

Tianshu Liu

ADDRESS:

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RESEARCH INTERESTS:

Aerodynamics
Fluid Mechanics
Heat Transfer
Measurement Techniques and Instrumentation Applied to Aerospace Engineering and Sciences

TEACHING INTERESTS:

Incompressible Aerodynamics
Compressible Aerodynamics
Wing and Body Aerodynamics
Experimental Aerodynamics
Viscous Flows and Boundary Layer Theory
Engineering Fluid Mechanics
Heat Conduction and Convection
Flight Testing Engineering
Aircraft Performance and Design
Image-Based Measurement Techniques for Aerospace Applications
Turbulence
Scaling and Similarity

CURRENT POSITION:

Professor
Director of Applied Aerodynamics Laboratory
Department of Mechanical and Aeronautical Engineering
G-220 Parkview Campus
Western Michigan University
Kalamazoo, MI 49008-5343

Specific Research Areas:

Experimental aerodynamics, Applied aerodynamics, & Theoretical aerodynamics models
Image-based measurement techniques for global flow diagnostics of various quantities (surface pressure, temperature/heat transfer, skin friction, velocity, and deformation)
Videogrammetric techniques and vision for aerospace applications
Flapping flight, Flight vehicle design, Flight tests
Turbulence and transition, Flow control, Bias error theory

Externally Funded Projects at WMU:

- “Integrated, Real-Time, Optical Measurement Technique for Aeroelastic Testing”, Air Force SBIR Phase II (with ISSI and Ohio State), 2009-2011, \$150,000 (WMU part), Co-PI
- “Aerodynamic Testing of Rear Mounted Automotive Spoilers”, 2010, Eaton, \$10,000, PI
- “Quantitative Global Heat Transfer in a Mach-6 Quiet Tunnel,” NASA NRA (NNX08AC97A), 2008-2011, \$180,000 (with Purdue University), Co-PI
- “Integrated, Real-Time, Optical Measurement Technique for Aeroelastic Testing”, Air Force SBIR Phase I (with ISSI and Ohio State), 2009, \$16,000 (WMU part), Co-PI
- “Study for Particle Motion and Collection on Wall in Oil Mist Separator,” Toyota and MIT Sloan Automotive Laboratory, 2007-2008, \$60,000, PI
- “Airfoil/Wing Flow Control Using Flexible Extended Trailing Edge,” Air Force Office of Scientific Research (FA9550-06-1-0187), 2006-2009, \$471,676, PI
- “Development of Photogrammetry Matlab Toolbox for Aerospace Applications,” NASA Langley Research Center through National Institute of Aerospace (T06-6081-WMU), 2006, \$79,085, PI
- “Experiments to Validate Math-Based Tools to Simulate ELPO Immersion and Drainage,” General Motor, 2006, \$38,482, PI
- “Integral Analysis of Entrance Oil Pressure at Intersection between Ring and Moving Piston Wall,” Sloan Automotive Laboratory, Massachusetts Institute of Technology (MIT), 2006, \$7,500, PI
- “Skin Friction Reduction Using Robust Nano Coatings,” Nanovere, 2007, \$1,000, PI

Research Equipment Acquired

Surplus equipment have been acquired from NASA Langley Research Center through the Stevenson-Wylder Act for Applied Aerodynamics Laboratory. The items are Digital camera (\$999.98), Motion Picture Camera (\$2,830), Digital Clock (\$300), Scope Cart (\$100), Oscilloscope (\$100), Thermometers (\$511.38), and Gas Regulators (\$2200). The total listed value of these items is \$7,040. The equipment has been shipped from NASA LaRC to AAL.

