NPARC Flow Simulation System

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What is NPARC?

The NPARC (**N**ational **P**roject for **A**pplication-Oriented **R**esearch in **C**FD) Alliance is a partnership between NASA GRC and the U.S. Air Force AEDC, with significant participation from Boeing, dedicated to providing an applications-oriented computational fluid dynamics (CFD) capability for the U.S. aerospace community, centered around the NPARC Flowfield Simulation System.

The NPARC Vision:

The Computational Tool of Choice for Aerospace Flow Simulation

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NPARC Alliance History

1993	• Formation of NPARC Alliance
1994-96	• Significant development of NPARC leads to large user base
1996	• McDonnell Douglas becomes an active partner
	• Code development groups at AEDC merge
	• Decide to merge NPARC, NASTD, NXAIR into Wind-US
1997	• Work begins on the NPARC Alliance Flowfield Simulation System centered on the Wind-US Navier-Stokes Code
	• McDonnell Douglas merges with Boeing
1998	• Wind-US Version 1.0 released
1999	• Wind-US Version 2.0 released
	• NASA Software of the Year Honorable Mention winner
2000	• Wind-US Version 3.0 released
2001	• Wind-US Version 4.0 released
2002	• Wind-US Version 5.0 released
2003	• BCFD (unstructured grid version) released to the Alliance
2005	• Wind-US 1.0 released (US for unstructured capability)
2007	• Wind-US 2.0 released

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Flow Simulation System

The *NPARC Flow Simulation System* has at its core the Wind-US CFD solver, but also consists of…

- common, portable file structure
- pre-processing utilities to set up the simulation
- post-processing utilities for examining the results
- web-based version control software
- web-based documentation
- web-based validation and verification archive

The NPARC Flow Simulation System assumes that the grid is generated using some other software system (e.g. Gridgen, ICEM CFD).

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Supported Platforms

Silicon Graphics

- IRIX 6.5, R10000, R12000, R14000, R16000 processors
- Multi-processing IRIX 6.5, R10000, R12000, and R14000 processors

Hewlett-Packard

- Multi-processing HPPA11, PA-8500 processor

Sun

- SunOS 5.*x*, SPARC4U processor
- Multi-processing SunOS 5.*x*, SPARC4U processor

Linux, X86 processor

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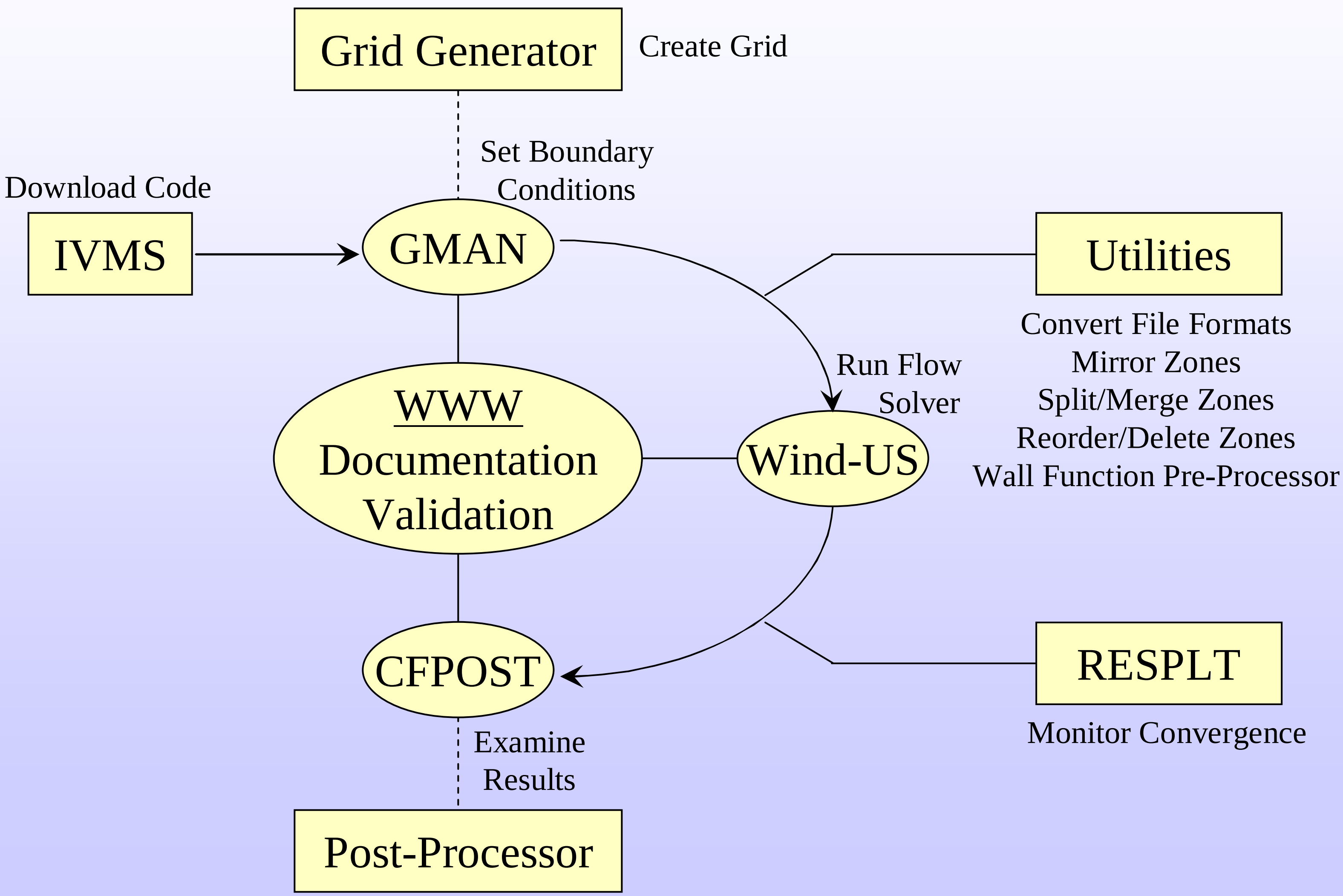
Basic Flow Simulation System



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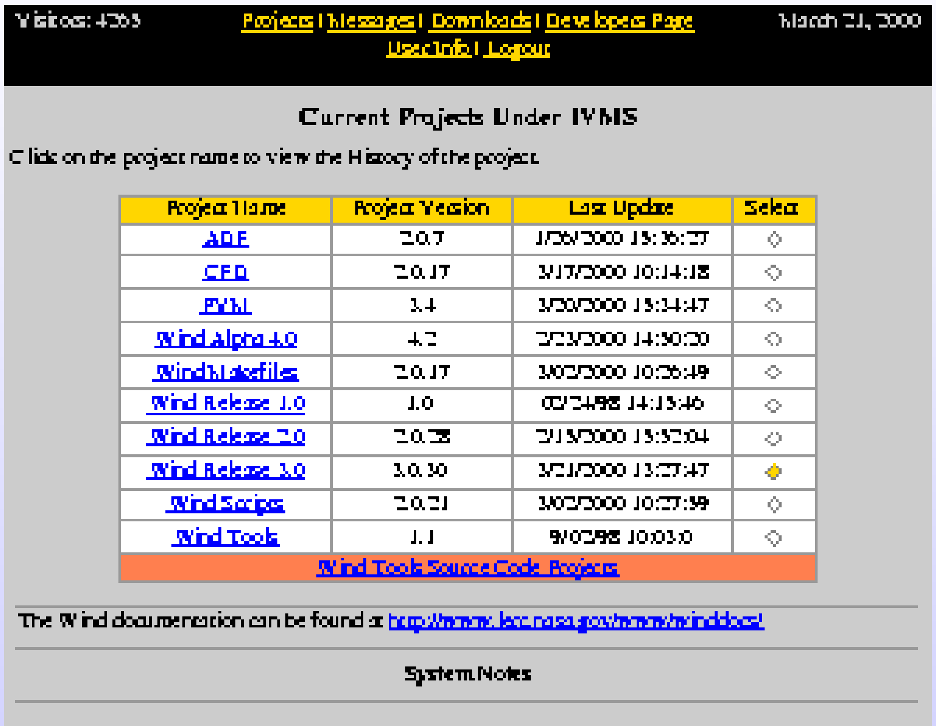
IVMS



