

# Tim Warburton

Department of Computational and Applied Mathematics  
Rice University  
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Houston, TX 77005-1892

## Education

Ph.D.	Applied Mathematics, Brown University, USA	1999.
Thesis:	<i>Spectral/hp Methods on Polymorphic Multi-Domains: Algorithms and Applications</i>	
M.Sc.	Applied Mathematics, Brown University, USA	1994.
B.A.	Mathematics, Oxford University, UK	1993.

## Research Interests

Analysis of modern, high-order, unstructured, finite-element methods. Development of associated efficient algorithms, including parallel computational techniques and advanced preconditioning methods for solving linear systems. Scientific computing applications for these methods including electromagnetics, acoustics and computational fluid dynamics in complex geometries. Simplification and introduction of these techniques to academic, defense and industrial environments. Development of artificial radiation boundary conditions for the time-domain Maxwell's equations.

## Academic Positions

1. July 2004 - present: Assistant Professor  
Department of Computational and Applied Mathematics, Rice University.
2. August 2001 - December 2004: Assistant Professor  
Department of Mathematics and Statistics, University of New Mexico.
3. October 2001 - present: Consultant  
Division of Applied Mathematics, Brown University.
4. June 2000 - August 2000: Visitor  
ICASE, NASA Langley Research Center.
5. October 1999 - August 2001: Visiting Research Associate  
Division of Applied Mathematics, Brown University.
6. November 1998 - October 1999: Research Officer  
Oxford University Computing Laboratory.
7. August 1993 - November 1998: Research Assistant  
Division of Applied Mathematics, Brown University.
8. September 1996 - June 1997: Teaching Assistant  
Division of Applied Mathematics, Brown University.

## Recent Presentations

1. *Advances in Wave Propagation with the Discontinuous Galerkin Method\**, Department of Mathematics, Rice University, Houston, TX, 2006
2. *Towards High Resolution Numerical Algorithms For Wave Dominated Physical Phenomena*, AFOSR Program Review, Atlanta, GA, USA, 2006
3. *Advances in Wave Propagation with the Discontinuous Galerkin Method\**, 7'th World Congress on Computational Mechanics, Los Angeles, CA, USA, 2006
4. *Advances in Wave Propagation with the Discontinuous Galerkin Method\**, SIAM Annual Meeting, Boston, MA, 2006
5. *Advances in Wave Propagation with the Discontinuous Galerkin Method\**, ICES, U. Texas at Austin, TX, USA 2006
6. *Advances in Wave Propagation with the Discontinuous Galerkin Method\**, Computational Methods for Electromagnetism, Southeastern Section MAA & SIAM Southeast Atlantic Section, Auburn, AL, USA, 2006
7. *Advances in Wave Propagation with the Discontinuous Galerkin Method\**, Advances in Computational Scattering, BIRS, Banff, Canada, 2006
8. *Advances in Wave Propagation with the Discontinuous Galerkin Method\**, Scientific Computing Seminar, University of Houston, Houston, TX, USA, 2006
9. *Advances in Wave Propagation with the Discontinuous Galerkin Method\**, Math Department, Texas A&M University, College Station, TX, USA, 2005
10. Poster, AFOSR Program Review, Long Beach, CA, USA, 2005
11. *Spurious Solutions and the Discontinuous Galerkin Method on Nonconforming Meshes*, Waves'05, Providence, RI, USA, 2005
12. *Solving Scattering Problems for Maxwell's Equations Using Polygonal Artificial Boundaries*, Waves'05, Providence, RI, USA, 2005
13. *Comparing Continuous and Discontinuous Galerkin Methods for Maxwell's Equations*, USNCCM8, Austin, TX, USA, 2005
14. *Spectrally accurate radiation boundary conditions on polygonal artificial boundaries with discontinuous Galerkin implementation*, ICOSAHOM04, Brown University, Providence, RI, USA, 2004
15. *Bridging the Divide Between Compatible and Weakly Compatible Finite Element Methods\**, CAAM, Rice University, Houston, TX, USA, 2004
16. \*, PDE's and Applications, Notre Dame University, South Bend, IN, USA, 2003
17. *High-order radiation boundary conditions for time-domain electromagnetics using an unstructured discontinuous Galerkin method\**, Second MIT Conference on Computational Fluid and Solid Mechanics, Boston, MA, USA, 2003
18. *High Order Nodal DG-FEM for the Maxwell Eigenvalue Problem*, USNCCM7, Albuquerque, NM, USA, 2003
19. *The Unstructured Spectral Element Method and USEMe Computer Code\**, Math Department, Notre Dame University, South Bend, IN, USA, 2003
20. \*, Math Department & Geophysics Department, University of Chicago, Chicago, IL, USA, 2003
21. *High-Order Unstructured Grid Methods for Time-Domain Electromagnetics \**, Computer Science Research Institute, Sandia National Laboratories, NM, USA., 2002

