CHINA'S FUTURE NUCLEAR SUBMARINE FORCE

EDITED BY
ANDREW S. ERICKSON, LYLE J. GOLDSTEIN,
WILLIAM S. MURRAY, AND ANDREW R. WILSON

JOINT PUBLICATION OF THE
CHINA MARITIME STUDIES INSTITUTE AND THE NAVAL INSTITUTE PRESS

China's Future Nuclear Submarine Force

Edited by Andrew S. Erickson, Lyle J. Goldstein, William S. Murray, and Andrew R. Wilson

PUBLISHED IN COOPERATION WITH
THE CHINA MARITIME STUDIES INSTITUTE

NAVAL INSTITUTE PRESS
Annapolis, Maryland

Note: The views represented in this book are those of the authors themselves and do not represent the official policies or assessments of the U.S. Navy or any other U.S. government agency.

Naval Institute Press
291 Wood Road
Annapolis, MD 21402

© 2007 by the United States Naval Institute
Annapolis, Maryland

All rights reserved. No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and recording, or by any information storage and retrieval system, without permission in writing from the publisher.

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA
China's future nuclear submarine force / edited by Andrew S. Erickson . . . [et al.].
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-1-59114-326-0 (alk. paper)
ISBN-10: 1-59114-326-8 (alk. paper)
1. Nuclear submarines—China. 2. Sea-power—China. 3. China—Military policy—21st century. I. Erickson, Andrew S.
V859.C6C55 2007
359.9'30951—dc22

2006039757

Printed in the United States of America on acid-free paper ♾

14 13 12 11 10 09 08 07 9 8 7 6 5 4 3 2
First printing

Contents

Andrew S. Erickson and Lyle J. Goldstein

China's Future Nuclear Submarine Force

Insights from Chinese Writings

Introduction

THE ADVENT OF THE YUAN-CLASS SSK in mid-2004 has had a major impact in transforming the assessments of Western naval analysts, and also of the broader community of scholars studying China's military modernization. In order to grasp the energy that China is now committing to undersea warfare, consider that during 2002–04 China's navy launched thirteen submarines,[1] while simultaneously undertaking the purchase of submarines from Russia on an unprecedented scale. Indeed, China commissioned thirty-one new submarines between 1995 and 2005.[2] Given this rapid evolution, appraisals of China's capability to field competent and lethal diesel submarines in the littorals have slowly changed from ridicule to grudging respect of late.[3] China's potential for complex technological development is finally being taken seriously abroad.

Whereas the Yuan's debut allegedly surprised Western analysts, the emergence of China's 093 SSN and 094 SSBN have been anticipated for some time. Nevertheless, these programs remain shrouded in mystery and there is little consensus regarding their operational and strategic significance. In the broadest terms, it can be said that a successful 093 program will significantly

enlarge the scope of Chinese submarine operations, perhaps ultimately serving as the cornerstone of a genuine blue-water navy. The 094 could take the survivability of China's nuclear deterrent to a new level, potentially enabling more aggressive posturing by Beijing in a crisis. Moreover, these platforms are entering the PLA Navy (PLAN) at a time when reductions are projected to occur in the U.S. Navy submarine force[4]—a fact duly noted by a senior PLAN strategist recently in one of China's premier naval journals.[5]

The PLA is notoriously opaque, posing major challenges for Western analysts. Official statements regarding the intentions of China's future nuclear submarine force are all but nonexistent.[6] Nevertheless, one of the most significant statements is contained in the 2004 PLA Defense White Paper's discussion of naval operations. Enhancing "nuclear counterattacks" capability was described as one of the PLAN's most important missions. Moreover, Chinese unofficial writings on defense issues are voluminous and growing more so. Among dozens of journals, magazines, and newspapers devoted to military affairs (not to mention hundreds of more technically oriented publications) are at least five focusing specifically on naval warfare.[7] This chapter will survey the available Chinese writings concerning the PLAN's future nuclear submarine force. Two caveats are in order. First, this chapter seeks to present the views of Chinese analysts, but does not render final judgment on the validity of those views. Such an approach will better acquaint a broader community of naval analysts with the essential primary source materials. Second, this is not a comprehensive study, but rather a preliminary research probe. These data need to be treated with a certain amount of caution and follow-on studies are necessary before major conclusions can be drawn.

The chapter begins with a brief survey of relevant elements from PRC writings concerning the PLAN's nuclear submarine history. A second section examines how PLAN analysts appraise developments among foreign nuclear submarine forces: what lessons do they glean from these other experiences? The third section concerns mission imperatives: what strategic and operational objectives are China's 093 and 094 submarines designed to achieve? The potential capabilities of these submarines are addressed in this chapter's fourth and final section.

Historical Perspectives

Chinese naval writings reveal an intense pride regarding Beijing's naval nuclear-propulsion program. These writings, in the "glorious genre" as it were, are well documented in John Wilson Lewis and Xue Litai's ground-

breaking and authoritative classic *China's Strategic Seapower*.[8] This article will not attempt to examine Chinese writings to check for consistency with the conclusions in the detailed study by Lewis and Xue (though this is a worthwhile project and should be undertaken given the wide variety of new Chinese secondary-source data). Rather, this analysis highlights several important trends in contemporary PRC discussions of the first-generation nuclear submarines in order to assess the prospects for the next generation.

In his recent autobiography, published in Chinese by the official PLA press in 2004, Admiral Liu Huaqing provides a unique level of detail concerning the foundation for China's contemporary development of nuclear submarines.[9] Credited with an instrumental role in modernizing China's navy, Admiral Liu presided over a steady improvement and expansion of China's submarine force as both commander of the PLAN (1982–88) and vice chairman of the Central Military Commission (1989–97). In 1984, Admiral Liu emphasized: "We must place importance on submarines at all times. . . . Nuclear-powered submarines should be further improved and used as a strategic task force."[10] Liu viewed nuclear submarines not only as "a deterrent force of the nation" but also as "an expression of our country's overall strength." As commander of the PLA Navy, Liu emphasizes, "I paid exceptional attention to the practical work of developing nuclear-powered submarines. From 1982 through 1988, I organized various experiments and training sessions in this regard. I also considered developing a second generation of nuclear-powered submarines."[11] PLAN emphasis on submarine development continues today. As the 2005 edition of the PLA's first authoritative volume on strategy emphasizes, "Stealth warships and new-style submarines represent the modern sea battle platforms."[12]

Chinese periodicals shed light on more recent factors shaping Chinese nuclear submarine force development. One important 2004 PRC survey of China's emerging nuclear submarine program from the journal 世界航空航天博览 (*World Aerospace Digest*), reviews a series of inadequacies in China's submarine force which became starkly evident during the 1990s. According to this report, the 1993 *Yin He* incident was an important event for crystallizing the PRC commitment to a new generation of nuclear attack submarines. Thus, when the Chinese freighter was inspected in Saudi Arabia before proceeding to Iran, the PRC high command was apparently "extremely furious, but had no recourse" [怒火万分却毫无办法]. At that point, the leadership redoubled its efforts to build a "capable and superior nuclear attack submarine that could protect China's shipping in distant seas." The author notes that "at present, our country only has five Han-class nuclear attack submarines. . . . This number is

insufficient and the capabilities are backward. . . . Thus, they are inadequate to cope with the requirements of the new strategic situation."[13]

The 2004 memoirs of former PLAN commander Admiral Liu appear to lend some credence to this sequence of events as they state that the Central Military Commission began development work on a "new generation nuclear submarine," probably the 093, in 1994.[14] "In 1990 the last [of the original five Han-class SSNs] was launched," Liu recalls:

> After I briefed President Jiang Zemin on this, he decided to personally inspect the launch of this submarine. At the time of inspection, he said resolutely: "Development of nuclear-powered submarines cannot be discontinued." On 29 May 1992, when forwarding the Navy's report on building nuclear-powered submarine units to President Jiang, I particularly stressed the need to continually develop science research and do successful safety work. President Jiang wrote a note on the report, giving his important instructions on this matter. Based on his instructions, in the course of developing nuclear-powered submarines, we formed a seamless and effective nuclear safety mechanism by drawing on the experience of foreign countries while taking our practical situation into account. The mechanism included regulations and rules, technological controls, and supervisory and examination measures. In 1994, in compliance with President Jiang's instructions, the Central Military Commission and its Special Committee adopted a decision to start developing a new generation of nuclear-powered submarines. Seeing that there were qualified personnel to carry on the cause and that new types of submarines would continue to be developed, I felt relieved.[15]

The above analysis in *World Aerospace Digest*, however, does cut against what appears to be conventional wisdom in China's naval literature, which tends to credit China's Han submarines with a significant role in the 1996 Taiwan Strait crisis. Thus, one report states that in mid-March 1996, "U.S. military satellites were unable to detect the position of [certain] Chinese nuclear submarines; it was as if they . . . had vanished." This narrative continues, "The U.S. carrier battle groups were unable to cope with the hidden, mobile, high-speed, undersea" threat posed by the Chinese nuclear submarines, and thus "were unable to approach the sea area within 200 nautical miles of Taiwan." Implying some uncertainty on this issue, the author asks, "Why did the U.S. carrier group suddenly change its original plan? Was it that they feared China's nuclear submarines?"[16] Another PRC report also alleges that U.S. military satellites lost track of China's SSNs and that the U.S. Navy was forced to retreat when confronted by the "massive threat of China's

nuclear submarine force."[17] Given the Han-class SSN's reputation as a noisy vessel, these statements might well be viewed with suspicion—and, indeed, they are not reproduced here to suggest their truth.[18] Nonetheless, these Chinese conjectures are related here because they could be indicative of the intellectual context within which 093 and 094 development has occurred.

Most China scholars agree that the intellectual space for debate and disagreement in China is, and has for some time been, rather wide. In this respect, the analysis from *World Aerospace Digest* is once again noteworthy. While the vast majority of PLAN writings concerning the single Type 092 Xia SSBN heap praise on China's technical achievements, this analysis breaks new ground (in the PRC context) by drawing attention to the Xia's inadequacies. It notes candidly, "the Xia-class actually is not a genuine deterrent capability." Noting the symbolic value of the vessel, the author explains that the Xia was important to answer the question of "having or not having" a nuclear submarine, but then enumerates the platform's numerous problems: high noise levels and radiation leakage, not to mention the short range of the single warhead carried by China's first-generation submarine-launched ballistic missile (SLBM), the Julang-1. Forced to approach the enemy's shores, and vulnerable to enemy ASW, the Xia "cannot possibly serve as a viable nuclear, second-strike force." It is no wonder, the author explains, that China did not opt to build a "whole batch" of these problematic submarines.[19] No doubt, such candid observations suggest that Chinese strategists do not necessarily overestimate the capabilities of their first generation nuclear submarines, perhaps adding additional impetus to the building of a second generation.

