ABOUT THE AUTHOR

Vice-Admiral Sir Ian McGeoch KCB DSO DSC MPhil was born in Helensburgh, Scotland, in 1914 and was brought up on the Firth of Clyde where 'messing about in boats' became his favourite pastime. A visit of the mighty battlecruiser HMS *Hood* clinched his determination to become a naval officer. In 1933 he joined HMS *Royal Oak*, a Jutland battleship, as a Midshipman. Service in the destroyer *Boadicea* and the cruiser *Devonshire* followed, but in 1937 he began to specialise in submarines. When war came in 1939 he was third hand of HM Submarine *Clyde*. By the end of 1944, McGeoch had become Staff Officer Operations to the admiral commanding the 4th Cruiser Squadron in the British Pacific Fleet, fighting alongside the US Third and Fifth Fleets in the battles leading to the Japanese surrender in Tokyo Bay on 2 September 1945. He returned to Britain early in 1946 after helping with the evacuation of former Allied POWs from Japan. Thereafter he held command and staff appointments culminating in 1964 in his promotion to flag rank. He became successively Admiral President of the Royal Naval College, Greenwich; Flag Officer Submarines (NATO **C**ommander Submarines East Atlantic); and Flag Officer Scotland and Northern Ireland (NATO **C**ommander Northern Atlantic Area). After his retirement in 1970 he gained an MPhil degree at Edinburgh University and from 1972 to 1980 edited *The Naval Review*. He was responsible for the 'War at Sea' sections of General Sir John Hackett's *The Third World War* and *The Third World War: The Untold Story*.

Ian McGeoch married Eleanor Somers Farrie, daughter of the Reverend Canon Hugh Farrie, in 1937. They have two sons and two daughters.

Vice-Admiral Sir Ian McGeoch KCB DSO DSC MPhil submarine career

On 31 August 1936, he began his career in submarines when he took the course at HMS *Dolphin*. It was interrupted in December 1936 owing to injury and resumed on 19 May 1937. In August 1937 he joined HMS *Clyde* at Malta (1st Submarine Flotilla) as Navigator and 3rd Hand, remaining in her until she returned to the UK in January 1940, after wartime deployment to the South Atlantic. Service as Lieutenant in HMS *H43* and HMS *Triumph* was followed by COQC, and command of *H43*, in December 1940. Appointed Spare CO in the 10th Flotilla, Malta, in April 1941 he was taking passage in HMS *Urge* (Lt BP Tompkinson) when she sank the Italian blockade-runner *Franco Martelli* in the Bay of Biscay. Following time in hospital and recuperation after an illness he re-qualified as a CO and was appointed to HMS *P228* building at Chatham, in May 1942. After work-up *P228* joined the 8th Flotilla based on HMS *Maidstone* at Gibraltar in time for Operation Torch in November 1942. In five patrols from there and later from Algiers and Malta, *P228* (named *Splendid* in January 1943) sank six Axis supply ships and an Italian destroyer, torpedoed another destroyer, sank two naval auxiliaries and landed agents in Sardinia.

While on her sixth patrol, *Splendid* was detected by the German-manned, (ex-Greek, British built) destroyer *Hermes*. Owing to excellent sonar conditions the submarine was unable to disengage and was at 300 feet when a third pattern of depth charges caused severe damage and the entry of water aft. As the deep diving depth gauge hit its stop at 500 feet and the boat was down by the stern it was deemed essential to bring her to the surface. As the crew abandoned the boat through the gun tower and conning tower hatches *Hermes* obtained direct hits with her main armament and 18 out of the crew of 48 were killed or mortally wounded. McGeoch was also wounded; his right eye was penetrated by a metal splinter as he left *Splendid* having ensured that no-one remained on board and that the boat would sink before the enemy could board her.

As a POW in Italy McGeoch escaped, but was recaptured, and when Italy surrendered he entered Switzerland, in order to obtain the best possible attention for his damaged eye. This achieved, he made his way via Occupied France to Spain, whence he reached Gibraltar and so returned to the UK.

On completion of the Naval Staff Course he was appointed Staff Officer (Operations) to the Vice Admiral Commanding 4th Cruiser Squadron, British Pacific Fleet and was present in Tokyo Bay at the surrender of Japan. McGeoch’s post-war career included service on the Naval Staff and the command of a frigate HMS *Fernie*, the 4th Submarine Flotilla (Sydney, NSW), the 3rd Submarine Flotilla, and the cruiser HMS *Lion*, becoming Flag Officer Submarines from 1965-67 and, finally, Flag Officer Scotland and Northern Ireland. He retired in 1970.

Awarded the DSO on 29 August 1944; the DSC on 10 October 1944.

He was made CB in the 1966 New Year’s List and KCB on 14 June 1969.

Ian McGeoch is a greatly respected and much-loved submariner, who is affectionately known by the nick-name ‘One-eye McGeoch’.

THE BRITISH POLARIS PROJECT

A STUDY OF

THE BRITISH NAVAL BALLISTIC MISSILE SYSTEM (BNBMS)

ITS ORIGINS, PROCUREMENT AND EFFECT

by

Ian McGeoch

MPhil University of Edinburgh

1975

Contents

PREFACE

I have many debts to acknowledge on completion of this thesis. First, without the warm encouragement and indispensable academic counsel of John Erickson, Professor of Defence Studies, University of Edinburgh, I should never have been able to undertaken, let alone complete, the task. Nor, without the patient and practical support of the University in which it has been my privilege to work, in according post-graduate status to a degree-less retired naval officer, would the continued activity required have been possible.

I am deeply indebted, also, to the many individuals who have spared the time to talk to me about their roles and functions in connection with the British Polaris project. May I apologise to them in advance for any errors, omissions, or misinterpretations in the use which I have made of the information which they gave me. In naming only some of those who have been good enough to contribute to my researches, amongst the many who did so, it is my intention rather to emphasise the authoritativeness of my sources, in a field so deficient in published literature than to imply any distinction in the degree of courtesy and cooperation with which my requests have been met: Admiral of the Fleet the Earl Mountbatten of Burma KG; Vice-Admiral Sir Hugh Mackenzie KCB DSO* DSC; Sir Rowland Baker; Rear-Admiral Levering Smith KBE USN; Rear-Admiral CWH Shepherd CB CBE; Admiral Sir Rae McKaig KCB CBE; Rear-Admiral Peter La Niece CBE; Rear-Admiral WTC Ridley CB OBE; Sir Leonard Redshaw; LNP Lewin Esq CBE; AA Pritchard Esq; and Professor Peter Nailor. The omission from these names of anyone directly concerned with the design and manufacture of the British ‘nuclear device’ which is incorporated in the United States’ Polaris missiles bought by Britain reflects the unsung skills and devotion of those whose work must still remain cloaked by secrecy.

The morale and enthusiasm of one unaccustomed to the rigours of academic life have been sustained by my colleagues in the Defence Studies Unit, Richard Sargent, Kathie Brown and Teresa Fitzherbert, to all of whom my greetings and warmest thanks for all their help. Inevitably last, chronologically, but of immediate consequence to the appearance of this study in final form, comes my tribute to June Wilson, for making tidy sense of many untidy drafts.

Finally, despite the extensive help which I have received in carrying out this research, the responsibility for what I have written is mine. It is my hope that I have been able to record enough about the British Polaris project to provide a starting point for more competent and detailed research into many specific aspects of this great end successful endeavour.

ABSTRACT

This study treats of Britain's involvement during the post Second World War era, in the maintenance of strategic nuclear response A comparison is made between nuclear power and sea power as types of power in the relations between states, and strategic nuclear weapons are identified as instruments of nuclear power', by analogy with warships as 'instruments of sea power'.

A brief summary is given of the evolution of Britain's strategic nuclear force, deriving from her participation in the Manhattan Project, which produced the first atomic bomb, and the struggle to retain, post1945, the power to conduct an independent foreign policy. This led to the decision to adopt Skybolt, an airborne strategic nuclear weapon being developed by the United States, and potentially capable of prolonging by up to a decade the operational life of the British V-bomber force. In December 1962 the United States government announced its intention to abandon Skybolt. Within the month, at talks between the Prime Minister and the President, at Nassau, the United States had agreed to sell Polaris missiles to Britain, in place of Skybolt.

It is shown that immense advances had been made by the United States, particularly in nuclear propulsion for submarines, and in developing solid-fuel rocket motors, leading to the Polaris Fleet Ballistic Missile System. Parallel British progress in nuclear propulsion and weapons is indicated; leading to an estimate of Britain's technical capacity to adopt Polaris immediately the political decision had been made.

The latter part of the thesis is devoted to a description of the manner in which the combined US-UK British Polaris Project was brought into being and managed. The emphasis here is on the factors which appear to have contributed most significantly to the undoubted success, in terms of military procurement, of the British Naval Ballistic Missile System. These features are summarised in the concluding chapter.

INTRODUCTION

The real safeguard today, the true deterrent, is the root knowledge that nuclear war has no victor. **(Ralph E Lapp)**

We live in the nuclear age, ushered in publicly by the bombing of Hiroshima in 1945. In terms of its effect upon the relations between states, nuclear power is a phenomenon of the same order as sea power, which it has displaced from the primacy accorded to it during the preceding centuries, without pressing the analogy too far it is possible to discern aspects of nuclear power, political, military and economic, which reflect the classic analysis of sea power made by AT Mahan.

One of these, in particular, seems to provide a useful frame of reference for the study of the British Polaris project, or to give it its formal designation, the British Naval Ballistic Missile System. Mahan referred to navies as 'the instruments of sea power'. Nuclear weapons and their delivery systems, by analogy, are the instruments of nuclear power. In his illuminating survey of 'the principle conditions affecting the sea power of nations' Mahan listed: 'geographical position, physical conformation, including as connected therewith, natural productions and climate, and extent of territory; number of population, character of the people and character at the government'. If one considers the factors affecting nuclear power, it is evident that only very large, wealthy, highly industrialized, scientifically advanced peoples, having ready access to uranium, and powerful governments, could be in the running as first-order nuclear powers.

The analogy between nuclear power and sea power ends abruptly when comparing the influence which each has had upon history. Sea power both emerged from, and contributed to, man's capacity to use the sea for transport and communication, with sea-fighting as an incidental, if inevitable, consequence of the struggles implicit in the growth and development of nations and colonial empires. Nuclear power, in the equivalent political connotation of the term, is a by-product of mankind's struggle to understand and master his natural environment. Sea power has been, all in all, a civilizing factor, and its instruments held as a manifest utility in the exercise of national power, whether in the operations of distant squadrons acting in support of political interests, in minor campaigns such as the suppression of the slave-trade, or in great wars, when 'The far-off, storm-beaten ships' were always ready to assert command of the sea. Above all, sea power and its instruments not only existed, but could be seen to exist, and measured, as a potential influence in the outcome of political, military and economic rivalries. A squadron of ships-of-the-line or dreadnought battleships being moved from British home waters, say, to the Mediterranean, could directly influence the policies of governments. Unchallenged, such a force threatened both the interruption of sea-borne trade aid and the movements of troops and their supplies by sea. In former times such power could be decisive in determining the policies of governments. If unable, either alone or in alliance, to accept the challenge, submission was the only course. Alternatively, decision by sea-battle might be sought. In terms of strategy, either 'side' might choose to resort to attrition of the enemy's naval forces, until a battle with favourable odds might be brought about and a decisive victory gained, or guerrilla warfare of the sea might be waged upon the enemy's commerce. Complex doctrine regarding the rights of neutrals, and of belligerents, became established. The importance of naval bases in relation to policy and strategy was paramount and demanded territorial conquests, and local defence effort, which otherwise would have been unjustified.

But the threat posed by sea power was not apocalyptic. It might be decisive, but it could not destroy the world. If, as affirmed by Clausewitz ‘war is the continuation of policy by other means’, then, in so far as it is credible, it is the *threat* of nuclear war which is now the continuation, or rather the continuous accompaniment, of policy. The deployment or redeployment of nuclear missiles, however, carries with it a sense of menace, and of potential disaster for which ‘threat’ is an inadequate term. Nuclear power, of which the military dimension consists (with one exception) in the capacity to devastate, or threaten to devastate utterly the hostile homeland, offers us no comparable utility to sea power. It cannot be used either strategically or tactically for attrition of the hostile armed forces, or for decisive battle, without loss of control of the situation; and where the enemy is also nuclear armed, a decisive battle is not to be contemplated; the consequence would be so utterly disastrous as to eliminate any possibility of ultimate advantage. The exception, an important one, is the capability to build, maintain and operate nuclear-powered warships, and especially submarines. This, though a significant factor in the comparison of naval forces, as instruments of sea power, is even more relevant to the military application of strategic nuclear weapons as an aspect of nuclear power. It has helped to ensure the existence of an invulnerable retaliatory strategic nuclear force. This, in turn, has profoundly modified, or perhaps one might say moderated, in the nuclear physical sense, the nature of nuclear strategy. Lord Fisher was fond of saying ‘Strategy governs ships, weapons govern tactics’; the equivalent today might be ‘National security demands nuclear deterrence, nuclear weapons govern strategy’.

The political power and influence conferred by possession of the full range of nuclear capabilities, both military end peaceful, is therefore something remarkably different from that deriving from sea-power. Nuclear power, as a source of energy, may yet make a contribution to civilization, in the broadest sense of’ that word, comparable with that attributable to the development of navigation. But so far, this has not been the case. Its utility for political leverage is of a highly specialized, and dubious, character. Again, though capable of providing an alternative source of energy, when the world’s readily available supply of fossil fuels has been used up, nuclear energy nevertheless creates, in being harnessed, by-products of barely imaginable toxicity and danger. Nor is its cost, in real terms, advantageous. Finally, as an instrument of military force the capacity to inflict, or threaten to inflict, catastrophic damage to life and property, accompanied by lethal and enduring contamination of the atmosphere over areas from a few square miles to hundreds, is, moral aspect apart, of questionable utility, even supposing the absence either of counter-measures or retaliation. Such a situation prevailed when the United States, acting as the dominant partner in the wartime alliance of the United Nations, bombed Hiroshima and Nagasaki, thus influencing the Japanese government to surrender unconditionally in this sole instance of nuclear weapons being used (and they were, of course, of primitive design and extremely modest explosive power by present standards) a government already facing defeat after a prolonged and exhausting war was influenced, by the prospect of swift and total devastation of the homeland, to desist from further fighting. The effect was due to what mounted to a sudden and marked augmentation of the destructive capability of Japan’s enemies. Her government’s will to resist was not merely weakened to the point of accepting defeat, it was completely paralysed.

It is not, perhaps, surprising that the United States, for a short period after 1945, conscious of having checked in its stride the conquering tyranny of the Axis dictatorships, envisioned a ‘Pax Americana’ in which a monopoly of nuclear weapons would play the part of the British navy in the epoch of the ‘Pax Britannica’. But, quite apart from the early erosion of that monopoly by Soviet Russia (which, after all, had borne the brunt of German military might), it quickly became apparent that the analogy between nuclear power and sea power was false. The barely credible threat of apocalyptic destruction proved, in practice, to be no substitute for the power to bring, with near certainty, adequate military force to bear upon complex political situations. ‘We have got the machine gun and they have not’ may not have been a morally impeccable basis for military intervention, but it had a credibility totally absent from ‘we have got the atom bomb and they have not’.

As to Soviet Russia, Great Britain and France, all of which believed themselves to be capable of making their own nuclear weapon systems, each felt, for similar reasons, the strongest compulsion to do so. Not, it would appear, from any carefully calculated intention of enhancing their influence in the world, or even of augmenting their capacity to project power, but as the *only* measure, in the absence of complete nuclear disarmament, capable of providing insurance against the fate of the Japanese government, namely total paralysis of the will to resist.

Not only does the negative, rigid, predominantly deterrent character of nuclear power contrast with the positive, flexible, thrusting nature of sea power, but also the difference between them is evident from quite a different aspect. Because the first application of nuclear physics for military purposes took place during the Second World War, when for Britain and the United States the prospect of the Germans ‘getting there first’ with a uranium bomb was almost too dreadful to contemplate, the secrets of how to design, build, test, store and deliver nuclear weapons were the most closely guarded of all. A tiny group of political leaders, scientists, administrators and military chiefs alone were aware of what was going on. The normal operation of the political process in the Western democracies -responsibility of the Prime Minister and his Cabinet to the electorate through Parliament, and of the President to his people through Congress - was suspended. Despite, or perhaps because of, an awareness that national objectives and interests would have to be completely reassessed in the light of this awful new power for destruction, such international accords as were made reflected a degree of secrecy and ambiguity rarely encountered since the Renaissance, and certainly not between friends and allies. It would be hard to find examples of treaties further removed from the liberal ideal of ‘open agreements openly arrived at’ than the Quebec Agreement of 1943 and the Hyde Park Aide Memoire of 1944.

Indeed the custodians of nuclear secrets, and especially military ones, have felt compelled to reveal them for discussion, not with their own peoples, but only with their ‘opposite numbers’ in other countries. Even where the intuition has been to inform electorates or their representatives, as for example, in the case of the 1958 Amendments to the Atomic Energy Act of 1954, the scientific and technical annexes of the agreement without which it could not be given effect were left to officials, scientists, engineers end military people who were ‘cleared’ for atomic secrets.

If the main spur to secrecy, prior to August 1945, was to keep ahead of the Axis powers, after that it was the growing evidence of ‘cold war’ between ‘the West’ and the Communist empire. The wave of idealism and hope which, in the United States, had envisaged the custodianship of nuclear secrets being handed to the United Nations quickly subsided, and the ‘Truman doctrine’ of confronting Communism to be followed by the Eisenhower-Dulles ‘massive retaliation’ strategy, took its place. Apart from military considerations, the expensively-learned technology associated with the application of nuclear physics both for military and for civil purposes had a high commercial, and therefore security, value. And it is indeed ironic that there lay at the root of the post-war misunderstanding between the United States and Britain, in regard to the continuation of nuclear collaboration in peacetime, the mistaken view that Britain was intent upon gaining commercial advantage from it; in fact, Britain’s primary intention was to provide herself with nuclear weapons and the means to deliver them. It merely seemed an unnecessary duplication of effort to have to do so on her own. For her part, Britain was inclined to feel that the United States wished to have a monopoly, in the West at any rate, of nuclear weapons, which would deprive Britain of much of the former influence in world affairs which she felt she should rightfully retain, having sustained the weight of the war against the dictators on her own for nearly two years.

Nuclear power, therefore, in both military and civil applications, is at once the most talked of, and the least widely understood political phenomenon. In its military form it is the most destructive and the least usable instrument; and its advent has coincided with a revolutionary era of world history. Mankind, deeply divided ideologically, has nevertheless become conscious of the relative smallness if the planet Earth, and the finite and tenuous nature of his life-support system whilst, at the same time he has achieved the astonishing feat of landing on the Moon. Furthermore, the presumed necessity to guard most jealously a nation’s nuclear secrets, whilst seeking simultaneously to deter nuclear enemies, has led, paradoxically, to analysis of each other’s nuclear potential in terms of ‘declaratory policy’ - ‘what they say they can and would do’, and operational policy - ‘what they really could and might do’ - a combination of chess with poker played for unlimited stakes.

It is against the background of nuclear power, in its comprehensive political, military and economic sense, that this study of one of the instruments of nuclear power, namely the British Polaris submarine force, has been carried out. That this weapon system makes use of the sea, for mobility and concealment does link some of the attributes of sea power with those of nuclear power, and to that extent it has a special character. But before Britain came to adopt, and adapt, the United States Polaris Fleet Ballistic Missile System she had invested successively in several other nuclear weapons systems of her own.

The first chapter of this study will be devoted to a brief description of these, as related to the development if British defence and overseas policy, leading first, to participation in the American Skybolt project, and then to the substitution of Polaris for Skybolt. Succeeding chapters will be devoted to a description of the fundamental scientific and technological developments in the United States, which made Polaris possible; of parallel British progress which enabled her to benefit directly from the American achievement; the central issues which determined, both for American and British leaders, the Polaris agreement at Nassau; the way in which the British Polaris project was organised, as a partnership between government and industry; and, finally, a summary of the management and progress of the British Polaris project, from its initiation in December, 1962, until its completion in 1970.

In form, therefore, this is a case study of a major international military procurement venture. It depends for its authority upon evidence obtained from many of those who played key roles in it and the confirmation thus obtained of what actually happened, rather than upon an exhaustive examination of official records, the most important if which, in any case, are not yet available to the public. The extent to which this account confirms, or throws doubt upon, the validity of any theories of international relations whether in terms if general systems or more specific theories; or about the political and governmental process; or about project management, must be decided by the reader.

Case studies of military procurement tend to be written in response either to exasperation with the apparent failure of the system to obviate prodigious waste of resources, as for example *The Politics of Weapons Innovation: the Thor-Jupiter Controversy* by Michael H Armacost (New York, 1969, Columbia University Press), who quotes Dr James R Killian

So far we have not been able, in the definition of the role and missions of the services, to keep pace with evolving weapons systems technology, and as a consequence we lengthen our lead-time, we make more difficult our decision making process, we needlessly increase costs, and we find it difficult to avoid friction and duplication of effort

Thirteen years after Dr Killian made this pronouncement it was disclosed that ten major missile projects, each representing an outlay of more than $l00M, had been cancelled prior to completion. Polaris, evidently, was not one of these; Skybolt was. In technological terms, therefore, Polaris seems to have bean based upon sound, if advanced, thinking and to have had real development potential; and its role must have been sufficiently distinctive, to have avoided serious overlapping with that of other major projects. Was this so?

The other major aspect of military procurement which has provoked critical analysis, in the form of a case study, is the growing evidence that, without the need for any conspiracy, there has grown up in the United States during the past two decades a military-industrial-political complex, a ‘weapons culture’, which threatens to undermine the power of society to control its destiny. In his book *Arms Beyond Doubt* sub-titled ‘The Tyranny of Weapons Technology’ (New York, 1970. Cowles Book Company Inc.), Dr Ralph E. Lapp affirms that:

The American people and Congress have become conditioned to accept technological innovation as essential to progress ... and, in the case of national security, to staying ahead of the Soviets

It is possible to discern in this determination to ‘stay ahead’ of the Soviets the manifestation, in an even more acute form, of that urge to have a navy ‘second to none’ which tended to embitter relations with Imperial Britain half a century ago. This tendency to equate world leadership with national security is exemplified in the testimony that General Earle G Whee1er, chairman of the Joint Chiefs of Staff, gave to the Stennis Subcommittee of the Senate Armed Services Committee in 1968, quoted by Dr Lapp:

Our national security objective is ‘to preserve the United States as a free and independent nation, safeguarding its fundamental values, and to preserve its freedom to pursue its national objectives as the leading world power.’ From this we produce our basic military objective, to deter aggression at any level and, should deterrence fail, to terminate hostilities, in concert with our allies, under conditions of relative advantage while limiting damage to the United States and minimizing damage to the United States and allied interests.

Dr. Lapp’s study, based upon a quarter of a century of close association with the development of nuclear weapons, is far removed from the works of theorists of nuclear strategy. It deploys his working knowledge of the technical possibilities and constraints of nuclear weapons development, and in particular, of the baneful influence upon ‘the balance of terror’ of anti-ballistic missiles. This leads him to analyze the American-Soviet nuclear confrontation in terms mainly of land-based ICBMs with their hardened silos requiring protection, and the far less defensible manned bomber for which the US Air Force seems still to yearn. Of the profoundly stabilizing SLBMs, especially Polaris, Dr Lapp says little, perhaps because it was decided by the US Government to develop ‘Poseidon’, as a vehicle for MIRVs (Multiple Independently targeted Re-entry Vehicles) that would better be able to penetrate the ABM defences that the Soviets might develop. Yet the crucial, and unique, importance of the Polaris armed nuclear powered submarine was, and still is, its capability of remaining concealed whilst posing a retaliatory threat of sufficient proportions and certainty to rule out, in any rational calculation, the possibility, let alone the probability, of the hostile power seeking to establish the capacity to strike, or threaten to strike first. Was the lack of confidence in Polaris justified?

Neither Michael Armacost nor Ralph Lapp includes consideration of the British Polaris project. Indeed, it is salutary for a citizen of the United Kingdom to become aware of the minuscule scale of Britain’ s armaments in comparison with those of the United States today. The present study is not however, concerned with either technological failure or the power of the military-industrial complex. It is an attempt to show how British governments and their officials, both military and civilian, together with scientific advisers, and British industry, succeeded in providing Britain with a Polaris force which was completed and deployed on time; which met the required performance standards; and which cost no more than the sum budgeted over a seven years programme. The method chosen was to give a vertical cross section of the evidence available, from the highest political level down through the naval staff and professional departments to the managers of shipyards and the workers in them. It is hoped that this picture of a programme - for Britain one of the largest ever undertaken - provides a useful insight into the governmental process; into the relationship between political leaders and their official advisers; into the management of large scale projects involving both government and industry; and, not least, of one aspect of the interdependence between Britain and the USA, which, together with the maintenance of an independent strategic nuclear deterrent, has formed the basis of Britain's policy for national security since Suez in 1956.

CHAPTER ONE

Move deterrents out to sea
Where the real estate is free
And they are far away from me

Anon XXth Cent.

It is a paradox of nuclear power that the terrifying potential for material destruction which its instruments have come to possess rules out rational intent to use them, whilst demanding the most rigorous rationality in planning to do so. In the early days of nuclear weapons research and development this was not so. Immediately prior to, and during the Second World War, British, American, French, and Canadian intentions coincided in making every effort to make a nuclear bomb operationally available before ‘ the Nazis’ could do so, and, if successful, to use it if need be with decisive effect. In the event, the war in Europe was over before the A-bomb was ready, and it was used against Japan, duly achieving the ‘decisive effect’ hoped for.

The first operational nuclear weapons were free-falling A-bombs carried by United States B-29 long-range bomber aircraft, which took off from Tinian, near Guam in the Caroline Islands, and flew over 1,000 miles to bomb Hiroshima and Nagasaki on 6 and 9 August 1945, respectively.

Two full and reliable accounts of the formulation of British nuclear arms policy and its application have recently been published. The first, *Britain and Atomic Energy 1939-45* which came out in 1964, as written by Margaret Cowing, Historian and Archivist to the United Kingdom Atomic Energy Authority; the second part of this work, *Independence and Deterrence: Britain and Atomic Energy 1945-52* was published in 1974. The second book, *Nuclear Politics: The British Experience with an Independent Strategic Force 1939-1960* was written by Andrew J Pierre, an American citizen, who from 1962-64, while with the Department of State, dealt with politico-military affairs at the American Embassy in London.

The record shows that, although thought was given to the possible effects of the development of the A-bomb upon Britain’s national objectives and purposes postwar, the main conclusion reached by the celebrated Maud Committee in this regard was: ‘*Even if the war should end before the bombs are ready the effort would not be wasted, except in the unlikely event of complete disarmament, since no nation would care to risk being caught without a weapon of such decisive possibilities.’*

The British decision to take immediate action with the maximum priority on the development of an atomic bomb was taken by Prime Minister and Minister of Defence Winston Churchill, on the advice of the Chiefs of Staff, on 3 September 1941. The Maud Committee had estimated that about two end a half years of R&D would be needed; the cost would be about £5M; the bomb would have a destructive effect equivalent to 1,800 tons of TNT, and would release large amounts of radio-active substance which would make the area where the bomb exploded dangerous for some time.

Not surprisingly, such a weapon seemed to offer the means to achieve, at last, the decisive results which, despite the confident predictions of so many, strategic bombing with conventional HE had failed to bring about, provided the bomb itself was not too large or heavy to be carried operationally by aircraft due to be in service by the end of 1943. The advent of the nuclear weapon need cause no alteration of existing strategic concepts for winning the war. In any case, with so much basic research and development to do, results could not be guaranteed within the stipulated period. But the diversion of resources originally envisaged, both of the highest scientific talent and money, would not prejudice the remainder of the war effort; the scientists were few in number and belonged to disciplines not directly engaged in other wartime R&D; and the money was not enough to make any impact on wartime defence spending. It was a sound decision.

The various strands of policy which, woven together, constitute national security policy, whether or not that term is used, cannot usefully be unraveled in the short space of an introductory chapter concerned with a single element of it, over a period of less than a decade. Nor is it strictly relevant to a study of nuclear weapon system as ‘instruments of nuclear power’ that the continuing debate about strategic theory should be analyzed and assessed here**.** Certainly, in Britain at any rate, the defence policy decisions by which resources have been allocated to nuclear weapons seem generally to have been made long before anyone outside the Cabinet of the day and their immediate professional advisers, political, scientific, military, economic and diplomatic, were aware of what was going on; and before the publication of theoretical discussions of nuclear strategy, which seem to have relied mainly upon given decisions, together with assumptions about what had been assumed by the decision- makers, in order to erect one or other theory of action.

Probably the most important single continuing factor in post-1945 British defence policy has been the acceptance, by both Labour and Conservative governments (although not necessarily by the respective Parliamentary parties) that so long as Britain *could* have an independent (however defined) nuclear deterrent force, she *must* have it. At the same time, a foreign policy of *interdependence* (however defined) has replaced, by force of circumstance, Britain’s former conception of being *primum inter pares* on the world stage.

The other determining factor of nuclear weapon policy has been the gradual recognition that nuclear power demands that national security policy be formulated with equal and simultaneous regard to foreign policy considerations, economic factors, scientific and technological prospects, and military appreciations. Until the Bahamas Conference in December 1962 (Nassau), it seems, nuclear weapons policy was dealt with officially as a part of defence policy, which itself was concerned with the provision of armed force (within the resources allocated, or said to be needed) as an instrument of foreign policy. That is to say, Britain, whilst disposing of a certain nuclear weapon capability, did not act consistently as if she believed that she was a nuclear power. Some significance must be attached, surely, to the absence from the Nassau meetings both of the British Chief of Defence staff (Admiral of the Fleet the Earl Mountbatten of Burma) and his American opposite number, General Maxwell Taylor, Chairman of the US Joint Chiefs of Staff. That this was arranged mutually by the Prime Minister and the President seems highly probable. The exercise of direct political authority over the military and the assumption of direct political responsibility for the operation of the primary military arm in time of peace, is the contemporary interpretation of Clemenceau’s comment that ‘war is too serious a matter to be left to the generals alone’.

The sequence of events by which Britain armed herself with nuclear weapons began with the decision taken by the Defence Sub-committee of the Cabinet in early January 1947, to manufacture a British atomic bomb. The decision was secret. The abrupt ending of Anglo-American nuclear collaboration in 1946 had made the decision almost inevitable. Its implementation seemed to present no insuperable difficulty. Through the Atomic Energy Act of 1946 Parliament had granted the government broad powers to control the use and exploitation of atomic energy. A nuclear research establishment had been built at Harwell, and the production of fissile material in certain factories was planned. But the fact that Britain was producing atomic bombs was kept very quiet; the only public statement about it was skillfully embodied in the answer to a Parliamentary question in May 1948. Not until February 1952, when Winston Churchill announced the plans for testing the first British-made atomic bomb at the Monte Bello Islands, did Parliament and the people become aware that nuclear bombs were being produced in Britain.

In the meantime, NATO had been formed in 1949, and the arrival at bases in East Anglia of Strategic Air Command's B-29 bombers, in 1948, coincided with public recognition of Britain's dependence upon American strategic nuclear deterrence for her security. The period during which Britain had felt, once again, that she was standing alone in a potentially hostile world, was short lived. But it had produced the decision to build the bomb, and even as this was being made ready for testing, the Chiefs of Staff, prompted by Winston Churchill, were turning their hands to a major review of defence policy.

According to Phillip Darby, this paper confirmed the central and overriding conviction, which British governments held firmly, that nuclear deterrence must be the foundation of defence policy. Although the United States possessed formidable nuclear forces, a British contribution to the total Western deterrent forces could be significant. Faced with serious doubts about NATO's determination to maintain enough armed men to counter the Soviet 'threat' in Europe, and being pressed for both political and military reasons to abandon conscription in Britain, the Chiefs of Staff adopted the concept of providing tactical nuclear weapons in order to offset NATO's comparative weakness in troops on the ground.

Arising from this global strategy paper, which was accepted by the government as a basis for long-term policy, plans were made to develop the V-bomber force at high priority as the delivery vehicles for Britain's atomic bombs. Whatever the scientific and technological assumptions upon which the global strategy paper was based, two developments of critical importance were on the way, which would soon have to be taken into account. In the first place, both in the United States and the Soviet Union, nuclear fission devices were about to be tested which foreshadowed the development of thermo-nuclear bombs, or war heads for missiles having an explosive power many thousands of times greater than that of an atomic, or fission, bomb. Although not revealed publicly for some fifteen months after the event, the first United States H-bomb was detonated at Eniwetok Atoll in 1953. The Soviet Union tested her first H-bomb in the same year. Britain, having decided, it must be presumed, not later than 1952, to develop her own H-bomb, carried out her own first test of one at Christmas Island in 1957. Any residual belief, on the part of military professionals or anyone else, that nuclear weapons could be regarded simply as bigger and better bombs had by this time been finally dispelled. At the same time, it could be argued that, given comparable delivery capacity, a relatively mall country like Britain could threaten to inflict, with H-bombs, incapacitating damage to a much larger country. In terms of the instruments of nuclear power, therefore, Britain's main concern was with the obsolescence that threatened to overtake her V-bombers almost before the full force had become operational.

The development and production of highly effective ground-to-air missile systems, together with comprehensive air warning coverage, added to advanced fighter aircraft with air-to-air missiles proceeded throughout the fifties. Although even a very high rate of attrition would permit the launching of several V-bombers, with the consequent obliteration of their city-targets, the credibility of the V-force was seriously undermined by the prospect. Furthermore, despite elaborate and well-practiced dispersal and take-off procedures, there remained a real risk that the V-force, or most of it, could be caught on the ground by Intermediate Range Ballistic Missiles fired from Western Russia. It was not until 1963 that the Fylingdales (Yorkshire) Anglo-American early warning station, which guaranteed four minutes warning of ballistic missile attack, was in operation.

Throughout the examination of various alternative means of delivering nuclear weapons with Soviet Russia as the primary target for deterrence, but not ignoring China, British governments and their professional advisers leaned towards a flexible solution. That is to say, it was held that

V-bombers could, if need be, carry out other tasks besides strategic deterrence, if armed with conventional weapons. Ballistic nuclear missiles, by contrast, could have no utility other than strategic deterrence. A similar argument could be, and was, used to support the operational requirement for an advanced strike-reconnaissance aircraft capable, amongst many roles, of performing ‘deep strike missions against hard targets’ which became the TSR-2, but was destined never to come into operational service**.** When, in due course, warships, and especially submarines, came under consideration as launching platforms for ballistic missiles, this possible flexibility of role was used, initially, as an argument in their favour.

But the evolution of nuclear deterrence technology was so rapid in the USA and the Soviet Union during the fifties and early sixties that Britain’s policy makers may be excused for displaying what appeared to be some unsureness of touch. Amongst the arguments and counter-arguments which were determinants of nuclear weapons and policy were, firstly, and absolutely fundamental, to what extent, if at all, could Britain have an independent nuclear deterrent, which would, of course, form part of the Western deterrent as a whole, if she had to depend for its procurement upon a resumption of nuclear collaboration with the United States? What, in fact, would constitute an independent deterrent? Presumably, full control over targeting and firing, and capacity to sustain interruption of the supply of spare parts, essential modifications and replacements without loss of readiness for long enough to permit the conduct of foreign policy untrammeled by the constraint of absolute dependence upon the government of origin of the nuclear weapons.

The second determinant of nuclear weapons policy derived from the group of technical considerations affecting the vulnerability of a system to pre-emptive attack. These included mobility and concealment, on the one hand, and for fixed installations, the ‘hardening’ of the launching sites and associated equipment. One of the most telling disadvantages of the ballistic strategic rocket solution was, until the late fifties, the need to use liquid fuel. This made fixed sites almost essential. Such lack of mobility not only held the danger, for a small and crowded country like Britain, of rendering huge loss of life, in the wake of an attack on the missile, inevitable; but it precluded ready deployments to oversees theatres and locations from which China, for example, could be brought within deterrent range, in support of Britain’s friends and allies. Two technical factors of great importance in selecting alternatives were the strike range, which could be guaranteed, and the accuracy of the weapon. Once a potential opponent had developed hardened sites, nuclear strategic weapons that lacked sufficient accuracy to ensure their destruction could not be regarded as equally effective, as elements in the whole spectrum of Western nuclear deterrence, with those which could, if required, be targeted against the potentially hostile missiles.

Looking further ahead, the capability of nuclear weapons to penetrate possible anti-ballistic missile screens had to be developed, and this meant increasing the number of separate re-entry vehicles carried in a single missile. Some of these might be decoys; and if the ‘live’ ones could be separately targeted, advantage could be taken of extra rocket payload to attack several targets at once, with a number of smaller yield warheads, rather than concentrating all the destructive power in one large one. By this means the ideal capability of being able to destroy, almost simultaneously, the entire hostile armoury and his main conurbations could be attained.

At this point, consideration of alternative nuclear weapon systems had to be governed by the view taken of the aim of nuclear deterrence, and how to achieve it. Assuming that Britain, with her comparatively small nuclear armoury, could not even entertain the notion of attempting to disarm Soviet Russia in order to forestall en expected attack, Britain’s national aim must be to maintain an invulnerable and effective retaliatory force of sufficient weight to inflict more damage on Soviet Russia than could be accepted as the price of destroying Britain. Such a force, whilst not contributing to any counterforce capability that the Western deterrent as a whole might dispose of, could add significantly to the counter-city force, and complicate, by increasing the geographical and time spread of nuclear retaliation, such defence measures as Soviet Russia might wish to take.

The outcomes of the first studies of a second generation British strategic deterrent, to succeed the V-bombers, was the liquid-fuelled ballistic rocket, 'Blue Streak'. As late as March 1960, the year in which 'Blue Streak' was abandoned, the recently retired Chief Scientific Adviser to the Minister of Defence said:

I conclude that even if 'Blue Streak' is not the best form of deterrent conceivable today, it will provide until 1970, and possibly well beyond, a very effective independent British contribution to the Western deterrent ……We in this country cannot possibly afford to stop the development of 'Blue Streak'; we simply must press ahead with it as rapidly as possible

Earlier in his talk Sir Frederick Brundrett had referred to the American success in firing solid-fuel rockets from submarines. But because these submarines would have to be nuclear-powered and specially designed, it seemed to him that Britain could not have an independent deterrent along these lines until 1970, and maybe even later.

The paradox for Britain, that in order to have an 'independent' deterrent she would have to seek a restoration of at least some degree of nuclear intimacy with the United States; this problem had been partially resolved in 1954, with the amendment of the McMahon Act of 1946, which earlier had effectively terminated the wartime nuclear collaboration. There seems little doubt, however, that this amelioration of the nuclear relationship took place mainly as a consequence of Britain's successful testing of her homemade atom bomb in 1952. Thereafter Winston Churchill had prevailed upon General Eisenhower, newly elected President, to use his power in Britain's favour and to the advantage of the United States in her confrontation with Soviet Russia and Communist China.

The Atomic Energy Act of 1954 permitted sharing data on external characteristics of nuclear weapons (size, weight, shape, yield and effects) but withheld information on the design and manufacture of the nuclear components. As a result of this action bilateral agreements were signed on 15 June 1955. The first provided for the exchange of information on military aspects of atomic energy including defence planning and training in the use of nuclear weapons but specifically excluded warhead design and manufacture. The second agreed to the exchange of information on the civil uses of atomic energy, including the transfer of fissile materials and equipment.

So far the RAF had been the only UK service directly concerned with the strategic nuclear deterrent But the Royal Navy had begun to develop the NA-39 (Blackburn 'Buccaneer') as a long- range, low-level penetration carrier-borne nuclear strike aircraft, in parallel with United States naval aircraft, for which the role had been established of being able to strike at the Soviet naval bases from which submarine and other operations against American/NATO trans-Atlantic shipping could be mounted. In addition, one of the Royal Navy's primary tasks in the Atlantic, as a member of NATO, would be to locate and destroy Soviet submarines at sea. With the advent at the nuclear powered submarine (the first one, USS *Nautilus* had proceeded on nuclear power on January 1955) the need for Britain's submarine fleet to 'go nuclear', if she was to continue to provide an effective anti-submarine force, was evident.

