15:49:49 OCA PAD AMENDMENT - PROJECT HEADER INFORMATION 03/05/96

Active

Project #: E-25-685   Cost share #:   Rev #: 13
Center # : 10/24-6-R7201-0A0   Center shr #:   OCA file #:
Work type : RES
Contract#: DE-FG05-91ER54122   Mod #: ADM. REVISION   Document : GRANT
Prime #:   Contract entity: GTRC

Subprojects ? : Y   CFDA: 81.049
Main project #:   PE #:

Project unit: MECH ENGR   Unit code: 02.010.126
Project director(s):
STACEY W M JR   MECH ENGR   (404)894-3714

Sponsor/division names: US DEPT OF ENERGY / DOE OAK RIDGE - TN
Sponsor/division codes: 141 / 017

Award period: 910601 to 960831 (performance) 960831 (reports)

Sponsor amount	New this change	Total to date
Contract value	0.00	522,196.00
Funded	0.00	522,196.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: SUPPORT OF U.S. ITER ACTIVITY

PROJECT ADMINISTRATION DATA

OCA contact: Jacquelyn L. Bendall 894-4820

Sponsor technical contact	Sponsor issuing office
ROBERT PRICE, ER 533 (301)903-3468	MAURICE JOHNSON (615)576-7599
U.S. DEPT. OF ENERGY OFFICE OF FUSION ENERGY MAIL STOP 256 WASHINGTON, DC 20585	U.S. DEPT. OF ENERGY OAK RIDGE OPERATIONS PROCUREMENT AND CONTRACTS DIVISION CONTRACT MANAGEMENT BRANCH BOX 2001, OAK RIDGE, TN 37830-8757

Security class (U,C,S,TS) : U   ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A   DOE supplemental sheet
Equipment title vests with: Sponsor   GIT X

Administrative comments -
ISSUED TO EXTEND PERIOD OF PERFORMANCE TO 8-31-96.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

U

NOTICE OF PROJECT CLOSEOUT

57550

Closeout Notice Date 10/25/96

Project No. E-25-685 Center No. 10/24-6-R7201-0A0

Project Director STACEY W M JR School/Lab MECH ENGR

Sponsor US DEPT OF ENERGY/DOE OAK RIDGE - TN

Contract/Grant No. DE-FG05-91ER54122 Contract Entity GTRC

Prime Contract No.

Title SUPPORT OF U.S. ITER ACTIVITY

Effective Completion Date 960831 (Performance) 960831 (Reports)

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

Comments

Subproject Under Main Project No.

Continues Project No.

Distribution 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

NOTE: Final Patent Questionnaire sent to PDPI.

E25-605

IT 4250.2
(9)
(Prior Editions Obsolete)

Department of Energy
Office of Energy Research (OER)
Face Page

OMB Control No.
1910-1400
(Public Disclosure
Statement on Back)

TITLE OF PROPOSED RESEARCH: "Support of US ITER Activity"

PLEASE TYPE THE FOLLOWING INFORMATION:

CATALOG OF FEDERAL DOMESTIC ASSISTANCE NUMBER: 81.049

CONGRESSIONAL DISTRICT:
Applicant Organ's Dist.: Fifth
Project Site's Dist.: Fifth

I.R.S. ENTITY IDENTIFICATION OR SOCIAL SECURITY NUMBER:
58-0603146

AREA OF RESEARCH OR ANNOUNCEMENT TITLE/NUMBER
BASIC ENERGY SCIENCES

HAS THIS RESEARCH PROPOSAL BEEN SUBMITTED TO ANY OTHER FEDERAL AGENCY? ☐ yes ☒ no
PLEASE LIST

DOE/OER PROGRAM STAFF CONTACT (if known)
S. Staten

TYPE OF APPLICATION: ☐ New ☒ Continuation
☐ Supplement ☐ Renewal ☐ Revision

PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR NAME, TITLE, ADDRESS AND PHONE NUMBER

W. M. Stacey
Regents' Professor
Nuclear Engineering MC0225
Georgia Tech
Atlanta, GA 30332

404-894-3714

8. ORGANIZATION TYPE: Local Government ☐
State Government ☐ Non-Profit ☐ Hospital ☐
Indian Tribal Government ☐ Individual ☐ Other ☐
Institution of Higher Education ☒ For-Profit ☐
(Small Business ☐ Disadvantaged Business ☐ 8(a) ☐
Women-owned ☐)

