bearings operating at high temperatures are an emerging technology making commercial inroads into several markets including aircraft auxiliary power units (APUs), microturbines, gas compressors and blowers, and turbochargers.

The general trend for foil bearings since their initial development over five decades ago is application to larger and more complex rotor systems. As this proliferation occurs, more practitioners will become actively involved with new machine development using foil bearings. Thus, there is a great need for application guidelines to establish the feasibility of proposed rotor systems and to identify existing machines that are good candidates for foil bearing use. Specifically, a method is needed to estimate foil bearing stiffness and damping behavior in order to foster advanced oil-free rotating machine development.

Methods to estimate critical stiffness and damping parameters, however, do not currently exist. The purpose of the methods put forth in this work is to establish simple tools capable of estimating foil bearing stiffness and damping coefficients suitable for oil-free rotor support design work. This has been accomplished by first coalescing all available empirical data on foil bearing performance that has been generated in the author's own laboratories, and by researchers working in university, government, and industrial laboratories. This information is examined and combined, then used to develop ROT for foil bearing stiffness and damping. These ROTs can then be combined with existing rules for load capacity to obtain credible feasibility assessments for proposed oil-free rotor systems.

The effort described has resulted in algebraic models for foil gas bearings that yield stiffness, damping, and load capacity values as a function of bearing size, design, and operating speed. With these models, one can easily determine the feasibility of building a foil bearing supported machine without incurring the expense of early experimental work. The models presented represent the only known and verified methods to predict conveniently foil bearing performance properties.

This work was done by Christopher DellaCorte of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18755-1.

Sampling and Reconstruction of the Pupil and Electric Field for Phase Retrieval

Goddard Space Flight Center, Greenbelt, Maryland

This technology is based on sampling considerations for a band-limited function, which has application to optical estimation generally, and to phase retrieval specifically. The analysis begins with the observation that the Fourier transform of an optical aperture function (pupil) can be implemented with minimal aliasing for Q values down to $Q = 1$. The sampling ratio, Q, is defined as the ratio of the sampling frequency to the band-limited cut-off frequency. The analytical results are given using a 1-d aperture function, and with the electric field defined by the band-limited $\mathrm{sinc}(x)$ function. Perfect reconstruction of the Fourier transform (electric field) is derived using the Whittaker-Shannon sampling theorem for $1<Q<2$.

The Fourier transform is constructed by periodic extension, i.e., by spacing copies of the transform in a definite way, recognizing that no aliasing occurs for values of the sampling ratio such that $1<Q<2$, which can be used to advantage in the application of phase retrieval estimation. A method was developed for propagating the electromagnetic field with no aliasing, which has been extended to 2-d optical apertures.

This work was done by Bruce Dean, Jeffrey Smith, and David Aronstein of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15947-1

Space Operations Learning Center Facebook Application

This app uses the latest networking technology to inspire young audiences to be interested in math, science, and engineering.

Goddard Space Flight Center, Greenbelt, Maryland

The proposed Space Operations Learning Center (SOLC) Facebook module, initially code-named "Spaceville," is intended to be an educational online game utilizing the latest social networking technology to reach a broad audience base and inspire young audiences to be interested in math, science, and engineering.

Spaceville will be a Facebook application/game with the goal of combining learning with a fun game and social environment. The mission of the game is to build a scientific outpost on the Moon or Mars and expand the colony. Game activities include collecting resources, trading resources, completing simple science experiments, and building architectures such as laboratories, habitats, greenhouses, machine shops, etc. The player is awarded with points and achievement levels. The player's ability increases as his/her points and levels increase. A player can interact with other players using multiplayer Facebook functionality. As a result, a player can discover unexpected treasures through scientific missions, engineering, and working with others.

The player creates his/her own avatar with his/her selection of its unique appearance, and names the character. The player controls the avatar to perform activities such as collecting oxygen molecules or building a habitat. From observations of other successful social online games such as Farmville and Restaurant City, a common element of these games is having eye-catching and cartoonish characters, and interesting animations for all activities. This will create a fun, educational, and rewarding environment.

