NRC FORM 189 (3-81)

U.S. NUCLEAR REGULATORY COMMISSION

PROJECT AND BUDGET PROPOSAL FOR NRC WORK

DATE OF PROPOSAL: July 1983

☐ NEW

☒ REVISION NO. 1

PROJECT TITLE
Development of Improved Physical Process Computer Codes for Risk Assessment (MELCOR)

FIN NUMBER
A1339

NRC OFFICE
Office of Nuclear Regulatory Research

NRC B&R NUMBER
601951

DOE CONTRACTOR
Sandia National Laboratories

CONTRACTOR ACCOUNT NUMBER
DE-AC04-76DP00789

SITE
Albuquerque, New Mexico

DOE B&R NUMBER
401001060

COGNIZANT PERSONNEL	ORGANIZATION	FTS PHONE NUMBER	PERIOD OF PERFORMANCE
NRC PROJECT MANAGER M. Cunningham	RES	443-7981	STARTING DATE March 1982
OTHER NRC TECHNICAL STAFF J. Martin	RES	443-7960	COMPLETION DATE March 1986
DOE PROJECT MANAGER R. N. Holton	DOE/ALO	846-5208	
CONTRACTOR—PROJECT MANAGER A.W. Snyder D. J. McCloskey	6400 6410	844-3092 844-8870	
PRINCIPAL INVESTIGATOR(S) D. C. Aldrich D. J. Alpert J. L. Sprung G. G. Weigand	6415 6415 6415 6444	844-9164 844-6982 844-0134 844-5544	

STAFF YEARS OF EFFORT (Round to nearest tenth of a year)	FY 84	FY 85	FY 86	FY	FY
Direct Scientific/Technical	13.0	9.0	7.0		
Other Direct (Graded)	0	0	0		
TOTAL DIRECT STAFF YEARS	13.0	10.0	7.0		
COST PROPOSAL					
Direct Salaries	1510	1120	920		
Material and Services (Excluding ADP)	27	24	7		
ADP Support	313	250	171		
Subcontracts	500	366	272		
Travel Expenses — Foreign					
Travel Expenses — Domestic	50	40	30		
Indirect Labor Costs	0	0	0		
Other (Specify)	0	0	0		
General and Administrative (%)	0	0	0		
TOTAL OPERATING COST	2400	1800	1400		
CAPITAL EQUIPMENT FIN CHARGED:	0	0	0		
#Includes $500K of carry-over from FY83 TOTAL PROJECT COST	2400#	1800	1400		

FY 84 — MONTHLY FORECAST EXPENSE

OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
200	200	200	200	200	200
APRIL	**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**
200	200	200	200	200	200

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PROJECT TITLE: Development of Improved Physical Process Computer Codes for Risk Assessment (MELCOR)

DOE PROPOSING ORGANIZATION: Sandia National Laboratories

FORECAST MILESTONE CHART: Scheduled to Start – △ – ▲ – Completed (Shown in Quarter Year)
PROVIDE ESTIMATED DOLLAR COST FOR EACH TASK FOR EACH FISCAL YEAR

TASK		FY 84 1st	FY 84 2nd	FY 84 3rd	FY 84 4th	FY 85 1st	FY 85 2nd	FY 85 3rd	FY 85 4th	FY 86 1st	FY 86 2nd	FY 86 3rd	FY 86 4th	FY 1st	FY 2nd	FY 3rd	FY 4th	FY 1st	FY 2nd	FY 3rd	FY 4th
MELCOR 1.0 - Model Development, Numerical Implementation, Verification	SCHEDULE	△			▲																
	COST	350																			
MELCOR 1.0 - Code Integration, Verification	SCHEDULE	△					▲														
	COST	650				150															
MELCOR 1.0 - Model/Code Sensitivity/Uncertainty Studies	SCHEDULE	△							▲												
	COST	250				300															
MELCOR 1.0-Documentation (reports, manuals, sample problems)	SCHEDULE	△							▲												
	COST	350				100															
MELCOR 1.0 - Applications Studies	SCHEDULE					△				▲											
	COST					250															
MELCOR 2.0 - Model Development	SCHEDULE	△							▲												
	COST	350				100															
MELCOR 2.0 - Code Development	SCHEDULE		△							▲											
	COST	300				600															
MELCOR 2.0 - Sensitivity/Uncertainty Studies	SCHEDULE		△								▲										
	COST	150				100				150											
MELCOR 2.0 - Documentation	SCHEDULE					△						▲									
	COST					200				300											
MELCOR 2.0 - Applications	SCHEDULE									△			▲								
	COST									950											
TOTAL ESTIMATED PROJECT COST		2400*				1800				1400											

