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PROJECTION MODELS FOR HEALTH EFFECTS ASSESSMENT IN POPULATIONS EXPOSED TO RADIOACTIVE AND NONRADIOACTIVE POLLUTANTS

Volume II

SPAHR Introductory Guide

by

James J. Collins and Robert T. Lundy

ARGONNE NATIONAL LABORATORY

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Division of Biological and Medical Research

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This is Volume I of a five volume series entitled Projection Models for Health Effects Assessment in Populations Exposed to Radioactive and Nonradioactive Pollutants, NUREG/CR-2364, ANL-81-59. The series presents version 4.1 of the Simulation Package for the Analysis of Health Risk (SPAHR) computer package and model. The complete series of SPAHR documentation is contained in the following five volumes:

Volume I	Introduction to the SPAHR Demographic Model for Health Risk J. J. Collins, R. T. Lundy, D. Grahn, and M. E. Ginevan
Volume II	SPAHR Introductory Guide J. J. Collins and R. T. Lundy
Volume III	SPAHR Interactive Package Guide J. J. Collins
Volume IV	SPAHR User's Guide J. J. Collins and R. T. Lundy
Volume V	SPAHR Programmer's Guide J. J. Collins and R. T. Lundy

PROJECTION MODELS FOR HEALTH EFFECTS
ASSESSMENT IN POPULATIONS EXPOSED TO
RADIOACTIVE AND NONRADIOACTIVE POLLUTANTS

ABSTRACT

The Simulation Package for the Analysis of Health Risk (SPAHR) is a computer software package based upon a demographic model for health risk projections. The model extends several health risk projection models by making realistic assumptions about the population at risk, and thus represents a distinct improvement over previous models. Complete documentation for use of SPAHR is contained in this five-volume publication. The demographic model in SPAHR estimates population response to environmental toxic exposures. Latency of response, changing dose level over time, competing risks from other causes of death, and population structure can be incorporated into SPAHR to project health risks. Risks are measured by morbid years, number of deaths, and loss of life expectancy. Comparisons of estimates of excess deaths demonstrate that previous health risk projection models may have underestimated excess deaths by a factor of from 2 to 10, depending on the pollutant and the exposure scenario. The software supporting the use of the demographic model is designed to be user oriented. Complex risk projections are made by responding to a series of prompts generated by the package. The flexibility and ease of use of SPAHR make it an important contribution to existing models and software packages.

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EXECUTIVE SUMMARY

Prediction of the health consequences to the general population of exposure to airborne and waterborne pollutants is becoming an important feature of environmental impact analyses. Such prediction requires not only knowledge of the dose term and the dose-response function, but also a model for projecting the health risk to some future population. Health risk projections entail considerable uncertainty about the measurement of the dosage that individuals receive and about the magnitude and nature of the biological response at a given population exposure. The uncertainties regarding the individual dose and the dose-response function have received much attention, but the uncertainty associated with the health risk projection model itself has not been fully addressed.

The purpose of this publication is threefold. First, the uncertainties in various health risk projection models will be addressed, and the assumptions inherent in each model will be stated explicitly. Second, a new model that is an extension of earlier models will be introduced. It is argued that this new model, referred to as the demographic model, is superior to previous models because it makes fewer assumptions about the population at risk and the potential of the population to change over time. Third, a computer package referred to as the Simulation Package for Analysis of Health Risk (SPAHR) is presented which facilitates the application of this model for various pollutants and populations at risk.

The core of any risk assessment scheme is the exposure-response model. This is the quantitative relationship between the level of exposure to the hazard of interest and the deleterious effects resulting from that hazard. If the population exposed to the hazard is homogeneous with respect to its likelihood of suffering ill effects from the exposure, estimation of effects is straightforward; we need know only the total number of persons exposed to estimate the effects. However, if the population is heterogeneous (i.e., different persons have differing risks of suffering health effects from exposure to the hazard), then a reasonable assessment of population risk depends upon the distribution of persons by level of risk.

Research indicates that risk levels are often related to the age and sex characteristics of the exposed population. This is true for both radiation and air pollution exposures. When the risk level is a predictable function of age and sex or some other traceable component of the demographic structure of the population, the estimation of projected health effects becomes less straightforward. If one adds to this complexity the long latency periods between exposure and response, the competing risks from other causes of mortality, and the changing demographic structure of the population over time, the projection of health effects becomes even more complex.

Evaluation of the health consequences for populations exposed to pollutants has become an important issue because of the increasing number of known or suspected carcinogens in the environment. To date, three projection methods have been used in health risk assessments: the single coefficient model, the multi-coefficient model, and the life table model. Each has its own shortcomings, as discussed in Volume I, Chapter 2. This document presents a fourth model that is more useful and realistic than the previous models because it incorporates age, fertility, and mortality structure, and can follow populations through time under changing levels of mortality, fertility, and pollution exposure. This model is referred to as the demographic model.

A sensitivity analysis of the demographic model indicates that population structure alone for a 100-year exposure to 1 rem may introduce more than a factor of 10 variation in the number of excess deaths. This finding substantiates the premise that the population structure may be more important in a health risk projection than the uncertainty inherent in the dose-response functions.

A comparison of the demographic model with the single coefficient model, the most widely used in health risk projections, is presented in Volume I, Chapter 7. It is concluded that the single coefficient model, even in a short-term projection, may seriously underestimate excess deaths since it is unable to accumulate exposure. For instance, comparison of the single coefficient model with the demographic model for continuous exposure to 0.87 ppb of benzene for 50 years yields widely different estimates of excess mortality. The single coefficient model estimates 2,250 deaths, while the demographic model estimates values from 6,386 to 17,568. In the years 2015-2020, the excess leukemia deaths projected by the demographic model are ten times as large as those of the single coefficient model.

The demographic model is also compared with the life table model used in the 1980 BEIR report to estimate excess cancer deaths from exposure to ionizing radiation. The life table model correctly estimates the increased individual probability of death associated with a given radiation scenario. However, the life table model yields misleading results in the estimation of excess deaths for a specific population. The results presented in the 1980 BEIR report underestimate excess deaths by 50% in some instances. For example, using the linear-quadratic, absolute risk model for a continuous exposure of 1 rad per year for 70 years, the life table model estimates 2459 excess male deaths per million while the demographic model estimates 3769 excess male deaths per million.

This document is divided into five volumes:

I. Introduction to the SPAHR Demographic Model for Health Risk

II. SPAHR Introductory Guide

III. SPAHR Interactive Package Guide

IV. SPAHR User's Guide

V. SPAHR Programmer's Guide

The first volume presents the theory behind the SPAHR health risk projection model and several applications of the model to actual pollution episodes. The elements required for an effective health risk projection model are specified, and the models that have been used to date in health risk projections are outlined. These are compared with the demographic model, whose formulation is described in detail. Examples of the application of air pollution and radiation dose-response functions are included in order to demonstrate the estimation of future mortality and morbidity levels and the range of variation in excess deaths that occurs when population structure is changed. Volumes II through V provide the potential user with detailed guidance and appropriate examples to aid in the interpretation of numerical demographic output from the application of the model to realistic circumstances.

1.0 INTRODUCTION

1.1 Overview of the SPAHR System

SPAHR, the Simulation Package for Analysis of Health Risk, is an integrated system of subroutines for projecting the expected human health impacts of exposure to various hazards, particularly those resulting from effluents related to energy production. SPAHR was developed because other methods of assessing impact either ignore or make unrealistic assumptions about the age and sex structure of the population. SPAHR addresses this problem by combining current approaches for assessing impact with the methods of demography.

