

Program Overview: Vortex Interaction Aerodynamics Relevant to Military Air Vehicle Performance

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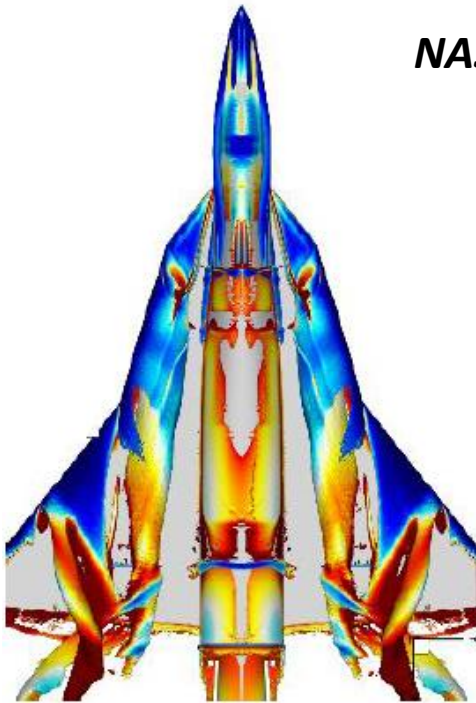
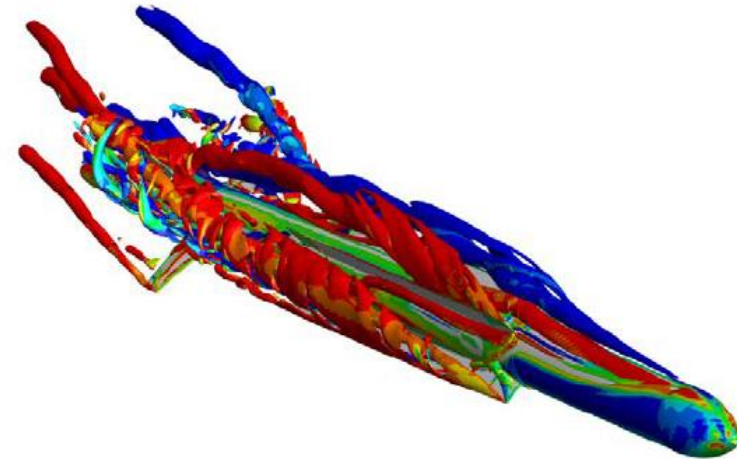
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Philotech, DEU

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Special Sessions: Vortex Interaction Aerodynamics: NATO/STO AVT-316

Outline

- **Background**
 - Vortex interactions
 - NATO Science and Technology Organization
- **AVT-316 research program**
 - Objectives, scope, etc.
 - Organization: two research facets
- **Special session reporting**
- **Concluding remarks**

Vortex Interactions

- **Aircraft develop complex vortical flows**

- Maneuver and high-lift flows
- Many interactions
 - Among vortices, with other flow features, with components, etc.

- **Many uses and consequences**

- Can augment high-lift performance
- Can also contribute adverse effects

- **Present work framed by 3 classes of vortex interactions**

- Vortex-vortex interactions
- Vortex-shock interactions
- Vortex-surface interactions

