Geometry Manipulation and Grid Generation Survey Results

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Abstract

In January of 1991, NAS users were sent a survey on Geometry Manipulation and Grid Generation software. Survey questions related to the user's current software and desired software and support. Thirty-four people responded. This document includes the specific comments received from the users as well as a summary of the responses. The users felt that government sponsored Geometry Manipulation systems are inadequate; commercial systems are expensive but capable. Grid Generation tools are inadequate. GRIDGEN is the best currently. Users want NAS to help. NAS should coordinate and disseminate information through seminars, libraries, and documentation. NAS should develop basic technology and comprehensive grid generation tools.

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1.0 Introduction

1.1 Background

In July of 1990 a Grid Generation Group was formed in the Systems Development Branch of the Numerical Aerodynamic Simulation Systems Division at NASA Ames Research Center in order to provide better tools and support to Computational Fluid Dynamics(CFD) research scientists. A Plan was formed involving information collection and dissemination, coordination of NASA efforts, and the development of improved tools. Part of the first task, information collection and dissemination, involved surveying current NAS users on the software they use for manipulating geometric objects and generating 3D grids about these objects as well as the support they desire from the NAS facility.

During the first quarter of 1991 both hard-copy and electronic versions of a Geometry Manipulation and Grid Generation Survey were delivered to NAS users. A copy of the survey is in Appendix A.

1.2 Goal

The goal of this survey was to better understand the current methods used for geometry manipulation and grid generation and to get direct user feedback on what assistance NAS should provide to improve the CFD development environment.

1.3 Organization Of This Report

This report contains five sections: Introduction, Objective Data, Subjective Comments, Summary, and Appendices. The Introduction provides a brief background, goals, and this description of the report organization. Due to the limited number of respondents and the nature of the questions in the survey, the section on Objective Data is very short. The majority of data from the survey is contained in the Subjective Comments section. The Summary contains the author's summation of the data. The appendix includes a copy of the original survey questionnaire that was sent to all NAS users.

1.4 Note of Appreciation

I would like to thank those NAS users who participated in the survey. The NAS Systems Development Branch staff has a much better understanding of the diverse needs of our research community thanks to your support of this effort.

2.0 Objective Data

2.1 Survey Respondents

This section contains numerical data on who responded to the survey. More than one person from some facilities responded to the survey.

34 people responded to the survey. 17 different facilities or companies were represented.

The number of respondents vs. type of facility is presented in the following table:

Type of Facility	Number of Respondents	
NASA facilities:	16	
Breakdown by NASA Center:	8	(Ames)
	6	(Langley)
	2	(Lewis)
Universities/Public research:	6	
Private companies:	12	

The University and private industry participants included:

Univ of Colorado, Boulder
Colorado State University
Univ of Trondheim, Div of Marine Hydrodynamics
University of Wisconsin, Madison
Cornell University, Xerox Design Research Institute
San Diego Supercomputer Center
SAIC/Annapolis
General Electric Aircraft Engines
IBM T. J. Watson Research Center
TRW, Inc.
Allison Gas Turbines
Boeing
Lockheed Aeronautical Systems
General Dynamics

2.2 Survey Results

This section contains tabulated survey data. Several people evaluated more than one package. 55 written evaluations were received. 32 different software packages were represented.

Software packages reviewed by NAS users included Geometry Manipulation Software (commonly called Computer Aided Design (CAD) tools) and Grid Generation Software. Several users provided comments on PATRAN, a commercial package used for finite element structural analysis. It is listed separately from the geometry and grid software. An overall rating was requested for each system reviewed as well as subjective comments on the strengths and weaknesses of each particular package. There was not enough data on most of the packages to compile objective results.

The following table summarizes the number of systems that were evaluated.

Area of Response	Number of Systems Evaluated
Geometry Manipulation Software	13
Government Sponsored	9
Commercial	4
Grid Generation Software	18
Government Sponsored	15
Commercial	3
PATRAN	1

The following table summarizes the overall opinion for the three most-commented-on grid generation packages. Several of the users did not provide an overall opinion. With such a small user sample size, these numbers mean very little but are included in lieu of any valid statistics.

Software package	Number of users	OVERALL OPINION: Excel	Good	OK	Bad	Useless
Eagle	5	0	1	1	0	0
Grape	5	0	0	0	1	0
Gridgen	10	2	1	1	0	0

3.0 Subjective Comments

Two of the survey questions were requesting subjective comments on the strengths and weaknesses of the current tools used by the user. Given the form of this survey and the diversity of the NAS user community requirements, it is not surprising that the majority of the survey response is in the form of lengthy narratives on the strengths and weaknesses of the packages the users currently have or recently used. The following sections list the user's opinion for each system. For some software packages, a brief explanation of the origins and hardware requirements of the software is provided at the beginning of the review. The order of the reviews within each section is random; no preference is intended by this.

Three packages, Eagle, Grape, and Gridgen were mentioned by several people. Nearly all of the other packages were reviewed by only one person. When the review was done by the developer, comments are noted as developer comments.

