GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. _____

Project No. G-37-613 (R5925-0A0) GTRC~~/GIT~~ DATE 6 / 24 / 85

Project Director: G. H. Meyer School/~~Lab~~ Math

Sponsor: McDonnell Douglas Corporation

Type Agreement: P.O. Z50028

Award Period: From 4/2/85 To ~~3/31/86~~ 4-30-88 (Performance) 4/30/86 (Reports)

Sponsor Amount:	This Change	Total to Date
Estimated: $		$ 55,102
Funded: $		$ 55,102

Cost Sharing Amount: $ N/A Cost Sharing No: N/A

Title: Joint Research with McDonnell Douglas Corporation

ADMINISTRATIVE DATA

OCA Contact John Schonk x4820

1) Sponsor Technical Contact:

D. P. Ames
McDonnell Douglas Corporation
Dept. 220, Bldg. 110
P.O. Box 516
St. Louis, MO 63166

2) Sponsor Admin/Contractual Matters:

Ken Suter
McDonnell Douglas Corporation
Dept. 763, Bldg. 33
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314/232-3252

Defense Priority Rating: N/A Military Security Classification: N/A

(or) Company/Industrial Proprietary: See Below

RESTRICTIONS

See Attached _____ 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 None Proposed

COMMENTS:

An advance budget has been set up for this project.

A Non-Disclosure Agreement is being executed for this project.

SPONSOR'S I. D. NO. 02.212.000.85.001

COPIES TO:

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/GTRI Supply Services
Research Security Services
~~Reports Coordinator~~ (OCA)
~~Research Communications~~ (2)
GTRC
Library
Project File
Other A. Jones

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 05/28/91

ct No. G-37-613 Center No. R5925-0A0

ct Director MEYER G H School/Lab MATH

sor MCDONNELL DOUGLAS HELICOP/

act/Grant No. Z50028 Contract Entity GTRC

Contract No.

JOINT RESEARCH WITH MCDONNELL DOUGLAS CORPORATION

ctive Completion Date 880430 (Performance) 880430 (Reports)

eout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	880629
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory & Related Certificate	Y	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments

roject Under Main Project No.

inues Project No.

ribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other	N
	N

1) Overview: I would like to propose a continuation of the joint research with MDRL which was initiated formally in April 1985 and is funded until March 1986. An effort at a level comparable to last year's funding is suggested. Moreover, the research objectives of last year's proposal remain unchanged in principle and provide a general basis for continued joint research.

2) Progress report on joint research carried out so far: To date all projects identified in last year's proposal have received some attention. Work was carried out by myself as principal investigator during release time from teaching in the winter and spring quarters and during the summer quarter. The work will continue until the end of the contract period. A graduate student, David E. Womble, is assisting. It is particularly helpful that he has mastered the communication (through his personal computer) between the Georgia Tech and McDonnell Douglas Cyber computers. We anticipate increasing use of this link to conserve contract computer funds for program development and interactive computing at Georgia Tech. Overall, experience has shown so far that projects can take on a time consuming life of their own, and that extended personal contact with collaborators is essential for project definition and direction. A discussion of individual research topics follow.

2i) Electro-magnetic signatures: Although this

topic is considered in the previous proposal the main research area, to date it has received a disproportionately small share of research time. The primary reason is that a clear definition of the project was necessarily delayed until after the contract was approved. Since this subject lies well outside my area of training and experience it is taking time to learn before meaningful research is possible. The rationale and techniques of the existing Fock theory are slowly unfolding.

2ii) Hydrodynamic stability: The method of continuous orthonormalization analyzed at MDRL [1] continues to prove itself an effective numerical method for Orr-Sommerfeld type equations. Building on previous research we have extended the method to a larger class of problems. As an application the 2-D Orr-Sommerfeld eigenvalue problem with general velocity profiles and constant tail conditions is solved reliably. A report on this research is in progress [2]. The method also provides a test code for the 3-D Orr-Sommerfeld eigenvalue problem, but so far convergence of the iterations remains a problem on which our work is continuing.

Continuous orthonormalization also proved to be a useful tool for the successful resolution of the boundary layer transition control problem [3]. A report on this work is now in progress at MDRL.

Finally, an application of the method of lines to

channel flow over a backward facing step is about to be initiated by David Womble and myself.

2iii) High accuracy shock calculations: Numerical experiments show that the continuous orthonormalization code can resolve the singularly perturbed Burger's equation. For a model problem with a shock like solution the numerical solution reproduces the analytic solution without oscillation or dispersion. These results have been sent to Dr. Agarwal for his review.

3. Research objectives for the future: Existing projects will require continued effort. A summary of the basic directions follows.

3i) Electro-magnetic signatures: An approximate analytic expression for the electric field in and outside a dielectric coating with non-conformal boundaries is to be derived with the Fock approximation. Limiting cases of cylinders and curved wave guides will serve as a check on the results. This work will continue to require cooperation with and guidance by Dr. Medgyesi-Mitschang. About 50% of the total contract time is suggested for this effort.

3ii) Shear flow: The close cooperation with members of the shear flow group (Drs. Bower, Kegelman, Pal) will be continued. Special emphasis will be placed on the methods of Kleiser for resolving three dimensional flows.

