



Integrity ★ Service ★ Excellence

Unsteady Aerodynamics & Turbulent Flows

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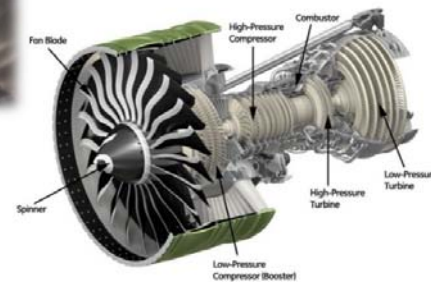
Air Force Relevance



Foundational research in *Unsteady Aerodynamics and Turbulent Flow* has impact across a wide range of Air Force Mission requirements

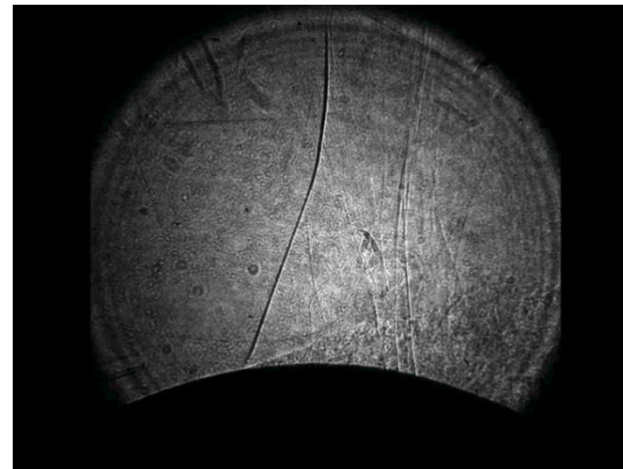
- **Aerospace Systems (RQ)**

- Air Superiority
- Rapid Global Mobility
- Agile Combat Support
- Affordable UAS



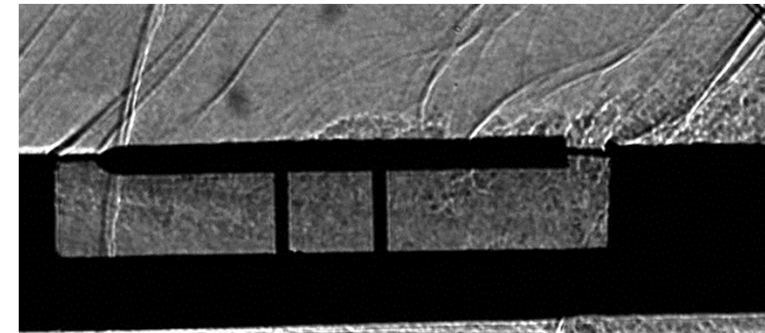
- **Munitions (RW)**

- Weapon Aerodynamics
- Weapon Guidance



- **Directed Energy (RD)**

- Aero Optics





Program Overview



- BLUF – aerodynamic flowfield physics must be more completely understood in time and space to exploit **non-steady, transient phenomena** for **enhanced controllability** and **maneuverability**
- Vision – revealing the dynamics of **unsteady and turbulent fluid-structure interactions** thereby providing deeper understanding of such flows
- Potential new capabilities – equation-based and/or data-driven fluid dynamics analyses leading to **physics-based predictive models** and **optimal flow sensing** for innovative flow control concepts leading to **enhanced air vehicle agility**
- **AF Relevance**
 - Lighter, more efficient aircraft for greater global mobility and reach
 - Greater vehicle mission diversity - more vehicle wt is payload, enabling more diverse missions
 - Air superiority - controlled extreme performance and maneuvering
 - Higher system efficiencies: engine performance, drag reduction, fluid transport (climate control, re-fueling)



Unsteady Aerodynamics

- **Characteristics:**

- rapid force/moment changes
- flow separation/reattachment
- large near-body vortices

- **Challenges:**

- Describe (large) vortex – wing interactions (e.g. gusts)
- Better understand force production from gusts
- Predict unsteady, nonlinear aerodynamic responses

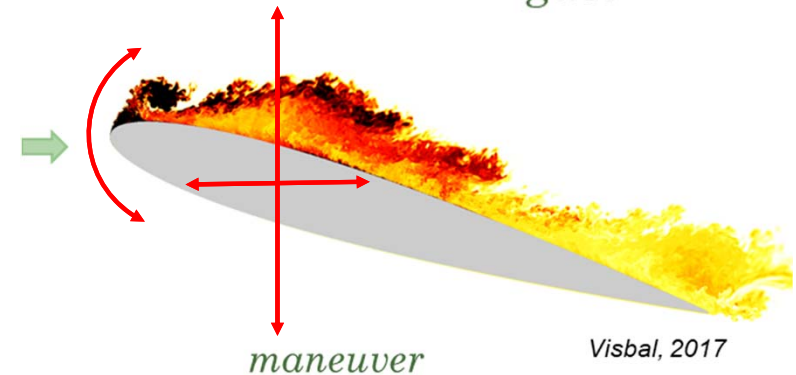
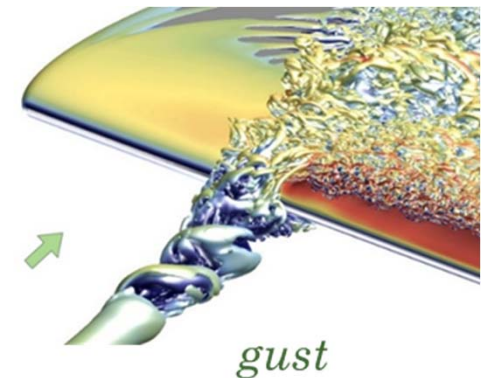
- **AF Tech Payoff:**