Following the phrase "User comments follow:," all statements are the opinions of a survey respondent and do not necessarily represent the views of this author or NASA.

3.1 Current Geometry Manipulation (CAD) Software

The following Geometry Manipulation Software was reported on by survey respondents. The software is broken down by it's origins and availability. The two categories are Government Sponsored (available for free or a nominal fee to U. S. researchers) and Commercially Available (usually available for a much larger fee.)

3.1.1 Government Sponsored Geometry Manipulation Software

3.1.1.1 BRL-CAD

BRL-CAD was developed and is currently being enhanced by the Ballistic Research Laboratory of the United States Army. The software runs on a variety of hardware platforms including SGI, Sun, Cray, and Apple Macintosh. User comments follow:

Specific Deficiencies:
"BRLCAD is only a solid modeler. It is difficult to query your model without shooting a ray at it. It was designed for vulnerability studies."

"BRLCAD can only create constructive solids from primitives but can import NURB splined solids from Alpha_1. The user interface is fair but not nearly as productive as Intergraph or ACAD. Furthermore, BRLCAD does not support IGES."

Specific Strengths:
"BRL-CAD is free and they distribute source. There is an immense database of BRL-CAD models, some of which are so detailed as to include the welds of materials."

"If you want to trace rays, BRL-CAD is extremely good at this application."

3.1.1.2 I3G

I3G was developed by McDonnell-Douglas under contract to the United States Air Force. The software runs on a variety of hardware platforms including SGI. One user listed I3G as a current tool, but no specific user comments were provided.

3.1.1.3 SMART

SMART was developed and is currently being enhanced by personnel at NASA Langley Research Center. The software runs on SGI workstations. User comments follow:

"SMART is a solid modeling design tool with some standard aerospace forms and is designed to interface with structural analysis packages."

Specific Deficiencies:
"Surface cuts, limited error recovery, user interface inconsistent."

Specific Strengths:
"Highly interactive, very flexible."

3.1.1.4 Alpha_1

User comments follow:

"Alpha_1 was funded by DARPA and developed by the University of Utah. Alpha_1 is a LISP based surface modeler that runs on several hardware platforms including SGI, Sun, and Hewlett Packard. Alpha_1 depends on Utah Common Lisp which has certain nonstandard extensions to Common Lisp. It will only run on machine where UCL has been ported. This can at best be described as a research code. To enter data, it is necessary to write a short R-Lisp program. The user interface is through GNUemacs. Alpha_1 has fairly sophisticated B-splines. Unfortunately, these are not interpolatory."

"It is not clear whether the DARPA funding makes the program available free to government agencies or whether they must pay a commercial fee for the product."

The one reviewer rated the system as useless.

3.1.1.5 WINGF/WING81F

WINGF/WING81F was developed by personnel at NASA Langley Research Center. The software runs on most UNIX platforms. User comments follow:

<u>Specific Deficiencies:</u>
"It is not a general purpose program."

<u>Specific Strengths:</u>
Works on "Generic airplanes."

3.1.1.6 HOMAR

HOMAR was developed by personnel at NASA Langley Research Center. The software runs on most UNIX platforms. User comments follow:

<u>Specific Deficiencies:</u>
"Very complicated discretely defined geometry."

<u>Specific Strengths:</u>

"Very fast, very little storage required."

3.1.1.7 ASTUD

ASTUD was developed by personnel at NASA Langley Research Center. The software runs on most UNIX platforms. User comments follow:

Specific Deficiencies:
"Manipulating I/O. Development has not proceeded to include multi component bodies greater than 2."

Specific Strengths:
"Interactive, fully menu driven with graphics. Generates its own I/O files. Very user friendly. Restart capability."

3.1.1.8 TECPLOT

TECPLOT is a commercial product from Amtec Engineering, Inc. The software runs on many UNIX platforms with graphics. User comments follow:

"This is a general purpose 3D plotting program that has data manipulation capabilities and can be used to generate text and/or geometries that can be added to data plots."

Specific Deficiencies:
None stated.

Specific Strengths:
"It is very versatile and easy to learn and can generate output in several different formats."

3.1.1.9 IDEAS

IDEAS (Interactive Design Evaluation and Assessment System) is being developed by SAIC with DARPA. Developer comments follow:

"The system integrates a geometry modeler, 2- and 3-D gridders, flow codes (potential flow and RANS) and performance evaluation codes. The system now uses a B-spline modeler (by May, a NURBS modeler) designed for conceptual design (rapid geometry manipulation and throughput) through interactive and scaled movement of the control net. The system uses I3G (Wright-Pat) and GRIDGEN (General Dynamics). The potential flow codes used are PMARC and VSAERO as well as several Rankine and Neumann panel codes for evaluation of free surface flows and a 6 DOF vehicle code for unsteady time domain solution for ships. The design evaluation codes used are for conventional ships and SWATH ships and include evaluation of seakeeping, wavemaking, powering and total % operability in different sea states for missions in specific ocean basins. The system is installed at NAVSEA, the Coast Guard, the Naval Academy, several Universities (including the Univ of MD which used it in designing their SunRacer solar powered vehicle) and is being installed at the American Bureau of Shipping and in European shipyards. The IDEAS system is currently being used in DARPA's AI and Design initiative as a test platform for an intelligent "design associate". It is currently being used on HPs, but is being ported to IBM/6000s."

