NASA Workshop on Future Directions in Surface Modeling and Grid Generation

W. R. Van Dalsem, R. E. Smith, Y. K. Choo, L. D. Birckelbaw, and A. A. Vogel

March 1992
NASA Workshop on Future Directions in Surface Modeling and Grid Generation

W. R. Van Dalsem, Ames Research Center, Moffett Field, California
R. E. Smith, Langley Research Center, Hampton, Virginia
Y. K. Choo, Lewis Research Center, Cleveland, Ohio
L. D. Birckelbaw and A. A. Vogel, Ames Research Center, Moffett Field, California

March 1992
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREFACE</td>
<td>v</td>
</tr>
<tr>
<td>CONFERENCE PROGRAM</td>
<td>vii</td>
</tr>
<tr>
<td>CONFERENCE COMMITTEE</td>
<td>ix</td>
</tr>
<tr>
<td>SESSION SUMMARIES</td>
<td></td>
</tr>
<tr>
<td>NASA Overviews</td>
<td>1</td>
</tr>
<tr>
<td>Aerospace Industry Overviews</td>
<td>2</td>
</tr>
<tr>
<td>DoD Overviews and Panel Discussion</td>
<td>3</td>
</tr>
<tr>
<td>University Overviews</td>
<td>4</td>
</tr>
<tr>
<td>Emerging Technology Briefings</td>
<td>6</td>
</tr>
<tr>
<td>Group Discussions and Panel Discussion</td>
<td>8</td>
</tr>
<tr>
<td>NASA Program Planning Session</td>
<td>9</td>
</tr>
<tr>
<td>CONFERENCE ATTENDEES</td>
<td>11</td>
</tr>
</tbody>
</table>
PREFACE

The NASA workshop was initiated by the Office of Aeronautics and Exploration Technology (OAET). The purpose was to assess U.S. capabilities in surface modeling and grid generation and take steps to improve the focus and pace of these disciplines within NASA. The organization of the workshop centered around overviews from NASA centers and expert presentations from U.S. corporations and universities. Small discussion groups were held and summarized by group leaders. Brief overviews and a panel discussion by representatives from the DoD were held, and a NASA only session concluded the meeting. The program for the workshop is attached. Also, attached is a list of workshop attendees.

To encourage candor, no written papers were required, and the public availability of vugraphs was left to the speaker's discretion. No vugraphs from individual presentations are included herein. Each session of the workshop was summarized by the session chairman, and an edited compilation of the summaries is presented herein.

In the NASA Program Planning Session summary there are five recommended steps for NASA to take to improve the development and application of surface modeling and grid generation.
## NASA Workshop on Future Directions in Surface Modeling and Grid Generation

### December 5-7, 1989

**NASA Ames Research Center, NAS Auditorium (Bldg. 258, Rm. 127)**

---

### Tuesday, December 5

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
<th>Chair(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00</td>
<td>Registration (NAS Lobby)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:30</td>
<td>Welcome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:45</td>
<td>Report on 1989 AGARD Meeting</td>
<td></td>
<td>Kristin Hessenius, NASA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Joseph Steger, U.C. Davis</td>
</tr>
</tbody>
</table>

#### SESSION 1  NASA Overviews

**Chair:** William Van Dalsem

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
<th>Chair(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:15</td>
<td>Ames Research Center</td>
<td></td>
<td>Alison Vogel</td>
</tr>
<tr>
<td>9:45</td>
<td>Langley Research Center</td>
<td></td>
<td>Robert Smith</td>
</tr>
<tr>
<td>10:15</td>
<td><strong>BREAK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td>Lewis Research Center</td>
<td></td>
<td>Yung Choo</td>
</tr>
<tr>
<td>11:00</td>
<td>Johnson Space Center</td>
<td></td>
<td>C. P. Li</td>
</tr>
<tr>
<td>11:30</td>
<td>Marshall Space Flight Center</td>
<td></td>
<td>Paul K. McConnaughey</td>
</tr>
<tr>
<td>12:00</td>
<td><strong>LUNCH</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### SESSION 2  Aerospace Industry Overviews

