GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No. E-16-638 (R6028-0A0) GTRC/GIT DATE 11 /12 /85

Project Director: S. G. Lekoudis School/Lab AE

Sponsor: National Science Foundation

Type Agreement: Grant No. ECS - 8513830

Award Period: From 10/1/85 To ~~9/30/86~~ 3/1/87 (Performance) ~~12/30/86~~ 6/1/87 (Reports)

Sponsor Amount:

	This Change	Total to Date
Estimated:	$	$ -0-
Funded:	$	$ -0-

Cost Sharing Amount: $ $200.00 Cost Sharing No: E-16-377

Title: Super Computer Use

ADMINISTRATIVE DATA

OCA Contact John B. Schonk X 4820

1) Sponsor Technical Contact:

Frank Huband
National Science Foundation
ENG/ECS
Washington, DC 20550

(202) 357-9618

2) Sponsor Admin/Contractual Matters:

Joe Carrabino
National Science Foundation
DGC/ENG
Washington, DC 20550

(202) 357-9602

Defense Priority Rating: N/A

Military Security Classification: N/A

(or) Company/Industrial Proprietary: N/A

RESTRICTIONS

See Attached N/A 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 N/A

COMMENTS:

This grant is for Super computer use only - no sponsor funds will be expended against this account.

No cost-sharing is required on this project.

COPIES TO:

SPONSOR'S I. D. NO. 02.107.000.85.116

Project Director	Procurement/GTRI Supply Services	GTRC
Research Administrative Network	Research Security Services	Library
Research Property Management	Reports Coordinator (OCA)	Project File

GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date: 8/5/87

Project No. E-16-638 — School/~~Lab~~: AE

Includes Subproject No.(s): N/A

Project Director(s): S.G. Lekoudis — GTRC / ~~GIT~~

Sponsor: National Science Foundtion

Title: Super Computer Use

Effective Completion Date: 3/1/87 (Performance) 6/1/87 (Reports)

Grant/Contract Closeout Actions Remaining:

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

Continues Project No. ______ Continued by Project No. ______

COPIES TO:

Project Director	Library
Research Administrative Network	GTRC
Research Property Management	~~Research Communications (2)~~
Accounting	Project File
Procurement/GTRI Supply Services	Other Angela D.
Research Security Services	Duane H.
Reports Coordinator (OCA)	Russ M.
~~Legal Services~~	

FORM OCA 69.285

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Georgia Institute of Technology School of Aerospace Engineering Atlanta, Georgia 30332	ENG8513830	ENG8513830
	4. Award Period From 3/01/86 To 3/01/87	5. Cumulative Award Amount 30 hrs of CPU time on U. Illinois CRAY-XMP

6. Project Title

Prediction of Rotor Flows Using the CRAY-XMP

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

A three-dimensional compressible Navier-Stokes solver, developed under the support of the U. S. Army Research Office, was vectorized for efficient performance on the CRAY-XMP class of machines. The resulting vectorized code was used to compute unsteady subsonic and transonic flow past a number of helicopter blade configurations. Good correlation with existing experimental data was observed. This computer code has been made available to a number of U. S. helicopter industries and government laboratories.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM: Check (✓)	Approx. Date
a. Abstracts of Theses		X			
b. Publication Citations		X			
c. Data on Scientific Collaborators			X		
d. Information on Inventions	n/a				
e. Technical Description of Project and Results		X (Included in abstract of Thesis)			
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
S. G. Lekoudis		6/29/87

PART IV - SUMMARY DATA ON PROJECT PERSONNEL

NSF Division ____________________

The data requested below will be used to develop a statistical profile on the personnel supported through NSF grants. The information on this part is solicited under the authority of the National Science Foundation Act of 1950, as amended. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. NSF requires that a single copy of this part be submitted with each Final Project Report (NSF Form 98A); however, submission of the requested information is not mandatory and is not a precondition of future awards. If you do not wish to submit this information, please check this box ☐

Please enter the numbers of individuals supported under this NSF grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

