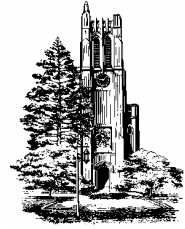
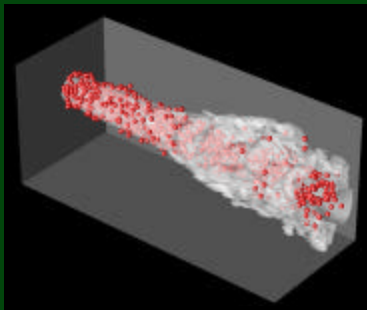


Michigan State University College of Engineering



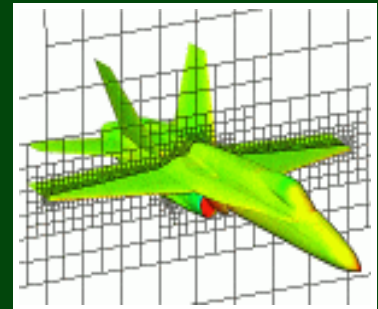
presents a short course on

Computational Fluid Dynamics Fundamentals and Applications



June 10-13, 2003

The Henry B. James Center
Michigan State University



A course for CFD practitioners and managers who are serious about using CFD to obtain useful answers to engineering problems.

Sponsored by

DaimlerChrysler Corporation, Ford Motor Company, General Motors Corporation, AVL Corporation, Parker-Hannifin Corporation, The Document Company Xerox, Michigan State University's Automotive Research Experiment Station (ARES), and Michigan State University's Computational Fluid Dynamics (CFD) Laboratory

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Short Course and Workshop Summary

This short course focuses on issues that affect accuracy and interpretation of CFD results; ability of CFD to impact design; and the capability of CFD to break into new application areas.

Topics addressed include: fundamentals of CFD, high-resolution schemes, level sets for free-surface flows, meshless methods based on wavelets, lattice Boltzmann methods, radiation heat transfer physics and modeling, computational aeroacoustics, primary atomization of liquid jets, modeling of engine sprays, and cavitation in hydro-mechanical systems.

There are also three workshops: a CFD Vendors Workshop, where leading CFD vendors will address latest developments and efforts on verification and validation; a User's Workshop, where experts in CFD will highlight challenges and issues; and a CFD Visions Workshop, where leaders in the field will propose ideas significant to the future of CFD.

Finally, there are four special talks: verification and validation efforts in the United States, verification and validation efforts in Europe, advances in CFD-based gas turbine combustor design tools, and a vision for the future of the aircraft industry.

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Institutional Sponsors

This CFD Short Course is partially sponsored by MSU's Automotive Research Experiment Station (ARES). ARES focuses on serving the research and development needs of the automotive industry. ARES encompasses twenty-eight professors with over 100 graduate students and research staff who perform research in the following laboratories:

- Powertrain Research Laboratory (Harold J. Schock, Head)
- Sensor Technology and Electric Motion Control Laboratory (Elias Strangas, Head)
- Multiphysics Computational Research Laboratory (Tom HP Shih, Head)
- School of Labor and Industrial Relations: Training Laboratories (Theodore Curry, Head)

**For more information on the mission and research activities in ARES contact:
Dr. Harold J. Schock, Professor of Mechanical Engineering and Director of ARES
Phone: 517-353-9328 Fax: 517-432-3341 E-mail: schock@egr.msu.edu**

