GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

# PROJECT ADMINISTRATION DATA SHEET

[x] ORIGINAL [ ] REVISION NO. _____

Project No. E-25-614 DATE 12/10/81

Project Director: Dr. John T. Berry - #3215 School/~~Lab~~ Mechanical Eng.

Sponsor: The Regents of the University of Michigan, Ann Arbor

Type Agreement: Subgrant (under NSF Prime No. MEA-8116694) Reference: P.O. No. K16185

Award Period: From 9/1/81 To ~~2/28/83~~ 8/31/83 (Performance) 2/28/83 (Reports)

Sponsor Amount: $78,793 Contracted through:

Cost Sharing: _____ GTRI/~~GIT~~

Title: The Test of Emerging Computer-Aided Design (CAD) Technologies in the Metal Casting Industries

ADMINISTRATIVE DATA OCA Contact Faith G. Costello

1) Sponsor Technical Contact:

Dr. Robert D. Pehlke
Department of Materials & Metallurgical Eng.
The University of Michigan
~~Ann Arbor, MI 48104~~
~~341~~ West Engineering Bldg
Ann Arbor, MI 48109

2) Sponsor Admin/Contractual Matters:

Kathryn R. Warner
Contracts Administrator
Office of Contract Administration
The University of Michigan
122 Research Adm. Bldg. North Campus
Ann Arbor, MI 48109

Defense Priority Rating: _____ Security Classification: _____

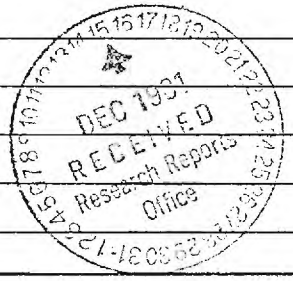
RESTRICTIONS

See Attached NSF Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval -- Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with sponsor

COMMENTS:




COPIES TO:

Administrative Coordinator
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
~~Reports Coordinator (OCA)~~
Legal Services (OCA)
Library
EES Public Relations (2)
Computer Input
Project File
Other _____

FORM OCA 4/731

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

## SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 11/1/83

Project No. E-25-614 School/~~Lab~~ ME

Includes Subproject No.(s) _____

Project Director(s) Dr. John T. Berry GTRI / ~~XXXX~~

Sponsor The Regents of the University of Michigan, Ann Arbor, MI

Title The Test of Emerging Computer-Aided Design (CAD) Technologies in the Metal Casting Industries

Effective Completion Date: 8/31/83 (Performance) 8/31/83 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [ ] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [X] Final Report of Inventions
- [X] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other _____

Continues Project No. _____ Continued by Project No. _____

COPIES TO:

Project Director (Berry)
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services
Library
GTRI
Research Communications (2)
Project File
Other _____

Form OCA 60:1028

Georgia Institute of Technology
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF MECHANICAL ENGINEERING
ATLANTA, GEORGIA 30332

October 25, 1983

Prof. Robert D. Pehlke
Materials and Metallurgical Engineering
The University of Michigan
3062 Dow Building
Ann Arbor, Michigan 48109

RE: Final Report, Subcontract No. MEA-8116694

Dear Bob:

This letter will serve as the Final Report on the Georgia Tech subcontract pertaining to the project "The Study of Emerging Computer-Aided Design (CAD) Related Technologies in the Metal Casting Industries."

1) Visits to Plants of Potential Industrial Partners

During the course of the contract, the undersigned and/or Dr. R. D. Pehlke visited a number of industrial organizations. They included:

| | | |
|---|---|---|
| TRW, Inc. | Cleveland, Ohio | April 27, 1982 |
| Hayes-Albion Corp. | Albion, Michigan | June 17, 1982 |
| Esco Corporation | Portland, Oregon | June 24, 1982 |
| AiResearch Casting Company | Torrance, California | June 25, 1982 |
| Abex Research Center | Mahwah, New Jersey | July 22, 1982 |
| Ford Motor Company | Redford Township, Michigan | August 11, 1982 |
| Borg-Warner Research Center | Des Plaines, Illinois | September 15, 1982 |
| McDonnell Douglas Automation Company | St. Louis, Missouri | October 26, 1982 |
| General Motors Manufacturing Research/ Central Foundry Division | Warren, Michigan | (Several contacts) |

In addition to these visits, several delegations from local organizations were received at Georgia Tech. These included ITT-Grinnell (Statesboro Foundry), E. V. Camp Steel Foundry (Atlanta), Higgins Foundry (Atlanta), etc. The trip reports resulting from these visits are attached. (See Appendix 1.)

2) Concluding Remarks

As a result of the visits and associated discussions in collaboration with the University of Michigan team, the decision was made to investigate the possibility of a joint proposal being drafted for Phase II of the investigation involving the General Motors Manufacturing Research/ Central Foundry group . In connection with this, the undersigned and his colleagues compiled the appropriate sections of a proposal, recently assembled at the University of Michigan, which is currently in the hands of General Motors, prior to being delivered tothe National Science Foundation.

Sincerely,

John T. Berry
(Professor)
Co-Principal Investigator

JTB:tgp

Attachments

cc: Office of Contract Administration

# APPENDIX 1

## TRIP REPORTS ASSOCIATED WITH POTENTIAL INDUSTRIAL PARTNERS

TRIP REPORT - TRW

April 27, 1982

Professors J. T. Berry and R. D. Pehlke visited the Research and Technical Center of TRW, Inc., at Cleveland, Ohio. They met at the Colwell Laboratory of the Turbine Components Division with the following individuals:

Tom Piwonka, Dept. Manager, Materials Research,
Colwell Laboratory

Roger Skrocki, Section Manager, Casting Research,
Colwell Laboratory

Gus Riehl, PWA Program Manager
(On staff to E. A. Stiegerwald, Vice President
of Casting)

Frank Moegling, Electrical Engineer,
Industrial Engineering Department

Randy Helmink, Principal Engineer, Colwell Laboratory

Jacob Mathew, Staff Engineer, CPEC

Bob Horton, Manager of Casting Technology, CPEC

Mike Dorsey, Engineer, Colwell Laboratory

Arden Bement, Vice President, Corporate Science
& Technology

The personnel reviewed overall corporate casting operations, including production facilities, development laboratories and product lines. The area of their interest for a demonstration program would not be in investment casting of directionally solidified or single crystal products, but in equi-axed, investment cast, high-temperature alloy components.

