CONGRESS OF THE UNITED STATES
JOINT COMMITTEE ON ATOMIC ENERGY

April 27, 1957

OUTLINE FOR OPEN HEARINGS:

"THE NATURE OF RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN"

May 27 - June 7, 1957

("Oral" denotes topic to be presented before JCAE orally, but may be read from prepared text)

("Insert" denotes topic to be presented by a prepared statement to be inserted in the record but not presented orally)

("Bibliography" denotes topic that should be covered, in addition to the above, by some references to the literature)

Any one or all of these methods of presentation may be indicated for the topics below

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I. Introduction (oral)**

A brief discussion for JCAE orientation, along the following lines:

A. The general nature of radioactivity and radiation

B. Why radioactivity, radiation, and nuclear energy are closely associated

C. Man's relationship to radioactivity and radiation

D. The general nature of the biological effects of radioactivity and radiation

E. The nature of the impact of applying nuclear energy for man's benefit on the health of individuals and on the health and welfare of the population as a whole

F. Some factors that might be considered in deciding whether or not the hazards associated with radiation and radioactivity are worth risking to try to get the benefits expected from applying nuclear energy.

**To be preceded by opening statement by the Hearing Committee Chairman to orient for the record the purpose, scope, and approach of the hearings.

II. Background Information - Radioactivity and Radiation (oral, insert if desired, bibliography if desired)

A. The nature of radioactivity and radiation

B. Mass, energy, and radiation

C. Quantum and corpuscular radiation

1. Energy relationships, the radiation field, definition of roentgen

2. Fundamental particles

D. Reactions of radiation with matter

1. Ionization and energy transfer

a. Definitions, quantitative relationships

b. Specific ionization

c. Chemical and physical changes

2. Penetration, absorption, attenuation, etc. of radiation

a. Definitions, quantitative relationships

3. Induced radioactivity

4. Secondary radiations

E. The phenomenon of radioactive decay

1. Modes of decay, decay chains, etc.

2. Definitions: half-life, average life, decay constant, curie, relation between mass, half-life, and curie for different isotopes

F. Neutron radiation

1. Special characteristics

G. Neutron fission and fission chain reactions

1. Fission, number of neutrons released, energy spectrum, prompt and delayed neutrons, fraction of total

2. Fission energy release, its nature and distribution by type (radiant, kinetic, potential, etc.), primary and secondary fission energy

3. Fission products: yield vs. mass number, physical and chemical properties (particle size, vapor condensability, water solubility, etc.)

   a. Radioactive decay of fission product mixtures, the simple models

   b. The limits of validity of the $t^{-1.2}$ law

H. Nuclear fusion and thermonuclear processes

1. Contrasts between fusion and fission, relationship to binding energy, energy and neutron release per unit weight of material consumed, etc.

2. Products and energy produced, including neutrons, gamma rays, and alpha particles

3. Radioactivity of fusion products

J. Particle accelerators and X-ray machines as sources of radiation and radioactivity

1. The potential radiation hazards associated with accelerators

III. Background Information - Controlled Fission and Fusion Reactions and Their Potential as a Source of Hazard (oral)

A fairly brief discussion for orientation, along the following lines:

A. Controlled fission reactions and nuclear reactors

1. Types and characteristics of neutron chain reactions as employed in reactors

2. Prompt and delayed neutrons and their role in control

3. Other reactor characteristics that lend themselves to application for control

4. Types and characteristics of reactors (from hazards standpoint)

   a. Research, test, power, production

   b. Liquid fuel, solid fuel, homogeneous

5. Sources of radiation and radioactivity hazards from reactor operation, associated chemical processing, and waste disposal, including liquid and gaseous effluents (bibliography, including recent AEC report)

B. Controlled thermonuclear reactions

1. Contrast control problems with fission reactor situation

2. Compare as potential source of radiation and radioactivity hazard

   a. Time schedule for controlled TN development

   b. Possible place in meeting power demand of future

IV. The Natural Occurrence of Radioactivity and Radiation (oral, inserts, and bibliography)

A review and discussion of this topic, citing as appropriate such treatments as appear in the National Academy reports, the U.K. Medical Council report, The World Health Crganization report (Sievert), the Government of India study, the statement by Dr. Warren Weaver (Hearings, Foreign Relations Subcommittee, January 16, 1957), the British Journal of Radiology (29, pp. 409-417, 1956), and Dr. Libby's article in Science