3.1.2 Commercially Available Geometry Manipulation Software

3.1.2.1 ACAD

User comments follow:

"ACAD was developed by General Dynamics at their Ft. Worth, Texas facility. The software runs on a variety of hardware platforms including SGI, Sun, and Apollo. This system is available as government sponsored software to the Electromagnetics Code Consortium. Availability to other users is unknown."

Overall opinion: good.

<u>Specific Deficiencies:</u>

"This is a preliminary design package and therefore it is weak in manufacturing details, such as numerical control machine tool path generation and simulation."

"This code was designed to be portable and therefore doesn't really use the window environment. It handles all the menus and picks itself."

<u>Specific Strengths:</u>

"The Electromagnetics Code Consortium has a good relationship with the developers and can ask for modifications and enhancements. ACAD was written by an aerospace company for aerospace applications, unlike Intergraph, and therefore has a lot of the features that we commonly use."

3.1.2.2 CATIA

CATIA is a commercial CAD system from Dassault Systems. It currently runs on IBM VM/CMS, MVS. User comments follow:

Overall Opinion: Good

Specific Deficiencies:
"This is a general-purpose CAD system, so only a small part of it is useful for surface geometry definition of the type I need. It does not provide enough control over tolerances and smoothness of its surface representations. It is not supported on all of the usual machines."

Specific Strengths:
"It is very good at manipulation and design of three-dimensional objects, and has a pretty good user interface. It is reliable."

3.1.2.3 I/EMS

I/EMS is a commercial CAD system from Intergraph. It currently runs only on Intergraph hardware although the company has announced they will port the package to Sun. User comments follow:

Overall rating: Excellent

"Good User Interface -- Full CAD/CAM system. It is a commercial turnkey system which runs on its own hardware. Like all expensive commercial systems, every option costs. There are clearly hundreds of man-years in this effort. It is a complete CAD system and not some mickey-mouse effort."

3.1.2.4 ICEM

ICEM is a commercial CAD system from Control Data Corporation (CDC). It runs on SGI workstations. It includes some Grid generation and CFD tools. User comments follow:

Overall opinion: Good

Specific Deficiencies:
"Cannot see the grid as each iteration proceeds. Can only view the final product. Very cumbersome to use. Learning curve is approx. 4 months."

Specific Strengths:
"Versatile. Interactive viewing allows user to see the geometry as it is created. Helps user develop spatial resolution."

3.2 Desired Geometry Manipulation Capability

The question "What Geometry Manipulation capabilities do you desire most that are unavailable in the tools you currently use?" was asked (see Appendix). User comments follow:

"A simple geometry construction tool would aid cases where adequate geometric descriptions are unavailable. For example, 3D spline based surface generation and patching schemes, routines which determine the intersection curve of two arbitrary surfaces, etc."

"Real Time movement of the object in the window."

"For preliminary design, a "graphical french curve" would be nice. I envision a mouse driven interactive tool to create curves which are smooth."

"Since the company changes its mind every few years concerning which tools will be used for CAD, the proper development/communication between designers and engineers is inhibited."

"Ability to interface directly with CAD data file standards (e.g. IGES, PATRAN) and to use CAD type surface definitions (e.g. NURBS)."

"Surface-surface intersections."

"A simple tool for modifying 3-D surfaces and redistributing points on 3-D surfaces. GRIDGEN can do this somewhat, but it is difficult to use."

"Depends on how the geometry of my next project is described by its provider."

"I need some form of simple 3D CAD system to be able to make simple aircraft parts. Not all of the functionality that I need is in a single code."

"CAD-like functionality is unavailable:
. IGES format exchange
. NURBS, parametric 1-d, 2-d, and 3-d.
. Monotone, Bezier, Ferguson, etc. surface splines and polynomials
. lack of robust surface intersection algorithms
. the ability to define collections of rudimentary objects
. sparse data set triangular patch interpolation"

"We want a full surface and solid modeling capability. We are interested in design and analysis of 'correct' geometry, not resplined copies. For Electromagnetic analysis, we require continuity of curvature. This is particularly true between surfaces of patches."

"To grid complicated geometries like a transition of geometries to circular to real three dimensional arbitrary geometry."

"The most important tool that I need and do not currently have is a CAD system for defining a smooth parameterization of general surface geometries in three dimensions. I need very tight control over accuracy and smoothness. I need accurate and smooth representations of the intersections of surfaces."

"Complex 3D solids modeling."

"Point-and-shoot capability for picking out data associated with a given cell and/or vertex; 3D, shaded, interactive animation."

"The ability to easily interrogate and plot the properties of surface on an IRIS workstation. Would like to to plot gradient, second derivative, curvatures, etc. Ideally this capability would be included within FAST."

"The ability to display a complete wireframe using the basic geometry database input."