3iii) Shock calculations: A continuation of research into numerical methods with orthonormalization to shock

problems would be welcomed if considered appropriate by Dr. Agarwal after an evaluation of the performance of this method for Burger's equation.

Overall, sufficient flexibility would be desirable to reorient our efforts as new needs arise at MDRL. The transition control work during this contract period is a good example for a newly conceived project.

References

1. G. H. Meyer, Continuous Orthonormalization for Boundary Value Problems, J. Comp. Phys, to appear.

2. G. H. Meyer, Continuous Orthonormalization for Multi-Point Problems, intended for 1986 ODE Conference, July 1986, Albuquerque.

3. W. W. Bower, J. T. Kegelman, G. H. Meyer, A Numerical Study of Instability-Wave Control Through Periodic Wall Motion/Blowing, paper for ASME Winter Meeting, November 1985, Miami.

G-37-613

WS-MDRL-2210
14 May 1986

MATHEMATICS RESEARCH DESCRIPTION

1) Overview: The research objectives of last year remain unchanged in principle and provide a general basis for continued research.

2) Progress report on research carried out so far: To date all projects identified in last year's proposal have received some attention. Work was carried out by Dr. G. H. Meyer as principal investigator during release time from teaching in the winter and spring quarters and during the summer quarter. A graduate student, David E. Womble, is assisting. It is particularly helpful that he has mastered the communication (through his personal computer) between the Georgia Tech and McDonnell Douglas Cyber computers. Increasing use of this link to conserve contract computer funds for program development and interactive computing at Georgia Tech is anticipated. Overall, experience has shown so far that projects can take on a time consuming life of their own, and that extended personal contact with collaborators is essential for project definition and direction. A discussion of individual research topics follow.

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2ii) Hydrodynamic stability: The method of continuous orthonormalization analyzed at MDRL (1) continues to prove itself an effective numerical method for Orr-Sommerfeld type equations. Building on previous research, the method has been extended to a larger class of problems. As an application the 2-D Orr-Sommerfeld eigenvalue problem with general velocity profiles and constant tail conditions is solved reliably. A report on this research is in progress (2). The method also provides a test code for the 3-D Orr-Sommerfeld eigenvalue problem, but so far convergence of the iterations remains a problem on which work is continuing.

Continuous orthonormalization also proved to be a useful tool for the successful resolution of the boundary layer transition control problem (3). A report on this work is now in progress at MDRL.

Finally, an application of the method of lines to channel flow over a backward facing step is about to be initiated by Dr. Meyer and David Womble.

2iii) High accuracy shock calculations: Numerical experiments show that the continuous orthonormalization code can resolve the singularly perturbed Burger's equation. For a model problem with a shock like solution the numerical solution reproduces the analytic solution without oscillation of dispersion. These results have been sent to Dr. Agarwal for his review.

3) Research objectives for April 1986 through March 1987: Existing projects will require continued effort. A summary of the basic directions follows.

3i) Electro-magnetic signatures:

1. Reformulate the Fock theory for axisymmetric bodies that are conducting or satisfy the Leontovich condition. The assumed solution for the wave equation in this case incorporates a Fourier expansion in the circumferential direction. The unknown coefficients arising from this approach at oblique illumination are solved through an integral equation using the Fock solution

as the basis set. This approach appears computationally very attractive since no geodesic paths need to be calculated.

2. Generalize the Fock theory for penetrable boundaries. The solution of this problem could yield valuable asymptotic representation for the surface fields and currents on such surfaces. Limiting cases for this solution are the classical results for perfectly conducting bodies and Leontovich surfaces. This generalization of the Fock theory could be incorporated into the methods described in paragraph 1.

3ii) Shear flow: The close cooperation with members of the shear flow group (Drs. Bower, Kegelman, Pal) will be continued. Special emphasis will be placed on the methods of Kleiser for resolving three dimensional flows.

3iii) Shock calculations: Research into numerical methods with orthonormalization to shock problems will be continued if considered appropriate by Dr. Agarwal after an evaluation of the performance of this method for Burger's equation.

Overall, sufficient flexibility will be maintained to reorient efforts as new needs arise at MDRL. The transition control work during the previous contract period is a good example for a newly conceived project.

References

1. G. H. Meyer, Continuous Orthonormalization for Boundary Value Problems, J. Comp. Phys. to appear.

2. G. H. Meyer, Continuous Orthonormalization for Multi-Point Problems, intended for 1986 ODE Conference, July 1986, Albuquerque.

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G-37-613

A Proposal for Continued Joint Research Between the McDonnell Douglas Research Laboratories and the School of Mathematics of the Georgia Institute of Technology

Submitted by

Gunter H. Meyer
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Submitted to

McDonnell Douglas Research Laboratories
Saint Louis, Missouri

April 1988

I. Summary

I would like to propose a continuation of the joint research with MDRL which began in April 1985 and is currently funded until March 31, 1988. The proposal is at the level of past proposals and suggests an effort of 4 man-months at a total cost of $70,506 for a continuation of current work from April 1, 1988 to March 31, 1989.