A. Naturally occurring radioactive materials and decay products and radiations

B. Cosmic radiations, composition, characteristics, effect of altitude

C. Spontaneous fission and induced radioactivity

D. Measurement methods and limitations of the data

V. The Production of Radiation and Radioactivity by Detonating Nuclear Weapons (oral, inserts, bibliography)

A. Description of nuclear weapon explosion

1. Heat, blast, radiation, and neutron production in a bomb - rough models for scaling and attenuation

2. Division of radiant energy into

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   a. Prompt gamma and X-rays

   b. Kinetic energy of neutrons - induce activity and cause direct damage

   c. Potential energy which will manifest itself as

      (1) Direct fission product activity

      (2) Induced radioactivity (e.g. C^{14})

B. The effect of weapon type and size from the point of view of fallout produced, both local and delayed

C. The effect of the type of burst on the radiation and radioactivity resulting and on the fallout produced

1. Air bursts

2. Ground or surface bursts

3. Underground bursts

4. Underwater bursts

VI. Atmospheric Transport, Storage, and Removal of Particulate Radioactivity (oral, inserts, bibliography)

A. The types of fallout defined and described, and the conditions under which each type is produced - physical characteristics of particles, cloud formation, condensation, etc.

B. Local fallout

1. The predictability of local fallout

a. Theory of predicting fallout

b. Models of radioactivity within the cloud (both Nevada and PPG), dependence on type and yield of weapon and type of scavenging material

c. Meteorological transport, examples of fallout under different winds, and in massive attacks

d. Uncertainties in model and meteorology

e. Weathering and redeposition of particles

f. Decay

2. Observed patterns of local fallout

a. Patterns of external radiation in Nevada and the PPG

b. Radiation levels as a function of time. Radiation dose to unprotected persons as a function of time of fallout from fallout

c. Fractions of fallout observed locally

d. Factors affecting patterns of fallout

e. Physical, chemical, and radiochemical properties

f. Deposition of toxic materials

C. Intermediate and delayed fallout

1. The production and distribution of fallout in the atmosphere

   a. Dependence on height of burst, yield, type of explosion, and scavenging material

   b. Observed or inferred physical, chemical and radiochemical properties, with special reference to fractionation

   c. Division of material: (local), tropospheric, and stratospheric; determining conditions

2. Transport through and removal from the atmosphere

   a. The stratosphere

      (1) Transport, mixing, possible methods of removal

      (2) Storage time; cumulative world-wide fallout as a function of time; predictions of future fallout from single event; from past weapons tests

      (3) Sources of information; measurements and estimates of radioactivity in stratosphere

   b. The troposphere

      (1) Tropospheric removal processes; storage time

         (a) Precipitation, interception, dry deposition

      (2) Possible regions of unusual removal (fallout) because of meteorology or topography

         (a) Exposure to prevailing winds and the sometimes accompanying effect, orographic rainfall

         (b) Effect of large bodies of water on the distribution of fallout on adjoining land areas

      (3) Meteorological tracking and other discussion of transport

3. Observed deposition on the ground

    a. Geographical distribution; dependence on physical factors

    b. Physical, chemical, and radiochemical properties, with special reference to fractionation

    c. Measurement techniques and limitations of the data

        (1) gummed paper, (2) gauze, (3) pots, collection of rainfall, and (4) soil samples

4. Quantitative predictions of future fallout

    a. From past tests

    b. From future tests

D. Interrelationships between study of fallout and study of meteorology; contributions of fallout studies to meteorology

VII. Local Fallout: The Mechanisms by Which it can Affect Man and the Measures He Can Take to Minimize Exposure (oral, inserts, bibliography)

A. The relative importance of external radiation compared with internal radioactive emitters for the local fallout situation

1. The source of the external radiation

    a. Properties

    b. Decay

2. Internal emitters

    a. Radioiodine, inhalation and ingestion

    b. Other emitters

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B. Shelter and shielding and their effects

C. Other immediate emergency measures that can reduce hazard

D. Dose and dose-rate vs. time

VIII. Delayed Fallout: The Behavior in Geological and Physical Processes and the Mechanisms by which Delayed Fallout Enters into the Biological Processes and Reaches Man (oral, inserts, bibliography)

