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ZHENG HE: AN INVESTIGATION INTO THE PLAUSIBILITY OF 450-FT TREASURE SHIPS

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This paper examines the issues and arguments surrounding the question of whether Zheng He's 鄭和 ships could have been the size recorded in the official Ming history (*Ming shi* 明史), that is, 44 *zhang* long by 18 *zhang* wide, or 447 by 183 feet.* It first examines the written sources, which include stone inscriptions, first-hand accounts, the *Ming Shilu* 實錄 or "Veritable Records," official and unofficial histories, illustrations, and shipyard treatises. It focuses primarily on sources dating before 1597 because of the relatively recent (in the last decade) assertions that the dimensions recorded in the *Ming shi* may have originated in the novel by Luo Maodeng 羅懋登 published in that year. In addition, it investigates the archaeological evidence derived from shipwrecks that have been excavated off the coast of China and Korea, and analyses the way in which one fine in particular – the 11-metre-long rudderpost discovered at the treasure-ship shipyard in Nanjing – has been interpreted. The paper examines what can be gained from comparisons of Zheng He's treasure ships with non treasure ships, both non-Chinese ships and Chinese ships of other periods. It probes what can be known about the size of the ships by reference not only to their dimensions, carrying capacity, and displacement, but also to their complement (the number of men needed to sail the ship), the amount of wood it would take to build them, and the impact of the resulting demand for wood on China's forests at the time. This question leads to consideration of such issues as the total number of ships that were built for the voyages, whether they were built from scratch or converted from ships used for other purposes, and ship repair schedules that help determine how often they had to be rebuilt over the 28-year period of Zheng He's maritime expeditions. The results of this investigation support the conclusion of Xin Yuan-ou 辛元歐, professor of shipbuilding engineering at Shanghai Jiaotong Univer-

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sity, who argues that it is highly unlikely that Zheng He's treasure ships were 450 ft long, and suggests that they were probably closer to 200–250 ft in length.

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At a conference entitled "Venture Toward the Seas" held in Taibei in September 2001,[1] Xin Yuan'ou, shipbuilding engineer and professor of the history of science at Shanghai Jiaotong University, presented a paper entitled "Guanyu Zheng He baochuan chidu de jishu fenxi" 關於鄭和寶船尺度的技術分析 (A Technical Analysis of the Size of Zheng He's Ships).[2] In this paper he argued that Zheng He's ships could not have been as large as recorded in the official Ming history (*Ming shi* 明史). According to that work, the ships constructed for Zheng He's maritime expeditions were 44 *zhang* 丈 long and 18 *zhang* wide, equivalent to 447 ft by 183 ft (138.4 m by 56 m).[3] A ship this size would have been roughly 1.4 times the size of an American football field,[4] and approximately the same size as the *USS Minnesota* (456 ft long by 78 ft 10 in wide), a steel battleship launched in 1905 and later used in the First World War.[5] In arguing against this size, Xin was motivated in part by an immediate, practical concern. Preparations were being made for the 600th anniversary of Zheng He's first expedition in 2005, and proposals were being put forward for the construction of replicas of Zheng He's ships. Xin was concerned that any such replica be of a realistic size so as to be economical, seaworthy and safe.

1 The conference, held 25–26 September 2001, was organised by the National Museum of Marine Science and Technology, the Wu Jing 吳京 Cultural Foundation, and National Taiwan Ocean University.

2 Xin Yuan'ou's paper has since been published in *Chuanshi yanjiu* 船史研究 17 (2002), pp. 1-20. Xin is professor of the history of science at Shanghai Jiaotong University, and has served as Director of the Chinese Academy of the History of Science and Technology, and President of the Chinese Marine History Researchers' Association.

3 Zhang Tingyu 張廷玉 *et al*. (ed.), *Ming shi* (Beijing 1974), *j*. 304, pp. 7766-7768. The standard *zhang* measurement used by the Ministry of Works in the Ming period was equivalent to 10 ft 2 in (3.11 m) in modern measurements. Xin Yuan'ou uses a different conversion rate: 12.5 ft and 3.81 m to one *zhang*. By his calculations the ships would have been 550 ft long and 225 ft wide (167.64 m by 68.58 m). It is usually assumed that these measurements refer to overall length and width of the ships. Because traditional Western discussions of ships use feet as the primary unit of measurement, I provide length measurements in feet first, followed by the equivalent in metres.

4 An American football field is 360 ft (110 m) long and 160 ft (49 m) wide.

5 Liang Qichao 梁啓超 remarked on the similarity in size between this ship and Zheng He's ships in his article "Zuguo da hanghaijia Zheng He zhuan" 祖國大航海家鄭和傳 (A Biography of China's Great Navigator, Zheng He), *Xin min* 新民, No. 69 (18 May 1905). The article was later reprinted in his collected works, *Yinbing shi heji* 飲冰室合集 (Shanghai 1936, rpt. 1941), vol. 3, *j*. 9, pp. 1-12. See Sally K. Church, "The Colossal Ships of Zheng He," in Claudine Salmon and Roderich Ptak (eds.), *Zheng He: Images and Perceptions. Bilder und Wahrnehmungen* (Wiesbaden 2005), pp. 155-176, esp. pp. 155-156.

Xin's main reasons for concluding that the ships could not have been this size are listed briefly here; they will be discussed in more detail later. First, he asserted that there is a natural limit to the size of a wooden ocean-going ship of about 7,000 tons displacement. Ships of the dimensions given in the *Ming shi* would have been 15,000–20,000 tons according to his calculations, and thus would have far exceeded this limit. Second, he noted that even with the benefit of modern technology it would be difficult to manufacture a wooden ship of 10,000 tons, let alone one that was 1½–2 times that size. It was only when ships began to be built of iron in the 1860s that they could exceed 10,000 tons. Third, Xin argued that the watertight compartments characteristic of traditional Chinese ships tended to make the vessels transversely strong but longitudinally weak. Ideally the tensile strength of a single tree trunk would provide the strength needed for the keel, or its Chinese equivalent, the *longgu* 龍骨 (literally "dragon bone"). However, for a ship 450 ft long, several trunks would need to be joined together to make this longitudinal strengthening member. A ship of these dimensions would also need masts that were 30 *zhang* (100 metres) tall. For these, several timbers would have to be joined together vertically. Moreover, because a single tree trunk would not be large enough in diameter to support such a tall mast, multiple timbers would need to be combined at the base as well. According to Xin, there is no evidence that China had the type of joining materials necessary to accomplish these tasks. In fact the archaeologist Richard Gould says of the treasure ships that since there is no evidence of "special construction techniques such as iron strapping for supporting the wooden hulls" of these ships, "there is something inherently improbable about the claims made for them in the Ming texts."[6] The high rigging that would have been necessary would also weaken the ship. Finally, Xin noted, in order to make the technological breakthroughs necessary to overcome these obstacles, China would have needed more time. It took four centuries for Western ships to make the relatively small increase in size from 1500 to 5000 tons displacement, and this was with the stimulus provided by warfare and competition among the various European powers. For Chinese ships to have reached three or four times this size in just two years (from Emperor Yongle's accession in 1403 to the launch of the first expedition in 1405), at a time when there was no such stimulus provided by intense naval activity, would have been highly unlikely.[7]

These arguments are persuasive, especially as they come from a professor of shipbuilding engineering. They raise serious questions about the dimensions re-

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6 Richard A. Gould, *Archaeology and the Social History of Ships* (Cambridge 2000), p. 198.

