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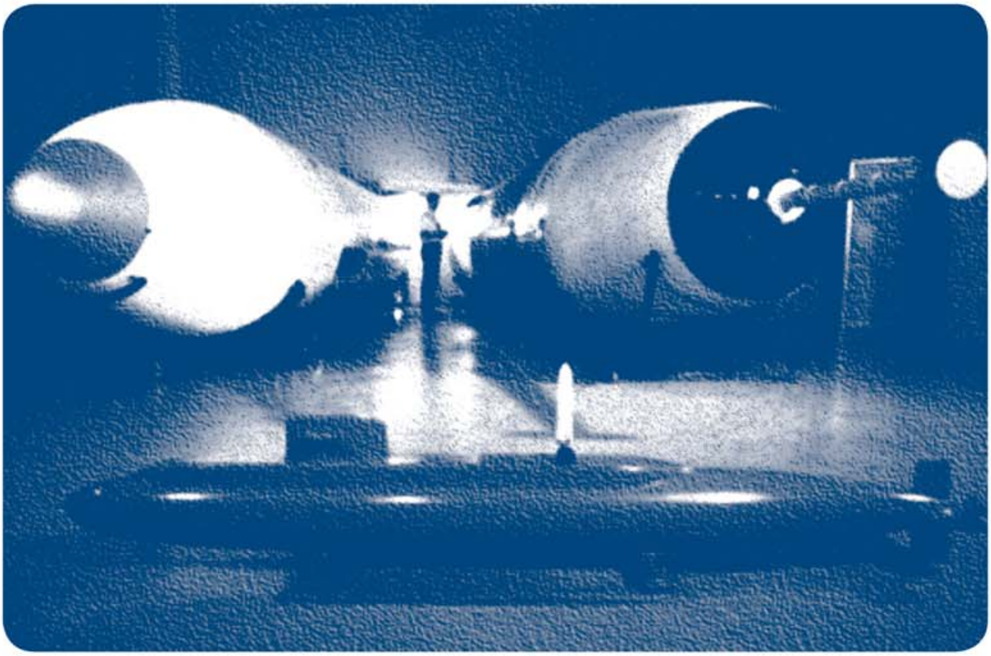
Nuclear strategy and the development of military technology

The case of the Fleet Ballistic Missile programme



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abstract

Recent perspectives on nuclear deterrence stress the importance of professional military organisations being managed through a check and balance system of civilian control. Nevertheless, nuclear weapons technology requires a degree of technical expertise which tends to limit civilian supervision of military research and development activities.

This study explores the conditions where civilian control of the development of nuclear weapons technology may be secured, or lost. Using the Fleet Ballistic Missile programme of the US Navy as a case study, the author analyses how research and development teams respond to political control and adapt to the evolution of nuclear strategy. Based on insights from organisation theory and historical institutionalism, the development of military technology is presented as a long-term process, during which civilian control is rapidly declining.

The case of the Fleet Ballistic Missile programme sheds light on the impact of organisational procedures and routines in the development of military technology. As the programme specialised in particular strategic issues, such routines and procedures progressively locked the evolution of nuclear weapons technology into a narrow framework and limited its adaption to the evolution of US nuclear strategy. In addition, attempts to increase the participation of civilian leaders in research and development activities did not appear as a successful approach in regaining control of nuclear weapons technology. Finally, the long-term evolution of the FBM programme contributes to explaining why some ballistic missiles currently under development seem to be locked in a Cold War framework, while current nuclear policies are addressing new threats such as proliferation, terrorism and transnational actors.

Keywords: nuclear weapons, Cold War, arms control, US Navy, military technology, innovation, United States, management and organisation theory.

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List of acronyms

ABM	anti ballistic missile
BuAer	Bureau of Aeronautics
BuOrd	Bureau of Ordnances
C3	command, control and communications
CEP	circular error probable
CNO	chief of naval operations
EMT	equivalent megatonnage
FBM	fleet ballistic missile
IAP	Improved Accuracy Program
ICBM	intercontinental ballistic missile
IRBM	intermediate range ballistic missile
Kt	kiloton
Mt	megaton
NSAM	National Security Action Memorandum
NSC	National Security Council
MRV	multiple re-entry vehicles
MIRV	multiple independently targetable re-entry vehicles
NAVWAG	Naval Warfare Analysis Group
OSD	Office of the Secretary of Defense
SCPO	Special Communications Project Office
SIOP	Single Integrated Operational Plan
SLBM	submarine-launched ballistic missile
SMP	Strategic Military Panel of the President Science Advisory Board
SPO	Special Project Office
SSBN	submersible ship ballistic nuclear (ballistic missile submarine)
SSPO	Strategic System Project Office
TCP	Technological Capabilities Panel
ULMS	Undersea Long-Range Missile System

Chapter 1

Introduction

More than 60 years after the atomic bombings of Hiroshima and Nagasaki, no consensus has yet been reached regarding the impact of nuclear weapons on international security. In the immediate aftermath of the Second World War, the immense destructive power of nuclear weapons was generally considered to bring the costs of a large war between great powers to an unacceptable level. While conventional military victory remained possible, the risk of a nuclear retaliation outweighed any possible gain from aggression or conquest. Bernard Brodie summarised this point in 1946, noting, "thus far, the chief purpose of our military establishment has been to win wars. From now on, its chief purpose must be to avert them".[1] For Brodie, the emergence of nuclear weapons implied that great powers had entered an era of deterrence, where political objectives would best be achieved by making threats instead of using violence. Today, this perspective is mainly supported by tenants of what is known as the "realist" theory of international relations. For these experts and scholars, nuclear weapons may still contribute to international stability and security, as their mere existence incites states to behave in an exceedingly cautious manner.[2]

Over the years, this approach has been criticised for oversimplifying the decision-making processes related to nuclear issues. During the Cold War, psychological studies on national security and foreign policy stressed how strategic misperceptions and cognitive biases could potentially lead to catastrophic deterrence failures.[3] More recently,

The author would like to thank Rolf Hobson, Torunn Laugen Haaland and Jacob Aasland Ravndal for their helpful comments on earlier drafts. Mary Curry, Marianna Enamoneta and Maxime Dressenetto also provided invaluable technical assistance and support on this study.

1 Bernard Brodie, *The Absolute Weapon* (New York: Harcourt, 1946), 44.

2 Kenneth N. Waltz, "More may be Better" in *The Spread of Nuclear Weapons, A Debate Renewed*, ed. Scott D. Sagan and Kenneth N. Waltz (New York: Norton, 1995), 5.

3 See: Robert Jervis, *Perception and Misperception in International Politics* (Princeton: Princeton University Press, 1976); Robert Jervis, *The Meaning of the Nuclear Revolution. Statecraft and the Prospect of Armageddon*, (Ithaca: Cornell University Press, 1989).

detailed analyses of US and Soviet Cold War policies have profited from insights rooted in organisation theory. In contrast to other critiques of nuclear weapons, organisational views on deterrence do not lead to definitive conclusions, but instead identifies under which domestic conditions and institutional settings deterrence may be stable, or unstable. From this perspective, the configuration of civil-military relations may seriously influence the shaping of nuclear policy. While military institutions play a decisive role in decisions concerning nuclear issues, organisational biases, inflexible routines and parochial interests occasionally affect their behaviour. In this context, "unless managed through a check and balance system of civilian control", military organisations "are unlikely to fulfil the operational requirements for stable nuclear deterrence".[4]

However, not all aspects of nuclear decision-making represent the same challenges for civilian authorities. As noted by Scott Sagan, declaratory policy and nuclear strategy is most often elaborated by political elites or under civilian supervision, and then used as a guideline by military commanders for the development of operational war plans.[5] In contrast, other nuclear issues are more difficult to control. Unlike declaratory policy, the development of nuclear weapons requires a degree of technical expertise, which prevents civilian authorities from directly managing research and development activities. This represents an important problem, as the development of military technology has a critical impact on the stability of nuclear deterrence. Given that nuclear policy is reliant on making threats instead of using force to achieve political objectives, the technical credibility of a given strategy is indeed paramount.[6] In order for civilian leaders to keep nuclear issues under political control, weapons systems under development must therefore satisfactorily address the problems posed by national security strategies.

The difficulty in managing the development of nuclear weapons raises some important questions regarding relations between the

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4 Scott D. Sagan, "More may be Worse" in *The Spread of Nuclear Weapons, A Debate Renewed*, ed. Scott D. Sagan and Kenneth N. Waltz (New York: Norton, 1995), 49.

5 While Sagan acknowledges that "war plans may not always fully reflect the expectations of senior civilian authorities", he argues that "declaratory policy is rarely completely inconsistent with classified nuclear doctrine". See: Scott D. Sagan, "The Case for Non-First Use", *Survival* 51, no. 3 (2009): 165.

6 See: Robert Powell, *Nuclear Deterrence Theory: The Search for Credibility* (Cambridge: Cambridge University Press, 1990); Richard Rosecrance, *Strategic Deterrence Reconsidered*, Adelphi Papers, no. 116 (London: International Institute for Strategic Studies, 1975).

strategic community and the military research community. Under which conditions may political control over the development of nuclear weapons technology may be secured, or lost? How do military organisations transform nuclear strategies into engineering problems during the development of new weapons systems? To what extent should civilian leaders intervene in the selection of technical solutions? How does the relationship between new strategies and aging technologies evolve over time?

In answering these questions, the Fleet Ballistic Missile (FBM) programme of the US Navy seems to provide the most rewarding case study. Active from 1955 to 1990, the FBM programme represented one of the most enduring research and development projects of the Cold War. In addition, it had to adapt to successive evolutions of US nuclear strategy. This project, among the least controversial weapons programmes in history, is believed to find its origins in the efforts of the Eisenhower administration in addressing the problem of missile vulnerability. Launched from submarines and supposedly immune to enemy action, the missiles developed within the FBM programme were considered to provide the so-called second strike capability that was the key to nuclear deterrence.[7] However, as US nuclear strategy progressively placed greater emphasis on striking hardened military targets, the programme faced the challenge of adapting to new missions, focusing on prompt, flexible and precise counterforce strikes.[8]

Another interesting characteristic of the FBM programme lies in its strong influence on current nuclear missile technologies both in the United States and abroad. For more than three decades, the FBM programme produced a family of five missiles, which remain today the backbone of US and British nuclear forces. While technologies initially developed within the programme differed significantly from the solutions adopted by other weapons systems, it progressively became the basis for the development of new ballistic missiles outside

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7 Harvey M. Sapolsky, "The U.S. Navy's Fleet Ballistic Missile Program and Finite Deterrence", in *Getting MAD: Nuclear Mutual Assured Destruction, its Origins and Practice*, ed. Henry Sokolski (Carlisle: Strategic Studies Institute, 2004), 123–136; Donald MacKenzie and Graham Spinardi, "The Shaping of Nuclear Weapon System Technology: US Fleet Ballistic Missile Guidance and Navigation. I : From Polaris to Poseidon", *Social Studies of Science* 18, no. 3 (1988): 419–463.

8 Donald MacKenzie and Graham Spinardi, "The Shaping of Nuclear Weapon System Technology: US Fleet Ballistic Missile Guidance and Navigation: II: 'Going for Broke' – The Path to Trident II" *Social Studies of Science* 18, no. 4 (1988): 581–624; Graham Spinardi, "Why the U.S. Navy went for Hard-Target Counterforce in Trident II: (And Why it Didn't Get There Sooner)", *International Security* 15, no. 2 (1990): 147–190.

the US Navy.[9] Today, even countries such as Russia, France and China rely on concepts first introduced by the FBM programme to develop a new generation of nuclear-armed missiles.[10] Therefore, by improving our knowledge of the dynamics that shaped the technological development of the FBM programme, we would significantly improve our understanding of the rationale behind the characteristics of current weapons systems.

Previous studies

The academic literature on nuclear weapons technology is characterised by the lack of a causal model explaining the dynamics that shaped the FBM programme and structured its relations with civil authorities and US nuclear policy. Only two major in-depth cases studies have previously dealt with the development of nuclear weapons technology within the FBM programme. In 1972, Harvey M. Sapolsky published *The Polaris System Development: Bureaucratic and Programmatic Success in Government*.[11] What he proposed was an analysis of the early history of the FBM programme, from the scope of management theory. Consequently, the connection between nuclear strategy and the development of weapons technology was not the primary focus of his study. Moreover, as the US Navy developed new nuclear missiles until the end of the Cold War, this case study presents only the first half of the history of the FBM programme.

Secondly, in 1994, Graham Spinardi published *From Polaris to Trident: the Development of US Fleet Ballistic Missile Technology*.[12] In contrast to Sapolsky's work, this case study presents the entire history of the FBM programme, from its origins to the end of the Cold War. Nevertheless, in Spinardi's words, his research "does not purport to be

9 Technologies such as solid propellant or multiple warheads, initially developed within the FBM programme, are now common features of ballistics missiles operated by the US Air Force: see: [Jane's], *Jane's Weapon System 1988–1989*, ed. Bernard Blake (London: Jane's Yearbooks, 1988), ref. 4561.111, 2716.111 and 17.111.

10 See: Pavel Podvig, ed., *Russian Strategic Nuclear Forces* (Cambridge: MIT Press, 2004); A. Ochsenbein "SS-NX-30 Bulava Datenblatt" (SS-NX-30 Bulava Datasheet), *dtig.orgefense*, 2 August 2007, Defense Threat Information Group, 26 April 2010 <online>; "M-51. Missile mer-sol balistique stratégique" (M-51 sea-based strategic ballistic missile), *www.defence.gouv.fr*, 2010, French Ministry of Defence – General Delegation for Ordnance, 26 April 2010 <online>; "JL-2 (CSS-NX-4). Chinese Submarine-Launched Ballistic Missile", *globalsecurity.org*, 2009, 26 April 2010 <online>.

11 Harvey M. Sapolsky, *The Polaris System Development: Bureaucratic and Programmatic Success in Government* (Cambridge: Harvard University Press, 1972).

12 Graham Spinardi, *From Polaris to Trident: The Development of US Fleet Ballistic Missile Technology* (Cambridge: Cambridge University Press, 1994).

an explanatory theory".[13] While existing theories about nuclear weapons technology are briefly commented, his main objective is to provide a method for constructing the history of the FBM programme.[14] The final conclusion reached by Spinardi is that "technology is not completely out of control [...], but neither is it very much under control".[15] This somewhat dry assessment should be understood as a call for more research on the relationship between US nuclear strategy and the FBM programme. Indeed, Spinardi's research raises the question as to how and why political control was lost over some aspects of military technology, but not others. Moreover, as Spinardi did not rely on a single analytical model to explain the dynamics of the FBM programme, it is difficult to generalise his findings and generate meaningful lessons in understanding current issues in nuclear weapons technology.

This study precisely aims at bridging this knowledge gap, and developing a causal model tracing possible processes through which political elites may gain or lose control over the development of nuclear weapons technology. It also challenges the conventional wisdom that the FBM programme was a project under tight civilian control, initially created to provide a survivable missile force. Instead, this study stresses how, in the long run, organisational procedures and routines increased rigidity in the functioning of the FBM programme, limiting the options offered to political leaders for the development of new nuclear weapons systems. Based on recently declassified documents and newly available material, it also addresses factual errors in previous historical studies of the FBM programme, and argues that the US Navy never directly answered the late evolution of US nuclear strategy toward counterforce strikes.

13 Ibid., 15.
14 Ibid.
15 Ibid., 193.

Chapter 2

The development of nuclear weapons technology

Strategy, bureaucracy and technological determinism

In spite of the importance of military technology for nuclear deterrence, there is no consensus as to how major nuclear weapons programmes respond to political control. Alternatively, based on the generalisation of observations made during in-depth case studies focusing on major technological changes in the US military, three main perspectives have emerged.

In what is often referred to as the politics-in-command perspective, the existence of a permanent connection between strategy and the evolution of military technology is clearly established.[16] Policy makers are in full control of weapons programmes, which are created, developed and selected in order to propose an optimal solution to national security threats:

> Political and military leaders [...], assess the threats to the security of their nations and alliances. They then select amongst the new technologies available, or provide resources for the creation of new technologies, in order to meet these threats rationally. Strategic goals come first, technology follows.[17]

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16 Note that "Politics-in-commands" is used here in a rather broad sense. See: Donald MacKenzie, "Toward an Historical Sociology of Nuclear Weapons", in *Arms Races: Technological and Political Dynamics*, ed. Nils Petter Gleditsch and Olav Njølstad (Oslo: International Peace Research Institute, 1990), 122.

17 Donald MacKenzie, "Technology and the Arms Race: Review of Innovation and the Arms Race: how the United States and the Soviet Union develop new military technologies by Matthew Evangelista", *International Security* 14, no. 1 (1989): 162.

A second perspective, based on insights from the bureaucratic politics theory, acknowledges the existence of a connection between nuclear strategy and the evolution of military technology, while refuting its benign nature.[18] Here, the formulation of strategy and the selection of weapons programmes are not understood as perfectly rational processes, but rather as "the product of the competition of purposes within individuals and groups".[19] As a result, military technology is not only developed to respond to meeting strategic challenges, but is also shaped to make some policy options and strategies more achievable than others.[20]

However, the capacity of political elites to influence or control the development of weapons programmes has been severely criticised by a third perspective often referred to as technology-out-of-control.[21] From this point of view, the key factor shaping the evolution of weapons programmes is technological determinism: instead of being developed in accordance with the demands of policy makers, "technologies change following their own internal logic or the careers, institutional and financial interests of their developers".[22] Weapons programmes are therefore developed not because they propose a solution to a particular strategic problem, but because some evolutions are "technically sweet" and create an irresistible technological momentum, or "creep".[23] In the most radical version of this perspective, the connection between strategy and military technology is reintroduced, but its causal order is reversed. Far from being the servant of strategy, the evolution of military technology eventually restricts the number of policy options available for political elites and strategy makers to the point where

18 For an overview of the bureaucratic perspective on military decision-making, see: Graham T. Allison, *Essence of Decision: Explaining the Cuban Missile Crisis* (Boston: Little, 1971).

19 Samuel P. Huntington, *The Common Defence* (New York: Columbia University Press, 1961), 2.

20 See: Allan Krass, "The Evolution of Military Technology and Deterrence Strategy", in *World Armaments and Disarmament: SIPRI Year Book 1981* (Stockholm: 1981); Alan Roberts, "Preparing to Fight a Nuclear War" *Arena*, no. 51 (Melbourne: 1981).

21 See: Ralph Eugene Lapp, *Arms Beyond Doubt: The Tyranny of Weapons Technology* (New York: Cowles Book Co., 1970); Deborah Shapley, "Technology Creep and the Arms Race: ICBM problem a Sleeper", *Science* 201, no. 4361 (1978); Marek Thee, *The Race in Military Technology* (Oslo: International Peace Research Institute, 1982); ——, *Impact of Military Technology on the Arms Race: Armaments Dynamics in the Nuclear Age* (Oslo: 1987); Herbert F. York, *The Origins of MIRV*. Report no. 9, (Stockholm: PRIO, 1975); ——, *Making Weapons – Talking Peace: A physicist Odyssey from Hiroshima to Geneva* (New York: Basic Books, 1988).

22 MacKenzie, "Toward an Historical Sociology of Nuclear Weapons", 122.

23 Dietrich Schroeer, *Science, Technology, and the Nuclear Arms Race* (New York: Wiley, 1984), 299; Shapley, "Technology Creep and the Arms Race".

they have "no real independent choice in the matter".[24] In other words, in the relationship between policy and the development of weapons programmes, military technology is the independent variable and strategy is the dependent variable.

History, institutions and nuclear weapons technology

In 1988, Mathew Evangelista proposed taking a first step toward the reconciliation of these three opposed perspectives in *Innovation and the Arms Race*.[25] In what was the first major departure from the tradition of single, in-depth case studies, Evangelista proposed a comparative analysis of the long-term development of thermonuclear and tactical nuclear weapons both in the United States and the Soviet Union. One of the main conclusions he reached was that politics-in-command, bureaucratic politics and technological determinism could not be conceptualised as general, universally valid theories. Instead, these three perspectives describe processes at work in different political conditions and at different stages of the development of military technology.

The approach proposed by Mathew Evangelista could have represented an important evolution of the research agenda. It called for what Donald Mackenzie defined as an "historical sociology" of military technology.[26] This view criticised previous case studies which focused on a decisive innovation or a particular weapons system for their short time perspective, while the relation between strategy and weapons programmes evolves only slowly over time.[27] Therefore, for an historical sociologist of nuclear weapons, the objective is not to produce a general theory such as politics-in-command or technological determinism. In contrast, what is to be addressed is how some particular weapons programmes emerge and are developed through phases where politics, bureaucracy and technological determinism influence their relation to the strategic problems.[28]

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24 Herbert F. York, *The advisors: Oppenheimer, Teller, and the Superbomb* (San Francisco: W.H. Freeman, 1976), 11.

25 Matthew Evangelista, *Innovation and the Arms Race: how the United States and the Soviet Union develop new military technologies* (Ithaca: Cornell University Press, 1988).

26 Donald A. Mackenzie, *Inventing Accuracy: An Historical Sociology of Nuclear Missile Guidance* (Cambridge: MIT Press, 1990); ——, "Toward an Historical Sociology of Nuclear Weapons".

27 Mackenzie, *Inventing Accuracy,* 8.

28 MacKenzie, "Toward an Historical Sociology of Nuclear Weapons", 137–138.

However, this interesting evolution of the research agenda was interrupted by the sudden end of the Cold War and the collapse of the Soviet Union. During the 1990s, most of academic attention drifted away from the issue of nuclear weapons, and a structured debate about nuclear weapons technology has still to reappear. This study proposes to reactivate the previous research agenda set by Mathew Evangelista and Donald McKenzie, and presents a theoretical model to analyse the case of the FBM programme from the perspective of historical sociology.

In proposing an historical sociology of the FBM programme, most social and political theories are unsuitable. Focusing on the immediate reaction of actors or organisations to their environment, such approaches artificially freeze time, "reducing a moving picture to a snapshot".[29] Instead, the occurrence and succession of different phases in the development of the FBM programme can be seen as the product of large processes at play over time. Under these conditions, the development of nuclear missiles within the US Navy is best understood from a historical institutionalist perspective, which proposes analysing the construction, maintenance and adaption of formal and informal institutions, as a long-term process.[30] Institutions are defined as "relatively enduring collections of rules and organised practices, embedded in structures of meaning and resources that are relatively invariant in the face of individual turnover and changing external circumstances".[31] The central idea of historical institutionalism is that "choices made at a point in time create institutions that generate recognisable patterns of constraints and opportunities at a latter point".[32] Historical institutionalism understands the evolution of institutions as a sequential process whose rhythm is set by the succession of critical junctures and path dependent processes.

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29 Paul Pierson, *Politics in Time: History, Institutions, and Social Analysis* (Princeton: Princeton University Press, 2004), 120.

30 See: Charles Tilly, *Big Structures, Large Processes, Huge Comparisons* (New York: Russell Sage Foundation, 1984).

31 James G. March and Johan P. Olsen, "Elaborating the New Institutionalism", in *The Oxford handbook of political institutions*, ed. R. A. W. Rhodes, Sarah A. Binder, and Bert A. Rockman (Oxford: Oxford University Press, 2006), 3. See also: James G. March and Johan P. Olsen, *Rediscovering Institutions* (New York: Free Press, 1989); James G. March and Johan P. Olsen, *Democratic Governance* (New York: Free Press, 1995).

32 Walter W. Powell, "Expanding the Scope of Institutional Analysis", in *The New Insitutionalism in Organizational Analysis*, ed. Paul J. DiMaggio and Walter W. Powell (Chicago: University of Chicago Press, 1991), 188–189.

Critical junctures

Critical junctures can be defined as major disclosures, "such as when people abandon previous views and come to hold new ones".[33] They represent "choice points when a particular option is adopted from two or more alternatives", over "relatively short periods of time".[34] From an historical institutionalist perspective, critical junctures may well account for the creation of the FBM programme and the emergence of its key institutions. Indeed, critical junctures are characterised by dramatic changes in the political/strategic environment, the introduction of new technologies, and by the creation of new organisations.[35] When these three conditions are simultaneously met, military organisations cannot rely on routines or existing technologies to shape their activity. On the contrary, in order to produce and survive, young organisations must seek and obtain support from political elites, and are therefore more inclined to directly frame their activity according to nuclear strategy. Therefore, critical junctures represent phases when political and military leaders were most likely to be in full control of the FBM programme.

How would the FBM programme connect new technologies with problems posed in the strategic environment during critical junctures? According to Lynn Eden, in such circumstances, doctrine is used as a guide to collective action.[36] Barry Posen defines military doctrine as the means chosen to achieve the goals set by a grand strategy. More precisely, doctrine addresses and determines "*What* means shall be employed? and *How* they shall be employed?"[37] Doctrine, Eden argues, "articulates purposes and includes assumptions and knowledge about the world that are incorporated into organisational approaches to problem solving".[38]

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33 Barry R. Weingast, "Persuasion, Preference, Change, and Critical Junctures: The Microfundations of a Mascroscopic concept", in *Preferences and Situations: Points of Intersection Between Historical and Rational Choice Institutionalism*, ed. Ira Katznelson and Barry R. Weingast (New York: Russel Sage foundation, 2005), 171.

34 Giovanni Capoccia and Daniel R. Kelemen, "The Study of Critical Junctures: Theory, Narrative and Counterfactual in Institutional Theory", paper presented at the ASPA 2005 Annual Convention, Washington D.C, 2005, 11.

35 Lynn Eden, *Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation* (Ithaca: Cornell University Press, 2004), 49–50. On the introduction of new technologies as a critical perturbation in the activity of military organisations, see: Ronald J. Kurth, *The Politics of Technological Innovation in the United States Navy*, (Cambridge: Harvard University, 1970).

36 Eden, *Whole World on Fire*, 52–53.

37 Barry Posen, *The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars* (Ithaca: Cornell University Press, 1984), 13.

38 Eden, *Whole World on Fire*, 52–53. See also: Posen, *The Sources of Military Doctrine*, 41–44.

In addition, bureaucratic politics may also have had an impact on the institutional setting of the FBM programme during critical junctures. Indeed, young organisations searching to secure their existence may have to face domestic opposition from rival organisations, public opinion or influential individuals.[39] In a context of inter-service rivalry, direct competition is not always the most efficient means to survive and produce. Instead, an organisation can choose to frame its activities in order, placing itself in a "niche" position, protected from competition. A good example is the US Army, which decided to specialise in tactical nuclear weapons after having lost a competition for strategic nuclear weapons against the Air Force.[40]

Organisational frames

In their attempt to solve strategic problems and face challenges from their bureaucratic environment, new weapons programmes generate and allocate resources, attention and expertise to some specific areas. A specific set of institutions is generated thus creating a frame for the general development of military technology.[41] Such structures enable the development of new weapons systems because they: assist actors in taking decisions when information and time are limited; coordinate their activity; control internal conflict; and propose a common goal to the entire organisation.[42] But such institutions also constrain the activity of participants by channelling their behaviour and excluding problems and solutions from the agenda. Whether they enable or constrain the development of military technology, such institutions represent "organisational frames", that is "a framework for action that structures how actors identify problems and find solutions".[43]

How can we identify and analyse the organisational frame that shaped the development of nuclear weapons technology within the FBM programme? According to Eden, frames can be "seen", or "read" in "enduring features of organisations, such as organisational routines, organisational expertise or specialised fields of activity.[44] While organ-

39 For a description of organisational behaviour in a bureaucratic politics environment, see: Allison, *Essence of Decision*.