Professor Berry reviewed current activities in Computer-aided Design of Castings at Georgia Tech and The University of Michigan. Professor Pehlke described the cooperative industry/university program development activities, and objectives of the demonstration project. An active discussion ensued of various components of CAD for castings and of aspects of a possible industry/university demonstration project at TRW.

After lunch, the group toured CPEC (Casting Process and Engineering Center), a full scale pilot facility where key units of the production facilities of the Turbine Components Division are duplicated and used in development programs. The vacuum melting and casting unit is heavily instrumented and the center has computer facilities for simulation and graphics display. Also present are various pieces of materials characterization equipment, including a small scanning electron microscope.

The center is primarily used for development of new casting technology and for study of various production problems for the Turbine Components Division.

Further discussion of the CAD-casting demonstration project revealed the following. First of all, TRW is very much interested in a cooperative demonstration program. They would look for a DOD agency, most likely the Air Force to provide support of their activities.

Several positive aspects are:

1. TRW is active in government contracting and is prepared for this approach to program support.

2. TRW has expertise in government contract reporting procedures.

3. The Casting Process and Engineering Center facilities could be made available in support of an industrial/ university demonstration program.

4. Many interested personnel in TRW would like to participate, particularly in CAD, of gating systems.

5. TRW has talented personnel who could participate in this program.

Some negative aspects are:

1. The process to be studied is very special; vacuum cast, investment cast and for special alloys (Ni-base).

2. The degree of sophistication of the available CAD-cast approaches may not be capable of handling all of the requirements for these processes and products.

At the conclusion of the meeting, TRW agreed to prepare a proposal concept paper on a cooperative industry/university demonstration project on CAD for casting. This document would outline industrial personnel assignments, possible funding and activity scenarios and will be sent to Professors Berry and Pehlke within the next few weeks for review and response.

RDP/gk
4/29/82

TRIP REPORT: HAYES-ALBION CORP.
June 17, 1982

Professors R. D. Pehlke and J. T. Berry visited the Albion, Michigan plant of the Hayes-Albion Corporation and during their visit held discussions with the following

Robert N. Eberhart
Manager, Castings Product Development

Allen Moore
Casting Design Engineer
Castings Product Development

Nick Januszewski
Sales Engineer
Castings Product Development

Ronald Salvatore
Plant Engineer, (Electrical)

Hayes-Albion is a large independent producer of castings, pressings and other metal products. The bulk of their business is in ferrous casting, particularly in ductile and malleable irons. The Albion Foundry is capable of producing some three hundred tons of metal per day from a melting facility which includes three thirty-ton electric-arc furnaces, three eighteen-ton coreless induction furnaces and two one hundred-ton channel type holding furnaces. An automatic pouring facility dispenses most of the molten metal. This facility is served by an automatic molding line capable of producing 300 molds per hour. A wide variety of core making processes are represented in the plant, which is notable because of the extensive use of programable control devices, data highways and modern analytical facilities for chemistry control. Some attempts have also been made to institute computer aided estimation of casting costs. One especially attractive facility is a prototype foundry immediately

adjacent to the main melting facility. The role of the casting product development group is to seek contact with designers at the prototype initiation stage, not only because of the increased probability for eventual sales of production castings, but because of the opportunity thereby afforded for interaction with the designer regarding castability at a particular part. A wide range of casting sizes can be accomodated (1 to 150 lbs.). Although many of the castings examined during an inspection of the foundry were of an automative/truck vehicular nature, castings for other markets, such as agriculture, appliance and general industrial use were in evidence.

Messrs. Januszewski and Moore reviewed the marketing philosophy of H-A and their procedures for making casting estimates on arrival. Mr. Salvatore later joined the group and Professors Pehlke and Berry informally conducted a review of both the current NSF research and implemention related work in the CAD for castings area at University of Michigan and Georgia Institute of Technology.

During the discussions which ensued, it was learned that H-A are members of the Metals Research Foundation (formerly the Malleable Research Foundation) which sponsors research programs in independent, university or member firm's organizations. It is presently supported by Wagner Castings, Dayton Malleable and Texas Foundries in addition to H-A. They (MRF) have supported work in such areas as fracture toughness and fatigue property determination in the immediate

past.

The H-A staff members present, who showed considerable enthusiasm for the type of program described in our discussions, felt that MRF would be an ideal organization to approach for support of their own in house activity.

The positive aspects of such a collaboration are:

1. Desire of H-A staff to become involved in CAD related activity.
2. Strong evidence of computer oriented thinking and implementational efforts mainly under Mr. Salvatore's leadership (PC usage in plant data highways, newly installed PDP 11-25 minicomputer with large spare memory capacity).
3. Acceptance by their top management of high technology ideas as evidenced above.
4. Proximity of plants to University of Michigan.
5. Membership and potential support of MRF for H-A's activities.

Disadvantages would be:

1. Current financial situation of the group (plant is working at 30% of capacity).
2. There may be some critical thermal data needs in working with ductile and malleable castings.

cc: Prof Pehlke
CADCAST Team Member

TRIP REPORT: ESCO CORPORATION
June 24, 1982

Professors Pehlke and Berry visited the Portland, Oregon, plant of Esco Corporation on the above date. Persons interviewed were:

Mr. A. Stubbs Davis
Foundry Technical Director

Mr. Perry Harvey
Manager, Production Engineering

Mr. Rick Miner
Products Engineering Manager
(Products Division)

Mr. Gary M. Deyerling
Project Engineer
(New Process Development Group)

The foundry operations of Esco at this location are capable of producing some 2000 tons per month of alloy steel castings of various grades. Foundries in Newton, Mississippi, and in Canada produce between them a further 2750 tons per month, when at full capacity. Although renowned for their impact and abrasion resistant steels in the earth moving and mining sectors, they also produce higher alloy grades for nuclear, shipboard, forestry and other industrial uses. The sizes of castings produced vary from a few ounces to 30 tons as cleaned. Their primary melting facility in Portland utilizes one three-ton, two two-ton, two one-ton basic electric arc furnaces. One fifteen-ton and five small basic lined coreless induction furnaces complete their melting equipment at

this location. Two Argon-Oxygen Decarburizing (AOD) vessels are available for use with stainless steel heats. The molding facilities utilize silica, zircon, chromite and magnesite sands and are especially noteworthy for a large scale V-process installation utilizing (unbonded) chromite sand. It is understood that both manpower and molding material costs are substantially reduced with this process. Additionally, a large number of core making processes are in use at the plant. They range from shell and the traditionally oil-bonded types through to air-setting and sodium silicate bonded types.