Even more important than the observations concerning history cited above, however, are the views of China's "founding fathers" of naval nuclear propulsion. Two of these founding fathers recently offered interviews to the press, in which they expounded on the outlook for nuclear submarines in naval warfare. First, Peng Shilu, designer of China's first naval nuclear reactor, was interviewed in 国际展望 (*World Outlook*) in 2002. Although Peng drafted his first reactor designs more than three decades ago, this engineer is unwavering in his commitment: "In the First World War, the battleship was the most important vessel; and in the Second World War, it was the aircraft carrier. [But in] the future, I believe the most critical naval asset will be the nuclear submarine." For Peng, the SSN's primary strengths are: high power, fast speed, large carrying capacity for equipment and personnel, extended deployment capability, as well as excellent concealment possibilities. According to Peng, "Nuclear submarines can go anywhere . . . their scope of operations is vast [and they are therefore] most appropriate to meet the security requirements of a great power."[20] Drawing on another interview with Peng Shilu, an analysis published in 2005 by China's Central Party School Press concludes: "[Such is] the huge superiority of nuclear propulsion [that it] simply cannot be compared with conventional propulsion."[21]

An interview with the Han submarine's chief designer, Huang Xuhua, which appeared in the military periodical 兵器知识 (*Ordnance Knowledge*) in 2000, is more explicit regarding some of the dilemmas confronting China's naval nuclear propulsion program. Huang discusses the conundrum for naval strategists posed by the option to choose between development of AIP (air-independent propulsion) technology and nuclear propulsion. The interviewer asks Huang directly whether it makes sense to continue with nuclear propulsion development, given recent world-wide advances in AIP technology. Huang points out that nuclear propulsion offers far more power, is likely much safer and more reliable, and enables submarines to stay submerged for longer periods of time. Taking Sweden's *Gotland*-class AIP-equipped submarine as an example, he suggests that this submarine's two weeks of submerged operations at an average speed of four knots might not "be adequate for combat requirements." Huang accepts that certain bathymetric conditions are ideal for AIP-equipped diesel submarines, such as those prevailing in the Baltic Sea (a small, shallow area). For Sweden, therefore, Huang says, "It is scientifically logical to select this type of submarine." The implicit argument, however, is that China confronts rather different, if not wholly unrelated, maritime challenges and requirements.

In making an argument for Chinese nuclear submarine development, Huang draws a parallel to Britain's deployment of SSNs during the Falklands War. He notes that their high speed was critical to their success in deploying to a distant theater in a timely fashion. Indeed, other PRC naval analysts have been impressed by the sea-control capabilities that British SSNs afforded during this scenario—the most intense naval combat since the Second World War.[22] Huang then makes the observation that such high-speed submarines are critical for a nation, such as the United Kingdom, that—in contrast to the United States—no longer possesses a global network of bases.[23] For the PRC, which takes great pride in its lack of overseas bases, this would appear to be an argument for SSNs serving as the basis of a blue-water navy with considerable reach. Indeed, writing in China's most prestigious military publication, 中国军事科学 (*China Military Science*), PLAN Senior Captain Xu Qi goes so far as to state that China's "navy must . . . unceasingly move toward [the posture of] a 'blue-water navy' [and] expand the scope of maritime strategic defense. . . ."[24]

Comparative Perspectives

The Falklands War is hardly the only naval campaign of interest to Chinese strategists, as PRC analysts produce an extraordinary volume of analyses concerned with modern naval warfare—often generated by carefully dissecting foreign secondary sources. There is a large appetite for information regarding the United Kingdom's history of nuclear submarine operations[25] and even such nascent nuclear submarine powers as India.[26] However, Chinese naval strategists evidently prioritize analyses of the American, the French, and especially the Russian nuclear submarine fleets.

From a very early stage, PRC engineers demonstrated concretely that they were not averse to adopting American designs, as they conspicuously embraced the teardrop configuration for their first generation of nuclear submarines in contrast to then-current Soviet designs.[27] Today the threat component is also evident in PLAN analyses of the U.S. submarine force. Chinese researchers display intimate familiarity with all U.S. Navy submarine force programs, including the most cutting edge platforms, such as Sea Wolf[28] and *Virginia*.[29] Additionally, there is great interest in the ongoing transformation of some SSBNs into SSGNs.[30] Ample focus is also devoted to the capabilities of the *Los Angeles*-class as the backbone of the U.S. Navy submarine force.[31] Beyond platforms and programs, there is also a keen interest in America's industrial organization for nuclear submarine production and maintenance.[32]

Chinese analysts also closely monitor French nuclear submarine development.[33] They have paid particular attention to the manner in which France strives to maximize the effectiveness of its second-tier nuclear submarine force.[34] The September 2005 issue of 舰船知识 (*Naval & Merchant Ships*) features a lengthy report, apparently by a Chinese naval officer studying in France, who has made multiple visits to French nuclear submarines based in Brest. This report makes note of numerous details, from the vast support network at the base to France's tendency to support a high quality of life aboard its nuclear vessels. Concerning the value of France's SSBN force, which is noted to comprise "80% of France's nuclear weaponry," the author quotes a French military expert as saying, "France's SSBNs ensure national security, carry out strategic nuclear deterrence and [have] basic power for independent national defense." Other issues highlighted in this report include personnel practices (e.g., age limitations, two crews per submarine), operations cycles (a 2/2/2 pattern for SSBNs that matches other Chinese discussions—see below), command and control arrangements, quieting technologies, and the small size of certain classes of French SSNs.[35]

It is with the Russian nuclear submarine force, however, that the Chinese navy feels the greatest affinity. This is not surprising and springs from historical, strategic, and perhaps even organizational-cultural affinities that appear to have been cemented since the passing of Sino-Soviet enmity in the late 1980s. Chinese analysts are well aware of the crisis that the Russian nuclear submarine force has suffered in recent years. They have written extensively on the *Kursk* tragedy and other accidents.[36] For instance, one source has documented the great embarrassment suffered during an SLBM test failure that was witnessed directly by Russian president Vladimir Putin in early 2004.[37] Chinese analysts note the vastly decreased building rate for Soviet nuclear submarines, and voice concern lest the legacy force be insufficient to contend with [抗衡] the United States.[38]

Nevertheless, respect for Russian nuclear submarine achievements has not diminished significantly.[39] A review of Soviet naval development that appeared in *China Military Science* in 1999 extols the virtues of nuclear submarines: "Relying on nuclear submarines, the Soviet Union rapidly overcame the unfavorable geostrategic situation, giving the USSR an ocean going navy with offensive capability."[40] Perhaps reflecting on internal debates in China regarding naval modernization, the author also describes how the Russian naval development encountered a major obstacle from a faction adhering to the notion that "navies have no use in the nuclear age" [核时代海军无用论].

Reflecting on today's Russian navy, 当代海军 (*Modern Navy*) lavished praise on the capabilities of a refurbished Typhoon-class SSBN, *Dmitry Donskoy*, that was relaunched in 2002;[41] it also hailed the 2001 launch of an Akula-class SSN, *Gepard*, which is described as the world's quietest nuclear submarine. The latter report also noted that *Gepard* has twenty-four nuclear-armed cruise missiles.[42] In a war game (of unknown origin) modeling a Russian-Japanese naval conflict, which was reported on in considerable detail in the October and November 2002 issues of *Naval & Merchant Ships*, the Russian nuclear submarine force overcame Japan's ASW forces and inflicted grave losses (thirteen ships sunk) on the Japanese navy.[43] This would appear to be a subtle argument that China also requires a substantial fleet of SSNs.

In Chinese naval periodicals, the affinity with the Russian nuclear submarine force is manifested by vast coverage of the most minute details of historical and contemporary platforms. In 2004–05, for example, the journal *Naval*

& Merchant Ships carried ten–fifteen-page special features, each devoted to outlining the development of a single class—such as the Victor, Delta, Oscar, and Alpha classes—complete with photo essays and detailed line drawings.[44] These features are suggestive of the volumes of data that have been made available over the last decade from the Russian side, and simultaneously the voracious appetite for such information within China's naval-studies community. Among such descriptions, perhaps no Russian submarine commands as much respect and interest as the massive Typhoon-class SSBN. Chinese analysts are captivated not only by this vessel's gargantuan proportions,[45] but also the efficiency of its reactors, its impressive quieting characteristics, the attention to crew living standards, as well as command and control equipment and procedures.[46] Evidently Chinese naval analysts appear to comprehend the strategic significance of a platform that could strike adversary targets from the "Russian-dominated Barents and Okhotsk seas."[47]

Western analysts have followed Russian arms transfers to China with an all-consuming interest. But the above discussions imply that one should not underestimate the transfer of software and expertise that has occurred in parallel with that of the hardware. The true dimensions of these intellectual transfers remain unknown.

Mission Imperatives

PRC writings concerning nuclear submarines do not hide the symbolic role of these vessels. One, for example, remarks on the precise correlation between membership in the UN Security Council and the development of nuclear submarines.[48] Indeed, it appears to be conventional wisdom in the PRC that nuclear submarines represent one of China's clearest claims to status as a great power [大国].[49] In 1989, after China's successful test of the JL-1 SLBM, then-Central Military Commission Vice Chairman Admiral Liu Huaqing stated,

> Chairman Mao said that "we will build a nuclear submarine even if it takes 10,000 years." . . . Our nuclear submarine [and its] stealthy nuclear missile both succeeded. This has [had] strong international repercussions. As Comrade Deng Xiaoping has said, if we did not have atomic bombs, missiles, [and] satellites, then we would not [enjoy] our present international status, and could not shape international great triangle relations [as a balancer to the Soviet Union]. Developing strategic nuclear weapons has therefore [had] great strategic significance for the nation.[50]

Beyond symbolism, however, what are the missions that Chinese strategists envision for the second generation of PLAN nuclear submarines?

