

Anna Thomas, Ph.D.

Director's Postdoctoral Fellow
Fuels & Combustion Science Group
National Renewable Energy Laboratory
Golden, CO, 80401, USA

Education **Stanford University**

Ph.D., Aeronautics and Astronautics, 2019.

Thesis: "Green In-Space Propellants: Ignition Chemistry of Hypergolic Ionic Liquids"

Topics: Propulsion, Chemical Kinetics, Hypergolic Propellants/Chemistry, Ionic Liquids, Spectroscopy

Advisor: Brian Cantwell, Edward C. Wells Professor

M.S., Aeronautics and Astronautics, 2016.

Georgia Institute of Technology

B.S., Chemical and Biomolecular Engineering, 2013.

Biotechnology Concentration, Honors Program, Graduated with Highest Honors

Research **National Renewable Energy Laboratory, Golden, CO**

Experience *Director's Fellow | Postdoctoral Fellow*, November 2019 - Present

- *In Situ* Investigations of Autoignition: Linking Ignition Properties with Fuel Composition; implementing *in situ* spectroscopy capabilities to study critical combustion chemistry that will enable the implementation of future alternative fuels and higher-efficiency engine technologies.

- Awarded the Director's Award for Exceptional Performance, September 2020.

- Founder and lead organizer of the NREL Diversity, Equity, and Inclusion discussion group/book club with over 50 participants - facilitating discussions on leadership and inclusion.

Air Force Research Laboratory, Edwards Air Force Base, CA

Pathways Program | Graduate Researcher, June 2016 - June 2019

- Investigated the chemistry and performance of molecular hypergols and hypergolic ionic liquids through Fourier transform infrared spectroscopy and density functional theory for application to in-space propulsion.

- This work resulted in invited talks, a publication featured as a cover article, and a Best Overall Student Paper award.

Stanford University, Stanford, CA

Graduate Research Assistant, September 2014 - June 2019

- Examined effects various conditions and factors have on hypergolic ignition (i.e. pressure and gases present prior to ignition). A droplet ignition chamber was constructed with the capability to study hypergolic combinations from vacuum to 500psi in a nitrogen inert environment with the aid of high speed imaging.

- National Science Foundation Graduate Research Fellowship awarded for 2014-2017.

- Received the Zonta Amelia Earhart Fellowship and Future Space Leaders Grant in 2017 acknowledging research efforts and scientific contributions.

Technische Universität München, Munich, Germany

Fulbright Research Fellow, August 2013 - December 2013

- Conducted research studying spray flame dynamics through experimentation using phase doppler anemometry.

- Created a MATLAB program to analyze flame dynamics data to facilitate finding transfer functions.

Department of Chemical and Biomolecular Engineering, Georgia Institute of Technology, Atlanta, GA

Undergraduate Researcher, August 2010 - May 2013

- Constructed E.coli to act as easy-read bio-indicators used for detecting zinc deficiencies in place of heavy, expensive machinery using synthetic biology and metabolic engineering methods.

- Independently lead project with help of faculty mentor.

- Received the President's Undergraduate Research Award twice in the fall of 2011 and fall of 2012 for research efforts.

Industry
Experience

The Boeing Company, Seattle, WA, June 2016 - September 2016

Boeing Research and Technology - Propulsion Technology Intern

Green propellants trade study, reaction control systems technology analysis, turbofan fan blade CFD and loading analysis, biofuels technology trade study.

The Boeing Company, Huntsville, AL, June 2015 - September 2015

Space Launch System (SLS) Propulsion Subsystems Research Intern

Cryogenic propellant management systems analysis and trade studies, hydrazine detonation/decomposition analysis and prediction model with adiabatic compression.

TWT GmbH, Munich, Germany, March 2014 - May 2014

CFD Intern

Computational fluid dynamics simulations for engine air cooling in cars using OpenFOAM.

Pratt & Whitney, East Hartford, CT, May 2012-August 2012

Combustor Aero Intern - Geared Turbofan Engine Combustor

Impedance rig testing and data reduction, quench hole flow testing and design, MATLAB scripts for data processing, and engine test smoke and emissions data reduction and analysis.

NASA Glenn Research Center, Cleveland, OH, May 2011-August 2011

NASA Aeronautics Scholarship Program - Research Intern

Alternative jet fuel combustion testing analysis and gas turbine engine combustor performance analysis. Data reduction and authorship on three technical documents for publication for the 14th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery.