9. CURRENT DOE AWARD NUMBER (IF APPLICABLE)
DE-FG05-91ER54122

10. WILL THIS RESEARCH INVOLVE:
10A. Human Subjects no ☒ If yes, ☐
Exemption No. ____ (or)
IRB Approval Date ____
Assurance of Compliance No. ____
10B. Vertebrate Animals no ☒ If yes, ☐
IACUC Approval Date ____
Animal Welfare Assurance No. ____

11. AMOUNT REQUESTED FROM DOE FOR ENTIRE PROJECT PERIOD $ 54,989

12. DURATION OF ENTIRE PROJECT PERIOD
10/1/91 (Mo/day/yr.) to 2/29/92 (Mo/day/yr.)

13. REQUESTED AWARD START DATE 10/1/91 (Mo/day/yr.)

14. IS APPLICANT DELINQUENT ON ANY FEDERAL DEBT?
☐ Yes (If "Yes," attach an explanation) ☒ No

16. ORGANIZATION'S NAME, ADDRESS AND CERTIFYING REPRESENTATIVE'S NAME, TITLE AND PHONE NUMBER

Georgia Tech Research Corp.
Centennial Research Building, Room 246
Georgia Institute of Technology
Atlanta, GA 30332-0420
R. D. Farmer/Contracting Officer
404-894-4817

SIGNATURE OF PRINCIPAL INVESTIGATOR/PROGRAM DIRECTOR 7/31/91
Date

PI/PD ASSURANCE. I agree to accept responsibility for the scientific conduct of the project and to provide the required progress reports if an award is made as a result of this submission. Willful provision of false information is a criminal offense. (U.S. Code, Title 18, Section 1001).

SIGNATURE OF ORGANIZATION'S CERTIFYING REPRESENTATIVE 8/2/91
Date

CERTIFICATION & ACCEPTANCE: I certify that the statements herein are true and complete to the best of my knowledge, and accept the obligation to comply with DOE terms and conditions if an award is made as the result of this submission. A willfully false certification is a criminal offense. (U.S. Code, Title 18, Section 1001).

NOTICE FOR HANDLING PROPOSALS
This submission is to be used only for DOE evaluation purposes and this notice shall be affixed to any reproduction or abstract thereof. All Government and non-Government personnel handling this submission shall exercise extreme care to ensure that the information contained herein is not duplicated, used, or disclosed in whole or in part for any purpose other than evaluation without written permission except that if an award is made based on this submission, the terms of the award shall control disclosure and use. This notice does not limit the Government's right to use information contained in the submission if it is obtainable from another source without restriction. This is a Government notice, and shall not itself be construed to impose any liability upon the Government or Government personnel for any disclosure or use of data contained in this submission.

PRIVACY ACT STATEMENT
If applicable, you are requested, in accordance with 5 U.S.C., Sec. 552A, to voluntarily provide your Social Security Number (SSN). However, you will not be denied any right, benefit, or privilege provided by law because of a refusal to disclose your SSN. We request your SSN to aid in accurate identification, referral and review of applications for research/training support and for efficient mana-

Proposal To the
U. S. DEPARTMENT OF ENERGY
For Renewal of Research on

"SUPPORT OF U.S. ITER ACTIVITY"
DOE GRANT DE-FG05-91ER54122

by

Nuclear Engineering and Health Physics Programs
School of Mechanical Engineering
and
Fusion Research Center
Georgia Institute of Technology
Atlanta, Georgia 30332

July 31, 1991

Principal Investigator:	Dr. W. M. Stacey
Title:	Callaway Professor
Department Affiliation:	Nuclear Engineering and Health Physics Programs School of Mechanical Engineering
Telephone:	(404) 894-3714
Proposed Start Date:	October 1, 1991
Proposed Duration:	5 Months
Funding Requirements:	$54,989

Endorsements:

W. M. Stacey, Jr.
Principal Investigator

Date: 7/31/91

W. M. Stacey, Jr., Director
Fusion Research Center

Date: 7/31/91

W. O. Winer, Director
School of Mechanical Engineering

Date: 8/1/91

SUMMARY

Grant DE-FG05--91ER54122 was awarded for a Project Period 6/1/91 - 5/31/92 and a budget period 6/1/91 - 11/30/91. The original proposed funding was $129,989. The amount $75,000 was obligated for the budget period. This proposal is for the additional $54,989 to be obligated. It is also proposed that the project period end on 2/29/92, which brings the funding period in line with the funds requested.