Course Synopsis

Day 1: Tuesday 8:00 - 5:30 pm

Registration and Continental Breakfast: 8:00 - 8:30 am

- Welcome and Introductions, Tom Shih, Michigan State University
 - **Fundamentals of CFD** (3 hrs): Tom Shih, MSU
 - > Basis of Finite-Difference & Finite-Volume Methods
 - > Methods for the Navier-Stokes Equations
 - > Modeling Issues
 - > Grid Generation
 - > Errors and Error Estimation
 - **Spectral and Spectral-Like Methods** (1 hr): Guowei Wei, MSU
 - > Overview of High-Order Local Methods (finite-difference, finite-volume)
 - > Overview of Global Spectral Methods (Fourier, Chebyshev)
 - > Local Spectral Methods (fundamentals and applications)
- Lunch: 12:30 to 1:30 pm**
- **Level Sets on Solution-Adaptive Cartesian Mesh** (1 hr): Z.J. Wang, MSU
 - **Meshless Methods Using Wavelets** (1 hr): Alex Diaz, MSU
 - **Introduction to Lattice Boltzmann** (1 hr): Hudong Chen, Exa
 - **VLES Turbulence Modeling by using the Lattice BGK Method** (1 hr): Steven Orszag, Yale University

Day 2: Wednesday 8:00 - 5:30 pm

Registration and Continental Breakfast: 8:00 - 8:30 am

- **Radiative Heat Transfer in Automotive Systems** (3 hrs): Jack Howell, University of Texas at Austin
 - > Fundamentals of Thermal Radiation
 - > Radiative Transfer Between and Among Surfaces
 - > Radiation Shields to Cure Underhood Problems
 - > Combined Mode Problems: Approximate Methods
 - > Some Applications
 - brake system shields
 - electronic module cooling (effects of radiation)
 - paint drying/curing improvements (inverse design & control)
 - **Computational Aeroacoustics, Part 1** (1 hr): Philip Morris, The Pennsylvania State University at College Park
 - > Overview of Classical Acoustics
 - > Lighthill's Acoustic Analogy
- Lunch: 12:30 to 1:30 pm**
- **Computational Aeroacoustics, Part 2** (2 hrs): Philip Morris
 - > Noise Predictions
 - direct calculations (CAA)
 - predictions based on traditional CFD
 - > Example Predictions
 - cavity noise
 - jet noise
 - airframe noise
 - **CFD Vendors Workshop (2 hrs): Latest Developments; Efforts on Validation and Verification**
 - > Adapco: Nick Appleyard
 - > ANSYS-CFX: Brad Hutchinson
 - > AVL: Ales Alajbegovic
 - > Exa: Hudong Chen
 - > Fluent: Sung-Eun Kim
 - > NUMECA: Charles Hirsch

Reception and CFD Vendor Poster Session & Demonstrations at the MSU Automotive Research Experiment Station (3361 Hulett Road, Okemos, Michigan), 6:00 - 8:30 pm.

Day 3: Thursday 8:30 - 5:30 pm

Continental Breakfast: 8:00 - 8:30 am

- **Verification and Validation Issues** (1 hr): Ray Cosner, The Boeing Company
 - **Verification and Validation Efforts in Europe** (1 hr): Charles Hirsch, Vrije Universiteit Brussel / NUMECA
 - **User's Workshop (2 hrs): Challenges and Issues**
 - > Vamshi Korivi, DCX: In-cylinder Flow Simulation using CFD
 - > Zhigang Yang, GM: Thermal Performance Comparisons between Condenser, Radiator, and Fan Modules
 - > Rajneesh Singh, GM: Surface Morphing Application for Aerodynamics
 - > Rajneesh Singh: Simulation and Design of Auto Sunroof Buffeting
 - > Cheng Qian, GM: Parametric Aerodynamics Design Optimization Process
 - > Erlendur Steinthorsson, Parker-Hannifin: CFD Analysis of Atomization and Sprays
- Lunch: 12:30 to 1:30 pm**
- **CFD Visions Workshop (2 hrs): Future of CFD**
 - > Keith Meintjes, GM: Role of CFD and CAE in Product Development
 - > Zhiyu (Allen) Han, Ford: CFD in Design and Analysis
 - > Chin-Yuan Perng, Ford: CFD Research at Ford
 - > Fred Shen, GM: CFD Research at GM
 - > Richard Sun, DaimlerChrysler: CFD Research at DCX
 - > David Caughey, Cornell: CFD Research in Academia
 - > Cristina Amon, Carnegie Mellon: CFD for MEMS and Nano-Scale Physics
 - **Recent Advances in Gas Turbine Combustor Design Tools** (1 hr): Hukam Mongia, General Electric Aircraft
 - **Future of The Aircraft Industry** (1 hr): Ray Cosner, Boeing