Casting rigging is designed by a small and obviously experienced group of production engineers. They currently utilize SCRATA designed and marketed CRUSADER program for riser design and location. The system, which was demonstrated to the writers, appears to be based upon the Chvorinov rule based Wlodawer book data plus SFSA derived feeding range information. The program is an interactive type and is capable of receiving digitized information on cross-sections, etc. The staff members concerned with its use are impressed with its obvious time savings but at the same time are anxious to pursue further the aspects of CAD which would permit further time savings, particularly casting estimation and yield calculations. They feel less enthusiastic about their current need for simulation of casting freezing sequences, although this may well reflect the somewhat strong views of one staff member.

During the course of the visit, Profs. Pehlke and Berry visited the foundry unit concerned, associated support facilities such as metallurgical and quality control units, and also made informal presentations related to the two NSF funded projects at U.M. and G.T. Some positive features of possible cooperation would seem to be:

(a) wide range of ferrous compositions poured;

(b) wide range of modern molding processes (especially V-Processes);

(c) wide range of molding materials;

(d) excellent facilities for evaluation of casting unsoundness (Betatron and Linatron units);

(e) familiarity with computer aided systems (SCRATA, CRUSADER AND CAPRA programs).

Negative aspects would be:

(a) location with respect to both U.M. and G.T.;

(b) current economic situation and its bearing on their potential investment in such an endeavor;

(c) possible doubt of certain staff members regarding current high technology CAD/simulation payoff.

TRIP REPORT - AIRESEARCH CASTING COMPANY

June 25, 1982

Professors J. T. Berry and R. D. Pehlke visited the research group and toured the research and production facilities of the AiResearch Casting Company at Torrance, California. They met and held discussions with

Glenn W. Brown
Chief - Research and Development

Michael J. Woulds
Staff Specialist - Cast Metals

These personnel reviewed the R & D activities of AiResearch and their production facilities. A tour was then conducted of the investment casting facility at the Division Headquarters, and of the iron and aluminum casting and R & D facilities.

AiResearch Casting Company is a division of Garrett Corporation, a wholly owned subsidiary of the Signal Companies. The company is actively engaged in supplying turbochargers and related components, as well as high temperature system components. R & D activities are directed to:

Metals
- Alloy development
- Directionally solidified columnar grain castings
- Single crystal super alloy
- Powdered metals forming development
- Hot Isostatic Pressing process development
- Metal matrix composition
- Casting process improvement

Ceramics
- Net shape forming methods
- Reaction bonded silicon nitride
- Sintered silicon nitride
- Hot pressing capability
- Hot Isostatic Pressing process development
- Sintered silicon carbides
- Carbon composites

The production facilities at AiResearch are summarized on the attached sheets. The opportunity for producing test or prototype castings in any of these technologies exists at AiResearch. The Research and Development facilities are very well equipped and instrumented and test runs could be made on most of the several production lines. Full inspection, quality control and metallurgical support are available.

The Research and Development group has support of management to implement computer assistance in the Casting Company. At present, however,

the R & D organization is presently seeking out various computer-aided design (CAD) systems for application within the division.

Professor Berry reviewed current activities in Computer-aided Design of Castings at Georgia Tech and The University of Michigan. Professor Pehlke described the cooperative industry/university program development activities, and objectives of the demonstration project. An active discussion ensued of various components of CAD for castings and of aspects of a possible industry/university demonstration project at AiResearch.

Further discussion of the CAD-casting demonstration project revealed the following. AiResearch is very much interested in a cooperative demonstration program. They would look for a DOD agency, most likely the Air Force to provide support of their activities.

Several positive aspects are:

1. There is a strong committment on the part of management for installation of a computer base to manufacturing design at AiResearch.

2. AiResearch is active in government contracting and is prepared for this approach, although would not be solely limited to outside support.

3. Several production facilities, and certain test facilities, could be made available to a demonstration program as required. These include nodular iron, aluminum and stainless/high temperature alloy investment castings.

4. There is a strong interest and committment of staff. Two prototype castings which have earlier development documentation were proposed for inclusion in a demonstration proposal: one an aluminum-sand casting and the second a 17-4 stainless air melt-investment casting.

5. The company has a high level of materials technology which would be directly involved in the program.

Some negative aspects are:

1. The company is not very highly advanced in CAD systems and the use of computers in research and development is limited.

2. The Los Angeles location is not proximate to Georgia Tech or the University of Michigan.

TRIP REPORT: ABEX RESEARCH CENTER
July 22, 1982

Prof. John T. Berry visited the Abex Research Center at Mahwah, New Jersey, on the above date. Abex personnel involved in the meeting were:

Bruce A. Heyer
Director - Foundry Research and Development

Mike Meslink
Director - Engineering Services

John A. Coughlin
Manager - Cast Metals Research

Manfred A. Walther
Research Scientist

Richard G. Bayer
Analytical Engineer

Abex is a large cast-product centered conglomerate; within their Cast Products Division alone there are steel, copper-base, ductile iron, high alloy, and wear resistant alloy foundries. The Waukesha Foundry Division also possesses high alloy, investment, aluminum, stainless, HSLA and centrifugal foundries. The AMSCO Division, Canadian and Mexican Division are all heavily steel foundry oriented. Finally, their Railroad Products Division, which posseses foundries in Calera, Alabama, and Baltimore, Maryland, as well as in Pennsylvania, cast large tonnages of brake shoes and wheels.

