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UTILIZATION OF AN EFFICIENT NUMERICAL METHOD  
FOR VISCOUS FLOW PROBLEM SOLUTIONS

FINAL REPORT

Prepared by

J. C. Wu

FEBRUARY 10, 1981

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U. S. ARMY RESEARCH OFFICE

CONTRACT NO. DAAG 29-80-C-0015

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (6)	2. GOVT ACCESSION NO. AD-A095758	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Utilization of an Efficient Numerical Method for Viscous Flow Problem Solutions .		5. TYPE OF REPORT & PERIOD COVERED Final, 1/4/80 to 12/31/80
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) J. C. Wu	(18) ARO	8. CONTRACT OR GRANT NUMBER(s) DAAG 29-80-C-0015 <sup>new</sup>
9. PERFORMING ORGANIZATION NAME AND ADDRESS Georgia Institute of Technology Atlanta, Georgia 30332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Research Office P. O. Box 12211 Research Triangle Park, NC 27709		12. REPORT DATE February 1981
		13. NUMBER OF PAGES 5
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) U. S. Army Research Office P. O. Box 12211 Research Triangle Park, NC 27709		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release, distribution unlimited		
(19) 16674.1-E		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES The view, opinions, and/or findings contained in this report are those of the author and should not be construed as an official department of the Army position, policy, or decision unless so designated by other documentation.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Aerodynamics, Computational Fluid Dynamics, Viscous Flows, Unsteady Flows		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes two workshops organized and conducted at two U. S. Army Laboratories for the purpose of transferring new knowledge and new techniques developed for the use of the integral-representation approach in computing complex viscous flows.		

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## STATEMENT OF PROBLEM

During the past ten years, a research program in computation fluid dynamics carried out at the Georgia Institute of Technology has demonstrated the suitability of an integral-representation approach for the numerical solution of complex general viscous flows. This approach possesses the distinguishing ability of confining the solution field to the vortical (viscous) region of incompressible flow. This ability has offered a superior solution efficiency. Several two-dimensional laminar flows about impulsively started and about oscillating airfoils have been studied numerically using this approach. Under the earlier support of the Army Research Office, a number of turbulent flows have also been solved using various algebraic and differential models of turbulence in conjunction with this integral-representation approach.

Many fluid dynamicists have become familiar with the basic concepts of this integral-representation approach and have expressed interest in its utilization. The adoption of this approach for the solution of complex problems, by individuals who had not participated in the active development of this approach, however, is difficult. One reason for this difficulty is that the integral-representation approach represents a major departure from previous approaches and therefore calls for entirely new numerical procedures. The development of these new procedures have progressed through many stages, each stage offering distinct opportunities for improvement of computational efficiency and/or accuracy. Many features introduced throughout the years and incorporated into the new procedures are now considered routine by those directly involved in the development of the integral-representation approach. Yet these features are novel to newcomers and represent substantial obstacles in the utilization of this approach. The present effort is directed toward the transfer of some of the new knowledge and new techniques developed for the integral-representation approach to interested scientists in selected Army Research Laboratories.

## SUMMARY OF RESULTS

Two workshops on the utilization of the integral-representation approach for viscous flow problem solutions were organized and conducted at the Aeromechanics Laboratory of the Army Air Research & Technology Laboratories, Moffett Field, California, and the Systems Simulation Directorate of Army Missile R & D Command, Redstone Arsenal, Alabama. Each of the two workshops contains ten focal points of study. Each focal point is presented through a lecture, followed by questions, answers, and discussions. In addition, an opportunity for participants to learn some of the program details were provided. User-oriented computer codes for solving the time-dependent Navier-Stokes equations for laminar flow past airfoils was prepared, transferred and stored in the computing facilities of the two Army Laboratories. Detailed program listing and instruction manual were made available and the computer codes were checked out prior to the presentation of the Workshops. Several participants gained experience in the use of these code during and after the Workshops.

The ten focal points of study are:

1. Fundamental Concept and Mathematical Foundation (Introduction)
2. Integral Representation for Elliptic Equations
3. Integro-Differential Procedure
4. Structure of Computer Code for Time-Dependent Separate Laminar Flows over Airfoils (The IDALA Code)
5. Application of the IDALA Code
6. Computation of Steady Separated Internal Flows (Structure and Application of a Streamlined Code)
7. Computation of Time-Dependent Separated Flows
8. Computation of Turbulent Separated Flows

9. Computation of Compressible Separated Flows

10. Separate Computation of Attached and Detached Regions in a General Viscous Flows

The Workshop in Redstone Arsenal, Alabama, was conducted in two parts. The first part, presented July 9 and 10, 1980, covered the first five focal points and the second part, presented on November 14, 1980, covered the remaining five focal points. The Workshop in Moffett Field, California, was conducted on September 22, 23, and 24, 1980, with a follow-up visit in December of 1980.

Participants of the Workshops were provided with copies of a set of 323 slides shown at the Workshops, program listings and instruction manuals for the time-dependent and steady separated flows, as well as other useful information concerning the integral-representation approach. It is felt that the new knowledge and techniques developed for the integral-representation approach were effectively transferred through the Workshops. In addition, it is felt that the participant have gained an appreciation of the scope of application and future potential of this approach.

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## PUBLICATIONS AND REPORTS

The objective of this project is to transfer, through Workshops, some of the new knowledge and new techniques developed for the integral-representation approach to interested scientists in selected Army Research Laboratories. Consistent with this objective, no journal articles were prepared under this contract. The following documents, however, have been prepared and have been supplied to each of the Workshop participants:

1. A. Sugavanam, S. Sampath, and J. C. Wu, "IDALA - A Manual for a Computer Code that Solves the Navier-Stokes Equations for Laminar Flow Past Airfoils using the Integral-Differential Approach," Georgia Institute of Technology Report, June 1980, 109 pp.
2. J. C. Wu and A. Sugavanam, "Integral-Representation Approach for General Viscous Flows - Slide Panels of Lectures," Georgia Institute of Technology Report, July 1980, 130 pp.
3. J. C. Wu, "Integro-Differential and Integral-Representation Approaches for the Numerical Solution of General Viscous Flows," - A list of articles authored by researchers at the Georgia Institute of Technology, January 1980, 3 pp.

In addition, copies of the following report, prepared under an earlier Army Research Grant (No. DAAG29-75-G-0147) were supplied to the Workshop participant:

M. M. Wahbah, "Computation of Internal Flows with Arbitrary Boundaries using the Integral Representation Method," Georgia Institute of Technology Report, March 1978, 84 pp.

## SCIENTIFIC PERSONNEL

The following scientific personnel participated in this project:

- J. C. Wu, Professor of Aerospace Engineering, served as the Director of this project. He, prepared, organized and conducted the two Workshops stated in this report.
- A. Sugavanam, Post-Doctoral Fellow, School of Aerospace Engineering, streamlined the IDALA computer code and gave several lectures of the Workshops.
- S. G. Lekoudis, Assistant Professor of Aerospace Engineering, gave several lectures of the Workshop.

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