- Internet Version Management System (IVMS) used for software version control and for distribution of software to users
- Accessed via the WWW
- GUI interface based on RCS, developed at Boeing
- Users can easily download current (and earlier) versions of Wind-US and its associated utilities
- Allows collaborative development at multiple sites

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Code Distributions

Wind-US Application Distribution - Contains the executable programs and files needed to run Wind-US on a specific supported platform.

Wind-US Build Distribution - Contains all source code needed to build the code, plus Makefiles for several platforms.

Tools Distribution - Contains executables for the pre- and post-processing tools used with Wind-US, including GMAN and CFPOST, for a specific supported platform. Tools also available individually as source code, with Makefiles.

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Availability

- NPARC Alliance software is available at no cost to U. S. companies, government agencies, and universities.
- May not be used for contract work with a non-U. S. organization.
- Release point is through AEDC.
- Non-government organizations must have an Export Control Number, i.e., be registered with the Defense Logistics Services Center Joint Certification Program.
- See the "Acquiring the Software" link on the NPARC Alliance home page (www.arnold.af.mil/nparc) for details and application forms, or send email to nparc-support@info.arnold.af.mil.
- Approved users download the software from the IVMS web site.

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Documentation

(WIND Documentation Home Page) (WIND User's Guide) (GMAN User's Guide) (CFPOST User's Guide) (WIND Utilities) (Common File User's Guide) (WIND Installation Guide) (WIND Developer's Reference) (Guidelines Documents)

(Introduction) (Tutorial) (Geometry and Flow Physics Modeling) (Numerical Modeling) (Boundary Conditions) (Convergence Monitoring) (Files) (Scripts) (Parallel Processing) (Keyword Reference) (Test Options)

WIND User's Guide

The "WIND User's Guide" describes the operation and use of the WIND code, including: a basic tutorial; the physical and numerical models that are used; the boundary conditions; monitoring convergence; the files that are read and/or written; parallel execution; a complete list of input keywords and test options; and where to go for additional help. It is based on the "NASTD User's Guide," written by R. H. Bush, M. Mani, T. R. Michal, and W. W. Romer of The Boeing Company.

The PDF form of the WIND User's Guide (1.03M, 181 pages) was created using pdfTeX and the hyperref package, and is designed to be printed. The HTML form is designed for interactive use, and the contents are listed below.

- Introduction
- Tutorial
- Geometry and Flow Physics Modeling
- Numerical Modeling
- Boundary Conditions
- Convergence Monitoring
- Files
- Scripts
- Parallel Processing
- Keyword Reference
- Test Options

The complete WIND User's Guide in HTML form is also available for installation on a local system. This is a gzip'ed tar file (185K, 799K gunzip'ed), and may be downloaded by clicking on the link while holding down the shift key, assuming your browser supports this capability. A dialogue box will appear for you to specify the directory and file name. To unpack the contents, do

```
gunzip -c user.tar.gz | tar xvf -
```

- All documentation is available at www.grc.nasa.gov/www/winddocs in both HTML and PDF formats
- Wind-US User's Guide - Describes the operation and use of the Wind-US code, including a tutorial, and descriptions of the physical and numerical models, boundary conditions, convergence monitoring, files, run scripts, parallel operation, and input keywords
- Separate user's guides for GMAN, CFPOST, and MADCAP, and for several smaller utilities distributed with Wind-US

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Additional Documentation

Wind-US Installation Guide - Describes how to download and install the executables for Wind-US and its associated "tools," and how to build a new executable from the Wind-US source code.

Wind-US Developer's Reference - Contains detailed information about the structure of the Wind-US code useful for those modifying the code (only available to Wind-US users).

Common File User's Guide - Detailed information about the common file library, a set of routines providing access to common files.

Guidelines Documents - Programming, documentation, and testing guidelines created for use by the NPARC Alliance during software development projects.

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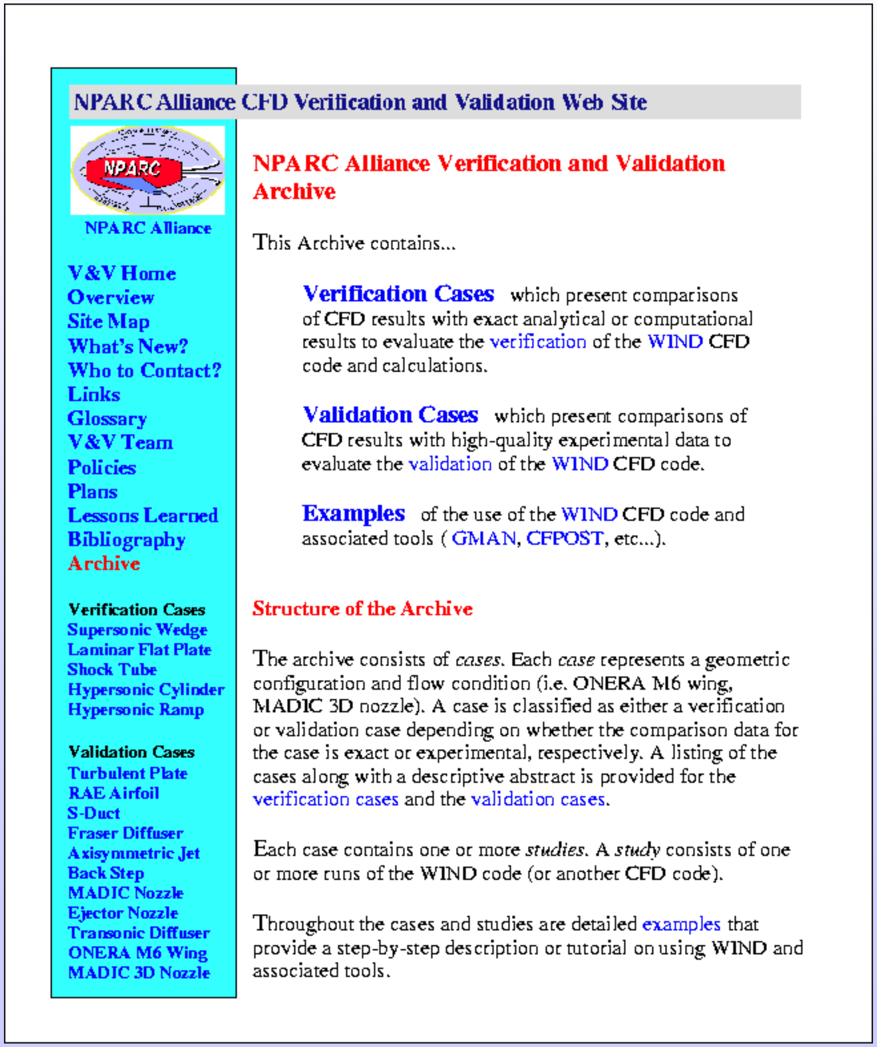
Verification & Validation