7 Xin Yuan'ou, "Guanyu Zheng He baochuan chidu de jishu fenxi," pp. 5, 7-8, 13. Xin was not the first to question the size of the ships given in the *Ming shi*. As early as 1947 Guan Jincheng 管勁丞 published an article challenging these dimensions, proposing a much more modest size of 20 *zhang* long by 2.4 *zhang* wide (204 ft by 25.5 ft). See his "Zheng He xia Xiyang de chuan" 鄭和下西洋的船, *Dongfang zazhi* 東方雜誌 43 (1947) 1, pp. 47-51, reprinted in *Zheng He yanjiu ziliao huibian* 鄭和研究資料匯編 (1985), pp. 268-272. There is by no means universal agreement among scholars on these points.

corded in the *Ming shi*, and the actual size of Zheng He's ships. In what follows I shall attempt to elucidate what can be known about the size of these ships from several different angles. First I shall consider the sources: if we cannot rely on the *Ming shi*, what Chinese sources are reliable for information about the ships, and what do they tell us? Second, what information can we glean from comparisons with Chinese ships of other periods and with non-Chinese ships? Third, what does the archaeological record tell us about the ships?

With regard to the sources, we know that these dimensions did not originate in the *Ming shi*. A number of works that predate the *Ming shi* contain these dimensions. The *Ming shi* was a rather late publication, begun soon after the Manchu conquest in 1644 and not completed until 1739. The earlier sources that mention the dimensions are *Kezuo zhuiyu* 客座贅語 by Gu Qiyuan 顧起元 (published in 1618); Tan Qian's 談遷 manuscript of *Guo Que* 國榷 (dating from between 1621 and 1656); Zheng He's family genealogy, *Zheng He jiapu* 鄭和家譜, which was kept exclusively in his family until 1936; and three relatively late versions of Ma Huan's 馬歡 *Yingyai shenglan* 瀛崖勝覽. The earliest extant edition of Ma Huan's work is the *Jilu huibian* 紀錄匯編 edition published by Shen Jiefu 沈節甫 (*jinshi* 1559) in approximately 1617. It is thought to be the closest to the first edition produced 1451.[8] This edition does not contain any reference to the size of the ships. The three later editions that do contain the dimensions are: the *Chaoshuo ji* 鈔說集 edition (dated after 1617), the *Sanbao zhengyi ji* 三寶征彝集 manuscript (also dated after 1617), and the *Qi shi Dansheng tang* 祁氏淡生堂 manuscript of 1620.[9] The dimensions also appear in Luo Maodeng's 羅懋登 novel about Zheng He's exploits, *Sanbao taijian Xiyang ji* 三寶太監西洋記, published in 1597, and Xin Yuan'ou follows Tang Zhiba 唐志拔 in arguing that this work, as the earliest one to contain the dimensions, is their most likely source.[10] It does not seem necessary to insist that this is the direct source used by the *Ming shi*, however, as the editors of the official history may have taken the dimensions from one of the other works mentioned above that may have served as an intermediary between the novel and the *Ming shi*.

There are some difficulties with the hypothesis that the dimensions came from the novel. First, we do not seem to have any other evidence linking the novel with the *Ming shi*, beyond its being the earliest known source to mention these figures. Second, it seems odd that the editors of the *Ming shi* would use a novel

8 J.V.G. Mills (tr., ed.), *Ying-yai sheng-lan. The Overall Survey of the Ocean's Shores [1433]*, Hakluyt Society Extra Series 42 (Cambridge 1970), pp. 37-38.

9 Of these I have only had the opportunity to see the novel and *Kezuo zhuiyu*.

10 Tang Zhiba 唐志拔, "Zheng He baochuan chidu zhi wo jian" 鄭和寶船尺度之我見, *Zheng He yanjiu* 鄭和研究 47 (2001) 2, pp. 26-32, esp. p. 27, reprinted in *Chuanshi yanjiu* 17 (2002), pp. 21-27. I have consulted a modern edition of the novel (Beijing 1995).

as their source. The explanation usually given is that the official documents concerning the voyages were all destroyed during the Chenghua 成化 period (1465–1487), and that there was no other source of information about the ships.[11] Yet the scarcity of documents does not prove that the *Ming shi* took its information from the novel. For one thing, it would have been quite possible simply to leave out this information. None of the three first-hand accounts, at least in their earliest editions, included such detailed information about the ships; why did the *Ming shi* find it necessary to do so?

If the editors took the dimensions from one of the other sources, there are several possibilities. One is that they mistook one of the later manuscripts or editions of Ma Huan's work, to which the dimensions had been added, as originals.[12] Another is that they took the dimensions from Gu Qiyuan's *Kezuo zhuiyu*, a collection of memorabilia about Nanjing. Lo Jung-pang points out a convincing connection between this work and the novel: the same error in the transliterated