The SPAHR system is designed similarly to SPSS, SAS, and other integrated computer packages. That is, it is composed of more or less independent routines tied together by a front-end program that implements free-format input, interactive-batch interfaces, standardized data files, and other enhancements that would ordinarily be beyond the capabilities of single purpose computer programs.

The major innovation in the SPAHR system is a projection model that includes an interface for exposure-response models and the ability to explicitly project mortality and population size. The design of the SPAHR system is sufficiently general, however, that programs originally designed for other demographically oriented calculations can easily be incorporated. The SPAHR projection model is one of many possible instructions that can be entered into the command processor. This design makes it possible to implement an assessment model in which other types of impacts having demographic components are integrated closely with the health impact analysis, thereby avoiding the complications that can arise if the demography is performed independently for each part of the analysis.

In addition to the life table and projection modules that form the core of the risk assessment process, a number of demographic utility programs from the book Population: Facts and Methods of Demography (Keyfitz and Flieger, 1971) have been incorporated into the SPAHR command set for the benefit of researchers who wish to use the results of these procedures as descriptive summary statistics for the populations being analyzed. The user is referred to Volume I in this series for further details on these procedures.

Volume III presents interactive modules that can be used in SPAHR to run various programs. These interactive modules are structured as question and answer routines, so that even those unfamiliar with SPAHR or with computers in general can perform sophisticated health risk assessments. Volume IV is a detailed user's guide written for those familiar with both SPAHR's demographic model and computer systems in general. The SPAHR Programmer's Reference Manual, Volume V of this series, gives detailed directions for incorporating other modules into the system.

1.2 Purpose and Scope

This volume is intended to give the user of the SPAHR program the information required to operate the program when it is up and running on the computer. It assumes that the user is familiar with the concepts and terms relating to demography and health risk assessment. It contains a brief description of all commands and options available in SPAHR, as well as a user-oriented description of the structure and operation of the control system and language processor.

Not all of the features of SPAHR will be of interest to the beginning user. A user who is new to the system and wishes to familiarize himself with its operation should begin with this volume, which is a brief guide to the use of SPAHR and does not assume prior knowledge of the contents of the rest of the manual. This volume contains references to other sections as they are needed. When familiar with this material, the user should proceed to Volume IV, which discusses the grammar and syntax of the language processor in some detail. Volume IV is a detailed reference to the structure and options of every command in the SPAHR system. It should be used to clarify questions as they occur to the user.

1.3 Command Summary

This section lists the commands available in this version 4.1 of SPAHR and gives a brief description of their use. The commands are described in detail in the SPAHR User's Guide, Volume IV.

Procedure Command Statements	
Command Name	Function
OPTIONS	Sets the default values defining files to be used for various purposes, i.e. numbers of sex and age groups, etc.
DATA	Enters primary demographic data into the main data blocks.
LIFETAB	Calculates a Life Table.
MULDEC	Calculates Multiple and Associated Single Decrement Life Tables for several causes of death.
PROJECT	Projects the population forward through time. Has the ability to project death rates as a function of exposure to toxic substances using the ADJUST subcommand.
ANALYSIS	Produces a summary analysis of the mortality and fertility rates in the current population. Indicates long-term growth by several indicators, stable population age structure, mean generation length, and other measures of demographic interest.

Language Statements	
Command Name	Function
DO	Defines groups of commands that are to be associated with each other for conditional or repetitive execution.
END	Terminates a DO-group or terminates execution of the SPAHR program.
IF	Permits conditional execution of a statement or group of statements depending on whether or not certain conditions have been met.
SET	Defines SPAHR variables.
PRINT	Prints out the current values of SPAHR variables.
TITLE	Sets the string of title information to be printed at the top of every page.

2.0 RUNNING SPAHR ON A COMPUTER

2.1 Overview of the SPAHR File Structure

All instructions to SPAHR are entered in a computer file called the command file. This file contains specific SPAHR procedure statements selected by the user to simulate various assessment models. The particular population for which the analysis is being performed is located in a file referred as the data file. The command file (the SPAHR procedure statements) and the data file (the demographic characteristics of the population being analyzed) are defined separately for the following two reasons.

1) The population being projected is distinctly different from the projection itself. The projection assumptions contained in the command file define a specific set of conditions. These conditions, however, must be applied to the age and sex structure of a specific population contained in the data file. The same conditions applied to different populations will yield different results. The user may, therefore, wish to apply the same analysis (contained in the command file) to several different populations (contained in several data files). This can be done by simply switching the data files rather than by reconstructing the command file each time.

2) With these two file structures, it is much easier to utilize a default population structure provided by SPAHR to simulate various mortality scenarios without providing a data file. The default file is the total U. S. population from 1969-71. Other population structures available in SPAHR are listed in the User's Guide, Volume IV.

2.2 The Command File Structure

The SPAHR procedural commands are composed of keywords and delimiters, and may include numbers. A command always begins with a keyword and ends with a delimiter. The keywords in SPAHR are straightforward mnemonics. For instance, LIFETAB constructs a life table, while PROJECT performs a population projection. The delimiters are used to divide the commands into sections as well as to separate individual commands.

Some commands in SPAHR may contain several sections. For example, the command PROJECT has a number of subcommands. In addition, a number (a scalar parameter) or a series of numbers (a data array or arrays) can be included in a command or subcommand. The command PROJECT with the further specification YEARS = 100 produces a 100-year population projection. A command, therefore, may contain one or all of the following:

1) Subcommands. Subcommands are logically separate parts of commands. They may contain their own groups of scalar parameters and arrays. For example, in the PROJECT command, the scalars and arrays that are an intrinsic part

of the projection process make up the main body of the subcommand. These parameters control such factors as the duration of the projection, the size and structure of the population being projected, and whether the projection will be in the period or cohort mode.

2) Scalar Parameters. The scalar parameter section follows immediately after a command. It is composed of keywords (e.g., BACKGROUND) or <keyword> = <value> assignments (e.g., REM = 0.1).

3) Arrays. Data arrays consist of a keyword giving the name of the array, followed by a set of numbers. Some data arrays may be multidimensional, consisting of groups of arrays, each with its own section name (DOSE in this example) preceding the group name (LUNG, BONE) and reading

DOSE LUNG 25*3.2, 15*1.5, 5*1.0 $$ BONE 30*2.0, 15*1.5;

SPAHR also utilizes four special symbols to separate commands and sections of commands. These four special symbols, referred to as delimiters, are defined as follows:

1) The single semicolon (;) is used to terminate an entire command. SPAHR interprets the single semicolon to mean "the command is now complete; go do it!" (e.g., PROJECT YEARS = 100;).

2) The double semicolon (;;) is used to terminate a subcommand. It is interpreted to mean "the subcommand is complete; however, another subcommand or command level array immediately follows" (e.g., PROJECT YEARS = 100 $ ADJUST MODEL = 5;; ADJUST MODEL = 6;).

3) The single dollar sign ($) is used to terminate a complete array or the group of scalar parameters following a command. It is interpreted by SPAHR as "the array is complete, but another array or subcommand follows" (e.g., PROJECT YEARS = 100 $).

4) The double dollar sign ($$) is used to terminate a section of a multidimensional array. For example, a multidimensional array would be used to define the dose levels for several disease groupings that are being used in an assessment. This symbol is interpreted as "this section of the array is complete, but another section of the array follows immediately" (e.g., DOSE LEUKEMIA 20*0.5 10*0.2 $$ LUNG 30*0.8;).

The examples that follow in Chapter 2.4 will clarify the use of these delimiters.

2.3 Constructing Command Files

A SPAHR job has three major steps:

1) The Data Entry step defines the base population for the analysis. It is accomplished by using the DATA command.

