
THE NUCLEAR DEPARTMENT, ROYAL NAVAL SCHOOL OF MARINE ENGINEERING – PROVISION OF NUCLEAR EDUCATION AND TRAINING TO THE NAVAL NUCLEAR PROPULSION PROGRAMME AND BEYOND

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Abstract. The Nuclear Department at HMS SULTAN provides education, training and research support to the Royal Navy Nuclear Propulsion Programme, as well as a growing number of civilian programmes within the wider British nuclear industry. As an aspiring centre of excellence in nuclear engineering, the Department will play an important role as a repository of nuclear knowledge for the foreseeable future.

1. INTRODUCTION

The Nuclear Department (ND) was formed within HMS SULTAN on 1 April 2001, following the integration of SULTAN's existing Nuclear Training Group and the Department of Nuclear Science and Technology, relocated from the now closed Royal Naval College Greenwich, London in October 1998. Both groups have a distinguished history with officers courses established at Greenwich in 1959 and ratings training established at HMS SULTAN in 1963. This co-location of nuclear systems' training, academics, and research placed, for the first time, the majority of Naval Nuclear Propulsion Programme (NNPP) shore based education and training on the one site. As systems training and education in nuclear reactor technology are integral to most courses offered by the Department, the integration enhanced aspirations to establish a centre of excellence in nuclear engineering for the Royal Navy. As of 2004, the ND functions as part of the Defence College of Electromechanical Engineering (DCEME) located at HMS SULTAN. The ND is also an Associated Institution of the University of Surrey with which it has had an alliance for almost 20 years.

The Department's primary purpose is to provide education and training for all naval and civilian personnel appointed to the NNPP and its secondary purpose is to provide research, consultancy and expert advice in support of the Programme. With over 40 years proven experience in the provision of high quality nuclear education and systems training the ND presently offers over 45 scheduled courses in all key disciplines, from 'cradle to grave', to a broad group of key customers, Figure 1. Five academic courses attract post-graduate qualifications, that are validated by the University of Surrey, whilst the majority of ND's NNPP systems training courses are necessary prerequisites for both officers and ratings in order to qualify as nuclear submarine reactor and propulsion plant watch-keepers.

The ND has a number of facilities and equipments that support education and training. These include high-fidelity (full scope) reactor plant simulators covering all in-service nuclear submarine propulsion plants, modern well-equipped radiation science/protection laboratories, extensive materials and chemistry laboratories, high pressure steam facilities, a bespoke irradiation facility, various maintainer training aids and an educational basic principles simulator (Telewall), capable of mathematically modelling and graphically displaying the load-following and self-regulating characteristics of a Pressurised Water Reactor (PWR) and its associated systems.