WORK EXPERIENCE:

9/2004-8/2008

Associate Professor

Department of Mechanical and Aeronautical Engineering

G-220 Parkview Campus

Western Michigan University

Kalamazoo, MI 49008-5343

9/1999-9/2004:

Research Scientist

Aerodynamics, Aerothermodynamics and Acoustics Competency (AAAC)

NASA Langley Research Center (LaRC), Hampton, VA 23681, USA

“Flapping flight and agile MAVs,” FY 2002, NASA MSB Branch Fund, PI

- “Building universal foundations for image-based measurements of motion fields and morphology of deformable matters,” FY 2001, NASA Creativity & Innovation Program (C&I), \$30,000, PI
- “Computer vision as a universal framework for image-based measurements in aerospace engineering and sciences,” FY 2001, NASA Intelligent Synthesis Environment (ISE) Program, \$150,000, PI
- “Optical measurements of static and dynamics aerodynamic loads,” FY 2001, NASA Integrated Instrumentation and Technologies System (IITS) Program, \$15,000, PI
- “Optical measurements of static and dynamics aerodynamic loads,” FY 2000, NASA Integrated Instrumentation and Technologies System (IITS) Program, \$7,000, PI
- “Artificial intelligent vision,” FY2000, NASA Intelligent Synthesis Environment (ISE) Program, \$110,000, PI

Other Studies Performed at NASA LaRC:

Flapping Wing and Unsteady Wake Topology

Design Methodologies for Flapping MAVs

Nano-Optic Sensor for Skin Friction

Separation and Wake Control of Airfoils Using Responsive Skin

Mechanism and Prevention of Frost Formation on Model Surface in National Transonic Facility (NTF)

Videogrammetric Measurements of Shape and Dynamics of Solar Sails and Large Space Structures

Columbia Debris Transport

Intelligent Expert System for Aerodynamic Design

2/1997-9/1999:

Research Scientist, High Technology Corporation, Hampton, VA 23666, USA

“Advanced photogrammetric systems for measurements of position and dynamic aeroelastic deformation of wind-tunnel models,” 1998, NASA SBIR Phase I, \$70,000, PI

“Further improvements of a single camera photogrammetric system and data-processing software for model deformation measurements,” 1999, NASA LaRC contract, \$89,000, PI

“Lifetime-based pressure-sensitive paint imaging system and its integration with model deformation measurement system,” 1999, NASA SBIR Phase I, \$80,000, PI

“Unification of modern aerodynamic measurement techniques in a single wind-tunnel test,” NASA ADTE program, Co-PI

1/1996-2/1997:

Postdoctoral Research Assistant, Purdue University, Indiana, USA

Luminescent oil-film skin friction meter

Pressure and temperature measurements on rotating blades in turbine engine using luminescent paints

Boundary-layer transition detection methods on aerodynamic models in cryogenic wind tunnels using temperature-sensitive luminescent paints

Development of cryogenic pressure- and temperature-sensitive paint system

2/1996:

Visiting Scientist, Japanese National Aerospace Laboratory (NAL), Tokyo, Japan

Boundary-layer transition detection on airfoils in the NAL cryogenic wind tunnel using luminescent paints.

8/1991-12/1995:

Research Assistant, Purdue University, Indiana, USA

Development of a system of temperature- and pressure-sensitive luminescent paints for aerodynamic testing

Study of flow and heat transfer structures in an acoustically-excited circular impinging jet

Study of heat transfer distributions on a waverider model in hypersonic flows using temperature-sensitive paints

Study of shock/turbulent-boundary-layer interactions using temperature-sensitive paints

Study of temperature and heat transfer distributions on a hot-film sensor in a flat-plate turbulent boundary layer

Random vortex-tube model for small-scale turbulence and the asymptotic probability density distribution of the dissipation rate

Exact solution of the Navier-Stokes equation — Non-orthogonal stagnation flow on the surface of a quiescent fluid

Design of the test section of the Purdue/Boeing subsonic wind tunnel

11/1988-8/1990:

Researcher, University of Houston, Houston, USA

Non-linear fundamental-subharmonic wave interaction in an axisymmetric jet

Instantaneous vorticity measurements using a nine-hotwire probe

12/1985-11/1988:

Lecturer, Nanjing University of Aeronautics and Astronautics, China

Boundary-layer transition control

Study of horseshoe vortices generated by heat pulses in a boundary layer

Control of the leading-edge vortices of a delta wing by introducing controllable perturbations

5/1985-12/1985:

