FY06-FY07

NPARC Alliance

Policies and Plans

The NPARC Alliance

Policies and Plans

NPARC Alliance Strategy

FY06 – FY07

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Preface

This document was prepared by the staff of the NPARC Alliance to address internal requirements of the NPARC Alliance. However, it also serves as a source of information on the NPARC association and is readily available to all NPARC users and other interested parties.

Questions or comments about the contents of this document can be made by phone, by electronic mail, or through the Internet

Support Line: 931-454-7885

Email: nparc-support@info.arnold.af.mil

WWW Home Page: http://www.arnold.af.mil/nparc

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The NPARC Alliance

Introduction

The NPARC (National Project for Application-oriented Research in CFD) Alliance is a partnership between the NASA Glenn Research Center (GRC) and the USAF Arnold Engineering Development Center (AEDC) dedicated to the establishment of a national, applications-oriented computational fluid dynamics (CFD) capability centered on the NPARC flow simulation software. This suite of computational tools is based on the Wind-US code, which is a general-purpose, applied CFD tool. Its further development and support is intended to enhance both the military and commercial competitiveness of the US, with particular emphasis on the needs of the aerospace community.

Background

GRC and AEDC formed the NPARC Alliance in response to a national requirement for a productive, user-friendly, well-maintained, well-documented, applications-oriented flow simulation tool. The PARC code, on which the NPARC code was based, had developed a wide following, with over 100 governmental, industrial, and academic institutions acquiring it. A variety of PARC code users approached both GRC and AEDC about establishing this CFD computer program as a formally supported national asset. In line with the evolving emphasis in both the National Aeronautics and Space Administration and the Department of Defense on the transfer and fostering of advanced technology, the NPARC Alliance was formed.

In FY96, McDonnell Douglas, a member of the NPARC Alliance Steering committee, offered to the Alliance the technology in their primary Navier-Stokes code, NASTD. During the same period of time, the flow solver NXAIR was also made available to the Alliance through organizational changes at AEDC. A committee was organized to determine an approach to take advantage of the technologies in each of these codes. It was decided to take the best capabilities of the three codes, NPARC, NXAIR and NASTD, and combine them into a single flow solver called WIND, which would become the Navier-Stokes flow solver supported by the Alliance. In addition, the Alliance would support a suite of computational tools to address the entire flow simulation system. WIND version 1.0 was released February 1998. The last version of WIND (Version 5) was released in October 2002.

October 2004, the Alliance released version 1.0 of the Wind-US as the successor to the WIND code. Wind-US is a combination of the WIND structured code with the ICAT unstructured code (which was obtained from Rockwell Science Center by Boeing and provided to the NPARC Alliance). Wind-US is the first NPARC-supported fluids solver with an unstructured grid capability.

Description

NASA GRC and AEDC are jointly committed to long-range maintenance and improvement of the NPARC flow simulation system, including the Wind-US code. The three main tasks of the NPARC Alliance are user support, software development, and code validation.

Support:

The NPARC Alliance supports the NPARC Alliance flow simulation system to meet the basic needs of the user community. This support consists of releasing the NPARC Alliance flow simulation system, assisting users in its application, holding training classes and developing training material, resolving bug reports and other problems, and disseminating NPARC Alliance news. Users and developers can obtain assistance from either AEDC or GRC personnel through the NPARC Hot-line (931-454-7885) or email (nparc-support@info.arnold.af.mil). All users are kept informed of recent modifications to the software and documentation, as well as upcoming NPARC Alliance conferences or workshops through appropriate media (e.g. email, World Wide Web on the Internet, user meetings and technical sessions at AIAA conferences).

Development:

The NPARC Alliance establishes directions for future development of the NPARC flow simulation system, develops enhancements, and incorporates improvements contributed by other developers. The NPARC flow simulation system developments continue to emphasize its strengths as a user-oriented, reliable CFD analysis tool. The primary flow solver, Wind-US, is the focus of the development, but the NPARC Alliance is committed to maintaining and enhancing utility programs for pre- and post-processing, such as GMAN, MADCAP, and CFPOST. While these utility codes will be supported, the Alliance will work with vendors of advanced grid generation and flow visualization software to ensure compatibility with the Wind-US code via database standards. The development team is also pursuing advanced technologies, such as multi-disciplinary simulation techniques.

Validation:

The NPARC Alliance coordinates the establishment and maintenance of a library or archive, of validation and verification data sets, check cases, and experimental data in order to provide a validation audit trail for the NPARC flow simulation system. The Alliance may also promote code validation experiments when inadequate data exists.

NPARC Association

The NPARC Association is a semi-independent interest group that provides a forum for NPARC Alliance code users to share their problems, developments, and plans. Membership is open to US government, commercial, and academic users of the NPARC flow simulation system (other interested parties may be invited to join, as appropriate). An advisory committee (NPARC Alliance Steering Committee), drawn from the Association is chartered by the NPARC Alliance to provide input to AEDC and GRC on the future direction of the NPARC Alliance and its development efforts.

Release Procedure

United States government, commercial companies and universities may readily obtain a copy of the NPARC flow simulation software and documentation by filling out a Software release form. The NPARC Software Release Instructions describe how to complete the form. Commercial companies and universities that would like to obtain the software must be registered with the Defense Logistics Services Center (DLSC) as “certified contractors.” To become registered a DD form 2345 must be completed. The DLSC can be contacted via the Internet at http://www.dlsc.dla.mil or at 1-800-352-3572. The NPARC flow simulation software has been installed at the four High Performance Computing Modernization Program Office Major Shared Resource Centers (HPCMPO MSRC) and the executables are available to DoD users at these sites. For DoD users at these sites, if the source is required the above-mentioned procedure must be followed.

Point of Contact

If you have any questions or comments concerning the NPARC Alliance or the NPARC flow simulation system, visit the NPARC Alliance web site at http://www.arnold.af.mil/nparc or call 931-454-7885 or send email to nparc-support@info.arnold.af.mil.

The NPARC Philosophy

The NPARC Alliance, although made up of two agencies from different branches of the federal government with customers in all types of commercial, academic, and governmental organizations, is guided by a common vision and mission.

Vision

The Computational Tool of Choice for Aerospace Flow Simulation

Mission

Develop, validate and support an integrated, general purpose, computational flow simulator for the U.S. aerospace community. Collaborate with users to ensure that this simulation capability is the system of choice in the analysis, design, and development of aerospace vehicles and components. Provide for the use of this flow simulator in related research and educational activities.

Goals

Reduced Costs

- Efficient development, maintenance, validation, and support processes
- Economical labor requirements (man-hours, skills and/or training)

World-class Capabilities

- Efficient, accurate and reliable
- Broad applicability
- High quality validation

Skilled Staffs

- Productive
- Flexible
- Responsive

Reduced Risks

- Broad experience base
- Extensive validation

Enhanced Mission

- Excellent customer relations
- Expanded and clarified roles within parent organization

Technology Transfer

- Well-received and recognized technology spin-offs
- Elevated stature, credibility and relevance

Enhanced Customer Support

- New tests and programs
- Computational work

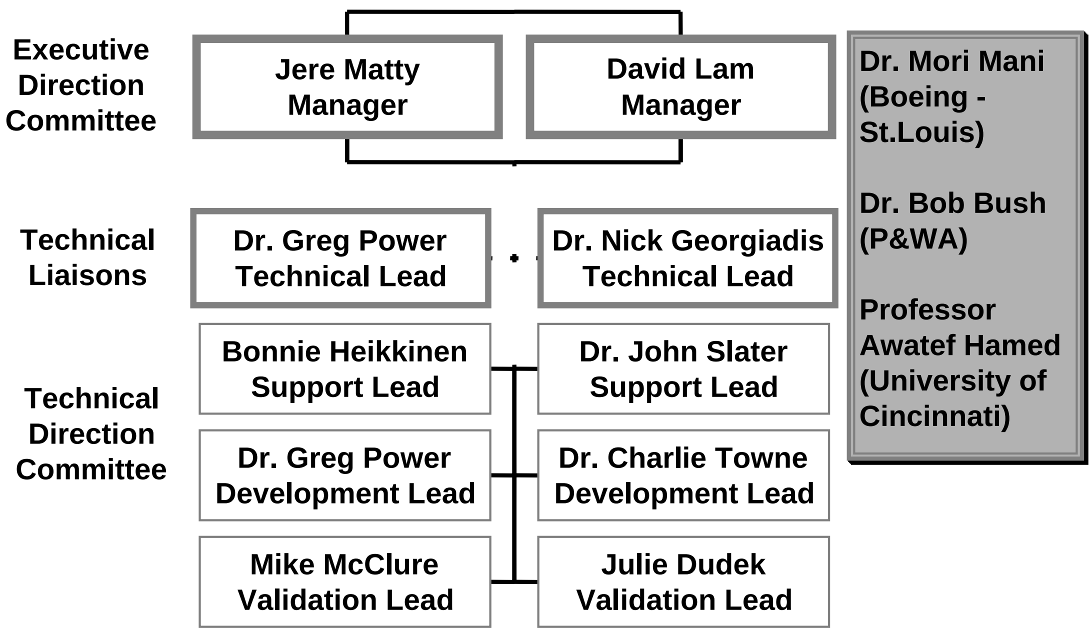
Actively Support U.S. Aerospace Industry

- Government laboratories
- Academic Institutions
- Large Corporations
- Small Businesses

NPARC Alliance Organization

The NPARC Alliance is a partnership between the USAF Arnold Engineering Development Center and the NASA Glenn Research Center. The basic organizational structure of the Alliance is diagrammed in the following figure. Issues requiring executive decisions are brought before the Executive Direction Committee. The Technical Direction Committee handles technical problems and planning. Each of the Support, Development, and Validation Teams are responsible for the day-to-day operations in their areas and are made up of one representative from each organization. The NPARC Association is a users' group which is co-chaired by NPARC user representatives selected by the Alliance.

