Final Report

NASA Grant NAG3-2309
(account #359-4163)

Workshop on Boundary Layer Transition
and Unsteady Aspects of Turbomachinery

John E. LaGraff
Principal Investigator
Syracuse University
Syracuse University, New York 13244

April 3, 2001
Final Report
NASA Grant NAG3-2309
(account #359-4163)
April 3, 2001

Workshop on Boundary Layer Transition and Unsteady Aspects of Turbomachinery

John E. LaGraff
Principal Investigator
Syracuse University
Syracuse, New York 13244

Abstract

A workshop was organized on the topic of the title and held on August 20-23, 2000 at the Syracuse University Minnowbrook Conference Center in Blue Mountain Lake, New York. Attendance was by invitation only, forty-two guests attended and thirty presentations were made. Support was received from NASA Glenn Research Center, the US Air Force Office of Scientific Research the European Office of Aeronautical Research and Development, the Asian Office of Aeronautical Research and Development and Syracuse University. This workshop was the third in a trienniel series beginning in 1993. A publication under a NASA CP number will be issued and include all abstracts. No full written papers were required. This report includes a list of attendees and the program of presentations. The next workshop is scheduled for August 2003.
Dr. Chris Murawski
AFRL/PRTT
Bldg. #18
1950 5th Street
WPAFB OH 45433-7251
chris.murawski@wpafo.af.mil

Professor R. Narasimha
Indian Inst. of Science
Center for Atmospheric & Ocean Sciences
Bangalore India 560012
roddam@caos.iisc.ernet.in
91 80 331-0969
91 80 334-6634

Professor T. W. Okiishi
Iowa State University
104 Marston Hall
Ames IA 50010

Dr. Louis Povinelli
Glenn Research Center
MS 5-3
Cleveland OH 44135

Mr. Tom Praisner
Pratt & Whitney
Turbine Design Systems Development
400 Main St., MS 201-09
East Hartford CT 06108

Dr. O.N. Ramesh
Whittle Laboratory
Madingley Road
Cambridge CB3 ODY Cambridge
onr@aer.iisc.ernet.in
44 1223-339835
44 1223-337596

Dr. A. Seifert
NASA Langley Research Ctr.
ICASE
Hampton VA 23681
seifert@eng.tau.ac.il

Dr. Terry Simon
University of Minnesota
Mechanical Engr.
111 Church St.
Minneapolis MN 55455
tsimon@me.umn.edu

Dr. Frank Smith
University College-London
Dept. of Mathematics
Gower Street
London WC1E 6BT England
frank@math.ucl.ac.uk

Dr. J. Steelant
ESTEC/ESA, Section TOS-MCT
Keplerlaan 1, P.O. Box 299
2200 AG Noordwijk
The Netherlands
jsteelan@estec.esa.nl
31 71 565-5552
31 71 565-5421

Professor Vassilios Theofilis
DLR Institute of Fluid Mechanics
Bunsenstrasse 10D-37073
Goettingen Germany
vassilis@thorin.sm.go.dlr.de

Lt. Col Kenneth Van Treuren
USAF Academy
P.O. Box 432
CO 80840-0432
kenneth-van-treuren@baylor.edu
ken.vantreuren@usafa.af.mil
719 333-9352
719 333 4813

Dr. G.J. Walker
Univ. of Tasmania
Dept. of Civil & Mech. Engr.
GPO Box 252C
Hobart Tasmania 7001 Australia
greg.walker@utas.edu.au
61 3 6226-2117
61 3 6226-7863

Dr. Zuolan Wang
University of Arizona
Research Associate, Dept of Aerospace & Mech
Bldg 119, Rm 614
Tuscon AZ 85721
zwang@engr.arizona.edu
520-621-8191
520-621-8469
PROGRAM

MINNOWBROOK III
20-23 AUGUST 2000

Boundary Layer Transition and Unsteady Aspects of
Turbomachinery Flows

Sunday - 20 August 2000

3:00 pm Minnowbrook Center Open to Participants/Registration begins
3:30 - 5:30 pm Visit to Adirondack Museum (optional)
6:30 pm Dinner
8:00 pm Welcome and Comments on Organization, Goals and Focus of Workshop
John LaGraff - Syracuse University
8:15 pm Roddam Narasimha - Keynote Speaker (30 minutes) - Indian Institute of Science
Subtransitions Revisited
9:00 pm Social get together

Monday - 21 August 2000

7:30 am Breakfast

Session 1 - Turbomachinery Disturbance Environment
Moderator: Ted Okiishi - Iowa State University

8:45 am Howard Hodson - Keynote (30 min) - Cambridge University, Whittle Laboratory
High Lift LP Turbines

9:15 am Greg Heitland - Honeywell Engines
Low Pressure Turbine Reynolds Number Effects: Small Engine Perspective

9:30 am J. Hourmouziadis - Technical University Berlin
Free Stream Unsteadiness and Turbulence. What is the Difference?

9:45 am Discussion

10:15 am BREAK
**Session 2 Natural or Bypass Transition?**
Moderator: Paul Gostelow – University of Leicester

10:45 am Gregg Walker – Keynote (30 min) – University of Tasmania
Natural Versus Bypass Transition on Axial Compressor Blades - A Need for Re-
Assessment?