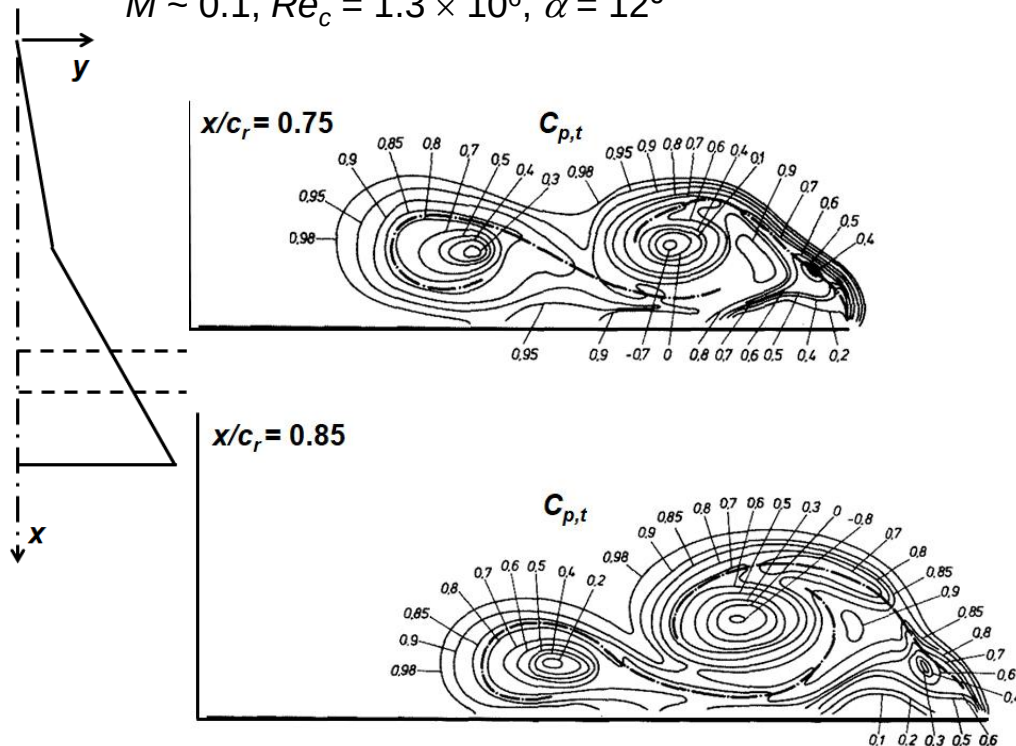


Brennenstuhl & Hummel, 1982

Frink, 2015

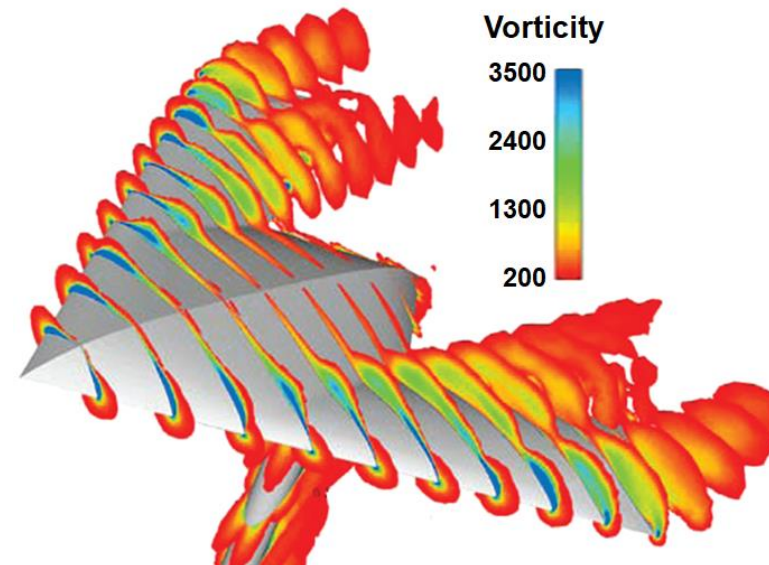
Vortex-Vortex Interactions

Double Delta Wing, $\Lambda_{le} = 80^\circ/60^\circ$
 $M \sim 0.1$, $Re_c = 1.3 \times 10^6$, $\alpha = 12^\circ$



Change in sweep produces two leading-edge vortices

SACCON, $\Lambda_{le} = 53^\circ$
 $M = 0.144$, $Re_{ref} = 1.6 \times 10^6$, $\alpha = 16.83^\circ$