In general, nuclear submarines are credited with having significant advantages over conventional submarines: "a large cruising radius, strong self-power [i.e., electrical power supply], high underwater speed, great diving depth, [relative] quietness and large weapons carrying capacity."[51] Perceived advantages of conventional submarines include "small volume, low noise, low cost, and mobility."[52] Underscoring the cost differential, an anonymous PLAN officer is cited as stating: "the price of one nuclear submarine can buy several, even more than ten, conventional submarines. . . . As a developing country, our nation's military budget is still quite low, and thus the size of the navy's nuclear submarine fleet can only be maintained at a basic scale [基本规模]."[53]

In 1989, as vice chairman of the Central Military Commission, Admiral Liu stated: "I believe that there are two issues in developing nuclear submarines: one is the development of SSBNs, and one is the development of SSNs. Both types of nuclear submarines should be developed, especially SSNs. Along with technological development, enemy ASW power has strengthened. Originally, using conventional submarines was sufficient to accomplish [our] missions, but now that has become problematic, [so] we must develop SSNs."[54]

To understand what strategic roles the 093 submarine might undertake, it is essential to return to the discussion initiated by both Peng Shilu and Huang Xuhua in part one of this chapter concerning the particular tactical and operational advantages of nuclear submarines. Indeed, the sophistication of PLA thinking on these issues is underlined by Huang's analysis of the different roles played by SSNs for each side during the Cold War. For the Americans, he says, they were a vital element of "global attack strategy" [全球进攻战略]. For the Soviets, by contrast, their roles were to stalk enemy carrier battle groups, as well as to defend Soviet ballistic-missile submarines.[55] Concurring with Peng and Huang, a third analysis from 国防 (*National Defense*) enumerates further advantages of nuclear submarines by emphasizing the all-important factor of the SSN's impressive power supply. Not to be underestimated, this supply of power can vastly improve the crew's quality of life (e.g., by providing for strong air conditioning) and support electronic combat systems. In terms of combat performance, it is said that SSNs can employ their speed to foil ASW attack, and are built solidly to absorb battle damage.[56]

A consistent theme in PRC writings concerning SSNs involves their ability to undertake long-range missions of extended duration. Consistent with the analysis above that cited the 1993 *Yin He* incident as lending significant

impetus for the 093 program, a recent discussion of China's nuclear submarine force in *Naval & Merchant Ships* refers to the enormous growth in China's maritime trade as a factor in shaping China's emerging nuclear submarine strategy.[57] Likewise, another article from 现代舰船 (*Modern Ships*) on PRC submarine strategy suggests, "Submarines are the PLAN's main long-distance sea force. . . . Protecting China's sea lines of communication has become an important aspect of maritime security. This is an important new mission for the PLAN."[58] If nuclear submarines can "break through the island chain blockade" [突破岛链封锁], they can conduct long-distance operations without hindrance from the enemy's airborne ASW. In contrast to diesel submarines, nuclear submarines are said to be far superior in combat situations in which air cover is lacking—a recognized vulnerability of the PLAN in distant operations. But overall, there is a strong emphasis on the imperative for Chinese nuclear submarines to function in a joint environment, thereby complementing other PLA strengths.[59]

Nevertheless, these same analyses also exhibit some conservatism, for example suggesting explicitly that China's new nuclear submarines will not operate beyond China's second island chain (running from the Japanese archipelago south to the Bonin and Marianas Islands and finally to the Palau group).[60] Indeed, nuclear submarines are also said to be critical in the struggle to establish sea control [制海权] in the littoral regions and in China's neighboring seas. The linkage between the 093 program and the Taiwan issue (first suggested in part one of this chapter) is relatively clear: "In order to guarantee the required national defense strength and to safeguard the completion of national unification and to prevent 'Taiwan independence,' over the past few years, China has increased indigenous production of new conventional *and* nuclear submarines . . . " [emphasis added].[61] There is an acceleration of not only the building rate, but also the pattern of submarine development: "China's construction of a new generation of nuclear-powered attack submarines breaks with past practice, in which China would first build one vessel, debug it repeatedly, and then begin small batch production. In this case, work on the later submarines began almost simultaneously with work on the first. . . . China is doing it differently this time . . . because of the urgency of the surrounding situation."[62] Consistent with the Taiwan scenario hinted at above, it is said that China's nuclear submarines will be ideal for attacking a likely enemy's lengthy seaborne supply lines.[63]

Disturbingly, one article actually does raise the possibility of a long-range land attack and even a nuclear-strategic role for China's future SSN.[64]

But it is the 094 SSBN, of course, that is envisioned to have the primary role in the nuclear-strike/deterrence mission. Indeed, the same analysis suggests that, in contrast to Russia, China is planning to base a higher proportion—as many as half—of its nuclear warheads on submarines.[65]

One Chinese expert identifies bathymetry as influencing SSBN development and deployment. He suggests that countries with shallow coastal waters on a continental shelf (e.g., China) face strong incentives to develop smaller SSBNs in order to better operate in local conditions.[66] Among the reasons cited by Chinese strategists for continuing development of their nation's SSBN program are the inherent stealth and mobility of the submarine, which combine to make it the "most survivable type of (nuclear) weapon" [生存率最高的武器]. The PLAN is pursuing the 094, therefore, in order to 1) guarantee via deterrence that mainland China is not struck by nuclear weapons and 2) "to make sure, in the context of regional war, to prevent direct intervention by a third party" [阻止'第三者'直接介入的效果]. In this analysis, China's nuclear forces are viewed as being critical to deterring Washington in a Taiwan scenario, and the author is unusually candid: "At present, our country's nuclear deterrent forces are insufficient; [therefore] the potential for U.S. military intervention in a cross-Strait conflict is extremely high."[67] Another source, citing China's development of the 094 submarine, emphasizes that "If a war erupts across the Taiwan Strait one day, facing the danger of China waging nuclear war, it will be very difficult for America to intervene in the cross-strait military crisis."[68]

Another PRC analysis draws a direct link between the 094 and U.S. missile defense capabilities. It proposes: "In the face of the continual upgrade of the U.S. theater missile system and the excited U.S. research and development of all sorts of new antimissile systems, of course we cannot stand by idly and watch. . . . We must . . . [adopt] countermeasures. The most important of these countermeasures is to exert great effort on developing new types of nuclear-powered strategic missile submarines which are more capable of penetrating defenses . . ." Failure to do so, according to these authors, will increase the likelihood that "the opponent's nuclear cudgel may some day come crashing down on the heads of the children of the Yellow Emperor."[69]

A somewhat more subtle justification for the 094 makes the argument in quasi-legalistic terms. Since China currently has a no-first-use (NFU) policy for its nuclear forces, it is said to require the most survivable type of nuclear weapons (e.g. SSBN-based). The same analysis cautions that there is no need

to build SSBNs in the excessive numbers that characterized the Cold War at sea. Rather, China will seek a "balanced" [均衡] nuclear force (both land- and sea-based), just as it will seek a balanced navy.[70]

Capabilities

For Western analysts, the most important details concerning the 093 and 094 submarines involve their projected deployment numbers and capabilities. Here we will examine both Chinese naval writings and related technical research to suggest a range of possibilities. It is imperative to reiterate that we do not endorse the estimates offered below, but are merely presenting the data for other scholars and analysts to consider.

A major theme of Chinese writings is that while China cannot yet build submarines that meet advanced Western standards in all respects, it is intent on building successful 093 and 094 submarines. According to one source, "The technology involved is relatively mature."[71] The situation is strikingly different from that surrounding China's first generation of nuclear submarines, which were built in the 1960s and 1970s when China was unstable, impoverished, isolated, and technologically backward. One author cites China's "successful economic reforms" over the "past twenty years" and the accompanying "technological progress" as providing the necessary expertise and adequate "resources" for successful nuclear submarine development.[72] China is finally poised to capitalize on its decades of experience with related development and manufacturing processes.[73] Because of these advances, China's new nuclear submarines will not necessarily be copies of either American or Russian submarines, but rather an indigenous Chinese effort that is informed by foreign best-of-breed technologies and practices. Nor will Chinese nuclear submarines necessarily be used in the same roles for which U.S. and Soviet submarines were optimized (e.g., antisubmarine warfare).[74]

The actual number of 093 and 094 submarines that China constructs and deploys will offer insight into its naval and nuclear strategies. One Chinese source suggests that by 2010, China will field a total of six 094 SSBNs, divided into patrolling, deploying, and refitting groups.[75] Consistent with this projection, another source suggests that these groups will comprise two SSBNs each.[76]

Another critical question concerns the 093 and 094 submarines' acoustic properties. Chinese sources universally recognize that noise reduction is one of the greatest challenges in building an effective nuclear submarine.[77] PRC scientists have long been conducting research concerning the fundamental sources of propeller noise. For instance, experts at China Ship Scientific Research Center developed a relatively advanced guide vane propeller by the late 1990s.[78] This, and the fact that China already has advanced seven-blade propellers with cruciform vortex dissipaters on its indigenous Song-class and imported Kilo-class diesel submarines, suggests that the 093 and 094 will have significantly improved propellers. A researcher in Qingdao's 4808 Factory also demonstrates Chinese attention to the need to use sound-isolation couplings to prevent transmission of vibrations to the ocean from major fresh-water circulating pumps in the steam cycle.[79] Advanced composite materials are credited with capability to absorb vibrations and sound.[80]

One Chinese researcher states that the 093 is not as quiet as the U.S. *Sea Wolf*-class or *Virginia*-class, but is on par with the improved *Los Angeles*-class.[81] Another analyst estimates that the 093's noise level has been reduced to that of the Russian Akula-class submarine at 110 decibels [分贝].[82] He states that the 094's acoustic signature has been reduced to 120 decibels. According to this report, this is definitely not equal to that of the *Ohio*-class, but is on par with that of the *Los Angeles*-class.[83] There is no additional information given to evaluate concerning the origins or comparability of these data.