The Research organization, the unit visited, has been in being since prior to World War II. An extensive research foundry forms the central part of that facility. The Center is funded on a project-by-project basis by the various corporate divisions. It is also involved in various in-plant projects and certain routine "fire-fighting" activities.

Being installed at the time of the undersigned's visit was a 5,000 lb. VIP induction melting furnace. Full scale molding, casting, cleaning and NDT facilities are available. Thirty professional staff members are involved with the research center activity:

10 metallurgists
13 ME/IE positions
7 foundry engineers

In addition to research activity, the Center will actually produce certain specialized castings and certain brake lining type ceramic products. An extensive system of support laboratories is available which embraces metallography (including X-ray diffraction and SEM) analytical techniques, sand testing, mechanical testing including a full scale creep facility.

The most significant part of the visit, however, centered around discussion of the center's computer simulation related activity. For some ten years they have had an interest in this area and regularly undertake both FDM solidification simulation and FEM stress analysis. (FDM with a home-developed software - Mr. Walther - much reference to RDP's AFS monograph.) The FDM work has frequently justified its existence on grounds of both interaction with the designer (elimination of padding on a pump body which otherwise would have been machined off by Abex) or by prediction of possible shrinkage sites. An example of such a simulation is the following: An axisymmetric case of an idler wheel was run for the undersigned on their system. Hardware consisted of a 780 VAX with a full-color Techtronix console. (A plotter and digitizer were also available.) It will be seen from the attached figure that centerline shrinkage in the rim of the idler was predicted. The simulation ran in real time (print-out attached was 3.50 minutes after fill). The starting point for simulations is wire frame. They have great interest in geometric models that can be utilized in connection with automatic enmeshment and displayed considerable interest in the Catronix CAT-1 development. A further example cited by them justifying use of FDM simulation was a casting where the simulation run resulted in an 80% reduction in defects.

They have some interest in lower level software, having recently bought J. Chuang's METECH program, and may obtain R. Kotchi's gating software. (NOTE: Kotchi formerly worked for Waukesha Foundry.) They are also about to become members of SCRATA and will then purchase CRUSADER and other SCRATA packages related to melting, etc.

Their present financial situation would limit their funding a co-operative effort internally but the situation may improve. At the present time they would prefer obviously to seek outside support. Both U.S. Navy and Army related agencies were mentioned. They did not at the time have special contacts in mind.

The advantages of working with such a group would be:

1. Research foundry facility (wide variety of molding techniques, good melt and instrumentation capacity).

2. Many examples and much experience to be drawn upon, especially in steel area.

3. Highly experienced and enthusiastic personnel.

Some disadvantages would be:

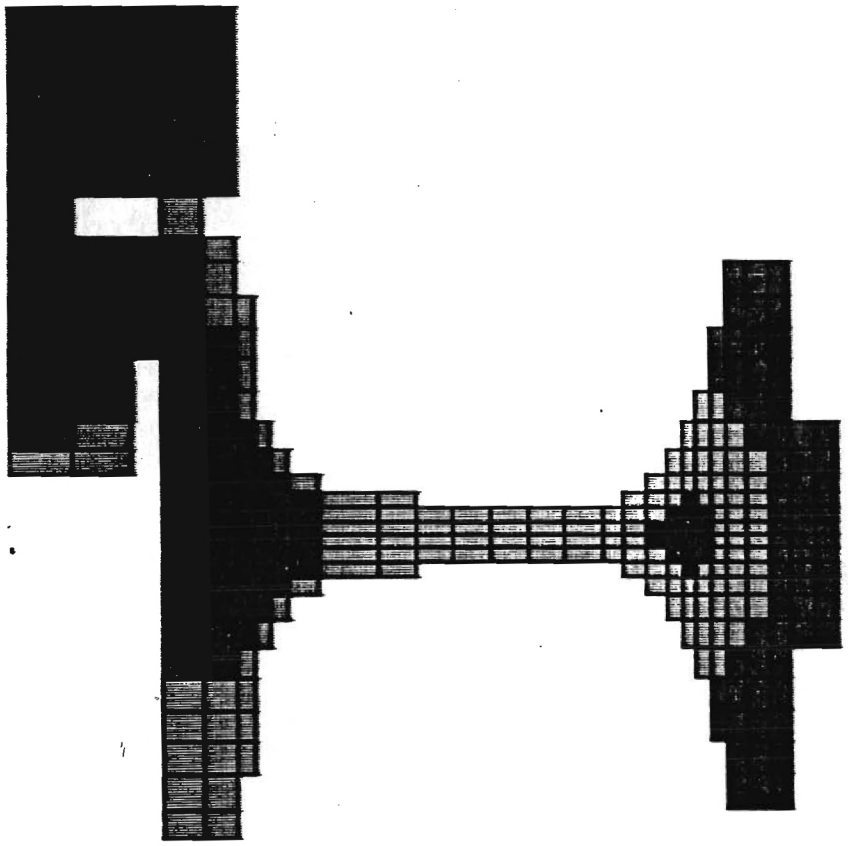
1. Pay-off would not be as significant as with a lower level technology organization.

2. Neither institution is in close proximity to Abex Research Center.*

3. Organization does not have very close links to potential sponsor.

---

* Teams could work in nearby foundry units. Example: Alabama or Ohio.



22-JUL-82

LIQUID

SOLIDUS

SOLID

TIME = 3.50 MINUTES

D9 IDLER SOLIDIFICATION - CATERPILLAR VERSION
->
->
->
->_

(i) To be on hand when I call G. Cole
(ii) File under trip reports

674

TRIP REPORT: FORD MOTOR COMPANY
PROCESS AND MANUFACTURING DEVELOPMENT CENTER
August 11, 1982

Professor Robert D. Pehlke visited the Process and Manufacturing Development Center of the Ford Motor Company in Redford Township, Michigan on the above date. Dr. Gerald S. Cole arranged for a seminar-type presentation and approximately 30 Ford staff attended. A list of attendees and corporate affiliation is attached. Of particular interest is the fact that several groups within the Ford organization attended this meeting including those in manufacturing development, scientific research and the casting division represented both by designers and by production personnel.