10. CONFLICT OF INTEREST INFORMATION
SEE NRC MANUAL CHAPTER 1102 FOR ADDITIONAL INFORMATION)

APPROVAL AUTHORITY-SIGNATURE

6415 6410 6400 6000

*Includes $500K carry-over from FY83

Development of Improved Physical Process Computer Codes for Risk Assessment (MELCOR) Fin No. A1339

1. OBJECTIVE OF PROPOSED WORK:

The MELCOR program has both short and longer term objectives:

Short Term: Modify the MARCH and MATADOR risk assessment codes to provide appropriate treatments for a limited set of significant deficiencies identified by peer review.

Longer Term: Develop a new, integrated set of risk codes, the MELCOR system of codes, to replace MARCH, MATADOR, and CRAC. The MELCOR codes should (1) appropriately model all phenomena essential to the description of severe LWR accidents, (2) provide "best estimate" consequence predictions for severe accidents, (3) permit meaningful estimates of the uncertainties associated with those consequence predictions to be made, and (4) be amenable to the incorporation of improved phenomenological models.

To achieve its longer term objective the, MELCOR code system should provide the following capabilities:

Physical Processes: The MELCOR code system will model the essential features of (1) core degradation (fuel overheating, melting, and slumping), (2) reactor coolant system thermal hydraulic behavior during degraded-core accidents, (3) melt entry into the lower plenum, including boiloff of water, attack on the pressure vessel, and the vessel failure modes, (4) molten fuel/coolant interactions in the pressure vessel and the reactor cavity, including debris bed coolability and steam explosions, (5) core-concrete interactions, (6) production and burning of combustible gases, and (7) pressure-temperature response within the containment.

Fission Product Behavior: The MELCOR code system will model the essential features of (1) fission product release from over-heated or molten fuel including chemical forms of important radioisotopes and aerosol production (mass and initial size distribution), (2) production of non-radioactive aerosols from structural materials and core-concrete interactions, (3) transport and deposition, including vapor deposition, gas-to-particle conversion, and aerosol agglomeration of materials within the reactor coolant system for various flow regimes, (4) transport and deposition of materials inside the containment, including effects on safety system operation, and aerosol agglomeration, and (5) source terms for ex-plant consequence analyses as perturbed by deposition during transport through the failed containment.

Ex-Plant Consequences: The MELCOR code system will model the essential features of (1) downwind transport, dispersion, and deposition of radioactive materials released from the failed containment, including the effects of topography and variable meteorology, (2) population dose due to expo- sure to the radioactive plume, to radionuclides deposited on the ground and to inhaled or ingested radionuclides (food and drinking water pathways), (3) population location as perturbed by emergency response (sheltering, evacuation, and relocation), (4) radiological health effects (early, late, and genetic) for significant organs, and (5) economic costs due to health effects, property damage, and damage to the reactor.

Coding and Code Structure: The MELCOR code system will (1) be structured, modular, portable, and thoroughly documented, (2) have executive control and data management modules (3) have discrete phenomena or groups of phenomena coded in separate modules which are therefore easily amenable to modification or replacement, (4) have variables easily accessible for uncertainty and sensitivity analyses, and (5) have calculational times and costs acceptable for PRA calculations.

Uncertainty/Sensitivity Analyses: In order to determine the uncertainties associated with calculational results obtained using the MELCOR code system, and the sensitivity of each result to the input data and phenomenological models used in that system of codes, a set of statistical methods and data appropriate for the performance of sensitivity and uncertainty analyses with the MELCOR codes will be developed as a part of this program.