Visiting Scientist, DLR Institute of Fluid Mechanics at Göttingen, Germany

Study of three-dimensional instability of a flat-plate laminar boundary layer by means of heat-pulsing arrays

EDUCATION:

PhD (1996), Aerodynamics, Aeronautics and Astronautics, Purdue University, USA

MS (1985), BS (1982), Aerodynamics, Nanjing University of Aeronautics and Astronautics, China

PROFESSIONAL SERVICES AND AWARD:

Reviewer for

AIAA Journal

AIAA Journal of Aircraft
AIAA Journal of Thermophysics and Heat Transfer
AIAA Journal of Aerospace Computing, Information and Communication
Experiments in Fluids
Measurement Sciences and Technology
Physics of Fluids
Review of Scientific Instruments
The Journal of The American Acoustics Society, Optical Engineering,
Sensors and Actuators
Journal of Fluids Engineering,
Journal of Aerospace Engineering
International Journal of Heat and Mass Transfer
Journal of Bionic Engineering
ASME Journal of Dynamic Systems, Measurement and Control
NASA SBIR Phase I and II,
NASA Institute for Advanced Concepts Phase II

Senior Member, AIAA

AIAA Aerodynamic Measurement Technical Committee, 2007

Session Chair, Skin Friction Measurement, Aerodynamic Measurement Technology and Ground Testing, AIAA Conferences, San Francisco, California, 5-8 June 2006

2007 Outstanding New Researcher Award of the College of Engineering and Applied Sciences at Western Michigan University

2009 The Kenneth Harris James Prize and The Thomas Hawksley Gold Medal of the Institution of Mechanical Engineers for the best paper on pressure sensitive paints in unsteady and hypersonic flows (with J. Gregory, A. Asai, M. Kamada and J. Sullivan)

PATENT:

“**Wind Oscillator for Power Generation**” Tianshu Liu (WMU), 2009, US Patent

“**Airfoil/Wing Flow Control Using Flexible Extended Trailing Edge**” by Qamar Shams (NASA LaRC) and Tianshu Liu (WMU), 2008, US Patent: LAR-17361-1

“**Aeroship**” by Tianshu Liu and William Liou, Provisional US Patent (WMU case #70 filed in 2005)

INVITED PRESENTATIONS:

“**Skin Friction Topology in Region with Penetrable Boundary**”, Michigan State University, 08/10/2010

“**Fluid Flow and Optical Flow — Global Diagnostics of Velocity and Skin Friction Fields**”, Beijing University of Aeronautics and Astronautics, 06/5/2010

“**Fluid Flow and Optical Flow — Global Diagnostics of Velocity and Skin Friction Fields**”, University of Notre Dame, 02/27/2009

“**Global Diagnostics of Velocity and Skin Friction Fields in Complex Flows**”, Case Western Reserve University, 12/16/2008

Lectures at The Chinese Aerodynamics Research and Development Center (CARDC), Sichun, China, December 16-19, 2007

(1) Fluid Flow and Optical Flow— Determination of Velocity Field from Images

(2) Pressure and Temperature Sensitive Paints

(3) Lift Enhancement Using Static Extended Trailing Edge

(4) Global Luminescent Oil-Film Skin Friction Meter

(5) Videogrammetric Techniques for Aerospace Applications

(6) AeroShip: A New Flight Platform

“Avian Wing Geometry and Kinematics,” AFOSR Biologically Inspired Flight for Micro Air Vehicles, Denver, June 21-23, 2006

“Flight Testing Engineering and Design”, Invited lectures at Tohoku University, Sendai, Japan, May 8-9, 2006

“A Unified View of Image-Based Measurements in Aerospace Applications”, Keynote Speech at the International Workshop on Molecular Imaging for Interdisciplinary Research, Tohoku University, Sendai, Japan, Nov. 8-9, 2004

“Comparative Scaling of Flapping- and Fixed-Wing Flyers”, 2003 Bioflight Workshop, NASA Langley Research Center (LaRC), Hampton, Virginia, August 7, 2003

“Pressure and Temperature Sensitive Paints”, AIAA Short Course, St. Louis, Missouri, June, 2002