As one of the largest manufacturing corporations in the world, relatively little need be said about the casting activity of the Ford Motor Company, both from a production standpoint and from a purchase standpoint. In fact the recent discussions regarding the relative importance of production, vis a vis the Rouge Steel Company spin off and the uncertainties existing in the casting division, need be of little concern when assessing the need and interest in computer aided design for castings. Whether the corporation produces or purchases castings for its manufactured products, the design, prototype development and quality assessment reside with the Ford Motor Company. Therefore computer aided design as evidenced in the discussion at the seminar meeting was subsequently focused on this subject and the possible responses which could be developed at Ford Motor.

The process and manufacturing development group includes departments dedicated to the many production and manufacturing areas associated with the production of the broad range of products at the Ford Motor Company, and is focused most heavily on automobile manufacture. This group has strong development activities in welding, forming, machining, wear, finishing, painting, and a number of other primary manufacturing and assembly functions. The organization also includes various industrial engineering study groups and a substantial maintenance and support function group.

Of particular interest to the potential University/Industrial demonstration program is the prototype foundry laboratory. This group is staffed with an exceptionally talented and industry-wide recognized group of individuals in casting. The facilities include a large high bay laboratory which has both ferrous and non-ferrous melting facilities; induction melting furnaces (100 and 250 pound) and a 5,000 pound electric arc unit and a 1,000 pound aluminum base alloy melting unit. Also included is a heavily computerized and instrumented die casting facility including a direct feed melting unit for aluminum alloys. Sand mold and core producing facilities also exist within this laboratory. The facilities do not include mulling and molding equipment for green sand, but this could easily be installed if that media were important to a development program. In addition, within the facilities are a fully equipped sand testing laboratory, various infrared and other baking facilities for preparation of special core and molding materials, and several x-ray units including a one million volt facility. By both reasonable proximity and in a close inner relationship of staff (a large number of personnel at this center

are long time scientific lab staff) the full high technology support facilities are available to this group, including close relationships with the computer science activities within the corporation, several of which are located within this center including geometric modeling activities.

Within the context and scope of the proposed University/Industry demonstration program this group could fully conduct such a program. However, to insure the impact of technology transfer, it will be necessary to involve with the casting prototype development group, computer oriented personnel within the organization and in particular within the casting division as well as casting designers and casting production personnel. This integration of these several groups within Ford Motor Company will be assessed and evaluated within the next three to four weeks to determine the interest and viability of such a program, including the substantial technology transfer of specific activities from the University groups at Georgia Tech and the University of Michigan.

The present financial situation is, of course, highly significant but the Ford Motor Company has made a high level formal commitment to computerization at every level and this would appear to be a special opportunity for casting within the corporation.

The advantages of working with this group would be:

1. Research foundry facility including the availability of all molding techniques, media and casting alloys, as well as full instrumentation capability and subsequent prototype testing facility.

2. The spectrum of castings utilized and/or produced would provide a wide range of foundry technology, including even steel castings which are not produced by the corporation but which are designed, purchased, evaluated, subsequently machined, and integrated into a complex manufactured article.

3. The staff are exceptionally qualified and have access to a wide range of high technology support.

4. The timing and the influence on this major utilizer of castings could represent a high impact and a high potential for imaging technology transfer in this area of manufacturing, i.e. the corporation is well situated both in terms of need and capability to adopt and utilize this technology and at present has a current level of technology against which the computer aided design could be compared.

5. The facility and supporting organizations are in close proximity to the University of Michigan, one of the participating academic institutions. However activities in this area for the Ford Motor Company are nationwide including the southeastern states.

Inter Office

Engineering and Research Staff

August 23, 1982

To: Attendees at CAD Casting Seminar, 8/11/82

From: G. S. Cole

Subject: Summary of Meeting and Announcement of Next Seminar on September 16th.

Unfortunately Professor Berry was unable to attend and thus you were exposed to only a limited presentation by Professor Pehlke of the CAD Casting program being run jointly by the University of Michigan and Georgia Institute of Technology. This program is in the last year of its 3-year sponsorship by the National Science Foundation (NSF) and the two professors have submitted a proposal to NSF for extending it an additional three years. The basis of this extension is that an industrial counterpart will participate to demonstrate the practicability of CAD in casting.

As Professor Pehlke indicated, both he and Professor Berry are visiting a number of industrial organizations (which maintain a foundry capability) to stimulate their participation in the program. We have scheduled Professor Berry to review his work in the area of heat transfer and CAD casting research and to discuss with us his perception of the NSF demonstration program. This will take place on Thursday September 16 at 10:00 a.m. in Conference Room A, MPL Glendale. Dr. Berry will also discuss recent conversations with his counterparts in Japan who are arranging a similar program with Hitachi.

The goal of the program is to demonstrate that Computer Aided Design of Castings can be profitable to those involved in using, designing and manufacturing castings. The University of Michigan and Georgia Tech portion of the program is to acquire the software and develop the methodology so that castings may be more cheaply and efficiently designed and manufactured.

The main objectives can be summarized as follows:

- Reduce Lead Times and Costs for Acceptable Casting Design
- Reduce Testing Time and Minimize Number of Casting Prototypes
- Increase Yield, Quality and Productivity of Castings

These objectives will be achieved by utilizing the software to create a complete heat transfer analysis of any given casting shape as well as developing a solid model of the cast component. Once the model has been entered on the computer both the design and manufacturing people will be able to communicate with each other via the computer to resolve differences of function and manufacturability in a timely fashion.

Another important advantage of the projected software capability is that group technology could be incorporated into the design. This would allow specific configurations of curvature, section sizes and so forth to be associated with specific casting defects and manufacturing problems. The result will be that design rules for manufacturing can be developed on a logical basis.

The industrial counterpart would do the practical verification and demonstration, as well as acquire the hardware and software so that CAD technology could be used on a day-to-day basis by those trained in the method.

