

# Stanford

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## Brian Cantwell

Edward C. Wells Professor in the School of Engineering and Professor of Mechanical Engineering, Emeritus  
Aeronautics and Astronautics

### CONTACT INFORMATION

- **Administrator**

Carolyn Edwards - Administrative Associate

**Email** edwardsc@stanford.edu

**Tel** (650) 723-2867

### Bio

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#### BIO

Professor Cantwell's research interests are in the area of turbulent flow. Recent work has centered in three areas: the direct numerical simulation of turbulent shear flows, theoretical studies of the fine-scale structure of turbulence, and experimental measurements of turbulent structure in flames. Experimental studies include the development of particle-tracking methods for measuring velocity fields in unsteady flames and variable density jets. Research in turbulence simulation includes the development of spectral methods for simulating vortex rings, the development of topological methods for interpreting complex fields of data, and simulations of high Reynolds number compressible and incompressible wakes. Theoretical studies include predictions of the asymptotic behavior of drifting vortex pairs and vortex rings and use of group theoretical methods to study the nonlinear dynamics of turbulent fine-scale motions. Current projects include studies of fast-burning fuels for hybrid propulsion and decomposition of nitrous oxide for space propulsion.

#### ACADEMIC APPOINTMENTS

- Fac Ret Replacement Teaching, Aeronautics and Astronautics
- Affiliate, Precourt Institute for Energy
- Affiliate, Stanford Woods Institute for the Environment

#### BOARDS, ADVISORY COMMITTEES, PROFESSIONAL ORGANIZATIONS

- Elected Member, National Academy of Engineering (2013 - present)

#### PROFESSIONAL EDUCATION

- PhD, Caltech (1976)

#### LINKS

- <https://web.stanford.edu/~cantwell/>: <https://web.stanford.edu/~cantwell/>

### Teaching

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#### COURSES

2023-24

- Aircraft and Rocket Propulsion: AA 283 (Spr)

#### 2020-21

- Air and Space Propulsion: AA 103 (Spr)
- Aircraft and Rocket Propulsion: AA 283 (Win)
- Fundamentals of Compressible Flow: AA 210A (Aut)

### STANFORD ADVISEES

#### Doctoral Dissertation Reader (AC)

Tejal Shanbhag

#### Doctoral Dissertation Co-Advisor (AC)

Efaine Chang

## Publications

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### PUBLICATIONS

- **Integral measures of the zero pressure gradient boundary layer over the Reynolds number range  $0 \leq R\text{-}\tau < \infty$**  *PHYSICS OF FLUIDS*  
Cantwell, B. J.  
2021; 33 (8)
- **Diode Laser Ignition Mechanism for Hybrid Propulsion Systems**  
Dyrda, D. M., Korneyeva, V., Cantwell, B. J.  
AMER INST AERONAUTICS ASTRONAUTICS.2020: 901–11
- **Diode Laser Ignition of a Poly(Methyl Methacrylate) and Gaseous Oxygen Hybrid Motor** *JOURNAL OF PROPULSION AND POWER*  
Dyrda, D. M., Mechentele, F. S., Cantwell, B. J., Karp, A. C., Rabinovitch, J., Jens, E. T.  
2020; 36 (5): 773–82
- **Optically Resolved Fuel Regression of a Clear Polymethylmethacrylate Hybrid Rocket Motor** *JOURNAL OF PROPULSION AND POWER*  
Mechentele, F. S., Hord, B. R., Cantwell, B. J.  
2020; 36 (5): 763–72
- **Hypergolic Ignition of Lithium-Aluminum-Hydride-Doped Paraffin Wax and Nitric Acid** *JOURNAL OF PROPULSION AND POWER*  
Stober, K., Cantwell, B. J., Otaibi, R. L.  
2020; 36 (3): 435–45
- **Experimental Visualization of Hybrid Combustion: Results at Elevated Pressures** *JOURNAL OF PROPULSION AND POWER*  
Jens, E. T., Karp, A. C., Miller, V. A., Hubbard, G., Cantwell, B. J.  
2020; 36 (1): 33–46
- **A universal velocity profile for smooth wall pipe flow** *JOURNAL OF FLUID MECHANICS*  
Cantwell, B. J.  
2019; 878: 834–74
- **Numerical investigation of the effect of obstacle shape on deflagration to detonation transition in a hydrogen-air mixture** *COMBUSTION AND FLAME*  
Coates, A. M., Mathias, D. L., Cantwell, B. J.  
2019; 209: 278–90
- **Experimental and numerical methods for radiative wall heat flux predictions in paraffin-based hybrid rocket engines**  
Leccese, G., Bianchi, D., Nasuti, F., Stober, K., Narsai, P., Cantwell, B.  
PERGAMON-ELSEVIER SCIENCE LTD.2019: 304–12
- **Hybrid rocket propulsion systems for outer planet exploration missions** *ACTA ASTRONAUTICA*  
Jens, E. T., Cantwell, B. J., Hubbard, G. S.  
2016; 128: 119-130