Day 4: Friday 8:00 - 5:00 pm

Continental Breakfast: 8:00 - 8:30 am

- **Sprays in IC Engines** (1 hr): Harold Schock, MSU
 - **Primary Atomization** (1.5 hrs): Jerry Faeth, University of Michigan at Ann Arbor
 - > Pulsed Shadowgraphy and Holography Measurements
 - properties of the liquid surface during primary breakup
 - properties of drops formed as a result of primary breakup
 - > Interpretation and Correlation of Results for Spray Modeling
 - **Modeling of Engine Sprays, Part 1** (1.5 hrs): Rolf Reitz, University of Wisconsin at Madison
 - > Governing Equations
- Lunch: 12:30 to 1:30 pm**
- **Modeling of Engine Sprays, Part 2** (1.5 hrs): Rolf Reitz
 - > Sub-models
 - atomization
 - droplet drag
 - droplet breakup/collision, vaporization
 - spray wall impingement
 - spray ignition/combustion
 - **Cavitation in Hydro-Mechanical Systems** (2.5 hrs): Steven Ceccio, University of Michigan at Ann Arbor
 - > The Physics of Cavitation
 - > Cavitation in Hydraulic Systems: Curse and Cure
 - > Useful Applications of Cavitation
 - > An Assessment of Current Cavitation Modeling

Instructors

Steven L. Ceccio (Ph.D., California Institute of Technology) is Associate Professor of Mechanical Engineering at The University of Michigan at Ann Arbor. He has done considerable research on traveling bubble cavitation. He has also conducted research on a variety of multiphase flows with an emphasis on experimental examination of high Reynolds number flows. Dr. Ceccio continues to study the inception and development of cavitation under sponsorship of the Office of Naval Research, the Department of Energy, and Industry.

Hudong Chen (Ph.D., Dartmouth) is Vice President and Chief Scientist of Exa Corporation. He has contributed significantly to the Lattice gas/Boltzmann methods for complex fluids, statistical physics and kinetic theory, and theoretical turbulence and modeling. Dr. Chen received the Research and Development Magazine Award for the top 100 Most-Significant New Technical Products of the Year in 1988. He also received the Excellence Performance Award from Los Alamos National Laboratory in 1988. Dr. Chen is a Fellow of the American Physical Society.

Raymond Cosner (Ph.D., California Institute of Technology) is on the staff of the Vice President - Engineering of Boeing Integrated Defense Systems with responsibility for technology roadmaps, strategic engineering staffing requirements, and internal technical reviews to assure engineering quality in Boeing products. From 1975 to 2002, Dr. Cosner focused on the development and application of CFD technology for aerospace product development. He had multi-year engineering assignments on the following programs: F-15, NASP, A-12, and F/A-18E/F. From 1999-2002, he led a Boeing-wide effort to establish a common CFD process and tool set. Dr. Cosner has had twenty-eight years of experience at McDonnell Douglas and Boeing. He has been an advisor in numerous Boeing programs, spanning the full line of Boeing products. He is a Boeing Senior Technical Fellow, currently Chair of Boeing Technical Fellowship.

Alejandro Diaz (Ph.D., The University of Michigan at Ann Arbor) joined Michigan State University in 1986 and is currently Professor of Mechanical Engineering. Previously he was a research scientist in Venezuela and a visiting professor in the Mathematical Institute of the Technical University of Denmark. Dr. Diaz has contributed significantly to the area of optimization and computational mechanics and its application to mechanical systems and structures.

