or an element into which functionally related sensors are grouped.

- “Element” can signify a component (e.g., an actuator, a valve), a process, a controller, an actuator, a subsystem, or a system.

- The term Integrated System Health Management (ISHM) is used to describe a capability that focuses on determining the condition (health) of every element in a complex system (detect anomalies, diagnose causes, prognosis of future anomalies), and provide data, information, and knowledge (DIaK) — not just data — to control systems for safe and effective operation.

A major novel aspect of the present development is the concept of intelligent integration. The purpose of intelligent integration, as defined and implemented in the present IHMS, is to enable automated analysis of physical phenomena in imitation of human reasoning, including the use of qualitative methods. Intelligent integration is said to occur in a system in which all elements are intelligent and can acquire, maintain, and share knowledge and information.

In the HDNIE of the present IHMS, an SoS is represented as being operationally organized in a hierarchical-distributed format. The elements of the SoS are considered to be intelligent in that they determine their own conditions within an integrated scheme that involves consideration of data, information, knowledge bases, and methods that reside in all elements of the system.

The conceptual framework of the HDNIE and the methodologies of implementing it enable the flow of information and knowledge among the elements so as to make possible the determination of the condition of each element. The necessary information and knowledge is made available to each affected element at the desired time, satisfying a need to prevent information overload while providing context-sensitive information at the proper level of detail.

Provision of high-quality data is a central goal in designing this or any IHMS. In pursuit of this goal, functionally related sensors are logically assigned to groups denoted processes. An aggregate of processes is considered to form a system. Alternatively or in addition to what has been said thus far, the HDNIE of this IHMS can be regarded as consisting of a framework containing object models that encapsulate all elements of the system, their individual and relational knowledge bases, generic methods and procedures based on models of the applicable physics, and communication processes (Figure 2). The framework enables implementation of a paradigm inspired by how expert operators monitor the health of systems with the help of (1) DIaK from various sources, (2) software tools that assist in rapid visualization of the condition of the system, (3) analytical software tools that assist in reasoning about the condition, (4) sharing of information via network communication hardware and software, and (5) software tools that aid in making decisions to remedy unacceptable conditions or improve performance.

This work was done by Fernando Figueroa of Stennis Space Center, John Schmalzel of Rowan University, and Harvey Smith of Jacobs Sverdrup.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager, Stennis Space Center, (228) 688-1929. Refer to SSC-00234.
Spline-Based Smoothing of Airfoil Curvatures

Spurious curvature oscillations and bumps are suppressed.

Langley Research Center, Hampton, Virginia

Constrained fitting for airfoil curvature smoothing (CFACS) is a spline-based method of interpolating airfoil surface coordinates (and, concomitantly, airfoil thicknesses) between specified discrete design points so as to obtain smoothing of surface-curvature profiles in addition to basic smoothing of surfaces. CFACS was developed in recognition of the fact that the performance of a transonic airfoil is directly related to both the curvature profile and the smoothness of the airfoil surface.

Older methods of interpolation of airfoil surfaces involve various compromises between smoothing of surfaces and exact fitting of surfaces to specified discrete design points. While some of the older methods take curvature profiles into account, they nevertheless sometimes yield unfavorable results, including curvature oscillations near end points and substantial deviations from desired leading-edge shapes.

In CFACS as in most of the older methods, one seeks a compromise between smoothing and exact fitting. Unlike in the older methods, the airfoil surface is modified as little as possible from its original specified form and, instead, is smoothed in such a way that the curvature profile becomes a smooth fit of the curvature profile of the original airfoil specification.

CFACS involves a combination of rigorous mathematical modeling and knowledge-based heuristics. Rigorous mathematical formulation provides assurance of removal of undesirable curvature oscillations with minimum modification of the airfoil geometry. Knowledge-based heuristics bridge the gap between theory and designers’ best practices.

In CFACS, one of the measures of the deviation of an airfoil surface from smoothness is the sum of squares of the jumps in the third derivatives of a cubic-spline interpolation of the airfoil data. This measure is incorporated into a formulation for minimizing an overall deviation-from-smoothness measure of the airfoil data within a specified fitting error tolerance.

CFACS has been extensively tested on a number of supercritical airfoil data.