AEDC-------------------- GRC <------------>NPARC Association



NPARC Users Association

Three levels of membership have been established for the NPARC Users Association, based on the responsibilities and level of participation of each association member. These levels have been established to formally acknowledge the active role that some users have taken in planning, development, and support of the NPARC Alliance.

Associate Alliance Member

These members work closely with the NPARC Alliance members in all areas, including development and planning. Some of the responsibilities and benefits of an Associate Alliance Member are:

- Active in planning NPARC Alliance activities and establishing policies.
- Willing to contribute man-hours and/or funding to advance NPARC Alliance software.
- Promotes the vision, mission, and goals of the NPARC Alliance.

- Active in developing the NPARC software tools and sharing developments with the NPARC Alliance.
- Dedicated users willing to assess code capability and functionality.
- Can be independent of version control, but encouraged to work under version control.

Current Associate Alliance Members are:

- The Boeing Company - Seattle, WA and St. Louis, MO

<u>Primary User</u>

These members also work closely with the NPARC Alliance members, but generally do not coordinate closely in development activities. Some of the responsibilities and benefits of a Primary User are:

- Contributes to the planning process of the NPARC Alliance.
- Promotes the vision and goals of the NPARC Alliance.
- Minor development activities.
- Dedicated users willing to assess code capability and functionality.
- Any development work is independent, but shared with NPARC Alliance.

Current Primary User members are:

- University of Tennessee Space Institute - Tullahoma, TN
- Hypercomp
- ITAC

<u>User</u>

These members use and develop the NPARC flow simulation software tools for their own internal purposes. There are over 380 registered user organizations of the NPARC Alliance software Wind and over 50 registered user organizations of the recently released Wind-US software.

- Provides input through user surveys and suggestions to the Association co-chairs or Alliance members.
- Independent developers and application-oriented users.
- Development work is independent, but sharing with the NPARC Alliance is encouraged.

Policies

NASA GRC and AEDC are jointly committed to the long-range maintenance and improvement of the NPARC Alliance flow simulation system. The three main tasks of the NPARC Alliance are user support, software development, and software validation.

Support Policies

The primary objective of the user support program is to provide support for the NPARC flow simulation system to meet the basic needs of the national user community while meeting the particular needs of Alliance members. Support for the NPARC flow simulation system consists of release of the NPARC Alliance software, user assistance in its application, resolution of bug reports, and other problems, and the dissemination of Alliance news. The policies established to guide the NPARC Alliance Support Team are detailed in the following paragraphs.

Alliance Plans

The Support, Development, and Validation Teams maintain a Policies and Plans document with approval of the Technical Direction Committee. This document covers the NPARC Alliance plans for a two-year period, with emphasis on the current year. The Policies and Plans document serves two purposes: first, to chart the specific course to be pursued by the NPARC Alliance and second, to guide the future direction of the NPARC flow simulation system. This second purpose helps to shape the planning activities of members of the NPARC Association. Associate Alliance Members will participate in the development of the Policies and Plans document.

Software Distribution

All initial requests for the NPARC flow simulation system must be made directly to the NPARC Support Team. The preferred method to request the software release form is via email to nparc-support@info.arnold.af.mil. The release form can then be emailed to the requester. The requester will then submit via email the completed software release form (Memorandum of Agreement). Initial requests will normally be processed in one to two weeks. Distributions will be made utilizing the Internet Version Management System (IVMS) and will consist of executables for requested machines and source code when requested by developers. Instructions on registration to IVMS will be sent to approved applicants. Approved applicants will have access to all versions of the software that are available via IVMS. All current documentation is accessible via the NPARC World Wide Web (WWW) home page (http://www.arnold.af.mil/nparc) of the NPARC flow simulation system. When available, examples and check cases will be included and provided via the web.

Since the NPARC flow simulation system embodies well-developed CFD technology, it cannot be released to all organizations that request it. US government agencies will always be eligible for the latest version. U.S. commercial firms and academic institutions will receive the latest version of the program if they qualify to receive export-controlled materials (other requests will be considered, but will generally not be granted). One copy of the NPARC flow simulation system (and future upgrades) will be supplied to each geographically, legally, or administratively distinct organization requesting it. Normally the program will not be released to individuals within an organization. The NPARC flow simulation system and all its documentation may be freely copied for use within and by the requesting organization; it may not be redistributed to other agencies (internal or external).

Candidate user organizations are required to sign a release form. Due to differences in legal requirements, different release forms are required for government agencies and for commercial or academic organizations. Each application is screened to verify the eligibility status of the requesting organization.

Software Maintenance

All user problems, which cannot be readily addressed, will be logged for correction, as either a software bug (does not behave as specified) or as a deficiency (works as specified, but not as desired). All bugs will be recorded, corrected, and documented. As quickly as possible, bug fix releases will be issued to correct the most egregious errors. Less serious errors will be corrected in the next minor or major release.

Direct User Support

The Alliance will assist with problems or questions involving the acquisition, application, or modification of the software supported by the NPARC Alliance. AEDC and/or NASA GRC personnel are available to help answer questions via telephone, email, and/or mutually acceptable site visits. A minimal amount of service (4 hours) is available, at no cost, to every user organization. A single phone number, the NPARC Alliance Hot-line number, will be distributed to NPARC Alliance users for this purpose. Calls will be screened and directed to the appropriate support personnel. As an alternative to the telephone, NPARC Alliance users can send help requests to a special NPARC Alliance email address. Email has been established as the preferred method of communication for detailed NPARC flow simulation system support issues. Each NPARC Alliance user organization may arrange to visit either AEDC or NASA GRC for a face-to-face consultation on any NPARC Alliance issue. These visits must be arranged well in advance and are at the discretion of the supporting agencies. As appropriate, seminars in the use and programming of the NPARC flow simulation system will be conducted.

Information Interchange

An NPARC Alliance home page (http://www.arnold.af.mil/nparc) is available on the World Wide Web to keep the user community informed of NPARC Alliance developments, applications, and other news. Users will be kept informed of recent modifications to the software and documentation, as well as upcoming NPARC Alliance conferences or workshops through appropriate media (e.g. periodic newsletters, email, and the WWW).

Most NPARC Alliance news of immediate interest (e.g. FAQ’s, bug fixes, new releases, upcoming user meetings, technical sessions, and training classes) will be broadcast over email. The NPARC newsletter will be prepared periodically and published on the WWW home page. Once a year, the NPARC Alliance Users Association meeting is held in conjunction with an appropriate professional meeting. These meetings are forums for the exchange of development and application experiences, and for the sharing of Alliance plans and activities. When possible, the NPARC Alliance will arrange for technical sessions relative to NPARC flow simulation system developments and applications at the same professional meeting.

Development Policies

The development of the NPARC flow simulation system will continue to emphasize its strengths as a set of user-oriented, reliable CFD analysis tools. This philosophy has led to a generalized user interface (e.g., boundary conditions), proven algorithms, and well-documented and calibrated physical models (e.g,. turbulence models and boundary conditions). The NPARC flow simulation system is a nationally used and nationally developed CFD suite of codes. Software enhancements are drawn from the NPARC Alliance Users Association members as well as the NPARC Alliance. The individual organizations of the NPARC Alliance and Association will continue to develop algorithms, physical models, etc. which reflect their particular needs. The Development Team will coordinate with the Support Team to provide communication between developers and users. The Development Team will coordinate with the Validation Team to identify validation needs and to identify requirements for the flow simulation system improvements based on the results of validation studies. Associate Alliance Members will actively develop NPARC Alliance software in coordination with the NPARC Alliance Development Team. Other User Association members are encouraged to coordinate development activities with the NPARC Alliance to facilitate incorporation of these developments into the official version of the software. The following policies are a statement of the responsibilities of the NPARC Alliance Development Team.

Programming Standards

The NPARC flow simulation system is designed to be extremely portable between machine types and operating systems. All codes are written using standards-compliant languages. Most routines in the major codes are written in Fortran, although some library routines are in C. Mixed language programming is, therefore, permitted, but should be kept to a minimum. New utilities may be written in language the developer prefers, provide no proprietary extensions are used. A formal document on programming standards of the NPARC Alliance is available to provide the specific guidelines to be used by the development community.

Enhancement

The NPARC Alliance will continue to enhance the capabilities of the NPARC flow simulation software. New versions are to be developed so that they represent the current state-of-the-art in CFD technology. Major releases represent major revisions to the programs, which will take place as often as is necessary to keep the programs current with user requirements.

The NPARC flow simulation system shall be maintained under a formal, software based, version control system (see IVMS Policies below). All NPARC Alliance Members and Associate Members shall have ready access to all versions of the program. The full identification for any version of the NPARC flow simulation software will have the following form: "*Software Name*" *major_number*.*minor_number* . Minor releases will include bug fixes only. All enhancements will be incorporated into the current alpha version, which will become the next major release.