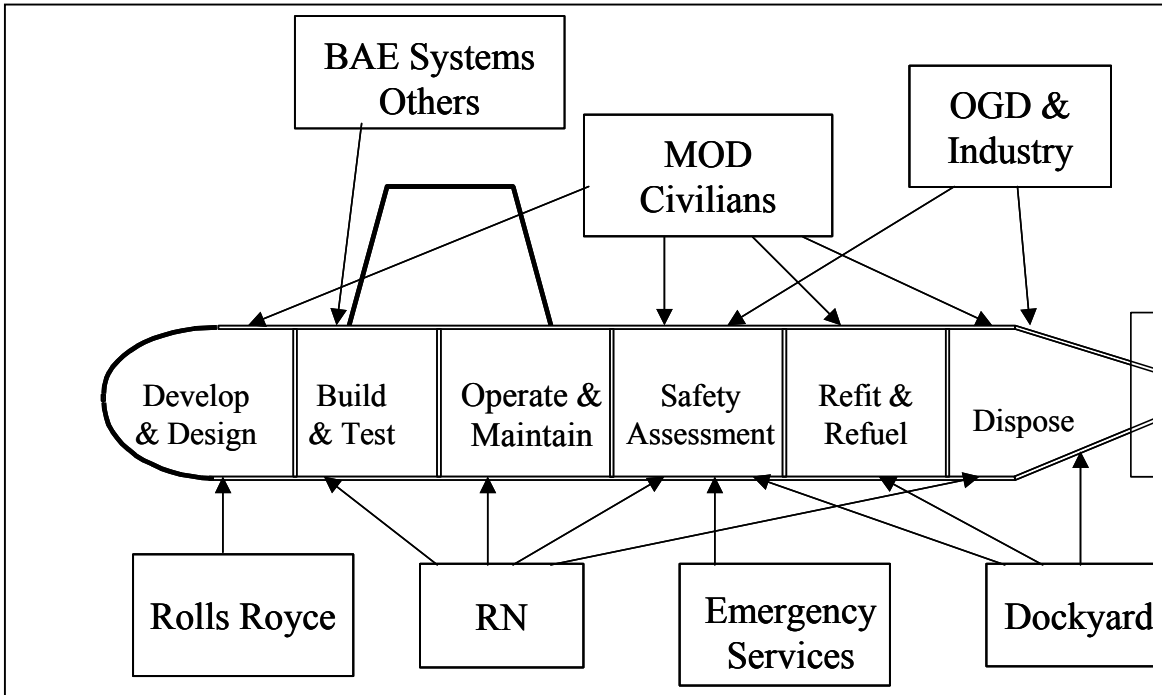


Figure 1. Customer Groups and Tasking

2. ORGANIZATION AND CAPABILITY

The ND structure, Figure 2, comprises five groups under a civilian, Senior Civil Service, Director who holds the chair of Professor of Nuclear Science and Technology and is accountable to the Commandant, DCEME. There are three main education and training groups covering:

- Nuclear and reactor physics and radiation protection;
- Reactor engineering and nuclear safety;
- Nuclear systems and operations.

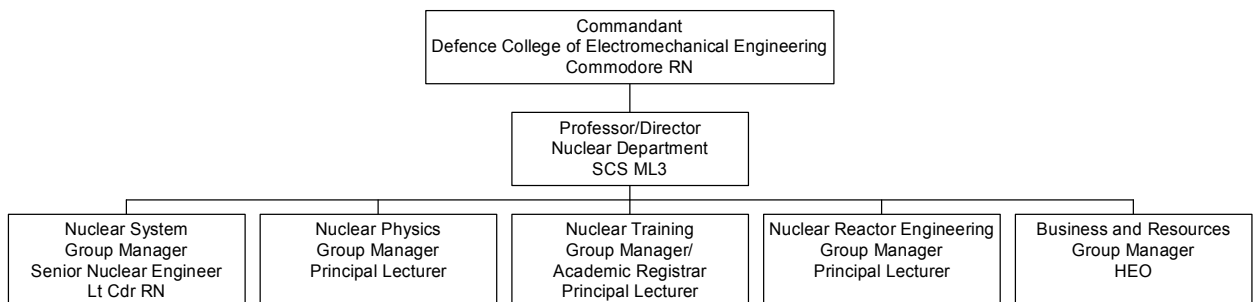


Figure 2. Nuclear Department Structure

In addition, the nuclear training group, led by the academic registrar, provides quality control, computing and information systems support while the business resources group cover administration and business services. A senior Naval Commander (Marine Engineer Submarines) provides the Director with NNPP oversight and advice. The full ND complement is just under 100, of which 35% are uniformed staff, primarily involved in systems and operations training; 25% are civilian professional lecturing staff involved in teaching underlying academic theory; 15% are civilian IT, laboratory and academic/technical support staff; and 25% are civilian training administration, finance and resources support staff.

Table I. Nuclear Department Capability

<i>Education/ Training</i>	<i>Research</i>
Nuclear & Reactor Physics	Accident Consequence
	Analysis
Radiological Protection	Reactor Design
Nuclear & Reactor Safety	Decommissioning
Reactor Engineering	Neutron Metrology
Thermal Hydraulics & Dynamics	Reactor Dynamics
Materials and Chemistry	Materials and Chemistry
Mathematics & Computing	Nuclear Safety
	Management
Systems Engineering & Operator	Basic Principles
Training	Simulation
	Knowledge Management

This grouping is unique in the UK and demonstrates the commitment to meeting the training needs of the submarine flotilla. The capability, shown in Table I, is wide ranging in all essential science and technology disciplines and this co-existence of nuclear subject matter experts is exploited in providing consultancy and research support to the NNPP.