**Chair:** Aaron Snyder

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
<th>Chair(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:00</td>
<td>McDonnell Aircraft</td>
<td></td>
<td>Ray Cosner</td>
</tr>
<tr>
<td>1:25</td>
<td>Pratt &amp; Whitney</td>
<td></td>
<td>David Ives</td>
</tr>
<tr>
<td>1:50</td>
<td>General Dynamics</td>
<td></td>
<td>John Steinbrenner</td>
</tr>
<tr>
<td>2:15</td>
<td><strong>BREAK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:30</td>
<td>Boeing Commercial Airplane</td>
<td></td>
<td>Bernard Su</td>
</tr>
<tr>
<td>2:55</td>
<td>General Electric</td>
<td></td>
<td>Ian Jennions</td>
</tr>
<tr>
<td>3:20</td>
<td>Calspan</td>
<td></td>
<td>Jack Benek</td>
</tr>
<tr>
<td>3:45</td>
<td>Grumman</td>
<td></td>
<td>Giuseppe Volpe</td>
</tr>
<tr>
<td>4:10</td>
<td><strong>BREAK</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### SESSION 3  DOD Overviews and Panel Discussion

**Chair and Panel Moderator:** Larry Birckelbaw

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
<th>Chair(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:25</td>
<td>Eglin Air Force Base</td>
<td></td>
<td>Dave Belk</td>
</tr>
<tr>
<td>4:25</td>
<td>Wright Aeronautical Laboratory</td>
<td></td>
<td>Don Kinsey</td>
</tr>
<tr>
<td>4:25</td>
<td>NSRDC (David Taylor)</td>
<td></td>
<td>Rod Coleman</td>
</tr>
<tr>
<td>4:25</td>
<td>Ballistics Research Laboratory</td>
<td></td>
<td>Charles Nietubicz</td>
</tr>
<tr>
<td>5:30</td>
<td><strong>SOFTWARE DEMONSTRATIONS</strong></td>
<td>NAS Graphics Laboratory</td>
<td></td>
</tr>
<tr>
<td>6:30</td>
<td><strong>SOFTWARE DEMONSTRATIONS</strong></td>
<td>Room 125</td>
<td></td>
</tr>
</tbody>
</table>

---

*PRECEDING PAGE BLANK NOT FILMED*
Wednesday, December 6

8:00    Registration (NAS Lobby)

SESSION 4    University Overviews
            Robert Smith, Chair

8:30    Block-Structured Grid Generation  Joe Thompson, Mississippi State
8:55    Unstructured Grid Generation    Timothy Baker, Princeton
9:20    Surface Modeling                Robert Barnhill, Arizona State
9:45    Surface Grid Generation         Ki D. Lee, University of Illinois

10:10    BREAK

SESSION 5    Emerging Technology Briefings
            Francis Enomoto, Chair

10:30    CAD Software Trends  Mark Sheppard, RPI
10:45    Computer Hardware Trends  Thomas Lasinski, NASA Ames
11:00    Standards  Velvin Watson, NASA Ames
11:15    Grid Quality Issues  Peter Eiseman, Columbia

11:30    LUNCH

12:45    Hyperbolic Surface Grid Generation  Joseph Steger, U.C. Davis
1:00    Hybrid AI/Procedural Systems  John F. Dannenhoffer III, UTRC
1:15    Interactive Grid Generation  Jeffery Cordova, Visual Computing

SESSION 6    Group Discussions and Panel Discussion
            Yung Choo, Chair

1:30 -- 3:30    Small Group Discussions (Bldg. 258, Rms. 111, 128, 221, & Bldg. T045, Rm. 115)

            Group                                  Moderator
            Surface Modeling and Surface Grid Generation  Pam Richardson
            Field Grid Generation                        Reese Sorenson
            Emerging Technology (Software)               Dennis Huff
            Emerging Technology (Hardware)               Bill Van Dalsem

3:30 -- 5:00    Group Reports and Panel Discussion
                Jerry South, Moderator

5:00 -- 7:00    SOCIAL HOUR
                NAS Lobby

Thursday, December 7

8:30 -- 12:00    NASA Program Planning Session  NASA ONLY

12:00    Adjourn

viii
NASA OAST
1989 GRID GENERATION
WORKSHOP COMMITTEE

NASA COMMITTEE
William Van Dalsem ARC
Robert Smith LaRC
Yung Choo LeRC
Alison Vogel ARC *