NASA Marshall Space Flight Center, Huntsville, AL, June 2010-August 2010

Systems Engineering Intern for the Ares I Upper Stage

NASA project management including configuration management as well as systems engineering for the Ares I rocket.

Teaching and
Mentoring

Guest Lecturer, Colorado State University and Colorado School of Mines, 2020

- Taught the aviation lectures for courses centered around energy solutions and transportation.
- Included case studies with students assigned to teams with titles of different stakeholders in the aviation industry to order to increase student engagement and participation on the topic of sustainable aviation technologies.

Advisor, MIT Practice School, 2020

- Advised a group of four MIT chemical engineering graduate students on a research project to design a flame speed experimental apparatus for fuel studies at NREL.

Mentor, Astronaut Scholarship Foundation, 2014 - Present

- Formally and informally mentor(ed) numerous undergraduate astronaut scholars on topics of research approach and writing, graduate school applications, fellowship applications, internships, industry interviewing techniques, resumes, and more.
- Formed productive mentorship relationships through active-listening and encouraging students to discover and acknowledge their strengths and share their enthusiasm about their work.

Research Mentor, Stanford University, 2015 - 2019

- Mentored undergraduate students working in the lab through teaching the necessary topics for understanding their research tasks, demonstrating proper lab safety measures, and taking the time to discuss their research ideas and questions.

Biochemistry Tutor, Office of Accessible Education, Stanford University, 2017 - 2019

- Tutored undergraduate students with learning disabilities.
- Provided different approaches for the students to try in order to find the learning techniques that proved successful for them.

Certified Hatha Yoga Instructor, National Renewable Energy Laboratory, 2019 - Present

- Taught yoga through the lab's fitness programs.
- Created classes and flows that met the needs of my colleagues for injury prevention and posture improvement.

Peer-Reviewed
Publications

Kim, Y., Thomas, A.E., Robichaud, D.J., Iisa, K., John, P.C.S., Etz, B.D., Fioroni, G.M., Dutta, A., McCormick, R.L., Mukarakate, C. and Kim, S., 2020. A perspective on biomass-derived biofuels: from catalyst design principles to fuel properties. *Journal of Hazardous Materials*. DOI: 10.1016/j.jhazmat.2020.123198. **Co-First Author**. (2020)

Thomas, A., Chambreau, S.D., Redecker, N.D., Esparza, A.A., Shafirovich, S., Ribbeck, T., Sprenger, J.A.P., Finze, M., Vaghjiani, G.L. FTIR Investigation of Thermal Decomposition and Hypergolic Reaction of a Dicyanoborohydride Ionic Liquid. *The Journal of Physical Chemistry A*. DOI: 10.1021/acs.jpca.9b09242. (2020)

Selected as cover article

Thomas, A.E., 2019. Green In-Space Propellants: Ignition Chemistry of Hypergolic Ionic Liquids. Stanford University Dissertation. (2019)

Thomas, A., Chambreau, S.D. and Vaghjiani, G.L., 2018. Ignition Delay Reduction with Sodium Addition to Imidazolium-Based Dicyanamide Ionic Liquid. *The Journal of Physical Chemistry A*. DOI: 10.1021/acs.jpca.8b08678. (2018)

Thomas, A.E., Saxena, N.T., Shouse, D.T., Neuroth, C., Lynch, A., Frayne, C.W., Stutrud, J.S., Corporan, E., Hankins, T. and Hendricks, R.C., 2012. Heating and Efficiency Comparison of a Fischer-Tropsch (FT) Fuel, JP-8+ 100, and Blends in a Three-Cup Combustor Sector. *ISRN Mechanical Engineering*, 2012(Article ID 920147). (2012)

Conference
Proceedings

Thomas, A.E., Chambreau, S.D., Esparza Hernandez, A.A., Shafirovich, E., and Vaghjiani, G. L. "Investigation of a Hypergolic Dicyanoborohydride-Based Ionic Liquid." June 2019 Joint Army-Navy-NASA-Air Force (JANNAF) Meeting, Dayton, OH. (2019)

Awarded Best Overall Student Paper

Thomas, A., and Cantwell, B. "Effect of Nitrous Oxide on the Ignition of Hypergolic Ionic Liquids." 54th AIAA/SAE/ASEE Joint Propulsion Conference, Cincinnati, OH, July 2018. (2018)