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11 J.J.L. Duyvendak translates the story of the documents' destruction by Liu Daxia 劉大夏 recorded in Yan Congjian's 嚴從簡 *Shuyu zhouzi lu* 殊域周咨錄 of 1574. See his "The True Dates of the Chinese Maritime Expeditions in the Early Fifteenth Century," *T'oung Pao* 34 (1938), pp. 341-412, esp. pp. 395-396. The historian Gu Yingtai 谷應泰 (1620–1690) in *Ming shi jishi benmo* 明史紀事本末 (1658; rpt. Beijing Zhonghua shuju, 1977), p. 362, says that the documents relating to the Annam campaign were burned, and gives the date of this event as 1480. Although it is often claimed that Liu Daxia burned the documents relating to Zheng He's maritime expeditions at the same time, we have no hard evidence of this other than Yan Congjian's work. Yan's work is authoritative on many points as he was an employee in the office in charge of foreign relations (*xingren si* 行人司). Some scholars think that only the documents relating to the Yongle emperor's Annam campaigns were destroyed. See Lo Jung-pang, "Policy Formulation and Decision-Making on Issues Respecting Peace and War," in Charles O. Hucker, *Chinese Government in Ming Times: Seven Studies* (New York 1969), pp. 41-72, esp. pp. 62-63, n. 79. The destruction of some documents during the Chenghua period is substantiated in several historical records, including Li Zhaoxiang's 李照祥 (fl. 1537–1553) *Treatise of the Longjiang Shipyard* [*Longjiang chuanchang zhi* 龍江船廠志] of 1553, which states that some documents relating to ships were burned (*Xuanlantang congshu xuji* 玄覽堂叢書續集, vol. 117, facsimile ed., *j*. 4, p. 5a). There is a modern edition of this work edited by Wang Lianggong 王亮功 (Nanjing 1999). The shipyard treatise confusingly says that the documents were burned before the Chenghua period. Gu Yingtai's *Ming shi jishi benmo* gives 1480 as the date for this incident. Tang Zhiba suggests that the fire in the archives may have been the same one recorded in the *Shilu* of 14 Jan 1482, which took place in the Nanjing Ministry of Works (Tang Zhiba, "Zheng He baochuan chidu zhi wo jian," pp. 27-28). Unfortunately he must have been working with a different edition of the *Shilu* than I have at my disposal. He quotes it as saying that all the documents in the Ministry were burned: *Nanjing gongbu suocun yiqie dang'an jun fen yu da huo* 南京工部所存一切檔案均焚於大火, but the Taiwan edition simply says that there was a fire in the Ministry of Works (*Nanjing gongbu huo* 南京工部火; see *Ming Xianzong Shilu*, Chenghua 18, 12th month, *gengwu* 庚午 [6th day], *j*. 235, p. 6b, p. 4002). It seems doubtful that this is referring to the same fire as that supposedly in the imperial archives, which at that time would have been in Beijing. See Tang Zhiba, "Zheng He baochuan chidu zhi wo jian," pp. 26-32.

12 Tang Zhiba, "Zheng He baochuan chidu zhi wo jian," pp. 26-32, pp. 26-27. In these editions, the dimensions are written in accounting-style characters, a style that was not used by Ma Huan as far as we know.

name of Bengal appears in the two works. Lo suggests that Gu Qiyuan may have had access to the novel and copied not only the name of Bengal but also the dimensions of the ships from it.[13] Like the novel, *Kezuo zhuiyu* gives the dimensions of the large ships as 44.4 *zhang* rather than the simpler number of 44 given in the *Ming shi*. It also gives the same dimensions as the novel for the second class of ships (37 *zhang* long by 15 *zhang* wide), which the *Ming shi* does not include. An important difference between the two works is in the number of ships. *Kezuo zhuiyu* says there were 63 of the largest ships, while the novel says it was 36. There is a theory that these two digits have been reversed, but the number 62 given in the *Ming shi* is different yet again. The *Ming shi* editors may have copied this number from *Kezuo zhuiyu*, reversing the order, but one wonders if they would have made a further error while doing so.[14] Because these explanations are so speculative and inconclusive, the most we can say is that the *Ming shi* may have used the novel as its source, or it may have used one of these other texts as an intermediary.

If the novel was the source, whether directly or indirectly, we must examine what it says about Zheng He's ships. It contains much that belongs to the realm of the fantastic, and many events are overblown and exaggerated. The characters often rely on magic or supernatural help, in both design and construction of the ships. In chapter 15, when the emperor consults the elder Jin Bifeng 金碧峰 for advice on carrying out the expeditions, the elder shows him various divine manuals that tell him the route they should follow, the countries they should visit, the personnel that will be needed to man the ships, and the types of ship that will be required. The manual on the ships divides them into five classes, giving the number of ships in each class that should be built, and the number of masts and dimensions for each. The details for each class of ship are as follows, in descending order of size: 36 nine-masted treasure ships measuring 44.4 *zhang* by 18 *zhang*, 700 eight-masted horse ships (*machuan* 馬船) measuring 37 *zhang* by 15 *zhang*, 240 seven-masted provision ships (*liangchuan* 粮船) measuring 28 *zhang* by 12 *zhang*, 300 six-masted transport ships (*zuochuan* 坐船) measuring 24 *zhang* by 9.4 *zhang*, and 180 five-masted combat ships (*zhanchuan* 戰船) measuring 18 *zhang* by 6.8 *zhang*. This comes to a total of 1,456 ships in the fleet, which as Xin says is approximately ten times the number documented in the historical sources (ranging from 48 to 250 on any given voyage). Moreover, the ships were

[13] He calls it Xigela 吸葛刺 instead of Banggela 榜葛刺. Lo Jung-pang, "Ships and Shipbuilding in the Early Ming Period," paper to the Association for Asian Studies Conference, Chicago, March 1961, p. 3. A copy of this paper is in the offprints collection at the Needham Research Institute.

[14] Zheng Hesheng 鄭鶴聲 asserts that the numbers are reversed in his article, "Zheng He chushi zhi baochuan" 鄭和出使之寶船, in: *Dongfang zazhi* 東方雜誌 40 (1944) 12, pp. 52-58; repr. in *Zheng He yanjiu ziliao huibian*, pp. 249-260, cf. p. 258. If this theory is true, it seems to support *Kezuo zhuiyu* as the source rather than the novel because the *Ming shi* would not only have needed to transpose the digits but also to change 63 to 62. There are other theories as well, outlined in Tang Zhiba, "Zheng He baochuan chidu zhi wo jian," p. 26.

not manufacturable by human hands in the novel; they could only be constructed with divine help from the immortal Lu Ban 魯班.[15]

Some of the sources that predate the novel mention more than one size of ship, but none gives as many as five different classes, and none mentions the number of masts.[16] A ship sent on an embassy to the Liuqiu 琉球 (Ryūkyū) islands during the Xuande 宣德 period (1425–1435) reportedly had five masts; this is the largest number of masts on a Chinese ship of early Ming that I have found documented so far. We know that during the Jiajing 嘉靖 period (1522–1567), the ship on which the official envoy Chen Kan 陳侃 travelled to these islands had five masts.[17] Scholars often quote *Tiangong kaiwu* 天工開物 in discussions of masts, particularly its statement that "A boat that approaches 100 *chi* in length must carry two masts,"[18] and they calculate that a ship 44 *zhang* long must therefore have had nine masts. This tallies with the nine mentioned in the novel for the largest ship. However, to say that a ship over 10 *zhang* long must have two masts is different from saying that there are two masts for every 10 *zhang* in length, no

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15 Luo Maodeng, *Sanbao taijian Xiyang ji*, chapter 15, pp. 121-122. Because there are 10 *chi* to one *zhang*, I have felt justified to use decimals. I have rearranged the list to put them in descending order of size. Construction is completed in chapter 16 (pp. 133-137), and the deity reveals himself to the emperor in chapter 17 (pp. 137-138). Pao Tsun-p'eng 包遵彭 repeats this information in his *On the Ships of Cheng Ho. Zheng He xia Xiyang zhi baochuan kao* 鄭和下西洋之寶船考 (National Historical Museum Collected Papers on the History and Art of China, 1st series, no. 6; Taibei and Hong Kong 1961), p. 7.

