Name: ________________________

RISK ASSESSMENT MODULE

INTRODUCTION

In this text, we are interested in project evaluation, particularly in the assessment of a technology-based option, whether it be airport location or infrastructure improvement. We call it technology assessment for short. Depending on whom you ask, technology assessment and its associated techniques have characteristics ranging from the mystiques of an art to the exact calculations of esoteric mathematical techniques. This activity module will help the reader to develop an assessment method that will complement the concepts introduced in Chapters 2 and 5 of the textbook, entitled “Economic methods of analysis,” and “Multicriteria Decision Making” respectively. In Chapter 2, we first discussed Cost-Benefit Analysis. In Chapter 5, we formally discuss evaluation methods based on multiple criteria, going beyond a single, aggregate metric such as cost or benefit.

Technology or project assessment is basically a two-step procedure. The *first* step involves the determination of the short-term effects such as costs and benefits (costs as measured by implementation and design efforts, and benefits as measured by efficiency, productivity, etc.) The *second* step involves the determination of the long-term effects, sometimes called secondary or higher-order effects, on the socioeconomic system.

It is this second step that presents the exceedingly difficult tasks of prediction and anticipation. For example, consider the case of the aerosol-spray-paint cans. When first introduced, their cleanliness and ease-of-use were immediately recognized as benefits. But who would have predicted these same spray cans would in the long run responsible for an increase in cost—witness defaced properties such as New York City's subway trains and stations.

Do not be misled by the already stated two-step procedure of project or technology assessment. It is more gray than black-and-white, more nascent than mature, and sometimes more ad hoc than codified. At the end, however, a decision has to be made regarding the most desirable option or options to follow. This module will begin exploring some of the analytical techniques in such decision-making. This module is divided into two sections. The first section deals with the "nuts and bolts." The second section allows the reader to apply these "nuts and bolts" in several illustrative exercises, ending with an interesting risk-assessment case study.

By the end of this exercise, the reader will have been exposed to:

a) Examples of rare events with high-value consequences
b) Risk analysis using event or decision trees
c) Examples of real-world decision-making.

COST-BENEFIT ANALYSIS

The procedure of cost-benefit analysis consists basically of the following steps:

1) For a set of stated purposes, the alternative projects to be undertaken are identified.
2) All relevant favorable and unfavorable impacts (both at the present and in the short term) on society are identified for each project.
3) Favorable impacts are listed under "benefits," while unfavorable impacts under "costs," and dollar values are assigned to these impacts.
4) The net benefit (total benefit minus total cost) is calculated for each alternate project.
5) A choice between alternatives is made based on their net benefits.

Some comments on steps 4 and 5 are in order: Net benefit is used here instead of a benefit-cost ratio because of the latter's potential for misinterpretation. Suppose there are two projects, A and B. Project A has a total benefit of $500,000 and a total cost of $100,000. The net benefit is: $500,000 – $100,000 = $400,000. The benefit-cost ratio is $500,OOO divided by $100,000 = 5. Project B has total benefit of $50,000 and the total cost of $5,000. The net benefit is $45,000 and the benefit-cost ratio is 10. We see immediately that though project A has the smaller benefit-cost ratio, it has the higher net benefit, which may be more desirable.

Step 5 is the culmination of the decision-making process using cost-benefit analysis. The choice is made based on some *criteria*. The criteria are decision rules. For example, we want to buy a car using the following decision rules: the car must be a current model with price range between $15,000 and $20,000. In this exercise, we will use only one central criterion: *select the alternative that produces the greatest net benefit*. Let us provide an explanation and caution. We picked this criterion to make the illustration simple. However, there are *many* criteria in making decisions. We have decided on a quantitative criterion, but there are other "soft" criteria such as political, social, religious and esthetic. Going back to the car purchasing example, one person's decision rule based on comfort and styling will produce a different choice than another person's decision rule based on fuel economy and safety.