“Image-Based Techniques for Wind Tunnel Testing”, George Washington University, Washington DC, April 8, 2002

“Pressure Sensitive Paints — Theories and Practices”, Keynote Speech at the Workshop on Molecular Sensors for Aero-Thermodynamic Research, Nagoya University, Nagoya, Japan, March 13, 2001

“Luminescent Molecule Sensors in Fluid Mechanics and Heat Transfer”, The University of Western Ontario, London, Canada, October 16, 1997

“TSP and PSP Developments at Purdue”, NASA Langley Research Center (LaRC), Hampton, Virginia, December 21, 1996

“Temperature- and Pressure-Sensitive Paints in Aerodynamics”, Japanese National Aerospace Laboratory (NAL), Tokyo, February 20, 1996

PUBLICATIONS:

Books and Book Chapter:

T. Liu and J. P. Sullivan, **“Pressure and Temperature Sensitive Paints,”** Experimental Fluid Mechanics Series, Springer-Verlag, Berlin (2004)

T. Jones, A. A. Dorrington, J. R. Blandino, C. Fraser and **T. Liu**, **“Photogrammetric Measurement Methods”** (Chapter 5), *Gossamer Structures*, AIAA Press, Washington DC (2006)

T. Liu, A. W. Burner and R. Pappa, **“Photogrammetric Techniques for Aerospace Applications,”** AIAA Press (accepted and in preparation of the final version) (2010)

Refereed Archival Publication:

- T. Liu, J. Rubal, J. Sullivan, S. Schneider, and H. Johnson, “Heat flux measurements on circular cone using temperature sensitive paint in a Mach-6 quiet tunnel,”** *Journal of Spacecraft and Rockets* (in preparation) (2010)
- T. Liu, S. Woodiga and Tian Ma, “Skin friction topology in region with penetrable boundary,”** *Journal of Fluid Mechanics* (submitted) (2010)
- T. Liu, B. Wang, J. Rubal, and J. Sullivan, “Correcting effect of lateral heat conduction in image-based heat flux measurements as an inverse problem,”** *International Journal of Heat and Mass Transfer* (in press) (2010)
- Z. Cai, T. Liu, B. Wang, J. Rubal, and J. Sullivan, “Numerical inverse heat transfer analysis for temperature-sensitive-paint measurements in hypersonic tunnels,”** *Journal of Thermophysics and Heat Transfer* (in press) (2010)
- T. Liu, “Probability density function of small separation between two inertial particles in homogeneous isotropic turbulence,”** *Physics of Fluids*, Vol. 22, Issue 4, pp. 045105-1 to 7 (2010)
- T. Liu, J. Montefort, W. Liou, and R. Pantula, “Effects of flexible fin on low-frequency oscillation in post-stall flows,”** *AIAA Journal*, Vol. 48, No. 6, pp. 1235-1247 (2010)
- T. Liu, J. Nink, P. Merati, T. Tian, Y. Li, and T. Shieh “Deposition of micron liquid droplets on wall in impinging turbulent air jet,”** *Experiments in Fluids*, Vol. 48, pp. 1037-1057 (2010)
- T. Liu, Z. Cai, J. Lai, J. Rubal, & J. Sullivan, “Analytical method for determining heat flux from temperature-sensitive-paint measurements in hypersonic tunnels,”** *Journal of Thermophysics and Heat Transfer*, Vol. 24, No. 1, pp. 85-94 (2010)
- S. Woodiga and T. Liu, “Skin friction fields on delta wings,”** *Experiments in Fluids*, Vol. 47, pp. 897-911 (2009)
- T. Liu, W. Liou and M. Schulte, “Aeroship: A hybrid flight platform,”** *Journal of Aircraft*, Vol. 46, No. 2, pp. 667-674 (2009)
- T. Liu, S. Woodiga, J. Montefort, K. J. Conn, and L. Shen, “Global skin friction diagnostics in separated flows using luminescent oil,”** *Journal of Flow Visualization and Image Processing*, Vol. 16, No. 1, pp. 19-39 (2009)
- T. Liu and L. Shen, “Fluid flow and optical flow”** *Journal of Fluid Mechanics*, Vol. 614, No. 11, pp. 253-291 (2008)
- J. Gregory, A. Asai, M. Kamada, T. Liu and J. Sullivan, “A review of pressure sensitive paints in hypersonic and unsteady flows,”** *Journal of Aerospace Engineering*, Vol. 222, Part G, pp. 249-290 (2008)
- T. Liu, P. Merati, S. A. Woodiga, C. Davis, C. H. Leong, J. Johnson, and K. H. Chen, “Drainage and filling in cylindrical and rectangular containers,”** *Journal of Automobile Engineering*, Vol. 222, No. D4, pp. 565-577 (2008)
- T. Liu, J. Montefort, S. Wodiga, P. Merati, and L. Shen, “Global luminescent oil film skin friction meter,”** *AIAA Journal*, Vol. 46, No. 2, pp. 476-485 (2008)
- T. Liu, J. Montefort, W. Liou, S. R. Pantula, and Q. Shams “Lift enhancement by static extended trailing edge,”** *Journal of Aircraft*, Vol. 44, No. 6, pp. 1939-1947 (2007)
- J. W. Naughton and T. Liu, “Photogrammetry in oil film interferometry”,** *AIAA Journal.*, Vol. 45, No. 7, pp. 1620-1629 (2007)
- T. Liu and J. Montefort, “Thin-airfoil-theoretical interpretation for Gurney flap lift enhancement,”** *Journal of Aircraft*, Vol. 44, No. 2, pp. 667-671 (2007)