40 Michael H. Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy* (New York: Columbia University Press, 1969).

41 Eden, *Whole World on Fire*, 50–51.

42 See: Herbert A. Simon, *Administrative Behavior: A Study of Decision-making Processes in Administrative Organization* (New York: Free Press, 1997, 1945); James G. March and Herbert A. Simon, *Organizations* (Cambridge: Blackwell Business, 1993, 1958), 160–61, 97–200.

43 Eden, *Whole World on Fire*,

44 Ibid., 55–56.

isational frames may vary greatly among different organisations, four of their key characteristics can be identified by answering the following questions: 1. What is the declared purpose or goal of the organisation in charge of developing a given weapons system? 2. What are the strategic problems identified and debated within the organisation? 3. What are the research strategies and technologies used to solve these problems? 4. What are the constraints and requirements placed on possible solutions?[45]

Path dependence

A distinctive feature of organisational frames lies in their ability to influence the development of technology both instantly and at a future time. Indeed, "past choices and actions structure future possibilities, both by shaping the understandings that actors bring to new situations and by shaping the social environment in which decisions are made and carried out".[46] In this regard, a concept central to the analysis of military institutions is that of *path dependence*, which describes how "organisational actors making rational decisions construct around themselves an environment that constrain their ability to change further in later years".[47] For a research and development project such as the FBM programme, path dependent processes imply that once an organisation "has started down a track, the cost for reversal is very high".[48] To illustrate this relatively abstract concept, Margaret Levy compares path dependent trajectories with the structure of a tree:

> For the same trunk, there are many different branches and smaller branches. Although it is possible to turn around and clamber from one to the other – and essential if the chosen branch dies – the branch on which a climber begins is the one she tends to follow.[49]

For Lynn Eden, the most powerful reason for the existence of path-dependant trajectories as followed by many military organisations and

45 Ibid., 49–57.
46 Ibid., 51.
47 Paul J. DiMaggio and Walter W. Powell, *The New Institutionalism in Organizational Analysis* (Chicago: University of Chicago Press, 1991), 61.
48 Margaret Levy, "A Model, a Method and a Map: Rational Choice in Comparative and Historical Analysis", in *Comparative Politics: Rationality, Culture and Structure*, ed. Mark I. Lichbach and Alan S. Zuckerman (Cambridge: Cambridge University Press, 1997), 28.
49 Eden, *Whole World on Fire*, 51.

weapons programmes is the self-reinforcing nature of their organisational frames.[50] Once created during a critical juncture, organisational frames evolve through a process of "positive feedback": the more they are applied, the more stable and the more profitable they become for the organisation concerned.

Why is this? The historical institutionalist literature proposes three key mechanisms that may be applied in the case of the FBM programme. Firstly, the environment – either at the strategic or bureaucratic level – may offer incentives to use certain organisational frames for an extended period of time. As the programme operates according to a given frame for a long period of time, it must invest in personnel, human networks, knowledge, hardware and resources. These *"sunk costs"* represent a capital that would be lost if radical changes were introduced. Furthermore, as some actors join and leave the organisation according to the evolution of their career or their age, the actual rationale behind the existence of routines is progressively forgotten. Thus, what was rationally set as an organisational frame at a critical juncture slowly becomes a ritual.[51] At this point, the reasons for the existence of a ritualised frame may well have ceased to exist. However, as there is no actor left to remember the actual rationale behind the frame, its existence would not necessarily be threatened.[52]

Secondly, this problem is reinforced by the fact that organisational frames shape the way in which organisational actors understand their environment. Ritualised frames produce *organisational knowledge*, understood as the "representations of the world that are articulated or assumed at the organisational level".[53] In this perspective, organisational frames are self-reinforcing, because the longer they exist, the more rigid they become. The more rigid they become, the less they allow actors to understand change in their environment, and the less the organisation understands change in its environment, the longer old frames persist and become more rigid.

Thirdly, historical institutionalists would expect the FBM programme to experience what economists call the problem of "*increasing*

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50 Ibid., 53.

51 John W. Meyer and Bryan Rowan, "Insitutionalized Organizations: Formal Strutures as Myth and Ceremony", *American Journal of Sociology* 83, no. 2 (1977): 340–363.

52 For a broader discussion of this issue, see: James G. March and Johan P. Olsen, "The New Insitutionalism: Organizational Factors in Political Life", *American Political Science Review* 78, no. 3 (1984): 734–749.

53 Eden, *Whole World on Fire*, 50.

returns".[54] Once a given research and development strategy is adopted, "the relative benefits of the current activity compared with other possible options increases over time".[55] This problem is partly connected to the existence and the self-reinforcing nature of organisational knowledge. Indeed, the "use of knowledge-laden routines leads to organisational learning, more refined routines and greater capacity to solve problems".[56] But technology also becomes a driving factor for organisational frames, as "the increasing efficiency of the adopted routines provides a powerful rationale for continued use and the approach taken seems more sensible than other approaches".[57] In other words, for a research and development project such as the FBM programme, once a given technology had been introduced, it becomes easier and more efficient to improve and develop it further, instead of searching for brand new solutions.

In a long-term perspective, a given organisational frame may become self-sustaining, because the three mechanisms presented above (sunk costs, organisational knowledge and the increasing returns of technology) are mutually reinforcing. As the environment provides a prolonged incentive for a given organisational frame, particular types of research and development activities are performed and become more efficient. But as technology becomes a reason, per se, to follow a given track, it also locks the organisation into a framework that fails to address the novel solutions required by the evolution of strategy.

Thus, the path-dependant evolution of military organisations and their research and development activities can account for some breaks in the connection between strategy and the development of military technology. As strategy evolves according to its own determinants – mainly threats to national security, but possibly bureaucratic interferences as well – the development of relevant solutions follows its own internal organisational logic, according to the path set by the organisational frame selected during the previous critical juncture. In the case of the FBM programme, this would mean that unless a new critical juncture occurs, political control over the development of the nuclear weapons technology is unlikely to be re-established.

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54 See: Brian W. Arthur, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor: University of Michigan Press, 1994); Pierson, *Politics in Time*. Paul Pierson, *Positive Feedback and Path Dependence* (Oxford: Oxford Univeristy Press, 2004).

55 Paul Pierson, "Increasing Returns and Path Dependence in the Study of Politics", *American Political Science Review* 94, no. 2 (2000): 252.

56 Eden, *Whole World on Fire*, 52.

57 Ibid., 52.

A brief outline of the chapters

The following chapters apply the institutionalist framework presented above to study how the FBM programme related to US nuclear strategy between 1955 and 1990. Chapter three deals with the emergence of the FBM programme between 1955 and 1960. It presents the creation of the programme as the result of critical juncture and explains how political elites achieved control over the initial development of nuclear weapons technology within the US Navy. Then, it sheds light on how the leadership of the FBM programme attempted to translate US nuclear strategy into engineering problems. Chapter four traces the evolution of the programme between 1960 and 1974. It stresses how the FBM programme became increasingly affected by sunk costs, organisational knowledge and the increasing returns of technology while addressing the problems posed by US nuclear strategy. Chapter five explains why the FBM programme became unable to fully adapt to the evolution of US nuclear strategy after 1974. Finally, chapter six presents the conclusions of this study. Using insights for the case of the FBM programme, it sheds new light on some key technical characteristics of current nuclear missiles and addresses contemporary issues of nuclear weapons technology.

Chapter 3

Framing the FBM programme

The birth of the FBM programme

In the immediate aftermath of World War II, adapting the development of nuclear weapons technology to nuclear strategy did not represent a critical problem for the United States. Indeed, following the atomic bombings of Hiroshima and Nagasaki, the country had only a limited nuclear stockpile and no well-established national nuclear policy. Instead, policy-makers, military commanders and scholars were engaged in an active debate to decide whether nuclear weapons should be used to win or deter future wars.[58]

Nevertheless, military services such as the Navy and the Air Force did not hesitate in developing new nuclear weapons and elaborating their war plans. With the end of combat operations in Europe and the Pacific, new justifications for resource attribution had to be found, and inter-service rivalries soon emerged. From the Air Force's point of view, future wars would be primarily fought by means of nuclear weapons. The entire stockpile was to be delivered at once, during a massive air offensive. A short campaign of strategic bombing aimed at industrial and urban centres would produce the general collapse of the opponent.[59] In contrast, Navy leaders did not believe that strategic

58 For an overview of this debate and detailed presentation of its main actors, see: Fred M. Kaplan, *The Wizards of Armageddon* (New York: Simon and Schuster, 1983).

59 For instance, the Air Force war plan *Harrow* planned to deliver 50 nuclear weapons on 20 Soviet cities. However, these numbers grew quickly and by December 1948, the Joint Chief of Staff approved war plan *Trojan* calling for delivering 133 bombs on 70 cities. See: David A. Rosenberg, "The Origins of Overkill. Nulcear Weapons and American Strategy", *International Security* 7, no. 4 (1983): 16. For further details about early Air Force nuclear war plans see: Alfred Goldberg, "A Brief Survey of the Evolution of Ideas about counterforce", memorandum RAND-5431-PR, October 1967 (revised March 1981), Eisenhower papers, box 9, The National Security Archive, Washington D.C.; Gregg Herken, *The Winning Weapon: the Atomic Bomb in the Cold War, 1945–1950* (New York: Knopf, 1980).

bombing alone could cause an opponent to capitulate. In their perspective, strategic bombing was held as "morally wrong and military unsound", as "levelling large cities has a tendency to alienate the affection of inhabitants and does not create an atmosphere of international good will after the war".[60] In the Navy's view, nuclear weapons did not necessarily have priority over other means of warfare and would only be used to assist the systematic destruction of the enemy's military assets. a doctrine known as *counterforce*. Indeed, according to the 1949 Emergency War Plan, in the event of an armed conflict, naval battle groups would be in charge of "the precision bombing of smaller elements of the selected target systems – elements not suitable for high altitude bombing but which must be cleared up to make the effort more effective".[61] The use of nuclear weapons was not considered relevant for all situations, and limited wars could well be fought only with conventional ammunition, as the Korean war was about to prove. If nuclear ordnance had to be utilised, it would be directed principally at targets of naval interest such as submarine pens, ports, shipyards, naval bases and "enemy airfields that posed a threat to carrier operations".[62]

During the first half of the 1950s, the main nuclear delivery vehicle developed by the Navy was the Regulus cruise missile, an unmanned aircraft able to strike targets at ranges less than 500 miles.[63] The Regulus was in accord with the nuclear doctrine of the Navy. Compared to the strategic bombers of the Air Force it was a short range system. For guidance, it relied on at least two surface radar stations. While this configuration prevented the Regulus from flying deep inside hostile territory, it provided the precision needed to strike most tactical targets such as hostile battle groups, naval bases, submarine pens and airfields. If more precision was needed, the missile could be controlled manually by an operator located in a chase plane flying in immediate proximity.

However, as a formal nuclear policy became more clearly established in the United States, nuclear operations within the US Navy were seriously perturbed. The endorsement of the strategy of massive

60 Rear Admiral Ralf Ofstie, "The National Defence Program: Unification and Strategy", testimony, March 1949, Hearings of House Armed Service Committee, Washington D.C., 183. The second quotation is from: Rosenberg, "The Origins of Overkill", 70.

61 "Navy Presentation about 14 March. Section three", Briefing, March 1949, Operational Archives, folder 1844/46, Naval Historical Center, Washington D.C.

62 Jeffrey G. Barlow, *Revolt of the Admirals: the Fight for Naval Aviation, 1945–1950* (Washington: Naval Historical Center, 1994), 115.

63 Technical characteristics of the Regulus missile are taken from: David K. Stumpf, *Regulus: America's First Nuclear Submarine Missile* (Paducah: Turner, 1996).

retaliation in 1953 constrained the Navy to dramatically change its nuclear doctrine, abandon cruise missile technology and create a new organisation to handle these problems. This crisis, therefore, presented the three conditions of a major critical juncture, which would eventually give birth to the FBM programme.

The strategy of massive retaliation

During the early 1950's, the increasing number of available nuclear weapons and the deterioration of relations with the Soviet Union accelerated the formulation of a formal nuclear strategy in the United States. In a meeting of 30 October 1953, the National Security Council (NSC) identified the basic problem of US security as being able "to meet the Soviet threat, [while] in doing so to avoid seriously weakening the U.S. economy or undermining [...] fundamental values and institutions".[64] The nature of the "Soviet threat" was not primarily understood as a direct nuclear attack on the United States, a scenario considered as rather improbable because the Soviet Union still lacked adequate delivery vehicles. In light of the Korean War experience and as a consequence of the American inferiority in conventional forces, the most likely threats to US security consisted in a potential military intervention against European allies or a Soviet attempt "to win allegiance of presently uncommitted areas of the world".[65]

To address these challenges, the new strategy called for "placing more reliance on deterrent power, and less dependence on local defensive power".[66] Instead of separating nuclear issues from conventional military threats and vital interests from peripheral ones, the United States would respond to any Soviet provocation by an instantaneous and disproportionate nuclear attack on the USSR and communist China.[67] By threatening to eradicate the industrial and demographic substance of the communist world, the objective was not to win a war, but to deter an opponent from initiating hostilities in the first place, even at the non-nuclear level. Under these circumstances, there was no need for superior conventional military capabilities to meet the Soviet

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64 "A report to the National Security Council on Basic National Security Policy", report NSC 162/2, 30 October 1953, personal collection, 1.

65 Ibid.

66 Secretary of State John Foster Dulles, "The Evolution of Foreign Policy", speech, 12 January 1954 (published on 25 January), Department of State Bulletin, Washington D.C. In the literature, this speech is often referred as the "Massive retaliation Speech". At the policy level, the strategy of massive retaliation was adopted on 30 October 1953, by NSC report 1662/2 quoted above.

67 Powell, *Nuclear Deterrence Theory*, 12–13.

threat, and the US economy and institutions would be spared a costly arms build-up. Known as "massive retaliation", this approach to national security represented the first formal nuclear strategy adopted by the United States, in the sense that it represented "a political-military means-ends chain, a state's theory about how it can best 'cause' security for itself".[68]

The strategy of massive retaliation was in total opposition to the counterforce doctrine initially adopted by the Navy. It implied that nuclear weapons had priority over conventional means of warfare and were to be used against civilian targets. In a classified speech at the Naval War College, Secretary of State John Foster Dulles pressed the Navy to radically change its nuclear operations approach and adapt more quickly to the new strategy. "Atomic forces are now our primary forces. It means that actions by other forces, on land, sea or air are relegated to a secondary role [...]. It means that nuclear weapons, fission and fusion, will be used in the next major war."[69] How those weapons would be employed was carefully defined during meetings of the NSC. In the advent of a Soviet attack on US interests, nuclear weapons would be used to inflict "massive retaliatory damages by offensive striking power".[70] The retaliation was to be conducted immediately, over large population centres, regardless of targets, of tactical value or naval interest.[71]

Ballistic missile technology

The strategy of massive retaliation not only implied that the Navy had to change its nuclear doctrine, it also forced the Navy to start the development of a totally new weapons system. In order to seriously threaten the demographic and industrial structure of the USSR, the United States had to be able to deliver nuclear weapons to targets located well inside the borders of the Soviet Union, preferably on Moscow. Because of its short range, the Regulus was unsuitable for the mission. In the first place, the Navy planned the development of a second generation of Regulus missiles, flying at higher altitudes

68 Posen, *The Sources of Military Doctrine*, 13.
69 John Foster Dulles, "Confidential Speech at the Naval War College", speech, 25 May 1954, Newport. Also quoted in: Kaplan, *The Wizards of Armageddon*, 183–84. I am grateful to Mary Curry from the National Security Archive (Washington D.C.) for access to this document and Fred Kaplan's research notes.
70 NSC report 162/2, 5.
71 Ibid. See also: "U.S. Objectives in the Event of General War with the Soviet Bloc", memorandum NSC 5410/1, 29 March 1954, Fred Kaplan Collection 80, box 1, The National Security Archive, Washington D.C.

and able to strike targets located 1,200 miles inland. However, taking into account the rapid progress in Soviet air defences and the advances in surface-to-air missiles, neither manned bombers nor cruise missiles were considered to be viable solutions in the long run.[72]

To address the technological challenge posed by the strategy of massive retaliation, a panel of experts was established around James Killian, the scientific adviser to the president. Officially known as the Technological Capabilities Panel (TCP), Killian's committee was tasked by President Eisenhower with defining what types of technologies were to be developed in order to protect US interests over the long term. The conclusions reached by the panel were summed up in a report presented to the NSC in February 1955.[73] The recommendations covered numerous aspects of US defence policy and proposed to launch very ambitious research programmes to develop communications, intelligence and warning systems.

Concerning the problem of performing nuclear strikes deep inside Soviet territory, the TCP recommended the development of intercontinental ballistic missiles (ICBM). ICBMs would merge technology from rocketry, artillery and nuclear weaponry to create a new weapons system with no known shield. A nuclear warhead was to be mounted on a guided rocket, which would accelerate until it reached a pre-set angle and velocity, well above the atmosphere. The warhead would then be released, and pursue its flight on an unguided and an unpowered trajectory. Falling on its target under the laws of ballistics – thus explaining the name of such missiles – a nuclear warhead would behave just as an artillery shell fired by conventional guns. Because most of the flight path was free from atmospheric friction, ranges of several thousand nautical miles and velocities of about 3.5 miles per second were achievable. From the United States, flight time to Moscow was about twenty to thirty minutes. Under these conditions, Soviet early warning systems and air defences would be futile.[74]

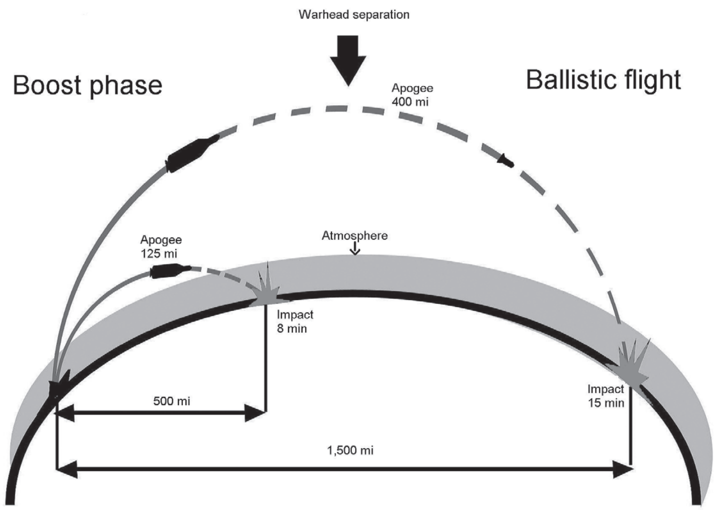
72 Central Intelligence Agency (CIA), "Air Defence of the Sino-Soviet Block, 1955–1960", National Intelligence Estimate NIE 1-5-55, 12 July 1955. Cruise missiles however, reappeared during the early 1980's, using terrain following navigation systems enabling to fly at extremely low altitude, thus avoiding radar detection.

73 Technical Capabilities Panel, "Meeting the Threat of Surprise Attack", report, 14 Feburary 1955, Scientific Advisory Committee, Washington D.C.

74 For a general-public description of ICBM technology, see: George Harry Stine, *ICBM: The Making of the Weapon that Changed the World* (New York: Orion, 1991). This estimation of ICBM flight time between the USA and the USSR is inferred from: Office of Technology Assessment (OTA), "Ballistic Missile Defence Technologies", report OTA-ISC-254, September 1985, Government Printing Office, Washington D.C., 94.

However, the TCP also predicted that the United States "would not have a militarily significant capability with the ICBM until about 1965, although a small number could be operational before that date".[75] A temporary weapons system was needed, involving simpler missiles with shorter range, able to reach the Soviet Union from overseas bases in Europe. As an interim solution, the panel of experts recommended that "there be developed ballistic missiles (with about 1,500 nautical miles range and megaton warhead) for strategic bombardment".[76] Because of their range, the weapons recommended by the TCP were referred to as intermediate range ballistic missiles or (IRBMs). As an emergency measure, pragmatism was the key word, and "both land-basing and ship-basing should be considered".[77]

Fig. 1: Typical IRBM flight trajectory



The creation of the Special Project Office

By February 1955, two of the three main conditions for a major critical juncture were in place. Firstly, the strategy of massive retaliation implied an important disclosure in the doctrinal environment of the Navy. Secondly, the Killian committee proposed abandoning cruise missiles in favour of ballistic missiles, a novel technology. However,

75 TCP, "meeting the Threat of a Surprise Attack".
76 Ibid.
77 Ibid.

the occurrence of a third event – the creation of a new organisation specifically tasked with designing a naval IRBM – was necessary in order to overcome bureaucratic opposition to the creation of the FBM programme.

Within the Navy, the opposition to a ballistic missile programme was twofold. Firstly, a large number of officers considered it an immoral project, as the purpose of ballistic missiles was to perform strikes over civilian targets. Secondly, there were technical objections to the sea-basing of ballistic missiles. In the Navy, the development of aerial weapons came under the purview of the Bureau of Aeronautics (BuAer) and the Bureau of Ordnances (BuOrd). However, both bureaus refused to support the development of ballistic missiles because their operation from ships was considered too dangerous and beyond the state of the art.[78] In September 1947, a German V-2 was test-fired from the deck of the aircraft carrier USS *Midway*. Although the missile flew successfully, it did not appear to be a useful weapon. The handling of its cryogenic liquid fuel and the countdown of several hours prior to launching were too complicated for naval operations.[79] In 1949, during operation *Crossover* another German V2 was set on fire on the deck of a mock-up ship to assess the potential damages resulting from a launch accident. The result was dramatic, exceeding by far the worst predictions of engineers, and leading them to abandon all research on ballistic missiles.[80]

The resistance of the Navy toward a sea-based IRBM was progressively overcome during the spring and the summer of 1955. In March, James S. Russell, one of the few supporters of a naval IRBM, became the secretary of the BuAer and began lobbying for the development of a naval ballistic missile.[81] On 17 August, Robert A. Carney was replaced by Arleigh A. Burke as chief of naval operations (CNO).[82] As opposed to Carney, Burke had "the desire to develop a distinctively naval contribution to national strategy" and was sympathetic

78 On technical of naval IRBMs within the US Navy, see: Gordon O. Pehrson, interview by John T. Mason, 5 February 1974.

79 Robert A. Fuhrman, "The Fleet Ballistic Missile System: Polaris to Trident", *Journal of Spacecraft* 5, no. 5 (1978): 267.

80 James Baar and William E. Howard, *Polaris!* (New York: Harcourt, 1960), 14.

81 Vincent Davis, *The Politics of Innovation: Patterns in Navy Cases*, Monograph series in World Affairs 4, no. 3 (Denver: The social Science Foundation and Graduate School of International Studies, 1966), 35.

82 For further details about Admiral Arleigh Burke, see: David A. Rosenberg, "Arleigh Burke: The Last CNO", in *Quarterdeck and Bridge: Two Centuries of American Naval Leadership*, ed. James Bradford (Annapolis: U.S. Naval Institute Press, 1996): 361–394.

to the idea of placing ballistic missiles at sea.[83] On his first day of office, he ordered a briefing about the capabilities of IRBMs, and took the definitive decision to initiate a research project after less than a week. On 13 September, the National Security Council ordered that the recommendations of the TCP be applied immediately.[84] At this time, the Navy had no choice but to go ahead with the development of a naval IRBM. However, internal resistance remained important within the Navy, and frictions between BuAer and BuOrd prevented any significant advances, as the two bureaus now sought control over the programme.

To overcome this problem, Burke adopted a radical and unprecedented solution. No research and development activities relative to a naval IRBM were to be conducted by the BuOrd or the BuAer. Instead, on 17 November, the Special Projects Office (SPO) was created with the specific task of handling the problems associated with the ship basing of ballistic missiles.[85] To direct the SPO, Burke decided to rely on an aviator, "because a technical expert would be too narrow minded" and appointed Rear Admiral William Raborn on 2 December.[86] Raborn and the rest of the SPO were separate from the normal hierarchy of the Navy and reported only to Burke. Burke wrote a letter that Raborn had to carry on his person whenever in service. The contents indicated that Raborn had *carte blanche* and "top priority" over any other Navy programmes to develop a naval IRBM.[87] The FBM programme was born.

Bureaucratic politics and counterforce strikes

Paradoxically, the National Security Council´s adoption of the recommendations proposed by TCP and the creation of the SPO did not imply that the Navy had fully secured the right to develop a naval IRBM. Because the FBM programme was created nearly nine months after the TCP report was published, the Navy was falling behind the Air Force and the Army in the race for an operational IRBM. In a context

83 Mackenzie, *Inventing Accuracy*, 136; Arleigh Burke, interview by John T. Mason, 12 December 1972.

84 Special Project Office [SPO], "Polaris Chronology. History of the Fleet Ballistic Missile Weapon System Development Program", Chronology, 1967, U.S. Nuclear History Collection, NH00031, DNSA, Washington D.C., 1.

85 Ibid., 1.

86 Quoted in: Spinardi, *From Polaris to Trident*, 25.

87 William Raborn, interview by John T. Mason, 15 September 1972.

of reduced military spending, President Eisenhower decided to fund no more than four ballistic missile programmes.[88] The Air Force was already developing two ICBMs, the Atlas and the Titan. In 1954, one year before the TCP published its recommendations, the Air Force also started the development of an IRBM with ideal characteristics (a range of 1,500 miles and a warhead of 1.44 megatons).[89] Early in 1955, the Army proposed a fourth missile programme, the Jupiter IRBM, with a performance similar to its Air Force counterpart.[90] As no room was left for the Navy, the SPO was in the awkward position of being ordered to develop a naval IRBM, but denied the necessary funds for the work.

In order to survive, the FBM programme had to first obtain domestic support, before it could even begin to develop a naval IRBM addressing the strategic problems faced by the United States. However, as a very young organisation, the SPO was not committed to any course of action. Having both the incentive and the capability to seize any opportunity to develop a naval IRBM, the FBM programme would address its bureaucratic environment with a high level of pragmatism during its first years of activity.

The Jupiter missile

To the few Navy leaders sympathetic to the development of a naval IRBM, the lack of funding initially appeared as the main threat to the existence of the FBM programme. In order to obtain a portion of the resources allocated to the development of other IRBMs by the Eisenhower administration, Admiral Burke searched for alliances even before he nominated Raborn as the head of the SPO. The Air Force had the most advanced project and proposed a smaller missile, but refused to ally with the Navy. However, Burke was more successful in persuading the Secretary of Defense that the Navy should team up with the Army.[91] On 8 November 1955, the Department of Defense ordered the Army to consider the possibility of a sea-based version for the Jupiter missile.[92] In December, the evaluation was completed, and the Department of Defense authorised the Army and the Navy to initi-

88 Sapolsky, *The Polaris System Development*, 7.

89 Clayton K. S. Chun, *Thunder over the Horizon : From V-2 Rockets to Ballistic Missiles* (Westport: Praeger Security International, 2006), 68.