3. ACADEMIC COURSES

It is beyond the scope of this article to describe all academic courses offered by the ND. However, the breadth of academic courses available can be encompassed by those validated for postgraduate qualification by the University of Surrey; the Nuclear Advanced Course (NAC), the Nuclear Reactor Course (NRC), the Nuclear Radiological Protection Course (NRPC), the Nuclear Dockyard Reactor Chemist Course (NDRC) and the Rolls Royce Nuclear Engineers Course (NEC). The main advanced courses undertaken by Naval Officers are the NAC and NRC, described below.

3.1. Nuclear Advanced Course

The aim of the NAC is to provide postgraduate-level education and training in nuclear technology, safety management and associated disciplines for naval and civilian personnel taking up appointments within the NNPP. The course provides sufficient breadth and depth of knowledge and understanding of nuclear technology which, together with the opportunity to apply this knowledge to real engineering problems. It ensures that personnel acquire and demonstrate a range of professional competences required for senior technical appointments in the fields of nuclear design engineering, nuclear safety management and project management in support of the NNPP. The NAC is a 45-week course and runs over an academic year from August to August. The course is made up of three individually validated modules.

Module 1, of 17 weeks duration, provides a foundation course in nuclear reactor technology. Subjects covered include Nuclear Science, Nuclear Fuel Cycle, Reactor Physics, Radiation Safety, Reactor Chemistry, Materials, Thermal-hydraulics, Reactor Dynamics and Plant Safety Analysis. Students are awarded a Postgraduate Certificate in Nuclear Technology (PgC (NT)) on successful completion of Module 1.

Module 2, of 14 weeks duration, caters for more advanced and specialist topics. Students study four mandatory subjects (Advanced Reactor Physics, Advanced Reactor Engineering, Nuclear Safety Management and Safety Case Development) and a further three specialist topics chosen from 14 optional study units. Students are awarded a Postgraduate Diploma in Nuclear Technology and Safety Management (PgD (NTSM)) on successful completion of Modules 1 and 2.

Module 3, also of 14 weeks duration, is devoted to project work. Students undertake either an individual project or a team-based design study. The project topics, which must be relevant to the NNPP, are proposed by staff within the ND or by external agencies involved in the naval or civil nuclear programme. Students are awarded the MSc in Nuclear Technology and Safety Management (MSc (NTSM)) on successful completion of Modules 1, 2 and 3.

3.2. Nuclear Reactor Course

The prime aim of the NRC is to educate Marine Engineering Officers in preparation for further training to qualify as a nuclear submarine Engineer Officer of the Watch/Day, Nuclear Technical Administrator and Environmental Control Officer. The course is also open to selected NNPP civilians. On successful completion of the NRC, Marine Engineering Officers and their civilian counterparts will have demonstrated sufficient knowledge in nuclear reactor technology and nuclear propulsion engineering so that, with further training, they can take up a wide range of nuclear submarine operational and support posts within the NNPP.

The course is full time and is conducted over 2 terms (26 weeks). The syllabus covers submarine systems, reactor engineering, mathematical methods, numerical analysis, statistics, atomic, nuclear and reactor physics, chemistry, materials, radiation protection, shielding, reactor dynamics and system design. Successful students are awarded the Postgraduate Diploma in Nuclear Reactor Technology (PgD (NRT)) on successful completion of both terms of the NRC that culminates in a research-based project related to the NNPP.

4. OPERATOR TRAINING

4.1. OFFICERS (SYSTEMS ENGINEER AND REACTOR PLANT SUPERVISOR)

Junior Marine Engineering Officers who have completed a relevant engineering or science degree attend the Systems Engineering Management Course (SEMC) at HMS SULTAN. The SEMC training pipeline is 104 weeks and is split into 5 distinct sequential phases. The initial phase/course is a rapid and intensive introduction to naval engineering. It is designed to put the marine engineering slant on to the various engineering or science degrees held by the junior officers. The next step is the Officers Nuclear Operators Course Phase 1 (ONOC1). This is a 7-week course, which introduces submarine systems and operations, with an emphasis on secondary systems, basic health physics and outline reactor operation. Following ONOC1 these officers will join a nuclear submarine for a 6 month Initial Sea Qualification (ISQ) period in order to qualify as a Main Machinery Space Operator, Electrical Panel Operator and as a Submarine Officer.