All major features of the NPARC flow simulation system are to be encapsulated in loosely connected components with well-defined interfaces. The interfaces are to be standardized so that user organizations can easily replace selected components with ones developed internally.

In coordination with the validation effort of the NPARC Alliance, a set of standard check cases will be established and used to evaluate new versions of the code. Periodically, the NPARC Alliance Technical Direction Committee will meet to select contributed modifications for inclusion in the NPARC flow simulation system. All enhancements will be reviewed to ensure the quality of the developments and to ensure that the developments are in keeping with the stated development policies. These selected modifications will be reworked, if necessary, to fit the format and philosophy of the rest of the program.

The contributor is responsible for submitting:

- Source code of affected routines.

- Theoretical and user documentation.
- Sufficient information to demonstrate the correctness and benefits of the submitted routines.
- Validation data sets and results as necessary to supplement validation data compiled by the Validation Team.

The Development Team will scrutinize these developments and recommend action to the Technical Direction Committee. The recommended actions could be incorporation as is, incorporation with modifications, or rejection. The criteria for judging these developments will include:

- Is it theoretically sound?
- Is it of benefit to a large number of users?
- Is it in keeping with the stated NPARC Alliance direction?
- Is it a proven technology or unproven research technology?
- Is it well coded?
- Is it well documented?
- Has it been or can it be validated?

The Technical Direction Committee will review the recommendations and take final action on an as-needed basis. A written explanation of the action of the Development Team will be sent to the contributor. For accepted modifications, acknowledgment of the contributor will be included in future documentation releases or as part of the version management history.

IVMS Policies

The Internet Version Management System (IVMS) provides a means for version control for a single project with developers at several different geographically distinct organizations. All official developments must be made through IVMS. All significant modifications must be cleared as "official" by the development team. Developers should only check out and lock those files required to make the necessary changes and these files should not be locked for an extended period. Prior to checking in the files, the modified or new routines should be linked to the latest Alpha version and tested by the developer. Also, prior to checking in the modified routines, the files will be sent to a developer at another site for independent verification. The user must specify a brief description of the changes with sufficient detail to readily determine what has been done. Any documentation changes should be forwarded to the individual responsible for maintaining the user's and programmer's documentation.

IVMS also provides a means for users to access the latest source and executables. To do so, there are levels of authorization within IVMS. At the user level, an individual may only download the executables for the NPARC flow simulations system. A user may also request access to the source code for viewing only (or local modification). Authorized developers can check out and check in source code for official development tasks. The software managers can upload the latest object libraries. Finally, administrators can approve new users and perform other IVMS administrative tasks.

Proprietary Versions

The Alliance seeks to leverage the talents and expertise of government, commercial, and academic users. As such, proprietary components may be developed by user organizations. However, proprietary components are considered independent development efforts, and it is the responsibility of the user organization to maintain compatibility with the production version of the software. Incorporation of these components into the production or alpha version is encouraged, but not required. Upon submission the Alliance will assume maintenance responsibility and make the components available for public use.

Communication

Developers and users are requested to provide copies of all publicly releasable publications that demonstrate the flow simulation system's capabilities to aid in future development planning. The Development team will coordinate with the Validation Team to identify validation needs for new capabilities and to identify requirements for improvements to the NPARC Alliance codes based on the results of validation studies.

Scope

One of the chief strengths of the NPARC flow simulation system is its broad scope in terms of flow physics, geometric complexity, and computational requirements. Features that are of interest to a limited subset of the user community are not generally pursued by the Alliance. However, it is the policy of the Alliance to ensure that these features can be readily incorporated by the user organization itself.

The NPARC flow simulation software provides the means to treat arbitrarily complex geometric configurations. With the migration to Wind-US, computational meshes to model the complex geometries can be generated using structured and/or unstructured grid methods. The primary flow solver provides a basic capability for mature physical algorithms, and a readily extendible platform for more complex physical algorithms. Wind-US can be used to solve the Euler equations and several forms of the Reynolds-Averaged Navier-Stokes equations (steady RANS, unsteady RANS, PNS, thin layer). Several turbulence models, ranging from algebraic to two-equation models, are supplied with the code. The capability to run hybrid RANS-LES simulations, such as the Detached Eddy Simulation (DES) method of Spalart, is also available. Boundary surfaces are treated as broadly as is consistent with the validated state-of-the-art. Several gas models may be used in conjunction with the flow solver.

While the NPARC Alliance is mainly concerned with the flow solver portion of a complete flow simulation capability, it is recognized that users require a complete system including pre-processing software (grid generators), and post-processing software (flow visualization software). The NPARC Alliance will provide a minimal capability for an entire system. Interface standards will be published to allow more capable or user supplied software to supplant the provided pre- and post-processing software. The NPARC Alliance will actively pursue pre- and post-processing vendors to provide software tools, which readily interface with the flow solver and associated tools.

The NPARC flow simulation system is readily configured to a wide variety of hardware and operating systems. Executables on supported platforms and the source code are available via IVMS. Makefiles are available for a number of platforms and operating systems. These makefiles can serve as examples for extension to non-supported architectures. The source code for all required libraries is distributed with the flow solver source, including the Parallel Virtual Machine (PVM) library and the Common File Format (CFF) library. Makefiles for supported hardware and operating systems include:

Hardware	Operating System
SGI	IRIX 5.3 - 6.5
HP	PA-Risc hardware running HP-UX
Sun	Solaris
PC	Linux
IBM	RS 6000 series AIX

Efficiency

The NPARC flow simulation system provides acceptable simulation times for many flows of interest to the aerospace community. Simulation turn-around times are appropriate to an aerospace design environment. That is, the total elapsed time from the initiation of the flow simulation process (surface modeling and grid generation) through the analysis of the results (flow visualization and data reduction) should be compatible with the design schedules of major aerospace organizations. The NPARC software is designed and supported so that third party developers can efficiently add customizations to the program and transplant these modifications to new releases of the code.

Ease of Application

One of the strengths of the NPARC flow simulation system has always been the relative ease with which users can apply the software to their computational problems. Users should easily be able to setup a flow simulation, guide the simulation process to completion, and examine the results. While the NPARC flow simulation tools provide a very general capability, the tools must be readily configured to each user's particular needs. As much as possible, the NPARC flow simulation system follows national standards on the format of input and output databases so as to facilitate the use of a variety of grid generators, flow visualizers, and alternate flow solvers.

Documentation

All documentation of the NPARC flow simulation system is maintained in electronic form via the NPARC WWW home page and kept up to date as upgrades or changes are made to the software. The documentation consists of NPARC flow simulation software User's Guides, Common File Programmer's Guide, Installation Guide, Utilities Guide, and Guidelines Documentation for programming, documentation, and testing.

The user documentation for the NPARC flow simulation system is kept current with the latest version of the programs. The documentation should be appropriate for users of the software tools as well as CFD program developers. The user's guides describe the operation and use of Wind-US, MADCAP, GMAN and CFPOST and each consists of an introduction, a tutorial, and a detailed reference section. Wind-US is the Navier-Stokes flow solver. GMAN is an interactive menu-driven pre-processor that is used to specify boundary condition types and zone connectivity in multi-zone grids. CFPOST is a post-processor that may be used to examine the contents of the Common Flow (.cfl) file created by Wind-US. MADCAP, once fully implemented, will provide the user access to the full range of tools and processes used to perform CFD analyses under one user interface, from geometry acquisition through grid generation, flow solver set-up and execution, and post-processing of results.

The Common File Programmer's Guide provides a detailed description of the *common file library* which is a set of routines that provides access to a file structure called the *common file.* The common file structure provides a flexible and extendible mechanism for storing CFD and other data.

The Installation Guides provide instructions on installing the software and associated pre- and post-processing tools.

The Guidelines Documents were created for use by NPARC Alliance members during software development projects. The programming guidelines deal almost exclusively with Fortran 90 and 77, since most NPARC Alliance software is written in that language, but some parts are also applicable to C. The guidelines are intended to enhance the maintainability, portability, and efficiency of the final product. The documentation guidelines describe the external documentation that will be released with the code in printable and/or electronic form. The testing guidelines are intended to be used during the development phase of the code and to provide guidelines for evaluating the overall functionality of the software and the functionality of specific features of the software. When appropriate, technical papers covering recent development efforts on the NPARC flow simulation system will be presented at appropriate technical conferences. Professional journal articles will be written to document significant developments.

Software Testing

There are two major levels of NPARC flow simulation software testing: alpha and beta testing. Alpha testing is defined as sufficient check-out of a particular feature, such that there are no known bugs in the operation of that feature. Alpha testing is primarily performed by the developer of the feature and others on the development team. Once several new features have been alpha tested and approved for inclusion in the official release, a "beta" test version of the code is released. The purpose of beta testing is to run the code on complex applications of current interest and applications with well-known solutions. This phase of testing is designed to determine the interaction of the new features with the code as a whole. Beta testing is performed by the NPARC Alliance (AEDC and NASA GRC) and the associate alliance members. Primary users will be permitted access to a beta version of the code for the purpose of beta testing on a case-by-case basis.