The player needs to accumulate points in order to be awarded special items needed for advancing to higher levels. Trophies will be awarded to the player when certain goals are reached or tasks are completed. In order to acquire some special items needed for advancement in the game, the player will need to visit his/her neighboring towns to discover the items. This is the social aspect of the game that requires the player to go out of his/her own establishment to explore what is in the neighborhood. Spaceville will take advantage of Facebook's successful architecture to inspire a new audience of scientists and engineers for the future.

This work was done by Ben Lui and Barbara Milner of Goddard Space Flight Center, Dan Binebrink of SGT Inc., and Heng Kuok of Sigma Space Corp. Further information is contained in a TSP (see page 1). GSC-16214-1

Rotorcraft Diagnostics

John H. Glenn Research Center, Cleveland, Ohio

Health management (HM) in any engineering systems requires adequate understanding about the system's functioning; a sufficient amount of monitored data; the capability to extract, analyze, and collate information; and the capability to combine understanding and information for HM-related estimation and decision-making. Rotorcraft systems are, in general, highly complex. Obtaining adequate understanding about functioning of such systems is quite difficult, because of the proprietary (restricted access) nature of their designs and dynamic models. Development of an EIM (exact inverse map) solution for rotorcraft requires a process that can overcome the above-mentioned difficulties and maximally utilize monitored information for HM facilitation via employing advanced analytic techniques.

The goal was to develop a versatile HM solution for rotorcraft for facilitation of the Condition Based Maintenance Plus (CBM+) capabilities. The effort was geared towards developing analytic and reasoning techniques, and proving the ability to embed the required capabilities on a rotorcraft platform, paving the way for implementing the solution on an aircraft-level system for consolidation and reporting.

The solution for rotorcraft can he used offboard or embedded directly onto a rotorcraft system. The envisioned solution utilizes available monitored and archived data for real-time fault detection and identification, failure precursor identification, and offline fault detection and diagnostics, health condition forecasting, optimal guided troubleshooting, and maintenance decision support. A variant of the onboard version is a self-contained hardware and software (HW+SW) package that can be embedded on rotorcraft systems.

The HM solution comprises components that gather/ingest data and information, perform information/feature extraction, analyze information in conjunction with the dependency/diagnostic model of the target system, facilitate optimal guided troubleshooting, and offer decision support for optimal maintenance.

This work was done by Deepak Haste, Mohammad Azam, Sudipto Ghoshal, and James Monte of Qualtech Systems for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18672-1.

Recursive Branching Simulated Annealing Algorithm

The algorithm can be applied to a wide variety of optimization problems.

Goddard Space Flight Center, Greenbelt, Maryland

This innovation is a variation of a simulated-annealing optimization algorithm that uses a recursive-branching structure to parallelize the search of a parameter space for the globally optimal solution to an objective. The algorithm has been demonstrated to be more effective at searching a parameter space than traditional simulated-annealing methods for a particular problem of interest, and it can readily be applied to a wide variety of optimization problems, including those with a parameter space having both discrete-value parameters (combinatorial) and continuous-variable parameters. It can take the place of a conventional simulated-annealing, Monte-Carlo, or random-walk algorithm.

In a conventional simulated-annealing (SA) algorithm, a starting configuration is randomly selected within the parameter space. The algorithm randomly selects another configuration from the parameter space and evaluates the objective function for that configuration. If the objective function value is better than the previous value, the new configuration is adopted as the new point of interest in the parameter space. If the objective function value is worse than the previous value, the new configuration may be adopted, with a probability determined by a temperature parameter, used in analogy to annealing in metals. As the optimization continues, the region of the parameter space from which new configurations can be selected shrinks, and in conjunction with lowering the annealing temperature (and thus lowering the probability for adopting configurations in parameter space with worse objective functions), the algorithm can converge on the globally optimal configuration.

The Recursive Branching Simulated Annealing (RBSA) algorithm shares some features with the SA algorithm, notably in-