The Predictor

Iteration 2 Substep 1 **June 1995**

A NEWSLETTER FOR THE NPARC USERS ASSOCIATION

From the Support Team

The Predictor/Corrector newsletter is a result of contributions from engineers involved in all aspects of the NPARC effort: support, development and validation. From NASA Lewis Research Center, contributors include: Rich Blech, Scott Townsend, Suresh Khandelwal, Zhigang Yang and Charlie Towne. From Arnold Engineering Development Center: Greg Power and Ralph Jones. If you have questions regarding any articles in this issue, contact the NPARC support hotline and we'll pass it along to the appropriate individual.

In addition to this publication, our World Wide Web server contains a wealth of information including abstracts for references, links to Home Pages for grid generation and flow visualization software, and a bulletin board for the use of NPARC user' s.

Our WWW URL is:
http://info.arnold.af.mil/nparc

Contact the support team at:

nparc-support@info.arnold.af.mil

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Parallel Processing and NPARC

There has been a recent explosion in the performance of commodity microprocessors, the impact of which is being felt in the engineering community. Design and analysis tools which once required mainframe computer support can now be run on desktop computers, such as Unix workstations and PC' s. While a single computer may be adequate for most applications, some may still require higher performance. In these cases, the options are to return to the mainframe (or supercomputer) environment, or to marshal the forces of many less powerful computers into a coordinated, powerful resource. The latter technique is referred to as parallel processing and has been a hot research topic for many years.

One form of parallel computer is typically assembled from commodity microprocessors into a dedicated, special purpose system. Examples of such systems are the Intel Paragon and Cray T3D parallel computers. Another form of parallel computer can be "assembled" by using multiple, existing workstations that are interconnected by a network, such as ethernet. This form of parallel computing is frequently referred to as "workstation clustering." Workstation clustering has been immensely popular since many organizations already have networked workstations available. There have been several success stories in the aerospace community where supercomputer performance has been achieved on real applications using workstation clusters.

The use of workstation clusters as a resource to be applied to a single

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application has been driven by a popular, public-domain software tool called Parallel Virtual Machine (PVM). PVM provides a library of routines that can be called from FORTRAN or C programs. These routines support the fundamental communication operations required for parallel computing. Typically, a user is responsible for partitioning the application into multiple tasks that can operate in parallel. These tasks require communication of information, and this communication of information is handled by PVM. For example, in NPARC, if the multi-block capability is used, each block can be viewed as a task which can run in parallel. Boundary condition information between neighboring blocks would be communicated using PVM routines. PVM also provides utilities that are useful in implementing fault tolerance and managing multiple processes.

As mentioned previously, one issue in parallel computing is the communication of information between processors. Another critical issue is load balancing. Load balancing requires that each processor have as equal a distribution of work as possible. Otherwise, the execution time of the application will be dominated by the processor with the most work to do. The measure of work depends on the size of the task (e.g. number of grid points) and the speed of the processor. An efficient parallel application will match an appropriate amount of work to each processor based on its capabilities. Load balancing can be done statically, at the initiation of the application, or dynamically, where the work distribution is updated periodically (as the application is running).

The handling of disk I/O is also critical in a parallel application. Each parallel task can read/write it's own results from a local disk, if it is available. The advantage of this approach is performance. The disadvantages are that most pre- and post-processors require files that are contiguous. This could be handled by rewriting the pre- and post-processors or providing a utility to decompose or assemble the data. Another approach to I/O is to have a "master" process which handles all disk I/O. While this is not the highest performance option, it is the most flexible and robust.

Finally, it is desirable that the parallel application be as reliable as possible. Reliability on multiple processors is more difficult to achieve than on a single processor. This is especially true in the case of networked workstations, where the individual computers may be geographically separated. It is highly desirable that a parallel application be able to detect the failure of a processor and recover from this failure. The recovery process could find a new processor to replace the failed one, or reallocate the tasks to the remaining operational processors. Ideally, the parallel application would be able to recover it's entire pre-failure state. Since the state of any interprocessor communication is very difficult to reconstruct, this is not currently possible. Current practice, in scientific applications, allows recovery from the last state represented in a restart file.

