Project #: E-16-699
Center #: R6603-0A0
Cost share #: E-16-335
Center shr #: F6603-0A0
Rev #: 0
OCA file #:
Work type : RES
Document : GRANT
Contract entity: GTRC

Subprojects ?: N
Main project #:

Project unit: AE
Project director(s):
HODGES D H AE
Unit code: 02.010.110

Sponsor/division names: ARMY / ARO, RES TRIANGLE PARK, NC
Sponsor/division codes: 102 / 001

Award period: 881001 to 890930 (performance) 891130 (reports)

Sponsor amount
Contract value 66,000.00
Funded 66,000.00
Cost sharing amount 22,114.00

Does subcontracting plan apply ?: N

Title: SYMBOLIC COMPUTATION LABORATORY

PROJECT ADMINISTRATION DATA

OCA contact: Ina R. Lashley
Sponsor technical contact
(000)000-0000

Sponsor issuing office
LARRY E TRAVIS, GRANT OFFICER
(919)549-0641
ARMY RESEARCH OFFICE
P O BOX 12211
RESEARCH TRIANGLE PARK NC 27709-2211

Security class (U,C,S,TS) : U
Defense priority rating : N/A
Equipment title vests with: Sponsor

ONR resident rep. is ACO (Y/N): Y
N/A supplemental sheet
GIT X

Administrative comments -
INITIATION OF EQUIPMENT GRANT. ARO WILL PAY MAXIMUM OF 75% UP TO $66,000 OF TOTAL PROJECT COST (PARA 4, P.2). SEE PARA 8.B, P.3 RE: SUBSTITUTE EQUIPMENT.
NOTICE OF PROJECT CLOSEOUT

Date 10/23/89

Project No. E-16-699

Center No. R6603-0A0

Project Director D. H. Hodges

School/Lab AE

Sponsor ARMY

Contract/Grant No. DAAL03-88-G-0083

GTRC XX GIT __

Time Contract No. N/A

Title Symbolic Computation Laboratory

Effective Completion Date 9/30/89 (Performance) 11/30/89 (Reports)

Closeout Actions Required:

- None
- Final Invoice or Copy of Last Invoice
- Final Report of Inventions and/or Subcontracts—Patent questionnaire sent to P/I.
- Government Property Inventory & Related Certificate
- Classified Material Certificate
- Release and Assignment
- Other

Includes Subproject No(s). ________________

Projects Under Main Project No. ________________

Continues Project No. ________________ Continued by Project No. ________________

Distribution:

- Project Director ________________
- Administrative Network ________________
- Accounting ________________
- Procurement/GTRI Supply Services ________________
- Research Property Management ________________
- Research Security Services ________________
- Reports Coordinator (OCA) X
- GTRC X
- Project File X
- Contract Support Division (OCA) 2
- Other ________________

______________________________

______________________________
Final Report on an Equipment Grant Entitled:

Symbolic Computation Laboratory
(Grant DAAL03-88-G-0082)

The Department of Defense
University Research Instrumentation Program

Submitted by:

Dr. Dewey H. Hodges, Principal Investigator
Professor, School of Aerospace Engineering
Georgia Institute of Technology
College of Engineering

Grant Period: October 1, 1988 – September 30, 1989

Submitted to:

U.S. Army Research Office
P.O. Box 1221
Research Triangle Park, NC 27709
Attn.: Dr. Gary L. Anderson
Summary

A new computing facility at Georgia Institute of Technology was created, in which faculty, research staff, and students can make use of the latest technology in symbolic computation. A room in the A. French Building, where most of the College of Engineering computers are located, was designated as the Symbolic Computation Laboratory. Therein are now housed a networked group of 4 Sun Series 3 Workstations equipped with the powerful symbolic manipulation software MACSYMA, several NEXT workstations supplied by the College of Engineering which include the software package Mathematica, a network capable of connection to the Suns from any node within the Georgia Tech network, an Apple laser printer, and other hardware and software that allows for a wide range of symbolic computational research. This laboratory is directed by Dr. Dewey H. Hodges, the principal investigator. The equipment was purchased with the $66,000 received from the U.S. Army Research Office and from an additional $22,000 supplied by the Institute through cost sharing. The Institute has undertaken the task of maintaining the equipment and software appropriately.

In accordance with the requirements for the final report contents, a breakdown of how the money was spent is attached along with a brief summary of the research projects that are presently using the equipment.

Research for Which the Equipment Will be Used

At Georgia Tech there are literally dozens of research projects within the College of Engineering which will be strongly enhanced now that such equipment is available. Perhaps nearly as significant as its use in research is the potential use of the system by undergraduate students. These systems are certain to become more common in industry, and experience gained by students will no doubt translate into increased marketable skills for them. For the sake of brevity, only a few examples of current research are described below.