16 The shipyard treatises of a hundred years later mention the number of masts, but these ships were all smaller. These treatises are discussed below.

17 Zheng Hesheng 鄭鶴聲 and Zheng Yijun 鄭一鈞, "Lüe lun Zheng He xia Xiyang de chuan" 略論鄭和下西洋的船 in their *Zheng He xia Xiyang lunwen ji* 鄭和下西洋論文集, vol. 1 (Beijing 1985; originally published in *Wenshizhe* 文史哲 3 [1984]), p. 62, cite Mao Ruizheng's 茅瑞征 *Huang Ming xiangxu lu* 皇明象胥錄 for the Xuande reference, which I have unfortunately been unable to consult, saying that the ship was 17 *zhang* long, with masts of *Cunninghamia* wood (*shan* 杉) and a rudderpost of teak (*tielimu* 鐵梨木). We have a rather detailed account of the Jiajing period embassy ship, which was slightly smaller – 15 *zhang* long, 2.6 *zhang* wide and 1.3 *zhang* deep – and carried about 350 people. The largest of its five masts was 7.2 *zhang* tall, and its rudder too was made of teak (*tielimu*). See Chen Kan 陳侃, *Shi Liuqiu lu* 使琉球錄 (1534), facsimile edition, in *Jilu huibian* 紀錄彙編, 66, pp. 15 and 20. Marco Polo famously said that there were four masts on Chinese ships, "and sometimes they have two additional masts, which they ship and unship at pleasure." In other words, they are retractable or removable. See Colonel Sir Henry Yule (trans., ed., and annot.), *The Book of Ser Marco Polo*, 3rd ed. by Henri Cordier, 2 vols. (London 1903), vol. 2 (Book III, chapter 1), p. 249. Pao Tsun-p'eng, in *On the Ships of Cheng Ho*, follows the novel in recording the dimensions of the ships, but does not go so far as to concur with the greatly inflated number of 1,456 ships mentioned in the novel, at least not for any single voyage. Instead he estimates that there were 317 ships on the first voyage.

18 Sung Ying-hsing, *T'ien-kung k'ai-wu: Chinese Technology in the Seventeenth Century*, trans. by E-tu Zen Sun and Shiou-chuan Sun (University Park, Penn. 1966), p. 174.

matter what kind of ship it is. People also fail to consider that some of the masts may have been smaller or retractable.[19]

The only works that are guaranteed to be free from the novel's influence are those written or produced before 1597, as there are no known versions of the novel before that date. Therefore, it seems wise, as Xin suggests, to examine the information about the ships that can be gleaned from sources predating the novel. The pre-1597 sources include stone inscriptions, first-hand accounts left by Ma Huan, Fei Xin 費信, and Gong Zhen 鞏珍, the itinerary containing a brief description of the ships found in Zhu Yunming's 祝允明 (1461–1527) miscellany *Qianwen ji* 前聞記 (ca. 1500), early historical records such as those in the *Shilu* 實錄 ("Veritable Records"), various illustrations, shipping and shipyard records, material about earlier Chinese ships included in the histories, and archaeological evidence. It seems safe to say that Zheng He's ships were not built in isolation, but arose out of a tradition of shipbuilding that was largely conservative (like most shipbuilding traditions). Ships for overseas voyages were also closely related to ships for other purposes, and sometimes were used for more than one purpose at a time – river transport of grain, ocean transport of grain, and military defense. For this reason I have considered canal ships, overseas transport ships, and naval ships as well. For comparative purposes, I have found it useful to examine Western ships from the "age of sailing ship," that is, from the 17th to the 19th centuries, partly because the records concerning these ships are so complete, and also because ships of wood and sail, no matter where they originate, share a number of basic characteristics and obey similar physical laws.

One of the difficulties involved in exploring what is known about Zheng He's ships before 1597 is that only a small amount of evidence is available. Moreover, what exists is scattered in various non-homogenous sources. Where there is information, it is often approximate, fragmentary, incomplete, and expressed in non-compatible units of measurement. It would be ideal if we had measurements for the same parts of all the ships that are discussed. Instead we have the length of one, the beam of another, the capacity for a third, the number of crew on a fourth, and so on. Some calculations, such as displacement, require knowledge of three or more variables, and these are not always available.[20] Although we can

[19] Xin emphasises the retractability of the masts on ships. If one examines the illustration of the 18th century *fengzhou* 封舟 that sailed on a diplomatic mission to the Ryūkyū islands, one can visualise the possibility of having three or four main masts and a number of small ones. It is reproduced in Joseph Needham, *Science and Civilisation in China*. Vol. 4, Pt. 3: *Nautical Technology*, figure 939, p. 405, from Zhou Huang's 周煌, *Liuqiu guozhi lüe* 琉球國志略 (1759) illustrations, pp. 33b-34a. The model of Zheng He's ship done in 1985 has nine main masts although they slightly vary in size. Xin argues that so many masts would block each others' wind.

[20] To calculate displacement using Xin's formula, one needs to know the length, beam, and draught of the ship, as well as an accurate idea of what coefficient to use. Displacement in tons is calculated by multiplying length, breadth, and draught together (as long as these are expressed in metres) and then multiplying the product by a coefficient of approximately 0.5 (Xin Yuan'ou, personal communication).

figure out displacement for some ships, and estimates can be made for others, no figures for displacement are given in any of the primary texts that provide measurements for Zheng He's ships.[21] Measurements of capacity can be expressed in the Chinese sources in *liao* 料, *hu* 斛, or *dan* 石 (*shi*, piculs), and for convenience I have converted these to tons burden.[22] Measurements of length are converted into both feet and metres in this paper since traditional Western measurements of ships tend to be in feet, while modern Chinese and Western measurements are usually in metres. There are also different ways of measuring the dimensions of a ship. For instance, the length might be taken at deck level or at the waterline. Most of the historical documents that give measurements for Chinese ships do not specify where they were taken; therefore I have assumed that the measurements are of overall dimensions, unless otherwise indicated.[23] There are also differences in the length of a *zhang* in different time periods,[24] and specialised regional and professional units existed as well, such as the *Huai chi* 淮尺.[25] Despite the Western "medieval rule," to which Lo Jung-pang refers, that a ship can carry one man for every ton of displacement,[26] it is difficult to arrive at a

[21] To calculate the displacement for the dimensions recorded in the *Ming shi*, Xin Yuan'ou supplied an estimate of six metres for the ships' draught. By multiplying 138 m by 56 m, then by 6 m, and finally by the coefficient of 0.5, Xin Yuan'ou arrived at 23,189 tons, which was then rounded off to 20,000 tons as the displacement implied by the *Ming shi*'s dimensions.