Version 3.0 of NPARC will support parallel operation using PVM on a heterogeneous network of workstations. Heterogeneous means that multiple vendor's workstations (e.g. IBM, SGI, HP, Sun) can be used together. Parallel operation on the Cray Y-MP is also supported (on multihead machines). A "coarse grain" model will be used, which exploits the multiblock capability in NPARC. Basically, each block can be treated as an individual task which can run in parallel. Static load balancing will be supported. Disk I/O will be performed through a master process. Fault tolerance will be supported to the extent that a failure will be detected, and automatic recovery from the last restart file attempted.

Experience in testing sample applications using PVM has shown that many users have difficulty in setting up and using the PVM environment. Significant effort has been made to automate this process. The intent is to minimize the need for expert system administration support to run NPARC 3.0 in parallel mode.

Future releases of NPARC will include support for dynamic load balancing, improved fault tolerance and options for improving performance.

Version 2.1 Available

Version 2.1 of NPARC was released in May. A major goal of the NPARC Alliance is to provide the most recent advances in the NPARC code to the users in a timely fashion. Major releases, e.g. version 2.0, 3.0, etc., represent changes to the code and/or documentation which could have a major impact on the codes accuracy, efficiency, or usability. Point releases, e.g. version 2.1, 2.2, etc., represent changes that may be of interest to a smaller cross-section of the user community.

The most important change to NPARC in version 2.1 is the incorporation of a new boundary-layer bleed and compressor face boundary condition, provided by Boeing (see related article). These BC’s were designed for use in High Speed Civil Transport inlet applications. Other important new features include a uniform flow rate boundary condition, and improvements to the k-ε turbulence model.

In addition to new features, minor bugs were also corrected in version 2.1. Boundary conditions affected include periodic, rotating wall, wake, variable inflow and the original bleed. Minor updates to the Baldwin-Lomax, Baldwin-Barth, and the k-ε turbulence models have also been included.

If you would like to obtain the new version or for further information contact the NPARC support hotline by phone or e-mail.

The NPARC Technical Report Server provides easy access to the NPARC (and other) reference database.

Boeing Contributes to NPARC Development

The NPARC code is based on the principle of providing a quality CFD tool to be used nationally to improve the military and economic competitiveness of the U.S. To do this most effectively, participation of government agencies, corporations, and universities in the development and validation of the NPARC code is encouraged. To this end, Boeing has recently provided two boundary conditions which have proved useful in the design of High Speed Civil Transport engine inlets.

The flow in a typical HSCT engine inlet at cruise conditions is supersonic through the throat region. A shock downstream of the throat results in subsonic flow at the compressor face. Transient flow conditions in the freestream can significantly affect the conditions at the compressor face, resulting in movement of the shock. Movement of the shock to a position even slightly upstream of the throat will result in the shock “popping out” of the inlet, a condition known as engine unstart. A proposed approach for stabilizing the shock position, even in the presence of transient conditions, is to remove a small amount of mass through slots or holes in the inlet surface, i.e. boundary bleed, in vicinity of the throat.

To model such a system, without modeling the entire engine and bleed system, two boundary conditions are required: a compressor face boundary condition models the effect of the engine on the inlet flow in response to changing conditions within the inlet and a boundary-layer bleed boundary condition models the conditions at the entrance to the bleed holes or slots in response to conditions in the vicinity of the bleed ports.

The boundary-layer bleed boundary condition provided by Boeing models the effects of 20° and 90° bleed ports based on empirical data. The user is only required to specify the bleed plenum conditions.

The compressor face boundary condition provides a model to specify known information at the compressor face to determine the steady state inlet flow field. The model is also designed to simulate the effects of transient disturbances on the conditions at the compressor face.

Thanks to Dave Mayer of Boeing for the contribution. If your organization would like to contribute in-house developments, contact the NPARC support hotline.