LANGLEY
Robert Smith
Jerry South
Mark McMillan
George Olsen
Ed Waggoner

LEWIS
Yung Choo
Aaron Snyder
Dennis Huff
Mathew Melis
Don Sosoka

AMES
William Van Dalsem
Alison Vogel *
Francis Enomoto
Reese Sorenson
Val Watson

* 3/90 replaced by Larry Birckelbaw
NASA OVERVIEWS

Overviews were presented by representatives from the Ames, Langley, and Lewis Research Centers and the Johnson and Marshall Space Centers. The NASA research and space centers have come to rely heavily on CFD to accomplish agency missions. Despite the broad range of applications among the centers, there is a universal requirement for sophisticated and rapid surface-modeling and grid-generation tools. Each center has addressed this requirement independently, and in all cases, significant resources have been allocated to the problem.

Among the research centers, the approach appears to be that individual organizations (sometimes division level, most often branch level) have dedicated just enough resources to satisfy their local needs. In the area of surface modeling, CAD/CAM packages originally chosen to satisfy engineering requirements (constructing wind tunnel models, etc.), have been pressed into service to supply CFD surface grids. For grid generation, specialized software for specific projects has been developed in-house or acquired from outside sources. Very few concerted efforts towards developing general purpose surface-modeling and grid-generation software are apparent. However, three notable efforts are the GRAPE code at Ames, the TURBO code at Lewis and the SMART code at Langley. Overall, there has resulted a proliferation of surface-modeling and grid-generation software packages. At the space centers, the requirement for rapid response to proposed design changes has generated more focused activities. At the space centers, much as in industry, there is a heavy reliance on acquired software.

At present, virtually all "project-oriented" CFD within NASA utilizes patched or overset structured-grid schemes. Unstructured schemes are under intensive study and produce impressive results, but appear to require additional advances before wide-spread application. Across the research centers, in addition to unstructured grid generation, there are research activities on adaptive techniques, expert systems, grid quality, and domain decomposition.
AEROSPACE INDUSTRY OVERVIEWS

Industry overviews were presented by representatives from McDonnell Douglas, Pratt & Whitney, General Dynamics, Boeing, General Electric, Calspan, and Grumman. The industry representatives indicate that their companies rely heavily on CFD for the design of advanced aircraft and propulsion systems. They feel that they are constrained by the quality of grids and the cost of creating them. They indicated that geometry modeling from blue prints (CAD data) and domain decomposition have been inefficient and labor intensive.

Interactive processes applied on advanced workstations have improved the situation. One notable example of this is the interactive menu-driven computer software system called GRIDGEN. With this software, which was developed by General Dynamics Corporation under contract to the Air Force, surface grid generation and domain decomposition has become a much quicker and easier visual process.

The industry representatives gave the impression that their grid generation efforts are well organized and highly focused to support company products. Although the industries have been using their resources for more near-term goals, they also expressed their interest in long-term technologies in unstructured grids, grid adaptation, grid quality and expert systems.
The DoD panel consisted of representatives from the Air Force (2), Army (1) and Navy (1). Each representative presented a short overview of their organizations' surface-modeling and grid-generation activity. In most respects, the DoD organizations have similar requirements as the NASA-OAET centers. They have a combination of ongoing research and projects.

In the 1980s, the DoD has sponsored major developments of grid-generation systems. The two most notable activities have been the GRIDGEN software mentioned in the industry overview and sponsored by the Air Force Wright Research and Development Center, and the EAGLE software developed by Mississippi State University and primarily sponsored by the Air Force Armament Laboratory, Eglin Air Force Base.

The Wright Research and Development Laboratory has assumed a government leadership role in the production of public-domain geometry modeling and grid generation software. Not only are they responsible for the GRIDGEN development, they are responsible for VIRGO, PLUTO, and I3G software. They publish a newsletter called *The Meshenger* to inform interested organizations on current grid generation activity. Also, they are now involved in a major procurement with Computation Mechanics Corporation for unstructured grid generation software.

The panel discussion, which followed the overviews, centered around the issues of future funding and the possibility of merging some of the more mature systems such as the EAGLE and GRIDGEN codes. There was a good deal of uncertainty about the future funding levels with the unstructured grid contract from Wright Research and Development Center being the only new contract activity.
UNIVERSITY OVERVIEWS

Four university representatives presented overviews. They were from Arizona State University, the University of Illinois, Mississippi State University, and Princeton University. Their respective topics of discussion were surface modeling, surface grid generation, block-structured grid generation and unstructured grid generation.

