15 January 1994

Dr. Edwin P. Rood
Fluid Dynamics Program (332FD)
Science Directorate/ONR
800 N. Quincy Street
Arlington, VA 22217-5000

Dear Ed:

We are enclosing the ARI-Closeout Report on hard copy and computer disk. Three "manuscripts", extracted from three recent Ph.D. Theses and which are in various stages of editing for publication submission, are attached.

We grately appreciate the opportunity of performing research of interest to ONR and we look forward to future opportunities for cooperation.

Sincerely yours,

Joseph T. C. Liu
Professor of Engineering
tel:401-863-2654
fax:401-863-1157

CC: Carl Cometta
ORA

1/24 called Fremon. left message to check to amount of award and end date at 1st page of report

ARI - CLOSEOUT REPORT
"Vortex Shedding and Vortex Wakes:
Dynamics, Instabilities and Modifications"

1. GRANT TITLE:
"Studies of Nonlinear Instabilities of Developing Wake Flows behind Bluff Bodies and Their Control"
Office of Naval Research, Fluid Dynamics Program
Grant N00014-90-J-1430

PRINCIPAL INVESTIGATOR AND INSTITUTION:
Joseph T. C. Liu
Brown University

2. TOTAL FUNDING AND TERM OF RESEARCH:
$ ~~294,432.00~~ 289,526.00
15 December 1989 - ~~15~~ 30 June 1993

3. RESEARCH OBJECTIVES:
To study nonlinear and secondary instability properties of wake flows behind bluff bodies and their control and modification

5. PAPERS:

a. Total papers to be submitted to refereed journals: 3
b. Total number published in refereed journals: 0
c. Total papers published in non-refereed journals: 0

6. NUMBER OF TECHNICAL REPORTS: 0

7. NUMBER OF BOOKS PUBLISHED: 0

8. NUMBER OF BOOK CHAPTERS PUBLISHED: 0

9. NUMBER OF PATENT APPLICATIONS: 0

10. SIGNIFICANT PRESENTATIONS:

a. Total number: 12
b. List of top 3:

- 1st European Fluid Mechanics Conference, Cambridge University, 14-20 September 1991: "Multiple mode evolution and control in spatially developing turbulent wakes"

- 22-24. 44th Annual Division of Fluid Dynamics Meeting, APS, Arizona State University, 24-26 November 1991:
  "Numerical computation of nonlinear unstable modes in axisymmetric wake flows" (Abstract in Bull. Am. Phys. Soc. 36 (1991))

- Office of Naval Research Workshop on Nonequilibrium Turbulence, Tempe, 10-12 March 1993: "Nonequilibrium (dynamical) subgrid closure in large eddy simulation"

11. HONORS AND AWARDS RECEIVED BY PI's:
Professeur Invite, Universite de Nantes, France, 1993 - 1994

12. NUMBER OF DIFFERENT POST DOCS SUPPORTED/PERSON-MONTHS: 0

13. NUMBER OF DIFFERENT GRADUATE STUDENTS SUPPORTED/PERSON-MONTHS: 3/42

14. MOST SIGNIFICANT PUBLICATIONS (include short abstract):
Three manuscripts, extracted from 3 Ph.D. Thesis, in various stages of editing and preparation, are attached. All three are significant in their respective areas of wake studies

15. ACCOMPLISHMENTS:
we studied nonlinear mode interactions in wake flows, with applications to mean flow and coherent mode control and modification in the following important problem areas:
    1.) developed simple integral energy method, leading to amplitude equations for

nonlinearly interacting coherent modes, coupled to mean wake flow properties (ceterline velocity defect, wake width), allowing "rapid" assessment of parameter ranges for wake flow modification and control; comparison with experiments in special cases

2.) obtained secondary instabilities properties of a numerically-computed two-dimensional nonlinear primary instablity mode with comparisons with experiments

3.) obtained numerical simulation of nonlinear development of axisymmetric and helical modes in an axisymmetric mean wake flow

16. SIGNIFICANT TRANSITIONS:

17. IMPACT OF RESEARCH:

While it is difficult, if not impossible to control the small scale turbulence, we thoroughly explored possibilities of controlling wake flow properties through control of coherent structures. Properly selected coherent modes, because of their connection with the mean flow and their sensitivity to initial conditions, could be used to advantage towards modification of both mean and oscillating properties of wake flows to the extent that they mask similar properties of an unmodified wake flow.

EXTRACTED FROM 1994 BROWN UNIVERSITY, DIVISION OF ENGINEERING PH.D. THESIS OF K. LEE.

TO BE SUBMITTED FOR PUBLICATION AFTER FURTHER EDITING AS K. LEE AND J.T.C. LIU

EXTRACTED FROM 1994 BROWN UNIVERSITY, DIVISION OF ENGINEERING PH.D. THESIS OF X. YU

TO BE SUBMITTED, AFTER FURTHER EDITING, AS X. YU & J.T.C. LIU