22. \*, Math Department, University of Arizona, AZ, USA, 2002
23. \*, NCAR (National Center for Atmospheric Research), CO, USA, 2002
24. \*, Math Department, University of New Mexico, Albuquerque, NM, USA, 2001
25. *Nodal Unstructured Spectral Elements for Conservation Laws* \*, Math Department, Texas A&M University, College Station, TX, USA, 2001
26. *High Order Finite Element Methods in Matlab and Beyond*, Division of Applied Math, Brown University, Providence, RI, USA, 2001
27. \*, CASC, Lawrence Livermore National Laboratory, Livermore, CA, USA, 2001
28. Finite Elements in Fluids 2000, Austin, TX, USA, 2000
29. *Application of Nodal unstructured spectral elements to Maxwell's equations*, p-FEM 2000, St. Louis, MO, USA, 2000
30. \*, Electromagnetics Research Branch, NASA Langley Research Center, Hampton, VA, USA, 2000
31. CERFACS, Toulouse, France, 1999
32. DGM99, Newport, RI, USA, 1999
33. *Overlapping Schwarz preconditioners for solving elliptic problems on polymorphic/hp elements*, ICIAM99, Edinburgh, UK, 1999

### Teaching Experience

1. Taught Numerical Methods For Partial Differential Equations, CAAM, Rice University, Spring 2005 & 2006.
2. Taught Computational Science I, CAAM, Rice University, Fall 2004, 2005 & 2006.
3. Created and taught an innovative course in numerical solution of partial differential equations using the discontinuous Galerkin method, University of New Mexico, Spring 2003.
4. Developed and taught an innovative course in introductory numerical computing, University of New Mexico, Spring 2002, Fall 2002, & Fall 2003.
5. Co-created a pioneering course on high performance scientific computing using remote learning technology on the Access Grid network. I led the project at the University of New Mexico end, and collaborated with faculty at the University of Montana and the University of Alaska, Fall 2001, Fall 2002 & Fall 2003 (without Grid component).
6. Created and taught a new, graduate level, two semester long, Applied Mathematics topics course: *Elements of High Performance Scientific Computing* at Brown University, Fall 2000 and Spring 2001.
7. Organized and presented a seminar series: *hp Finite Elements* for the graduate students and faculty of the Oxford University Computing Laboratory, Spring 1999.
8. Provided mentoring for graduate students in the Center for Fluid Mechanics, Brown University, 1996 to 1998.
9. Teaching assistant in charge of computing assistance for *all* Brown University, Applied Mathematics courses with computational content, Fall 1996 and Spring 1997.

### Professional Service

1. Chair for minisymposium session on Discontinuous Galerkin Methods at WCCM07.
2. Co-organizer of two minisymposia at ICOSAHOM 2004.