A final word before we begin the illustrative exercises, Estimation of the dollar values of the favorable and unfavorable impacts involve complex economic and mathematical techniques and *subjective criteria* or value judgments. Discussions on these techniques are found in the text; it is beyond the scope of this exercise. We don't have to get involved with them because we are playing a game here—a decision making game. You are the decision maker. You have a staff trained in policy analysis. The staff presents to you monetary benefits and costs; these numbers were calculated with as much objectivity as possible. Based on the various *criteria,* you make the final decision. In our example, we will use one *central criterion*: select the alternative that produces the greatest net benefit.

EXERCISES

Please fill in the blanks. The dollar values represent millions, but the last three digits are not shown for ease of calculation.

Case 1: Use the central criterion to decide.

A new modern electric power plant is proposed. The new plant will cost $500,000. Net savings over the years on energy costs are calculated to be $750,000. The net savings over the years on maintenance costs are calculated to be $150,000. The net benefit is:

$750,000 + $150,000 – (   ) = (   )

Using the central criterion, do you build or not? Please give the reason for your answer.

Case 2: Using the central criterion, choose one of many alternative projects.

Five different types of electric power plants are proposed. Your analyst team gives you the following information:

Plant	Initial cost	Savings on energy	Savings on maintenance	Total benefit	Net benefit
A	500	750	150		
B	700	700	50	750	
C	200	200	275		
D	200	250	100		
E	75	60	540		

Note: All figures are in millions of dollars.

The plant with the largest net benefit is (   ),

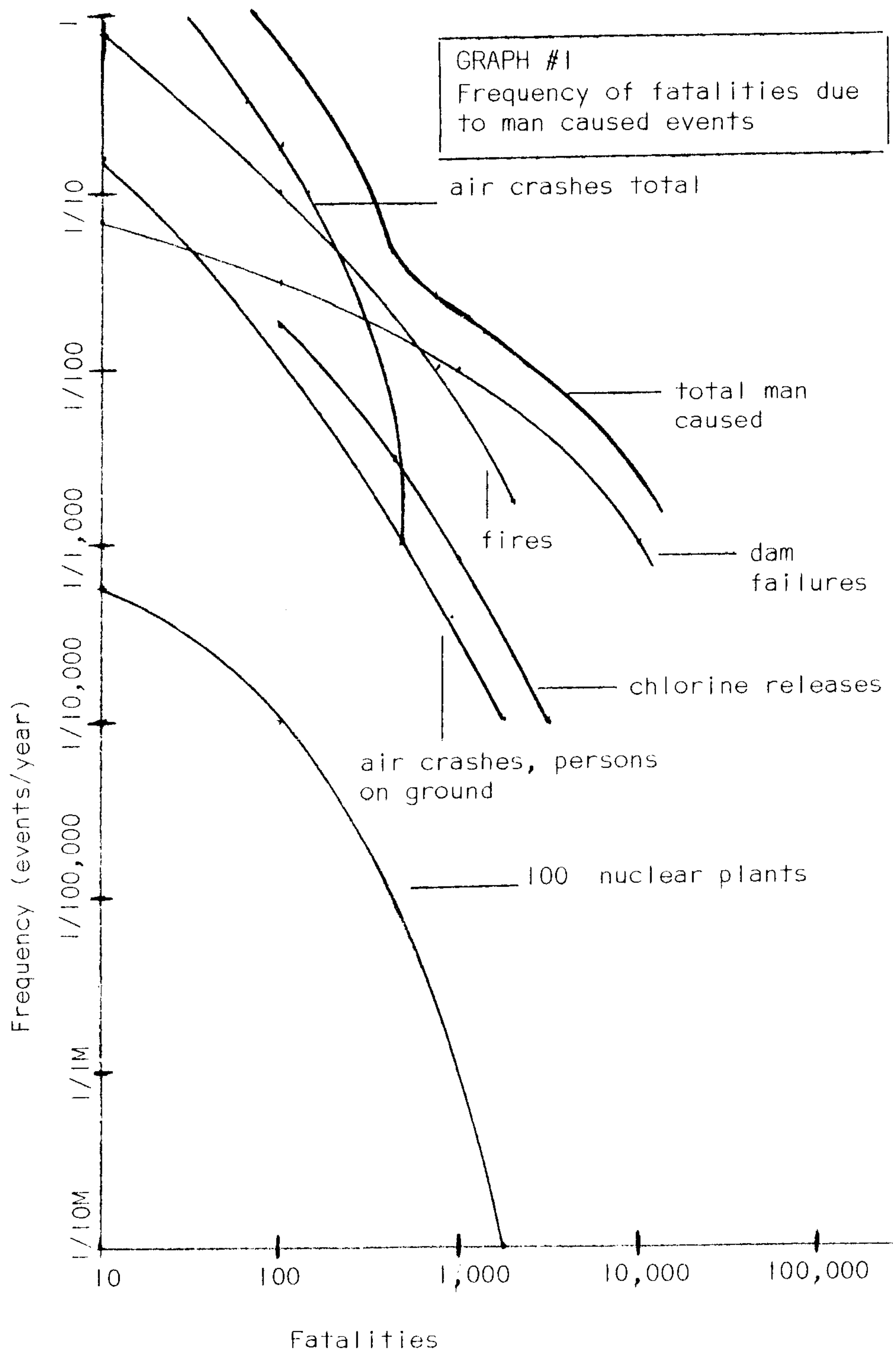
Case 3: Decisions on a number of projects, subject to a constraint on a resource. Suppose we want to build all five power plants at five different locations; however, we have a limited capital budget of one billion dollars. Which plants should we build? One way of approaching this decision-making problem is to rank the plants by their net benefit/initial-cost ratios and to calculate the cumulative initial cost. For example, Plant E has net benefit of $525,000 and initial cost of $75,000. The net benefit/initial-cost ratio is $525,000 divided by $75,000 = 7. Please fill in the missing:

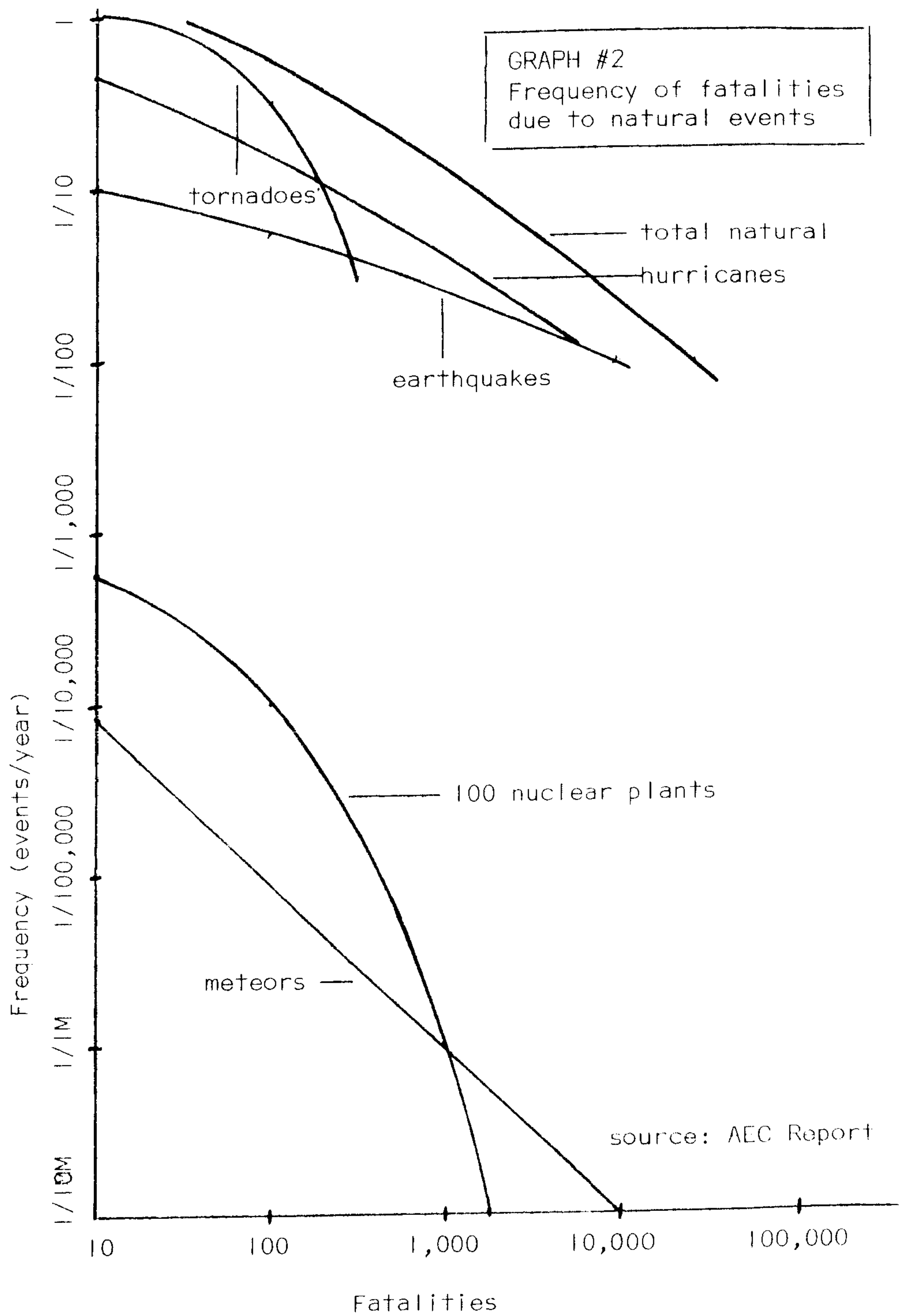
Plant	Initial cost	Net benefit	Net-benefit / Initial-cost	Cumulative initial costs
E	75	525	7.0	75
C	200	275	1.375	275
A	500			
D	200			
B	700		0.071	1,675