Your input at the September 16th meeting would be valuable for a meaningful discussion of the NSF program.

A list of attendees at the first CAD Casting meeting is enclosed.

# List of Attendees

| | | | |
|---|---|---|---|
| Research-MPL | Director's Office | M. Humenik, Jr. | 592-2030 |
| | Surface & Foundry Processing | J. D. Alstetter | 592-2529 |
| | | G. S. Cole | 592-2530 |
| | | B. V. Kovacs | 592-2535 |
| | | R. Nowicki | 592-2280 |
| | | C. A. Stickels | 323-1118 |
| | | G. R. Wlodyga | 592-2534 |
| | Manufacturing Systems | J. Grant | 592-2531 |
| | Machining Department | S. Taraman | 592-2640 |
| Research Planning/Services | | | |
| | Analytical Sciences | F. Bliss | 337-5051 |
| | | N. Laurance | 323-1028 |
| | | R. Temple | 322-6856 |
| Powertrain Research | | | |
| | Spark Ignition Engineering | R. Dekold | 323-4026 |
| | | M. Mahoney | 323-1033 |
| | | P. Maldague | 323-1753 |
| | | E. F. Petrak | 337-5127 |
| | | K. Strand | 322-8478 |
| Casting Division | | | |
| | | R. Clark | 322-8893 |
| | | W. Justusson | 323-4747 |
| | | R. Martin | 322-4054 |
| | | R. Morgensteren | 594-1473 |
| | Tooling Design | R. A. Weiss | 594-0697 |
| PCPEO | | | |
| | Experimental Fabricating Dept. | M. T. Chaney | 322-9227 |
| | Experimental Engine Tooling | H. Sarkisian | 323-4811 |
| | Engineering Computer Graphics | R. Danczak | 594-1234 |
| | | T. Papke | 322-9433 |
| | | J. Vivier | 594-1234 |

TRIP REPORT: BORG-WARNER RESEARCH CENTER
September 15, 1982

Prof. John T. Berry visited the Borg-Warner Research Center in Des Plaines, Illinois, on the above date. Borg Warner personnel involved in the meeting were:

Sue Thomas
Metals and Materials Research

Marvin Sussman
Computers and Materials Behavior

Vance Browne
Mechanical Design

Rudy Hempl
Design and Powder Metallurgy

John Zambrow
Metals and Materials Research

The Borg Warner organization is a large conglomerate of specialist equipment producers, with worldwide operations. In addition to their most well known products which are automatic and manual automobile transmissions, they also manufacture pumps, bearings, powder metal products, etc. They consume a large number of permanent mold and die-casting, the majority of which is obtained from outside vendors. Within the group, however, are three foundries and a powder metallurgy operation, all of whom are interested in CAD/CAM applications.

The larger of the two domestic business units producing castings is the Byron Jackson Pump Division, situated in Tulsa, Oklahoma. A wide variety of gray iron castings of complex design are poured in resin bonded sands. Pressure tightness in centrifugal pump bodies is of particular interest.

The second domestic unit is the Sealmaster Bearing Division in Aurora, Illinois. This unit produces gray iron pillar blocks for its bearings using a permanent mold technique, which is probably unique at the present time in this application.

The third metal casting operation is in Australia and is involved with the production of iron castings for general engineering usage.

The Research Center itself has a well equipped materials processing facility, especially in the area of metal casting. Work is currently being commenced on solidification processing technology related projects, under Mrs. Thomas. The center has also developed considerable expertise in the area of FEM stress of various engineering components. They currently use PREP 7 as a preprocessor in the production of wire frame mesh models. These are then interfaced automatically with an SDRC version of NASTRAN. Typical of components that have been analyzed using this routine are large

and complex pump rotors and housings in various materials. They currently do not have a geometric modeler fully installed but have plans to incorporate both a Unigraphics (turnkey) system which includes such a feature, as well as PADL 1.0, into their repertoire. A VAX unit is currently used for their NASTRAN activity.

They expressed considerable interest in the CADCAST project, although realizing that the metal casting operations were somewhat specialized, in terms of becoming an industrial partner. They were particularly aware of casting quality related rewards associated with solidification pattern simulation.

The advantages of working with such a group would be:

1. Research foundry facility, especially instrumentation capabilities.

2. Unique nature of iron permanent mold facility.

3. Experience in FEM stress analysis.

4. Relevance of quality control aspects of pressure tight complex castings manufactured by or for several operating divisions.

The disadvantages would be:

1. Relatively narrow range of products involved.

2. Limited number of personnel currently involved in solidification processing related activity.

3. Lack of proximity of business units to either Georgia Tech or the University of Michigan.

TRIP REPORT: MCDONNELL DOUGLAS AUTOMATION COMPANY
ST. LOUIS, MISSOURI
October 26, 1982

Professors Robert D. Pehlke, J. A. M. (Toby) Boulet, and John T. Berry visited the McDonnell Douglas Automation Company (MCAUTO) campus on the above date. MCAUTO personnel involved in the meeting were:

D. P. Fousek
Graphic Products - MCAUTO

Lawrence E. Nolan
Section Manager, CAD/CAM Product Design-Analysis - MCAUTO

T. F. McFadden
Product Design-Analysis - MCAUTO

R. J. Rothfuss
Manager, CAD/CAM Support Center - MCAUTO

Mark O. Pruitt
Senior Engineer - Production - McDonnell Aircraft Co.

MCAUTO, a division of the McDonnell Douglas aerospace conglomerate, is one of the largest computer service companies in the world. They offer on-line service to some ten thousand users through their extensive 75-acre campus which employs 2500 persons and maintains eleven IBM and five CDC mainframe computers in addition to numerous mini-computers which can stand alone or be linked to the mainframe complex. Amongst the services supplied are such items as remote job processing, batch processing, programming, applications software, data base management as well as consultation. Not on the campus but within the MCAUTO company is also a computer aided design and manufacturing subdivision, which undertakes work both for the aircraft company as well as outside organizations.