The proposed work scope remains unchanged, namely to continue our work in support of the U.S. ITER activity. Specifically, it is proposed to continue our transport analysis of ITER burn control scenarios with the 1-1/2D code WHIST, to study impurity seeding operating scenarios, and to contribute to the development of the proposed new systems and operational code for the ITER Engineering Design Activity (EDA). In addition, support is requested for the PI to provide services requested by DOE in support of the organization of the ITER EDA. A detailed description of these activities is provided in the original proposal.

This proposal transmits a supplemental budget required to support work through the remainder of the Project Period.

E23-683

DOE F 1332.16 (10-84)
(Formerly RA-427)

OMB Approval
No. 1910-1400

U. S. DEPARTMENT OF ENERGY

UNIVERSITY CONTRACTOR, GRANTEE, AND COOPERATIVE AGREEMENT RECOMMENDATIONS FOR ANNOUNCEMENT AND DISTRIBUTION OF DOCUMENTS

See Instructions on Reverse Side

1. DOE Report No.

2. DOE Contract No.
DE-FG05-91ER54122

3. Title
Support of U.S. ITER Activity

4. Type of Document ("x" one)
☐ a. Scientific and technical report
☐ b. Conference paper:
Title of conference ______
Date of conference ______
Exact location of conference ______
Sponsoring organization ______
☒ c. Other (Specify) "Proposal & Progress Report"

5. Recommended Announcement and Distribution ("x" one)
☒ a. Unrestricted unlimited distribution.
☐ b. Make available only within DOE and to DOE contractors and other U. S. Government agencies and their contractors.
☐ c. Other (Specify) ______

6. Reason for Recommended Restrictions

7. Patent and Copyright Information:
Does this information product disclose any new equipment, process, or material? ☒ No ☐ Yes If so, identify page nos. ______
Has an invention disclosure been submitted to DOE covering any aspect of this information product? ☒ No ☐ Yes
If so, identify the DOE (or other) disclosure number and to whom the disclosure was submitted.
Are there any patent-related objections to the release of this information product? ☒ No ☐ Yes If so, state these objections.
Does this information product contain copyrighted material? ☒ No ☐ Yes
If so, identify the page numbers ______ and attach the license or other authority for the government to reproduce.

8. Submitted by — Name and Position (Please print or type)
W. M. Stacey, Jr., Callaway Professor of Nuclear Engineering

Organization
School of Mechanical Engineering, GA Tech, Atlanta, GA 30332

Signature	Phone	Date
	404-894-3714	1/13/92

FOR DOE OR OTHER AUTHORIZED USE ONLY

9. Patent Clearance ("x" one)
☐ a. DOE patent clearance has been granted by responsible DOE patent group.
☐ b. Report has been sent to responsible DOE patent group for clearance.

Proposal to The
U. S. DEPARTMENT OF ENERGY
For Renewal of Research on

"SUPPORT OF U.S. ITER ACTIVITY"
DOE GRANT DE-FG05-91ER54122

by

Nuclear Engineering and Health Physics Programs
School of Mechanical Engineering
and
Fusion Research Center
Georgia Institute of Technology
Atlanta, Georgia 30332

January 13, 1992

Principal Investigator:	Dr. W. M. Stacey
Title:	Callaway Professor
Department Affiliation:	Nuclear Engineering and Health Physics Programs School of Mechanical Engineering
Telephone:	(404) 894-3714
Proposed Start Date:	March 1, 1992
Proposed Duration:	3 Years
Funding Requirements:	$427,019

Endorsements:

W. M. Stacey
Principal Investigator

Date: 1/13/92

W. M. Stacey, Director
Fusion Research Center

Date: 1/13/92

W. O. Winer, Director
School of Mechanical Engineering

Date: 01/17/92

SUPPORT OF U.S. ITER ACTIVITY

ABSTRACT

It is proposed to continue our work in support of the U.S. participation in the ITER Engineering Design Activity (EDA). Our contributions will be in two task areas: In the System Studies activity we will provide support for the development and use of the *SUPERCODE,* the fast 1½-D systems and operational code for the ITER EDA. In the Confinement/Plasma Performance activity we will continue our work on burn control, including simulations using 1½-D transport codes, and the development of burn control requirements for ITER. In addition, we will continue to provide direct support to DOE in activities related to the planning and implementation of the ITER EDA.