It is conceivable, if unlikely, that the PRC has achieved a major scientific feat concerning the propulsion system for nuclear submarines. As Shawn Capellano-Sarver's contribution to this volume suggests, a wide variety of Chinese sources claim that China has succeeded in developing a high-temperature gas-cooled reactor (HTGR) [高温气冷堆] suitable for use in its new-generation nuclear submarines. This development is described as being a "revolutionary breakthrough" [革命性突破].[84] Another source elaborates: "HTGR is the most advanced in the world, [its] volume is small, [its] power is great, [its] noise is low—it is the most ideal propulsion system for a new generation of nuclear submarines. The United States and Russia have both not achieved a breakthrough in this regard. According to Western reports, in the first half of 2000, China successfully installed an HTGR on a nuclear submarine. If this information is true, the 093 uses this advanced propulsion technology."[85]

This same analyst suggests that the need to incorporate the new HTGR explains why 093 development has stretched out over a number of years.[86] HTGR development is indeed cited as a major component of China's 863 High Technology Plan [863高科技计划] to develop selected key technologies.[87] The Institute of Nuclear Energy Technology (INET) at Qinghua University has constructed a ten megawatt HTGR, HTR 10.[88] Qinghua and MIT

signed a collaborative HTGR research agreement in 2003.[89] The Chief Scientist and Office Director in charge of energy technology development for the 863 Plan write that HTR 10's "high level results" make it "one of the most promising fourth generation systems."[90] In the area of nuclear reactor design, construction, and components, robust indigenous research has been supplemented by extensive technological assistance from such Western corporations as Westinghouse.[91]

As implied above, some Chinese analysts believe that the HTGR promises to give PLAN submarines unprecedented maximum speed.[92] China's Han submarines, by contrast, are said to have a maximum speed of twenty-five knots, while the Xia has a maximum surface speed of sixteen knots and underwater speed of twenty-two knots.[93] As mentioned before, however, Huang Xuhua believes that submarine speed is less important than concealment, which in turn depends on minimizing a submarine's acoustic signature.[94] Another possible benefit of advanced nuclear propulsion is increased reactor safety.

Despite the above speculation, there are substantial reasons to doubt that China would be willing or able to put such an immature technology in its second generation of nuclear submarines—as this would constitute a substantial risk on the investment. Moreover, as Shawn Capellano-Sarver points out, "The technical difficulties that would have to be overcome with the blowers (the need for magnetic bearings) and the fuel-loading system to make an HTGR compatible with a submarine are formidable. This makes the probability of the 093 being equipped with an HTGR small."[95]

As for armaments, the same analyst states that the 093 submarine may be equipped with "Eagle Strike" YJ-12 [鹰击-12] supersonic antiship cruise missiles.[96] The YJ-12 has been developed as part of a larger Chinese quest for improved cruise missiles, particularly submarine-launched variants.[97] The PLAN is presently working to equip "attack submarines with long distance, supersonic, low altitude missile travel, high accuracy, and strong anti-interference antiship missiles, with the combat capability to attack enemy surface ships from mid- to long-range."[98]

The 093 is said to have 65cm torpedo tubes.[99] In his interview, Huang discusses the engineering issues associated with torpedo tube diameter, explaining that "wider tubes support superior torpedoes and are *not* for . . . missiles or sound-dampening."[100] As for the number of missile tubes in the 094, two sources predict sixteen tubes compared with the Xia's twelve.[101] A third source forecasts between twelve and sixteen tubes.[102]

Admiral Liu Huaqing has recounted China's initial failure and ultimately successful effort to test launch the JL-1, or CSS-N-3, SLBM on 12 October 1982 from a submerged Golf-class submarine. This made China the fifth nation to have an undersea nuclear capability. "Launching carrier rockets from underwater has remarkable advantages, compared with using land-based or airborne strategic nuclear weapons," Liu emphasizes. "This is because the launching platform . . . has a wide maneuver space and is well-concealed. This gives it better survivability and, hence, greater deterrent power."[103] The JL-1 was test-fired successfully from the Xia on 15 September 1988.[104] According to one PRC analyst, "China believes that although the U.S. thinks the Xia-class submarine is too noisy and easy to detect, the Chinese navy is capable of going into the Pacific without detection because of its special tactics."[105]

The 094's JL-2 SLBM is projected to have a range of eight thousand kilometers,[106] compared to twenty-seven hundred kilometers for the JL-1.[107] There is also speculation that, in contrast to JL-1, JL-2 will have multiple independently targeted reentry vehicles (MIRVs). This would enhance nuclear deterrence by increasing China's number of undersea warheads and significantly bolstering their chances of penetrating an American national missile defense (NMD). One Chinese source predicts that each JL-2 SLBM will carry three to six warheads.[108] Another article makes the extremely ambitious claim that JL-2s already carry six to nine warheads each, and in the future will carry fourteen–seventeen.[109]

The question of how Beijing will communicate with its newly modernized submarine fleet constitutes a major operational challenge.[110] If China emulates other submarine powers, it is likely to pursue total redundancy for submarine command and control, relying on multiple means employing different physical principles. Extremely low frequency (ELF) communications have the advantage that messages can be received at depths of two to three hundred meters, thereby maximizing submarine stealth and survivability. There are major problems with ELF in practice, however, and it is not clear that China has mastered this technology. Most submarine communications are conducted across a wide range of frequencies, ranging from very low frequency to extremely high frequencies; submarines receive messages through exposed antennas while at periscope depth, or via floating or shallowly submerged antennas while near the surface. China might therefore create a dedicated maritime aircraft squadron for communications with its submarine fleet, if it has not already done so. A lengthy profile in *Naval & Merchant Ships* of the "U.S. Take Charge and Move Out" (TACAMO) air fleet, which

supports American SSBN operations, may buttress the general conclusion that Beijing is determined to perfect its communications with its submarine fleet as it launches a new generation of nuclear vessels.[111]

The SSBN communications issue is especially acute, but China has been grappling with this particular problem for more than two decades. According to Admiral Liu Huaqing, China on 16 April 1984 used "the satellite communications system for our nuclear-powered submarines to test the channels" of the Dong Fang Hong-2 communications satellite, which had been launched eight days before. "The navy's satellite communication system for its nuclear-powered submarines was the first one to open a test communication line with the satellite," Admiral Liu reports. "The success of the nuclear-powered submarine's experiment on instantaneous transmission of messages via the satellite . . . pushed China's submarine communication to a new level."[112]

Centralization is arguably essential for SSBN command, control, and communication (C_3), particularly in the highly centralized PLA. However, it is unclear to what extent this would be technologically possible for China. "At present China's communications infrastructure is vulnerable to a first strike," Garth Hekler, Ed Francis, and James Mulvenon contend. "As a result, the SSBN commander would require explicit and restrictive rules of engagement and . . . targeting data, lest crisis communications with Beijing reveal [the SSBN's] position to hostile attack submarines or if the submarine is cut off from Beijing after a decapitating first strike." On the broader question of submarine force command and control doctrine, it is suggested, "While the PLAN may recognize the effectiveness of decentralized C_3 for certain types of submarine missions, it appears to be seeking to create a more tightly centralized submarine C_3 system by developing command automation, network centric warfare strategies, and advanced communications technologies."[113]

Chinese naval planners realize that rapidly improving equipment is useless without corresponding improvement in human performance. The PLAN has for some time been pursuing nuclear submarine missions of extended duration. In his recently published memoirs, Admiral Liu relates that he raised the priority of long duration exercises for PLAN nuclear submarines in order to test all parameters of these new capabilities.[114]

Apparently as part of these expanded activities, current PLAN Chief of Staff Sun Jianguo reportedly commanded Han 403 during a mid-1980s mission of ninety days[115] that broke the eighty-four-day undersea endurance record previously set by USS *Nautilus*.[116] Chinese military medical journals evince a very clear interest in undersea medicine, and especially issues surrounding physical and psychological challenges related to lengthy submerged missions.[117]

An even more important challenge for nuclear submarine effectiveness is maintaining a cadre of quality technical personnel. According to one Chinese source, "The greatest problem facing submarine forces today is: it is difficult to have skilled technical operators; especially officers, because they must have good nuclear reactor equipment maintenance and repair skills."[118]

Conclusion

Chinese analysts acknowledge that America has long been dominant in undersea warfare, especially after the Cold War.[119] Many Westerners are therefore surprised that China would have the temerity to challenge the United States directly in this specialized domain of warfare. And yet PLAN analysts keep close tabs on U.S. Navy submarine build rates, and carefully probe for potential USN submarine force vulnerabilities.[120] They have monitored the 8 January 2005 accident involving USS *San Francisco* with great interest.[121] A 2006 article by a senior PLAN strategist suggests that "China already exceeds [U.S. submarine production] five times over" and that eighteen U.S. Navy submarines based in the Pacific might be at a severe disadvantage versus seventy-five or more Chinese submarines.[122] While these assessments are ultimately attributed to an American source, the PLA Navy analyst makes no effort to deny or reject these assessments.

It is widely held that the trajectory of Chinese nuclear propulsion may be one of the best single indicators of whether or not China has ambitions to become a genuine global military power.[123] With no need to surface in order to recharge batteries or any requirement for refueling, not to mention unparalleled survivability if acoustically advanced and properly operated, nuclear submarines remain ideal platforms for persistent operations in far-flung sea areas. They will form an efficient means for China to project power should it choose to do so. Available information on Chinese SSN and SSBN build rates currently suggests the continuation of a moderate development plan.[124] However, Washington should, at a minimum, develop contingency long-range planning for a determined PRC naval challenge, spearheaded by a new and formidable force of Chinese nuclear submarines.