In the course of the visit, demonstrations of their FASTDRAW wire frame modeler were witnessed (see attachment). The system concerned is able to construct doubly curved complex surfaces using a B-spline routine, given arbitrary points on various X-Y, Y-Z planes, as indicated in the attachment. The operator also showed how a milling cutter path could then be indicated adjacent to the patches generated during the earlier surface construction. (Tapes could then have been prepared from this routine, had this been desired.)

In a subsequent discussion it was learned that MCAUTO hopes to integrate a (true) solid geometric modeler into their system in the upcoming year. However, it was noted that the present system permits the automatic two- or three-dimensional enmeshment of the wire frame models referred to above. The FASTDRAW command library supports definition of cylindrical, spherical, conical and toroidal surfaces in addition to the complex surface routines mentioned earlier.

After discussing the various aspects of the CADCAST implementation project, the MCAUTO/McDonnell Aircraft personnel concerned indicated their high level of interest in the Georgia Tech/University of Michigan proposal. Although the McDonnell organization does not possess a metal casting facility, they are extensive users of castings (mainly in secondary structures, although they have been following the work of Boeing and others on primary structure castings applications with interest).

It was generally concluded that their principal strength would lie in making available to our project use of their various software packages in modeling the various test and production castings likely to be involved in our implementational study. Although their experience had so far only linked FASTDRAW to stress-analysis codes such as STRUDL, NASTRAN, ANSYS, etc., they felt that linkage with an FDM or FEM conductive heat transfer program in either the public or private domain would not pose any difficult problem. The Georgia Tech/University of Michigan representatives promised to review the possibilities of aligning an organization such as MCAUTO with a producer of metal castings in the near future.

The advantages of working with such a group would be:

1. Availability of comprehensive, well supported commercial software packages for wire framing, enmeshment and interfacing with solvers.

2. Availability of skilled personnel, experienced in dealing with complex geometries seen in actual commercial castings and forgings.

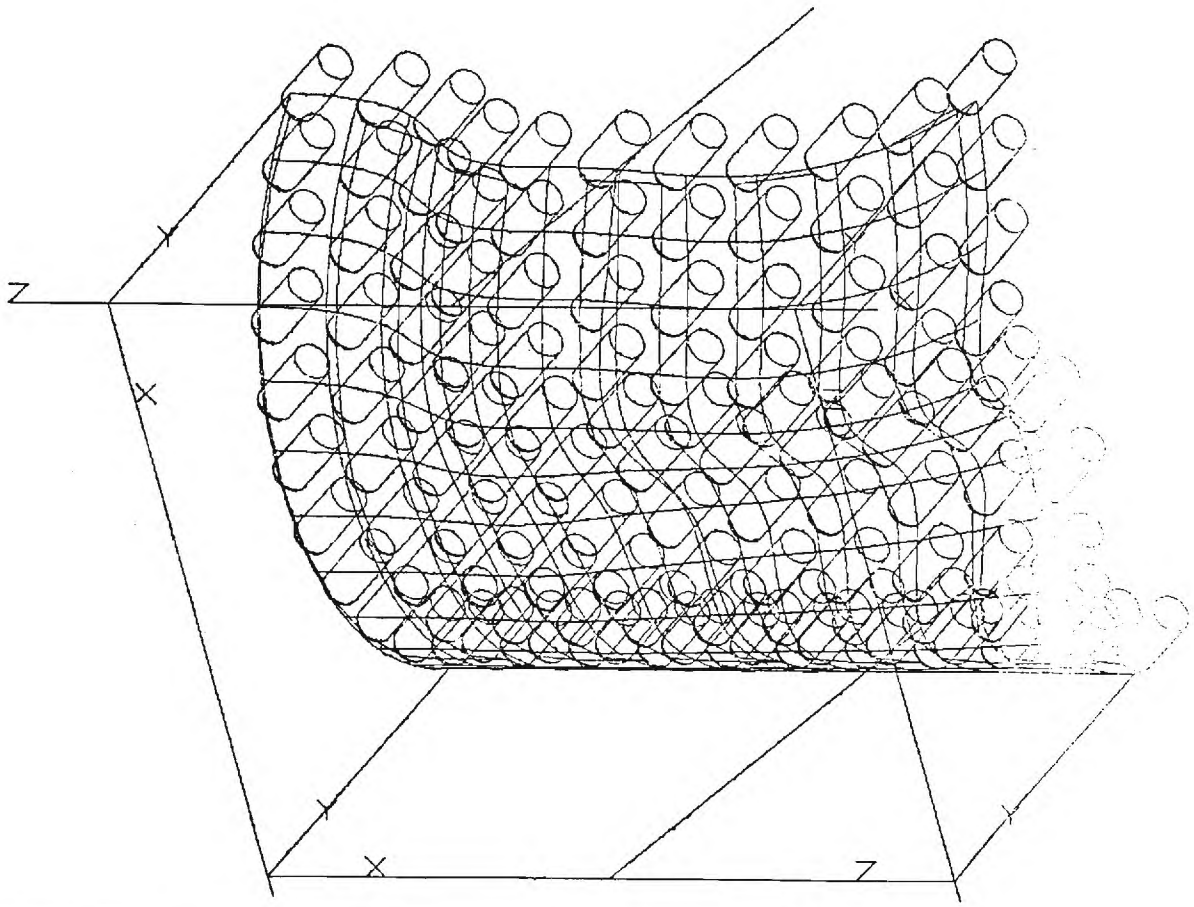
3. A fairly high level of interest in the organization for this topic, in particular from the standpoint of becoming linked with a major casting producer/user.