2. SUMMARY OF PRIOR EFFORTS:

FY83 Results: Modifications of MARCH and MATADOR (Program Plan Tasks 1.1 thru 1.4) were completed. Coding protocols, a code architecture, and a data management system for MELCOR were developed (Program Plan Task 2.2.1). Sensitivity and Uncertainty analysis methods suitable for use with MELCOR were identified and compared (program Plan Task 2.2.2). Thermal-hydraulic, fission product, and off-site consequences phenomena that are essential to the modeling of severe LWR accidents were identified and reviewed, and an appropriate representation for each essential phenomenon was recommended for implementation in MELCOR (Program Plan Tasks 2.2.3 and 2.2.4).

3. WORK TO BE PERFORMED AND EXPECTED RESULTS:

Task Descriptions

Task 2.0 MELCOR

Task 2.2 MELCOR 1.0 (Completion Date: September 1984)

2.2.5 Model Development: for some phenomena identified as significant by the phenomena assessments performed during FY83, the models recommended for use in MELCOR version 1.0 need to be modified. In this task model simplifications which will enhance execution speed and alterations required to ensure compatibility between recommended models will be made. Major modifications to recommended models or development of new models will be deferred to Task 2.4.1, Model Development for MELCOR 2.0.

2.2.6 Model Implementation: appropriate numerical solution methods for each model (or groups of models) will be identified, and each model (or group of models) will be coded following the protocols established during Task 2.2.1, Code Architecture, which was completed during FY83.

2.2.7 Model Verification: model algorithms, numerical implementations, and coding will be verified. Wherever possible, model performance will be verified by performance of test calculations and by comparison of results to experimental data or to results obtained by other codes.

2.2.7a Peer Review: the results of Tasks 2.2.5 thru 2.2.7 will be presented for review to an expert panel composed of NRC staff and consultants.

2.2.8 Model Sensitivity/Uncertainty Calculations: using techniques shown to be appropriate during Task 2.2.2, Sensitivity/Uncertainty Analysis Methods, which was completed during FY83, sensitivity and uncertainty analyses will be performed on all models coded in Task 2.2.6, using input parameter uncertainty estimates developed by this task.

2.2.9 Model Integration: the subroutines (executive control, data management, and phenomenological modules) individually coded and verified during Tasks 2.2.6 and 2.2.7 above, will be integrated into the overall code architecture previously developed during Task 2.2.1, which was completed during FY83.

2.2.9a Peer Review: MELCOR 1.0 will be presented for preliminary review to an expert panel composed of NRC staff and consultants.

2.2.10 Code Verification: subroutine interfaces, data flow, executive control logic, and related coding will be verified. Wherever possible, code predictions will be compared to experimental data (if such global data is available) or to the predictions of other risk codes (the RSS codes, KESS).

2.2.11 Code Sensitivity/Uncertainty Calculations: using techniques previously selected during Task 2.2.2, Sensitivity/Uncertainty Analysis Methods, which was completed during FY83, full sensitivity and uncertainty analyses will be performed on Version 1.0 of MELCOR.

2.2.12 Documentation: the results of Tasks 2.2.1 thru 2.2.11 will be documented. Documentation will include phenomena assessment reports covering thermal-hydraulic processes, fission product behavior, envivironmental pathways, health effects models, and economic effects models; and model description and user's manuals for MELCOR 1.0. The user's manual will include sample problems.

2.2.12a Peer Review: MELCOR 1.0 and all associated documentation will be presented for review to an expert panel composed of NRC staff and consultants.

Task 2.3 MELCOR 1.0 Applications: in support of FSRAP and SARRP, MELCOR will be used to analyze representative sets of severe LWR accident sequences (this task may be funded separatefly from MELCOR).

2.3a Peer Review: the results of application calculations will be presented for review to an expert panel composed of NRC staff and consultants.