1. PROGRESS REPORT OF WORK TO DATE

Georgia Tech has been one of the participating institutions from the beginning of the ITER Conceptual Design Activity (CDA). During the first part of the CDA, our major contribution was in the area of burn stability and control of ITER. We developed methodologies and computational tools to evaluate a large number of potential methods for the control of the thermonuclear burn conditions in ITER near thermally unstable operational points and to determine the technological requirements on the associated ITER hardware systems [1-3]. The results of our work, along with those from the other participants in the US system and operational studies group, helped to define the recommendations for a primary and secondary control scheme for ITER [4-5].

During the current FY, while continuing our burn control studies, most of our effort within the US ITER System Studies activity has been in the development of physics modules for the *SUPERCODE.* This is a fast, time-dependent 1½-D systems and operational code for the ITER EDA [6]. Our task has been the development of fast but accurate routines for the modelling of neutral beam heating and current drive, fueling, and impurity transport. We have developed, tested and installed the modules for neutral beam deposition, heating and current drive. Work on the development of additional modules is in progress.

At the same time, we have undertaken work on the evaluation of impurity seeded operating scenarios for ITER, to alleviate the deleterious divertor conditions present at the hybrid and steady-state modes of operation [7]. For the purposes of this work, a multi charge state impurity transport routine has been implemented in the WHIST transport code, for a more consistent analysis of the effect of the injected impurities. Preliminary results appear encouraging [8], and we are currently improving our computational tools for a more accurate assessment of the viability of the concept of impurity seeding.

The PI has provided direct support to DOE in the evaluation of the ITER CDA design by serving as a participant in the US National Review and in the planning for the ITER EDA by serving as a member of the QEN multi-site Working Group and as co-chairman of the US SWG-1 Group.

2. PROPOSED WORK

2.1 System Studies Activity

Our intended workplan for our participation in the ITER System Studies activity during the fiscal year 1992, includes the continuation of the *SUPERCODE* and impurity seeding tasks. More specifically:

SUPERCODE: We will continue the development of physics modules for the code. At the present time we have completed the development and implementation of the neutral beam heating and current drive module. This module is based on a diffuse-beam model and can calculate the neutral beam (NB) deposition profile, the heating power to the plasma ions and electrons, the NB-driven current profile, the fast ion beta and the fusion power due to beam-plasma interactions. This model, while fast and simple, is remarkably accurate when compared with results from more sophisticated NB deposition codes. However, it does have its limitations since it can only model beamlines whose centerline lies on the midplane, and cannot take into account the complete MHD geometry of the plasma. It is anticipated however that it would be adequate for most of the *SUPERCODE* simulations, with the possible exception of design optimization studies depending critically on NB geometry and shape parameters. For these cases, we are planning to provide a more accurate, albeit computationally slower, multi-pencil beam model that would allow arbitrary beam orientation (including off-midplane injection) and exact treatment of the MHD geometry. It is anticipated that both models will be available in the code by incorporating fast/slow switches.

The first version of the *SUPERCODE* will be run with fixed density profiles. i.e. no transport of the densities of the various ion species will be attempted. However, the density transport option will be soon implemented, and an accurate determination of the different fueling sources will be needed. We are planning to provide such modules, for gas puffing and pellet injection fueling. Both fueling methods will be feedback-controlled, using the edge density for the gas puffing and the central density for the pellet injection as control variables.

Another important area, in which we are planning to contribute modules, is impurity transport. The first version of the *SUPERCODE* will assume impurity profiles that are proportional to the electron density profile, and impurity concentrations given by the latest ITER design guidelines [9]. However, a more accurate impurity model will be needed in order to investigate operating scenarios relying on impurity seeding or gas injection. We are already studying such operating scenarios (see the Impurity Seeding task below) using time-dependent, multi charge state, impurity transport routines. Direct implementation of such routines into the *SUPERCODE* would not be practical, since it would violate the most important requirement of the code, i.e. *speed*. We do expect however to use the experience gained from our impurity transport simulations, to come up with simpler models that would contain most of the essential physics. Such models could be based on the transport of a few important charge states, or on parametric fits that would be derived from the more accurate full impurity transport simulations, and would be valid in the parameter range of interest.