Validation & Verification Policies

The primary responsibility of the NPARC Validation Team is to validate the NPARC flow simulation system for a wide range of flow parameters and geometric configurations, and to establish an archive of cases that can be accessed by the NPARC Alliance community to support independent assessment of the software's capabilities. The validation and verification (V&V) effort must establish the following:

1) The basis upon which confidence in results produced by the NPARC flow simulation system is founded.
2) The practical limits on the accuracy of predictions for flow phenomena pertinent to aerospace systems.

Such confidence can only be achieved through a continuous process of careful application of the codes to a wide range of "*unit problems*", "*benchmark cases*", "*subsystem cases*", and "*complete system cases*" and complete documentation of the results. Here, "*unit problems*" focus on a single phenomenon and simple geometries whereas "*complete system cases*" focus on geometries and flows more representative of typical aerospace systems and their components. "*Benchmark cases"* involve fairly simple hardware but typically two (possibly coupled) physical flow phenomenon. "*Subsystem cases*" involve components of complete systems with more complete flow physics included. The development of code-confidence will be a continual process driven by changing conditions such as the availability of new or better experimental data, bug fixes, and the addition of new capabilities to the codes. A thorough V&V effort will not only build the credibility of the NPARC software, but will also help minimize support needs by providing numerous examples of well-executed problems.

In addition to the formal V&V effort itself, the Validation Team will assist the Support Team in developing and maintaining a subset of validation cases and studies as "examples" and in providing tutorials showing new users how to run the suite of codes for a variety of flow fields and geometric configurations. Assistance will also be provided to the Development Team in creating and archiving a set of check cases (typically unit problems or benchmark cases) that can be run to verify that code changes have not introduced new problems affecting existing capabilities and to verify proper installation on a new computer system. The Validation Team will coordinate with the Development Team to correct weaknesses in the NPARC Alliance software, and to anticipate validation needs relative to on-going and planned development work.

The V&V effort is an on-going activity. Users are encouraged to propose candidate validation and verification problems and to submit documentation and results from independent V&V efforts through the NPARC Users Association. Additional discussion of the Validation effort may be found in Tatum & Slater, "The Validation Archive of the NPARC Alliance," AIAA Paper No. 99-0747, January 1999.

Code Evaluation Policy

A wide variety of problems representing a mix of flows relevant to aerospace systems will be identified for definition as validation and/or verification cases. A "case" represents a single geometry and/or flow condition. "Studies" of these cases will be conducted via multiple computer runs to determine the strengths and weaknesses of the NPARC flow simulation system for a variety of geometric configurations, and over a range of flow parameters. Computed results will be compared with benchmark-quality experimental data, well-accepted computational results, and/or analytic solutions.

As indicated above, the V&V effort will focus on problems ranging from "unit cases" to "complete system problems." The "unit" and "benchmark" problems (see representative list below) will provide a vehicle for evaluating the ability of the software to predict fundamental fluid dynamic phenomena relevant to the performance of aerospace systems.

- Falkner-Skan flows
- Couette flows
- Flat plate boundary layers (including heat & mass transfer, moving wall)

- Curved wall boundary layers
- Flow through screens
- Free shear layer (laminar and turbulent)
- Flow past simple bodies (e.g. cylinder, sphere, cone, and airfoil)
- Curvature induced secondary flows
- Entrainment flows
- Shock/boundary-layer interactions
- Flow separation
- Vortex flows
- Jet flows (impingement, jet in a cross-flow, jet/jet interaction)
- Wake flows
- Forward and aft facing step
- Chemically reacting flow
- Flow involving a rotating coordinate system

The inclusion of "subsystem" and "complete system" problems in the V&V effort is aimed at demonstrating the usefulness of the code in supporting the design and analysis of realistic aerospace systems. Representative problems of these classifications include:

- Propulsive nozzle/aft body
- Airfoil cascade
- Diffusing duct
- Propulsion system inlet (subsonic and supersonic)
- Ejector nozzle
- Wing/body combination
- Moving-body/store-separation problems

Code Validation

The term "validation" has been used in a variety of ways in the literature. For this effort, the Alliance will be guided by the following definition: *The process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model. (AIAA G-077-1998)*

A prior definition, adapted from one given by Mehta ("Computational Requirements for Hypersonic Flight Performance Estimates," Journal of Spacecraft and Rockets, Vol. 27, No. 2, 1990, pp. 103-112) gives insight into the general understanding of what this definition entails.

> *A code is said to be validated if the following conditions are met: 1) a comparison of computed results with detailed surface and flow field experimental data and/or other well-accepted solutions shows that the code is able to accurately model the critical physics of the flow; 2) the accuracy and limitations of the experimental data are known and understood; and 3) the accuracy and limitations of the code's numerical algorithms, grid density effects, convergence effects, and physical basis are known and understood. The range of applicability of the validated code depends on the range of flow parameters and/or geometric configurations for which the code has been validated.*

Of course in practice, the accuracy and limitations of the experimental data and the computational results cannot be *fully* "known and understood." In addition, the degree to which the code must "accurately model the critical physics of the flow" will depend on how the results are to be used. These factors will inevitably introduce some blurring of the line between the states of validation and non-validation. Furthermore, we agree with Roache ("Perspective: A Method for Uniform Reporting of Grid Refinement Studies," **Journal of Fluids Engineering**, Vol. 116, September 1994) that, in the strictest sense, a "code cannot be validated in any general sense," only a specific calculation or set of calculations. Thus, while the prior definition provides details into what is ideally expected of a validation effort, the goals approach impractical limits. The AIAA definition emphasizes, "determining the degree" of accuracy relative to real-world physics *(not a simple yes or no), a*s well as focusing on the code's "intended uses." This is believed to be a more practical definition.

Validation has also been described as *"solving the right equations"*. It is not possible to validate the entire CFD code. One can only validate the code for a specific range of applications for which there is experimental data. Thus one truly validates only a model or a simulation. Applying the code to flows beyond the region of demonstrated validity is termed prediction.

Validation examines whether the conceptual models, computational models as implemented into the CFD code, and the computational simulation agree with real-world observations. The strategy is to identify and quantify error and uncertainty through comparison of simulation results with experimental data. The experimental data sets themselves will contain bias errors and random errors, which must be properly quantified and documented as part of the data set. The accuracy required in the validation activities is dependent on the application, and so the validation should be flexible to allow various levels of accuracy.

Studies will be conducted to determine the strengths and weaknesses of the NPARC flow simulation system for a variety of geometric configurations and over an extensive range of flow parameters. The Validation Team will coordinate with the Development Team to correct weaknesses and to anticipate validation needs relative to on-going and planned development work.

The accuracy and limitations of the software will be investigated by examining the sensitivity of the results to various input options such as mesh density, turbulence model, and artificial viscosity model. The validation effort is expected to be an on-going activity. Users are encouraged to propose candidate validation problems and submit documentation and results from independent validation efforts through the NPARC Alliance Association. In fact, the Validation Team can only function to maximum effectiveness when all users accept responsibility to contribute to the validation process.

Code Verification

Verification assessment examines 1) if the computational models are the correct implementation of the conceptual models, and 2) if the resulting code can be properly used for an analysis. The strategy is to identify and quantify the errors in the model implementation and the solution. The two aspects of verification are the *verification of a code* and the *verification of a calculation*. The objective of verifying a code is *error evaluation*, that is, finding and removing errors in the code. The objective of verifying a calculation is *error estimation*, that is determining the accuracy of a calculation.

Verification is defined as follows:

> *The process of determining that a model implementation accurately represents the developer's conceptual description of the model and the solution to the model. (AIAA G-077-1998)*

Verification has also been described as *solving the equations right*. It concerns itself more with mathematics rather than engineering. It looks for errors in the programming and implementation of the models.

Selected verification studies will be established and documented in coordination with the Support Team and designated as "examples." These example studies are designed to meet two primary goals. The first is to provide users with quick, but limited validation of the NPARC software over a wide range of flows. These example verification studies may be indicative of the capabilities of the flow simulation program, but do not necessarily meet the formal definitions of validation and verification in that they do not examine in detail the sensitivity of the results to various input parameters or confirm that the simulation agrees with real world observations. The second goal of the example studies is to provide the new user with clear examples of how to properly setup and execute the NPARC flow simulation system for a variety of geometries and flow conditions. In this way, the example studies should help to minimize the need for users to seek direct help from the Support Team.

"Check" Studies

Test cases will be established to judge the functionality of a newly installed and/or modified code. Check studies will be made to document the numerical solutions of such cases. These cases and studies will be developed and maintained in conjunction with the Development Team. The primary intent of the check cases is to provide the Development Team with a tool to ensure the integrity of all mechanical aspects of code operation. At least one of these cases will be an installation check case that is intended for use by new recipients of the NPARC flow simulation system to verify that the code has been properly installed on their computer system.

Documentation Policy

A consistent format for the documentation of validation and verification studies is necessary to ensure an adequately thorough representation of a given case and to permit a comparison of conclusions drawn from a variety of studies. Documentation of the V&V effort will be developed with the goal of highlighting the primary focus and all pertinent findings for each validation or verification study and will include sufficient detail to allow independent repetition of each study. The standards for documentation will be maintained in a separate publication for use by the user community in submitting validation cases and/or studies to the NPARC Alliance for inclusion in the validation archive.

A variety of methodologies for performing and reporting V&V studies (including sensitivity studies) are described in "Verification and Validation in Computational Science and Engineering" by P. J. Roache (1998). The Alliance recommends these techniques as standards for submittal of V&V cases to the Archive.