Universities have been instrumental in the development of surface modeling technology starting with project MAC at MIT in the early 1960s, and grid generation technology starting at Mississippi State University in the early 1970s.

Surface modeling and surface grid generation continue to be the most time-consuming and tedious aspect of the overall grid-generation problem. Even though surface modeling has reached a high level of sophistication, it has been directed primarily at visualization and manufacturing rather than analysis such as CFD. It is now an objective to direct the attention of Computer-Aided-Geometry-Design (CAGD) expertise in the university community towards CFD requirements. Surface-surface intersection, topology and surface smoothing are being investigated for the purpose of creating CFD grids.

Blocked-structured grid generation, with continuity across block boundaries or overlapping, is highly developed. Algebraic and differential techniques, developed largely in the university environment, are efficiently applied to compute grid points in the interior of blocks. The difficulties with blocked-structured grids are the logistics of domain decomposition and the transfer of information between partially overlapping blocks. Often, intelligent decisions (artificial or human) are required to achieve acceptable results.

Currently, for unstructured grid generation, there are two competing techniques: (1) Delaunay triangulation; and (2) advancing front. The primary advantage of these techniques, compared with blocked-structured grid generation, is that regions can be decomposed into tetrahedral cells without defining complex intermediate block-boundaries. Both unstructured techniques, although well-developed, are computationally time-consuming compared to structured techniques. At the time of the workshop, there was no generalized unstructured grid-generation software, such as GRIDGEN or EAGLE, publicly available. However, it is likely that such software will be forthcoming in the near future. The most important aspect of unstructured grids, relative to CFD, is the development of efficient robust and accurate solution techniques for the governing equations of motion.
Universities continue to be committed to the development of grid-generation technology. Topics such as software user-friendliness, data management, surface smoothness, grid quality, visualization, and artificial intelligence are being investigated for surface modeling and grid generation. At Mississippi State University the Center for Computational Field Simulation has been established. This center, under the sponsorship of the National Science Foundation, has as one of its primary purposes the advancement of surface modeling and grid generation. The center is proposing a national coalition for the development of a comprehensive surface-modeling and grid-generation code.
EMERGING TECHNOLOGY BRIEFINGS

The purpose of this session was to take a glimpse at new technical developments affecting surface modeling and grid generation. Specific topics centered around computer architecture and performance, automated grid generation, grid quality, man-machine interaction/visualization and standardization. The speakers were from NASA, industry and academia. Perhaps the most profound effect on surface modeling and grid generation is computer performance and architecture. Surface modeling, domain decomposition and grid generation are inherently interactive processes. During the 1980s, scientific workstations with graphics firmware emerged, and since their introduction, there has been significant improvements in performance. It is anticipated that in the next five years, high performance workstations will have the computational power of current low-end supercomputers. The impact of this increased performance will not only allow more complex and refined geometries to be analyzed, but will also provide a capability to perform additional and new functions simultaneously with surface modeling and grid generation. These functions include grid-quality analysis, expert advising, and solution visualization. The trend in computer architecture is toward parallel processing, and this implies that techniques and algorithms must be developed for this environment.

Transfer of geometry, grids and CFD data between individuals and organizations requires that standard formats be established. Also, software standards are necessary to execute the same codes on a variety of equipment. The standards that relate to geometry, computer graphics and grids are IGES, LaWGS and PDES/STEP. The graphics standards are GKS and PHIGS. The DoD is mandating the use of IGES (and PDES in the future) through its Computer Aided Acquisition and Logistics (CAAL) initiative. Non-uniform Rational B-splines (NURBS) are expected to become a standard for surface representation. The PLOT3D format has become a defacto standard for CFD data, and the FAST interface software potentially could become a standard interface within NASA for high performance workstations.