Gerald M. Faeth (Ph.D., Pennsylvania State University) is A.B. Modine Professor of Aerospace Engineering and Head of the Gas Dynamics Laboratories at The University of Michigan at Ann Arbor. Also, he is Professor Emeritus of Mechanical Engineering at The Pennsylvania State University. Dr. Faeth has conducted extensive research in turbulent multiphase flow and liquid atomization phenomena. He has received the AIAA Propellants and Combustion Award, the ASME Heat Transfer Memorial Award, and the NASA Public Service Medal. Dr. Faeth is a Fellow of AIAA, ASME, and the American Association for the Advancement of Science (AAAS). He is also a member of the National Academy of Engineering.

Jack R. Howell (Ph.D., Case Institute of Technology) is the Earnest Cockrell, Jr. Chair and Baker-Hughes Centennial Professor at the University of Texas at Austin. Before joining UT, he taught at the University of Houston, and prior to that was in the Thermal Analysis Section at NASA Lewis (now Glenn) Research Center. He has spent much of his research career on radiative heat transfer problems, developing solution techniques and design methods. His text with Robert Siegel, *Thermal Radiation Heat Transfer*, is now in its fourth edition. Dr. Howell has received the ASME Heat Transfer Memorial Award, the AIAA Thermophysics Award, and the Max Jakob Award for his radiation research. He is a Fellow of ASME and AIAA, and is a Foreign Member of the Russian Academy of Sciences.

Charles Hirsch (Ph.D., Université Libre de Bruxelles) is Professor and Head of the Department of Fluid Mechanics at Vrije Universiteit Brussel. He is President of NUMECA International. Dr. Hirsch has contributed very significantly to CFD. He has edited 20 books, authored/co-authored more than 350 journal and conference papers, and wrote a two-volume definitive textbook on CFD. Dr. Hirsch is Editor-in-Chief of John Wiley's Series on Computational Methods in Applied Sciences and the European Editor of the International Journal of Computational Fluid Dynamics.

Hukam Mongia (Ph.D., University of Massachusetts) joined the Garrett Engine Company in 1972, where he was promoted in 1981 to Senior Supervisor, Combustors. He joined Allison Gas Turbines in 1984 as Chief, Combustors R&D and CFD. In 1994, he moved to GE Aircraft Engines as Manager, Advanced Combustors Engineering, Advanced Engineering Programs Department. Dr. Mongia is responsible for

providing leadership in technology, and the transition of technology into combustion products, design methodology and tools. He has been involved in the design and development of numerous advanced technology and engine combustors and the formulation and successful application of empirical/analytical design methodology in the combustion design process.

Philip J. Morris (Ph. D., University of Southampton, UK) is the Boeing / A. D. Welliver Professor of Aerospace Engineering at Pennsylvania State University. He joined the Aerospace Engineering Department at Penn State in 1977 after working at the University of Toronto and the Lockheed-Georgia Company. Dr. Morris conducted extensive research in computational aeroacoustics, noise prediction, acoustic and electromagnetic scattering, thermoacoustics, and protective technology. He received the 1999 AIAA Aeroacoustics Award. Dr. Morris is a Fellow of the American Physical Society and AIAA.

Steven A. Orszag (Ph.D., Princeton University) is the Percey F. Smith Professor of Mathematics and Chair of Applied Mathematics at Yale University. Previously, he was Professor of Applied Mathematics at MIT (1967-84) and the Forrest Hamrick Professor of Engineering at Princeton (1984-98). Professor Orszag's research interests have been in applied mathematics and computational/computer science, including fluid dynamics (especially turbulence), electronic chip design, thin film materials, and computer and storage architecture. He has written over 400 papers, 10 books, and has 12 patents/pending. His current research/development efforts center on networked storage systems, lattice methods for fluids, GMR materials, and optical methods for chip metrology.

