/





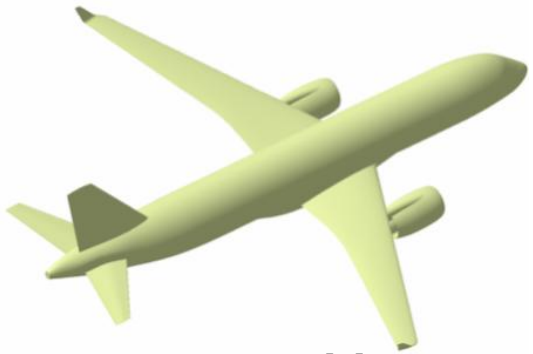
Cristofaro, M., "Towards computational flight dynamics of complete aircraft", **MSc Thesis**, University of Southampton, 2014; available at www.ceasiom.com

Regional Transport Jet

Parameter	Value
Range	2,600 km
Cruise Mach	0.78
Cruise altitude	10,668–11,887 m
Number of engines	2
Number of passengers	110
Landing field length	1,450 m
Take off field length	1,550 m
Long. ref. length	3.6 m
Lat. ref. length	30 m
Wing area	105 m^2

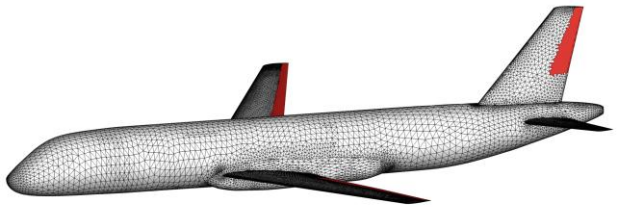
Parameter	Value
MTOW	$4.97 \cdot 10^4$ kg
CG location	(16.13, 0, 0.0236) m
Ixx	$1.11 \cdot 10^6$ kg·m^2
Iyy	$1.90 \cdot 10^6$ kg·m^2
Izz	$2.87 \cdot 10^6$ kg·m^2
Ixz	$6.72 \cdot 10^4$ kg·m^2
Ixy, Iyz	0 kg·m^2

Howe's W&B



CAD model

1:23 WT model at DNW

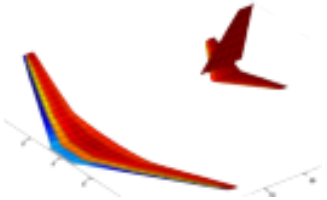


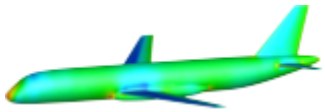
Euler mesh, approx. 500k points

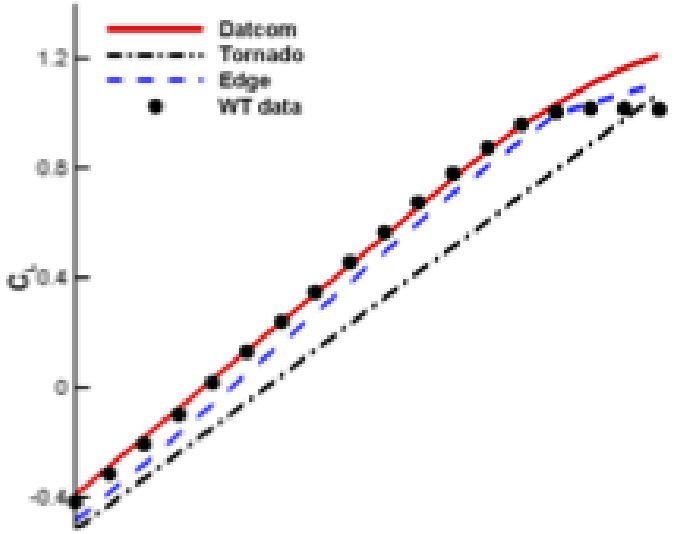
CAD model → CEASIOM model → SUMO mesh generator → Euler sol

