October 22, 1980

MEMORANDUM FOR: Robert F. Whipp, Chief
Information Security Branch
Division of Security

FROM: Gerald K. Tomlin, Chief
Safeguards Research Branch
Division of Safeguards, Fuel Cycle
and Environmental Research

SUBJECT: SECURITY REVIEW OF VOLUME I, SUMMARY REPORT, "ADVERSARY ACTIONS IN THE NUCLEAR POWER FUEL CYCLE: REFERENCE EVENTS AND THEIR CONSEQUENCES"

Please review the enclosed document entitled, "Adversary Actions in the Nuclear Power Fuel Cycle: Reference Events and Their Consequences" for security classification. I need your review as soon as you can perform it, but no later than November 7, 1980.

Thank you for your help.

Sincerely,

Gerald K. Tomlin, Chief
Safeguards Research Branch
Division of Safeguards, Fuel Cycle
and Environmental Research

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OFFICE ►	SAFER:RES DKJ				
SURNAME ►	GTomlin:jh				
DATE ►	10/22/80				

A3044

5

July 20, 1979

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, NY 11977

Dear Dr. Cusack:

This letter constitutes a report of the status of work performed under contract BNL 430602-S, Consequence Estimation, as of 15 July 1979.

At this point the program's conclusion awaits the successful implementation of the selected aerosol atmospheric transport model within the modified Consequence of Reactor Accident Code which we now call NUCRAC. This model has been chosen to satisfy the requirements that such transport analysis treat particle size distributions ranging from a few tenths of microns to hundreds of microns activity median aerodynamic diameter AMAD, that it provide for continuous depletion of the aerosol cloud and that all this be accomplished within the weather data framework of the original CRAC. As implemented, the model consists of several subroutines, which calculate various constituent parameters and a driver routine which assembles these into local air and ground concentrations and performs the averaging process required for use in the balance of the consequence assessment routines in NUCRAC. The subroutines have been thoroughly tested and perform as required. However, problems have been encountered in the driver routine which must handle up to 10 release puffs, 12 particle size groups, and 54 nuclides, distributing them over 34 intervals in 16 angular segments, according to weather characterized by 7 stability categories. I believe we are nearing an end to these difficulties. However it is clear that this will not come in time to meet the current deadline for the contract, which is the end of July. I estimate that from the time that the problems with NUCRAC are solved it will take 30 days to prepare and submit the report.

I therefore request an extension of two months in the contract period, at no cost to Brookhaven National Laboratory.

If you have any questions regarding this report, please call me at (312) 885-6800.

Sincerely,

Dean C. Kaul

DCK:jj

A3044

6

November 15, 1978

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter forwards a report of progress for work begun under BNL 374708-S (T.O. #5) and continued under BNL 430602-S, Consequence Estimation, for the period to 15 November 1978.

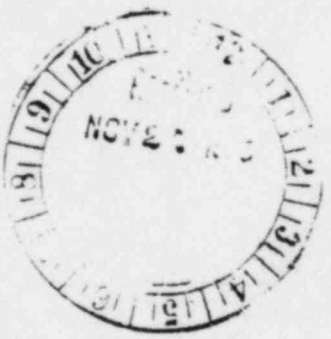
Reference event scenarios, including detailed descriptions of radionuclides released to the environment, assumptions by which they were produced, the general outline of activities required to produce each event, are currently in draft form and will be available for review in early December. In the meantime work progresses slowly on the final integration of CRAC modifications. It is hoped that this process can be completed for production of event consequence estimates before the end of December.

If you have any questions please call me at 312/885-6800.

Sincerely,

Dean C. Kaul
Principal Investigator

DCK:ko



A3044

7

16 October 1978

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter is submitted as a report of progress for work begun under BNL 374708-S (T.O. #5) and continued under BNL 430602-S, Consequence Estimation, for the period to 13 October 1978.

The computer code developed for calculation of consequences from the explosion of clandestined nuclear devices has been completed and is being used to compute such consequences for postulated events in Washington, D.C., and Chicago, Illinois.

Radionuclide release source terms have been produced for all reference events. Consequence determination for these events awaits completion of the CRAC code revision. Most particularly it awaits completion and integration of the atmospheric transport and pathways to man subroutines. Completion of these is being expedited.

If you have any questions, please call me at 312-885-6800.

Sincerely,

Dean C. Kaul
Principal Investigator

DCK:jj

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A3044

8

September 15, 1978

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter is submitted as a report of progress for work performed under BNL 430602-S, Consequence Estimation, for the two month period ending 15 September 1978.

As of this date the status of various portions of this project are as follows:

1. Nuclear Explosives. The code which is capable of assessing consequences (health effects and property damage) of the explosion of a clandestined nuclear device is complete and running (on the SAI DEC 10). Analysis of such consequences for several scenarios involving Washington, D.C., and Chicago, Illinois, are being performed.

2. Environmental Release. Source term definition for environmental release is nearly complete with only two release terms remaining to be defined. Those are: a. release from reactor facility spent fuel storage, and b. release from reactor facility gaseous waste storage.

3. Atmosphere Transport. The improved atmospheric transport model is operational on the BNL computer and is being integrated into the modified CRAC code.

4. Pathways to Man and Human Dosimetry. Transfer coefficients for the following pathways have been or are being developed:

Milk
Meat
Fresh vegetables
Wheat
Corn
Other vegetable products

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Other SAI Offices: Albuquerque, Ann Arbor, Arlington, Atlanta, Boston, Chicago, Huntsville, Los Angeles, McLean, Palo Alto, San Diego, Sunnyvale, and Tucson

CRAC is being modified to determine the total transfer to man via these pathways rather than individual consumption. The total transfer approach has the advantage of conserving dispersed activity and leading directly to the determination of total man-REM. An individual consumption routine is being retained for use with interdiction criteria. Pathways development is well behind the original schedule. However, it is hoped that the new models will be incorporated into modified CRAC by the end of September.

CRAC is being modified to expand the number of nuclides considered for ingestion and the number of particle size distributions for inhalation. Dosimetry for the former has been obtained using the INREM code. Dosimetry for the latter is being provided by Roger Blond (NRC) from unpublished portions of the Reactor Safety Study Data Base.

5. Health Effects and Property Damage. Results of this task have been incorporated into modified CRAC.

Major emphasis is being placed on completion of modified CRAC. It is hoped that the code can be completed and tested by early October. Production runs of reference event consequences will follow immediately thereafter.

If you have any questions, please call me at 312-885-6800.

Sincerely,

Dean C. Kaul
Principal Investigator

DCK:jj

9

July 18, 1978

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter forwards a report of progress for work begun under BNL 374708-S (T.O. #5) and continued under BNL 430602-S, Consequence Estimation, for the period to 15 July 1978. This report is in the form of a project status summary, providing background, project status and future plans.

If you have any questions regarding this report or any other matter, please call me at (312) 885-6812.

Sincerely yours,

Dean C. Kaul
Principal Investigator

DCK:jj

Enclosure

Science Applications, Inc. One Woodfield Place Bldg., 1701 E. Woodfield Rd., Suite 819, Schaumburg, IL 60195, 312/885-6800

PROJECT STATUS SUMMARY
BNL 430602-S, CONSEQUENCE ESTIMATION

Background

The Consequence Estimation Project was initiated in the summer of 1976. Its objective is to identify a set of reference events which could conceivably result from adversary actions in the nuclear power fuel cycle and ultimately to provide estimates of the consequences of each event in terms of health effects and property damage to a level of accuracy which is commensurate with the state-of-the-art within the various methodologies involved.

The rationale for the project is that, of the component of the risk equation,

$$\text{Risk} = \text{Frequency} \times \text{Magnitude}$$

$$\frac{\text{(Consequence)}}{\text{(Unit time)}} \quad \frac{\text{(Attempts}}{\text{(Unit Time}} \times \frac{\text{Events)}}{\text{Attempt)}} \quad \frac{\text{(Consequences)}}{\text{(Event)}}$$

the last is the least ambiguous and most amenable to quantification. Also, because of this, such risk is many times perceived by the layman in terms of magnitude alone, without regard to frequency. For these reasons it has been deemed desirable to obtain consequence estimates for each postulated event which are as accurate as a balanced use of available methodology will allow.

The Consequence Estimation Project was planned in three phases. The first, completed in 1977, was intended to identify and describe the reference events and to provide a first order approximation of their consequences in order that they might be compared on a relative basis. In all, some 21 event times were postulated in 5 categories.