90 For a detailed account of the competition between the Air Force and the Army over the development of the first generation of IRBMs, see: Armacost, *The Politics of Weapons Innovation.*

91 Raborn, interview. Burke extensively relied on Secretary of Navy Charles Thomas to obtain support from the Secretary of Defense.

92 SPO, "Polaris Chronology", 1.

ate the joint development of the Jupiter, allotting 50.8 million dollars for the fiscal year 1956.[93]

At the very beginning of 1956, the first few rules framing the activity of the FBM programme began to appear, but remained relatively limited. Officially, the purpose of the programme was "to handle the problems associated with the ship-launched weapons system" developed by the Army.[94] However, as an organisation, the SPO was actually much more committed to assuring its own survival than to anything else.[95] In a tight budgetary context, and with many detractors left in the Navy, the SPO would probably have been disbanded if Burke had left the office of Chief of Naval Operations. Therefore, in Raborn's perspective, developing a sea-based IRBM had to become something comparable to a religious commitment.[96] He communicated with his engineers through an internal publication named "The Dope", the main purpose of which was to boost morale, and explain external threats to the programme.[97] Furthermore, engineers had to abandon other personal goals and commit entirely to the organisation. Known as "Raborn's tigers", members of the SPO were totally dedicated to the FBM programme, and spent every Saturday as well as many Sundays at their offices.[98]

As the general architecture of the Jupiter IRBM had already been defined by the Army, the only research and development problem left to the SPO was to adapt the missile to its new naval environment. As discussed previously, in 1956 the Navy had only very limited experience in operating ballistic missiles from ships. An immediate consequence being that the SPO could not rely on any existing framework to propose solutions to this technical problem. Instead, engineers directly addressed external criticism of the FBM programme as it appeared, and designed individual solutions to each. An obvious risk was that the overall coherence of the project would suffer, but it allowed

93 "Memorandum for the Chairman, Joint Army-Navy Ballistic Missile Committee", memorandum, log no. 55-2889, 20 December 1955, Digital National Security Archives, NH00549, Washington D.C., 2.

94 SPO, "Polaris Chronology. History of the Fleet Ballistic Missile Weapon System Development Program", 1.

95 See: Sapolsky, *The Polaris System Development*, 14–60.

96 Raborn, interview. During the same interview, Raborn also declared that developing successfully a naval IRBM took the proportion of "evangelic faith."

97 Even Arleigh Burke occasionally contributed to this publication. See: Arleigh Burke, "National Strategic Target List and Single Integrated Operational Plan, Special Edition of Flag Officers Dope", memorandum, 4 December 1960, U.S. Nuclear History, NH00291, DNSA, Washington D.C.

98 Clement Hayes Watson, interview by John T. Mason, 17 November 1972; Raborn, interview.

the FBM programme to survive its detractors, which was *in fine* the principal objective of the SPO.

The main criticism raised against the FBM programme originated from the Navy itself and was the direct continuation of those formulated before the creation of the SPO. Firstly, there were still an important number of Navy leaders who considered Ballistic Missiles as immoral weapons. They were joined in their criticism by naval aviators who feared that developing a new weapons system would have a negative impact on conventional forces and the construction of new aircraft carriers, by taking valuable budgetary resources away.[99] As a former aviator, Raborn took the criticism seriously and addressed the issue personally. He proposed to senior Navy leaders and naval aviators to aim future naval IRBMs at targets of naval interest and at Soviet air defences. This implied that the naval version of the Jupiter system was to be developed with characteristics optimised for counterforce strikes, but it made sense both *vis-à-vis* the Navy's interests and the strategy of massive retaliation. By suppressing air defences deep inland, the naval IRBM would allow carriers at sea to launch their aircraft unopposed over Soviet territory.[100] As the Air Force would also benefit from the destruction of Soviet air defences, it would be possible to execute massive retaliation more effectively and with a higher degree of confidence before ICBMs could be deployed in great numbers. The intention of the SPO to develop a naval IRBM suitable for counterforce strikes was made public when Burke, as Chief of Naval Operations, presented the FBM programme to the House Appropriations Committee for the first time on 6 February 1956, stressing the necessity and the possibility of striking tactical targets.[101]

A second type of criticism against the FBM programme was rooted in the technical challenges implied by the development of naval IRBMs, with the handling of cryogenic fuel being the principal source of concern.[102] The solution proposed by the SPO was to deploy the Jupiter on the easiest sea platform at its disposal. While the Regulus missile could be fired from aircraft carriers, cruisers and submarines, the Jupiter was to be first deployed exclusively on mariner-class cargo

99 Robert Halley Wertheim, interview by John T. Mason, 23 January 1981.
100 Ibid.
101 Burke, Arleigh, "Department of Defense appropriations, 1957", testimony, February 1956, Hearings of the House Armed Service Committee, Washington D.C., 659.
102 Thomas S. Gates, interview by John T. Mason, 3 October 1972; Watson, interview.

ships.[103] The dead-line for the first test launch was 1 January 1960. A hypothetical deployment of ballistic missiles onboard submarines would not occur before 1965, and would only be considered if the experience on surface ships was conclusive.[104]

The new basing plan adopted by the SPO helped to solve problems relative to navigation, communications and launch operations, but did little to address the handling and safety issues raised by cryogenic fuels. However, this problem soon became critical when the Air Force began to attack the FBM programme on the grounds that fuelling an IRBM at sea would take too long and would be too dangerous to have any usefulness.[105] In order to resolve this recurring issue, the SPO decided to exchange the liquid fuel of the Jupiter missile for a solid, storable propellant.[106] The new missile was called Jupiter S – S for "solid". As the SPO had no engineers with a background in solid propellants, the Jupiter S would be powered by an existing technology, a cluster of six small "Big Stoop" sounding rockets.[107] A second stage was added, constituted of a single Big Stoop rocket. However, as the SPO decided to rely on a primitive solid propellant technology, the size and weight of the missile grew to monstrous proportions, and the effective range was likely to be much below the 1,500 miles required by the Killian committee.[108]

At this early stage of the FBM programme, the constraints and requirements placed on the development of a naval IRBM were minimal. The counterforce doctrine selected by the Navy implied that the missile might have to trade some characteristics in order to increase precision as well as command and control communications. However, those problems were still considered to be remote, and in the SPO's

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103 Burke, interview; Ronald J. Kurth, *The Politics of Technological Innovation in the United States Navy*, 239.

104 Fuhrman, "The Fleet Ballistic Missile System: Polaris to Trident": 267.

105 "Minutes of the 4th meeting OSD (Office of the Secretary of Defense), Ballistic Missiles Committee, Held 15 January 1956, in Room 3E912 at 1430", minutes, OSD-BMC ¾, 13 March, 1956, U.S. Nuclear History, NH00557, DNSA, Washington D.C., 2.

106 Sapolsky, *The Polaris System Development*, 27; Spinardi, *From Polaris to Trident*, 28.

107 Sounding rockets are small, low-cost research rockets using solid propellant, typically used to conduct scientific experiments in the upper atmosphere or on sub-orbital flight trajectories.

108 Preliminary studies of the SPO concluded to a missile with a 120-inch diameter and a weight of 160,000 pounds. See: J.D. Hunley, "Minuteman and the development of Solid Rocket Launch Technology", in *To Reach the New Frontier: A History of U.S. Launch Vehicles*, ed. Denis R. Jenkins and Roger D. Launius (Lexington: Univervisty Press of Kentucky, 2002), 241; Sapolsky, *The Polaris System Development*, Wernher Von Braun has been quoted saying that with a cluster of Big Stoop rockets, any IRBM fired from the Atlantic Ocean would not be able to strike targets located further than the Simplon Tunnel between Switzerland and Italy. Not quite the optimal target for a strategy of massive retaliation against the Soviet Union.

perspective, it was considered that with sufficient money and gifted engineers, any problem could be fixed in time.[109] Once again, pragmatism was the key word, and the entire early organisational frame of the FBM programme was well summed up when Raborn declared in anger "I don't care how big and ornery it is, we're gonna take the bastard to sea!"[110]

Table 1: Primitive organisational frame, Jupiter S missile

purpose/goal of the organisation	survival, adapting the Jupiter missile to a naval environment
problems addressed	any bureaucratic or technical critic to the FBM programme
solutions proposed	developing a tactical weapons system able to support carrier groups by striking military targets of naval interest, developing a solid propellant missile
constraints on possible solutions	–

From Jupiter to Polaris

By early summer 1956, the FBM programme began to generate a relative consensus within the Navy. So far, the informal institutions constituting the organisational frame of the programme were relatively limited, but they were flexible and enabled to address the main bureaucratic threats to the programme. The next step for the SPO was to obtain support from policy makers outside the Navy, by explaining the contribution of a Naval IRBM to the strategy of massive retaliation. Indeed, as the FBM programme secured the right to develop a naval version of the Jupiter missile, it was the Jupiter programme itself that became threatened.

In the first place, the Jupiter missile had been launched by the Army to gain a more important role in nuclear warfare. Until 1955, the Army only had control over small, low-yield nuclear weapons that could be used at the tactical level on the battleground, but not to deter the Soviet Union. The purpose of the Jupiter missile was to open the gates of strategic nuclear weapons to the Army, but it had virtually the exact same performances as the Thor IRBM proposed by the Air Force,

109 Raborn, interview.
110 Baar and Howard, *Polaris!*, 52.

placing the whole programme in a delicate situation.[111] As the Air Force began the development of the Thor one year before the Army, it had a decisive lead and would achieve an operational capability first. Furthermore, the Jupiter programme was led by Wernher von Braun and a team of German rocket scientists that conceived the missile as the basis for a future space launch vehicle.[112] The result was a very large weapons system, difficult to transport and to handle, while the Air Force's missile could easily be airlifted to Europe within hours.

As the FBM programme only consisted in adapting the Jupiter to a naval environment, there was little the SPO could do to help the Army securing the whole project. It became progressively apparent that the Army was unable to save the Jupiter missile from the Air Force's attacks.[113] In order to survive and save the FBM programme, the SPO had to end its cooperation with the Army and design a naval IRBM of its own.

To end the collaboration with the Army, the SPO once again proceeded in a very pragmatic manner. During the hot months of 1956, the Navy organised the "Naval Academy of Science", a summer study on anti-submarine warfare. The objective was not to discuss ballistic missiles. However, Edward Teller – the chief designer of the hydrogen bomb – was invited to give a conference about the possibility of replacing conventional warheads placed in depth charges and torpedoes with nuclear ones.[114] Teller first met scepticism, as current nuclear warheads were far too voluminous to fit torpedoes. However, he successfully convinced his audience that smaller warheads in the megaton range would soon be available and criticised the Navy for planning to "put a 1956 warhead in a 1965 weapons system".[115] Vice Admiral Lawson P. Ramage was present and understood immediately the implications for the FBM programme. If a smaller warhead could be utilised, the missile would not only be much lighter, but the quantity of solid propellant required to achieve a given range would be dramati-

111 See: Philip J. Klass, "Hybird IRBM Fight May Fall Into Management, Not Technical Fields," Aviation Week, 24 June 1957; "Why Two IRBMs?", Aviation Week, 25 November 1957.

112 For more details on the Jupiter missile as first step toward the development of space launch vehicles, see: Michael J. Neufeld, *Von Braun: Dreamer of Space, Engineer of War* (New York: Alfred A. Knopf, 2007).

113 Armacost, *The Politics of Weapons Innovation*, 82–128.

114 Spinardi, *From Polaris to* Trident, 29–30. For more details on Teller's work, see: York, *The advisors*.

115 William F. Whitmore, "Military Operation research – A personal Restrospective" *Publications in Operations Research* 9 (1963), 263.

cally reduced.[116] Ramage did not wait for the conference to finish but rushed immediately to report Teller's prediction to Raborn and the rest of SPO. Simultaneously, Raborn was informed that two junior researchers from the Office of Naval Research had achieved a massive breakthrough in solid propellant performances by using an aluminium additive.[117] If Teller was right and if the new solid propellant technology held its promises, a very light IRBM suitable for naval operations – weighing only one third of the Jupiter S – would be within reach within a couple of years.

By September 1956, the SPO had a bureaucratic incentive and a technological opportunity to abandon the Jupiter S and develop a new ballistic missile of its own. The Navy, its mind assuaged by the organisational frame of the SPO, was now ready to support the project and the future of the FBM programme was back in the hands of the National Security Council.[118] However, duplicating the performances of the Thor and the Jupiter was not enough, as the Navy would be confronted with competition from projects that had a two years advantage.

Returning to the basic strategic problems that led to the concept of massive retaliation, Raborn noticed that the issue of keeping defence spending at a low level remained unaddressed by the Air Force and the Army. While the ultimate logic of the Thor and Jupiter missiles was to allow the US economy to save some of the money allocated to conventional defence, both were very expensive weapons systems. On 15 November 1956, Raborn held a long presentation to the Secretary of Defense about the advantages of a small naval IRBM using solid fuel. He concluded his briefing by presenting an expected saving of 500 million dollars.[119] The Secretary of Defense was enthusiastic, declaring "Well Admiral, you've shown me a lot of sexy slides this morning, but I tell you that last slide where you showed that tremendous saving was the sexiest one of all."[120]

With the implicit support of the Department of Defense for the development of a small naval IRBM, the last step for the SPO was

116 Weight is known to have a "multiplier effect" on the range of ballistic missiles: even very slight variations of weight can increase range by several dozens or hundreds of miles.

117 Raborn, interview; Pehrson, interview. See also: Hunley, "Minuteman and the development of Solid Rocket Launch Technology": 241–243.

118 Sapolsky, *The Polaris System Development*, 32–33.

119 Raborn, interview. During this interview, Raborn remembered having presented a saving of 50, not 500 million dollars. While the precise presentation given by Raborn on November 1956 is not available, all declassified minutes of meeting relative to the FBM programme present an estimated saving of half a billion dollars.

120 Raborn, interview; Watson, interview.

to kill the Jupiter programme. Only two days after Raborn met the Secretary of Defense, the Navy voted with the Air Force in the Joint Chief of Staffs against the Jupiter missile.[121] Now, the SPO had free scope. By 8 December, the Department of Defense ordered the FBM programme to terminate all cooperation with the army and to begin the development of a small, solid propellant missile, named Polaris.[122]

Polaris as a weapon of massive retaliation

With the FBM programme having secured relatively strong support from the rest of the Navy and being freed from the tutorship of the Army, the next step for the SPO was to design a missile that would be optimally suited for massive retaliations. Developing a totally new weapons system represented a more complex task than the mere adaptation of an existing missile to the naval environment. With little experience in the general design of ballistic missiles, the FBM programme now faced the challenge of selecting the most suitable missile technologies for national strategy. However, the youth and flexibility of the FBM programme could be used once again to adapt its activities through trial and error. The only difference being that instead of focusing on bureaucratic politics, the FBM programme was now directly addressing the problems posed by US nuclear strategy.

Political opposition to counterforces strikes

Immediately following authorisation of the development of the Polaris missile, the National Security council ordered Raborn to present the new research and development agenda of the FBM programme by 11 January. With only four weeks notice, the presentation given by Raborn was directly inspired by concepts previously developed for the Jupiter S missile. The basic argument developed to convince the National Security Council that the FBM programme was a priority

121 Armacost, *The Politics of Weapons Innovation*, 118. From a bureaucratic perspective, it is interesting to note that the Jupiter missile was eventually not cancelled, but transferred into the hands of the Air Force.

122 Strategic Systems Project Office (SSPO), "FBM Facts/Chronology. Polaris-Poseidon-Trident", rapport, 1990, Natural Resource Defense Council Research Collection, record 431, Box 30, The National Security Archives, Washington D.C., 3.

for national security was that Polaris would perform the same tasks as Jupiter, only more efficiently.[123]

The purpose of the whole FBM programme was described as developing a "smaller, lighter missile" enabling strikes on "a greater choice of targets [...], to wipe out even a very hard target".[124] Despite a few elusive references to the concepts of deterrence and retaliation, the presentation indicated that the FBM programme was only working on three practical problems related to striking military targets. Firstly, in order to obtain the precision required to destroy hard targets, accurate navigation systems had to determine the exact position of the launching ship. Secondly, a procedure to prepare and launch the missile safely and with a "high rate of fire" had to be determined. Thirdly, in order to decide whether or not more missiles should be used against the same set of targets, it would be necessary to assess the probable impact point, to detect if a nuclear explosion occurred in the neighbourhood of the target and to evaluate damages.[125] The solutions proposed by Raborn and the SPO were to convert a civil freighter into a test-bed for navigation equipment, to convert a second ship to practice launch operations, and to develop more advanced command and control communications.[126] In order to provide the precision required by counterforce strikes, the use of a star-tracker allowing accurate navigation by means of one or several star-sightings was considered.[127] Furthermore, better communication assets had to be developed in order to obtain information about target damage. Once again, pragmatism was a key word, and the constraints on potential solutions remained limited to keeping the weight of the missile under 30,000 pounds.

While the presentation given by Raborn stated that the Polaris missile would be "an immediate retaliatory weapon", the National Security Council was left with the feeling that the FBM programme was not entirely framing its activity around the issue of deterrence, as required by the strategy of massive retaliation.[128] From the perspective

123 William F. Raborn, "Presentation to the National Security Council on the Fleet Ballistic Missile Project", presentation, 11 January 1957, U.S. Nuclear History, NH0568, DNSA, Washington D.C., 38–39, and slides no. 1–5.

124 Ibid., 39. So called "hard targets" are military targets which structure have been reinforced to withstand the blast of surrounding nuclear explosions.

125 Raborn, "Presentation to the National Security Council on the Fleet Ballistic Missile Project", 41–42 and slide 3.

126 Ibid., slide 3.

127 Wertheim, interview. For a technical account of star-tracker technology and its early application to ballistic missiles, see: "Stellar-inertial Guidance Reduces Errors", *Aviation Week,* 17 March 1958.

128 Raborn, "Presentation to the National Security Council on the Fleet Ballistic Missile Project", 40.

of the SPO, the concept of retaliation was not necessarily related to deterrence and called for a different set of targets, mainly of a military nature.129 In contrast, other ballistic missile programmes presented that day to the National Security Council were more directly defined as deterrent systems.130 As a result, the FBM programme was given a lower funding priority than any other ICBM and IRBM programme.[131]

Table 2: Aborted counterforce organisational frame, Raborn's presentation to Joint Chiefs of Staff, 11 January 1957

purpose/goal of the organisation	provide a "smaller, lighter missile", with the capability to wipe out "even a very hard target"
problems addressed	1. precision 2. high rate of fire 3. target damage assessment
solutions proposed	1. develop equipments for precise navigation 2. practice high rate of fire 3. develop communication assets
constraints on possible solutions	missile weight under 30,000 pounds

The NAVWAG study

Changing the organisational frame of the FBM programme was not an insoluble problem for the SPO. There had been no sunk costs so far. The characteristics of the Polaris missile had not yet been precisely defined and no production parts had been produced. By chance, only three days after Raborn's presentation, the Naval Warfare Analysis Group (NAVWAG) finished an independent study on the potential contribution of the FBM programme to National Security. The NAVWAG was constituted of a group of civilians formally connected to the Navy but working independently, and had not been implicated in the previous

129 "Proceedings of the Steering Committee of the Polaris-submarine Special Task Group. Second Meeting 24–25 January 1957", minutes, 02075730059, 25 January 1957, U.S. Nuclear History, NH00569, DNSA, Washington D.C., 3.

130 See: "Presentations on the U.S. Ballistic Missiles Programs before the National Security Council, 11 January 1957", report, 11 January 1957, U.S. Nuclear History, NH00568, DNSA, Washington D.C.

131 See: Norton Garrison, "Memorandum for Special Assistant for Guided Missiles, Office of Secretary of Defense, Subj: FBM (Polaris) Priority", memorandum, Op-51/nc – 0089P51, 7 February 1957, personal archive; "Agenda of the 28th meeting OSD Ballistic Missile Committee, to be Held 13 February 1957, in Room 3E131 at 1000 Hours", agenda, OSD-BMC 2/28, 13 February 1957, U.S. Nuclear History, NH00571, DNSA, Washington D.C., 5–6.

activities of the SPO.[132] Its vision of the FBM programme was a radical departure from how the Navy and the SPO had considered ballistic missiles and nuclear warfare until then. Furthermore, it contained all the information needed by the SPO to redefine the organisational frame of the FBM programme.

The main conclusion reached by the NAVWAG study was that the purpose of the FBM programme should be expressed as "a deterrent capability".[133] The goal of the whole programme was therefore to produce a missile capable of destroying "very highly defended population or industrial targets", especially Moscow.[134] The two main problems recognised by the NAVWAG study were the vulnerability of the launching platform and the ability of the missile to produce an adequate level of destruction over the target area.[135] The proposed solution for the vulnerability issue was to develop missiles with a range of 2,500 miles that could be fired from submarines. The implicit logic was that a greater missile range would offer more sea room for the submarine to hide. However, as the development of the FBM programme was an emergency measure, surface ship basing and a minimal range of 1,150 miles were acceptable for initial missiles. In order to provide an adequate level of destruction over the target area, the solution proposed was to develop a warhead with a circular error probable (CEP) of four miles.[136] A yield of one megaton was still considered optimal, however a 0.4 megaton warhead was considered as acceptable for the first generation of missiles. In contrast to what Raborn told the NSC, the NAVWAG study stipulated that "missile characteristics desirable for other targets should be deferred beyond this initial stage".[137] Finally, the main constraint on the development of these solutions was the need to meet the tight schedule imposed by the competition with the Air Force. As a "considerable growth potential" was anticipated, low-performance solutions could be adopted on the first generation of Polaris missiles as interim fixes.[138]

132 Keith R. Tidman, *The Operations Evaluation Group: A History of Naval Operations Analysis* (Annapolis: U.S. Naval Institute Press, 1984), 186.
133 Naval Warfare Analysis Group (NAWVAG), "Study 1, Introduction of the Fleet Ballistic Missile into Service", report, NAVWAG 1, 30 January 1957, U.S. Nuclear History, NH00570, DNSA, Washington D.C., 1.
134 Ibid., 2.
135 Ibid., 2–3.
136 Ibid., 2.
137 Ibid.
138 Ibid., 1.

As a naval aviator, Raborn was reluctant to accept the concepts proposed by the NAVWAG study, as all consideration of supporting aircraft carrier strikes were abandoned. As a very religious individual, using atomic weapons to burn cities, industries and civilians was also in contradiction with his personal ethics. Until late June 1957, Raborn would still make some sporadic comments presenting the Polaris missile as a weapon whose "tactical mission would be to beat down fixed base air and missile defences to pave the way for carrier strikes aimed at mobile or concealed targets".[139] However, the decision to apply the NAVWAG study as the organisational frame of the FBM programme was taken at a higher level. With Raborn's "idealism" blocking any evolution toward the deterrent force sought after in the strategy of massive retaliation, Burke decided to intervene directly. In a memorandum of 15 January 1957, he enforced the NAVWAG study as the new framework of the FBM programme. The purpose, problems and potential solutions outlined in the study were "approved as the basis of Navy planning for the introduction of the FBM into service", and were "specifically applicable to the drafting of the operational requirements, and development characteristics [...] and shall be used as a guideline".[140]

Placed directly under the orders of Burke, Raborn had no choice but to apply the memorandum. In less than two months (February and March), the SPO applied the recommendations of the NAVWAG group to determine the specification of the Polaris missile and draft the first blueprints.[141] The result was a two-stage, very small missile, measuring less than 30 feet, weighting 28,800 pounds, with a range of 1,150 miles and a single warhead of 600 kilotons. The guidance system would be exclusively inertial and was supposed to provide an accuracy of 4-miles CEP. [142] Without the help of a star-tracker, this would be insufficient for striking hardened military targets but precise enough for hitting Moscow. With a flight time of less than fifteen

139 "Navy views Polaris as a Support Weapon", *Aviation Week*, 17 June 1957.

140 Arleigh Burke, "Extract from CNO Memorandum, subj: Introduction of the Fleet Ballistic Missile into Service", memorandum, 15 January 1957, personal archive.

141 SPO, "Polaris Chronology", 4.

142 An inertial guidance system consisting of a stable platform held on a known orientation by three gyroscopes (one by axis), regardless of the movements of the missile. On the stable platform is mounted a set of three accelerometers (one by axis). Knowing the location of the launch platform, position of the missile can be inferred by integrating acceleration along the three axes against time. For more detail on inertial guidance system, see: Mackenzie, *Inventing Accuracy*, especially 1–94.

minutes, a terminal speed several times higher than any surface-to-air missile, Polaris would outclass the most advanced Soviet air defences.

Table 3: Basic organisational frame, NAVWAG study no. 1

purpose/goal of the organisation	providing a deterrent capability
problems addressed	1. vulnerability 2. destruction of urban-industrial targets
solutions proposed	1. sea basing, large patrol areas 2. military payload equivalent to a yield between 0.4 and 1Mt over a 4-miles diameter area
constraints on possible solutions	achieve surface launch capability before 1961

Adjusting Polaris to the strategic environment

The changes imposed by Burke on the FBM programme had not been implemented in vain. In the eyes of Secretary of Defense Thomas Wilson, the new technical characteristics of Polaris made it "a more desirable weapons system", and the FBM programme was attributed the highest priority level for defence spending and industrial procurement.[143] By the summer of 1957, the only task left to the SPO was to complete the development of the Polaris Missile, and carry out some fine tuning to adjust or even attempt to stay ahead of changes in the strategic environment.

The Sputnik years

With the key characteristics of the Polaris defined, the next step for the FBM programme was to define the characteristics of the launching platform. While Burke ordered the SPO to apply the recommendations given by the NAVWAG study, he did not order the organisation to immediately develop a missile launched from submarines. In his memorandum of 15 January, Burke acknowledged that a nuclear ballistic missile submarine (SSBN) would be "the optimum launching vehicle in terms of survival and economy of forces".[144] However, as the achievement of efficient solutions depended on the constraint of meet-

143 Secretary of Defense Charles Erwin Wilson, "Memorandum for the President", memorandum, 7 May 1957, U.S. Nuclear History, NH 00575, DNSA, Washington D.C., 1.
144 Burke, "Extract from CNO Memorandum", 1.

ing a tight schedule, Burke ordered SPO designers and the bureau of ships to determine in the first place "what type of *surface* combatant ship is best suited for task force employment of the FBM".[145] The objective was to achieve a surface launch capability by 1961, and a hypothetical submarine launch capability by 1965, but only if submarine basing would be within the state of the art by then.[146]

However, on 15 May 1957, the USSR began to test fire a new missile design, known as the R-7 rocket. According to US intelligence, the size and flight characteristics of the R-7 seemed to indicate that the USSR was about to achieve the capability of delivering very large nuclear warheads directly over continental America.[147] Soviet progress in rocketry generated the belief in the United States that a "missile gap" existed.[148] It also generated a perception of mutual deterrence, where both sides were prevented from using nuclear weapons because of the threat of annihilation by retaliation in kind.[149] Finally, it threatened the credibility of the strategy of massive retaliation. At a time when the manned bomber was still the backbone of US nuclear forces, a surprise R-7 attack on mainland and overseas bases could leave the country with extremely limited retaliatory power.[150]

In order to propose a useful contribution to national security and support the credibility of the strategy of massive retaliation, ballistic missiles under development had to be *invulnerable* to a Soviet surprise attack. The solution proposed by the Air Force was to conceal mis-

145 Burke, "Extract from CNO Memorandum", 1. Emphasis added.

146 SPO, "Polaris Chronology", 5.

147 On American intelligence monitoring Soviet ICBM tests, see: Donald MacKenzie, "The Soviet Union and Strategic Missile Guidance", *International Security* 13, no. 2 (1988): 5–54; Mackenzie, *Inventing Accuracy*, 299–303.