Following ISQ, these officers return to ND for the 26-week NRC, designed to educate rather than train, as outlined above. Following NRC the officers undertake the 10-week ONOC Phase 2 (ONOC2), which concentrates on primary systems, instrumentation, operations and the safety philosophy of the nuclear plant. The last 4 weeks of ONOC2 are spent in the high fidelity simulators, learning the subtle science and exacting art of reactor plant supervision. ONOC2 culminates in a formal simulator and oral examination, which determines whether the

student is able to pull together all of his extensive education and training to date and if he possesses the correct mental picture of the nuclear submarine propulsion plant as a whole and its interactions with the rest of the submarine. Successful candidates are then required to go on to complete additional On Job Training (OJT) on a nuclear submarine. Within about 5 months of joining they will normally qualify in all subordinate propulsion watch-keeping positions (e.g. Reactor Panel Operator) and then pass a very rigorous oral and simulator examination before formally qualifying as an Engineer Officer of the Watch on a nuclear submarine, most probably some 130 weeks after commencing their initial SEMC training.

4.2. Artificers (Technician and Specialist Diagnostician)

Submarine streamed Marine Engineering Artificers who have just completed the Marine Engineering Artificers Qualification Course (MEAQC) and gained a Higher National Diploma (HND) will undertake the Nuclear Propulsion Systems Course (NPSC) within the ND, which includes a large proportion of simulator time. Following NPSC they undertake further training at sea, complete a comprehensive task book, understudy qualified personnel and take a series of written and oral examinations in order to qualify as a critical and shutdown nuclear steam raising plant watch-keepers. Between three and six years after completing the NPSC the experienced Artificer returns to the ND for the Nuclear Propulsion Operators Course (NPOC), having qualified at sea as either Electrical Panel Operators or Main Machinery Space watch-keepers. The NPOC lasts for 10 weeks and covers the operation of the nuclear plant in much more detail, including primary and secondary mechanical and electrical systems, plant operations and philosophy and academic subjects such as reactor physics, reactor materials, chemistry and failure studies. Extensive training is carried out in the simulators, with the bulk of training aimed at future qualification at sea as a Reactor Panel Operator. Following the NPOC, Artificers return to sea, complete another task book, understudy qualified personnel and take a series of written and oral examinations in order to qualify as a Reactor Panel Operator or as a Machinery Space Artificer. The last rung of the Artificer's nuclear training ladder is the ND's 18-week Nuclear Propulsion Supervisors Course (NPSupC), which for the select few, occurs anywhere between 4 and 8 years after the NPOC. It is aimed at preparing Chief Petty Officer Marine Engineering Artificers for future qualification as nuclear plant supervisors. The NPSupC covers both theory and practice. Academic subjects include reactor physics, reactor dynamics, chemistry, metallurgy, health physics and failure studies. Significant time is dedicated to reactor engineering and reactor operations and the course ends with an oral board covering every aspect of plant theory and operation. The NPSupC is followed by personnel administration, submarine fire-fighting, technical administration and management courses, on completion of which the Artificer return to sea and qualify as a Nuclear Chief of the Watch.

4.3. Mechanics

The ND teaches the nuclear part of the 6-week Marine Engineering Mechanics Initial Career Course (Submarine). The course includes an introduction to a 'conceptual' submarine, a reasonably detailed overview of electrical and mechanical plant operations and elementary academics including basic atomic/nuclear physics and health physics. On completion of this course the Marine Engineering Mechanics are transferred to Devonport or Faslane to take the Submarine Qualifying Course (SMQ) before being sent to sea to obtain their submarine qualification and qualify as basic machinery watch-keepers.

5. OTHER COURSES

In addition to the traditional and often mandated naval operator and civilian educational courses outlined above, ND offers a range of bespoke on site and peripatetic educational and training courses to both the NNPP and the wider UK nuclear industry. These commercial courses are normally delivered by ND staff and are subject to formal contract, which is

administered by Flagship Training Ltd (FTL), the commercial partner of the Naval Recruiting and Training Agency (NRTA). FTL was formed in December 1995 through a joint venture, the present main partners being BAE Systems and Vosper Thornycroft (UK).