1. Detonation of a nuclear device fabricated using Strategic Nuclear Material stolen from the nuclear industry.
2. Dispersal of safeguarded materials, stolen from the nuclear industry, by various means at locations other than nuclear facilities.
3. Sabotage of nuclear power reactor facility components.
4. Sabotage of irradiated fuel reprocessing and oxide conversion facility components.
5. Sabotage of mixed oxide fuel fabrication facility components.

Variations on these events increased the actual number considered to approximately 42. These events and an initial estimate of their consequences are described in the Report, "Adversary Actions In the Nuclear Power Fuel Cycle: I. Reference Events and their Consequences" SAI-121-612-7803, the latest draft of which is dated October 1977. Consequence estimates reported therein are derived from initial SAI estimates of amounts of radionuclides released to the environment for each event, with transport, deposition and health effects calculated for uniform population distributions and extremes in atmospheric conditions using the Consequences of Reactor Accidents Code (CRAC). CRAC is the embodiment of the WASH 1400 methodology. Sixteem events or event subtypes were identified as being potentially consequential, i.e., likely to result in one or more fatality. These are given in Table III-2 (encl. 1) from the phase 1 report and are listed in order of descending estimated severity.

The objective of the second phase of the report was to survey available technology over and above that available in CRAC to determine those the addition of which would yield a better, more balanced consequence estimation code for the specific events of interest. The outcome of this phase was that improvements in atmospheric transport modeling, modeling of radionuclide pathways to man, and health effect computations were identified as being necessary to produce a modified CRAC code suited to program needs.

Phase 3 of the Consequence Estimation Project commenced in the Summer of 1977 and is now nearly complete. The scope of this effort was to implement the modifications to CRAC recommended in phase 2, to develope accurate representations of environmental releases for each event specified in phase 1, and, combining the results, to produce best estimates of the consequences of each reference event.

Project Status

The current status of the various parts of this program are as follows:

1. Nuclear Explosives

   Nuclear explosives consequence estimation methodology is in two parts.

   a. initial phenomena

      A model which treats the distribution of initial nuclear explosive phenomena (blast, thermal radiation, nuclear radiation) on a two dimensional grid is in the

final stage development. This model allows the effects of these phenomena to be tabulated for health effects and property damage for an arbitrary distribution of persons and buildings. The model is specifically tailored to device yields of 100 tons to 15 kilotons, which are considered to be the lower and upper limits conceivable for clandestined nuclear devices. The models will be exercised for events in urban Chicago and Washington, D.C. for which extensive population and other asset distribution information have been collected.

b. fallout

A model which may be used to determine fallout distribution in time and space in a format which is compatible with CRAC is in the final stages of development. This routine will replace the transport portion of CRAC for the purpose of fallout consequence calculation. The balance of the consequence calculation will be performed using CRAC.

2. Environmental Release

Environmental release methodology is designed to produce the radionuclide source terms which subsequently may be treated with CRAC for consequence determination. Modeling efforts in this area are complete with the resulting methodology currently being used to produce source terms for each of the reference events. At the present time approximately half of the required source terms have been produced. Several phenomenology codes have been used in sequence to produce these source terms, a process which includes release from initial containment, transport through a facility and exit to the environment. In addition to producing the specific source terms of interest the codes will be used to produce simple parameters which will enable someone to vary those source terms to some extent, based on the needs of specific facilities.

3. Atmospheric Transport

An entirely new air transport and dry deposition calculational routine has been designed to replace that currently in CRAC. This routine has several improvements over that which it replaces. First, it specifies air and surfaced density variations in two dimensions and provides a variable spatial mesh overlay to that currently in CRAC in order to take advantage of the added detail. Second, it handles the settling and deposition processes separately, the latter being dependent on the concentration next to the ground surface. Third, it conserves mass on a continuous basis. This new routine is currently running but requires some additional development to reduce its execution time.

4. Pathways to Man and Human Dosimetry

Current CRAC indirect pathways (inhalation of resuspended material and ingestion of milk products and general foodstuffs) have been expanded to treat a larger fraction of the 54 nuclides currently available for assessing dose from direct pathways (cloud and surface exposure and cloud inhalation). Additional indirect pathways such as aquatic food chains and water supply contamination have also been added. While some of the current CRAC routines have been retained, their function has been greatly altered. Population dose from exposure through indirect pathways is now calculated on the basis of total activity transferred via a given pathway and subsequently consumed rather than multiplying a maximum individual dose by an estimated exposed population. This guarantees that the amount of activity available is conserved. The maximum individual dose calculation in CRAC has been retained for use with interdiction criteria only. When completed these routines will include dosimetry for the range of particle sizes from .2 to 10μ (MMAD) rather than just the 1μ dosimetry available in the current CRAC. Information available from the source terms and modified by the transport routine will allow selection of the proper dosimetry. The pathways and dosimetry routines are probably the farthest from completion, however SAI is confident

that they will be finished in time to allow the project to be finished within the current contract term.

5. Health Effects and Property Damage

Property damage routines in CRAC remain unchanged while specific changes have been made to the routines for assessing health effects. Of these changes the most important is the incorporation of a radionuclide inventory-dependent criterion for assessing the incidence of fatalities from the early lung death syndrome. Also some ambiguities involved in accounting for population age distribution at and subsequent to the time of exposure have been removed. These changes have been implemented and were used in the production of consequence data in support of the phase 1 report.

An Interim Product

The methodology described above has been used in an interim state (less the new atmosperic transport and parts of the new pathways and dosimetry routines) to produce an assessment of the consequences of sabotage of a generic spent fuel storage facility ~~(ONWI-2)~~. This is in support of the safeguards portion of the EIS for such a facility. Preliminary results contained therein indicate that sabotage within the storage pool itself resultsin vanishingly small health effect consequences, while events which occur in the air outside the pool may result in considerable latent effects, the exact number of which are dependent on the season of the year in which the event occurs. Consequences of this event will be recalculated upon completion of the methodology development portion of the program.

Consequence Estimation Project Deliverables

The final products of the Consequence Estimation Study are planned as follows:

1. A final report containing a description of the reference events, a tabulation of their associated consequences, and a detailed description of the methodologies used to calculate these consequences.

2. Codified routines for consequence estimation as follows:

   a. Nuclear explosive initial phenomena consequence assessment.

   b. Nuclear explosive fallout distribution calculation.

c. Modified CRAC, a code for calculating consequences of radionuclide release to the environment, beginning with atmospheric, aquatic or terrestrial transport and culminating in assessment of health effects and property damage.

3. Users manual for the codes specified in 2. above.

The methodology developed for this program is intended to be very flexible and amenable to the treatment of a wide range of problems. It is also intended that documentation and user instructions will be better than those of its predecessor, CRAC. However, owing to it increased complexity it is likely to be just as subject to inadvertent misuse as the older code. It should be noted that the level of effort required to understand the code well enough to use it (or as was usually the case, not use it) the the analysis of problems other than the reactor accident releases for which it was originally intended was about six man months. This suggests that, unless a potential user has that much resource to expand, he might be wise to consider allowing the originators of the code or some other group which has obtained the requisite knowledge to exercise the code on his behalf.

Future Plans

The methodology developed for this project is, as noted above, quite flexible, certainly flexible enough to treat most problems of current interest to the safeguards community. However, the methodology also has great potential for use in accident consequence analysis. It appears to be adequate to treat most such events in the fuel cycle and, because of the capacity of the modified CRAC to treat complex event descriptions, it may even be used on a site specific basis.

One class of problems which is not currently amenable to treatment with the modified CRAC is that involving long term waste storage. To enable the code to treat such problems would require augmentation of the current radionuclide inventory available for analysis in CRAC with additional long-lived radionuclides typical of radioactive waste. Such waste is of course of interest 10, 100, 1000 or even 10,000 years hence. Inclusion of such nuclides would require determining their rate of migration through the various pathways to man and subsequent dosimetry for the various organs. Meaningful analysis of the long term risk of accident or sabotage involving waste storage would also require the development of some meaningful basis or rationale which accounts for changes which may take place in the

environment and in land use over extended periods of time. Even the current interest in long term waste management the extension of modified CRAC to determine consequences from release events involving such waste storage would seem desirable. SAI is interested in performing such modifications as may be necessary to accomplish this extension and in analysing the various storage options currently being considered.