"Easy 3-D intersection line geometry."

"A library of basic geometry tools to perform such functions as curve-curve, curve-surface, surface-surface intersections, as well as the elementary operations such as rotation, translation of scaling. Should be available in workstation and non-workstation modes, with choice of splines, NURBS in particular"

3.3 Current Grid Generation Software

The following Grid Generation Software was reported on by survey respondents. The software is broken down by its origins and availability. The two categories are Government Sponsored (available for free or a nominal fee to U. S. researchers) and Commercially Available (usually available for a much larger fee.)

3.3.1 Government Sponsored Grid Generation Software

3.3.1.1 GRIDGEN

GRIDGEN was developed by General Dynamics under contract to the United States Air Force. The software runs on SGI workstations and Cray computers. User comments follow:

Overall opinion: 2 excellent, 1 good, 1 OK, 6 no response

<u>Specific Deficiencies:</u>
"Databases must already be in rectangular arrays. Input data must be discrete points (a temporary condition I believe). No surface intersection capability. All I/O in workstation binary (unreadable from standard FORTRAN on 4D series machines). Volume grid generation runs in fairly antiquated batch mode."

"This program does not have the capabilities of modifying geometry and flow field grid generation parameters easily. It does not have set defaults on flow field parameters and cannot control grid continuity across adjoining blocks (CFD zones) easily. It is therefore cumbersome to use and slow for CFD flow field grid generation. Other deficiencies include no journal (session) file for replaying the grid generation process for rapidly modifying flow field grids and it requires a smooth surface grid used for defining the configuration."

"The manual is confusing for novices in grid generation."

"The most recent version (6.00) of Gridblock seems to have lost the ability to display a complete wireframe picture using the geometry database. Previous versions were able to do this. This makes it difficult to choose points for edge definition."

"Lacks an interface to CAD standard geometry entities and file types. Also lacks unstructured grid capability."

"Lack of ease in mapping grid on multi-block parametric surface (GRIDGEN2D) when user has already defined boundaries of grid from multi-block parametric surface (in GRIDBLOCK), not portable to other platforms hurts use in a small budget project, can only view one index plane at a time when examining 3D grid (GRIDVUE3D)."

"The 4 step process of 1: blocking, 2: connecting and surface patching, 3: 3D grid generation and 4: viewing the grid is extremely labor intensive. Real time movement of even just the connecting patch definition files is not recommended on anything but a Power Series SGI workstation."

"Problems retaining data in such a way that the data can be recovered in the event of a mistake. Not Compatible with the NASA standard PLOT3D format."

Specific Strengths:

"Almost too many to list. Interactive. User friendly (except when it calls you names). Wide variety of surface generation tools. Complete system from domain decomposition to surface generation to volume grid generation."

"GRIDGEN, GRIDBLOCK—virtually flawless, some inefficiency in designation of viewing surfaces. Defaults are frequently correct, intuitive feel to interface, shallow learning curve. Should be used as a template into which new surface and volume grid methods can be appended."

"This program does have extreme flexibility for flow field grid generation. In addition, it has the capability of gridding individual blocks and then concatenating them to create a single flow field grid (zone). It allows for the specification of slope boundaries (e.g. surface and outer flow boundaries). It also can solve the 3D-PDE Poisson's equations, elliptically, to arrive at smooth grid transitions to within small error tolerances (iteratively). It has the potential of being the single best grid generator."

"Have not completed an entire grid generation application yet. Have used the code to define blocks and make a surface grid. Overall pleased with the code. Graphic manipulations are useful, complete and relatively fast."

"Easy to use, good user interface, robust methods."

"Zonal decomposition and boundary condition 'automation' (GRIDBLOCK), compatibility with the TEAM code, connectivity information when making common interface grids (GRIDGEN2D), general approach is that of one who has actually done the difficult multizone complex configuration grid generation tasks."

"Very general code with many options for surface panel grid definition."

"Very interactive and widely scoped in capability."

Someone stated they were porting GRIDGEN to an IBM RS/6000.

3.3.1.2 EAGLE

EAGLE was developed by Mississippi State University under contract to the United States Air Force. The software runs on SGI workstations and Cray computers. User comments follow:

Overall opinion: 1 good, 1 OK, 3 no response

Specific Deficiencies:
"Cannot see the grid as each iteration proceeds. Can only view the final product. Learning curve is approx. 3 months. NAMELIST is slow and probably not the most efficient way to set up the input."

"-Not sufficiently interactive (workstation version not on par with GRIDGEN)
-Namelist input with character variables impedes portability (not ANSI standard Fortran)
-Input sets are unwieldy to debug, impossible for the occasional user.
-Redimensioning an entire grid is difficult because the number of points on each edge is specified in numerous places in the namelist (connectivity checking can be time consuming)
-No periodicity condition for turbomachinery grids"

"Too complicated and time consuming."

Specific Strengths:
"Has developed a 'grid generation language'. Currently run the batch version of the code. This is easier in a multi-user environment where there are limited workstation terminals. Runs can be entered via a NAMELIST file and submitted and the workstation just used for viewing the grid. This should be a very

powerful code once the interactive FAST version is released this summer."

