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Statement of Arnold B. Joseph, Marine Scientist,
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before the House of Representatives
Merchant Marine & Fisheries Committee
Subcommittee on Oceanography
September 20, 1967

Mr. Chairman, thank you for the opportunity to appear before your subcommittee this morning to review and discuss the Atomic Energy Commission's ocean science and engineering research and development program. Accompanying me this morning is Mr. Stanley Seiken of our Division of Reactor Development and Technology. Mr. Seiken and I represent the technical side of AEC's operations which has intimate contact both with the research and development programs and with the staff of the National Council on Marine Resources and Engineering Development. We are in position to report, first hand, on certain aspects of AEC's marine program which are of interest to this committee.

In his testimony before this subcommittee two years ago, Dr. George M. Kavanagh, then our Deputy Assistant General Manager for Research and Development, briefly outlined the nature and objectives of AEC's oceanographic programs in relation to management's views on certain legislative proposals then pending before your committee. I would like to refer to and expand on Dr. Kavanagh's outline description of our marine programs to indicate the direction taken and progress made since then and their relationship to the Marine Council's goals.

As Dr. Kavanagh outlined, the AEC's marine-related research and development program is in three distinct areas, each of which is directly related to our major mission of development, use and control of atomic energy. We conduct a marine environmental science research program, and an ocean engineering program which are directly related to oceanography; less directly related are our programs in food

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irradiation, water desalination and nuclear ship propulsion. I think it will be readily obvious that these programs are compatible with the goals of the National Marine Council.

The AEC's marine sciences research program is concerned with the effect of radioactivity which has been or may be released to the marine environment. Special attention is given to the means of transport of radioactivity through water and marine life into the human food-chain. This program of studies is somewhat different from the usual single discipline approach to studying ocean problems. This program integrates marine biological studies with associated work in chemical and physical oceanography.

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Of approximately 60 research projects in the marine sciences, about half deal with biological aspects, i.e., either with radioecology--the relationships of marine biota to radioactivity in their environment, or with radiobiology--the biological effects of radioactivity on various marine organisms. The other research projects deal with geochemical aspects or with physical oceanographic aspects usually in a way that links the two sciences. All of them relate to radioactivity in the marine environment. Rather than try to indicate progress on each of these projects, I will highlight selected projects and developments, which we think indicate the quality and scope of the AEC effort.

A substantial effort is supported in studies aimed at understanding, quantitatively, the marine food web. The AEC's interest in such work is intrinsic since, in order to predict the amount of radioactivity that will be taken up by fish in any contamination event, it is necessary to know the possible routes and the stoichiometric relationships (relations between the properties of substances and their composition) of the added, radiochemical elements to those which make up

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the environment. The sequence first requires an understanding of the natural system upon which are superimposed the modifying effects of the contaminants. Food web studies are fundamental not only to the AEC's problem involving radioisotopes, but also to many other problems of understanding, using, and controlling the sea and its resources. For example, an understanding of the food web is necessary for predicting the effects of any other non-nuclear contaminant. Also, if "farming" the sea is to be a reality, it is necessary to know the factors which make for optimum growth of desired species and those which are detrimental. AEC contractors have made significant contributions over the past several years by way of developing instruments, and techniques for identifying and measuring nutrient cycles and trace substances necessary to life in the sea; also to distinguish living from non-living organic substances. An automatic analyzer system has been developed to determine nitrates, phosphates, silicates and chlorophyll automatically and continuously on shipboard while the vessel is underway. This should be a great aid in describing the reasons for the "patchy" distributions of plankton in the sea. DOE ARCHIVES

AEC is also concerned with understanding the life cycles and distributions of fish populations in the sea in order to predict the uptake and possible effects of radioactivity, somatically and genetically, on the species. Toward this end, AEC has financially supported projects with the Bureau of Commercial Fisheries in geographical areas of direct concern to AEC, i.e., off the Columbia River and the aerospace launch pads on both coasts. A spinoff of the Columbia River project has been the discovery of a large hake population residing at several hundred feet. In a related project AEC is supporting work at Scripps Institution of Oceanography which is shedding light, literally and figuratively, on fish and shellfish populations, apparently thriving at depths below 1000 fathoms.