Validation Cases

Each validation case will be documented in a fashion consistent with the established standards as part of the validation database archive and maintained on the NPARC WWW pages in a format compatible with current web-browsers. The Validation Team will also maintain a collection of Validation Abstracts summarizing all validation calculations performed by or coordinated through the Alliance to compliment the electronic archival of validation data and results.

Verification Studies

In conjunction with the Support Team, detailed documentation will be developed for each of the verification studies. Documentation for the complete collection of verification studies will be available through the validation archive. The documentation will include:

- a description of the problem being solved;
- a description of the computational mesh and initial condition files including, where appropriate, listings of codes and input used to create these files;
- a discussion and listing of the input used to run the code and any pre- or post-processing software
- a discussion of the computed results and convergence history.

Check Studies

In conjunction with the Development Team, detailed documentation will be developed for each of the check studies. The documentation for the check studies will be included as part of the Testing Guide, and will also be available as part of the validation database archive.

Archive

For validation and verification cases to be of maximum benefit to the user community, they must be available in such a form that all comparisons made during the original validation exercise can be repeated with relative ease by independent code users and as significant code enhancements are implemented. Therefore, a formal electronic archival system will be maintained for the retention of all information necessary to repeat such comparisons for each validation case and study.

The established archive format will be used to maintain a collection of validation, verification, and check studies that can be accessed by NPARC Alliance users and developers. The inclusion of validation cases and studies in the archive will require the approval of the Technical Direction Committee. The inclusion of new cases in the archive will be announced to users through the various NPARC Alliance information interchange forums.

This archive will include all experimental data used for comparison with computed results, the input files needed to run the studies, the output files, and written documentation providing an overview of each study and a discussion of results. In addition, the archive will include a summary feature, which allows investigating archive contents and accessing visual summaries of individual studies through a collection of Validation Abstracts.

A web page template for validation and verification cases and studies has been published on the NPARC WWW Validation site and newly published documentation will conform to the general guidelines provided therein.

Documentation and Archive Standards

Documentation and archive standards will be maintained in a separate publication to aid the user community in preparing and submitting validation applications for inclusion in the validation archive. The documentation standards will include the minimum documentation requirements and format of such documentation. The archive standards will include the type and extent of data required and the format of the electronic files.

Documentation and Archive Updates

For each new code release, features may be added which could impact the results for previously executed validation or verification cases, e.g., a new turbulence model or an upwind algorithm. Selected cases will be reanalyzed using the current version to identify the impact of the new features and to maintain a database, which reflects the most recent software version. The documentation and archive entries for the selected cases and studies will be updated accordingly.

Plans

The following NPARC Alliance plans detail efforts directed to implementing the policies outlined in the previous section. While some of the tasks will continue into the indefinite future (e.g. the support activities), the intent is to concentrate on the current fiscal year (2006), and less definitely, on future plans and NPARC Alliance-related developments.

Support Plans

The support effort is geared to activities and projects that directly impact the users of the NPARC flow simulation system. AEDC personnel are primarily responsible for executing the support plans with assistance from NASA GRC personnel as required. Both organizations contribute resources for this purpose.

Activities

Much of the support effort is devoted to on-going activities. User problems are to be resolved as appropriate to the resources of the Alliance, products must be distributed to users and other interested parties, and NPARC Alliance related developments must be logged for future reference.

Resolve Problems

Problems which users encounter in using the NPARC flow simulation system are to be resolved as expediently and completely as resources allow. Bug reports will be recorded, evaluated, fixed (according to seriousness and resource availability), and reported. Every user organization will be provided with a reasonable level of technical support (up to 4 hours) for problems in applying or modifying NPARC Alliance software. This would include help provided over the telephone and during visits to AEDC or NASA GRC.

Distribute Software and News

Information, as well as NPARC software, is to be distributed to users on request and when required to prevent erroneous results. The NPARC flow simulation system will be distributed to authorized requesters as per the NPARC Alliance Support Policy. Bugs, usage advisories, and other news of immediate interest to NPARC Alliance users must be expeditiously distributed by email and electronic bulletin boards.

Log Developments

In addition to bug reports and usage problems, all other occurrences which are of interest to users or developers are to be logged for future reference and reporting. The NPARC Alliance user database will be maintained and kept up-to-date. Any article, report, or other document which details applications and/or modifications to the NPARC flow simulation system will be logged. News of interest to either NPARC Alliance users or developers will be recorded. Requests for specific modifications and/or extensions are to be documented and given to the Development Team.

Maintain World Wide Web Service

The NPARC Alliance will maintain a WWW site at http://www.arnold.af.mil/nparc. The information on the WWW home page will be updated as new information is available. Certain updates will be provided in coordination with other support tasks, for example, the Policies and Plans document, the newsletter, FAQ's, and the application summaries. After each professional meeting, at which papers related to NPARC flow simulation system are presented, the reference databases will be updated. Changes to other information on the WWW home page or the addition of new information will be made during regular updates.

Projects

A variety of support efforts are either unique or occur according to a predictable and regular schedule.

Plan Alliance Tasks

Many on-going activities, which will be conducted into the indefinite future, such as strategic and tactical planning fall into well-defined patterns. In particular, the vision and mission statements of the Alliance need to be reviewed periodically, while the Alliance policies and plans need more frequent analysis and revision.

The NPARC Alliance Policies and Plans document will be reviewed and revised during an NPARC Alliance workshop to be held in the third quarter of the fiscal year. Revision and update to the Policies and Plans document will be based upon the experiences of the Alliance members, guidance from the NPARC Alliance Steering Committee, and the results of the user survey. An electronic user survey is available via the WWW for the NPARC Alliance users to provide their specific requirements and concerns to the Development Team.

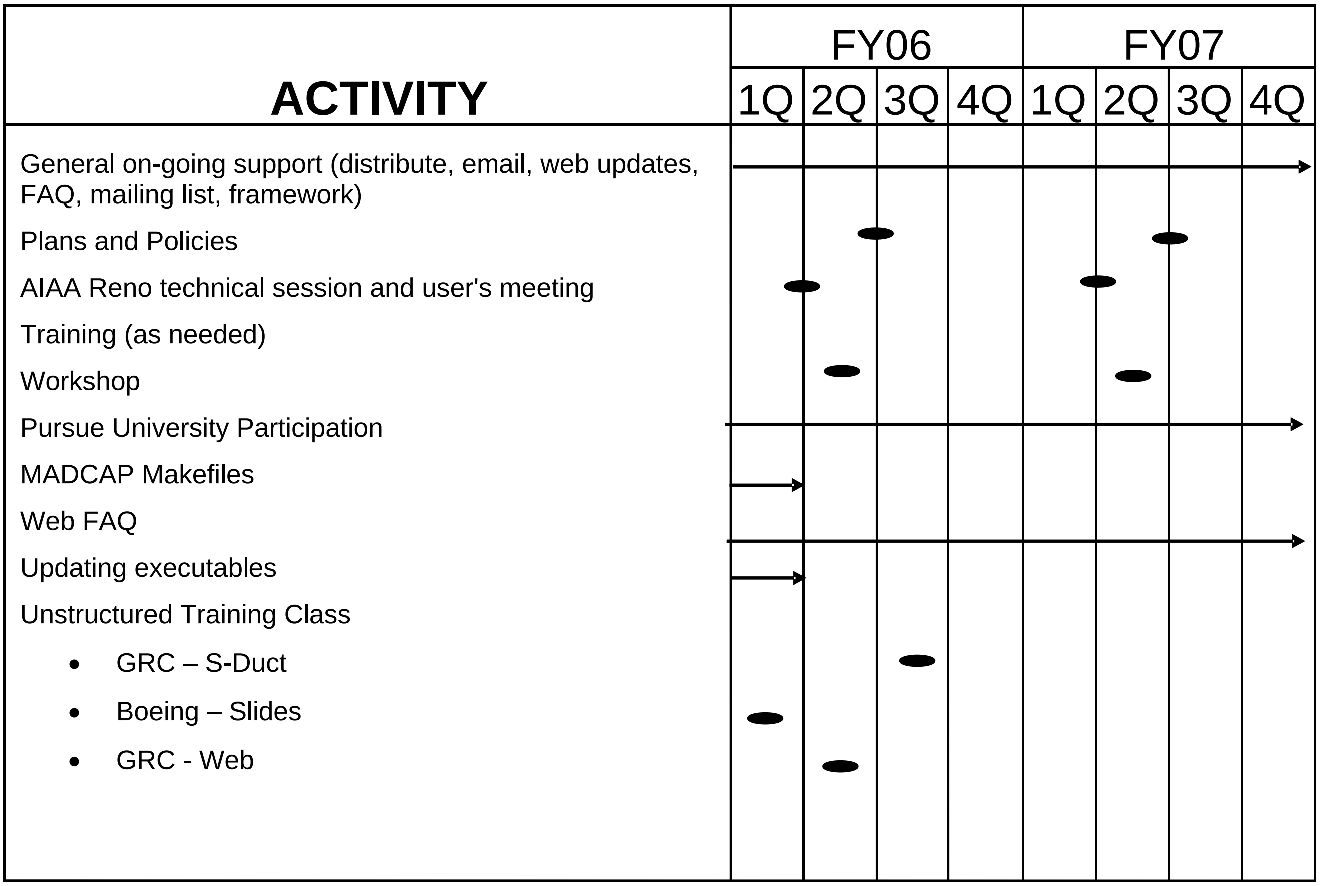
Distribute NPARC News

Most information gathered by the NPARC Support Team does not require immediate dissemination to the user base. Instead, this information is assembled into appropriate media and distributed according to a regular schedule. At present, user meetings are scheduled once each fiscal year. These meetings are held in conjunction with an appropriate professional society meeting. Current plans call for only one user meeting which will be held in conjunction with the AIAA Aerospace Sciences meeting in the winter. When possible, one or more technical sessions of the professional meeting will be dedicated to the presentation of recent NPARC flow simulation system developments and applications.