2) The Preliminary Demographic Analysis step uses the base population defined in the DATA command to calculate life tables and other measures required for all subsequent analyses. It uses the LIFETAB and sometimes the MULDEC commands.

3) Determination of the actual Population at Risk and Health Effects Projection is the final step. Here data from the first two steps together with exposure data for the hazard(s) of interest are used to generate estimated excess mortality and related measures. This step uses the PROJECT command and its associated ADJUST subcommand.

Most of the options and parameters relating to risk assessment are found in the ADJUST subcommand, which as its name suggests is designed to adjust mortality rates as the consequence of exposure to various hazards. Briefly, the ADJUST subcommand has the following features:

1) A variety of models relating mortality and hazard exposure is available through the ADJUST subcommand. The models are selected by using the MODEL parameter. Relative risk versions of the models may be specified by using the REL parameter. The default period of risk (30 years for most cancers except leukemia) can be reset to lifetime risk by using the LPLAT parameter.

2) Exposure to the hazards of interest may be defined in two ways. If the exposure level is constant over the period of exposure, a single dose rate may be entered by assigning the dose rate to a single-valued parameter named REM (or SO_2 or whatever dose keyword is appropriate for the model). On the other hand, if the exposure rate varies over time, an annual exposure for each year is entered using a separate array named DOSE.

3) New causes of death can be defined, or coefficients for causes of death already defined may be changed, with the use of the COEFS, LATENT, and PLATEAU arrays.

4) Up to five ADJUST subcommands may be defined for each PROJECT command. Thus the effects of a variety of hazards operating simultaneously may be assessed as competing risks.

5) ADJUST relates causes of death, risk model coefficients, and, in the case of radiation models only, hazard exposures through the use of a cause name of one to eight characters. An example is the projection of radiogenic lung cancer using the BEIR I relative risk model. The ADJUST subcommand will define a new cause of death named LUNG (the name of the newly defined cause will later be changed to make it unique), and exposure levels will be used from the DOSE array following the keyword LUNG. To change the predefined coefficients of the model relating lung exposure to mortality, the user specifies the keyword LUNG within

the COEFS array. SPAHR will use the LUNG death rates entered in the DATA step as the basis for its relative risk calculations.

The questionnaire table below will help the inexperienced user perform health risk analyses with SPAHR. In the interest of brevity, the table omits most of the options available, which are illustrated in the set of command file examples in Chapter 2.4. The user is also urged to consult the User's Guide, Volume IV, for a complete description of the options available for both the data and projection steps.

To use the questionnaire table, start with Question 1, answer it yes (Y) or no (N), follow the appropriate instruction(s), and then enter a carriage return. Elements enclosed in <> are values provided by the user. Each instruction group terminates by telling the user which question to answer next. Go immediately to that question, which may <u>or may not</u> be the next question in the table.

<u>QUESTIONNAIRE TABLE</u>

<u>Data Entry Step</u>

1.0 Is this a batch job?
- Y: Enter OPTIONS BATCH;. Go to 1.1.
- N: Go to 1.1.

1.1 Do you want to use the default population?
- Y: Enter the line DATA ; LIFETAB ; MULDEC ;. Go to 3.0.
- N: Enter the keyword DATA. Go to 1.2.

1.2 Is the data to be entered on a separate file?
- Y: Go to 1.3.
- N: The data will be entered in free format as part of the command file. Enter the DATE=<year> parameter and any other single-valued data items desired, terminating them with a $ delimiter.
  Enter array data items as needed, being sure to terminate the last one with a ; delimiter. Go to 2.0.

1.3 Is the data file on unit 4 (i.e., the default file)?
- Y: Go to 1.4.
- N: Enter the INPUT=<file unit> parameter. Go to 1.4.

1.4 Is the data file written in free format?
- Y: Enter a ; delimiter. Go to 2.0.
- N: Enter the FORMAT=<format number>.
  Enter a ; delimiter. Go to 2.0.

Preliminary Demographic Analysis Step

2.0 Were deaths or death rates by cause of death entered in the data file?
Y: Enter LIFETAB ; MULDEC ;. Go to 3.0.
N: Enter LIFETAB ;. Go to 3.0.

Population at Risk and Health Projection Step

3.0 Enter PROJECT STOP=<final year of projection>. (The starting year is the year associated with the population in the Data Entry step.) Do you want to estimate the effects of exposure to some hazard?
Y: Enter a $ delimiter.
Enter ADJUST. Go to 3.1.
N: Enter a ; delimiter. Go to 4.0.

3.1 Is the hazard of interest ionizing radiation?
Y: Enter MODEL=6. (Other models are listed in Volume IV.) Go to 3.2.
N: Go to 3.6.

3.2 Do you wish to assume a lifetime risk period?
Y: Enter LPLAT. Go to 3.3.
N: Go to 3.3.

3.3 Do you want to use the relative risk version of the model?
Y: Enter REL. Go to 3.4.
N: Go to 3.4.

3.4 Is the exposure level constant for the duration of exposure, and does it come from a single source (e.g., whole body irradiation)?
Y: Enter REM=<annual dose rate>. Go to 3.5.
N: Enter a $ delimiter.
Enter DOSE.
Follow this with an annual dose rate history for all specific organ doses. (For detail, refer to Volume IV, the SPAHR User's Guide.)
Enter a ; delimiter. Go to 4.0.

3.5 Does the exposure continue throughout the duration of the projection?
Y: Enter a ; delimiter. Go to 4.0.
N: Enter STOP=<final year of exposure>.
Enter START=<initial year of exposure> only if it is not the same year as the start of the projection.
Enter a ; delimiter. Go to 4.0.

3.6 Enter the parameter MODEL=<n>, where n refers to one of the air pollution indexed models described in the User's Guide (Volume IV).
Enter the <dose keyword> = <annual dose rate> parameter(s) appropriate to the model selected. Note that there may be more than one pollutant dose required. Go to 3.5.

Job Submission Step

4.0 You have finished constructing the command file. Submit your job to the computer as shown in Chapter 2.6.

2.4 Examples of Command Files

This section illustrates the proper use of the SPAHR model for specific purposes. We will assume for the rest of this section that the data file entered in the EXEC card is the one used in the example data set discussed in Chapter 2.5.

The following eight examples range in complexity from the very simple to the very sophisticated. Each assessment model has been chosen to demonstrate the flexibility of SPAHR. These examples by no means cover all possible uses of SPAHR. A more complete exposition of other SPAHR options is introduced later. However, in most cases one of these examples can be modified by the user to fit a particular assessment model.

2.4.1 Radiation Risk: Constant Exposure

We wish to project the effects of a constant whole body exposure of 0.1 rem during a 100 year period. The exposure commences in the initial year of the projection.

```
DATA ; LIFETAB ; MULDEC ;
PROJECT STOP=2070 $
   ADJUST MODEL=6 REM=0.1 ;
END;
```

The DATA command reads in the contents of the data file. The LIFETAB command calculates the life table for all causes of death and initializes the age-specific death rates that are needed in the projection. The MULDEC command does the same for death rates by cause. The PROJECT command sets the STOP parameter at the year 2070. Because the date associated with the population is 1970, this will give us a 100-year projection. The parameter section of the PROJECT command is terminated with a dollar sign, so either array or subcommand sections may follow. In this case, the ADJUST subcommand has been called to set up the change in mortality rates that will result from an exposure. The ADJUST subcommand has been indented to show that it refers to the PROJECT command. This is not required, however. The dose response model selected using the MODEL parameter is 6, which is the radiation risk model derived by WASH-1400 (USNRC, 1975). The REL parameter is <u>not</u> included, so we are using the absolute risk model. The exposure level is set to 0.1 rem using the REM parameter. The exposure begins by default at the beginning of the projection, which is 1970.