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Seawater, while one of the most abundant substances in the world, is an extremely complex chemical system. Worldwide fallout and other radioactive substances, natural as well as man-made, which find their way to the sea are being employed to unravel some of the ocean's mysteries. The vastness of the sea, coupled with its complex chemistry, makes it extremely difficult to find and measure this radioactivity. Physicists, chemists and radiochemists, with AEC support, have invented instruments and developed techniques to measure extremely low concentrations of radioactivity and related trace elements in sea water. One such development is resulting in what appears to be a new understanding of chemical mixing in the sea. An in situ instrument utilizing KCFC, potassium cobalt ferrocyanide, a chemical sorber which selectively extracts cesium from sea water, is being used to measure vertical profiles of cesium-137--a radioactive fallout element. In its first year of use in the Pacific Ocean, it enabled the detection of narrow-band concentration peaks some distance below the surface. Heretofore, it was assumed that the radiocesium had a more or less uniform gradient from the surface down.

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In addition to this cesium work, the distribution of other fallout and natural radioisotopes is being studies to describe oceanic mixing and circulation processes in the Atlantic basin as well as in the Pacific.

In some work radioisotopes are purposefully introduced, under controlled conditions and in limited amounts to study ecological relationships among plants, animals, water and sediments. As it turns out this is one of the best ways to measure energy flow through the trophic levels and the cycling rate of nutrients into and out of the biota.

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Radioisotopes are also being put to work in instruments for scientific purposes. Many of these instrument developments are being made in cooperation with other government agencies to assist them in their primary missions.

We have several projects in cooperation with the Naval Oceanographic Office. One involves the DWICA--a Deep Water Isotopic Current Analyzer. This device, developed by AEC, measures water current speeds as low as 0.002 knots and as high as 10 knots in water depths to 6000 feet, a significant extension of range over mechanical current meters. The principle of operation is to pulse out a small amount of a short-lived radioisotope such as iodine-131 and measure it a fixed distance away with a radiation detector. NAVOCEANO is assisting in field tests and further development of the device. NAVOCEANO is also conducting field tests of an *in situ* sediment density probe. This device measures density of the ocean floor by measuring back-scattered radiation from a sealed gamma emitting source. Once perfected this unit will greatly speed up the search for ocean sites suitable for construction of offshore oil drilling platforms, bridge piers and emplacement areas for facilities such as the Sea Labs.

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AEC has recently developed a new technique for tagging sands with a short-lived rare gas radioisotope and an instrument to measure its radioactivity *in situ*. This system is being employed in a truly cooperative venture involving five Federal agencies--Department of the Army, Department of the Navy, Department of the Air Force, NASA and AEC--and the State of California. The project deals with measuring littoral drift along the coast of California.

We think we have made significant progress in our oceanographic nuclear power program. In the course of the recent years, the military, scientific and commercial activities and interests of the United States have fostered the establishment of manned and unmanned remote bases and scientific sites in the polar regions

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of the world, in the tropics of Asia and Africa, on the surface of the oceans and very recently in the depths of the oceans all of which require power or energy to operate. Forecasts of future oceanographic power requirements indicate a need for wide ranges in such parameters as power levels, lifetimes, degree of maintenance and attendance. Although the full range of applications has not been defined, it is recognized that a variety of specific systems will be required. The AEC has maintained close liaision with the agencies, institutions and organizations involved in terrestrial and oceanographic activities in order to assess the need and requirements. These discussions have made clear that nuclear power will materially enhance the ability to pursue many potential oceanographic and ocean engineering applications, and may ultimately be a necessity for some applications.

Inherent in the ability to successfully pursue these oceanographic programs is the need for unattended and highly-reliable sources of electrical energy. The intrinsic characteristics of nuclear power systems, particularly their ability to operate under a variety of environmental conditions, justify their development and application not only from a logistic viewpoint but from an economic viewpoint as well. This effort is in keeping with our mission to develop new uses for atomic energy.