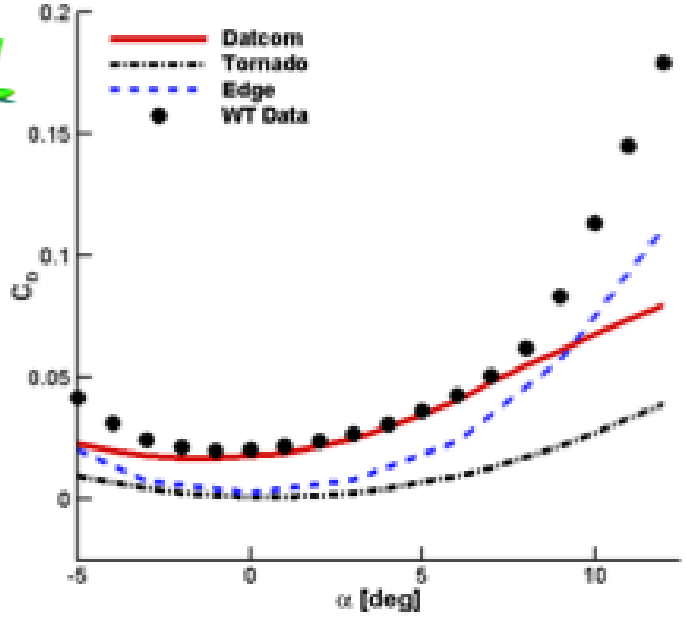
Aero Data Validation

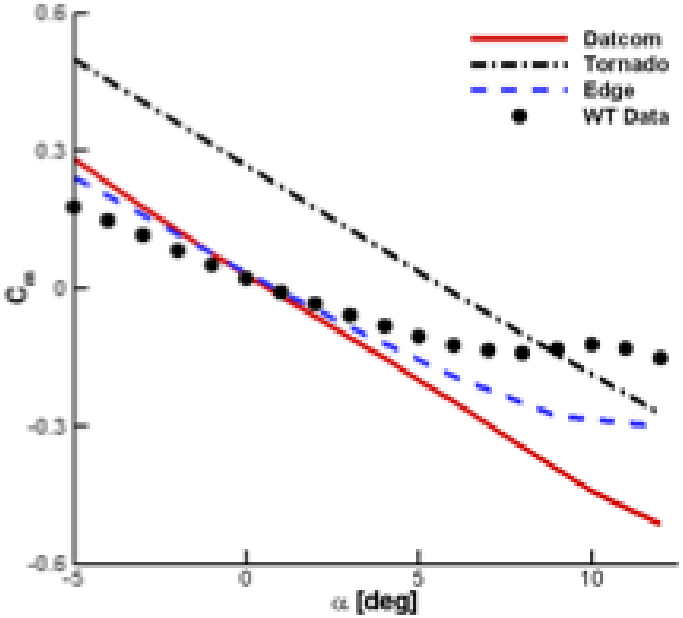
- WT data (M = 0.17, Re = 1.93 10^6)
- Datcom
- VLM (Tornado)
- Euler (Edge)









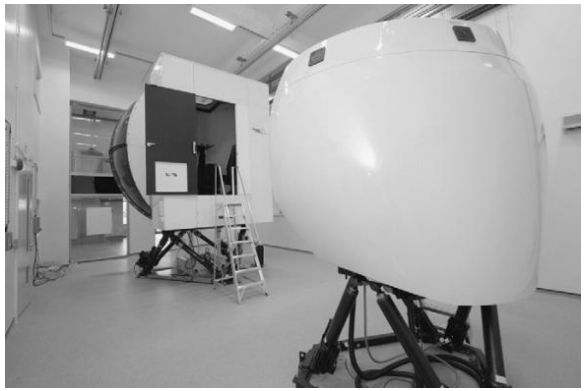


Aero Tables

Tabulated forces and moments

Assumptions

- longitudinal/lateral separation
- stability derivatives (static, control, dynamic)
- no significant unsteady effects