Notes

1. Changing assessments are discussed, for example, in Jim Yardley and Thom Shanker, "Chinese Navy Buildup Gives Pentagon New Worries," *New York Times*, 8 April 2005, http://www.nytimes.com/2005/04/08/international/asia/08china.html?ex=1270612800&en=c76dc1da37f15f20&ei=5090&partner=rssuserland.
2. Ronald O'Rourke, "China's Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress," Congressional Research Service Report for Congress, updated 29 August 2006, Order Code RL 33153: 8.
3. See Yardley and Shanker, "Chinese Navy Buildup Gives Pentagon New Worries."
4. In a recent comprehensive, independent review, four of five proposed alternative force structures for the U.S. Navy envisioned substantial reductions in the submarine force. See *Options for the Navy's Future Fleet* (Washington, D.C.: Congressional Budget Office, May 2006), 39.
5. 杨毅 [Yang Yi], "谁的潜艇今后说了算?" ["Who Can Estimate the Future Number of Submarines?"], 舰船知识 [*Naval and Merchant Ships*] (July 2006): 28.
6. See PRC Ministry of Defense, "China's National Defense in 2004," http://www.chinadaily.com.cn/english/doc/2004-12/28/content_403913_4.htm. Other indications of increased prioritization of China's nuclear submarine force include personnel appointments. The previous PLAN Commander, Admiral Zhang Dingfa [张定发], a former nuclear submariner, may have been involved in China's development of naval strategic nuclear weapons. See Chi Hsiao-hua, "High-level Shuffle in the Navy is Not Aimed at the Taiwan Strait," *Sing Tao Jih Pao*, 8 January 2005, A30, FBIS document no. CPP20050108000049. Another nuclear submariner, Rear Admiral Sun Jianguo [孙建国], was selected to be chief of Naval Staff in January 2005.
7. These would include, at a minimum, 当代海军 [*Modern Navy*], 舰船知识 [*Naval and Merchant Ships*] 人民海军 [*People's Navy*], 舰载武器 [*Shipborne Weapons*], and 现代舰船 [*Modern Ships*].
8. See John Wilson Lewis and Xue Litai, *China's Strategic Seapower* (Stanford, Calif.: Stanford University Press, 1994).
9. 刘华清 [Liu Huaqing], 刘华清回忆录 [*The Memoirs of Liu Huaqing*] (Beijing: People's Liberation Army, 2004). All original quotations from Liu's autobiography were checked against the wording in the FBIS translation of Chapters 16–20, #CPP20060707320001001. Wording different from the FBIS translation is used whenever the authors felt that it better reflected Liu's meaning or would be more comprehensible to the reader.
10. Ibid., 468.
11. Ibid., 474.
12. Peng Guangqian and Yao Youzhi, eds., *The Science of Military Strategy* (Beijing: Military Science Publishing House, 2005), 411.
13. Data in this paragraph are derived from 林长盛 [Lin Changsheng], "我国核潜艇的战力" ["The Combat Power of China's Nuclear Submarines"], 世界航空航天博览 [*World Aerospace Digest*], no. 103 (September 2004): 31. *World Aerospace Digest* is a semimonthly journal published by China Aerospace Technology Group, Inc. This article is perhaps the most comprehensive analysis to date of PRC nuclear submarine capabilities. Although this is a PRC source, Lin is actually a former Taiwanese military officer who recently spent time in the U.S. on a research fellowship. For Lin's background, see William Chien, "U.S. Military-Iraq," VOA News Report, 22 April 2003, www.globalsecurity.org/wmd/library/news/iraq/2003/iraq-030424-20194149.htm; http://www.1no.net/2004/12-22/0442319087-7.html. Lin's publications include "Counting China's ICBMs," *Studies on Chinese Communism* 37, no. 7 (July 2003): 80–90.
14. Liu Huaqing, *The Memoirs of Liu Huaqing*, 477.
15. Ibid., 476–77.
16. The above quotations in the paragraph are from 刘耿 [Liu Geng], "如果大陆不得不用武力解放台湾美国会武装干扰马?" ["Will the U.S. Interfere Militarily if Mainland China Has No Choice But to Use Force to Liberate Taiwan?"], 军事展望 [*Military Prospect*] (September 2002): 41–42.
17. 简杰 [Jian Jie], "神话中德双子座: 传说中的中国21世纪军事安全的海上长城—西方媒体报道中国下一代核潜艇" ["The Legend of the Virtuous Twins: Discussion of China's 21st Century Military Security Maritime Great Wall—The Western Media Cover China's Next Generation Nuclear Submarine"], 国际展望 [*World Outlook*], no. 448 (August 2002), editor's text box, 22.
18. 王逸峰, 叶景 [Wang Yifeng, Ye Jing], 从中日核潜艇事件看我核潜艇的突防 ["What the Nuclear Submarine Incident Between China and Japan Tells Us About the Ability of China's Nuclear Submarines to Penetrate Defenses, Part 1"], 舰载武器 [*Shipborne Weapons*] (January 2005): 27–31. For more on this episode, see Andrew Erickson, Lyle Goldstein, and William Murray, "'Gate Crashing': China's Submarine Force Tests New Waters," *Chinese Military Update* 2, no. 7 (April 2005): 1–4.
19. Data in this paragraph derived from 林长盛 [Lin Changsheng], "我国核潜艇的战力" ["The Combat Power of China's Nuclear Submarines"], 世界航空航天博览 [*World Aerospace Digest*], no. 103 (September 2004): 33.
20. 赵楚 [Zhao Chu], "与中国核潜艇之父面对面: 揭开共和国军备发展史上最神秘一页; 本刊副主编独家专访我国第一代核潜艇总设计师彭士禄院士" ["Face to Face with the Father of China's Nuclear Submarine: Revealing the Most Mysterious Page in the History of the Republic's Weapons Development; This Journal's Deputy Chief Editor's Exclusive Interview With Peng Shilu, Chief Designer of China's First Generation Nuclear Submarine"], 国际展望 [*World Outlook*] (2002): 18. *World Outlook* is a semimonthly journal published by the respected Shanghai Institute of International Studies (SIIS). This multidisciplinary research institute's seven departments covering national and regional studies and five issue-related research centers are dedicated to advancing China's knowledge of international affairs and improving its foreign policy-making.

    For further information concerning Peng Shilu's role in China's nuclear submarine development, see 彭子强 [Peng Ziqiang], 中国核潜艇研制纪实施 [*The Research and Development of Chinese Nuclear Submarines*], 中共中央党校出版社 [Chinese Communist Party Central Party School Press] (Beijing, 2005), 108–27;

李觉 [Li Jue], 当代中国的核工业 [*Modern China's Nuclear Industry*] (Beijing: 中国社会科学出版社 [China Social Sciences Press], 1987), 303.

21. 彭子强 [Peng Ziqiang], 中国核潜艇研制纪实施 [*The Research and Development of Chinese Nuclear Submarines*], 中共中央党校出版社 [Chinese Communist Party Central Party School Press] (Beijing, 2005), 111.

22. 严烈 [Yan Lie], "大海深处的感觉—访海军某核潜艇艇长闫保健" ["A Feeling for the Ocean Depths—A Visit with Naval Nuclear Submarine Commander Yan Baojian"], 航海 [*Navigation*] no. 1 (1998): 1.

23. Unless otherwise specified, all data from this and the preceding paragraph are derived from 吴锴 [Wu Kai], "攻击型核潜艇的计划思想—再访黄旭华院士" ["An Interview with Huang Xuhua: SSN Design Philosophy"], 兵器知识 [*Ordnance Knowledge*] 152, no. 6, (June 2000): 23–25. *Ordnance Knowledge* is a bimonthly journal of the China Ordnance Society.

24. *China Military Science* is published by the PLA's Academy of Military Sciences. See 徐起 [Xu Qi], "21世纪初海上地缘战略与中国海军的发展" ["Maritime Geostrategy and the Development of the Chinese Navy in the Early 21st Century"], 中国军事科学 [*China Military Science*] 17, no. 4 (2004): 75–81. Translation by Andrew Erickson and Lyle Goldstein published in *Naval War College Review* 59, no. 4 (Autumn 2006).

25. "英国机敏级攻击核潜艇立体剖视图" ["A Three-Dimensional Cutaway View of Britain's 'Swiftsure' Class Nuclear Attack Submarine"], 舰船知识 [*Naval & Merchant Ships*] 304, no. 1 (January 2005); 关朝江 [Guan Zhaojiang], "英国皇家海军的2010舰队" ["The United Kingdom's Naval Fleet in 2010"], 舰载武器 [*Shipborne Weapons*], no. 11 (2004); 世界核潜艇简介 (四) ["A Synopsis of World Nuclear Submarines (Part 4)"], 国外核新闻 [*Foreign Nuclear News*], no. 7 (2001): 10–12; 迎南 [Ying Nan], "透视英国 '水下核幽灵'" ["A Penetrating Look at England's 'Underwater Nuclear Spirit'"], 当代海军 [*Modern Navy*] no. 2 (1998): 37–38; 那刹 [Na Sha], 英国三叉戟导弹核潜艇将只携带96枚核弹头 ["England's Trident Guided Missile Submarine Only Carries 96 Nuclear Warheads"], 国外核新闻 [*Foreign Nuclear News*], no. 3 (1994): 11.

26. 杨力 [Yang Li], "印度核潜艇研制发展现状" ["The Present Situation of Indian Nuclear Submarine Development"], 国外核新闻 [*Foreign Nuclear News*], no. 11 (2002): 12–13; 袁海 [Yuan Hai], "'强大的蓝水海军' 计划最重要部分—印度自制核潜艇最新情" ["The Most Important Component of the 'Powerful Blue Undersea Navy' Plan—The Latest News on India's Self-Built Nuclear Submarine"], 国际展望 [*World Outlook*], no. 5 (2002): 25–27.

27. Peng Shilu discusses some details of this decision in 赵楚 [Zhao Chu], "与中国核潜艇之父面对面" ["Face to Face with the Father of China's Nuclear Submarine"], 国际展望 [*World Outlook*] (2002): 19.

28. 曹志荣 [Cao Zhirong], "枭雄梦断冷战 群狼险变抓狼 回眸SSN-21 '海狼'" ["The SSN-21 Sea Wolf"], 舰船知识 [*Naval & Merchant Ships*], no. 10 (2004): 16–19.

29. 河山 [He Shan], "'弗吉尼亚'号能否成为新世纪海上霸主" ["Can the Virginia Class Become the New Century's Maritime Hegemon?"], 当代海军 [*Modern Navy*], no. 10 (2004): 18–21.

30. 董露, 郭纲, 李文胜 [Dong Lu, Guo Gang, and Li Wensheng], "析美国战略导弹常规改装的动因及影响" [Analysis on the Motives and Effects of U.S. Strategic Missiles Armed with Conventional Warheads], 中国宇航学会 [China Space Institute], paper distributed but not presented at "10th PIIC Beijing Seminar on International Security," Program for Science and National Security Studies & Institute of Applied Physics and Computational Mathematics, Xiamen, China, 25-28 September, 2006; 林一平 [Lin Yiping], "美国海军改装部分弹道导弹核潜艇为巡航导弹核潜艇" ["The USN Refits a Portion of SSBNs into Cruise Missile SSNs"], 飞航导弹 [*Winged Missiles Journal*] no. 7 (2002): 13; 曹志荣 [Cao Zhirong], "'俄亥俄'变脸" ["The 'Ohio' Suddenly Turns Hostile"], 舰船知识 [*Naval & Merchant Ships*] 1 (2004): 46–48.

31. 止戈 [Zhi Ge], "别无选择 洛杉矶级:梦开始的地方" ["Don't Be Left Without Options: The Place Where the Dream Began"], 舰船知识 [*Naval & Merchant Ships*], no. 8 (2002): 31–37.