NPARC Alliance CFD Verification and Validation Web Site

NPARC Alliance

V&V Home
Overview
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What's New?
Who to Contact?
Links
Glossary
V&V Team
Policies
Plans
Lessons Learned
Bibliography
Archive

Verification Cases
Supersonic Wedge
Laminar Flat Plate
Shock Tube
Hypersonic Cylinder
Hypersonic Ramp

Validation Cases
Turbulent Plate
RAE Airfoil
S-Duct
Fraser Diffuser
Axisymmetric Jet
Back Step
MADIC Nozzle
Ejector Nozzle
Transonic Diffuser
ONERA M6 Wing
MADIC 3D Nozzle

NPARC Alliance Verification and Validation Archive

This Archive contains...

Verification Cases which present comparisons of CFD results with exact analytical or computational results to evaluate the verification of the WIND CFD code and calculations.

Validation Cases which present comparisons of CFD results with high-quality experimental data to evaluate the validation of the WIND CFD code.

Examples of the use of the WIND CFD code and associated tools (GMAN, CFPOST, etc...).

Structure of the Archive

The archive consists of *cases*. Each *case* represents a geometric configuration and flow condition (i.e. ONERA M6 wing, MADIC 3D nozzle). A case is classified as either a verification or validation case depending on whether the comparison data for the case is exact or experimental, respectively. A listing of the cases along with a descriptive abstract is provided for the verification cases and the validation cases.

Each case contains one or more *studies*. A *study* consists of one or more runs of the WIND code (or another CFD code).

Throughout the cases and studies are detailed examples that provide a step-by-step description or tutorial on using WIND and associated tools.

- NPARC Alliance Verification & Validation (V&V) WWW site at www.grc.nasa.gov/www/wind/valid
- Validation archive presents Wind-US code results; all input/output files may be downloaded.
- Verification cases present comparisons of CFD results with exact analytical or computational results.
- Validation cases present comparisons of CFD results with high-quality experimental data.
- Includes detailed examples showing how to set up and run a case, using GMAN, Wind-US, CFPOST, and other Wind-US utilities.

Support

- NPARC Alliance Support Team provides direct user support via email (nparc-support@info.arnold.af.mil) or telephone (931-454-7455).
- National user's meetings once a year (AIAA Aerospace Sciences Meeting)
- Technical papers (AIAA Aerospace Sciences Meeting, etc…)
- Training classes.
- Annual Workshop produces *Policies and Plans* document.
- User's mailing list (nparc-users@info.arnold.af.mil).
- NPARC Alliance WWW site (www.arnold.af.mil/nparc).
- Online documentation (www.grc.nasa.gov/www/winddocs).
- NPARC Talk email list (nparctalk@lists.nasa.gov).
- Online bibliography (www.grc.nasa.gov/www/wind).

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Code Development

- Development of Wind-US and utilities is continuous (Boeing, AEDC, NASA GRC).
- GRC efforts focused on developing tool for simulating inlet and nozzle flows (VG model, turbulence, bleed).
- Development efforts / contributions / suggestions by users are encouraged for all aspects of the system.
- IVMS allows distributed development while maintaining strict version control.

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New in Wind-US 2.0

- Wind-US 2.0 released July 2007.
- Almost entirely Fortran 90.
- Increased commonality between the structured and unstructured solvers.
- Unstructured solver was rewritten and improved.
- Temporal keyword for time iterations for unsteady solutions.
- Most boundary conditions use same coding for both structured and unstructured solvers.
- Various turbulence models (e.g. SST, DES) now available for unstructured solver.
- Chemistry restructured and improved.
- Chemistry keyword changed and not backward compatible.
- See online documentation for detailed list.

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Future Activities

- Enhanced physical modeling capabilities: turbulence, transition, chemically reacting flows, boundary conditions, vortex generators.
- Complete conversion to CGNS database format.
- Consolidation of tools under a common GUI (MADCAP). This will eventually replace GMAN.
- Investigate framework options for future CFD systems and multi-disciplinary applications (store-drop, aeroelasticity, structures).

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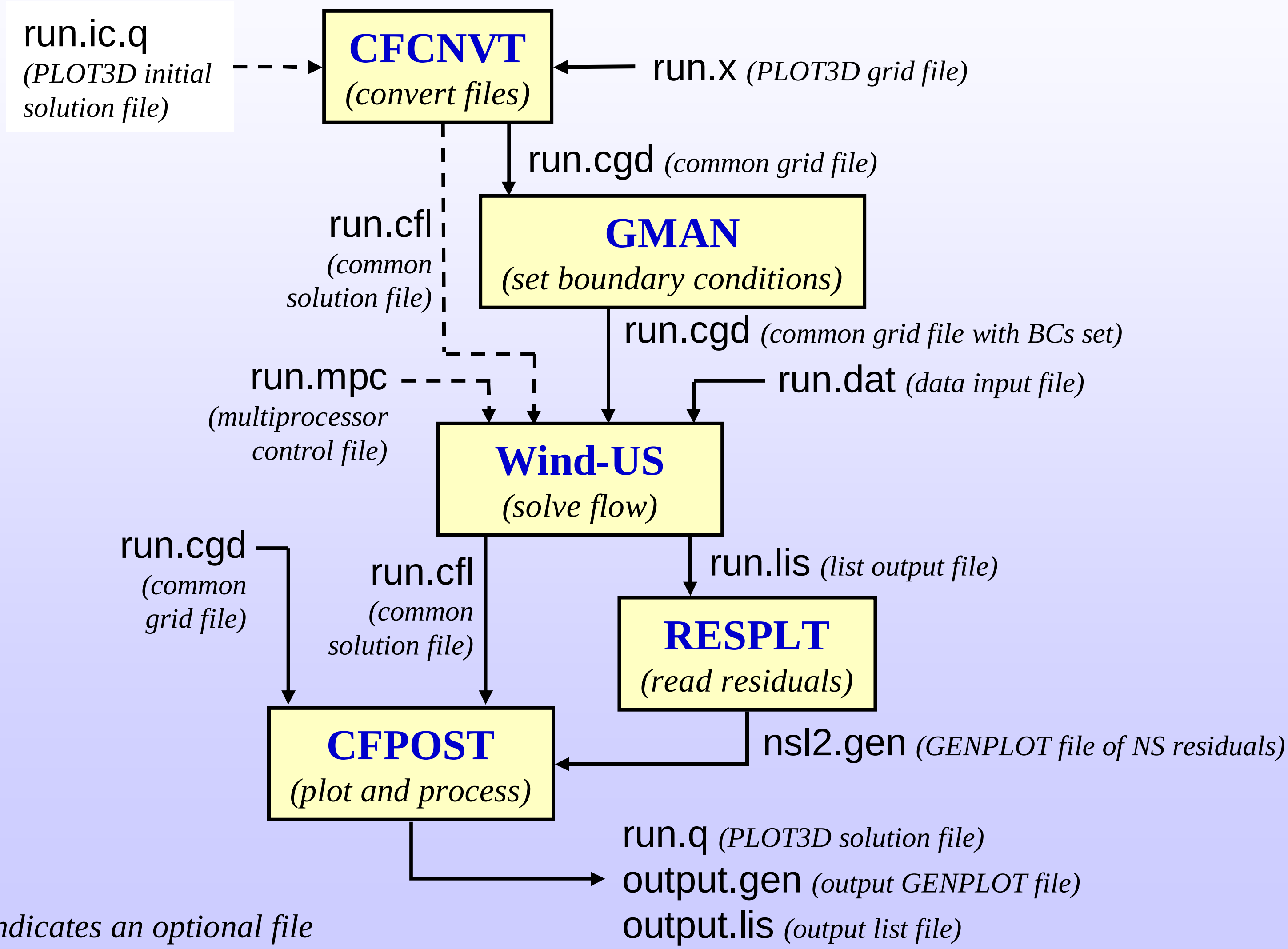
Flowchart