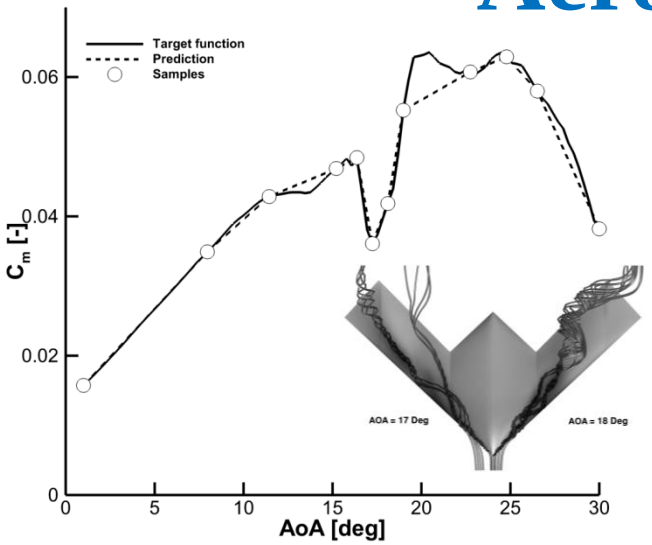


Flight conditions: > 100k points

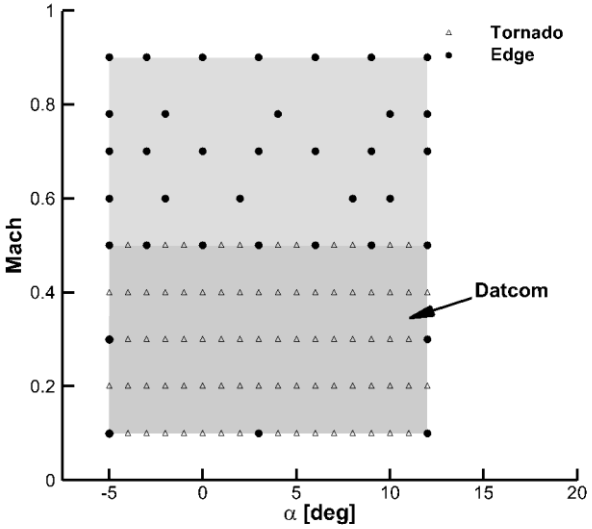
Validity restricted to benign flow conditions (landing, take-off, gust encounter?)

α	M	β	δ_{ele}	δ_{rud}	δ_{ail}	...	p	q	r	C_L	C_D	C_m	C_Y	C_l	C_n
x	x	x	–	–	–	–	–	–	–	x	x	x	x	x	x
x	x	–	x	–	–	–	–	–	–	x	x	x	x	x	x
x	x	–	–	x	–	–	–	–	–	x	x	x	x	x	x
x	x	–	–	–	x	–	–	–	–	x	x	x	x	x	x
x	x	–	–	–	–	x	–	–	–	x	x	x	x	x	x
x	x	–	–	–	–	–	x	–	–	x	x	x	x	x	x
x	x	–	–	–	–	–	–	x	–	x	x	x	x	x	x
x	x	–	–	–	–	–	–	–	x	x	x	x	x	x	x

Aero Tables for S&C

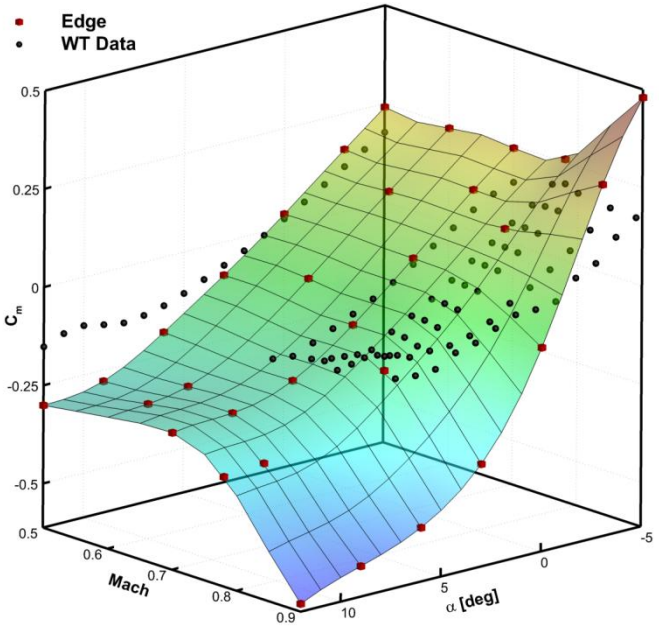


Efficient search of nonlinearities; few CFD samples



Data fusion (models/wind tunnel/flight testing)