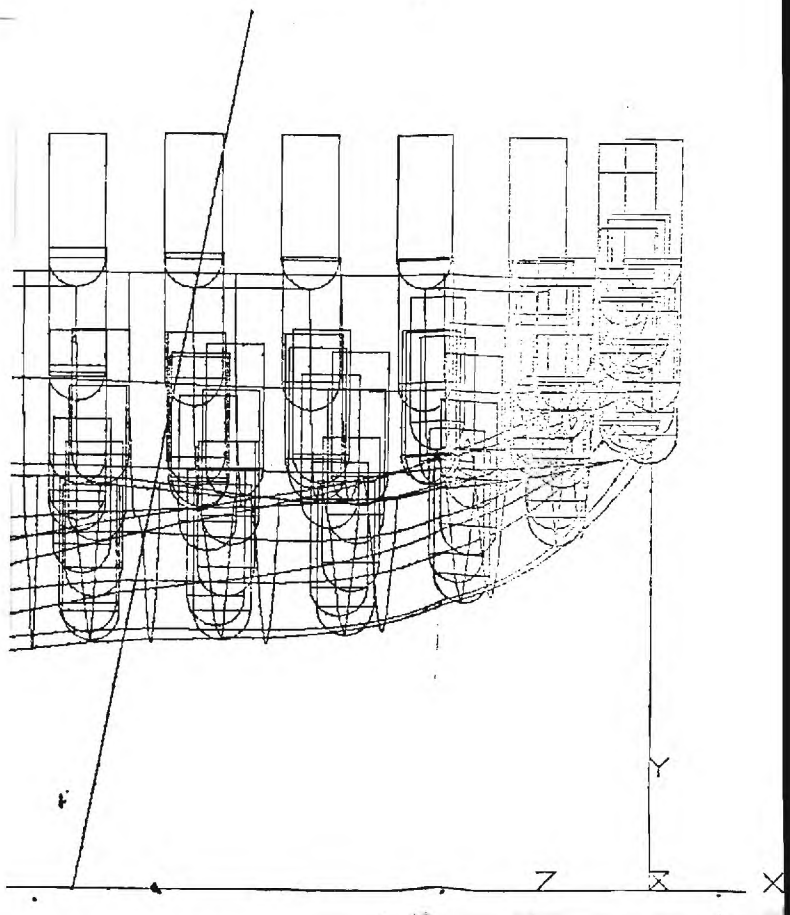
Some disadvantages would be:

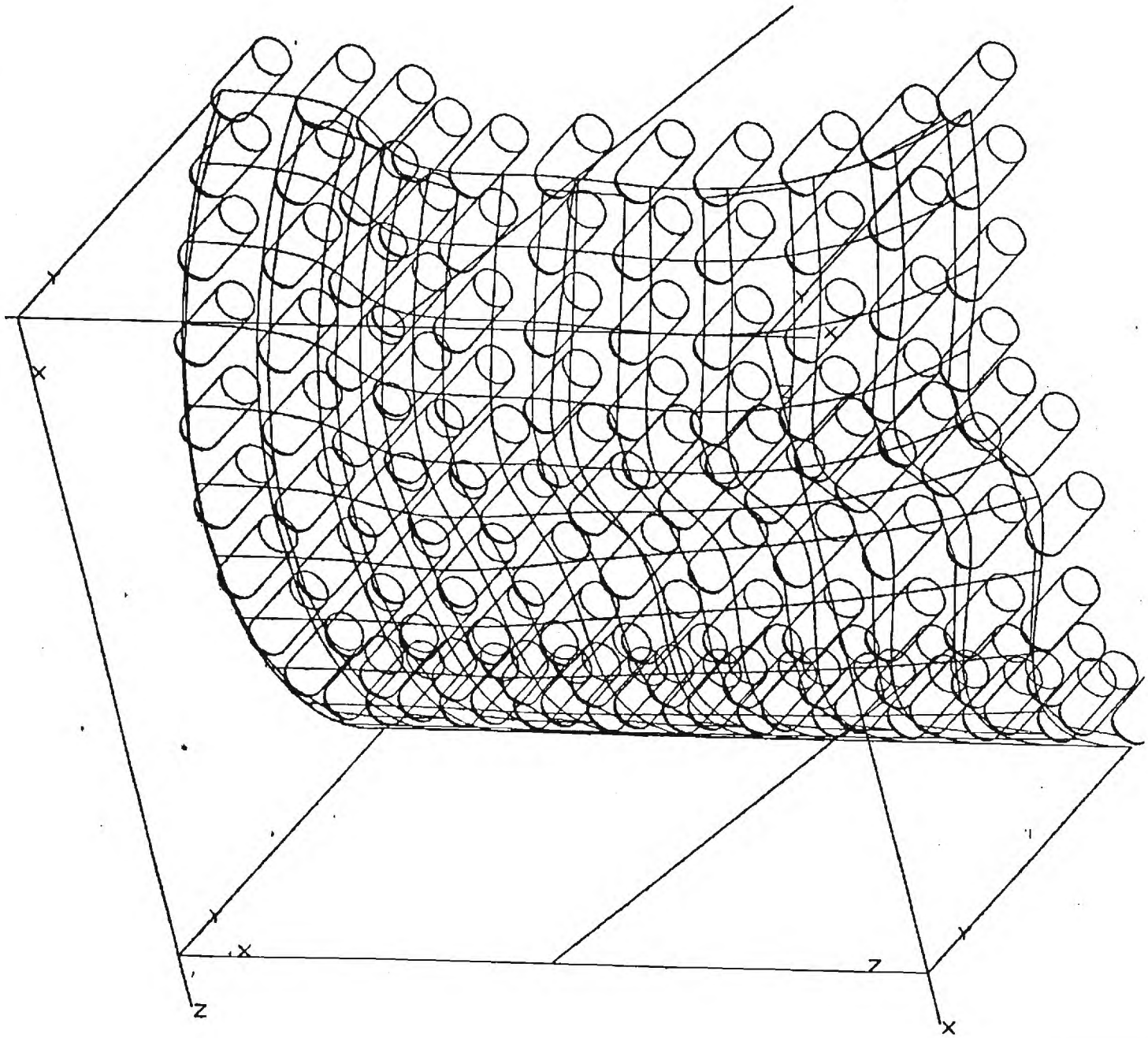
1. Organization does not possess a metal-casting unit, although they do possess individuals with knowledge of castings applications (within the McDonnell Aircraft organization).

2. Neither the University of Michigan nor Georgia Tech is in close proximity to St. Louis.

3. FASTDRAW is not solid modeler based in its nature.


Y
Z
X
Y
X
Z
Y


Y
Z
Z
X


Y
X
Y
X
Z
X
Z
X