- - - - *Indicates an optional file*

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Primary Parts of the System

CFCNVT

Converts the PLOT3D grid and solution files (run.x, run.ic.q) into the common file format (run.cgd, run.cfl).

GMAN

Reads the common grid file and allows for manipulation of the grid and setting of boundary condition types onto zone boundaries and overlapping regions.

Wind-US

Solves the flow equations with inputs from the common files and input data file. Outputs the solution to the common solution file and creates a list output file.

RESPLT

Reads the list output file and generates GENPLOT files of convergence histories.

CFPOST

Post-processor. Reads the common grid and solution files and lists flow field variables, integrates fluxes and forces, creates and plots line and surface GENPLOT files, creates PLOT3D files, and generates output reports.

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Other Utilities

B4Wind-US GUI interface for converting NPARC files to Wind-US common file format
CFAVERAGE Average values in multiple common flow files
CFBETA Create a mirror image of a common grid for sideslip (beta) cases
CFREORDER Delete and reorder zones from common grid or flow file
CFSPLIT Split a zone of a common grid or flow file
CFCOMBINE Combine zones of common grid or flow file
DECOMPOSE Split zones in common grid and flow files for efficient parallel processing
RECOMBINE Convert DECOMPOSE'd common flow file back to original zones
CFSEQUENCE Extract a sequenced grid and solution from existing common files
CFSUBSET Remove grid points from common grid or flow file
FPRO Operate on data in common flow file
GPRO Operate on data in common grid file
JORMAK Find boundaries in common grid file and write subset info for CFPOST or PLOT3D
THPLT Read a common time history file and create a GENPLOT file
ADFVIEWER ADF file viewer/editor from CGNS project with GUI

MADCAP Replacement for GMAN and a unified GUI for many of these utilities

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Wind-US Files

Principal Input Files

Input Data File (*.dat). Contains keyword input describing the flow problem and how Wind-US is to be run. *(ASCII file)*

Common Grid File (*.cgd). Contains the computational grid (*x*,*y*,*z*) and boundary condition types and zone coupling data set using GMAN. *(binary file)*

Principal Output Files

List Output File (*.lis). Contains listing of input parameters, job statistics, error messages, residuals and integrated convergence information. *(ASCII file)*

Common Flow File (*.cfl). Contains the flow, turbulence, and chemistry field, as well as reference state and basic information on simulation. *(binary file)*

Common File Format (CFF)

- Used for common grid (*.cgd) and flow (*.cfl) files.
- Also used for some other Wind-US-related files.
- Self-documenting database structure developed at Boeing.
- Compact, easily accessible, portable.
- Common grid and common flow files supported by several commercial grid-generation (e.g., ICEM, Gridgen) and post-processing packages (e.g., Fieldview, Ensight).
- CGNS now supported.

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Wind-US Files (cont)

Other / Optional Input Files

- Multi-processor control file (*.mpc)
- Chemistry data file (*.chm)
- Wind-US stop file (NDSTOP)

Other / Optional Output Files

- Global Newton file (.cfk) [eliminated in next release.]
- Boundary data file (.tda)
- Time history file (.cth)

Further information is in *Wind-US User's Guide*:

www.grc.nasa.gov/www/winddocs/user/files.html

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CFCNVT

- Common File Convert (CFCNVT).
- Converts several file formats to the common file format for Wind-US.
- Grid and flow files can be converted.
- Flow file can be used as initial condition for flow field in Wind-US.
- Text-based program can be run interactively or in batch mode.
- Reply to a few prompts depending on the input file format.
- Start analysis process assuming we have a grid file.

```
      ******* Common File Convert Utilities ******
CFCNVT - Version 1.45 (last changed 2001/12/14 18:24:56)

  0: Exit program
  2: Import   a Common File
  3: Compress a Common File
  4: Break Common File into multiple transfer files
  5: Combine multiple transfer files into Common File
  6: Append one Common File to another
  7: Convert Common File binary to a text file
  8: Convert Common File text to a binary file
 11: Convert PLOT3D/Pegsus file to Common File
 12: Convert GASP     file to Common File
 13: Convert OVERFLOW file to Common File
 14: Convert Common File to OVERFLOW file
 15: Convert CFPOST GPV file to Common File GPC
 16: Convert ascii rake to Common File rake CGF
 17: Convert Pegsus 4.0 files to Common File

 Enter the number from one of the above requests
```

- PLOT3D format (option 11) is a common grid file format output by grid generation software.
- An initial flow field can be generated with another small program, output to the PLOT3D format, and then converted to a common flow file using CFCNVT.

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GMAN

- Grid Manager (GMAN).
- GMAN can be run in interactive mode using graphical menus or commands, or in batch mode using scripts.
- Input is the common grid file (*.cgd).
- Switching to graphics mode is done by “swi” or “switch”.
- Journal file is output for rerunning GMAN in batch mode.

What does GMAN do?

Set units for grid and flow (EE or SI)
Set boundary condition types
Display grid and boundary condition types
Compute zonal connectivity
Perform hole-cutting and grid overlapping
Scale, translate, rotate grid
Add or replace zone from other file
Basic grid generation (seldom used)

```
                         ***** gman *****

        Select the desired version from the following list.

0) END
1) gman_pre optimized version
2) gman_pre.old optimized version

Enter number of executable.......[1]:

 *****************************************************************************
 * Warning: This software 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. Violation of these export-control       *
 * laws is subject to severe criminal penalties. Dissemination of this        *
 * software is controlled under DoD Directive 5230.25 and AFI 61-204.         *
 *****************************************************************************
          GMANPRE - Version 6.153 (last changed 2002/11/05 20:30:13)
                    Appending to journal file 'gman.jou'.
  Enter SWITCH or GRAPHICS to change to graphics mode.
 GMAN: file run.cgd
 File run.cgd successfully opened.
 4 zones, file dimensions are 73x49x33
 Global Title:
 GMAN: units fss
 Current file units are in
 Current file units are in
 Units have been changed to ft
 GMAN: swi
```