- T. Liu**, “**Weight criterion on flow control in level flight**,” *Journal of Aircraft*, Vol. 44, No. 1, pp. 348-351 (2007)
- T. Liu**, “**Time-area-averaged momentum stream tube model for flapping flight**”, *Journal of Aircraft*, Vol. 44, No. 2, pp. 459-466 (2007)
- T. Liu**, “**Comparative scaling of flapping- and fixed-wing flyers**”, *AIAA Journal*, Vol. 44, No. 1, pp. 24-33 (2006)
- T. Liu**, K. Kuykendoll, R. Rhew and S. Jones, “**Avian wing geometry and kinematics**”, *AIAA Journal*, Vol. 44, No. 5, pp. 954-963 (2006)
- T. Liu**, “**Optimum bifurcating-tube tree for gas transport**”, *Journal of Fluids Engineering*, Vol. 127, No. 3, pp. 550-553 (2005)
- T. Liu**, “**Geometric and kinematic aspects of image-based measurements of deformable bodies**”, *AIAA Journal*, Vol. 42, No. 9, pp. 1910-1920, (2004)
- T. Liu** and J. Sullivan, “**In-situ calibration uncertainty of pressure-sensitive paint**”, *AIAA Journal*, Vol. 41, No. 11, pp. 2300-2302, (2003)
- T. Liu**, “**Pressure-correction method for low-speed pressure-sensitive paint measurements**”, *AIAA Journal*, Vol. 41, No. 5, pp. 906-911, (2003)
- T. Liu**, D. Barrows, A. Burner and R. Rhew, “**Determining aerodynamic loads based on optical deformation measurements**”, *AIAA Journal*, Vol. 40, No. 6, pp. 1105-1112, (2002)
- T. Liu**, T. Togerson, J. Sullivan, R. Johnston, and S. Fleeter, “**Transonic rotor blade pressure measurement using fluorescent paint**”, *Journal of Propulsion and Power*, Vol. 18, No. 2, pp. 491-493, (2002)
- A. Burner, **T. Liu**, S. Garg, T. Ghee and N. Taylor, “**Aeroelastic deformation measurements of flap, gap and overhang on a semispan model**”, *Journal of Aircraft*, Vol. 38, No. 6, pp. 1147-1154, (2001)
- T. Liu**, N. Teduka, M. Kameda and K. Asai, “**Diffusion timescale of porous pressure-sensitive paint**”, *AIAA Journal*, Vol. 39, No. 12, pp. 2400-2402, (2001)
- A. Burner and **T. Liu**, “**Videogrammetric model deformation measurement technique**”, *Journal of Aircraft*, Vol. 38, No. 4, pp. 745-754, (2001)
- T. Liu** and T. Finley, “**Estimating bias error distribution**”, *Review of Scientific Instruments*, Vol. 72, No. 9, pp. 3561-3571, (2001)
- T. Liu**, M. Guille and J. Sullivan, “**Accuracy of pressure sensitive paint**”, *AIAA Journal*, Vol. 39, No. 1, pp. 103-112, (2001)
- T. Liu**, L. Cattafesta, R. Radezsky and A. W. Burner, “**Photogrammetry applied to wind tunnel testing**”, *AIAA Journal*, Vol. 38, No. 6, pp. 964-971, (2000)
- A.W. Burner, **T. Liu**, S. Garg, J.H. Bell, and D.G. Morgan, “**Unified model deformation and flow transition measurements**”, *Journal of Aircraft*, Vol. 36, No. 5, pp. 898-901, (1999)
- L. Cattafesta, **T. Liu** and J. Sullivan, “**Uncertainty estimates for temperature sensitive paint measurements with CCD cameras**”, *AIAA Journal*, Vol. 36, No. 11, pp. 2102-2108 (1998)
- T. Liu** and J. Sullivan, “**Luminescent oil-film skin friction meter**”, *AIAA Journal*, Vol. 36, No. 8, pp. 1460-1465 (1998)
- T. Liu**, B. Campbell, S. Burns and J. Sullivan, “**Temperature- and pressure-sensitive paints in aerodynamics**”, *Applied Mechanics Reviews*, Vol. 50, No. 4, pp. 227-246 (1997)
- K. Asai, H. Kanda, T. Kunimasu, **T. Liu** and J. Sullivan, “**Detection of boundary layer transition in a cryogenic wind tunnel by using luminescent paint**”, *Journal of Aircraft*, Vol. 34, No. 1, pp. 34-42 (1997)