Table III-2

EVENTS ESTIMATED TO PRODUCE ONE OR MORE LATE FATALITIES PER OCCURRENCE[a]

(Listed in Descending Order of Severity)

Event No.	Description
1	Nuclear Device Explosion
4.6	High-Level Liquid Waste Tank Sabotage at Reprocessing Plant
3.1 (PWR 1)	Reactor Sabotage Leading to PWR 1 Release
2.5 (PuO_2)	PuO_2 Dispersal in Building Ventilation System
2.1 (PuO_2)	PuO_2 Dispersal by Explosive Loading
2.2 and 2.3 (PuO_2)	PuO_2 Dispersal by Fire Lofting and Aircraft Release
2.2 (Spent Fuel)	Spent Fuel Dispersal by Fire Lofting
5.1	PuO_2 Storage Sabotage at Fuel Fabrication Plant
4.4.2	$Pu(NO_3)_4$ Storage Sabotage at Reprocessing Plant
2.2 (High-Level Waste)	High-Level Waste Dispersal by Fire Lofting
4.8	PuO_2 Conversion Facility Sabotage at Reprocessing Plant
3.1 (PWR 7)	Reactor Sabotage Leading to PWR 7 Release
5.3	MO_x Fuel Blender Sabotage at Fuel Fabrication Plant
4.5	High-Level Liquid Waste Concentrator Sabotage at Reprocessing Plant
4.2	Dissolver Solution Sabotage at Reprocessing Plant

(a) Certain events, for which consequence estimates were not possible within the scope of this phase of the study (see Appendix D), are not included in this ranking. It is possible that some of these events could produce one or more late fatalities per occurrence.

June 29, 1978

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter is submitted as a report of progress for work begun under BNL 430602-S (T.O. #5) and continued under BNL 430602-S, Consequence Estimation, for the period to 15 June 1978.

Environmental Release and Health Effects and Property Damage subtasks are nearing completion as originally scheduled. Radiocontaminant release source terms have thus far been developed for the following events:

2.5	Dispersal by Building Ventilation System
3.3/4.1	Sabotage of Spent Fuel Storage
4.2	Sabotage of Dissolver Solution in the Remote Maintenance and Scrap Cell
4.5	Sabotage of High-Level Liquid Waste (HLLW) Concentrator
4.7	Sabotage of Off-Gas Handling System
4.8	Sabotage of Plutonium Oxide Conversion Cell
5.1	Sabotage of Bulk PuO_2 Storage Area
5.2	Sabotage of Filtration within the MO_x Process Ventilation System
5.3	Sabotage of MO_x Fuel Blender

The Atmospheric Transport and Pathways to Man subtasks have experienced some delays in obtaining data and producing the calculational routines that are to be used to modify the CRAC routines. In the case of the Atmospheric Transport subtask the problem is simply one of combining a number of routines into a single transport module that is designed to replace similar routines in the Current CRAC. It is expected that this will have been successfully completed by the end of June, with the new module incorporated into CRAC early in July. In the case of the Pathways subtask the problem is one of data acquisition and generation. CRAC routines are being enlarged and their number increased to handle additional

nuclides in existing pathway treatments and additicnal pathways as well. Data to support these changes have simply been slower in coming than we thought they would be. In addition, there seems to be some confusion over data transfers between NRC (Blond) and SAI. These are the dosimetric data for particle sizes other than 1 micron. Problems in their transfer are currently being worked out. In any event I do not envisage the completion of this subtask until the end of July.

The nuclear explosive subtask is nearing completion with the fallout routines essentially complete and the prompt effects routines nearly so. Population and physical description data bases have been developed for the cities of Washington, D.C., and Chicago, IL. These will be used to assess the effects of clandestined nuclear explosions. Specific locations chosen for the events in these two cities are, respectively, on Pennsylvania Avenue in front of the White House, and beside the Picasso sculpture of a lion(?) in the Daley Civic Center Plaza. The former is of interest as a result of the article in the Washington Post, while the latter might be the result of an attack by nuclear-armed art critics.

At the present time it appears that the project is approximately two months behind the schedule originally set down in the program plan. Thus, the final report will probably be submitted in mid-September rather than mid-July as originally planned. As a result, I would like to suggest that a no-cost extension of the contract be granted, extending the period of performance to 30 January. This will cover any interactions which take place concerning our work subsequent to the submission of the final report. I hope this meets with your approval.

Sincerely yours,

Dean C. Kaul
Principal Investigator

DCK:ko

A3046

11

April 14, 1978

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter is submitted as a report of progress for work begun under BNL 374708 (T.O. #5) and continued under BNL 430602-S, Consequence Estimation, for the period ending 10 April 1978.

I. Nuclear Explosives

The urban nuclear explosive effects model is in preparation and is expected to be at least partially operable by the end of the next period. This model includes the consequences of blast, thermal and initial radiation free fields resulting from nuclear explosive detonation in an urban environment.

II. Environmental Release

Individual source terms for events described in the October 1977 Phase I report are being prepared for consequence analysis.

III-V Atmospheric Transport, Pathways to Man and Human Dosimetry and Health Effects and Property Damage

The contributions from these methodologies are being combined in a revised CRAC code which will treat site specific as well as generic events. A brief outline of the Atmospheric Transport modification was described in the report for the preceeding period. Pathway revisions include the addition of meat and aquatic pathways as well as an increase in the number of nuclides treated in all pathways. In addition, population dose calculation will be based on total contaminated crop production rather than individual consumption as is currently the case in CRAC. The revised CRAC consequence routines should be ready to process reference event source terms by the end of the next period (10 May).

If you have any questions concerning this report, please call me at (312) 885-6800.

Sincerely,

Dean C. Kaul
Principal Investigator

DCK/rmp

Science Applications, Inc. One Woodfield Place Bldg., 1701 E. Woodfield Rd., Suite 819, Schaumburg, IL 60195, 312/885-6800

A2644 Immerman

12

March 20, 1978

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter is submitted as a report of progress for work begun under BNL 374708-S (T.O. #5) and continued under BNL 430602-S, Consequence Estimation, for the period to 10 March 1978.

I. Nuclear Explosives

A grid having units of the size of average square city blocks has been chosen as the basis for representing urban and suburban areas subject to initial nuclear explosive effects. Assets such as people and buildings can be located uniformly over a specific block and arbitrarily within the grid. Radii for damage, death or injury from blast, thermal and initial radiation will be overlaid to determine damage and casualties. These radii are currently being calculated. They will vary for any specific effect as a function of the nature of the device considered, its yield, its disposition, and some of the characteristics of its immediate surroundings.

II. Environmental Release

Technology is in hand to produce nearly all the detailed source terms called for by the events agreed to in Phase I. Work continues on the remaining technology, its codification for ultimate transfer to NRC, and the production of individual source terms.

III. Atmospheric Transport

The model for transport of radioactive debris not originating from nuclear explosives is similar to that used in WASH 1400 (CRAC) in that it is a plume model. However, unlike that in WASH 1400, it differentiates between settling velocity and deposition velocity. The former is treated as the gross downward motion of the cloud, while the latter is dependent on the concentration of particles at any specific location. As a result of this dependence, the initial release mass is conserved on a continuous basis. The chosen model also differentiates from that described in WASH 1400 in that the deposition varies in the radial and lateral directions from the source.

It is intended that these calculations be made on a radial grid which is similar to that in WASH 1400 but having finer mesh spacing. As such they can be made a part of the CRAC routines, utilizing the population and agricultural data bases already developed.

IV. Pathways to Man and Human Dosimetry

All pathway models are now nearly complete. Consultation is in progress between Dennis Buckley, pathways director, and the Chicago staff (project integrators) on the manner in which they will be inserted into the consequence estimation model system. This integration process involves maintaining internal consistency in producing population dose and dose to individuals as well as maintaining consistency with CRAC.

V. Health Effects and Property Damage

Models derived from the basic CRAC methodology await integration with the pathways dose routines. We are currently reviewing the comments on our proposed acute effects lung model. It would appear that the main comments center on whether this model is ours or that of Wells (It is the latter adapted to our needs) and the necessity of changing variables from those specified by Wells (Wells' data are for individual isotopes for which the biological/radioactive half life may be represented by a simple exponential which effectively comprises one of his parameters; Our problems are mainly for mixes of elements where no such representation is possible; Thus, some modification or variation in Wells' parameters was necessary). In any event, the model description is being rewritten to clarify the points in question, though the model remains unchanged.