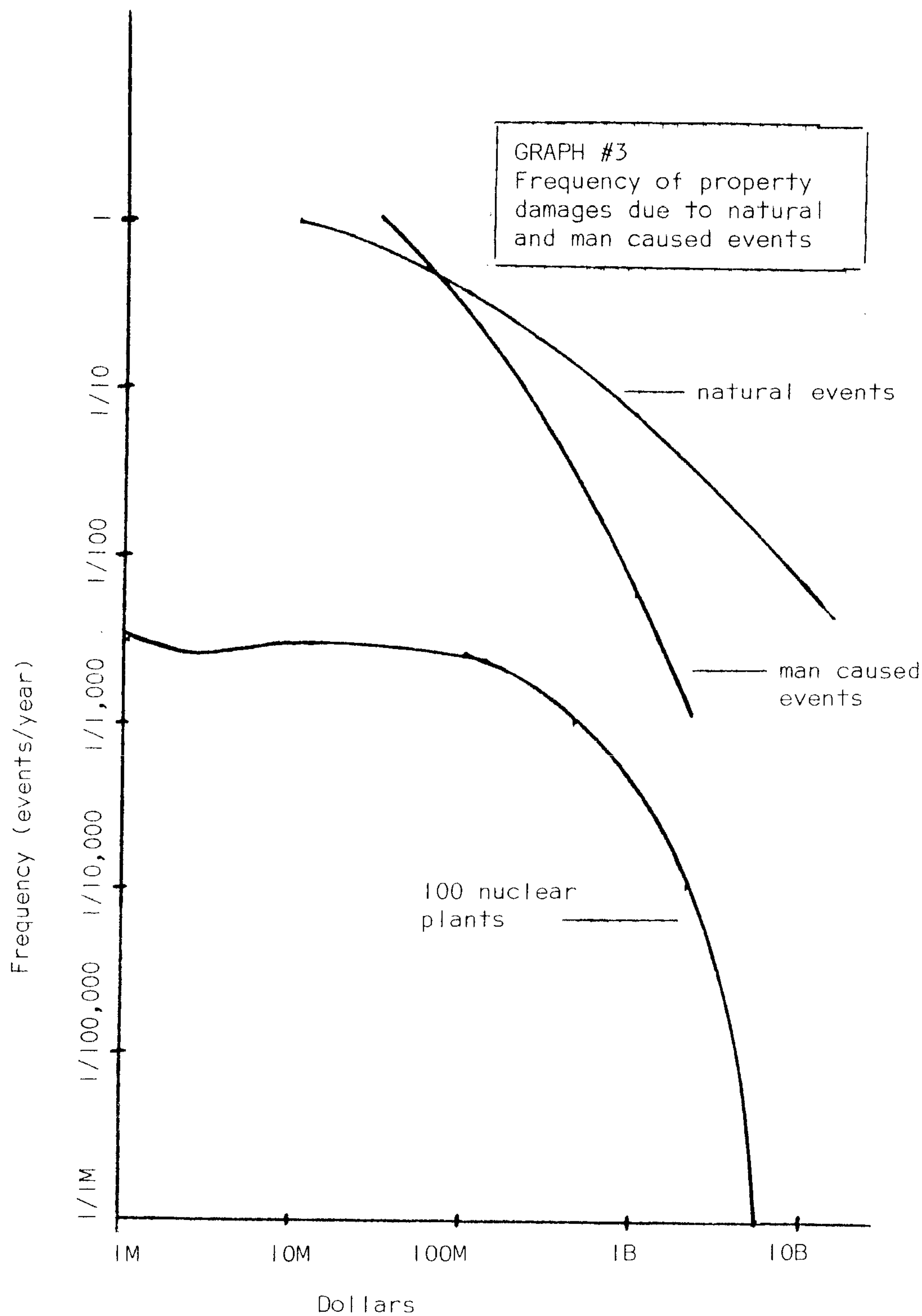
Note: Columns 2, 3, 5 are in millions of dollars.

