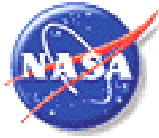# An Assessment of the Unstructured-Grid Software TetrUSS for Drag Prediction on DLR-F4 Configuration

Shahyar Z. Pirzadeh
Richard A. Wahls

NASA Langley Research Center
Hampton, Virginia

Unstructured Grid Solver USM3Dns

- Developed at the NASA LaRC   (Frink, 1992, 1996)

- Tetrahedral cell-centered, finite volume Euler and N-S solver

- Specifications:
  - ❍ Roe's flux-difference splitting
  - ❍ spatial discretisation through an analytical reconstruction scheme
  - ❍ implicit backward-Euler time stepping
  - ❍ Spalart-Allmaras one-equation turbulence model
  - ❍ optional modeling of viscous sub-layer with a wall function
  - ❍ memory requirement: 1400 bytes/cell

  - ❍ speed: 34 μsec/cell/cycle on CRAY C90
 - ❍ runs on UNIX and Linux platforms

s.pirzadeh@larc.nasa.gov
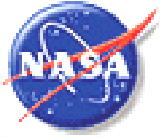
DLR-F4 Wing-Body Configuration

CASE 1 (single point): $M_\infty = 0.75$, $C_L = 0.5$, $Re = 3.0 \times 10^6$

Data	α (degrees)	C_L	C_D	C_M
ONERA	0.192	0.50	0.0290	-0.126
NLR	0.153	0.50	0.0290	-0.130
DRA	0.179	0.50	0.0279	-0.137
USM3Dns[1]	-0.300	**0.50**	0.0277	-0.158
USM3Dns[2]	**0.175**	0.56	0.0303	-0.156

[1] USM3Dns computation at $C_L = 0.5$
[2] USM3Dns computation at $\alpha = 0.175°$ (average of experimental values)
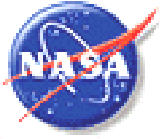
s.pirzadeh@larc.nasa.gov
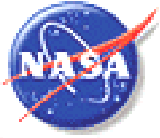
DLR-F4 Wing-Body Configuration

CASE 1: $M_\infty = 0.75$, $\alpha_{avg.} = 0.175°$, $C_L = 0.5$, $Re = 3.0 \times 10^6$

- ○ ONERA Data
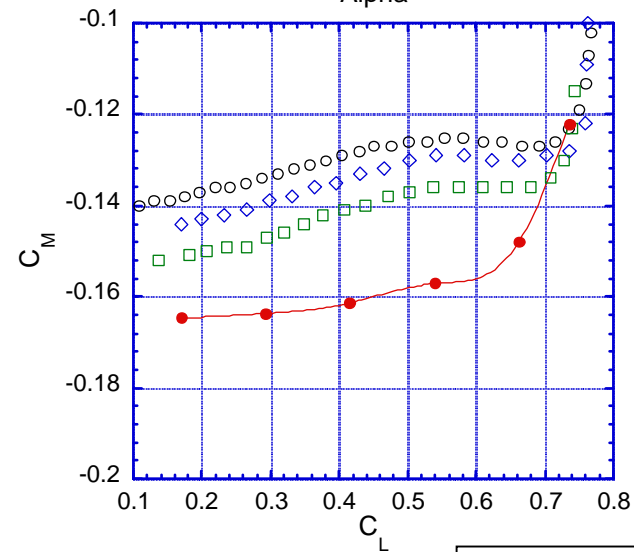- □ DRA Data
- ◇ NLR Data
- ——— USM3Dns ($C_L = 0.5$)
- – – – USM3Dns ($\alpha = 0.175°$)