- T. Liu** and J. Sullivan, “**Heat transfer and flow structures in an excited circular impinging jet**”, *International Journal of Heat and Mass Transfer*, Vol. 39, No. 17, pp. 3695-3706 (1996)
- T. Liu**, B. Campbell and J. Sullivan, “**Heat transfer measurement on a waverider at Mach 10 using fluorescent paint**”, *Journal of Thermophysics and Heat Transfer*, Vol. 9, No. 4, pp. 605-611 (1995)
- T. Liu**, B. Campbell and J. Sullivan, “**Fluorescent paint for measurement of heat transfer in shock/turbulent boundary layer interaction**”, *Experimental Thermal and Fluid Science*, 10, pp. 101-112, (1995)
- T. Liu**, B. Campbell and J. Sullivan, “**Surface temperature of a hot film on a wall in shear flow**”, *International Journal of Heat and Mass Transfer*, Vol. 37, No. 17, pp. 2809-2814 (1994)
- T. Liu**, “**A note on the probability distribution of the dissipation rate in locally isotropic turbulence**”, *Physics of Fluids A* 5(9), pp. 2234-2238 (1993)
- T. Liu**, “**Non-orthogonal stagnation flow on the surface of a quiescent fluid — An exact solution of the Navier-Stokes equation**”, *Quarterly of Applied Mathematics*, Vol. L, No. 1, pp. 39-47, March (1992)
- T. Liu**, S. Shi and M. D. Zhou, “**Horseshoe vortices generated by heat pulses in boundary layer**”, *Journal of Experimental Mechanics*, Vol. 4, No. 3, pp. 290-296 (1989)
- C. Dai, **T. Liu**, Y. Teng and M. Xiao, “**Measuring techniques for wall shearing stress in turbulent boundary-layer**”, *ACTA AERONAUTICA ET ASTRONAUTICA SINICA*, Vol. 9, No. 5, pp. 203-210 (1988)
- M. D. Zhou and **T. Liu**, “**Stability investigation in nominally two-dimensional laminar boundary layer by means of heat pulsing**”, *Perspectives in Turbulence Studies*, Ed. H. U. Meier and P. Bradshaw, Springer-Verlag, Berlin (1987)