148 On the reaction of the Eisenhower administration to the R-7 rocket and the alleged missile gap, see: "Memorandum of Conference with the President, November 4, 1957", memorandum, 6 November 1957, Nuclear History Program Collection, box 1, The National Security Archives, Washington D.C. See also: Peter J. Roman, *Eisenhower and the Missile Gap* (Ithaca: Cornell University Press, 1995).

149 While the USSR detonated a nuclear device for the first time on 29 August 1949, Soviet capabilities to delivery vehicles were very scarce and their capabilities limited until the R-7 became operational. First, Soviets lacked long range bombers in adequate numbers. Second, U.S. Air Force officers planned to use a fraction of their nuclear arsenal to destroy Soviet bombers on the ground. As General Curtis Le May put it: "If I see that the Russians are amassing their planes for an attack, I'm going to knock the shit out of them before they take off the ground". Quoted in: Kaplan, *The Wizards of Armageddon*, 134.

150 This issue was anticipated as soon as 1954, but failed to attract decisive attention from policy makers until the Soviet Union began flight testing its first R-7 rockets. See: Hoffman et al., "Selection and Use of Strategic Air Bases", report R-266, 1954, RAND, Santa Monica.

siles in hardened underground silos.[151] The Navy, however, was in a more delicate situation. In 1946 and 1955, two campaigns of nuclear tests – operations Crossover and Wingwam – demonstrated that once located, surface units and SSBNs were vulnerable even to relatively imprecise and low yield weapons.[152] However, at that point, the SPO had invested little in research and development activities concerning surface basing of the Polaris missile. A second-hand freighter had been bought in January, but its main purpose was to test navigation equipments, and the characteristics of an operational platform remained to be defined.

With the recent tensions generated by Raborn's presentation still in mind, the SPO did not wait for political pressure to include the problem of vulnerability in the organisational frame of the FBM programme. Considering the conclusions of the NAVWAG study, SSBNs were determined as being the most survivable launch platform. Their mode of propulsion allowed them to remain hidden underwater until food provisions and human endurance were exhausted. While there were still concerns about whether or not launching a ballistic missile from a submarine was within the state of the art, the SPO took immediate and pragmatic action. To pre-empt the critics of the National Security Council and the Department of Defense about the vulnerability of the Polaris missile, the SPO did not design a new SSBN but proposed to adapt a nuclear powered submarine already in construction and to place sixteen Polaris in it amidships. By 18 June 1957, the characteristics of the SSBN were set definitely, more than three months before the original schedule. Accordingly, by 1 July Burke was able to reduce the development programme for the submarine basing of the Polaris missile by two years. It was due to be commissioned by 1 January 1963.[153]

The choice of accelerating the development of a submarine launch platform for the Polaris missile proved to be a wise move. On 4 October 1957, an R-7 rocket placed "Sputnik", the first manmade earth satel-

151 See: Major General Jacob E. Smart, "Plan for Decreasing the Vulnerability of the Strike Force", memorandum, 17 January 1959, Fred Kaplan Collection 80, box 1, The National Security Archive, Washington D.C.; Jerome B. Wienser, "Vulnerability of ATLAS Missile Sites", memorandum K-S-8199, 3 December 1959, Nuclear History Program Collection, Box 2, The National Security Archives, Washington D.C.; "SAC Shapes Missile Force for Survival", *Aviation Week*, 20 June 1960.

152 See: Samuel Glasstone and Philip Dolan, "Shock Effects of Surface and Subsurface Bursts", report, 1977, *The effects of nuclear weapons*, US Department of Defense, Energy Research and Development Administration, Washington D.C.

153 SPO, "Polaris Chronology", 4.

lite, into orbit. This event triggered panic among US political elites.[154] In the context of the coming 1960 election, the Democratic Party exaggerated the importance of the missile gap and put pressure on the Eisenhower administration to close it by accelerating the development of invulnerable ballistic missiles.[155] With already four months of research and development activities regarding SSBN basing for the Polaris missile, the SPO was in a good position to answer the call. During November, mock-ups of the Polaris missiles were fired from a fixed underwater tube to demonstrate the feasibility of the project.[156] On 26 November, key decision makers were informed that an operational Polaris missile could be embarked onboard submarines as early as October 1960.[157] The interim solution of placing ballistic missiles onboard surface units was discarded. By 9 December, the Secretary of Defense accepted the development plan of the FBM programme. He ordered to proceed directly and with maximum priority the commissioning of the first generation of Polaris missiles and tripled the programme funding accordingly.[158]

Submarine communications

While adapting the FBM programme to address the challenge of survivability had been a relatively painless process, it placed important constraints on the solutions proposed for other components of the Polaris system, especially on control and communications assets. As radio waves only superficially penetrate the surface of the oceans, communications with SSBNs on patrol were difficult. Furthermore, two-way communications implied that submarines would emit radio waves, thus revealing their position to enemy units equipped with direction-finding equipment. Exotic solutions were considered, but were

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154 See: "Implications of the Soviet Earth Satellite for U.S. Security", memorandum NSC 5520, 18 November 1957, Nuclear History Program collection, box 1, The National Security Archive, Washington D.C.; CIA, "Main Trends in Soviet Capabilities and Policies, 1957–1962", National Intelligence Estimate NIE 11-4-57, 11 December 1957, Nuclear History Program Collection, box 2, The National Security Archives, Washington D.C.

155 Christopher A. Preble, "Who Ever Believed in the Missile Gap? John F. Kennedy and the Politics of National Security", *Presidential Studies Quarterly* 33 (1983): 801–826.

156 "Polaris Begins Underwater Tests", *Aviation Week*, 4 November 1957.

157 SPO, "Polaris Chronology", 5.

158 This decision is quoted in: "Comments and Recommendations on Report to the President by the Security Resources Panel of the ODM (Office Defense Mobilization) Science Advisory Committee", report to the National Security Council NSC-5724/1, 16 December 1957, U.S. Nuclear History, NH00407, DNSA, Washington D.C., 19. See also: SPO, "Polaris Chronology", 5; "Boost for Polaris", *Aviation week*, 28 October 1957. For more details on the acceleration of the FBM program after the launch of the first earth satellite by the Soviet Union, see: Burke, interview; Gates, interview.

almost immediately rejected.[159] In case of failure, the development of uncertain technologies would jeopardise the entire programme, and the problem of communications subsequently threatened to become the "Achilles heel of the entire Polaris operation".[160] Accordingly, virtually no research and development activities were conducted by the SPO, and submarines would have to rely on existing technology consisting of random wire antennas trailed right below the surface of the ocean.[161] This system was considered relatively unreliable, and Burke decided that each SSBN crew must "not only use direct data from its commanders in the United States", but also would "get the dope", or in other words, "listen to several news stations [in order to figure if] the Soviets have attacked the United States".[162]

In a new study published in November 1957, the NAVWAG group proposed to turn the constraints on control and communications assets into an advantage for the FBM programme by seeking support from those who were criticising the logic of massive retaliation.[163] In the context of mutual deterrence implied by the R-7 rocket, the threat of camping out massive retaliation was no longer credible against limited Soviet provocations because it would imply that the United States would suffer intolerable destruction by retaliation in kind. Scenarios for more progressive retaliations were proposed by the Air Force, but were unpractical. Indeed, if command and control centres were destroyed during the first hours of a nuclear exchange, there would be no means of controlling conflict escalation and termination. By relying on news channels as much as on direct orders, SSBNs were less affected by this problem, as submarine commanders could receive orders prior to departure to stop retaliations if means of surrender was heard over the radio.

Another important shortcoming of the strategy of massive retaliation was that virtually all nuclear weapons would be delivered at once. With its urban centres totally destroyed, and no more nuclear attack to fear, the Soviet Union would have nothing to lose in push-

159 John Buescher, interview by John T. Mason, 4 March 1982. Morse code by underwater explosions and permanent connections between submarines and their bases by the means of a coop wire were initially considered.
160 Quoted in: Sapolsky, *The Polaris System Development*, 238. Watson, interview.
161 Spinardi, *From Polaris to Trident*, 81.
162 Burke, interview.
163 NAVWAG, "Study 5, National Policy Implications of Atomic Parity (u) (Revised)", report NAVWAG 5, 20 November 1957, U.S. Nuclear History, NH00094, DNSA, Washington D.C.

ing forward the attacks it started in the first place.[164] In contrast, the invulnerability of SSBNs and the relative independence from command and control centres would allow for a low rate of fire retaliations, possibly extended over several weeks. This was the reasoning of "torturing the opponent", by burning its civilians when they would leave atomic shelters after each previous attack.[165] As "people could not live out their life in shelters", slow rate of fire retaliations would "force the aggressor [the Soviet Union] to capitulate, to surrender his remaining stockpile, to change his form of government, to renounce any gains from his aggression, and to assist his erstwhile victim in reconstruction".[166]

Table 4: Basic organisational frame, NAVWAG study no. 5

purpose/goal of the organisation	providing a deterrent capability
problems addressed	1. vulnerability 2. destruction of urban-industrial targets
solutions proposed	1. SSBN basing, large patrol areas 2. military payload equivalent to a yield between 0.4 and 1Mt over a 4-miles diameter area
constraints on possible solutions	achieve submarine launch capability before September 1960, communication systems excluded from the research agenda

From a counterforce organisational frame that held the bombing of cities as immoral to a deterrent frame that explicitly argued in favour of torturing civilians, the FBM programme had come full circle. This illustrates not only the capability of the SPO to efficiently adapt to its strategic and bureaucratic environment in order to produce and to survive, but also demonstrates how open the opportunity set was during this critical juncture. After a difficult birth, the FBM programme was now called a "sound concept" and found wide support from policy makers (both supporters and critics to the strategy of massive retaliation) and the Navy.[167] During the years 1958 and 1959, virtually no modifications were applied to the organisational frame of the FBM programme. Engineers developed the solutions established after the two

164 For instance, it is not the atomic bombings of Hiroshima and Nagasaki *per se* that forced Imperial Japan to capitulate, but the threat of *further* nuclear attacks.
165 NAVWAG, "study 5", 26.
166 Ibid., 26.
167 "Polaris on Submarine Called Sound Concept". *Aviation Week*, 25 November 1957.

NAVWAG studies and Burke secured the funding of the programme by presenting its purpose, problems and potential solutions in numerous classified and public presentations.[168] By 15 October 1960, Polaris A-1 became operational when the nuclear powered submarine USS George Washington departed for its first operational patrol with 16 missiles on board.[169] The organisational frame of the FBM programme had allowed the SPO to successfully develop a challenging military technology – the naval IRBM – and policy makers to obtain a weapons system ideally suited for their strategic need. In the next chapter, we shall see how the development of successors to the original Polaris A-1 missile contributed to solidify the framework that shaped the development of new missiles within the FBM programme.

168 For examples, see: Arleigh Burke, "Remarks by Admiral Arleigh Burke, USN, Chief of Naval Operations, at the Secretaries Conferences", speech, 21 June 1958, Operational Archives, Arleigh Burke papers, Command Files post 1 Jan 46, off box, Naval Historical Center, Washington D.C.; Arleigh Burke, "Address by Admiral Arleigh Burke, USN, Chief of Naval Operations Before the Air War College – Maxwell Air Force Base, Alabama", speech, 22 May 1958, Operational Archives, Arleigh Burke papers, Command Files post 1 Jan 46, off box, Naval Historical Center, Washington D.C.; Arleigh Burke, "Address by Admiral Arleigh Burke, USN, Chief of Naval Operations before the San Jose State College, California", Department of Defense press release no. 237–60, 4 March 1960, Operational Archives, Arleigh Burke papers, Command Files post 1 Jan 46, off box, Naval Historical Center, Washington D.C.

169 SPO, "Polaris Chronology", 5.

Chapter 4

Technology and path dependence

Sunk costs

When Polaris A-1 first became operational at the end of 1960, the FBM programme had reached the term of its initial mission. Originally, the SPO was only supposed to design a naval IRBM and its corresponding launch platform, to test these elements and produce an original batch of 205 missiles. Once this mission was completed, the FBM programme would be disbanded and research and development activities redistributed among other bureaus of the Navy.[170] However, because of its early commissioning, Polaris A-1 was only an interim weapons system, far from the ultimate objective of a 2,500 mile range and one megaton yield set by the NAVWAG studies. Accordingly, work on possible improvements for the original missile began even before Polaris A-1 became operational, and the FBM programme was allowed to survive, at least until a missile with optimal performance was commissioned.

The decision to develop an improved version of the original Polaris missile was taken simultaneously with the decision to accelerate the FBM programme after the launch of an earth satellite by the Soviet Union.[171] The rationale for this decision was simple. Polaris A-1 was a crash programme, an interim weapon, and therefore "performance was a manipulatable variable".[172] In contrast, for improved versions of the Polaris missile, schedule was not paramount and performance more

170 Sapolsky, *The Polaris System Development*, 214–15.
171 SPO, "Polaris Chronology", 5.
172 Sapolsky, *The Polaris System Development*, 141.

important. The objective was that by 1962, a range and destructive power closer to the original recommendations of the TCP would be on offer. Meeting the maximum performances recommended by the NAVWAG studies was not an immediate objective, but ear-marked for a third follow-on missile.

Polaris A-2: "a minimum change concept"

Despite a relatively relaxed time schedule, the SPO did not have completely free scope to develop a successor to the original Polaris A-1 missile. Eisenhower's ambition to reduce the defence budget and achieve an arms control agreement with the USSR did not generate a strong interest for an immediate follow-on missile.[173] Primarily concerned with limiting military spending, the administration called for a new missile with "minimum change concepts," or best, for a missile that "didn't require new concepts at all".[174] Developing a brand new missile and relying on innovative technical solutions was not an option.

The demand of policy makers to reutilise existing solutions for a new missile placed the SPO in a delicate situation. With limited funding to improve Polaris A-1, the organisation faced, for the first time, the issue of sunk costs. As significant sums had been invested in solutions such as solid propellant or missile warheads, developing new technologies was difficult. In this context, the SPO decided to base its new submarine-launched ballistic missile (SLBM) on Polaris A-1 blueprints, and only improved discrete components of the missile.[175] This improved weapons system, named Polaris A-2, therefore prolonged not only the solutions but also the technologies that characterised the organisational frame of the FBM programme.

Two types of technologies were particularly affected by the mechanism of sunk costs. Firstly, to improve performances regarding anti-city retaliation, the SPO decided to improve nuclear yield. However, since the United States was observing a moratorium on nuclear tests, developing a new warhead appeared risky and costly.[176] Instead, the SPO decided to conserve the same warhead as previously selected for Polaris

173 See: Roman, *Eisenhower and the Missile Gap*.
174 Buescher, interview.
175 Ibid.
176 On the 1958 moratorium and the 1963 Partial Test Ban Treaty, see: Benjamin P. Greene, *Eisenhower, Science Advice, and the Nuclear Test-ban Debate, 1945–1963* (Stanford: Stanford University Press, 2007), Robert A. Divine, "Early Record on Test Moratoriums", *Bulletin of the Atomic Scientists* 42, no. 5 (1986): 24–26.

A-1. A minor improvement in the quality of the uranium tamper of the warhead made it possible to achieve a yield of 800 kilotons.[177]

Secondly, the issue of sunk costs also determined which type of propulsion system was to be used for Polaris A-2. Concerning the problem of survivability, limited funds prevented the SPO from considering new basing modes or investigating technologies to significantly increase the submarines' stealth properties. However, missile range could be improved at relatively low cost by reducing inert weight and improving the propulsion of Polaris A-1.[178] Therefore, the SPO was left with no other solution but to increase range to provide SSBNs greater patrol areas to increase the survivability of the SLBM force, a solution previously identified by the NAVWAG studies.[179] Shortly after the SPO began the development of the Polaris A-1 missile, safe and storable liquid fuels suitable for naval operations had become available.[180] Known as hypergolic fuel, this new technology presented a higher specific impulse, – that is better performances – both at the theoretical and practical level.[181] However, since 1956, significant funds had been invested in developing solid propellants, and this field had become a recognised speciality of the SPO.[182] As Polaris A-2 was a minimal change concept, switching back to liquid fuels did not figure as a solution for the SPO.

Instead, the propulsion system adopted for Polaris A-2 entailed virtually no development costs. During the development of the A-1 missile, an alternative type of solid propellant had been investigated by the SPO as a back-up solution, should the main propulsion project fail. But the backup propellant turned out to perform better, and while it could not be tested in time for Polaris A-1, it was decided for use in the second stage of Polaris A-2.[183] As the organisation was reluctant to change too much of the Polaris missile at once, it was decided that

177 [Jane's], *Weapon systems 1969–70*, ed. R.T. Pretty and D.H.R. Archer (Jane's yearbooks, 1969), ref. 1130.411.
178 Spinardi, *From Polaris to Trident*, 63–65.
179 NAVWAG, "Study 1", 2–3.
180 By the time the SPO proceeded to the development of Polaris A-2, hypergolic fuels were tested for the Air Force's Titan II ICBM, and were already successfully deployed on the Soviet Navy's R-21 SLBM. See: Podvig and Bukharin, *Russian Strategic Nuclear Forces*, 315–19.
181 On liquid fuels and solid propellant performances, see: George P. Sutton, *Rocket Propulsion Elements* (New York: Wiley, 2001).
182 The reputation of the SPO in this field was such that he Air force attempted to get implicated in the activities of the FBM programme when developing the solid propelled Minuteman ICBM. See: Hunley, "Minuteman and the development of Solid Rocket Launch Technology", 229–300.
183 Spinardi, *From Polaris to Trident*, 64.

this more effective – but unproven – propellant was not to be used for the first stage of the new missile. Instead, an ordinary Polaris A-1 first stage was used, but stretched by three feet, just enough to achieve a range of 1,500 miles.[184] This low-cost development policy proved successful when Polaris A-2 was commissioned on June 26, 1962, with range and yield exactly matching the requested performances.[185]

Polaris A-3: getting deeper into sunk costs

The sunk costs of previous research and development activities were further reinforced by the development of a third generation of Polaris missile, known as Polaris A-3. In November 1960, one of the last decisions of the Eisenhower administration regarding the FBM programme had been to order the development of a third version of the Polaris missile, meeting the highest performance objectives recommended by the NAVWAG studies (range 2,500 miles, yield one megaton).[186] As its predecessor, Polaris A-3 was to be a minimal adaptation of existing technologies.[187] To improve missile range and nuclear yield at low costs, a scaled-up version of Polaris A-2 represented the most straightforward approach. However, the Navy had already invested in a large fleet of SSBNs, so Polaris A-3 had to fit within the launch tubes of existing submarines.

Achieving a range of 2,500 miles and a yield of one megaton without increasing missile size proved to be a tough challenge for the SPO. The 1958 moratorium on nuclear tests and the 1963 Partial Test Ban Treaty prevented the development of new nuclear ordnance and the warhead design used for Polaris A-1 and Polaris A-2 had reached its theoretical limits.[188] Furthermore, the SPO proved unable to develop a new solid propellant able to provide a range of 2,500 miles.[189] In order to meet requested performance objectives, it became obvious that

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184 "Missiles 1962", *Flight International*, 8 November 1962, 748.

185 SPO, "Polaris Chronology", 12.

186 Ibid., 9.

187 Buescher, interview.

188 On the 1958 moratorium and the 1963 Partial Test Ban Treaty, see: Greene, *Eisenhower, Science Advice, and the Nuclear Test-ban Debate, 1945–1963*; Divine, "Early Record on Test Moratoriums", 24–27.

189 Confident that the new propellant developed for Polaris A-2 had demonstrated sufficient reliability during flight tests, the SPO decided to improve slightly its formulation and used it for both stages of Polaris A-3. However, the larger volume of propellant led to an unacceptable increase of pressure and temperature in the engine of the first stage. After a nozzle broke down during a ground test of Polaris A-3, the formulation of the propellant had to be reduced. See: SPO, "Proceedings of the Special Project office. Task II – 29th Meeting, Monitor and sponsor the Fleet Ballistic Missile Development Program", minutes STG task II-29, 29 January 1962, Nuclear History Collection, NH 00745, DNSA, Washington D.C., 27–29.

the FBM programme would have to find a cheap way to develop new technologies for Polaris A-3. Because of the sunk costs of solid propellant, the SPO refused to switch to liquid fuel. Instead, the organisation decided to distribute the payload of Polaris A-3 among three smaller warheads.[190] This solution relied on a conceptual trick, but made it possible to improve range and yield while keeping other solutions developed for Polaris A-1 and A-2 intact, including the propulsion system.

Regarding the objective of achieving a one megaton yield, the concept of multiple warheads relied on an intriguing property of nuclear effects against non-hardened targets. As the yield of devices tested before the 1954 moratorium increased, the radius of blast damages did not follow on a one-to-one ratio, but was equal to only 2/3 of the yield progression.[191] The reduction in blast damage efficiency was measured in terms of equivalent megatonnage (EMT). One of the important conceptual implications of this phenomenon was that against soft targets – and soft targets only – several "small" nuclear warheads have a higher destructive power than a single large, high-yield weapon. For the SPO, the discovery of the equivalent megatonnage effect represented an excellent occasion to avoid the cost and technological risk of developing a new high-yield warhead. As a small backup warhead with a yield of 200 kilotons had been tested before the moratorium, the SPO decided to use three multiple re-entry vehicles (MRV) based on this existing design for Polaris A-3.[192] Providing a yield of 600 kilotons, this combination made it possible to reach approximately the equivalent megatonnage of a single one-megaton weapon (660 kilotons).[193]

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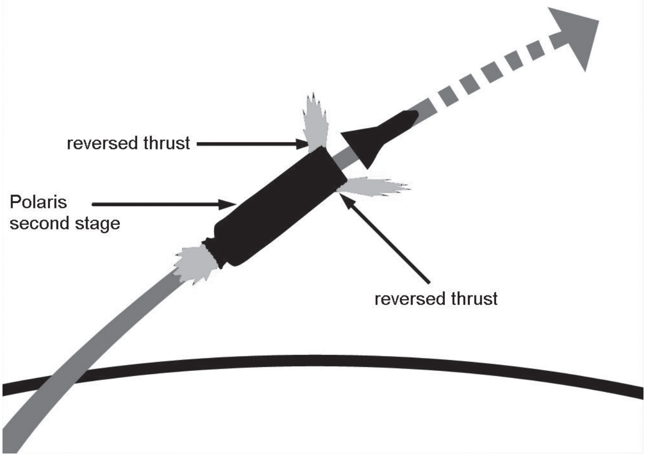
190 Spinardi, *From Polaris to Trident*, 67.

191 Robert Erhlich, *Waging Nuclear Peace: The Technology and Politics of Nuclear Weapons* (Albany: State University of New York Press, 1985), 73–79.

192 For a discussion of the MRV system developed for Polaris A-3, see: SPO, "Proceedings of the Special Project office. Task II – 37th Meeting, Monitor and sponsor the Fleet Ballistic Missile Development Program", minutes STG task II-37, 24 May 1963, Nuclear History Collection, NH 00763, DNSA, Washington D.C., 117–142.

193 Spinardi, *From Polaris to Trident*, 67.

Fig. 2: Thrust termination system



With regard to range objectives, multiple warheads contributed towards reducing inert weight in three different ways. Firstly, because of the equivalent megatonnage effect, multiple warheads had a much better yield-to-weight ratio than a single nuclear weapon. Secondly, multiple warheads eliminated the need for a heavy thrust termination system. As solid propellant rockets could not be throttled back or shut down, the second stage of Polaris A-1 and A-2 was equipped with vents at its upper end. Blowing up the vents would briefly invert the thrust and produce a short backward momentum, allowing the warhead to separate from its booster (see figure 2.1.3-1).[194] On Polaris A-3 however, small-size warheads could be ejected laterally, allowing the second stage to pursue its flight on a trajectory between the three warheads until burnout (see figure 5.1.3-2).[195] The need for a heavy thrust termination system was eliminated. Thirdly, Multiple Warhead technology improved accuracy. As warheads were released at a more precise velocity and avoided interference with hot gas emissions from the thrust termination system, the circular error probable was reduced.[196] This effect was first unexpected, but it gave Polaris A-3 an excellent

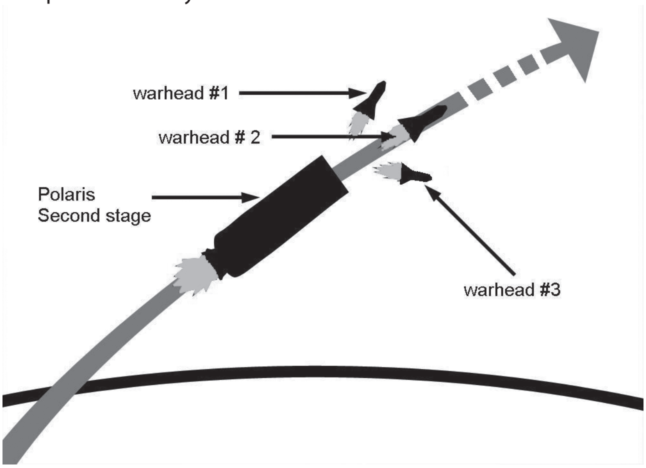
194 For a more precise description of thrust termination systems see: Sutton and Biblarz, *Rocket Propulsion Elements*, 9, 526–27.

195 SPO "Proceedings of the Special Project office, Task II – 37th Meeting", 117–135. See also: Chuck Hansen, *U.S. Nuclear Weapons: The Secret History* (New York: Orion Books, 1988), 205; Spinardi, *From Polaris to Trident*, 68; Mackenzie, *Inventing Accuracy*, 259.

196 Avoiding interferences with hot gas emissions from the thrust-termination system essentially improved down-range accuracy, or in other words, reduced the chances that the warhead fell short or too wide of its intended target. Improving down-range accuracy was particularly welcome because this was the most important source of inaccuracy for Polaris A-1 and A-2. Jack W. Dunlap, interview by John T. Mason, 2 October 1972.

accuracy of 0.5 miles which could be used to relax the size and weight of the inertial guidance system.[197]

Fig. 3: Multiple warhead system



As for Polaris A-2, the inexpensive development policy selected by the SPO for Polaris A-3 proved successful. On 28 September 1964, the missile became operational when the USS *Daniel Webster* left for patrol area with 16 missiles onboard.[198] With an equivalent megatonnage roughly equal to a single megaton warhead and a range of 2,500 miles, Polaris A-3 met the highest objectives set by the NAVWAG studies and represented the ultimate version of the Polaris missile.