Principal Investigator: The P.I.'s recent work in rotorcraft stability has focused on the application of multibody dynamics and the finite element method to rotorcraft stability analysis. Rotorcraft systems are modeled as both solid and fluid components, and thus fluid-solid interaction is important. Equations of motion for these systems are noted for their complexity, and a Symbolic Manipulator is not only helpful in their derivation but in their solution as well.
Another noteworthy example of the P. I.'s work involves the nonlinear theory of beams such as in modeling helicopter rotor blades. The equations for determination of elastic constants of nonhomogeneous, anisotropic beams are extremely complex. This work will proceed more efficiently with a Symbolic Manipulator.

In still other work, the P. I. is involved in application of advanced unsteady aerodynamic analyses to rotor blade aeroelasticity and application of classical dynamics and finite elements in time to trajectory optimization problems. In both projects, ways of simplifying the formulation are being sought, and a Symbolic Manipulator will make a big difference.

Other Research Impacted by the New Equipment: Dr. David A. Peters is known for his work in the area of rotorcraft response, vibration, and unsteady aerodynamics. Currently he is developing a new unsteady aerodynamic theory based on potential flow and finite states. This model should be simpler than previously developed theories in that it can easily be incorporated into existing aeroelastic analyses. Its main advantage, however, is its expandability. More state variables (i.e., degrees of freedom) can easily be added to increase the accuracy. The implementation of this theory requires the calculation of several matrices which, if they can be determined in closed form, will minimize the computational effort. The process of determining these matrices will be greatly expedited by a Symbolic Manipulator.

Another area of Dr. Peters' current interest is the development of time domain finite elements. His previously developed time finite elements are actually competitive with time-wise integration of ordinary differential equations. Extension of these elements to nonlinear systems with a mixed formulation is being investigated jointly with the P. I. The progress of this work would also be greatly enhanced by a Symbolic Manipulator. (A proposal for extending this work is in preparation.)

Several other investigators in the School of Aerospace Engineering are supported by the U.S. Army Research Office through the Center of Excellence for Rotary Wing Aircraft Technology. Those whose work would be benefitted by a Symbolic Manipulator are Prof. E. A. Armanios (composite materials), Prof. S. V. Hanagud (nonlinear dynamics and system identification), and Dr. A. J. Calise (control theory).

In the School of Mechanical Engineering, Prof. Wayne Book and his co-workers are undertaking the modeling of flexible manipulator arms. Their work has historically relied on SMP running on a VAX. Now that the new equipment is available, his work should benefit greatly.
# How the Grant Money was Spent

## Hardware:

<table>
<thead>
<tr>
<th>Items</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sun Microsystems, Inc.</strong></td>
<td></td>
</tr>
<tr>
<td>Sun 3/260HM-P11 Server with 575MB, 8MB EEC RAM, 64KB Cache</td>
<td>35,897</td>
</tr>
<tr>
<td>Option 150A / Floating Point Accelerator Board</td>
<td></td>
</tr>
<tr>
<td>Option 450A / Ethernet Controller for Server</td>
<td></td>
</tr>
<tr>
<td>SYSL2 / Sun OS2 Release 4.0</td>
<td></td>
</tr>
<tr>
<td>SM2-01 (1/4&quot; media documentation)</td>
<td></td>
</tr>
<tr>
<td>FOR-1.1-4-3-5 / Sun FORTRAN</td>
<td></td>
</tr>
<tr>
<td>FOR-1.1-4-3-0 / FORTRAN documentation</td>
<td></td>
</tr>
<tr>
<td>3 Sun 3/60M-12M Workstations with 19 in. Screens and Mice</td>
<td>25,883</td>
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<tr>
<td>3 Option SYSL Sun OS2 Release 4.0 for Workstations</td>
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<tr>
<td><strong>LaserWriter Interface kit</strong></td>
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<tr>
<td><strong>Total for Sun Microsystems</strong></td>
<td>63,580</td>
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<tr>
<td><strong>Apple Computer</strong></td>
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<tr>
<td>Macintosh IIX160 (equipped to run Mathematica)</td>
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<tr>
<td><strong>Apple LaserWriter Printer</strong></td>
<td>3,550</td>
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<td><strong>Total for Apple Computer</strong></td>
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<td><strong>Digital Equipment Corporation</strong></td>
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<td>Ethernet transceivers and cables</td>
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<tr>
<td><strong>Miscellaneous hardware</strong></td>
<td>157</td>
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<tr>
<td><strong>Software:</strong></td>
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<tr>
<td><strong>Symbolics, Inc.</strong></td>
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<tr>
<td>4 MACSYMA Software Packages (including 1 year contract)</td>
<td>5,430</td>
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<tr>
<td><strong>Sun Microsystems</strong></td>
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<td>Sun Mathematica</td>
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<td><strong>Arbortext:</strong></td>
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<td>The Publisher</td>
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<tr>
<td><strong>UK Atomic Energy Authority:</strong></td>
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<tr>
<td>Harwell subroutine library plus documentation on tape</td>
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<tr>
<td><strong>International Mathematical and Statistical Library:</strong></td>
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<tr>
<td>IMSL mathematical group source plus 1 year service</td>
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<tr>
<td><strong>Miscellaneous software</strong></td>
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<tr>
<td><strong>Total</strong></td>
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