Admiral Mountbatten, who had become First Sea Lord and Chief of the Naval Staff in April 1955, has recorded that on 4 November 1955, he was flown to Kay 'west from Washington by the Chief of Naval Operations, Admiral Arleigh Burke, in the course of a visit to him, in order to go to sea in the first submarine designed hydrodynamically for high speed when fully submerged, USS *Albacore* (owing to nuclear security restrictions still in force Mountbatten could not then be embarked in the nuc1ear powered USS *Nautilus*). On return to harbour

Admiral Burke had telephoned his office in Washington, Lord Mountbatten recalls:

He then drove me to the aircraft and expressed great indignation. He said that he had wanted to be friends with the USAF and had offered to go shares in their new Intermediate Range Ballistic Missile Thor if they would change the fuel from liquid to solid, to enable it to be fired from submerged submarines. They had categorically refused. He had then and there given the order to start work at once on a solid fuel IRBM to be mounted in a new class of large nuclear submarine. I said "Since the USAF does not support you, would you accept support from the RN?" I then offered to send a hand-picked RN officer, with missile experience, to join his special team. He accepted, and ever after the First Sea Lord had his own representative in the Polaris Project. This stood us in very good stead when we obtained help over our own Polaris submarine from the Americans at the Nassau Conference between President Kennedy and Prime Minister Macmillan.

Not surprisingly, perhaps, Britain asked, within the next few months, for assistance in building a nuclear-powered submarine. The American Department of Defence supported this request, as it would increase the total nuclear-powered submarine strength of NATO, which would be of direct advantage to the security of the US since in anti-submarine warfare there is no substitute for numbers of up-to-date submarines. In June 1956, according to Andrew J Pierre:

..in spite of objections from the Atomic Energy Commission and the Joint Committee on Atomic Energy, the Defense Department with White House and Department of State support used a legal technicality to conclude an agreement to give the British data on the nuclear submarine Nautilus, including information on nuclear ship propulsion reactors.

The way was thus clear for Britain to have the capability should the situation eventually require it, to opt for the American submarine- launched Polaris ballistic missile system, to replace the V-bombers as the nuclear deterrent. It is of interest, as an example of the all- pervasive effects of security in regard to nuclear armaments, that Sir Frederick Brundrett, speaking in March 1960, could give no inkling of any possibility that Britain might be provided by the United States with help in regard to the Polaris system, which would enable her to have it in service well before 1970.

The problem remained, however, that the V-bomber force (which was not to reach its peak until 1963), was rapidly being overtaken by obsolescence. It was decided therefore that to prolong its credibility was the first requirement. Work had been started therefore in l955 on a 'stand-off' bomb of 200 miles range called 'Blue Steel'. This would certainly enhance the ability of the V-bomber force to attack their targets from beyond the range of maximum anti-air defence concentration. But this was a short-term solution. Prior to the decision to cancel ''Blue Streak'', with Polaris seemingly a long way off, the most convincing alternative seemed to be to join in the American Skybolt project. This was a USAF airborne missile, of about 1,000 miles range. Although there were several problems to be overcome, in particular the accuracy of airborne navigation required if the system accuracy was to be high, good progress was being made with Skybolt when Prime Minister Macmillan met President Eisenhower at Camp David in March 1960, and the agreement was made that US Polaris submarines could be based in the Holy Loch. Although not specifically dependent upon that agreement, a promise was given by the President that Britain would be permitted to buy the Skybolt missile once it had reached the production stage. It seems, also, from Macmillan 's subsequent comments that be extracted from the President, at the same time, an undertaking that if Skybolt should not come to fruition, Britain would have the option of having Polaris instead.

It has been stated that:

In retrospect, the failure of the Royal Navy to make a strong case to the Cabinet for acquiring

Polaris rather than Skybolt before, and at the time of, the 'Blue Streak' cancellation, was an irresponsible mistake. The Admiralty had been watching the development of Polaris closely since 1956 and recognized that it was an ideal strategic system for Britain because it was not subject to surprise attack (as was any weapon located on British soil) because it permitted a delay in retaliatory action (and, therefore, gave time for verification of the source of an enemy attack and consultation with the United States), and because it moved the nuclear force away from the homeland. But the Navy chiefs were not enthusiastic about Polaris, being worried about its costs and the accompanying drainage of skilled technicians. The 'senior service' was more interested in maintaining the 'traditional' navy of surface ships that controlled the seas and was fighting for a new generation of aircraft carriers. It was unwilling to sacrifice a 'balanced' fleet on the altar of a seaborne nuclear force. The Board of Admiralty, therefore, put forth strong reservations to the entire 'independent deterrent' concept, rather than advising the Cabinet that if it was the Government's political policy to maintain the nuclear force, Polaris was the most suitable weapons system for it. If the costs of the Polaris submarines were to be separated, so that either they here not part of the regular Navy budget, or the budget was proportionately increased, there would have been less opposition to the Navy's taking over the deterrent mission. But given the past rigid pattern of defence allocations this was not considered likely to occur. Nevertheless, some senior Navy officers acknowledged that the choice of Skybolt in 1960 was perhaps only a 'postponement' of Polaris, and that the undersea missile might become the successor to Skybolt in the 1970.

No authority is given by Professor Pierre for his statement of the Admiralty position at the time of the decision to adopt Skybolt. An alternative view is that the advice given to the Minister of Defence by the Admiralty was objective, soundly based, and far from meriting the epithet 'irresponsible mistake'. Early in 1958, the Admiralty had informed the Secretary of State for Defence fully about the status of the Polaris project, which was confidently expected to meet its objectives, and be ready for operational deployment in late 1960. In arguing the virtues of the Polaris ballistic missile submarine system, the Admiralty Board did not omit to mention that the submarines would have a conventional armament, as well as the Polaris missiles, so that if, in the future, there should be nuclear disarmament, or even, conceivably, a requirement for submarine operations after launching of the Polaris missiles, the vessels would have considerable utility. Far from being irresponsible, Admiralty policy seems to have been wise, and in the best interests of the country.

There were two or three overriding considerations. Firstly, because both Polaris and Skybolt were American projects, with roughly the same dates of operational availability, and because the missiles could only be obtained if and when the Americans succeeded in producing them, Britain's choice of one or the other, in 1960, could not be crucial to her own deterrent status. In either case the V-bombers must be kept 'in business' for as long as possible. Secondly, despite having received from the United States the complete reactor and associated steam propulsion plant for HMS *Dreadnought*, her first nuclear powered submarine, it would be 1963 before she was ready for sea, and later still before a British designed submarine reactor plant was ready, without which Britain could not build her own ballistic missile submarines, and thus provide at least an entirely 'independent' launch platform for Polaris. Finally, and probably most important of all, the Royal Navy was determined to avoid seeming to wish to deprive the RAF of the strategic nuclear deterrent role upon which its existence as an independent service might be thought to depend. That this was no idle thought may be gleaned from the determination with which the RAF and its political supporters pressed for the TSR-2 strike-reconnaissance aircraft to be accorded a long-range nuclear role. This had become feasible with the marked reduction in the size and weight of A-bombs, as a result of technological advance. It is possible, more than ten years after the Skybolt decision was taken, to gauge the strength of this feeling, by the intensity of the concern with which the American decision to cancel Skybolt was greeted. It is true that the manner in which the change in policy was transmitted to the British government was somewhat casual, but there were extenuating circumstances.

Just about the time that Mr. McNamara, President Kennedy's Secretary of State for Defense, had come to the conclusion that Skybolt was costing too much for the benefits it was supposed to confer, the Cuba crisis intervened, in October 1962. By the time McNamara was ready to get the President's approval to cancel Skybolt, which would mean at least some protest from the Joint Chiefs of Staff, Christmas was approaching. The British Defence Ministry and Foreign Office were not unaware that Skybolt was 'in trouble', but no official intimation was forthcoming from Washington. All that McNamara could do, in advance of Presidential confirmation of his decision, was to inform the British Ambassador, and to telephone Mr. Thorneycroft, the Minister of Defence in London, warning him that Skybolt might be cancelled. The Prime Minister, Macmillan, assumed that if he had finally decided to cancel Skybolt, the President would have telephoned him also.

In the event, McNamara's meeting with the President took place in November and Skybolt was cancelled 'subject to consultation with the British'. The Defense Secretary decided to fly to London on 11 December (he had a NATO ministerial meeting in Paris on 12 December) and inform Thorneycroft of the position.

Unfortunately, on 7 December the Skybolt decision leaked to the press. By December 11, when McNamara reached London, the place was in an uproar. He did not improve the public look of things by criticizing Skybolt to the press when he deplaned. Soon after, he and Thorneycroft began their consultation.

It so happened that Prime Minister Macmillan had already arranged to meet President Kennedy at Nassau, in the Bahamas, on 18 December. The occasion was to have been one of the periodical meetings between Macmillan and the President of the United State, which the Prime Minister had initiated with Eisenhower and continued with Kennedy. It was with very little preparation, on either side, therefore, that the Skybolt question, suddenly overshadowing all else, had to be dealt with.

Macmillan has recorded:

I immediately (13 December) sent a message to our Ambassador in Washington on how the Nassau meeting should be handled. It seemed that it ought to start right away with the Skybolt question:

'My difficulty is that if we cannot reach agreement on a realistic means of maintaining the British independent deterrent, all the other questions may only justify perfunctory discussion, since an "agonizing reappraisal" of all our foreign and defence policy will be required.'

Looking back, Macmillan wrote:

The President did not want to give us Polaris on political grounds, for fear of upsetting all the Europeans Nations who, with the exception of France, had no nuclear development. On the other hand, I was determined to get Polaris and felt that we had a right to it. In return we would be prepared to make it clear that in natural circumstances we would regard our nuclear power as available to NATO and thus add to its strength.

The Admiralty Board may not have seemed to be unduly anxious for the Royal Navy to become responsible for the strategic nuclear deterrent. But, as the source of the professional advice upon which the Prime Minister had mainly to rely, it had evidently been impressed upon him the special advantages for Britain of Polaris. By maintaining an intimate, though unadvertised, association with the USA's Polaris programme; and by pressing on with the development of a British-built nuclear-powered submarine, the Navy had ensured that

Macmillan could in due course press with complete confidence for Polaris.

The next three chapters provide an outline of the scientific and technical progress, in which Britain shared, leading to her capacity to adopt Polaris immediately when Skybolt was cancelled.

CHAPTER 2

THE REVOLUTION IN NUCLEAR PROPULSION

'Underway on Nuclear Power'

Commander Eugene Wilkinson USN
USS *Nautilus* 17 January 1955

'*Accordingly, the President and the Prime Minister agreed that the United will make available on a continuing basis Polaris Missiles (less warheads) for British submarines'*. In these words the President of the United States of America agreed to 'make available' to Britain the fruits of the most significant and successful weapons development and procurement programme of the nuclear era. The politico- military considerations that led to this decision have been briefly described. But in obtaining Polaris, Britain 'bought in' (on generous terms) to a missile programme and its support organisation which merit description in considerable detail. Not only is this indispensable to an understanding of Polaris weapon system as a whole, but in fairness to the American people the British should be made aware of the nature and scale of the military-scientific-industrial effort of which they have become the beneficiaries.

The concept of a weapon system, consisting of separate elements - launcher, vehicle, warhead and control - is modern. It reflects the exponentially increasing complexity of technology. But a fleet ballistic missile system existed, although not recognized as such, in World War I. It took the form of a 12-inch gun mounted in a submarine (the British M1). Its purpose was to bombard targets on land in situations that precluded the use of surface ships. The capacity of the submarine for concealment prior to opening fire was to be exploited. In World War II a bombardment weapon was once again mounted in a submarine. This time the missile was not a shell fired from a gun, but the rocket-propelled missiles known as V1 and V2 and the submarine was a German U-boat. Fortunately, despite some successful trials, an operational weapon system was not developed before Germany capitulated.

By the time naval thinking turned once again to this potent combination of submarine and ballistic missile, a revolution had taken place in submarine propulsion. As long ago as 1937, Dr Hellmuth Walter had submitted to the German Navy plans for a turbine-driven submarine using oxygen generated by hydrogen peroxide to produce steam whilst submerged. By December 1943 the first two Walter boats, *U-792* and *U-794*, were ready for sea trials. They achieved twenty-five knots submerged for short intervals, and twenty knots for five and a half hours.

After World War II, the United States obtained the Walter boat, *U-1406*, and set up a facility at the Engineering Experimental Station at Minneapolis, where five advanced chemical plants were tested. The Royal Navy also experimented with the Walter cycle. Two submarines, HMS *Explorer* and *Excalibur*, were built and tested. There is little doubt that had not a further, and far more dramatic, development taken place, operational submarines would have been powered by HTP (High Test Peroxide) steam turbines. But, once again, scientists had been at work on the frontiers of knowledge. The application of nuclear fission energy to generate steam to operate a turbine-driven submarine had been studied in the United States Naval Research Laboratory as early as l939. However, the Manhattan Project, which had concentrated all the relevant scientific and technological capacity of both Britain and the United States on producing the 'atom bomb', delayed development of the nuclear submarine power plant for some seven years.

Late in 1945 it was proposed by Messrs Gunn and Cooley of the US NavA-1 Research Laboratory that a nuclear submarine propulsion plant would be practicable. Technical surveys predicted that, given high enough priority, an atomic powered submarine capable of over twenty knots submerged speed, and of virtually unlimited endurance, could be operating within two years. The report proposed a liquid metal, sodium potassium, as the heat transfer agent in the reactor and predicted that *'This fast submerged submarine will serve as an ideal carrier and launcher of rocketed atomic bombs'*. Not a bad description of the Polaris weapon system, still a decade away. However, there being no direct interest in naval nuclear propulsion at the time, this report, along with others proposing naval plants, was pigeonholed.

In April 1946, leading members of the Manhattan Project turned their attention to the peaceful uses of atomic energy. As a start, through the agency of the Project's Oak Ridge Laboratory in Tennessee several large industrial companies, such as General Electric, Babcock and Wilcox the boiler builders, and Monsanto Chemicals, together with various Federal Agencies, and the US Navy, were invited to help design and build a nuclear power reactor. The first fruit of this collaborative enterprise was called the 'Daniels Pile', after Darmington Daniels, professor of chemistry at the University of Wisconsin, who had become the chief technical consultant on the reactor project.

This reactor was designed to be enriched-uranium fuelled, beryllium-moderated, and high temperature helium-cooled. Although it was never actually constructed, the 'Daniels Pile' was significant in several ways. It provided evidence of the national effort to develop nuclear power for peaceful purposes; it provided a conspectus of the technical problems of developing, designing and building a power reactor; and it united the best scientific and engineering talent in support of reactor development. Two other factors were of specific importance in determining the direction of advance. First, the type of reactor investigated was later considered to have possibilities for naval application; and, secondly, the senior officer of the team assigned by the US Navy to the Oak Ridge project was a certain Captain Hyman Rickover USN. It was this team that in due course designed, developed and produced the first nuclear propulsion plant, installed in the US submarine *Nautilus*. In parallel with the Oak Ridge investigations the General Electric Company, as a contractor-operator associated with the Manhattan Project, became involved in studying the possibilities of a liquid metal-cooled, enriched-uranium power breeder reactor for naval propulsion. From this study eventually came the propulsion plant for USS *Seawolf*, the world's second nuclear-powered submarine.

Given the novelty and immense significance of nuclear power research and development, it is not surprising that during this preliminary period, 1946-48, much personal and departmental manoeuvring took place. It was necessary to establish a congruent scheme of relationships whereby objectives, both national and departmental, could be given precision and gain acceptance; whereby political control could effectively be exercised; whereby resources of money, materials and human talent could be allocated in support of chosen objectives; and whereby the responsibility for various aspects of nuclear matters, as a whole, could be clearly defined.

From this maelstrom of administrative and technical activity the figure of Captain Rickover emerged as dominating the naval nuclear scene following upon his re-appointment to the Bureau of Ships as an assistant to its chief, Admiral Mills. Furthermore, to the pervasive influence of Rickover must mainly be attributed not only the decision of the US Navy to 'go nuclear', but also the support of the US Atomic Energy Commission in this bold end costly undertaking. Without this assurance, the Navy could not have made any progress. The 1946 the Congressional Atomic Energy Act had specified that all work involving nuclear materials would be assigned to the Atomic Energy Commission. This 'nuclear package' was adjudged to include the reactor core, its pressure vessel, controls, and the primary coolant out to its thermal energy conversion boundary. Furthermore, all fissionable and special materials were to be owned solely by the AEC. Consequently, a nuclear reactor programme could be wider-taken only by the AEC, within its own approved efforts, and within its own direct or sub-contracted facilities.

The key practical outcome of Rickover's determined lobbying within the Department of the Navy was achieved in 1948. It took the form of a letter from the Chief of the Bureau of Ships, Admiral Mills, to the Atomic Energy Commission, stating that ('the Navy') believed that a nuclear-powered submarine was practicable; that it was needed, and given enough priority, could be in being by the mid-1950s. In Fiscal year 1949, accordingly, the AEC budgeted the first monies (about half a million dollars) for this effort.

Organisationally, the necessary integration of thought and direction was achieved by 'double-hatting'

This was accomplished at the headquarters level by Rickover's assignment as Chief of Bu-Ships' Nuclear Power Division, and at the AEC as Chief of the Naval Reactor Branch of the Division of Reactor Development. His Washington-assigned officers also peopled both organisations. Likewise, in the field, many of the assigned naval personnel had at least two, and sometimes three, hats as, for example, Bu-Ships' representative, AEC Regional Operations Office Chief, and working scientist assigned to a National Laboratory. (Naymark p59)

But organisation is not enough. In order to drive through to successful completion a project of such originality, complexity and magnitude as the deve1opment and production of a nuclear powered submarine, certain conditions must be met. First, there must exist a number of individuals, nuclear scientists, technologists and engineers, fired by enthusiasm for the project as a whole. Secondly, one or two of these people must be, *par excellence* creative administrators. That is to say, they must be masters of the workings of the bureaucracy both formal and informal; of the politics of resource allocation and administration; of the role and capacities of both governmental and commercial undertakings relevant to the project; and must possess**,** in addition, that innate power of appraising, selecting, rejecting, and combining the factors in a situation, in order to maintain progress towards the achievement of an objective, which is an indispensable element of leadership in society.

Captain Rickover certainly showed these qualities; so did Walter Zinn, one time director of the Atomic Energy Commission's Argonne (Chicago) National Laboratory. It was under Zinn's impulsion that basic reactor research, with a breeder reactor as its first priority, was first applied to development in the form of the Naval Reactor Programme. The scientific and technical judgement of these two men both depended upon and was instrumental in providing, scientific and technical data in rapidly increasing depth and extent. There were critical decisions to be made also in regard to the building of alternatives to the prototype stage in order that the final decision could be made on empirical, as well as theoretical, considerations. But too many prototypes would be wasteful of time and resources; judgements must be made, ultimately, by feel, as well as knowledge.

It was seen to be most important, in the *application* of what reactor research had already discovered, and in *guiding* its proper progress towards a ship propulsion plant, to involve an experienced naval shipbuilder from the start**.** But he would have to be much more responsive to changing requirements, as developments progressed, than was usual in naval shipbuilding production, which is traditionally geared to standard contract procedures based on fixed and agreed designs. For this reason Rickover selected the independent Electric Boat Company, rather than a US navel shipyard, as the primary building yard. This choice reflected the most important single decision following upon the establishment of a Naval Reactor Project, namely, that the first naval reactor should be installed in a submarine.

It is difficult to establish how and when this decision was actually made, and by whom. For it has to be remembered that, whilst the Chief of Naval Operations (Admiral Chester Nimitz) had agreed to the establishment of a naval nuclear propulsion project, it had not been either necessary or expedient to examine the merits of the submarine or the surface ship, respectively, as a vehicle for the prototype plant. Indeed, in 1946, when the question was first, most secretly, mooted the achievement of an operational plant must have seemed very far away. But there is no doubt that from the point of view at advantage gained the possibility of a ‘true submarine’, namely one that could sustain total submergence almost indefinitely whilst proceeding at high speed, was orders of magnitude greater than any advantage to be obtained by a surface warship from such a power plant. The selection of Electric Boat, pioneers of submarine construction, for what would soon become known as the ‘*Nautilus*’ project, was natural, and complemented the assignment already given to the Westinghouse Company of responsibility for the overall design of the nuclear propulsion plant for a submarine.

The reactor itself and its auxiliaries were to be designed and built by the company operated, but government owned, Bettis Atomic Power laboratory (BAPL). The critical decision, to which reference has already been made, that the first reactor plant should be used to drive a submarine, led immediately to consideration of the type of submarine hull which would be most suitable in order to produce an operational addition to the fleet. The US Navy’s submarine experience in World War II had been gained almost entirely in the offensive against Japanese shipping. The initial design parameters given to Westinghouse, BAPL and Electric Boat were of a hull size corresponding to that of existing, large, diesel-electric submarines of the US Navy, namely 18 feet diameter and about 300 feet long, with a displacement of about 2,000 tons. The question was, could a reactor be designed which would be neither too large nor too heavy to be put into a hull of this size?

The weight of a nuclear power plant is concentrated in the shielding, mainly of lead, with which the reactor must be surrounded in order that radiation of all kinds emanating from the uranium core can be contained. Simple arithmetic shows that even a small change in reactor size therefore brings about a marked change in the overall weight of the plant. But a small size reactor must be fuelled with highly enriched uranium. In the late 1940s very little of such material could be spared from the weapons programme. This requirement imposed further restrictions on the reactor design so that the possible types of reactor-cycle that might meet the criteria were reduced to three main variants. These were looked at in turn. First, the gas-cooled reactor; because of the relatively poor heat-transfer properties of gas, and of the temperature limitations of materials available in the late 1940s, and owing to the bulky energy conversion equipment needed to produce steam to drive the turbines, a gas-cooled reactor could not be designed small enough for the purpose. Secondly, therefore, the possibility of a liquid sodium-cooled reactor was examined. Although this could be designed down to size, owing mainly to the excellent heat transfer properties associated with sodium, serious difficulties were foreseen in overcoming certain chemical and metallurgical problems, and in designing a leak-proof system. The cycle that found most favour, therefore, was a light-water-moderated-and-cooled reactor. Its advantage included feasibility of small reactor size, stability of power-output, utilization mainly of known technology, and a high safety factor. The main disadvantages that had to be accepted were the very high pressure required in the primary system (to prevent the water boiling) and low-pressure (saturated) steam on the secondary side, necessitating the use of relatively inefficient turbines.

By a joint decision of the US Navy and the US Atomic Energy Commission, therefore, it was decided to build two pressurized water-cooled submarine thermal reactors, to be known as STR Marks I and II. It was this second version, the STR Mark II, which propelled the *Nautilus*. However, there were many unknown factors. Could neutrons and gamma rays in the core dissociate the water to H_2 and O and other compounds in untenable amounts? Could corrosion resistant structural materials be found for the hull that would withstand radiation damage to their structure and prevent deterioration of physical properties? Would the reactor be stable under all operating modes, as, for example, in a submarine subject to motion in a seaway and steep angles when diving and surfacing? Would corrosion problems in high temperature water deteriorate materials or heat transfer surfaces?

In case experience should prove the STR I and II unsatisfactory for these or other reasons, a back-up or alternative project was undertaken, namely to design and build a liquid-metal cooled reactor. Known as the SIR Mark A (Submarine Intermediate spectrum Reactor), this reactor was built at the General Electric-operated Knolls Atomic Power Laboratory. It was the Mark B version of this reactor that in due course propelled the submarine *Seawolf*.

Some idea of the intensity of research and development which followed from these seminal decisions may be gained from the following: at Argonne and Oak Ridge water capsule tests were carried out, which showed water-separation to be a manageable phenomenon in an operating reactor, a nuclear-fuel development programme was undertaken involving the Argonne, Oak Ridge, Brookhaven, Ames, and Bettis AEC Laboratories, and at Batelle Memorial Institute, MIT and Sylvania, among private and university complexes. A Hanford production reactor was made available, without interrupting its weapons program, to irradiate fuel. Out of this effort came a fuel element that not only met but also far exceeded the original requirement for core life.

The need for neutron economy in the core made stainless steel a poor choice for fuel and structural purposes. The low neutron absorption of zirconium was proven at Oak Ridge; and demonstrated to be corrosion resistant and strong enough, by the fuel development laboratories. The alloy was developed largely at the Bettis Laboratory, and then rushed into large-scale production by Rickover.

The neutron physics of a compact thermal reactor were verified by a critical assembly (ZPR-l) at Argonne, with Bettis' physicists participating. Heat transfer and mechanics experiments at Argonne and elsewhere verified that thermal energy could safely be transferred from the reactor core to the water coolant at higher rates than those pertaining to fossil fuelled boilers.

In 1951, therefore, the US Navy was able to authorize the construction of the *Nautilus* by the Electric Boat Company at Groton, Connecticut, whilst the AEC authorized the STR Mark II plant that would propel *Nautilus*, the keel of which was laid on 14 June 1952 by President Truman.

As the project moved more and more from R&D towards engineering and production, so Rickover's planning, co-coordinating and monitoring role became of overriding importance. By the end of 1949 thousands of people in government service and the universities were directly engaged in the *Nautilus* project, and sub-contract work had been farmed out to hundreds of industrial suppliers throughout the United States:

Yet every technical detail was minutely checked over, reviewed and approved by Argonne and Rickover's AEC Washington Group for the nuclear part at the plant, and by Bu-Ships for the more conventional engine room equipment. The conventional equipment, however, had elements at unconventionality. Completely enclosed water circulating pumps (canned rotor motor.) were conceived by Argonne and Westinghouse, and developed by the industrial firm. Low-pressure steam turbine was required, so industry turned its design requirements back twenty years and upgraded it with new materials, hydraulics and machines developed in the interim.

In accordance with the sound practice in development at limiting the amount of innovation undertaken simultaneously Rickover, with the concurrence of Bu-Ships, had originally planned to use a conventional submarine hull for the nuclear propulsion prototype, although trials with the much more perfectly shaped *Albacore* had already begun. But by 1950 the concept of the reactor and its shielding when the final design stage was reached, was found to demand a hull diameter of 30 feet, bringing the displacement of the submarine to over 3,000 tons. As an insurance against machinery breakdown that might jeopardize the safety of the submarine, it was planned to have two sets of steam turbines and twin propellers, although there would only be one reactor. By this stage, also, another decision of critical importance had to be made - should the prototype reactor plant be built as a test-bed only, spreading the machinery out for ease of testing, and replacement in the event of failure; or should it be built, *ab initio*, as for a submarine, with consequent extra difficulty and cost of modification in the event at failure? The gamble (for, despite the care taken to ensure success, it must be classed as such) was taken to build a submarine prototype in a section of submarine hull in a tank of sea water, so as to reproduce with as much exactitude as possible the conditions of operation.

Construction of this submarine prototype began at AEC's Nuclear Reactor Testing Station, at ARCO, Idaho, in 1950 and was completed in 1953. The work was carried out by the Westinghouse - Bettis-E1ectric Boat Division plant-ship integrated team, under the operational control of Westinghouse. A year later work was begun on the second reactor plant. It had been possible owing to the successful progress of R&D with STR I to make STR II almost identical with it, so that any problems thrown up by the operation at STR I could be directly related to, and corrected in, STR II, thus saving time and cost in completing the submarine propulsion unit. It was at ARCO on 3 May 1953 that STR I manned by Westinghouse engineers and a naval crew went 'critical'. On 31 May it produced power.

During the next two years the building of *Nautilus* proceeded apace. A full size wooden 'mock up' of the submarine had been built, in which it was possible to try out every pipe-run, power cable and siting of equipment before going ahead with the assembly of the actual submarine. From 1953 onwards test results and operating experience from the STR I plant at ARCO were used to improve the reactor in *Nautilus*, which was launched on 21 January 1954 by Mrs. Dwight D Eisenhower. One year later, on 17 January 1955, Commander Eugene Wilkinson - who had started his nuclear indoctrination five years earlier at Argonne as a senior physicist on the basic reactor design - commanded the ship as she headed seaward. Wilkinson's engineers pulled out the control rods**,** water coursed past the uranium fuel elements and generated steam on the secondary side of the boilers, the turbines turned over, and the message went out to the world, 'Underway on nuclear power'. Thus, five end a half years after work was started on the *Nautilus* prototype concept in 1949, 19 months after this prototype generated power, 31 months after the ship's keel was laid, and after approximately 200 million dollars' worth of national effort, USS *Nautilus* went to sea as an operational unit of the US Fleet.

The history of the submarine**,** as an instrument of sea power, has been marked by its capacity to instill fear. When Robert Fulton tried to sell his plan for a submersible warship to the British Admiralty in 1805, the First lord (Admiral Earl St Vincent) is reputed to have turned him away with the remark: 'We should not encourage a mode of warfare which our superiority at sea does not require but which, in the hands at an enemy, might destroy that superiority. At the turn of the century, when operational submarines were in being, The Controller of the Navy, Sir Arthur Wilson, declared that submarines were 'damned un-English'.

The feat of Germany's U-boats in almost starving Britain into surrender in World War I was achieved at the expense of bringing the United States into the war on the side of the Allies against the Central Powers. Between the wars efforts were made to 'outlaw' the submarine. Most naval officers ('submariners' have, until recently, formed only a small minority) would have been glad to see this happen. Fear of being unable to counter the ever extending radius of action, weapon load and manoeuvrability of submarines has led to persistent under-estimation of their potential in war. As in 1914 when the armoured cruisers HMS *Hogue*, *Aboukir* and *Cressey* were operated in such a way as to be sitting targets for a comparatively primitive submarine so, in 1939, British aircraft carriers were sent U-boat hunting in the Western

Approaches. Not surprisingly, HMS *Courageous* was soon sunk and *Ark Royal* escaped only through the premature explosion of a torpedo from *U-39.* A total of seven aircraft carriers, one battleship, ten cruisers and thirty destroyers were destroyed by submarine attack between 1939 and 1945.

As to anti-submarine measures, the concealment afforded by the sea remained, despite immense R&D expenditure, sufficient to maintain the ability of submarines to achieve both strategic and tactical surprise. The fear of the submarine in general war persisted. Two factors specially affected the attitude of the major naval powers towards submarines in the decade after 1945. First, with the advent of the 'Cold War', when the United States suddenly had to measure her military power against that of the Soviet Union, it became evident that the naval strength of the latter was concentrated in her modern and rapidly growing submarine fleet. In consequence, it seemed natural for the US to respond by increasing its own submarine force and, despite the inherent problems associated with submarine versus submarine action, her submarines were given an anti-submarine role as their primary task. Secondly, in the course of the Korean War, despite the continuous activity of American, British and Commonwealth naval forces, not a single submarine attack on any of them took place - nor was even the presence of a single submarine reported throughout these operations The reason for this paradox deserves, but does not seem to have received, careful study.

By 1955, therefore, when *Nautilus* was busy proving the complete success of her nuclear-propu1sion plant by steaming over 20,000 miles totally submerged and, of course, without refueling, tactical thought in the surface- and air-minded naval hierarchies ignored the ever-increasing military potential of submarines. Even within the submarine arm of the United States Navy, enthusiasm for the nuclear powered *Nautilus*, and the single propeller, hydrodynamically shaped *Albacore* did not amount to a revolution in tactical thought. Faster, deeper-diving and more manoeuvrable submarines would, of themselves, it was believed at first, be a sufficient guarantee of advantage over the only credible enemy submarine force, namely that of Soviet Russia. Existing sonar (ie acoustic detection systems, both active, in which sound pulses are transmitted and echoes received, and passive, in which no sound is transmitted), would be improved in the normal course of development. Torpedoes, the main armament of the submarine, would be specially designed to attack deep diving submarines. The submarines themselves would be made capab1e of extremely quiet running, so as to reduce to the minimum the range at which they might be detected by passive means. In short, orders of magnitude improvement in the tactical capabilities of the submarine were not perceived as correspondingly disturbing to the relationship of submarines with surface naval forces.

In the meantime in the USA, no more conventionally-powered (diesel-electric) submarines would be built. Instead, a class of 'production' nuclear-powered submarines, somewhat smaller than *Nautilus* (the *Skate* class) was begun; in the same year *Seawolf*, the prototype powered by a liquid sodium reactor, was completed. Although this plant proved to have many desirable operational characteristics, it also turned out to have certain handicaps of maintenance and inherent safety that resulted in severe operational restrictions. In due course, therefore, the original test reactor STR Mark I, similar to the STR Mark II that had been installed in *Nautilus* was used to re-engine *Seawolf*, which then became an operational submarine.

In parallel with the 'true submarine' development, which was being pushed ahead with astonishing rapidity, skill and singleness of purpose, as an anti-submarine-submarine, there was built a submarine *Triton* which reflected the uncertainties facing the United States naval staff about the future shape and size of its fleet. In the first place, it was desired to gain experience of a multiple-reactor power plant, with a view to installing such a plant in a fleet aircraft carrier, still regarded as the major unit of naval power upon which to build a modern fleet. Secondly, the necessity to station air-defence pickets a hundred miles or so distant from the carriers in a task force had raised an awkward dilemma.

The frigates used for picket duty, despite being costly and powerful ships, were not likely to survive for long as independent units against the expected scale of air and submarine attack. It was therefore envisaged that a nuclear-powered submarine, able to steam continually at sufficient speed to maintain station on the carriers, and equipped with the necessary radars and communications on telescopic masts, could act as a submersible picket - at least she could evade air attack, and in some circumstances might be less liable than a surface ship to destruction by an enemy submarine. These fond hopes were not, however, realizable, and after *Triton* had gone round the world without surfacing at all in much less than 80 days in 1960, and thus created a record for submerged endurance and sustained submerged speed, she was not further employed in her original role of air-defence picket with a carrier task force.

A different conception of the possibilities of the nuclear-powered submarine was to use it as the vehicle for the 600-mile range ‘Regulus’ cruise missile. The nuclear-powered USS *Halibut* had been ordered as early as 1956, as an addition to two conventionally-powered ‘Regulus’ armed submarines then under construction. But development of the Polaris ballistic missile overtook that of ‘Regulus’, and the *Halibut* reverted to the anti-submarine role, along with *Nautilus*, *Seawolf*, and *Skate*, her three sister ships.

Finally, in the group of early nuclear-powered submarines, there came *Tullibee*, designed as a test-bed for the evaluation of new sonar sets and other advanced equipment specially related to the anti-submarine role.

Impelled by the need to keep the lead over soviet Russia, believed to have been achieved with *Nautilus*, the US Navy did not await the outcome of prolonged trials and evaluations with the various types of nuclear-powered submarine which had followed her into commission in rapid succession before combining in one design the two cardinal innovations recently made. In April 1959, USS *Skipjack* was commissioned. Her hull was of the now familiar short, beamy but perfectly streamlined shape proved by *Albacore* to be easily driven and maneuverable, with a single, large screw abaft the cruciform arrangement of rudder and after hydroplanes. Her power plant was a pressurized water-cooled reactor of the type that had proved so successful in *Nautilus*. It was onboard USS *Skipjack* at sea, on 11 April 1959 that there took place a remarkable, although not unique, ‘Hearing’ before the Joint Committee on Atomic Energy of the Congress of the United States. It is worthwhile, repeating here the words with which its chairman, Senator Clinton P Anderson, opened the session:

This is an official meeting of the Joint Committee on Atomic Energy. We meet this evening in executive session aboard the US nuclear submarine Skipjack, *more than 400 feet below the surface of the Atlantic Ocean and approximately 135 nautical miles out of New London, Connecticut. We are present here today to receive a report from Vice Admiral HG Rickover, Assistant Chief for Nuclear Propulsion, Bureau of Ships, and Commander William W Behrens, Commanding Officer of the USS* Skipjack *on the operation of this new nuclear submarine, which completed its first sea trials on 10 March 1959, just thirty-two days ego. We are present here today to observe for ourselves the operation of this outstanding submarine and thus obtain firsthand knowledge of what has been accomplished.*

It was four years ago last month, on 20 March 1955 that the Joint Committee held a hearing aboard the USS Nautilus, the world’s first nuclear submarine. We met as a committee below the surface of the Atlantic in approximately the same location as we are now.

Having invented, developed and deployed operationally a force of nuclear-powered submarines designes specifically to counter the threat posed by a large and potentially hostile Soviet Russian submarine fleet, the United States was about to marry this uniquely appropriate deployment and launching vehicle to an Intermediate Range Ballistic Missile. This combination would provide a fleet ballistic missile system of crucial significance to the establishment of a stable system of strategic nuclear deterrence. The IRBM became known as Polaris. The following chapter describes briefly how Polaris was brought into being, mounted in a nuclear-powered submarine, tested and deployed, all within the phenomenally short period of five years.

CHAPTER III

POLARIS: THE AMERICAN EXPERIENCE

By the end of my administration Polaris gave the United States an extremely mobile, practically invulnerable retaliatory capacity.

President Eisenhower

In his memoirs, *Waging Peace*, Dwight D Eisenhower wrote:

Deeply concerned in 1953 at the previous lack of attention given to missile development, my administration quickly turned to outstanding scientists and engineers to determine the feasibi1ity of developing effective weapons of this character. On 10 February 1954 one of those scientific groups, headed by Dr. John von Neumann, reported the possibility of a major breakthrough - as the result of AEC research - in reducing the size of missile warheads, and recommended development of a correspondingly designed intercontinental ballistic missile (ICBM). Because it takes two hundred pounds of launching weight to put one pound of warhead on target several thousand miles away, and because the first atomic warheads weighed nine thousand pounds, this reduction was a requisite to the development of an effective ICBM. By May the Castle bomb tests in the Pacific had substantiated the von Neumann findings. In accordance with this report, the Air Force reshaped its program mid began to accelerate work on an ICBM. By early 1955 its Atlas project was mushrooming……In February of 1955 a second scientific committee, headed by Dr. James R Killian, recommended that we develop, along with the ICBM, an intermediate-range ballistic missile (IRBM) with a range of fifteen hundred miles. By the summer of 1955 the Air Force research and development ICBM program had been given the highest priority and by December we concluded it wise to assign highest priority to program for two ICBMs, 'Atlas' and 'Titan', and two IRBMs, 'Jupiter' and 'Thor'. To these programs we devoted all the resources that they could usefully absorb at any given time.

Because the Army had stated a requirement for a *mobile* IRBM and resources did not permit a *third* IRBM program, the US Navy was instructed to share with the newly formed Army Ballistic Missile Agency the development of 'Jupiter'; in particular it would investigate the possibility of adapting 'Jupiter' to be launched from ships. The Secretary of the Navy thereupon set up, on 17 November 1955, a Special Projects Office to handle the problems associated with the ship-launched weapon system. Because the major problem was the patent unsuitability of liquid-fuelled rockets for shipboard use, on 28 November the US Navy formally stated, as being within the overall plan for the development of ‘Jupiter’, the requirement to develop a solid propellant ballistic missile for use in submarines. The submission stated:

On a long-term basis the Navy proposes a solid propellant development program pointed towards surface ship and eventual submarine use. This development should be initiated immediately to alleviate the serious hazards and difficult logistic, handling, storage, and design problems associated with liquid fuels. Development of a solid propellant missile and submarine system appears feasible, but not in the timescale of the original approach. The solid propellant is an integral part of the submarine programme.

The target date of an operational ship-based Jupiter system had been set at 1965.

The US Navy, in setting up the Special Projects Office, which quickly became known inside the Navy as SP, intended to create an organisation capable of exercising overriding authority over whatever government departments or industrial plant, and whichever individuals in any organisation, would or could contribute to the achievement of the objective - to get an operational IRBM to sea at the earliest possible moment. Most important of all was to select the right men to head up the Special Projects Office - someone who could ‘deliver the goods’. The Chief of Naval Operations, Admiral Arleigh Burke, selected Rear Admiral William F Raborn Jr., a seasoned naval aviator who had subsequently become Deputy Director of Guided Missiles. In order to provide Raborn with the necessary authority, the Secretary of the Navy (Gates) and Admiral Burke jointly signed a letter that stated:

If Rear Admiral Raborn runs into any difficulty with which I can help, I will want to know about it at once, along with his recommended course of action .... if he needs more people, those people will be ordered in. If there is anything that shows this project up beyond the capacity of the Navy and the department, we will immediately take it to the highest level end not work our way up through several days.

There can be little doubt that in seeking to extend its activities from ‘within the overall plan for the development of ‘Jupiter’ to ‘the development of a solid fuel propellant’ that is to say far beyond the limit, originally set, namely ‘to develop the ship launching system, the Navy was circumventing the constraints intended to be laid upon it by the Secretary for Defense, through his Ballistic Missile Committee.