Training on Wind-US

A training class on the structure and use of NPARC flow simulation software will be offered to the user community as the need arises.

NPARC Support Schedule



Development Plans

The NPARC Alliance development efforts are directed toward improving Wind-US in the following four areas:

- "User friendliness" for both application and development efforts
- Turn-around time for a given application
- Quality of solution over a wide range of conditions
- Expanded capabilities of the primary flow solver through improved physical models, boundary conditions, etc.

The development effort with the migration to Wind-US is now focusing on structured and unstructured grid solution methods and a CFD system for improving the solution process in general, and for multi-disciplinary applications in particular.

Development is primarily directed at transitioning proven technologies, developed in universities, government labs, or industry labs, to the CFD user community on a national level. All organizations in the NPARC Alliance are responsible for executing the development plans with significant support from Associate Alliance Members.

The Wind-US Flow Solver

The NPARC flow simulation system is centered on the Wind-US flow solver and represents a merger of the capabilities of four existing CFD codes: NPARC 3.0 (NPARC Alliance), NXAIR (AEDC), NASTD (McDonnell Douglas, now Boeing), and ICAT (Rockwell Science Center and Boeing). While there are certain capabilities that do not completely replace the original flow solvers, the merger is considered complete. The next phase for development of the code is to improve the robustness and functionality of existing capabilities, and to extend many of the capabilities currently available for structured grids to the new unstructured grid solver. Focus areas for the next two years will include:

- User interface
- Developer's documentation
- Multi-disciplinary coupling
- Advanced grid-to-grid coupling
- Chemistry
- Unsteady flow
- Turbulence modeling
- Inlet flow control
- Improved code infrastructure
- Unstructured and hybrid grids

Details are presented in the schedule.

CFD System Development

The NPARC Alliance acknowledges that the flow solver is only one piece of the entire flow simulation process. Two of the primary aspects of the simulation process are grid generation and post-processing, including flow visualization and engineering data reduction. In association with the flow solver, a set of software tools has been provided to meet the rudimentary CFD system needs of most users, excluding grid generation. To allow more flexibility, interface standards have been published, allowing individuals, organizations, or commercial vendors to connect other pre- and post-processing tools into the NPARC Alliance CFD system.

Two important concepts are currently being explored relative to a CFD system: a Local Framework and a Global Framework. The Local Framework incorporates different components within a single source code allowing each to share information more readily and communicate more efficiently. This is the approach taken at a fairly low level for turbulence models, chemistry models, etc. A similar approach was used at a higher level for incorporation of unstructured technology (see the section on Unstructured Flow Solver). The Global Framework is a concept for coupling a variety of software packages that are intended to work together in a loosely coupled fashion. The Global Framework must control the execution of the software packages and the exchange of information. Examples of uses of the Global Framework are moving body problems (flow solver, force integrator, six degree of freedom code, and hole cutting and interpolation code) and multi-disciplinary applications (flow solver and structural analysis code). Development of this concept has been funded by the DoD High Performance Computing Modernization Office (HPCMO) through the Common HPC Scalable Software Initiative (CHSSI) as the CFD-9 project. The result of this project is FD-CADRE (Fluid Dynamics – Computational Analysis of Dynamically Responsive Environments), a system for moving-body simulations using unstructured overset grid technologies.

Unstructured Flow Solver

The NPARC Alliance recognizes the growing need for flexibility in the type of grids used to solve complex flow problems. Unstructured grids are becoming more prevalent. Unstructured grids decrease the time requirements for surface and volume grid generation. The NPARC Alliance has evaluated several codes and shared experiences among members. Boeing-St. Louis has incorporated the ICAT unstructured grid technology as a tightly-coupled component within the Wind framework and has produced Wind-US, which has become part of the software suite. The NPARC Alliance members will also continue to participate in the Boeing/AFRL lead Unstructured Grid Consortium to determine how best to contribute to this effort.

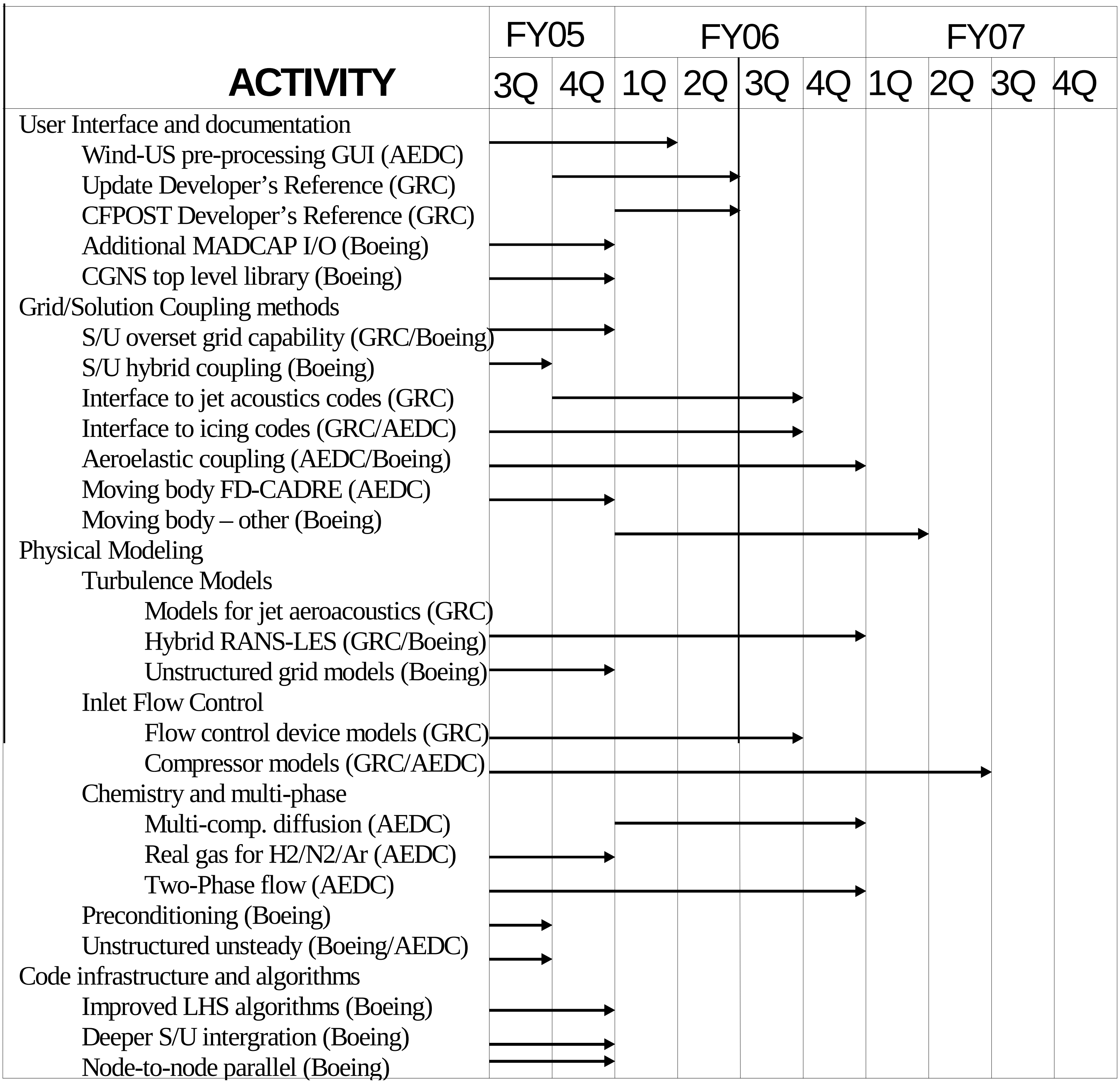
Utilities

The NPARC Alliance now formally supports and maintains the utilities associated with the Wind-US code. These tools are licensed to AEDC, and thus, the NPARC Alliance, for unrestricted use and modification. The tools have been placed under version control with source available for upgrades and enhancements. Various tools will be added or modified for use with unstructured grids, and converted to work with CGNS databases. Work will continue on consolidating the tools under a common GUI (MADCAP) to improve the ease of use and expand the capabilities.

Software Development

There are many aspects of software development beyond development of the solver and other tools. Changes to the software are made for improvements in usability and maintainability. The Internet Version Management System (IVMS) has significantly improved cooperation among developers. Further enhancements to IVMS will be accomplished as needed. The documentation is continually updated to reflect new code features. To further enhance cooperation and coordination, a programmer’s guide has been developed to complement the programming standards. This programmer's guide will continue to be enhanced. To facilitate coordination of development activities, a developer's teleconference will be held monthly to discuss current development efforts at each organization and reprioritize efforts when appropriate.