Argonne Spent Fuel Storage Generic EIS

The meeting held under NMSS (Mathews) auspices on 2 March was very useful to me in gauging the potential impact of this work and its future application. Of particular interest to me was the need to carefully examine the variations on events of borderline or lesser importance as expressed by members of NMSS. Apparently this information will be a part of the total body of data on which a decision whether or not to safeguard is based. I believe the methodology which we are producing will certainly be flexible enough to treat the effects of nearly any variation on the current reference events which can be conceived. However, I would like to reiterate a point I made at the meeting: This project has emphasized contaminant transport from its point of origin and the resultant health effects and property damage. It has not emphasized the improvement of the initial source terms for these events, i.e., nature of release from primary containment, by analytical means. These source terms are derived from single pieces or combinations of experimental data. Such derivation is many times intuitive and nearly always could use a stronger experimental base. This base continues to be the

limiting factor in our ability to treat currently defined events or variations thereon. However, new data are appearing regularly and hopefully will continue to appear. Therefore, we hope to exercise the methodology developed under this research contract in continuing support of NRC according to its needs.

The CRAC Code

During this period, the Chicago staff has analyzed the CRAC Code in detail as a result of the need to provide interim data on the Generic Fuel Storage EIS. This analysis has turned up a number of errors or problems in the code, particularly in the chronic exposure section. These problems seem to be of major importance in borderline or lesser events, in which inventories and areas of contamination differ markedly from the major reactor events described in WASH 1400. The most significant problem found to date is the failure of CRAC to conserve activity in calculating population dose. For example, it computes dose to a single man, eating contaminated milk and food from initial contamination to infinity, and then assumes that anyone eating any of the food received the same number of curies. At the same time, the populations consuming these food stuffs are calculated dependent on their value rather than their quantity. Modifications to these and other routines are being made as an interim measure and in preparetion for incorporating the new pathway and dosimetry models. This work is being coordinated with Roger Blond (NRC), CRAC's guardian. The interim modified CRAC will be used to generate a new set of spent fuel storage data for NMSS by the end of the month. It is my intent to supply most, if not all, of the Consequence Estimation Routines in the form of a new CRAC code at the conclusion of this project. In so far as all modifications and additional may be fit into one computer, it shall be done.

If you have any questions about this report, please call me at 312-885-6800.

Sincerely,

Dean C. Kaul
Principal Investigator

DCK/rmp

13

February 23, 1978

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter is submitted as a report of progress for work begun under BNL 374708-S (T.O. #5) and continued under T.O. 430682-S, Consequence Estimation, for the period to 10 February 1978. In my report of progress, I shall refer to the Phase 3 program plan, previously forwarded, of which I am enclosing (Encl. 1) a copy for your convenience.

I. Nuclear Explosives

In accordance with the schedule, work performed in this time period was relevant to Task 2, Consequence Assessment. Particular attention was paid to blast induced personnel casualty and property damage criteria. Methods for applying criteria for such effects as a function of range have been obtained and are being used to produce a parametric data base which is yield dependent.

An example of urban area descriptions has been obtained from Defense Civil Preparedness Agency (DCPA). This includes the resident population and available shelters and their protection factors on a 2 min. x 2 min. grid. Methods for varying this population distribution with time of day are being sought, while algorithms for predicting the fraction of people out of doors for various times of day are in hand. Also in hand are descriptions and distributions of construction types in average urban locations for various regions of the country. Thus, we are very close to having complete descriptions of average urban areas for use in the nuclear explosive and other events.

II. Environmental Release

The planned work on initial source characterization (Task 1 and 1a) has been completed. Literature sources have been collected which define the characteristics of fuel materials and provide estimates of airborne particle size distributions both within facility working areas and within ventilation systems. The particle size distributions appear to have a mass median diameter

of about 1-10 microns and a standard deviation of 1.5-2.5. Computations have been performed to estimate the dispersal range for explosively lofted powders, and for the maximum size of liquid droplets for the case of liquid wastes.

The nuclear fuel cycle facility characterization (Task 2) is almost complete. Transport paths within facilities have been identified for each reference event and some have been diagrammed in detail. This task will be completed when the remainder of the pathways have been diagrammed.

The aerosol transport model development work (Task 3) is nearly complete. A computer program has been developed to calculate aerosol deposition in both horizontal and vertical ducts. The programmed analytical models have been verified with some limited experimental results. Work is proceeding to determine the effect on aerosol duct deposition due to a polydisperse (multi-particle size) distribution and also due to impaction in duct bends.

Task 4, a fluid and thermal analysis to give improved estimates of the dispersed source, was initiated. Limited analysis is expected because recent information indicates that an extended boiloff from the HLLW tank event may not be a credible occurrence.

III. Atmospheric Transport

Since the last reporting period, our efforts have been concentrated mainly on converting the Department of Defense Fallout Prediction System, DELFIC, from the UNIVAC 1108 system to the CDC-7600 system. The conversion has been completed and the DELFIC program is operational. As a sample of the kind of results one obtains with DELFIC a problem was prepared simulating a 10kt ground burst. Figure 1 shows the development of the nuclear cloud in terms of its radius (upper most curve) as a function of time, and the altitude of the cloud base and cloud top as a function of time. The fallout pattern of the radioactive materials on the ground as dictated by the characteristics of the windfield. The one used in the present problem is shown in Figure 2. A part of the fallout pattern as generated by the DELFIC program is shown in Figure 3. Drawn by hand are shown approximate dose contours for 10 and 100R accumulated during the first 50 hours. As may be noted in this figure, the 100R contour extends to approximately 4km.

In order to determine fallout in the U.S., an appropriate data base of winds and atmospheric conditions is required. We intend to use the MRC Low Altitude Meteorological Data Base.* A program has been

*Mission Research Corporation, "A Low Altitude Meteorological Data Base", DNA 4102T, August 1976.

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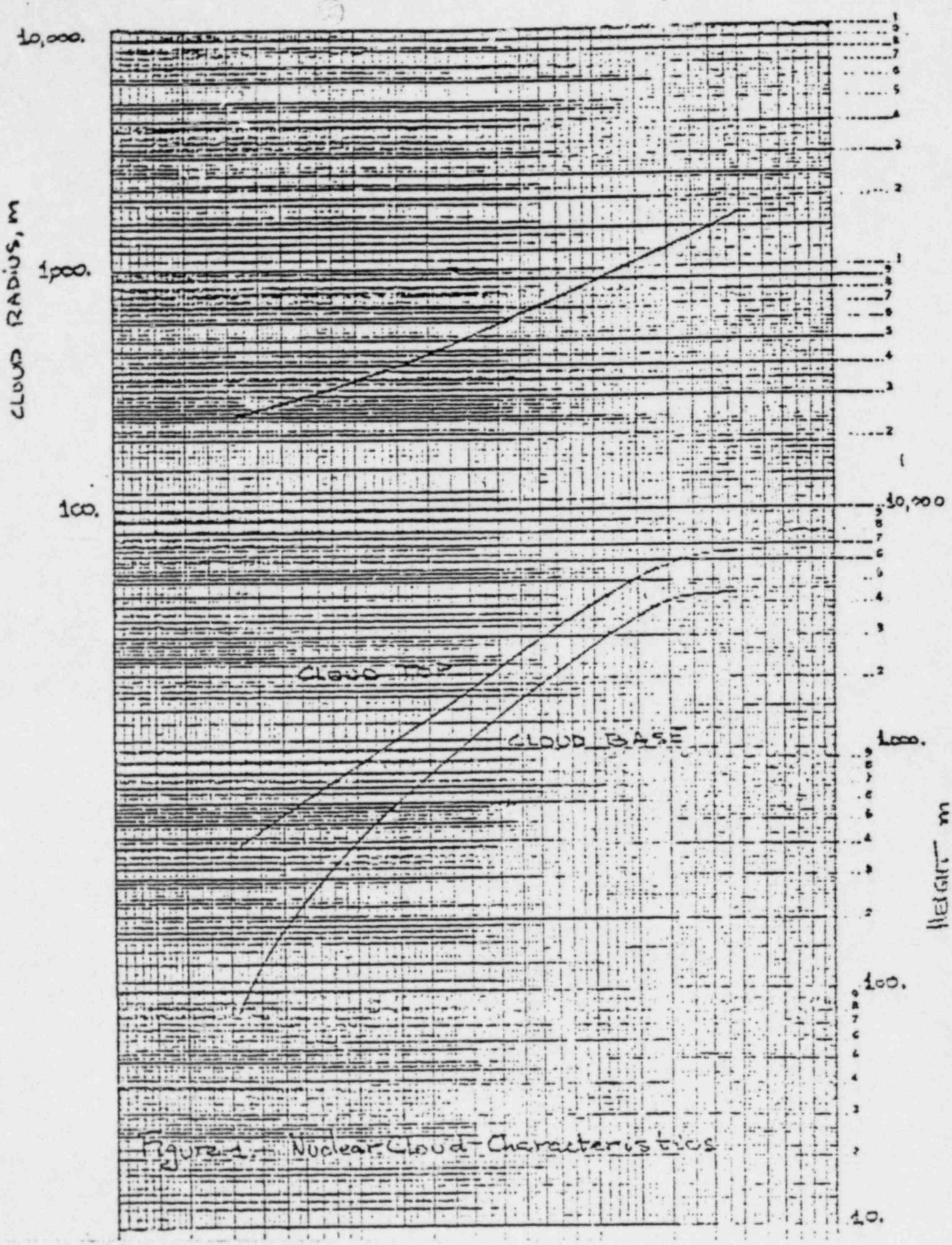