In the application of expert or knowledge-based systems, some progress has been made with 2D problems. However, expert systems are likely to play a more important role in the 1990s. Expert systems are good for data-driven and goal-driven tasks. Specialized software must be applied to the data to invoke rules for a given analysis. Most CFD and grid generation have been driven by algorithms in procedural systems. A hybrid system, which would use an expert system to control a set of procedures that share a data pool, would combine the efficiency of procedural systems with the flexibility of expert systems. It is hypothesized that such a system is ideally suited for grid adaptation, domain decomposition, solution interpretation, and design iteration.
Grid quality measures, such as orthogonality and smoothness are inherent in a grid generation technique. When these variables have poor quality, they can adversely affect a solution of the flow equations. Also, the ability of a grid generation technique to concentrate grid points, where there are high gradients in the solution domain, directly affects solution accuracy. Most often, grid quality is visually evaluated, similar to solution evaluation, using workstation technology. The use of expert systems to aid in the evaluation is emerging.

Grid adaptation, which is closely associated with grid quality, conforms a grid to meet the accuracy requirement of a given solution. Considerable research has been performed in this area, but automated grid adaptation is not extensively used today for most CFD calculations. This is because of the additional computational overhead and the difficulty in maintaining good grid quality during the adaptation process. However, it is anticipated that emerging computer hardware and algorithm technology will eventually allow virtually all flow solutions to have adaptive grids.

High performance workstations have revolutionized surface modeling and grid generation through visualization and interactive responses. The use of two-dimensional images to visualize three-dimensional domains is at a very high level of development. The use of holography, to create three-dimensional rendering of objects, and lasers, to rapidly construct plastic models, are emerging technologies that will likely enhance to the ability to evaluate grids and flow field solutions.
GROUP DISCUSSIONS AND PANEL DISCUSSION

Group discussions on Surface-Modeling and Surface-Grid Generation, Field-Grid Generation, Emerging Technology (Software) and Emerging Technology (Hardware) were held. In addition to a broad-based discussion, each group was asked to express what they thought should be NASA's role relative to the group subject. After the group discussions, the group leaders formed a panel to present what occurred in the individual meetings. The main issues and roles are:

Issues

Surface modeling is highly developed but needs to be focused for CFD application.

General surface-modeling and grid-generation software (not research codes) are required to support CFD analysis about complex configurations.

The skills for advanced CFD applications must include surface modeling and grid generation. (A critical mass must be achieved.)

Research is still required in grid adaptation, grid quality unstructured algorithms, domain decomposition, expert systems, and parallel processing.

NASA's Roles

Continue to perform research on new grid-generation technology.

Establish standard formats for grids and CFD solutions.

Establish central libraries of software, grids and CFD solutions.

Support the coordination of surface modeling, grid generation and CFD within the U.S. government and industry.

Develop, within the agency, a first-rate surface-modeling and grid-generation capability to support advanced CFD applications.
NASA PROGRAM PLANNING SESSION

This session focused on what NASA can and should do to improve its surface-modeling and grid-generation capabilities. First, NASA is in a good position to establish standards and maintain libraries of grid and CFD data. The NAS facility and organization can be brought to bear on this item. The personnel at the research and space centers involved with geometry and CFD have been largely identified and provide a basis for coordination between centers. The agency management should be made aware that a critical mass of skills must be devoted to geometry technology to support CFD applications. NASA must identify CAD and grid-generation software to be used for advanced CFD applications.

CONCLUSIONS AND RECOMMENDATIONS

It was re-affirmed at the workshop that geometry modeling and grid generation are critical in computational aerospace design. It was evident that significant progress in grid generation methods and tools has been made over the last decade. Also, surface modeling through CAD is quite advanced but not well coordinated with grid generation for CFD. Faster and better surface-modeling and grid-generation tools are still needed as we challenge more complicated geometries and pursue more accurate numerical predictions.

Problems that were identified at the workshop can be summed up as follows:

- Few organizations have large, well-equipped, multi-disciplinary efforts required to produce useful surface-modeling and grid-generation tools. Because the development teams must include specialist from several discipline areas, obtaining the proper skill mix and coordination are not easy.

- Activities in the U.S. lack coordination and cooperation.

Basic technologies that require further development include:

- Geometry acquisition and modeling techniques
- Effective user interfaces
- Solution-adaptive grid generation techniques
- Automatic domain decomposition
- Grid generation algorithms
- Grid generation expert systems
- Grid quality analysis

In addition, the geometry-modeling and grid-generation techniques need to be extended across disciplines (aerodynamics, structures, heat transfer).
Based on the workshop findings and the organization committee's subsequent discussions, the following recommendations are being made to NASA-OAET and local management:

1. Establish a Surface-Modeling and Grid-Generation Focal Group at each NASA Research Center that performs a significant amount of Computational Fluid Dynamics. The focal group would coordinate the surface modeling and grid generation activity at the center and be sufficiently manned to serve as a critical mass for new developments and applications.