Kriging interpolation + iterative sampling

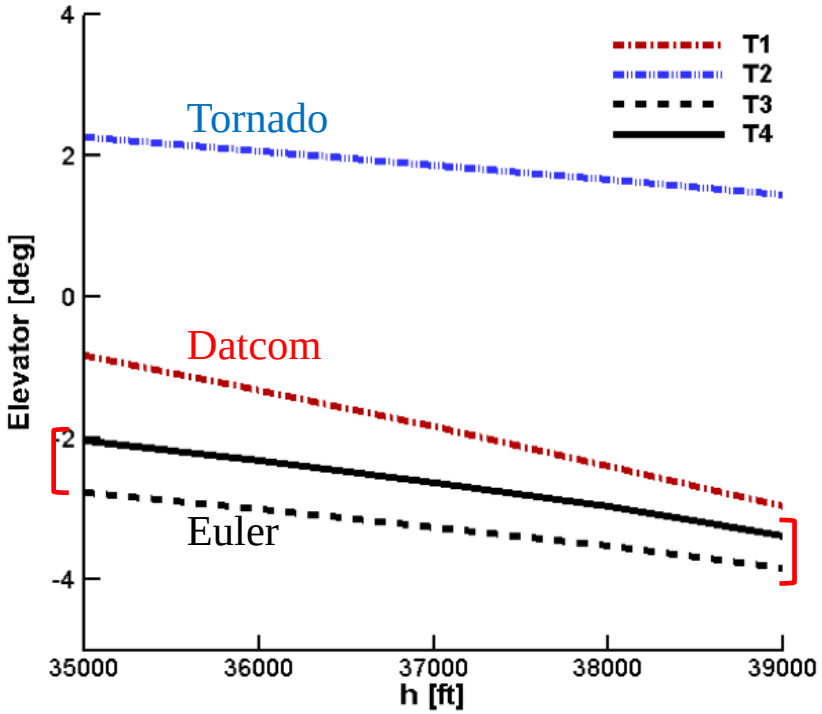


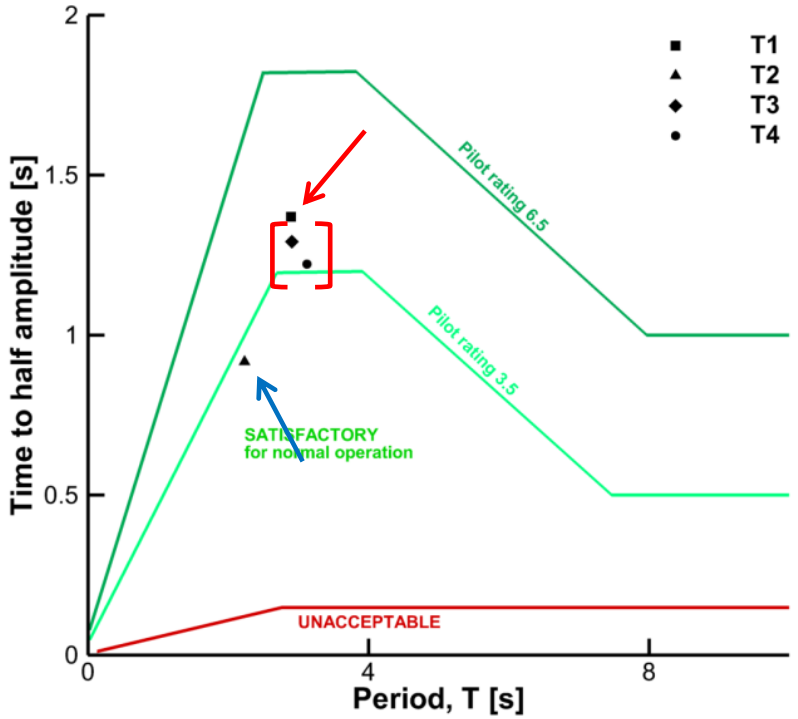
Da Ronch et al., "On the generation of flight dynamics aerodynamic tables by computational fluid dynamics", **Progress in Aerospace Sciences**, 2011; 47: 597-620. doi: 10.1016/j.paerosci.2011.09.001