6. FACILITIES

6.1. Basic Principles and Full Scope Training Simulators

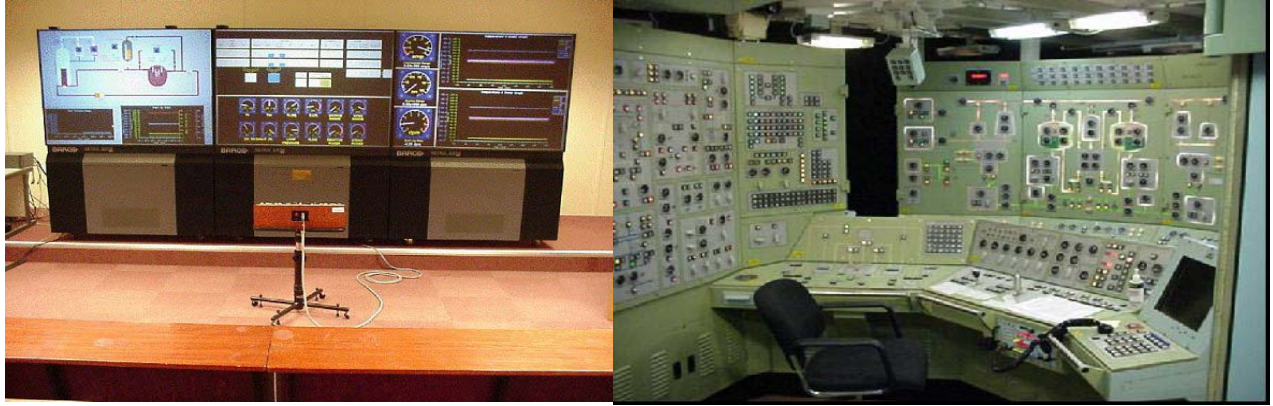


Figure 3. Telewall (left) and Nuclear Submarine High Fidelity Simulator (right).

The ND has an educational (basic principles) simulator called ‘Telewall’, which is primarily designed to support the civilian lecturing staff by providing real time simulation of the behaviour of a nuclear submarine PWR in a classroom environment. It is intended to demonstrate the principles of plant operation and show the students how the plant responds without requiring a full understanding of the equations which govern the response. It is PC based, with a large-screen, back projection, displays that normally show a basic plant diagram, a representation of the onboard instrumentation and a number of transient graphs. The specific instruments shown, and the parameters plotted can be changed by the instructor. The system also includes a console that allows the students to control the plant, enabling them to carry out the required drills. The simulator can be used to model the plant in a wide range of normal and abnormal operating conditions. Plant parameters can be changed, allowing their effect on the response of the plant to be demonstrated. As the simulation is based on a mathematical model, rather than look-up tables, the plant can be taken outside its normal operating envelope and accident scenarios may be simulated. Fault conditions can be placed on the system and the students can learn how to recognise the faults and how to recover from them. The ‘Telewall’ can also be used to show how the plant is protected against abnormal conditions, and the effects of not having this protection. It can model all current cores and can be used to demonstrate the differences between them.

High fidelity nuclear submarine ‘Manoeuvring Room’ simulators (full scope), capable of simulating most of the nuclear steam raising plant in all critical and shut down conditions, form a vital part of ND’s training facilities and are used for both training and examination. These units are able to simulate most known normal, abnormal and emergency conditions and situations that could be encountered on the reactor and propulsion plant and are particularly useful in simulating fault conditions that could not be realistically exercised on a live reactor plant. The ND has three different high fidelity simulators covering all types of in-service nuclear submarine (Swiftsure, Trafalgar and Vanguard Class). Each of the main operator courses spend a great deal of time in the classroom, learning about the reactor from both theoretical and operational perspectives before consolidating their knowledge by conducting hands on practical training in the simulator. Artificers joining the NPSC train as Electrical Panel Operators, while those students on the NPOC train as Reactor Panel Operators.

Simulator technology has changed significantly over the past three decades with a transition from alarms, bells and buzzers in the Swiftsure Class simulator to the LEDs, touch sensitive computer displays, ergonomic design, ‘calming colour scheme’ and electronically synthesised sounds of the modern Vanguard Class simulator. The ND’s high fidelity simulators are expensive and complex training aids, but the training value they add to the courses is priceless. They firmly underpin and consolidate all classroom training and are by far the best place to get it wrong in order to learn how to get it right!

6.2. Teaching and Research Laboratories

Practical demonstrations of radiation and nuclear phenomenon, engineering equipment and steam facilities form an integral part of all courses. In addition, the MSc students obtain practical experience in reactor neutronics using either the Consort research reactor at Imperial College, London or the Neptune zero energy reactor at Rolls Royce, Derby.