To reflect this important range improvement, the expression "naval IRBM" disappeared in favour of "submarine-launched ballistic missile" (SLBM). However, this success came at a price for the FBM programme. The development of Polaris A-2 and A-3 had significantly increased the sunk costs introduced during the initial development of the original Polaris A-1 missile. For the first time, the development of relevant technologies within the FBM was not only affected by the strategic or bureaucratic environment, but also by previous choices made by the SPO. Solutions that were initially considered as interim

197 Mackenzie, *Inventing Accuracy*, 429. Originally, Polaris A-3 had a CEP of 1.2 mile. However, during a set of flight tests, the SPO used a different – and more favourable – method of calibration for monitoring instruments. Consequently, it is difficult to assess precisely the actual accuracy of the missile. See: SPO, "Proceedings of the Special Project office. Task II – 46th Meeting, Monitor and sponsor the Fleet Ballistic Missile Development Program", minutes STG task II-46, 19 November 1964, Nuclear History Collection, NH 00796, DNSA, Washington D.C., 84–85.

198 SPO, "Polaris Chronology", 16.

fixes were now included as basic features of SLBMs. Moreover, while the MRV technology utilised on Polaris A-3 incurred modest development costs compared to a radical shift in missile design, it still introduced new sunk costs, and increased the commitment to the general design of the original Polaris missile.

Organisational knowledge

During the development of Polaris A-2 and A-3, the evolution of US nuclear strategy contributed to reinforce the specialisation of the FBM programme on issues related to deterrence and anti-city retaliations. As policy makers proposed incentives encouraging the FBM programme to repeatedly address these issues, the strategic purpose of the programme began to be ritualised by members of the SPO. Once an important field of research, the issue of counterforce strikes was now on the point of being excluded from the competences of the FBM programme.

The strategy of flexible response and the FBM programme

On 20 January 1961, John Fitzgerald Kennedy was inaugurated as President of the United States. In contrast to Eisenhower, who worked toward a reduction of military spending, Kennedy believed that a massive arms build-up was necessary to close the missile gap, and turned this idea into his main campaign argument.[199] After only nine days in office, he ordered a dramatic acceleration of the FBM programme.[200] Indeed, Robert McNamara, the new Secretary of Defense, had both a new nuclear strategy for the United States as well as a precise idea of what the FBM programme should contribute.

McNamara's central criticism of the strategy of massive retaliation was that it was "too drastic for use except in extreme circumstances," and therefore that "most communist challenges could not be resisted".[201] The retaliatory power conferred upon the Soviet Union by its new ICBM capability would deter the United States from using nuclear weapons. Therefore, Soviet leaders could slowly attack US interests by limited but repeated provocations – a strategy which Kennedy

199 Preble, "Who Ever Believed in the Missile Gap? John F. Kennedy and the Politics of National Security".
200 SPO, "Polaris Chronology", 10.
201 Lawrence Freedman, *The Evolution of Nuclear Strategy* (London: Macmillan, 1981), 218.

himself called "Sputnik diplomacy".[202] Instead, McNamara proposed a strategy of *flexible response* which would make it possible to deter even limited Soviet attacks on US interests, by developing capabilities to respond to any provocation across the spectrum of conventional and nuclear warfare. The strategy of flexible response envisaged three levels of reaction to the Soviet threat. Firstly, limited provocations and conventional attacks on allied countries would be deterred (or fought) by conventional forces.[203] The second level of reaction implied the use of nuclear weapons, but in a rather limited and controlled way, rather than the all-out attack planned by Eisenhower and Dulles.[204] The third level of reaction was supposed to deter the most critical threat to US interests, a massive nuclear attack on American urban-industrial centres. In this scenario, the United States would use the full strength of its nuclear arsenal to perform retaliatory strikes over the Soviet Union.[205]

The doctrine implied by the strategy of flexible response relied on two opposed, but complementary concepts. Firstly, *city-avoidance* implied that in the first stages of a nuclear war, Soviet military forces and assets would be targeted, but not civilian areas. This point was made publicly in a speech given by McNamara on 16 June 1962 at the University of Michigan: "The principal military objectives, in the event of a nuclear war stemming from a major attack on the alliance, should be the destruction of the enemy's military forces, not of his civilian population."[206] The rationale behind this argument was not to win the war, but to maintain an element of deterrence even after the war was declared, by giving the Soviet Union "the strongest imaginable incentive to refrain from striking our own [US] cities".[207]

The opposite, but complementary idea was that of *mutual assured destruction*. If the Soviet Union did not spare American urban

202 John F. Kennedy, *The Strategy of Peace* (New York: Harper & Brothers, 1960), 37.

203 Secretary of Defense Robert S. McNamara, "Remarks of the Secretary of Defense At the University of Michigan, Ann Arbor, Michigan", Department of Defense Press Release no. 980–62, 16 June 1962, Fred Kaplan Collection 80, box 2, The National Security Archive, Washington D.C., 8; Robert S. McNamara, "Statement of the Secretary of Defense before the Senate Subcommittee of Department of Defense Appropriations, the Fiscal Year 1936–67, Defense Program and 1963 Defense Budget", statement, 14 February 1962, Nuclear History Collection, NH00439, DNSA, Washington D.C., 7–10, 41–87.

204 See: "Procedures for Nuclear Weapons Use", National Security Action Memorandum NSAM-122, 16 January 1962, Presidential Directive Collection, PD00793, DNSA, Washington D.C.

205 "Proposed Policy Directive: Military Elements of National Security Policy", memorandum, I-18802 (draft), 18 July 1961, Nuclear History Collection, 00151, DNSA, Washington D.C., 5.

206 McNamara, "Remarks of the Secretary of Defense at the University of Michigan, Ann Arbor, Michigan", 9.

207 Ibid., 10.

centres, the United States would retaliate "from the grave" and eradicate the demographic and economic substance of the communist bloc. Nevertheless, even in this ultimate scenario, the role of strategic nuclear weapons was slightly different to that on which the strategy of massive retaliation rested. Indeed, McNamara considered that even the most destructive nuclear exchanges would end up in a process of political bargaining.[208] Holding some of the enemy's urban centres hostage was supposed to provide a better position for negotiations than a situation in which all Soviet cities and civilian assets had been previously destroyed.

Taken as such, the strategy of flexible response offered the FBM programme as many incentives to address problems attached to counterforce strikes as to stay with the heritage of the NAVWAG studies. However, from McNamara's perspective, the ultimate threat of mutual assured destruction was the keystone of the architecture of the strategy of flexible response.[209] As the strategic forces used for threatening Soviet cities would have to be available after a potentially prolonged conflict that had escalated across the spectrum of warfare – including extended nuclear exchanges – the need for more survivable retaliatory weapons systems was obvious. With its airfields and ICBM bases relatively vulnerable, the long-term survivability of the Air Force's nuclear weapons was in doubt.[210] In contrast, the FBM programme was considered to be the best solution available in a short-term perspective. This point of view was shared by McNamara who stressed that "Polaris [...] because of its especially invulnerable nature is well suited to serve as strategic reserve force".[211] Therefore, the strategy of flexible response prolonged the original goal of the FBM which was already "to provide a deterrent capability".[212]

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208 Freedman, *The Evolution of Nuclear Strategy*, 10; William W. Kaufmann, *The McNamara Strategy* (New York: Harper & Row, 1964), 75.

209 McNamara's emphasis on mutual assured destruction is sometimes presented as the result of the hostility of the public opinion toward the concept of city-avoidance. In addition, alternative accounts of US nuclear strategy stress that despite the "no-city" concept introduced by Robert McNamara, the actual target of US nuclear forces was remarkably stable during this period. For more details, see: Freedman, *The Evolution of Nuclear Strategy*, 215–42; Scott D. Sagan. *Moving Targets: Nuclear Strategy and National Security* (Princeton: Princeton University Press, 1989).

210 Kaplan, *The Wizards of Armageddon*, 254–55. About the lack of confidence of the Air Force in the survivability of its missile force see: General Thomas Power, "Letter to General Curtis E. LeMay, Chief of Staff", letter, 1 May 1962, U.S. Nuclear History, NH00074, DNSA, Washington D.C.

211 McNamara, "Remarks of the Secretary of Defense at the University of Michigan, Ann Arbor, Michigan", 11.

212 Quoted from: NAWVAG, "Study 1", 1.

The new strategy also confirmed and reinforced the main problems addressed by the FBM programme during the development of Polaris A-1. Indeed, implicit to the objective to develop deterrent reserve force was the problem of enabling SSBNs and their missile payload to survive extended nuclear exchanges or anti-submarine warfare operations conducted by the Soviet Navy. Moreover, the concept of mutual assured destruction implied that the problem of producing maximum destruction of urban-industrial areas of the communist bloc was more important than ever.

To ensure that the FBM programme would durably frame its activities around the concept of mutual assured destruction and not city avoidance, McNamara added financial incentives. While denying the Air Force the necessary funds to develop the XB-70 counterforce bomber, the Department of Defense allowed seven different budget extensions to the FBM programme between 1960 and 1964, in order to commission new submarines and allow the SPO to complete the development of Polaris A-2 and A-3.[213] In consequence, retaining the organisational frame established during the development of Polaris A-1 made sense for the FBM programme both with regard to the strategic environment and from the perspective of the budgetary competition between the Navy and the Air Force.

Losing track of counterforce

The financial incentives placed by Robert McNamara on the FBM programme to pursue the development of purely deterrent anti-city SLBMs, had a strong impact on the research agenda of the SPO. Officially, the organisation had abandoned all research on counterforce strikes in the beginning of 1957, when the recommendations of the first NAVWAG study were adopted as the basis for the development of Polaris A-1.[214] However, until 1962, counterforce issues continued to be studied as a small backup project, should US nuclear strategy change and abandon the concept of anti-city retaliations. This decision was characteristic of the pragmatism of the SPO during the first years of its existence. Unable to foresee the result of the 1960 presidential election, and at a time when the strategy of flexible response was still a very abstract and poorly defined concept, the organisation probably considered it safer not to place all its eggs in one basket.

213 SPO, "Polaris Chronology", 9–16. See also: Kaplan, *The Wizards of Armageddon*, 255.

214 See: Burke, "Extract from CNO Memorandum, subj: introduction of the Fleet Ballistic Missile into Service".

Based on the experience of the aborted Jupiter S missile, three low cost solutions were proposed to transform Polaris missiles into specialised counterforce weapons if required. Firstly, a very accurate guidance system could be developed by using a star-tracker.[215] Secondly, a single large warhead could be developed to replace the original payload of Polaris A-3.[216] Thirdly, in order to assess damages and coordinate further attacks, a "tactical monitoring system" could be mounted in the nose cone of the missile.[217] After burnout and warhead separation, it would send a five-second signal to the launching submarine indicating that missile flight was successful.[218] However, after the strategy of flexible response was duly explained by policy makers and McNamara provided a financial incentive to focus on deterrent issues, these three technologies were progressively abandoned.[219]

Once excluded from the research agenda, counterforce issues disappeared almost immediately from the organisational knowledge of the SPO. A possible reason for that might be the very high rotation rate of SPO personnel. By 1962, Burke and Raborn had already put a term to their involvement in the FBM programme.[220] By 1964, virtually all key leaders who had participated in the initial development of the Jupiter S missile had left the organisation.[221] Instead, a new generation of officers and engineers arrived, but as counterforce research

215 For a technical account of this system, see: SPO, "Proceedings of the Special Project office. Task II – 33th Meeting, Monitor and Sponsor the Fleet Ballistic Missile Development Program", minutes STG task II-33, 21 September 1962, Nuclear History Collection, NH 00752, DNSA, Washington D.C., 40–47.

216 Ibid., 44. During this meeting, the possibility to use the multiple warheads to perform simultaneous hard target strikes was also considered.

217 SPO, "Proceedings of the Special Project office. Task II – 29th Meeting", 30–34.

218 Ibid., 30–34.

219 The development of a single, large yield warhead for Polaris A-3 was discussed for the last time on 22 March 1963. The development of a star-tracker was progressively abandoned during the following year. Finally, the tactical monitoring system was authorised to survive because of its extremely light weight. But as it implied both two-way communications and near-surface operations, submariners delayed its operational deployment until the system was finally abandoned in 1968. See: SPO, "Proceedings of the Special Project office. Task II – 36th Meeting, Monitor and sponsor the Fleet Ballistic Missile Development Program", minutes STG task II-36, 22 March 1963, Nuclear History Collection, NH 00761, DNSA, Washington D.C.; "Proceedings of the Special Project office. Task II – 43th Meeting, Monitor and sponsor the Fleet Ballistic Missile Development Program", minutes STG task II-43, 28 May 1964, Nuclear History Collection, NH 00785, DNSA, Washington D.C., 257.; Spinardi, *From Polaris to Trident*, 221n.

220 Burke retired from the Navy on 21 August 1961 and Raborn left the SPO six month later.

221 See participant lists enclosed with the minutes of the 2nd (24–25 January, 1957) and 46th (19 November 1964) meetings of Polaris Steering Task Group. None of the key speakers present in 1957 were part of the 1962 meeting. The only exceptions were Dr. Draper (an external consultant on gyroscope issues), and Admiral Levering Smith, the technical director of the SPO. However, Smith had a reputation of being a great adversary to counterforce ideas.

was being abandoned, they were not well informed about this field of activity of the FBM programme. As a result, after 1964, there are no available publications or minutes of meetings of the SPO acknowledging the fact that a counterforce research project had ever existed within the organisation. In contrast, when interviewed, most former SPO leaders evinced the belief that the FBM programme had always been addressing problems attached to survivability and anti-city retaliation.[222] This evolution of organisational knowledge placed a new constraint on the development of SLBM technology, by totally excluding an important set of solutions that could be useful if the evolution of US nuclear strategy were to place emphasis on counterforce strikes.

As a side effect of the eviction of counterforce issues from the research agenda of the SPO, the deterrent purpose of the FBM programme soon became ritualised by its members. Because the objectives of the organisation had remained unchanged since 1957, the second generation of SPO leaders knew little about the rationale behind the choice of the objectives of the FBM programme. From 1962 onwards, the new leadership of the SPO found it difficult to recall why the purpose of the FBM programme was to provide a deterrent capability against urban-industrial targets. During key meetings of the organisation, newcomers occasionally expressed doubts about the strategic purpose of the FBM programme, and the rationale behind it.[223] However, by then virtually no SPO leader had been a part of the initial decision to set the development of deterrent, anti-city weapons as the main purpose of the FBM programme, and the question was left unaddressed. Instead, it was decided to keep sending missile proposals until policy makers manifested their opposition.[224]

While losing sight of the rationale behind the actual goals of the FBM programme represented a first step toward ritualising the organisational purpose of the SPO, this process was accelerated when policy makers and media presented deterrence as a particularly noble mission. In November 1962, immediately after the Cuban Missile crisis, President Kennedy sent a letter to the SPO stressing the great contribution to national security made by the survivability of Polaris missiles.[225] Later, Soviet premier Nikita Khrushchev was quoted in *Time Magazine* saying that "Polaris was one of the main considerations

222 Gate, interview; Shugg, interview; Buescher, interview.
223 SPO, "Proceedings of the Special Project office. Task II – 33th Meeting", 74–75.
224 Ibid., 219.
225 Wertheim, interview.

in his pulling back in the Cuban crisis".[226] In the eyes of the organisation, this confirmed that the purpose of the FBM programme was to provide a survivable anti-city deterrent, an interpretation that generated great enthusiasm.[227] Burke, Raborn and other pioneer figures of the FBM programme were idolised, and new infrastructures such as buildings and support centres were named after them.[228] Established as a ritual, the contribution of SLBMs to nuclear deterrence made it difficult for the SPO to change its objectives, and hence the general frame of the FBM programme. Indeed, as Polaris A-3 was commissioned on September 1964, the specialisation of the SPO in the issue of survivable, deterrent missiles became understood as the traditional role of the FBM programme, not only for members of the organisation, but also for external observers.[229]

Table 5: Basic organisational frame, Polaris A-2 and A-3

purpose/goal of the organisation	providing a deterrent capability available even after a prolonged nuclear exchange
problems addressed	1. vulnerability 2. destruction of urban-industrial areas
solutions proposed	1. SSBN basing, increased range for larger patrol areas thanks to low inert weight, provided by multiple warhead technology 2. high equivalent megatonnage for maximal effects against urban-industrial targets, provided by multiple warhead technology
constraints on possible solutions	low-costs development communication systems excluded from the research agenda research on counterforce strikes excluded from the organisational knowledge of the SPO

226 Philip A. Beshany, interview by John T. Mason, 8 November 1977, printed transcript (extracts) consulted off box at the Operational Archives of the Naval Historical Center, Washington D.C.
227 Beshany, interview.
228 SPO, "Polaris Chronology", 16.
229 On the commissioning of Polaris A-3, see: SPO, "Polaris Chronology", 17.

Increasing returns of technology

During the development of Polaris A-3, the key characteristics of the FBM programme had been remarkably stable. Neither the purpose, problem, solutions or constraints that defined the organisational frame of the SPO had experienced significant changes. Regarding SLBM technology, the mechanism of sunk costs had reinforced the technical solutions adopted previously by Polaris A-1. In this context, the SPO soon proposed to develop yet another missile as a direct evolution of existing technologies. The new project was known as Polaris B-3. Except for a 20-inch increase in missile diameter in order to accommodate more multiple warheads, no changes in missile technology was introduced compared to the Polaris A-3.[230] However, as no grounds were found in the strategic environment to justify an improved version of the Polaris missile, the Department of Defense denied the SPO the authorisation to develop a new SLBM.[231]

This refusal almost killed the FBM programme. By the spring of 1963, the SPO began to transfer its research and development activities away from the field of ballistic missiles and toward deep submerged rescue systems.[232] Nevertheless, the emergence of operational anti-ballistic missile (ABM) defences in the Soviet Union saved the FBM programme just before all research on SLBM technology was abandoned. While the problem of ABM defences was relatively new to the FBM programme, the SPO did not only search for an efficient solution with regard to this evolution of the strategic environment, but also for the technology that would best use previous work on the rejected Polaris B-3 proposal.

The emergence of Anti-Ballistic Missile defences

During a military parade on 7 November 1964, Soviet air defences displayed an ABM defence system, known as *Galosh*.[233] Included in the

230 A missile with a greater diameter could be installed in former SSBNs because of a new, thinner missile casing developed for an aborted project to provide NATO allies with Polaris missiles mounted on truck and trailers. See Spinardi, *From Polaris to Trident*, 84.

231 Robert S. McNamara, "Recommended FY 1964 – FY 1968 Strategic Retaliatory Forces", memorandum, 21 November 1962, Cuban Missile Crisis Collection, CC02519, DNSA, Washington D.C., 22–23.

232 This decision was taken following the lost with all hands of the attack submarine USS *Thresher,* on 10 April 1963. See: Spinardi, *From Polaris to* Trident, 90.

233 [Jane's], *Weapons systems 1974–75*, ed. R.T. Pretty and D.H.R. Archer (London: Jane's yearbooks, 1974), ref. 2932.131. The concept of ABM defences was known since the first days of long-range rocketry. It consisted in destroying incoming warheads thanks to an interceptor missile, either by direct impact or by detonating a nuclear charge. For an overview of the concepts and technologies employed by ABM defences, see: Ashton B. Carter and David N. Schwartz, *Ballistic Missile Defence* (Washington D.C.: The Brookings Institution, 1984).

parade was a mysterious interceptor missile, the A-35. Nothing but the missile casing and the four nozzles of the first stage was revealed to western eyes, but it sufficed to trigger panic in the US strategic community.[234] In contrast to intelligence estimates expecting Soviet ABM defences to be operational by the end of the decade, the A-35 proved that the Soviet Union already had an operational system providing at least a limited protection to Moscow. Moreover, there were indications that interceptor missiles would be equipped with a very large thermonuclear warhead (2-3 megaton), implying that even a relatively imprecise interception would destroy one or several incoming missiles.[235]

Arguably, the emergence of Soviet ABM defences offered the SPO a good opportunity to change its organisational frame and renew SLBM technology. As it appeared that the Soviet Union might have the capability to intercept incoming missiles, the problem of anti-city retaliation was reopened. Based on the first intelligence reports anticipating the commissioning of ABM defences around Moscow and Leningrad, the Department of Defense proposed that the SPO reactivate research into SLBMs.[236] The problem of anti-city retaliation was reformulated as the "penetration of defended urban-industrial targets".[237]

Probably influenced by the radical design of the A-35 interceptor, and the criticism that the United States was failing to develop new weapons systems, President Johnson intervened personally to encourage the FBM programme to develop a brand new missile.[238] On 5 January 1965, only eight weeks after the first display of the Galosh system, the President ordered the SPO to initiate a concept study for a second generation SLBM, named Poseidon C-3.[239] To favour the development of a brand new missile, and not just an improved version of the Polaris system, budgetary limitations inherited from the Eisenhower era were lifted. Instead, 35 million dollars were allocated to the FBM programme for the preliminary design of an original SLBM, removing the barrier of sunk costs to the development of new technologies.[240]

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234 [Jane's], *Weapon systems 1969–70*, ref. 2932.131.

235 For a complete description of the Galosh ABM system, see: Podvig, *Russian Strategic Nuclear Forces*, 413–18.

236 Sapolsky, *The Polaris System Development*, 220.

237 "Memorandum for the Secretary of Defense", National Security Action Memorandum 254, 18 July 1963, Presidential Directive Collection, PD01004, DNSA, Washington D.C., 1; CIA, "Soviet Military Capabilities and Policies (1962–1967)", National Intelligence Estimate NIE 1-4-63, 22 March 1963, personal archive.

238 Spinardi, *From Polaris to* Trident, 90.

239 Ted Greenwood, *Making the MIRV: A Study of Defense Decision Making* (Cambridge: Ballinger, 1975), 6.

240 Ibid., 6.

For the first time since 1957 and the development of Polaris A-1, the SPO had a strong incentive and the financial means to dramatically change its organisational frame by proposing totally new solutions.

The difficult development of penetration aids

By the time President Johnson launched Poseidon C-3, the most promising solution to defeat ABM defences was the concept of *penetration aids*. Explored since 1962 at the theoretical and experimental level in anticipation of future ABM systems, the concept had been tested with success against anti-missile radar prototypes developed by the US Army.[241] The basic idea was to develop a package of countermeasures that could be added to single warhead missiles or replace one of the three warheads of Polaris A-3.[242] Penetration aids consisted of two chaff packs (to blind Soviet early warning radars), several decoys (to delay identification of the actual warhead) and an electronic jammer (to deny fire control radars range information).[243] In addition, missile and warhead electronics would be "hardened" against electromagnetic impulses released by the nuclear warheads of ABM interceptor missiles.

However, this solution was never adopted by the FBM programme. As was the case with most brand new technologies, penetration aids were initially very difficult to transform into an operational system. Firstly, flight tests conducted between 1962 and 1964 shed light on the difficulty of correctly ejecting chaffs and decoys from the rest of the payload.[244] Secondly, radars utilised by the Galosh system were operating at relatively low frequencies (100 to 200 Mhz). Contrary to other wave lengths, this allowed operators to infer the size of the target, and therefore identify actual warheads among smaller decoys. This technical problem had been anticipated by the SPO since May 1964, and implied that "a successful decoy would have to be given the size and the substance of a real re-entry body".[245]A major consequence was that in order to carry a single warhead and multiple decoys of the right size, Poseidon would have to carry a huge payload. Thirdly, as Galosh was a long range system, there was a risk that ABM defences could have time to discriminate the actual warhead from decoys by test-

241 For example, see: SPO, "Proceedings of the Special Project office. Task II – 29th Meeting", 64.
242 Ibid., 35–69.
243 Ibid., 35–79, especially pages 41, 42, 45, 48, 49 and 62.
244 Ibid., 35–69.
245 SPO, "Proceedings of the Special Project office. Task II – 43th Meeting", 137.

ing many parameters such as temperature, shape, weight, structure, or electromagnetic properties.[246] To solve this issue, the Strategic Military Panel of the President Science Advisory Board (referred in this study as SMP) recommended complex solutions. Inflatable balloons would be used as very large decoys, and the actual warhead would be hidden in one of them. Other balloons would embark equipment necessary to simulate weight, temperature and other characteristics of the warhead. It was understood that the decoys would burn during atmospheric re-entry, but at that time, there would be too little time left for efficient ABM defence.[247] Therefore, penetration aids represented not only a difficult technology to develop, but also an inefficient solution to the problem of anti-city retaliations, as it implied delivering a very large payload over urban areas while using only a fraction of it to destroy the target.

In spite of these limitations, most ballistic missile operators decided to develop and commission penetration aids. Between 1965 and 1967, the Air Force commissioned the Minuteman II ICBM, equipped with a small penetration aids package providing a fair level of confidence against the main urban-industrial targets of the Soviet Union.[248] Similarly, the British Royal Navy began the development of countermeasures for its ballistic missile force purchased in the US, in order to assure that even a limited SLBM retaliatory attack could enable at least one warhead to reach Moscow.[249] For these two organisations, penetration aids technology was not only possible, but also represented the best solution to the problem of ABM defence as it existed in the mid-1960s.

Multiple warheads as a solution to ABM defences

The FBM programme never adopted penetration aids because a technology already developed by the SPO could also be used to defeat ABM systems. One of the interesting conclusions reached during research on penetration aids was that decoys and actual warheads should ideally appear identical in size and weight.[250] Provided that "the best

246 Richard L. Garwin, interview by author, 22 September 2009.
247 Ibid.
248 [Jane's], *Jane's Weapon System 1987–1988*, ed. Bernard Blake (London: Jane's Yearbooks, 1987), ref. 2716.111.
249 The British SLBM force relied on Polaris A-3 missiles purchased in the United States. To retrofit the *Chevaline* penetration aids package developed by British engineers, the Royal Navy had to remove one of the three warheads of its Polaris missiles. Lawrence Freedman, *Britain and Nuclear Weapons* (London: MacMillan, 1980), 48.Carter and Schwartz, *Ballistic Missile Defence*, 262.
250 SPO, "Proceedings of the Special Project office. Task II – 43th Meeting", 137.

decoy is one that weighs as much and looks just like, and therefore might be as well, a warhead," the technology of multiple warheads featured by Polaris A-3 offered excellent prospects for the penetration of defended urban-industrial targets.[251] The only development work left to the SPO was to increase the number of warheads deployed by a single missile against ABM defences, and design a system to disperse the payload so that a single A-35 interceptor would not destroy several re-entry vehicles.