[22] It appears that during the Ming these were all equivalent to each other, and were all measurements for capacity rather than displacement. There is often confusion in China as well as in the West between tons burden *vs* tons displacement. A picul was equivalent to approximately 133 lbs (Hoshi Ayao, *The Ming Tribute Grain System*, translated by Mark Elvin [Michigan Abstracts of Chinese and Japanese Works on Chinese History, No. 1, Center for Chinese Studies, University of Michigan (Ann Arbor, MI 1969)], p. 105).

[23] The Longjiang shipyard treatise gives both length overall (L_{oa}) and length at waterline (L_{wl}), but the ships recorded in this work are probably smaller than Zheng He's ships. Needham was able to whittle down the size of Zheng He's ships by estimating that although the overall length was about 450 ft, the length at waterline would have been 310 ft. This enabled him to say that those who supplied the huge dimensions as this big were "not spinning a yarn" (Needham, *Science and Civilisation in China*, Vol. 4, Pt. 3, pp. 480-482).

[24] Joseph Needham, *Science and Civilisation in China*, Vol. 4, Pt. 1, *Physics*, figure 287, opposite p. 45.

[25] According to Needham, the *Huai chi* was 1.12 ft long, slightly larger than the standard Ministry of Works *chi* (Needham, *Science and Civilisation in China*, Vol. 4, Pt. 3, p. 482, note a). Qiu Guangming 丘光明, in *Zhongguo lidai duliangheng kao* 中国历代度量衡考 (Beijing 1992), p. 98, says that the *Huai chi* was a Song measurement of about 35-36 cm, as opposed to the usual 31.1. I have not found evidence that the *Huai chi* was used in shipbuilding, other than the reference in Zhou Shide 周世德, "Cong Baochuanchang duogan de jianding tuilun Zheng He baochuan" 從寶船廠舵杆的鑑定推論鄭和寶船, *Wenwu* 文物 (1962/3), pp. 35-40, esp. p. 38.

[26] Lo, "Ships," p. 3. William Ledyard Rodgers discusses the "medieval rule for men in proportion to tonnage." *Naval Warfare Under Oars, 4th to 16th Centuries: A Study of Strategy, Tactics and Ship Design* (Annapolis, Maryland 1940, 1967 rpt.), p. 28. It is a general rule concerning the number of men a wooden ship can carry, but in practice ships carried fewer men because of the need to carry provisions, horses, equipment and other necessities, perhaps one man for every four tons of ship. I am grateful to Martin Evans for pointing me to this reference via

precise formula for calculating the size of a ship from its complement, or number of sailors on board. The amalgamation of all these various measurements into a comprehensible picture has been a challenging aspect of this study.

I shall begin by examining what is said in the pre-1597 primary texts about the ships. Two inscriptions dating from the Zheng He era give details. They are the Changle 長樂 inscription found at the port by that name on the coast of Fujian province, which was a regular stopping place for the outgoing voyages, and the Jinghai temple 靜海寺 inscription in Nanjing, where Zheng He supposedly went to pray for safe journeys. The Changle inscription,[27] composed and inscribed on a stele in 1431, says that there were over 100 ships on the seventh expedition. It should be noted right away that numbers like one hundred, one thousand, or ten thousand are often rough estimates, or simply a way of saying "a large number." However, when this inscription says "over a hundred," it is probably fairly close to the truth, given the numbers mentioned in the other sources. In fact "one hundred" seems to be a rather conservative number, compared to the 250 mentioned in Yan Congjian's 嚴從簡 *Shuyu zhouzi lu* 殊域周咨錄 of 1574, a work also dating from before 1597. According to Yan, this number of ships (*jianbo* 艦舶) was ordered in 1403 for the first voyage.[28] Apart from calling them "giant ships" (*jubo* 巨舶), the inscription does not mention their size. Care must be taken not to assume too much from such hyperbolic terms, which simply mean that they were large by the standards of the day, or in the writer's eyes. Xu Jing 徐兢, author of a Northern Song account of a diplomatic voyage to Korea in 1123 used the term "giant ships," but the ships he was describing were only 85 ft long.[29]

While the Changle inscription mentions the number of ships but not the size, the inscription at Jinghai temple in Nanjing mentions the size but not the number. It says that Zheng He commanded "ocean-going ships" (*haichuan* 海船) that were 2,000-*liao* 料 in 1405 and 1,500-*liao* in 1409.[30] The *liao* is usually thought

the email list "Marine History Information Exchange," where I received assistance from Steven Toby, Jim Klein, and Frank Pierce Young. Not all experts agree that this rule is true.

27 The stele at Changle was set in place after the seventh expedition had left Nanjing and arrived in Changle. Dated in the second winter month of Xuande 6 (5 December 1431 – 3 January 1432), the inscription is discussed and translated in J.J.L. Duyvendak, "True Dates," pp. 342-343 and 349-355.

28 Yan Congjian, *Shuyu zhouzi lu*. Zhongwai jiaotong shiji congkan series, vol. 13 (Beijing 1993), *j*. 8, p. 306. Yan Congjian served in the official messenger service (*xingren si* 行人司) which was engaged in low-level diplomatic activity during the Jiajing period (1522–1566).

29 Xu Jing, *Xuanhe fengshi Gaoli tujing* 宣和奉使高麗圖經 (1124; facsimile rpt. of 1167 edition, Taipei 1974), *j*. 34, pp. 4a-6b, esp. 6b.

30 "Nanjing Jinghaisi canbei" 南京靜海寺殘碑 (Stele fragment at Nanjing's Jinghai temple), Zheng Hesheng 鄭鶴聲 – Zheng Yijun 鄭一鈞, *Zheng He xia Xiyang ziliao huibian* 鄭和下西洋資料彙編 (Jinan 1980), vol. 1, p. 202. This inscription is undated, but a stele was set up in the first month of 1409 at a temple by this name dedicated to the Celestial Goddess who protects seamen. Xiang Da 向達 asserts that the temple was set up after 1425. See his *Zheng He hanghai tu* 鄭和航海圖 (Beijing 1961), p. 33.

of as a unit of capacity, probably equivalent to 500 lbs.[31] Thus these ships were 500 and 375 tons respectively. The inscription also mentions eight-oared ships (perhaps escort ships) in both years.[32] It is not clear whether anything should be read into the difference in the size for the two years. However, the existence of different sizes of ship is an important feature of many different accounts, and thus seems likely to be true. If 500 tons in capacity is equivalent to 800 tons displacement,[33] these ships were 800 and 600 tons displacement respectively. Xin Yuanou argues that if ships of the massive size recorded in the *Ming shi* had been among the fleet, they would have been mentioned in this inscription.[34] However, it is difficult to sustain this argument given that the inscription has not been entirely preserved; some of the text has worn away to the point of illegibility.