Rolf D. Reitz (Ph.D., Princeton University) is Wisconsin Distinguished Professor of Mechanical Engineering and Director of the Engine Research Center at The University of Wisconsin at Madison. Prior to 1989, he spent six years at the General Motors Research Laboratories, and five years on the research staff at Princeton University and at the Courant Institute of Mathematical Sciences, New York University. His research interests include IC engines and sprays. He is currently developing advanced computer models for optimizing fuel injected engines, including diesel and direct injection spark-ignited engines. Dr. Reitz is a Fellow of SAE. He is Past Chairman of the Institute of Liquid Atomization and Spraying Systems – North and South America, and is Editor (Americas) and co-founder of the International Journal of Engine Research. Dr. Reitz serves on the

Editorial Board of Atomization and Sprays and is an organizer of the Annual SAE Congress Session - Diesel Fuel Injection and Sprays.

Harold J. Schock (Ph.D., Michigan Technological University) is Professor of Mechanical Engineering and Director of Michigan State University's Automotive Research Experiment Station. Before joining MSU, he was Deputy Chief of the Turbine and Rotary Engine Branch and Head of the Intermittent Combustion Engine Technology Section at NASA – Lewis (now Glenn) Research Center. Dr. Schock has conducted extensive research for the automotive industry, the general aviation aircraft industry, and government laboratories in the development and application of laser diagnostic techniques for piston and Wankel engine combustion chamber flow fields, sprays, and torque converters. Dr. Schock is a Fellow of SAE.

Tom IP. Shih (Ph.D., The University of Michigan at Ann Arbor) joined Michigan State University as Professor of Mechanical Engineering in 1998. Previously, he was a Research Engineer at NASA – Lewis (now Glenn) Research Center, Assistant Professor and Associate Professor at the University of Florida, and Associate Professor and Professor at Carnegie Mellon University. Dr. Shih has conducted extensive research for industry and government laboratories in the development and application of CFD to study a wide range of problems in propulsion and aerodynamics, including internal and film cooling of gas-turbine components, boundary-layer control, IC engines, iced airfoils, and spray forming. Dr. Shih is a Fellow of ASME and an Associate Fellow of AIAA.

Z.J. Wang (Ph.D., University of Glasgow) joined Michigan State University in 2000 as Associate Professor of Mechanical Engineering. Previously, he was at Oxford University and the CFD Research Corporation. Dr. Wang has conducted extensive research in CFD with focus on algorithm development for grid generation and high-resolution schemes. For his contributions, he received a Bill Morton CFD Prize from Oxford University in 1995.

Guowei Wei (Ph.D., British Columbia) joined Michigan State University as Associate Professor of Mathematics in 2002. Previously, he was a Research Assistant Professor at the University of Houston, Assistant Professor and Associate Professor at the National University of Singapore. Dr. Wei has had extensive research experience on local spectral methods, quantum Boltzmann equation, methods for controlling chaos and turbulence, image processing, and pattern recognition. Details of his research can be found at www.math.msu.edu/~wei.

The James B. Henry Center

3535 Forest Road, Lansing, MI 48910

Phone: 517-353-4350 or toll free at 1-800-356-0796

Fax: 517-353-0796 Web: www.msuhenrycenter.org

DIRECTIONS

From Downtown Lansing - Proceed south on either Capital Avenue or Cedar Street to I-496 East. I-496 East will merge with US-127 South. Stay on US-127 South and take Jolly Road exit. Turn left on Dunckel Road. Go approximately 1/2 mile and turn left on Collins Road. As Collins Road begins to curve to the right turn left on Forrest Road. The Henry Center, Candlewood Suites, Forest Akers Golf Course and University Club will be on the immediate right.

From Capital City Airport - Take W. Airport Service Drive East, turn right onto Capitol City Boulevard. Turn right onto N. Grand River Avenue. In less than a mile, turn left (south) onto Waverly Road. Take I-496 (east) towards Lansing. I-496 East merges with US-127 South. Exit US-127 at the Jolly Rd. exit (1st exit north of I-96 intersection). At the end of the exit ramp go east on Dunckel. Turn left (north) on Collins Road. In approximately one mile, turn left (west) on Forest Road. The Henry Center for Executive Development and Candlewood Suites is located on the immediate right.