It is not possible in a short space, nor is the information available, to chronicle the comings and goings, the memoranda, the meetings and the telephone calls, by which the ground was prepared, the wording of the final document agreed, and the signature of the Secretary of State for Defence obtained. Of such mutable *minutiae* are matters of great moment in the destinies of nations comprised. But one thing is certain. Unless Admiral Arleigh Burke, Chief of Naval Operations, had himself been absolutely convinced of the extreme danger which threatened the USA, with the prospect of Soviet Russia achieving strategic nuclear superiority; and unless he himself had been fully aware of the profound significance of a submarine-borne ballistic missile system, it is highly improbable that the necessary singleness of purpose, energy and initiative to create Polaris would have been forthcoming.

It was an act of faith, but one soundly based upon the reasoning expressed in a jingle that Burke appended to a personnel letter written to Mountbatten (First Sea Lord) on 26 February 1959:

Move deterrents out to sea
Where the real estate is free
And where they’re far away from me

And not only ‘out to sea’, it is necessary to add, but ‘under the sea’. For the unique merit of the submarine launched ballistic missile system (SLBM) is its invulnerability to pre-emptive strike. That is to say, whereas it is at least conceivable, and possible, for one nation to strike first in the hope of knocking out a high proportion of any land-based strategic nuclear weapons which the adversary may possess, and thus limit its retaliatory power to an ‘acceptable’ degree (taking anti-ballistic missile defences into account), this situation cannot be brought about when a large proportion of the retaliatory force is widely deployed throughout the depths of the oceans, where it cannot be located accurately, let alone neutralized. Thus, the SLBM provides a credible ‘second-strike’ capability such that the fear of being ‘Pearl Harbor’d’ to the point of total and immediate defeat need no longer be entertained. A surface-ship mounted ballistic missile system, although feasible, could not benefit from the immunity from location and attack (when seeking to remain concealed), which is the primary characteristic of the submarine.

Let us now look, for a moment, at the elements of the problems of creating, from scratch, a submarine launched ballistic missile system, as they appeared to Rear Admiral ‘Red’ Raborn when he began work on 5 December 1955, as Director Special Projects:

- There was no small, proven nuclear warhead of sufficient yield
- There was no guidance system of sufficient precision
- Existing fire control systems fell far short of the requirements for speed and accuracy
- There was no ship or submarine navigation system capable of providing, whenever required, a position of astronomical observatory precision
- It was not even possible to determine true north - information indispensable for the direction of a missile to its target
- There was no ship, let alone submarine, equivalent to the launching pad ashore. The requirement was to protect the missiles from damage owing to the ship’s movement in a seaway, to preserve it from the effects of prolonged exposure to the sea environment, and to maintain it at constant readiness at all times
- Finally, and most fundamental of all, there existed no solid propellant for a rocket. Liquid propellants could be handled at sea, but they were dangerous

It is small wonder that, when interviewing Raborn as he reported for duty, the Chief of Naval Operations had said: ‘Anytime it looks as if you’re batting your head against a technological wall - if you see the job isn’t technically feasible - it will be cut dead’.

Probably the most valuable aspect of the priority accorded to Polaris, in the initial stage of the programme, was the authorization to Admiral Raborn to choose forty naval officers and technical experts to form the nucleus of his management team. For Raborn, supported by the Chief of Naval Operations, was determined to bring to bear on the Polaris project the latest and best in managerial skills and technique. Almost immediately, therefore, he and his key men set out on a tour of industry in the United States, hoping to pick from General Motors, say, or the du Pont Corporation, the secrets of large scale, dynamic management.

It is, perhaps, hardly surprising that Raborn and his team did *not* find exactly what they were looking for, because in the methods of ‘big business’; the objective of maximizing long-term profitability differs fundamentally from that of creating an operational missile system with certain characteristics by a given date. At the same time, the history of weapon development showed many examples of abortive or cancelled projects, with subsequent large-scale waste of resources. Raborn was determined to avoid such an outcome for Polaris. Not only was it essential, in his view, that his project *be* well managed but also it must be *seen* to be well managed. Only thus could he hope to retain the confidence of the politico-military establishment sufficiently to permit him the freedom from interference that he believed to be indispensable if he was to justify that confidence. Furthermore, by using the combination of management techniques best suited to his purpose, and proclaiming the novelty and effectiveness of the whole package, he could hope to gain acceptance of his relentless approach to project management.

The objective demands of an effective management system can be less injurious to *amour propre* than the somewhat arbitrary, and often abrasive, interventions of a powerful personality driving main1y ‘by the seat of his pants’. It is possible for all concerned, from the leader downwards and outwards, to have a love-hate relationship with a management system which impartially records success and failure, progress and delay; but the dynamic lender, operating as such, tends to bring about the division of his group into those who love, or at any rate respect him, and those who hate, or at any rate despise him.

Not only, as it is now easy to see, do the objectives of ‘big business’ and weapons project differ, but so does that other cardinal factor in successful large scale development and production activity, namely motivation - or lack of it. Much has been written and said about the motivation of individuals engaged at various levels in commerce and industry. The matter is complex. But in the late 1950s no one concerned with Polaris whether directly serving the government, or engaged in contract work, needed motivating, once the significance of the project had been explained to him. The future security of the United States was at stake. The Soviet Union must on no account achieve a dominating military-strategic lead. This simple, stark and incontrovertible (for loyal Americans) proposition, undoubtedly provided many individuals with a conscious sense of common purpose, simple and direct, who formerly had been responding, more or less, to the usual amalgam of social, economic, domestic and professional pressures. As we shall see in examining the British Polaris project, a quite different reason there provided motivation almost, if not quite, of American intensity, with similar benefit.

By mid-1956, in order to give effect to his ideas on systematic management, Raborn had enlisted the services of Gordon Pehrson, a civil servant who had experience of organizing procurement for the armed forces, and ‘a deep personal interest in developing innovative management control systems. Despite the initial division of Raborn’s immediate staff into two camps, the planner-managers and the technical decision makers, both groups were equally loyal to him personally. Disagreement between them became a source of creative tension rather than of bitterness, jealousy, scorn or disrespect. By January 1957 Pehrson had prepared a memorandum for Staff, to be signed by Raborn, which contained the essence of the future Polaris Management System. It stressed the need to develop an integrated planning and evaluation system for the entire programme that ‘would use a common format and common terms’. ‘I must be able’ the memorandum stated ‘to reach down to any level of Special Projects Office activity and find a plan and a performance report that logically and clearly can be related to the total job we have to do’. AdmirA-1 Raborn had (already) established a Progress Analysis Branch, later the Progress Evaluation Branch, in the Plans and Progress Division. Two other components in the management system were a Management Centre’ and a ‘Weekly Staff Meeting’. A rigid format was developed in which the first presentation was that of the independent evaluator (the head of the Progress Analysis Branch) who reported on the overall programme. He was followed first by the Technical Division Branch heads, who reported their sub-systems, and then either by representatives of the field offices or contractors who made special presentations.

Management is the process of deciding what has to be done, in what order, by whom, and then seeing that it is done properly and in time. By mid-1957 a series of Program Management Plans had been prepared, one for each of the several ‘end products’ that would together form the entire Fleet Ballistic Missile System. Each plan showed in detail the content, in terms of material needed and time for completion, of each element, in the form of subordinate plans logically inter-related. The possibilities were unambiguously delineated. ‘Milestones’ (time-related goals) for the completion of' each stage of each plan were established.

In the early stages of the project, whilst so many problems remained to be solved, and the prospect faced that new problems might still present themselves, the monitoring of progress by this Programme Evaluation and Review Technique involved acceptance of highly subjective assessments of progress by those responsible. In order to codify this subjectivity, therefore, a series of definitions of degrees of progress, or lack of it, were established as follows:

In Good Shape	No immediate problems that may endanger proper accomplishment.
Minor weakness	Some event, action, or delay has occurred which will impair progress against major objectives in one or more branches, requiring timely action by Director Special Projects.
Major weakness	Some event, action or delay has occurred which will impair progress against major objectives in one or more branches requiring timely action by SP. Required action may be a policy decision within SP, an appeal to higher authority for assistance, or decision.
Critical	Some event, action, or delay has occurred which impedes a successful accomplishment of one or more program objectives. Such a setback to the program requires reorientation or reprogramming of the FBM effort, with the advice end consent of NAVBMC and CRO.

Whatever importance may be attached to this use of a specially developed management technique in the success of the Polaris project, it would be a mistake to underestimate the value of such a discipline for generating creative achievement. When all is said and done, planning is a creative activity. So is research. Development, however, is primarily the application of knowledge and expertise; its major element is the judgement and evaluation of alternatives, in combining the results of research in order to achieve an objective. But the management technique used may itself undergo development, in response to lessons learned or demands made upon it. Under Raborn' s influence Special Projects made a point of documenting its management technique, for publication by the Navy Department. By 1962, a revised edition of Polaris Management gave, as the responsibilities of Special Projects:

- Developing, testing, and producing the Polaris missile.
- Coordinating construction of nuclear powered submarines and development of advanced communications systems.
- Developing, testing and producing launching and handling, fire control and navigation systems.
- Training Fleet Ballistic Missile personnel, including crews and personnel of nuclear powered submarines, submarine tenders, and the missile assembly, storage and issue facilities.
- Conducting tests to insure that fully operational weapons systems are turned over to the fleet on or before the required time.
- Constructing and equipping the overall system production facilities, including buildings, production, test and inspection testing, and maintenance facilities.
- Management of fiscal and other resource matters for the entire Fleet Ballistic Missile Program.

It will be noted that, in regard to the construction of nuclear powered submarines and development of advanced communications systems, the responsibility of Special Projects was specified as 'co-ordination'. This relationship with Bu-Ships and the shipyards associated with building the Polaris submarine fleet was a useful basis upon which to build the British Polaris project, which, as we shall see, was dovetailed neatly into SP's plans and Programs once the Nassau Agreement had been signed.

Two paragraphs headed 'Organisation of Special Projects Office', from the same document (Polaris Management 1962), encapsulate the system:

The management structure of Special Projects is special and unique in the organisation of the Navy - a Manhattan District type organisation. The office has a relatively small military and civilian staff that is essentially a task force with responsibility matched with authority to achieve high priority goals in the shortest time possible. Key positions involving technical direction, planning and administration have been filled by eminently qualified and experienced Naval officers and highly trained and experienced Civil Service employees. Approximately 400 people are located at the headquarters of Special Projects. This group, consisting of some 80 officers, 8 enlisted man, and 320 civilians, provide management and technical direction as well as clerical services to support the FBM Program effort. An additional 500 are stationed in the field at major contractors' plants. Still another 500 assigned to Special Projects are at the Naval Weapons Annex, Charleston, South Carolina.

The Director of Special projects, Rear Admiral IJ Galantin (from 26 February 1962) *reports directly to the Secretary of the Navy. The flu FBM Program is reviewed and approved as a total package. The full range of FBM Program responsibilities - development, production, construction, logistics, and operations - is considered as an integrated entity. The total program is reviewed by the Ballistic Missile Committee of the Navy, the office of the Secretary of Defense, the Joint Chiefs of Staff, and the National Security Council. Program control, in terms of numbers of systems and budget, rests with the Secretary of Defense. Operating and performance requirements of the weapon system are established by the Chief of Naval Operations.*

The Director of Special Projects, as weapons systems manager, has broad discretion to specify and coordinate requirements and areas of' work. He has control of available funds required to implement the numerous decisions regarding alternate scientific and engineering courses of action involved in the complex and urgent FBM Program. In summary, the determination and phasing of work to be done, technical direction of effort, evaluation of performance, and the responsibility for funding are vested in the Special Projects Office.

The officer whom Admiral Raborn had selected for the key poet of Technical Director in Special Projects, had already, in a sense, selected himself:

Work ... was in progress at the Navy's Inyokern, California Ordnance Testing Station. A group of engineers under the direction of a brilliant Navy commander, Levering-Smith, was putting together a series of increasingly more advanced solid fuelled missiles. The propellants were more powerful and the motors were large.

In late 1950 Smith's group constructed a relatively huge solid propelled missile. It was called 'Big Stoop'. This two-stage experimental missile was built specifically to determine whether it would be possible, with solid fuel, to deliver one of the heavy nuclear warheads of this period - a warhead weighing thousands of pounds.

'Big Stoop' successfully flew about 20 miles on each of three flights in 1951. (The promise of this experiment was ignored by authority for another four years despite the Korean War)

It is evidence from the recollection of Lord Mountbatten quoted in Chapter I that the Department of the Navy, and more particularly the office of the CNO, had retained in its collective consciousness the conviction that the Navy would one day need a solid-fuel missile and that it knew how to make one. By appointing Levering-Smith, now Captain USN, as Director, Technical Division, Special Projects Office, the US Navy was ensuring that no time would be lost in applying to Polaris the fruits of earlier experience in the all-important solid-fuel propulsion field.

In examining the stages through which the fleet ballistic missile project passed in evolving into the Polaris Programme it is important to note that the role of the Technical Division was cardinal. Levering-Smith recalls that:

On the failure of 'Jupiter', as predicted, I was told to get a budget out within two months for the first year's work. As it was December, no appropriations were available in that financial year. Burke (CNO) went to Gates (Sec. Navy), and after much argument, managed to get $360,000 (no doubt by giving up something else). I was then sent for and asked what I needed. I replied '25 million dollars' What was to be done? Raborn said 'Use Polaris priority to take over the necessary plant' I responded 'We should have a short-term advantage at the expense of long-term animosity'.

So they didn't do that; nor did they get the 25 million dollars, but they did get something near it. Again, as Technical Director, Levering-Smith was involved in building up the team. He recalls that:

Raborn was told he could have forty hand-picked officers and keep them for at least five years. Soon after that, a senior captain, who was Raborn's deputy, and a good man, saw that a captain junior to him had been selected for promotion to rear admiral. The deputy complained that if he stayed with SP he would lose his promotion. Smith said it was a test case for getting people for five years. Burke was asked to intervene with the Selection Committee. He said he could not do it. The officer left and went to a cruiser in refit. He was selected for promotion next time; with no more experience than if he had stayed with SP. So the rule was adopted that only officers who would go to an appointment indispensable (eg qualifying time in sea-command) to their further promotion would be released.

Before chronicling the more important events in the remarkably rapid progress of the Polaris programme, it will be helpful to set down the main principles that were adopted, from the outset, in regard to technical direction and control. The most important of these were established in the form of 'guidelines' laid down by Levering-Smith. These were designed to facilitate the rapid, sharply focused and coordinated technological progress required to bring forth the FBM system. Some of these maxims for the conduct of the Programme were codified in directives; some remained simply guides for the Admiral's own actions. The feature common to all was their relationship to the central concept of the Programme, namely, the need to make, and simultaneously to harmonize, specific advances in a dozen technologies.

To this end, the performance requirements of the various elements in the FBM system were to be set by the Technical Director in conjunction with the leading experts in the relevant technologies. In other words 'the state of the art', pushed to its practical limits within the time scale, would generate, the operational capability of the system as developed, and not a sot of performance characteristics rigidly laid down by headquarters staff not directly concerned with the technologies. This way, 'the best' was less likely to become the enemy of 'the good'; time and resources would not be frittered away on striving for marginal improvements not critical to the achievement of the timely deployment of a satisfactory operational system.

At the same time, by encouraging (and of course finding) competition between groups, seeking, in each technological field, the best solution to a problem, Levering-Smith was able to consider alternative solutions, and seek the 'best buy' in each case. He disposed quite firmly, also, of another perennial source of weakness in programmed development. He insisted that the objective of the programme was a deployable FBM system, and not the advancement of technology. Only those who have been involved with the conduct of R&D, in general, can appreciate the vital significance of this and the personal and professional excellence of a director who can exercise such authority without forfeiting the loyalty, or at any rate dampening the enthusiasm, of his field teams. As a corollary to insistence upon systems development rather than technical advancement, Levering-Smith made sure that no technological tasks other than those contributing directly to the deployment of a submarine-launched ballistic missile system were undertaken.

Although the advances that had to be made if the Polaris FBM System was to be created were technological rather than scientific, scientists were periodically invited to review progress. Their confirmation of the progress reported not only served to sustain the confidence of the administration in the Program, but ‘bolstered the self-confidence of engineers engaged in the very uncertain effort of developing several technologies’.

A further decision by Levering-Smith, based no doubt upon experience, was that ‘naval laboratories were not to be used in the development effort unless they possessed a technical competence unavailable in private organisations. Naval laboratories .. are considered too unresponsive to programme priorities to be used unless there was no alternative’.

Having established decentralization and competition between groups at the core of organisational relationships throughout the programme, Levering-Smith had to determine how best to exercise his own personal judgement and control over such a large and complex undertaking. The method he chose was to ensure that the interface specifications would be established early and monitored tightly:

The mechanism for control was the co-ordination drawings maintained by Vitro Laboratories for the Technical Director. At meetings, among system contractors, the branches and the central staff, the characteristics and outputs of the subsystens (usually in the form of electronic signals and the like) would be specified and recorded on drawings. From that point on, all work within the sub-System was the responsibility of subsystem contractors and the relevant branch, but all changes affecting systems interfaces (eg fire-control system/navigation system) were considered fundamental and required formal approval. For a long period Admiral Smith himself signed (‘authenticated’) all co-ordination drawings and reviewed all deviations. Nothing appears to symbolize the Admiral’s deep involvement more than the attention he paid to controlling the co-ordination drawings.

Admiral Smith, however, was also aware that the program ran on money as well as on engineering drawings. After having some development contracts delayed because the program’s financial office miscalculated the need, he made it his own policy to gain control of internal budget allocations. At his suggestion the SP office Board of Directors was established and given authority to approve the budget requests of all branches in the Office.

Finally, at the instigation of Levering-Smith, the Program took as its own measurement of technical success the operational reliability of the FBM system. Reliability and methods to achieve it became program fetishes. An elaborate system of technical documentation was established to ensure that components matched design specifications and that discrepancies would be traced to their source. The quality control procedures inPolaris manufacturing facilities exceeded in stringency those applied in other projects. The test process included both subsystem tests and integrated system tests. Independent evaluations occurred at a number of points. The design of the system itself included duplication navigation$_1$ fire control, launch and ship-system components.

There were those who argued that too much testing may actually impair the reliability of a system; others opined that 'the reliability effort became so ritualistic, expensive and advertised that it most likely had its origins in motivations as political and opportunistic as PERT'. Within the Programme, however, it is noted with pride that no submarine petrol has been aborted due to technical failure'.

The FBM Programme was unique in many ways. Perhaps the most important, in terms of exercising effective control over rapid and complex development, was the decision to retain this control firmly in the hands of the Special Projects Office. Hitherto it had been customary, once the procurement stage had been reached, to charge the leading industrial contractor with the management of the project. Never, on the record, very satisfactory, this system could not have coped with the demands of synergy - the simultaneous pushing to the limit, and application of a dozen different technologies in pursuit of a single, complex weapon system.

Summary of Polaris Progress	
In order to understand the magnitude of the achievements in which Britain was in due course enabled to participate, it will be helpful to set forth the sequence of major events, as the United States Navy's Fleet Ballistic missile Programme moved forward:	
1955	
28 Nov .	US. Navy stated long-range objective to develop a solid-propelled ballistic missile for use in submarines.
December	Rear Admiral William F. Raborn USN reported as Director, Special Projects. The Navy Fleet Ballistic Missile Weapon System operational requirement was issued. The need for extension of research and technical know-how beyond the state-of-the-art was recognized for the following areas: inertial guidance, hypersonic aerodynamics, liquid and solid rocket motors and propellants, and ship navigation. The office of Secretary of Defense authorized the Army and Navy to proceed with the 'Jupiter' programme.
1956	
March	The Joint Army and Navy Ballistic Missile Committee authorized a navigation system development program, a weapon system test and development program, an FBM surface combatant development program, and an FBM submarine development program.
April	Feasibility study contract awarded to Lockheed Aircraft Corporation to determine suitability of missile development for submarine environment.
July	The Fleet Ballistic Missile program at this date had as its objective a ship-based liquid propellant missile adaptation of 'Jupiter'.
18 July	Office of Secretary of Defense Scientific Advisory Committee (OSDAC) reaffirmed its recommendations concerning the Navy's solid propellant project. Specifically, it recommended: (1) a full-fledged solid propellant missile program instead of the existing test vehicle program (2) elimination of instructions to contractors that as much as possible

	of the ‘Jupiter’ nose cone guidance, and control components be applied to the solid propellant vehicle, since the suitability of the components was very questionable.
September	The Atomic Energy Commission (AEC) estimated that a suitable warhead would be available for a smaller ICBM by 1965, with an even chance of attainment by 1963.
23 Qct	OS~SAC recommended that the Navy solid IRBM program ‘receive top priority, equal to that of the other IRBM programs ... and that its final objective be the development of a missile of the Polaris type. In the 30,000 pound class, capable of a range of 1500 nautical miles in the 1962-63 period.’
November	Eleventh test of solid propellant missile thrust water control devices known as ‘jetavators’ was successfully completed. The Secretary of State for the Navy proposed the Polaris program to the Secretary of Defense and requested authorization to delete the interim liquid missile launching capability from merchant hulls.
18 Dec	Joint Army Navy Ballistic Missile Committee was dissolved.
19 Dec.	The Secretary of the Navy reaffirmed the highest Navy priority for the FBM program and established the Navy Ballistic Missile Committee (NAVBMC) to direct the progress. The Special Projects Office, previously charged with the development of the ship-based aspects only of the weapon system, was given the responsibility for development of the entire system.
1957	
January	The FBM Navigation Development and Host ship, USS began operations at sea. Special Projects (SP) organised Polaris-Submarine Special Steering Group, later known as the Steering Task Group (STG), to formulate FBM goals and plans. Members were drawn from top levels of participating agencies and contractors. The STG tasks were to advise an optimum missile and submarine envelope and thereafter to assist in monitoring and sponsoring later contingent developments. The Chief *of* Naval Operations (CNO) established interim (1963) and optimum (1965) goals for the PBM program. SP began scheduling the program in phase with reasonable expected advances in the state-of-the-art to assure attainment of program goals and maximum economical use of resources.
February	CNO issued a requirement for a 1500 nautical mile solid propellant ballistic missile capable of being launched from a submerged submarine, to be operational by 1965.
28 March	The highest total impulse ever achieved in the USA by a solid propellant rocket motor was attained in a static firing of a Polaris test vehicle by Aerojet General Corporation.
March	The overall dimensions of the Polaris missile and the corresponding partners

	for the FBM submarines were established. It was vital that this should be done early in the program because of submarine design and construction lead-times.
18 June	CNO approved the ship characteristics of the FBM submarine. (This approval was given three and a half months sooner than the complex procedure customarily requires).
1 July	The FBM Program at this date had as its objective to provide, an FBM submarine weapon system with a 1500 nautical mile range ready for operational evaluation not later than 1 January 1963.
October	The Atomic Energy Commission estimated that the Polaris warhead development program could attain Polaris requirements in 1960.
22 Oct	Sec Navy proposed to Sec Defense an acceleration of the FBM program. It included: (1) Attainment by December 1959 of an operable 1200-mile range missile launched from land or sea; (2) Attainment by early 1962 of an operational capability of two FBM submarines and a third three months later; (3) Attainment by mid-1963 of a missile of the performance specifications previously set up as a goal for 1965 (1500 mile range).
November	The compressed air launching subsystem was proven by successful operation of Peashooter, an experimental tube launcher at San Francisco Naval Shipyard.
26 Nov	NAVBMC informed OSD that, for the same dollar requirement. reported an 22 October, the FBM program could be accelerated to provide an operational Polaris submarine system, with a 1200 mile range missile, by October 1960.
9 Dec	Sec. Del. authorized acceleration of the Polaris program to achieve the first Polaris/submarine weapon system in 1960.
December	Preliminary design for the first submarine was completed and contract design started - both ahead of schedule.
20 Dec.	SP and the Bureau of Ships (Bu-Ships) forwarded to CNO a plan for maximum acceleration which gave their best judgment of results possible under 'national emergency' conditions. It was emphasized that the earliest submarine completion dates (December 1959/ January 1960) could be met only under the most optimistic conditions, 'assuming every possible breakthrough and key personnel working with maximum force end motivation'. Streamlined decision making processes and optimum fiscal support also were identified as necessary to meeting such dates.
1958	
11 Jan	First FBM test flight, Point Magu, California.
January	Constructions begun on the first three FBM submarines. The first one, USS

	George Washington had been laid down as USS Scorpion but was cut in two and had a 130-foot weapon system section inserted.
12 Feb.	The President signed the fiscal year 1958 Supplemental Appropriation Act, including funds for construction of the first three Polaris submarines (SSBNs). Construction had begun in January using funds 'borrowed' from other Navy programs.
23 March	First launching from the submerged tactical launcher facility (Pop Up) off San Clemente Island, California, was successful.
9 April	As a result of Sec Def action on the Fiscal Year 1959 augmentation budget, the Navy submitted to OSDBMC a plan to provide a five submarine capability with a 1200 nautical mile range missile by mid-1961 with the first submarine ready-for-sea by April 1960.
23 April	Fiscal Year 1959 funds were delegated to long lead-time items for the fourth and fifth SSBNs.
7 May	CNO promulgated the concept of operations for the FBM weapon system mid directed cognizant Navy action to place the system in operational status in 1960.
1 Jul	FBM program at this date had as its objective a complete Polaris/Submarine weapon system with a 1200 mile range missile in 1960 with a three submarine capability by mid-1961. Three submarines were authorized at this time.
26 July	Sec Def. authorized procurement of long lead-time items for SSBNs 6-9.
29 July	Construction of submarines four and five authorized by the President.
22 Aug	The President signed the Department of Defence Fiscal year 1959 Appropriation Act. Funds for SSBNs 6-9 were withheld. Funds for SSBNs 4-5 which were provided for in the Act had been apportioned in July.
25 Aug	Deputy Sec Def. granted authority to delegate funds for procurement of long lead-time items for submarines as then proposed for the fiscal year 1960 FBM program budget (SSBNs 10-14).
28 Sept	The first Polaris (AX series - 'x' signifies 'experimental') began flight-testing. As was to be expected in the pioneer work in large solid propellant rockets, of which Polaris was the first, the record of successful flights in the early phases was not spectacular. The failures were important because of what could be learned from them, but the successes were even more significant.
30 Sept.	CNO approved construction of the Polaris Missile Assembly facility at Charleston, South Carolina. This is where the tactical missiles are assembled, checked out and loaded on FBM submarines before going on operational patrol.
5 Dec	The Weapon System Test Ship, USS *Observation Island* was completed on schedule and commissioned.

23 Dec	The President authorized construction of the sixth SSBN.
1959	
1 March	Construction of the team training Facility at the Naval Base, New London, Connecticut, to support submarine crew training began.
20 April	First fully successful Polaris AX vehicle flight test.
9 June	First FBM submarine, USS *George Washington* launched at Groton, Connecticut.
27 June	The President authorized construction of SSBNs 7-9.
1 July	FBM Program at this date had as its objective a complete Polaris/submarine system with a 1200 mile range missile by 1960. Nine submarines and one submarine tender (depot-ship) were authorized.
14 August	First air-eject launched test flight at Cape Canaveral, Florida, fully successful. The missile, Polaris AX14, was launched from a ship motion simulator tube (which was not, however, in motion), was ignited when 60 feet in mid-air.
27 August	First submarine launch of a large solid-propellant ballistic missile Polaris test vehicle launched from the USS *Observation Island* at sea off Cape Canaveral. Ship had complete submarine-type launching and fire control system. Missile was launched by compressed air.
21 Sept.	Following the development plan, after 17AX flight-tests the first pre-prototype tactical version of the missile, A-1x, was successfully launched from USS *Observation Island*.
30 Dec.	The first FBM submarine, USS *George Washington* was commissioned at Groton, Connecticut.
1960	
7 Jan	First inertially-guided Polaris test vehic1e flight at Cape Canaveral.
29 March	First fully integrated FBM system test (A-1X test vehicle launched from USS *Observation Island*. Submarine type navigation, fire control and launching equipment used. Missile inertially guided). Naval Weapons Annex, Charleston, South Carolina, commissioned.
14 April	First successful underwater launch of a large solid propellant ballistic missile, San Clemente Island, California. (Polaris flight test vehicle using reduced quantity of propellant to produce planned 23-second flight. Launched from static underwater launcher).
25 April	First 1,000 nautical mile Polaris test vehicle flight.
1 July	Polaris FBM program at this date had as its objective a complete submarine system with a 1200-mile range missile by October 1960. Nine submarines and two tenders were authorized.
8 July	First IBM weapon system tender, USS *Proteus* commissioned.

15 July	President authorized construction of SSBNs 10-14.
20 July	The first and second attempts to fire Polaris missiles from a submerged submarine were successfully achieved from USS *George Washington* off Cape Canaveral. The first missile fired was the 31st A-1X to be flight-tested.
15-18 Oct	USS *Patrick Henry* successfully fired four Polaris test vehicles 500 miles at sea, under operational rather than test conditions.
10 Nov.	First test vehicle in the second generation. 1,500 nautical mile range, Polaris A-2 was successfully launched at Cape Canaveral. Missile went over 1,400 nautical miles. When Polaris A-l development flight tests ceased, in mid-November, the totals stood at 28 successes, 11 partial successes and 1 failure. Development flight testing of the second generation, Polaris A-2 continued in parallel with submarine firings of the Polaris A-1. Originally conceived as basically an A-1 with a 30-inch longer first stage, the A-2 has developed into amissile with many advances over the A-l, and has enjoyed a high degree of success in development flight tests.
15 Nov	USS *George Washington* (SSBN 598) departed Charleston, South Carolina, to go on operational patrol. She carried 16 tactical Polaris A-1 1200-mile range missiles.
22 Nov.	USS *Ethen Allan* (SSBN 608) launched. First submarine designed from keel up as an SSBN submarine.
30 Dec.	USS *Patrick Henry* (SSBN 599) departed Charleston to go on operational patrol with 16 Polaris A-1 missiles.
1961	
1 Jan	The VLF Naval Radio Station at Cutter, Maine, went on the air one year ahead of original schedule.
21 Jan	USS *George Washington* arrived New London, Connecticut, having completed her first patrol. She had been gone 67 days and had set a new record for length of time submerged - 66 days and 10 hours. She came alongside the tender *Proteus*, which was to complete her first FBM submarine upkeep in the stateside port before sailing to Holy Loch, Scotland.
29 Jan.	President Kennedy authorized the acceleration of the of the Polaris program. As a result construction of SSBNs 15-19 (initially planned for Fiscal Year 62 budget) were authorized in FY 1961. The third submarine tender was also authorized for FY 61.
3 March	USS *Proteus* arrived at Holy Loch, Scotland.
8 March	USS *Patrick Henry* returned from patrol and came alongside USS *Proteus* in the Holy Loch, having bettered the *George Washington's* record by staying submerged 66 days and 22 hours.
27 March	The President announced plans for 10 SSBNs to be included in the FY1962 program. Funds were accordingly added to the FY 1962 budget request.

1 July	FBM Program at this date had as its objective the deployment of two more submarines carrying the 1200-mile range Polaris missile by the end of 1961 and the deployment of the 1500-mile A-2 missiles in the *Ethan Allen* class submarines during 1962. Nineteen SSBNs and three tenders were authorized.
Oct-Dec.	During this period a series of A-2 missiles was modified to flight-test certain sub-systems and equipment designed for use later in the A-3.
7 Dec	Last production model of Polaris A-1 delivered.
23 Dec.	First launch of 1500 nautical mile range Polaris A-2 test vehicle from submerged submarine off Cape Canaveral (USS *Ethan Allen*).
1962	
26 Feb	Rear Admiral Ignatius J. 'Pete' Galantin relieved Vice Admiral William J Raborn Jr. as Director, Special Projects Office.
23 April	Department of Defense (DoD) announces se1ection of various facilities planned for Polaris support in Pacific Area. Puget Sound Naval Shipyard at Bremerton, Washington, was selected as FBM submarine overhaul (refitting} yard: the Naval Ammunition Dept. at Bangor, Washington, selected for the Polaris missile assembly facility PMFPAC); Pearl Harbor, Hawaii, was chosen as the location of the crew training facility.
6 May	USS *Ethan Allen*, operating in the Pacific successfully fired a **Polaris** missile with nuclear warhead. Successful nuclear detonation achieved.
1 June	USS *Hunley* commissioned at Newport Virginia. First submarine tender to be built from keel up expressly to serve FBM submarines.
1 July	FBM program had at this date as its objective the deployment of three additional submarines carrying Polaris A-2 missiles and delivery to the fleet of the operational Polaris A-3 by mid-l964. Twenty-nine submarines and three tenders were authorized.
7 August	First flight test of Polaris A-3 at Cape Canaveral. (Second stage malfunction). Polaris A-3 is a significantly greater advance over A-2 than was **Polaris** A-2 over A-1. Its range is designed to be 2500 nautical miles (2880 statute miles) It continues pioneering the leading edge of state-of-the-art which has marked the US Navy's scientific endeavours ever since Thomas A Edison set up the first Navy research laboratory during World War I. In particular it continues the rapid pace of significant advances across a wide band of the sciences which have marked the Polaris Fleet Ballistic Missile weapon system program. In terms of hardware design Polaris A-3 is approximately an 85% new missile. While the Navy-Industry team which developed Polaris Al and A-2 includes many of the nation's most experienced rocket scientists, the task of developing a missile of 60% more range (A-3) with no increase in the overall size of the missile (A-2), was obviously an awesome challenge. Some less than fully successful flight tests could be expected. A series of different difficulties, each relatively minor of itself, denied the developers test crews complete success

	until the seventh flight. Extensive static testing and ground tests played an important role in isolating these hardware malfunctions and in verifying the soundness of the basic A-3 design concept. In April 1963 the development flight test programme leap-frogged R&D problems by going to the prototype tactical version and a highly successful flight on 17 June, this more advanced model was successfully tested for the first time in a tube-launched firing from the USS *Observation Island* at sea. The first successful A-3 launching from a submerged submarine took place on 26 October 1963, and on 26 September 1964 *USS Daniel Webster* sailed for the Pacific to carry out the first operational patrol with 16 A-3 missiles on board.

But by this time the British Polaris submarine programme, initiated at Nassau by agreement between President John F Kennedy and Prime Minister Macmillan in December 1962, was well underway. The following chapter is devoted to a description of the *Dreadnought* Project, but for which Britain would have been unable to build her own nuclear-powered submarine in time to adopt the Polaris Missile in place of Skybolt, when this was cancelled in 1982.

CHAPTER IV

(*This chapter is based almost exclusively on the author's personal archives and on the record of interviews with leading personalities involved: reference to personal material is duly registered under* <u>*personal archives:*</u> <u>*interview material*</u> *is similarly identified by person/date. It will be understood nonetheless that it has not been possible to cite specifically from materiel which remains security-classified.)*

THE DREADNOUGHT PROJECT

When I became First Sea Lord I decided that we must have a class of ship armed with surface-to-air guided missiles; and we must have nuclear-powered submarines.

(Lord Mountbatten)

It might have been supposed that the Royal Navy's self-esteem wou1d suffer a mortal blow in being relegated to second place in the world's navy league with the emergence, after World War II, of a vastly predominant US Navy. That this was not so may be attributed mainly to three factors. In the first place, the mutual respect of the two navies, born of years of allied operations in a World War; the intimate professional relationship, and numerous personal friendships, mitigated any possible sense of inferiority. Secondly, the evident need to work together in countering the threat from increasing Soviet sea-power brought a fresh impetus to co-operation. Thirdly, the establishment in 1947 of an independent United States Air Force, which threatened to diminish the role and importance of the US Navy, provided an additional bond of fellow feeling with a Royal Navy now deprived, by the Royal Air Force, of its former primacy as 'Britain's sure shield'.

Furthermore, despite the reestablishment of the peacetime primacy of political considerations over the organisation of military victory, strong Anglo-American military (including scientific) links were retained. These, although progressively diminished in scale and scope, survived the periodical crises in political relations mid public sentiment arising from the abrupt ending of lend-lease by President Truman in 1945; the termination of collaboration in nuclear research and development brought about by the McMahon Act of 1946; the Suez Crisis of 1956, and the tensions of alliance politics associated with nuclear strategy which came to a head in the early sixties.

In addition to maintaining a strong Naval Mission in Washington, together with numerous NATO appointments that meant working closely with US Naval officers, both the Fleet Air Arm and the Submarine Service maintained, mainly through a series of exchange appointments, continual and close association with developments in these two arms. In so far as Polaris was concerned, the 'special relationship' of these two naval arms had conflicting consequences. The Fleet Air Arm, striving to maintain its existence, upon which it believed the future of the Royal Navy to depend, was fighting on two fronts. Internally, it suspected that the submarine arm was seeking to supplant it, as the Navy's main striking force; externally, it sought continually to counter the pretension of the RAF based upon the theory of 'the indivisibility of air power', that it could provide whatever air borne 'instruments of sea-power' might be needed in the future. The assumption by Admiral Sir Caspar John of the post of First Sea Lord, consequent upon the sudden death after a few months in office of Lord Mountbatten's successor, Admiral Sir Charles Lambe, brought about an accentuation of this conflict. Whereas Sir Charles Lambe had personally contributed, some years previously, to a post-war resolution of the respective and complementary roles of the Navy and the RAF in future maritime strategy and operations, Sir

Officer Submarines during the latter part of Sir Caspar's period as Vice Chief of the Naval Staff, and later, when he became First Sea Lord, was Rear Admiral AR Hezlet, a most distinguished and dedicated submarine protagonist.

The British Submarine Service, on the other hand, had become conscious, since 1947, of having acquired a new primary role that would markedly augment its importance relative to the other main arms of the Fleet. It was to be first and foremost an anti-submarine force, in an epoch when the only potential major naval threat was posed by a large, and growing, Soviet Russian submarine fleet. Furthermore, with Britain's security at sea, as elsewhere, coming more and more to be based upon the NATO alliance, the British submarine force became correspondingly more closely integrated, both operationally aid technically, with that of the United States. Without a break, therefore, after 1949, the Flag Officer Submarines, nationally and in his NATO capacity as Commander Submarines Eastern Atlantic, maintained close touch with his American opposite number both in person and at staff level.

This increase in the importance of the submarine arm, relative to surface ships and aircraft, in the conduct of anti-submarine warfare, arose before the advent of nuclear power. It derived from the marked improvement in the underwater speed and endurance of conventional submarines brought about by the intensity of various research and development reinforced by operational experience. Perhaps, therefore, it is not surprising that the Admiralty did not initially attach overriding importance to the development of a submarine reactor as a feature of the atomic energy programme. When asked for their views on reactor policy their Lordships, whilst in favour of nuclear propulsion for submarines, evinced no sustained enthusiasm for the project:

Harwell formed an enriched reactor group – ERG - late in 1949 in order to extend a study which had been under discussion for more than a year. The original proposal was for an orthodox, graphite-moderated, gas-cooled lattice reactor that would use uranium enriched to twice the normal concentration of U-235. From the outset such a reactor was assumed to serve several purposes. It would be useful both as a high-flux experimental reactor and also for power, for it would generate the greatest amount of heat in the smallest possible volume. At first, 'power' in this context meant primarily power for naval propulsion, and ERG's objective was defined as the production of a reactor of value to the Royal Navy for the installation in a submarine. **...** *Submarine propulsion seemed to be the most direct and justifiable application of nuclear power.* **...** *Admiralty views were to be obtained at all stages of design and construction.* **...** *When Harwell asked the Navy at the beginning whether they thought it a really worthwhile proposition, the answer was 'an unequivocal yes'. Before long the Admiralty suspected that Harwell was not very keen on the submarine reactor, but Cockcroft said they were, provided the Admiralty considered the requirement important enough to justify the effort. Information from the United States in 1951 showed that they, with their much more highly enriched fuel, were designing much smaller submarine reactors….Penney had written at the end of 1951 that he could not think why Britain wanted a nuclear submarine, which was just as much an instrument of war as an atomic bomb. 'What we have done', he wrote, 'is to contract to build a power reactor in the most cramped of all ships, such that we lose the ship, the reactor, and the crew if the reactor fails when the ship is underwater as it must be most of its normal cruising.'* **...** *late in the year 1952 Harwell's Atomic Energy Board were perturbed because the Navy had not given extensive thought to the tactical use of nuclear submarines.* **...** *In October 1952 the Chiefs of Staff agreed that the Submarine project should not have a high priority, nor be allowed to interfere with any of the existing programmes or with the piles then needed to produce extra plutonium. Because enriched reactors and submarines were bound together, the decision not to pursue nuclear submarines vigorously had important consequences for future British nuclear power development.* (Gowing pp 273-276)

The trans-Atlantic information exchange, upon which participants in the professional in-fighting referred to above based their respective arguments, was informal. That is to say, once the respective governments had agreed upon the establishment of naval missions and exchange technology, governed by the McMahon Act of 1946, subsequently amended, and certain matters of national political and defence policy of a particularly sensitive nature. When it is recalled that the United States, in particular, had reason to be deeply concerned with the preservation of security in regard to military matters, the degree of trust placed in the Royal Navy by the US Navy was remarkable. It is not necessary, in describing the background to the establishment of the British Polaris Executive, to deal further with exchanges between the Fleet Air Arm and the US Naval Air Arm. But examples of the 'state of play' in regard to submarine developments are to be found in the archives of the Flag Officer Submarines. Although these cannot be quoted *in extenso*, it is permissible to follow here, in outline, the picture of developments in the Unites States which the Flag Officer Submarines was able to provide in his capacity as advisor to the Admiralty Board on submarine matters. Apart from the exchange of personal visits made by successive FOSMs with their USN opposite numbers, continuity of information was provided, from 1955 onwards, by the establishment of a Staff Officer (Submarines) on the staff of the Admiral British Joint Services Mission, Washington (whose post in 1962 was combined with that of the British Naval Attaché).