We propose to build plants E and (_____, _____ ,_____) because their cumulative initial cost is less than one billion dollars, our resource constraint.

The following represents a classic report for nuclear power plant safety: Nuclear Regulatory Commission (1975). “Reactor Safety Study — An Assessment of Accident Risk in U.S. Commercial Nuclear Power Plants.” WASH-1400, NUREG 75/014. From this report, we excerpted three graphs:




GRAPH #2
Frequency of fatalities due to natural events
tornadoes
total natural
hurricanes
earthquakes
100 nuclear plants
meteors
source: AEC Report
Frequency (events/year)
1
1/10
1/100
1/1,000
1/10,000
1/100,000
1/1M
1/10M
10
100
1,000
10,000
100,000
Fatalities


GRAPH #3
Frequency of property damages due to natural and man caused events
natural events
man caused events
100 nuclear plants
Frequency (events/year)
1
1/10
1/100
1/1,000
1/10,000
1/100,000
1/1M
1M
10M
100M
1B
10B
Dollars

Case 4: An assessment of commercial nuclear power plants.

Nuclear power plant safety is basically a *low probability, high risk event*. The methodologies of assessing such an event are highly debated among analysts. This exercise will help you to gain some insights into the methodologies used by the analysts in preparing the report for the U.S. Atomic Energy Commission (AEC). Nuclear plant accidents or risks had to be estimated rather than measured by the staff analysts because there are no historical precedents of such accidents. For example, there were approximately 50 nuclear plants operating by the mid-70's in the U.S. and there had been no accident (until Three-Miles Island in Pennsylvania in 1979). The basic results of this assessment are:
1) The consequences of potential reactor accidents are no larger, and in many cases, are much smaller than those of non-nuclear accidents.
2) The likelihood of reactor accidents is much smaller than many non-nuclear accidents having similar consequences.

Non-nuclear accidents include both man-made and natural events such as dam failures, airplane crashes, earthquakes, explosions and fire, etc. Note that the worst possible scenario of a nuclear accident is called "China Effect," where the nuclear core of a U, S, plant burns itself through the Earth, all the way to China. The basic methodology of the AEC study was to determine the risks of 100 nuclear plants in the U.S. and compare these risks with man-caused and natural events. The results are presented in graphs #1, #2, #3. The graphs are from the AEC report. Incidentally, the AEC report was directed by a MIT nuclear engineering professor that required 50 man-years of work and a budget of three million dollars. Can a benefit-cost analysis be performed on the study itself?