- **Symmetries and analytical solutions of the Hamilton-Jacobi-Bellman equation for a class of optimal control problems** *OPTIMAL CONTROL APPLICATIONS & METHODS*  
Rodrigues, L., Henrion, D., Cantwell, B. J.  
2016; 37 (4): 749-764
- **Schlieren and OH\* chemiluminescence imaging of combustion in a turbulent boundary layer over a solid fuel** *EXPERIMENTS IN FLUIDS*  
Jens, E. T., Miller, V. A., Cantwell, B. J.  
2016; 57 (3)
- **A new boundary layer integral method based on the Universal Velocity Profile** *Physics of Fluids*  
Cantwell, B. J., Bilgin, E., Needels, J. T.  
2022
- **Similarity solution of fuel mass transfer, port mass flux coupling in hybrid propulsion** *JOURNAL OF ENGINEERING MATHEMATICS*  
Cantwell, B. J.  
2014; 84 (1): 19-40
- **Nitrogen removal with energy recovery through N2O decomposition** *ENERGY & ENVIRONMENTAL SCIENCE*  
Scherson, Y. D., Wells, G. F., Woo, S., Lee, J., Park, J., Cantwell, B. J., Criddle, C. S.  
2013; 6 (1): 241-248
- **Review and evaluation of models for self-pressurizing propellant tank dynamics**  
ZIMMERMAN, J., E., WAXMAN, B., S., CANTWELL, B., J., ZILLIAC, G.  
2013
- **Hybrid rocket propulsion and in-situ propellant production for future Mars missions**  
BOIRON, A., J., CANTWELL, B., J.  
2013
- **Mass flow rate and isolation characteristics of injectors for use with self-pressurizing oxidizers in hybrid rockets**  
WAXMAN, B., S., ZIMMERMAN, J., E., CANTWELL, B., J., ZILLIAC, G.  
2013
- **Similarity solution of fuel mass transfer, port mass flux coupling in hybrid propulsion.** *Journal of Engineering Mathematics*  
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- **A thermal model for analysis and control of drilling in icy formations on mars** *PLANETARY AND SPACE SCIENCE*  
Szwarc, T., Aggarwal, A., Hubbard, S., Cantwell, B., Zacny, K.  
2012; 73 (1): 214-220
- **Visualization of the liquid layer combustion of paraffin fuel for hybrid rocket applications**  
CHANDLER, A., A., JENS, E., CANTWELL, B., J., HUBBARD, G., S.  
2012
- **Initial experimental investigations of self-pressurizing propellant dynamics**  
ZIMMERMAN, J., E., CANTWELL, B., J., ZILLIAC, G.  
2012
- **Peregrine Hybrid Rocket Motor Ground Test Results**  
ZILLIAC, G., WAXMAN, B., S., DYER, J., KARABEYOGLU, M., A., CANTWELL, B., J.  
2012
- **Effects of injector design and impingement techniques on the atomization of self-pressurizing oxidizers**  
WAXMAN, B., S., CANTWELL, B., J., ZILLIAC, G.  
2012
- **Feasibility of a single port Hybrid Propulsion system for a Mars Ascent Vehicle** *ACTA ASTRONAUTICA*  
Chandler, A. A., Cantwell, B. J., Hubbard, G. S., Karabeyoglu, A.  
2011; 69 (11-12): 1066-1072