NPARC Development Schedule



Validation and Verification Plans

For the current year, V&V activities will focus on five primary areas:

- Validation and verification of unstructured-grid methods
- Inclusion of new V&V cases
- Inclusion of a test suite of "check" cases
- Re-execution of existing V&V cases with Wind-US version 1.0
- Verification using Method of Manufactured Solutions

Both organizations in the NPARC Alliance are responsible for executing the validation plans with significant support from Associate Alliance Members.

Brief individual task descriptions are provided below.

Validation and Verification of Unstructured-Grid Methods

Efforts of previous years have concentrated on verification and validation of structured-grid methodologies. Efforts are now focusing on unstructured-grid methods. The Wind-US flow solver will be subjected to rigorous and methodical testing for accuracy, robustness and sensitivity to inputs. Verification testing on simple unit cases will ensure that the code is solving the equations correctly. Validation tests will compare results of the various simulations to real world data. The goal will be to provide a new generalized-grid flow solver capability that is as robust and reliable as the current structured-grid solver.

Inclusion of New V&V Cases

Regardless of the grid methodology employed, the NPARC flow simulation system continues to be extended into regimes of advanced flow phenomena. Some of these include flows over moving and deforming bodies, more complete chemistry, flow in electromagnet fields, flows in rotating coordinate systems, and flows with buoyancy. Also, the capability to model some flow phenomena, such as unsteady vortex shedding should now be greatly expanded. Priority this fiscal year will be given to evaluating the following features: finite rate chemistry, time accurate Newton, shear layers, secondary flows and rotating frame of reference. Appropriate data sets have been identified for several of these phenomena, as identified in the schedule below.

Inclusion of a Test Suite of "check" cases

There has long been a need for a comprehensive set of check cases which exercise a wide range of code features and options. Developers need an easy-to-use suite of cases to run when code modifications are made. This will ensure that a given modification either improves or benignly effects the existing code, and that seemingly unrelated portions of the code are not inadvertently "broken" by given modification A readily-available suite of test cases setup up to be executed with minimal effort would provide a means for easily comparing solutions with the newly modified code to previous versions. This suite would also be useful to users who want to check newly installed code.

Re-execution of Existing Cases

Many of the existing cases on the NPARC Alliance Verification and Validation web site have been run several years ago, and never repeated with newer versions of the code. The task of re-execution of existing cases involves first re-running all existing cases with Wind-US 1.0 using the existing structured grids with the structured solver. Then each structured grid will be converted to an unstructured grid and the case will be run with the unstructured solver. This will result in additional unstructured cases being added to the archive, and will demonstrate the use and performance of Wind-US for unstructured cases. For all cases run, the computational times will be recorded for comparison.

Method of Manufactured Solutions

The method of manufactured solutions (MMS) is a means of verifying that numerical methods have been properly implemented and that they correctly solve the equations which they are intended to solve. It is a rigorous method for finding and eliminating coding mistakes. The MMS has been applied to a subset of problems using Wind-US, as described in, C.C. Nelson and C.J. Roy, “Verification of the Wind CFD Code Using the Method of Manufactured Solutions,”, AIAA-2004-1104, which states the following.

While any given series of MMS runs can only examine a subset of the available options in a modern production flow solver, within that subset, the results that it yields are fairly conclusive….The term “manufactured” solutions…refers to the fact that solutions are arbitrarily chosen (or manufactured). The governing equations are then modified by the addition of source terms such that the manufactured solution satisfies the governing equations.

An extensive set of MMS verification cases has been completed. Due to the copious amount of data involved in setting up, computing, running and post-processing these cases, and the limited amount of storage space available on the V&V archive, a selected set of these cases will be placed on the website. This will illustrate the performance of the code for a subset of problems, and serve as an example of the MMS which users may emulate for other V&V problems.

NPARC VALIDATION SCHEDULE

ACTIVITY	FY06				FY07			
	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Unstructured validation of basic physics (GRC)	→							
Cases to evaluate code features:								
• Finite rate chemistry								
o Burrows-Kurkov (GRC)	→							
o Re-entry F (Boeing)	→							
• Time accurate – Newton								
o Circular Cylinder (ITAC)	→							
o WICS Bay (AEDC)	—	—	→					
• Shear Layers (GRC)	→							
• Secondary Flows (GRC)	→							
• Rotating frame of reference								→
Test Suite (ITAC)				→				
Re-run existing cases with Wind-US 1.0								
• Structured (AEDC, GRC)					→			
• Unstructured (AEDC, GRC)					→			
Verification: MOMS (ITAC)	→							
Redesign validation site to include unstructured & code features (GRC)	→							

Appendices

Three appendices are provided to give the interested reader a little more background on the NPARC Alliance and the NPARC flow simulation system. The first covers the NPARC Association, a user group established by the Alliance. The NPARC flow simulation system is briefly described in the second appendix. Finally, the last appendix contains copies of the release forms used in obtaining the NPARC flow simulation software suite.

The NPARC User Association

The NPARC User Association is the NPARC flow simulation user group.

The official NPARC Users Group

The NPARC Association is a semi-independent interest group, which provides a forum for the NPARC flow simulation software users to share their problems, developments and plans involving this software suite. Membership is open to government, commercial and academic users of the NPARC flow simulation system (other interested parties may be invited to join, as appropriate).

Association Organization

The Association is led by co-chairmen selected by the NPARC Alliance. Meetings are organized and supported by the Alliance, but run by the Association co-chairs.

The Steering Committee

An advisory committee, drawn from the Association is chartered by the NPARC Alliance to provide input to AEDC and NASA GRC on the future direction of the NPARC Alliance and its development efforts.

Meeting Plans

The next two Association meetings are scheduled for the following AIAA conferences. Meeting times and places can be determined at registration at the respective conference.

Conference	Place	Dates
AIAA Aerospace Science Meeting	Reno, NV	1/06
AIAA Aerospace Science Meeting	Reno, NV	1/07

For More Information

If you have any questions concerning the NPARC flow simulation system or the NPARC Alliance, visit the NPARC Alliance web site at http://www.arnold.af.mil/nparc or call 931-454-7885 or send email to nparc-support@info.arnold.af.mil.

The NPARC Alliance Flow Simulator

The primary flow solver of the NPARC Alliance, Wind-US, embodies the most recent, proven CFD technology available. It is a general-purpose fluid flow simulator ideally suited to applications which involve complex geometries. In the hands of a fluid dynamicist with a basic familiarity with CFD technology, the NPARC flow simulation system is a powerful tool for the analysis of various complex geometries.

General Description

Wind-US is a general-purpose Navier-Stokes computational fluid dynamics tool applicable to a wide variety of aerospace design and analysis problems involving fluid flow. It is actively supported by the NPARC Alliance, a partnership between the NASA Glenn Research Center and the USAF Arnold Engineering Development Center. This Alliance seeks to enhance the military and commercial competitiveness of the United States through the establishment of the NPARC flow simulation system as a national resource.

The NPARC flow simulation system includes rudimentary grid generation and flow visualization software. A well-defined interface standard allows users to supply their own pre- and post-processing software or access to commercially available programs. A graphical user interface is provided to allow easy specification of boundary conditions and grid connectivity for multi-zone applications.

Wind-US is used to calculate the properties of a fluid flow based on specified boundary surfaces and flow conditions. These boundary surfaces can be quite complex and the fluid can be treated generally. Inviscid and viscous flows can be calculated. Viscous flows can be laminar or turbulent and can be treated as fully viscous or as thin shear layer flows. This computer program may be used to simulate steady state and transient flows. The code is written primarily in Fortran, has been ported to most computer architectures (SGI systems with MIPS cpus; HP-UX systems; Linux on Intel systems; Sun Solaris on Ultrasparc systems, IBM RS6000 workstations and SP supercomputers), and can be run in parallel using standard protocols. It is robust and easy to use. Anyone who is familiar with computers and has a basic understanding of the physics of fluid flows should have little trouble learning how to apply the NPARC suite of codes.

The NPARC flow simulation system has had a demonstrable impact on aerospace propulsive applications as diverse as supersonic and hypersonic inlet design, complete aircraft analysis, rocket nozzle failure analysis, and turbine engine exhaust mixer design. This computer program also has proven capable of treating many other aerodynamic problems, such as missile nose cone analysis, instrumentation probe design, and ducted flow analysis.

Technical Features

The principal distinguishing features of the NPARC flow simulation system are its generality, flexible grid requirements, robustness, and modeling versatility.

Generality

The basis of the algorithms used in Wind-US is the time-dependent form of the Reynolds-averaged Navier-Stokes equations. Various specializations are provided. For example, the viscous terms can be selectively calculated so that a thin-layer simulation can be performed or an inviscid (Euler) flow-field calculated. Similarly, for viscous simulations the fluid flow can be treated as laminar or turbulent as desired.

Grid Flexibility

One of the distinguishing features of Wind-US is its ability to compute flows using structured, unstructured, or hybrid grids. Traditionally, structured grids are well-suited to viscous problems requiring fine control of the mesh resolution in specific regions. Unstructured grids are typically easier and faster to generate, especially for complex configurations. With Wind-US, both types of grids may be used, even in a single problem.