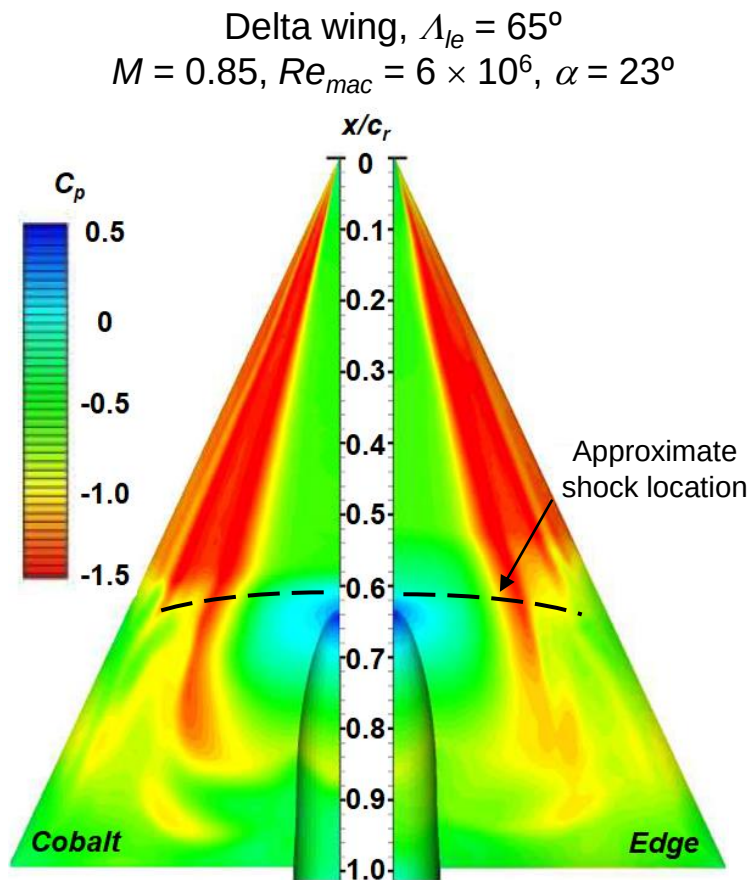


Spanwise leading-edge radius and thickness variations produce multiple leading-edge vortices

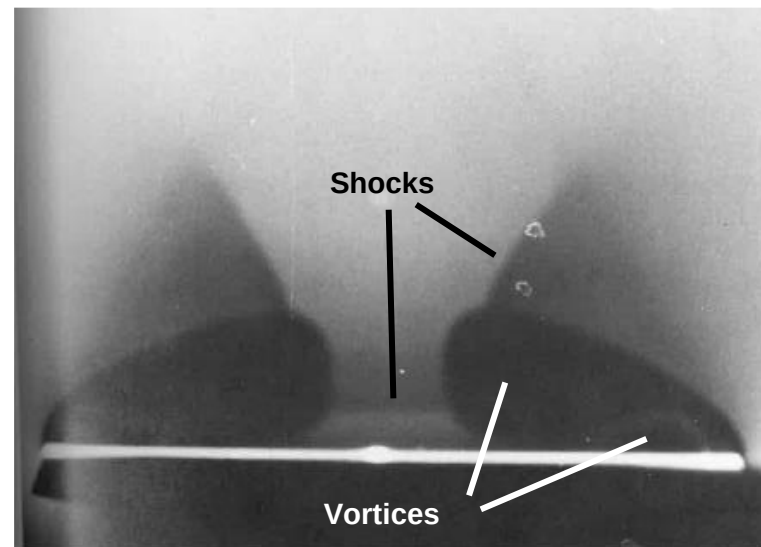
Schiavetta et al., 2008

Miller & Wood, 1985

Vortex-Shock Interactions



Delta wing, $\Delta_{le} = 75^\circ$
 $M = 2.8$, $Re_{mac} = 2.5 \times 10^6$, $\alpha = 20^\circ$