$\eta_1 = 0.185$

$\eta_2 = 0.238$

$\eta_3 = 0.331$

$\eta = y/s$

$\eta_4 = 0.409$
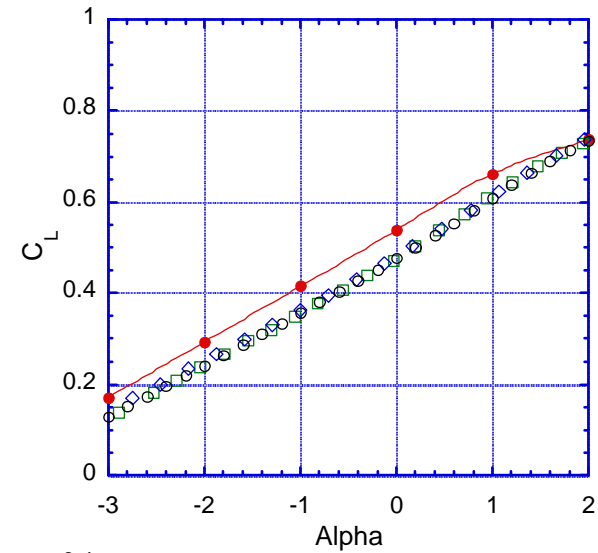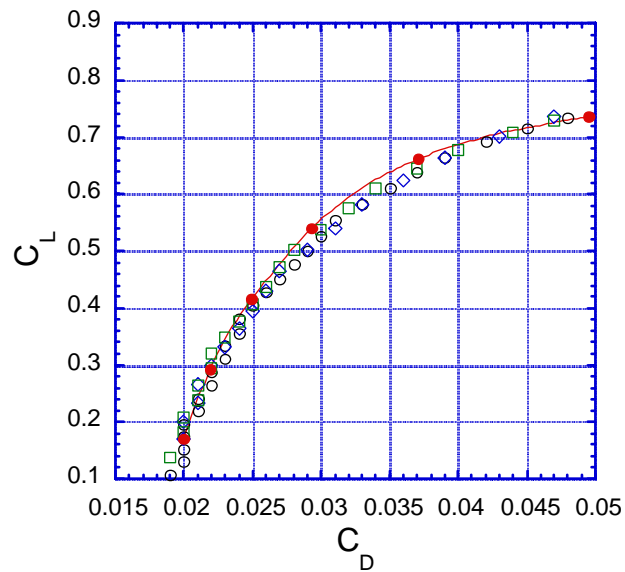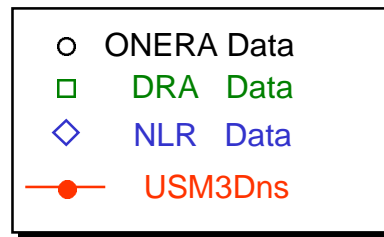
$\eta_5 = 0.512$