Red boxes indicate inputs to prompts

The MADCAP program will eventually replace GMAN

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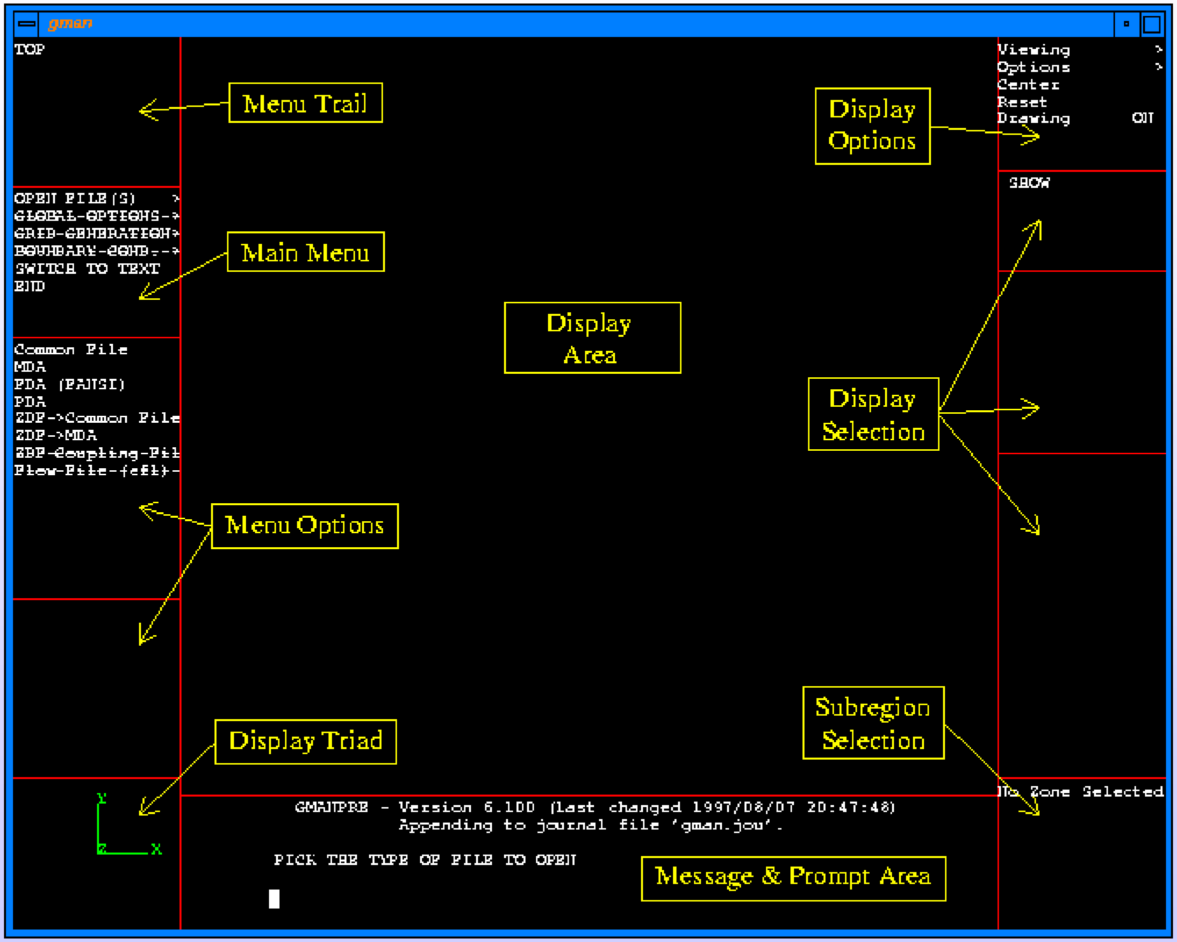
GMAN: Graphics Mode

Quick Reference:

- Hierarchy of menu items is from top to bottom.
- Left mouse button selects a menu item.
- A line through a menu item indicates that item can't be chosen.
- A "*" in front of a menu item indicates that item is the default.
- Mouse Buttons in Display:
  LEFT: Rotation
  MIDDLE: Zooming
  RIGHT: Translation



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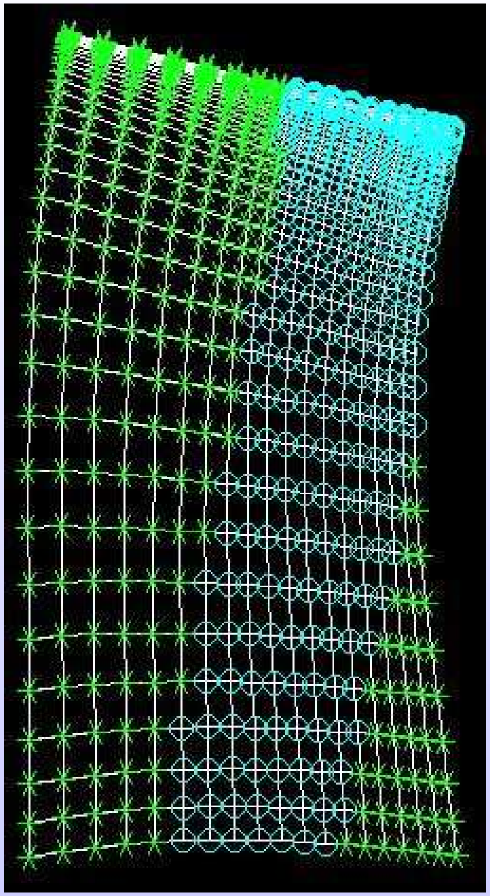
GMAN: Boundary Conditions

- GMAN is used to assign boundary condition types to each grid point on a zonal boundary.
- Zonal boundaries:
  I1, IMAX, J1, JMAX, K1, KMAX
- Subregions of boundary grid points can be defined to specify multiple BC types on a zonal boundary.
- Process for specifying BC type:
  1. Select zone (i.e. zone 1)
  2. Select boundary (i.e. K1)
  3. Select subregion (i.e. j1 j21 i2 i14) *optional*
  4. Select BC type
  5. Update file

BC types available:
- Undefined
- Reflection
- Freestream
- Viscous wall
- Arbitrary Inflow
- Outflow
- Inviscid Wall
- Self-Closing
- Singular Axis
- Mixed-Axis Wall
- Bleed
- Pinwheel Axis
- Frozen
- Chimera Boundary

Sample of journal file created created during an interactive session with GMAN

```
1
file run.cgd
units inches
ZONE 1
  BOUNDARY K1
    VISCOUS WALL
    UPDATE
  BOUNDARY JMAX
    SUBAREA K1 K45 I13 I20
    VISCOUS WALL
    UPDATE
```