We are also planning to assist the LLNL *SUPERCODE* group in other, non-physics, computational aspects of the project.

After the first version of the *SUPERCODE* becomes available (early next year), we will actively use the code to undertake several system studies. This would include parametric studies of different configuration options, analysis of NB current-driven steady-state scenarios, burn control scenarios, impurity seeding operation, etc. depending on the needs of the System Study activity.

Impurity Seeding: We will continue our work on the evaluation of impurity seeded operating scenarios for ITER. High in our priority list, is the implementation of the edge model developed by W. Barr [10] which will take into account the ITER magnetic geometry at the SOL. Also, recycling of the seeded impurities which has been neglected in our present calculations, will be included. The issue of edge thermal stability after the impurity injection will be investigated in more detail. The results of the impurity simulations will also help us in the development of fast impurity transport modules for the *SUPERCODE* (see above).

2.2 Confinement/Plasma Performance Activity

Our main task for this activity is burn control analysis including simulations using 1½D transport codes, and the development of burn control requirements for ITER.

We have already established the capability of 1½-D transport simulations of burn control scenarios using the WHIST code [11], from our work during the ITER CDA [3]. During the current FY, we continued our burn control work, at a reduced level of effort, studying control scenarios based on spatially-resolved neutron measurements .

We are planning to continue our burn control simulations during the EDA phase of the ITER project. Particular emphasis will be placed on issues that were identified as critical at the International Workshop on ITER Burn Control (Garching, July 16-18, 1990), in which we participated. These issues include the definition of the minimum diagnostic requirements for controllability, the identification of worst case transients, and the study of the effect of perturbations introduced by sawteeth oscillations and pellet injection on the thermal stability. We will also extend our transport simulations to evaluate alternative control methods such as modulation of the fueling mix, density control and injection of impurities. Earlier 0-D simulations had indicated that these methods can be effective for the control of even true ignited operating points [2], alone or in conjunction with heating power feedback. However, profile effects are believed to be very important and should be addressed before a credible control scenario based on any of these methods is proposed.

2.3 Direct Support of DOE

The PI will continue to provide direct support to DOE/OFE, as requested, on the planning and implementation of the ITER EDA. It is anticipated that the present activities in support of preparation for SWG-1 will continue and that new activities will be identified by DOE/OFE.

REFERENCES

1. S.W. Haney, L.J. Perkins, J. Mandrekas, and W.M. Stacey, "Active Control of Thermonuclear Burn Conditions for the International Thermonuclear Experimental Reactor," *Fusion Technology* **18**, 606 (1990)

2. J. Mandrekas, W.M. Stacey, "Evaluation of Different Control Methods for the Thermal Stability of ITER," *Fusion Technology* **19**, 57 (1991)

3. J. Mandrekas, H. He, W.M Stacey, "1½-D Transport Studies of ITER Burn Control Scenarios," *Fusion Technology* **19**, 1307 (1991)

4. L. J. Perkins, S.W. Haney, J. Mandrekas, S.K. Ho, et al., "US Studies in Thermonuclear Burn Control for the International Thermonuclear Experimental Reactor (ITER)," Lawrence Livermore National Laboratory report, *to be published*, 1991

5. K. Borrass, S.Cohen, F. Engelmann,...J. Mandrekas,..."Plasma Operational Control in ITER," IAEA-CN-53/F-3-6, *presented at the 13th International Conf. on Plasma Physics and Contr. Nucl. Fusion Research*, International Atomic Energy Agency, Wash. D.C., 1990.

6. L.J. Perkins, J. Galambos, S. Haney, "The SUPERCODE: A time-dependent 1½D Systems Code for Comprehensive Design and Operational Analysis for the ITER EDA," LLNL memorandum, June 22, 1990.