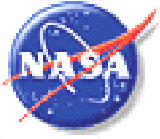$\eta_6 = 0.636$

$\eta_7 = 0.844$
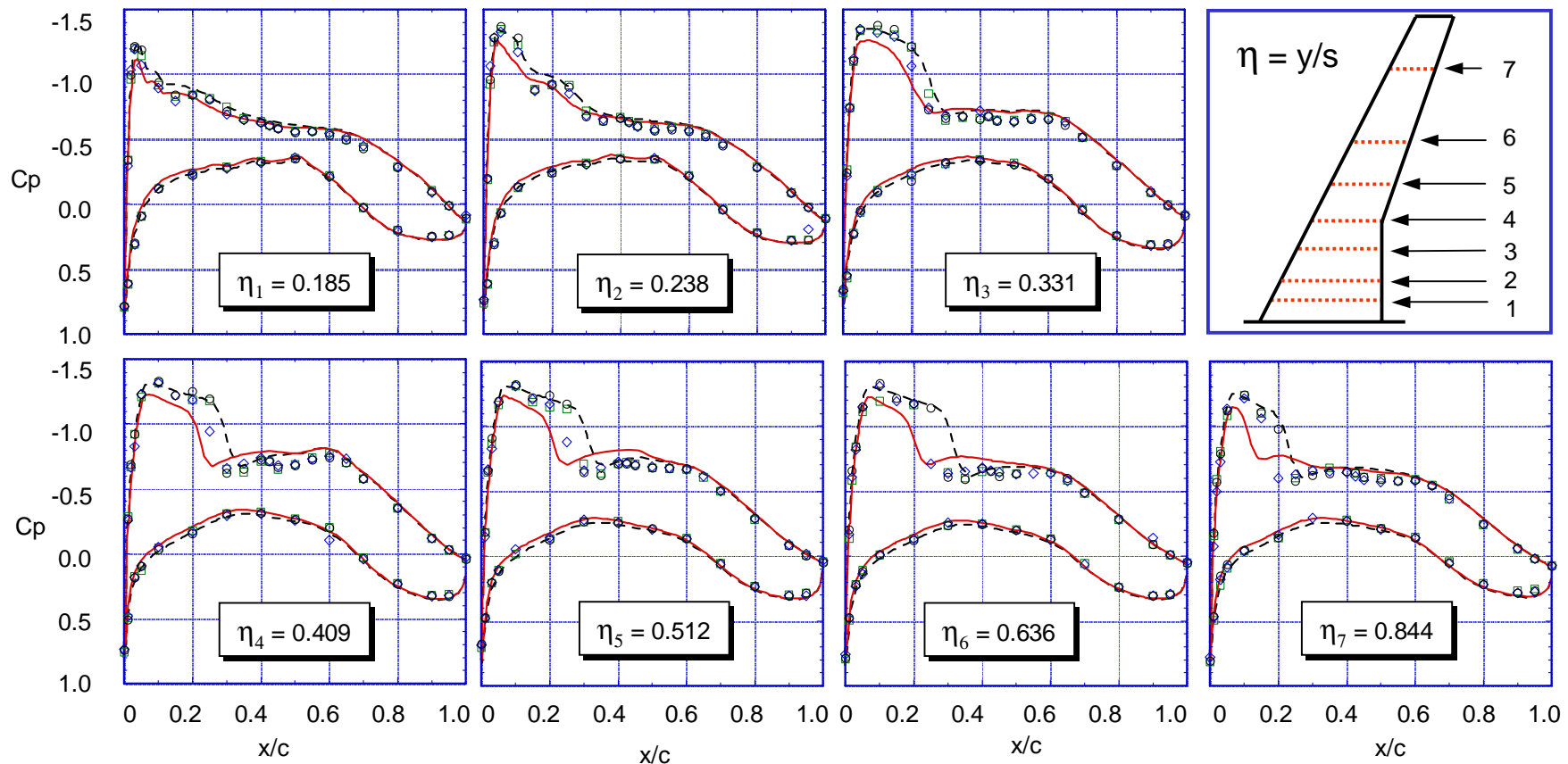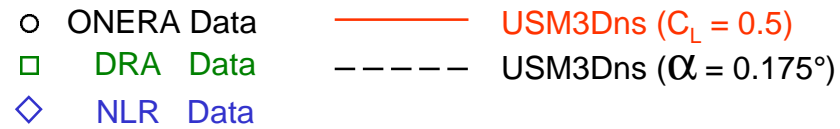
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DLR-F4 Wing-Body Configuration

CASE 2
Drag Polar

$M_\infty = 0.75$, $Re = 3.0 \times 10^6$

○ ONERA Data
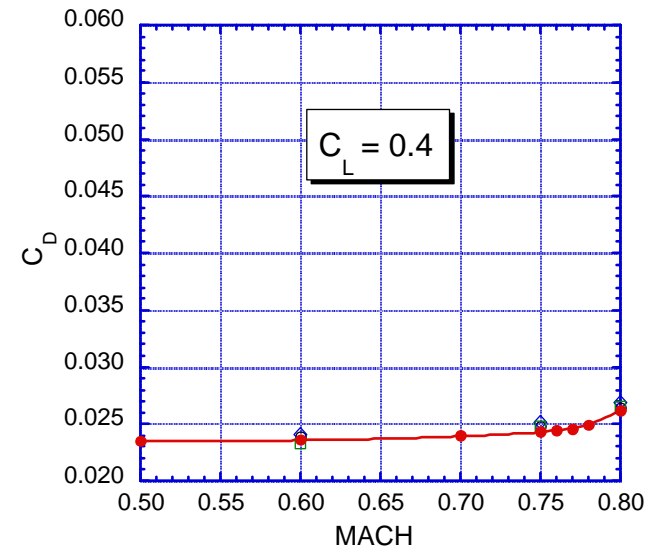□ DRA Data
◇ NLR Data
●— USM3Dns