Another source, also a fragment, mentions several different sizes of ship. This is an itinerary of the seventh voyage (1431–1433) written by an anonymous passenger and collected in Zhu Yunming's *Qianwen ji*.[35] In addition to a list of dates recording the expedition's arrival at each place along its route, the text also contains a short description of the ships on the voyage. It mentions eight-oared ships of large and secondary classes (*da ba lu* 大八櫓 and *er ba lu* 二八櫓), and lists the names of five other ship types or models (*chuanhao* 船號), each of which, it says, was divided into different classes or rates (*shuxu* 數序).[36] Here again, there is no reference to extremely large ships, but as before, the text is incomplete, and one must be careful not to read too much into its silence on the subject.

The three major first-hand accounts of the voyages give us only slightly more information on the ships than what is outlined above. Ma Huan, in his *Yingyai*

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31 The *liao* has recently been the subject of a study asserting that the *liao* is actually a measure of a ship's loaded displacement. However, it seems sometimes to be used as a unit of capacity, so I shall continue to refer to it this way. See André Wegener Sleeswyk, "The *Liao* and the Displacement of Ships in the Ming Navy," *The Mariner's Mirror* 82 (1996) 1, pp. 3-13. Sleeswyk says that it is equivalent to 1,000 lbs, but I still rely on Lo Jung-pang's estimate of 500 lbs, made in "The Emergence of China as a Sea Power During the Late Song and Early Yuan Periods," *Far Eastern Quarterly* 14 (August 1955) 4, pp. 489-503, esp. p. 493, n. 18. In this note Lo says that the colossal dimensions "are excessive when compared with the known tonnage of vessels of the period."

32 Lo suggests they were escort ships, see "Ships," p. 2.

33 Xin Yuan'ou, "Guanyu Zheng He baochuan chidu de jishu fenxi," p. 8; Needham, *Science and Civilisation*, Vol. 4, Pt. 3, p. 481.

34 Xin Yuan'ou, "Guanyu Zheng He baochuan chidu de jishu fenxi," p. 13.

35 Hok-lam Chan, "Chu Yün-ming," in L. Carrington Goodrich and Fang Chao-ying (eds.), *Dictionary of Ming Biography* (New York 1976), p. 395.

36 Included in Xiang Da's edition of Gong Zhen, *Xiyang fanguo zhi* 西洋番國志 (Beijing 1961), p. 57. The names he gives for these ships are Qinghe 清和, Huikang 惠康, Changning 長寧, Anji 安濟, and Qingyuan 清遠. They have different "orders" or "classes": *yi, er deng hao* 一, 二等號. These colourful ship names do not correspond to anything in the other records that concern the voyages, though there are some similarities with the names given to the *kezhou* in Xu Jing's *Xuanhe fengshi Gaoli tujing*, *j*. 34, pp. 4a-7a. The names do not shed any light on the size or nature of the ships beyond that they were different sizes.

shenglan, mentions the "great fleet" of treasure ships (*dazong baochuan* 大艐寶船) in his chapter on Palembang, but says nothing about how big or even how many they were. In his Siam chapter he mentions that Chinese traders on the voyages used small ships (*xiaochuan* 小船) to go ashore, presumably while the larger ships were anchored in the harbour. He thus corroborates the existence of a variety of ship sizes in the fleet. He points out that the fleet divided and reassembled in certain places, such as Melaka, but does not say how many ships constituted the subdivisions. On only two occasions does he mention the number of ships. The first is in his description of the dangers of sailing near the Maldives, where he says that, because of the treacherous shoals around the islands, only one or two treasure ships went there at all. The second is his comment that only "several treasure-ships" went from Calicut to Aden on the sixth voyage in 1421.[37] Despite his dramatic reference to the ships as "whale-like" (*jing zhou* 鯨舟) in the poem that prefaces his work, we know no more from this inflated term than from the "giant ships" mentioned above.

At the beginning of the first chapter of his *Xingcha shenglan* 星槎勝覽, Fei Xin says that the fleet of the third expedition (his first voyage, 1409–1411), consisted of 48 "ocean-going ships," each with twelve sails.[38] An entry in the *Shilu* of the year before that expedition's departure (dated 14 February 1408) states that the emperor ordered the construction of 48 treasure ships (*baochuan*). It is tempting to see the *Shilu* entry as the record of Yongle's requisition for these very ships. Fei Xin refers to the ships as *haibo* 海舶 (*haichuan* in some editions), and the term *baochuan* in the *Shilu* suggests that they were for the voyages.[39]

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[37] Feng Chengjun 馮承鈞 (ed.), *Yingyai shenglan jiaozhu* 瀛崖勝覽校注 (Beijing 1955), p. 55. Mills, *Ma Huan*, p. 155. Gong Zhen says that three ships went from Calicut to Aden on this voyage, *Xiyang fanguo zhi*, p. 35. Ma Huan notes that the seven men who went to Makkah (Mecca) during the seventh expedition did so on a foreign ship rather than a Chinese ship. Feng, *Yingyai shenglan jiaozhu*, p. 72.

[38] J.V.G. Mills and Roderich Ptak, *Hsing-ch'a sheng-lan: The Overall Survey of the Star Raft* (Wiesbaden 1996), p. 33. I follow Feng Chengjun's edited edition where the number of sails is mentioned: Feng Chengjun 馮承鈞, *Xingcha shenglan jiaozhu* 星槎勝覽校注 (Taibei 1962, reprint of 1938 ed.), p. 1.