Thomas, A., and Cantwell, B. "Hypergolic Ionic Liquids as Green Propellants." International Astronautical Congress, Adelaide, Australia 2017. IAC-17,C4,10,7,x36690. (2017)

Thomas, A., and Cantwell, B. "Hypergolic Ionic Liquids: Ignition Delay Dependence on Pressure." In 53rd AIAA/SAE/ASEE Joint Propulsion Conference, Atlanta, GA, July 2017 (p. 5070). (2017)

Thomas, A., Stober, K. J., Al Otaibi, R., Alotaibi, M., Almuqati, N., Evans, B. J., and Cantwell, B. J.. "Ignition Delay Testing of Various Hypergolic Ionic Liquids and Oxidizers." AIAA 2016-4564, 52nd AIAA/SAE/ASEE Joint Propulsion Conference, Salt Lake City, UT, 25-27 July 2016. (2016)

Stober, K. J., Thomas, A., Evans, B., and Cantwell, B. "Investigation of Green Hypergolic Propellants for Hybrid Rockets." AIAA 2016-4564, 52nd AIAA/SAE/ASEE Joint Propulsion Conference, Salt Lake City, UT, 25-27 July 2016. (2016)

Stober, K.J., Narsai, P., Venkataraman, K., Thomas, A., and Cantwell, B., "Flame Emission Spectroscopy for Testing a Paraffin-Based Hybrid Rocket," AIAA 2016-4564, 52nd AIAA/SAE/ASEE Joint Propulsion Conference, Salt Lake City, UT, 25-27 July 2016. (2016)

Stober, K.J., Thomas, A., Evans, B., and Cantwell, B., "An Investigation of the Hypergolic Performance of Additives to Paraffin Wax for In-Space Propulsion," 39th Propellants and Explosives Development and Characterization (PEDCS) JANNAF Meeting, Salt Lake City, UT, 7-11 December 2015. (2015)

Saxena, N. T., Thomas, A. E., Shouse, D. T., Neuroth, C., Hendricks, R. C., Lynch, A., and Hankins, T. Alternate-fueled combustor-sector emissions. NASA technical memorandum. Washington, D.C.: National Aeronautics and Space Administration. (2012)

Thomas, A.E., Saxena, N.T., Shouse, D.T., Neuroth, C., Hendricks, R.C., Lynch, A., Frayne, C.W., Stutrud, J.S., Corporan, E. and Hankins, T. "Heating and Efficiency Comparison of a Fischer-Tropsch (FT) Fuel, JP-8+100, and Blends in a Three-Cup Combustor Sector," Proceedings of ASME Turbo Expo 2012 GT2012 June 11-15, 2012, Copenhagen, Denmark. (2012)

Thomas, A.E., Saxena, N.T., Shouse, D.T., Neuroth, C., Hendricks, R.C., Lynch, A., Frayne, C.W., Stutrud, J.S., Corporan, E. and Hankins, T. "Alternate-Fueled Combustor-Sector Performance." in Submitted to Proceedings of the 14th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC14 '12), Honolulu, HI, February 27th-March 2nd, 2012. (2012)

Saxena, N. T., Thomas, A.E., Shouse, D.T., Neuroth, C., Hendricks, R.C., Lynch, A., and Hankins, T., "Alternate-fueled combustor-sector emissions," in Submitted to Proceedings of the 14th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC14 '12), Honolulu, HI, February 27th-March 2nd, 2012. (2012)

Saxena, N.T., Thomas, A.E., Johnson, S., Venners, J.P. and Hendricks, R.C., "Green Planet Architecture-A Methodology for Self-Sustainable Distributed Renewable Energy Ecosystems." in Submitted to Proceedings of the 14th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC14 '12), Honolulu, HI, February 27th-March 2nd, 2012. (2012)

Presentations and Lectures "Aviation Technology," **Guest Lecture**, Course: Energy for Transportation, Colorado School of Mines, October 2020. (2020)

"From Space to Ground and Everything in Between: How Spectroscopy Coupled with Computational Chemistry Methods Can Be the Fast(er)-Track to Alternative Fuel Selection," Fuels and Combustion Science group meeting, NREL, October 2020. (2020)

"Aviation Technology," **Guest Lecture**; Course: Transportation, Energy, and the Environment; Colorado State University; February 2020. (2020)

"Investigation of a Hypergolic Dicyanoborohydride-Based Ionic Liquid," June 2019 Joint Army-Navy-NASA-Air Force (JANNAF) Meeting, Dayton, OH. Oral presentation. (2019)