Because radiation-induced cancers have a latency period between exposure and response, the deaths from these cancers will continue after the exposure has ceased. Since we are assuming that exposure starts in 1970 and continues throughout the duration of the projection, many of the cancers that have been induced in this population will not have been observed by the time the projection ends.

2.4.2 Radiation Risk: Background Exposure Levels

As in the example in Chapter 2.4.1, we are interested in the effects of a constant level of exposure. However, rather than projecting the effects of an exposure that starts at some defined point in time, we wish to estimate the effects of an exposure to which the population has already been subjected for a long time, and which will continue indefinitely. To do this, we would modify our previous example as follows:

```
DATA ; LIFETAB ; MULDEC ;
PROJECT YEARS = 100 $
   ADJUST BACKGROUND MODEL=6 REM=0.1 ;
END;
```

The DATA command reads the default file, allocated to unit 4 (see Chapter 2.6.1.1), which contains the cause-of-death data, so we must enter the MULDEC command to set the appropriate death rates. PROJECT once again generates a 100-year projection. However, because we specified the BACKGROUND parameter, the ADJUST routines calculate the death rates appropriate to the exposure level specified in the REM parameter on the assumption that the exposure had prevailed for the previous hundred years. These newly calculated death rates are then subtracted from the death rates for the same causes that were read in using the DATA command. Thus we are left with two sets of death rates. The original death rates have been reduced to the levels that would have occurred without the background radiation exposure, and the death rates due to the background exposure levels are now given as a set of independent and invariant death rates in their own right. The total number of deaths that will be projected remains the same.

If the original set of data does not include rates for all of the causes defined in Model 6, only the identically named causes will be affected. However, the total baseline rates that are defined for the projection (displayed on SPAHR output tables as cause name -BASELN-) will be decreased by the full complement of background radiation-induced deaths, including those for which no separate set of death rates was provided in the original data.

2.4.3 Radiation Risk: Variable Dose, Single Organ

We wish to project the effects in the lung of a radiation dose that varies over time for 100 years. No exposure is assumed to any other organ.

```
DATA ; LIFETAB ; MULDEC ;
PROJECT STOP=2070 $ ADJUST MODEL=6 $
DOSE LUNG 25*3.2 15*1.5 15*0.5 5*0.1 ;
END ;
```

This example is identical to the one in Chapter 2.4.1 except for the dose term. Because we have specified a dose to a particular organ using the DOSE array of the ADJUST subcommand, all other doses are assumed to be zero. In this case, only one organ is affected, and the doses to this organ are 3.2 rem for 25 years, 1.5 rem for 15 years, 0.5 rem for the next 15 years, and 0.1 rem for the last five years. The increment of exposure over the background level is limited to a period of 60 years (25+15+15+5) starting in 1970. There will therefore be a period of 40 years starting in 2030 during which no radiation exposure is being accumulated. However, excess cancer deaths will still occur among the exposed population during the period following the cessation of exposure. The 40-year period allowed in this example does not cover all of the 15-year latency and 30-year plateau period assumed by the model, a total of 45 years after exposure ceases. Thus to see all cancers generated under this model we would have to raise the STOP parameter in PROJECT to 2075 or 2080.

2.4.4 Radiation Risk: Constant Dose and Background, Single Organ

We wish to examine the effects of a radiation dose in the lung simultaneously with the effects of a background dose to the same organ. We further wish to use the relative risk model, and to substitute effect coefficients of our own choosing for those supplied with the SPAHR model. We would set up the problem as follows:

```
DATA ;
LIFETAB ;
MULDEC ;
PROJECT STOP=2200 $
   ADJUST MODEL=6 REL LPLAT BACKGROUND START=1870 STOP=1970 $
   DOSE LUNG 100*0.560 $
   COEFS LUNG MALE 0 0.02 0.006 0.006 $$ FEMALE=MALE ;;
   ADJUST MODEL=6 START=2000 STOP=2100 REL LPLAT $
   DOSE LUNG 100*2.95E-4 ;
END;
```

Once again we use the default data file. The first ADJUST subcommand defines the background effect. We use the BACKGROUND parameter to tell SPAHR to calculate the adjusted rates one time only at the beginning of the projection, and to set the starting date of the exposure explicitly at 100 years prior to the beginning of the projection.

Because we are restricting our attention to the lung, we cannot simply enter the REM parameter. That would assign the indicated dose to all organs. Instead, we use the DOSE array and then enter the LUNG dose as 100*0.560. This indicates that the first 100 years all have the identical dose of 0.560 rem. This is followed by delimiter $ to indicate that another array follows as part of the current ADJUST subcommand. The array COEFS, which follows, alters the coefficients of the current mortality adjustment model, in this case the relative risk version of Model 6. Following the COEFS keyword we find the LUNG keyword, telling SPAHR which segment of Model 6 is to be altered; then comes the keyword MALE. Next we enter four numbers that are respectively the coefficients for in utero, 0-9.9, 10-19.9, and 20+ age groups. The last number is followed by a $$, so that more of the COEFS array is anticipated. The next expression, FEMALE = MALE, informs SPAHR that the coefficients entered for the males are also to be used for the females. This is followed by a double semicolon, which tells SPAHR that no more data is to be processed by the current subcommand, but that more subcommands or arrays will follow before we are finished with the PROJECT command.

We then find another ADJUST subcommand. This one, like the previous one, specifies Model 6 with the relative risk option (REL) and lifetime plateau (LPLAT). We set the START parameter of this ADJUST command to 2000, so that the exposure will not start until the year 2000, or 30 years after the projection begins. The DOSE array entered next specifies 100 years of 0.000295 rem in each year from 2000 to 2100. The DOSE array is terminated by ;, which indicates the end of the PROJECT command as well.

2.4.5 Radiation Risk: Lifetime Plateau

We wish to project the effect of the 60-year lung dose in the example in Chapter 2.4.4 on the assumption of a lifetime plateau period and to register all cancers thus generated. Furthermore, we wish to compare the estimated levels of radiation-induced cancers with their levels from other causes.

```
DATA ; LIFETAB ; MULDEC ;
PROJECT STOP=2130 $
ADJUST MODEL=6 LPLAT $
DOSE LUNG 25*3.2 15*1.5 15*0.5 5*0.1 ;
END;
```

We code the projection to run for 100 years following the cessation of exposure to allow the persons born at the end of the exposure period to experience their full potential life spans. This means that we set the STOP parameter to 2130, or 60 (exposure duration) + 100 (upper reasonable limit on human life span) + 1970 (year the process was initiated) and add the $ delimiter. Then we enter the LPLAT (lifetime plateau) parameter in the ADJUST subcommand to substitute the lifetime plateau period for the default 30-year plateau for all nonleukemic cancers in the model and again use the delimiter $. To determine the number of cancers that would occur at the prevailing rates for lung tumors in 1970, we read in the default data set because this data set includes deaths for lung cancers.

2.4.6 Confidence Intervals: Monte Carlo Projections

We now wish to know not only the expected number of deaths, but also the statistical error associated with this number. For this we must use the RANDOM=n option of the PROJECT command, which causes SPAHR to repeat the projection n times, perturbing the numbers projected in an appro, iately random fashion each time. This procedure is referred to as a Monte Carlo simulation. The means and standard deviations of each item in the projection are then computed and printed out. To do this for n = 100 times for constant exposure as shown in the example in Chapter 2.4.1, we enter

```
DATA ; LIFETAB ;
PROJECT RANDOM=100 STOP=2070 $
ADJUST MODEL=6 REM=0.1 ;
END;
```

Remember that the estimates of the standard deviations produced by this method are themselves random variables, so the precision of the esti. .es is in part a function of the number of randomized repetitions. The RANDOM parameter should always be set in excess of 50 for such purposes.