Vortex induces shocks

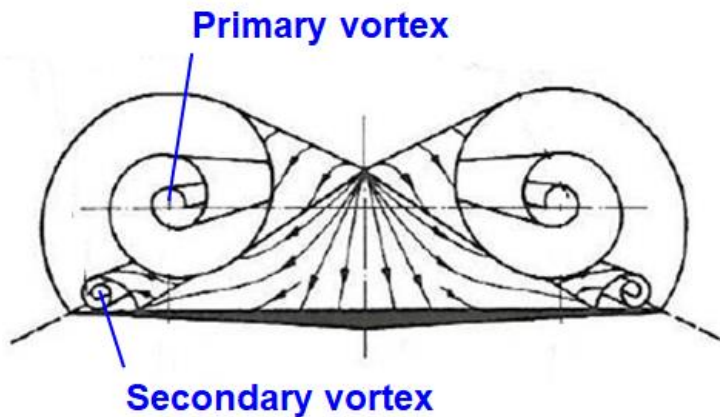
Shocks affect $V_{\theta, vtx}$

Hummel, 1979

Near, Inc., 2019

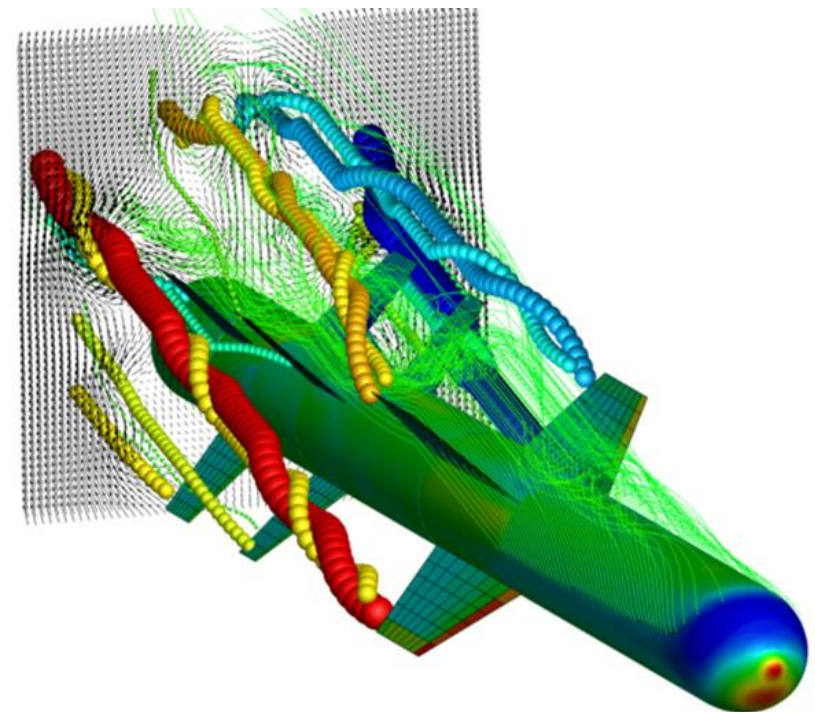
Vortex-Surface Interactions

$$M = 0.6, \alpha = 24^\circ, \lambda = 0^\circ$$



Primary vortex induces a spanwise boundary-layer flow. Subsequent secondary separation produces the secondary vortex.

