



## Modernizing Fortran 77 Legacy Codes

**The investment in established codes is preserved as modern capabilities are added.**

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An incremental approach to modernization of scientific software written in the Fortran 77 computing language has been developed. This approach makes it possible to preserve the investment in legacy Fortran software while augmenting the software with modern capabilities to satisfy expanded requirements. This approach could be advantageous (1) in situations in which major rewriting of application programs is undesirable or impossible, or (2) as a means of transition to major rewriting.

Programs written in Fortran 77 and other early versions of Fortran retain much intellectual and commercial value. These codes have been carefully validated and often perform excellently, even on modern computers. However, the early versions of Fortran are often not adequate for the increasingly complex systems typically encountered in current practice. For example, early Fortran programs may not utilize dynamic memory or their data structures may not reflect problem domains well. Often, user interfaces are poor or nonexistent. On the other hand, modern programming languages (most notably, object-oriented languages) offer much better support for complex programming projects.

The developers of the present incremental approach have found that con-

trary to the conventional wisdom among object-oriented programmers, it is not necessary to redesign codes from the bottom up to make them object-oriented. Many object-oriented programs make use of non-object-oriented libraries for basic functions — for example, calling operating systems. The important question in modernization of a legacy code is whether the subroutines in the code have sufficient basic functionality. For most legacy codes that have been in use for a decade or more, this is the case. The weaknesses of legacy codes arise with respect to flexibility, extensibility, and related issues.

The present incremental approach is based partly on the assumption that such weaknesses can be addressed at a higher level, by building interface software libraries that mediate between main programs and underlying legacy codes. Major goals in this approach are to increase program safety, simplify interfaces to subroutines, add dynamic memory management, encapsulate different parts of programs, add abstract data types that reflect the problem domains, and add or improve user interfaces.

The present incremental approach can be characterized as one of building modern superstructures around legacy codes rather than completely rewriting those codes. Building such a superstruc-

ture increases the opportunity to reuse the intellectual capital already invested in the legacy code and entails less risk that the rewrite might not work properly. As much as possible, one avoids modification of original subroutines; instead, one strives to embed the modern features in an interface library.

This approach admits of several methodologies. One such methodology is based on Fortran 90, because this language has modern features yet maintains compatibility with older Fortran software. Other methodologies could be based on other modern computing languages (for example, C++) in which one can write programs capable of calling the original Fortran subroutines. Once software constructed following this approach works correctly, there is always the option of replacing individual pieces of the legacy code, and eventually even the entire code. One important advantage of the use of a software superstructure is that the legacy code can still be used during a modernization effort.

*This work was done by Viktor Decyk and Charles Norton of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-21166.*

## Active State Model for Autonomous Systems

**Autonomous systems would be able to diagnose themselves and respond accordingly.**

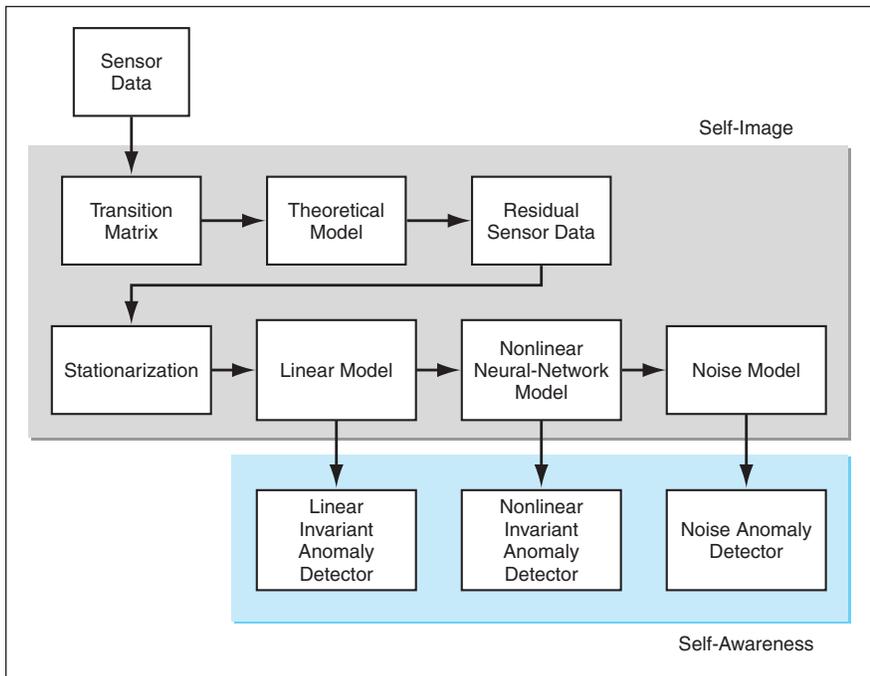
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The concept of the active state model (ASM) is an architecture for the development of advanced integrated fault-detection-and-isolation (FDI) systems for robotic land vehicles, pilotless aircraft, exploratory spacecraft, or other complex engineering systems that will be capable of autonomous operation. An FDI system based on the ASM concept would not only provide traditional diagnostic

capabilities, but also integrate the FDI system under a unified framework and provide mechanism for sharing of information between FDI subsystems to fully assess the overall "health" of the system.

The ASM concept begins with definitions borrowed from psychology, wherein a system is regarded as active when it possesses self-image, self-awareness, and an ability to make decisions itself, such that

it is able to perform purposeful motions and other transitions with some degree of autonomy from the environment. For an engineering system, self-image would manifest itself as the ability to determine nominal values of sensor data by use of a mathematical model of itself, and self-awareness would manifest itself as the ability to relate sensor data to their nominal values. The ASM for such a system



This **Flow Chart** depicts stages of computation in the gray-box approach to self-image and self-awareness of a complex engineering system.

may start with the closed-loop control dynamics that describe the evolution of state variables. As soon as this model was supplemented with nominal values of sensor data, it would possess self-image. The ability to process the current sensor data and compare them with the nominal values would represent self-awareness. On the basis of self-image and self-awareness, the ASM provides the capability for self-identification, detection of abnormalities, and self-diagnosis.

In our practical implementation of the ASM, we use the “gray-box” approach to implementing self-image and self-aware-

ness (see figure). The “gray-box” approach differs from the “black-box” and “white-box” approaches in the following way: It involves the use of mathematical models that are characterized as being of a mixed-signal or “gray” type, meaning that they include both deterministic and stochastic models. The deterministic or the “white” model is used to filter out what is known about the system. What is left after filtering is the residual, or unknown, components of information on the system. The residual information is mathematically modeled by use of stochastic techniques, i.e., “black-box.” The

behavior or “health” of the system can then be monitored by comparing the residual against its nominal values through the stochastic model. The advantages of the gray-box approach are that (1) it maximizes the use of both sensory information and any information previously available in the form of a mathematical model and (2) offers both sensitivity to truly functional damage and insensitivity to mere operational disturbances.

Another essential component of the ASM is the active system exchange (ASE), which includes a flexible database that stores all relevant FDI and other information to synthesize data and data-driven models sufficient for intelligent decision-making. The ASE would provide crucial information from all FDI subsystems and would allow an intelligent agent such as planning software to make decisions based on summarized understanding of the system health. When the full ASM architecture is implemented, it will provide a framework for a fully autonomous system that would be able to monitor and predict equipment failures, reconfigure the control subsystem of the system in response to an equipment failure, take appropriate action in response to unexpected events, and replan the mission of the system, as needed, in real time.

*This work was done by Han Park, Steve Chien, Michail Zak, Mark James, Ryan Mackey, and Forest Fisher of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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