"-Grid created from input file, can be used as a "boiler plate" to create similar grids, it
reduces time in production mode.
-Lots of choices for distribution of points."

"Arbitrary geometries especially good for structured Euler grids."

3.3.1.3 GRAPE

GRAPE was developed by personnel at the NASA Ames Research Center. The software runs on SGI workstations and Cray computers. User comments follow:

Overall opinion: 1 Bad, 4 no response

Specific Deficiencies:
"GRAPE-unpredictable numerical stability bounds, requires user mods to code for virtually
all applications.
3DPREP-user interface requires inefficiently large quantity of mouse clicks and type-ins,
more defaults req'd to reduce labor. Non-intuitive."

"Has difficulty generating grids around sharp edges. Could use more options for outer boundary shape. Input controls are quite tedious. Very computationally expensive."

Specific Strengths:
"Orthogonality of grid cells. Multi-block capability."

3.3.1.4 S3D

S3D was developed by personnel at the NASA Ames Research Center. The software runs on SGI workstations. User comments follow:

Overall rating: Good

Specific Deficiencies:
"Surface gridding process only based on previous iteration of surface grid and not on original surface definition. Possible loss of accuracy through repeated approximation."

Specific Strengths:
"Good surface intersection properties. Interactive. Direct approach."

3.3.1.5 O & C Grid Generation for Turbomachinery (3D)

O & C Grid Generation was developed by personnel at Allison Gas Turbines. The software runs on SGI, Amdahl, Sun, IBM RS6000, and Cray. Developer comments follow:

Overall rating: none

Specific Deficiencies:
"Problems with highly twisted and highly ramped compressor blades which possess very small radius leading and trailing edges."

Specific Strengths:
"Very small wall clock time to develop a grid; it draws data directly from the design file."

3.3.1.6 GRID3D

GRID3D was developed by personnel at NASA Langley Research Center. The software runs on SGI workstations. User comments follow:

Overall rating: none

Specific Deficiencies:
"Can not be used for configurations with sharp edges. Not enough control over

outer boundary. Grid orthogonality is not guaranteed."

Specific Strengths:
"Simple to use and modify. Runs very fast on a workstation."

3.3.1.7 GRID3F

GRIDF was developed by personnel at NASA Langley Research Center. The software runs on SGI workstations. User comments follow:

Overall rating: none

Specific Deficiencies:
"Uses a two dimensional interpolation routine for individual cross-sections sometimes causing discontinuities between adjacent grid planes. Grid orthogonality is not guaranteed."

Specific Strengths:
"It is able to handle sharp edges somewhat (or quite well with minor changes). The code is easy to use and modify and runs fast on a workstation."

3.3.1.8 HYGRID

HYGRID was developed by personnel at the University of Colorado, Boulder. The software runs on SGI workstations. User comments follow:

Overall rating: none

Specific Deficiencies:
"The code is perhaps too specialized to create grids about wave-rider vehicles with sharp leading edges. Grid orthogonality is not guaranteed."

Specific Strengths:
"Works well on configurations with a sharp leading edge. Has a flexible outer boundary definition. Runs quickly on an SGI workstation."

3.3.1.9 CMPGRD

CMPGRD was developed by personnel at the IBM T. J. Watson Research Center. The software runs on most UNIX platforms as well as some PC and other IBM systems. Comments from the developer follow:

Developer's overall opinion: Excellent

Specific Deficiencies:
"This is not a general-purpose grid-generation program. It relies on other packages for geometric design and surface grid generation."

Specific Strengths:
"This is a system for combining component grids to form a composite overlapping grid, and for managing the related data structures. It is more powerful and automatic than CHIMERA/PEGASUS, which NAS currently uses for overlapping grid generation. Forthcoming versions will support distributed grid data structures for parallel computation of PDEs on MIMD and shared memory machines."

3.3.1.10Meshgen, Meshedit, Makemesh, Makegrid

Meshgen, meshedit, makemesh, and makegrid were developed by personnel at the Xerox Design Research Institute, Cornell University. Meshgen, makemesh, and makegrid run on any UNIX platform, Meshedit runs only on Sun. The software is "research grade" and not yet available to the public. Comments from the developer follow:

Overall rating:
Excellent : meshgen
Good: meshedit,makegrid
Bad: makemesh

"These codes were developed primarily for FEM simulation of semiconductor devices. Other uses include thermal analysis and fluid dynamics. They are all 2D codes, with meshgen restricted to first order triangles, and makegrid to rectangles. Meshedit is a graphical editor for 2D supermeshes. It (and meshgen) may be extended to 2+1/2 D (3D surfaces) in the near future, mostly to support boundary element methods."

Specific Deficiencies:
"Makemesh is an old 2D mesh refiner which supports several element types and orders, but is hard to use."