WWW Access to References and Archives

The NPARC Alliance WWW 'home page' (and related information) undergoes regular updates as we strive to keep the information current and increase the overall utility of the service. With the next update planned for late June/early July of this year, look for enhancements to the NPARC reference service and the beginnings of our network accessible validation archive.

In updating our reference service, we have worked with various members of the NASA Technical Report Server (NTRS) Team in a effort to make our reference information accessible via standard search tools in use by a number of technical report services. The site we have looked to as a model for implementing our service is the NTRS accessible at URL:

http://techreports.larc.nasa.gov/cgi-bin/NTRS

Currently the NPARC reference data base includes approximately 85 references spanning the years 1986 to 1995 and we expect the number of references to grow to over 100 by the end of 1995. If you have any comments on the service or suggested improvements, let us know via Email to nparc-support@info.arnold.af.mil or through the request for feedback link on the reference search page, accessible from the NPARC 'home page'.

Thanks to Sean Fuller, the AEDC WWW adminstrator, for his help in implementing the reference indexing software.

With the validation archive, the Alliance plans to make available data, NPARC inputs and computed results drawn from the Model and Example validation problems as they are completed (see the Code Validation Update article). The structure and content of the information will no doubt change as we refine our offering. However, our goal is to provide ready access to the information required to perform independent assessment of NPARC capabilities, baseline files for the setup of common problems, and logical starting points for the extension of validation activities conducted by Alliance members. In addition, we encourage NPARC users to submit results from independent validation efforts for inclusion in the archive. If you have any suggestions relative to the structure and/or content of the archive prior to its introduction, contact the Validation team via Email:

nparc-valid@info.arnold.af.mil

User Association Meetings

Approximately 22 NPARC users attended the User Association Meeting held January at the Aerospace Sciences meeting in Reno. The Alliance members representing NASA LeRC and AEDC presented a short overview of the NPARC Alliance followed by a discussion of progress in 1994 and plans for 1995.

Based on a comparison between planned activities and actual accomplishments for 1994, it was concluded that, while the plans for 1994 plans were optimistic, a great deal was accomplished, including a completely revised user’s manual. Plans for 1995 have included some lessons learned from the effort in 1994.

It was announced that the 1995 Plans and Policies document of the NPARC Alliance was nearly complete and would be available to users on request. The major accomplishment for 1995 is to be the completion and release of a parallel version of NPARC (see related article). This effort would include the participation of MCAIR to assist in the implementation of fault tolerance software in the parallel code.

Other planned accomplishments for 1995 include an interface to turbulence model modules developed by CMOTT (Center for Modeling of Transition and Turbulence) at NASA LeRC and an updated one equation turbulence model.

Several user comments were offered from the floor:

1. Does a two phase flow model exist for NPARC? (No)

2. Will there be comparisons of NPARC results against other Euler/Navier-Stokes codes for validation cases? (Yes, but primarily comparison with data)

3. Can an early release of the parallel code be obtained? (Our policy is to do all Beta testing at NASA LeRC and AEDC with a few exceptions)