Figure 1. Nuclear Cloud Characteristics

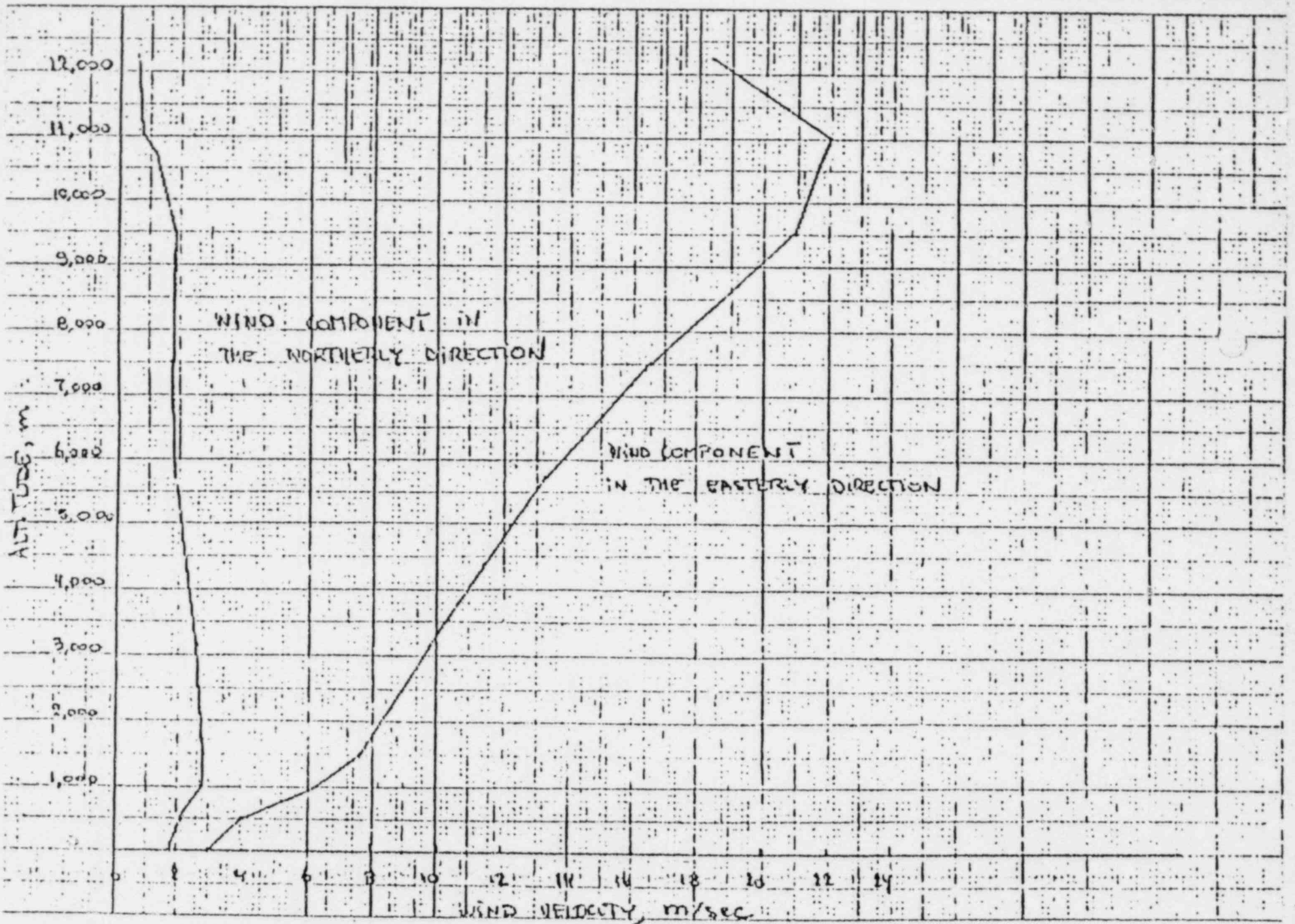


Figure 2. Wind Velocity components for the Sample Problem

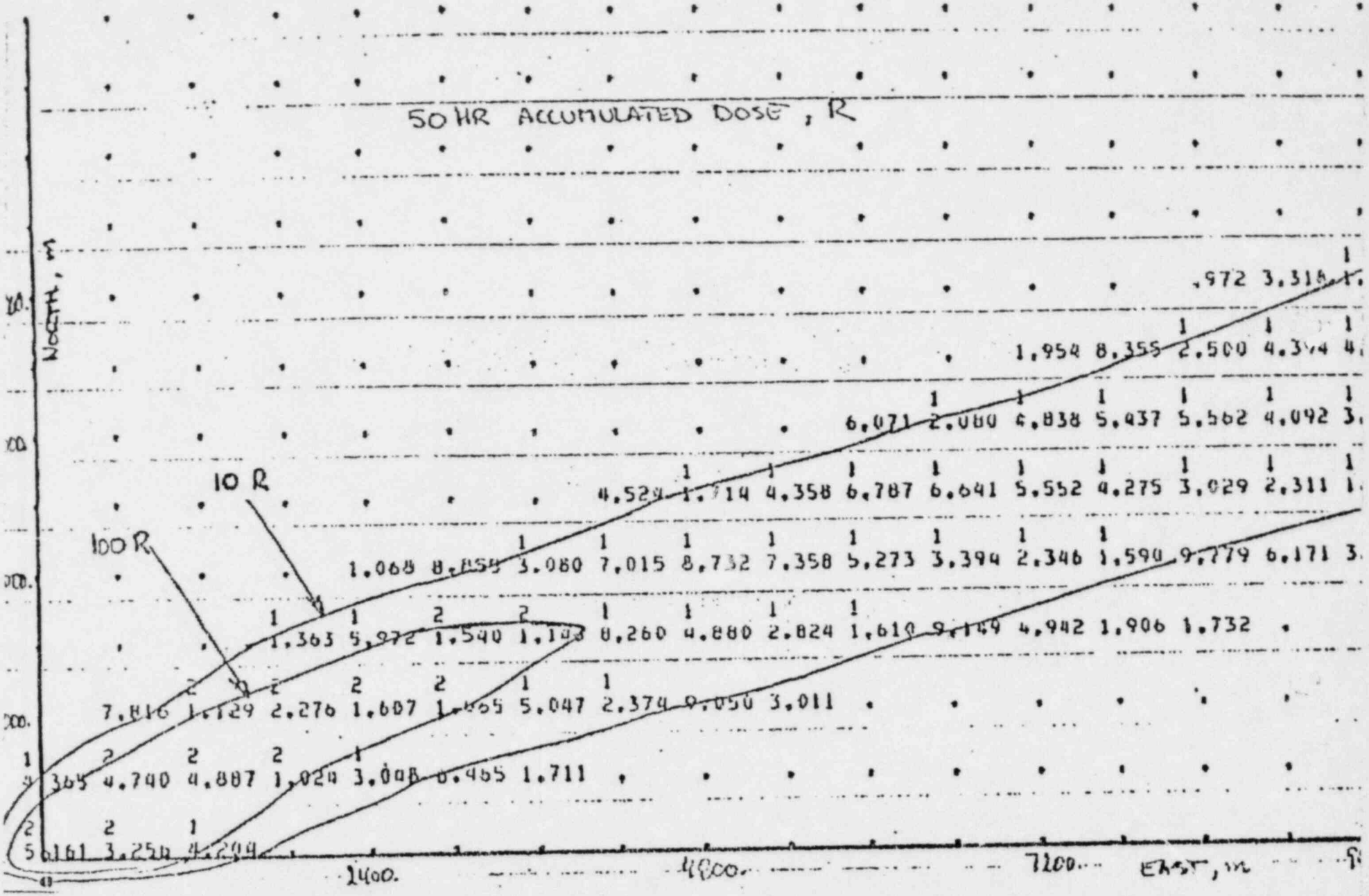


Figure 3. 50 hrs accumulated dose on the ground

developed to access this data base and to convert the information to the format of DELFIC. This program is now operational and has been tested.

