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School of Aeronautics and Astronautics
Special Seminar

Entropy Mystique: The Second Law of Thermodynamics in Aerospace Systems Analysis & Design

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Abstract: All physical processes generate entropy: Life itself may well be impossible without a means for entropy production. Conversely, one of the early developers of the theory of entropy, Rudolf Clausius contemplated a morose perspective: "…entropy tends to a maximum…when the maximum is reached, no further changes can occur; the world is then in a dead stagnant state." Given the universal applicability of the concept of entropy, the almost reverent recognition that the second law of thermodynamics holds a central place in modern science, it is surprising that the mention of entropy often elicits confusion, blank stares, and sometimes even bland indifference when presented to most audiences, even those technically inclined. For the past decade, we have labored to tease out the practical implications and applications of the second law, by developing methods useful for the analysis and design synthesis of aerospace vehicles.

Aerospace vehicle design has historically been conducted in stages of (mostly independent) development of engine, airframe, avionics & control, and then perhaps life cycle maintenance and optimization after-the-fact. This (conventional) approach saved money in the past as components and systems were re-used from one system to another (e.g. using the same, or nearly the same, engine in more than one aircraft.). However, this approach does not necessarily produce the optimum system performance. In fact, after integration of all subsystems into an overall system, the ad-hoc approach often introduces a penalty for each subsystem compared to its "stand alone" performance. Overall system performance is often quite different than the standalone subsystem's performance may suggest.

Advanced design methodologies now based on various forms of the second law (exergy, entropy, and availability) are in various stages of development and implementation. However, these approaches, in general, are not well accepted by the engineering and design community at-large due to the sometimes nebulous terminology and often ill-suited use of example problems. Many of these newer approaches appear to lack relevance to the aerospace community. We will present a few simple examples using a methodology for analysis, based on combined energy and entropy principles (1st and 2nd Laws) and compare to the traditional methodology that employs energy principles only (1st Law). The understanding gained from the simpler systems translates directly into more complex systems and provides the foundation for more sophisticated analysis, design, and optimization.

Author Bio: Dr. José Camberos is a native of Mexico, raised in Southern California. He earned his Bachelor of Science degree in Mechanical and Materials Science Engineering from the University of California at Berkeley. He continued his education at Stanford University and earned his Master of Science degree in Aerospace Engineering and a Ph.D. in the same field. In addition to his technical degrees, Dr. Camberos also earned a Master of Arts degree in the history and philosophy of science. In 1992, Dr. Camberos joined the Flight Dynamics Directorate under the Air Force Senior Knight Program, joining the Thermal Structures Branch where he was involved in the research and development of analytical techniques for thermophysical fluid-structure interactions in the Extreme Environment Structures core area. In 1999, he joined the Computational Sciences Branch where he worked on the development of a finite-volume time-domain computational electromagnetics code. In 2005, he joined the Multidisciplinary Technologies Center and jointly with Dr. Dave Moorhouse pursued the development of exergy–based analysis and design for aerospace vehicle systems analysis and design. Dr. Camberos currently serves as Assistant to Chief Scientist of the Air Vehicles Directorate and continues to pursue technical activities related to multidisciplinary analysis and design optimization.