Green = viscous wall
Aqua = bleed region

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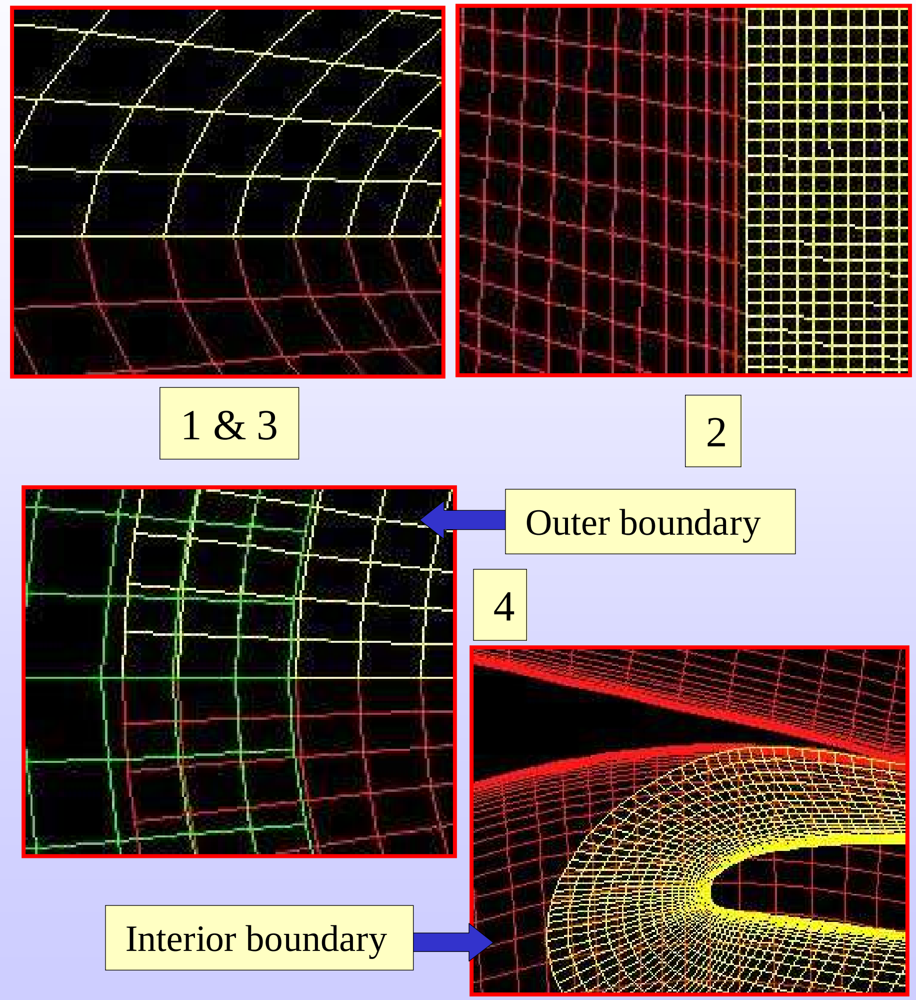
GMAN: Zonal Connectivity

- Flow information is exchanged across zonal boundaries.
- Connectivity defines how a zonal boundary is connected to other zonal boundaries.

Types of Zonal Connectivity

1) Abutting, Point-to-point match
2) Abutting, Non point-to-point match
3) Overlapping, Point-to-point match
4) Overlapping, Non point-to-point match

- GMAN can automatically compute zonal connectivity for abutting (1 & 2).
- Overlapping (overset) grids use tri-linear interpolation to exchange information.
- Point-to-point match is best since direct transfer is possible and interpolation errors are minimized.



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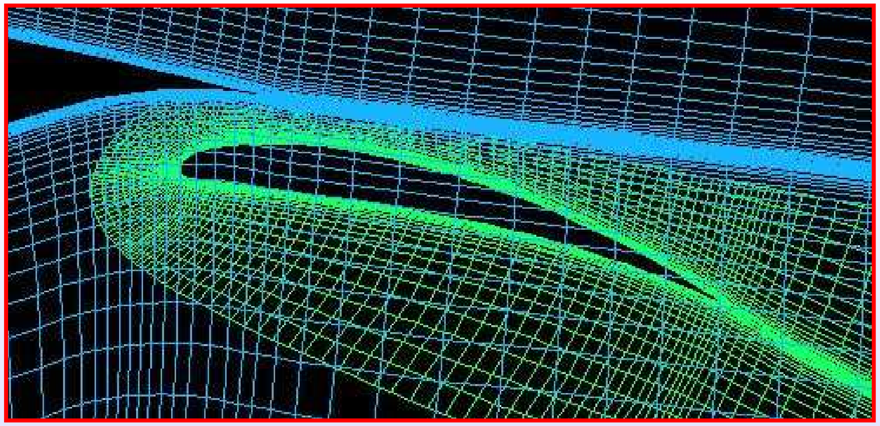
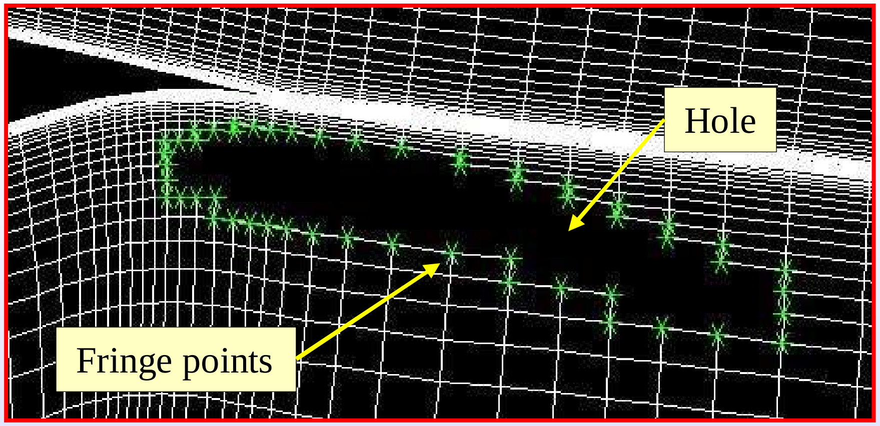
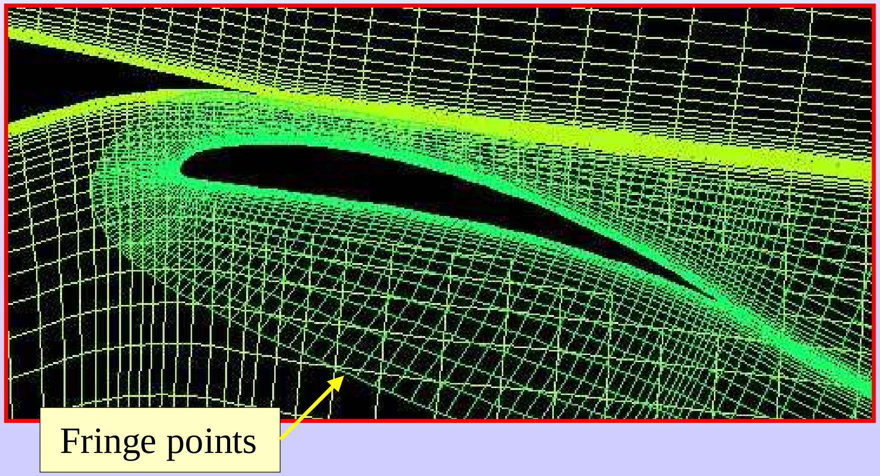
GMAN: Overlapped Grids





Example of NLR Airfoil with flap

- Flap grid overlaps airfoil grid.
- Use flap grid to cut a hole in airfoil grid.
- Indicate edge points of cut are fringe points to interpolate boundary information from flap grid solution.
- Outer edge of flap grid is fringe boundary of flap grid and receives interpolated data from the airfoil grid.



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Wind-US

- Wind is not an acronym.
- Solves several types of equations.
- Contains variety of features and numerical methods.
- Basic input files required are:
  - Input data file (*.dat)
  - Common grid file (*.cgd)
  - Common solution file (*.cfl) *optional*
- Wind-US is executed using the `wind` script with text prompts and responses.
- Wind-US is run as a batch execution.
- Simulation times to iterative convergence can range from minutes to days.