Conference Papers:

- T. Liu**, B. Wang and S. Woodiga, “**Physics-based optical flow method in global flow diagnostics**,” The 27th AIAA Aerodynamics Measurement Technology and Ground Testing Conference, Chicago, IL, June 27-July 1, (2010)
- T. Liu** and S. Woodiga, “**Experimental examination of skin friction topology in separated flows**,” AIAA Paper 2010-0045, Orlando, Florida (2010)
- Gregory, J. W., Kumar, P., Peng, D., Fonov, S., Crafton, J. and **Liu, T.**, “**Integrated optical measurement techniques for investigation of fluid-structure interaction**,” AIAA Paper 2009-4044, San Antonio, TX (2009)
- T. Liu**, J. Montefort, W. Liou, R. Pantula, & Q. Shams, “**Post-stall flow control using a flexible fin on airfoil**,” AIAA Paper 2009-1106, Orlando, FL (2009)
- T. Liu**, Z. Cai, J. Lai, J. Rubal, & J. Sullivan, “**Analytical methods for determination of heat transfer fields from temperature sensitive paint measurements in hypersonic tunnels**,” AIAA Paper 2009-0736, Orlando, FL (2009)
- T. Liu**, “**Flight testing on Cirrus aircraft**,” AIAA Paper 2009-0571, Orlando, FL (2009)
- T. Liu**, S. Woodiga, J. Montefort, K. J. Conn, and L. Shen, “**Mapping skin friction fields in complex flows using luminescent oil**,” AIAA Paper 2008-0267, Reno, NV, (2008)

- T. Liu** and L. Shen, “**Determination of velocity and skin friction fields from images by solving projected motion equations**,” 22nd International Congress on Instrumentation in Aerospace Simulation Facilities (ICIASF), Pacific Grove, CA (2007)
- T. Liu**, J. Montefort, W. Liou, S. R. Pantula, and Q. Shams “**Static extended trailing edge for lift enhancement: experimental and computational studies**,” 3rd International Symposium on Integrating CFD and Experiments in Aerodynamics, U.S. Air Force Academy, CO, USA, (2007)
- T. Liu** and M. Schulte, “**Flight testing education at Western Michigan University**,” AIAA Paper 2007-0700, AIAA Conferences, Reno, NV (2007)
- T. Liu** and W. Liou, “**Aeroship – A new flight platform**,” AIAA Paper 2006-9322, 25th Applied Aerodynamics Conference, 5-8 Jun (2006), San Francisco, California
- J. P. Roy, C. Britcher, and **T. Liu**, “**Extracting dynamic loads from optical deformation measurements**”, AIAA Paper 2006-2187 (2006)
- T. Liu** and G. Fleming, “**Videogrammetric determination of aircraft position and attitude for vision-based autonomous landing**”, AIAA Paper 2006-1437, Reno, January (2006)
- Trisiripisal, P., Parks, M. R., Abbott, A. L. **Liu, T.** and Fleming, G. A., “**Stereo analysis for vision-based guidance and control of aircraft landing**”, AIAA Paper 2006-1438, Reno, January (2006)
- T. Liu**, “**A unified view of image-based measurements in aerospace applications**”, Proceedings of MOSAIC, the International Workshop on Molecular Imaging for Interdisciplinary Research, Tohoku University, Sendai, Japan, (2004)
- T. Liu**, K. Kuykendoll, R. Rhwe and S. Jones, “**Avian wings**”, *AIAA Paper* 2004-2186, Portland, Oregon (2004)
- T. Liu**, “**Geometric, kinematic and radiometric aspects of image-based measurements**”, *AIAA Paper* 2002-3239, St. Louis, MO, June, (2002)
- A. W. Burner, **T. Liu**, and R. DeLoach, “**Uncertainty of videogrammetric techniques used for aerodynamic testing**”, *AIAA Paper* 2002-2794, St. Louis, MO, June, (2002)
- P. A. Parker and **T. Liu**, “**Uncertainty analysis of the single-vector force balance calibration system**”, *AIAA Paper* 2002-2792, St. Louis, June, (2002)
- T. Liu** and T. Finley, “**Estimating bias error distribution**”, *AIAA Paper* 2001-0162, Reno, Jan., (2001)
- T. Liu**, D. Barrows, A. Burner and R. Rhew, “**Determining aerodynamic loads based on optical deformation measurements**”, *AIAA Paper* 2001-0560, Reno, Jan., (2001)
- T. Amer, **T. Liu** and D. Oglesby, “**Characterization of pressure sensitive paint intrusiveness effects on aerodynamic data**”, *AIAA Paper* 2001-0556, Reno, Jan., (2001)
- A. W. Burner, **T. Liu**, S. Garg, T. A. Ghee and N. J. Taylor, “**Aeroelastic deformation measurements of flap, gap and overhang on a semispan model**”, *AIAA Paper* 2000-2386, Denver, June, (2000)
- T. Liu**, S. Garg, N. Lachendro, M. Guille, and J. Sullivan, “**Lifetime methods for pressure sensitive paints**”, Proceeding of the 7th PSP Workshop, Purdue University, Oct. 11-13, 1999.
- T. Liu**, R. Radeztsky, S. Garg and L. Cattafesta, “**A videogrammetric model deformation system and its integration with pressure paint**”, *AIAA Paper* 99-0568, Reno, January, (1999)