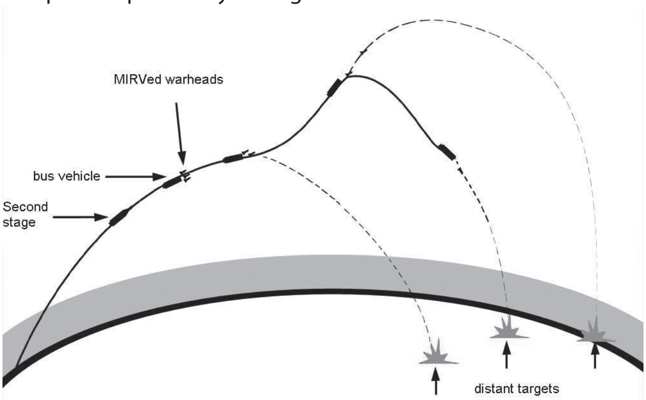
In order to increase the number of warheads delivered by a single missile, the SPO resuscitated Polaris B-3, the preliminary design of which had been achieved during the summer of 1964.[252] Based on previous studies, the organisation considered it possible to fit up to 16 warheads of 100 kilotons in a single B-3 missile.[253] The development of Polaris B-3 also included a new warhead separation system, as the very large payload could not be properly ejected by the same method as used on Polaris A-3.[254] This separation system was improved at low costs by relying on technologies previously developed for space exploration. In order to enable a single rocket to perform multiple satellite launches, the Air Force and NASA had developed a post-boost vehicle, or "bus".[255] The bus was placed at the top of the booster and supported the satellites. After the rocket had achieved earth orbit, the bus would separate and use small engines to place each satellite on its own specific orbit.[256] With regard to ballistic missile technology, a single bus vehicle could vector several warheads at different speeds and in different directions, thus ensuring proper separation and allowing several distant targets to be reached with precision.[257]

This evolution of multiple warhead technology was soon referred to as MIRV (or multiple independently re-targetable vehicles). While the engine of the bus had to be stopped and restarted during warhead release, the SPO categorically refused to employ liquid fuels because of its commitment to solid propellant technology. As a result, Poseidon's bus had a relatively poor performance, and in order to maintain a range

251 Robert Wertheim, quoted in Spinardi, *From Polaris to Trident*, 92.
252 Robert Lindsey, "B-3 Polaris Expected to be Operational in '70", *Missiles and Rockets*, 24 August 1964.
253 SPO, "Proceedings of the Special Project office. Task II – 43th Meeting", 141.
254 Spinardi, *From Polaris to Trident*, 88.
255 Garwin, interview.
256 Ibid.
257 SPO, "Proceedings of the Special Project office. Task II – 45th Meeting, Monitor and sponsor the Fleet Ballistic Missile Development Program", minutes STG task II-45, 30 September 1964, Nuclear History Collection, NH 00793, DNSA, Washington D.C., 152.

of 2,500 miles, the number of warheads had to be reduced from 16 to 14, and their yield from 100 to 40 kilotons.[258] This configuration nevertheless achieved an equivalent megatonnage of 560 kilotons, which was still above the 500 kilotons limit considered satisfactory by the SPO.

Fig. 4: Multiple independently re-targetable vehicles



Multiple warheads technology presented increasing returns because its benefits grew over time and offered better capabilities than other solutions such as penetration aids. The mechanism by which MIRVed warheads were adopted was indeed fundamentally different from previous technological choices made the SPO. While the selection of solid propellant in 1957 was the pragmatic choice of an organisation looking for optimal solutions regarding bureaucratic and strategic problems, MIRVed warheads represented the best technology only in the specific context of the FBM programme. Indeed, for an organisation such as the Air Force with no previous experience in multiple warheads, the development of MIRV technologies was potentially as difficult as the implementation of penetration aids. Furthermore, as the equivalent megatonnage effect does not apply to hardened military targets, small MIRVed warheads would have been unsuitable for the counterforce missions planned by the Air Force. In contrast, multiple warheads technology was better suited to other problems addressed by the FBM programme. Indeed, by off-loading warheads from Poseidon's bus, missile range could be significantly improved if a new threat to submarine

258 [Jane's], *Weapons systems 1974–75*, ref. 1133.411.

survivability was to appear.[259] Moreover, by allowing each re-entry vehicle to be independently targeted, a single Poseidon missile could strike several cities, and adjust the number of warheads according to the size, geography and level of ABM defences of each urban centre.

Table 6: Basic organisational frame, Poseidon C-3

purpose/goal of the organisation	providing a deterrent capability available even after a prolonged nuclear exchange
problems addressed	1. vulnerability 2. penetration of defended urban-industrial targets
solutions proposed	1. SSBN basing, increased range for large patrol areas thanks to low inert weight, provided by multiple warhead system 2. high equivalent megatonnage for maximal effects against urban-industrial targets, multiple warhead system for increased ABM defences penetration
constraints on possible solutions	communication systems excluded from the research agenda research on counterforce strikes excluded from the organisational knowledge of the SPO

The fact that multiple warhead technology was a good solution in the particular context of the FBM programme did not imply that the reaction of the SPO was irrational with regard to the strategic environment. Instead, the increasing returns of technology meant that multiple warheads were a sensible choice when taking into consideration the strategic problems, the mission, and the organisational capabilities of the SPO. In this regard, policy makers considered the solution adopted by the FBM programme as optimal.[260] In their opinion, when Poseidon C-3 became operational on 30 March 1971, the FBM programme had become the specialist within a very particular and precise field: the development of a survivable deterrent against defended urban-industrial areas.[261]

259 Spinardi, *From Polaris to Trident*, 107.
260 "Third Report of the Defense Science Board task Force on Penetration", report, 15 September 1967, Nuclear History Collection, NH 00534, DNSA, Washington D.C., 7.
261 See: "Strategic Offensive and Defensive Forces", Memorandum, 9 January 1969, Nuclear History Collection, NH 00476, DNSA, Washington D.C.

A self-sustaining weapons programme

While sunk costs, organisational knowledge and the increasing returns of technology played an important role in the development of the FBM programme after 1960, only discrete aspects of missile technology had been affected by these issues. So far, the evolution of nuclear strategy had always been at the origin of the development and commissioning of new missiles by the SPO. However, as the FBM programme was about to experience an important crisis shortly after the initial development of the Poseidon missile, these three organisational features progressively became self-reinforcing. For the first time in the history of the FBM programme, a new SLBM would be developed, not as a result of the evolution of nuclear strategy, but as a consequence of previous activities of the SPO. While the new missile proposed by the FBM programme fitted well with previous and existing US nuclear policies, it presented the first sign of emancipation of the FBM programme from the strict control of US policy makers.

Bureaucratic politics and the Strat-X study

During the development of the Poseidon missile, the bureaucratic environment of the SPO presented a grave threat to the FBM programme. The pertinence of survivability and anti-city retaliations, the two key problems that structured the activities of the programme, was contested by some bureaucrats from the Navy and the Department of Defense. Paradoxically, this crisis was triggered by the adoption of multiple warhead technology for land-based ballistic missiles. In 1964, the Air Force launched an independent research project on multiple warhead and MIRV technologies, totally independent of the FBM programme.[262] In contrast to the SPO, the Air Force was a strong supporter of counterforce strikes. In order to persuade policy makers to fund its project, the Air Force argued that MIRVed ICBMs could provide "a war-fighting capability for precise surgical strikes against military targets within or near urban areas, and for symbolic countervalue attacks against dams, nuclear facilities or other nonurban but important targets".[263] This proposal led some key leaders of the Department of Defense to reconsider the purpose of MIRVed missiles and to at-

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262 See: Daniel Ruchonnet, "MIRV: A Brief history of Minuteman and Multiple Reentry Vehicles", report COVD-1571, February 1976, Nuclear History Collection, NH00840, DNSA, Washington D.C.

263 Greenwood, *Making the MIRV*, 50. In comparison, the SPO presented MIRVed warheads as "a solution to the technical problems involved in providing a high confidence and cost-effective means of penetrating ABM systems," Ibid., 260.

tempt to redefine the problems addressed by the FBM programme. Influenced by his background in economics, McNamara considered MIRVed missiles as an opportunity to strike more military targets with a smaller missile force. As the Secretary of Defense, he proposed that new SLBMs should also address the issue of counterforce by solving the problem of destroying several hardened targets at a distance of 75 miles.[264] Moreover, bureaucratic pressures were also placed on the FBM programme by a group of naval officers, who named itself "the Great Circle Group". From their perspective, the interest displayed by the Air Force and the Department of Defense in the problem of counterforce implied that unless the FBM programme proposed a missile capable of destroying hard targets, the Navy would be progressively marginalised.[265]

However, adversaries of counterforce strikes were plentiful, especially within the Office of the Secretary of Defense (OSD). Their primary objective was not to directly reinforce the deterrent role of the FBM programme, but rather to block the development of the WS-120A, a large and revolutionary Air Force missile using MIRVed technology for counterforce strikes. In November 1966, members of the OSD successfully imposed that a comparative study of different types of ballistic missiles was to be carried out before the Air Force would be authorised to proceed with the development of the WS-120A.[266] According to Graham Spinardi, the main purpose of this study – named *Strat-X* – was probably to kill the Air Force's missile and commit policy-makers to the development of a purely deterrent system in the long-term.[267] But in order to reach their objective, members of the OSD needed to be absolutely certain that a deterrent weapons system would win the competition, and not the WS-120A.

In charge of defining the evaluation criteria of the Strat-X study was Lloyd Wilson, a former engineer who developed the original multiple warhead system of Polaris A-3.[268] To ensure the defeat of the WS-120A, Wilson shaped the evaluation criteria according to solutions already developed within the FBM programme, so that the SPO

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264 Robert S. McNamara, "Recommended FY-1966-1970 Programs for Strategic Offensives Forces, Continental Air and Missiles Defense Forces, and Civil Defense", draft Memorandum, 3 December 1964, Nuclear History Collection, NH00455, DNSA, Washington D.C., 30.

265 Spinardi, *From Polaris to Trident*, 91.

266 See: "Task Order for Work to Be Performed by the Institute for Defense Analyses", task Order T-56, 22 November 1966, personal archive.

267 Spinardi, *From Polaris to Trident*, 113.

268 Unpublished Memoires of Art Lowell, 2001, personal archives.

had the best chances of winning. Missiles in competition were “to provide *economic surviving penetration payload* for targeting against the *urban/industrial* base of the Soviet Union”.[269] Counterforce capabilities were relegated as a secondary, optional characteristic.[270] In other words, missile proposals should address the problems of vulnerability and penetration of defended urban-industrial centres, and these two problems only.

For the SPO, the immediate consequence of the Strat-X study was to confirm the strategic problems that shaped the initial development of Poseidon C-3, and temporarily protect this project from bureaucratic attacks. Moreover, in 1968, the Undersea Long-range Missile System (ULMS) concept proposed by the FBM programme logically won the competition.[271] As the WS-120A was cancelled, supporters of a counterforce posture were obliged to back off, at least temporarily.[272] Facing a public opinion hostile to counterforce ideas, President Nixon decided to end discussion in 1969, by declaring that “there is no current U.S. programme to develop a so called hard target MIRV capability”.[273] While the SPO was renamed “Strategic Systems Project Office” (SSPO) after minor changes in the structure of the Navy, the organisation was *de facto* due to produce a new SLBM on the grounds of the problems of vulnerability and the destruction of defended urban-industrial centres. While these two problems fitted well with the strategic objectives set by McNamara for the strategy of flexible response, the origins of ULMS proposal were not rooted in any evolution of US nuclear strategy. Instead the new proposal was the pure product of the interaction of bureaucratic politics and the experience previously gathered to the SPO.

Increasing returns and sunk costs reloaded

The Undersea Long-range Missile System was to be a paradigm design of the FBM programme. As its name explicitly indicated, the solution

269 Lloyd H. Wilson, “Memorandum for the President, Institute for Defense Analyses, Director, Strat-X Study Group. Subject: Strat-X Steering Committee Guidance on Study Ground Rules”, memorandum, 16 January 1967, personal archive. Italics are from the original document.

270 Ibid.

271 D. Douglas Dalgleish and Larry Schweikart, *Trident* (Carbondale: Southern Illinois University Press, 1984), 42.

272 Supporters of a counterforce posture would make a striking come back in the late 1970s, and the WS-120A project would be resuscitated as the “MX” missile. In the meanwhile, the Air Force retrofitted MIRV technology on Minuteman missiles.

273 Alton Frye, *A Responsible Congress: The Politics of National Security* (New York: McGraw-Hill, 1975), 55.

proposed by the SSPO to the problem of vulnerability was once again to place ballistic missiles in submarines and increase their range in order to allow wider patrol areas. Confident in the experience gathered during the development of previous SLBMs, the SSPO proposed during the Strat-X study to develop a 6,000-miles missile. This was more than twice Poseidon's range, but the challenge was considered worthwhile because it would multiply by 15 the sea-room available for submarine patrols.[274] To achieve this range, the ULMS proposal planned to develop a new submarine, able to launch a much larger missile.[275] The original constraints on size and weight set for early Polaris missiles had long been forgotten, but there was no one left in the Department of Defense or in the Navy to complain about it. In this context, the problems of survivability and penetration of defended urban-industrial targets contributed towards reinforcing solutions and technologies utilised on Poseidon in two different ways.

Firstly, with regard to range objectives, multiple warhead and MIRV technology presented increasing returns. When the design of the new launch submarine began in 1970, it was immediately caught up in a bureaucratic fight of epic proportions. The object of the conflict was the propulsion system of the submarine. The SSPO and Admiral Rickover – the father of nuclear propelled submarines – disagreed fundamentally about which nuclear reactor was to be used.[276] Concerned that this conflict could postpone the commissioning of the ULMS missile, the SSPO decided to go ahead with an interim missile able to fit Poseidon launch tubes.[277] This turned the initial ULMS proposal into a minimum change concept and the missile was renamed EXPO, for extended range Poseidon.[278] However, in May 1972, the missile was renamed Trident D-4, and then Trident I D-4 in March 1974, to stress that it was just a first step toward a larger weapons system meeting the standards set by the original ULMS proposal.[279] As an interim weapons

274 Dalgleish and Schweikart, *Trident*, 42.

275 Stockholm Peace Research Institute (SIPRI), "Advances in U.S. Soviet Strategic Nuclear Forces During SALT", in *Year Book 1972. World Armaments and Disarmament* (New York: Oxford University Press, 1972): 8.

276 For an overview of the numerous controversies around the personality and action of Rickover, see: Thomas B. Allen and Norman Polmar, *Rickover: Controversy and Genius. A biography* (New York: Simon and Schuster, 1982).

277 Spinardi, *From Polaris to Trident*, 122–123. Spinardi gives a very detailed history of the ULMS submarine controversy pages 115–125. See also Dalgleish and Schweikart, *Trident*.

278 Robert C. Aldridge, *First Strike: The Pentagon's Strategy for Nulcear War* (Boston: South End Press, 1983), 84–86; Norman Polmar, *The Naval Institue Guide to the Ships and Aircrafts of the U.S. Fleet* (Annapolis: U.S. Naval Institute, 2005), 531.

279 SSPO, "FBM Facts/Chronology. Polaris-Poseidon-Trident", 42.

system, Trident I had a range objective of 4,000 miles.[280]At first, the SSPO envisaged developing a new solid propellant with a higher specific impulse.[281] However, in the face of unexplained engine failures, engineers had to limit the performance of the propulsion system, and it became necessary to reduce inert weight and find room inside the missile in order to store more propellant.[282]

The situation of the FBM was remarkably similar to that of the early 1960s when the SSPO faced the challenge of increasing the range Polaris A-3 without modifying missile dimensions. As multiple warheads had already been used to solve this situation, this technology was well known within the SSPO and enabled range to be increased relatively easily. To begin with, the bus vehicle and the payload could be made much lighter. As the USA and the Soviet Union were about to reach an agreement prohibiting ABM systems, the number of warheads could be reduced.[283] Each side was authorised to retain one limited ABM system to protect its capital, but the problem of penetration was greatly relaxed. In these conditions, the SSPO came up with the number of eight warheads for optimal anti-city retaliations and penetration of limited ABM systems. To conserve a satisfactory equivalent megatonnage, a new warhead of 100 kilotons was selected.[284] As this new warhead was slightly lighter than those used on Poseidon, the weight reduction achieved was even greater, and the yield-to-weight ratio was dramatically improved.

Additionally, the solution of multiple warheads also allowed more space for propellant. By placing the eight warheads at the periphery of the bus vehicle, a central pit could be opened in the payload section. This allowed the SSPO to install a third stage in the Trident missile without increasing its length. Indeed, "instead of being below the post-boost [bus] vehicle containing the guidance systems and warheads, as was conventional, the third stage motor went effectively to the top of the missile with re-entry bodies, guidance system arranged

280 Dalgleish and Schweikart, *Trident*, 31,; SIPRI, "SALT II: An analysis of the arguments", in *Year Book 1980. World Armaments and Disarmaments* (New York: Oxford University Press, 1980): 225.

281 "Updated Propulsion System Seen Extending Trident Range", *Aviation Week and Space Technology*, 1 September 1984.

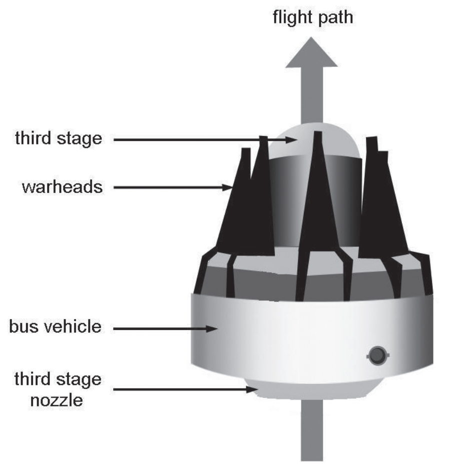
282 United State's Senate, "Committee on Armed Services, Fiscal Year 1977, Part 12, Research and Development", Washington D.C. U.S. Government Printing Office, 1976, 6617; Spinardi, *From Polaris to Trident*, 130.

283 See: "Treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitation of anti-Ballistic Missile Systems", Moscow, 6 May 1972 <online>.

284 See: [Jane's], *Jane's Weapon System 1987–1988*, ref. 2840.411.

round it".[285] The extra impulse provided by this original system was relatively modest, but it was sufficient to give Trident I a range of 4,000 miles.

Fig. 5: Trident third stage and bus vehicle



The second mechanism by which the strategic problems identified by the Strat-X study reinforced technologies already used on Poseidon C-3 was the issue of sunk costs. As Trident I had to maintain a level of accuracy comparable to Poseidon despite increased range, an improved guidance system was needed. The difficulty did not lie in replicating previous levels of accuracy, but by doing so without a new, complex and expensive technology. For this reason, the SSPO decided to re-utilise Poseidon's guidance system for Trident I, with only minor improvements to reduce production costs.[286] In order to maintain accuracy over longer flight paths, a star-tracker was added to this basic system, a combination known as stellar-inertial guidance.[287] Stellar-inertial guidance represented a low-cost "fix" to previous guidance systems because the SSPO had already been developing this technology when working on the backup counterforce version of Polaris A-3. Furthermore, after being abandoned by the SSPO, this technology had been further improved by private companies and had become mature

285 Spinardi, *From Polaris to* Trident, 126.
286 Ibid., 132.
287 Mackenzie, *Inventing Accuracy*, 274–75.

enough to represent the safest and most competitive option for a cheap and accurate guidance system.[288]

It must be noted that the SSPO did not consider using stellar-inertial guidance for counterforce strikes. Instead, it was considered that this technology reinforced the deterrent capabilities of the SLBM forces by decreasing submarine vulnerability. Indeed, in stellar-inertial guidance, the role of the star-tracker was to reduce the loss of accuracy due to uncertainty about the position of the launching submarine. Therefore, the need for radio navigation fixes near the surface – where submarines were vulnerable – was reduced. The argument according to which stellar-inertial guidance was not utilised to develop counterforce capabilities is confirmed by the fact that the SSPO did not search for maximal accuracy. With a CEP of 0.25 miles, Trident I exactly matched the accuracy of the Poseidon missile and fell short of the accuracy level of some sophisticated and purely inertial guidance systems.[289]

When Trident I became operational on 20 October 1979, the organisational frame of the FBM programme had become self sustaining.[290] Sunk costs, organisational knowledge and the increasing returns of technology had produced a strong rationale for the SSPO to continue addressing the problems represented by vulnerability and the penetration of defended urban-industrial targets, as demonstrated by the Strat-X study. As the SSPO repeatedly engaged with these strategic issues, sunk costs and the increasing returns of technology further increased the specialisation of the SPO, therefore placing new incentives to focus on problems related to anti-city strikes. Arguably, the organisational frame of the SSPO had become path dependent, in the sense that the development of new SLBM was mainly rooted in previous technologies developed within the FBM programme. In this context, the question as to whether or not the FBM programme could adapt to a major change in US policy was raised.

288 See: Ibid., 242–47.
289 Ibid., 429.
290 SSPO, "FBM Facts/Chronology. Polaris-Poseidon-Trident", 53.

Table 7: Basic organisational frame, Trident I C-4

purpose/goal of the organisation	providing a deterrent capability, defined as "a surviving penetration payload for targeting against the urban/industrial base of the Soviet Union" (set by the Strat-X study)
problems addressed	1. vulnerability 2. penetration of defended urban-industrial targets
solutions proposed	1. SSBN basing, increased range for larger patrol areas thanks to low inert weight, provided by multiple warhead system 2. High equivalent megatonnage for maximal effects against urban-industrial targets, multiple warhead system for increased ABM defences penetration
constraints on possible solutions	communication systems excluded from the jurisdiction of the SSPO research on counterforce strikes excluded from the organisational knowledge of the SSPO

Chapter 5

The limits of adaptation

The Trident II missile

During the development of Trident I, the issues of sunk costs, organisational knowledge and increasing returns of technology had little impact on the capability of the SSPO to propose relevant weapons systems to US nuclear strategy. While these three organisational features progressively locked the evolution of the FBM programme into a narrow and path-dependent framework, US nuclear strategy had also remained remarkably stable. Although the ability of the FBM programme to develop new technologies and propose new conceptual solutions had been seriously weakened, the adaptability, flexibility and pragmatism of the SSPO had not been challenged since the initial design of Polaris A-1.

However, the development of a new SLBM during the two last decades of the Cold War would eventually shed light on the weaknesses of the FBM programme. Following its purely bureaucratic and internal logic, the SSPO proceeded to the development of an improved version of Trident I, matching the initial performance objectives set by the Strat-X study.[291] This missile was to be commissioned by 1989 and would take full advantage of the larger launch tubes of forthcoming SSBNs.[292] This relaxed development schedule and increase in missile size placed the SSPO in a relatively favourable position for developing new technologies, or improving existing ones to match changes in the strategic environment. However, as US nuclear strategy resumed its evolution during the late 1970s and early 1980s, the ability of the

291 See: Dalgleish and Schweikart, *Trident*, 42–43.
292 SSPO, "FBM Facts/Chronology. Polaris-Poseidon-Trident", 57; Spinardi, *From Polaris to Trident*, 141.

FBM programme to adapt its activities and propose relevant solutions was about to be put to the test.

The Schlesinger doctrine

During the latter development years of the Trident I missile, US nuclear policy went through important changes. After Robert McNamara left the office of Secretary of Defense in February 1968, the doctrinal concepts of city avoidance and mutual assured destruction became increasingly criticised within the Department of Defense and the executive branch.[293] The main argument against McNamara's heritage was that in spite of its name, the strategy of flexible response could lead to nothing other than a mutually assured destruction scenario. While the concept of city-avoidance had been implemented to encourage the Soviet Union to spare US cities, it did not include any options for a limited use of nuclear weapons. Instead the smallest counterforce strike proposed by the Single Integrated Operational Plan (SIOP) consisted of 2,500 nuclear bombs and warheads, used simultaneously against 1,700 targets.[294] Collateral damage and radioactive fallout would have caused an estimated 16 million fatalities, mainly in the Moscow area.[295] In this context, it was doubtful that the Soviet Union would recognise the so-called limited character of any US nuclear strike and would refrain from retaliating against cities.

While the need for a more flexible doctrine had been understood since the early years of Richard Nixon's presidency, it was believed that technology was unable to provide decision makers with limited strike options.[296] However, by early 1973, improvements in command, control and communications (C^3) technologies as well as the retrofit of

293 William Burr, "The Nixon Administration, the 'Horror Strategy', and the Search for Limited Nuclear Options, 1969–1972: Prelude to the Schlesinger Doctrine", *Journal of Cold War Studies* 7, no. 3 (2005): 34–78; William Burr, "'Is It the Best they Can Do?': Henry Kissinger and and the U.S. Quest for Limited Nuclear Options", in *War Plans and Alliances in the Cold War: Threat Perceptions in the East and the West*, ed. Sven Holtsmark, Vojtech Mastny, and Andreas Wenger (London: Routledge, 2006), 118–140; Kaplan, *The Wizards of Armageddon*, 366–69.

294 "U.S. Strategic Objectives and Force Posture Executive Summary", memorandum, 7 January 1971, U.S. Nuclear History Collection, The National Security Archive, Washington D.C. 28–29. The SIOP is the nuclear war plan of the United States. It encloses several pre-established target lists to be submitted to the President in case of a nuclear conflict.

295 Natural Resource Defense Council, "The U.S. Nuclear War Plan. A time for Change", report, June 2001, Washington D.C., 45, fig. 4.4. See also: William Burr, "The Nixon Administration, the SIOP, and the Search for Limited Nuclear Options, 1969–1974", *www.gwu.edu*, 23 November 2005, National Security Archive Electronic Briefing Book No. 173, 26 April 2010 <online>.

296 Terry Terriff, *The Nixon Administration and the Making of U.S. Nuclear Strategy* (Ithaca: Cornell University Press, 1995); Olav Njølstad, *In Search for Superiority. U.S. Nuclear Policy in the Cold War* (Oslo: Norwegian Insitute for Defence Studies, 1994), 39.

MIRVed warheads on Air Force ICBMs opened new perspectives for more efficient and more discriminate counterforce strikes.[297] During the summer and fall of 1973, James Schlesinger and Henry Kissinger were respectively appointed Secretary of Defense and Secretary of State. Despite personal rivalry and important disagreements over US policy toward the Soviet Union, both agreed on the need to design a new doctrine that would take full advantage of available technologies in order to better control and prevent the escalation of nuclear war. Their objective was to enable policy makers trapped in a nuclear conflict to avoid mutual assured destruction, a scenario considered by Kissinger as the "height of immorality".[298]

Based on previous studies performed by James Schlesinger during his work at the RAND Corporation, President Nixon proposed a new nuclear doctrine on 17 January 1974.[299] The document, entitled "Planning the Employment of Nuclear Weapons" explicitly stated that the new doctrine did "not constitute a major new departure in US nuclear strategy", but was rather "an elaboration of existing policies".[300] Indeed, the main objectives of US nuclear strategy were still "(1) to deter nuclear attacks against the United States", "(2) to deter attacks – conventional and nuclear – by nuclear powers against U.S. allies" and "(3) to inhibit coercion of the United States by nuclear powers."[301] Furthermore, the basic distinction between a nuclear exchange restricted to counterforce strikes and an all-out nuclear war was maintained. However, the new doctrine called for important changes in future US strategic weapons systems and their employment during a conflict against the Soviet Union.