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The recent and initial effort of AEC has been directed towards the design and development of the 1st-generation of isotope devices in order to provide proof-of-principle. These first units were designated SNAP-7 (meaning Systems for Nuclear Auxiliary Power) and were powered by strontium-90. These devices have successfully demonstrated the feasibility of long-lived isotope power systems that are capable of unattended and safe operation in a variety of environments hostile to man. This development effort was completed in 1966.

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Six first generation SNAP's, each providing between 7.5 watts and 60 watts of electrical power were placed in service in a variety of oceanic situations as indicated in the following table. (See Figure)

These first generation units have been successful in demonstrating the capability of isotope power sources for long-term unattended operation under severe environmental extremes and without compromise to the health and safety of the general public or to marine life. Of the six prototypes developed and tested, four were unqualified successes. The remaining two experienced failure of electrical components and so were only partially successful.

The success of the SNAP-7 program has had two important results. First, it has demonstrated to the oceanographic community the capabilities of isotope power which in turn has resulted in an increasing demand for oceanographic nuclear power. Secondly, the data and operational experience obtained from these prototypes have indicated where improvements in technology are required to develop a second generation of economically attractive energy sources. We think that isotope power systems may be developed within the technology available in the next two or three years to be economically attractive for many more oceanographic and terrestrial applications. These include undersea navigational aids; ocean-moored buoys; seismological stations; unattended weather stations and military ocean-engineering missions.

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To meet the primary user requirements of long life, demonstrated reliability and cost-effectiveness, the AEC has under way, or planned, research and development programs of wide scope to meet many needs in a timely and technically sound fashion. These possible applications are summarized in the following table. (See Figure)

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SNAP-7 ISOTOPIC POWER SYSTEMS

DESIGNATION	POWER	USE	DATE OF INSTALLATION	STATUS
SNAP-7A	10 watts	U. S. Coast Guard Buoy Curtis Bay, Md.	Jan. 1964	Removed from buoy in FY 1967 for disassembly and examination
SNAP-7B	60 watts	Offshore Oil Platform Gulf of Mexico	Aug. 1966	Performance stable in Chesapeake Bay lighthouse for 2 years. Relocated to Gulf oil platform
SNAP-7C	10 watts	U. S. Navy Weather Station, Antarctica	Feb. 1962	Established record for unattended Antarctica weather station operation. Operation satisfactory.
SNAP-7D	60 watts	U. S. Navy NOMAD Weather Station located in center of Gulf of Mexico	June 1964	System successfully withstood major hurricances. Performance stable.
SNAP-7E	7.5 watts	U. S. Navy Acoustic Beacon Atlantic Ocean, 750 miles east of Jacksonville, Fla.	July 1964	System operation satisfactory.
SNAP-7F	60 watts	Disassembled	--	Operated for 6 months on offshore Gulf oil rig; subsequent power loss. Disassembled and being examined.

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TERRESTRIAL ELECTRIC POWER

APPLICATIONS

Power Level	Microwatts	100 - 1000 Milliwatts	10 - 100 Watts	1 - 10 Kilowatts
Isotope Selection	Pu-238	Pu-238/Sr-90 Pm-147	Sr-90	Co-60/Sr-90 Ce-144
Areas of Application	Cardiac Pacemaker Biomedical Stimulation	Oceanographic Instrumentation Cable Boosters Underwater Weapons	Weather Stations Buoys, Microwave Repeater Stations Oceanographic Seismographs & Instrumentation	Antarctic Support Stations Deep Sea Mining & Exploration Military Communications
Application Criteria	Extended Life Reliability Safety	Costs Ease of Handling Reliability Safety	Costs Extended Life Reliability Safety	Costs Reliability Safety

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As may be seen, this program consists of four elements classified according to power level, isotope selection, area of application and application criteria. The underlying objective is to develop a base of isotope power systems technology that will be applicable to a wide variety of marine and terrestrial applications within discrete power levels. The selection of these power levels is tied to user need that has been identified to date. As future needs become defined, additional program elements will be considered.