Equation Sets in Wind-US:

- Reynolds-Averaged Navier-Stokes (RANS)
- Turbulence
- Chemistry
- Magneto-Fluid Dynamics (MFD)

Features of Wind-US:

- Cell-vertex, finite-volume formulation
- Time-marching (steady or unsteady)
- Space-marching for supersonic flows
- Propulsion-specific boundary conditions
- Multi-zone, structured grids
- Abutting or overlapped zones
- Parallel and multi-processor operation

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Wind-US: Input Data File

- Input data file (.dat) is ASCII file.
- File contains descriptive keywords.
- “Test” options used for special cases.
- Online documentation lists all keywords.

Example Input Data (*.dat) file:

```
RAE 2822 Airfoil. 2D Transonic Flow.
Mach = 0.729. Alpha = 2.31 deg.
Single zone C-grid 369 x 65.

/Freestream      Mach  p(psi) T(R) AOA  Beta
freestream static 0.729 15.8  460.0 2.31 0.0

downstream pressure freestream zone 1

turbulence model spalart allmaras

dq limiter on

implicit boundary on

cycles 200
iterations per cycle 10 print frequency 10

cfl 5.0

end
```

First 3 lines are for titles.

“/” indicates a comment line .

Freestream keyword sets reference conditions, which are input in units consistent with grid file.

Specifies additional information for the outflow boundary condition.

Specifies choice of turbulence model.

Specifies use of limiter for change in solution (dq) over an iteration.

Specifies use of implicit boundary conditions on the airfoil surface.

Specifies the number of cycles to run.

Specifies the number of iterations per cycle and print frequency to list output file.

Specifies the CFL number.

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Wind-US: Select Keywords

Some of the other most commonly used keywords include:

AXISYMMETRIC Indicates flow domain is planar, axisymmetric.

BLEED Specifies input for mass flow and porous bleed models.

FIXER Turns on algorithm to fix bad points in flow (I.e. negative pressure).

IMPLICIT Specifies algorithm to use for implicit time-marching.

MASS FLOW Specifies input for outflow boundary condition.

RHS Specifies algorithm to use for numerical flux.

SEQUENCE Option to use coarser grid that is sequence of full grid.

SMOOTHING Specifies algorithm for artificial dissipation.

THIN SHEAR LAYER Option to use thin shear layer assumption.

TVD Specifies algorithm for TVD limiting of flux terms.

WALL FUNCTION Option to use a wall function for turbulence modeling.

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Wind-US: Block Keywords

Block keywords are input as a block of keywords that follow a certain format:

- ARBITRARY INFLOW   Proves input for the arbitrary inflow boundary condition
- CHEMISTRY   Provides input for the chemistry model
- LOADS   Provides input for summing forces on surfaces
- ACTUATOR / SCREEN   Provides input for the actuator disk / screen model
- VORTEX GENERATOR   Provides input for the vortex generator model

```
arbitrary Inflow
  total
  hold_totals
  zone 1
  uniform 0.6 14.0 460.0 0.0 0.0
endinflow
```

```
chemistry
  fuel air ratio 1.0
  file h2air-7sp-std-15k.chm
  finite rate
  mass fractions 0.993 0. 0.007 0. 0. 0. 0.
endchemistry
```

```
loads
  print totals zones lift frequency 10
  reference area 1.0
  reference length 1.0
  reference moment center 0.0 0.0 0.0
  zone 1
  subset I 33 337 j 1 1 k 1 1 force noslip
endloads
```

Wind-US: Flow Initialization

Wind-US requires an initial flow field to start the marching schemes. Some options for obtaining this include:

- Default initialization is uniform flow based on “freestream” values.
- Initial flow solution can be from common solution file (*.cfl).
- Arbitrary inflow can initialize a zone.
- Boundary layer initialization on a wall (one j or k surface per zone).
- Re-initialization of a “bad” zone.
- Initialization of turbulence and chemistry values.

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wind Script

- Command-line script to run Wind-US.
- Graphical interface also available.
- Wind-US may be run interactively, via Unix **at/batch** commands, or via NQS system.
- Executable need not reside on local system.
- May run on a remote system.
- Type wind –help to get list of options.

```
Wind syntax is as follows:

wind [-debug] [-debugger debugger] [-binroot dir] [-runinplace] [-runque que]
     [-runroot dir] [-help] [-dat datfile] [-grid grid file] [-(no)parallel)]
     [-flow flowfile] [-list listfile] [-program windversion] [-batch]
     [-queue_name que] [-begtime time] [-endtime time] [-walltime time]
     [-remoterun] [-cfdrootrem] [-ncpu number] [-memory number]
     [-tmpdir dir] [-grpcharge grp] [-nice_val n] [-not_nice] [-usessh]
     [-mp] [-mpmode mode] [-nzones nzones] [-nobg]
```

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Wind-US: Parallel Operation

- Wind-US may be run in parallel on a multi-processor system, or on a cluster of heterogeneous systems.
- Fault-tolerant master-worker approach.
- Grid zones are distributed from the master to the worker systems for processing.
- PVM message passing is used on clusters; PVM or MPI may be used on multi-processor systems.
- PVM supplied with Wind-US; MPI must be pre-installed.
- User specifies hosts via Multi-Processing Control (*.mpc) file.

Multi-Processing Control (*.mpc) file:

```
# loadlimit 1800
host saturn nproc 12
```

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RESPLT

- RESPLT: Residual Plotter.
- Reads the List Output File (*.lis) and extracts residual and other iterative convergence information and creates an ASCII GENPLOT file (*.gen) for plotting by CFPOST.
- Text-based program can be run interactively or in batch mode.
- Reply to a few prompts depending on what information is to be extracted.
- Asks for the name of the GENPLOT file to output.

```
                        ***** resplt *****

          Select the desired version from the following list.

0) END
1) resplt optimized version

Single program automatically selected.

  Enter full name of output list file:
run.lis

Exit                     0
Select Zone(s)          91
Select Frequency        92
Confined Outflow
  Mass Flow Ratio       15
  Back Pressure         16
  Average p0            93
Residuals      Big      L2        Integ. Planes Zone Grand
  NS             1       2          Force     11    5     8
  k-e            3       4          Lift      17   18    19
  B-B           20      21          Moment    12    6     9
  S-A           22      23          Momentum  13    7    10
  SST           24      25          Mass      14   26     -
NEWTON NS       51      52
Time History            53

Enter Selection
```

Red box indicate inputs to prompts

Sample of Selections:

2	L2 norm of residual of RANS equations per zone
23	L2 norm of residual of Spalart-Allmaras turbulence equation
17	Lift on surfaces as indicated by the LOADS keyword