- enhance/diminish energy exchange between flow & structure
- relax structural rigidity constraints (wing & blade)
- exploit vortices for enhanced mixing

Steady



Unsteady





Turbulent Flows



- **Characteristics:**

- Unsteady
- Linear(L) & Non-linear(NL) dynamics
- Multi-scale motions
- Highly diffusive & dissipative

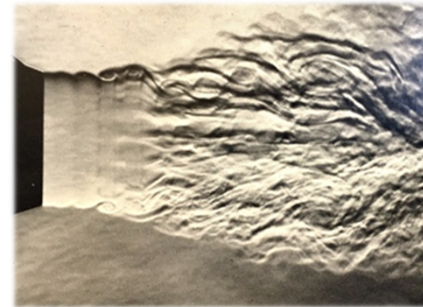
- **Challenges:**

- Understanding balance of roles between linear and nonlinear dynamics
- Exploring interactions between disparate scales
- Simplify, predict & control turbulence

- **AF Tech Payoff:**

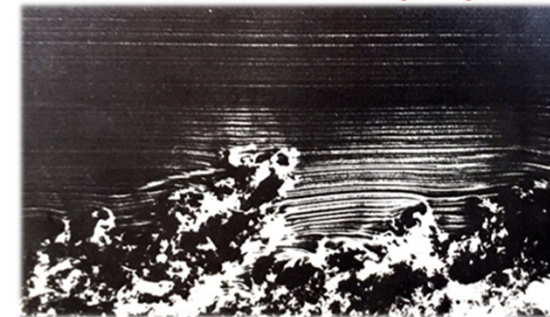
- Increased efficiency: enhanced mixing, drag reduction
- Improved modeling → faster design cycles

turbulent jet



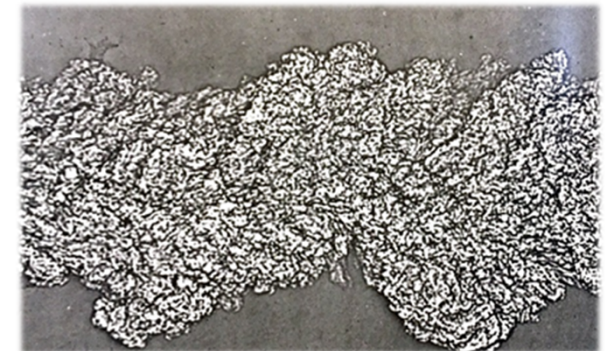
Bradshaw, Ferriss, Johnson, 1964

turbulent boundary layer



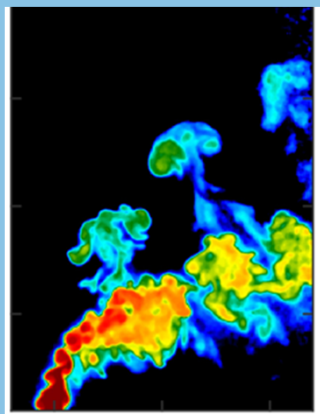
Corke, Guezennec, Nagib

turbulent wake

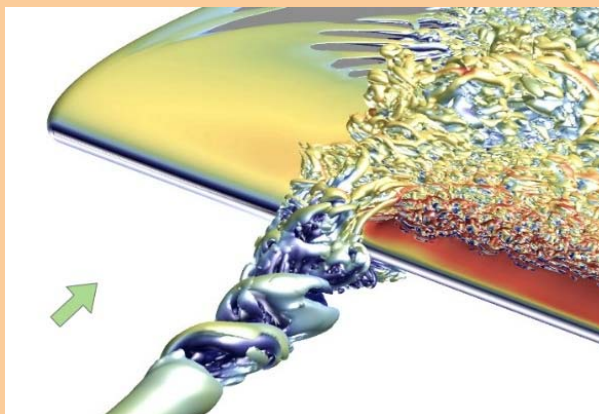




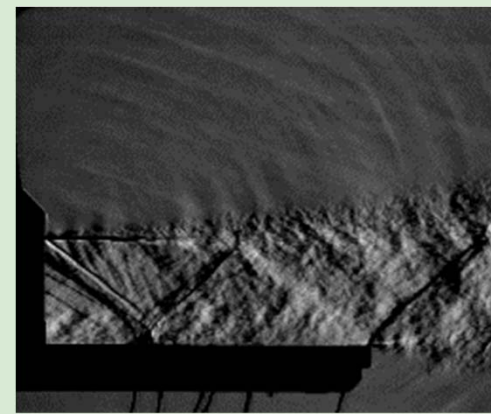
Program Sub-Areas



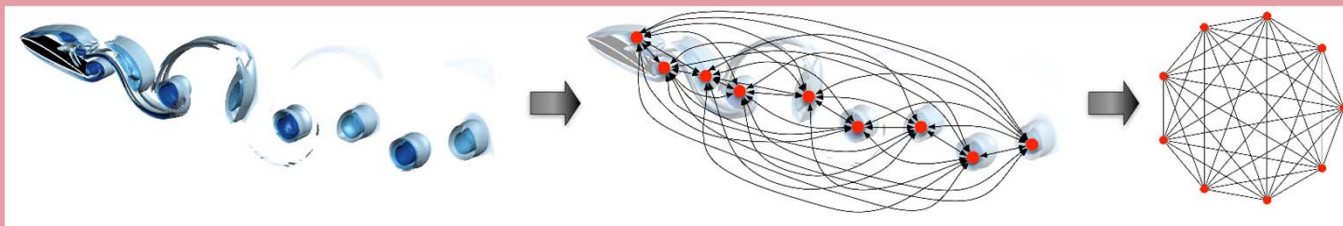
Flow Physics for Control



Unsteady Aeromechanic Interactions



Turbulence Studies & Boundary Layer Transition



Novel Approaches for Flow Control