Of greatest interest to oceanographic and ocean engineering activities are the three (3) highest power output units. (The development of low power microwatt systems does not appear to have oceanographic application at this time.) AEC is undertaking to design, develop, test and demonstrate isotopic power systems in the 100 - 1000 milliwatt range for specialized military and commercial application including oceanographic instrumentation, undersea cable boosters and undersea weapons activation. Primary objectives are low costs, reliability, safety, compactness and ease of handling. We hope these development programs will culminate in the demonstration of proven prototype systems in areas of application for which they will ultimately find greatest use.

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A major research and development effort in FY 1968 is directed towards the development of a series of compact and highly reliable isotopic power systems in the 10 - 100 watt power range. It is planned that this program will lead toward the development of a second generation of radioisotope power systems that possess the required reliability, operating lifetime and economic advantages necessary to achieve widespread applicability in marine and remote terrestrial environments. This program consists of two specific projects: SNAP-21 and SNAP-23.

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SNAP-21 is a two-phase project to develop a series of compact strontium-90 power systems for deep-sea and ocean-bottom application. The first phase of design and component development effort on the basic 10-watt system has been successfully completed. A second phase systems development and test effort has been under way since July 1966 and will extend through 1970. A series of 10 and 20 watt fueled prototype power systems will be fabricated, assembled and tested under actual environmental conditions to demonstrate attainment of all performance objectives. Compatibility of material, components and design is a major objective.

The SNAP-23 project involves the development of a series of economically-attractive strontium-90 power systems for remote terrestrial application. This project will result in the fabrication of 25, 60 and 100 watt units capable of long-term operation in surface buoys, offshore oil platforms, weather stations and microwave repeater stations.

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In regard to higher powered kilowatt systems, the AEC has become increasingly aware of the potential needs for large isotope plants for Man-in-the-Sea type of activities; for offshore oil exploration; ASW systems; manned and unmanned research stations and the like. Our evaluation and assessment of these potential needs have resulted in AEC initiation of a research and development program directed toward the eventual development of isotope powered systems in the 1 - 10 kw range. The first phase of this program consists of an extensive applications engineering and design study to evaluate alternate energy conversion cycles, plant configurations, isotope fuel requirements, performance requirements, environmental constraints, and economic criteria. In the course of this study, liaison will be conducted with potential users in order to match alternate concepts with broad

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areas of application. The final objective of this initial effort, once the parametric, conceptual design and cost effectiveness studies are completed, is to define and assess the technological advancements required to develop the various power systems that offer greatest promise and to determine the resources and time required to pursue this development. This assessment will form the basis for preparation of detailed development plans relating to the implementation of the required base technology programs. There is little question that the development of an engineering capability in this high power area will require the commitment of extensive funding on the part of the AEC. For this reason, it is mandatory that a very careful assessment be made at some time prior to commitment of these resources.

Specific accomplishments cannot yet be cited for nuclear reactors in oceanographic applications since this program is in its infancy. However, the AEC has provided compact nuclear reactor power sources for a variety of specialized applications, several of which can be expected to furnish valuable technology to this program.

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The AEC's current plans to develop the technology for oceanographic nuclear reactors are presently being formulated. Studies are being conducted to assess the capabilities of appropriate reactor plants and will be followed by careful economic assessment.

As I mentioned at the outset we think all of AEC's marine programs contribute to attainment of the Marine Council's goals. Although ours is a modest program, we think it is an important one not only toward solving problems with radioactivity of primary concern to AEC but also in its multi-disciplinary approach to understanding the real environment. Our contributions in advanced technology stand on their own merits.

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We are cooperating with the Marine Council in every way possible. AEC Chairman Seaborg, as a member, has participated in the meetings of the Council. AEC has partially funded the Marine Council's data management study and has provided manpower to assist in contractor selection and review of work under this contract. Previously, we likewise supported the interagency buoy study. AEC has nominated personnel to serve on five of the Marine Council's committees and panels which were established to review and discuss agency programs related to oceanography. These committees, for the most part, are only getting started this month. We also have arranged to review our marine programs with the National Marine Commission.

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On the whole, we think the Council is doing a remarkably thorough job in stirring things up, in arousing national and international interest in marine developments, in identifying gaps in the total Federal program and in effecting inter-agency contacts on program areas.

Mr. Chairman, that concludes my statement.

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