A. The relative importance of internal emitters compared with external radiation in general for the long-run fallout situation (other than local fallout)

1. Factors of interest; criteria for deciding what radiation and which emitters should be worried about

   a. Yield

   b. Half-life

   c. Physical distribution

   d. Physical, chemical, and radiochemical properties

   e. Uptake by plants from soil

   f. Uptake by animals and man from diet, water, and air

   g. Retention and distribution in man

Note: This topic up to this point is primarily an orientation for the detailed treatment to follow in the remainder of this and the following topics

B. Deposition on and migration in soil and transport by surface waters

1. Dependence on chemical properties

   a. Strontium

   b. Cesium

   c. Plutonium

   d. Rare earths

2. The effect of river basin and ground water flow patterns; the effect of porous substructure such as Idaho lavas; the effect of inland sinks such as Salton Sea

3. Effect of soil type and rock structure

4. Mechanisms for fallout penetration into soil

5. Decay

C. The effect of agricultural practices on the distribution of fallout

1. Possibilities for modifying agricultural practices

2. Possibilities for liming soils

D. The effect of fallout on water supplies for human, agricultural, and industrial use

   1. Possibilities for water treatment

E. Possibilities for modifying present food collection and distribution and handling systems to guard against hazard

F. Behavior in oceans mixing above thermocline, waste disposal techniques and ultimate effects

G. Entry into biological processes including man's food chain

   1. Deposition and retention on surfaces of vegetation

   2. Uptake by vegetation from soil

      a. Characteristics for various plants and various radioactive materials

         (1) Strontium

         (2) Cesium

         (3) Rare earths

         (4) Plutonium

      b. Dependence on soil characteristics

      c. Other factors: decay, biological half-life, effective half-life

   3. Soil-plant discrimination factors

   4. Uptake by marine life and algae

   5. Uptake by animals, animal products, and man

H. Retention and decay in animals and man

   1. Distribution of fallout in body tissues, fluids, milk

      a. Tendencies for localization

         (1) Radioiodine

      b. Dependence of equilibrium values on effective half-life

   2. Discrimination factors (preferential uptake of particular fallout products by particular species of plants, animals, and man); types and how measured or inferred

a. Experiments for determining discrimination factors

b. Numerical values for the various factors

c. Combining values for the individual factors

IX. A Detailed Discussion of the Occurrence of Strontium^{90} and Cesium^{137} in the Atmosphere, Biosphere, and its Uptake and Behavior in Man (oral, inserts, and bibliography) NOTE: Sr^{90} will be outlined in detail below

A. Distribution, storage time, and fallout rate from atmosphere

1. Combination of local and world-wide fallout of Sr^{90} resulting from fractionation; long half-life; stratospheric holdup and mixing; decay

B. Deposition on soil and plants - variations of Sr^{90} level in environment as a result of weapons detonated in a relatively short period of time - from a few months to two or three years

1. Predicted fallout as a function of mixing and time

2. Effects of retention of fallout on surfaces of vegetation

C. The calcium model as a basis for predicting Sr^{90} behavior

1. Similarities and differences in behavior in the biosphere and in man

a. How much do we know about calcium?

b. How much do we know about strontium?

2. Influence of amount of calcium in soil, diet; dilution and discrimination

a. Dependence of occurrence of Sr^{90} in animal and plant life on calcium in soil and diet

b. Practicability of controlling occurrence of Sr^{90} by adding calcium to soil and diet

(1) calcium additives to milk

c. Removal of Sr^{90} from foods JCAE

(1) calcium considerations

D. Deposition in man - variations of Sr^{90} level

1. Function of age and time and location

2. Observed occurrence in man and corresponding observed occurrences in soil and food

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E. Observed occurrence of Sr^{90} in soil, food, and man (brief summary with detailed supplementary insert)