Vortex-vortex interactions also result

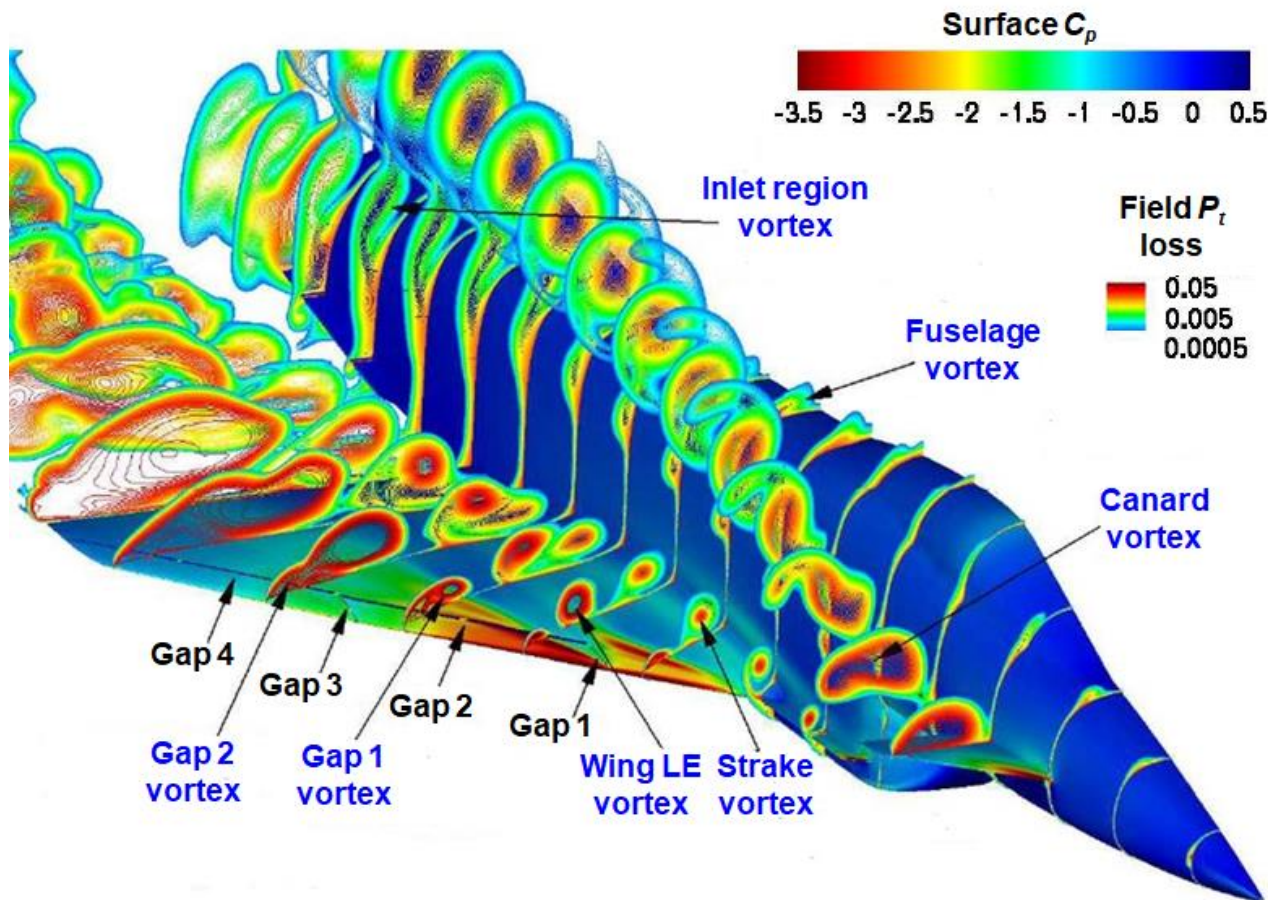


Upstream tip vortex interacts with downstream fin

Boelens, 2009

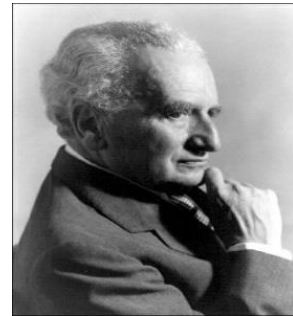
Aircraft Practicalities Produce Complex Interactions

X-31, $\Lambda_{le} = 57^\circ/45^\circ$
 $M = 0.18$, $Re_{mac} = 2.07 \times 10^6$, $\alpha = 20.06^\circ$



NATO Science and Technology Organization (STO)

- **Origin: AGARD, Advisory Group for Aerospace Research and Development**
 - Promote and conduct co-operative scientific research as well as the exchange of technical information of mutual benefit amongst NATO member nations and organizations
 - Vision of Maurice von Kármán, founded by his son Theodore (1952)
- **STO is the largest such collaborative body**
 - 30 NATO nations and 40 NATO partners, over 3500 scientists and engineers; participants represent leading national labs, industry, and academia
 - More vehicle-centric slant than AGARD for collaborative work
 - Broad scope of technologies, many of dual use (military/commercial)
- **Current work performed under the auspices of the STO Applied Vehicle Technology (AVT) Panel**



Vortex Interaction Aerodynamics Relevant to Military Air Vehicle Performance (AVT-316)

- **Objectives**

- **Evaluate capability of current CFD** to predict vortex-interaction effects for select air configurations
- **Extend understanding of vortex-interactions** through numerical and physical experimentation
- **Enhance predictive capability** for vortex interaction effects and provide future recommendations