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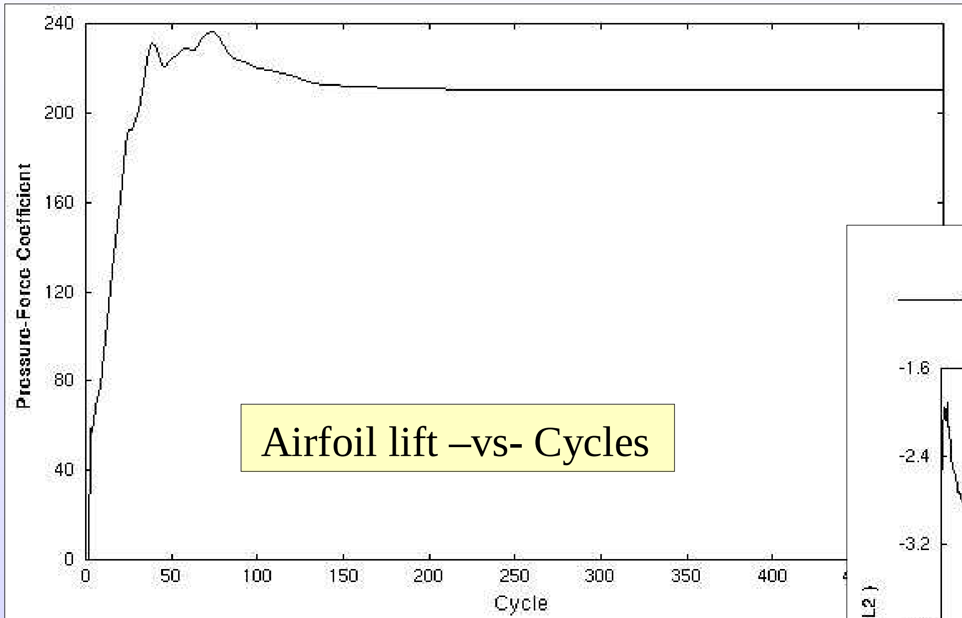
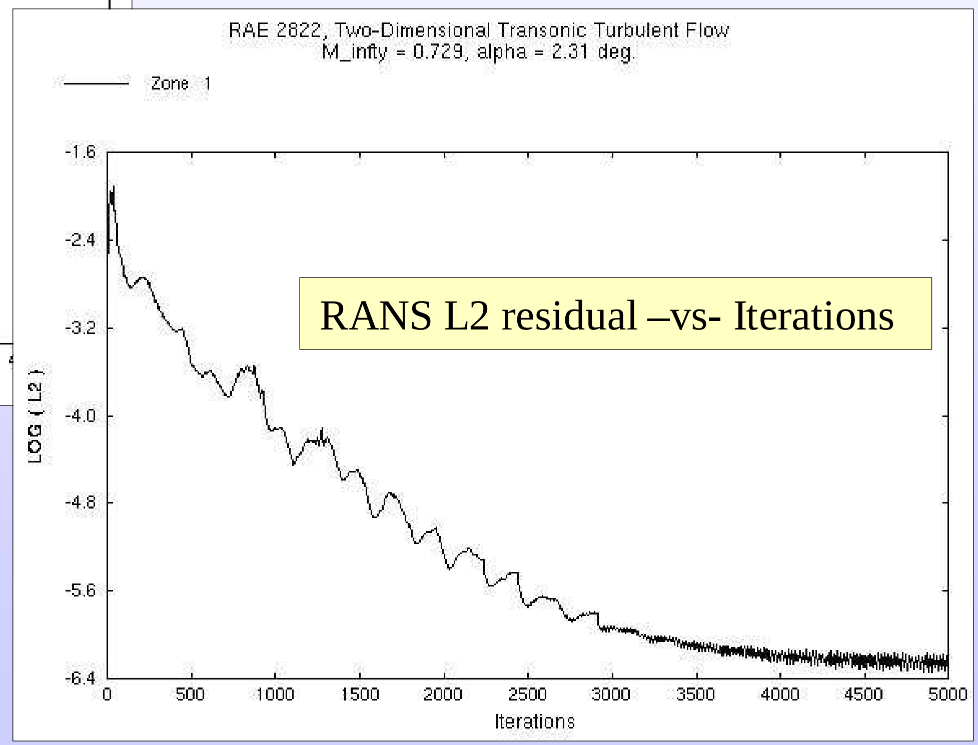
RESPLT: CFPOST Plotting





CFPOST can then plot the ASCII GENPLOT file.

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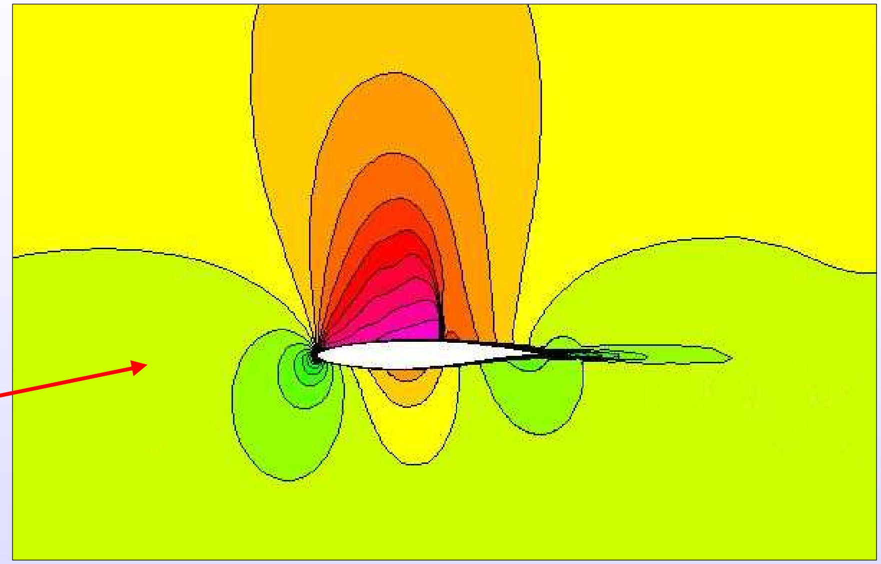
CFPOST

- CFPOST: Common File Post-Processor.
- Text-based program requires sequence of commands and can be run interactively or in batch mode.

What does CFPOST do?

Plots GENPLOT files
Creates contour plots
Creates velocity vector plots
Outputs PLOT3D grid & solution files
Computes forces and moments
Integrates fluxes (mass, momentum, …)
Averages flow over a cut or surface
Propulsion-specific analysis (rakes)

3D flow visualization is better performed using packages such as FAST, Fieldview, Tecplot, or Ensight.



```
                 ***** cfpost *****

  Select the desired version from the following list.

0) END
1) cfpost_pre optimized version

Single program automatically selected.

     CFPOST - Version 3.163 (last changed 2002/11/05 20:28:28)

| CFPOST>
```

Prompt waiting for commands

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CFPOST: Command Sequence

General sequence of CFPOST commands:

1) Specify grid file
2) Specify solution file
3) Specify units
4) Specify zone
5) Specify surface, cut, subset, etc…
6) Specify variables
7) Specify operation (plot, integrate, …)
8) quit to exit

To plot a GENPLOT file:

```
plot data nsl2.gen
quit
```

To create PLOT3D files:

```
grid run.cgd
solution run.cfl
units fss
zone 1 to last
  subset i all j all k all
plot3d x run.x q run.q unformatted mgrid
quit
```

To create a report of forces on a wing:

```
grid run.cgd
solution run.cfl
units fss
zone 3
  subset k all i all j 1
integrate force output forces.lis –
  iviscous –
  reference length 1.0 –
  reference area 1.0 –
  reference moment 0.0 0.0 0.0
quit
```

To create a plot file of Cp distribution at a cut along a wing:

```
grid run.cgd
solution run.cfl
units fss
zone 2
  subset i all j 1 k all
cut at z 0.25
variables x; Cp scale –1
genplot output cp.gen
quit
```

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Summary of the System

- Many options exist for using the programs that make up the NPARC Flow Simulation System.
- The previous presentation discusses one approach:

  CFCNVT ⇒ GMAN ⇒ Wind-US ⇒ RESPLT ⇒ CFPOST

- Online documentation provides further information.
- Best way to learn is to see a demonstration and get some hands-on experience.