F. Predicted occurrence from weapons tests held prior to 1957

1. Relation to accepted concentration standards (the basis of which is to be discussed later)

<u>NOTE</u>: Cs^{137} will be outlined below

G. Distribution in the physical environment

1. Half-life, stratospheric storage, chemical properties, similarities to potassium

2. Deposition

H. Occurrence in food supplies; probable sources

1. Potassium model for discussing behavior of Cs^{137} in biosphere

J. Observed occurrence in humans - relationship to acceptable concentrations, on basis to be discussed later

K. Predicted occurrence in humans as a result of weapons tests to 1957

X. The Effects of Radiation on Man (oral, inserts, bibliography)

SOMATIC EFFECTS - PATHOLOGY

A. Introduction and orientation: distinction between somatic and genetic effects, between acute effects of high level radiation and long-term effects of low level radiation and radioactivity, between damage <u>per se</u> and the standards developed to protect against damage

B. Early effects of exposure of animals and man to external radiation

1. Gamma and x-radiation: syndrome of radiation sickness

a. Fallout on Marshallese: Rongelap, Uterik

(1) Children recently returned to Marshall Islands

b. Los Alamos incidents

c. Other examples - radium

2. Beta radiation - beta burns

a. Marshallese

b. Other examples - radium

C. Early effects of exposure to internal radiation

D. What are the criteria for picking out the harmful radioelements included in fallout?

   1. How sure are we that all the harmful ones have been picked out

      a. Strontium

      b. Cesium

      c. Rare earths

      d. Plutonium

      e. Iodine

E. Delayed effects due either to single massive doses or to protracted chronic exposure; enumeration of effects of interest; dose dependence

   1. Examples

   2. Relationships between the two types of dosings

F. Mechanisms and responses of man to radiation and radioactivity

   1. Briefly review chain of events

      a. Physical effects

      b. Biochemical and chemical effects

      c. Cellular effects

      d. Effects on whole organism

   2. Processes of physical interaction - physical effects

      a. Significance of alpha, beta, gamma rays, and neutrons in the process

      b. Significance of these rays with regard to penetration and whether introduced <u>within</u> the organism or arising from <u>outside</u>

   3. Chemical and biochemical changes

      a. Direct effect of ionization on vital cell molecules

      b. Indirect effects as a result of ionization of water in the presence of oxygen

      c. Relationship and importance

4. Cellular changes

   a. Range of sensitivity of cells

      (list most sensitive - gonads - to least sensitive - nerve, muscle, bone)

   b. Relate sensitivity of nucleus to cytoplasm

5. Effects on the whole organism

   a. Range of survival dose on mammals (guinea pigs 200 r, rabbits 800 r)

   b. Compare with non-mammalian radiation (virus, for instance, 1,000,000 r)

      (1) Point out species variation and position of man

6. Clinical syndrome in man (nausea and vomiting, hematopoietic depression, epilation, bleeding, etc.)

   a. Special place of hematopoietic response to radiation

   b. Delayed effects

      (1) Reduced longevity

         (a) reduction in life expectancy - validity of concept at low levels of radiation

      (2) Production of leukemia and neoplasms (tumors)

G. Relationships of damage mechanisms to dosages

1. Aplastic anemia, leukemia, and cancer as a result of exposure to radiation

   a. Doses at which observable damage occurs; relationship of probability of damage to dose and dose rate; latent periods; doubling doses; relationship to tissue irradiated

   b. Relative importance of cancer and leukemia under various conditions: external source; exposure of various critical organs to radiation from external and internal sources: lungs, gut, thyroid, skeleton, etc.

GENETIC EFFECTS

H. The nature of genetic effects: evidence, experience, data

J. Relationship between radiation and change in mutation rate

1. Natural mutation rate (2%)

2. Dose necessary to double mutation rate (50 r)

3. Apparent linear non-threshhold relationship between dose and effects

4. Cumulative character of genetic effects

5. Mechanics of introducing and eliminating mutants in genetic pool

K. Predicted increase in mutation rate as a result of postulated increase in radiation levels from fallout

1. Effects on population, as individuals and as a whole

METHODS AND STANDARDS OF RADIATION PROTECTION AS APPLIED TO FALLOUT PROBLEMS

L. Standards for external-radiation effects: the concepts and definitions relating the amount of damage to the amount and kind of radiation causing the damage

1. Definitions and concepts behind the units used for dose rate, cumulative dosage, biological effectiveness, etc.: the r, rad, rem, RBE; ionizing density; linear energy transfer