2. Establish a NASA Surface-Modeling and Grid-Generation Steering Committee to coordinate NASA's geometry-modeling and grid-generation activities and to oversee and advocate these activities. This committee should be led by NASA headquarters.

3. Improve coordination of U.S. activities through the development and implementation of:
   - An aerospace geometry exchange standard,
   - Geometry-data and grid-generation software libraries.
Charge the Numerical Aerodynamics Simulation (NAS) organization with the responsibility of implementing and maintaining geometry-data and software libraries.

4. Implement future NASA software for surface modeling and grid generation using the FAST interactive graphics environment. Make the FAST library available to U.S. industry/university community for new structured-grid implementations. Also, begin development of FAST enhancements required for a complete grid-generation user environment, including (for example) a data base system for unstructured grids. Finally, begin design and implementation of a next-generation user/developer grid generation environment utilizing recent advances in software technology.

5. Define the requirements for NASA geometry-modeling software. This should be the first task for the NASA steering committee. Evaluate candidate existing public domain and commercial packages.
CONFERENCE ATTENDEES
Dr. Yung K. Choo
NASA Lewis Research Center
MS 5-11
21000 Brookpark Road
Cleveland, OH 44135-3191

Ms. Carol Davies
NASA Ames Research Center
MS 230-3
Moffett Field, CA 94035

Dr. Peter Eiseman
Program Development Corp. of Scarsdale, Inc.
300 Hamilton Ave. Suite 409
White Plains, NY 10601

Dr. Gil Chyu
NASA Ames Research Center
MS 227-6
Moffett Field, CA 94035

Dr. Roderick M. Coleman
David Taylor Naval Research Center
Code 1501
Bethesda, MD 20084

Mr. Francis Enomoto
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Dr. Jeffery Cordova
Visual Computing
883 N. Shoreline Blvd. B210
Mountain View, CA 94043

Mr. Jim Fenbert
NASA Langley Research Center
MS 412
Hampton, VA 23665-5225

Mr. Gary Cosentino
NASA Ames Research Center
MS 227-6
Moffett Field, CA 94035

Dr. Raymond E. Gaugler
NASA Lewis Research Center
MS 412
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. Ray Cosner
McDonnell Aircraft Company
Mail Code 0341260
P. O. Box 516
St. Louis, MO 63116-0516

Mr. Ray Gonzalez
NASA Johnson Space Center
Mail Code ED311
Houston, TX 77058-3696

Dr. Russell Cummings
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Ms. Aga Goodsell
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Dr. John F. Dannenhoffer III
Computational Fluid Dynamics Research
United Technologies Research Center
East Hartford, CT 06108

Mr. Clyde Gumbert
NASA Langley Research Center
MS 159
Hampton, VA 23665-5225

Dr. Terry Holst
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035
Mr. Dennis L. Huff
NASA Lewis Research Center
MS 77-6
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. Danny P. Hwang
NASA Lewis Research Center
MS 86-7
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. David Ives
Pratt & Whitney
Mail Stop 161-16
East Hartford, CT 06108

Dr. Ian Jennions
General Electric Company
MDA - 323
1 Neumann Way
Cincinnati, Ohio 45215

Mr. Paul Keller
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Dr. Don Kinsey
WARCMM
Wright-Patterson AFB, OH 45133

Dr. Goetz Klopfer
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Dr. Stephen Klotz
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Mr. Ronald Langhi
NASA Ames Research Center
MS 227-6
Moffett Field, CA 94035

Dr. Thomas Lasinski
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Dr. K. D. Lee
Univ. of Illinois at Urbana-Champaign
101 Transportation Building
104 South Mathews Avenue
Urbana, IL 61801

Dr. C. P. Li
NASA Johnson Space Center
Mail Code ED311
Houston, TX 77058-3696

Dr. Jim Luckring
NASA Langley Research Center
MS 280
Hampton, VA 23665-5225

Dr. Raymond Luh
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Mr. Mike Madson
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Mr. Paul K. McConnaughy
NASA Marshall Space Flight Center
MS ED32
Marshall Space Flight Center
AL 35812-5001