7. J. Mandrekas, L.J. Perkins, W.M Stacey, "Proposed Work on ITER Impurity-Seeding Operating Scenarios," ITER memorandum, June 25, 1990

8. J. Mandrekas, H. He, W.M. Stacey, and L.J. Perkins, "Impurity-Seeded Operating Scenarios for ITER, " *Bull. Am. Phys. Soc.*, **35**, 1923 (1990)

9. N.A. Uckan, and ITER Physics Group, *ITER Physics Design Guidelines*: 1989, IAEA, Vienna, 1990

10. W. L. Barr, "A Model for the Edge Plasma near a Poloidal Divertor," *Fusion Technology* **19**, 498 (1991)

11. W.A. Houlberg, S.E. Attenberger, and L.M. Hively, "Contour Analysis of Fusion Reactor Plasma Performance," *Nucl. Fusion*, **22**, 985 (1982)

E25-685

DOE F 1430.22
(04-91)
All other editions are obsolete
(Replaces DOE F 538)

OMB Control No. 1910-1400
Burden Disclosure Statement on Back

U.S. DEPARTMENT OF ENERGY
NOTICE OF ENERGY RD&D PROJECT

1. DOE CONTRACT OR GRANT NUMBER DE-FG05-91ER54122

☐ New contract ☒ Continuation/Revision

2. A. NAME OF PERFORMING ORGANIZATION Georgia Tech Research Corporation

B. Department or Division Nuclear Engineering Program

C. Street Address 620 Cherry St.

City Atlanta State GA Zip 30332

D. Type of Performing Organization (circle only one two-letter code)

CU–College, university, or trade school
EG–Electric or gas utility
FF–Federally funded RD&D centers or laboratory operated for agency of US government
IN–Private industry
NP–Foundation or laboratory not operated for profit
ST–Regional, state, or local government facility
TA–Trade or professional organization
US–Federal Agency
XX–Other

3. PRINCIPAL OR SENIOR INVESTIGATOR

A. Last Stacey First Weston MI M.

B. Phone: Commercial 404-894-3714 FTS

4. DOE SPONSORING OFFICE OR DIVISION Dept. of Energy - Office of Fusion Energy

5. TITLE OF PROJECT

Support of U.S. ITER Activity

6. DESCRIPTIVE SUMMARY (limit to 200 words)

It is proposed to continue our work in support of the US participation in the ITER Engineering Design Activity (EDA) as part of the U.S. Home Team Design Activity, including associate JCT member support. Our contribution will be in two task areas. In the System Studies activity we will continue our participation in the development and use of the SUPERCODE, the fast 1-1/2-D systems and operational code for the ITER EDA. In the Confinement and Plasma Performance task area, we will coninue our work in the modeling and analysis of radiative edge operating scenarios for ITER with impurity seeding. In addition, we will continue our work on burn control and the development of burn control requirements for ITER.

7. RESPONDENT INFORMATION. List name and address of person filling out this form. Give telephone number and extension where person can be reached. Record the date this form was completed or updated. This information will not be published.

Last Stacey First Weston MI M.

Address Fusion Research Center, GA. Institute of Technology, ESM Bldg., Room 110A

City Atlanta State GA Zip 30332

Phone 404-894-3714 Date 8/27/92

INSTRUCTIONS
NOTICE OF ENERGY RD&D PROJECT

Notice

If in the past six months you have completed a Statement of Work (SOW) or brief project description for DOE, complete only the additional data elements on this form and send it and a copy of the completed SOW or description to U.S. Department of Energy, Office of Scientific and Technical Information, Post Office Box 62, Oak Ridge, TN 37831.

1. CONTRACT OR GRANT NUMBER

   The DOE contract or GRANT number under which the work is being performed. Check correct block for new contract or revision/continuation of prior contract.

2. A. NAME OF PERFORMING ORGANIZATION

   Provide company or institution name of the organization doing the work.

   B. DEPARTMENT OR DIVISION

   List the department or division of the performing organization.

   C. MAILING ADDRESS

   Provide the complete mailing address.

   D. TYPE OF PERFORMING ORGANIZATION (circle only one two-letter code)

   CU EG FF IN NP ST TA US XX

3. PRINCIPAL OR SENIOR INVESTIGATOR

   A. Name of person chiefly responsible for the performance of the project.

   B. Give telephone number, including area code, and if you have an FTS number, please include it.

4. DOE SPONSORING OFFICE OR DIVISION

   List the DOE organization that is funding the work.

5. TITLE OF PROJECT

   Be as specific as possible. Use words that are descriptive of the work done.

6. DESCRIPTIVE SUMMARY

   Include objectives, approach, and expected results. Quantify where possible.

7. RESPONDENT INFORMATION

   List name and address of person filling out this form. Give telephone number and extension where person can be reached. Record the date this form was completed or updated. This information will not be published.