It is not possible, at this juncture, to establish precisely how the political exchange 1eading up to the 1956 Amendment of the McMahon Act was brought about. The fact is, that following upon the meeting at Camp David in March 1960, between Prime Minister Macmillan and President Eisenhower, the Atomic Energy Act of 1946, already amended in 1954, was further amended in terms summarized as follows:

In June 1956 in spite of objection from AEC and JCAE, the Defense Department with White House and the Department at State support used a legal technicality to conclude an Agreement to give the British data on the nuclear submarine Nautilus, including information on nuclear ship propulsion reactors.

This favourable response to Britain's request for help in the development of an atomic submarine reflected the importance attached by the US Navy to enabling Britain to contribute to the total strength of the nuclear powered submarine force of the West, believed to be essential in countering the large and rapidly growing submarine arm at the Soviet Navy, already capable of deploying nuclear armed missiles off the Eastern Seaboard of the United States.

Reverting to FOSM's advice to the Admiralty Board, there is evidence that already, in December 1955, FOSM had pointed out that, although the general development of submarines would be governed by the Admiralty Directive of 1948, namely that '*In war the primary operational function of our submarines would be the interception, and destruction of enemy submarines'..... the development of a strike submarine in some form was 'a clear requirement'*.

It was also represented that, as nuclear propulsion development had only just started in Britain, it was unlikely to be at sea in British operational submarines for at least ten years. It was further submitted by FOSM that Britain had fallen far behind the US in the marine application of nuclear power, owing to the government policy of concentrating upon building nuclear power stations. But some of this work would be applicable (to marine propulsion) and the Engineer-in-Chief's group at Harwell had lately been reinforced (1955) by the addition at a Constructional end an Electrical Officer. A hint of the possibility of the United States 'opening up' on nuclear information was given, no doubt arising from the representations made at Camp David, to which reference is made above.

It seem reasonable to deduce that, following upon Admiral Mountbatten's visit to the US Chief of Naval Operations, Admiral Arleigh Burke, referred to in Chapter 1, which took place in November 1955, Mountbatten had appreciated that unless Britain could build an operational nuclear-powered submarine within five or six years, she could not hope to participate in the US nuclear-powered, ballistic missile-armed submarine programme.

requirement to develop a British nuclear reactor for submarine propulsion, with or without American scientific and technical assistance. Rear Admiral Ridley CB has recalled in the following terms, during an interview in 1973, the genesis of the British naval reactor:

I was appointed, in January 1956, as a Commander, to join the Naval Group at the Atomic Energy Authority's Establishment at Harwell. Before joining I underwent a six weeks course in nuclear physics at Salford Technical College. Thereafter, on joining Harwell, I took part in the design of the Royal Navy's first reactor, called Neptune. *The impulse for Neptune was given in April 1955, when Mountbatten, on becoming First Sea Lord, had invited a group of naval officers, naval constructors and representatives of the AEA and industry, to formulate proposals for the introduction of nuclear powered submarines into the fleet. It was decided that* Neptune *would be a zero energy experimental and research reactor, to be produced by a team composed of representatives of the AEA, the Royal Navy and the Royal Naval Scientific Service, the Royal Corps of Naval Constructors, and the shipbuilding and engineering concerns Vickers, Rolls Royce and Associates, and Foster Wheeler. Prior to work on Neptune being started, Vickers Metropolitan in conjunction with the AEA had begun work on a prototype propulsion reactor, but progress had been delayed owing to the requirement for 'enriched fuel (Uranium 235) which was not then being produced in the UK.*

Progress with *Neptune* however, was good. The Naval team felt sure that, given enough money, they could produce an operational pressurized-water-cooled submarine reactor. In November 1957 *Neptune* 'went critical'. In the meantime, under continual pressure from the First Sea Lord (Mountbatten), plans for Britain's first nuclear powered submarine were being progressed. She was to be called *Dreadnought*. Cutting across established departmental boundaries, but without, however, full project autonomy, particularly as regards finance, a *Dreadnought* Project Team (DPT) had been formed, with headquarters in the Admiralty buildings at Bath. Leading the DPT was Mr. Rowland Baker (later Sir Rowland Baker, Royal Corps of Naval Constructors) Ridley was Baker's deputy. Mr. John Starks, who had been staff constructor to FOSM, was in charge of hull design; Mr. Henry Fitzer, of the Electrical Engineering department and Mr. Henry Baines, responsible for 'planning and progress', formed the nucleus of the *Dreadnought* Project Team.

In terms of management the *Dreadnought* Project Team never achieved the formal status of an autonomous, self-accountable, body either technically or financially. Yet because it owed its existence directly to the urgent directive of the Board of Admiralty, and in particular the personal intervention of the First Sea Lord, ways were found to enable the DPT to function, informally, as a project group. The Director of Navy Contracts set up a 'cell' within the DPT; members of DPT rapidly developed their own trans-Atlantic contacts; existing relationships with British nuclear power, shipbuilding and engineering industry quickened; additional members of the team were recruited, on the basis of secondment, from Admiralty Departments, in particular that of the Director of Naval Construction. It was indeed this Department that felt most keenly the loss of direct control over the most important innovation in naval construction for half a century - since Fisher's *Dreadnought* battleship in fact.

The task which faced the DPT was far beyond the design and construction of a evolutionary warship, and a submarine at that. Even with the advantage of the unbroken exchange of technical information with the Americans in non-nuclear matters the design of the submarine's hull alone was a formidable task. There first had to be a change in basic shape from 'long and thin', adequate for underwater speeds up to about fifteen knots, to 'short and fat', hydrodynamically essential in order to achieve the much higher submerged speeds which nuclear power made feasible. Secondly, the new shape demanded far more than merely the adaptation of established techniques, and the extrapolation of accumulated data in regard to every aspect of submarine design. Thirdly, new materials were needed, particularly steel for the pressure hull capable of being welded without loss of strength and other qualities. New weapon systems, communications, navigation equipment and submarine control gear had to be incorporated in the design of what was intended to be not merely the prototype of a nuclear-powered submarine of

This daunting design task had to be progressed without delay yet continually taking into account the necessity to accommodate the, as yet, far from complete design of the nuclear reactor, its heavy shielding, its instrumentation and auxiliary machinery, together with the ‘conventional’ steam turbine plant, with its condensers, gearing and the electric power generators and distribution systems indispensable to the propulsion plant as a whole, and the operation of the submarine.

In all this, decisions had continually to be made; work put in hand through a multitude of contracts; rigorous quality controls of the standard demanded by Admiral Rickover had to be established and maintained. Secrecy, in regard especially to American technology and practice, was a constant preoccupation. And above all, there was the predominating feature of all things nuclear, namely SAFETY. We have seen in Chapter II (and see also Appendix I), some of the detailed nuclear safety legislation that Rickover had obtained through Congress. Although in Britain the Atomic Energy Authority, rather than Parliament, was the source of nuclear safety rules and regulations, the effect of these upon design parameters, modes of operation and standard practices were continuing, pervasive and mandatory.

So far we have been considering the task of the DPT in terms of producing a single operational submarine, HMS *Dreadnought* that was to be a British version of the nuclear powered attack submarine (SSN) USS *Skipjack*. But Lord Mountbatten’s vision had extended, from the outset, far beyond that revolutionary project. In the first place, Britain, whilst welcoming American nuclear experience (particularly in regard to the reactor core), must design and build her own submarine reactor and associated propulsion plant. The intention was, therefore, to set in train, as a separate project from *Dreadnought* though associated with it, the design and construction of a British submarine reactor at Dounreay, near Thurso on the Pentland Firth, close by the AEA’s experimental reactor plant. In order to match the design with a submarine hull a full scale ‘mock-up’ of one was built at Southampton.

Admiral Rickover seemed not to be averse to this British initiative. No doubt the evidence of the Royal Navy’s determination to ‘go nuclear’, with or without American assistance was a factor in securing Rickover’s continuing, if sometimes prickly, support. Indeed, ‘Rick’s’ technique of persuasion, alternating swiftly, and unpredictably, between enthusiastic approval and unconcealed disdain, has bees remarked upon by those closely associated with his impact upon the British Energy’s nuclear projects. A particular and recurrent source of friction arose from the DPT’s most comprehensive (and as it turned out prudent) ‘shopping list’ of ‘spare gear’ for HMS *Dreadnought* By the time (to look ahead for a moment), the Admiralty had decided in l958 to utilize the complete *Skipjack* plant to power *Dreadnought*, the Americans were no longer building *Skipjack* class reactor plants. Hence the source of appropriate spares would, but for *Dreadnought’s* requirements, have dried up.

It is evident from the foregoing brief description of the genesis and early development of the *Dreadnought* Project, that it was a project in name and intention rather than in nature. This is not to diminish its importance, either as an innovation or as an undertaking *per se*. To set up within the Admiralty, and in advance of the major organisational reforms then in prospect, an inter-departmental project-orientated group, with project-related autonomy in technical matters, was a bold move. By calling the group a *‘team’*, it was hoped, no doubt, to make up by good spirit and enthusiasm for certain fundamental organisational deficiencies in the arrangement. The most frustrating of these was the retention by the Director of Naval Construction of financial control and responsibility for the *Dreadnought* Project. Despite the wide range and complexity of new technical knowledge that had to be acquired, assimilated and applied in designing and constructing *Dreadnought* she was funded as if she had been merely the first of a new class of an existing type of warship, eg a new cruiser or a new destroyer.

To compound the difficulties of financial provision expenditure and control, the Dounreay weakness arising from this quasi-project management also related to the novelty of the task. The individuals who were seconded from the existing technical departments to become members of the DPT remained responsible to, and under the technical authority of, the chiefs of these departments. In principle, and in regard to normal technical standards, this was a reasonable provision, but the DPT were dealing with technology so advanced that the expertise developed rapidly, in many instances, beyond the 'state of the art' as understood by the parent departments.

A particularly difficult period for the financial support of the *Dreadnought* Project arose from the determination of the government, in the autumn of 1957, to effect a severe reduction in defence expenditure - the famous 1957 Defence White Paper. The new policy envisaged a major switch of emphasis, and correspondingly resources, from conventional forces to the nuclear deterrent. In the course of the Admiralty's review of expenditure, carried out in the form of provisional or 'shadow' cuts under the respective votes, the Deputy Technical Chief Executive of the DPT, Captain Ridley, was asked to suggest a figure by which the *Dreadnought* Project could be cut in the forthcoming financial year. He replied 'A cut is impossible, I need £1.7 million more'. Indeed, so desperate was the situation, if *Dreadnought* was ever to be built, that Captain Ridley had the unusual experience, for a naval officer, of going to the Treasury to argue his case. The security requirements, policy implications and technical complexity of the problem were such that the 'usual channels' for discussion of particular item of expenditure between the Admiralty and the Treasury were deemed inadequate. The particular requirement, in the instance quoted, was to get an allocation of US dollars for the purchase of some special steel that was indispensable to the construction of *Dreadnought***.** It is recorded that the Treasury saw the point and agreed to authorize the dollars needed.

Throughout 1956 and 1957 the *Dreadnought* Project Team, and the associated group working on the Dounreay submarine reactor end hull, worked hard to lay the foundations of Britain's nuclear-powered submarine fleet. The general line of policy advocated by the Team, and supported by the Admiralty Board was to build two submarine reactor plants to the same general design. Of these, the Dounreay reactor would be the prototype, and it was hoped that this could 'go critical' in 1961. It ought then to be feasible to incorporate whatever modifications appeared to be required into *Dreadnought's* reactor; Britain could thus expect to have her first operational nuclear-powered submarine at sea by 1965, at the earliest.

As will be seen, this timescale was the main factor leading to the decision that was about to be taken by the Admiralty Board to buy an American submarine reactor in the first instance. For this to be possible, however, certain restrictions on the provision of nuclear information by the United States would have to be removed. As recorded by Professor Pierre:

As a result of the 1954 Act, two bilateral agreements were signed on 15 June 1955. The first provided for the exchange of information on military aspects of nuclear energy including defence planning and training in the use of nuclear weapons but specifically excluded warhead design and fabrication. The second agreed to the exchange of information on civil uses of atomic energy, including the transfer of fissile materials and equipment. The following year the British asked for assistance in order to help in the development of an atomic submarine. The Department of Defense supported the British request as it would increase the total submarine force strength of the West. In June 1956, in spite of objections from the ACE and JCAE, the Defense Department with White House and Department of State support used a legal technicality to conclude an agreement to give the British data on nuclear ship propulsion reactors.

The movement towards greater intimacy of nuclear collaboration gained fresh momentum in the aftermath of the Suez crisis of November 1956. Prime Minister Macmillan, coming to office in January 1957, had determined to repair the damage to Anglo-American relations caused by that crisis. Following upon meetings with President Eisenhower at Bermuda in March, and in Washington in October, a much-improved climate of trans-Atlantic understanding prevailed. The 'meeting of minds' had received a particularly sharp impulse on 4 October 1957, with the continental ballistic missile.

The October talks resulted in a 'Declaration of Common Purpose' by which the President was committed to 'request the Congress to amend the Atomic Energy Act as may be necessary and desirable to permit close and fruitful collaboration of scientists and engineers of Great Britain, The United States and other friendly countries'.

It is evident that the necessary political conditions had now been created for the First Sea Lord to pursue his intention, formulated during their crucial visit to the USN Chief of Naval Operations in November 1955, that the Royal Navy should be ready, if need be, to participate in the American Navy's Polaris programme**.** Reliable information, provided continually by the Royal Navy's observers with the Special Projects Office, had already reported rapid acceleration of the Polaris programme following closely on Sputnik. It was now planned to have an operable 1200-mile range missile ready by December 1959; an operational capability of three FBM submarines by the spring of 1962; and the attainment by mid-1963 of a missile of the performance specifications previously set up as a goal for1965 (1500 mile range). If Britain were to acquire Polaris, her procurement programme would have to be planned as a part of the rapidly expanding US project. A completion date of 1965 for Britain's first nuclear-powered submarine, even if achieved, would be too late to provide for the eventuality of taking up on option on Polaris, should Skybolt fail.

The alternative, of Britain buying a submarine nuclear power-plant for *Dreadnought*, would follow from the forthcoming amendment of the Atomic Energy Act. Negotiation would, however, be delicate. Would Admiral Rickover be disposed to hand over to the British Admiralty, lock, stock and barrel, the fruits of his own personal high endeavour? He was known to be out of sympathy with most other American admirals, some of whom had actively sought his relegation to retirement rather than promotion to flag rank; would he cooperate any more readily with British admirals?

Confident that he could win over Rickover, Mountbatten nevertheless sought the support of the Chief Scientific Adviser to the Ministry of Defence, Sir Solly Zuckerman, in making the approach. Rickover proved to be amenable. In March 1958, he visited Britain. The First Sea lord had organised a meeting, in the Admiralty, of the nuclear submarine advisory Committee. This group included senior members of the Naval Staff; the Admiralty Departments; the Atomic Energy Authority and the shipbuilding and nuclear engineering industrial group, Rolls-Royce, Vickers and Foster-Wheeler. The Permanent Secretary of the Admiralty, Sir John Lang, was prepared to present the committee's findings. These corresponded to the plans outlined above for completing *Dreadnought* with a British reactor, similar to that being built at Dounreay, and modifying it during construction in accordance with the experience gained with the Dounreay reactor. The time-scale stretched into the mid-60s.

Somewhat to the surprise, not to say chagrin, of the committee assembled on the appointed day, Mountbatten having introduced Admiral Rickover announced forthwith the decision to buy an American nuclear reactor for *Dreadnought.* The British group, confident of their ability to develop submarine reactors, given time and money, received the First Sea Lord's somewhat startling and unexpected decision glumly. More than professional pride was at stake. If Britain were to buy the complete reactor plant, rather than develop her own, she would become totally dependent upon American good will for the indefinite future. This would deny her, for example, the prospect of any share of a possible future oversees market for maritime reactors and associated technology. No doubt, some may have reflected, this apparently so generous and helpful Rickover offer had not been made without some element of national advantage in mind, as well as that of adding to the military strength of an ally. Furthermore, it soon became apparent that for Admiral Rickover, the deal was to be, not only the reactor plant itself, but the complete 'after-end' of the USS *Skipjack* design. This was to be 'married' to the fore part (comprising torpedo compartment and sonar outfit, crew accommodation quarters and control room) of HMS

And so it was that the Royal Navy's first nuclear-powered submarine was driven by an American power plant. But the development of a British submarine reactor plant at Dounreay was continued. Not only wou1d this provide the design, construction and operating experience indispensable to further independent development; it would provide the full-scale training facility without which officers and men to man future submarines could not become qualified, nor techniques developed for safe operation, maintenance and repair.

Given the clear-cut decision to 'go American' with *Dreadnought*, the work of the DPT suddenly became focused upon three new aspects of the project. First, the necessary scheme had to be devised, and the drawings prepared, for the far from simple operation of matching and mating the *Skipjack* after part with its complex machinery and numerous systems, high pressure air, high and low power electrical, hydraulic and water, both salt and fresh, to the British 'fore-end'. Secondly, contract arrangements had to be made between Vickers of Barrow, who would build the submarine, and the American General Dynamics Corporation (Electric Boat Co of Groton, Connecticut), where USS *Skipjack* was building, due to be launched in May 1958, and completed a year later. The reactor and propulsion plant in *Skipjack* were being manufactured by the Westinghouse Electric Co of USA, with whom Rolls-Royce and Associates Ltd worked directly in producing the reactor plant for *Dreadnought* to US specifications.

In the circumstances it was remarkable that by August, 1958, it was possible to sign the contract for *Dreadnought* construction; to lay her keel in 1959; to launch her (despite six months' delay owing to difficulties with the brazing of certain pipe-joints) on 21 October 1960; and to commission her in April 1963.

Early in May 1959 Admiral Sir Charles Lambe became First Sea Lord in place of Lord Mountbatten, who was to become Chief of the Defence Staff. That Lambe enjoyed, as had Mountbatten, the confidence of his American 'opposite number' is evident from the recollection of Admiral Burke:

…..in May of 1959, the Royal Navy had committed itself to the building of the Dreadnought *class of submarine which was based on the United States Polaris (sic) submarines. The exchange of complex technical information was a sticky enough problem, but the training of personnel - shipyard personnel, shore-based personnel, shipboard personnel, was nearly impossible to solve. On the part of the Royal Navy they needed the experience which United States people had accumulated without going through the expense and the false starts which we experienced. On our part the training of additional people put a severe burden not only on our school system and our shipboard training facilities, but also on our normal operating people. The fact that this could be accomplished was largely due to the understanding of Admiral Lambe.*

In the latter part of 1959 we had many discussions on our mutual problems, such as the value of navigational satellites; the naval command relationship within NATO; the establishment of mutually advantageous facilities for units of our fleets, including Holy Loch for the United States Polaris submarines; the nuclear weapons policies of NATO and our various allies; the gradual withdrawal of the Royal Navy from the Indian Ocean area, and the necessity for the United States to fill the vacuum that the British withdrawal would create. The remarkable thing about the discussions of all those confidential and serious matters was that our opposites in the other navies were kept informed, informally, of our discussions, so that we all could maintain confidence one in the other.

A second nuclear-powered submarine, similar to *Dreadnought*, but slightly larger to accommodate the British designed and population plant, was ordered by the Admiralty in August 1960. To be named *Valiant*, she also would be built by Vickers Ltd Shipbuilding Group, with nuclear plant by Rolls-Royce and Associates; steam turbine machinery by the English Electric Company, Rugby, and electrical propulsion machinery and controls by Laurence Scott and

Such activity by the DPT was made possible by the adoption of a receptive, if pragmatic, approach to systematic management. Critical path techniques, with programme evaluation and review, using ‘milestones’, as in American practice, was virtually essential, if progress at Barrow was to keep in step with that at Groton, Connecticut. Budgeting, also, became more comprehensive and reliable, once the main contract had been let. It is of interest, however, that the First Sea Lord, had achieved the insertion into the Admiralty Estimates of provision for *Dreadnought* at short notice, by personally ‘winning over’ the Chancellor of the Exchequer, Sir Derek Heathcote-Amery.

Seeing the need to provide education in nuclear physics for prospective nuclear submarine officers and Admiralty civilian engineers, a small training reactor was bought by the Navy from the Hawker Siddeley Nuclear Power Company Ltd. This reactor, called *Jason* which had been operated at the Company’s works at Langley, near Slough, was installed at the Royal Naval College, Greenwich, where on 6 November 1962 it went ‘critical’.

Two by-products of the *Dreadnought* project, which were to contribute to the success of the British Polaris programme when it was undertaken, were quality control and weapon system engineering. In regard to the first of these the standards of the Admiralty Overseeing Service (Mr Brockensha, Principle Ship Overseer at Vickers Barrow) were traditionally high, and could cope with the even more exacting standards imposed upon every aspect of nuclear-powered submarine construction. The second discipline imposed by *Dreadnought’s* construction, in parallel with her American counterparts, lay in the need to achieve timely provision, at the building yard, of the weapon system and all items of Admiralty-supplied equipment. In the case of *Dreadnought* the development of a revolutionary new sonar equipment, to be built ‘wrapped-around’ the submarine’s large, new-style, blunt bow, had to be sufficiently advanced for incorporation without delaying the launch-date. This was achieved by the department of the Director General Weapons, under those aegis came the Admiralty Underwater Establishment at Portland.

The foregoing review of the progress made in Britain towards building up a nuclear-powered submarine force, whilst far from being a complete account, should serve to set the scene for the major political decision about to be taken at Nassau where, on 18 December 1962, the Prime Minister, still Harold Macmillan, met the President, now John F. Kennedy, to discuss ‘a wide range of topics.

CHAPTER V

GREAT BRITAIN BUYS POLARIS

Polaris was the best bargain the British taxpayer ever had.
(Sir Leonard Redshaw)

Given the political and historical background already outlined in Chapter I, and the remarkable degree of mutual confidence established between Macmillan and Kennedy, the rapidity with which agreement was reached at Nassau on issues of profound consequence for the two nations, and immense complexity, may not seem surprising. Nevertheless, looked at in retrospect, the degree of reliance placed by the two leaders upon the governmental officials, both service and civilian, of both countries to give effect to the far-reaching agreements entered into was remarkable. For the wide range of topics' discussed included a nuclear test-ban treaty with the USSR, as a preliminary to 'successful negotiations on wider issues of disarmament; the prospect for an enduring settlement of the future of Berlin; the reconciliation of differences between Pakistan and India; the current state of affairs in the Congo; and Britain's application to join the Common Market.

The Polaris decision itself was reached, it appears, after considerable discussion of possible alternatives, as set forth in the 'Statement on Nuclear Defence Systems', dated 21 December 1962. As far as the actual arrangements for procuring a British Polaris force was concerned, the following guidance was deemed sufficiently explicit for the political decision to be given effect:

(8) Accordingly, the President and the Prime Minister agreed that the United States will make available on a continuing basis Polaris missiles (less warheads) for British submarines. The United States will also study the feasibility of making available certain support facilities for such submarines. The UK Government will construct the submarines in which these weapons will be placed and they will also provide the nuclear warheads for the Polaris missiles....

To those few in the Admiralty who were aware of what was on the agenda at Nassau, receipt of the first intimation that Britain was going to have Polaris was the signal to initiate the immediate action required:

- To select and appoint a Project officer; install him; give him a directive and a staff.
- To define the project.
- To determine the nature and content of the Agreement which would be required in order to give effect to paragraph 8 of the 'Statement on Nuclear Defence Systems', of 21 December 1962.
- To estimate, and allocate, the necessary funds to get the Project underway.
- To assess, and plan for, the probable impact of Polaris upon the Royal Navy, in terms of manning, training, deployment, operations and support.

Vice Admiral Sir Hugh Mackenzie has described how, on 28 December 1962, he was sent for by the First Sea Lord, Admiral Sir Caspar John, who told him of the Government's decision to create a British Polaris force, with American help, in order to replace Skybolt as the strategic nuclear deterrent, and that he would be required to take charge of the Project.

Mackenzie, then a junior Rear Admiral, had been appointed Flag Officer Submarines, only six months previously. He would have to start work on Polaris immediately, and a new FOSM would be appointed as soon as practicable. Mackenzie was not too happy with the prospect of having to leave the Submarine Command, but on 31 December, after a weekend 's reflection, he gave the First Sea Lord his decision to accept the Polaris appointment.

Whitehall, where the Admiralty was now housed. He had been allocated ‘one empty office, one desk and one chair’. No announcement had as yet been made, either within the Navy, or to the Press, of Mackenzie’s appointment to head up the British Polaris Project. Nor was this done for nearly four weeks. This made life particularly difficult for him, in his attempts to create, rapidly, from scratch, an entirely new organisation. The main reason for the delay was, according to Mackenzie, an attempt by the Air Ministry to retain responsibility for maintaining the strategic nuclear deterrent, despite the substitution of Polaris, a submarine-launched ballistic missile system, for Skybolt, which would have been carried by the V-bomber force. It appeared that Mr Julian Amery (Minister of Aviation) was active in this argument. The British public was first informed of the new situation by Chapman Pincher, writing in the *Daily Express* of 12 January 1963, well in advance of any official announcement of Mackenzie’s appointment.

By this date Mackenzie had been in Washington for four days with a group headed by the Vice-Chief of the Naval Staff (Vice-Admiral Sir Varyl Begg), and including Sir Solly Zuckerman (Chief Scientific Adviser to the Secretary of State for Defence) and representatives of the Air Ministry. Their principle host was Rear Admiral IJ ‘Pete’ Galantin USN who had succeeded Vice-Admiral William F ‘Red’ Raborn, as Director Special Projects Office, on 26 February 1962.

In the course of a series of meetings ‘extremely close and cordial relationships were established and the general lines of a Polaris agreement between the two Governments were worked out’.

It is worth recalling that at this time (January 1963) ten SSBNs of the United States Navy were already in commission; of these, five had been constructed according to the original plan, by adapting the existing USS *Skipjack* class of nuclear powered ‘attack’ submarines, and five were of similar, but slightly modified design. USS *Lafayette*, the first SSBN to be designed as such from the keel up, was nearing completion at ‘Electric Boat’, Groton, Connecticut. She wou1d be able to carry 16 A-3 Polaris missiles, with a range of 2,500 m. Although the A-3 had first been flight-tested on 7 August 1962, the first sea-borne launch of an A-3 did not take place until 11 July 1963. One of the first questions to be decided, therefore, was whether or not Britain should opt for the A-3, not yet fully proven, or accept the proven A-2 with 1,000 miles less range than the A-3. However, the President had already authorized the construction of additional SSBNs up to a total of thirty-five, with ‘long lead-time’ items for another six. This total force of forty-one SSBNs of which thirty-one would be capable of carrying the A-3 missile, could, it was appreciated, be added to economically by increasing the order for missiles, spares end associated components by the number which Britain would require. This initially important figure, the number of Polaris missiles Britain would require, had not been written into the Nassau ‘Statement on Nuclear Defence System’; nor was it mentioned in the ‘Polaris Sales Agreement’ of 6 April 1963, when this was published. Was there some ‘rationale’ for the calculation of the size of an SSBN force which the British could use in determining their own requirements? The total of forty-one SSBNs which the Americans had decided upon, must presumably have some national basis, if so, what was it?

According to Harvey M Sapolsky:

In the late 1950s as the number of submarines authorized for construction increased rapidly, it became obvious that a final goal for the size of the FBM fleet had to be determined. The Naval staff unit monitoring the Polaris program obtained at this point a list of active Soviet targets from the Joint Strategic Targeting Agency. It then calculated the number of Polaris missiles needed to eliminate these targets. Information gathered for the calculations covered the characteristics of the Polaris (range, reliability, warhead yield, and so forth); the characteristics of the submarines (patrol duration, overhaul schedules, and so forth), and the characteristics of the targets (size, dispersal, protection, and so forth). Ignored was information on the strategic systems of the other services (their costs, assignments, reliability, and so forth). Given the constraint of 16 missiles per submarine, the number of Polaris missiles needed to cover all *submarines to allow for a margin of error, and, as some say, the operational convenience of organizing five squadrons of nine submarines each. The political backing the proponents had obtained for the Polaris was sufficient to prevent Secretary of Defense Robert McNamara from doing anything more with the Navy's FBM fleet objective, when it was presented to him, than removing the four extra submarines.*

For Britain, intent upon establishing an 'independent' nuclear deterrent force, within the context of the North Atlantic alliance, at minimal cost in the years ahead, such calculations were irrelevant. To be credible in the political sense, the SSBN force would have to be, at the very least, British manned, controlled, operated and maintained, in order to establish the concept at 'independence', which seemed to be of over-riding political importance. From the military point of view, a capability for absolutely certain retaliation with Polaris missiles, should Britain be subjected to nuclear attack, must be established. With two SSBNs always deployed, at operational readiness, military credibility could certainly be claimed. Thirty-two cities in the Soviet Union could be subjected to a degree of destruction a good deal greater than that which devastated Hiroshima. Even if some accident, however improbable, should temporarily reduce the operational force to a single SSBN, sixteen cities in the Soviet Union (it seems to have been assumed that the USSR was the only country which had to be deterred from bombarding Britain with nuclear weapons) could still be obliterated. In order to ensure that the SSBNs (barring accidents) could be deployed continually, a total force of five SSBNs would be needed. As to the cost, once the initial outlay had been made, at some considerable sacrifice to the remaining components of the British defence budgets during the next five years or so, the maintenance costs of the force of five SSBNs would not be such as to cripple Britain's armed forces, in the longer term.

In order that Britain's **Polaris** project should mesh with that of the USA, the two programmes would have to be closely coordinated. The British team in Washington rapidly became aware of the challenge that faced them. Indeed the capacity of the British Government and administration, the Royal Navy, its technical support departments, and British industry would be severely tested in producing a Polaris force according to a strict timetable, and to the most exacting technical standards in a number of novel fields.

On his return to London from Washington, in mid-January 1963, after the preliminary meeting with Special Projects, Rear-Admiral Mackenzie conferred with Admiral Sir Michael Le Fanu, who had relieved Admiral Sir Peter Reid as Controller of the Navy late in 1961. Nearly four years previously, 'when the possibility of adopting Polaris had first been considered (Skybolt having at that time been selected, for reasons already given - see Chapter 1, p28), the then Rear-Admiral Le Fanu had been instructed by the First Sea Lord (Mountbatten) to prepare a feasibility study and outline plan for managing this major task should it have been undertaken. He had drawn up a scheme for project management, using a group freed from departmental constraints, and having much in common with that developed by the US Special Projects Office. This plan was now resurrected.

Mackenzie had himself already reached some conclusions regarding the organisation that he would need, and the principles upon which he would operate. His primary role would inevitably have two aspects. First, to establish and maintain a close, continuing and comprehensive relationship with the Special Projects Office in Washington. Britain was buying the Polaris missiles only, and not the submarines themselves. The most critical areas of co-ordination related to the establishment and execution of a joint programme for the timely supply and delivery of Polaris missiles to the British submarines, and for test firings at Cape Canaveral.

The second aspect of Mackenzie's task would be to establish, within the admiralty, a position of authority commensurate with his unique, and novel, responsibility. Given the full support of the Controller of the Navy, he could exercise control and co-ordination over the technical team that would have to be built up in Bath. It was evident that, so far as the hulls and nuclear power effective inter-departmental group**,** would form the main part of the Polaris group. It would be necessary to graft on to the DPT a missile section, and to achieve for the combined group a new identity.

The organisation of the British Polaris project was given formal and authoritative shape in an Office memorandum dated 8 February 1963, by the Permanent Secretary to the Admiralty Sir Clifford Jarrett.

Summarized this Memorandum recorded that the Board of Admiralty had approved the following organisation for handling the Polaris project**,** which would consist of four nuclear submarines each equipped with sixteen missiles. It was to be decided later in the year if a fifth submarine was to be added. Owing to the obsolescence of the bomber force, which would cease to provide an effective deterrent by 1967, the first Polaris submarine was to be completed for sea-trials in 1967 and accepted into service in January 1968. The Board did not find it possible to give indiscriminate overriding priority to the Polaris programme, but wished it to be clearly understood that it was their intention that the programme would be achieved by the set dates.

The appointment of Rear Admiral Hugh Mackenzie DSO* DSC, a distinguished submarine officer, as Chief Polaris Executive (CPE) had already been announced. He would work under the superintendence of the Controller of the Navy but could have direct access to all members of the Board. He would be responsible for the planning and timely execution of the programme, but not for ‘matters of international policy and operational issues affecting the use and deployment of the submarines’.

CPE would be assisted by a Technical Director Polaris, a Chief Administrative Officer and an Assistant Polaris Executive. He would have a senior naval officer as his link with the Ministry of Aviation. These men would form CPE’s Management Team; additions would shortly be made to cover the logistic and maintenance element of the programme.

The Memorandum went on to designate Mr R Baker RCNC, the energetic Technical Chief Executive of *Dreadnought* as head of an integrated ship and weapon organisation at Bath. He would be responsible to the Chief Polaris Executive ‘for the design of the submarines and the incorporation of the weapon-system and for co-ordination of the production of both the vessels and all those elements of their equipment for which the Admiralty was responsible; but he would continue to be responsible to the Director General Ships for the remainder at the nuclear submarine programme (*Dreadnought*, *Valiant*, *Warspite* and their successors) and for the Reactor Training Establishment at Dounreay. Mr Baker (whose new ‘short title’ DPT (Director Polaris Technical) happily coincided with that which he already used as head of the *Dreadnought* Project Team) was to be assisted by two deputies, Mr .J Palmer, RCNC (a Deputy Director of Naval Construction) for the submarine side of the programme; and Captain CWH Shepherd, RN to deal with the weapon system. Although working to CPE’s directions, Mr. Baker and his deputies were to remain responsible to the heads of their parent departments ‘for the professional and technical quality of their work and for matters of routine administration’.

The Chief Administrative Officer to CPE was to be responsible for organisational and administrative questions and ‘for ensuring that satisfactory system of financial control of the programme’ was established. It was further laid down that ‘the Polaris management team would be served by ‘a special section with the duty of plotting the programme and evaluating its progress’.

Limitations to the authority of CPE, in relation to Heads of Departments, Divisions and Branches within the Admiralty were set in tile following terms:

- Staff would be *allocated* to work directly for CPE (eg members of the Ship and weapon departments working on Polaris under DPT)

Departments, to give either their whole time, or over-riding priority, to Polaris matters.
- Officers of *suitable standing* (ie rank not lower than Commander or Head of Section) would be appointed by the heads of their departments or branches to act as Polaris Liaison Officers in order to ensure the support needed for the Polaris programme

In order to resolve promptly any serious disagreement between CPE and a Head of Department, Division or Branch, the matter was to be referred at once to Polaris Committee comprising:

- The Assistant Chief of level Staff (Chairman)
- The Deputy Secretary (G)
- The Chief Polaris Executive
- The Assistant Chief of Naval Staff (Weapons)
- A secretary provided by the Military Branch of the Secretariat.

This Committee was:

(a) To consider and decide any conflicts of priorities which may arise inside or outside the Admiralty between the Polaris programme and other commitments
(b) When requested by CPE to give directions in any case where he finds himself unable to take or ensure measures for the timely or adequate fulfillment of the Polaris programme.

- Board approval to 'incur commitments' would be sought through the appropriate Secretariat branch.

- Should the Polaris Committee be unable to resolve any matter within its terms of reference it was to be referred to the First Lord, who would confer with the Board members concerned.

The main features and governing instructions of the Polaris Executive having been determined, CPE's next task was to ensure the appointment, as soon as possible, of the individuals who would fill the key posts. As his deputy, designated Assistant Polaris Executive, Mackenzie selected Captain RA McKaig RN, a seaman officer and communications specialist who had served as Executive Officer of the Boys Training Establishment HMS *Ganges*, under Mackenzie's command. As Chief Administrative Officer the Secretary of the Admiralty selected Mr RNP Levin. To represent his in Washington, as his Liaison Officer with the Director Special Projects, Mackenzie chose Captain Peter la Niece RN, a seaman officer, specialist in Gunnery, who bad already served (1957-59) as accredited RN Liaison Officer with Special Projects in company with Commander HR Cecil Young RN, an Ordnance Engineer.

The speed and sureness of touch with which the Polaris team was built up (within a month of the signing at the Nassau agreement, a period which included Christmas and New Year, not normally associated with an intensification of bureaucratic activity) indicates the elimination of any misgivings which the Admiralty may have entertained about taking on Polaris. On the contrary, a spirit of 'we'll show 'em what the Navy can do' infused the enterprise from the moment the flag fell. It cannot be denied, however, that the preparatory measures set in train by Lord Mountbatten, when First Sea Lord, for an eventuality which he firmly believed would arise, and with which he was fundamentally in accord, made possible the rapid and effective action which took place during the first three months of 1963.

Before the end at January, and hot on the heels of Chapman Pincher's disclosure, (who told him?), the Admiralty monthly the Admiralty Monthly News Summary published the following:

Polaris for Skybolt

focused world attention upon the Royal Navy. They imply, first and foremost, that the mantle which accompanies the holding of the deterrent by this country is to descend upon the Navy. For a long time there have been those who maintained that the choice of a proved weapon already in operational service, as is Polaris, one moreover, that is virtually impossible to locate and destroy, would be the best one. That opinion has now been vindicated.

The spirit in which we receive these decisions must above all be a sobering one, for the responsibilities are immense. It has been officially stressed that the weapon will be in a British submarine, manned by British officers and men, with a British warhead and under British control.

Our consciousness that this is a great day for the Navy must not cause us to lose sight at the fact that this latest development is a Defence burden that is to be accepted as an addition to present tasks. The primary role of the Navy remains the same, that of maintaining our freedom to move forces and supplies about the seas. Thus, the Navy must continue to be capable of operating a balanced fleet that can meet potential threats from the sir, the surface and under the sea. Hence our need for the variety of types of ship for which we make provision in the Navy today, Carriers, Commando Ships, Assault Ships, Guided Missile Destroyers, Frigates, Hunter-Killer submarines and so on.

This issue contains news of outstandingly successful sea trials of our first nuclear submarine Dreadnought*; the* Valiant*, with all-British nuclear propulsion, is progressing. A training reactor is now in operation at Greenwich. The Navy and the shipbuilding industry alike feel equal to the challenge of building a Polaris submarine force.*

Whatever may be decided about the composition and size of this force, one thing is certain: the traditional role of the Navy remains unchanged.