From Detroit or Ann Arbor - Take I-96 West towards Lansing. Take US-127 North towards East Lansing. Exit US-127 at the Jolly Road exit (1st exit north of I-96 intersection). At the end of the exit ramp go east on Dunckel. Turn left (north) on Collins Rd. In approximately one mile, turn left (west) on Forest Road. The Henry Center for Executive Development and Candlewood Suites is located on the right.

From Grand Rapids - Take I-96 East to US-127 North. Stay on US-127 North and take the Jolly Rd exit. Turn left on Dunckel. Go approximately 1/2 mile and turn left (north) on Collins Road. As Collins Rd begins to curve to the right turn left on Forrest Rd. The Henry Center, Candlewood Suites, Forest Akers Golf Course and University Club will be on the immediate right.

From Jackson - Take I-94 East to US-127 North. Stay on US-127 North and take the Jolly Rd exit. Turn left on Dunckel Rd. Go approximately 1/2 mile and turn left (north) on Collins Road. As Collins Rd begins to curve to the right turn left on Forrest Rd. The Henry Center, Candlewood Suites, Forest Akers Golf Course and University Club will be on the immediate right.

From Flint - Take I-69 to US-127 North. Stay on US-127 North and take the Jolly Rd exit. Turn left on Dunckel Rd. Go approximately 1/2 mile and turn left (north) on Collins Road. As Collins Rd begins to curve to the right turn left on Forrest Road. The Henry Center, Candlewood Suites, Forest Akers Golf Course and University Club will be on the immediate right.

From Battle Creek or Kalamazoo - Take I-94 East to I-69 North. Follow I-69 North to I-96 East. Take I-96 to US-127 North. Stay on US-127 North and take the Jolly Road exit. Turn left on Dunckel Rd. Go approximately 1/2 mile and turn left (north) on Collins Road. As Collins Road begins to curve to the right turn left on Forrest Road. The Henry Center, Candlewood Suites, Forest Akers Golf Course and University Club will be on the immediate right.



Registration Information

Registration Fee:

The course registration fee is \$1,250. For full-time students, the registration fee is \$250. This fee covers course lecture notes, four continental breakfasts, four lunches, refreshments, and a reception.

To Register:

Please mail, FAX, or e-mail registration form to Bobbie Slider before June 6, 2003:

Phone: 517-355-3338, FAX: 517-353-1750, E-mail: slider@egr.msu.edu

Mailing Address: Department of Mechanical Engineering, Michigan State University
2555 Engineering Building, East Lansing, Michigan 48824-1226

Lodging Information:

A block of rooms have been reserved at the Candlewood Suites at MSU, located adjacent to the James B. Henry Center (www.candlewoodsuites.com). Two types of suites are available: regular (\$82) and one-bedroom (\$102). This price includes a temporary pass to the University Club with all of its amenities. All suites have kitchenettes, and the hotel has a grocery store. For reservation, please call 517-351-8181 and tell them that you are attending the CFD Short Course to get the discounted rates, which are guaranteed until May 16, 2003.

For additional information about the short course and the workshops, please contact:

Professor Tom I-P. Shih, CFD Laboratory, Department of Mechanical Engineering, Michigan State University
(phone: 517-432-3658, e-mail: tomshih@egr.msu.edu, web: <http://www.egr.msu.edu/~tomshih>)
2452 Engineering Building, East Lansing, MI 48824-1226

Registration Form

Short Course on CFD Fundamentals and Applications

June 10-13, 2003

Michigan State University

(please type or print)

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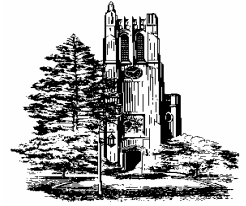
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