Abstract: Many current methods of analysis and design are performed using ad-hoc heuristic and/or parametric methods are inefficient, but more importantly—may be ineffective as well. Every experiment is designed—unfortunately most are improperly designed based upon lack of knowledge of the physics and/or lack of statistical knowledge. Several examples will be introduced that demonstrate the benefit of using physics-based design (1st & 2nd Laws of Thermodynamics) coupled with advanced statistical techniques (Design of Experiments (DoX), inferential statistics, response surfaces, canonical and/or orthogonal designs, hyperspace visualization). An overview of Design of Experiments (DoX) will be provided with emphasis on data-driven statistical models from experiments as well as simulation-based statistical models relevant to AEDC. A mechanical system (steam plant), an electrical system (simple circuit), and an aerospace system (supersonic turbojet and wing section) will be used to demonstrate the statistically-based analysis, design, and optimization process.

Throughout the process, emphasis is placed on correctly employing physics (2nd Law in particular) as well as statistically-designed analysis points for increased leverage of information after the data is taken. The focus in the statistical modeling is to gain knowledge, not gather data. Combing the proper physics with the statistical design and analysis of the information provides a unique and powerful interpretation of the data, providing maximum utility of the information with minimum number of data points required. This information is further leveraged with advanced visualization techniques to enable the entire design and/or analysis space to be simultaneously interpreted.

The processes overviewed are easily adapted to existing systems, such as those at AEDC. Employing advanced statistical techniques with physics-based modeling and simulation can provide insights not possible with current analysis techniques. The goal of applying these techniques is to improve the efficiencies of large power systems, saving energy (money), time, as well as reducing the carbon footprint of these systems.
Author Bio: Dr. John H. Doty earned his Bachelor of Science degree in Chemical Engineering from Clarkson University in Upstate New York. After working as a process/production engineer for Occidental Petroleum, he joined the US Air Force and earned his B.S. and M.S. in Aeronautical Engineering at the same time from the Air Force Institute of Technology. He joined the Air Force Research Laboratory and worked on combustion, flow mixing, and aero-acoustic effects in F-4 engines as well as advanced analyses for exotic engine cycles as a lead engineer for the National AeroSpace Plane (NASP) program. He continued his education at Purdue University, earning his Ph.D. in Mechanical Engineering.

In 1991, Dr. Doty joined the Air Force Institute of Technology (AFIT) as an assistant professor, developing the hypersonics curriculum supporting the NASP program. Additional research focused on computational techniques in hypersonic propulsive techniques, design of optimal hypersonic wind tunnels, as well as statistical designs using Design of Experiments (DoX). In 1995, he joined the faculty at the US Naval Academy, focusing on space-based applications supporting the US Navy and the US Space Program with NASA, including the Hubble Space Telescope, the mission to Mars, and Navy flight test programs.

In 1998, he retired from the Air Force to pursue consulting work at the highest levels of government, developing policies and procedures for the US Army as well as systems engineering consulting, emphasizing business workflow, process efficiency, requirements management, and product development. Dr. Doty then joined the faculty at the University of Dayton in 2002 and began research with AFRL in 2007, working with both the Air Vehicles and Propulsion Directorates on analysis and design of aerospace systems using combined 1\textsuperscript{st} & 2\textsuperscript{nd} Laws of Thermodynamics, statistical Design of Experiments (DoX), hyperspace visualization techniques, and data-based and physical modeling and simulation using stochastic mathematics. His current research focuses on the science of integration, developing advanced mathematical techniques to capture salient physical models of complex systems for multidisciplinary analysis and design optimization.