Specific Strengths:
"Meshedit is very easy to use and allows the user to specify geometry, region properties, degree of refinement, and all related boundary information. Curved edges are supported via splines. Its output is used by makegrid, which generates a 2D FE mesh, passing along all region and boundary properties supplied by meshedit. It produces VERY good meshes (at least I think so) quickly (e.g., 2000 triangles in about 30 seconds on a SPARCstation-1+). It may generate some obtuse triangles (5-10%), but my applications don't care."

3.3.1.11TCGRID

TCGRID (Turbomachinery C Grid) was developed by personnel at NASA Lewis Research Center. The software runs on Cray computers. Comments from the developer follow:

Developer's overall opinion: Excellent

Specific Deficiencies:
"Batch only."

Specific Strengths:
"3-D C- and H- type grid generator for turbomachinery.
Uses standard LeRC blade definition.
Uses 2-D GRAPE variant on several blade-to-blade sections, then reclusters spanwise for viscous grid. Very fast: .5M point viscous grid in 1.5 min on Y-MP.
Standard PLOT3D output, also used by my 3D solver.
Also does algebraic H-block upstream and O-block in tip clearance."

3.3.1.12 BCON

BCON was developed by personnel at Boeing and is available to government research personnel. The software runs on SGI workstations. User comments follow:

Overall opinion: OK

Specific Deficiencies:
"Does not save journal file; i.e. no play back mode. One error and you have to start over."

Specific Strengths:
"Good for multi block geometry. Good front end to EAGLE."

3.3.1.13hypgen

hypgen was developed by personnel at NASA Ames Research Center. The software runs on SGI workstations. No user comments were provided except an overall rating.

Overall opinion: Excellent

3.3.1.14Delaunay/Hydro

Delaunay/Hydro was developed by personnel at NASA Ames Research Center. The software runs on Cray computers with grid generation on an IBM PC. Developer comments follow:

Overall opinion: Good

Specific Deficiencies:
"Doesn't yet incorporate self-gravity; grid gets tangled under extreme conditions."

Specific Strengths:
"Two-dimensional speed, three-dimensional (well, 2.5) galactic models."

3.3.1.15SAIC Unstructured Gridder

SAIC Unstructured Gridder is under development by SAIC for the Air Force. The software will be public domain. Developer comments follow:

"It generates a tetrahedral mesh and is designed for adaptive refinement. It is tied to a B-spline fit to the input geometries (the Air Force provided point files as its specific input) but we intend to tie it to the same modeler as for the structured gridders. It is now used in conjunction with our own Godunov solver, but could be tied to Lohner's and Jameson's codes. We are also seeking funding for expansion of this system into an integrated design system, including automatic generation of sensitivities, use of the sensitivities in concurrent design and in guiding optimizers for both the direct and inverse problems."

3.3.2 Commercially Available Grid Generation Software

3.3.2.1 AGPS

AGPS (Aero Grid and Paneling System) was developed by Boeing and is a proprietary system used internally. No user comments were provided.

3.3.2.2 VisualGrid

VisualGrid is a commercial grid generation package from Visual Computing. VisualGrid runs on SGI workstations. User comments follow:

Overall opinion: Excellent

<u>Specific Deficiencies:</u>
"Currently only for two-dimensions"

<u>Specific Strengths:</u>
"User interface, number of good tools available for building zonal boundaries and grids."

3.3.2.3 ICEM

ICEM is a commercial CAD package with some grid generation tools. See section 3.1.2.4.

3.4 Desired Grid Generation Capability

The question was asked; What Grid Generation capabilities do you desire most that are unavailable in the tools you currently use (see Appendix)? Answers follow:

"Simultaneous control of, or at least feedback on (Always important), stretching rates, cell aspect ratio, skewness, orthogonality at boundaries, first-cell spacing at boundaries (Wish list), interactive display on IRIS (not a substitute for the features above), ability to use as an adaptive method, and given a preliminary solution provide good handling of sharp corners and strongly concave areas."

"Reliable multiple block structured grid generators coupled to a CAD system. This is particularly important for design. Good unstructured grid generators, which preserve orthogonality between the mesh faces and dual mesh edges and can be coupled with solution adaptive procedures."

"To do these at a interactive level."

"When I use a curvilinear, logically-rectangular grid, I need to be able to evaluate the function (and its derivative) that maps the unit cube onto the grid. An estimate of the smoothness of this function would be very useful."

"Full 3D volume finite elements from a solid modeling program. Better 3D boundary element mesh generators (see comment above)."

"Unstructured grid generator, Adaptive grid generator, etc"

"Would like to be able to see the grid evolve."

"Unstructured as well as structured grid generation capability. Would like to be able to use a control point methodology to manipulate specific regions of grid points, such as Eiseman is working on."

"Grid adaptation to a partially solved CFD calculation, for enhanced, rapid and refined solutions. In addition, grid generation codes are needed to interface refined zonal solutions to an original grid for continued CFD configuration zonal solutions. As far as I know, there are no simple grid generation tools for axisymmetric configurations (e.g. ellipses, circles, etc.) for spinning a profile about an axis."

"Generation of single/multiblock structured/unstructured grid. Solution adaptive capabilities. Availability of flow solvers to which the adaptive grid can be coupled."