3. Reviewer for SINUM.
4. Reviewer for Monthly Weather Review.
5. Reviewer for Journal of Scientific Computing.
6. Reviewer for Computing in Science and Engineering.
7. Reviewer for Journal of Computational and Applied Mathematics.
8. Reviewer for Computational Methods in Applied Mechanical Engineering, 2005.
9. Reviewer for Microfluidics and Nanofluidics, 2005.
10. Reviewer for International Journal for Numerical Methods in Fluids, 2005.
11. Reviewer for SIAM Computational Science and Engineering Book Series, 2005.
12. Reviewer for Applied Numerical Analysis and Computational Mathematics, 2005.
13. Reviewer for SIAM Journal on Scientific Computing, 2005.
14. Reviewer for Applied Numerical Mathematics, 2005.
15. Reviewer for Journal of Fluids Engineering (ASME), 2006.
16. Reviewer for Theoretical and Computational Fluid Dynamics, 2006.
17. Reviewer for Journal of Computational Physics, 2006.
18. Reviewer for Journal of Engineering Mathematics, 2006.
19. Reviewed for DOE applied mathematics, 2004 & 2005.
20. Reviewed for NSF DMS, 2005 & 2006.

### **Departmental and University Service**

1. Tommy Binford, graduate student in CAAM (Advisor) (Masters 2006).
2. Larkin Spires, graduate student in CAAM (Advisor).
3. Josef Sifuentes, graduate student in CAAM (Master's Thesis Committee).
4. Patricia Howard, graduate student in CAAM (Master's Thesis Committee).
5. Leila Issa, graduate student in CAAM (Master's Thesis Committee).
6. Edward Castillo, graduate student in CAAM (PhD Thesis Proposal Committee).
7. Todd Watermann, Ph.D. CS Rice University (Ph.D. Thesis Committee, 2006).
8. Allan Engsig-Karup, Ph.D. Danish Technical University (Ph.D. Thesis Committee, 2006).
9. Jesper Grooss, Ph.D. Danish Technical University (Ph.D. Thesis Committee, 2005).
10. Miroslav Joler, Ph.D. in ECE, U. New Mexico (Ph.D. Thesis Committee).
11. Manuela Longoni de Castro, Ph.D. in Math& Stats, U. New Mexico (Ph.D. Thesis Committee & sponsor).
12. Dagoberto Justo, Ph.D. in Math & Stats, U. New Mexico (Ph.D. Thesis Committee & sponsor).
13. Served on CAAM Graduate Committee, Rice University 2005.

14. Served on the CAAM A-exam Committee, Rice University.
15. Served on the CAAM Computing Committee, Rice University 2004 & 2005
16. Served on the Computer Use Committee for the Math and Stats Department at UNM.

### Recent and Current Funding

1. *High-Order Finite Element Methods for Solution of Partial Differential Equations*, PI: Tim Warburton, Sandia University Research Program, 10/01/02-09/30/03, \$35,000.
2. *High-Order Finite Element Methods for Solution of Partial Differential Equations (supplement)*, PI: Tim Warburton, Sandia University Research Program, 6/01/02-09/30/03, \$9,700.
3. *High-Order Finite Element Methods for Solution of Partial Differential Equations (renewal)*, PI: Tim Warburton, Sandia University Research Program, 10/01/03-09/30/04, \$40,000.
4. *Adaptive, High-Resolution Simulation Methods for Wave Propagation in Heterogenous Media*, PI: Thomas Hagstrom, CO-PI: Tim Warburton, Army Research Office, 03/01/03-02/28/06, \$270,000.
5. *Collaborative Research ITR: An Integrated Simulation Environment for High-Resolution Computational Methods in Electromagnetics with Biomedical Applications*, PI: Tim Warburton, CO-PI's, Thomas Hagstrom (UNM), Moysey Brio (U. Arizona), Anne Gelb (Arizona State), Jan Hesthaven (Brown U.), Henry Tufo (U. Colorado at Boulder), NSF, 09/01/03-08/31/07, \$340,000 (UNM), \$1,000,000 (Total Project).
6. *Compatible and Nearly Compatible Finite Element Discretizations: Algorithms, Analysis and Applications*, PI: Tim Warburton, DMS-Computational Mathematics, NSF, 07/01/05 - 06/30/08, \$186,195.
7. *Towards High Resolution Numerical Algorithms for Wave Dominated Physical Phenomena*, PI: Tim Warburton, AFOSR, 07/01/05 - 11/30/06, \$ 242,259.

