U.S. Air Force Research Laboratory’s Need for Flow Physics and Control with Applications Involving Aero-Optics and Weapon Bay Cavities

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When the Calculations say it should work sometime the Physics doesn’t listen
Consequence

• Store Motion
  — Deploys Properly
  — Becomes unstable in flight
  — Strike aircraft

• Flow Physics
  — Damage to Aircraft, Equipment and Store
    • Mainly from Acoustic levels
Flow Control

- Geometry Modification
  - Fences, Spoilers, Rod-in-Cross Flow

- Open Loop Control
  - Pulsed Blowing, Suction, Plasma

- Closed Loop Control
  - Feedback Flow Control with Pulsed Blowing

- You name it, it has been tried
  - The shot gun approach
Flow Physics

- Trisonic Gasdynamic Facility
  - PIV
    - Seeding Methods
      - CO₂
      - ViCount Fluid
  - Optic Nozzle Blocks
  - Seedless PIV
  - PSP

- Advance Diagnostic Development Inside a Cavity (ADDICT)
  - Examine how flow control effects the flow physics at 10% scales cavity
Near Field Aero Optics Flow Control

Click to play animation
filename: 03Light Sheet.mwv
Background on Aero Optics

Optical Path Length

\[ OPL = \int_{y_1}^{y_2} n(x_o, y) dy \]

Integration of index over path length

Optical Path Difference

\[ OPD(x_o) = OPL(x_o) - \bar{OPL} \]

The difference between mean and instantaneous OPL

Emerging Distorted Wavefront

Original Planar Wavefront
Aero-Optic Interactions

- Turbulence
- Vibrations
- Aircraft Motion
- Laser Emitter

Aircraft Boundary Layer
- Shear Layer
- Wake
- Shocks
- Flow Control

Near Field
- Aero Optic Distortions

Reduce Density Fluctuations to Increase Energy on Target

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Flow Control for Aero-Optics

- Used Shot Gun Approach for Flow Control
  - Pulse Blow, Pins, Combustions, etc.
- One of the best but not yet completely proven methods
  - Closed Loop Control using Split POD.
    - Split POD was developed by Chris Camphouse
    - Separate baseline from control flow field properties to produce proper actuation characteristics for Closed Loop Flow Control
- Provides Flow Physics Knowledge to the Flow Control Device
Closed Loop Flow Control for Near Field Aero-Optics

Pressure Time Series

Pressure Autocorrelation

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Conclusions

• To develop New Flow Control Techniques
  – Knowledge of the Flow Physics with and without control
  – How does Flow Control Effect Flow Physics
    • What Works to Optimize the Design?
  – Energy or Work Efficiency of the Control Technique
    • Cost - Risk - Benefit Analysis
  – Supportability, e.g. (size of equipment, computational power, power supply)
    • Allows Designer to include Flow Control in Plans