- **Surface Structure and Reactivity of Rhodium Oxide** *JOURNAL OF PHYSICAL CHEMISTRY C*  
Scherson, Y. D., Aboud, S. J., Wilcox, J., Cantwell, B. J.  
2011; 115 (22): 11036-11044
- **High performance hybrid upper stage motor**  
KARABEYOGLU, M., A., STEVENS, J., GEYZEL, D., CANTWELL, B., J  
2011
- **Hybrid propulsion for solar system exploration**  
CHANDLER, A., A., CANTWELL, B., J., HUBBARD, G., S.  
2011
- **Thin film stability of melting solid fuels with application to hybrid propulsion**  
CANTWELL, B., J.  
2011
- **A Small-scale planar nitrous oxide monopropellant thruster for “green” propulsion and power generation**  
SCHERSON, Y., D., LOHNER, K., CANTWELL, B., J., KENNY, T.  
2010
- **A two-stage single port hybrid propulsion system for a Mars ascent vehicle**  
CHANDLER, A., CANTWELL, B., J., HUBBARD, G., S.  
2010
- **Recent advances In hybrid propulsion.** *International Journal of Energetic Materials and Chemical Propulsion*  
CANTWELL, B., J., KARABEYOGLU, M., A., ALTMAN, D., A  
2010; 4 (9): 305–326
- **Status update report for the Peregrine sounding rocket project: part III**  
DORAN, E., DYER, J., MARZONA, M., T., KARABEYOGLU, M., A., ZILLIAC, G., MOSHER, R., Cantwell, B. J.  
2009
- **Recent Advances In Hybrid Propulsion.**  
CANTWELL, B., J., KARABEYOGLU, M., A., ALTMAN, D., A.  
2009
- **A monopropellant gas generator based on N<sub>2</sub>O decomposition for “green” propulsion and power applications**  
SCHERSON, Y., D., LOHNER, K., CANTWELL, B., J., KENNY, T.  
2009
- **Modeling of N<sub>2</sub>O decomposition events**  
KARABEYOGLU, M., A., DYER, J., STEVENS, J., CANTWELL, B., J.  
2008
- **Development of scalable space-time averaged regression rate expressions for hybrid rockets** *AIAA/ASME/SAE/ASEE 41st Joint Propulsion Conference*  
Karabeyoglu, M. A., Cantwell, B. J., Zilliac, G.  
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- **Gravity currents in horizontal porous layers: transition from early to late self-similarity** *JOURNAL OF FLUID MECHANICS*  
Hesse, M. A., Tchelepi, H. A., Cantwell, B. J., Orr, F. M.  
2007; 577: 363-383
- **Test Facility Development for the 15,000 lb Thrust Peregrine Hybrid Sounding Rocket**  
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- **Nitrous oxide hybrid rocket motor fuel regression rate characterization**  
DORAN, E., DYER, J., LOHNER, K., DUNN, Z., CANTWELL, B., J., ZILLIAC, G.  
2007