DLR-F4 Wing-Body Configuration

CASE 3&4
Constant C_L Mach Sweep
Drag Rise Curves

$Re = 3.0 \times 10^6$

Legend:
- ○ ONERA Data
- □ DRA Data
- ◇ NLR Data
- ● USM3Dns

Plot: $C_L = 0.4$ — C_D vs MACH

Plot: $C_L = 0.5$ — C_D vs MACH
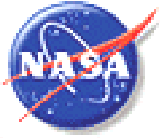

Plot: $C_L = 0.6$ — C_D vs MACH
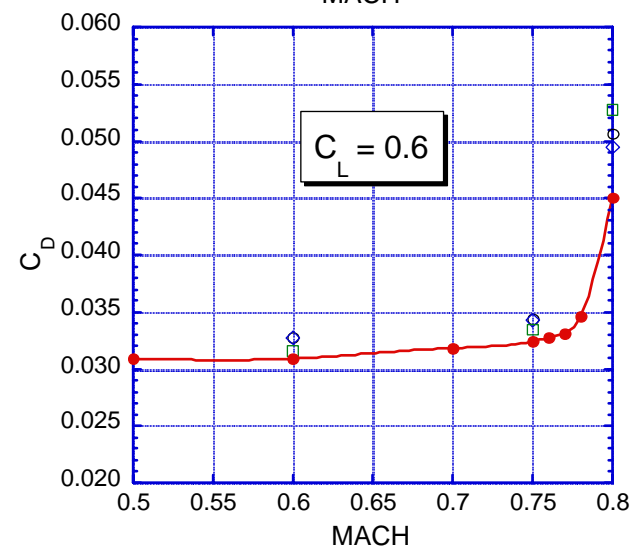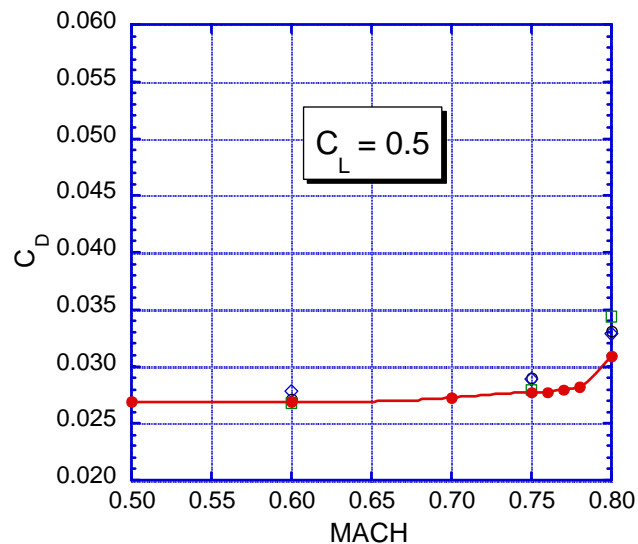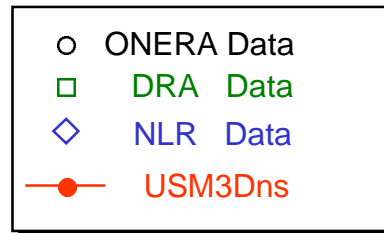
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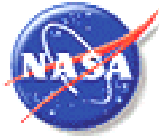
Concluding Remarks

- **TetrUSS** is a practical unstructured grid software system suitable for prediction of aircraft forces and moments

- A salient feature of the system is ease of grid generation for complex configurations with **VGRIDns**

  - N-S grids were generated for DLR-F4 configuration in days

- **USM3Dns** is a robust unstructured grid solver

  - Current DLR-F4 cases were computed with the **wall-function** (WF) option of USM3Dns on a grid similar to the standard (provided) grid with fewer number of cell layers in the boundary layer

    - The WF grid contains 2.4 million cells

  - All computations were performed "smoothly" with fast convergence (on average 1500 cycles per solution)

  - **Flux limiter** in USM3Dns was recently isolated as cause of over-prediction of wing pressure drag by 35 to 50 counts on advanced subsonic transport configurations