Figure 4. A selection of laboratory facilities

The ND has a bespoke Irradiation Facility used primarily for low and high dose-rate irradiation and instrument calibration and operated by ND Staff for teaching and research purposes. The major equipments within the facility are a 14 MeV (D-T) Neutron Generator, 225kV X-ray source and a Pantatron cobalt/caesium assembly. The facility, which has remote operation capability and incorporates extensive safety systems, is also fitted out with instrument calibration jigs and a variety of radiation metrology equipment.

Each of the major academic and training courses within ND will spend some time in the two main radiation science/protection teaching laboratories, which are also used for staff and student research purposes. Related facilities include high and low activity source stores, with a range of sealed and unsealed radioactive sources and an extensive range of radiation monitors, the majority of which are the same as those used by the Submarine Flotilla. Practical instruction includes primary coolant drills, ways of shielding against radiation, and methods of preventing radioactive contamination. To assist in this type of teaching the

laboratories are fitted out with simulated submarine bulkheads, portable air sampling equipment, hand contamination monitors, contamination simulator and associated monitors. Various fixed and portable detector systems, computer based multi-channel analysers, sample preparation facilities, neutron sources, electronic personal dosimeters and biological phantoms.

Materials and Chemistry form an important part of the theoretical and practical training requirements of Officers, Artificers and Mechanics destined for the NNPP, in particular potential material failure mechanisms and the need for careful water chemistry control of both primary and secondary systems. ND's materials/radiochemistry teaching laboratories and facilities, which are also used for staff and student research purposes, include a scanning electron microscope, spectrometers, spectrophotometers, liquid scintillation counters, optical/camera microscopes, ion chromatography devices, hardness and tensile testers and specimen preparation facilities.

Shore steam training is also very important to the Submarine Flotilla, which is now the only user of steam propulsion within the Royal Navy. The ND has the only shore based High Pressure Steam Facility (HPSF) dedicated to training in the UK. It is used for training all ranks of uniformed students, consists of a commercial high-pressure steam boiler, an 'Allens' type steam turbo-alternator, a Braby distiller and other relevant auxiliary machinery and control fittings.

Vanguard Class nuclear submarine reactor instrumentation maintainers were originally sent to Rolls Royce Naval Marine in Derby to train up on its Post Design Support Facility (PDSF), within which were replicas of the onboard instrumentation and equipments. A purpose built Vanguard Maintainer Training Aid (MTA), housing most of this instrumentation, was installed in HMS SULTAN in December 1995. The complete Vanguard training suite has since proved to be an excellent and most valuable training facility. In addition to the Vanguard MTA, the ND has various other maintainer training aids including submarine high power electrical breakers, air particulate detectors and both Swiftsure and Trafalgar Class reactor instrumentation suites to facilitate maintainer training across the spectrum of submarines classes.

7. CONCLUSIONS

The ND HMS SULTAN is considered to be a 'one-stop' facility, capable of providing a very wide range of nuclear academic, training, research and consultancy services to the NNPP and, increasingly to some parts of the UK's nuclear industry. The Department aspires to excellence in education and training in nuclear power disciplines and in so doing, it contributes to the inculcation of the necessary safety culture required to responsibly design, build, operate, maintain, refit and finally decommission the nuclear fleet. In providing this vital support to the NNPP the ND augments its delivery of education and training with external lecturers from Service and civilian organizations working at the 'coal face', thus balancing academics with practical engineering challenges. The educated and trained strength is therefore totally fit for purpose for the Fleet and organizations that support the NNPP.

This article would not be complete without a quotation from the father of naval nuclear propulsion, Admiral Hyman G. Rickover, USN [1]:

'All organizations and contractors involved in the program had to have technically trained and qualified people. That included design engineers, field representatives, technical auditors and inspectors.

All who made decisions in acquisition, design, operation, maintenance and training, had to have a fundamental understanding of the technology and a commitment to the technical aspects of the job, as well as the determination to see that careful attention was paid to technical details.'

REFERENCES

- [1] RICKOVER H. G., “Principles of the Naval Nuclear Propulsion Programme”, Memorandum to Naval Reactors, 20 August 1979.

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