OMB Disclosure Statement

Public reporting burden for this collection of information is estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Office of Information Resources Management Policy, Plans, and Oversight, AD-241.2 - GTN, Paperwork Reduction Project, (1910-1400), U. S. Department of Energy, 1000 Independence Avenue, S.W., Washington, DC 20585; and to the Office of Management and Budget (OMB), Paperwork Reduction Project, (1910-1400),

Proposal To the
U. S. DEPARTMENT OF ENERGY
For Renewal of Research on

"SUPPORT OF U.S. ITER ACTIVITY"
DOE GRANT DE-FG05-91ER54122

by

Fusion Research Center
Georgia Institute of Technology
Atlanta, Georgia 30332

August 27, 1992

Principal Investigator:	Dr. W. M. Stacey
Title:	Callaway Professor
Department Affiliation:	Nuclear Engineering Program School of Mechanical Engineering
Telephone:	(404) 894-3714
Proposed Start Date:	January 1, 1993
Proposed Duration:	1 Year
Funding Requirements:	$127,207

Endorsements:

W. M. Stacey, Jr.
Principal Investigator

Date: 8-25-92

W. M. Stacey, Jr., Director
Fusion Research Center

Date: 8-25-92

SUPPORT OF U.S. ITER ACTIVITY

ABSTRACT

It is proposed to continue our work in support of the U.S. participation in the ITER Engineering Design Activity (EDA) as part of the U.S. Home Team Design Activity, including associate JCT member support. Our contributions will be in two task areas. In the System Studies activity we will continue our participation in the development and use of the SUPERCODE, the fast 1½-D systems and operational code for the ITER EDA. In the Confinement and Plasma Performance task area, we will continue our work in the modeling and analysis of radiative edge operating scenarios for ITER with impurity seeding. In addition, we will continue our work on burn control and the development of burn control requirements for ITER.

1. SYSTEM STUDIES TASK AREA

1.1 SUPERCODE Development

<u>Progress Report of Work To Date:</u>

We have been participating in the development of the SUPERCODE, the new fast 1½-D systems and operational code for the ITER EDA [1], since its inception in 1990. We have provided models and routines for the self-consistent, profile-dependent evaluation of neutral beam deposition, heating and current drive [2], the implementation of theory-based transport models including the Rebut Critical Electron Temperature Gradient model, the calculation of the bootstrap current, and the accurate calculation of the peak neutron wall load (modules *Beams, Boots, NDWallLoad*, and routines *rebutChiElec, rebutChiIon, neoclassicalChi*, and *nocentiniChi* of the *VarTr* module). These routines greatly enhance the capabilities of the SUPERCODE and extend its usefulness as a modern systems analysis tool for the design of ITER and other future tokamak reactors.

At the same time, we have provided benchmarks with the transport code WHIST, and have used the SUPERCODE for the study of possible operating scenarios for ITER.

<u>Proposed Work:</u>

The SUPERCODE is already operational and is being used for the analysis of ITER EDA operating scenarios. During the course of the EDA, it is expected that the code will be extensively used by the members of the Joint Central Team. At the same time, the code will be continuously maintained and upgraded. We intend to continue our contributions to the development of the SUPERCODE during the fiscal year 1993. For this, one of us (JM) could become an associate member of the JCT for a closer cooperation between developers and users of the code. Specifically, regarding the upgrading of the physics models of the code, we will provide modules for:

- <u>ICRF heating and current drive:</u> Most accurate calculations for fast wave heating and current drive are performed using time-consuming numerical codes based on ray tracing or full wave techniques. Such methods cannot be implemented in the SUPERCODE, whose primary requirement is computational speed. Instead, a routine based on M. Brambilla's recent work [5] will be developed, that is based on analytic estimates of the wave behavior near resonances, and on simplifications of the real geometry. The routine will be benchmarked extensively against full wave calculations performed by D. Batchelor's group at ORNL.