Task 2.4 MELCOR 2.0 (Estimated Completion Data: September 1985): the following nine tasks (Tasks 2.4.1 thru 2.4.8 and Task 2.5) essentially repeat Tasks 2.2.5 thru 2.2.12 and Task 2.3, using MELCOR 1.0 as a starting point. Therefore, task descriptions are ommitted.

2.4.1 Model Development (see Task 2.2.5): major model modifications and development of new models will be performed during this task.

2.4.2 Model Implementation (numerics, coding, see Task 2.2.6)

2.4.3 Model Verification (test calculations, QA, see Task 2.2.7)

2.4.4 Model Sensitivity/Uncertainty Calculations (see Task 2.2.8)

2.4.5 Model Integration (see Task 2.2.9)

2.4.5a Peer Review (see Task 2.2.9a)

2.4.6 Code Verification (see Task 2.2.10)

2.4.7 Code Sensitivity/Uncertainty Calculations (see Task 2.2.11)

2.4.8 Documentation (see Task 2.2.12)

2.4.8a Peer Review (see Task 2.2-12a)

Task 2.5 MELCOR 2.0 Applications (see Task 2.3)

The phasing of the above tasks is depicted in the milestone chart presented in Figure 1.

4. DESCRIPTION OF ANY FOLLOW-ON EFFORTS:

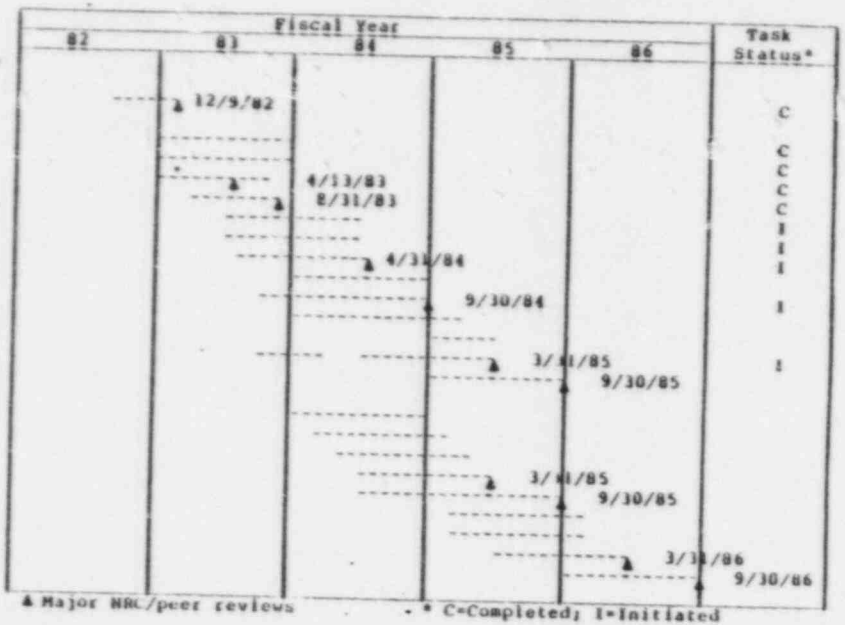
Tasks 2.2.5 through 2.2.9 (see task descriptions above) will begin in FY83 but will not be completed until FY84. Tasks 2.2.10 through 2.4.5 will begin during FY84. Tasks 2.4.6 through 2.5 will begin during FY85.

Development of Improved Physical Process Computer Codes for Risk Assessment (MELCOR)