Complex geometries may also be broken into a number of grid blocks. Grid blocking circumvents computer memory limitations, simplifies grid generation around complex geometries and permits grid embedding techniques. Structured and unstructured grids may be used in separate zones, as appropriate. Structured grids may be overlapped or embedded within another grid using overset (Chimera) grid technology. Grid zones or blocks may also abut one another. Adjoining grid blocks do not need to have an exact match of grid points.

Another distinguishing feature of Wind-US is its generalized treatment of boundary conditions with structured grids. Physical and computational boundaries may be located on any grid surface without restriction. Any portion of any grid surface may be a boundary surface. Common boundary conditions (e.g., slip and no-slip wall, symmetry plane, and free-stream) can easily be selected for each boundary. These features allow complex geometries to be readily treated using a single grid.

Robustness

In practical applications Wind-US has been found to be very robust. The user has complete control over the iteration process both globally and on a block by block basis.

Modeling Versatility

Another distinguishing feature of Wind-US is its flexible turbulence modeling capabilities. With structured grids, algebraic models are available for relatively simple flow simulations. For more complex flows, several turbulence models are available including the Spalart-Almaras one-equation, the Chien k-epsilon and Menter SST linear two-equation, and the Rumsey-Gatski nonlinear k-epsilon based algebraic stress models. Various hybrid RANS-LES models may be used in conjunction with the one-equations and/or two-equation models. A wall-function option exists for each of these turbulence models. With unstructured grids only the Spalart-Allmaras and Goldberg pointwise one-equation models are currently available, although other models are being added.

Almost any flow idealization can be simulated: 2-D, axisymmetric, or 3-D; inviscid, laminar, or turbulent; steady state or transient. Algorithms include an approximate factorization algorithm, a point Jacobi algorithm, or a Runge-Kutta multilevel scheme. With structured grids, the implicit algorithms can also be used in conjunction with a Newton iterative method which allows for very large time steps, resulting in significant performance enhancements for time accurate simulations.

Parallelization

Wind-US can be run in parallel on multi-processor or distributed processor systems using either MPI or PVM protocols. The code uses a coarse grain paradigm by assigning groups of grid zones to separate processors. A short text-based file indicates how many and which processors are to be utilized. To optimize load balancing, the zones are apportioned to the processors by size. A utility is included with the tools to improve the parallel performance by further subdividing the grid zone structure to maximize utilization of the processors.

For More Information

If you have any questions concerning the NPARC flow simulation system or the NPARC Alliance, call 931-454-7885 or send email to nparc-support@info.arnold.af.mil.

NPARC Release Forms

In order to obtain a copy of the NPARC flow simulation software and documentation, you must fill out the appropriate AEDC Software Release Form. To receive an electronic version of the AEDC Software Release form, please email nparc-support@info.arnold.af.mil. The NPARC Software Release Instructions describe how to complete the form.

NPARC Software Release Instructions

Thanks for your interest in the NPARC flow simulation system package. This software, developed and maintained by the U.S. government, is provided free-of-charge, but with limited eligibility and usage rights.

Eligibility

The NPARC flow simulation software is releasable to all U.S. owned companies, public and private universities (which are registered with the Defense Logistics Information Services as “certified contractors”), and government agencies. Only U.S. citizens and resident aliens may have access to the software. Although requests from foreign owned, controlled, or influenced (nonresident foreign nationals on the board of directors) corporations will not generally be granted, a limited number of requests from foreign entities (e.g., Canadian organizations) will be considered on a case by case basis.

Allowable Uses

The NPARC flow simulation software may be used for any purpose in the national interest. This includes enhancing either the economic or military competitiveness of the United States. It may not be used in a contract with a foreign government. Other restrictions are detailed in the Memorandum of Agreement -- NPARC Software Release Form.

The Software Release Form

The Memorandum of Agreement -- NPARC Software Release Form is the legal mechanism for obtaining release of the NPARC Flow Simulation Software from its custodian, the Arnold Engineering Development Center (AEDC). The information, required to complete the form may be typed or hand written in ink. Pay particular attention to the following portions of the form:

<u>Paragraph 1.</u>

Distribution Media:	IVMS
Usage Description:	Please give a general description of how your organization intends to utilize the NPARC software system in the immediate future.

<u>End-of-Form Blocks</u>

Requester:	In all cases, the “requester” should be the manager of the entity encompassing the sub-entities which will be using the NPARC software. The “requester” is responsible for enforcing the export controls on the NPARC software package.
Technical Contact:	The “technical contact” is the person responsible for receiving and maintaining the organization’s copy of the NPARC software package; and is the point of contact for technical and logistical issues concerning NPARC.
Gray-Shaded Blocks:	These blocks are for AEDC use only.

Contacts

The completed form should be return to the Support team via email.

One should expect to receive the software about two weeks after delivery of the AEDC Software Release Form.

Memorandum of Agreement

AEDC Software Release

U.S. Government

Date:

1. On behalf of the U.S. Government agency listed below, I request release of the following US Air Force software package (computer programs, system description, and documentation):

Distribution format and media:

The requested software package will be used as follows:

2. I understand that the requested software package contains technical data whose export is restricted by the Arms Export Control Act (Title 22, U.S.C., Sec 2751, *et seq.*) or Executive Order 12470, and that violations of these export laws are subject to severe criminal penalties. Further dissemination of this software is controlled under DoDD 5230.25 and AFI 61-204, and is limited to object or executable code.

Requester

Signature:
Printed Name:
Requesting Organization:
Address:
City, State and ZIP Code:

Requester: Technical Contact

Name:
Phone Number:
E-Mail Address:

AEDC OPR Certification / Verification

Name, Initials, and Date:

AEDC Software Release Authority

Signature:
Printed Name:
Test Operations Directorate Arnold AFB, TN 37389-9010

Memorandum of Agreement

AEDC Software Release

U.S. Commercial & Educational and Canadian Organizations

Date:

1. I/we the undersigned, on behalf of the Requesting Organization listed below (hereafter referred to as the "Requester"), request release of the following US Air Force software package (computer programs, system description, and documentation, collectively, the "Package"):

Distribution format and media (default - electronic dissemination via Internet, FTP, etc.)

The requested software package will be used as follows:

2. I/we understand that the Package may be subject to limited rights or other restrictions or constraints. In consideration therefore, the Requester agrees:

   a) The Requester shall not knowingly release or disclose the Package to third parties (other than the Requesting Organization).

   b) To strictly abide by and adhere to any and all restrictive markings placed on the Package.

   c) That any restrictive markings on the Package shall be included on all copies, modifications, and derivative works, or any parts or options thereof, in any form, manner or substance, which are produced by the Requester including but not limited to incorporation of the Package into any other data, technical data, computer software, computer software documentation, computer programs, source code, or firmware, or other information of like kind, type or quality. In all such events, Requester shall clearly denote where such Package derived data initiates and concludes by use of annotations or other standard markings.

3. The Requester and the Software Release Authority agree that:

   a) No guaranties, representations, or warranties either express or implied shall be construed to exist in any language, provision, or term contained in these materials or in any other documentation provided herewith (all such items are collectively referred to as the "Agreement"), and furthermore, the releasing organization disclaims and the Requester waives and excludes any and all warranties of merchantability and any and all warranties of fitness for any particular purpose.

   b) The Requester shall obtain from the releasing organization all of the Package (defined in paragraph 1 above), or any other products or services contemplated by the Agreement, in an "as is" condition.

4. The Requester's use of the Package shall not prevent the Government from releasing the Package at any point in the future.

5. The Requester shall not offer the released Package or any modified version thereof for resale to the Government, in whole or as part or subpart of a Government deliverable, without explicitly stating that he is doing so by providing certification documentation (e.g., Section K of the Government solicitation) to the contracting officer before contract award.

6. The Requester may use the released Package in a contract with the Government, but understands that the Government shall not pay the Requester for rights of use of such Package in performance of Government contracts or for the later delivery to the Government of such Package. The Requester may be entitled to

compensation for converting, modifying, or enhancing the Package into another form for reproduction and delivery to the Government, if authorized under a contract with the Government.

7. The Requester is not entitled to any released Package that is subject to national defense security classification or the proprietary rights of others. The Requester shall report promptly the discovery of any such restricted material included with the Package to the US Air Force Software Release Authority below, and will follow all instructions concerning the use, safeguarding, or return of such material. The Requester shall not copy, or make further study or use of any such material later found to be subject to such restrictions.

8. I/we understand that the Package received is intended for domestic use (US and Canada) only. It will not be made available to other foreign owned or controlled corporations, or other foreign governments; nor will it be used in any contract with another foreign government.

9. The Requester and the Software Release Authority intend that all agreements under this Memorandum of Agreement shall be governed by the laws of the United States of America.

10. The undersigned Requester has the authority to bind the requesting organization to the terms of this Agreement.

Requester

Signature:
Printed Name:
Requesting Organization:
Address:
City, State and ZIP Code:

Requester: Technical Contact

Name (if different from Requester):
Phone Number:
E-Mail Address:

AEDC OPR: Export-Control Info

Export Control Number & Expiration Date::
Data or Document Custodian's Name:
Phone Number:
E-Mail Address:

AEDC OPR: Certification/Verification

Name, Initials, and Date:

AEDC Software Release Authority

Signature:
Printed Name:
Test Operations Directorate Arnold AFB, TN 37389-9010