[39] Feng, *Xingcha shenglan jiaozhu*, p. 1. The *Shilu* entry is: Yongle 6, 1st month, 17th day, *dingmao* (14 February 1408), "[The emperor] ordered the Ministry of Works to build 48 treasure ships" (*j*. 75, p. 2b, p. 1032). The mention of twelve sails is consistent with the observations of Yuan dynasty ships by Marco Polo and Ibn Battuta. See Yule, *The Book of Ser Marco Polo*, vol. 2 (Book III, Chapter 1), p. 249; and H.A.R. Gibb (trans.), *The Travels of Ibn Battuta, AD 1325–1354* (London 1994), vol. IV, pp. 809, 812-813. Zheng and Zheng emphasise that these 48 were built within one year; they were ordered in 1408 and ready for deployment in 1409 ("Lüe lun," pp. 55-56). In Fei Xin's comment, "Treasure ships from other foreign countries come here" (*ta fan baochuan dao bi* 他番寶船到彼) he seems to be referring to foreign ships as *baochuan*, although by "foreign" he may mean "foreign to Champa." Because the comment is confusing, we cannot draw any conclusions from it about his use of the term *baochuan*. See Mills and Ptak, *Hsing-ch'a sheng-lan*, pp. 33, and note 6. Fei Xin says that the Zhu 朱 and Jing 景 editions have *haichuan* instead of *haibo*. The editions of Fei Xin's text are discussed in Mills and Ptak, *Hsing-ch'a sheng-lan*, pp. 9-18, and Feng, *Xingcha shenglan jiaozhu*, pp. 3-4.

Gong Zhen provides valuable information about the ships used on the expeditions in his preface to *Xiyang fanguo zhi* 西洋番國志, where he mentions the "one hundred treasure ships" (*baozhou bai sou* 寶舟百艘) in the fleet. This figure tallies with the number mentioned in the Changle inscription, though this is not surprising since both Gong Zhen's text and the inscription were referring to the seventh voyage. Gong goes on to describe the ships as "lofty and majestic in physical form and appearance" (*ti shi wei ran* 體勢巍然), and "incomparably gigantic" (*ju wu yu di* 巨無與敵).[40] As before, it is tempting to see such effusive descriptions as indications of an unusual size, but caution is advised; the Song diplomat Xu Jing noted that his 85-ft ships: "had the majestic quality of great mountains" (*wei ru shan yue* 巍如山嶽).

Gong Zhen's short section on the ships is particularly notable because of his reference to specially designated water-carrying ships on the voyages. His text is the only evidence we have for the existence of such ships. By far his most significant statement about Zheng He's ships is that "the mat sails, cloth sails, anchors, and rudder required 200-300 people to handle them."[41] Possessing a modesty that gives it a ring of truth, this statement is the only clue in any of the first-hand accounts as to the size of the ships. Although in sailing there is no strict rule concerning the number of men per ship, there are some guidelines that can be followed. One such guideline is the Western medieval rule of one man per ton of displacement, which would put Gong Zhen's ships at 200-300 tons. However, in practice there were fewer men per ton, primarily because of the variable quantity of supplies that would be carried on different lengths of journey. It seems that one man for every two-four tons was more realistic; this would make Gong Zhen's ships between 400 and 1,200 tons.[42] The largest of these is much smaller than the 20,000 tons that Xin Yuan'ou calculated as the amount of displacement appropriate for the dimensions given in the *Ming shi*.[43] Gong Zhen does not mention ships even close to this size. Because his text is not a fragment like the others, and since he seems to have been quite interested in and observant of ships, it does not seem likely that there were ships of a huge size on this voyage.

Since the *Shilu* of each emperor's reign were compiled during the reign of the subsequent emperor, the entries to be consulted here, all dated before 1450, are well before the 1597 cut-off date for our discussion. Two such entries mention the numbers of men on board ships that were part of Zheng He's fleet. The first refers to the ship of the eunuch Zhang Qian 張謙, who had been sent as an envoy

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40 Gong Zhen, *Xiyang fanguo zhi*, preface, p. 2.

41 Gong Zhen, *Xiyang fanguo zhi*, preface, pp. 1-2. He describes this number of men being kept busy handling this equipment.

42 Rodgers, *Naval Warfare Under Oars*, p. 28.

43 Guan Jincheng states that the displacement for a ship of this size would be 22,000 tons, and if it had a very deep draught it could go up to 33,000 tons. Xin rounds the figure to 20,000. Ideally the length and width should be measured at the waterline (Xin Yuan'ou, personal communication).

to Brunei in 1408 and 1410–1411. He must have commanded a ship on Zheng He's fourth voyage (1415–1417), because the *Shilu* records that his ship was attacked by 4,000 pirates off the coast of Zhejiang on its return "from the Western Oceans" in 1417. After a series of twenty skirmishes, the entry says, and with only 160 men on board, Zhang Qian was able to escape the assault and return to port with his ship in tact. He was rewarded for his success against great odds on 28 July 1417; this commendation is the event recorded in the *Shilu*.[44] It should be noted that the figure of 160 men on board this ship is only slightly smaller than the 200-300 mentioned by Gong Zhen. The second relevant reference in the *Shilu* is to a shipwreck that occurred on the seventh voyage. A *Shilu* entry of 1448 records the return to China of three men who had been in the eunuch Hong Bao's 洪保 fleet on the 1431–1433 voyage. It seems that their ship, which originally had a complement of 300 men, ran into trouble off the coast of Africa and drifted with its 100 survivors to a country called Buguo 卜國, probably Brava [Brawa 卜剌哇] on the African coast.[45] The original complement of this ship is at the upper end of the range described by Gong Zhen. While these two passages are consistent with the complement mentioned by Gong Zhen, they are only isolated instances and we cannot draw any conclusions from them about the rest of the ships in the fleet.

Song Li 宋禮, Minister of Works from 1405 to 1422, appears to give us a contemporary rule of thumb concerning the number of men per ship. In addition to directing the repair and reconstruction of the northern section of the grand canal, he also oversaw the shipbuilding activities that came under the administration of Ministry of Works.[46] He advocated the transport of grain by inland waterway rather than by sea, arguing that ships for canal transport required a smaller num-

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44 *Ming shilu*, Yongle 15, 6th month, 15th day, *jihai* (28 July 1417), *j.* 190, p. 2a, p. 2013. Lo's figure of 120 men on this ship does not correspond to the number given in the edition of the *Shilu* I have consulted. The incident is also recorded in *Ming shi*, *j.* 7, p. 97, but with no details about the ships or crew. Zhang had been charged with accompanying the new king of Brunei back home after his father's death in China in 1408 (Yongle 6, 12th month, 4th day, *dingchou*, 20 December 1408), and was sent as an envoy to that country in 1410 and 1411 (Yongle 9, 2nd month, 2nd day, *guisi*, 24 February 1411). Only a few months after returning from the Western Oceans, he was sent to Gumalalang on a diplomatic mission. This was in the 9th month of 1417, which begins on 10 October. See *Ming shi*, "Gumalalang", p. 8379; *Ming shilu*, Yongle 15, 9th month, 6th day, *mouwu*, 15 October 1417, *j.* 192, p. 3b, p. 2026. He returned from Gumalalang in 1420 (*Ming shilu*, Yongle 18, 10th month, 10th day, *yisi*, 15 November 1420, *j.* 230, p. 1a, p. 2229).