The graphs can easily be read. For example, in Graph #1, a consequence of 100 fatalities has a likelihood of 1/10,000 per year for nuclear plant accidents. In other words, the report claims that with 100 nuclear plants operating in the U.S., there is a 1/10,000 chance per year of a plant accident that would cause 100 fatalities. The procedure is simply to first pick out the desired fatalities, then go vertically up to the appropriate curve (example: nuclear plants, or dam failures, or fires for Graph #1) and then read the matching frequencies on the left. As an exercise in reading the graphs, please complete the following:

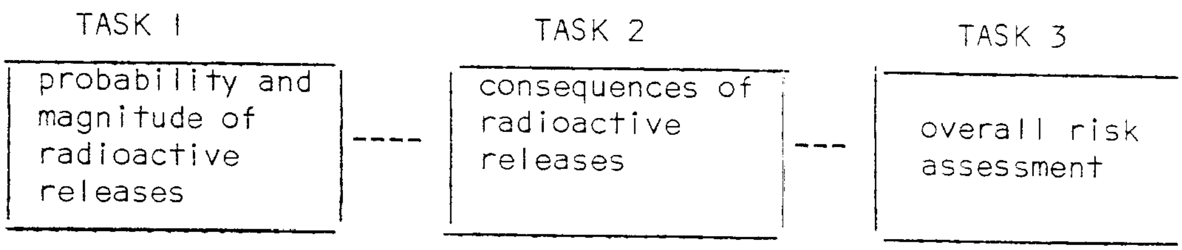
For Graph #1, which is plotted in logarithmic scale:

	Fatalities (consequences)	Frequency (likelihood) per year
Nuclear plants	100	1/10,000
Air crashes, persons on ground	100	1/100
Chlorine releases	100	
Fires	100	

Dam failures	100	
Air crashes, total	100	
Total man-caused	100	

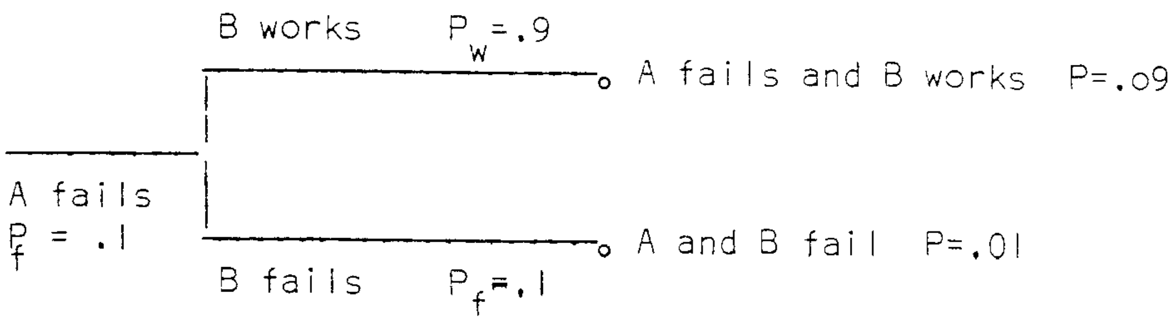
Now double check your log scale readings before proceeding to the next paragraph.

In arriving at the results represented by the graphs, the assessment methodology was divided into three main tasks:



Task 1 involves the studies of potential nuclear-plant accidents and the assignment of probabilities and magnitudes to the potential radioactive releases. The basic methodology was to define accident *sequences* and their associated probabilities of occurrence. The technique used is called *event trees* or *decision tree*. The event tree is a logical method of identifying the possible outcomes of a given event. We will work oui some illustrative examples.