The Polaris Executive having been set up as a project organisation to manage the Polaris programme, the next action immediately required was formal project definition. The Nassau Statement on Nuclear Defence systems had referred to the construction by ‘the United Kingdom Government’ of the submarines that would carry the Polaris missiles. This left wide open the extent to which the British Polaris submarines would resemble those of the USN. Given that the dimensions, launching apparatus and fire-control of the Polaris A-3 (or possibly A-2) must be accommodated within the diameter of the submarine hull, scope for variation of the US design of SSBN lay, primarily, in the number of missiles carried. The choice of sixteen missiles per submarine had been made, originally, in a somewhat arbitrary fashion. Might it not be feasible to adapt Britain’s planned fleet of nuclear-powered ‘attack’ submarines (following *Dreadnought*, *Valiant* and *Warspite* had already been authorized) to combine two roles? The lengthening of these submarines sufficiently to accommodate eight Polaris missiles, perhaps they could retain their high speed, manouevrability, and the appropriate weapons and equipment to enable them to perform equally well either in the strategic deterrent role, as ballistic-missile submarines, or as part of the Navy’s anti-submarine forces in its ‘traditional role’. It did not take a lengthy study to conclude that the dual-role policy would be unsound. The indispensable characteristic required in a nuclear strategic deterrent is military credibility. How could the continuous readiness to fire a Polaris force be assured if, at any moment, its operational task might be switched from remaining undetected, somewhere under the ocean, with missiles at the ready, to engaging in the equally exacting but quite different task of locating end destroying (or training to do so) hostile submarines? Furthermore, much of the navigational data and fire control system for Polaris would be required even if the missile battery was reduced by half.

But there was an even more compelling, and practical, reason for adopting the American SSBN design *totus porous*, as old Lord Fisher would have said. Owing to the highly disciplined exercise of the ‘weapon system concept by Raborn and his Special Projects team, even small variations in the sub-system designs would require a disproportionate amount of intricate re-the navigation and fire-control systems**.** The probability, if major re-design had to be carried out, of unacceptable delay in achieving an operational Polaris force was too great to be ignored. Given that the submarines were to be built in British shipyards, however, even to copy the American USS Lafayette design could call for the preparation of about 5,000 new working drawings; the utilization of the full submarine-building capacity of two major British shipyards, and varying degrees of productive effort on the part of some 800 sub-contractors.

The third major decision, therefore, in defining the Polaris project, was to determine how best to integrate the SSBN programme with the SSN programme that was already well underway. It might be practicable to follow the American example, at the outset of their Polaris program, by cutting in half HMS *Valiant* which had been laid down by Vickers Shipbuilders Ltd., Barrow-in-Furness, on 22 January 1962, and was due to be launched at the end of 1963. But it was appreciated, not only that the time which must necessarily elapse before the SSBN design drawings that were ready would be lost; but that the work force at Vickers who would be employed in completing the fitting out of HMS *Valiant*, provided she were launched, could not be economically employed elsewhere pending the launch of the first SSBN. There would be the important advantage, also, of getting the sea-trials of *Valiant* done in time to prove the British submarine reactor plant that was to power the SSBNs. It was decided, therefore, to complete both *Valiant* and *Warspite,* which could be laid down on the building slip vacated by *Valiant*. The first SSBN, HMS *Resolution**, could therefore be laid down at Vickers, Barrow, early in 1964, to be followed, approximately one year later by *Repulse*. In between these two would be *Renown* to be laid down by Cammell Laird, at Birkenhead, in mid-1964, and *Revenge*, a year later. (**Names for the SSBNs were chosen by Lord Mountbatten and approved, in accordance with normal practice, by the Monarch. As usual, however, the names were not made public until the time of launching*).

The submarines would take about eighteen months to build to launching date and eighteen months to complete, with a prolonged weapon-system trials period to follow. On this basis it should be feasible to set as the Project’s first objective the operational deployment of the first British SSBN by mid-1968, with three more to follow at six-monthly intervals, and still the possibility of a fifth SSBN to be added to the force.

By May 1963 the ‘letters of intent’ to shipyards Vickers and Cammell Laird had been amplified by letting the main contracts. When negotiating the contract Vickers:

…..understanding of the position at the time was that whilst the Ministry of Defence (Navy) was satisfied that Vickers was the most appropriate organisation to act as lead yard, they did not consider that Vickers had adequate capacity to build all four SSBNs to the programme of developments, which was then spaced at six-monthly intervals. Vickers did suggest that they had the capacity to meet the programme end, indeed, the actual deployment would probably have supported that view but at some detriment to the attack boat (SSN) programme.

No special incentive was offered by the Government to the ship-builders but capital investment needed specifically for the Polaris program was funded jointly by the Ministry of Defence (Navy) and the shipbuilders. In the case of Vickers it was necessary to provide:

…additional facilities and equipment such as frame jigs; erection jigs; end three rolling spindles for welding units together; automatic welding and cutting machines, also large turn-tables for machining hoops; a new pipe production shop, and new offices for technical staff. In addition, the main assembly shop was extended and a decision made to move the SSBNs on to No.4 berth, which necessitated specialized strengthening for these ships but offered better craneage facilities than were available on No.10 berth previously used for nuclear submarine construction.

It was necessary, also, to create a weapons department of up to about one hundred and sixty personnel in order to cover interfacing of systems and control of a large number of weapon

It was not possible, at the outset, to assess the degree of profitability, which might be hoped for from the contract. But, finally, Vickers received a reasonable return on the basis of their capital employed.

The project was discussed with Trade Unions from the start and a degree of responsibility prevailed as a result; however, it was a period when the state of labour relations, both nationally and in Barrow, was quite good and was maintained at a high level throughout the contracts, with the exception of one prolonged strike by the AUWE men which was not allowed to interfere with programme dates. Near the completion of the second vessel a general running down of nuclear submarine activity was recognized, and this led to some uneasiness in labour relations. The gap was quickly filled with the award of the first-of-class of the Type 42 destroyer. A reasonable level of shift working, but not extending generally to three shifts, was obtained. Security was not a problem that materially effected production.

Vickers ran down all commercial work would interfere with the nuclear submarine programme. There was obviously a tailing-off period that encompassed, in particular, the 100,000-ton oil tanker British Admiral, so that by the end of 1965 the whole of the Barrow resources were devoted to Polaris and nuclear powered fleet submarines.

The responsibility of the lead yard took the form of bringing the follow yard (Cammell Laird) up to a capability equivalent to the lead yard having built and commissioned Dreadnought, and in the process of building Valiant and Warspite, all nuclear powered fleet submarines. A special responsibility evolved on the lead yard to procure all materials, including United States furnished materials; all test documentation; and all plans required by the follow yard to build the vessels. In addition, guidance and special training was given on the setting-up of health physics, noise testing, project control, weapon system testing and machinery commissioning.

The experience at Cammell Laird shipbuilders, in undertaking to build two SSBNs without having had previous nuclear-powered submarine building experience, was disastrous. According to Mr J Graham Day, Managing Director and Chief Executive since 1967, the company has never fully recovered from the effects of the Polaris programme. Unlike Vickers, which was already building nuclear-powered submarines when the Polaris order came along and has continued to build nuclear submarines, Cammell Laird had the mortification of turning itself into a nuclear yard, only to be deprived of further nuclear submarine orders on completion of the two SSBNs one SSN (HMS *Conqueror*).

The impact of Polaris on both management and labour at Cammell Laird was all the more traumatic because the plan allowed only six months between SSBN 01 (Vickers) and SSBN 02 (Cammell Laird). This was by no means a long enough lead for all, or even a high proportion of the lessons on the learning curve at Vickers to be assimilated and passed on to Cammell Laird. In particular Vickers had had the inestimable advantage, since 1958, of working closely with the Electric Boat Company of U.S.A. on the *Dreadnought* project. As this involved the ‘mating’ of a USS *Skipjack* design after part, built under license arrangements, to the British- designed forepart, much experience bad been gained:

…it was found that Vickers personnel were talking the same language as regards standards and quality control as the Americans and hence no special difficulty arose (with the SSBNs) on this account.

Those problems, however, were all in the future as CPE and his newly formed management team set about developing their plans.

It was appreciated from the start that the Project would have to encompass, besides the construction, trials and testing of the submarines, with their Polaris missiles, (and British made facilities for both submarines and missiles, with, in addition, storage for a number of missiles and warheads. To select and train the necessary crews for the SSBNs together with base support and training staff, both naval and civilian, would be an additional major task. Finally, the construction and equipment of a communications, command and control system of sufficient flexibility, security and reliability to ensure no mistakes would be an essential adjunct to the Project.

Thus the project was defined in terms of the construction, equipment and bringing into service of four (and possibly five British SSBNs similar to the USS *Lafayette* (616) class, each armed with sixteen Po1aris Missiles (probably the A-3), by the end of 1969 (for four boats). To achieve this, a three (or three and a half year gap between the completion of the third SSN (*Warspite*) and the completion of the fourth SSN (*Churchill*) was to be accepted.

Work had already begun within the Admiralty, in consultation with the Foreign Office and the Treasury, upon the preliminary drafting of the Polaris Sales Agreement which would be necessary to set the conditions for giving effect to the Polaris provisions of the Bahamas agreement on nuclear defence systems. It has been remarked that prior to the Nassau agreement, nuclear weapons policy was regarded as primari1y Ministry of Defence business, after it the Foreign and Commonwealth office became responsible for Britain's nuclear deterrent policy. The Polaris Sales Agreement, between the Government of Great Britain and Northern Ireland and the Government of the United States of America was signed in Washington on 6 April 1963 and entered into force at once. It has been characterized by the Assistant Polaris Executive as 'an international treaty rather than a working document'. As such, although duly 'Presented to Parliament by the Secretary of State for Foreign Affairs', it had to be actually ratified by the US Congress.

During February senior members of the staff of DPT were given access by the Electric Boat Company of Groton, Connecticut, to details of the construction of the USS *Lafayette* class submarine. It was then possible to work out the basis of contract between the Admiralty and Electric Boa t, for the provision of the necessary drawings, services and material to enable the construction drawings for the British submarines to be prepared forthwith.

The Polaris Sales Agreement, which related specifically to the missiles, was negotiated by a team sent to Washington in March 1963 by the Admiralty, under the leadership of Mr James Mackay, the Deputy Secretary (G). This team included CPE (Rear Admiral Mackenzie), his Administrative Officer (Mr RNP Lewin); Mr. Alan Pritchard (designated by Materiel 1 Branch as Polaris representative), and Mr. E Hedger (designated by Contracts Branch).

The first, and as it turned out, the only major difficulty in negotiating the Sales Agreement arose from the failure of the Heads of Government in their 'Statement on Nuclear Defence Systems to mention the basis upon which the cost to Britain of buying Polaris missiles would be calculated. In particular, because of the enormous expenditure by the USA on research and development, it was perhaps natural that the American negotiators should assume that Britain would be expected to pay an appropriate share of this R&D, added to the production costs of the Polaris missiles and associated equipment and services.

Mr Alan Pritchard recalls that this matter was personally negotiated on the telephone by the Prime Minister with President Kennedy, who settled for the addition of five per cent on the retail price of the missiles as a contribution by Britain to the hidden costs. Harold Macmillan's published diary entry about this matter concludes: 'Not a bad bargain. But it has caused me some sleepless nights'. This was certainly a not ungenerous interpretation of the Nassau agreement and some Americans, including the Secretary at Defense, Robert McNamara, were displeased.

The matter of R&D share having been decided, progress with drafting the agreement was steady and comparatively uncontentious, though hectic for the officials concerned.

Article I recorded the genesis at the Agreement as being paragraphs 8 and 9 of the Nassau 'Statement on Nuclear Defence Systems'.

Article II recognized 'the complexity of the effort provided for in this Agreement and the need for close coordination between the contracting governments in giving effect to its terms'. It went on to establish the Department of the Navy and the Admiralty' or such other agency as the Government of the United Kingdom shall designate' as the Executive Agencies of their respective Governments in carrying out the terms of the Agreement. It further authorized, in a phrase of such practical significance, 'Appropriate representatives of the Executive Agencies ... to enter into such technical arrangement as consistent with this Agreement as may be necessary'.

The volume of 'Polaris Technical Arrangements' which resulted from this provision and the following Article (III) became the 'bible' of the 'coalface workers' on both sides of the Atlantic.

Each Government's Executive Agency was to designate 'a Project Officer, with direct responsibility and authority for the management of the activities of that Government under this Agreement'. And each Project Officer was to designate liaison representatives 'to act on his behalf in capacities specified in technical arrangements'

Article II ends with the establishment of a Joint Steering Task Group, comprising the respective Project Officer (or their representatives), their principal liaison representatives and 'selected leaders among scientists, industrialists arid procurement executives in the two countries'. The Joint Steering Task Group was to meet approximately every two months alternately in the United Kingdom and in the United States.

Article III specified what the Government at the United States agreed to provide in the first instance and on the basis of a 'shopping list' already prepared:

a Polaris missiles (less warheads but including guidance capsules):

b. Missile launching and handling systems;

c. Missile fire control systems;

d. Ships navigations systems;

e. Additional associated support, test and training equipment and services including, but not limited to:

 (i) Test and check-out equipment, specialized power supplies, power distribution systems and support equipment associated with the items enumerated in sub-paragraphs a, b, c and d at this paragraph and adequate in type and quantity to meet the requirements of installations both aboard ship and ashore;

 (ii) Specialized equipment including the types specified in sub-paragraphs a, b, c, d, and e(i) of this paragraph for use in such support and training facilities as may be provided by the Government of the United Kingdom;

 (iii) Construction spares and spare parts adequate In scope and quantity to ensure the continued maintenance at the equipment specified in sub-paragraphs a, b, c, d, e(i) and e(ii) at this paragraph.

 (iv) Latest available United States technical documentation including specifications, blueprints and manuals covering the missiles and equipment listed in sub-paragraphs a, b, c, d, e(i), e(ii) and e(iii) at this paragraph in sufficient scope and operation and maintenance of the Government of the United Kingdom of all equipment purchased under the terms at this Agreement;

(v) Services, including:

(a) use, as appropriate, of existing support and missile range facilities in the United States;
(b) assistance in programme management techniques and, in addition, those engineering and lead shipyard services required to ensure proper system integration, installation, and check out in the United Kingdom; to the extent required and available appropriate modification, maintenance, and overhaul of the equipment listed in sub-paragraphs a, b, c, d, e(i), e(ii), (iii) of this paragraph;
(c) research, design, development, production, test, or other engineering services as may be required to meet specific United Kingdom requirements;
(d) training of naval and civil personnel in the service of the Government of the United Kingdom contractors to the extent to which they are involved in the inspection, installation, operation, maintenance, repair, and modification of the equipment listed in sub-paragraphs a, b, c, d, e(i),e(ii), e(iii) of this paragraph.

Article IV, no doubt with the A-3 Polaris missile in mind, stated that future developments relating to the Polaris Weapon System shall, in the areas enumerated in Article III, be made reciprocally available.

Article V reaffirms that Britain 'will provide the submarines' and the warheads for the missiles; it emphasizes the need for close co-ordination in order to assure compatibility of equipment. The need for this must govern the information exchanges. But the sale of, or transmittal of information concerning the nuclear propulsion plants of US submarines was specifically excluded from the Agreement.

In **Article VI** it is made clear that the British were, in effect, buying directly into the already scheduled United States production programme for missiles and equipment. Although deliveries to Britain would be in accordance with British requirements, these requirements must be 'consonant' with the American 'fabrication schedule'.

Article VII deals with the obligations of the United States, and the requirements of the United Kingdom, in regard to the inspection and certification of supplies ('which term throughout this article includes, but without limitation, raw materials, components, intermediate assemblies and items').

In **Article VIII** the Government of the United Kingdom agrees to 'indemnify and hold harmless' the Government of the United States against 'any liability or loss resulting from unusually hazardous risks attributable to Polaris missiles or equipment supplied or to be supplied to the United Kingdom etc.

Article IX establishes the mutual interest at the governments in righting claims for compensation in respect of the alleged use of unlicensed patent rights, and makes clear the undertaking of the British Government to reimburse that of the United States if a settlement is called for.

Article X deals first with the delivery of equipment other than the missiles, and the undertaking of the United States to provide 'such technical installation end testing services as are required by the Government of the United Kingdom for the satisfactory installation, check-out and testing of that equipment in submarines and supporting facilities of the United Kingdom.'

In the second part of this article the United States undertakes to deliver the missiles, after initial check-out, to such United States supply points as are agreed by the Executive Agencies of both Governments.'

Article XI might be termed the 'small print' of the Agreement and is worthwhile for that reason if no other, quoting in full:

1. *The charges to the Government at the United Kingdom for missiles, equipment arid services provided by the Government of the United States will be:*

   a. *The normal cost of missiles and equipment provided under the joint United States-United Kingdom production programme integrated in accordance with Article VI. This will be based on common contract prices together with charges for work done in United States Government establishments and appropriate allowance for use of capital facilities and for over-head costs.*

   b. *In addition of 5% to the common contract prices under sub-paragraph 1(a) of this Article for missiles and equipment provided to the United Kingdom Government, as a participation in the expenditure incurred by the Government of the United States after January 1 1963, for research and development.*

   c. *Replacement cost of items provided from United States Government stock or, with respect to items not currently being procured, the most recent procurement cost.*

   d. *The actual cost of any research, design, development, production, test or other engineering effort, or the services required in the execution of this Agreement to meet specific United Kingdom requirements.*

   e. *The cost of packing, crating, handling and transportation.*

   f. *The actual costs of any other services, not specified above, which the Project Officers agree are properly attributable to this Agreement.*

2. *Payments by the Government of the United Kingdom in accordance with paragraph I of this Article shall be made in United States dollars. Payments to United States agencies and contractors will be made, as they become due, from a trust fund which will be administered by the United States Project officer. All payments out of the trust fund shall be certified to be in accordance with the terms of the Agreement. The trust fund will consist initially of a sum to be paid as soon as possible after entry into force of this agreement and to be equivalent to the payment estimated to fall due during the first calendar quarter of programme operations. Before the end of that quarter and each succeeding quarter deposits shall be made by the Government of the United Kingdom with the object of having sufficient money in the fund to meet all the calls which will be made upon it in the succeeding three months.*

3. *If, at any time, the unexpended balance in the Trust Fund established pursuant to paragraph 2 of this Article falls short of the sums that will be needed in a particular quarter by the Government of the United States to cover;*

   a. *payment for the value of items to be furnished from the stocks of, or services to be rendered by, the Government of the United States;*
   b. *payment by the Government of the United States to its suppliers for items and services to be procured for the Government of the United Kingdom; and*
   c. *estimated liability or cost that may fail to be met by the Government of the United States as a result of the termination of such procurement contracts at the behest*

the Government of the United Kingdom will pay at such time to the Government of the United States such additional sums as will be due: should the total payments received from Government at the United Kingdom prove to be in excess of the final costs to the Government of the United States, appropriate refund will be made to the Government of the United Kingdom at the earliest opportunity with final adjustment being made within thirty days of determination of said final costs.

4. *The United States Project Officer will maintain a record of expenditures under this Agreement in accordance with established Navy Special Projects Office Accounting procedures which record will be available for audit annually by representatives of the Government of the United Kingdom.*

Articles XII and **XIII** spell out in stark detail such matters as ensuring to the Government of the United Kingdom 'royalty-free, non-exclusive, irrevocable license for its governmental purposes' to use inventions and original technical information related to the work in hand.

Article XIV is primarily concerned with security, bath commercial and military, and requires the United Kingdom Government to provide 'substantially the same degree of protection afforded by the Government of the United states in order to prevent unauthorized disclosure or compromise'.

The penultimate **Article XV** seeks to ensure the accountability to their respective Governments of their representative for the execution of the agreement, in the following terms:

Annually, on or before the first of July, the Project Officers will prepare a formal joint report to the contracting Governments at action taken and progress made under this Agreement and a forecast of schedules and costs for completion. In addition, other more frequent joint reports will be submitted, and agreed upon by the Project officers, to the heads of the Executive Agencies.

Finally, **Article XVI**:

This Agreement shall enter into force on the date of signature.

IN WITNESS THEREOF the undersigned, being duly authorized thereto by their respective Governments, have signed this agreement.

DONE in duplicate at Washington this sixth day of April 1963.

For the Government of the United States of .America:

DEAN RUSK

For the Government of the United Kingdom of Great Britain and Northern Ireland:

D ORMSBY GORE

Captain Peter La Niece, newly appointed as Liaison Officer for the Chief Polaris Executive with the Director, Special Projects, recalls his arrival in Washington on the day, 6 April 1963, on which the Polaris Missile Agreement had been signed. It happened to be a Saturday. Within twenty-four hours La Niece had been asked by an American newsman whether or not Britain had paid her subscription to the Polaris club, as provided for in the Sales Agreement. Priority telegrams exchanged with London resulted promptly in La Niece receiving through a Treasury representative attached to the British Embassy, Washington, a cheque for $1,000,000 made out to the Polaris Trust Fund. The problem was to locate and identify, as soon as possible, the individual to whom the cheque should be handed. According to La Niece, this was eventually achieved at a cocktail party on the Sunday evening

Back in London, after the Polaris Sales Agreement had been negotiated, the Chief Polaris Executive had to begin licking his newly created project team into shape. Already, during his absence in Washington there had been a certain amount of ‘jockeying for position’. As Captain Rae McKaig, CPE’s deputy, put it

When (CPE) went to the States in early 1963 for the essential preliminary step of negotiating the PSA, he left behind a bunch of prima donnas hastily assembled by Their Lordships - who started off with great energy in all directions - including his Deputy! We also applied ourselves with equal energy to an internal power/status struggle. (C.P.E.) stopped, this with an iron hand - and then set out to get us moving down the same road. I don’t think you will find anyone, civil or military, high or low, who wears the Polaris tie, who doesn’t look back on their days serving him as the most inspiring in their service career.

He also had en incredible ability to win the trust of Americans and industrialists - and having been FOSM, but never served in the Admiralty, he seemed able to appeal to the fundamental in Board Members’ responsibilities without getting caught in the meshes of the machine.

As one of my staff said: ‘I never came out of CPE’s office without feeling better, even if he’d slapped my scheme down..

This tribute to Admiral Mackenzie’s qualities of leadership, coupled with his whole-hearted commitment to the philosophy of modern management, indicate the key to the success, both of the American Polaris Program, under Raborn, Galantin and Levering-Smith; and its British counterpart, under Mackenzie and Baker, although the responsibilities differed to some extent in nature, and, of course, in scale. In the United States, Special Projects were directly responsible for producing only the Polaris missiles, and for coordinating the FBM system as a whole. In Britain, the Chief Polaris Executive and his Technical Director were responsible for producing the complete British Naval Ballistic Missile System, and, in addition, for the nuclear-powered attack submarine (SSN) programme.

In the next chapter we shall see Admiral Mackenzie identified as having highest priority, now that the Project had been broadly defined and the Sales Agreement signed, the need to educate, enthuse and inform, not only his whole Polaris team, but the Naval Staff, the Admiralty Departments, Divisions and Branches, other Ministries and Industry. It was a daunting task.

CHAPTER VI

THE POLARIS EXECUTIVE

Rickover to Mountbatten:
'You must have a tough project manager for your Polaris program. Have you got a real son-of-a-bitch for the job?'
Mountbatten to Rickover:
'We don't breed them like that over in Britain'

(Lord Mountbatten, 1973)

If the primary motivation of those engaged in the US Navy's Polaris Programme was 'we have got to beat the Russians!' that of Britain's Polaris team was 'Let's beat the Americans'. And if the US Navy's preferred management method was bred by 'Special Projects out of American Industry', that of the Admiralty (it did not dwindle into MoD Navy until 1964) was 'By Samuel Pepys out of Special Projects'. That is not to say that British industry, and especially shipbuilding, was not heavily involved; it is to emphasise the cardinal importance, for the successful completion of the British Polaris Project, of the close, continuous and cordial relations which were established and maintained between the organisation set up by the Admiralty Board and the US Navy's Special Projects office.

It would be a mistake to assume too readily that such a high degree of co-operation could have been taken for granted. Politically, the Anglo-American 'special relationship', revitalized by Prime Minister Macmillan and President Kennedy, was seen by many people in Britain to bring with it the risk both of Britain's exclusion from Europe and the withering away of the Commonwealth. That the subject of renewed Anglo-American co-operation should be nuclear weapons, about which (cf. the Campaign for Nuclear Disarmament) 'the less said the better', also moderated overt enthusiasm. As to the Naval Staff, accustomed for a decade to the RAF being responsible for Britain's strategic deterrent force, the advent of Polaris was greeted with something less than unconfined joy. Indeed, Lord Mountbatten has affirmed that, both as First Sea lord and Chief of the Defence Staff, he had consistently supported the RAF's 'V-Bomber' force (even to the extent of transferring money from Naval to RAF votes), because he believed in the deterrent policy as the corner-stone of Britain's security. However, should the Navy be thought to be attempting a 'take-over' of' the deterrent role from the RAF, bitter inter-service rivalry might result. He therefore encouraged the Naval Staff to take a critical view of the possible effects upon the Navy's existing role and tasks if it should assume responsibility for the strategic nuclear force.

As to the capacity of the Admiralty to work directly with the US Navy Department, to the extent which Polaris would require, this would be asking a lot of such a long-established and powerful institution. Its general managerial competence, of which the Admiralty was justly proud, was based upon a style of administration evolved from centuries of experience in war and peace; strong in continuity, weak in innovation, its primary concern was the efficient conduct of the Navy's business. Yet the feeling prevailed, especially in the higher echelons, that the Navy's business was the country's business. It might no longer be rational to expect a crowd to gather in Downing Street shouting 'We want eight — we won't wait?' To lobby publicly for eight frigates, let alone eight capital ships, would be unrealistic, future, as in the past, there could be no relaxation of vigilance **...** ‘England expects ...’ (or if it doesn’t it ought to ...). For all its innate conservatism, therefore, the Admiralty machine was capable of immediate response to a new, and firm, hand on the tiller. Thus, from 18 April 1955, when Admiral Mountbatten became First Sea Lord, already convinced, as we have seen from Chapter 1, that the Navy would one day be called upon to build a Polaris submarine force, the Admiralty began to ensure that it would not be found wanting when the day came.

During the three months or so between the Nassau Agreement and the signing of the Polaris Sales Agreement on 6 April 1963 a number of major decisions were taken by the Chief Polaris Executive, with the full support of the Admiralty Board. On 6 February CPE had been given (as recounted in the previous chapter) a clearly defined task and a Management Team to help him to accomplish that task satisfactorily and by the planned date. It was CPE himself who had determined that the date could be met. As Admiral Mackenzie has recalled:

The first Long Cast Programme, which was made in February 1963, was in fact largely adhered to ‘to the day’. The credibility of the V-bomber force had already become considerably eroded by 1963. It was therefore a question of getting Polaris to sea at the earliest possible date. Initially, it simply was not practicable to work out in any detail precisely how long it would take to complete the programme and the original long cast was therefore made as a matter of’ judgment based upon the professional experience of the senior officials involved backed up, of course, by the American experience to date. The Americans gave us all the priority needed and accepted the view that the British Polaris Programme was in essence a part of their overall programme, with the same urgent need to meet dates. Particularly careful co-ordination was required in the installation, setting to work, testing and tuning, and firing of test missiles. The main threats to meeting the programmed arose from the difficulties experienced by the two shipyards in overcoming technical problems and in providing manpower to the scale necessary; and in the construction of the base, armament depot and housing.

On 8 February CPE began to issue the series of Polaris Executive Acquaints, by means of which he provided relevant information to all concerned, as appropriate; gave directions requiring action to implement the programme, and established procedures to be followed by the Polaris Executive. The first of these acquaints (for which a standard format was soon introduced), was a seminal document and is reproduced here in full:

POLARIS EXECUTIVE ACQUAINT No PE 1A/1/63 - 8th February 1963

POLARIS ORGANISATION – INFORMATORY NOTES

Introduction

Office Memorandum No.93/63 (O&M 120/2/63 of 6th February 1963) lays down, in broad terms, the responsibilities of the Chief Polaris Executive and the procedure for resolving any conflicts over priorities, which may arise inside or outside the Admiralty.

The following informatory notes summarize the task of the CPE and the lines on which the organisation is being developed to achieve the task; as the organisation develops there will be changes in it.

2. Background

Government authority has been given to order four 16-missile submarines with the option on a fifth; the decision on the fifth to be taken during the course of this year. The missiles will probably be of the A-3 (2,500 mile) type.
(b) The submarines will be of British design and construction, consisting essentially of the SSN 02 hull (and propulsive machinery), lengthened to incorporate the Polaris weapon system.

(c) With certain possible exceptions (eg in the navigation sub-system) it will be the intention to

USA.

(d) The warhead will be of British manufacture. R&D and production in this field is the responsibility of the Ministry of Aviation who are also responsible for the re-entry vehicle.

(e) Remaining armament, machinery and ancillaries will, in principle, be of UK design and manufacture.

3. The Aim

To deploy on station the first RN Ballistic Missile submarine, with 16 missiles and with full support, in July l968, and thereafter the remainder at six-monthly intervals. These dates cannot be allowed to slip.

4. The Task

The task involved in achieving the Aim includes:

A. Planning and managing the whole project.

B Designing and building the submarines.

C (a) Procuring from the USA, installing and testing the missile system: designing, producing and installing, as may prove necessary, command and control facilities including shore based communications.

(b) Designing, producing and mating the war-heads and Re-entry Vehicles with the missiles.

(c) Fitting the missile armament and associated systems into the submarine hull.

D The selection and training of naval manpower to man the submarines and associated fleet maintenance facilities. The planning and provision of Welfare facilities afloat and married quarters at base ports.

E Planning and providing support, including spares missile and weapon system assembly, storage and test facilities, specialized refitting arrangements, and the selection and training of personnel to man them.

F Financial oversight of the project.

5. **External relationships**

The Board have stated categorically their intention that the aim in paragraph 3 above shall be achieved by the dates laid down. Where possible, this will be done through the normal Admiralty organisation and it follows that CPE must rely to a very great extent on the enthusiastic and urgent co-operation of existing Divisions and Departments; this must include timely warning of impending difficulties and delays. CPE's own staff will be restricted to the minimum technical, professional and administrative elements essential to fulfill his responsibilities.

In meeting this challenge, CPE asks for nothing more than the continuation of the co-operation, understanding and goodwill already shown by Divisions and Departments.

6 **Organisation of CPE Staff**

(a) The organisation is rapidly taking shape and Appendix 1 shows the present constitution. In addition, a Joint UK/US Steering Group will be established between the Chief Polaris Executive and the

Anglo-US aspects of the programme as a whole.

(b) The Chief Polaris Executive will be the responsible UK 'Point of Contact' with the United States authorities on all Polaris project matters and initially all requests for information, action and sponsorship of missions, etc, to the US concerning the project should be handled through his Office.

(c) Until the formal Government-to-Government agreement establishing the terms under which the missile system is to be purchased by the UK has been signed, such requests to the US authorities will have to be severely restricted. Negotiation of this agreement is in progress.

PROJECT MANAGEMENT AND INFORMATION

7 **(a) Management techniques**

Further details will be promulgated on the techniques and organisation to be established to keep CPE and the Board informed of progress with the Polaris project, but these will almost certainly involve accurate and timely returns of information in standard format to permit potential delays and bottlenecks to be foreseen and avoided.

(b) Longcasts

PE LONGCAST No. 1/63 dated 6th February 1963 has been issued with an explanatory note for the information of all concerned with the Polaris project. Amended versions will be issued at intervals together with a monthly Acquaint and Shortcast.

When the principal milestones have been established, it is the intention that the Longcasts and Shortcasts shall form a basis for project action.

(c) "Field Working Parties"

In certain of the principle project fields in the PE Longcasts, action is being initiated to propose bodies to:

(i) Agree requirements.
(ii) Allocate responsibilities
(iii) Seek approval, coordinate and direct action to meet requirements within programme dates
(iv) Establish any subsidiary bodies necessary to ensure timely action.
(v) Keep Polaris projects under review in the field concerned.

These field working parties may be either internal to the Polaris organisation (eg Field Project Management) in which case other Divisions or Departments may be asked send representatives as required, or, by agreement, sponsored by authorities external to the Polaris organisation (eg Field 5 - Naval Manpower and Training).

In all cases, it will be CPE's intention to a offer Chairman, Executive Secretary and Steering Member to each Field Working Party.

Further details of bodies set up will be circulated as they are established.

(signed) HS MACKENZIE

CHIEF POLARIS EXECUTIVE
8th February 1963

This document deserves analysis. It may be said to enshrine the style of Admiralty administration that prevailed, at any rate within the higher echelons of this great department of state, at the beginning of the Office Memorandum in which the Admiralty Board's intention, in giving effect to the political decision at Nassau was laid down. O&M was a comparatively new (post World War II) element in the Whitehall administrative machine. It was a concession, indeed response, to the dramatic extension of the executive role of the bureaucracy, which increasingly interventionist government had brought about. No longer confining its activities to the formulation of policy, legislation, and the overall administration of the country's business, the Civil Service had been forced to participate in the management, on behalf of the government of the day, of large-scale enterprises -for example the railways, coal-mining, the steel industry, and of course the entire panoply of Social Services associated with the Welfare State. Traditional administrative practices, which had evolved with the growth of the Civil Service since the Northcote-Trevelyn reforms took effect in the 1870s, accelerated by two world wars separated by a devastating world 'slump', were blended with 'modern management techniques', resulting in an 'Organisation and Methods' branch being established within each major government department. The primary concern of O&M, therefore, was to introduce into the executive activity of government a systematic approach to the setting and achievement of specific, concrete objectives, without diminishing, or at any rate seriously compromising, the traditional and indispensable requirement to maintain Ministerial accountability to Parliament, together with firm and detailed control over the expenditure of public funds, and the administration of the Law.

Ten years before the British Polaris project was undertaken, the Admiralty had set up a 'Fleet Work Study' group, in order to demonstrate to the Navy the advantages to be gained from the systematic study of many, mainly routine, tasks still generally carried out in ways which were apt to reflect a surplus, rather than a scarcity, of manpower. Officers and senior ratings were trained to analyze a task by the network method, to determine the 'critical path' towards its completion, to devise more efficient procedures, to propose the automation of appropriate elements, and to test and report on the resulting innovations. Care was taken to ensure the willing co-operation of the responsible 'authorities' whose 'management practices' were under review.

In a Memorandum issued in 1955 (Manex 2), by the Fleet Work Study group, the concept of 'management' was clearly differentiated from 'leadership' that was defined as 'the kind of behaviour in a man which inclines others to accept his guidance'. Management was established as 'getting things done through people in an organisation'. 'Command', on the other hand, was officially defined as 'The authority vested in officers and ratings over their subordinates' (vide Queen's Regulations and Admiralty Instructions); 'this official form of authority being essential for the maintenance of stability in a fighting service'. 'Implicit in command', the Memorandum added 'is the wholehearted acceptance of full responsibility for decisions and results'. 'Leadership', it went on to say 'creates a form of authority over people which does not rely on official compulsion and inspires subordinates to do their best in achieving the objectives which the leader has set'. 'In brief', it was stated:

Command	-	sets the 'course and speed'.
Leadership	-	gets the maximum effort out of the crew.
Management	-	keeps the ship and equipment maintained, the weapons ready, the engines running and the ship well administered.

Management' was further defined in terms of both 'art' and 'science'. The 'artistic' aspect was said to give 'the opportunity for exercising skill, initiative and 'value judgement' in making the innumerable decisions which constitute the focal activity of management. The 'scientific' aspect became increasingly important, however, as the consequences of misplaced initiative, misuse of resources, and unsound decisions were accentuated with the rapid growth in complexity and cost of weapons and equipment, and the shortage of trained men. By proceeding systematically, it was argued, step by step on the basis of a body of ascertained fact (as far as humanly possible), the manager would be freer to concentrate his 'artistic' capabilities on those aspects which could be decided only by 'value-judgements', and on his dealings with people.

The function of the manager could be summed up as 'to decide what has to be done; when it has to be done; who is to do it; what he needs to enable him to do it; to see whether it is being done properly and to time; and if not, to take the necessary corrective action; the principles underlying all forms and levels

Effort'. These four principles were further broken down into 'nine practical components', viz:

Executive Components	Deciding Communicating Inducing Coordinating
Structural Components	Organisation
Mechanical Components	Planning Provision of resources Matching of Men/Jobs Control

Returning to 'Polaris executive Acquaint No. PE1A/1/63', its conformity with the 'Fleet Work Study' group's recommended principles and practices of management are apparent. The 'Introduction', 'Background', 'Aim' and 'Task' combine to *communicate a clear cut decision, and the delegation of authority*; they exert strong motivation, ('The Board have stated categorically their intention that the aim ... shall be achieved by the dates laid down'); and they provide for *economy at effort* ('where possible this will be done through the normal Admiralty organisation'.) Under 'Project Management and Organisation', CPE Acquaint No 1A gives essential guidance on *planning* ('when the principal milestones have been established, it is the intention that 'longcasts' and 'shortcasts' shall form a basis for project action'); included also are *provision of resources (*under 'Background'); *matching men and jobs* ('Field working parties'); and *control* ('... accurate and timely returns of information in standard format to permit potential delays and bottlenecks to be foreseen and avoided').

Thus, the Admiralty and the Royal Navy did not have to rely entirely upon the adoption of Special Project's justly famed management technique in undertaking virtually to form part of the American Polaris programme. But, whereas American industry had long since been infused with the spirit of scientific and systematic management (not always welcomed by the fiercely individual entrepreneurs who had founded the great corporations), British industry, and especially heavy industry, remained, with a few exceptions, impervious to the onset of modern, systematic management. Powerful, knowledgeable men continued to drive huge, labour intensive plants, with the help of a few seasoned managers' rudimentary planning, rough and ready cost control, and traditional methods of quality assurance which were quite inadequate to meet Polaris system standards.

In addition to the emphasis placed by the Admiralty Board upon modern management, the Chief Polaris Executive himself was aware of the urgent need to obtain, rapidly, all the information needed to plan and execute the programme; and to 'educate' all concerned in Polaris. 'There was not much known of Polaris', Admiral Mackenzie recalled 'within the Naval Staff or Admiralty Departments. It was therefore necessary to indoctrinate them. Press publicity was also required, particularly as the air-lobby continued to be hostile. The Controller (Admiral Le Fanu) and the Civil Lord (Orr-Ewing) were, respectively, very helpful in this matter'.

The Polaris Sales Agreement, about to be negotiated in Washington, would make detailed provision for the information exchange. But there was no time to waste. Already, during the first visit of an Admiralty team to Washington to discuss Polaris, in January, the Director Special Projects had agreed to send his Head of Logistics, Captain PA Hollings USN on a two-week attachment to the Staff of CPE in London. Early in March, therefore, Hollings' visit was arranged, with the tasks:

(a) to arrange for the attachment of a small number of USN officers to CPE's staff in London and Bath.

(b) to make detailed arrangements for co-operation in the procurement of US produced items and documentation required for the Polaris Ballistic Missile programme.

The Director of Stores, whose organisation would have a vital part to play in providing a ready supply was not represented at the USS *Hunley* visit. This was surprising, but understandable. It was not until 1 May 1963, that Captain L Bomford RN took up duty as Polaris Logistics Officer responsible for:

(a) The planning and progressing of the Polaris support programme as a whole, including dockyards and maintenance, naval stores, armament supply and works elements;

(b) The planning and progressing of requirements for the SSBN Operating Base, and cooperation with the Ministry of Public Works to achieve the timely completion of the Works element of the base:

(c) The progressing of the materiA-1 support elements of the programme to get the submarine weapon system to sea according to the planned timetable.

The Polaris Logistics officer was to act, also, as 'the principal point of contact with Admiralty departments concerned with Polaris Logistics requirements; and he would 'Normally work to the Technical Director Polaris.'

These were extremely onerous responsibilities, and it might be asked why the PLO was not made a member of the Polaris Management Team, as foreshadowed in the original Board Minute setting up the Polaris Executive (see Chapter V). On the other hand the PLO was powerfully aided, from November 1963 onwards, by the appointment to the Polaris Executive of an Assistant Director of the Directorate of Stores and the Directorate of Armament Supply, respectively. The PLO was provided, also, with an Assistant of commander's rank. To complete this all-important Logistic Support team, there was a representative of the Ministry of Public Works and Buildings. By this time, with the rapid increase in direct dealings between CPE and SP, it had become essential for CPE to call a halt to the indiscriminate use of phrases like 'the Polaris system' (to mean anything from the missile alone to all measures necessary to operate it). He had therefore issued a statement, under the heading 'British Naval Ballistic Missile System'; giving the recommended nomenclature to be adopted for its component parts.