32. See, for example, 曹杰荣 [Cao Jierong], "美国核潜艇建造大哥大 百年老厂通用动力公司电船分公司" ["The Construction of USN SSNs: A Hundred Year Old Factory Jointly Used by General Dynamics and Electric Boat"], 舰船知识 [*Naval & Merchant Ships*] 1 (2005): 58–61.

33. See, for example, 伊凡 [Yi Fan], "法国梭鱼级攻击型核潜艇" ["France's 'Barracuda' Class Attack Submarine"], 全球军事 [*Militang*], no. 3 (2005): 17; no author, "法国梭鱼攻击核潜艇方案论证接近尾声" ["The Demonstration of France's Barracuda-Class Attack Submarine Nears a Conclusion"], *Intelligence Command Control & Simulation Techniques* 2, no. 27 (2005): 100.

34. 樊海刚, 尹文立 [Fan Haigang and Yin Wenli], "法国海基战略核力量探秘" ["Finding the Secret of the Strategic Nuclear Forces at France's Naval Bases"], 环球军事 [*Militang*], no. 10 (2005): 20–21.

35. 明周 [Ming Zhou], "零距离接触法国核潜艇" ["In Direct Proximity to French Nuclear Submarines"], 舰船知识 [*Naval & Merchant Ships*] 9 (2005): 18–21. *Naval & Merchant Ships* is a semitechnical monthly publication of the Chinese Society of Naval Architecture and Marine Engineering.

36. 春江 [Chun Jiang], "苏联/俄罗斯核潜艇的十二次重大事故" ["Twelve Major Accidents of Soviet/Russian Nuclear Submarines"], [*Quality and Reliability*], no. 5 (2000): 30; 宋宜昌 [Song Yichang], "从'库尔斯克'号事件看俄军事战略的变化" ["Looking at Russia's Military Strategic Change from the 'Kursk' Incident"], 舰船知识 [*Naval & Merchant Ships*] 253, no. 10 (2004): 13–14; 王子聿 [Wang Ziyu], "永远的'库尔斯克'号" ["The Eternal 'Kursk'"], 舰船知识 [*Naval & Merchant Ships*] 253, no. 10 (2004): 18–19.

37. 王晓龙 [Wang Xiaolong], "俄'台风'级战略核潜艇真的徒具虚名？前北方舰队司令语出惊人" ["Does Russia's Typhoon Class Strategic Submarine Really Have an Undeserved Reputation? A Former North Sea Fleet Commander's Alarming Report"], 当代海军 [*Modern Navy*], no. 7 (July 2004): 54.

38. 吴健 [Wu Jian], "'北报巨鲸'在复苏—发展中的俄海军核潜艇部队" ["Reporting on a 'Huge Northern Whale' Coming Back to Life—The Russian Navy Nuclear Submarine Force Under Development"], 当代海军 [*Modern Navy*], no. 2 (1999): 29.

39. 辛文 [Xin Wen], "俄罗斯核潜艇惊心动魄四十年" ["The Soul Stirring Forty Years of Russian Nuclear Submarines"], 国外核新闻 [*Foreign Nuclear News*], no. 8 (2000): 11; 王存琳 [Wang Cunlin], "俄罗斯海上战略核力量的崛起—俄罗斯核潜艇舰队今昔" ["The Rise of Russia's Strategic Nuclear Power at Sea—The Past and Present of Russia's Nuclear Submarine Force"], 上海造船 [*Shanghai Shipbuilding*], no. 2 (2000): 53–64; "俄罗斯的核潜艇反应堆" ["Russian Nuclear Submarine Reactors"], 国外核新闻 [*Foreign Nuclear News*], no. 10 (1998): 12; 高艺, 黄展烽, 赵克文 [Gao Yi, Huang Zhanfeng, and Zhao Kewen], "游弋大洋深处的幽灵—扫描俄罗斯核潜艇" ["A Specter Cruising the Ocean Depths—Scanning Russia's Nuclear Submarines"], 中国民兵 [*Chinese People's Militia*], no. 6 (2005): 60–61.

40. 刘一建 [Liu Yijian], "核时代与戈尔什科夫 '核海军制胜论'" ["The Nuclear Age and Gorshkov's 'Winning Victory By Way of the Nuclear Navy'"], 中国军事科学 [*China Military Science*], no. 2 (1999): 154.

41. 吴大海 [Wu Dahai], "巴伦支海上刮起新'台风'" ["Raising a New 'Typhoon' on the Sea"], 当代海军 [*Modern Navy*] 109, no. 10 (2002): 25–26. *Modern Navy* is published by the official PLA Navy newspaper, *People's Navy*.

42. 海生 [Hai Sheng], "俄罗斯'猎豹'重拳出击" ["Russia's 'Gepard' Heavy Fist Launches an Attack"], 当代海军 [*Modern Navy*] 98, no. 11 (2001): 6.

43. 王新森 [Wang Xinsen], "俄罗斯核潜艇决战日本'八八舰队'(上)" ["Russian Nuclear Submarines Decisively Engage Japan's '88 Fleet' (Part 1 of 2)"], 舰船知识 [*Naval & Merchant Ships*] 278, no. 10 (October 2002): 25–29; 王新森 [Wang Xinsen], "俄罗斯核潜艇决战日本'八八舰队'(下)" ["Russian Nuclear Submarines Decisively Engage Japan's '88 Fleet' (Part 2 of 2)"], 舰船知识 [*Naval & Merchant Ships*] 278, no. 11 (November 2002): 27–32.

44. 王凌, 沈巍岗 [Wang Ling and Shen Weigang], "用钛合金建造潜艇" ["Using Titanium Alloy to Build Submarines"], 舰船知识 [*Naval & Merchant Ships*] 311, no. 8, (August 2005): 44–45; 王凌, 袁仲 [Wang Ling and Yuan Zhong], "A级核潜艇出笼的前前后后" ["The Whole Story Behind the Appearance of the A Class Nuclear Submarine"], 舰船知识 [*Naval & Merchant Ships*] 311, no. 8 (August 2005): 46–49; 王子聿, 王凌 [Wang Ziyu and Wang Ling], "A级攻击型核潜艇" ["A Class Nuclear Attack Submarine"], 舰船知识 [*Naval & Merchant Ships*] 311, no. 8 (August 2005): 50–53; 王子聿 [Wang Ziyu], "绝密: D级弹道导弹核潜艇: D-1型" ["Top-Secret: The D Class SSBN: Type D-1"], 舰船知识 [*Naval & Merchant Ships*] 298, no. 7 (July 2004): 25–28; "改发16枚弹道导弹的D-2型" ["Type D-2: Transformed to Fire 16 ICBMs"], 舰船知识 [*Naval & Merchant Ships*] 298, no. 7 (July 2004): 29; 王子聿 [Wang Ziyu], "首装分导弹头的D-3型" ["Type D-3: The First With MIRVed Warheads"], 舰船知识 [*Naval & Merchant Ships*] 298, no. 7 (July 2004): 30–32; 止戈 [Zhi Ge], "D级终结者: D-4型" ["The Last of the D-Class: The D-4"], 舰船知识 [*Naval & Merchant Ships*] 298, no. 7 (July 2004): 33–34; 王子聿 [Wang Ziyu], "V-1型: 苏联第一级水滴型核潜艇" ["Type V-1: The Soviet Union's First Teardrop-Shaped Submarine"], 舰船知识 [*Naval & Merchant Ships*] 294, no. 3 (March 2003): 17–20; 袁仲 [Yuan Zhong], "加大火力的V-2X型" ["Type V-2—With Added Firepower"], 舰船知识 [*Naval & Merchant Ships*] 294, no. 3 (March 2003): 21–22; 王子聿 [Wang Ziyu], "V-3型攻击核潜艇" ["The Type V-3 Nuclear Attack Submarine"], 舰船知识 [*Naval & Merchant Ships*] 294, no. 3 (March 2003): 22–24; 王子聿, 王凌, [Wang Ziyu and Wang Ling], "奥斯卡级: 巡航导弹潜艇之魁" ["The Oscar Class: Chief Among Cruise Missile Submarines"], 舰船知识 [*Naval & Merchant Ships*] 279, no. 12 (2002): 18–21; 王子聿, 王凌, [Wang Ziyu and Wang Ling], "'花岗岩'历时16年的杰作" ["The 'Granit' Missile: A Masterpiece With a History of 16 Years"], 舰船知识 [*Naval & Merchant Ships*] 279, no. 12 (2002): 22–23; 钱普 [Qian Pu], "奥斯卡级: 反舰作战组织实施" ["The Oscar Class: Carrying Out Anti-Ship Battle Operations System"], 舰船知识 [*Naval & Merchant Ships*] 279, no. 12 (2002): 24–25.

45. 易佳言 [Yi Jiayan], "台风级的排水量" ["The Typhoon Class's Displacement"], 舰船知识 [*Naval & Merchant Ships*], no. 9 (2004): 15.

46. 王子聿 [Wang Ziyu], "世纪梦魇: 台风级战略导弹核潜艇" ["Nightmare of the Century: The Typhoon Class SSBN Nuclear Submarine"], 舰船知识 [*Naval & Merchant Ships*], no. 12 (2004): 26–31.

47. 吴健 [Wu Jian], "'北报巨鲸'在复苏—发展中的俄海军核潜艇部队" ["Reporting on a 'Huge Northern Whale' Coming Back to Life—The Russian Navy Nuclear Submarine Force Under Development"], 当代海军 [*Modern Navy*], no. 2 (1999): 30; 王子聿 [Wang Ziyu], "世纪梦魇: 台风级战略导弹核潜艇" ["Nightmare of the Century: The Typhoon Class SSBN Nuclear Submarine:], 舰船知识 [*Naval & Merchant Ships*], no. 12 (2004): 26; and 刘一建 [Liu Yijian], "核时代与戈尔什科夫 '核海军制胜论'" ["The Nuclear Age and Gorshkov's 'Winning Victory By Way of the Nuclear Navy'"], 中国军事科学 [*China Military Science*], no. 2 (1999): 151.

48. 林长盛 [Lin Changsheng], "我国核潜艇的战力" ["The Combat Power of China's Nuclear Submarines"], 27.

49. No author, "于勇: 核动力的守护者" ["Valiant Yu: Guardian of Nuclear Power"], 人民海军 [*People's Navy*] (September 15, 2005): 3; see also 长风 [Zhang Feng], "核潜艇与中国海军" ["Nuclear Submarines and China's Navy"], 舰船知识 [*Naval & Merchant Ships*] (March 2005): 12.