11:15 am Howard Hodson – Cambridge University, Whittle Laboratory
Separation Bubble and Turbulent Spot-Wake Interactions in the Turbomachinery
Environment at Reynolds of Around 130,000

11:30 am Discussion

12:15 pm LUNCH

**Session 3 Spots and Calmed Regions**
Moderator: Chris Murawski – AFRL/PRTT/WPAFB

2:00 pm Terry Jones – Osney Labs-Oxford University
Visualization of Transitional Heat Flux in the Presence of Freestream and Pressure
Gradient

2:15 pm Mark Johnson – University of Liverpool
The Initiation and Development of Turbulent Spots

2:30 pm O.N. Ramesh – Cambridge University, Whittle Laboratory
On The Dynamics of the Calmed Region Behind a Turbulent Spot

2:45 pm Howard Hodson – Cambridge University, Whittle Lab
The Visualisation and Measurement of the Onset, Turbulent Spot Production Rate,
Intermittency and Heat Transfer During Wake-Induced Transition Using
Thermochromic Liquid Crystals

3:00 pm Discussion

3:30 pm BREAK

**Session 4 Modeling and Computation**
Moderator: Lou Povinelli – NASA Glenn Research Center

4:00 pm David Ashpis – NASA Glenn Research Center
NASA Low Pressure Turbine Program

4:15 pm Erik Dick – University of Gent
ERCOFTAC Thematic Workshop on Transition

4:30 pm Johan Steelant – ESTEC-European Space Agency
Modelling of By-Pass Transition by Means of a Turbulence Weighting Factor

4:45 pm Thorwald Herbert – Ohio State University
Toward Direct Numerical Simulations of Turbine Flows

5:00 pm Discussion
6:30 pm  Dinner

8:00 pm  Working Group Meeting I

**Tuesday - 22 August 2000**

7:30 am  Breakfast

**Session 6 Wake Interactions**  
Moderator: Howard Hodson – Cambridge University, Whittle Laboratory

8:30 am  Terry Simon – University of Minnesota  
Experimental Investigation of Transition to Turbulence under Low-Pressure Turbine Conditions: Measurements with and without Wakes

8:45 am  Paul Durbin – Stanford University  
Direct simulation of unsteady wakes and transition in a turbine passage

9:00 am  Frank Smith – University College London  
Unsteady Stator-Row with Wake Passings

9:15 am  Paul Gostelow – University of Leicester  
Relaxation Following Wake Impingement on Reattaching Flow

9:30 am  Discussion

10:00 am  BREAK

**Session 7 Laminar Separation**  
Moderator: Terry Simon – University of Minnesota

10:30 am  Tom Corke – University of Notre Dame  
LPT Separation Control Using Phased Plasma Arrays

10:45 am  Lennart Hultgren – NASA Glenn Research Center  
Experimental Investigation of Separated and Transitional boundary Layers Under Low-Pressure Turbine Airfoil Conditions

11:00 am  Vassilios Theofilis – DLR Goettingen  
Global Linear Instabilities in Laminar Separated Boundary Layer Flow

11:15 am  Avi Seifert – NASA Langley Research Center/Tel Aviv University  
Active Control of a Transitional Separation Bubble at Low Reynolds Number and Elevated Free-Stream Turbulence

11:30 am  Discussion

12:15 pm  LUNCH
**Session 8 Turbines**
Moderator: Terry Jones – Osney Labs-Oxford University

2:00 pm  Dan Dorney – Virginia Commonwealth University  
Simulations of Boundary Layer Development in Low Pressure Turbines

2:15 pm  Bob Boyle – NASA Glenn Research Center  
Effect of Favorable Pressure Gradients on Turbine Blade Pressure Surface Heat Transfer

2:30 pm  Ricardo Martinez-Botas – Imperial College  
Mixed Flow Turbines: Unsteady Performance and Flow Characteristics

2:45 pm  Aaron Byerley – USAF Academy  
The Effect of Turbulence Length on Low Pressure Turbine Blade Heat Transfer

3:00 pm  Discussion

3:30 pm  BREAK

**Session 9 Roughness/Free Stream Disturbances**
Moderator: John LaGraff – Syracuse University

3:45 pm  Jeffrey Crouch – Boeing Commercial Airplane Group  
Estimating Transition Location in the Presence of Roughness and Free-Stream Disturbance

4:00 pm  Don McEligot – Idaho National Engineering Lab  
Effect of a Square Rib on Development of the Viscous Layer for a Turbulent Boundary Layer

4:15 pm  Open

4:30 pm  Torsten Fransson – KTH Stockholm  
A Basic Nozzle Test Facility For Fluid-Structure Interaction in Transonic Flow

4:45 pm  Discussion

6:30 pm  Dinner

8:00 pm  **Session 11**  
Working Group Meeting II
Wednesday - 23 August 2000

7:00am  Breakfast

Session 11
Moderator: Paul Gostelow – University Leicester

8:00 am  Report of ad-hoc working groups – Ted Okiishi
          Wrap-up discussion - Roddam Narasimha

9:45 am  Conclusion of workshop

10:00 am  First van leaves for Syracuse Airport

10:30 am  Second van leaves for Syracuse Airport

11:30 a.m.  Box lunches for all participants available on departure

12 noon  Vacate Center