- **Scope**

- Vortex interactions that occur **between vortices**, between **vortices and shocks**, and/or between **vortices and vehicle components**
- Vortex interactions that are relevant to **maneuver performance** of military air vehicles
- **Numerical and experimental** investigations

AVT-316: Resources, Organization & Outcomes

- **Resources**

- 5-year program: 2018-2022
- Sustained participation: 47 researchers, 22 institutions, 9 countries
- CFD studies, wind tunnel experimentation

- **Organization**

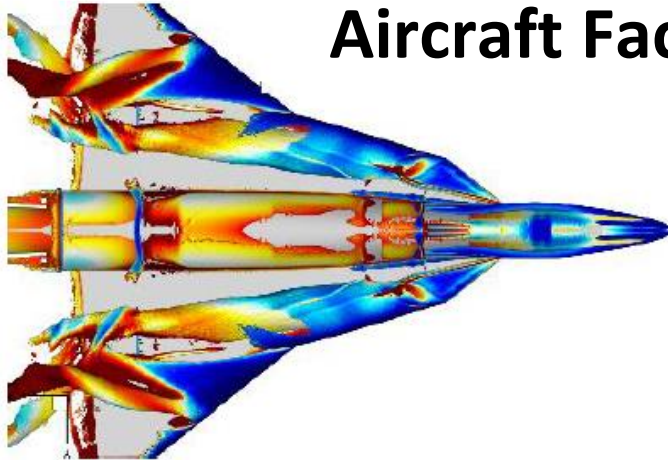
- Aircraft facet
- Missile facet

- **Outcomes**

- NATO comprehensive Technical Report, AIAA sessions, possible journal articles
- Professional enrichment

Aircraft Facet

$M = 0.85$
 $Re_{ref} = 12.53 \times 10^6$
 $\alpha = 20^\circ$



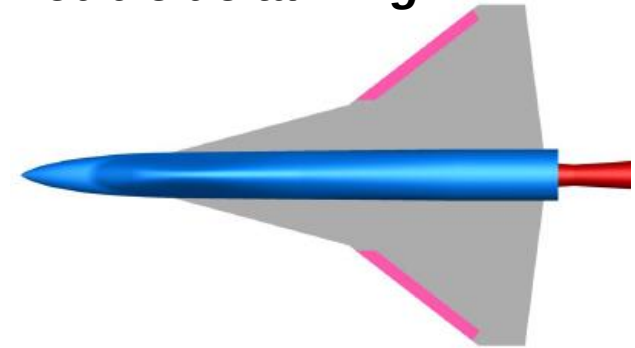
- **Studies**

- Double and triple delta wings
- Subsonic and transonic maneuver conditions
- Details originated from industry interests

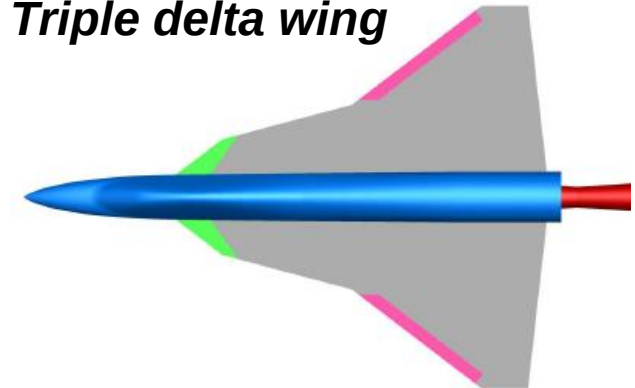
- **Assessments**

- New experimental data, 2 facilities
- Correlations with experiment
- Numerical modeling