2.4.7 Sensitivity Analysis

The examples in Chapters 2.4.1-2.4.6 have estimated the effect that various circumstances of exposure will have on a particular population. In this example, however, we are interested in the effect of a single exposure situation on various populations. For this task we want to put data for a number of different populations on the data file and to repeat the same set of commands several times. We would do this in the following way:

```
DO NPOP = 1 TO 10 ;
DATA INPUT=11 FORMAT=2 ;
LIFETAB;
STDATE = DATE + 100 ;
PROJECT STOP = STDATE POPSIZE=1000000 $
   ADJUST MODEL=6 REM=0.1 ;
END ;
END ;
```

The DO statement tells SPAHR that the statements between it and the next END statement are to be repeated 10 times. (If some other number of populations are in the data file, replace the 10 with that other number.) The DATA statement will read in data for a new population each time it is repeated. The INPUT=11 statement means that we are using file unit 11 instead of the default file. Therefore, an additional file unit should be specified in the job control, as shown in an example in Chapter 2.6.1.1. Furthermore, the FORMAT parameter has been set to 2, telling SPAHR that the data file on unit 11 is a fixed-format data file in the Keyfitz standard format. This format is described in the SPAHR User's Guide, Volume IV. The LIFETAB command calculates the lifetable and the age-specific death rates.

Each population in the data file may be associated with a different date. This is true, for example, for the set of sample population data that is distributed with the SPAHR system for test purposes. Because we wish to run each projection for the same length of time (in this case 100 years), we must set the STOP date in the projection to the start date plus 100 years. We do this by defining a SPAHR variable named STDATE as the sum of the predefined variable DATE (which is set by the DATA command to the date associated with the current population) plus 100 years.

The PROJECT command sets the STOP parameter to STDATE, so that the projection will run for 100 years. The POPSIZE parameter insures that all of the test populations start out at exactly the same size, whatever their actual size in the original data. The ADJUST subcommand specifies that the WASH-1400 absolute risk model (MODEL=6) will be used for a constant dose of 0.1 rem beginning in the first year of the projection (USNRC, 1975).

The first END statement indicates the end of the repeated loop. The second END statement is required to end the SPAHR run.

2.4.8 Variable Baseline Rates

In this example we estimate the effects of variable rates of birth and death on the radiation risk projection. We do this by selecting a set of birth and death rates that our assumed population will have at a particular point in time and by defining the period during which the population shifts from its original rates to the new rates. We set up the SPAHR problem as follows:

```
DATA ; LIFETAB ; MULDEC ;
PROJECT STOP=2020 STOPBR=2005 STOPDR=2000 $
BIRTHL 0 0 0 0.00097 0.05923 0.1324 0.1185 0.0594 0.0253
       0.0062 0.0004 $
DEATHL MALE 0.02114 0.00084 0.00047 0.00049 0.00147 0.00199
            0.00169 0.00185 0.00260 0.00420 0.00685 0.01099
            0.01755 0.02709 0.04047 0.05830 0.08696 0.12611
            0.18558 $$
     FEMALE 0.01615 0.00066 0.00032 0.00028 0.00053 0.00066
            0.00073 0.00097 0.00151 0.00232 0.00374 0.00560
            0.00831 0.01223 0.01925 0.03135 0.05351 0.08871
            0.15983 $
ADJUST MODEL=6 START=1980 $
   DOSE LEUKEMIA 20*0.5,10*0.2 $$
        LUNG 30*0.8 $$
        BONE=LEUKEMIA / 2 $$
        STOMACH=BONE $$ PANCREAS = BONE $$ ALIMENRY=BONE $$
        OTHER=BONE ;
END ;
```

We read in the default data file. The PROJECT command, however, has additional parameters. The STOP parameter gives the year in which the projection is to end. The STOPBR parameter indicates the year in which the final birth rates (from array BIRTHL described below) are fully in effect. Prior to this year, the birth rates for each projection interval are calculated by interpolating linearly between the actual birth rates of the population (which were entered in the DATA command and passed by default to PROJECT) and the birth rates given in the BIRTHL array. The STOPDR parameter specifies a parallel procedure for the age-specific death rates fed in through the DEATHL array.

The BIRTHL array, like the BIRTHR array in the data file, is a one-dimensional array of age-specific birth rates. It is terminated with $, so another array or subcommand is expected to follow.

The keyword DEATHL introduces a two-dimensional array with the qualifiers MALE and FEMALE allocating age-specific death rates. These are the death rates toward which the population moves gradually between the start of the projection and the year 2000 (the year assigned to STOPDR) and are the actual rates in effect thereafter. This array is terminated with $ as well, indicating that more of the PROJECT command follows, namely an ADJUST subcommand. This ADJUST specifies the WASH-1400 absolute risk model (USNRC, 1975; MODEL=6) and also specifies a variable sequence of doses for LEUKEMIA and LUNG cancers, 20 years at 0.5 rem followed by 10 years at 0.2 rem for leukemogenic exposure and 30 years at a constant 0.8 rem for lung exposures. We further specify that the rest of the defined cancers will have a dose equal to that assigned to BONE, which in turn is defined to be half of the LEUKEMIA dose. These levels are used in the DOSE array only to illustrate the method by which they were specified. Leukemia and lung doses are entered in the usual way: keyword followed by a space followed by a set of numbers. The other doses, however, are specified as arithmetic expressions. The = sign that follows the keyword tells SPAHR which entry mode is being used. In this example, BONE, STOMACH, ALIMENRY and OTHER are equal to LEUKEMIA divided by 2. The BREAST keyword was not used, because in this example no breast exposure is assumed.

2.5 The Structure of Data Files

The SPAHR program produces analyses of specific populations. A population can be completely characterized for SPAHR by providing the following data:

1) The year associated with the population.

2) The number of people in the population by sex and age group.

3) The number of deaths by sex and age group.

4) The birth rates by age group of mother.

5) The number of deaths by age, sex, and cause of death.

These are referred to as raw demographic data. They are entered into a data file in free format, which means that they can be put anywhere on the card image and on as many card images as needed. It also means that each item must be identified with appropriate keywords and terminated with appropriate delimiters. The keywords are English language mnemonics, and with the possible exception of DDC (which stands for deaths by cause), their interpretations are clear. POP, for example, refers to the living population, DEATHS indicates deaths from all causes combined, and BIRTHR refers to birth rates. The cause-of-death names that follow the DDC keyword are a compromise between the names assigned to these causes in WASH-1400 (USNRC, 1975) and the requirement of the IBM computer for names no longer than 8 characters. These names are also used when referring to the causes of death in the DOSE and COEFS arrays of the ADJUST subcommand, as illustrated in Chapter 2.4.4.