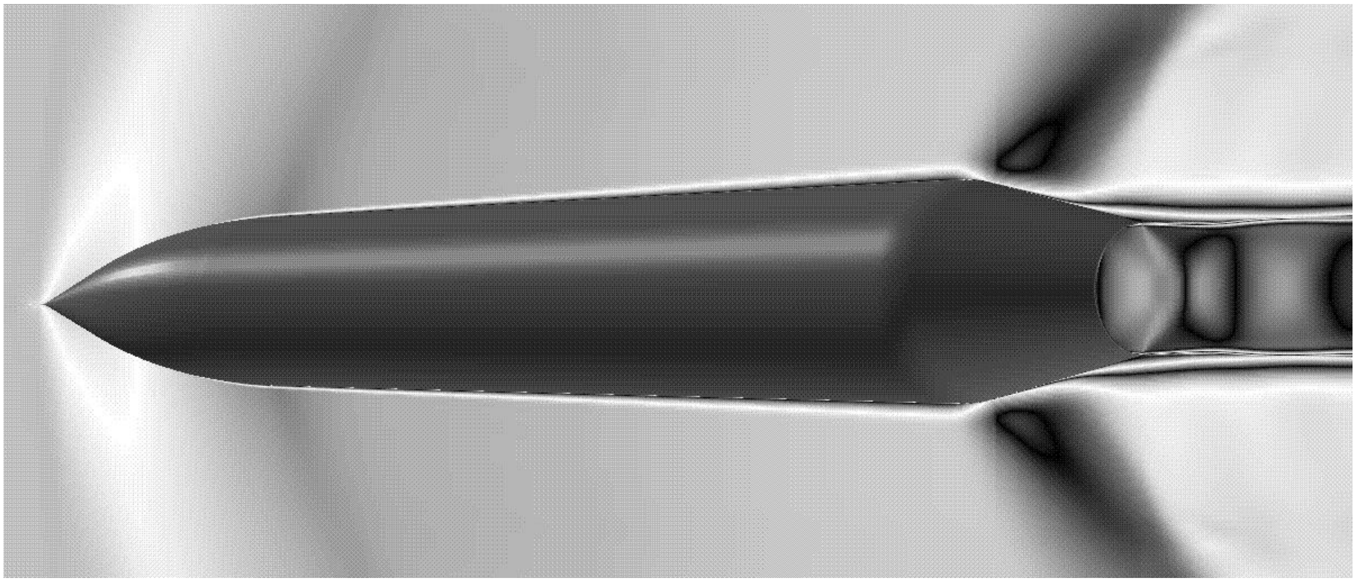
4. Can the NPARC Alliance support the GRIDGEN code? (NASA LeRC is supporting some modifications and the Alliance is looking at providing easier access to GRIDGEN for NPARC users)

The users provided a “wish list” of development suggestions to the NPARC Alliance members including more accurate treatment of large temperature gradients, two-phase flow modeling, rotating reference frame, multi-component mixing with equilibrium and kinetic chemistry, generalized equations of state, job history tracking, and spray (droplet) modeling. Plans for 1996 are underway, so let us know your ideas on improving or expanding the scope of NPARC.

Upcoming NPARC User Association Meetings:

- 31st Joint Propulsion Conference, July 10-12, 1995, San Diego, CA

  There will be two technical sessions devoted to NPARC applications and development.



Computed Mach number distribution at a flight Mach number of 1.2 and design nozzle pressure ratio.

- 34th Aerospace Sciences Meeting, January 15-19, 1996, Reno, Nevada

  There will be at least one technical session devoted to NPARC.

Thanks to Jerry Paynter (Boeing), your NPARC Association co-chair, for providing the minutes .

Code Validation Update

The Validation Team is continuing in its efforts to develop a database of validation cases covering a range of flow parameters and geometric configurations. Model validation studies have been completed for both laminar and turbulent flat plate boundary layers. As a supplement to the cases in the User's Guide for NPARC Version 2.0, Example validation cases have been completed for the Sajben diffuser, an ejector nozzle, and an HSR boat-tail. Access to the files used in these studies, and the documentation, will soon be available through the NPARC WWW server and via anonymous ftp (see the WWW Access to References and Archives article).

Model validation studies that are either already underway, or scheduled to begin in the near future, include:

- Subsonic diffuser flow (Fraser flow A)
- Flat plate boundary layer with heat transfer
- 3-D glancing sidewall shock/boundary layer interaction
- Supersonic free jet
- Moving normal shock

Selected cases from this list may also be documented as example cases.

Papers describing the current status of the overall validation effort, and the detailed results from the subsonic diffuser flow study, are planned for presentation at the 1996 AIAA Aerospace Sciences Meeting in Reno, NV.

In addition to these activities, the NPARC team has been offered the opportunity to participate in the CFD code validation activities being conducted under the auspices of the NASA sponsored MADIC effort. In particular, computations are being performed for the axisymmetric nozzle/aft-body configuration (see illustration) reported in NASA Technical Paper 1766, 'Investigation of Convergent-Divergent Nozzles Applicable to Reduced-Power Supersonic Cruise Aircraft,' by Bobby L. Berrier and Richard J. Re (December 1980). A comparison of results from a number of codes will be reported in a future technical paper.