Invited talk

"Green Propellants: The Chemistry and Chemical Kinetics of Hypergolic Ionic Liquids," Thesis Defense, Stanford, CA, March 2019. Oral presentation. (2019)

"Effect of Nitrous Oxide on the Ignition of Hypergolic Ionic Liquids," 54th AIAA/SAE/ASEE Joint Propulsion Conference, Cincinnati, OH, July 2018. Oral presentation in the Propellant and Combustion session. AIAA-2018-4963. (2018)

"Infrared spectroscopy studies of the hypergolic reaction and decomposition of a dicyanoborohydride ionic liquid," the 255th ACS National Meeting, New Orleans, LA, March 18-22, 2018. Oral presentation in the Physical Chemistry of Ionic Liquids, Division of Physical Chemistry session (paper ID: 2864693 PHYS 22). (2018)

"Hypergolic Ionic Liquids as Green Propellants," Presentation to King Abdulaziz City for Science and Technology representatives as research update, March 2018. (2018)

"Green Propellants," Zonta International Amelia Earhart Awards Luncheon, NASA Ames Research Center, CA, January 20th, 2018. Presentation as award recipient. (2018)

"Hypergolic Ionic Liquids as Green Propellants." International Astronautical Congress, Adelaide, Australia 2017. IAC-17,C4,10,7,x36690. (2017)

Presentations
Continued

“Hypergolic Ionic Liquids: Ignition Delay Dependence on Pressure.” In 53rd AIAA/SAE/ASEE Joint Propulsion Conference, Atlanta, GA, July 2017 (p. 5070). Oral presentation. (2017)

“Hypergolic Green Propellant Alternatives,” Affiliates Meeting, Stanford, CA, April 2017. Poster presentation to affiliates. (2017)

“Synthesis, Ignition, and Kinetics of Hypergolic Ionic Liquids as Green Propellant Alternatives,” JPL Visit, Stanford, CA, March 2017. Oral presentation to JPL representatives. (2017)

“Considering Green Propulsion Alternatives,” Astronaut Scholar Technical Conference, Cocoa Beach, FL, May 20th, 2017. Oral presentation to fellow scholars, community, and astronauts. (2017)

“Ignition Delay Testing of Various Hypergolic Ionic Liquids and Oxidizers.” AIAA 2016-4564, 52nd AIAA/SAE/ASEE Joint Propulsion Conference, Salt Lake City, UT, 25-27 July 2016. (2016)

“Synthesis and Ignition of Ionic Liquids as Hypergolic Propellants,” JPL Visit, Stanford, CA, February 29th, 2016. Oral presentation to JPL representatives. (2016)

“Synthesis and Ignition of Green Hypergolic Propellants,” Astronaut Scholar Technical Conference, Cocoa Beach, FL, May 14th, 2016. Oral presentation to fellow scholars, community, and astronauts. (2016)

“Synthesis and Ignition of Hypergolic Propellants,” Stanford Aero/Astro PhD qualifying exams oral presentation, November 5th, 2015. (2015)

“Fundamental Studies of Green Rocket Propellants,” Astronaut Scholar Technical Conference, Cocoa Beach, FL, May 30th, 2015. Oral presentation to fellow scholars, community, and astronauts. (2015)

“Heating and Efficiency Comparison of a Fischer-Tropsch (FT) Fuel, JP-8+100, and Blends in a Three-Cup Combustor Sector,” Proceedings of ASME Turbo Expo 2012 GT2012 June 11-15, 2012, Copenhagen, Denmark. Oral presentation. (2012)

“Alternate-Fueled Combustor-Sector Performance.” in Submitted to Proceedings of the 14th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC14 '12) Honolulu, HI, February 27th-March 2nd, 2012. Oral presentation. (2012)

“Green Planet Architecture-A Methodology for Self-Sustainable Distributed Renewable Energy Ecosystems.” in Submitted to Proceedings of the 14th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC14 '12), Honolulu, HI, February 27th-March 2nd, 2012. Joint oral presentation. (2012)

“Combustor Sector Performance with Synthetic-Paraffinic-Kerosene Fischer-Tropsch Fuel,” 2011 Workshop on Environment and Alternative Energy, European Space Agency Technical Center, Noordwijk, Netherlands, November 16th, 2011. Oral presentation. (2011)

