Project Title: Utilization of an Efficient Method for Viscous Flow Problem Solutions

Project No: E-16-659

Project Director: Dr. James C. Wu

Sponsor: U. S. Army Research Office; Research Triangle Park, N. C.

Agreement Period: From 1/4/80 Until 6/30/80

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Defense Priority Rating: n/a

Assigned to: Aerospace Engineering (School/Laboratory)

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February 17, 1981

Date:

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Project No: E-16-659

Project Director: Dr. James C. Wu

Sponsor: U.S. Army Research Office; Research Triangle Park, N. C. (#DAAG29-80-C-0015)

Effective Termination Date: 12/31/80

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Grant/Contract Closeout Actions Remaining:

- [X] Final Invoice and Closing Documents
- [ ] Final Fiscal Report
- [X] Final Report of Inventions
- [X] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

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(School/Laboratory)

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Suspense
UTILIZATION OF AN EFFICIENT NUMERICAL METHOD
FOR VISCOS FLOW PROBLEM SOLUTIONS

FINAL REPORT

Prepared by

J. C. Wu

FEBRUARY 10, 1981

for

U. S. ARMY RESEARCH OFFICE

CONTRACT NO. DAAG 29-80-C-0015

GEORGIA INSTITUTE OF TECHNOLOGY

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**Title:** Utilization of an Efficient Numerical Method for Viscous Flow Problem Solutions

**Author:** J. C. Wu

**Performing Organization:** Georgia Institute of Technology

**Report Date:** February 10, 1981

**Abstract:**
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.
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
5. Application of the IDALA Code
7. Computation of Time-Dependent Separated Flows
8. Computation of Turbulent 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.
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:


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:

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.