### Publications

Ph.D. Thesis:

1. *Spectral/hp Methods on Polymorphic Multi-Domains: Algorithms and Applications*, Brown University, 1999.

Journal Articles:

1. Allan P. Engsig-Karup, Jan S. Hesthaven, Harry B. Bingham, and **T. Warburton**, *DG-FEM solution for nonlinear wave-structure interaction using Boussinesq-type equations*, in preparation for Coastal Engineering, 2006.
2. T. Binford, D. P. Nicholls, N. Nigam, and **T. Warburton**, *Exact Non-Reflecting Boundary Conditions on General Domains and hp-Finite Elements*, in preparation, 2006.
3. F.X. Giraldo and **T. Warburton**, *A High-Order Triangular Discontinuous Galerkin Ocean Model: Barotropic Formulation*, submitted to International Journal of Numerical Methods in Fluids, 2006.
4. **T. Warburton** and T. Hagstrom, *Taming the CFL Number for Discontinuous Galerkin Methods on Structured Meshes*, submitted to SIAM Journal on Numerical Analysis, 2006.
5. **T. Warburton**, *An Explicit Construction for Interpolation Nodes on the Simplex*, available online at Journal of Engineering Mathematics, 2006.
6. **T. Warburton**, *Continuous and Discontinuous Galerkin Discretizations Applied Together to Maxwell's Eigenvalue Problem on Non-conforming Meshes*, in preparation, 2006.
7. **T. Warburton** and M. Embree, *On the Role of the Penalty in the Local Discontinuous Galerkin Method for Maxwell's Eigenvalue Problem*, Computer Methods Applied Mechanical Engineering, Vol 195, Issues 25-28, pp. 3205-3223, 2006.