“Green Planet Architecture: A Methodology for Self-Sustainable Distributed Renewable Energy Ecosystems,” 2011 Workshop on Environment and Alternative Energy, European Space Agency Technical Center, Noordwijk, Netherlands, November 16th, 2011. Joint oral presentation. (2011)

“Combustor Sector Performance with Synthetic-Paraffinic-Kerosene Fischer-Tropsch Fuel,” 2011 Workshop on Environment and Alternative Energy, European Space Agency Technical Center, Noordwijk, Netherlands, November 16th, 2011. Student poster. (2011)

“Protein/Metabolite Interactions,” 2011 AIChE Annual Student Conference, Minneapolis, MN, October 14-17th, 2011. Student poster. (2011)

“Protein/Metabolite Interactions: Engineering Yeast for Biofuel Applications,” 2011 Air Productions Research Symposium, Georgia Tech, Atlanta, GA, April 2011. Student poster. (2011)

Awards and Fellowships

Director's Award for Exceptional Performance

Nominated by my team to receive distinguished award for research contributions.

Except from nomination letter: *"In the relatively short time that she has been at NREL, Anna has made significant scientific contributions to the group and has also impacted the NREL community at large. She has shown outstanding technical leadership in design and development of an optically accessible chemical reactor and associated spectroscopy setup for the study of advanced fuel autoignition and soot formation chemistry."*

Director's Fellowship - National Renewable Energy Laboratory

One of four selected for the prestigious fellowship covering three years of postdoctoral work.

Best Student Paper

June 2019 Joint Army-Navy-NASA-Air Force (JANNAF) Meeting, Dayton, OH.

Zonta Amelia Earhart Fellowship

One of 35 selected internationally, 2017-2018.

Future Space Leader Grant

One of seven selected nationwide for conference travel funding, 2017-2018.

National Science Foundation Graduate Research Fellowship

Three years fellowship funding for graduate studies, 2014-2017.

Fulbright Research Grant - Germany

Grant awarded for 10 months of research (experimental combustion instabilities and CFD) in Munich, Germany preceded by a 7-week intensive German language course in Marburg, Germany, 2013-2014.

Astronaut Scholarship

1 of 22 students nationwide selected to receive the Astronaut Scholarship and represent Georgia Tech, 2012-2013.

NASA Aeronautics Scholarship

1 of 20 selected nationwide to receive the two-year scholarship and NASA internship based on a written plan for future aeronautics research, 2010-2012.

President's Undergraduate Research Award

Award received based on research proposal and progress in both fall 2011 and fall 2012.

Air Products Undergraduate Sustainability Research Program

Funding received by Air Products for research in spring 2011 and spring 2013.

Languages and Skills

Languages: English (native), French (Advanced), German (Intermediate), Spanish (Beginner)

Computational: MATLAB, Gaussian, GaussView, LaTeX, Julia, Python, CHEMKIN.

Chemical Diagnostics: Fourier transform infrared (FTIR) spectroscopy; gas chromatography (GC); mass spectroscopy (MS); thermogravimetric analysis coupled with mass spectrometry (TGA-MS); attenuated total reflectance (ATR); high speed imaging.

Design: optical-access reactor design; laboratory space and apparatus design; hybrid rocket motor design, build, and test with a team.

Other Laboratory Techniques: hypergolic ionic liquid synthesis; hypergolic ignition delay testing at atmospheric conditions; synthesis of pyrophoric igniter materials; combustion instabilities hot-fire testing; phase doppler anemometry; combustion one-sector rig testing under forced and stable conditions; aerodynamic flow testing using pressure sensor analysis; polymerase chain reactions (PCR); gene transformations; DNA mini-prep; yeast and E. coli. transformations; enzymatic DNA digestions; PCR and primer design; gene insertion and ligation; lathe; mill; sand casting.

References **Robert (Bob) McCormick** - National Renewable Energy Laboratory
Postdoctoral Fellowship Mentor/Advisor, Senior Research Fellow
Email: Robert.McCormick@nrel.gov
Phone number: 303-385-7258
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Golden, CO 80401

Steven (Steve) Chambreau - Air Force Research Laboratory
PhD Co-Advisor, Physical Chemist
Email: steven.chambreau.ctr@us.af.mil
Phone number: 650-942-4492
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Tehachapi, CA 93561

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William (Bill) Kindred - National Renewable Energy Laboratory
Collaborator on Diversity, Equity, and Inclusion work; Director of Diversity and Inclusion
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