A complete description of Intentional Release Atmospheric Transport will be forthcoming in the report of progress for the next period.

IV. Pathways to Man and Human Dosimetry

Phenomenology models identified in Tasks 1 through 5 have been acquired, modified and tested. At present, modeling of an urban water supply system is progressing. The determination of radionuclide decontamination factors for various mechanisms, such as settling and coagulation, is being accomplished. Completion of the urban water supply model is expected by the end of February.

Dose rates resulting from deposited radionuclides in urban environments will be calculated using EXREM-III. Work has been undertaken to determine appropriate shielding and geometry correction factors to apply to the urban environment. Depending upon the urban environment model (number of buildings, types, population density, etc.) which is agreed upon, appropriate factors will be applied based on this work. Two reports that have been studied are:

1. "Calculation of Dose Rates Arising From Radioactive Fallout Upon an Urban Environment," Martin D. Cohen, MAGI (MR-7027), DCPA, June 1972.
2. "Structure Shielding in Reactor Accidents," Zolin A. Burson and A.E. Profio, Health Physics, Volume 33, 1977.

V. Health Effects and Property Damage

The CRAC code which embodies the WASH 1400 methodology has been acquired as per Task 1. Modifications of the health effects criteria treatment in that code called for in Task 2 are completed. However, modularization of that portion of the code awaits a final decision on the handling of population distribution and disposition at the dosimetry-health effects interface. It is probable that the population figures will be handled in the Health Effects section, since this section is also affected by population age distribution, while, according to current practice, dosimetry is not.

Further improvements to the lung model (Task 3) await our review of comments on the current version.

Impact of Health Effects (Task 4) will be demonstrated by listing numbers of mortalities and morbidities by health effect type for each reference event.

Argonne Spent Fuel Storage Generic EIS

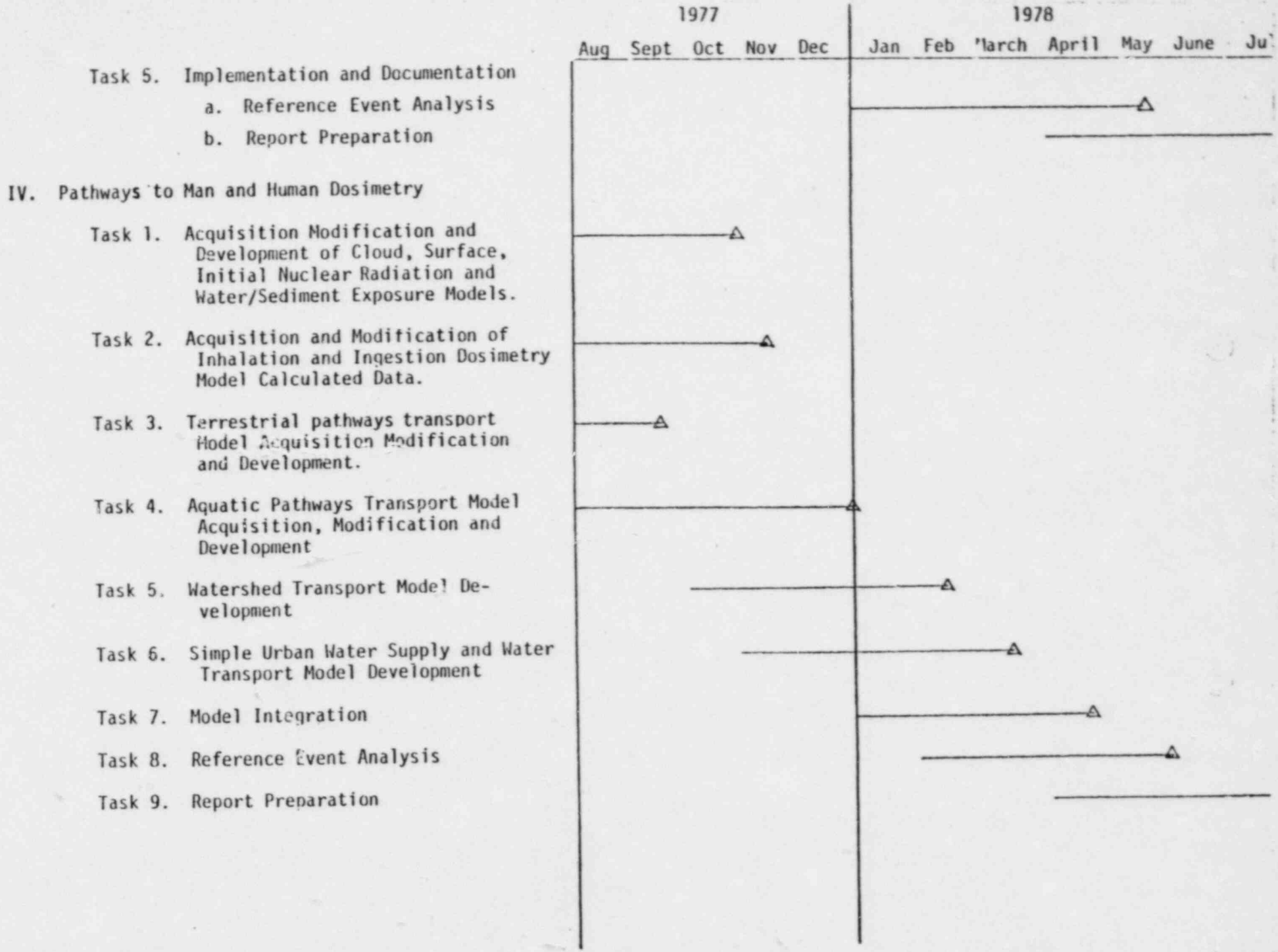
A letter (Encl. 2) has been forwarded to DEIS (Opelka) Argonne National Laboratory specifying the SAI concepts of the various reference events associated with the remote fuel storage facility. ANL has agreed to the list with the addition of a ground level release to the cask unloading cell related events. Subsequent to this agreement, the radionuclide source terms and other source descriptive material has been generated and forwarded for analysis through the consequence methodology system as outlined in the above progress report. It is likely that such analysis will take somewhat longer than the period agreed to for delivery of initial data with ANL. Therefore, the revised CRAC code will be used to generate initial health effect numbers for the 2 March submission, with the Consequence Phase 3 methodology numbers to follow in a week or two.

If you have any questions regarding this report, please call me at (312) 885-6800.