- T. Liu, R. Radeztsky, S. Garg and L. Cattafesta, “**A photogrammetric model deformation system and its integration with pressure paint**”, *1998 Pressure Sensitive Paint (PSP) Workshop*, Boeing Company, Seattle, WA, October, (1998)
- T. Liu and J. Sullivan, “**Applications of Temperature and Pressure Sensitive Paints**”, *AGARD Conference Proceedings CP-601: Advanced Aerodynamic Measurement Technology*, presented at the *81st Meeting and Symposium of the Fluid Dynamics Panel*, Seattle, WA, 22-25 September, (1997)
- S. Torgerson, T. Liu and J. Sullivan, “**Rotor blade pressure measurement in a rotating machinery using pressure and temperature sensitive paints**”, *AGARD Conference Proceedings CP-598: Advanced Non-Intrusive Instrumentation for Propulsion Engines*, presented at the *Propulsion and Energetics Panel (PEP) 90th Symposium*, Brussels, Belgium, 20-24 October, (1997)
- A.W. Burner, R. Radeztsky and T. Liu, “**Videometric Applications in Wind Tunnels**”, *SPIE's International Symposium on Optics, Imaging and Instrumentation*, San Diego, California, USA (1997)
- T. Liu and J. Sullivan, “**Luminescent oil-film skin friction meter**”, *AIAA Paper 97-2216* (1997)
- T. Liu, R. Johnston, S. Torgerson, S. Fleeter and J. Sullivan, “**Rotor blade pressure measurement in a high speed axial compressor using pressure and temperature sensitive paints**”, *AIAA Paper 97-0162* (1997)
- Torgerson, S. D., Liu, T. and Sullivan, J. P., “**Use of pressure sensitive paints in low speed flows**”, *AIAA Paper 96-2184*, (1996)
- K. Asai, H. Kanda, T. Kunimasu, T. Liu and J. Sullivan, “**Detection of boundary layer transition in a cryogenic wind tunnel by using luminescent paint**”, *AIAA Paper 96-2185*, (1996)
- T. Liu, B. Campbell and J. Sullivan, “**Accuracy of temperature sensitive fluorescent paint for heat transfer measurement**”, *AIAA paper 95-2042*, (1995)
- T. Liu, B. Campbell and J. Sullivan, “**Remote surface temperature and heat transfer mapping for a waverider model at Mach 10 using fluorescent paint**”, *AIAA Paper 94-2484* (1994)
- B. Campbell, T. Liu and J. Sullivan, “**Temperature sensitive fluorescent paint systems**”, *AIAA Paper 94-2483* (1994)
- M. Hamner, B. Campbell, T. Liu and J. Sullivan, “**A scanning laser system for temperature and pressure sensitive paint**”, *AIAA Paper 94-0728* (1994)
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