User's can contact the Validation Team via:

- The NPARC WWW Bulletin Board, accessible from the NPARC Home Page.

- Email: *nparc-valid@info.arnold.af.mil*

CMOTT Turbulence Subprogram for NPARC

A turbulence model subprogram for the NPARC code, developed at the Center for

Modeling of Turbulence and Transition (CMOTT), will be released to the NPARC user community this summer as a part of the NPARC Version 2.2 release. This turbulence subprogram is designed to be included in any Navier-Stokes solver through a standard interface, allowing users to choose turbulence models from the CMOTT subprogram in addition to the models currently available in the NPARC code. Since the subprogram is developed and maintained separately from the NPARC code, new releases of the subprogram, with updates or new models, may be obtained by users and incorporated independent of the NPARC release schedule.

Turbulence models currently included in the subprogram are: the Baldwin-Lomax mixing length model, the Chien k-ε eddy viscosity model, the Shih-Lumley k-ε eddy viscosity model, and the CMOTT realizable k-ε eddy viscosity model. In the CMOTT model, C_μ is dynamically determined by flow conditions and the realizability of Reynolds stresses is ensured. The turbulence subprogram will be available for both 2D/axisymmetric and 3D applications. Model documentation and model validations for benchmark flows will also be included in the release.

Version 3.0 On Track

The major efforts associated with version 3.0 of NPARC are well under way. The parallel effort, outlined in an accompanying article, includes plans for a robust implementation applicable to heterogeneous workstation clusters. Access to the CMOTT turbulence modeling library should also be available in 3.0.

Work on a generalized blocking approach has resulted in a prototype code that eliminates the requirement that users specify block pairs. This effort is now turning to a more general interpolation strategy, providing the user with more flexible block interfacing capability.

In addition to an upgraded one-equation turbulence model, a k-ω turbulence is nearing completion and will be available for version 3.0, if not earlier.

Also planned for release with version 3.0 are utility programs to aid the user in generating Namelist input and initial restart files for NPARC. These utility codes should help to reduce time consuming user errors.

Version 3.0 is currently slated for release by the end of the calendar year. An additional point release (2.2) will be made available if selected developments are completed ahead of schedule.

Frequently Asked Questions

The user support team receives many calls and email messages requesting information on code operation. We thought the answers to some of the most frequently asked questions might be of interest to the community as a whole.

Why does the code abort in INSUB (the subsonic inflow BC) when subsonic outflow is expected?

The type "0" BC allows inflow or outflow at the boundary. If the flow vectors are into the domain, the specified pressure is assumed to be the total pressure. For outflow, it is the static pressure. If your velocity vectors in the initial restart file are not clearly in or out, e.g. zero velocity or vectors parallel to the boundary, then the wrong subroutine may be called, i.e. INSUB instead of OUTSUB. The code is then faced with a static pressure in the flowfield greater than the specified pressure which is assumed to be the total pressure. The code then complains loudly and aborts. To remedy this situation, make sure that all vectors in the initial restart file are pointing out of the flow field at the outflow boundary.

Can transition to turbulence be modeled or predicted using NPARC?

Prediction of transition is an ongoing research topic and, as such, there are no general, reliable models available. However, some models have been successful for certain classes of problems. The algebraic RNG model available in the NPARC code has been demonstrated to predict transition for certain flat plate and airfoil cases. Since many factors influence transition, e.g. pressure gradient, surface roughness, freestream turbulence, etc., the accuracy of any transition model for all applications is in question. An input variable is provided to tune the model to a particular problem. Once tuned, the same value may be used for similar problems.

If the transition location is known, there is currently no capability to simply specify the location. However, it may be possible to break a block into two blocks with the interface at the transition point. By specifying laminar flow in the upstream block and turbulent flow in the downstream block, transition, similar to a trip wire, can be modeled.