"Specific types of complex turbomachinery geometries: splitters, part-span shrouds, etc."

"Our application is for internal flows (internal combustion engine manifolds). However, Gridgen was developed primarily for external, aerodynamic flows. Examples and specific capabilities for internal flows would be useful."

"Wing-pylon-nacelle junctions with overlap (i.e. when the pylon covers only part of chord and nacelle) are extremely difficult to grid."

"Consideration for geometries with rotational symmetry should be addressed equally with those that have planar symmetry. (Airplanes often have planar symmetry, but turbines, propellers, etc. have rotational symmetry.)"

"A 'smart' surface grid generation scheme (i.e. Automatically clusters near regions of high curvature in three dimensions) would be useful."

"A library of some of the more traditional geometries should be a part of any new tools, i.e.: 2D wing, 3D wing, 2D duct, 3D duct, and even a wing/body configuration."

"Periodic boundary condition(turbo-machinery.) Global grid redimensioning."

"For complex geometry, it must:
- -generate grid(including setup time) in 2 hours
- -be solution adaptive to resolve all length scales
- -grid must be good enough and reliable enough to guarantee no compromise of solution accuracy."

"The capability that seems to be overlooked is the use of the actual geometry definition (complex 3D surfaces) when mapping a grid on to a solid surface. The use of geometry defined by a set of curves as the definition limits my ability to re-distribute points along a curve (parametric or otherwise) with confidence that I have not changed the surface definition. You are only as good as your defining geometry and surface panel definitions are not good enough!"

"Automated blocking for structured grids."

"Volume grid smoothing."

"Block topology setup: auto-blocking process."

"An elliptic solver similar to 3DGRAPE with more flexibility in the outer boundary shape definition and the ability to handle sharp edges."

3.5 PATRAN

Three people responded with fairly long discussions on their use of PATRAN. PATRAN is a commercial product from PDA Engineering that runs on many platforms including SGI, Sun, Cray, and many other hardware platforms. It was rated good by 2 users and bad by one. User comments follow:

"We know of the product from the Finite Element World where it is heavily used. As a first step into the "grid"-world we try to use it modeling CFD. The application is surface floating ships and offshore structures."

Specific Deficiencies:
"Difficult to have results presented (postprocessed) unless you have data at the element nodes, i.e. when you have control points where you evaluate physical quantities such as pressure, velocity,... on the body surface. We also have a special problem related to the free surface (wave making). When simulating dynamic problems with a moving free surface it seems difficult to find a geometric tool than can cope with it. We need visualization of every timestep with changing geometry (=wet body surface). We have little experience using PATRAN where it is meant to be used, in structure analysis."

"It does not have unstructured grid capabilities."

"This program does not have the capability of solving the Poisson's 3D-PDE elliptically. It is cumbersome to use because it is set up for Finite Element grid generation. In addition, it is somewhat expensive to operate. It does have the capability of 3D flow field grid generation, but does not control slope continuity and slopes in general along boundaries."

Specific Strengths:
"It seems to be running on a lot of HW. Good support."

"This program does have extreme flexibility for flow field grid generation. It has a programmable language for writing rapid grid generation programs. With the use of its programmable language, it can be ported to just about anywhere, and can have grid solvers added for slope continuity and boundary slope definition. It does have a session (journal) file to rapidly modify a given configuration in a playback mode. It also lends itself well to the generation of unstructured grids."

3.6 Desired NAS Support

The question was asked, "In what ways do you see NAS supporting your Geometry and Grid Generation needs?" User comments follow:

"I didn't know you were interested. If you make good software available (especially on SGI machines) I'll probably use it. Especially if you publicize it so that I know it's on the machines."

"Maintenance and updates to the codes I use. Access to trial versions of new software."

"Develop a cohesive graphics interface and distributed proc. CAD and grid generation family of codes. Disparate systems with overlapping functionality such as the volume grid portions of GRIDGEN and GRAPE should be merged into a seamless package. Addition of HYPGEN into the GRIDGEN family would be useful."

"NAS should concentrate its resources on the part of the problem which is unique to CFD and CEM. It doesn't make sense to rewrite the surface geometry routines which are available from existing CAD codes."

"By having this questionnaire, I am sure something good will come out for generating grids reliably at quicker, easier and faster way, which will be very useful to the NAS users"

"Since I can only use NAS computers over the Internet, I doubt that I can effectively use most of the interactive tools available at NAS. I consider that I am more of a provider of grid generation tools than a user. I would be happy to provide the CMPGRD system for use at NAS."

"We would like to use public domain tools more frequently. It does not pay to purchase expensive commercial tools for a couple of people in research."

"GAS on an SGI workstation is probably sufficient for the animation, but access to such a system is a problem. Virtual reality system (dataglove) would probably be fun and useful but is also probably overkill."

"Grid generation programs should be documented, kept at a central place and fully supported."

"The establishment of a grid generation center with a consolidation of various grid codes for different applications, including updates and documentation. User support hotline and documentation of known bugs and details of updates underway. With the prevalence of limited budgets, the U.S. government agencies should team with academia and industry to develop an industry standard grid generation package. Joe Thompson of MSU is currently trying to pull this off."