Sincerely,

Dean C. Kaul
Principal Investigator

DCK/rmp
Encl.(2)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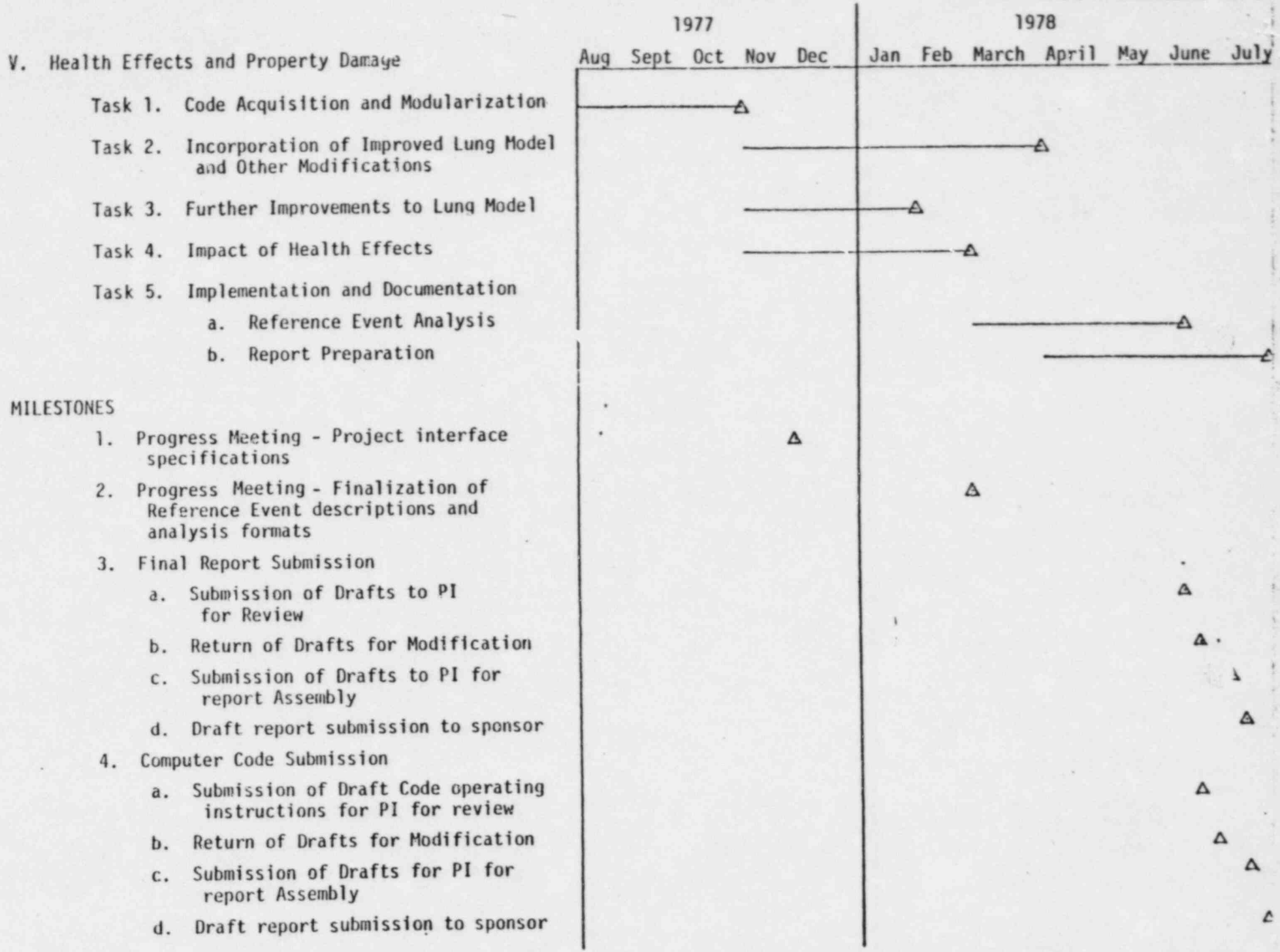
Task 5. Implementation and Documentation
a. Reference Event Analysis
b. Report Preparation
IV. Pathways to Man and Human Dosimetry
Task 1. Acquisition Modification and Development of Cloud, Surface, Initial Nuclear Radiation and Water/Sediment Exposure Models.
Task 2. Acquisition and Modification of Inhalation and Ingestion Dosimetry Model Calculated Data.
Task 3. Terrestrial pathways transport Model Acquisition Modification and Development.
Task 4. Aquatic Pathways Transport Model Acquisition, Modification and Development
Task 5. Watershed Transport Model Development
Task 6. Simple Urban Water Supply and Water Transport Model Development
Task 7. Model Integration
Task 8. Reference Event Analysis
Task 9. Report Preparation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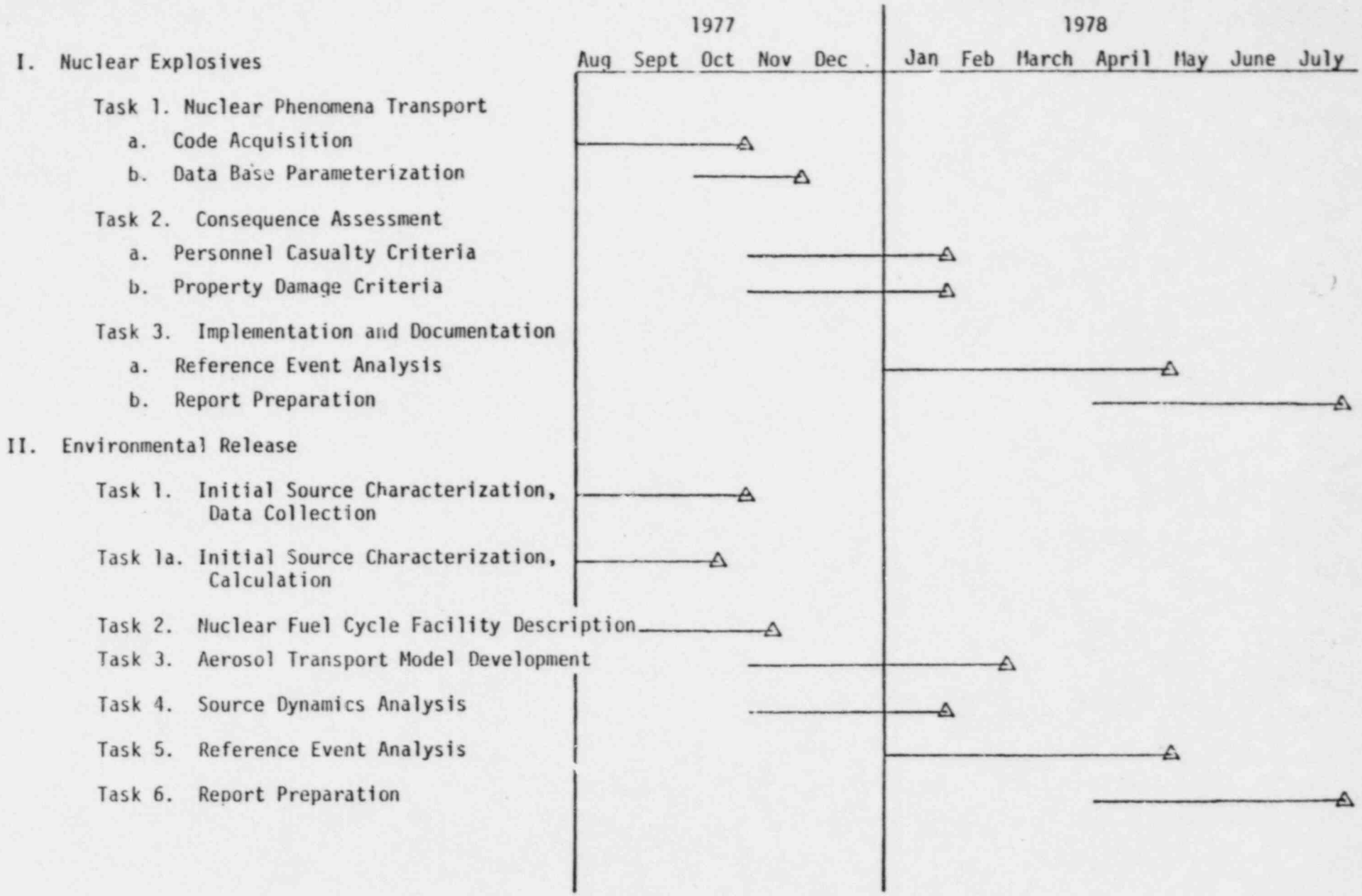
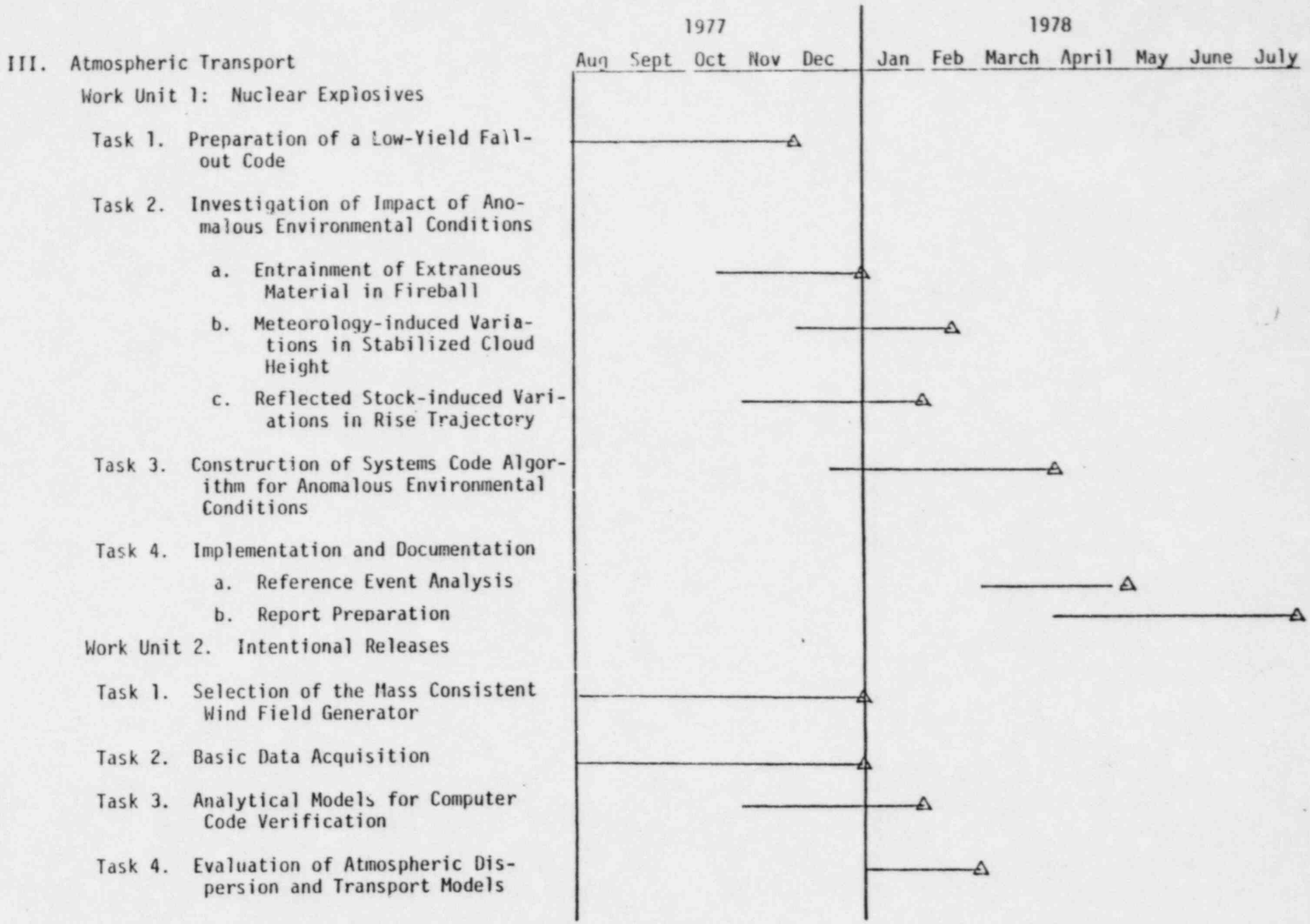
V. Health Effects and Property Damage
Task 1. Code Acquisition and Modularization
Task 2. Incorporation of Improved Lung Model and Other Modifications
Task 3. Further Improvements to Lung Model
Task 4. Impact of Health Effects
Task 5. Implementation and Documentation
a. Reference Event Analysis
b. Report Preparation
MILESTONES
1. Progress Meeting - Project interface specifications
2. Progress Meeting - Finalization of Reference Event descriptions and analysis formats
3. Final Report Submission
a. Submission of Drafts to PI for Review
b. Return of Drafts for Modification
c. Submission of Drafts to PI for report Assembly
d. Draft report submission to sponsor
4. Computer Code Submission
a. Submission of Draft Code operating instructions for PI for review
b. Return of Drafts for Modification
c. Submission of Drafts for PI for report Assembly
d. Draft report submission to sponsor