- **Design and development of a sub-scale nitrous oxide monopropellant gas generator**  
LOHNER, K., DYER, J., DUNN, Z., DORAN, E., KRIEGER, B., DECKER, V., Cantwell, B. J.  
2007
- **Modeling feed system flow physics for self-pressurizing propellants**  
DYER, J., DORAN, E., DUNN, Z., LOHNER, K., ZILLIAC, G., CANTWELL, B., J.  
2007
- **Investigation of feed system coupled low frequency combustion instabilities in hybrid rockets**  
KARABEYOGLU, M., A., STEVENS, J., CANTWELL, B., J.  
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- **Modeling of hybrid rocket low frequency instabilities** *AIAA/ASME/SAE/ASEE 39th Joint Propulsion Conference*  
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- **Development of scaleable space-time averaged regression rate expressions for hybrid rockets**  
KARABEYOGLU, M., A., CANTWELL, B., J., ZILLIAC, G.  
2005
- **Design of an orbital hybrid rocket vehicle launched from Canberra air platform**  
KARABEYOGLU, M., A., FALCONER, T., CANTWELL, B., J., STEVENS, J.  
2005
- **Evaluation of the homologous series of normal-alkanes as hybrid rocket fuels**  
KARABEYOGLU, M., A., CANTWELL, B., J., STEVENS, J.  
2005
- **Scale-up tests of high regression rate paraffin-based hybrid rocket fuels** *AIAA 41st Aerospace Sciences Meeting and Exhibit*  
Karabeyoglu, A., Zilliac, G., Cantwell, B. J., DeZilwa, S., Castellucci, P.  
AMER INST AERONAUT ASTRONAUT.2004: 1037-45
- **Transient modeling of hybrid rocket low frequency instabilities.**  
KARABEYOGLU, M., A., DEZILWA, S., CANTWELL, B., J., ZILLIAC, G.  
2003
- **Modeling the slump characteristics of the hydrocarbon-based hybrid rocket fuels.**  
KILIC, S., KARABEYOGLU, M., A., STEVENS, J., CANTWELL, B., J.  
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- **Scale-up tests of high regression rate paraffin-based hybrid rocket fuels.**  
KARABEYOGLU, M., A., ZILLIAC, G., CANTWELL, B., J., DEZILWA, S., CASTELLUCCI, P.  
2003
- **Development of high-burning-rate hybridrocket- fuel flight demonstrators.**  
KARABEYOGLU, M., A., ZILLIAC, G., CASTELLUCCI, P., URBANCZYK, P., STEVENS, J., INALHAN, G., Cantwell, B. J.  
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Karabeyoglu, M. A., Cantwell, B. J.  
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KARABEYOGLU, M., A., CANTWELL, B., J.  
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- **Oscillatory flow states in an enclosed cylinder with a rotating endwall *JOURNAL OF FLUID MECHANICS***  
Stevens, J. L., Lopez, J. M., Cantwell, B. J.  
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- **Turbulence structures of wall-bounded shear flows found using DNS data *JOURNAL OF FLUID MECHANICS***  
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- **Correlation of wingtip noise with mean flow parameters**  
MATHIAS, D., L., PYE, J., D., CANTWELL, B., J.  
1998
- **Pipes and Channels. *In the Report of AGARD fluid dynamics panel working group 21 A Selection of Test Cases for the Validation of Large-Eddy Simulations of Turbulent Flows***  
MOSER, R., D., CANTWELL, B., J., PURTELL, L., P.  
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- **Discriminant-based analysis of the dynamics of turbulent flow**  
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- **Discriminant-based analysis of the dynamics of unsteady flow.**  
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1998
- **Near wall turbulence: A remembrance of Steve Kline.**  
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1998
- **Low speed flow studies using the pressure sensitive paint technique.**  
BROWN, O., C., MEHTA, R., D., CANTWELL, B., J.

