



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

JAN 30 2002

Purdue Research Foundation
ATTN: Thomas Wright
1063 Hovde Hall, Purdue University
West Lafayette, IN 47907-1063

Dear Mr. Wright:

SUBJECT: TASK ORDER NO. 14 ENTITLED "TWO PHASE CFD ENHANCEMENTS FOR
NPHASE CODE" UNDER CONTRACT NO. NRC-04-97-046

In accordance with Section G.4, Task Order Procedures, of the subject contract, this letter definitizes Task Order No. 14. This effort shall be performed in accordance with the enclosed Statement of Work. The period of performance for Task Order No. 17 is February 1, 2002 through November 30, 2002. The total estimated cost for full performance of the basic task order is \$100,000. Funds in the amount of \$100,000 are hereby obligated for performance of this task order.

Accounting data for Task Order No. 14 is as follows:

B&R No.: 260-15-11-020-5
Job Code: Y-6749
BOC Code: 252A
RES ID: RES-C02-342
Appropriation No.: 31X0200
Obligated Amount This Action: \$100,000

The following individuals are considered by the Government to be essential to the successful performance of the work hereunder:



RECEIVED
DISTRIBUTION OF INFORMATION

The contractor agrees that such personnel shall not be removed from the effort under this task order without compliance with Contract Clause H.1.1. Personnel

RECEIVED

TEMPLATE-ADM001

ADM02

Purdue

Contract No. NRC-04-97-046

Task Order No. 14

Page 2 of 2

The issuance of this task order does not amend any terms or conditions of the subject contract.

Your contacts during the course of this task order are:

Technical Matters: James Han, Project Officer
(301) 415-6773

Contractual Matters: Stephen Pool, Contract Specialist
(301) 415-8168

Please indicate your acceptance of this task order by having an official, authorized to bind your organization, execute three copies of this document in the space provided and return two copies to the Contract Specialist. You should retain the third copy for your records.

Sincerely,


Stephen M. Pool, Contracting Officer
Division of Contracts and Property
Management

Enclosure:
As stated

ACCEPTED: TASK ORDER NO. 14


NAME

FEB 6 2002
DATE

Eric E. Fulkerson
Sr. Contract Manager

TITLE

Statement of Work for Task Order #14, "Two-Phase CFD Enhancements for NPHASE Code," under Contract #NRC-04-97-046, "Thermal-Hydraulic Research"

I. Background

The NRC uses computer models to study the flow phenomena associated with reactor safety issues. Generally, one-dimensional flow models are used to study the entire reactor coolant system under a wide variety of flow conditions including multi-phase thermal-hydraulics. These models are applied in system codes such as TRAC-P and RELAP5. These codes, however, are limited in their ability to predict multi-dimensional flow phenomena and rely on correlations based upon data from limited experiments. Computational fluid dynamics (CFD) is a technique suitable for multi-dimensional analysis but is not considered a mature technology for use in multi-phase flows associated with reactor system accidents. CFD is used primarily to predict multi-dimensional single phase flow phenomena over limited regions of the reactor coolant system. Multi-phase CFD techniques suffer from convergence issues and a lack of physical models. Validation of these techniques is also needed.

II. Objective

The objective of this work is to develop a multi-dimensional multi-phase CFD tool for use in reactor safety analysis. The work will proceed on the NPHASE CFD code which has already demonstrated the potential for this type of analysis in previous work. The NPHASE code will be improved in the areas of robustness and ease of use and will be delivered to the NRC with documentation for NRC's use.

III. Work Requirements ^{2/21}
(4/16/02 - 11/30/02)

There are three tasks. Task 1 focuses on numerical improvements; the goal is to improve the robustness and speed of the code with fundamental numerical enhancements. Task 2 develops a more streamlined interface to make the code easier to use for persons not directly involved with the code development. Task 3 provides documentation and bundles the code for NRC's use.

Task 1. Numerical Improvements

It has been demonstrated that several numerical elements of the NPHASE code give rise to quantifiably improved robustness, convergence rates, and accuracy compared to schemes which appear in the literature and those currently employed in the commercial CFD codes. The purpose of this task is to advance the promising baseline capabilities of NPHASE and converts this code into a mature multi-phase CFD simulator. The task consists of five subtasks.

Subtask 1.1. Coupled Phasic Exchange Algorithm

This subtask shall: (1) implement the pressure-velocity-volume fraction correction scheme element of CPE into the NPHASE code, (2) test and verify its improved accuracy and robustness, and (3) document the results.

Subtask 1.2. Staggered Force and Mass Transfer Implementation

This subtask shall: (1) reformulate all non-dispersive NPHASE interfacial force discretizations to be staggered, (2) demonstrate improved accuracy and convergence for "simple" multi-dimensional flow, and (3) document the results.

Subtask 1.3. Well-Posed Two-Fluid Compressible Formulation

This subtask shall: (1) select and install well-posed two-fluid system (probably EPRI system), (2) test the well-posed system against classical Q1D test case, (3) verify robustness for a multi-dimensional, adiabatic two-phase transient, and (4) document the results.

Subtask 1.4. Flux Limiting for High-Order Volume Fraction Convection Discretization

This subtask shall investigate alternative flux limiters for volume fraction and document the results.

Subtask 1.5. Evaluate and Implement Advanced Artificial Dissipation Methods

This subtask shall: (1) investigate alternatives to Rhie-Chow continuity dissipation, (2) investigate alternatives to 2nd-order full upwinding for scalar dissipation, and (3) document the results.

Estimated Level of Effort: 4 staff-months
Estimated Completion Date: November 30, 2002

Task 2. User Interface Advancement

Currently, NPHASE is executed using a series of command line execution statements and manual UNIX file manipulation procedures. This process is cumbersome, especially for parallel jobs which require significantly more pre-processing. The problem setup process can be significantly automated for NRC's use with a modest amount of user interface development effort.

This task shall construct automated scripts and GUI drivers to facilitate model import, domain decomposition, boundary condition specification, input file setup, code execution and output file reassembly. The results shall be documented.

Estimated Level of Effort: 1 staff-month
Estimated Completion Date: November 30, 2002

Task 3. Documentation and Software Bundling and Delivery

This task shall document all the work performed and prepare a completion letter report. In addition, NPHASE and all attendant front and backend routines shall be bundled for convenient execution on NRC LINUX clusters.

Estimated Level of Effort: 1 staff-month
Estimated Completion Date: November 30, 2002

IV. Monthly Progress Report

In addition to the deliverables listed for each task, the contractor shall provide a monthly technical progress report by the 20th of the following month. The report summarizes activities of the month under this Task Order, which include the work performed during the period, milestone status, and anticipated and encountered problem areas.

V. Meetings and Travel

There will be two one-day meetings at the NRC headquarters in Rockville, Maryland. Each meeting will be attended by one or two persons from this Task Order.