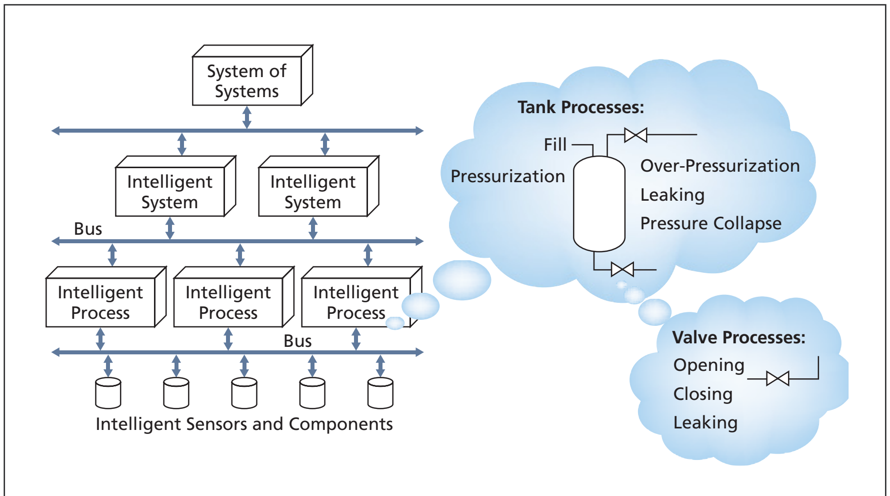


Figure 2. **Multiple Process Models** make possible an effective integrated approach.

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 IIHMS, 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 IIHMS, 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 IIHMS. 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 IIHMS 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.

Delay Banking for Managing Air Traffic

Delay credits could be expended to gain partial relief from flow restrictions.

Ames Research Center, Moffett Field, California

Delay banking has been invented to enhance air-traffic management in a way that would increase the degree of fairness in assigning arrival, departure, and en-route delays and trajectory deviations to aircraft impacted by congestion in the national airspace system. In delay banking, an aircraft operator (airline, military, general aviation, etc.) would be assigned a numerical credit when any of their flights are delayed because of an air-traffic flow restriction. The operator could subsequently bid against other operators competing for access to congested airspace to utilize part or all of its accumulated credit. Operators utilize credits to obtain higher priority for the same flight, or other flights operating at the same time, or later, in the same airspace, or elsewhere. Operators could also trade delay credits, according to market rules that would be determined by stakeholders in the national airspace system.

Delay banking would be administered by an independent third party who would use delay banking automation to continually monitor flights, allocate delay credits, maintain accounts of delay credits for participating airlines, mediate bidding and the consumption of credits of winning bidders, analyze potential transfers of credits within and between operators, implement accepted transfers, and ensure fair treatment of all participating operators.

A flow restriction can manifest itself in the form of a delay in assigned takeoff time, a reduction in assigned airspeed, a change in the position for the aircraft in a queue of all aircraft in a common stream of traffic (e.g., similar route), a change in the planned altitude profile for an aircraft, or change in the planned route for the aircraft. Flow restrictions are typically imposed to mitigate traffic congestion at an airport or in a region of airspace, particularly congestion due to inclement weather, or the unavailability of a runway or region of airspace.

A delay credit would be allocated to an operator of a flight that has accepted, or upon which was imposed, a flow restriction. The amount of the credit would increase with the amount of delay caused by the flow restriction, the exact amount depending on which of several candidate formulas is eventually chosen. For example, according to one formula, there would be no credit for a delay smaller than some threshold value (e.g., 30 seconds) and the amount of the credit for a longer delay would be set at the amount of the delay minus the threshold value. Optionally, the value of a delay credit could be made to decay with time according to a suitable formula (e.g., an exponential decay). Also, optionally, a transaction charge could be assessed against the value of a delay credit that an operator used on a flight different from the one for which the delay originated or that was traded with a different operator.

The delay credits accumulated by a given airline could be utilized in various ways. For example, an operator could enter a bid for priority handling in a new flow restriction that impacts one or more of the operator's flights; if the bid were unsuccessful, all or a portion of the credit would be returned to the bidder. If the bid pertained to a single aircraft that was in a queue, delay credits could be consumed in moving the aircraft to an earlier position within the queue. In the case of a flow restriction involving a choice of alternate routes, planned altitude profile, aircraft spacing, or other non-queue flow restrictions, delay credits could be used to bid for an alternative assignment.

This work was done by Steve Green of Ames Research Center.

This invention is owned by NASA and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Technology Partnerships Division at (650) 604-2954. Refer to ARC-15392-1.

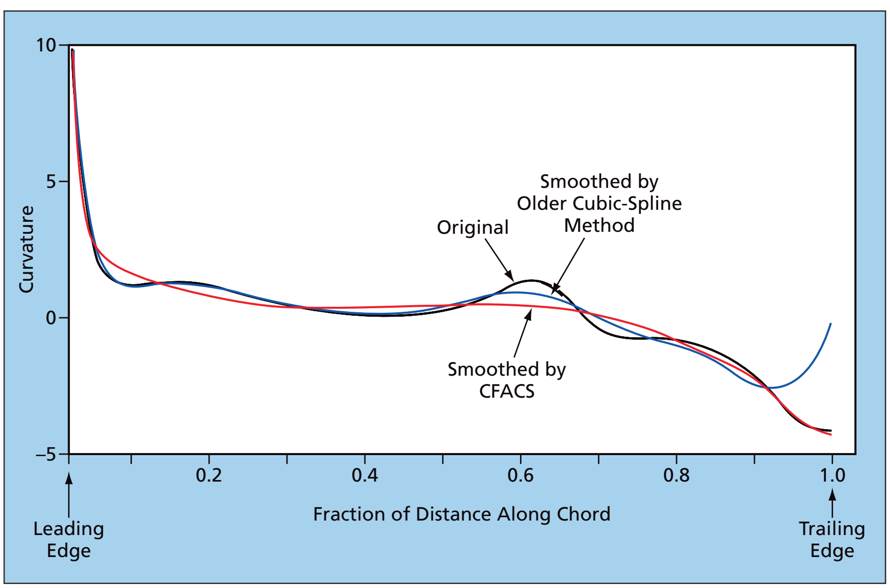
Spline-Based Smoothing of Airfoil Curvatures

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.



Curvature Profiles were computed for the lower surface of a supercritical airfoil. The CFACS profile closely fits the original profile at the trailing edge, whereas the profile generated by the older cubic-spline smoothing method exhibits substantial bias away from the original profile at the trailing edge.

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