Illustration 1)



Consider just two components of a nuclear plant, the main cooling pipe and the station electric power. Call them A and B respectively. If A fails, then B either works or fails, We can represent this by an event tree. Let P_f and P_w represent respectively the probabilities of failing and working. Note that the probability of a *sure event* is 1 and the probability of a no event is 0; also $P_w + P_f = 1$. This is similar to tossing a coin. P_h, the probability of a head is I/2 and P_t the probability of a tail is ½. Therefore, $P_h + P_f = 1$. The probability of the main cooling pipe, A, fails *and* the station electric power, B, fails is $0.1 \times 0.1 = 0.01$. The probability of the main cooling pipe, A, fails *and* station electric power, B, works is 0.1 × 0.9 =0.09. Here, A is known as the *initiating event*, because we are assuming A fails, and then we work out the *possible sequences*. In this example, there are two sequences: either A fails and B works or A fails and B fails. Note that we have arbitrarily assigned probability of failure as 0.1 and probability of working as 0.9 for ease of calculation.

Illustration 2)

Suppose we consider three components of a nuclear plant, the main cooling pipe, call it A, the station electric power, call it B, and the emergency cooling system, call it C. Using A as the initiating event, please complete the event tree:

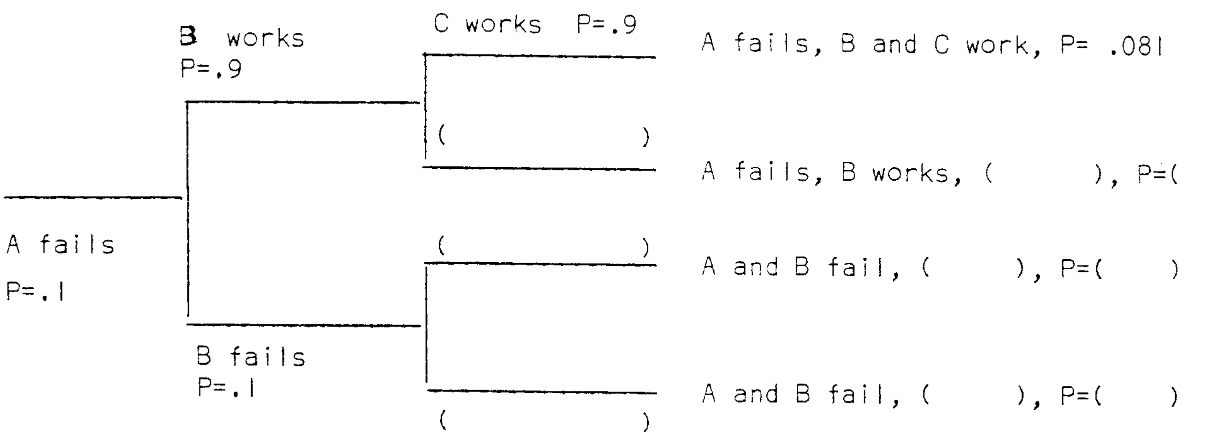


Illustration 3)

Suppose in addition to A, B, C, we consider a 4th component, the containment system, call it D, Please construct an event tree for the 4 components, with event A fails as the initiating event, assuming P(D works) = 0.9. Sketch the event tree on a separate page.

Using the event tree methodology and re1ated techniques, the AEC analysts were able to determine the probability and magnitude of radioactive releases; thus Task I was completed and the analysts proceeded to Task 2, the consequences of radioactive releases. The AEC analysts calculated the consequences of radioactive releases as dependent on