The main nuclear employment scenario considered by President Nixon was referred to as "escalation control" or "intra-war deterrence".[302] The objective was to maintain deterrence even after the outbreak of a nuclear conflict and "to seek early war termination on terms acceptable to the United States and its allies, at the lowest level of conflict feasible".[303]

297 Lawrence D. Freedman, interview by author, 30 September 2009.
298 "Minutes of the Verification Panel Meeting held 9 August 1973. Subject: Nuclear Policy (NSSM-169)", memorandum for Henry Kissinger, 15 August 1973, The National Security Archive, Washington D.C.
299 "Policy for Planning the Employment of Nuclear Weapons", National Security Decision Memorandum (NSDM)-242, 17 January 1974, The National Security Archive, Washington D.C.
300 Ibid., 1.
301 Ibid., 2–3.
302 Ibid., 2. See also: Njølstad, *In Search for Superiority*, 38–47; Freedman, *The Evolution of Nuclear Strategy*, 360–365.
303 "Policy for Planning the Employment of Nuclear Weapons", NSDM-242, 2.

In contrast to a massive and instantaneous counterforce attack *à la* McNamara, the United States would perform pre-programmed "limited" nuclear strikes, against "selected" targets, "in conjunction with supporting political and military measures – including conventional forces".304 All counterforce strikes would not be executed simultaneously, but rather according to a precise time and pace carefully defined during peace time "in order to provide the enemy opportunities to reconsider its actions". 305 If, for whatever reasons, conflict escalation could not be controlled, a second employment scenario for a general nuclear war was considered. In this situation, the main priority would be the "maintenance of survivable strategic forces in reserve for protection and coercion during and after major nuclear conflict".306 While these survivable strategic forces – most probably SLBMs – would be used during a massive, instantaneous strike, the annihilation of Soviet population was not the primary objective. Instead, "systematic attacks on Soviet military, economic and political structures" would be performed in order to reduce "the enemy's post-war power", and therefore the risk of a new Cold War and nuclear conflict.307 The problem of pure anti-city retaliations, central to the organisational frame of the FBM programme, had virtually disappeared from US nuclear policy.

The new doctrine was voluntarily leaked to the public and the Soviet Union by James Schlesinger on 4 March 1974, and immediately became attached to the name of the Secretary of Defense.[308] For the first time in US nuclear history, counterforce strikes were clearly and officially defined as the main problem to be addressed by *all* strategic forces. The emphasis placed by the Schlesinger doctrine on the new role of ballistic missiles was so great that Henry Kissinger recommended that President Nixon change NSDM-16 – the document containing presidential directives for nuclear weapons acquisition – before endorsing the new doctrine.[309]

With regard to the development of military technology, the main peculiarity of the Schlesinger doctrine was that not only doctrinal problems but also likely solutions were handed over to weapons sys-

304 Ibid., 2.
305 Ibid.
306 Ibid., 2–3.
307 Henry Kissinger, "Memorandum for the President. Subject: Nuclear Policy", memorandum, 7 January 1974, the National Security Archive, Washington D.C., 2.
308 James Schlesinger, "Strategic Forces", speech, Defense Department Annual Report, 4 March 1974.
309 Kissinger, "Memorandum for the President. Subject: Nuclear Policy", 2.

tems designers. As the goal of the Schlesinger doctrine was to make limited strikes clearly distinguishable from an all-out attack, it was necessary to develop "a more efficient hard-target-kill capability" in order to reduce the number of missiles necessary for a counterforce attack.[310] To this end, future weapons systems would have to enhance performance in terms of "accuracy, nuclear yield and the number of warheads applied to the target".[311] Finally, because the perspective of pure anti-city retaliations had vanished and because "a set of hard targets might be the most appropriate objective for our [U.S.] retaliation", the FBM programme was not exempted from addressing the problems and possible solutions identified by the new doctrine.[312]

Organisational knowledge and opposition to counterforce strikes

For the FBM programme, the technical requirements imposed by James Schlesinger on the development of new ballistic missiles was bad news. The SSPO had long excluded counterforce issues from its organisational knowledge. Instead, the organisation was committed to the development of a second version of the Trident missile, meeting the 6,000 miles objective of the initial ULMS concept.[313] As no initiative to address the problems posed by the new doctrine was taken, the lack of reactivity and adaptability of the FBM programme became obvious.

The first indication that the FBM programme had difficulties adapting to the Schlesinger doctrine came in November 1974. In order to reinforce the support of policy makers to the development of a second version of the Trident missile, the SSPO published a booklet explaining the contribution of the FBM programme to national security. Based on the criteria of the Strat-X study, this short publication presented the purpose of the programme as providing a "survivable deterrent to nuclear war for the 1980's and beyond".[314] The booklet also demonstrated that the problems and solutions attached to the Schlesinger doctrine had not been integrated into the organisational

310 Schlesinger, "Strategic Forces". It must be noted that Schlesinger also called for the parallel development of low yield weapons to limit collateral damages when striking targets located near or inside urban areas. However, low-yield nuclear weapons are not considered as strategic but as tactical weapons, and therefore lay outside the scope of this study.

311 James Schlesinger, "Strategic Forces".

312 Ibid.

313 Spinardi, *From Polaris to Trident*, 141.

314 SSPO, "Trident System", rapport, 1974, Operational Archives, Command File Post 1 JAN 74, Naval Historical Center, Washington D.C., 3.

frame of the FBM programme. Indeed, this publication did not contain a single reference to characteristics such as missile accuracy or nuclear yield. Instead, missile range, increased patrol areas and submarine survivability – three issues ignored by Schlesinger during his presentation of the new doctrine – were heavily emphasised.[315]

The gap between the "old" conception of deterrence proposed by the FBM programme and the concepts of counterforce, limited strikes and intra-war deterrence was obvious, and would heavily penalise the SSPO. In the context of the economic downturn following the 1973 oil crisis, the US Congress refused to fund the development of a second version of the Trident missile, but instead authorised the Air Force to resuscitate the WS-120A under a new name: the MX missile.[316]

High accuracy imposed on the FBM programme

This first conflict between the FBM programme and US nuclear strategy was overcome when the executive branch intervened directly to force the SSPO to develop a missile with the technical characteristics suggested by James Schlesinger. In 1975, the Department of Defense successfully persuaded the Congress to fund the "Improved Accuracy Program" (IAP) as a part of Trident I development activities.[317] Work on a second version of the Trident missile was still denied, but the results of the IAP could be applied to existing weapons systems and the Congress was committed to the long-term support of the FBM programme. The SSPO remained unenthusiastic about developing missile guidance solely for the purpose of counterforce strikes. The possibility of improving SLBM accuracy beyond that of Trident I was disputed and the cost of the IAP was – probably deliberately – overestimated at 1.5 billion dollars.[318] Schlesinger did not agree and decided to "push" the FBM programme once more for maximal accuracy by personally meeting with the director of the SSPO in order to explore

315 Ibid., 10, 11, 16, 21.
316 Traditionally, the US Congress is relatively hostile to counterforce ideas. However, in 1974, the Nixon administration successfully convinced the Armed Force Committee that better capabilities against hard targets were needed. See: Håkan Karlsson, *Bureaucratic Politics and Weapons Acquisition: The Case of the MX ICBM Program* (Stockholm University, Department of political science, 2002), 188–211.
317 Spinardi, *From Polaris to Trident*, 143. For more details on the IAP and the decision to allow funds for improving SLBM accuracy, see also : United State's Senate, "Committee on Armed Services, Fiscal Year 1975, Authorization for Military Procurment, Part 6, Research and Development", 3289.
318 United State's Senate Armed Service Committee, "Committee on Armed Services, Fiscal Year 1975, part 6", 3298; Spinardi, *From Polaris to Trident*, 142.

possible improvements in missile guidance.[319] Several technologies such as GPS guidance, better exploitation of previous flight-test data, and more precise submarine navigation assets were initially considered. Eventually, it appeared that the best possible increase in missile accuracy would be realised by improving the stellar-inertial guidance system of Trident I.[320]

High accuracy was considered by Schlesinger as a solution to the problem of counterforce strikes. However, based on his recommendation to rely on technology previously developed for Trident, high accuracy suddenly became compatible with the rest of the organisational frame of the FBM programme for two reasons. Firstly, as the SSPO had sunk costs in the guidance system of the Trident I missile, improving stellar-inertial technology represented the most sensible way to develop a new guidance system for future SLBMs. Secondly, as stellar-inertial technology reduced the need for submarines to perform position fixes near the surface, a more accurate star tracker might further reduce the need for position fixes and improve submarine survivability. Therefore, in the particular perspective of the FBM programme, stellar-inertial technology also proposed increasing returns, because it could serve as a solution to the problem of vulnerability. For this reason, the SSPO began the development of a new star-tracker and broke new ground in this challenging technology.[321] In contrast, the development of inertial components of guidance systems did not receive much attention during the Improved Accuracy Programme, as they could not improve survivability of the missile force.[322] However, by 1977, the SSPO had made significant progress in the area of missile

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319 The choice of the expression “to push” is from James Schlesinger himself, during an interview with Donald Mackenzie. See: *Inventing Accuracy*, 287.

320 Mackenzie, *Inventing Accuracy*, 284; Spinardi, *From Polaris to Trident*, 145–46.

321 The technology employed on Trident I relied on a Vidicon tube, a variation of conventional cathode ray tubes used in regular televisions and low-end consumer cameras. However, Vidicon tubes were subject to various kinds of interferences and not least to “Vidicon microphony,” a phenomenon occurring when intense noises or vibrations bended the surface of the sensor and distorted the picture generated by the star-tracker. To overcome this problem, the SSPO decided to switch to solid-state electronics and developed the first operational Coupled-Charge Device (CDD). While CDD represent today a common feature for general public digital cameras, by the time this technology was considered by many as beyond the state of the art. On 6 October 2009, George Elwood Smith and William Sterling Boyle were awarded Nobel Prize in Physics for the development of early CCD sensor technology. See: Ove Strindehag, *Optimized performance of the vidicon* (Göteborg: Scandinavian Univeristy Books, 1963); Mackenzie, *Inventing Accuracy*,251–90; Julio Sanchez, *Space Image Processing* (Boca Raton: CRC Press, 1999), 90–91.

322 While gyroscopes used in Trident II guidance system represented direct adaptations of those used for Trident I, accelerometers were more complex and proved challenging to manufacture. However, their design was still inspired by the pendulous accelerometers used on Polaris missiles. See: Mackenzie, *Inventing Accuracy*, 290. See also: Spinardi, *From Polaris to Trident*, 145–46.

accuracy and the Congress allowed the development of a new missile, named Trident II D-5.[323]

Improving nuclear yield from the perspective of anti-city strikes

The decision of the Congress to fund the development of Trident II D-5 was also motivated by a new presentation booklet explicitly stating that "Trident II would have a greater payload and improved accuracy".[324] The expression "greater payload" was an obvious allusion to Schlesinger's requirement that the nuclear yield of new ballistic missiles be increased. In contrast to its initial resistance to develop a more accurate missile, the SSPO had no objections to increasing the military payload for Trident II. Indeed, as long as the new missile would be equipped with multiple warheads, any improvement in nuclear yield would increase the total equivalent megatonnage of the missile and therefore its ability to destroy soft targets such as urban centres.

In order to increase nuclear yield of Trident, the FBM programme took full advantage of the increasing returns of multiple warhead technology. In 1979, the first large SSBN, initially intended for Trident missiles, was launched.[325] While the submarine was not yet operational, it was now certain that Trident II would be housed in larger launch tubes.[326] The SSPO therefore began the preliminary design of the new missile as a scaled-up version of Trident I. By using an enlarged bus vehicle, the eight warheads carried by Trident I could be improved and eventually achieved an individual yield of 475 kilotons.[327] This represented an impressive equivalent megatonnage of 3.8 megatons, more than any single warhead SLBM of comparable size could ever deliver. Therefore, in comparison with single warhead technology, the further development of the MIRV vehicle used on Trident I presented a better potential to improve destruction of defended urban-industrial targets. As a consequence, improving nuclear yield of the Trident II missile as

323 Spinardi, *From Polaris to Trident*, 146.

324 SSPO, "Trident System", rapport, 1977, Operational Archives, Command File Post 1 JAN 74, Naval Historical Center, Washington D.C., 2.

325 SSPO, "FBM Facts/Chronology. Polaris-Poseidon-Trident", 52.

326 The first Trident II submarine was commissioned on 11 November, 1981 and was equipped as an interim measure with Trident I missiles. See: Mathew M. Wald, "First Trident Sub is Commissionned in Connecticut", *New York Times*, 12 November 1981; "1st Trident Sub Is Commissioned", *Washington Post*, 12November 1981.

327 Spinardi, *From Polaris to Trident*, 153.

requested by James Schlesinger was not only technologically "sweet", but represented an excellent occasion to improve anti-city capabilities.

Survivability versus counterforce

With a predicted accuracy of 0.06 miles (120 meters) and eight MIRVed warheads of 475 kilotons, the future Trident II was considered by some policy makers and the public opinion as a good hard-target killer.[328] However, the SSPO never primarily considered Trident II as such. During the development years of Trident II, the organisation reaffirmed on several occasions that the supposed first strike and counterforce capabilities of the missile were a "myth", arguing instead that the problem of survivability was the key to the Trident programme.[329] Naturally, the communication agenda of the SSPO was shaped partly by the need to reduce public opposition and win the support of the Congress – an institution traditionally hostile to counterforce ideas. Nevertheless, this line of argument seems to have been genuine. In 1990, several years after the counterforce controversy was over, a third booklet was published to present the result of the Trident II project. Expressions such as "hard-target," "counterforce" or "intra-war deterrence" were still carefully avoided. Instead, the declared purpose of the FBM programme was still "to prevent nuclear war", and the emphasis was put on more time on improving survivability provided by developing long range SLBMs.[330]

The technical characteristics of Trident II tend to confirm that the FBM programme did not attempt to optimise the missile for counterforce strikes. Indeed, the SSPO refused to increase missile payload to a proportion that could have conflicted with submarine survivability.

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328 For example, see: United State's Senate, "Committee on Armed Services, Fiscal Year 1982, Part 9", hearing, Natural Resource Defense Council Research Collection, record 431, box 30, The National Security Archive, Washington D.C., 291; United State's Senate, "Committee on Armed Services, Fiscal Year 1985, Part 6", hearing, Natural Resource Defense Council Research Collection, Record 431, box 30, The National Security Archive, Washington D.C., 110–111; Wayne Biddle, "New Trident Missile Bears a Payload of Apprehension", *New York Times*, 9 September 1984; "Why Fly Trident II?", *Seattle Post-Intelligencer*, 5 December 1986; "Newest U.S. Submarine called nightmare for the Soviets", *Houston Chronicle*, 18 December 1986. This debate also reached the academic community, through a set of articles published mainly in the Journal of Peace Research. For example, see: Desmond J. Ball, "The Counterforce Potential of American SLBM Systems", *Journal of Peace Research* 14, no. 1 (1977); Albert Langer, "Accurate Submarine Launched Ballistic Missiles and Nuclear Strategy", *Journal of Peace Research* 14, no. 1 (1977); Robert D. Glasser, "Enduring Misconceptions of Strategic Stability: The Role of Nuclear Missile-Carrying Submarines", *Journal of Peace Research* 29, no. 1 (1992).

329 For example, see: John M. Weinstein, "Trident II Remains Vital to Deterrence", *New York Times*, 24 March 1986.

330 SSPO, "FBM Facts/Chronology. Polaris-Poseidon-Trident", 3.

Initially, several different adaptations of the Trident I missile were considered in order to take advantage of the extra room allowed by larger launch tubes.[331] In terms of payload, the best performances for counterforce strikes were presented by a design known as "D-5 clear deck", where the third stage was omitted to liberate space for two to four extra warheads.[332] The "D-5 clear deck" would have had the same range as Trident I, and therefore failed to generate interest within the SSPO. Instead, by including a third stage at the expense of extra warheads, the SSPO augmented the range of Trident II to 6,000 miles.[333] The loss of counterforce power represented by this decision should not be underestimated. Considering that new SSBNs had 24 launch tubes, the installation of a third stage on Trident II implied a potential loss of 48 targets per submarine, and the reduction of 22,800 kilotons of the total megatonnage of the missile force – more than the total yield delivered by 24 Trident I missiles.

Table 8: Basic organisational frame, ULMS proposal, Trident II D-5

purpose/goal of the organisation	"to prevent nuclear war" (SSPO presentation booklet, 1990)
problems addressed	1. vulnerability 2. penetration of defended urban-industrial targets
solutions proposed	1. SSBN basing, increased range for larger patrol areas thanks to low inert weight, provided by multiple warheads system 2. high equivalent megatonnage for maximal effects against urban-industrial targets, multiple warhead system for increased ABM defences penetration
constraints on possible solutions	communication systems excluded from the jurisdiction of the SSPO research on counterforce strikes excluded from the organisational knowledge of the SSPO

331 Spinardi, *From Polaris to Trident*, 146–47.

332 Dalgleish and Schweikart, *Trident*, 32–35. There is no official data about the exact number of extra warheads the "D-5 clear deck" would have carried. The numbers presented in this study represent the most conservative estimate.

333 Officially, the SSPO and the Navy have not released any information about Trident II range, except the statement "superior to 4,000 miles." However, Trident II's actual range of 6,000 miles range was leaked apparently for the first time in a 1997 publication of the U.S. Naval Institute. See: Friedman, *The Naval Institute Guide to World Naval Systems 1997–1998*, 189.

War-fighting or fighting change?

The evolution of nuclear strategy toward counterforce strikes during the early development of Trident II sheds light on interesting features of the FBM programme. The organisational knowledge of the SSPO prevented the organisation from recognising and addressing the Schlesinger doctrine in the first place. But under the constraints of policy makers, the FBM programme was able to adapt its activities and propose some changes in the design of the Trident II missile. However, political control over the activities of the FBM programme was only superficial. During the early development of the Trident II, the FBM programme did not seek to optimise missile technology for counterforce strikes. Instead, characteristics suitable for counterforce strikes were developed only if they also improved survivability and anti-city strikes, and exploited the sunk costs and the increasing returns of previous SLBM technologies. As the FBM programme was pursuing the development of the Trident II missile, a new evolution of US nuclear strategy would call for missile characteristics opposed to the previous activity of the FBM programme. This would shed light on the incapacity of policy makers to control the development of military technology outside the organisational framework of the FBM programme, and impose solutions that cannot be linked to previous sunk costs or increasing returns of previous technologies.

The countervailing strategy

From 1976 to 1983, the Schlesinger doctrine progressively evolved into a countervailing strategy. At the origin of this change was an important modification of the strategic balance between the United States and the Soviet Union. For several years, Soviet leaders had been trying to achieve nuclear parity with US strategic forces. Firstly, from 1965 to 1972, the USSR sought to counteract the quantitative advantage of the United States by commissioning two new types of ICBMs in large numbers.[334] Secondly, from 1972 to 1980, Soviet ballistic missiles were modernised to feature high accuracy, MIRVed payloads, and high-yield warheads.[335] Because of these characteristics, new Soviet missiles were considered by the United States as counterforce weapons. In public opinion and among most policy makers, a feeling of vulnerability soon appeared. In 1976, the belief that the Soviet Union could

334 Podvig *Russian Strategic Nuclear Forces*, 6–8.
335 Ibid., 16–19.

eliminate as much as 90 per cent of US land-based missiles during a pre-emptive attack began to emerge.[336] Thanks to SLBMs and manned bombers, the ability of the United States to perform some kind of nuclear retaliation was not in doubt. However the capability to perform one of the limited scenarios proposed by the Schlesinger doctrine after enduring a Soviet first strike was uncertain. A "window of vulnerability" was opened.[337]

The new strategic situation became an important political issue following the publication of two controversial articles by Paul Nitze in 1976.[338] Nitze was a former member of the TCP panel that recommended that Eisenhower develop IRBMs in 1955, and was extremely influential among defence intellectuals and the executive branch.[339] His two articles presented a nightmare scenario in which the Soviet Union could destroy virtually all US ICBMs while retaining a large reserve force.[340] As of 1976, land-based ICBMs were the only counterforce weapons systems in the US strategic arsenal, Nitze argued that the United States would have lost the capability to perform limited nuclear strikes and control conflict escalation. Within the department of Defense and the strategic community, many were uncertain about whether escalation, once begun, could be controlled, even under the most favourable conditions. But if American cities were to be left intact by the first attack, the United States would certainly be deterred from striking back against Soviet urban, industrial and economic centres in fear of a retaliation in kind.[341] Under these circumstances, US decision-makers would be left with only two alternatives: to surrender or to commit suicide by performing a major retaliation on Soviet cities. Therefore, for the communist bloc, a nuclear war was not only possible, but winnable.[342]

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336 Warner R. Schilling, "U.S. Strategic Nuclear Concepts in the 1970s: The Search for Sufficiently Countervailing Parity", *International Security* 6, no. 2 (1981): 69. The belief that a pre-emptive attack could destroy 90 per cent of U.S. ICBMS was also widely spread within the general public see: Strobe Talbott, "The Vulnerability Factor", *Time Magazine*, 31 August 1981.

337 Pavel Povdig, "The Window of Vulnerabilit that Wasn't: Soviet military Buildup in the 1970's", *International Security* 33, no. 1 (2008): 118–138.

338 Paul Nitze, "Assuring Strategic Stability in an Era of Détente", *Foreign Affairs* 54, no. 2 (1976): 207–232; Paul Nitze, "Deterring our Deterrent", *Foreign Policy* 25 (1976): 195–210.

339 On Paul Nitze's influence on the emergence of the countervailing strategy, see: Kaplan, *The Wizards of Armageddon*, 377–84; Strobe Talbott, *The Master of the Game: Paul Nitze and the Nuclear Peace* (New York: Vintage books, 1988).

340 Nitze, "Assuring Strategic Stability in an Era of Détente".

341 Nitze, "Deterring our Deterrent".

342 Ibid.; Colin S. Gray, *The MX ICBM and National Security* (New York: Praeger, 1981), 17.

Initially, the scenario presented by Paul Nitze was understood as "paper and pencil strategy".[343] His argument was valid from a conceptual point of view, but it was the height of abstraction and relied on too many doubtful assumptions.[344] However, during the late 1970s, US policy makers became progressively convinced that Soviet doctrine was oriented toward nuclear war-fighting and considered victory possible.[345] Still, a successful Soviet pre-emptive strike was considered unlikely. But in order to prevent the Soviets "from doing something stupid", President Carter progressively came to the conclusion that "the most potent deterrent America could possess was a capacity to engage, and win a war".[346]

Between 1977 and 1980, the Carter administration published several directives to transform this conclusion into an actual strategy.[347] For the first time the concept of countervailing was applied in nuclear strategy, implying that the United States now envisaged assuring its national security by being ready to *fight* a nuclear war. The doctrinal background of the new strategy was rooted in the heritage of James Schlesinger. Indeed, in order to conduct war-fighting operations, the concept of limited counterforce strikes was essential because of the need to precisely discriminate targets from their environment and employ forces effectively – that is to use the right number of warheads per objective, without overkill.

The new doctrine attached to the countervailing strategy had nevertheless two noteworthy differences with what Schlesinger had previously proposed. Firstly, the infrastructure of the communist party, centres of political decisions, military command posts and Soviet communications assets were introduced as a new category of targets, and

343 Freedman, interview.
344 Kaplan, *The Wizards of Armageddon*, 379. Lacking intelligence data on Soviet missiles, Nitze had to assume values such as silo hardiness, missile accuracy and number of MIRVed warheads. His assessment of Soviet forces turned to be proved wrong after the Cold War.
345 Nitze, "Assuring Strategic Stability in an Era of Détente", 215–17; Njølstad, *In Search for Superiority*, 49.
346 Freedman, interview; Njølstad, *In Search for Superiority*, 122.
347 "U.S. Nuclear strategy", Presidential directive PD/NSC-18, 24 August 1977, Presidential Directives, part II, PR 01359, DNSA, Washington D.C.; "National Security Telecommunications Policy", PD/NSC-53, 15 November 1979, Presidential Directives, PD 01526, DNSA, Washington D.C.; "Nuclear Weapons Employment Policy", Presidential Directive PD/NSC-59, 25 July 1980, Presidential Directives, PD 01530, DNSA, Washington D.C. It must be noted that the copy of PD/NSC-59 available at the National Security Archive is very highly excised. More detailed data can be found in Njølstad, *In Search for Superiority*, 48.

given the highest priority.[348] The objective was to reduce the ability of the Soviet leadership and the communist party to control the USSR and coordinate nuclear war-fighting operations. Secondly, while Schlesinger called for *pre-planned* limited strikes, the countervailing strategy asked for increased flexibility and the ability to make *tailor-made attacks*, according to the evolution of war.[349] Indeed as the combat progressed, the Soviet leadership might change location and some US silos would be destroyed, being unable to cover their initially intended targets. Additionally, enemy silos that had already fired their missile would not present any military value. Therefore, survivable C^3 assets became as important as the survivability of the missile force itself.[350]

While the Carter administration stopped short of publicly calling the countervailing strategy a "winning strategy", the Reagan administration did not display the same restraint.[351] With victory set as a clear objective for nuclear strategy, the early 1980s were characterised by a re-activated arms race between the United States and the Soviet Union. The appearance of mobile ICBMs in the USSR led American policy-makers to devise a new Single Integrated Operational Plan, including 4,000 re-locatable targets.[352] In order to perform disarming strikes against mobile ICBMs, the Congress allocated funds for developing communications networks able to survive up to 180 days during a nuclear conflict.[353] However, finding a survivable basing mode for land-based ICBMs such as the MX missile proved to be more difficult than first expected.[354] After many proposals were rejected, a presiden-

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348 Desmond J. Ball, *Targeting for Strategic deterrence*, Adelphi Papers, no. 185 (London: International Institute for Strategic Studies, 1983): 23; Njølstad, *In Search for Superiority*, 50.

349 "Nuclear Weapons Employment Policy", PD/NSC-59; Njølstad, *In Search for Superiority. U.S. Nuclear Policy in the Cold War*.

350 "National Security Telecommunications Policy", PD/NSC-53, 1–2.

351 Robert Scheer, *With Enough Shovels: Reagan, Bush and Nuclear War* (New York: Random House, 1982); Freedman, *The Evolution of Nuclear Strategy*, 387–88.

352 Desmond J. Ball and Robert C. Toth, "Revising the SIOP: Taking War-fighting to Dangerous Extremes", *International Security* 14, no. 4 (1990): 72–77; Njølstad, *In Search for* Superiority, 51. See also: William M. Arkin, "Why SIOP-6?", *Bulletin of the Atomic Scientists* 39, no. 4 (1983): 9–10.

353 Ball and Toth, "Revising the SIOP: Taking War-fighting to Dangerous Extremes", 68; Loren B. Thompson, *The emergence of American Central Nuclear Strategy, 1945–1984* (Washington D.C: Geortown Univeristy, 1986), 530–531.