In addition to the early visits of 'key British Polaris people' to the United States, to acquire as much knowledge as possible, an soon as possible, about the American Polaris program, arrangements were made to visit USS *Hunley* in the Holy loch. This depot-ship, together with a floating dock and some welfare, social and recreational facilities ashore in the neighbourhood, formed the US Fleet Ballistic Submarine Operating Base. CPE's Assistant, Captain McKaig, with Captain Shepherd and Mr RJ Daniel, accompanied by a dozen staff officers including two representatives of the Flag Officer Submarines, made the visit early in April. Every assistance was given by the US Navy to CPE's team, in a most cordial atmosphere. Subjects covered included all aspects of SSBN operational support and, in particular, maintenance of the missile-launching, fire control and navigation systems; the ship systems generally both mechanical and electrical; repairs of all kinds; and missile storage, testing and handling.

As a result of this visit CPE acquired a working knowledge of:

(a) The programme undertaken by US Polaris submarines during their stand-off period between patrols, including maintenance and work-up:

(b) What facilities were required and provided to fulfill the above programme; and

(c) How the facilities provided were organised and manned.

In the meantime, the Programme Evaluation Section foreshadowed in the original Board decision of 6 February had been established in CPE's office. In a Polaris Executive Acquaint of 6 March, it was laid down that the Critical Path Scheduling technique would be used, employing a master project network, operated in London and covering all elements of the Naval Ballistic Missile System. Subsidiary networks covering fields of sub-fields of the Polaris Executive longcasts would be operated by those responsible for the areas concerned.

(a) Prepare, in conjunction with the authorities involved, a master network embracing the entire project.

(b) Provide Departments, etc, initially, with lists of events and activity deletions and additions to the network.

(c) Agree with Departments the responsibility for reviewing and reporting on the individual activities in the network.

(d) Establish a standard form of activity time return.

(e) Collate activity turn returns from responsible quarters, arrange and prepare computer input documents at monthly intervals.

(f) Arrange with Head of O&M for the necessary computer facilities to process input data.

(g) Evaluate and present computer output data to the Polaris Management Team.

(h) Maintain mid improve the master network.

(i) Supply a consultant service to Departments on the Critical Path Scheduling Technique.

(j) Provide for the education of network staff nominated by Departments for the operation of subsidiary and other networks.

(k) Coordinate the receipt and distribution of computer input and output data for subsidiary and other networks.

Already, by 11 March, the embryonic organisation set out in the Acquaint of 8 February had been ‘fleshed out’, and an amplifying acquaint issued giving an organisation which reflected the growing-pains associated with the prior existence at Bath, in full working order, of the *Dreadnought* Project Team (see Chapter IV above). The dynamic leader of this team, Mr. Rowland (later Sir Rowland) Baker, was still responsible directly to the Director General Ships, for the nuclear-powered general-purpose (SSN) submarine building programme, whilst also being responsible directly to CPE for the SSBNs. He was not prepared, at that stage, therefore, to abandon the series of short titles by which the members of his team had for many months (in some cases years) been known, both internally, within the Admiralty Departments, and even more important, in dealing with outside authorities. Thus, while the Polaris Executive, London, received designations such as PE 00 (CPE), PE2 (Assistant Polaris Executive), PE3 (Chief Administrative Officer) and PE31 (Deputy CAO), in the Polaris Executive, Bath, the main short titles remained firmly self-evident (to the initiated, at any rates), e.g. D.P.T. (Director Polaris Technical), DDNC(P) (Deputy Director (Design)), DDW(P) (Deputy Director (Weapons)), ADME(NP) (Assistant Director, Nuclear Propulsion), ADEE(NP) (Assistant Director, Electrical Engineering). It was not until 10 July 1963 that a uniform system of short titles was established throughout the Polaris Executive. By then CPE had accepted responsibility for the SSN programme as well as for the SSBNs, and for coordinating the two programmes. The requirements of Polaris had now begun to impinge more directly upon the *Dreadnought* project. The design parameters for the British SSBN were set. The decision had been taken to utilize the British *Valiant* nuclear powered general purpose submarine hull design, rather as the Americans had done originally with that of the *Skipjack* by incorporating a center section embodying sixteen missile launchers and associated fire control and navigation system. Under the direction of Mr SJ Palmer RCNC, assisted by Mr HJ Tabb RCNC, the detailed design work for Britain’s ballistic missile submarine proceeded apace.

In the meantime, CPE had become involved in four major decisions. The one which undoubtedly caused most controversy was whether or not to adopt a British designed fire control (including Inertial Navigation) system designed at the Admiralty Compass Laboratory, in conjunction with the Sperry to urge CPE strongly to ‘opt’ for the British (so far unproven) fire control/navigation system instead of the Autonetics design installed, and successful, in the US SSBNs. The Deputy Director Weapons (Polaris), at Bath, was the technical officer responsible for the Polaris weapon system, and hence for the fire control/navigation system which formed part of it. In his view any variation from the complete American system could not possibly be risked. He did, however, agree that, owing to improvements in the reliability of the American SINS since it was first used in their SSBNs, Britain would be justified in equipping her SSBNs with two, instead of three, SINS. On the general point of accepting the American Polaris weapon system complete Shepherd was adamant. He was all for the ‘Chinese copy’ principle - if they (the Americans) paint power cable blue and white, we’ll paint it blue and white!’

The next decision which had to be made as soon as possible, so that Special Projects could plan the British requirements into their procurement programme, was whether to accept the tried and proven A-2 missile, with 1500 nautical miles range, or to go for the A-3, which would not be ready to undergo final acceptance trials until December 1963. The Treasury, according to Admiral Mackenzie, was ‘very frightened of the unknown and inclined to settle for the A-2’. CPE managed to persuade the Treasury to support his decision to go for the A-3. But as Captain Shepherd put it, ‘This decision was really taken by Solly Zuckerman and Peter Thorneycroft - Zuckerman was sceptical at first but I pressed hard – “Look at SP’s resources. They are bound to do it”’ So A-3 it was.

A third vital decision that had to be made as soon as possible, once the Polaris project had been defined, was which shipyards would build the submarines and of these, which would be selected as the ‘lead’ yard. Only one British shipyard, namely Vickers at Barrow-in-Furness, had any experience of building nuclear-powered submarines. *Dreadnought*, nearly completed, and *Valiant* were already building there, with *Warspite* ordered, and due to be laid down in December 1963. Vickers had already built over 150 submarines. Not far away, at Birkenhead, was Cammell Laird, another well-known submarine building yard. But Scotts of Greenock, and HM Dockyard, Chatham, were also builders of good submarines. More than submarine building experience was, however, required for the SSBN programme. Never before had a British shipyard been required to build a complete weapon system of such complexity as Polaris into a ship. The capital investment in plant and skilled people required to enable this to be done, to the unprecedently exacting standard of assured quality demanded, were formidable.

In the event**,** by the middle of May 1963, main contracts for two SSBNs each had been let to Vickers, which would be lead yard, and Cammell Laird. It had been decided also, that Vickers would complete *Valiant*, already building, and to be powered by the first British designed and built nuclear reactor plant; but there remained an option in regard to *Warspite*, which had been ordered but was not due to be laid down until October 1963. She might have been ‘turned into’ an SSBN, on the drawing board, as it were; the design of the SSBN hull system, as already pointed out, consisted of inserting a ‘missile section’ into a *Valiant/Warspite* hull. However, CPE, mindful of the serious gap in the SSN programme, which would in any case result from the Polaris decision, succeeded in obtaining Board approval for *Warspite* (SSN 03) to be completed whilst the first SSBN was still in its earlier stages at construction.

The fourth major decision of the first half of 1963 was where to locate the British Polaris Submarine Operating Base, Missile Depot and Submarine Refitting facilities. This study was undertaken, at CPE’s request, by the Naval Staff. It has been thought by some that the eventual selection of Faslane, in the Gareloch, for the submarines and Coulport in lower Loch Long, for the missiles, indicate the use of the same study which had led to the selection of the Holy Loch for the American Polaris Squadron in 1959. This was not the case. Every location in Britain was examined which might meet the requirements. These included the minimum safety distance (as laid down by the Atomic Energy Authority) from densely populated areas; sufficient depth of water and manoeuvring space in the approaches; short transit to ocean exercise and operational areas; acceptable logistic support possibilities, and available civilian workforce. It appears that Devonport met most of the parameters, except distance from a conurbation. Faslane and Coulport having been selected, the choice of Rosyth as the SSBN refitting yard fell into place, almost as a matter of geography.

Although the Admiralty and the Ministry of Aviation (for the British nuclear warhead and re-entry vehicle development) were the departments of state primarily concerned with creating the RNBMS concerned their responsibilities. An interdepartmental Committee was therefore set up, under the chairmanship of the Permanent Secretary to the Admiralty, with representatives from the Ministry of Aviation, the Treasury and the Foreign end Commonwealth Office; provision was made for representatives of other Ministries to be called in when required.

In addition, in response to the suddenly expressed desire of the Minister for Defence that the Polaris project should be run by a 'Dr Beeching' ('to give an image of good management' a well known and successful business man, Sir Frederick Hooper, who was Chairman of the Schweppes soda water company, was appointed as Honorary Adviser to CPE, and remained for a year. 'Ho certainly was helpful' according to Admiral Mackenzie, 'with the budget and planning of a major project and with overall advice'.

The main impetus and direction in the achievement of CPE's objective, however, from his own Management Team. As we have seen the Program Evaluation section had been set up on 6 March within the Polaris Executive. By early May CPE was ready to issue an Acquaint establishing the pattern of Polaris Progress and Management Meetings. The purpose of the Progress Meetings was:

(i) For CPE to give directions or make announcements of general application or interest affecting the BNBMS programme.

(ii) To hear Programme Evaluation Reports.

(iii) For CPE to receive progress reports from PE Staff on their specific fields of responsibility.

(iv) To hear special reports (eg from Missions returning, or visitors from the USA).

Those attending would be the Management Team, Deputy and Assistant Directors and Polaris designated Staff from other Departments of Assist ant Director level and above. These meetings would take place in Bath (Foxhill) fortnightly, on alternate Mondays.

The purpose of the Management Team Meetings was:

To discuss and resolve matters of policy affecting the direction and progress of the MNBMS programme, current or foreseen.

Those attending would be:

(a) The Management Team, consisting of CPE, the Polaris Project Officer, Ministry of Aviation; the Chief Administrative Officer, the Technical Director, Polaris, and the Assistant Polaris Executive.

(b) The Deputy Directors (Design) and (Weapons) would be co-opted to attend if necessary.

These meetings would take place weekly, either in Bath, on the day of the Progress Meeting, or in London.

In a note to the members of his Management Team, dated 7 May 1963, CPE wrote:

Now that the initial scramble of forming the Polaris Executive is astern of us and the size and scope of our task is becoming clearer, we need to get a grip on the direction and management of the project to ensure our goals are met. I should hum to use the Management Team forum for free and frank dissuasion to this end and accordingly do not intend to set any fixed agenda.

CPE's Chief Administrative Officer, Mr NP Lewin, assisted by his Deputy, Mr P Nailor, and his Programme Evaluation Officer, Mr EA Robins, had by the end of May prepared a PE Acquaint, for approval and issue by CPE, setting out the procedures which it was intended to employ in assessing be operated by the Programme Evaluation Section, it was laid down that a presentation from this would be made to the Management Team at four weekly intervals, evaluating the status of the project as a whole, and highlighting the critical and near critical areas. This report would be supported by longcast type milestone presentation of critical areas, set against the scheduled completion dates. In addition, there would be a digest presentation of the current state of major facets of the project using the USN Status Report format, namely

Status of Major Components

In Good Shape: (‘No problem’)	All aspects of the programme (or component) are progressing satisfactorily as evidenced by performance facts. There are no immediate problems that may endanger programme accomplishment. Milestone slippage, if any, can be rescheduled without requiring significant amount of additional effort on the part of CPE or contractors, and without requiring rescheduling of other milestones.
Minor Weakness: **(‘**A mall problem. but I can handle it?’)	The program is generally progressing satisfact-orily, but some event, action or delay has occurred or is anticipated which will require additional effort and emphasis on the part of the responsible section and/or contractor. No major set-back is anticipated for the programme (component) and no action or decision is required by CPE.
Major Weakness: (‘Admiral, I need help!’)	Some event, action or delay has occurred which will impair progress against major objectives in one or more sections, requiring timely action by CPE. Required action may be a policy decision within the Polaris Executive, an appeal to higher authority for assistance or decision etc.
Critical: (‘Admiral, you need help!’)	Some event, action or delay has occurred which seriously impedes successful accomplishment of one or more major programme objectives. Such a setback to the programme requires reorientation or reprogramming of the BNBMS effort, with the advice and consent of the Board.

In addition to the four-weekly report of the Programme Evaluation Section, progress reports would be required from each of the PE officers in charge of the ‘fields’ and ‘sub-fields’ into which the project had by now been divided. Subsidiary networks were to be created for:

(a) Each submarine in each building yard.

(b) The Polaris warhead and re-entry body.

(c) The works and installations at: Rosyth Dockyard, The Faslane Base and RNAD Coulport

(d) Each of the separate group of works and installations in the Training facilities.

programme Management Plans (PMPs) which were about to be prepared. These would eventually supersede the Polaris Executive Plans (PEPPLANS) which CPE had ‘set the ball rolling’ with.

CPE also announced, at this time, his intention to hold very soon a series of BNBMS Programme Management Indoctrination Courses for his own staff, and others concerned.

It is of interest to note the way the BNBMS Project Progress Meetings had evolved, between May and July 1963, when a revised procedure for these meetings was promulgated. In future they were to be held on Tuesdays instead of Mondays, and would alternate between London and Bath, instead of being always at Bath.

The weekly Management Team meetings, however, were to continue as before, alternately in London and Bath. The purpose of the Progress Meetings was now declared to be:

(a) To present CPE with a review of the current state in all major fields of the project and to provide the basis for future action.
(b) To provide those responsible for particu1ar aspects with a general picture of progress in the project as a whole.
(c) To provide a basis for collated project status reports to SPRN in Washington.

The attendance list was extended to include the following:

(a) The BNBMS Management Team Special Projects Liaison Officer UK
(b) The Field Officers who were nominated as:

Mr SJ Palmer OBE ADNC	P.10	SSN and SSBN design and construction
Captain CWH Shepherd OBE RN	P.11	Weapon System Equipment
Captain L Bomford CBE RN	P.12	Logistic Support, Dockyards, Base, Armament Depot, Stores
Commander A.T. Usher RN	P.62	Re-entry system development
Commander JS Launders DSO DSC RN	P.23	Operations Support Systems
Commander HN Ellis RN	P.01	Training and Manpower RN Polaris School
Commander J Grimwood RN	P.01	Public Relations
Mr. A Pritchard	P.36	Finance

Significant in the above list of ‘fields’ within the BNBMS Programme is the comprehensive support role of Captain Bomford (P.12). To determine, itemize, negotiate, plan and coordinate the support elements involving respectively logistic support, Dockyards, Base, Armament Depot and Stores was a most daunting challenge both to managerial skill, and to the responsiveness of the major functional organisations concerned.

We notice, also, at this stage, nomination of Mr Pritchard as field officer for Finance. As an Ministry official he had been involved, as a Principal in Military Branch, in the 1958 negotiations of a nuclear ‘enabling’ agreement with Washington; he had dealt also with policy discussions deterrent, in 1959; and he had helped to negotiate the Polaris Sales Agreement. Now in Material Branch I of the Admiralty Secretariat, but responsible directly to CPE's Chief Administrative Officer, Pritchard was established alongside the Polaris technical sections at Foxhill. He remembers vividly a Sunday afternoon meeting at Rowley Baker's house, early in l963. All the old *Dreadnought* Project Team were present. Baker was not enthusiastic about 'the CPE set-up'. Pritchard, however, was 'sold' on Project Management. The British Polaris Executive, as compared with the American Special Project Office, was, in the event, a compromise. It was based upon the principle that in all the Departments, Divisions and Branches concerned, (and very little of the Admiralty and the Royal Navy was not, in some way or other, concerned), the 'Polaris dedicated' individuals would do what was needed, when it was needed, whilst continuing to 'owe professional allegiance' to their departmental heads. There can be little doubt that the Head of Department affected most, in terms of the proportion of his total responsibility, which was diverted to the BNBMS programme, was the Director General Ships (Mr Alfred Sims RCNC). Whatever his personal feelings, however, the DGS accepted the situation loyally, and continued to provide the professional advice and support required, in his capacity as head of the Royal Corps of Naval Constructors.

Returning to Finance, Mr. Pritchard has made the important point that the BNBMS programme was unique, certainly in regard to Defence procurement, in that political approval for the entire project had preceded formal and detailed costing prior to Nassau, the Government had been informed that it could have a four boat Polaris force for roughly £350m. In estimating this figure, the usual attempt to minimize the forecast cost had not been made. Normally the pressure to cut defence estimates, in order to get political approval, is so severe that an element of unreality enters into the calculations , as presented. The usual consequence, on approval of a specific item being obtained, is for Departments to have recourse to many time-, and ultimately money-wasting strategies in order to finance what has been approved.

Harvey M Sapolsky noted this phenomenon in his study of the US Polaris Project:

But it is a mistake to believe that the Polaris program's success in meeting or perhaps even bettering its cost and time estimates provides a potential forerunner for reform. The Polaris program appears to have been subject to many of the same problems that beset programs with substantial overruns. Its ability to meet self-generated estimates, however, stems from its own unique advantage - overwhelming and dependable political support. SP and the Polaris contractors provided honest, accurate estimates because they could afford to provide honest, accurate estimates. ... Congress and the President wanted Polaris, and they were prepared to pay for it.

As it turned out, the original (Nassau) estimate of £350M capital cost (for four SSBNs) spread over a nine year period, was found to be not far out by the time the detailed costing had been completed towards the end of 1963; the figure came to £370M in round figures. Adding another £80M for running costs during the last four years or so of the period, during which the SSBNs would be deploying, CPE was faced with responsibility for controlling a total expenditure of about £450M. This was certainly the largest single industrial undertaking, in the time-scale, ever attempted in Britain. That financial control was exercised effectively is borne out by the fact that virtually the entire BNBMS Programme was achieved within this budget. The only important shortcoming lay in the field of the submarine base at Faslane, for which the estimates of cost put up by CPE were at first regarded by the Second Sea Lord's Department as unacceptably high. Indeed, in Admiral Mackenzie's view the Second Sea Lord's Department was 'the most difficult to deal with throughout the programme' This despite the setting up by the Second Sea Lord of a 'Polaris Naval Manpower and Training Working Party' to determine conditions of service; volunteers; SSBN and support complements; new Rating Categories; and Polaris Training both in the UK and the USA.

The reasons for this clash are plain. Whereas it is not too difficult, given the political authority and the will, to procure material equipment, the sudden unforeseen demand for highly skilled officers and men which the Navy had to face, in order to man, support, maintain and operate the SSBNs, placed a heavy strain on the system. Manpower (and still more officer) planning in a voluntary Service has to be based on foresight. Whereas it had been agreed 'between Ministers' (though informally) that the cost of the BNBMS could not come out of Navy Votes but be absorbed in the Defence Vote as a whole, the necessary officers and men (over 6o% being in highly skilled categories) had to be found by the Royal Navy; furthermore, the costs of recruiting, training and supporting these people and their families, could not, in practice, all be separately attributable to Polaris. These officers and men would spend only a part of their time with the BNBMS. A proportion of their service would be in other ships, submarines and establishments.

In deciding, therefore, during 1963, how best to integrate the BNBMS Programme into naval plans for the next decade at least, the Admiralty Board had a complex task in which it could be said the only fixed and clearly delineated feature was their determined intention to deploy in 1968-70 a force of four SSBNs (with the possibility of a fifth still awaiting decision). This, it should be remembered**,** was at the beginning of the epoch of the highly charged and critical fleet aircraft carrier controversy, which was not terminated until the Government, in January 1960, announced that British forces would be withdrawn from the Far East and Persian Gulf by 1971, and the carrier force phased out.

Three major factors governed the development of the Admiralty's case for a new generation of fleet aircraft carriers. First of all, and before the Polaris decision was taken, the battleground of defence policy formulation was not whether Britain should maintain a capacity for unilateral military intervention 'East of Suez'; but, assuming that her 'vital interests' necessitated such provision, how it was to be dome. Broadly, the alternatives lay between a primarily seaborne assault capability, with carrier borne air support, or a mainly airborne deployment scheme, dependent upon island staging posts, and the ability to seize airfields on land sufficiently near to the objective, and promptly enough to provide adequate air cover and support in the face of the comparatively modest scale of opposition envisaged. According to Dr. Phillip Derby, 'A committee headed by JC Kendrew, a part- time scientific adviser to the Ministry of Defence, was appointed to make a dispassionate examination of the issue, and it reported in favour of the carrier. The project then went before the Chiefs of Staff Committee, but the opposition of the Chief of the Air Staff forced the Navy to convey its case direct to the Minister without the support of the Chiefs of Staff Committee. The upshot was that on 30 July 1963 Thorneycroft announced the government's decision to build a new 50,000-ton carrier. Together with HMS *Eagle* and *Hermes* suitably modernized, this would give Britain a force of three carriers until about 1980. Thus was a heavy burden on the Navy's resources of all kinds undertaken simultaneously with the BNBMS Programme, although replacement of the only cruisers left in the Navy, the three *Lion* class ships, was not provided for, and the rate of replacement of frigates and destroyers was slowed down. This in addition, of course, to the gap which would develop in the nuclear-powered general purpose submarine programme, already referred to, The Naval Staff worked under great pressure at this time.

Reverting now to CPE's own activities, he was ready by September 1963, as we have seen, to implement the plans for systematic management which had been prepared under the enthusiastic and creative guidance of his Chief Administrative Officer. A system of Programmes and plans had been worked out and was already in use within the Polaris Executive and said to be 'proving their worth'. The 'many other authorities within and outside the Admiralty without whose co-operation, goodwill and drive the Navy's task of creating a force of Polaris equipped nuclear submarines within the tight time-scale laid down by the Government will not be achieved' were invited to 'contribute actively to the overall plan and participate in its evolution rather than concentrate on their particular bits in isolation so far as is practicable and appropriate they should employ a common system of planning and reporting progress against plans'.

In laying down the principles upon which Programme Management Plans were to be based, CPE gave precedence to 'Management by Exception' in two paragraphs which merit quotation in full:

Management may be defined as the process of identifying objectives, placing then in the right order of priority and of planning and employing resources to accomplish them. CPE is adopting a method of management that will encourage everyone connected with the programme to concentrate his efforts on those aspects of the total task that at any time threaten to delay the achievement of its objectives. This method is called 'Management by Exception'. It involves a thoroughgoing delegation of responsibility for getting every aspect of the job done, and should make the most effective use of the available managerial skill while minimizing the use of money and manpower to buy time. Management by exception enables managers at all levels of responsibility to apply their energies particularly to those areas of foreseen or current weakness that are most critical for the timely completion of their tasks instead of directing equal effort to every real or imagined difficulty.

The economy of effort implied by management by exception is fully achieved only if:

(a) realistic plans for carrying out the total task and its parts are worked out, agreed by and disseminated among those authorities involved, at an early stage of the project;

(b) progress against these plans is honestly and regularly reported on; and

(c) means exist to test, improve and modify those plans as the project proceeds.

CPE's acquaint went on to describe the system of field officers, to whom the different parts of the programmes had been delegated, and the nature of their responsibilities. Then he laid down the 'principal tools' that he had adopted to aid himself, his field officers and other authorities involved in planning and managing the project, namely:

(a) Program. Management Plans (PMPs)

(b) The Reporting System.

(c) Network Scheduling.

Of these, the PMPs would be: 'the initial, the most widely used, and therefore in many ways the most important management technique used in the BNBMS Programme. PMPs are essentially milestone charts drawn up in a special way. ... They enable the responsibility (whether within or out side the Polaris Executive) to be pinpointed, and provide a ready means of presenting and disseminating agreed plans to all concerned with their execution.'

The Reporting System, as established, involved, first, the preparation and circulation of proposed PMPs, for concurrence by the field officers, then issue in approved form; thereafter the submission of a Report Form showing the status of that PMP at the fortnightly Polaris Progress Meeting; end subsequently updating and revision, as necessary.

Network Scheduling, the third 'aid to management' specifically adopted, was described as: 'Breaking down a task into a number of discrete processes or activities. It has the special merit of displaying their later relationships (PERT and 'critical path scheduling' being of the same family of techniques). It lends itself, with the aid of computers, to determining the effect of possible trade-offs in money, effort or other resources and of working out the effect of delays on final completion dates.' As a feature of PMPs the responsibility for action, in regard to the achievement of each successive milestone, was carefully defined in three categories

(a) *Supporting*. This is a person who has a major ro1e in helping the number of CPE's staff (shown as having the first responsibility) to get the Action Milestone completed in time.

(b) *Monitoring.* This is a person who cannot get on with some aspect of his own job until the Action Milestone is completed.

(a) *Contractor.* This is the person who actually does the work leading up to the accomplishment of the Action Milestones.

NB These definitions are not self-evident and deserve careful study (eg the term 'Contractor' is used in its widest and not in a narrow industrial sense).

Each long-term PMP generated a 'family' of subordinate PMPs, such that there were normally three levels of PMP related to each major component of the BNBMS. It was laid down that:

PMP families should first be prepared in rough form from the top level downwards and then in smooth form from the bottom level upwards. In the first instance the task of the family is related to time. In the second instance, the jobs facing each management level are assessed in detail and the schedule effects on the remainder of the task are accommodated. The final result is a task completely defined in terms of its component jobs in relation to time.

It cannot be determined to what extent the institution of this detailed management system contributed to the timely and satisfactory completion of the BNBMS Programme within the planned budget. It can only be stated that such an achievement was, and remains, unique in the history of large-scale defence procurement in Britain. Although the opinions of those who had a key part to play in the BNBMS Programme are not unanimous, either one way or the other, on balance those who began by opposing CPE's management system came grudgingly to admit that it was a help, rather than a hindrance. Those who espoused the cause from the start regarded their faith as having been fully justified. Of course, there could be no substitute for technical expertise and dynamic activity in so many advanced fields. But it remains for others to prove that they can achieve, by different methods, the standard of performance set by the Polaris Executive, as a managerial organisation.

Having said so much it is of interest that one of the most complex tasks, organisationally, and the most pressing in terms of criticality for the BNBMS Programme as a whole, was ‘to design, construct, and equip (including procurement, installation, testing and tuning, and setting to work)’ the Royal Naval Polaris School at Faslane. On 2 September a Sub-project Management organisation was set up, within the Polaris Executive, ‘to be ready by 1 July 1966 to start training BNBMS weapon personnel in accordance “with the approved recommendations of the Polaris Planning and Training Working Party’. Although sited in the submarine maintenance base, for convenience, security and support, the RNPS was not the responsibility of the field officer responsible for the Base, Captain Bomford, but of Commander HM Ellis RN, who was directly responsible to the Assistant Polaris Executive, as field officer for ‘Training, Manpower and the RN Polaris School’. As Sub-project Team leader, Ellis’s responsibilities included:

(a) The formulation of Training Requirements;

(b) Overall co-ordination and submission of plans for achievement of the end objective;

(c) Necessary liaison with the Chief Administrative Officer on all policy and budgetary matters;

(d) The Chairmanship of the Sub-project team;

(a) Reports on progress of the Sub-project.

Responsibility for the functional installation (ie one complete set of Polaris launch, fire control and navigational equipment) was assigned to a member of the Director Polaris Technical staff; and the Sub-Project team was ‘to work within the overall organisation for the construction of the Polaris Operating Base as established by the Polaris Logistics Officer (Captain Bomford).’

It had become all too evident by September 1963 that time was not on the side of CPE and his men, even although 1968 still seemed a long way ahead. To Captain Shepherd, in particular, the urgent need to start planning the support aspects of the BNBMS on ‘Day one’ had all along been apparent, a point of view which he had strongly pressed. Directly relevant to this, as to all other aspects of the programme, was the matter’ of communications. It was fortunate, and perhaps not entirely fortuitous, that Admiral Mackenzie’s Assistant Polaris Executive, Captain Rae McKaig, a Communications specialist. For, as may be imagined, the two Project Officers, one British and one American, required by the Polaris Sales Agreement, must have direct, secure and uninterrupted transatlantic communication. Also, between CPE in London and the Polaris Executive in Bath; and between these offices and the shipyards, the Naval Stores depot at Copenacre, the Armament Depot at Coulport and the Operations Base at Faslane, There would inevitably be a rapidly growing communications load. This traffic was duly provided for, with the assistance of the GPO. A particular feature was the provision of a CPE-SPRN teleprinter circuit for trans-Atlantic ‘staff officer to staff officer’ traffic. The London end was in the Admiralty’s Whitehall Wireless centre not far from CPE’s office, and the Washington end was in the US Navy’s Special Project’s Communication Centre, to which the office of SPRN (CPE’s Liaison Officer with Special Projects) was adjacent. This circuit, which was used freely but subject to certain strict rules, was termed TWX**,** known colloquially as ‘Twix’. All messages on TWX were formally recorded and handled in accordance with correct procedure. The circuit was authorized to be used for up to one hour at each of two periods during the twenty-four hours, and was subject to interruptions for the passage of higher priority traffic.

Another of the administrative matters that was ‘special to Polaris’ was Security. From the very beginning of the BNBMS Program, exceptionally strict security precautions had to be observed. These had to satisfy US, as well as British, requirements. Special checks were established first, at CPE offices within the Ministry of Defence Building in Whitehall; then in the Polaris Executive offices at Foxhill, Bath, and, as the Programme progressed, at the Faslane Base, the RNAD at Coulport, HM Dockyard Rosyth; the Naval Stores Depot at Copenacre, and the shipyards. Nuclear reactor R&D, production and operation required not only security but stringent safety requirements. These included monitoring both nuclear plant and the environment; the establishment of emergency procedures in case of a nuclear accident, and the systematic checking of individuals for radiation levels. A Nuclear Safety Committee already existed, under the aegis of the Atomic Energy Authority, and CPE was represented on, and advised by, the Authority.

By October 1963 CPE had seen his organisation take shape. Most of the key decisions affecting the planning of the BNBMS Programme (still often referred to simply as Polaris, but now with the understanding that it was a total system) had been taken. The Polaris Executive had grown from eleven, on 8 February, to approximately sixty people, of whom about half were naval officers and half Admiralty civilians.

Individuals in the numerous Departments, Divisions and Branches within the Admiralty concerned with the Polaris programme had been *allocated, designated*, or appointed as *Polaris Liaison Officer* by their Directors or Heads of Department. Much indoctrination in the task and the way it was to be tackled had been carried cut. The shipyards had been selected. The location of the Operating Base had been decided. CPE’s Liaison Officer with Special Projects, Captain PG La Niece RN., had been selected, appointed, briefed and installed in Washington, where he was rapidly building up his team of specialists. Trans-Atlantic co-operation was developing well, from the regular meetings of the Joint Steering Task Group (‘Formal but friendly’), through the informal exchanges between the Polaris Management team in UK and their opposite numbers in Special Projects, to the frequent
And usually somewhat hectic staff level visits to American Polaris ‘activities’ or ‘facilities’; and to shipyards and component manufacturers all over the United States. The detailed ‘shopping list’ arising from the Polaris Sales Agreement was nearly complete, and so were the budget figures and financial plans for training British naval and civilian (including shipyard and reactor builders) personnel in the United States were well advanced. Main contracts had been prepared. In Foxhi1l, Bath, Rowley Baker’s team had all but completed the design of Britain’s ballistic missile submarine. HMS *Dreadnought* was being successfully operated.

As far as CPE himself was concerned, whilst not dissatisfied with progress during the first nine months (gestation period?), he was acutely aware of’ two major issues which might at any moment become ‘critical’, in terms of his own Progress Evaluation technique. Firstly, he was far from being convinced that either of the selected builders, Vickers and Cammell Laird, would succeed either in recruiting enough skilled technical people, especially for the unprecedented amount of complex electrical work required early in the building schedule; or that their managements had accepted the necessity, upon which CPE was bound to insist, of participating in the systematic management process which he had initiated. Secondly, a grave shortcoming had become uncovered (about which it is not, even now, permitted to be specific) in certain materials used for the primary circuit of the *Valiant* design reactor plant. Attempts to solve this problem through normal administrative channels were ruled out of court. It is understood that discussions took place between Sir Solly Zuckerman (Chief Scientific Adviser to the Ministry of Defence) and Admiral Rickover, ‘which resulted in a resolution of the problem. But it was potentially most serious

Thirdly, in summing up the first phase, it may recorded that CPE had himself come to the conclusion that five, and not four, SSBNs would be essential, if the BNBMS was to be a credible strategic nuclear deterrent force. His field officer for Operation Support Systems, Commander JS Launders DSO DSC RN had plotted for years ahead the operational cycles of the SSBNs, from deployment through periodical maintenance and the completion of major refits in Rosyth Dockyard. It was clear to see that only with a total force of five SSBNs could a minimum requirement of two submarines (providing thirty-two missiles) *continually* on operational patrol be met. Reduced to four, the total force could be guaranteed to provide thirty-two missiles ‘at the ready’ only intermittently. For considerable periods there might well be only sixteen missiles at sea.

With a general election in the offing, the present Parliament having almost run its course, the Conservative Government was not prepared to confirm the decision which, apparently, it had been inclined to take, in favour of the ‘fifth boat’.

On 4 November, to mark as it were ‘the end of the beginning’ of the BNBMS Programme, CPE and his Management Team gave a Polaris Presentation’ to ‘The Minister of Defence, other Ministers concerned, and senior officers (including those of the other Services) and officials.’ The content, production and stage management of this presentation were accorded much thought and care. It was organised jointly by CPE, and the Assistant Chief of Naval Staff, with a security level of TOP SECRET. The Polaris Executive was allotted forty minutes, which CPE split up thus:

Subject	**Approx time**	**Speaker**
(a) The Task	4	CPE
(b) How it was being achieved (Organisation and Finance)	8	Chief Administrative Officer
(c) The Weapon Control System and Missile	12	DD Weapons (Polaris) Polaris Project Officer Ministry of Aviation
(d) The Submarine System	6	DD Naval Construction (Polaris)
(e) The Support System (Manpower and Training)		Assistant Polaris Executive
(t) Achievements to date	6	CPE

The Controller of the Navy would then summarize the major production problem areas.

There were three rehearsals of this Presentation. At the second of these the Vice Chief of the Naval Staff and the Controller were present, and the third was attended by the Board and Admiralty representatives. Four minutes was not much time in which to present the achievements of the previous nine months But morale was high in the Polaris Executive, and the confidence of the Board of Admiralty that its task would be achieved in the time allowed was reinforced. For their part, the Board approved the design of the SSBN that had just been completed, and the keel of SSBN01 was laid at Vickers of Barrow-in Furness on 26 February 1964, by Sir Alfred Sims, the Director General Ships. As the Admiralty News Release recorded:

The keel laying on 26 February is only an indication of the widespread effort which has been deployed over the past thirteen months in this country, with the assistance of the US Navy, directed at having the first British Polaris submarine operational by mid-1968, with the remainder following at six-monthly intervals.

CHAPTER VII

MILESTONES

We planned in 1963 to fire our first missile at 1115 EST (Eastern Standard Time) on 15 February 1968; we failed by 15 milliseconds. We were told in 1963 that there must be a continuous deterrent from July 1968; this was achieved.

Rear Admiral CH Shepherd, CB CBE
Deputy Controller (Polaris)

The problem for British shipbuilders

Months before the keel (a prefabricated circular section of the submarine weighing well over 100 tons) of the first SSBN was laid, work had begun on fabricating the steel work and preparing the building and fitting out berths for the ballistic-missile submarines, at Barrow and Birkenhead. In each yard management, technical staffs and skilled workers were briefed, organised and given special indoctrination and training (many in the United States). The total task was broken down into its component parts; the Trade Unions were consulted over work schedules; construction of special buildings to house the inspection, test and quality control teams and their equipment was put in hand. The selection of about 800 sub-contractors was begun, and their contracts worked out and offered. Much of this activity was, of course, normal for shipyards, such as Vickers and Cammell Laird, with three or more generations of experience in building large warships. But at almost every turn the Polaris submarines presented novel problems. One of the first to be encountered was in testing the integrity of the welding of the special 'high-yield' steel used in hull construction. The methods used in this 'non-destructive' testing included ultra-sonic examination. In the early stages it was found difficult to get a consistent result by this means. And acute apprehension was felt when it was reported that 'hair-cracks' had appeared in the vicinity of welds in the hull of the Vickers-built nuclear powered submarine *Dreadnought* when she was taken in hand for her first refit. British made steel, thought to be easier to weld satisfactorily, did seem prone to the development of hair-cracks, associated with laminations of the structure of the metal, owing to a high silicon content. The equivalent American steel, believed by some to be more difficult to weld properly, did not appear to laminate to the same extent.

Another major problem associated with the 'learning curve' inseparable from new production processes of much complexity, was the organisation and supervision of the work force, and the temper and propensities of these staunch, but stubborn men. Put starkly, the following comparisons between British and American shipyard production indicate the difficulty of achieving the target dates set for launching and completion of the SSBNs (and the SSNs, for that matter, as delays with them could prejudice the SSBN programme):

In all contracts with British industry it was necessary to allow about two and a half time as long for the job to be completed. Expenditure on 'overheads' needed to be increased by about 300% to equal the corresponding American levels. The British would not work three shifts. By comparison, at Electric Boat (Groton, Connecticut) for example, there were two huge car parks, one always empty, the other full; when a new 'shift' came in, they could park their cars with minimum delay; proceed to the security check; there receive a job card and proceed direct to their places of work in or around the submarines. By comparison, in the British yards, much time was wasted, and *confusion caused, by lack of proper organisation and supervision.*

The extent of this weakness was revealed during the enquiry into an accident which occurred to one of the SSBNs. A skilled worker, who normally had mate with him, inadvertently boarded the wrong submarine and, after hours of delay (his movements during this period were finally established, and reflected no credit either on himself or the management of that particular yard), opened a wrong valve. This caused a near disaster. The submarine was partially flooded.

Not surprisingly, the close and detailed monitoring of progress insisted on by CPE and especially the preparation and processing of the ship networks, was not at first welcomed. Fortunately CPE had made sure that the requirement to establish and use these procedures was written into the contracts. CPE's Programme Evaluation Group helped to introduce the procedures, where possible.

Programme evaluation and review

In the event, the poor quality of the shipyard networks in the early stages of their development 'gave rise to doubts as to their efficacy but CPE persisted in requiring their use, and they were found to give their best value during the middle construction period'.

CPE's Programme Evaluation Group also helped to train staff in HM Dockyard, Rosyth, assisting them in the preparation, updating and finally the computer processing of a series of networks on the planning programme of the first refit of HMS *Dreadnought*. This experience proved to be most helpful in planning the SSBN refits that followed *Dreadnought's* in due course.

Fears that the Programme Evaluation Group operated as a sort of spy-system for CPE were sometimes expressed. These were groundless, in that the Group was not qualified to evaluate the technical data upon which the networks were based. Nevertheless, the networks certainly imposed a discipline upon any manager or technical officer inclined to take a decision without sufficient consideration of possible effects upon other aspects of the programmes.

Establishing financial control

The Programme Evaluation and Review Technique (PERT) did not, in its original form, take any account of financial expenditure. To obviate this shortcoming, Special Projects had evolved and applied an expenditure recording amplification of PERT known as PERT COST. The idea was to mesh with the breakdown of work required to establish the 'work packages' which, cumulatively, would result in the completion of tasks at various levels; to estimate the costs of these separate ' work packages', monitor the costs of work actually performed and compare these with the estimated costs, on a cumulative basis.

It is by no means certain that the introduction of PERT COST did in fact contribute to the success of the US Polaris Program. It was expensive to install and operate. According to Sapolsky:

The Polaris programme moved ahead without the usual financial restraints that burden governmental undertakings. This is not to say that SP's financial procedures were criminally lax.

They can be more accurately described as well-focused. The management of money was not isolated from the management of technology, but rather was intimately related to it. Special Project's staffs are properly praised not for their accumu1ation of book-keeping records, but rather for their contribution to speeding the achievement of FBM program objectives.

Those responsible for controlling the finances of the British Polaris programme believed that Special Project's 'audit' of the US contractors was not taut enough. SP was not authorized to go into a contractor's plant to monitor work done, but paid on invoice. It was decided, therefore, to monitor the UK contractors' work. Not only did this provide a more positive check on actual costs, but also it provided an additional check on progress. When costs for a particular item were rising unexpectedly fast CPE's financial controller would enquire what was going wrong. The contractors did not like this procedure at first, but perhaps because CPE paid promptly for work done, it came to be accepted. Once this was the case regular and timely expenditure according to the programme's budget was an indicator of satisfactory progress, and *vice versa*.