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- **Vortical Flow Field Investigation Using the Pressure Sensitive Paint Technique at Low Speed**  
SHIMBO, Y., MEHTA, R., D., CANTWELL, B., J.  
1997
- **Direct Numerical Simulation of a Temporally Evolving Incompressible Plane Wake: Effect of Initial Conditions on Evolution and Topology, JIAA-TR 118,**  
SONDERGAARD, R., CANTWELL, B., MANSOUR, N.  
1997
- **Reynolds number invariance and the dilation group of turbulence**  
CANTWELL, B., J.  
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- **On the dynamics of turbulent boundary layers. In *Self-sustaining Mechanisms of Wall Turbulence***  
CANTWELL, B., J., CHACIN, J., M., BRADSHAW, P.  
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- **Study of turbulent boundary layer structure using the invariants of the velocity gradient tensor. TF Report 70 Department of Mechanical Engineering, Stanford University.**  
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- **Study of turbulent boundary layer structure using the invariants of the velocity gradient tensor EXPERIMENTAL THERMAL AND FLUID SCIENCE**  
Chacin, J. M., Cantwell, B. J., KLINE, S. J.  
1996; 13 (4): 308-317
- **Topology of fine-scale motions in turbulent channel flow JOURNAL OF FLUID MECHANICS**  
Blackburn, H. M., Mansour, N. N., Cantwell, B. J.  
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- **Study of the velocity gradient tensor in turbulent flow. JIAA-TR 114**  
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1996
- **Application of the Pressure Sensitive Paint Technique to Steady and Unsteady Flow, JIAA-TR 115**  
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- **Experimental Study of Vortex Breakdown in a Cylindrical, Swirling Flow**  
STEVENS, J., L., CELIK, Z., Z., CANTWELL, B., LOPEZ, J., M.  
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- **Lagrangian study of velocity gradient tensor dynamics in turbulent flow.**  
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- **A STUDY OF THE FINE-SCALE MOTIONS OF INCOMPRESSIBLE TIME-DEVELOPING MIXING LAYERS Symposium on Turbulence, in honor of the 60th Birthday of William Craig Reynolds**  
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- **The effect of initial conditions on the development of temporally evolving planar three-dimensional incompressible wakes.**

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- SONDERGAARD, R., MANSOUR, N., N., CANTWELL, B., J.  
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- **ON THE BEHAVIOR OF VELOCITY-GRADIENT TENSOR INVARIANTS IN DIRECT NUMERICAL SIMULATIONS OF TURBULENCE** *PHYSICS OF FLUIDS A-FLUID DYNAMICS*  
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  - **VORTEX DRIFT .1. DYNAMIC INTERPRETATION** *PHYSICS OF FLUIDS A-FLUID DYNAMICS*  
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  - **VORTEX DRIFT .2. THE FLOW POTENTIAL SURROUNDING A DRIFTING VORTICAL REGION** *PHYSICS OF FLUIDS A-FLUID DYNAMICS*  
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  - **Vortex drift II: The flow potential surrounding a drifting vortical region.** *Phys. of Fluids*  
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  - **On the behavior of velocity gradient tensor invariants in direct numerical simulations of turbulence.** *Physics of Fluids A*  
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  - **INVESTIGATION OF A COFLOWING BUOYANT JET - EXPERIMENTS ON THE EFFECT OF REYNOLDS-NUMBER AND RICHARDSON-NUMBER** *JOURNAL OF FLUID MECHANICS*  
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  - **EXACT SOLUTION OF A RESTRICTED EULER EQUATION FOR THE VELOCITY-GRADIENT TENSOR** *PHYSICS OF FLUIDS A-FLUID DYNAMICS*  
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  - **THE GEOMETRY OF TURBULENT FINE SCALE STRUCTURE** *11th Australasian Fluid Mechanics Conference*  
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  - **A study of the fine scale motions of incompressible time-developing mixing layers.**  
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- **THE EFFECT OF MACH NUMBER ON THE STABILITY OF A PLANE SUPERSONIC WAKE** *PHYSICS OF FLUIDS A-FLUID DYNAMICS*  
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- **FULL NUMERICAL-SIMULATION OF COFLOWING, AXISYMMETRIC JET DIFFUSION FLAMES** *PHYSICS OF FLUIDS A-FLUID DYNAMICS*  
Mahalingam, S., Cantwell, B. J., FERZIGER, J. H.  
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