2. Kinds of radiation and varying conditions of exposure

3. Simplifying assumptions to get practical standards

4. Calculation of dose and dose rate resulting from several kinds of radiation acting together

5. Calculation of dose and dose rate resulting from one or several kinds of radiation acting on different parts of the body

M. Standards for internal-radiation effects

1. Definitions and concepts behind the measurement of internal body burdens and dosages; the models used

a. Maximum permissible concentration

b. Safety factors

(1) Population vs. occupational dose

(2) Young vs. adult

(3) Whole body vs. localized dose

c. Relationships between internal and external radiation dose

2. Calculation of cumulative dose rates and dosages from external radiation and internal radiation of various kinds and under various conditions of exposure

N. Philosophy: the assumptions and models behind the establishment of the standards

1. Historical trends to the present and trends for the future

2. The validity of the assumptions now used in the light of up-to-date knowledge

3. Possibility of hazards resulting from low-level exposure: threshhold considerations

a. Why do we not know whether or not there is a threshhold for each of the various radiation effects of interest? How and when can we improve knowledge on this point?

b. A radiologist may believe that the existence of a threshhold is probable or he may not...what are the pros and cons?

c. What about the acceptability of the currently recommended standards under either belief of (b)?

4. The probable trend of the standards for the future

a. Will new standards have to be developed to cover certain hazards not now adequately protected against?

b. Are the standards defined in such a way that they can be ranked for any given situation so that the proper standard among several can be chosen to give the least likelihood of hazardous exposure? Is there any ambiguity if several standards apply?

c. Do there now exist, or are there likely to be, different standards in use by the U. S. and other governments, or by the U. S. and states and municipalities?

SPECIFIC QUESTIONS FOR DISCUSSION

A. All low level effects are extrapolations from high level effects. How secure is this extrapolation? Discuss its relationship to the non-threshhold character of genetic effects, and to the question of threshhold of bone cancer

B. Are there any distinctions between temporary and permanent (long term) damages, between repairable and irreparable damage?

C. Are there special criteria for small groups of persons as compared with large populations with regard to radiation? Is there a difference between small and large populations? Between large populations and the whole population? Does the distinction apply only to genetic effects?

D. Discuss the known effects of radiation on such aspects of the human being as mental posture, personality, intelligence, other, etc.

E. Are there any chemical reinforcements of body defenses against radiation? What about drugs recently announced as being of possible use for x-ray dosages?

F. What is to be gained or lost by the record-keeping recently proposed for each person covering his lifetime history of radiation dosage?

G. How much radiation and radioactivity was man naturally exposed to and medically exposed to before weapon firing began?

H. Are the dosage standards for individuals and populations adequate for Sr^{90}? What are the factors for genetics, skeleton age, age of individual, health of person, etc.?

J. How adequate is the radium model as a basis for predicting Sr^{90} damage in man?

K. What is the behavior of radioiodine in man from a damage and dosage point of view? What about Cs^{137}, C^{14}, etc.?

L. Is the biological effect of Sr^{90} and its daughter Y^{90} similar or the same as that of external radiation of any sort?

XI. The Impact of the Present State of Affairs: Summary, Interrelationships, and Implications on Policy (oral, inserts, bibliography)

A. In essence, what is the state of our knowledge in the areas discussed as relevant to the "fallout problem"; what do we know about:

1. The amount of radiation and radioactivity released by weapons fired to date

(a) by the U. S.

(b) by others

2. The amount of local and delayed fallout created by these weapons

3. Where this fallout is

(a) how much has decayed

(b) how much has fallen out and where

(c) how much is still up there and where

4. What has happened to the ground fallout that has fallen out

(a) how much got on or in soil and where

(b) how much got on plants

(c) how much got in the ocean

(d) how much got elsewhere

(e) how much of all this has decayed after it fell out

(f) how much has directly affected man as external radiation

(g) how much as internal radiation

5. The mechanisms by which fallout gets distributed in the atmosphere and on the earth

6. The mechanisms by which fallout gets into the biosphere and to man - or gets to man directly

7. The mechanisms by which exposure to fallout leads to damage

8. The amount of damage, if any, that man has so far sustained from fallout

9. The mechanisms and measurement of biological damage from radiation

10. The relationships between damage and dose

B. Using the knowledge now available, how well can one predict - and how would one predict - the following:

1. The amount of fallout still to fall out from weapons already fired

2. Where this fallout will fall out

3. What will happen to it

   (a) how much will decay or otherwise be harmless

   (b) how much will directly effect man as internal or external radiation

   (c) how much damage, if any, man will suffer from it

C. Using the knowledge now available, how much information does one need to postulate concerning the characteristics of future weapon firings (test or war) so that one could predict with a certainty appropriate for policy-making purposes the same sort of information as discussed above for future firings?