Double delta wing



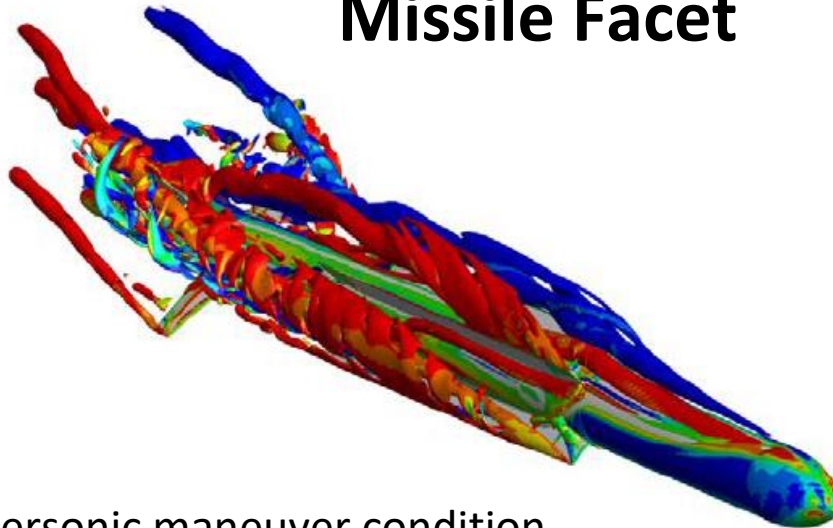
Triple delta wing



Stephan Hitzel, Lead, Airbus D&S / Philotech

Missile Facet

$M = 1.4$
 $Re_d = 4.89 \times 10^6$
 $\sigma = 15^\circ, \lambda = 2.5^\circ$



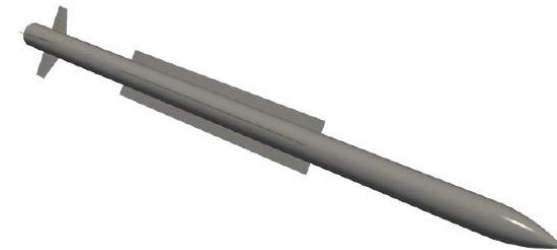
- **Studies**

- OTC1, supersonic maneuver condition
- LK6E2, transonic maneuver conditions
- Details originated from industry interests

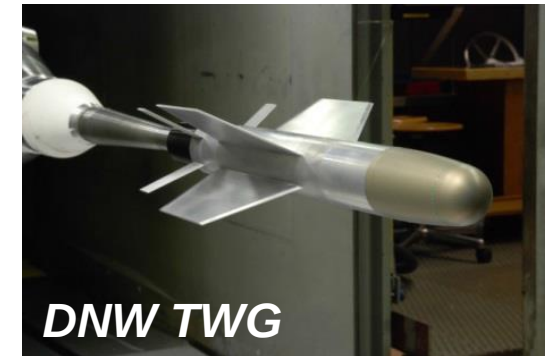
- **Assessments**

- Numerical modeling (includes blind CFD)
- Legacy and new experimental data, 1 facility
- Correlations with experiment

OTC-1



LK6E2



Nigel Taylor, Lead, MBDA

SciTech 2022 AVT-316 Special Sessions

- **Seven special sessions**

- 4 Aircraft Facet
- 3 Missile Facet

- **22 papers**

- AVT-316 Overview
- 10 Aircraft Facet
- 11 Missile Facet

- **Open forums**

- APA-23, Tuesday
- APA-82, Thursday

Session	Topic	Day	Time	Papers
APA-07	Aircraft Aerodynamics I	Mon	09:30 – 11:10	3
APA-98 ^{\$}	Aircraft Aerodynamics II	Mon	11:30 – 1:10	3
APA-08	Aircraft Aerodynamics III	Mon	02:00 – 03:40	3
APA-23*	Aircraft Aerodynamics IV	Tue	09:30 – 11:10	2
APA-39	Missile Aerodynamics I	Wed	09:30 – 11:10	4
APA-59	Missile Aerodynamics II	Wed	04:00 – 05:40	4
APA-82*	Missile Aerodynamics III	Thu	04:00 – 05:40	3

*Includes open forum

^{\$}Virtual Session

Concluding Remarks

- **Collective body of work**
 - 47-person 5-year effort
 - Vortex interaction aerodynamics
 - Aircraft and missile interests
 - Numerical and experimental assessments
- **Appreciate opportunity enabled by the AIAA to highlight some of the AVT-316 findings**
- **Special thanks to the AVT-316 research participants**