The age groups in SPAHR are defined as follows: 0-1, 1-4, 5-9, 10-14, and so on in 5-year age groups to 85+ for a total of 19 age groups. If more than 19 numbers are placed in an age-specific array, the last one is assumed to be age unknown. All numbers (if any) between the 19th and the next-to-last are assumed to be 5-year age groups terminating in an open-ended group and are therefore added into the 19th group by SPAHR to form the 85+ age group. A comprehensive discussion of SPAHR data files and their interactions with the DATA command is given in Volume IV. This volume should be read carefully after you have become familiar with the basic data set shown in the following example. This example is reproduced from the SPAHR User's Guide, Volume IV, where a detailed description and interpretation of each item may be found.

```
PARMS DATE=1970 $
NAME UNITED STATES (WHITE) 1970 $
POP MALE 1501250 5873083 8633093 9033725 8291270 6940820
   5849792 4925069 4784375 5194497 5257619 4832555 4310921 3647243
   2807974 2107552 1437628 805564 486957 $$
      FEMALE 1433839 5614968 8264333 8647392 8079090 7341007
   5962122 5042368 4936494 5412335 5587023 5169302 4695581 4157467
   3491080 2874531 2114943 1314258 889855 $
DEATHS MALE 31725 4910 4099 4382 12200 13812 9897 9130 12459 21819
   35992 53092 76502 98781 113614 122829 124979 101556 90339 320 $$
      FEMALE 23151 3714 2646 2410 4672 4826 4360 4899 7447 12557
   20873 28920 39009 50841 67187 90091 113145 116567 142201 143 $
BIRTHR 3*0 0.0011 0.0674 0.1506 0.1348 0.0676 0.0287 0.0071 0.0004$
CAUSES LEUKEMIA LUNG STOMACH ALIMENRY PANCREAS BREAST BONE THYROID
   OTHER CANCER ='CANCER'= LEUKEMIA + LUNG + STOMACH +
      ALIMENRY + PANCREAS + BREAST + BONE + THYROID + OTHER $
DDC LEUKEMIA MALE 25 247 344 229 211 155 120 117 153 182 298 368
   535 695 829 941 928 659 318 89 10 1 0 $$
   FEMALE 36 195 283 163 153 117 82 95 127 166 224 300 369 432
      550 687 761 649 348 109 21 2 0 $$
   LUNG FEMALE 1 2 3 2 3 5 13 47 187 410 885 1358 1645 1648 1477
      1256 1093 711 335 95 18 2 1 $$
      MALE 3 2 0 2 7 15 31 100 349 1119 2314 4073 6556 8312 8616
      7359 5136 2417 775 173 20 4 5 $$
   STOMACH FEMALE 0 0 0 0 0 4 5 15 47 83 167 232 375 484 668 823
      985 863 504 145 25 5 0 $$
      MALE 0 0 0 0 3 4 14 24 72 142 266 461 758 1027 1247 1337
         1292 978 450 133 21 0 0 $$
   ALIMENRY FEMALE 7 7 6 6 11 22 40 84 158 372 831 1477 2228 2847
      3714 4379 4607 3728 2080 706 129 11 3 $$
      MALE 7 18 3 2 27 32 51 80 164 403 859 1606 2762 3762 4209
         4431 4167 2908 1433 383 48 6 2 $$
   PANCREAS MALE 0 1 0 0 1 5 8 7 36 106 218 398 571 820 999 1120
      1193 891 504 138 22 1 1 $$
      FEMALE 0 0 0 0 1 3 5 27 78 153 349 657 1014 1314 1506 1430
      1292 770 350 83 12 0 1 $$
   BREAST FEMALE 0 0 0 0 0 12 92 311 680 1408 2525 3181 3657 3360
      3220 2884 2626 1819 997 354 81 9 0 $$
      MALE 6*0 1 1 1 4 12 24 22 25 39 28 36 24 10 2 1 1 0 $$
   BONE FEMALE 2 6 18 54 57 18 21 5 16 18 25 37 65 59 73 79 73 63
      35 18 0 0 $$
   MALE 0 1 14 54 121 54 15 15 14 19 39 54 70 88 106 90 85 68 28 11
      0 0 0 $$
   THYROID FEMALE 0 0 1 0 3 3 2 4 8 7 18 22 44 74 76 125 117 84 44
      16 1 0 0 $$
      MALE 3*0 1 1 3 6 5 6 12 14 29 42 40 51 44 40 32 10 2 3*0 $$
   OTHER FEMALE 31 178 193 191 245 302 425 393 940 1695 3075 4100
      4686 6046 6526 6654 6230 4491 2332 786 7 14 9 $$
      MALE 30 233 347 238 371 601 557 572 771 1358 2312 3621 5374
         7241 8088 8657 8492 3802 1369 188 55 3 1 ;
```

The data in this example were taken either from the U. S. Census for 1970 or the Vital Statistics of the United States for 1970. When entering data into a SPAHR data file, remember that SPAHR can only read the first 72 characters (including the blanks) on each card.

READ THIS IF YOU USE WYLBUR !!!!

The WYLBUR text editor stores files in two ways: compressed and uncompressed (CARD). Unless it is directed to store in CARD format, it will use the compressed format. Unfortunately, most computer programs cannot read compressed format. Consequently, when manipulating the data file using WYLBUR, you must always remember to SAVE the data file using the CARD option!! You need not do this with the command file, because when you RUN the command file, it is decompressed automatically.

2.6 Job Control

This section describes the instructions that must be given to the operating system in order to make SPAHR work properly. As of this writing, SPAHR has been successfully transferred to two computer centers. Two major classes of systems will be discussed here.

The OS batch system was the original IBM 360 operating system developed in the early 1960's. It has undergone several metamorphoses in its history, but the job control language (JCL) commands have remained remarkably consistent throughout this time. It is primarily a batch processing system. The other type of IBM operating system that will be discussed in this section is the CMS (for Conversational Monitoring System), which, as the name implies, is designed for interactive use.

2.6.1 OS Job Control Language

This section is primarily for the user who is not thoroughly familiar with JCL. It assumes the existence of a cataloged procedure, which is a large block of JCL cards that have previously been set up to do most of the job control work. More complete details, including a suggested cataloged procedure, are described in the SPAHR Programmer's Guide (Volume V).

The OS JCL statements needed include (in this order):

1) A JOB card (required in all systems). This tells the system the priority, amount of memory, and amount of time to be allocated to the job. It also tells the system who is paying for the job.

2) A PROCLIB DD card (required on some OS/MVS systems). This tells the job where the cataloged procedure that executes SPAHR is to be found.

On other systems, the proclib is a system file that does not need to be identified explicitly.

3) An EXEC card. This tells the system to execute SPAHR and is also used to pass certain parameters, such as the file name of the default data file, to the cataloged procedure.

4) Other DD (Dataset Definition) cards. These may be needed if files in addition to those defined in the cataloged procedure are needed in the SPAHR program.

5) A SYSIN DD * card. This tells the system that the cards immediately following are the SPAHR command file.

Beyond these general rules, most IBM OS environments have their own set of unique characteristics as far as extra control cards, file naming conventions, required job card parameters, and so forth, are concerned. In the sections that follow we will discuss the specific implementations at two sites where SPAHR has been implemented and is currently operational.

2.6.1.1 <u>OS/MVT Argonne National Laboratory</u>

The examples shown below are all based upon the implementation at the central computer facility at Argonne National Laboratory (ANL).

A SPAHR job has the following general appearance (words in lowercase letters indicate items that the user must define in his own program):

```
//jobname JOB (Fxxxxx,y,0,z),usrname,REGION=350K
<cua card>
// EXEC SPAHR,DATA='data set name'
//SYSIN DD *
OPTIONS BATCH ;
... other SPAHR command statements ...
END ;
```

The items that must be defined by the user are:

jobname — is a string of 1-8 characters selected to create a unique name for the job.

xxxxx — is your 5-digit badge number.

y — is your estimated number of thousands of printed lines.

z — is your estimated sum of CPU and WAIT time in minutes.

usrname — is your name or some other arbitrary string of uppercase letters.

<cua card> — is a valid Computer Use Authorization (CUA) card.

'data set name' — is the name given to the data file (see Chapter 2.5). It is assumed that this file has already been created and cataloged on the system <u>before</u> you submit your SPAHR job.

<u>Further Notes on Jobs Run at ANL</u>

If you submit the job using either WYLBUR or TSO, you need to insert a //*MAIN ORG=dest card after your CUA card if you want to obtain your printed output elsewhere than at the central computer facility in Building 221.