Mr. Mark McMillin
NASA Langley Research Center
MS 365
Hampton, VA 23665-5225

Mr. John Melton
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035
<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
</table>
| Dr. Marshal Merriam      | NASA Ames Research Center  
                           MS 202A-14  
                           Moffett Field, CA  94035                                          |
| Mr. Merritt Smith        | NASA Ames Research Center  
                           MS T045-2  
                           Moffett Field, CA  94035                                          |
| Mr. David P. Miller      | NASA Lewis Research Center  
                           MS 77-6  
                           21000 Brookpark Road  
                           Cleveland, OH  44135-3191                                         |
| Mr. Robert Smith         | NASA Langley Research Center  
                           MS 125  
                           Hampton, VA  23665-5225                                          |
| Mr. Young-June Moon      | NASA Lewis Research Center  
                           MS SVR-1  
                           21000 Brookpark Road  
                           Cleveland, OH  44135-3191                                         |
| Dr. Charles Nietubicz    | Ballistics Research Laboratory  
                           Aberdeen Proving Ground  
                           Maryland, 21005-5066                                              |
| Mr. Aaron Synder         | NASA Lewis Research Center  
                           MS 5-11  
                           21000 Brookpark Road  
                           Cleveland, OH  44135-3191                                         |
| Ms. Pam Richardson       | Code RF, Headquarters  
                           Washington DC  20546                                              |
| Mr. Reese Sorenson       | NASA Ames Research Center  
                           MS T045-2  
                           Moffett Field, CA  94035                                          |
| Dr. Yehia Rzik           | NASA Ames Research Center  
                           MS 258-1  
                           Moffett Field, CA  94035                                          |
| Mr. Don J. Sosoka        | NASA Lewis Research Center  
                           MS 142-2  
                           21000 Brookpark Road  
                           Cleveland, OH  44135-3191                                         |
| Dr. Mani Salas           | NASA Langley Research Center  
                           MS 258-1  
                           Hampton, VA  23665-5225                                          |
| Mr. Jerry South          | NASA Langley Research Center  
                           MS 128  
                           Hampton, VA  23665-5225                                          |
| Dr. Mark Sheppard        | Rensselaer Design Research Center  
                           Rensselaer Polytechnic Institute  
                           Troy, NY  12180-3590                                              |
| Dr. Sharon Stanaway      | NASA Ames Research Center  
                           MS 258-1  
                           Moffett Field, CA  94035                                          |
| Dr. Joseph L. Steger     | Department of Mechanical Engineering  
                           University of California  
                           Davis, CA  9561                                                   |
| Mr. John Steinbrenner    | General Dynamics Corporation  
                           Mail Zone 267  
                           P. O. 748  
                           Fort Worth, TX  7610                                               |
**Title and Subtitle:**

NASA Workshop on Future Directions in Surface Modeling and Grid Generation

**Authors:**

W. R. Van Dalsem, R. E. Smith (NASA Langley, Hampton, VA 23665), Y. K. Choo (NASA Lewis, Cleveland, OH 44135), L. D. Birckelbaw, and A. A. Vogel

**Performing Organization:**

Ames Research Center
Moffett Field, CA 94035-1000

**Sponsoring/Monitoring Agency:**

National Aeronautics and Space Administration
Washington, DC 20546-0001

**Abstract:**

This publication is a summary of the paper sessions and panel discussions of the NASA Workshop on Future Directions in Surface Modeling and Grid Generation held at NASA Ames Research Center, Moffett Field, California, December 5-7, 1989. The conference was initiated by the Office of Aeronautics and Exploration Technology (OAET). The purpose was to assess U.S. capabilities in surface modeling and grid generation and take steps to improve the focus and pace of these disciplines within NASA. The organization of the workshop centered around overviews from NASA centers and expert presentations from U.S. corporations and universities. Small discussion groups were held and summarized by group leaders. Brief overviews and a panel discussion by representatives from the DoD were held, and a NASA only session concluded the meeting. In the NASA Program Planning Session summary there are five recommended steps for NASA to take to improve the development and application of surface modeling and grid generation.