Initial S&C

T1: Datcom
T2: Tornado
T3: Euler Kriging
T4: Euler+WT fusion

Impact of Aero models





Trim analysis

Dynamic stability: short period

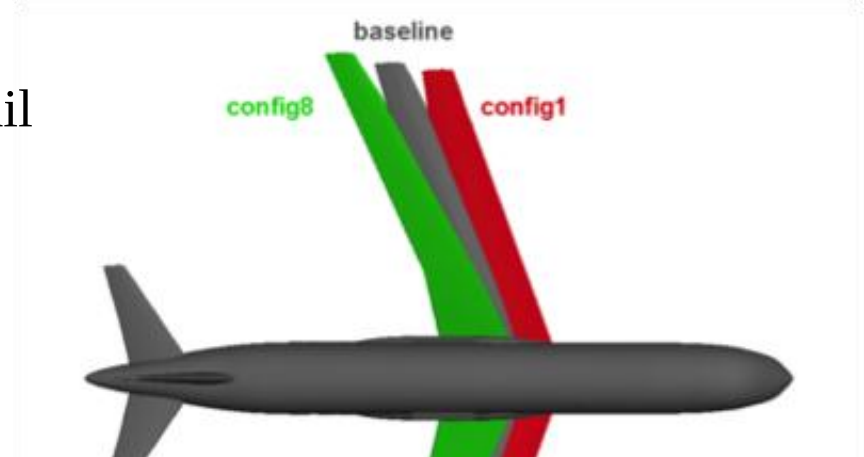
Geometry Changes

For each new configuration

1. change geometry
2. regenerate Euler mesh
3. estimate W&B (Hoke)
4. update aero tables
   - 19 CFD calcs
   - data fusion
5. evaluate S&C
6. back to 1.

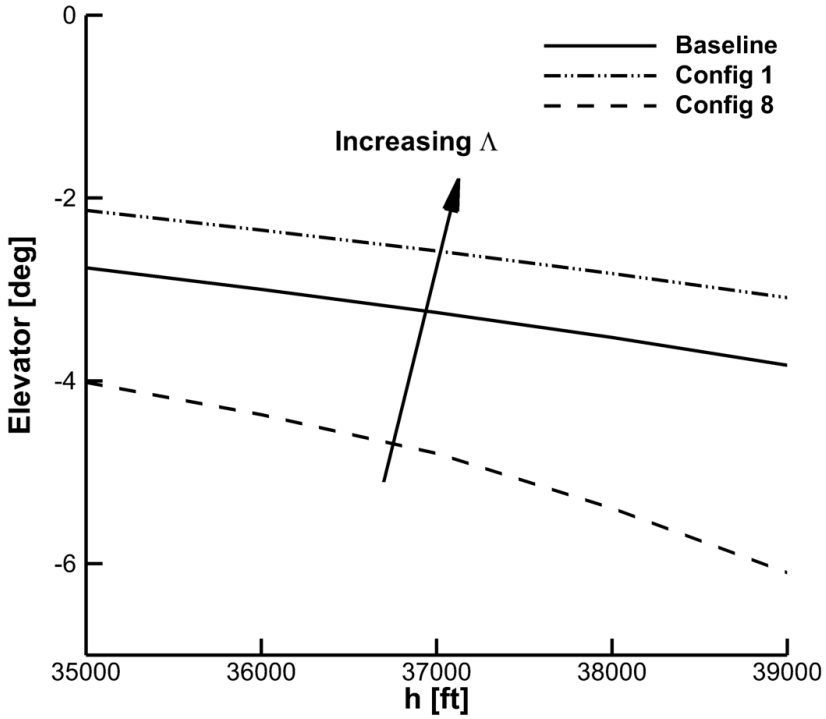
Configuration	Λ_{LE} $[deg]$	AR [–]
Baseline	27	9.4
Configuration 1	20	9.0
Configuration 2	20	9.4
Configuration 3	20	10.0
Configuration 4	27	9.0
Configuration 5	27	10.0
Configuration 6	33	9.0
Configuration 7	33	9.4
Configuration 8	33	10.0