The PROCLIB DD card mentioned above is not used at ANL. Instead, the SPAHR cataloged procedure is located on one of the system procedure libraries.

The // EXEC SPAHR card tells the computer system to start executing the cataloged procedure. It must be entered with the spaces as shown. Furthermore, there may not be spaces between SPAHR, DATA=, and 'data set name.' The 'data set name' (data file) is set by default to 'B28118.SPAHR.DATA1.' Therefore, entering

```
// EXEC SPAHR
```

is the functional equivalent of entering

```
// EXEC SPAHR,DATA='B28118.SPAHR.DATA1'
```

The file specified in the DATA parameter will always be assigned to file unit number 4. Therefore, all SPAHR DATA commands that reference this data file must either specify INPUT=4 or omit all references to the INPUT parameter.

The OPTIONS BATCH card tells SPAHR that it is operating in batch mode.

The END statement tells SPAHR that the run is ended.

The ... other SPAHR command statements ... that form the remainder of the command file vary with the task that SPAHR is being called upon to perform. Examples of command files are given in Chapter 2.4.

A complete SPAHR job at the ANL center would look like this:

Example OS Batch Job 1

```
//TESTJOB1 JOB (xxxxx,5,0,5),NAME,REGION=350K
<cua card>
//*MAIN ORG=ANLOS.RADS07
// EXEC SPAHR
//SYSIN DD *
OPTIONS BATCH ;
DATA PR1 ; LIFETAB ; MULDEC ;
PROJECT STOP=2070 $
   ADJUST MODEL=6 REM=0.1 ;
END ;
```

A description of this sample job is given in Chapter 2.4.1.

A more complex SPAHR job at the ANL center, using an extra data file and multiple SPAHR tasks, might look like this:

Example OS Batch Job 2

```
//TESTJOB2 JOB (xxxxx,5,0,5),NAME,REGION=350K
<cua card>
//*MAIN ORG=ANLOS.RADS07
// EXEC SPAHR,DATA='B24329.SPAHR.DATA2'
//FT11F001 DD DISP=SHR,DSN=B24329.SPAHR.DATA4
//SYSIN DD *
OPTIONS BATCH ;
* first major task:  project the U.S. Black Population
DATA ; LIFETAB ; MULDEC ;
PROJECT STOP=2070 $
   ADJUST MODEL=6 REM=0.1 ;
   *
   * second major task:  project a set of other populations,
   * the data for which are located on unit 11 in Keyfitz
   * standard format.
   *
DO NPOP = 1 TO 10 ;
   DATA INPUT=11 FORMAT=2 PR1 ;
   LIFETAB ;
   STDATE = DATE + 100 ;
   PROJECT STOP = STDATE POPSIZE=1000000 $
      ADJUST MODEL=6 REM=0.1 ;
   END ;
END ;
```

This extension of Example Job 1 requires an extra data file like the one used in the example in Chapter 2.4.7.

IF YOU USE WYLBUR:

The WYLBUR system at ANL implements a number of useful features regarding job submission. Of greatest interest for the user is the ability of WYLBUR to construct the JOB, CUA, and MAIN cards. Thus for submission through WYLBUR, Example Job 1 could be rewritten as

```
// JOB
// EXEC SPAHR
OPTIONS BATCH ;
DATA PR1 ; LIFETAB ; MULDEC ;
PROJECT STOP=2070 $
   ADJUST MODEL=6 REM=0.1 ;
END ;
```

If you want your job to print out at RADS station 7, you would place the above job in your WYLBUR ACTIVE file and enter the command

```
run dest rads07
```

2.6.1.2 OS/MVS National Institutes of Health, Bethesda

The examples shown below are all based upon implementation at the NIH central computer facility in Bethesda, Maryland.

A SPAHR job has the following general appearance: (Words in lowercase letters must be defined by the user in his own program.)

```
//jobname JOB ...
//PROCLIB DD DISP=SHR,DSN=name of procedure library
// EXEC SPAHR,DATA='data set name'
//SYSIN DD *
OPTIONS BATCH ;
... other SPAHR command statements ...
END ;
```

The jobname is a string of up to 8 characters that is assigned by the user to create a unique name for the job. At the NIH center this should consist of the three assigned user initials followed by some unique group of additional characters. The job control options will depend on the size of the job. A job card of the form

```
//KFE001 JOB (WDC1,280,B),SPAHR
```

will suffice for most jobs.

The //PROCLIB DD card following the job card tells the system where to find the SPAHR cataloged procedure.

The // EXEC SPAHR card tells the computer system to start executing the cataloged procedure. It must be entered with the spaces as shown. Furthermore, there may be no spaces between SPAHR, DATA=, and 'data set name'. The 'data set name' (data file) is set by default to 'WDC1KFE.SPAHR.DATA1'. Therefore, entering

```
// EXEC SPAHR
```

is a functional equivalent of entering

```
// EXEC SPAHR,DATA='WDC1KFE.SPAHR.DATA1'
```

The file specified in the DATA parameter will always be assigned to file unit number 4. Therefore, all SPAHR DATA commands that reference this data file must either specify INPUT=4 or omit all references to the INPUT parameter.

The //SYSIN DD * card tells the computer that all records following that card are SPAHR command statements.

The OPTIONS BATCH card tells SPAHR that it is operating in batch mode.

The END statement tells SPAHR that the run is ended.

The ... other SPAHR command statements ... that form the remainder of the command file vary with the task that SPAHR is being called upon to perform. Examples of command files are discussed in Chapter 2.4.

A complete SPAHR job at the NIH center would look like this:

Example OS Batch Job 3

```
//KFE001 JOB (WDC1,280,B),SPAHR
//PROCLIB DD UNIT=FILE,VOL=SER=FILE29,DISP=SHR,
// DSN=WDC1KFE.PROCLIB
// EXEC SPAHR
//SYSIN DD *
OPTIONS BATCH ;
DATA PR1 ; LIFETAB ; MULDEC ;
PROJECT STOP=2070 $$
   ADJUST MODEL=6 REM=0.1 ;
END ;
```

A description of this sample job is given in Chapter 2.4.1.

A more complex SPAHR job at the NIH center, using an extra data file and multiple SPAHR tasks, might look like this:

Example OS Batch Job 4

```
//KFE002 JOB (WDC1,280,B),SPAHR
//PROCLIB DD UNIT=FILE,VOL=SER=FILE29,DISP=SHR,
// DSN=WDC1KFE.PROCLIB
// EXEC SPAHR,DATA='WDC1KFE.SPAHR.DATA2'
//FT11F001 DD DISP=SHR,DSN=WDC1KFE.SPAHR.DATA4,UNIT=FILE,
// VOL=SER=FILE29
//SYSIN DD *
OPTIONS BATCH ;
DATA ; LIFETAB ; MULDEC ;
PROJECT STOP=2070 $
   ADJUST MODEL=6 REM=0.1 ;
DO NPOP = 1 TO 10 ;
   DATA INPUT=11 FORMAT=2 PR1 ;
   LIFETAB ;
   STDATE = DATE + 100 ;
   PROJECT STOP = STDATE POPSIZE=1000000 $
      ADJUST MODEL=6 REM=0.1 ;
   END ;
END ;
```

This extension of Example Job 3 requires an extra data file like that found in the example in Chapter 2.4.7.

