AFOSR Perspective on Integrating Analysis Tools

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AFOSR Perspective on Integrating Analysis Tools

Presentation Outline

• Brief overview of AFOSR
• Integration of Analysis Tools
  – Benefits
  – Methodology
• Future directions/emphasis
Air Force Research Laboratory (AFRL)

HQ AFRL

Technology
- Air Vehicles
- Space Vehicles
- Information
- Munitions
- Directed Energy

Directorates
- Sensors
- Materials & Manufacturing
- Human Effectiveness
- Propulsion

AFOSR

BASIC RESEARCH IS THE FOUNDATION

AFOSR is the Sole Manager of AF Basic Research

http://www.afrl.af.mil/
AFOSR Basic Research Areas

Aerospace, Chemical & Materials Sciences (NA)
- Structural Mechanics
- Materials
- Chemistry
- Fluid Mechanics
- Propulsion

Physics & Electronics (NE)
- Physics
- Electronics
- Space Sciences
- Applied Math

Mathematics, Information & Life Sciences (NL)
- Info Sciences
- Human Cognition
- Mathematics
- Bio Sciences

Sub-thrusts

Areas of Enhanced Emphasis
- Information Sciences
- Mixed-Initiative Decision Making
- Adversarial Behavior Modeling
- Novel Energy Technology
- Micro Air Vehicles
- Nanotechnology
NAME: Rhett Jefferies

NO. OF YEARS AS OSR PM: 2

BRIEF DESCRIPTION OF PORTFOLIO:
Advance fundamental understanding of complex time dependent flows, their interactions & control; develop physically-based models & novel concepts

SUB-AREAS IN PORTFOLIO:
• Active flow control effectors
• Low Reynolds number / Micro Air Vehicle aerodynamics
• Shear layers and vortex flows
• Micro-fluidics

TECHNICAL APPROACH PRIORITIES:
• Integrated theoretical, numerical & experimental tools
• Multi-disciplinary innovation
• Technology transition
The Science of Laminar to Turbulent Transition

AFOSR-Sponsored Research Explores the Fundamental Physics of Transition

- Acoustic and Vortical Disturbances
- Laminar Inflow
- Roughness

Receptivity

- Freestream Boundary Layer
- Common scale
- Receptivity Measurements
  G. Brown, Princeton

Stability Theory

- Transient Growth
- Stability Theory
  Transient Growth Theory
  Development – E. Reshotko, CWRU

Nonlinear Interactions

- Turbulence Modeling
  Direct Numerical Simulation of Breakdown - H. Fasel, U. of Arizona

Stability Theory Methods (15% of core):

- Analysis of relevant configurations helps identify which mechanisms are most critical
- Major opportunity to transition methods to industry and advanced programs
Integrated Analysis Tools

CFD

Numerical

IFD

TFD

Theoretical

EFD

Experimental
Integrated Fluid Dynamics (IFD): Benefits

- Gain new insights into flow physics
Boundary Layer Laminarization by Ultrasonically Absorbing Coating (UAC)

Premature transition reduces efficiency of propulsion system and aerodynamic control surfaces.

Laminarization initially predicted using variant of Orr-Sommerfeld stability theory.

By increasing the laminar run from 20% to 80% it is feasible to decrease gross vehicle take-off weight by factor of 2.

Laminar flow on smooth surface

Premature transition reduces efficiency of propulsion system and aerodynamic control surfaces.

Laminar flow on porous surface

By increasing the laminar run from 20% to 80% it is feasible to decrease gross vehicle take-off weight by factor of 2.

Laminarization initially predicted using variant of Orr-Sommerfeld stability theory.

Dr. N. Malmuth, Teledyne
Integrated Fluid Dynamics (IFD): Benefits

• Gain new insights into flow physics
  – Example: Ultrasonically Absorbing Coating (UAC)

• Develop novel integration methodologies
  – Low order model representation
  – Incorporate PIV as initial condition in CFD
Study of Heat Transfer Augmentation under Large-Scale Freestream Turbulence*

Time-Resolved DPIV Measurements of 2-D Velocity Field Normal to a Plate

Time-Resolved Simulation of Experimental Heat Transfer

Experimental velocity used as initial condition for CFD model to predict the time-resolved wall heat flux

Vlachos, VA Tech (2007)

*Supported by NSF
Integrated Fluid Dynamics (IFD): Benefits

• Gain new insights into flow physics
  – Example: Ultrasonically Absorbing Coating (UAC)

• Develop novel integration methodologies
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• Cut time & cost for technology development/transition
  – Use TFD, CFD for parameter sweep to refine EFD reqmts
  – Incorporate UAV flight test data

• Enable multi-scale analysis and design
  – Move from low to high Re#
  – Incorporate lower order techniques for design
Integrated Fluid Dynamics: Methodology

• Integration can occur on many levels
• Goal is to move beyond CFD-EFD data comparison
• Take advantage of strengths of TFD, EFD, CFD
  – TFD seems under-utilized but may provide great insight
  – Once validated, CFD can be used for numerical “experiments”
  – Flight test
• Low Re# flows allow max use of analysis tools
• Innovation key for successful integration
Future Directions/Emphasis

• Encourage PIs to creatively integrate analysis tools
  – Funded efforts must address IFD
  – Collaboration crucial for success

• Establish successful case studies for methodology
  – Emphasize IFD process used to get results
  – Organize focused reviews/workshops/conferences
  – Adopt standard procedures for successful IFD

• Utilize national data repository to enable IFD analysis