"Solving 3D-PDE Poisson's equations for flow field grid slope continuity, determining the truncation error due to the grid used for different CFD programs and aiding in rapid grid generation."

"Most of the capabilities that what I would like to have could be incorporated into the FAST software as 'add on' modules."

"Formation of a special interest group, or user group, that would have input on the geometry/grid manipulation tools that NAS is going to support. the objective here is to ensure that NAS does something that could be of use to a wide spectrum of researchers, as opposed to a handful of people."

"Tool to test overall 'goodness' of a grid."

"As a resource for general questions regarding grid generation. A potential source for advice on methods and codes. E-mail service is very convenient. Interaction with other users would be very helpful (maybe through a question answer bulletin board)."

"Geometry manipulation and grid generation takes up 90 percent of my time. The remaining 10% is used to do actual work (i.e. analysis and design). I wish NAS could provide automated grid generation procedures so that I can spend 90% of my time doing useful work."

"Standardize grid file formats (i.e. PLOT3D style). This simplifies comparisons between various analysis techniques."

"Simplify graphics interfaces for 3D grid construction."

"Continual improvement and automation of developed grid generation tools."

"Creation of a publicly accessible library of conventional test-type grids."

"Writing of support documentation."

"NAS should be a pathfinder, and a clearing house for new tools. In the past, NAS has been an available source of information, especially for workstation based tools."

"NASA should be doing leading edge flow solution algorithm research to develop flow solver technology which defines the grid requirements. Don't do grid generation research in a vacuum. The main reason that we have so much trouble with grid generation today is that our flow solver algorithm technology is too limited."

"As a forum to discuss and evaluate the rapidly changing field of Solid Modeling and computer graphics, as well as current CFD software available. One can be overcome by the choices to be made concerning hardware and software and one needs to talk with other users with similar problems to hash out what is the best route your company should follow (both long term research and short term project applications.)"

"The role of NAS and NASA is that of providing basic research into new grid generation methods (PDE, algebraic), artificial intelligence (automation) and new, novel technologies (e.g. stereo viewing). These basic technologies should be developed in a generic manner so that they may be easily incorporated into existing industry codes. NAS and NASA should not be developing complete grid generation packages including user interface, graphics, etc."

"Maintain a library of programs. Maintain lines of communication."

4.0 Summary

4.1 Geometry Manipulation Capability

There are several government sponsored systems available and a plethora of commercial CAD systems on the market. Commercial CAD systems are well ahead of any government sponsored systems. There is no clear tool of choice among the simple government sponsored systems or the more robust commercial packages. The commercial systems were not well represented in this survey.

Many users desire a "simple" geometry construction tool. They also want elaborate spline based geometry and complete surface-to-surface intersection-curve determination with a mouse and menu driven graphical interface. Existing government sponsored software is inadequate. Apparently, most NAS users do not have access to commercial CAD systems which probably have the desired features but may be cumbersome to learn and operate.

4.2 Grid Generation Capability

Most grid generation tools are government sponsored. There are several aerospace companies with their own in-house systems and a few commercial packages are available.
The tool of choice at this time is GRIDGEN judging by the number of users and the degree of satisfaction among those users.

Users have a big list of complaints about grid generation tools.

Specific areas that require improvement in structured gridding include manual control and feedback on numerous grid measures during grid generation, automatic block topology setup, automatic point clustering and solution adaptive techniques, visual feedback on the grid generation process including measures of grid quality, improved algorithms for sharp corners and concave areas, and robust performance.

The unstructured grid area is in need of basic tools including solution algorithms capable of utilizing unstructured grids.

The propulsion development people are unable to use many of the existing tools because they do not take into consideration several unique aspect of radially symmetric problems.

4.3 Desired NAS Support

Users were pleased to have a chance to help guide NAS support. There were three main suggestions for NAS grid generation support.

Well over half the suggestions related to NAS providing access to information, software, and coordination/standardization. Some specific requests include:

Provide a central repository for:
- library of useful software
- library of test grids
- documentation
- new tools

Provide full support, including:
- a distribution process
- publicity on the library
- maintenance and updates
- documentation for useful packages
- advice on methods and codes
- technical forum, covering
    - grid generation
    - Solid Modeling, computer graphics, and CFD
- development or coordination of a standardized grid file format

This NAS library should get feedback from users on what packages NAS will support.

The other two requests are somewhat in conflict. Some users felt NAS should develop extensive grid generation capabilities such as grid quality measurement tools, simplified graphics interfaces for 3D grid construction, a cohesive graphics interface, improved and automated grid generation tools, and flow solver technology which defines grid requirements. This would lead to developing a comprehensive package providing a seamless environment.

Other users felt NAS should stick with basic research in the parts unique to CFD and CEM(Computational Electro-Magnetics) including basic methods and algorithms, AI (Artificial Intelligence), and new technology such as stereo viewing. These users felt that NAS should not develop comprehensive packages, especially in the CAD area.

Appendix A