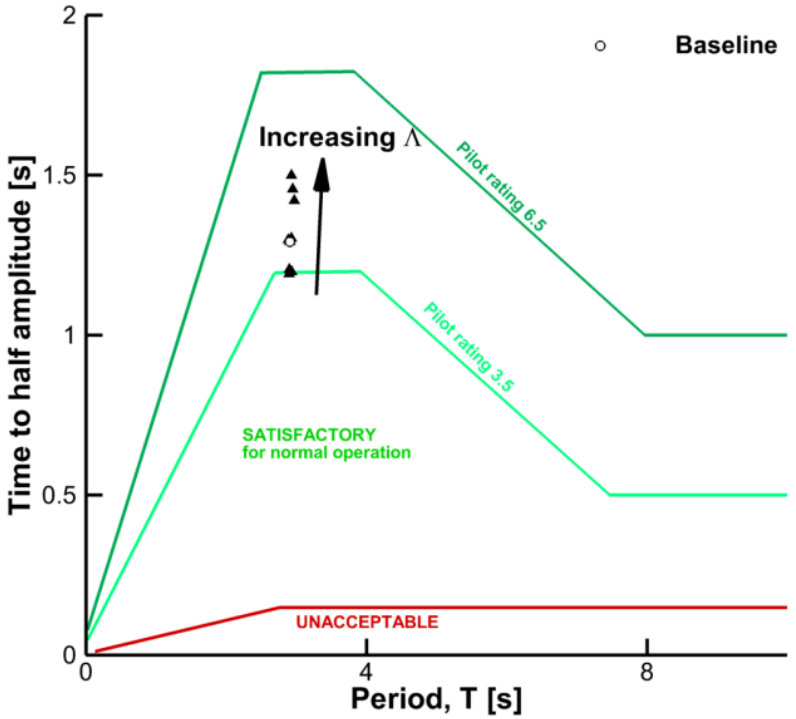
Geometry changes: wing and horizontal tail



Modified S&C

Impact of wing geometry for CFD-based aero tables





Trim analysis

Dynamic stability: short period

Frequency Domain Solvers

Dynamic derivatives

- periodic forced motion in WT

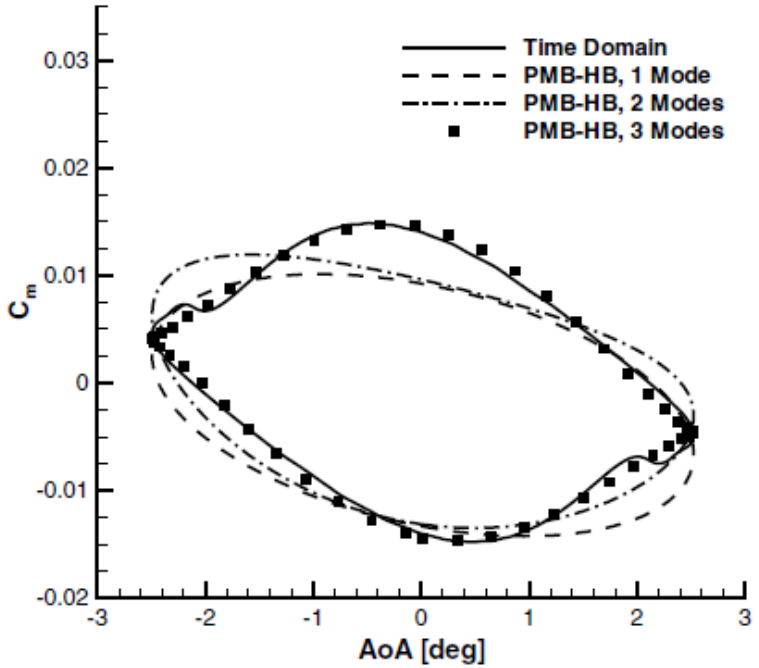
CFD techniques

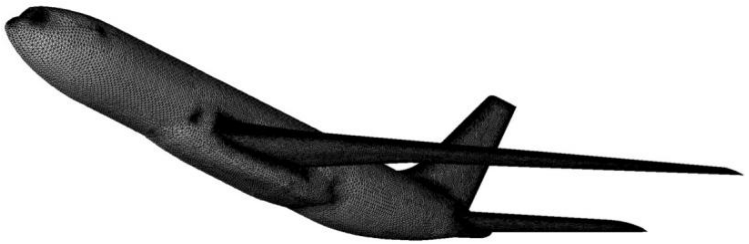
- Harmonic Balance
- Linear Frequency Domain

$$\omega \underline{\underline{D}} \underline{W}_{HB} + \underline{R}_{HB} = \underline{0}$$

Speedup ~10-10^2 compared to unsteady CFD

Tested on transonic unsteady flows





Da Ronch et al., "Linear frequency domain and harmonic balance predictions of dynamic derivatives", **Journal of Aircraft**, 2013; 50 (3): 694-707. doi: 10.2514/1.J052309

Conclusions

New methods and CPACS compatibility in CEASIOM

Impacts of models on S&C

Toward CFD-based reduced models

S&C constrained optimisation

Contact Information

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