354 See: Jeffrey G. Barlow, "Insuring Survivability: Basing the MX missile", report, 27 May 1980, personal archive; Jeffrey R. Smith, "A Last Go-Around for the MX Missile", *Science* 218 (1982): 865–866; J. Raloff, "Regan's MX 'Peceakeeper' Draws Fire". *Science News* 122 (1982): 536; Colin S. Gray, *The Future of Land Based Missile Forces*, Adelphi Papers, no. 140 (London: International Institute for Strategic Studies, 1977); Gray, *The MX ICBM and National Security* ; Barry R. Schneider, Colin S. Gray, and Keith B. Payne, *Missiles For the Nineties: ICBMs and Strategic Policy* (Boulder: Westview Press, 1984); Hebert Scoville, *MX: Prescription for Disaster* (Cambridge: MIT press, 1982); For an analysis of the MX programme from the bureaucratic politics perspective, see: Karlsson, *Bureaucratic Politics and Weapons Acquisition*.

tial commission on strategic forces finally concluded in 1983 that a survivable basing mode for ICBMs was impossible and called instead for increased reliance on SLBMs.[355] For the FBM programme the challenge was now to design a missile with an actual war-fighting capability, flexible enough to adapt promptly to the evolution of the conflict and not just to perform pre-planned options.

Submarine communications

As early as 1979, the problem of communications between the National Command Authority and submarines on patrol was identified as the main obstacle to using SLBMs for war-fighting missions.[356] Peace-time systems were able to "provide reliable communications to the strategic submarine forces", but war-time command and control capabilities were considered insufficient.[357] At the time, communications with submerged submarines relied on two different systems. Firstly, during normal operations, command and control of SSBNs was supported by land-based Very Low Frequency (VLF) radio stations. However, VLF transmissions are characterised by a very limited bandwidth. In optimal conditions the maximum transfer data rate was only about 67 words per minute.[358] Secondly, during war-time, or if land-based radio stations were destroyed, surveillance aircrafts trailing a long aerial would be used to deliver emergency action messages with a comparable data-rate.[359]

War-time communications with submarines were inadequate for three reasons. Firstly, the airborne system had been allowed to decay and its operational capabilities were doubtful.[360] Secondly, in the con-

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355 Known as the "Report of the President's Commission On Strategic Forces", or the "Scowcroft Commission Report", this document is partly reproduced in Philip Bobbitt, Lawrence Freedman, and Gregory F. Treverton, *U.S. Nuclear Strategy: A Reader* (London: McMillan, 1989), 477–510. The Congress also considered replacing the MX missile by Trident II. See: House Appropriation Committee (HAC), "Department of Defense Appropriation, Fiscal Year 1984", Washington D.C., U.S. Government Printing Office, part 1, 475.

356 The expression National Command Authority refers to the lawful source of orders during a nuclear war, that is the President and the Secretary of Defense.

357 Government Accountability Office (GAO), "An Unclassified Version of a Classified Report Entitled 'The Navy's Strategic Communications Systems – Need for Management Attention and Decision Making", report PSAD-79-48A, 2 May 1979, Natural Resource Defense Council Research Collection, record 431, box 30, The National Security Archive, Washington D.C., I.

358 Ibid., 33.

359 Ibid., I-II, 8.

360 Ibid., 9, Spinardi, *From Polaris to Trident*, 83–84. Supposed to provide a *permanent* airborne alert in order to defeat a potential surprise attack on land based communication stations, the system was operational only 25 per cent of the time by 1980. See: House Appropriation Committee (HAC), "Department of Defense Appropriations for Fiscal Year 1982", Washington D.C., U.S. Government Printing Office, hearing, part 7, 4048.

text of a nuclear war in which mobile missiles and Soviet leadership might constantly change their location, slow communications were irrelevant. As communications were ciphered and each submarine would have a missile force totalling up to 192 warheads, re-targeting would take hours.[361] When striking fixed missile bases, there was a risk that enemy missiles would have left their silos before retargeting was completed. This problem was reinforced by the low rate of fire of submarines, taking several minutes to launch an entire force of 24 Trident II.[362] Thirdly, as submarines could not communicate back to the National Command Authority, there was no way to be certain that SSBNs had received proper re-targeting information.[363] While the objective was to control conflict escalation or to perform efficient war-fighting operations, a significant risk existed of striking unintended targets such as the Kremlin or a random dam in Siberia.

The inability of SLBMs to conduct proper war-fighting operations due to the lack of efficient C^3 assets was widely recognised during the 1980s.[364] However, there is no declassified document or available material indicating that the SSPO ever directly addressed this problem during the development of Trident II or before the end of the Cold War. The reason for this is simple. Since Polaris A-1, the organisational frame of the FBM programme limited the development of advanced communications systems for SSBNs. As research into command, control and communications was eventually transferred to another branch of the Navy in 1967, developing a coherent C^3 system for Trident II was no longer the responsibility of the SSPO.[365] The path dependent evolution of the FBM programme had materially locked the organisation into a very specific and restricted field of activities.

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361 192 warheads represent the payload carried by a force of 24 trident II missiles, each equipped with eight warheads. Beside the coordinates of the target allocated to each warhead, messages sent to submarine had to enclose an authentication key, fusing parameters for proper explosion, and the timing of the attack.

362 "Congressional Record – House of representative", minutes, 18 June 1985, Natural Resource Defense Council Research Collection, record 431, box 30, The National Security Archive, Washington D.C., 4471.

363 This problem was noticed by Henry Kissinger as early as 1969. See: Laurence E. Lynn, "Memorandum for Dr. Kissinger, Subject: the SIOP", minutes of telephonic conversation, 8 November 1969, Nixon Presidential Material, NSC files, box 384, folder SIOP, National Archives, College Park, 7.

364 Michael F. Altfeld and Stephen J. Cimbala, "Trident II for Prompt Counterforce? A critical Assessment", *Defence Analysis* 3, no. 4 (1987): 349–359; Schneider, Gray, and Payne, *Missiles For the Nineties*; Gray, *The Future of Land Based Missile Forces*, 9; Gray, *The MX ICBM and National Security*, 85.

365 Bruce G. Blair, *Strategic Command and Control: Redefining the Nuclear Threat* (Washington D.C.: Brookings Institution, 1985), 169; Spinardi, *From Polaris to Trident*, 83; Sapolsky, *The Polaris System Development*, 240.

The Navy organisation in charge of the development of C3 technologies for SSBN operations was the Special Communications Project Office (SCPO). Established in the immediate aftermath of the Strat-X study, the objective of this organisation was to design the means to receive "communications at all time from the National Command Authorities and Commander in Chief to the deployed FBM forces [...] during and after heavy nuclear and electronic attack".[366] The solutions proposed by the SCPO relied on a network of extremely low frequency (ELF) radio stations named "Austere ELF".[367] The advantages of this system were its virtual immunity to jamming and interferences generated by nuclear explosions, coupled with a better penetration of sea water allowing SSBNs to remain at greater depths. However, with regard to the countervailing strategy, Austere ELF had highly undesirable characteristics. Given that the original purpose of the SCPO was to exclusively develop a means to *receive* radio signals, two-way communications were left unaddressed. Moreover, extremely low frequencies are characterised by their very poor bandwidth, and it would have taken more than 15 minutes to communicate a group of three letters to a submarine.[368] Instead of increasing SSBNs' responsiveness to the National Command Authority, the "Austere ELF" proposal presented the risk of further reducing the flexibility of the SLBM force.[369]

In light of these conditions, why did policy makers refrain from imposing on the SCPO the development of efficient C3 assets? A possible answer lies in the organisational knowledge attached of the FBM programme. Excluded from the research agenda of the SSPO during the development of Polaris A-1, two-way communications were soon regarded as an "impossible technology".[370] As all research on SSBN communications were excluded from the FBM programme in 1967, the SSPO was unable to pursue and endorse evolutions in radio-communications technologies. As late as October 1988, representatives

366 United State's Senate Armed Service Committee, "Fiscal Year 1973 Authorization for Military Procurement, Research and Development, hearings, part 5", Washington D.C., U.S. Government Printing Office, 2844. Quoted in Blair, *Strategic Command and* Control, 169.

367 Walter Sullivan, "How Huge Antenna Can Broadcast Into the Silence of the Sea", *New Yorks Times*, 13 October 1981.

368 Stockholm Peace Research Institute (SIPRI), "Command and Control of the Sea Based Nuclear Deterrent: The Possibility of a counterforce role", in *Year Book 1979. World Armament and Disarmaments* (New York: Oxford University press, 1979), 402.

369 Eventually, the Austere ELF proposal was abandoned on the ground of environmental and public health concerns. See: Spinardi, *From Polaris to Trident*, 82.

370 Polaris Command Communications Committee, "Where did the $100 millions go? Polaris Command Communications Yield Summary", Washington D.C.: Special Project Office, 11 May1964. Quoted in Sapolsky, *The Polaris System Development*, 239.

of the Navy and the SSPO presented two-way communications and submarine responsiveness to the National Command Authority as impossible to achieve in the "foreseeable future".[371] Whether this was a genuine belief within the FBM programme, or an argument developed by the SSPO to avoid developing a technology perceived as undesirable, is an open question. However, policy makers seem to have been persuaded that an efficient command, control and communications chain could not be established with submarines on patrol. Despite the absence of improvement in flexibility and responsiveness to the National Command Authority, neither the Department of Defense nor the Congress opposed the commissioning of the Trident II missile in 1990.[372]

The failure of the FBM programme to develop relevant C3 technologies, illustrates the limits of political control over military technology. As the SSPO could not rely on any technology previously developed within the FBM programme, two-way communications were simply declared beyond the state of the art. In addition, as the organisational knowledge of the SSPO contaminated political elites, all impartial and independent control of the technological development of the FBM programme was lost. While Trident II had acceptable capabilities against hardened targets, the failure to swiftly retarget the SLBM force at sea implied that this weapons system was ineffective for the flexible and tailor-made counterforce strikes envisaged by the countervailing strategy.

The SUM proposal

Contrary to the belief held by the SSPO, the Navy, the Congress and the Department of Defense, efficient C^3 assets adapted to SLBM operations were probably well within the state of the art by the early 1980s. However, in order to develop two-way communications without decreasing submarine survivability, an important departure from the organisational frame of the FBM programme was necessary. Such a departure was proposed in 1981 by two noted defence scien-

371 James R. Woosley, "Remarks at the conference 'The Future of Land-based deterrent'", speech, October 17, 1988, Washington D.C., personal archive, document provided by *The Heritage Foundation*.

372 SSPO, "FBM Facts/Chronology. Polaris-Poseidon-Trident", 7.

tists and Pentagon consultants, Richard Garwin and Sidney Drell.[373] Anticipating the conclusions of the Scowcroft commission report about the vulnerability of land-based missiles, the two scientists investigated a method "to provide a survivable, sound and economical approach to basing the MX missile system".[374] The result of their research was known as the smallsub undersea mobile (SUM) missile system, but presented substantial differences with SLBMs operations as they were conceived by the SSPO.[375]

As Garwin and Drell developed the SUM proposal, they identified three key problems. Firstly, the missile force had to be survivable, i.e. relatively immune to a pre-emptive attack and able to maintain operational capabilities during a nuclear war. Secondly, missiles had to feature high accuracy and responsiveness to the National Command Authority. Thirdly, the whole system had to be more cost-effective than the MX basing modes previously rejected by the presidential commission on strategic forces.[376] The solution proposed to solve the problem of vulnerability was to base the MX missile on board submarines. However, contrary to large SSBNs, SUM-submarines would be limited in size, have conventional diesel-electric propulsion and only carry two missiles in external canisters.[377] The intercontinental range of the MX missile would not be used to provide large patrol areas, but instead to allow submarines to stay within the coastal waters of the United States, under the permanent protection of the surface fleet.[378] In order to solve the problem of accuracy and responsiveness to the National Command Authority, Garwin and Drell proposed several distinct technical solutions. Firstly, submarine position at launch would be determined thanks to GPS navigation. To enforce the sur-

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373 Richard Garwin is a noted physicist who developed the first thermonuclear device under the supervision of Edward Teller. During the three following decades Garwin worked for IBM and the Department of Defense as one of the main experts on nuclear weapons technology. Garwin was also an active member of the Jason Defense Advisory Group and was awarded the National Medal of Science in 2002. Sidney Drell is an expert in theoretical physics, nuclear weapons technology, arms control and public policy. Drell also worked fort the Jason Defense Advisory Group and is a fellow of the Hoover Institution, an important US public policy think thank.

374 Garwin, interview.

375 See : Sindey D. Drell and Richard L. Garwin, "Basing the MX Missile: A Better Idea", *Technology Review, edited by the Massachusetts Instiute of Technology*, no. 050081MXTR (1981): 29.

376 Garwin, interview.

377 Office of Technology Assessment (OTA), "MX Missile Basing", report NTIS #PB82-108077, September 1981, U.S. Government Printing Office, Washington D.C., 172; Drell and Garwin, "Basing the MX Missile: A Better Idea", 25.

378 SUM submarines were planned to operate within 600 miles of US cost line, with possible extension to 1,000 or 1,500 miles. See: OTA, "MX Missile Basing", 180; Drell and Garwin, "Basing the MX Missile: A Better Idea", 24.

vivability of this part of the system, it was also planned "to deploy thousands of 'pseudolite' GPS stations on US territory that would give GPS-equivalent accuracy if GPS [satellites] were destroyed".[379] After launch, accuracy would be further improved by the use of a stellar-inertial guidance system. Secondly, in order to be in permanent contact with the National Command Authority, each submarine would be equipped with several mechanical "fish" patrolling directly above the submarine, at very low depth.[380] Because of their proximity to the surface, the "fish" would be able to pick up radio signals easily before sending them back to the submarine as mega-hertz acoustic waves. For tactical and two-way communications, SUM-submarines would have used expandable surface buoys that could be trailed at a distance of more than 20 kilometres thanks to a thin fibre-optical cable.[381] Finally, the only constraints placed on the development of the system were cost effectiveness and a relatively short development time for technological solutions.[382]

According to the SUM proposal, each submarine could have made extensive use of two-way communications systems because the survivability approach selected by Garwin and Drell differed significantly from that of the FBM programme. Instead of focusing on the vulnerability of each submarine, the point of the SUM system was to increase the survivability of the missile force as a single entity. As each SUM-submarine would carry no more than two missiles, a fleet of more than 50 vessels would be deployed to assure that at least 100 missiles were on permanent alert at sea.[383] Therefore, the use of communication buoys by a single submarine would not reveal the location of more than two per cent of the submarine fleet. As two-way communications would only be used to confirm re-targeting immediately prior to launch, by the time the enemy had discovered the position of a SUM submarine, it would be empty or have only one remaining missile on board. Therefore, the use of advanced and active communications by SUM submarines would never expose more than one missile at a time, accounting for one per cent of the total missile force. Furthermore, two more protective measures assured the safety of SUM-submarines

379 Electronic correspondence with Richard Garwin, September 2009.

380 For a description of this system, see: Richard L. Garwin, "Fish-Ragu (Fish, Radio-Receiving and Generally Useful)", Technical note JSN-81-64, August 1981, JASON Defense Advisory Group / SRI international, Arlington.

381 Garwin, interview.

382 Electronic correspondence with Richard Garwin, September 2009.

383 OTA, "MX Missile Basing", 171; Drell and Garwin, "Basing the MX Missile: A Better Idea", 28.

that had fired one of their missiles. Firstly, because the communication buoy could be trailed tens of kilometres behind the vessel, the use of direction-finding equipment could only provide a very approximate position of the submarine.[384] Secondly, as SUM-submarines would not roam the oceans but remain in coastal waters, they would be protected by surface units once their location was revealed to the enemy.[385]

Table 9: Summary of the SUM proposal

purpose/goal of the organisation	"provide a survivable, sound and economic basing mode for the MX missile"
problems addressed	1. vulnerability 2. high accuracy and responsiveness to the National Command Authority 3. cost effectiveness
solutions proposed	1. submarine basing, SLBM operations from friendly waters under protection of the surface fleet 2. GPS navigation/stellar -inertial guidance, communication "fish", two-way communications buoy 3. small submarines, diesel propulsion
constraints on possible solutions	proposed solutions are to be less expensive than other suggested basing modes

In contrast to most weapons systems developed during the 1980s, the SUM proposal relied on well-proven technology. The MX missile selected by Garwin and Drell had already been developed by the Air Force and did not encounter any failure during its flight tests. Diesel-electric submarines had been used since World War I, and it was considered that Germany had already developed a vessel perfectly adapted to the SUM system.[386] Finally the "fish" and surface buoy used for communications relied on cheap technology and could be assembled for less than 1,000 dollars per unit.[387] The total cost of 55 SUM-submarines, three operating bases, 100 MX missiles and the exploitation of the system during a ten year period was estimated at $ 30 billion, less than any other land-based solutions considered at the

384 Garwin, interview.
385 Furthermore, coastal and shallow waters are known to represent a very difficult environment for Anti-Submarine warfare. See: Kosta Tsipis, *Tactical and Strategic Antisubmarine Warfare* (Cambridge: MIT Press, 1974).
386 OTA, "MX Missile Basing", 171.
387 Garwin, "Fish-Ragu (Fish, Radio-Receiving and Generally Useful)", 13.

time by the Department of Defense.[388] A survivable SLBM force with a high degree of responsiveness to the National Command Authority was not only possible, but technologically "sweet" and affordable.

Given these conditions, why did the SUM system never leave the drawing board? The answer to this question seems to lie in the organisational frame of the FBM programme. According to Richard Garwin, the SUM system "was not so much rejected as ignored", because "neither the Air Force nor the Navy [i.e. the SSPO] wished to sponsor it".[389] While the causes of the Air Force refusal stand beyond the scope of this study, the refusal of the SSPO can be explained by its particular organisational knowledge. As the issue of two-way communications and C^3 with the National Command Authority had been excluded from the research agenda of the FBM programme, there was little chance that the value added by the SUM proposal would be acknowledged. While the SSPO merely ignored the SUM proposal, the rest of the Navy literally "hated" this project.[390] As the US Navy had sunk costs in nuclear propulsion for almost thirty years and just cleared the controversy about the new Trident submarine, the SUM system and its potential German-made diesel-electric submarine was considered a sacrilege.[391] Compared with the ease with which the FBM programme switched from surface ships to submarine basing during the development of the Polaris A-1 missile, the reaction of the SSPO clearly illustrated how a efficient adaption to nuclear strategy had now become impossible.

The argument proposed by Richard Garwin to explain why the SSPO and the Navy ignored the SUM system is difficult to verify as there is no available documents from the FBM programme discussing the SUM project. Nevertheless, the absence of such documents tends to confirm the account given by Garwin. Arguably, the SUM proposal had its own limitations. In contrast to their nuclear counterpart, diesel

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388 OTA, "MX Missile Basing", 210; Drell and Garwin, "Basing the MX Missile: A Better Idea", 28.

389 Garwin, interview. In addition, the author has not been able to find any congressional record or technical evaluation sceptical about the SUM system. On the contrary, the evaluation of the Office of Technology Assessment was very positive. See: OTA, "MX Missile Basing".

390 Quoted from Richard Garwin, electronic correspondence, 21 September 2009. This expression was also repeated during his interview.

391 On the emergence of nuclear submarine propulsion within the US Navy, see: Theodore Rockwell, *The Rickover effect: How one Man Made a Difference* (Annapolis: Naval Institute Press, 1992); Richard G. Hewlett, *Nuclear Navy, 1946–1962* (Chicago: University of Chicago Press, 1974). For an example of criticism against SUM-submarines on the grounds of their small size and non-nuclear propulsion, see: Dalgleish and Schweikart, *Trident*, 289–93.

submarines need to snorkel close to the surface to recharge their batteries, making them easier to detect and to track down. Accordingly, snorkelling operations must be carefully planned so as to only expose a few submarines simultaneously, and allow time for their dispersion before new units could recharge their batteries.[392] In addition, carrying missiles in external canisters raised safety issues and environmental risks in case of submarine collision. With 14 underwater collisions reported between 1962 and 1984 – five of which involving nuclear missile submarines – patrol routes would have to be precisely determined to remove any risk of accident among the 50 planned SUM submarines.[393]

These difficulties might have made the actual development of the SUM system more challenging than first assessed by Garwin and Drell. Nevertheless, the mere existence of the SUM proposal shed light on how scientists outside the FBM programme reacted to the countervailing strategy, by devoting important efforts to optimise counterforce capabilities and developing adequate communications and control technologies. A course of action that was never envisaged by the SSPO, locked as it was in a narrow technological framework by nearly 30 years of path dependent evolution.

392 Assuming a speed of five knots, a submarine snorkelling every 24 hours could only be localised on average with a precision of 120 nautical miles. This represents a circular area of 45,000 squared miles, so a barrage attack with nuclear weapons would have to use 600 warheads with a five miles kill radius in order to destroy a single SUM submarine spotted while snorkelling. See: OTA, "MX Missile Basing", 176–182.

393 Dalgleish and Schweikart, *Trident*, 42.

Chapter 6

Conclusion

Far from being a well-controlled weapons programme finding its origins in the problem of missile vulnerability, the FBM programme presented complex dynamics throughout its history. Paradoxically, SLBM technology initially emerged with ambitions of providing a tactical, war-fighting weapons system, but eventually failed to provide such a capability when 30 years later, US nuclear strategy placed its emphasis on counterforce strikes. In the meanwhile, the FBM programme had become the specialist of survivable strategic forces and retaliatory strikes on urban-industrial centres.

This study revealed two essential misunderstandings of previous accounts of the FBM programme. The first being the belief expressed by Harvey Sapolsky, that SLBMs were initially developed as purely deterrent weapons. While this author acknowledged that some documents from the FBM programme were addressing counterforce issues, he described them as a "smokescreen" to win the support of naval aviators.[394] From his perspective, the SPO never seriously envisaged developing and commissioning the Jupiter and Polaris missiles as counterforce weapons. However, this study has rejected this interpretation, for two reasons. Firstly, the documents produced by the SPO presenting the counterforce potential of its SLBM project were not only addressed to naval aviators, but also to policy makers who favoured the concepts of deterrence and massive retaliation. Secondly, the FBM programme did not only purport to develop technologies relevant for counterforce strikes, but also had an active research project on this issue until 1964.

The second misunderstanding identified by this study is the widespread belief that Trident I and Trident II missiles had a counterforce

394 Sapolsky, *The Polaris System Development*, 44, 220.

and war-fighting capability.[395] For instance, Spinardi argued that the history of the programme could be understood as a relatively uncontrolled evolution from deterrence to counterforce.[396] In contrast, based on recently available documents and current declassifications, this study presented evidence to the contrary. From this new perspective, the history of the FBM programme is to be understood as a process by which counterforce ideas were progressively excluded and the deterrent mission of SLBMs reinforced.

However, Spinardi was correct when he concluded that "technology is not completely out of control [...], but neither is it very much under control".[397] This study has further developed this idea in order to determine more precisely by which process political control over some precise technologies was gained, or lost. As the FBM programme was created in the midst of a critical juncture, its survival was threatened and its leadership was pushed towards searching permanent support at the bureaucratic and strategic level. Because the programme could not rely on any previous missile technology, it had to invent efficient solutions *ex-nihilo,* and was free to change its activities to match the evolution of its strategic and bureaucratic environment. However, during the development of new generations of SLBMs, the FBM programme became locked in a narrow framework as it followed a path dependent evolution. Concluding that technological determinism directly explains the evolution of the FBM programme would nevertheless be too simple. Instead, particular SLBM technologies such as solid propellant, multiple warheads or stellar inertial guidance, contributed to modify organisational interests of the SSPO and limited the set of attractive solutions proposed to policy makers.

What lessons can be learned from the case of the FBM programme to better an understanding of current issues in nuclear technology? Firstly, this study sheds new light on the nature and limits of political control over the development of nuclear weapons technology. Such control cannot be merely understood as the ability of civilian leaders to change the course of main weapons programmes. Indeed, while civilian authorities, to a certain extent, had some influence on the activities

395 Ball, "The Counterforce Potential of American SLBM Systems"; Langer, "Accurate Submarine Launched Ballistic Missiles and Nuclear Strategy"; Glasser, "Enduring Misconceptions of Strategic Stability: The Role of Nuclear Missile-Carrying Submarines".

396 Spinardi, "Why the U.S. Navy went for Hard-Target Counterforce in Trident II" ; MacKenzie and Spinardi, "The Shaping of Nuclear Weapon System Technology".

397 Spinardi, *From Polaris to Trident*, 193.

of the SSPO until the term of the FBM programme, they still failed to obtain a weapons system adapted to the countervailing strategy. Instead, political control may be defined as the ability of civilian leaders to initiate weapons programmes at their discretion, and to reject any proposed solutions unless they precisely match particular specifications. From this perspective, civilian authorities do not necessarily need to address intricate issues such as propulsion or guidance systems to keep a tight control of military technology. During the 1950s and 1960s, civilian authorities kept SLBM technology under tight control threatening to reduce SPO resources or to close down the FBM programme; but refrained from intervening directly in the research agenda. In contrast, James Schlesinger achieved only limited results by directly addressing the practical development of guidance systems or missile payloads with engineers from the SSPO.

Secondly, as the SPO/SSPO introduced most of the solutions currently used in ballistic missile technology in the US and abroad, the history of the FBM programme provides new insights about the technical characteristics of current nuclear weapons systems and their origins. The majority of long range ballistic missiles currently under development rely on solid propellant, multiple warheads and stellar-inertial guidance.[398] While these technologies currently represent the most efficient solutions to addressing problems relative to propulsion, penetration of ABM defences and accuracy, this study demonstrated that this has not always been the case. Instead, solid propellant was initially developed to face safety issues, multiple warheads to reduce inert weight and stellar-inertial guidance to keep accuracy constant without making submarines vulnerable during navigation fixes. However, as several decades of development have increased the returns of these technologies while other fields of research – such as liquid fuels – have been allowed to decay, they may currently represent the most sensible option for engineers developing nuclear weapons.

In this context, the path dependent evolution of the FBM programme may well contribute to explaining why some ballistic missiles under development seem to be locked in a Cold War framework, while current nuclear policies address new threats such as proliferation, terrorism and transnational actors. As current weapons programmes exploit the sunk costs and increasing returns of technologies developed

398 See: A. Ochsenbein "SS-NX-30 Bulava Datenblatt"; "M-51. Missile mer-sol balistique stratégique"; "JL-2 (CSS-NX-4)".

by SSPO during the Cold War, they are unlikely to easily adapt to new policies or strategic problems. Neither are they likely to invest in totally new technologies that would initially be less efficient than the existing ones. In addition, current constraints on military spending represent a major obstacle to the creation of new organisations dealing with the development of nuclear technology. These conditions create an unfavourable environment for the occurrence of a new critical juncture that may reconnect nuclear strategy and the development of nuclear weapons technology.

There is, however, still place for moderate hope. As current weapon programmes face limited and unstable funding, their survival might be conditioned to the development of ballistic missiles contributing more directly to national security and increasing the credibility of new nuclear policies. This might present sufficient incentives to significantly reframe the activity of some of the most threatened weapons programmes, and search for alternative technologies more suitable for current nuclear employment scenarios. Such an evolution is most likely to occur within the United States, which is likely to launch the development of a successor to Trident II in the next decade. As more than twenty five years will separate the two missiles, the missile development team would be totally renewed. Under these conditions, the next US ballistic missile might be less affected by the organisational knowledge, sunk costs and increasing returns inherited from the FBM programme. After having locked the evolution of ballistic missiles into a path dependent framework, time might eventually become the best ally of a new generation of sound, safer and more sensible nuclear weapons.

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