2.6.2 SPAHR under CMS

We assume that you are logged in to CMS, and further assume the existence of a file named TEST DATA A identical to the data set in Chapter 2.5. We are operating in an interactive system, so we will enter commands at the terminal as we go. Because we have not specified OPTIONS BATCH ;, we will get prompts from SPAHR as needed. In the sample sessions below, lines that are typed in lower-case letters and begin with a period are entered by the user. Lines that do not begin with a period and are printed in uppercase letters are generated by SPAHR. The period at the beginning of the input lines is printed out as a prompt by CMS to tell you that it is ready to receive input. You must end each line typed in at the terminal with a carriage return. Otherwise the computer will not know that you have finished typing.

CMS Example Session 1

```
.spahr * test
<SPAHR>VERSION 3.4

COMMAND-
.data ;
<DATA>UNITED STATES (WHITE) 1970
COMMAND-
.lifetab ;
<LIFE TABLE> EXPECTATION OF LIFE FEMALE 75.616 MALE 67.942
<LIFETAB> PRINTED PAGES 1 TO 1 ON FILE 3
COMMAND-
<muldec>
<MULDEC> CAUSE OF     COHORT DEATHS        YEARS LOST
          DEATH      FEMALE      MALE     FEMALE     MALE
         LEUKEMIA      671.       743.     0.129     0.131
         LUNG         1240.      4895.     0.219     0.677
         STOMACH       721.       898.     0.087     0.103
         ALIMENRY     3499.      2967.     0.459     0.352
         PANCREAS     1061.       779.     0.160     0.085
         BREAST       3040.        25.     0.552     0.003
         BONE           80.        89.     0.017     0.018
         THYROID        82.        35.     0.011     0.005
         OTHER        5756.      5643.     0.970     0.808
         CANCER      16141.     16074.     2.756     2.334
<MULDEC> PRINTED PAGES 2 TO 5 ON FILE 3
COMMAND-
project stop=2070 term $
MORE ?
.adjust model=6 rem=0.1 ;
<PROJECT> ( 0) POP. IN 2070 IS 292544256.
<PROJECT> PRINTED PAGES 6 TO 15 ON "ILE 3
COMMAND-
.end ;
<SPAHR> NORMAL TERMINATION.
```

We initiated the SPAHR run by issuing the spahr * test command at the terminal. The * in this example is a CMS convention that indicates that the file will be input by the user at the terminal. The spahr told the system to execute the EXEC file named SPAHR EXEC. The * was defined in the EXEC file to mean that the command file would be entered in interactive mode directly from the terminal. The word test told the system to attach a file named TEST DATA.

NOTE: Because SPAHR is written in FORTRAN, all CMS disk files it reads must be fixed-length files (RECFM F) with a logical record length of 80 bytes (LRECL 80). Variable length CMS files or those that use one of the compressed formats generally cause problems without any clear indication of the reason.

SPAHR then printed out a line identifying the version number and prompted the user for a command by typing COMMAND-. At this point the user entered a command, in this case a DATA command. SPAHR interpreted the command, read in a population, and printed out the name of the population. Another command prompt was then issued, which was answered with a LIFETAB command. LIFETAB executed as ordered and printed out its log file line by way of confirmation. Because LIFETAB wrote something on the print file, the SPAHR command processor also printed out a log file line telling us which page(s) in the print file are associated with this command. A similar sequence was followed for the MULDEC command. When we entered the PROJECT command, however, the first line terminated with a dollar sign ($). SPAHR recognized from this that we were not yet finished with the command and prompted us to enter more information (MORE ?). When finished with the projection, we entered the END command, and SPAHR returned us to the CMS system. The print file (unit 3) remains behind in the form of a file named SPAHR LISTING A. You may print it out by using the CMS PRINT command or look at it by using the text editor.

NOTE: If you execute SPAHR in this fashion twice in a row, the print file SPAHR LISTING A generated the first time will be overwritten by the one generated the second time around. Plan your sequence of activities accordingly!!

CMS can also run in noninteractive mode. To illustrate this, we create a file named COMFILE COMMAND with instructions similar to those in CMS Example Session 1, as follows:

```
Example CMS File COMFILE COMMAND A

OPTIONS BATCH ;
DATA ;
LIFETAB ;
MULDEC TERM=0 ;
PROJECT STOP=2070 TERM DOSINT=6 $$ ADJUST MODEL=6 REM=0.1 ;
END ;
```

(Notice that we have changed the job slightly. We have suppressed the MULDEC terminal output by specifying TERM=0 in the MULDEC command, while increasing the amount of log file output from the PROJECT command by specifying DOSINT=6.) Now we can execute a SPAHR job with a single command as shown here:

```
CMS Example Session 2

.spahr comfile test
<SPAHR> VERSION 4.1

COMMAND-
DATA ;
<DATA> UNITED STATES (WHITE) 1970
LIFETAB ;
<LIFE TABLE> EXPECTATION OF LIFE FEMALE 75.616 MALE 67.942
<LIFETAB> PRINTED PAGES 1 TO 1 ON FILE 3
MULDEC TERM=0
<MULDEC> PRINTED PAGES 2 TO 5 ON FILE 3
PROJECT STOP=2070 TERM DOSINT=6 $$ ADJUST MODEL=6 REM=0.1 ;

   INTEGRATED DOSE ESTIMATORS

CAUSE          DEATHS        MAN-DOSE       ESTIMATOR
LEUKEMI1       5.274E+04     2.421E+09      2.179E-05
LUNG    1      4.723E+04     2.421E+09      1.951E-05
STOMACH1       1.417E+04     2.421E+09      5.853E-06
ALIMENR1       4723.         2.421E+09      1.951E-06
PANCREA1       4723.         2.421E+09      1.951E-06
BREAST 1       3.852E+04     2.421E+09      1.591E-05
BONE    1      1.037E+04     2.421E+09      4.286E-06
THYROID1       2.075E+04     2.421E+09      8.571E-06
OTHER  1       3.164E+04     2.421E+09      1.307E-05
 EXCESS1       2.249E+05     .0             .0
<PROJECT> ( 0) POP. IN 2070 IS 292544256.
<PROJECT> PRINTED PAGES 6 TO 15 ON FILE 3
END ;
<SPAHR> NORMAL TERMINATION.
```

Notice that SPAHR issued a single COMMAND- prompt line at the beginning and did not echo back the OPTIONS statement. This is because until it processed the OPTIONS statement, it assumed that it was executing interactively. You will notice a similar phenomenon when you run ordinary OS batch jobs.

The SPAHR exec file is self-documenting. If you enter the line

```
.SPAHR ?
```

you will receive a listing of the current options available in the exec file. These typically include methods for directing the print file to a line printer instead of leaving it on disk, for placing the log file on disk instead of printing it out at the terminal, and for various other purposes. The listing will also identify the default data file name. The recommended exec file given in the SPAHR Programmer's Guide will produce the following response:

```
SPAHR fn1 fn2 ( PRINT xxx LOG yyy)

where fn1   is the file name of 'fn1 COMMAND *', which is the SPAHR
            command file.  If a '*' is entered here, command lines will
            be taken directly from the terminal.

      fn2   is the file name for 'fn2 DATA *', which is a SPAHR data
            file that will be allocated to unit 4.  This is set by
            default to 'TEST'.

      xxx   (default DISK) is the disposition of the SPAHR print file
            allocated to unit 3.  It may be one of:

            DISK  - Directs that the print file be placed on disk file
                    'SPAHR LISTING A'.

            PRINT - Directs that the print file be allocated to your
                    CMS virtual printer.

      yyy   (default TERM) is the disposition of the SPAHR log file
            allocated to unit 6.  It may be one of:

            TERM  - Directs that the log file be printed out at the
                    user's terminal.

            DISK  - Directs that the log file be placed on disk file
                    'SPAHR LISTING A'.

            PRINT - Directs that the log file be allocated to your CMS
                    virtual printer.
```

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