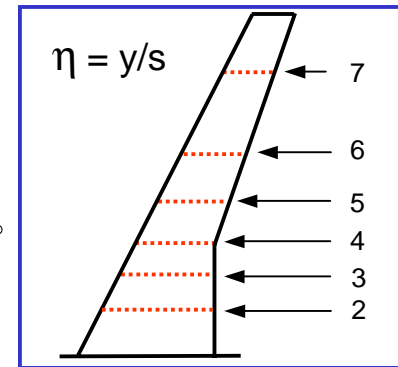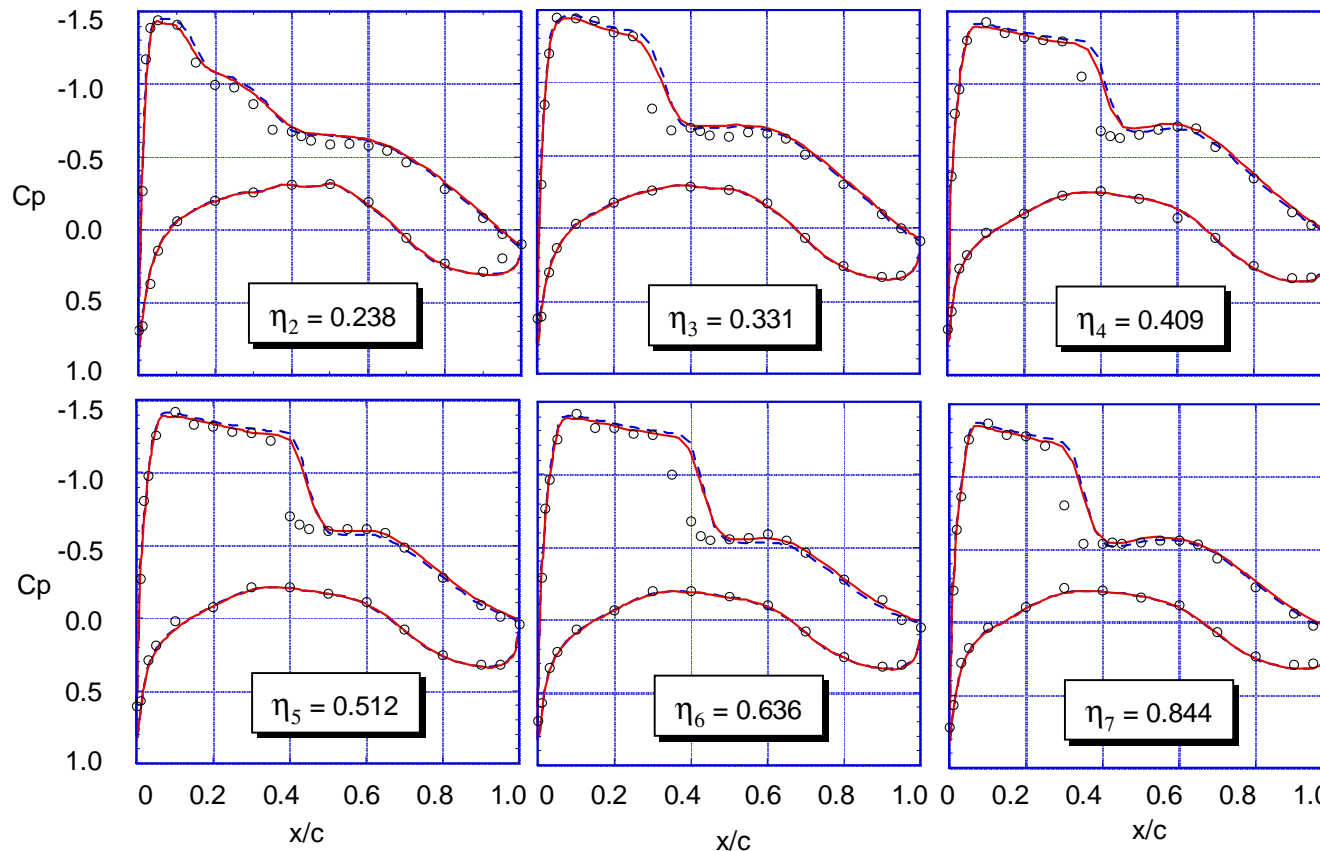 - Current solutions on DLR-F4 were computed <u>without</u> limiter

DLR-F4 Wing-Body Configuration
Effect of Flux Limiter on USM3Dns Computed Drag

Legend:
- ○ Experimental Data
- —— USM3Dns (with limiter)
- - - - USM3Dns (without limiter)

$M_\infty = 0.75$, $\alpha_. = 0.93°$, $Re = 3.0 \times 10^6$

Panels (Cp vs x/c):
- $\eta_2 = 0.238$
- $\eta_3 = 0.331$
- $\eta_4 = 0.409$
- $\eta_5 = 0.512$
- $\eta_6 = 0.636$
- $\eta_7 = 0.844$

$\eta = y/s$

Data	C_L	C_D
Experim.	0.602	0.0352
USM3Dns	0.650	0.0412
USM3Dns (no limiter)	0.653	0.0364

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