The Penn State Astrobiology Research Centers (PSARC)

Christopher H. House, Director

Proposed Participants:
Neyda Abreu (Earth Sciences and Mathematics), Philip C. Bevilacqua (Chemistry), Sven G. Bilen (Engineering Design), Susan L. Brantley (Geosciences), Rebekah I. Dawson (Astronomy and Astrophysics), Min Ding (Smeal College of Business), Matt S. Fantle (Geosciences), Brad Foley, Eric Ford, Katherine H. Freeman (Geosciences), Christopher H. House (Geosciences), James F. Kasting (Geosciences), Jack Langelaan (Aerospace Engineering), Christine D. Keating (Chemistry), Jennifer L. Macalady (Geosciences), Suvrath Mahadevan (Astronomy and Astrophysics), Jessie R. Reimink (Geosciences), Alex Rattner (Mechanical Engineering), Steinn Siggurdson (Astronomy and Astrophysics), Jason T. Wright (Astronomy and Astrophysics), Darren Williams (Astrophysics and Physics), Alex Wolszczan (Astronomy and Astrophysics)

Rationale:
Overview
The re-envisioned Penn State Astrobiology Research Centers (PSARC) would foster NASA-relevant research across Pennsylvania State University, enabling effective collaboration related to the **Origin of Life**, **Life Detection**, **Life in Extreme Environments**, and **Planetary Science**. The center would carry on this role in a new era for astrobiological research at Penn State. Presently, there more than half a dozen focused groups and centers at Penn State working within the field of astrobiology. The proposed PSARC would provide a means for these different focused teams to have cross-communication and coordination without diminishing their team coherence. The primary activities would be social coffee hangouts, brain storming events, project and proposal development, and constructive representation of astrobiology to Penn State administration. There is a need for a long-term, stable organizational entity devoted to astrobiology at Penn State because of the high number of faculty involved, our recognized leadership in the area, and the excellent prospects for future collaborative projects. Overall, the primary objectives of PSARC align with the goals of EESI by being dedicated to promoting interaction among faculty and students in an interdisciplinary field within the environmental sciences and fostering the securing of extramural funding for multi-PI projects.

History and Landscape
In 1998, the original Penn State Astrobiology Research Center was formed when Penn State joined the NASA Astrobiology Institute. Penn State's direct NAI involvement continued with another 5-year project called "The Evolution of a Habitable World." In 2008, Penn State received a third NAI grant for the project "Signatures from Earth and Beyond," and a fourth NAI grant for Dr. Katherine Freeman's project "The Origins of Molecules in Diverse Space and Planetary Environments and Their Intramolecular Isotope Signatures." This legacy of successful research as part of the NASA Astrobiology Institute has had a positive impact on Penn State students and faculty. It has provided a stable environment for collaboration, fostered communication, and encouraged expanded astrobiological research at Penn State. Recently, NASA has retired the NAI model with a recognition that astrobiological research now permeates through many of its various grant programs and flight missions. Similarly, over the past twenty years, a number of different focused groups and centers for astrobiological research have been

formed by Penn State faculty. The Center for Exoplanets and Habitable Worlds (CEHW) was established in 2008 by Dr. Alex Wolszczan to promote research related to the discovery and understanding of planets and possible habitable wolds outside of the Solar System. Led by Katherine Freeman, the newly formed Astrobiology Center for Isotopogue Research (ACIR) seeks to discover and document isotope patterns in organic molecules found in meteorites, dissolved in deep Earth fluids, from individual living organisms, within microbial ecosystems, and in organics associated with minerals and ice. Employing advanced computational tools and a rich observation portfolio, they plan to build a predictive understanding of how abiotic and biotic processes and environments are encoded in the isotopes of simple to complex organic compounds. The Penn State Extraterrestrial Intelligence Center (PSETI) is the academic hub for the search for technological signs of life elsewhere in the universe. It is an interdisciplinary center, focused on developing SETI as a discipline, educating the next generation of SETI researchers, fostering international collaboration through an annual symposium, and developing and searching for "technosignatures" as a path to life detection. It is headed by Prof. Jason T. Wright. Penn State is also a member of the NASA NFOLD research network through the Laboratory for Agnostic Biosignatures project headed by Dr. Sarah Stewart Johnson at Georgetown University. This team is working to understand how biosignatures can be applied assuming as little as possible about life as we know it from Earth. Penn State is part of the NASA Dragonfly Mission. Finally, the NASA Pennsylvania Space Grant Consortium (PSGC) has been promoting NASA-relevant space-related higher education since 1989. Penn State is the PSGC's lead institution, which hosts the Student Space Programs Laboratory (SSPL) and Lunar Lion teams. If funded, the PSARC would include leadership from each of these various focused groups, as well as a wide assortment of faculty engaged in astrobiology and poised for continued success with NASA-funded projects. The PSARC would provide a stable framework for the on-going astrobiological conversations at Penn State, as well as for the strategic expansion of astrobiological research including the anticipated submission of NASA mission concept proposals.