Fin No. A1119

Milestone Chart

			Task Status*
2.0	MELCOR		
2.1	Program Plan		
2.2	MELCOR 1.0		
	2.2.1	Code Architecture (structure, data management)	C
	2.2.2	Sensitivity/Uncertainty Methods Data	C
	2.2.3	Phenomenon Assessments	C
	2.2.4	Phenomenon Sensitivity Calculations	C
	2.2.5	Model Development (mathematical representations)	C
	2.2.6	Model Implementation (numerics, coding)	I
	2.2.7	Model Verification (test calculations, QA)	I
	2.2.8	Model Sensitivity/Uncertainty Calculations	I
	2.2.9	Model Integration	I
	2.2.10	Code Verification (test calculations, QA)	I
	2.2.11	Code Sensitivity/Uncertainty Calculations	
	2.2.12	Documentation (reports, manuals, sample problems)	
2.3	MELCOR	1.0 Applications	I
2.4	MELCOR	2.0	
	2.4.1	Model Development (mathematical representation)	
	2.4.2	Model Implementation (numerics, coding)	
	2.4.3	Model Verification (test calculations, QA)	
	2.4.4	Model Sensitivity/Uncertainty Calculations	
	2.4.5	Model Integration	
	2.4.6	Code Verification (test calculations, QA)	
	2.4.7	Code Sensitivity/Uncertainty Calculations	
	2.4.8	Documentation (reports, manuals, sample problems)	
2.5	MELCOR	2.0 Applications	



▲ Major NRC/peer reviews

* C=Completed; I=Initiated

5. RELATIONSHIP TO OTHER PROJECTS:

The following programs are developing information that is pertinent to the development of the MELCOR codes:

Programs at Sandia National Laboratories	Fin No.
Identification of Dominant Severe Accident Sequences	
Accident Sequence Evaluation Program (ASEP)	A1228
Integrated Reliability Evaluation Program (IREP)	A1241
Zion/Indian Point Risk Assessment Evaluation	A1125
Severe Accident Sequence Analysis (SASA)	A1258
Station Blackout Accident Analysis	A1302
Severe Accident Risk Reduction Program (SARRP)	A1322
Full Scope Risk Assessment Program (FSRAP)	A1241
Event Sequences Contributing to the Overall Frequency of Core-Melt	A1298
Physical Processes Significant During Severe Accidents	
Melt Progression Phenomenology (MELPROG)	A1342
LWR Severe Fuel Damage and Quench Experiments	A1335
LWR Degraded Core Coolability Studies	A1340
PAHR Molten Pool Behavior	A1181
Containment Analysis	A1198
RELAP5/RALOC Assessments	A1205
Containment Integrity	A1249
Combustible Gas in Containment	A1255
Hydrogen Behavior (HECTR)	A1246
Severe Accident Sequence Analysis (SASA)	A1258
Severe Accident Risk Reduction Program (SARRP)	A1322
Molten Core/Concrete Interaction Study (CORCON)	A1019
Core Melt/Coolant Interaction (steam explosions)	A1030
In-Core Phenomenology	A1016
Hydrogen Burn Survival Analysis	A1306
Hydrogen Burn Survival Experiments	A1270
Hydrogen Mitigation	A1336
Penetration Integrity	A1375
Debris Bed Coolability	A1263
Fission Product Behavior During Severe Accidents	
Containment Analysis (CONTAIN)	A1198
High Temperature Fission Product Transport and Chemistry	A1227

Consequences of Severe Accidents

LWR Consequence Modeling	A1042
Financial Risks of Reactor Accidents	A1334
Localized Deposition from Wet Plumes	A1369

Other Programs

A number of programs (e.g., IDCOR, SCDAP, TRAP-MELT, KESS follow-on studies, Sizewell PWR inquiry) at other laboratories (both domestic and foreign) will develop information pertinent to the MELCOR program. To avoid duplication of effort, wherever possible these programs will be closely followed and their results used.

6. REPORTING SCHEDULE

Monthly program reports will be provided. Problems will be immediately reported by phone and confirmed later in writing. Technical results will be published as NUREG or SAND documents.

No more than 30 copies of any interim report will be furnished to the NRC project monitor.

W. L. Garner, Supervisor, Technical Writing Division, Sandia National Laboratories Albuquerque, has been designated as the authorizing official for publications for NRC form 426.

7. SUBCONTRACTOR INFORMATION:

Portions of the MELCOR program may be best performed under subcontracts. The following subcontracts are presently in place:

Subtask	Subcontract
Radiological Health Effects	Harvard University
Health Effects Advisory Panel	12 consulting contracts
Uncertainty Analysis	University of Arizona
Statistical Methods	Texas Technical University
BWR Modeling	Oak Ridge National Laboratory

Other subcontracts may be placed if deemed appropriate.