This close and effective control of expenditure was not effected without much forethought and detailed planning, coupled with meticulous execution. Given full responsibility, by Board decision, 'for ensuring that a satisfactory system of financial control of the programme was established', CPE's Chief Administrative Officer certainly appeared to have all the authority required in order to exercise centralized coordination and control. On the other hand, in the terms of reference of the Polaris Committee, it was laid down that CPE must seek Board approval to 'incur commitments' through 'the appropriate Secretarial Branch'.

The basis for the Financial and Budgetary Control of the BNBMS Programme was set forth in a Polaris Executive Acquaint issued in December 1963. Its aims were given as:

(a) to assist in the estimating and control of expenditure to ensure that the programme is carried out as economically as possible within the timetable;

(b) to act as a supplementary aid to the assessment of physical progress.

The budget would consist of about 350 'line items' each of which would be:

(a) concerned with a distinct activity under the programme:

(b) attributable to one Admiralty, Ministry of Aviation, or Ministry of Public Buildings and Works Vote and sub-head:

(c) the responsibility of a particular PE field officer.

Expenditure incurred and estimates for further expenditure would be reviewed quarterly, in the course of a BNBMS Progress Meeting. Field officers would be responsible for providing this information, and for its validity, in the UK; BMS expenditure in the United States would be monitored and provided by SPRN.

A major task had to be undertaken by the organisation of the Director at Navy Contracts, who designated his Deputy, Mr. EF Hedger, to provide all necessary support to CPE. Mr. Hedger had taken part in the negotiation of the Polaris Sales Agreement. His responsibilities included settling, as soon as possible, the prices to be paid under the respective fixed price contracts and their terms; and assisting the field officers with their budgeting and cost monitoring tasks.

The costs were grouped in two ways. In the first, they were divided between items procured other than under the Polaris Sales Agreement; these included, for example, purchases under the Electric Boat Contract, radio and radar equipment, sonar equipment. In addition, there were all the Admiralty supplies and services, from *The Pay of Ratings* through to *'Water drawn through Mains at Admiralty Shore Establishments'*. Then there were Ministry of Public Building and Works payments**,** as for example *Dredging*; and there were the Polaris missiles themselves, their *'SPALT'* (Special Project Alterations) *kits and modification hardware* and all the rest of the items obtained under the Polaris Sales Agreement.

The second way of grouping costs was in a series of budget headings showing the line items for which each field officer was responsible. The main headings were:

'Capital Costs - Submarines', divided into 'Ship-Costs', 'Weapon and Control System Costs'**,** and 'Other Building Costs';
'Capital Costs - Missiles', divided into 'Polaris Missiles' (including Guidance Packages) and 'Torpedoes';
'Capital Costs - Operations Support System, divided into 'Communications Facilities', 'Base Support Facilities', 'Training Facilities', 'Accommodation and welfare Facilities', 'Land Acquisition', 'New Floating Dock', and 'Navigation Surveys';
'Capital Costs - Logistic Support System', divided into 'Armament Depot Facilities', 'Dockyard Facilities', 'Repair Facility at Base', 'Storage and Repair Facilities outside Base and Dockyard', and 'Sea and Road Transport Vehicles';
'Capital Costs - Research/Development', divided into 'Ship Systems', and 'Missile Warhead and Re-entry Body';
'Capital Costs - Miscellaneous Expenses', divided into 'HQ Expenses', "Miscellaneous Training Expenses', and 'Lump Sum Payments to US Government;
Running Costs - Maintenance and Repair of Submarines and Machinery Ashore', divided into 'Repair, Docking and Refitting of Submarines', and 'Replacement Costs' (including Fissile Material);
'Running Costs - Modification, Repair, Replacement and Proving of Missiles' divided into Guidance Capsules', 'Replacement of Missiles', 'Proof Test Missile Firings' and 'Replacement Torpedoes';
'Running Costs - PAS', being 'Running costs of the Port Auxiliary Service Craft';
'Running Costs - RNAD Support'
'Running Costs - Victualling Stores and Public Utility Services';
Running Costs - Naval Personnel outside HQ' divided into crew of SSBNs' and 'other Navy personnel'; and finally,
'Running Costs - Civilian Personnel outside HQ'.

Thus, by an examination of the budget breakdown, it is possible to see, set out in logical form, all the main elements of the BNBMS. Were it required in this survey to show this in greater detail, and in the same logical forn, it would be necessary merely to list the 'line items' contained in each element. But even then, the full scale and complexity of the systems would not be apparent.

The logistic support programme

In addition to establishing firm financial controls, it was necessary to set up, as soon as possible, a really effective logistic support organisation. Captain L Bomford, the Polaris Logistics Officer, with his Naval Stores and Armament Supply colleagues, had realized, very soon after being appointed to their tasks, that the major elements of the BNBMS programme for which they were responsible could cause delay to the progress of the programme as a whole. To take the supply of stores and spare parts first. It would be necessary to make-up, list awl identify by a code system, each of the replaceable items, amounting to about 30,000, which went into an SSBN. Furthermore, initial outfits of these stores and spare parts must be ready at the building yard in good time to be embarked without interfering with other building, finishing, or testing and trials work. Some of these items would come direct from factories in the United States; others from factories in Britain. Spare parts in a category known as 'pedigree parts' by the USN would require special testing and care in storage, and individual documentation. Above all, the exacting requirement to maintain the deterrent, once deployed, at better than ninety-nine per cent of operational readiness, could not be met by existing arrangements for the supply of naval stores.

It was decided, therefore, to locate a single BNBMS stores complex at Copenacre, in Wiltshire. A computer was needed to provide the necessary 'stock control' and instant recovery of stores and spare parts. A comprehensive ready use stock of stores and spare parts was provided at Faslane, the Polaris Operating Base. Individuals were selected and specially trained in Polaris support, some in the United States.

Indeed, the training requirements of the BNBMS programme had, by 1964, begun to take shape, as a major administrative task involving many people and organisations outside the Polaris Executive.

The training programme

As provided for in the Polaris Sales Agreement, all the naval officers and men, and all the civilians, both Government-employed and otherwise, who required training at the USN Ballistic Missile School, Dam Neck, Virginia, received it. It fell to Captain La Niece, SPRN, in his office within the US Special Projects building, to arrange, organise and administer this training. Matters of travel, pay, allowances, accommodation, work, play and behaviour had to be dealt with. On the whole the British trainees conducted themselves well.

In the United Kingdom training of officers and men, was organised and carried out under the *aegis* of the Second Sea Lord and Chief of Naval Personnel, although the Flag Officer Submarines was responsible for all submarine training. In regard to the nuclear power plant, it will be remembered that the DSMP (Dounreay Submarine Prototype), was under construction since 1960. Despite serious delays owing to an unsatisfactory specification for the metal used in the primary circuit, this reactor went critical on 7 January 1965. The company who had designed the reactor, Rolls Royce and Associates, continued to maintain it; and were able to use it to some extent for Research end Development. But its main purpose was to provide submarine officers and men with reactor-operating experience.

A series of nuclear physics courses for officers, in varying degrees of depth, was begun at the Royal Naval College, Greenwich, where the zero energy research reactor, *Jason*, had gone critical in November 1962. For example, seamen officers appointed to command SSBNs were given an acquaintance course in nuclear physics, and training at the DSNP, sufficient to enable them to understand the fundamental characteristics of a pressurized-water- moderated submarine reactor (its control arrangements, instrumentation end safety requirements).

Manning the SSBNs

Because the SSBNs would operate a cycle of approximately two months at sea alternating with one month in harbour, they would have two crews, each of 13 officers and 137 men. Whist one crew had the submarine on patrol, the other would be on leave for a couple of weeks and then doing advanced and refresher training, breaking in new members of the crew, and assisting the Base Staff until its next turn at sea. Once all four SSBNs were in commission, therefore, manning them would be a total of 104 officers, nearly all Lieutenant Commanders or Commanders, and 1096 ratings, sixty percent of whom would be Petty Officers or Chief Petty Officers. Although, in theory, the equivalent of only one crew would be needed for the SSBN in refit, this could not in practice offset the requirement to ensure adequate ‘spare numbers’, ready to take the place of individual a in a duty crew who might fall out, for sickness or other reasons; nor would it be sufficient to provide a training ‘pipe-line’, providing reliefs for officers and men who had completed the limit of six patrols in succession which would normally be set. The full requirement, for a force of four SSBNs amounted, therefore, to nine crews.

The special manning requirements of individual SSBNs included Medical Officers and Sick Berth attendants specially trained in nuclear medicine, radiation hazards and nuclear safety of the environment. Although almost all members of the Submarine Service of the Royal Navy are volunteers, it was necessary to ‘select by invitation’ in certain categories where there were shortages, in order to man the SSBNs.

As the work of building and equipping the Polaris submarines proceeded, hour by hour, day by day, week by week and month by month, a host of new technical problems were met and mastered by the skill, ingenuity, experience and determination of the shipbuilders and engineers at Vickers, Cammell Laird and the numerous sub-contractors all over Britain. An adequate account of the technical achievements of the British Polaris Project cannot be included within the compass of this study; but without the technical skills even the most effective organisations and leadership would hew been of little avail.

The operational programme

The operational issues, inevitably including matters of the highest security classification, were in the province of the Naval Staff. For this reason it is not possible to give here more than an indication of decisions which had to be made; the tasks which had to be completed ‘on time’; and the naval staff and hydrographic organisation which achieved these objectives in parallel with CPE’s programme.

In mid-1963 a Naval Staff Polaris Progress Committee was formed, chaired by the Assistant Chief of Navel Staff (Rear-Admiral Hill-Norton), with members of the various naval staff divisions - Plans, Operations, Intelligence, Communications, Navigation - together with representatives of CPE, the Flag Officer Submarines, the Hydrographer of the Navy, and Military Branch of the Admiralty Secretariat. This Committee, of which the membership varied depending upon the subjects under review, met frequently in 1963, then, as the work became more clearly defined, split into sub-committees, with full committee meetings quarterly to revue progress. When CPE had developed his system of programme management plans (PMPs) towards the end of 1963, he obtained the co-operation of the Naval Staff in utilizing PMPs, and coordinating their activities directly with those of the Polaris Executive.

The matters that fell to the Naval Staff to deal with included the command and control of the SSBNs, which involved putting into effect reliable methods of assuring an unambiguous ‘firing chain’ in two sets of circumstances. Firstly, when the SSBNs were being operated as part of an alliance force, and, secondly, in the event of independent action by Britain being required. The provision and manning of a Polaris command centre had to be undertaken. It was necessary, also, to consider the operational patrol areas, to ensure that suitable charts were available, and that navigational aids, particularly in regard to egress and ingress from and to the operational base, were adequate for the safe movement, in all conditions of light and weather, of these 8,000-ton vessels, the SSBNs, which would have a draft of over thirty feet**.**

The development and installation of the communications system themselves, once the policy had been decided, was a major technical task.

Other matters of critical importance and high sensitivity, with which the Polaris Progress Committee dealt were targeting; deployment plans; provision for continuing analysis of the performance of the BWBM system as a whole; the logistic plan for supporting the BNBMS once the force had been built and deployed, and the Polaris Executive disbanded; provision for the continuing recruitment, training and appointment of officers and men for the Polaris force; the command and organisation of the Clyde Submarine Base at Faslane; the operational test firing program for the SSBNs; and legislation to create a Dockyard Port at the Gareloch, Lower Loch Long and adjacent Clyde waters.

It cannot be said that this last it was exactly an example of good public relations on the part of the Ministry of Defence (Navy). Local public opinion in the Helensburgh area was allowed to batten on fears that both recreational sailing and yachting, and the interests of commercial shipping, would be seriously prejudiced by the stringent regulations imposed by the establishment of a Dockyard Port. Furthermore, the residents of the area were not, on balance, inclined to welcome the advent of the Polaris operating base, despite the easement of local rates, and the flow of money into local shops and services, which it might be expected to bring. The situation was much ameliorated by the calling of a public meeting in Helensburgh by the Captain-in-Charge, Clyde, (Captain JD Turner DSO DSC RN, a submarine officer), through which many questions raised by the public received satisfactory answers. Although relationships between the Royal Navy and the civilians in the neighbourhood of the Clyde Submarine Base have not invariably been smooth, feelings have never run high. As time goes on the Faslane Base has become more and more a ‘part of the scenery’; and, incidentally, considerable trouble has been taken to landscape the base, the design of which was submitted to the Fine Arts Commission of Scotland. It is the large floating dock, rather then the base itself, which is the main eyesore.

The lovely, peaceful, unspoilt, Faslane Bay of pre-1939 days had already been desecrated, in environmental terms, during World War II by the building of an emergency port to take the place of Glasgow’s docks should these have been destroyed by bombing. After the war the ship-breaking firm of Metal Industries Ltd. had taken over most of the port installations. In consequence a row of pathetic, rusty hulks, in varying depths of dismantlement, had perpetuated the wartime dishevelment of Faslane. In 1957 that part of the Reserve Fleet of laid-up HM Ships that had for long shared Faslane and the Gareloch with Metal Industries was finally paid off. It was then decided to relocate at Faslane the Third Submarine Squadron, with its depot Ship, based since the war in Rothesay Bay, in Bute. To that extent, therefore, a submarine base already existed at Faslane before the decision was taken to make it the operating bass for the SSBNs.

The fifth boat

For the Polaris Progress Committee, in 1964, a major conundrum affecting many of their deliberations was the political indecision over ‘the fifth boat’. As we have seen, Government policy was initially to order four SSBNs, leaving in abeyance the possibility of a fifth. This remained the situation until May 1964. At about this time, it appears, the British Cabinet was about to make a decision in regard to the fifth boat. Despite CPE’s strong representations that five boats would be essential in order to maintain at least two continually on station, and thus allow for the possibility of one being temporarily out of action without breaching the integrity of the deterrent, the Cabinet were of a mind to settle for the final total of four, as envisaged. But word came that the French had decided to build a ballistic missile submarine force of five boats. Could Britain allow herself to appear less determined than France to maintain her ‘independent’ deterrent?). No. For a few months, therefore, CPE and the naval Staff used as an assumption that the BNBMS would consist of five, and not four,

But 1964 was an election year. The Labour Party was under strong pressure from its left-wing unilateralists to promise, if elected, to cancel the Polaris programme. The leader of the party, Mr Harold Wilson, was loath to commit himself or his party to such a step. At the same time there was a body of opinion, apart from the ‘nuclear disarmers’ and the ‘pacifists’, who questioned the logic of Britain’s nuclear defence policy. They questioned it on three main grounds. Firstly, the political credibility of a so-called ‘independent’ nuclear force, which in fact was supplied, as to its most important elements, by a foreign power, namely the United States of America; even though she was an ally. Secondly, the military credibility of the BWBMS in the event (said by some to be quite probable), of a ‘breakthrough’ in anti-submarine capability, and the emergence of effective anti-ballistic missile systems, and, thirdly, the questionable logic of allocating such a high proportion of the nation’s resources available for defence to the nuclear deterrent, at the expense of what really constituted effective defence, namely the conventional armed forces.

Britain’s Chief of the Defence Staff at this juncture was Lord Mountbatten. He had recalled how Mr. Harold Wilson sought his advice informally, in regard to British defence policy in general, and the Polaris programme in particular, at the time of the General Election of October 1964. It seems that Mr Wilson invited Mountbatten to engage in a prolonged private discussion of these crucial matters. If Mountbatten succeeded in convincing Mr. Wilson personally that Britain needed Polaris, then he, Mr Wilson, undertook to carry his Cabinet colleagues of the new government with him. The upshot was that Mountbatten succeeded in convincing Wilson. The next problem was to convince the Cabinet. It seem that Mr Wilson had determined that, if forced to do so, he should sacrifice the ‘fifth boat’, in order to keep the BNBMS in being, as Britain’s independent nuclear deterrent. In the event, this is what took place. The fact remains that the reduction of the total SSBN force from five to four downgrades its deterrent power by more than twenty per cent. On the other hand, as, no doubt, Mountbatten pointed out to Wilson, the existence on operational patrol of even one SSBN, with its sixteen missiles, which at any moment the Prime Minister of Britain may order to be fired or withhold from firing, is a factor which could be of critical importance in computing the complex balance of world-wide destructive power.

The Atlantic Nuclear Force

From the advent of the Labour Government in October 1964, therefore, continuation of the

BNBMS programme was assured though limited to four SSBNs. To that extent the apprehensions of the Naval Staff, and the uncertainty, were assured. But throughout 1963, 1964 and into 1965, a new political complication had to be contended with. This arose out of on American proposal for an Atlantic Nuclear Force, which might take one of two forms. It could be multi-national, by which was intended, it seems**,** a force consisting of nuclear armed units each manned by its own nationals but under international (ie NATO) control; or it could be multilateral, in which the units would be mix-manned, and so financed, controlled and operated as to provide the non-nuclear powers in NATO with some degree of direct control over its use. This scheme, known as the MLF (multi-lateral force), was for a time strongly advocated by the United States, and particularly by the State Department. It must be remembered that the Polaris missile itself could have been mounted in surface ships, rather then submarines. Whereas the prospect of ballistic-missile submarines manned by polyglot crews was difficult for the Naval Staff to take seriously, the surface-ship proposal was, as a result of American pressure, given the benefit at a feasibility study. USS *Claude V Ricketts* was commissioned with a crew of officers and men drawn from several members of NATO. The ship was not armed with ballistic missiles. No particular difficulties were experienced in running the ship; little more, in fact, than in running an ocean-going merchant ship with a crew of mixed nationality. But it made politicians face the reality. 'Whose finger would be on the nuclear trigger?' was the fundamental issue. USS *Claude V Ricketts* remained an American ship, under American command; the experiment was of no significance. The MLF proposal was eventually dropped. But its possible ramifications in practical terms preoccupied the Naval Staff for many months.

Conflicts of naval policy

Besides coping with Polaris and its problems the Naval Staff was taking part, throughout the BNBMS programme in the great debate within the Ministry of Defence about the future of the fleet aircraft carrier to which reference has already been made. It is probable that the tendency to deplore, as inter-service rivalry, the feverish attempts of the Government's military-advisers to 'get the right answer' is misconceived. Certainly, the Service chiefs and their staffs themselves saw the struggle as vitally affecting the future of their Services. But that seems to have been at the root of the trouble was the absence of a commonly held body of systematic thought about international relationships; about the politico-military interface; about the elements of national security, grand strategy and the contemporary factors affecting them; and within each Service about its role, its function, its strategy and its tactics. Writing of this period, Phillip Darby has said

By February 1963 there was little doubt that Britain's remaining overseas commitments were likely to become more rather than less burdensome, but the next eighteen months drove the point home with a vengeance. Indonesia's confrontation of Malaysia, disturbance in Aden and fighting in the mutinies in East Africa, and the continuing demand of Cyprus and British Guiana all placed severe strains on British forces….

A year later Denis Healey could say;

..overwhelmingly our most important and worthwhile jobs in the ten or twenty years we can foresee ... will be not so much be the protection of specific national interests overseas as the prevention of anarchy and war in those areas of the world, many of them newly independent, in Asia, the Middle East and Africa and perhaps in Central America, where we and we alone have at present the political right and the physical capacity to intervene effectively.

Despite these politico-military stresses and strains the impetus and focus of the BNBMS programme were maintained as successive ‘milestones’ were approached, reached on time, and passed.

Major milestones

A major milestone, and one which put fresh heart into all concerned, was reached on 15 September l966. On that day, at Vickers yard, Barrow-in-Furness, HM Queen Elizabeth the Queen Mother, launched SSBN01, which at that instant became the *Resolution*. Press reaction in Britain was almost entirely descriptive of the event, with, in *The Times,* reference to *Resolution* as ‘symbol of a major, root change in Britain’s defence policy, in which the nuclear deterrent is going to pass from the RAF to the Navy’. A small CND protest march took place in Barrow-in-Furness, and the correspondence columns of *The Times* included some letters concerning the propriety of the traditional Christian ‘blessing’ being accorded, at the launching ceremony, to the *Resolution* ‘and all who sail in her’. There seemed to be little awareness of the magnitude and complexity of the task being undertaken by the British shipbuilding industry, in conjunction with the Admiralty, in producing the BNBMS nor of the astonishing American achievement in developing the Polaris missile system, and the advantageous terms upon which it was being made available to Britain. Politically the occasion passed off without comment.

The publicity, such as it was, was most welcome to both CPE and the Admiralty Board. From CPE’s point of view the fillip to the morale of all who were directly associated with the hard and exacting work of the programme came at a time when the initial enthusiasm and professional interest might have begun to wane. It gave him the opportunity, also, to publish a booklet, aimed at all those serving, or about to serve, in the BNBMS and their families, giving in simple terms an explanation of its various elements. The Ministry of Defence (Navy), into which the Admiralty had been transformed on 1 April 1964, was glad to have help in recruiting for the BNBMS, which had not been proving too easy. In addition, CPE noted a restoration of Special Project’s confidence in its British off-shoot. It is not denied that some doubts about the firmness of Britain’s intention to complete the BNBMS had arisen over the 1964 General Election period; and the possible consequences of the Ministry of Defence’s firm opposition to the MLF proposal being overruled had, for a time, tended further to erode SP’s confidence.

Further important milestones reached in 1966 included the completion of the Polaris Training School at Faslane and the arrival there of the first group of officers and men for training; the completion and occupation of the first group of married quarters at the Base; and the arrival and securing in position of the newly-built floating dock for SSBNs, AFD 60. At Coulport on Loch Long, work was proceeding apace with the new Armament Depot. The main offices were completed and occupied and certain other establishments associated with the operation of the Depot were completed.

In February 1967 SSBNO2 was launched at Cammell Laird, Birkenhead, by Mrs Healey, wife of the Secretary of State for Defence. At Barrow, *Resolution* was going through the complex sequence of testing aid setting to work each system and subsystems of the ship, her propulsion plant, and auxiliary machinery; her conventional weapons and equipment, including communications; and the Polaris launching, fire-control and navigation systems. To achieve this ‘checkout’, and finally integrate the subsystems into fully operational systems, a comprehensive dockside test organisation had had to be built and manned.

Sir Leonard Redshaw recalls:

I remember a stormy meeting called by CPE to decide how we were going to recover a serious slippage in Resolution's programme. I was urged to 'change the management'. I said 'No'. We could do it. Changing the management would not help. There were forty of my chaps sitting behind me. My faith in them was justified. We succeeded in carrying out Resolution's 'testing and tuning' in less time than the Americans had ever taken. It meant working literally 'round the clock' for weeks. The telephone would ring say at 2.00 am in a man's home to say that he was needed, and he would turn out and go down to the submarine to do his stint.

The major snags of the programme were undoubtedly caused by late delivery of materials from United Kingdom sources. Early in the programme a conference was held with sub-contractors to impress upon them the importance of time and delivery of equipments for the submarines and though valiant efforts were made the result was still an average lateness of major items of six to twelve months. Despite this it was found possible to complete the Vickers boats on time, but the follow yard was struggling to cope with this situation, on top of learning to build the nuclear submarines. The most difficult delays were with noise measurements for machinery and shock requirements for castings, particularly the non-ferrous types, and newly designed equipment such as electrolysers and CO_2 *scrubbers which had to be installed deeply in the boats. Bilge and ballast pumps also created 'hiccups' but these were no greater than in other first-of-class vessels.*

There was a strong sense of co-operation between the Ministry of Defence (Navy) and the contractors in identifying and unscrambling those areas of difficulty. Hitherto I had believed that there was little variation in ability between civil servants of a particular grade and professional qualification. But Polaris changed that. It seemed that the ones allocated to the programme were all exceptional. In any event, they were not afraid to take decisions. Rowley Baker, for example, would make important technical decisions without delay; and the standard of the Principal Naval Overseers was uniformally high.

The next important milestone was *Resolution* sailing in June for her Contractor's Sea Trials. These proceeded satisfactorily, use being made of the Faslane base for support, according to plan. The Clyde Submarine Base was formally commissioned in August as HMS *Neptune*, together with the Missile Module Repair and Calibration Facility, these being checked-out and declared operational two months later. Then, on 4 November, Lady Zuckerman, wife of the Chief Scientific Officer to the Ministry of Defence, launched Vickers' second SSBN, HMS *Repulse*. On this occasion it looked for a moment as if real disaster had struck the BNBMS programme. Coming off the slipways *Repulse* eluded the waiting tugs and went aground. Fortunately she was refloated at the next high tide.

The year 1967 had not, however, been without its major setback as a consequence of the accidental flooding of SSBN02, already referred to, a major readjustment of PMPs had to be undertaken, in order to achieve recovery of the BNBMS programme. Whilst the deployment of SSBN01, *Resolution*, was unaffected and her test firings scheduled for 15 February 1968 could (and did) take place as scheduled, the sequence and timing thereafter was by no means clear. The plan had called for deployment of *Resolution* (Vickers, in mid-1968), and thereafter at six-monthly intervals *Renown* (Cammell Laird), *Repulse* (Vickers) and *Revenge* (Cammell Laird). It now appeared that *Repulse* might well be ready for Contractor's Sea Trials before *Renown;* if these were satisfactory *Repulse* would have to precede *Renown* in order of acceptance into the

Fleet, working up test- firings at Cape Canaveral and deployment.

In the event, the final programme was based upon acceptance of *Repulse* in September 1968, with *Renown* and *Revenge* following in November l968 and December 1969 respectively. Fortunately, no further major setbacks were experienced, although there were undoubtedly some ‘near misses’, details of which it is not necessary to publish. Because the first SSBN did not have to go into refit until 1970, and then only because of the need to establish the optimum refit cycle of the force, the integrity of the SSBN, since first deployment in July 1968, has been continuously maintained.

The 1968 Statement on the Defence Estimates

The 1968 Statement on the Defence Estimates contained the following:

Nuclear Strategic Forces

The Medium Bomber Force

2. In 1968 the main United Kingdom contribution to the western strategic nuclear deterrent will, as hitherto, be the medium bomber force of the RAF. But the Royal Navy will begin to take over the role when the first of the Polaris submarines becomes fully operational during the year. The two Victor 2 Mk 2 Blue Steel Squadrons will then be withdrawn from service during the second of 1968.

The Polaris Force

3. HMS *Resolution*, the first of the four Polaris submarines referred to in the previous paragraph was accepted into service by the Royal Navy in October 1967. She is undergoing final trials and work-up, which include final trials and test-firings off Cape Kennedy. She will be operational in the spring of this year, as planned. The second and third submarines, HMS *Renown* and *Repulse*, will carry out sea-trials later this year, becoming operational in 1969; they will be followed by HMS *Revenge* in 1970.

CHAPTER VIII

CONCLUSION

O Lord, when thou givest to Thy servants to endeavour any great matter, grant us also to know that it is not the beginning, but the continuing of the same until it be thoroughly finished that yieldeth the glory.

Sir Francis Drake

In the introduction to this study the hope was expressed that this 'picture of a programme' would provide a useful insight into the governmental process; into the relationship between political leaders and their official advisers; into the management of large-scale projects involving both government and industry; and, not least, of one aspect of the policy of 'interdependence' between Great Britain and the USA which, together with the maintenance of an 'independent' strategic nuclear deterrent, has formed the basis of British foreign and defence policy since 1957.

It is often, perhaps too often, said in regard to the relations between states, that whereas military capabilities cannot rapidly be altered either in potency or character, political intentions can change almost overnight. To accept this proposition without qualification is to deny the importance which must surely be attached to the notion of congruence, in the use of a nation's resources, between ends and means; and it is to ignore the abiding factors, besides military strength, which operate continually upon the calculus of a nation's security as perceived by its leaders, tending to dampen down the oscillations of its policy towards other states. In international relations, as in domestic politics, 'success' and 'failure' are relative, and highly subjective terms. But in the former, maintenance of, or accretion to, a nation's power to influence its external environment in ways favourable to itself might be called 'success'; and in the latter maintenance at, or accretion to, the well-being of the people. The reverse would in both cases be 'failure'.

In the case of the British decision to buy Polaris from the United States (which meant overcoming considerable US reluctance to sell it, the indications are that it was a 'good', rather than a 'bad' decision. That is to say**,** for Britain to remain a nuclear power in the military sense seems to have been at least marginally advantageous. The evidence for this is to be found, surely, in the *Statement on Defence Estimates 1975* in which a Labour government, over twelve years after the decision to buy Polaris was taken by a Conservative government, can write:

d. The NATO nuclear deterrent. NATO strategy is founded on the triad of conventional, tactical nuclear and strategic nuclear weapons. The Polaris force, which Britain will continue to make available to the Alliance, provides a unique European contribution to NATO's strategic nuclear capability out of all proportion to the small fraction of our defence budget which it costs to maintain. We shall maintain its effectiveness. We do not intend to move to a new generation of strategic nuclear weapons.

With the cancellation of Skybolt in 1962, a decision to maintain a strategic nuclear deterrent force of her own meant for Britain, Polaris - there was no alternative. Quite possibly, the record shows, Britain would not have had that alternative but for the initiative of Lord Mountbatten, in his capacity as First Sea Lord.

It has been said that ’Art is more God-like than Science - Science discovers, but Art creates.’ The art of policy-making is combination. It is a creative process in which an individual human being, presented with a number of relevant factors, is able to associate them in such a way as to generate an impulse for decisive action. Amongst the factors relevant to the decision which Macmillan had to make were, first, the unique characteristic of the nuclear-submarine- borne ballistic missile system, as being virtually invulnerable to pre-emptive strike, and hence *par excellence*, a retaliatory system; and second, the fact that Britain knew how to build the submarines and was geographically well placed to deploy them. The capacity to design and manufacture an effective nuclear warhead compatible with the Polaris missile was also indispensable to the main political element in the decision, namely that the weapon system must be ‘independent’ of external constraints upon its deployment and operation. Only thus could the symbolism of Britain’s new role in the world be given effect. Even the inevitable reliance upon American industry for maintenance spares and modifications for the Polaris missiles could be offset against certain (unspecified) British contributions to nuclear weapons technology, in giving effect to the ‘interdependence’ which formed with ‘independence’ the twin themes of Macmillan’s policy. On the home front there was need for some tangible success if Macmillan were to retain enough support to continue to lead his party, and the country, out of its post-Suez depression. Dean Acheson, the former Secretary of State, speaking at West Point in November 1962, had declared that in his opinion Britain’s role was ‘played out’

Additional factors which affected the Polaris decision were economic. First of all there was the movement towards joining the European Common Market, as an alternative to the pattern of importing bulk foodstuffs and raw materials from empire and other world-wide sources, in exchange for goods manufactured at competitive prices, based on Britain’s cheap food and coal, and hence low wages and power costs. Britain’s entry into Europe was not much welcomed by France, but British commitment to an ‘independent’ nuclear deterrent would be in line with France’s determination to possess her own; secondly, there was the chronic state of depression of the British shipbuilding industry, which seemed unable to operate profitably despite the high level of skills and vast experience available within it. What better than an order for four or five nuclear-powered submarines? From the Treasury point of view, the main disadvantage of Polaris had applied equally in the case of Skybolt, namely the expenditure of dollars affecting adversely the balance of payments. As an element of defence costs as a whole, over several years, the Polaris cost, estimated at a total of £350M would have seemed to be bearable, about one third only being in dollars.

Given the basic decision that Britain had to remain a nuclear power for as long as she could, almost the only countervailing argument to buying Polaris was put forward by, and on behalf of, the RAF. The Prime Minister and his Secretary of State for Defence, Mr Peter Thorneycroft, must have been well aware of the fact, as the Minister for Aviation, Julian Amery (Macmillan’s son-in-law) knew, that despite rumours of shortcomings from the American point of view:

Considering intended British uses, Skybolt appeared to have no major flaw except for the need for guidance to hit city-sized targets, a relatively modest technical requirement; besides, it was the cheapest thing in sight and kept the navy quite as happy as the Air Force.

Unfortunately, from the RAF point of view, quite another consideration bad begun to be taken into account, particularly by the scientific advisers to the respective governments. As long ago as 1955 the American Armed Forces had set in train feasibility studies of anti-ballistic missile systems, in order to provide defence against the inter-continental ballistic missile which would shortly become operational. By 1962, in July:

A missile fired from Kwajalein successfully intercepted an Atlas 1 warhead fired from Vandenberg Air Force Base in California.

It must have seemed that the future of the manned bomber, in any strategic role, was problematical. Nor were attempts to question the invulnerability of the Polaris system on grounds of inevitable progress in anti-submarine detection, very convincing. Many senior defence scientists in Whitehall had first hand experience of the apparently inherent difficulties of achieving operationally significant improvements in the range and certainty of submarine detections. Finally, Macmillan, writing of the cancellation of Blue Streak says:

Although there were the usual difficulties and setbacks in its development, undoubtedly this instrument of warfare could have been successfully perfected. Yet, partly because of the objection then felt by the Chiefs of Staff to installing these fixed-site rockets near the large centres of population in so small an island, and partly because of the high state of efficiency that the Air Force had reached, the Government had decided to rely upon a mobile weapon. Accordingly I had reached an agreement with President Eisenhower that he would supply us with a new device to be launched from the bombers on which the Americans had made great progress. It had been named Skybolt.

This objection to the proximity of probable nuclear targets to centres of population applied, although in lesser degree, to the airfields from which the V-bombers, even with Skybolt as their weapon, would have to take off; an airborne alert was out of the question for Britain to sustain. The advantage of ‘moving deterrents out to sea’ was evidently not lost upon Mr Macmillan. It should be recorded, however, in support of those who believed that Skybolt need not have been cancelled, at any rate on technical grounds, that:

A very successful test was made on the day after our conference ended. Did the President and Mr McNamara know about this or did they expect another failure? But, whatever the test may have shown, it is clear that the American Defense Minister and the White House decided - on wider grounds - to concentrate on Minuteman (the Intercontinental Rocket) and Polaris (the Submarine weapon). It is also clear to me that they are determined to kill Skybolt on good general grounds - not merely to annoy us or to drive Great Britain out of the nuclear business.

It is evident from Mr Macmillan’s own account of the Bahamas Meetings (and others) (eg Richard Neustadt’s *Alliance Politics*) that he had become fully persuaded that he could press the President for Polaris. Although the Chief of the Defence Staff, Lord Mountbatten, was not present at Nassau, he is surely justified in saying (see Chapter I above) that his own offer to the Chief of Naval Operations in 1955, to collaborate with and support him in the development of Polaris: ‘stood us in very good stead when we obtained help over our own Polaris submarines from the Americans at the Nassau Conference between President Kennedy and Prime Minister Macmillan.’

To sum up the process by which this most important, and at least marginally successful, politico-military decision was made, it was certainly an example of that combination of factors into an impulse for decisive action that is the art of statesmanship. But a corrective to any tendency to theorize about decision-taking, as such, is provided by the report that Mr Macmillan, on being asked by one of his closest advisers what it was that had finally decided him to go for Polaris, replied 'I don't know, really- it was just that I had a feeling in my water that it was the right thing to do'.

That such a major issue between two governments as 'Polaris for Skybolt' could arise so suddenly, and be settled so swiftly, reflects two countervailing effects of the wide network and close-knit texture of the personal relationships that underpinned the relations between London and Washington in the 50s and 60s. As Richard Neustadt has pointed out:

Accurate perception of each other's objective., motives and intentions was precluded by the very intimacy of the relationship between the governmental machines in London and Washington and this precipitated the Skybolt crisis - but once resolved, it was this very 'cousinly' relationship which enabled the British Polaris Project to prosper.

There can be little doubt that the satisfactory outcome of this particular politico-military interaction owed much to the individual capacities of, and harmony between, the chief scientific advisers to the Prime minister and the President, respectively Sir Solly (later Lord) Zuckerman and Dr Jerome B Wiesner. And a measure of the confidence which these men inspired in their political masters, Zuckerman served from 1959 until 1966 as Scientific Adviser to the Ministry of Defence (and subsequently to the Prime Minister) and Wiesner as Science Adviser to the President throughout Kennedy's administration. The role of scientific adviser to political leaders is a modern phenomenon, deriving from the application of scientific discovery of the most advanced kind to war, and the preparation for war – to 'defence' for want of a better word. In Britain its advent is associated with Professor Lindemann's service to Winston Churchill in the 1930s when that statesman was seeking, from the back benches, to alert government and people to the reality, the nature and the scale of the military preparations being made by Nazi Germany. The top scientist could perform two invaluable, but quite distinct, functions. He could evaluate the scientific background to military technologies, judge the merits of alternative proposals, and interpret them to the politicians and recommend the initiation of research and development along potentially valuable lines. But, in addition, he could act as**,** prima facie, as an objective referee of the competing claims, on the part of the individual fighting services, for a larger share of available resources in pursuit of their particular missions.

From the informal (and often far from apolitical, cool or objective) inter-relationships of the early days, the scientific adviser had by 1963, in Britain at any rate, become institutionalized:

42. The work of the Chief Scientific Advise covers all aspects of defence that are affected by scientific advance, in particular defence research end weapons development. This work is of critical importance because modem weapons systems are becoming increasingly complex, sophisticated and costly, and are liable to rapid obsolescence because of the pace of scientific and technical development.

In the United States President Eisenhower had already established the role. Writing of November 1958, and his administration's response to the launching by the Russians a year previously of Sputnik he relates:

I was appointing Dr James R Killian, president of Massachusetts Institute of Technology, as Special Assistant to the President for Science and Technology, a new post

Both Sir Solly Zuckerman and Dr Killian' s successor, Dr. Wiesner, were present at the Nassau meetings.

Much has been made by some commentators, notably Professor Pierre (see, for example, Chapter I) and John Newhouse, of the reluctance of the Royal Navy to adopt Polaris and with it the responsibility for maintaining the British strategic nuclear deterrent. Newhouse writes (of the 1960 Skybolt decision):

Still, the Skybolt proposal did not go unopposed in London. Pockets of resistance were found in the Foreign Office and the Ministry of Defence. The AEA had doubts, too, based on information it was getting from the AEC in Washington. So did Sir Solly Zuckerman, Scientific Adviser to the Prime Minister, although it is unlikely that he did anything about them. And a senior member of the Defence Ministry recalls that he and many of his colleagues began to argue instead for Polaris, as soon as they 'saw the Americans put their money on it in 1959. That is when we should have taken it - as soon as Blue Streak proved that Britain could not build a missile independently. Perhaps we had to go through the Skybolt experience to learn the lesson.'

In fact the US Navy was urging the British to take Polaris instead of Skybolt (the fearsome. figure of Admiral Rickover became involved in the effort to 'sell' Polaris to London), and Washington made it clear that Polaris was available. But the alliance between the two Air forces was not matched by the Navies. The Royal Navy simply did not want Polaris. This disheartened the Whitehall bureaucrats who did, and who were counting on the sailors to 'do the running' and offset the Air Forces lobbying for Skybolt. But the traditionalist Royal Navy feared that Polaris would drain off resources from the classical modes (surface ships). 'Who wants to make a career under the waves?' is the way the then First Sea Lord, Caspar John, liked to put the question. Watkinson says he never presided over any meetings on the issue in which his service chiefs were divided and this is doubtless true.

It is true, also, as we have seen (Chapter IV) that that whatever conflict of opinion there was within the Royal Navy (and few except very senior officers and officials were aware of any) Lord Mountbatten had succeeded when First Sea Lord in getting Britain into the nuclear submarine business - an indispensable preliminary for her ever to have a Polaris option; and that as early as 1957 the First Lord, the Earl of Selkirk, had publicly proclaimed the potency of the nuclear-powered, strategic missile armed submarine. Furthermore, in 1959-60, before the Skybolt decision, the Admiralty had planned in considerable detail how it would set about producing, rapidly and efficiently, a Polaris force. To criticize 'the admirals' for being loathe, in 1959, to prejudice their 'traditional' naval forces in going over to Polaris, is to misread the facts. For centuries Britain's safety and prosperity, as acknowledged by all, had depended upon sea power. Indeed, even in 1961 the Minister of Defence, Harold Watkinson, could say in the debate on the Defence

We do not propose to leave the Arabian Peninsula and our treaty obligations there. We do not intend to leave places like Hong Kong defenceless or to abandon those members of the Commonwealth in whose defences wee have agreed to share

And the White Paper itself had said:

3. The soviet fleet of submarines is of great size. Mr Khrushchev has claimed the possession of nuclear submarines. We must expect the number of these to increase and that they will carry nuclear missiles.