- ODE solvers for time-dependent capabilities: The current version of the SUPERCODE can run only in steady-state mode. While this is sufficient for the majority of system and optimization runs, some important phenomena such as burn control scenarios and start-up simulations cannot be analyzed. We intend to provide the required numerical routines that will give time-dependent capabilities to the code.
- Calculation of fueling sources: In the current version of the SUPERCODE, only the temperature profiles are transported. The density profiles remain fixed, and only the average density and the edge-to-average density ratio can change. Although the code has the capability to transport the densities of the different species built-in, to activate it requires routines for the calculation of the relevant fueling sources. We will develop and implement such routines based on fast but accurate models, for both pellets and gas puffing fueling.
- Impurity radiation routines: Currently, impurity radiation is included in the SUPERCODE using the simple fits that were developed during the ITER CDA [6]. However, a more accurate impurity model will be needed in order to investigate operating scenarios relying on impurity seeding or gas injection. We are already studying such radiative edge operating scenarios (see the Impurity Seeding task below) using a time-dependent 1½-D transport code, coupled with multi charge state impurity transport routines. While direct implementation of such routines into the SUPERCODE would not be practical, we do expect to use the experience gained from our impurity transport simulations to come up with simpler models that would contain most of the essential physics. Such models could be based on the transport of a few important charge states, or on parametric fits that would be derived from the more accurate full impurity transport simulations, and would be valid in the parameter range of interest.

In addition we will provide benchmarks with the transport code WHIST, and will assist the LLNL SUPERCODE group with other, non-physics, computational aspects of the project as needed.

2. POWER & PARTICLE CONTROL

2.1 Modeling of Radiative Edge / Impurity Seeding

Progress Report of Work To Date:

During the last two years, we have been involved in the evaluation of ITER operating scenarios with impurity seeding [7-9]. Such scenarios have been proposed as a way to alleviate the divertor heat load through increased radiation levels from the plasma edge and divertor regions. Recent experimental results [10] have also demonstrated that plasma conditions in which a large part of the power is exhausted by radiation can be obtained and maintained without serious contamination of the core plasma.

For the purposes of this work, a multi charge state impurity transport routine has been developed and implemented in the WHIST 1½-D transport code, providing us with an advanced computational capability. Unlike previous studies that analyzed the effect of impurity seeding by assuming a background plasma with constant properties, our treatment allows for a more self-consistent analysis of the effect of enhanced edge radiation on the power balance of the core and edge plasmas.

Our results have indicated that impurity seeding is a promising method to alleviate the deleterious divertor conditions, specially for the hybrid and steady-state modes of operation of ITER.

Proposed Work:

We propose to continue our modeling and analysis of radiative edge operating scenarios for ITER with impurity seeding, building upon our substantial computational capability in this area. Our first task during the new year would be to implement a simple but comprehensive divertor model for a better estimation of the peak divertor heat load. The model will be based on the well-known two-point divertor models [11-12], but with extensions for an accurate estimate of the radiative power levels from impurities in the SOL and divertor chamber and with inclusion of effects due to neutrals. This divertor model would be coupled, as a boundary condition, to our 1½-D transport calculational model. A Ph.D. student of our group is doing his thesis on this subject. The second task that we will undertake is an analysis of the effectiveness of impurity seeding in the plasma edge in reducing the divertor heat load in ITER, in both the driven and ignited modes of operation, thereby exploiting our (possibly unique) computational capability. We will also examine the sensitivity of our calculations to the transport models for the impurities and the main plasma species. In addition, the important issue of edge thermal stability during impurity seeding will be investigated in detail.

3. CONFINEMENT AND PLASMA PERFORMANCE TASK AREA

3.1 Burn Control Analysis

Progress Report of Work To Date:

During the current year we have been doing mostly maintenance work, upgrading our computational tools for the burn control activity. In particular, we have been upgrading the MHD equilibrium routines of the WHIST 1½-D transport code (the older routines had problems finding MHD equilibria for a large number of possible operating points of the CDA and HARD ITER designs) and installed new theory-based transport models.

Proposed Work:

For the new year we are planning to carry out simulations of burn control scenarios for the ITER EDA design, using WHIST and the recently developed fast 1½-D systems and operational code for the ITER EDA, the SUPERCODE. The use of a systems code will make it possible to include in our analysis in a self-consistent way the effect of thermal instabilities on the different parts of the reactor, as well as to assess the constraints and evaluate the requirements that these parts may impose on the controller. The advanced physics models of the SUPERCODE will ensure that no compromises are made in the evaluation of the physics-related parts of the calculations. Emphasis will be placed on a number of critical issues, including the definition of the minimum diagnostic requirements for controllability, the identification of worst case transients, and the study of the effect of perturbations introduced by sawteeth oscillations and pellet injection on the thermal stability of ITER designs. Possible new methods of burn control, based on control of the edge conditions and hence of the confinement properties, will be studied.

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