Consequence Estimation - Phase 3, BNL 374708-S (T.O. #5), SAI 1-XXX-00-950

Program Plan

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III. Atmospheric Transport
Work Unit 1: Nuclear Explosives
Task 1. Preparation of a Low-Yield Fallout Code
Task 2. Investigation of Impact of Anomalous Environmental Conditions
a. Entrainment of Extraneous Material in Fireball
b. Meteorology-induced Variations in Stabilized Cloud Height
c. Reflected Stock-induced Variations in Rise Trajectory
Task 3. Construction of Systems Code Algorithm for Anomalous Environmental Conditions
Task 4. Implementation and Documentation
a. Reference Event Analysis
b. Report Preparation
Work Unit 2. Intentional Releases
Task 1. Selection of the Mass Consistent Wind Field Generator
Task 2. Basic Data Acquisition
Task 3. Analytical Models for Computer Code Verification
Task 4. Evaluation of Atmospheric Dispersion and Transport Models

February 15, 1978

Mr. Jim Opelka
Division of Environmental Impact Studies
Argonne National Laboratory
Argonne, Illinois 60439

Dear Mr. Opelka:

The event list which I sent you yesterday contained an error. The following is the correct list:

1) Single fuel element breach in air in cask unloading cell, release via:
   a) normal building ventilation system.
   b) normal ventilation with HEPA filters disabled.

2) Single fuel element breach under water in storage pool, release via:
   a) normal building ventilation system.
   b) normal ventilation with HEPA filters disabled.
   c) power to ventilating fans shut off, two holes in opposite walls allowing natural ventilation.
   d) added release to ground water via damage to pool allowing contaminated water to leak into ground. It will be assumed that make-up water will be added to keep up the water level in the pool, and that the leakage will continue for a period of thirty (30) days.

Consequences will be evaluated on a per fuel element basis for the youngest possible spent fuel and one or two later ages.

If you have any further questions, please feel free to call me.

Sincerely,

Edward S. Sachs

Edward S. Sachs
Research Scientist

ESS/rmp
cc: David Matthews, USNRC
William Immerman, USNRC

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Science Applications, Inc. One Woodfield Place Bldg., 1701 E. Woodfield Rd., Suite 819, Schaumburg, IL 60195, 312/885-6800

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November 18, 1977

Dr. John Cusack
Brookhaven National Laboratory
Technical Support Organization
Upton, New York 11977

Dear Dr. Cusack:

This letter is submitted as a report of progress for project BNL 374708-S (T.O. #5), Consequence Estimation, for the period to 10 November 1977. During this period a revised draft of the report, "Adversary Actions in the Nuclear Power Fuel Cycle: I. Reference Events and Their Consequences," (SAI-121-612-7803), was forwarded to you and to NRC for review. This is the latest draft description of work done under Phase 1 of the project.

The Phase 2 (Methodology) report is continuing to undergo revision, especially that portion having to do with health effect criteria. It is unlikely that this revision process will cease until such time as the final consequence estimates are made for Phase 3. Thus, while various revised sections of the Phase 2 report will be submitted for peer review between now and that time, it is probably fruitless to attempt to publish a comprehensive methodology document during a period in which that methodology is in such a state of flux. In keeping with this policy of review by section, that pertaining to health effects criteria will be submitted for peer review in early December.

On Wednesday, 2 November, we met with members of the Environmental Impact Studies Division of Argonne National Laboratory, regarding SAI's input to the Spent Fuel Storage Facility Generic Environmental Impact Statement. This input had been requested by Dave Mathews, NRC (NMSS), last Spring. The Argonne personnel were not clear as to what SAI has to provide. We informed them that we would provide consequence values in terms of health effects and property damage for safeguards related portion of the EIS. The Argonne personnel indicated that they had spoken with Bob Mullen, NRC (NMSS), who apparently expressed doubt in SAI's ability to provide such numbers or to provide them by the EIS input deadline of March 1978. However, we assured the Argonne personnel that we could provide such data based on variations on our reference event 4.1, spent fuel sabotage at a reprocessing plant. To expedite the production of such data we received from Argonne copies of the Exxon Oak Ridge Reprocessing Plant Draft Environmental Report and a GE Sabotage Analysis for spent fuel at their Morris, Illinois facility.

Science Applications, Inc. One Woodfield Place Bldg., 1701 E. Woodfield Rd., Suite 819, Schaumburg, IL 60195, 312/885-6800

Other SAI Offices: Albuquerque, Ann Arbor, Arlington, Atlanta, Boston, Chicago, Huntsville, Los Angeles, McLean, Palo Alto, San Diego, Sunnyvale, and Tucson.

Members of the SAI Consequence Estimation research staff will meet on 6 and 7 December to take stock of progress and to finalize plans for the completion of the method modification and development portion of this phase of the effort. My December progress report will contain a report of that meeting's accomplishments.

If you have any questions concerning the project, please call me at (312) 885-6800.

Sincerely,

Dean C. Kaul
Principal Investigator

DCK:ko