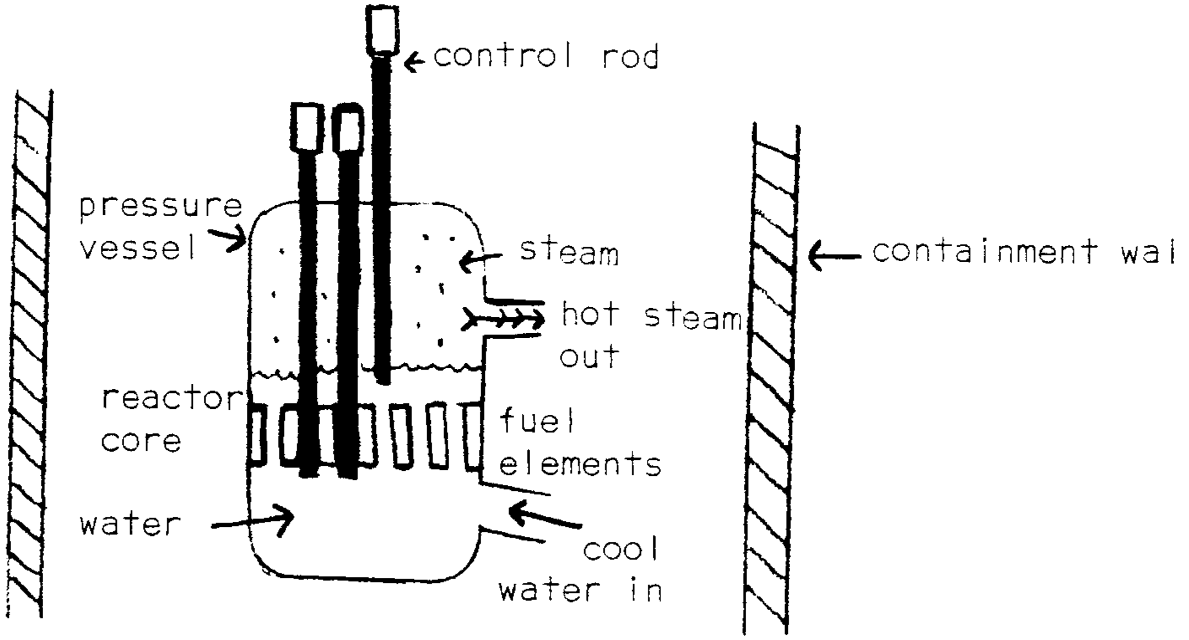
1) dispersion in the environment, atmospheric and fluid dispersions;
2) number of people and property exposed;
3) effects of exposure on people and contamination of property—the health effects.

Again, probability techniques were used in these calculations.

Finally, with Task 2 completed—yielding estimated numerical risks from potential nuclear accidents—the results were compared to various risks of non-nuclear accidents, thus giving some perspective. Task 3 is thus called overall risk assessment, which is represented partially by the three graphs.

A SIMPLE INITIATING EVENT

In the previous three illustrations, we have considered four components of a nuclear plant. In this section we briefly digress to look at a simple engineering scenario, The majority of domestic U.S. reactors are boiling-water reactors.



Consider just two events; the initiating event: the cooling pipe breaks; and the next sequence event: the containment wall. When the pipe breaks, the water leaks out into the containment structure. Inside the pressure vessel, the fuel elements heat up and eventually result in a chemical explosion, scattering the nuclear fuel elements. If the containment structure is sufficiently strong, the scattered nuclear fuel elements are prevented from dispersing into the environment. If the containment structure is not sufficiently strong, the nuclear fuels are scattered by the explosion into the environment. Note that in this type of reactor, the water acts as a *moderator*, a so called nuclear catalyst, The water helps to increase the chain reaction rate. If the water leaks out, the chain reaction is slowed, the fuel elements heat up from this slowed chain reaction because of no cooling wafer; eventually, a thermal explosion and not a nuclear explosion occurs.

OP-ED

The AEC's Reactor Safety Studies has shown the risk of nuclear plant to be smaller than other man-caused or nature-caused accidents, However, this is not the end of the story, Other analysts were critical of the results of the report. They questioned the AEC's methodologies in its analysis. Some criticisms are:
1) The AEC was unlikely to identify all of the important-accident sequences.
2) The AEC did not judge the design and adequacy of the equipment.
3) What is the role of human error and other human behaviors?
4) Structural failures lack large empirical basis.

5) Failure rates are suspect.

Here is another opinion in this nuclear controversy. In fact, a searching examination of performance records and experimental results over the 1980's left one shaken by the potential for disaster. Skepticism had grown among knowledgeable experts about the ability of unproven safety systems to prevent catastrophic accidents because of random failures or human malice. Thousands of unexpected engineering failures, some of which narrowly avoided causing serious releases of radioactive materials (as In the Browns Perry fire of March1976) have placed the quality of design, construction, maintenance, and adequate federal regulation in serious doubt. Maybe a lesson can be learned from the nuclear controversy in the 1980's: there were many experts and many analyses, but as in this case, the decision-making process becomes not a technical process, but more important, a political process