8. H. Salman, J.S. Hesthaven, **T. Warburton** and G. Haller, *Unstructured Spectral Element Simulation of a Flameholder Flow with Active Control*, available online at Theoretical and Computational Fluid Dynamics, 2006.
9. F. X. Giraldo and **T. Warburton**, *A Nodal Triangle-based Spectral Element Method for the Spherical Shallow Water Equations on Unstructured Grids*, Journal of Computational Physics, Vol 207, Issue 1, pp. 129-150, 2005.
10. T. Hagstrom and **T. Warburton**, *High-order radiation boundary conditions for time-domain electromagnetics using unstructured discontinuous Galerkin methods*, in preparation, 2004.
11. J.S. Hesthaven and **T. Warburton**, *Discontinuous Galerkin Methods for the Time-Domain Maxwell's Equations*, Applied Computational Electromagnetics Society Newsletter, Vol. 19, No. 1, 2004.
12. Thomas Hagstrom and **Tim Warburton**, *A New Auxiliary Variable Formulation of High-Order Local Radiation Boundary Conditions: Corner Compatibility Conditions and Extensions to First Order Systems*, Wave Motion, Vol. 39, 327-338, 2004.
13. J. S. Hesthaven and **T. Warburton**, *High-Order Nodal Discontinuous Galerkin Methods for the Maxwell's Eigenvalue Problem*, Phil. Trans. R. Soc. Lond. A, Vol 362, pp.493-524, 2004.
14. **T. Warburton** and J.S. Hesthaven, *On the Constants in hp-Finite Element Trace Inverse Inequalities*, Computer Methods Applied Mechanical Engineering, Vol. 192, No. 25, pp. 2765-2774, 2003.
15. J. S. Hesthaven and **T. Warburton**, *High-Order Accurate Methods for Time Domain Electromagnetics*, Submitted Computer Modeling Engineering Science, 2002.
16. P. Dutta, **T.C. Warburton** and A. Beskok, *Electroosmotic Flow Control in Complex Micro-Geometries*, Journal of Microelectromechanical Systems, 11:36-44, 2002.
17. P. Dutta, **T.C. Warburton** and A. Beskok, *Numerical Simulation of Mixed Electroosmotic/ Pressure Driven Flows in Complex Micro-Geometries*, Journal of Numerical Heat Transfer, Vol 41, 2:131-148, 2002.
18. J.S. Hesthaven and **T. Warburton**, *Nodal High-Order Methods on Unstructured Grids, I. Time-Domain Solution of Maxwell's Equations*, Journal of Computational Physics, Vol. 181, No. 1, Sep 2002, pp. 186-221
19. F. X. Giraldo, J. S. Hesthaven, and **T. Warburton**, *Nodal High-Order Discontinuous Galerkin Method for the Spherical Shallow Water Equations*, Journal of Computational Physics, Vol. 181, No. 2, Sep 2002, pp. 499-525.
20. **T. Warburton**, L. Pavarino and J.S. Hesthaven, *A Pseudo-Spectral Scheme for the Incompressible Navier-Stokes Equations Using Unstructured Nodal Elements*, Journal of Computational Physics, 164:1-21, 2000.
21. L.F. Pavarino and **T. Warburton**, *Overlapping Schwarz Methods for Unstructured Spectral Elements*, Journal of Computational Physics, 160:298-317, 2000.
22. A. Beskok and **T.C. Warburton**, *An Unstructured H/P Finite Element Scheme for Fluid Flow and Heat Transfer in Moving Domains*, Journal of Computational Physics, Vol. 174, 2:492-509, 2001.
23. A. Beskok and **T.C. Warburton**, *Arbitrary Lagrangian Eulerian Analysis of a Bidirectional Micro-Pump Using Spectral Elements*, International Journal of Computational Engineering Science, Volume 2, March 2001.
24. R.M. Kirby, **T.C. Warburton**, I. Lomtev, and G.E. Karniadakis, *A Discontinuous Galerkin Spectral/hp Method on Hybrid Grids*, Journal of Applied Numerical Mathematics, 33:393-405, 1999.
25. **T. Warburton** and G. Karniadakis, *A Discontinuous Galerkin Method for the Viscous MHD Equations*, Journal of Computational Physics, 152:608-641, 1999.
26. **T.C. Warburton**, S.J. Sherwin, and G.E. Karniadakis, *Spectral Basis Functions for 2D Hybrid hp Elements*, SIAM Journal of Scientific Computation, Volume 20, 5:1671-1695, 1999.

27. **T. Warburton**, I. Lomtev, Y. Du, S. Sherwin and G. Karniadakis, *Galerkin and Discontinuous Galerkin Spectral/hp Methods*, Special edition of *Spectral, Spectral Element, and hp Methods in CFD* in Computer Methods in Applied Mechanics and Engineering, 175:343-359, 1999.

Conference Proceedings:

1. **T. Warburton**, *Spurious Solutions and the Discontinuous Galerkin Methods on Nonconforming Meshes*, Proceedings of the 7th International Conference on Mathematical and Numerical Aspects of Wave Propagation, WAVES 2005, Providence, RI, June 20-24, 2005.
2. T. Hagstrom and **T. Warburton**, *High-Order Radiation Boundary Conditions for Time-Domain Electromagnetics Using An Unstructured Discontinuous Galerkin Method*, Accepted to the Second M.I.T. Conference on Computational Fluid and Solid Mechanics, June 17-20, 2003, Cambridge, Massachusetts.
3. C. Chauviere, J.S. Hesthaven, A. Kanevsky, and **T. Warburton**, *High-Order Localized Time Integration for Grid-Induced Stiffness*, Accepted to the Second M.I.T. Conference on Computational Fluid and Solid Mechanics, June 17-20, 2003, Cambridge, Massachusetts.
4. J.S. Hesthaven and **T. Warburton**, *High-Order Unstructured Grid Methods for Time-Domain Electromagnetics*, Proceedings of 40th AIAA Aerospace Sciences Meeting and Exhibit, January 14-17, 2002, Reno, Nevada.
5. J.S. Hesthaven and **T. Warburton**, *High-Order/Spectral Unstructured Grid Methods for the Time-Domain Solution of Maxwell's Equations*, Fourth International Workshop on Computational Electromagnetics in the Time-Domain: TLM/FDTD and Related Techniques, Nottingham, UK, C. Christopoulos (Eds), 47-53, 2001.
6. P. Dutta and **T.C. Warburton**, and A. Beskok, *Numerical Modeling of Electrokinetically Driven Micro Flows*, Proceedings of ASME IMECE meeting, MEMS Vol 1, pp-467-474, 1999.
7. **T. Warburton**, *Application of the Discontinuous Galerkin Method to Maxwell's Equations Using Unstructured Polymorphic hp-Finite Elements*. International Symposium on Discontinuous Galerkin Methods, 1999.
8. R.M. Kirby, **T.C. Warburton**, S.J. Sherwin, A. Beskok and G.E. Karniadakis, *The Nektar Code: Dynamic Simulations without Remeshing*. The 2nd International Conference on Computational Technologies for Fluid/Thermal/Chemical Systems with Industrial Applications.
9. R.M. Kirby, **T.C. Warburton**, I. Lomtev, and G.E. Karniadakis, *A Discontinuous Galerkin Spectral/hp Method on Hybrid Grids*. International Conference on Spectral and High Order Methods, June 1998.
10. A. Beskok and **T.C. Warburton**, *Micro-fluidic design and fluid-structure interaction analysis of a micro-pump*, IMECE 98, Proceedings of the ASME Dynamic Systems and Control Division, 1998.
11. **T.C. Warburton**, I. Lomtev, R.M. Kirby and G.E. Karniadakis, *A Discontinuous Galerkin Method for the Compressible Navier-Stokes Equations on Hybrid Grids*, Tenth Int. Conf. on Finite Elements in Fluids, January 5-8, 1998, Tucson, Arizona.
12. S.J. Sherwin, **T.C.E. Warburton** and G.E. Karniadakis, *Spectral/hp Methods for Elliptic Problems on Hybrid Grids*, Tenth Int. Conf. on Domain Decomposition Methods, August 10-14, 1997 Boulder, Colorado.
13. **T.C. Warburton** and G.E. Karniadakis, *Spectral Simulations of Flow Past a Cylinder Close to a Free Surface*, ASME paper FEDSM97-3389, 1997.
14. **T.C. Warburton**, S.J. Sherwin and G.E. Karniadakis, *Unstructured hp/spectral elements: Connectivity and optimal ordering*, Int. Conf. on Comp. Engin. Science, July 30-August 3, 1995, Mauna Lani, Hawaii.

Technical Reports:

1. David M. Day, Ranjeet S. Patil, and **T. Warburton**, *Discontinuous Galerkin Discretizations Applied to Eigenvalue Problems on Non-Conforming Meshes*, CSRI Technical Report, Sandia National Laboratory, 2004.

### Software

1. Co-developer of Nektar from 1994 to 1998 <http://www.nektar.info>, (hp-FEM solver for compressible & incompressible Navier-Stokes and MHD)
2. Lead developer of USEMe, 1999 to present, <http://www.useme.org>, (unstructured discontinuous Galerkin spectral element solver for electromagnetics)
3. Lead developer of Sledge++, 2003 to present, (object oriented C++ computational library for adaptive, high-order, finite element, edge element and discontinuous Galerkin on conforming, non-conforming & overlapping meshes)