*U.S. Citizens/ Permanent Visa	PI's/PD's		Post-doctorals		Graduate Students		Under-graduates		Precollege Teachers		Others	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
American Indian or Alaskan Native												
Asian or Pacific Islander												
Black, Not of Hispanic Origin												
Hispanic												
White, Not of Hispanic Origin	✓				✓							
Total U.S. Citizens	1				1							
Non U.S. Citizens	0				0							
Total U.S. & Non-U.S. ..	1				1							
Number of individuals who have a handicap that limits a major life activity.	0				0							

*Use the category that best describes person's ethnic/racial status. (If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America, and who maintains cultural identification through tribal affiliation or community recognition.

ASIAN OR PACIFIC ISLANDER: A person having origins in any of the original peoples of the Far East, Southeast Asia, the Indian subcontinent, or the Pacific Islands. This area includes, for example, China, India, Japan, Korea, the Philippine Islands and Samoa.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa or the Middle East.

THIS PART WILL BE PHYSICALLY SEPARATED FROM THE FINAL PROJECT REPORT AND USED AS A COMPUTER SOURCE DOCUMENT. DO NOT DUPLICATE IT ON THE REVERSE OF ANY OTHER PART OF THE FINAL REPORT.

Part III, 1.b

List of publications that benefited from the computer resources provided by this project:

1. Wake, B. E., and Sankar, L. N., "Solutions of the Navier-Stokes Equations for the Flow about a Rotor Blade," Proceedings of the American Helicopter Society Specialists' Meeting on Aerodynamics, Texas, February 1987.

2. Wake, B. E., Sankar, L. N., and Ruo, S. Y., "An Efficient Procedure for the Numerical Solution of Three-Dimensional Viscous Flows, AIAA 87-1159-CP, June 1987.

3. Wake, B. E., "Solution Procedure for the Navier-Stokes Equations Applied to Rotors," Ph.D. Dissertation, Georgia Institute of Technology, April 1987.

SUMMARY

The aerodynamics of a helicopter blade is very complex. In forward flight, transonic flow may be present on the advancing side while, on the retreating side, dynamic stall is a problem. These two effects severely limit the forward-flight speed of a helicopter. The most difficult aspect of the rotor problem is the wake. Since most of the lift of a helicopter blade is generated near the tip of the blade, a very strong tip vortex is formed. This tip vortex induces a large downwash which has a significant effect on the blade loads. Thus, in addition to solving the equations which govern the flow, the wake effects must be included.

A solution procedure for the unsteady, three-dimensional Navier-Stokes equations has been developed and applied to helicopter rotors. The procedure is an efficient hybrid ADI scheme in which the radial and viscous terms are treated explicitly. This procedure solves the Navier-Stokes equations in a time-accurate manner. Steady solutions are obtained by marching through time and asymptotically converging to steady state. The procedure was originally developed for the Euler equations, and upgraded for the Navier-Stokes equations. Turbulence is included by an algebraic eddy-viscosity model. An unsteady grid is utilized to incorporate the blade motion. Arbitrary motions due to cyclic pitch, flapping, lead-lag motions and aeroelastic deflections can also be incorporated into the unsteady grid

terms. The equations are formulated for a curvilinear coordinate system, enabling completely arbitrary rotor-blade geometries. To account for the effect of the rotor wake, the transpiration-velocity technique is used. Since the solver includes all effects of viscosity and compressibility, it may be used to compute the flow on the advancing, or retreating, side of the rotor. Currently, retreating-side calculations are a too demanding for present-day computers.

Initially, as a test of the flow solver in the transonic regime, quasi-steady Euler calculations were made for a high-speed nonlifting ONERA blade. Unsteady Euler and Navier-Stokes calculations were also performed for this configuration to examine the viscous and unsteady effects. Lifting hover results have been made for a two-bladed rotor with 0012 blade airfoil sections. For this case, a detailed comparison with experimental results in the tip region is done. Also, unsteady Euler results have been obtained for a lifting OLS rotor.