8. The primary purpose of our defence policy is, therefore, that it should protect us, our allies and our friends, against the whole spectrum of possible aggression and military threats…

Here, surely, were more than enough classic tasks for the egregiously small navy to which Britain had already been reduced; and it made sense to let the RAF wield the nuclear deterrent. Besides, nuclear-powered-anti-submarine-submarines would be needed, and to build rapidly a force of Polaris submarines would inevitably delay the construction of these. There was not much wrong with the Navy's professional judgement.

That the instruments of nuclear power quite suddenly, in historical terms, supplanted those of sea power in political importance (if not in utility), had in 1959 been perceived by only a very few naval officers, of whom Mountbatten was one, and had been articulated by none. It is, perhaps the hallmark of that congruence, referred to above, which differentiates the sound and durable defence decision from the unsound and soon discredited one, that the ultimate (it would appear) expression of Britain's nuclear standing in the world should be a warship of colossal power.

Turning now to the implementation of the 'Polaris for Britain' policy decision one is struck immediately by three well attested facts:

- the British Naval Ballistic Missile System was completed, tested as an integral part of the US Navy's Polaris programme, and deployed at precisely the date, and for the exact cost, predicted five years previously;

- it met, and has continued to meet, the stringent performance tests, required of it as a system, namely readiness and reliability of over 99%;

- and with the completion, by the end of 1975 of successful and timely refits of all four SSBNs, by HM Dockyard Rosyth, the effectiveness of the force, on a continuing basis, has been proved.

Not without reason did Sir Derek Rayner, Chief Executive of the Defence Procurement Executive 1970-72 remark;

They (the civil servants, defence scientists and officers of the armed forces) might show more initiative if they were applauded for their achievements instead of simply pilloried for their mistakes. We've all heard about the Blue Streak debacle but who congratulated them on getting Polaris ready on time - a terribly complicated business…

So, indication has been given, in this study, of the American achievements that were essential preconditions for the development of an operational system. These were:

- nuclear propulsion for submarines;
- a solid-fuel rocket of range 1,000 miles or more;
- a megaton yield nuclear warhead small enough to be carried by that rocket.

It has been shown that the masterful engineering genius of Rickover; the persistent technical brilliance of Levering Smith; and the scientific preeminence of the AEC, harnessed by Raborn's organizing ability and dedication, backed by Top Priority, produced the FBM system in record time. Seeking reasons for this success beyond the star quality of these men, and of many of their colleagues in the Polaris programme both in government service and in industry, Harvey Sapolsky rejects the simplistic view that the use of certain innovative management techniques was of critical importance. PERT (Programme Evaluation and Review Technique), for example, though undoubtedly useful as an aid to effective management, was much more so as a means of preserving the autonomy of the Project, and its continued political support:

The Special Projects Office has gained an international reputation for the innovativeness and effectiveness of the management control system it has employed in the development of the FBM system.

Acquired quite early in the FBM programme, this reputation seems to have aided greatly the effort to develop Polaris. Expensive and risky technological ventures such as the FBM are regularly disrupted and demoralized by the intervention of high-level officials in day-to-day program management and by frequent outside reviews of program progress.

…..

The introduction of innovative management techniques by the Special Projects office had little to do with the technical development of the FBM system. PERT, the Management Centre, and the other management techniques discussed... were essential to the Polaris Program, but only as major components of an externally oriented strategy of managerial innovation. This strategy, ... was designed for a political purpose - to gain control over the organisational and financial resources thought necessary for the successful development of the FBM system. The effective use of the resources obtained and the actual development of the FBM system, however, were necessarily the result of other factors.

Important among these factors was the quality of the leadership provided by the Technical Director of the Special Projects Office. With a technical philosophy formulated in numerous policy decisions and official directives, Admiral Levering Smith established guidelines that facilitated the rapid, sharply focused and coordinated technological progress required to bring forth the FBM system....

A second factor was the organisational structure of the Special Projects Office and the FBM Program. Best described as decentralized and competitive, this structure facilitated a rapid end synchronized advance on all the technologies that comprised the FBM system

A third factor was the esprit de corps *generated within the Special Project Office and the Polaris Program by Admiral Raborn (in spite of the potentially divisive et structural arrangements).*

That these factors had much to do with the success of the Polaris programme there can be no doubt. But it has to be remembered that the enterprise had to he sustained, at the highest intensity of endeavour, for five years or more. During this time setbacks were experienced; heavy demands upon the nation’s resources for other weapon programmes were being made; the US Navy itself had reason to feel the diversion of funds, skilled men, and above all the sense of mission, to Polaris. Well aware of this, the Chief of Naval Operations, Admiral Arleigh Burke, did not discourage a member of his staff from entering the *United States Naval Institute of Proceedings* Prize Essay Competition with a contribution entitled ‘Finite Deterrence, Controlled Retaliation’. In a letter to Lord Mountbatten, dated 28 February 1959 (one of several kept, in the Admiralty, in what was irreverently known to the secretariat as the ‘Dear Dickie’ file), Arleigh Burke writes:

Whether land-based systems are located in the United Kingdom, the United States or for that matter in any other nation in the free world, it appears axiomatic that the enemy will know their exact geographical location and this, in my opinion is where the great defect of land-based IRBMs lies. If, possessing this knowledge, the Soviet believes that he is capable of destroying these sites before they can react to his attack, then the deterrence has failed, regardless of whether or not the Soviets are correct in the belief that they could destroy all the missiles before they could be launched. If the deterrence fails to deter, the armaments of the proponents of land-based systems, that they can achieve some degree of invulnerability by hardening, dispersal, holes-in-the ground, etc. become academic because the general war will have commenced. As accuracy of ballistic missiles increase, and it will, there will be an increasing number of ballistic missiles taken out by initial surprise attack.

In this regard, the March issue of Naval Institute of Proceedings *contained an extremely interesting article written by Commander Backus of my staff. Commander Backus spent several years in London in our Office of Naval Research program and is a very knowledgeable young man. ... I will send you several reprints of this article as soon as it comes off the press for your use should you so desire.*

Not surprisingly, perhaps, the essay by Commander Backus won the USNIP prize for 1959; indeed, his theme 'You cannot deter the calculating, aggressive controlling group in the Kremlin once you permit them to believe they can destroy a major portion of our retaliatory forces by an unexpected, devastating first blow,' is well argued, and the case for 'the Navy's Fleet Ballistic Weapon System (Polaris plus the nuclear- powered submarine)' as possessing inherent invulnerability to a considerably higher degree than are' other system conceived, under development, or in existence for the same purpose' is convincing.

It was this unique quality of Polaris, as a system, in competition with several others, each so costly as to prejudice the prospects of all its competitors, upon which it was possible to build political, public and naval support in the United States. When the time came in Britain to adopt Polaris, there was no competition. There was no need for a Polaris lobby in the purlieu of Parliament, let alone in the country. Lord Mountbatten, now Admiral of the Fleet and Chief of the Defence Staff was concerned that there should be no inter-service bickering over what was essentially a *fait accompli*. Public opinion in Britain was not noticeably stirred by the 'Statement on Nuclear Defence Systems' included in the joint communiqué issued on 21st December 1962 by the President and the Prime Minister.

'Informed opinion' remained sceptical. The Defence Correspondent of *The Times*, for example, in two long articles on successive days headed 'Britain without Skybolt' questioned the whole concept of an 'independent nuclear striking force'

…..this (the official view) implies that Britain can support a separate policy of nuclear deterrence based on 'the second- strike capability'.... This may make sense for vast countries like the United States or the Soviet Union. For a small and densely populated island it is a doubtful proposition. Even if it is accepted, it is hard to show this degree of independence and 'second strike' power can ever, in fact, be achieved.

He goes on to say that**:** 'if Britain had (Polaris) now it would be the perfect instrument for those who subscribe to the case for nuclear independence. Unfortunately the Government decided in

1959 that Polaris was too easily detectable and chose Skybolt instead.' He predicts that Polaris will be rendered obsolescent by advances in submarine detection before the force is deployed; and that in any case it will inevitably cost much more than expected ('It is worth recalling that the cost of Skybolt had risen to four times the original estimates before it was abandoned.') Finally he doubts the Navy's assertion that the Polaris fleet could be built by 1968 or 1969, saying that the Government regard 1970 or 1972 as a more realistic target: 'This latter date is based partly on the possible attitude of the trade unions to the plan, and partly on the need to placate the vociferous aircraft lobby.'

No question seems to have arisen regarding Britain's capability to build nuclear-powered submarines, fit the complex missile launching gear and fire-control systems, and make the whole thing work properly. Still less, it appears, did anyone doubt Britain's ability to design and manufacture the nuclear warheads for the missiles. True the research and development had been done by the Americans, but the level of managerial and technical skills required for even the production of the Polaris system was extremely high. How was it done?

Whereas the primary concern of the Director Special Projects was, as we have seen, to maximize political and bureaucratic support for his programme whilst minimizing interference within it; and the purpose of PERT and other innovative management techniques was at least partly cosmetic, there is no evidence of ulterior motive on the part of the Admiralty's Polaris Executive. What happened was that the spirit of Samuel Pepys prompted the Navy's Senior administrators to emulate his style and in so doing hope to match his achievement. In his recent, and most elegant, biography of Pepys, Richard Ollard describes the work of:

The Special Commission of 1688

Rebuilding the Fleet

Firstly, repairs were fully and effectively carried out: secondly, they did not exceed the original estimate of their cost; and thirdly, they were complete in less than the original estimate of the time required.

In conception, execution and style the Special Commission was Pepysian through and through. He drafted its terms, he chose its members, he kept, as he said himself 'my daily eye upon them'. The key appointment was that of Sir Anthony Deane (naval architect) and Will Hewer, next to Deane: and a strong contingent of sea officers, notable among them Sir John Narborough and Sir John Berry, combined expert knowledge with personal friendship, both of long standing.'

Its second source of strength was that it combined financial and executive control.... The Commissioner' own budget carefully costed and rigidly adhered to ... it was, in a word, to be Pepys put into commission: inquiring, enforcing, reproving, watching, reporting, minuting. ... From its constitution in April 1686 to its dissolution, its work done, on October 12th 1688, it provided new, swift channels for the day-to-day administration of the navy as well as giving the service a refit from truck to keel.

The Special Commission had succeeded brilliantly because it was special, with a limited task a clear brief, and means proportionate to its ends.

In a passage of equal significance to a study of project management, Richard Gilard continues:

Why if the Commission performed such prodigies was it dissolved? Should it not have been institutionalized and decent internment given to the old Navy Board. Pepys, highly as he valued its achievement and admired the triumph of his own administrative workmanship, does not seem to have thought so. Historical study and reflection had induced in him, as it does in others, a scepticism towards simple solutions. Until April 6th 1688, in an informal discussion of the navy in general, attended only by himself, the King and Godolphin, he noted in his own hand:

Its science the most extensive of any viz.

Climates	*Comoditys*
Accounts	*Trades*
Thrift	*Provisions*
Seamanship	*Shipbuilding*
Navigation	*Discipline*
Sea-laws	*Winds*
Tides	*Seas*

Noe One man qualify'd for all. Nor fit to bee trusted alone. Therefore ye old Constitution provided for all, by a Plurality properly qualif'd.

Quite correctly, therefore, in accordance with Pepysian example and precept, the Ministry of Defence (Navy) dismantled the Polaris project as such, with the completion of the task that it was set up to do. The reorganisation consisted, in essence, of allowing the poet of Chief Polaris Executive to lapse and substituting an Assistant Controller (Polaris), in charge of a small Polaris Executive. This was necessary in order to provide a continuing link with Special Projects (now institutionalized as the Strategic Systems Projects Office, and directed by Rear Admiral Levering Smith, Honorary KBE; with the submarine-refitting yard, with Flag Officer Submarines, and with the Ministry of Aviation.

No formal study of the work of the Polaris Executive is yet available, but it is understood that an official history of it is under preparation by Professor Peter Nailor, Department of Politics, University of Lancaster. The conclusions that follow, based on so provisional a study as the present one, must inevitably be tentative.

First, Polaris affords further evidence of the displacement of sea power by nuclear weapon power, as the primary expression of global political power; and of the negative utility of the instruments of nuclear power in comparison with the positive utility (when sea power was paramount) of the instruments of sea power.

Secondly, the unique character of the Polaris system, as an invulnerable, retaliatory or 'second-strike' strategic nuclear deterrent force, accounts, at least in large part, for the faith in its eventual success which inspired and sustained the dedication of those involved in the programme (both in America and in Britain); and gained for it a continually growing body of political, bureaucratic and popular support in the Unites States. In Britain, this characteristic enabled both the main political parties to subscribe to Polaris for Britain, despite the existence of currents of political opinion hostile to Britain's remaining a nuclear weapon power, and sceptical of the notion of an 'independent' nuclear deterrent.

Thirdly, we have seen how Harold Macmillan seized upon Polaris as the proper successor to Skybolt, in giving effect to his policy for ‘interdependence’ coupled with ‘independence’; that he was able to do so has been shown to be the consequence of far-sighted preparations by the Royal Navy, attributable mainly to Lord Mountbatten’s role as ‘military statesman’ (the phrase is Professor LW Martin’s), coupled with that of Sir Solly Zuckerman, as Chief Scientific Adviser to the Secretary of State for Defence.

Fourthly, it has been possible to examine and compare the American Polaris management experience with that of its much smaller, but relatively of equivalent scale, British counterpart. Of the lessons learned, or for which the evidence is convincing, other than the fundamental one of having a good product backed by unflinching political will, probably the most important is the necessity to adjust operational requirements, for a developing weapon system, to the ‘state of the art’ in the relevant technologies, in order to produce an operational weapon quickly enough to pre-empt obsolescence before achievement. It seems clear, also, that both in development, and in production, the imposition of firm engineering discipline, especially at the interfaces between sub-units, is indispensable. For monitoring progress, identifying potentials for delay in time for corrective action to be taken before the programme as a whole suffers irretrievable setback, a centralized system of evolution and review is indispensable. The project team itself must have good leadership, and sufficient autonomy to ensure first**,** full financial control over all aspects of the project, and secondly, the power to delegate responsibility, and authority in proportion, as required for the execution of the programme.

Finally, the British Polaris project was an example of close cooperation between several government departments and industry, with an international dimension of critical importance which worked. The industries concerned (except steel) were part of the private sector of the economy. By the careful and prudent drafting of contracts and a high standard of overseeing in the shipyards and elsewhere, good relationships and efficient results generally were achieved. All those concerned in one way or another with the British Polaris project have reason to be proud of the part they played in what has undoubtedly been a success; in the history of large scale weapon procurement projects delays, cost over-runs and cancellations have been more common than timely, cost-held and fully efficient results.

As a rider to these conclusions it seems appropriate to consider possible gains to British managerial, technical and industrial skills and capacity arising from ‘spin-off’ from the Polaris programme. Although research might reveal firm evidence of this, in one or more fields, the prospect is not hopeful. To begin with, during a period of rapid change, as Britain strives to cope with the application of ‘space-age’ science and technology, there is a danger of being deceived by the logical fallacy of *post hoc ergo propter hoc*. At the same time it seems not unreasonable to associate with the Polaris experience the following remarks published (within the Royal Navy) by the Controller of the Navy Admiral Sir Horace Law KCB OBE DSC in 1969:

New features in Design, Construction and Contracts for New Ships

Quality Assurance

During the last three years a considerable change has taken place in our attitude towards quality. It is now considered that we stand a better chance of getting a quality ship or product by insisting that we only place orders with those Firms whose network of technical and administrative procedures gives us confidence that we will get the specified items at the right time and the right place. The organisation we require firms to have to assure this is laid down in two contractual documents - GRAQs (The General requirements for the Assurance of Quality in Surface Ships, and SCITs (Standard Conditions of Inspections and Tests) for equipment made in factories. This has meant that an era of Inspection by Naval Inspection Services has come to an end and is being rapidly replaced by Quality Auditing of Ship-builders and Main and Sub-contractors; in fact, more inspection of software than of hardware. These concepts have, in turn, led to a necessity to reorganise six Overseeing Services into one. These six were the Constructive, Electrical, Engineering, Stores, Dockyards and Royal Fleet Auxiliaries. A large re-complementing exercise as well as a training programme has been necessary, and I am indeed grateful for the way the members of the Overseeing Service have responded to the need to change their attitudes, procedures and, in some cases, their homes. Recently a team of industrialists known as the RABY Committee has been looking at all the Overseeing Services and Inspectorates run by the Ministry of Defence and the Ministry of Technology, and have reported favourably on the way the Navy is doing its work.

Dockside Test Organisation

In the past considerable criticism has been leveled, quite fairly, at the lack of impact that the ship's staff standing by a New Construction Ship have been able to make. Under the new quality assurance contracts the Shipbuilder has to produce a Dockside Test Organisation supported by Test Groups for the ship, propulsion, and Weapons systems. The ship's staff will be official and active members at both Test Groups and the Test Organisation which will carry out the trials. In this way we hope that ship's staff of the future will know their ship systems end equipment better than hitherto, and will also have the capability of participating officially in the acceptance of their ship.

Batch ordering of ships

Allied to the quest for quality are four subjects that have been receiving a lot of attention. They are - Reliability, Value Engineering, Configuration Control and Integrated Logistic Support; and some or all of these activities are to be found in our most recent ship contracts. In future, ships will be ordered in batches and all ships of a batch are to be similar. The means of assuring this is a computer-operated technique known as Configuration Control. Fleet Support is now being thought of at the earliest Design Stage possible. This means that the repair policy is decided upon, and the necessary access route provided, for those equipments that will be repaired by replacement. Upkeep Support Teams which include representative from the ship and Weapons Departments, Spare Gear Sections, Stores Departments, Ships' Maintenance Authority and Dockyards, are already actively involved in both Type 42 and Type 21 Projects.

It seems probable also, that the policy of rationalizing shipyards, so that only a snail number could retain the special capacity needed for warship construction, and of those each to specialize in a specific type, or types, of vessel, received fresh impulse and direction as a result of the Polaris programme. Vickers Shipbuilders Ltd, Barrow-in-Furness, for example, is the only yard in Britain to retain the potential to build nuclear-powered submarines. And it is conceivable that the shape of the Procurement Executive which has been created, since 1970, in the Ministry of Defence, owes at least as much to the Polaris Executive as it does to the great multiple store, Marks and Spencer, by whom Sir Derek Rayner was seconded to that Ministry in order to reorganise its system of procurement.

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ANNEX 1

Summary of Joint Committee on Atomic Energy of Congress Hearing onboard USS *Skipjack* 4 April 1959

Replying to the Senator, Admiral Rickover said:

'Thank you very much, sir. I want to say one thing right at the beginning, and that is that each one of these nuclear submarines constitutes a complete task force in itself. Each of these ships is able, on its own, to perform functions that outstrip the requirements placed on it. Sometimes people ask why these submarines are so big and complex; why don't we make them tiny? Some people would like to see nuclear submarines operate like airplanes - small craft with only few people aboard, dashing out on a quick mission and then having to return to some protecting ship or base. I believe strongly that such a concept is a degradation of the tremendous potentiality of these ships. In a large surface ship task force the Navy makes a tremendous investment to get a self-sufficient offensive capability where and when it wants it, with a capability for staying there and doing a job. Now in the nuclear submarine we have such a capability at low cost. The ocean acts as its protecting screen and its armor. As a result, the submarine can be made all weapon, rather than part weapon, part shield. Therefore we should look at each new improved feature which is added to the submarine as an increase in the effectiveness of this one-ship task force, rather than concern ourselves unduly over the fact the submarine may be getting bigger than other submarines or bigger than somebody's idea of an underwater 'pursuit ship'.

Perhaps I have belabored this point but I think it is an important one. With this concept in mind we lay out the machinery in these ships so that the ship's force can maintain it. We also provide installed spares of all-important equipment wherever practicable. This permits ships to stay at sea for several months and even to stay submerged for two months or more. It means we can operate throughout the whole Arctic region any time of the year and surface at will through the many openings or thin spots in the ice. It means that the ship does not have to return to base servicing after a few hours of operation as an airplane does, or as a 'small' submarine with 'aircraft' type engines would.

The real significance of these polar voyages is that another large area of the world - larger than the whole United States - which was heretofore secure from war has now been exposed by these exploits. The entire northern coastline of Russia, formerly protected by the Arctic icepack, is now exposed and of course, the same applies to Alaska and to Canada.

So far as the ship is concerned, it is the fastest submarine in the world. It has made a speed of over (classified) knots. The highest previous speed for a nuclear ship was (classified) knots, by the *Nautilus*. ….A surface ship often can't make her maximum speed because of the variable surface conditions of the sea or because of heavy weather; a nuclear submarine isn't affected by these weather conditions.

Our hard-worked diesel submarines now steam about (classified) miles a year, at an average speed of less than (classified) knots. A small fraction of this, less than fifteen percent, is totally submerged. On the other hand, our nuclear submarines are now averaging about 40,000 miles a year, of which as much as ninety per cent is completely submerged.

After some further discussion, Senator Anderson remarked:

More money has already been spent on the modern airplane than all the research and development money spent on nuclear submarines, including the cost of your land prototypes and your laboratories, and all of your research and development, and the complete cost of the reactor plants for the first two nuclear submarines; isn't that correct, Admiral?

Admiral Rickover, 'Yes, Sir'

The Joint Committee hearing then continued:

Senator Anderson Will you tell us about reactor safety? The danger to the people on it? The danger to people who come near it? Is there any danger? Can you tell us that?

Admiral Rickover; 'Yes, Sir. I would like to spend a little time on this if I may. I think it's very important. First, before getting to the details of the safety of any one ship, I must tell you that there is a question in some people's minds as to whether the AEC has any responsibility at all for the safety of these ships once they have been turned over to the Navy.'

Representative Holifield, 'I think the law is very clear on that. It certainly was intended to be. We have a copy of the act here. Let me read you the pertinent section from the law. The Atomic Energy Act of 1954 states:'

Chapter 14. General Authority _Sec. 161. General Provisions. - In the performance of its function the Commission is authorized to:

Establish by rule, regulation or order each standard, and instructions to govern the possession and use of special nuclear material, source material, and byproduct material as the Commission may deem necessary or desirable to promote the common defense and security or to protect health or to minimize danger to life or property:

And if that isn't enough, the Commission is authorized in the next paragraph (161c) to

make each studies and investigations, obtain such information, and hold such meetings or hearings as the Commission may deem necessary or proper to assist it in exercising any authority provided in this act, or in the administration or enforcement of this act, or any regulations or orders issued there- under.

This authority carries with it the responsibility to exercise that authority to protect and to minimize danger to life or property.

The responsibility of the Navy for running its ships in no way relieves the AEC of the responsibility for protecting the public. After all, the AEC and its agents made the uranium, they designed and built the reactor, said they designed and built the reactor plant and its safety system. They reviewed its safety and then they turned it over to the Navy. Do you think they can now walk away and forget it?

Admiral Rickover: 'I don't sir. I was just pointing out that some people in the Commission apparently think so. They seem to think the law isn't explicit on this point. They have lawyers researching it right now. They think that the AEC must either man the ships themselves or else forget about them.'

Representative Holifield. But a reactor in a ship, when it's in a port is just like any big reactor on land. In fact it may be closer to a lot of people than many central station reactors that are located out in the country. The AEC can certainly not look the other way whenever a nuclear ship comes into port and still claim responsibility for protecting the public from civilian reactors.'

Senator Anderson. 'Admiral, how do you handle the safety when you turn one of these reactors over to the Navy?'

Admiral Rickover. 'It's quite straightforward. Before the *Nautilus* reactor was started we drew up an agreement between the AEC and the Department of Defense which recognized that each authority had responsibilities where the safeguard aspects of naval reactors was concerned. Nobody questioned it then; it is only recently that the AEC responsibility in this area has been questioned. This agreement, and the memorandums of understanding between the AEC and the Navy which followed it, provided that the AEC could present the design of the reactor plant to the Advisory Committee on Reactor Safeguards for a safety review and that the results of this review would be forwarded by the AEC to the Navy for their guidance. The reactor plant would then become the responsibility of the Navy, except that the Navy was obligated to make available to the AEC all pertinent information and data concerning operation, including safety standards and operational experiences.

This arrangement has worked well. The Navy, after considerable study, has set up a procedure whereby nuclear ships do not go into ports without authorization from the Chief of Naval Operations. He makes the decision, but he sets out the advice of the AEC. In accordance with the terms of the memoranda of understanding between the Navy and the AEC, this is done informally with me and my people on a day-to-day basis, and the Chairman of the AEC is officially informed whenever basic policy matters are involved. For example, the Chief of Naval Operations has sent letters to the Chairman of the AEC forwarding naval instructions for nuclear ships regarding operation, selection, and training of personnel, and maintenance and repair of the nuclear plants.'

The hearing continued with the putting on record of the instructions that Admiral Rickover had referred, together with excerpts from the exchange of correspondence between the Advisory Committee on Reactor Safeguards, the Atomic Energy Commission and the Naval Reactors Branch.

In reply to further questioning, ***Admiral Rickover*** *commented*:

I have always said - and the words are contained in the CNO instruction - that the operation of nuclear submarines is not entirely without reactor hazards but should be considered an acceptable risk. Our attitude is that we will not necessarily take a risk, even a remote one. We design the utmost safety into them. We review the design and fabrication in detail. Everything involving safety or radiation I get into personally. I am only talking about naval ships now, you understand. The merchant ship program is not mine. I'm sure you are aware that there is concern in some ports of the world about a nuclear ship going into a port**.** The Danes not letting the *Skate* in, and the attitude of the British about the *Skate* entering one of their ports are examples. As this goes on this may become more of an issue. I say that we have the responsibility to assure the public we are not taking any unnecessary or unreasonable risks.

After further discussion it was established that ultimate responsibility for reactor safety could not be abrogated by the AEC when a ship (or submarine) went into international waters, or the national waters of another country, subject to permission.

Admiral Rickover *then continued*:

Now I will tell you just how safe these plants are and to what degree we control radioactivity.

I have always insisted that reactor plant designs under my cognizance use all reasonable conservatism wherever radiation or radioactivity are involved. I am under continual pressure from many quarters to relax this conservatism by reducing the weight of the radiation shielding. I have resisted these pressures and, as a result, our ships have been able to meet even the recently decreased permissible civilian radiation doses without changes in designs or operating procedures. In all matters where shielding, radiation or safety are concerned, I personally go over the designs. I lay it all out and go over it in detail end approve it myself. No one else in my organisation has that authority. I will not delegate that authority to anyone. I consider that important.

We have gone about as far as we can in reducing radiation and increasing shielding. Further restrictions with regard to radiation or radioactivity could impair the military effectiveness of our nuclear powered naval ships. This even applies to civilian reactors. Further radiation restrictions would also impose an intolerable expense and administrative burden on the civilian reactor program.

Because of the current interest by Congress and the public in these matters of radiation I have recently reexamined this subject in considerable detail and in particular the question of what it would mean to reduce the permissible radiation levels still further on our ships or at the Shipping Port Atomic Power Station. I have readied the following conclusions:

First. Using preset radiation standards, nuclear powered naval ships and the Shipping Port station provide adequate protection for the reactor plant operators and for the public.

Second. Radioactivity discharged to the environment by naval reactors and by the Shipping Port station is insignificant; it has been shown to be so small as to have no detectable effect on the environment. The amounts of radioactivity discharged are trivial compared with that discharged by some other reactors now considered acceptable.

Third. Further lowering of the permissible levels of radiation and radioactivity would pose serious problems by requiring heavier shielding in ships, by restricting the pressure of all reactor plants, by increasing the difficulty of controlling trace quantities of radioactivity in air and waste water, and by complicating the problem of measuring and monitoring radiation and radioactivity.'

Admiral Rickover went on to explain in detail the criteria used in establishing radiation and shielding levels, and referred to the disposal of radioactive wastes. In summing up he gave some comparisons

First let's take wristwatches: as I have stated, the radiation from ordinary wristwatches produces more airborne activity than is currently permissible aboard ship.

Next let's take cosmic radiation: the ship's monitoring equipment in engineering quarters and living quarters shows no detectable increase when the reactor is started up and brought to power. Yet these same detectors show a twofold or threefold decrease in the background level when the cosmic radiation aboard is decreased by the ship submerging.

Then consider fallout and natural background variations**:** the environmental monitoring program at shipyards and at Shipping Port cannot detect the radioactivity discharged to the environment by our reactor plants, yet they show seasonable variations in natural radioactivity and easily pinpoint each major weapons test by the United States, United Kingdom, or the USSR.

Turning from considerations of reactor safety, the Committee took a look at future developments. Senator Anderson then asked Admiral Rickover 'Why do you think the natural circulation system should be developed? What are its advantages?" ***To which Admiral Rickover replied:***

The basic consideration is simply that it is simpler. It is more reliable. There are fewer parts. The more parts and. machinery you have, the more difficulties you have. With such a reactor we will be able to eliminate all the primary coolant pumps and check valves, and all the electrical supplies and controls that go with them. This also makes the plant more efficient and quieter. This added reliability is particularly necessary because we expect to have those submarines under ice. We want to make them as reliable no possible.

Finally, Mr. Canton Shugg, General Manager, Electric Boat Division. General Dynamic Corp, in response to a question, replied:

I would like to say for the several thousand Electric Boat employees that this is more than just a job for them. They are interested in these ships personally - they are devoted to this new nuclear submarine program and its development and many of them work overtime to get the job done correctly.

Asked how many sub-contractors rectors there were for these submarines,

***Rickover* replied**:

About 500 or 600 I believe. A sizeable portion of these are small business firms.

Admiral Rickover receives Congressional Gold Medal: 15 April 1959

On 15 April 1959, four days after the historic meeting of the Congressional Committee on Atomic Energy on board USS *Skate* took place another, more formal meeting of the Committee, this time in the new Senate Office Building, Washington DC. There, in a distinguished company, effect was given to a joint resolution of the 85th Congress of the United States of America: ‘That in recognition of the
achievements of Rear Admiral Hymen George Rickover, United States Navy,
in successfully directing the development and construction of the world’s first
nuclear-powered ships and the first large scale nuclear power reactor devoted exclusively to the production of electricity, the Chairman of Joint Committees on Atomic Energy, on behalf of Congress, is authorized to present to Admiral Hyman George Rickover, United States Navy an appropriate gold medal ..‘.

In replying, *Admiral Rickover* began ‘Thank you, Senator Anderson. Congress has authorized a total at thirty-three nuclear powered submarines. Of the thirty- three, five are presently in operation and the others are either under construction or shortly will be under construction. Twenty-two of the submarines are attack submarines. Nine will be capable of carrying the Polaris-type missile. One, the largest submarine in the world, the *Triton*, will be a radar picket submarine which will be fast enough to operate with a task force; the last one is a submarine which will carry Regulus guided missiles.’

ANNEX II

Digest of Statements on Polaris made in Parliament Since October 1964

Since 1964 there have been many references to Polaris in Parliament in the course of debates and in answers to Parliamentary Questions. This digest aims to summarize the most important statements; but is not exhaustive.

The SSBN building programme

On 13 February 1967 Mr Mason said: ‘We intend that HMS *Resolution* should deploy operationally by mid-1968 and that the other submarines should follow her at six-monthly intervals. On 8 November 1967 Mr Mason said that HMS *Repulse* was due to be commissioned in the autumn of 1968, the remainder to follow at six-monthly intervals.

The strength of the Force - No intention to expand or improve it

On 9 November 1967 Mr Healy said: ‘We have no intention of increasing the Polaris Force beyond its present planned strength of four submarines; and on 6th December 1967, he said that ‘The decision not to proceed with the construction at the fifth submarine ... is unchanged.’ On 14 February 1968 Mr Healey said that he was quite satisfied that the Polaris submarines would provide an effective contribution to the western nuclear strategic deterrent; and reiterated in answer to a supplementary question that the contribution made by the four Polaris boats was a very substantial one indeed.

Improvements to the Deterrent

On 13 February 1967 Mr Healey said that there were no plans to replace the warheads of our Polaris missiles. On 13 June 1967 the Prime Minister said, in answer to a question from Mr Winnick; ‘If my hon. Friend is referring to a proposal to replace the Polaris missile by Poseidon missiles the answer is that Her Majesty’s Government have no such intention ... I have made it plain that we are not concerned at all the new generation of military weapons.’ On 5 July 1967 Mr Healey referred a questioner to the Prime Minister’s statement and said he had nothing to add.

Deployment East of Suez

On 22 June 1966 Mr Springfield Digby asked the Secretary of State what investigations he had made into a suitable site for Polaris submarines in the Indian Ocean, and Mr Healey said ‘None’. He also said that ‘the Indian Government will receive no defence assistance which they do not request, and that there is no proposal by HMG unilaterally to provide nuclear defence for India. On 1 December 1966 Mr. Rankin asked the Prime Minister if he would ensure that his offer of Polaris submarines for a Joint Indian Ocean nuclear force, did not interfere with his policy of nonproliferation. The Prime Minister said that be had made no such offer and that the rest of the question did not therefore arise. On 8 November 1967 Mr Healey said that ‘Polaris submarines will be capable of operating East of Sues but we have no plans to deploy them there.’

Polaris Warheads

There was a series of questions on 20 July 1965, about the underground testing of Polaris warheads, and again on 18th November of the same year. On 8 December 1965 Mr Healey gave an assurance that the nuclear test conducted in September 1965 was the only test of a a nuclear warhead or component of a nuclear warhead conducted by the Government since 1964. This statement was reiterated on 6 May1966. There have been various questions about the nature of the Polaris warhead and the answer has invariably been that the information is classified. On 14 February 1968 Mr Mason, in answer to a question, refused to re-classify information about the warhead.

Nuclear Safety

On 11 May 1966 Mr Mallalieu made a statement about precautions against fire in nuclear warships and warships carrying nuclear weapons in the Holy Loch and Firth of Clyde. He said that all HM ships were designed to minimize fire risk and had trained staff on board to deal with fires. There was no possibility of any fire leading to a nuclear explosion. There were highly trained staff afloat and ashore to deal with nuclear hazards. Responsibility for the safety of USN vessels rested with the United States. On 13 March 1968 Mrs Ewing asked about the risk of nuclear explosion being occasioned by accident. Mr Healey said that there was no risk of a nuclear weapon being used accidentally. In the unlikely event of a weapon being involved in an accident there would be no danger of a nuclear explosion. At worst there would be the detonation or burning of ordinary high explosive resulting in some radioactive contamination in the immediate vicinity. This would be dealt with by specially trained staff.

Atlantic Nuclear Force

References to the Atlantic Nuclear Force were made in 1965 and 1966, mainly by the Prime Minister. In answer to various questions he said that we were opposed to the mixed manning of Polaris but reiterated on many occasions his aim to 'internationalize the deterrent'. The dates on which answers were made on this subject were 11 May 1965, 14 December 1965, 25 January 1966, 3 March 1966, 12 May 1966 and 19 May 1966.

Nassau Agreement

On 14 December 1965 the Prime Minister said: 'As for the Nassau Agreement I made it clear last December that changes would be necessary arising out of our proposals for the Atlantic Nuclear Force. If those proposals go through it would be necessary to re-negotiate the Nassau Agreement.' On 3 March 1966 the Prime Minister said: 'The operative part of the Nassau agreement that requires changing is the part that is based on the prediction that we have an independent nuclear deterrent. That prediction was blown up 18 months ago'. Mr Heath then reminded the Prime Minister of his statement that the Polaris force was like trying to add a dried pea to the top of a mountain. Was that still his view? In his reply the Prime Minister said, *inter alia*, that we kept the Polaris submarine programme because production was beyond the point of no return.' On 19 May 1966 the Prime Minister in answer to a question about re-negotiating the Nassau Agreement, said that there were two relevant parts of the Agreement 'One of them is a the clause which gave Britain the right, allegedly, to withdraw the deterrent when British interests were considered to be involved. This we have always made clear will require re-negotiation when we have a collectivized deterrent. This is what we will do.' On 19 May 1966 the Prime Minister said: 'Of course we intend to re-negotiate the Nassau Agreement as soon as we have reached agreement with our allies on the basis of settling the nuclear problem with NATO. ... we are committed to see whether we can get a collectivized nuclear deterrent within NATO. Then of course, the relevant parts of the Nassau Agreement will be re- negotiated.' On

18 January 1967 the S of S was asked when it was intended to re-negotiate the Nassau Agreement. He said 'When it is necessary.' On 22 February 1968 Mr Drayson asked the Secretary of State for Foreign Affairs 'if, following the successful launching of the first Polaris missile from HMS *Resolution* he now proposed to re-negotiate the Nassau Agreement?' Mr Mulley said 'No'.

Poseidon C3

See questions in paragraph 4 above. On 18 January 1967 Mr Brooks asked some questions about the C3 missile (Poseidon) which the United States are adopting. Mr Healey said 'Although the US is planning to produce Poseidon to replace the A-3 in some of its own Polaris submarines it is by no means planning to take all the A-3 missiles out of service. I satisfied on the evidence available to me that there is no danger that the A-3 missile will not be capable of carrying out all its functions during the period we envisage having it in service.'

Nuclear Submarine Cores

On 8 November 1967 Mr Mason said: 'All cores for fleet submarines, with the exception of the first core for HMS *Dreadnought* have been made in this country by Rolls Royce. The production rate and the building and evaluation programme have been established. So far these cores have been built to American design. Moreover, Rolls Royce has now developed a more powerful all-British core which will begin evaluation trials this year. This will be installed in the improved Valiant Class boats.'

Assignment of the Polaris Force

On 31 May 1967 Mr Healey said: 'It is the intention that the Polaris Force will be assigned to NATO and that its missiles will be targeted by the appropriate NATO authorities. Detailed arrangements will be made in due course before the first boat became operational in 1968. ... Broadly speaking the terms on which the Polaris submarines will be assigned will be similar to those on which the V-Bombers are assigned today.' On 28 November 1967 Mr Healey said that when complete the force of four Polaris submarines would take the place of the V-Bombers as our contribution to the collective Western strategic nuclear deterrent.

Operational availability

On 23 February 1965 Captain Kirby asked the Secretary of State to what extent HMG's decision to complete only four SSBNs would affect the contribution to the Western deterrent. Mr Healey said: 'Such a force (ie of four submarines) will be able to keep one submarine on station and often two. It will make a substantial contribution to the Atlantic nuclear force.'

Expenditure on Polaris

On 23 January 1968 Mr Mason said that the total capital expenditure up to 30 November 1967 on the Polaris submarine programme was just over £200M**,** including £32.5M for the Base. He said 'The total estimated capital costs are £350M (for the whole capital programme) and £45M (for the Base).' (The £45M is included within the £350M). On 23 November 1967 Mr Emrys Hughes asked the Secretary of State what plans he had for reducing expenditure on the Polaris Programme in view of the need to reduce public expenditure. Mr Mason said 'None'. On 19 December 1967 Mr. Barnett asked what was the estimated cost of the Polaris programme in 1967/68 and 1968/69, and what was the estimated coat on the basis at an immediate cancellation of the whole programme. Mr Mason said: 'About £70M and £55M respectively. Immediate cancellation would save only a small proportion of these sums because more than 90% of the capital cost of the programme had already been committed.' On 21 December 1967 Mr Foley said that the running cost of an SSBN was about £5M per annum, or slightly less than £100,000 per week. This statement was reiterated to Mr Emrys Hughes on 7 March 1968. On the same day Mr. Hughes was also told that the cost of HMS *Resolution's* DASO was £1.5M and that this figure covered the cost of both missile firings. On 24 February 1967 Mr Mason said that the cost of an SSBN inclusive of weaponry at the time of the Nassau Agreement was £50M; and that the current estimate was £52M.

Credibility

On 9 November 1967 Mr Brooks asked whether in the light at Russian ABM preparations he intended to improve the credibility of the British strategic nuclear deterrent by increasing the size of the Polaris force and equipping with multiple warhead missiles. Mr Healey said that there was no intention of increasing the Polaris force and referred to previous answers about the decision not to accept Poseidon or a new generation of nuclear missiles (see paragraph 4 above).

Why ***the Government didn't cancel Polaris***

On 8 November 1967 Mr Hayle asked for an assurance 'that at the time of the 1964 Election the Polaris program…had reached a stage when it was impossible to stop its progress or cancel the production of the submarines because they could not be adapted for any other purposes'.
Mr Mason said 'Yes'. This confirmed the Prime Minister's statement on 3 March 1966 that 'we kept the Polaris submarine programme because production was beyond the point at no return.' (See paragraph 9 above).