Funding Opportunities:
The primary funding opportunities are from the NASA research and analyses programs (e.g., Exobiology, Habitable Worlds, and ICAR), as well as the PI-lead NASA mission concept programs (Explorer, Discovery, and New Frontiers).

Center Needs:
The new re-envisioned PSARC is proposed to share space with the Pennsylvania Space Grant Consortium. Additionally, the center requests $4,910 (±714) per year to enable activities that actively engage the community and facilitate proposal and project development, and travel for project development at NASA Centers by two PSARC faculty per year.

Yearly Budget:
Nine group meals with twelve people at each meal (9x12x$30 = $3,240).
Travel = $956 to $2,383
Three-night trip to NASA GSFC (two people) per year* = $956-$2,383
Rental Car = $99, Gas = $35, Lodging (2x$96 per night) = $576
Food ($41 per day per person) = 246
Or a three-night trip to JPL in Pasadena, CA = $2,383

Two airline tickets = $1,000, Lodging (2x$181 per night) = $1,086, Food ($49.50 per day per person) = $297

Management Structure:
Because PSARC is envisioned to facilitate discussion between faculty that are already involved in more focused groups and centers, we propose to have a seven-person council that represents these focused groups, managed by three PSARC-specific leads. The leads would be the Director plus Deputy Directors representing the College of Science and the College of Earth and Mineral Sciences.

- Director Christopher H. House (Geosciences)
- College of Science Deputy Director Steins Siggurdson (Astrophysics and Astronomy)
- College of Earth & Mineral Sciences Deputy Director: Jennifer Macalady (Geosciences)
- Astrobiology-related Penn State Center Directors on PSARC council:
  Katherine Freeman (ACIR), Eric Ford (CEHW), James F. Kasting (Astrobiology dual-title program), Jason Wright (PSETI),

Prior Expenditures and Past Work:
The original PSARC reviewed above was directly involved with four successful multi-investigator proposals from the NASA Astrobiology Institute (1998, 2003, 2008, and 2018), a successful NFOLD proposal in 2018, as well as two successful, large NSF instrument development proposals for new spectrographs for Earth-based telescopes. PSARC was also involved with facilitation of several failed NASA proposals for NAI, NFOLD, and ICAR funding, as well as a failed NASA Discover-program mission concept proposal. This past history provides an appropriate view of the kinds of outcomes that this effort aims to continue to deliver for the Pennsylvania State University.

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Professional Preparation

1999 Ph.D. in Geology, University of California, Los Angeles
"Carbon Isotopic Fractionation by Diverse Extant and Fossil Prokaryotes"
Graduate advisor – J. William Schopf, Ph.D.

1995 B.S. in Biochemistry & Cell Biology, University of California, San Diego
Undergraduate advisor – Stanley L. Miller, Ph.D.

Appointments

2012-present	Professor of Geosciences, The Pennsylvania State University
2008-present	Pennsylvania Space Grant Consortium, Director
2008-present	Penn State Astrobiology Research Center, Director
2000-present	Huck Institute for the Life Sciences faculty appointment, Penn State
2006-2012	Associate Professor of Geosciences, Penn State
2000-2006	Assistant Professor of Geosciences, Penn State
1998-1999	Research Assistant, IGPP Center for Astrobiology, UCLA
1997-1997	Visiting Researcher, Lehrstuhl für Mikrobiologie, Regensburg, Germany
1996-1998	Teaching/Research Assistant, ESS, UCLA
1993-1994	Summer Fellow, NSCORT in Exobiology

Honors and Awards

2017-present	Member of the European Science Foundation's ESSC ExoOceans Study Group
2016	Fellow of the Geological Society of America (GSA)
2016-present	Co-chair of NAS Committee for Astrobiology and Planetary Sciences (CAPS)
2016-present	Participating Scientist for the Mars Science Laboratory (MSL) Mission
2012-2016	Member of NASA Advisory Council, Planetary Sciences Subcommittee
2006-2007	Ocean Drilling Program Distinguished Lecturer
2005-2008	Scientific Ocean Drilling Vessel (SODV) Program Advisory Committee Member
1996-1997	Graduate Fellow, UCLA Center for the study of Evolution and the Origin of Life
1994-1995	Adjunct Fellow, NSCORT in Exobiology

Select Peer-reviewed Journal Publications

Rodriguez, L. E., House, C. H., Smith, K. E., Roberts, M. R., & Callahan, M. P., 2019. Nitrogen heterocycles form peptide nucleic acid precursors in complex prebiotic mixtures. *Scientific Reports*, *9*, 9281.

Smith, K. E., House, C. H., Arevalo, R. D., Dworkin, J. P., & Callahan, M. P., 2019. Organometallic compounds as carriers of extraterrestrial cyanide in primitive meteorites. *Nature com.*, *10*, 2777.

Stein, N., et al., 2018. Desiccation cracks provide evidence of lake drying on Mars, Sutton Island member, Murray formation, Gale Crater. *Geology*, *46*, pp.515-518.