50. Liu Huaqing, *The Memoirs of Liu Huaqing*, 476.

51. 吴毅平, 刘江平 [Wu Yiping, Liu Jiangping], "多面杀手—现代核潜艇" ["Multi-Faceted Assassin—The Modern Nuclear Submarine"], 当代海军 [*Modern Navy*], no. 5 (2002): 27.

52. 张学诚, 殷世江 [Zhang Xuecheng, Yin Shijiang], "常规潜艇将更有魅力" ["Conventional Submarines are Even More Fascinating"], 当代海军 [*Modern Navy*], no. 6 (2002): 9.

53. "钢铁鲨鱼" ["Steel Shark"], 三联生活周刊 [*Sanlian Life Weekly*] 20 (May 19, 2003): 29–30, as cited in Toshi Yoshihara, "U.S. Ballistic-Missile Defense and China's Undersea Nuclear Deterrent: A Preliminary Assessment," in this volume.

54. Liu Huaqing, *The Memoirs of Liu Huaqing*, 476.

55. 吴锴 [Wu Kai], "攻击型核潜艇的计划思想—再访黄旭华院士" ["An Interview with Huang Xuhua: SSN Design Philosophy"], 兵器知识 [*Ordnance Knowledge*] 152, no. 6 (June 2000): 22.

56. 高运 [Gao Yun], "核潜艇的优点及缺点" ["The Strengths and Weaknesses of Nuclear Submarines"], 国防 [*National Defense*], no. 6 (1996): 45. Researchers at a PLAN submarine base and China's Naval Engineering Academy have discussed methods to improve the repair of nuclear submarines in war. See 董富生, 赵新文, 蔡琦 [Dong Fusheng, Zhao Xinwen, and Cai Qi], "核潜艇战损修理研究" ["Study of Repair of Damaged Nuclear Submarines in War"], 中国修船 [*China Ship Repair*], no. 4 (1999): 35–37.
57. 长风 [Zhang Feng], "核潜艇与中国海军" ["Nuclear Submarines and China's Navy"], 舰船知识 [*Naval & Merchant Ships*] (March 2005): 12.
58. 沈游 [Shen You], "新世纪潜艇创新发展前瞻" ["Looking Ahead at the New Century's Nuclear Submarine Development and Innovation"], 现代舰船 [*Modern Ships*] no. 5 (2005): 15–16. *Modern Ships* is published by the state-owned China Shipbuilding Industry Corporation (CSIC). Directly supervised by China's State Council, CSIC is China's largest designer, manufacturer, and trader of military and civilian vessels and related engineering and equipment. CSIC's 96 enterprises, 28 research institutes, and 6 laboratories reportedly employ 170,000.
59. The three sentences above are all drawn from 长风 [Zhang Feng], "核潜艇与中国海军" ["Nuclear Submarines and China's Navy"], 12.
60. For the first and second island chains, see 徐起 [Xu Qi], "21世纪初海上地缘战略与中国海军的发展" [Maritime Geostrategy and the Development of the Chinese Navy in the Early 21st Century], 中国军事科学 [*China Military Science*] (Vol. 17, No. 4) 2004, pp. 75–81. Translation by Andrew Erickson and Lyle Goldstein published in *Naval War College Review* 59, no. 4 (autumn 2006), esp. map and translators' note 11.
61. 王逸峰, 叶景 [Wang Yifeng and Ye Jing], "从中日核潜艇事件看我核潜艇的突防" ["What the Nuclear Submarine Incident Between China and Japan Tells Us About the Ability of China's Nuclear Submarines to Penetrate Defenses, Part 2"], 舰载武器 [*Shipborne Weapons*] (February 2005): 40.
62. Ye Jing, "What the Nuclear Submarine Incident Between China and Japan Tells Us About the Ability of China's Nuclear Submarines to Penetrate Defenses," *Jianzai Wuqi* (March 1, 2005), FBIS #CPP20050324000211. The precise Chinese citation of the above article is: 王逸峰, 叶景 [Wang Yifeng and Ye Jing], "从中日核潜艇事件看我核潜艇的突防" ["What the Nuclear Submarine Incident Between China and Japan Tells Us About the Ability of China's Nuclear Submarines to Penetrate Defenses, Part 3"], 舰载武器 [*Shipborne Weapons*] (March 2005): 49.
63. 长风 [Zhang Feng], "核潜艇与中国海军" ["Nuclear Submarines and China's Navy"], 12.
64. 林长盛 [Lin Changsheng], "我国核潜艇的战力" "[The Combat Power of China's Nuclear Submarines"], 27–28.
65. Ibid., 27.
66. See 吴谐 [Wu Xie], "战略核潜艇设计方案简析" ["A Basic Analysis of SSBN Design Plans"], 兵器知识 [*Ordnance Knowlege*] 4, no. 198 (April 2004): 53, as cited in Toshi Yoshihara, "U.S. Ballistic Missile Defense and China's Undersea Nuclear Deterrent: A Preliminary Assessment," in this volume.

67. This paragraph is entirely drawn from ibid., 33.
68. "中国海上威慑进入一个崭新时代—093型，094型核潜艇最新消息" ["China's At Sea Deterrent: Entering a Brand New Era—The Latest Information on China's Type 093 and 094 Submarines"], 军事纵横 [*Military Overview*], no. 101, 53.
69. This paragraph is drawn entirely from Ye Jing, "What the Nuclear Submarine Incident Between China and Japan Tells Us About the Ability of China's Nuclear Submarines to Penetrate Defenses," *Jianzai Wuqi* (March 1, 2005), FBIS #CPP20050324000211. The precise Chinese citation of the above article is: 王逸峰, 叶景 [Wang Yifeng and Ye Jing], "从中日核潜艇事件看我核潜艇的突防" [What the Nuclear Submarine Incident Between China and Japan Tells Us About the Ability of China's Nuclear Submarines to Penetrate Defenses, Part 3], 舰载武器 [*Shipborne Weapons*] (March 2005): 51.
70. This paragraph is entirely drawn from 长风 [Zhang Feng], "核潜艇与中国海军" ["Nuclear Submarines and China's Navy"], 12.
71. Ye Jing, "What the Nuclear Submarine Incident Between China and Japan Tells Us About the Ability of China's Nuclear Submarines to Penetrate Defenses," *Jianzai Wuqi* (March 1, 2005), FBIS #CPP20050324000211. The precise Chinese citation of the above article is: 王逸峰, 叶景 [Wang Yifeng and Ye Jing], "从中日核潜艇事件看我核潜艇的突防" ["What the Nuclear Submarine Incident Between China and Japan Tells Us About the Ability of China's Nuclear Submarines to Penetrate Defenses, Part 3"], 舰载武器 [*Shipborne Weapons*] (March 2005): 49.
72. 林长盛 [Lin Changsheng], "我国核潜艇的战力" ["The Combat Power of China's Nuclear Submarines"], 31.
73. 长风 [Zhang Feng], "核潜艇与中国海军" ["Nuclear Submarines and China's Navy"], 13.
74. Ibid., 13.
75. 简杰 [Jian Jie], "神话中德双子座" ["The Legend of the Virtuous Twins"], 23.
76. 林长盛 [Lin Changsheng], "我国核潜艇的战力" ["The Combat Power of China's Nuclear Submarines"], 33.
77. See, for example, 高运 [Gao Yun], "核潜艇的优点及缺点" ["The Strengths and Weaknesses of Nuclear Submarines"], 国防 [*National Defense*], no. 6 (1996): 45.
78. 沈泓萃, 姚惠之, 周毅, 王锡良 [Shen Hongcui, Yao Huizhi, Zhou Yi, and Wang Xiliang], "增效降噪的潜艇前置导叶螺旋桨研究" ["Submarine Guide Vane Propeller for Increasing Efficiency and Reducing Noise"], 舰船力学 [*Journal of Ship Mechanics*] 1, no. 1 (August 1997): 1–7.
79. 赵洪江 [Zhao Hongjiang], "主循环水管路更换挠性接管技术" ["Study of Replacing Techniques for Flexure Joint-Pipe of Main Circulating Water-Piping"], 中国修船 [*China Ship-Repair*], no. 6 (1997): 21–23.
80. 任勇生, 刘立厚 [Ren Yongsheng and Liu Lihou], "纤维增强复合材料结构阻尼研究进展" ["Advances in Damping Analysis and Design of Fiber Reinforced Composite Material Structures"], 力学与实践 [*Mechanics & Engineering*] 26, no. 1 (February 2004): 9–16.

81. 简杰 [Jian Jie], "神话中德双子座" ["The Legend of the Virtuous Twins"], 23.
82. 林长盛 [Lin Changsheng], "我国核潜艇的战力" ["The Combat Power of China's Nuclear Submarines"], 33.
83. Ibid., 33. Decibel levels can be measured in various ways and thus are difficult to interpret out of context.
84. Ibid., 32.
85. 简杰 [Jian Jie], "神话中德双子座" ["The Legend of the Virtuous Twins"], 22–23.
86. Ibid., 22. An Internet source asserts, "plans to deploy this class of nuclear powered SSBNs are said to have been delayed due to problems with the nuclear reactor power plants." See "中国防务周刊对于094的介绍" [*China Defense Weekly* on the 094's Introduction], June 22, 2005, http://military.china.com/zh_cn/critical3/27/20050622/12422997.html.
87. 863 Plan Research has also focused on potential future propulsion technologies, such as magnetic fluid propulsion. This would use powerful electromagnets to quietly move sea water through a propulsor nozzle near the tail of a submarine. See 阮可强, 冯运昌 [Ruan Keqiang and Feng Yunchang], "863计划能源技术领域: 光辉十五年" ["The Energy Technology Domain of the 863 Plan: Fifteen Years of Brilliance"], 高科技与产业化 [*High Technology & Industrialization*], no. 1 (2001): 33.
88. See 吴宗鑫 [Wu Congxin] 先进核能系统和高温气冷堆 [*An Advanced Nuclear Reactor System: The High Temperature Gas Cooled Reactor*] (Beijing: Qinghua University Press, 2004), 204–6; Xu Yuanhui, "Power Plant Design; HTGR Advances in China," *Nuclear Engineering International* (16 March 2005), 22, http://web.lexis-nexis.com/universe/printdoc; as cited in Shawn Cappellano-Sarver, "Naval Implications of China's Nuclear Power Development," in this volume.
89. Elizabeth Thomson, "MIT, Tsinghua Collaborate on Development of Pebble-Bed Nuclear Reactor," MIT press release 22 October 2003, available at http://web.mit.edu/newsoffice/2003/pebble.html. As cited in Shawn Cappellano-Sarver, "Naval Implications of China's Nuclear Power Development," in this volume.
90. 阮可强, 冯运昌 [Ruan Keqiang and Feng Yunchang], "863计划能源技术领域: 光辉十五年" ["The Energy Technology Domain of the 863 Plan: Fifteen Years of Brilliance"], 高科技与产业化 [*High Technology & Industrialization*], no. 1 (200): 32–33.
91. "西屋公司在中国赢得两项合同" ["The Westinghouse Corporation Gains Two Contracts in China"], 中国核信息网 [China Atomic Information Network], August 19, 2004, http://www.atominfo.com.cn/newsreport/news_detail.aspx?id=3149.
92. 林长盛 [Lin Changsheng], "我国核潜艇的战力" ["The Combat Power of China's Nuclear Submarines"], 33.
93. 简杰 [Jian Jie], "神话中德双子座" ["The Legend of the Virtuous Twins"], 22.
94. 吴锴 [Wu Kai], "攻击型核潜艇的计划思想—再访黄旭华院士" ["An Interview with Wang Xuhua: SSN Design Philosophy"], 兵器知识 [*Ordnance Knowledge*] 152, no. 6 (June 2000): 23.