1. Is such a prediction possible even assuming unlimited information concerning the firing characteristics? How would it be made?

2. Is a postulated rate of firing (yield per unit time) meaningful? What in principle does "present rate of firing" mean? Is a postulated rate of firing sufficient information by itself for making the sort of prediction named here?

3. How does one take into account such problems as divers sites of firing, firing of weapons whose characteristics are not known, differences in weapon type and burst

4. Are the present criteria for biological damage adequate and are the related measurements adequate so that one could predict with a certainty appropriate to policy-making the future hazard, if any, owing to future weapon firings - even if he could forecast how much fallout there would be and what would happen to it? If the criteria are adequate, how are they put together?

5. If one had before himself a working definition of hazard that was satisfactory from a moral or ethical, social, political, and economic point of view, and if this definition was stated in terms of measureable or observable phenomena in nature (including man), does sufficient information exist so that he could determine, again with a degree of certainty appropriate to policy-making, whether or not a hazardous situation exists now or will exist in the future for various possible circumstances of weapon firings and radioactive fallout? Could he determine the degree of hazard? If their answers are "no", is it possible to state what information is lacking and how it might be obtained?

XII. The Impact of the Present State of Affairs: What Should the Research Program in the Physical, Geological, Biological, and Medical Sciences Be? (oral, inserts, bibliography)

A. Information sources and distribution

1. Do and must private research groups depend on the government, particularly the AEC, for most of their data? To what extent does the depth and breadth of the research program rest on what the government is doing and on what the government is willing to turn over to private research institutions?

2. Is scientific information adequately and promptly distributed and available?

3. To what extent are government classification and other information-withholding mechanisms interfering with the distribution of information to the public and to scientific groups?

4. How much and what kind of data on radioactive fallout remains classified? What justification is given by AEC and other government agencies for continued classification of such information? How much effort does the government make to let it be known that material has been declassified after that action has actually occurred?

5. Is information exchange occurring properly between the U. S. and foreign countries and the U. N.? Is the U. S. adequately represented on international scientific and policy-making groups related to this problem?

B. The Research Program: what is the extent of research on radioactive fallout?

1. Is the AEC presented with a conflict of interest when it is required to act on the one hand as an agent in developing nuclear weapons, and on the other hand as an agent in providing safeguards against weapon hazards? If a conflict does exist, what would be effective ways of removing or at least minimizing it?

2. How much of the research is being done by the government and how much by private research groups under government sponsorships and with government funds?

3. Are there serious soft spots in either the experimental or theoretical aspects of the sciences related to fallout; in particular are there any that limit a thorough understanding of the civilian and military implications of fallout?

4. How well is the research program in balance?

5. Is the general level of the research program adequate in view of the obvious policy implications of fallout in such areas as weapons testing, nuclear weapons bans, civil defense, the military posture?

6. Is the scope of inquiry on fallout problems broad enough so that it is not likely that the U. S. could be surprised by an enemy using the properties of fallout in a manner that we have no notion of how to cope with?

7. Is the atmospheric, biospheric, and medical sampling program adequate? Should more work be done, for example, on determining the normal incidence of bone cancer in areas of various background levels?

8. What, if any, data should be sought after urgently on grounds that it may never again become available assuming tests continue; that is, what virgin data and what check points should be found?

9. Should the U. S. prepare, through cooperative programs, to process fallout samples from all parts of the world?

10. Are federal funds made available for fallout research adequately protected?

11. Is cooperation between government and non-government research adequate?

12. If the program is inadequate, should Congress increase appropriations for fallout research?

C. JCAE information

1. Should the results of fallout research be made available to and reviewed by the JCAE as well as the AEC?

2. Would the creation of a special group of scientists be an effective way of reviewing information and resolving differences of opinion?