Franz, H. B., Fischer, W. W., Grotzinger, J. P., & Farley, K. A., 2017. Large sulfur isotope fractionations in Martian sediments at Gale crater. *Nature Geoscience*, *10*, 658-662.

Sutter, B., et al., (2017). Evolved gas analyses of sedimentary rocks and eolian sediment in gale crater, mars: results of the curiosity Rover's Sample Analysis at Mars (SAM) instrument from Yellowknife Bay to the Namib Dune. *Journal of Geophysical Research: Planets*.

Oehler, D. Z., Walsh, M. M., Sugitani, K., Liu, M. C., & House, C. H., 2017. Large and robust lenticular microorganisms on the young Earth. *Precambrian Research*, *296*, 112-119.
Brandt, L.D. and House, C.H., 2016. Marine Subsurface Microbial Community Shifts Across a Hydrothermal Gradient in Okinawa Trough Sediments. *Archaea*.
House, C. H., Oehler, D. Z., Sugitani, K., and Mimura, K., 2013. Carbon isotopic analyses of ca. 3.0 Ga microstructures imply planktonic autotrophs inhabited Earth's early oceans. *Geology*, *41*(6), 651-654.
Cameron, V., House, C. H., and Brantley, S. L., 2012. A First Analysis of Metallome Biosignatures of Hyperthermophilic Archaea. *Archaea*.
House, C.H., Beal, E.J., and Orphan, V.J., 2011. The Apparent Involvement of ANMEs in Mineral Dependent Methane Oxidation, as an Analog for Possible Martian Methanotrophy. *Life.* 1: 19-33.
Callahan, M.P., Smith, K.E., Cleaves, H.J.,II, Ruzicka, J., Stern, J.C., Glavin, D.P., House, C.H., and Dworkin, J.P., 2011. Carbonaceous meteorites contain a wide range of extraterrestrial nucleobases**.** *Proceedings of the National Academy of Sciences*.
Beal, E.J., House, C.H., Orphan, V.J., 2009. Manganese- and Iron- Dependent Marine Methane Oxidation. *Science*, 325: 184 – 187.
Cameron, V., Vance, D. Archer, C. House, C.H., 2009. Nickel Stable Isotopes: A Novel Isotope Biomarker. *Proceeding of the National Academy of Sciences*, 106: 10944-10948.
Orphan, V.J., and House, C.H., 2009. Geobiological investigations using secondary ion mass spectrometry (SIMS): microanalytical analysis of extant and ancient microbial processes. *Geobiology*, 7: 360 – 372.
House, C.H. 2009. The Tree of Life viewed through the contents of genomes. *Methods in Molecular Biology*, 532: 141-161.
Zerkle, A.L., C.K. Junium, D.E. Canfield, House, C.H., 2008. Production of ^{15}N-depleted biomass during cyanobacterial N_2-fixation at high Fe concentrations, *JGR*, 113: G03014.
Biddle, J.F., Fitz-Gibbon, S.T., Schuster, S.C., Brenchley, J.E., House, C.H., 2008. Metagenomic signatures of the subseafloor biosphere. *PNAS*, 105: 10583-10588.
Ferry, J.G, and House, C.H., 2006. The Stepwise Evolution of Early Life Driven by Energy Conservation. *Molecular Biology and Evolution*, 23: 1286-1292.
Zerkle, A.L., House, C.H., Cox, R.P., Canfield, D.E., 2006. Metal limitation of cyanobacterial N2 fixation and implications for the Precambrian nitrogen cycle. *Geobiology*, 4: 285-297.
Zerkle, A.L., House, C.H., Brantley, S., 2005 Genomic Study of Biogeochemical Signatures for Microbial Metabolisms through Time. *American Journal of Science*, 305: 467-502.
D'Hondt, S., and 34 others., 2004. Distributions of Microbial Activities in Deep Subseafloor Sediments. *Science*, 306: 2216-2221.
House, C.H., Schopf, J.W., Stetter, K.O., 2003. Carbon isotopic fractionation by Archeans and other thermophilic Prokaryotes. *Organic Geochemistry*, 34: 345-356.

Graduate Students Advised

Karianne L. C. Smith (M.Ed.), Aubrey Zerkle (Ph.D.), Jennifer Biddle (Ph.D., co-advised), Jim Moran (Ph.D.), Vyllinniskii Cameron (Ph.D.), Beth A. Bauman (M.S.), Burt Thomas (Ph.D., co-advised), Emily J. Beal (Ph.D.), Moshe Rhodes (Ph.D.), Amanda Martino (Ph.D.), Karen Smith (Ph.D.), Peter Ilhardt (M.S.), Leah Brandt (Ph.D.), Regina Wilpiszeski (Ph.D.), Laura Rodriguez (Ph.D.), Greg Wong (Ph.D.), Andrew Hyde (Ph.D.), Esther Muñoz (Ph.D.), Hillary Smith (Ph.D.).

Postdoctorial Students Advised

Jennifer Biddle, Ph.D., Lisa Steinberg, Ph.D., Rachel Wagner, Ph.D., and Jeff Havig, Ph.D.