II. Current Status of Joint Research

Overview: Since the inception of this joint program research has been carried out in the three broad categories of i) electro-magnetic signatures, with Dr. Medgyesi-Mitschang, of ii) control of transition to turbulence in shear flows, with Dr. Bower and colleagues, and of iii) time accurate integration of flow equations, with Dr. Agarwal.

During the past contract period funding from MDRL has been used for release time in every quarter of the academic year and for partial support during the summer of 1987. In addition, I have spent three weeks at MDRL during the year to maintain personal contact with my collaborators.

A graduate student has assisted with programming tasks during the winter quarter. Another graduate student is presently writing a master's thesis on a topic related to our joint research. Both are supported with contract funds.

Finally, equipment funds provided by MDRL and augmented by Georgia Tech (75% MDRL — 25% Georgia Tech) were used to buy a Macintosh II microcomputer with a color monitor, an 80 M internal disk, 8 M RAM, an ImageWriter II printer, a Hayes moden (all inventoried by GT) and some software. We are still learning to use this equipment properly.

Research Results for 1987-1988

1) Electro-magnetic signatures: Earlier efforts have continued to clarify the structure of the Fock functions for a body of revolution where a separation of variables can be applied in the azimuthal variable. The basic goal is the development of a set of Fock functions for the surface fields which almost correctly describe the actual fields on the scatterer and which would provide highly conforming basis functions for a Galerkin solution of the integral equations for the

surface fields. Such functions are now available which approximately satisfy the reduced Helmholtz equation and the Leontovich boundary conditions on the body of revolution. Their use as Galerkin basis functions is pending.

A better understanding of the Fock formalism has also shown that the restriction to an elliptic paraboloid can be relaxed somewhat to bounded shapes which are parabolic only in the direction of the ray. In order to evaluate the Fock functions in the new geometry geodesics must be computed. We are currently working on a computer program in which the geodesic is approximated by a piecewise cubic Hermite polynomial whose coefficients are to be found by applying Newton's method to the Gaussian quadrature of the path length integral.

2) Laminar flow control: Contributions to this ongoing effort have consisted primarily of providing, maintaining and extending the numerical tools required for the computer solution of the Orr-Sommerfeld equation and the associated energy equation. These lead to very stiff boundary value problems which challenge the best numerical methods extant. In addition, we have examined the behavior of finite channel flow with increasing channel width, although only for a Pohlhausen flow profile. The goal is to gain a better understanding of the point spectrum for the Orr-Sommerfeld equation on a finite interval and of the role of the continuous spectrum for Blasius boundary layer flows. This study is not yet complete and runs parallel to current efforts of our group to reproduce the dominant mode result by a direct inversion of the Fourier integrals.

In conjunction with this effort we have examined Kaplan filtering (a highly efficient method for eigenvalue calculations for the Orr-Sommerfeld equation) as a general boundary value solver for non-constant coefficient equations. Extensive experiments with second and fourth order equations have led to the conclusion that Kaplan filtering is too dependent on the structure of the problem to merit consideration as a general method for linear boundary value problems. On the other hand, the method of continuous orthonormalization, which is used extensively in our transition control studies, has been successfully extended to multi-point and periodic boundary value problems.

Finally, efforts are underway by Mr. M. Eidenschink, a graduate student in the Georgia Tech School of Mathematics, to systematically compare the peformance of various commerical boundary value solvers when applied to the Orr-Sommerfeld

equation with high Reynolds numbers. We hope to assure that our workhorse method of continuous orthonormalization is the appropriate choice for future transition control studies.

3) Time accurate integration of flow equation: Current MDRL codes for the numerical solution of the 2-D Reynolds averaged Navier-Stokes equations are solved with an explicit Runge-Kutta method whose performance degrades because the system of equations is stiff. However, neither the complexity nor structure of the equations permit a straightforward changeover to implicit Runge-Kutta methods which are usually advocated for stiff equations. Model studies were carried out during the year with a space discretized fourth order parabolic equation employing IMSL explicit and implicit initial value routines. They show that sufficient differences in their performance exist to warrant further experiments with implicit or partially implicit methods, particularly for those problems where the degree of stiffness is increased through the presence of reaction terms.

Presentations of MDRL Connected Work (in addition to work originating in the Laboratory)

Invited Address: "Continuous orthonormalization with applications," presented at Equadiff, International Conference on Differential Equations, held at Xanthi, Greece, August 1987.

Publication: "Continuous orthonormalization for multi-point problems for linear ordinary differential equations," SIAM Journal on Numerical Analysis 24 (1987), 1288-1300.

New Research

The research proposed for the period of April 1, 1988 to March 31, 1989 is a continuation of work in progress and is consistent with IRAD plans for 1988. The following problems are to be addressed:

1) Electro-magnetic signatures: The interpretation of the Fock formalism as a singular limit of the Helmholtz equation remains the primary topic of interest. We hope to extend and adapt the discussion of Zauderer* to treat the case of scattering from a regular paraboloid in order to clarify the role of the various approximations used in the Fock theory to obtain Airy functions. A better understanding of the interplay between ray tracing, geometrical optics, the Fock