95. Shawn Cappellano-Sarver, "Naval Implications of China's Nuclear Power Development," in this volume.
96. 吴锴[Wu Kai], "攻击型核潜艇的计划思想—再访黄旭华院士" ["An Interview with Wang Xuhua: SSN Design Philosophy"], 兵器知识 [*Ordnance Knowledge*] 152, no. 6 (June 2000): 23.
97. See, for example, 田金文 [Tian Jinwen], "如何提高巡航导弹生存能力和打击效果" ["How to Improve Cruise Missile Survivability and Attack Effectiveness"], 航天电子对抗 [*Aerospace Electronic Warfare*], no. 1 (2005): 12–14; 曹晓盼 [Cao Xiaopan], "中国的巡航导弹现状" ["The Current Status of China's Cruise Missiles"], 舰载武器 [*Shipborne Weapons*] (November 2004): 26–27.
98. 赵正业 [Zhao Zhengye], 潜艇火控原理 [*Principles of Submarine Fire Control*] (Beijing 国防工业出版社 [National Defense Industry Press], September 2003), 329, 332.
99. 简杰 [Jian Jie], "神话中德双子座" ["The Legend of the Virtuous Twins"], 23.
100. 吴锴 [Wu Kai], "攻击型核潜艇的计划思想—再访黄旭华院士" ["An Interview with Huang Xuhua: SSN Design Philosophy"], 25.
101. 简杰 [Jian Jie], "神话中德双子座" ["The Legend of the Virtuous Twins"], 14.
102. 林长盛 [Lin Changsheng], "我国核潜艇的战力" ["The Combat Power of China's Nuclear Submarines"], 33.
103. Liu Huaqing, *The Memoirs of Liu Huaqing*, 497.
104. For a history of JL SLBM development, see 台风 [Tai Feng], "'巨浪' 冲天举世惊中国海军潜射弹道导弹" ["'Great Wave,' A Shock Soaring Throughout the World: The PLAN's SLBM"], [*Shipborne Weapons*], no. 9 (2004): 32–35.
105. "终报震慑:中国的战略导弹"["EntirelyFrightful:China's Ballistic Missiles"], 军事纵横 [*Military Overview*], no. 101: 13.
106. 简杰 [Jian Jie], "神话中德双子座" ["The Legend of the Virtuous Twins"], 23.
107. One Internet source speculates that the JL-2 is an underwater variant of China's DF-31. See "漏斗子关于094和巨浪言论" ["Opinions Regarding 094 and Julang"], 读卖新闻 [*Mainichi Daily News*], June 21, 2005, http://military.china.com/zh_cn/critical3/27/20050621/12418878.html.
108. 简杰 [Jian Jie], "神话中德双子座" ["The Legend of the Virtuous Twins"], 23. An unofficial posting on China Central Television's website claims seven–eight warheads per JL-2. See "现在中国的巨浪二型潜射弹道导弹" ["China's Current JL-2 SLBM"], 央视国际首页 > 论坛首页 > 网评天下 [China Central Television International Lead Page > Forum Lead Page > China Commentary Network, August 4, 2004, http://bbs.cctv.com.cn/forumthread.jsp?id=4513301.
109. 严烈 [Yan Lie], "大海深处的感觉—访海军某核潜艇艇长闫保健" ["Becoming Aware of the Ocean Depths—Visiting a Certain Naval Nuclear Submarine's Captain Yan Baojian"], 航海 [*Navigation*] no. 1 (1998): 1, 27. By way of comparison, when first deployed in 1971 the U.S. Navy's Poseidon SLBM could reportedly carry as many as fourteen MIRVs. France's M-4 SLBM reportedly carries up to six MIRVed warheads. In 2001, a noted Chinese nuclear expert claimed that "China

has the capability to develop . . . MIRVs . . . but has not done so. . . ." See Li Bin, "The Impact of U.S. NMD on Chinese Nuclear Modernization," Working Paper, Pugwash Workshop on East Asian Security, Seoul, April 2001.

110. This entire paragraph is drawn from Stephen Polk, "China's Nuclear Command and Control," chapter 1 in Lyle Goldstein and Andrew Erickson, eds., *China's Nuclear Force Modernization*, U.S. Naval War College Newport Paper no. 22, April 5, 2005, 19–20.

111. 王新森 [Wang Xinsen], "魔鬼的天籁: 对潜通信中继机" ["The Call of the Devil: Submarine Communications Aircraft"], 舰船知识 [*Naval & Merchant Ships*], no. 287 (August 2003): 42–45.

112. Liu Huaqing, *The Memoirs of Liu Huaqing*, 501–2.

113. Garth Hekler, Ed Francis, and James Mulvenon, "C3 in the Chinese Submarine Fleet," in this volume.

114. Liu Huaqing, *The Memoirs of Liu Huaqing*, 474–77, 494.

115. 彭子强 [Peng Ziqiang], 中国核潜艇研制纪实施 ["The Research and Development of Chinese Nuclear Submarines"], 中共中央党校出版社 [Chinese Communist Party Central Committee Party School Press] (Beijing, 2005), 286.

116. 黄彩虹, 寒羽 [Huang Caihong, Han Yu], 核潜艇 [*Nuclear Submarines*] (Beijing: People's Press, 1996), 91, Caltech Chinese Association online library at http://caltechc.caltech.edu/~caltechc/clibrary/CD%20056/ts056058.pdf, accessed on 1 March 2005.

117. 吕家本，王盛龙，刘文 [Lu Jiaben, Wang Shenglong, Liu Wen, et al.], "'银参冲剂'对核潜艇远航艇员保健效能的评价" ["Evaluation of Health Protective Effects of 'Silver Ginseng Medicine' on the Crew of a Nuclear Submarine During a Long Voyage"], 中华航海医学杂志 [*Chinese Journal of Nautical Medicine*] 5, no. 4 (December 1998): 241–44; 房芳, 吴力克, 毕可玲, 梁冰, 赵红 [Fang Fang, Wu Like, Bi Keling, Liang Bing, and Zhao Hong], "水面舰艇和核潜艇对艇员血液细胞成份和某些流变学指标的影响" ["The Effects of Long-Term Voyages on the Blood Cell Components and Rheology of Sailors on Naval Ships and Nuclear-Powered Submarines"], 解放军预防医学杂志 [*Chinese People's Liberation Army Journal of Preventive Medicine*], no. 4 (2004): 261–64; 马彩娥, 吕发勤, 宓传刚, 杜莉, 孙湖山 [Ma Cai'e, Lu Faqin, Mi Chuangang, Du Li, Sun Hushan], "核潜艇艇员远航后心脏超声心动图随访观察" ["Echocardiographical Follow-up Studies of the Hearts of Nuclear Submarine Sailors After Lengthy Voyages"], 心脏杂志 [*Chinese Heart Journal*], no. 1 (2004): 71–75; 赵红, 吴力克, 梁冰, 刘文, 房芳, 杨朋 [Zhao Hong, Wu Like, Liang Bing, Liu Wen, Fang Fang, and Yang Peng], "水面舰艇及核潜艇长航对艇员心里健康水平的影响" ["The Effects of Long-Term Voyages on the Psychological Health of Sailors on Naval Ships and Nuclear-Powered Submarines"], 解放军预防医学杂志 [*Chinese People's Liberation Army Journal of Preventive Medicine*] 20, no. 5 (October 2002): 332–35; 余浩, 项光强 [Yu Hao and Xiang Guangqiang], "核潜艇艇员个性心理特征分析" ["Analysis of Submariners' Personalities"], 海军医学杂志 [*Journal of Navy Medicine*] 21, no. 1 (March 2000): 7–8.

118. 高运 [Gao Yun], "核潜艇的优点及缺点" ["The Strengths and Weaknesses of Nuclear Submarines"], 国防 [*National Defense*], no. 6 (1996): 45.

119. 赵大勋, 李国兴 [Zhao Daxun and Li Guoxing], 美国海军潜艇设计特点及质量控制 [*USN Submarines' Design Characteristics and Quality Control*], 哈尔滨工程大学出版社 [Harbin: Harbin Engineering University Press], 2000, 2.

120. 河山 [He Shan], "'弗吉尼亚'号能否成为新世纪海上霸主" ["Can the Virginia Class Become the New Century's Maritime Hegemon?"], 当代海军 [*Modern Navy*], no. 10 (2004): 18–21.

121. 止戈 [Zhi Ge], "'旧金山'号核潜艇事故分析" ["An Analysis of the 'San Francisco' Nuclear Submarine Accident"], 舰船知识 [*Naval & Merchant Ships*], no. 3 (2005): 59.

122. 杨毅 [Yang Yi], "谁的潜艇今后说了算?" ["Who Can Estimate the Future Number of Submarines?"], 舰船知识 [*Naval and Merchant Ships*] (July 2006): 28.

123. This paragraph draws on the introduction to this volume.

124. After launching the first 093 in 2002, China now may be working on hull three of that class. The first 094 was reportedly launched in 2004. See Richard Fisher, "Submarine Incident Highlights Military Buildup," *Asian Wall Street Journal*, 17 November 2004, http://www.strategycenter.net/research/pubID.51/pub_detail.asp.