45 *Ming Yingzong shilu* 明英宗實錄, Zhengtong 13 (1448), 8th month, *renxu*, *j.* 169, pp. 2b-3a, pp. 3260-3261. The incident is mentioned in Chen Guodong, "Zheng He chuandui xia Xiyang de dongji: sumu, hujiao yu changjinglu" 鄭和船隊下西洋的動機：蘇木，胡椒與長頸鹿, *Chuanshi yanjiu* 17 (2002), pp. 121-134. These are probably the Chinese survivors who ended up in Pate, Kenya.

46 Lee Hwa-chou, "Sung Li," in Goodrich and Fang (eds.), *Dictionary of Ming Biography*, pp. 1224-1225. This particularly concerned the construction of 41 *baochuan* in 1419.

ber of men than ocean-going ships to transport the same amount of grain, and were therefore cheaper. He says:

> A single sea-going vessel (*haichuan*) needs a crew of 100 men to transport 1,000 piculs. However, when one considers the cost, one can use 20 river boats, each carrying 200 piculs and requiring a crew of 10 men to transport 4,000 piculs.[47]
>
> 計海船一艘，用百人而運千石，其費可辦河船容二百石者二十，船用十人，可運四千石.

This rather cryptic passage needs some elaboration to be understood. He seems to be saying that when one calculates the number of men necessary to transport 4,000 piculs by the two means of transport, one finds that the ocean-going ship would require 400 men, whereas the river or canal ship would require only 200. He seems to be saying that river transport is half the cost of ocean transport. It is clear from this passage that regular ocean-going transport ships had a capacity of 1,000 piculs (*dan* 石), which was equivalent to 1,000 *liao*, or 250 tons. Presumably this was the optimum size of ship – the safest for the cargo – as we know that the loss of grain shipments at sea was a recognised problem.[48] The standard number of men on an ocean-going grain transport seems to have been 100, and the ratio of crew to capacity on these ships was one man per 10 *liao*, or 2.5 tons. Song Li's statement makes clear that this ratio was different for river and canal boats, which could get by with one man for every 20 *liao*, or five tons.[49] The larger crew for ocean-going ships was probably necessary because of their greater size, larger equipment (such as anchors and rudder), and more complicated rigging.

Can Song Li's rule of thumb for the complement of ocean-going ships (one man per 2.5 tons) be applied to the ships on Zheng He's voyages? While the aim in grain transport was to maximise the load while minimising the crew, would the same have been true for Zheng He's ships? This is difficult to say. Perhaps the aim of some ships was to transport the maximum number of people and others to transport the maximum quantity of cargo. Since there were specialised water carrying ships, there was probably specialisation in the other ships; we know that there was a variety of sizes of craft on the voyages. We also know, from the military conflicts in which Zheng He's ships engaged while on foreign shores, that some of these ships played a military role.[50] Military ships may have been designed to carry more men per ton than cargo ships in order to maximise the num-

47 *Ming shi*, "Biography of Song Li," *j*. 153, p. 4204. From Elvin's translation it is not immediately clear that "20 of them" refers to ships rather than men, *The Ming Tribute Grain System*, p. 10. Another reason for preferring canal transport was that there would be fewer losses due to shipwreck.

48 In 1374, forty grain-transport ships were lost at sea, resulting in a loss of 4,700 piculs of grain, 717 soldiers, and 40 horses. Elvin, *The Ming Tribute Grain System*, pp. 7, 11.

49 Notice that this is a lower rate of men per ton than is specified by the "medieval rule."

50 One such conflict took place in Ceylon on the return voyage of the third expedition in 1411, when the Chinese were victorious against the king Alagakkonara after several battles. Duyvendak, "True Dates," p. 368; Mills, *Ma Huan*, p. 12.

ber of combat soldiers transported.[51] Lo Jung-pang mentions that some military ships of 700 *liao* (175 tons) in the early Ming were manned by 400 men – almost one man for every two *liao*, or one man per half-ton. Some combat ships of 400 *liao* (100 tons) had a crew of 100 men, which is equivalent to one man for every four *liao*, or one man per ton.[52] It seems likely that, just as there were ships of varying sizes, there were also different proportions of men per ship. Certainly Song Li's rule is well documented, and it may be the only reliable guideline we have. If we use this rule to calculate the size of the ships mentioned by Gong Zhen and in the *Shilu* entries, we find that their capacities would have been between 375 and 750 tons (obtained by multiplying the complement of 160-300 men by 2.5).

There is another method by which we can estimate the average number of men per ship, and Xin explores this method as well.[53] If we take the total number of people who travelled on each voyage, for which we have consistent figures of between 27,000 and 28,000, and divide it by the total number of ships in the fleet, we find that for the 62 ships mentioned in the *Ming shi*, we have an average of 435-450 men per ship, a somewhat higher number than that mentioned by Gong Zhen. An even higher complement of 560-585 would be right if we consider Fei Xin's 48 treasure ships to be the only ones used on the third voyage, although this is probably unlikely. The 100 ships mentioned in the Changle inscription average out to 270-280 men per ship, while Yan Congjian's figure of 250 gives us 108-112 men per ship.[54] By applying Song Li's rule to these complements, we can obtain capacities of 1,087-1,125 tons, 1,400-1,462 tons, 675-700 tons, and 270-280 tons respectively.

Lo Jung-pang estimated that there were 500 men per ship – this accords well with the figures obtained here – yielding a capacity of 1,250 tons on the basis of Song Li's formula.[55] This formula can also help us calculate the complement of the ships mentioned in the Jinghai temple inscription for which we know the capacities alone. There would be about 150 men aboard the 1,500-*liao* (375-ton) ships and 200 men on the 2,000-*liao* (500-ton) ships. While these are close

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51 I am told that such a ratio as one man per ton of ship would apply more closely to a warship (where it was desirable to have as many fighting men aboard as the ship could carry) than to other types of ship. (Martin Evans, personal communication.)

52 In the Song we have records of 800-*liao* warships carrying 200 men; this is the same ratio. Lo Jung-pang, "The Decline of the Early Ming Navy," *Oriens Extremus* 5 (1958), pp. 149-168, especially p. 159; For the Song ship, see Lo, "Decline," p. 151, n. 4. A grain transport ship would try to maximise the cargo it carried and minimise the number of men, whereas a combat transport ship would carry as many men as it could.

53 See his in "Guanyu Zheng He baochuan chidu de jishu fenxi," p. 8.

54 Pao Tsun-p'eng does not consider the 62 treasure ships mentioned in the *Ming shi* among Yan Congjian's total of 250.

55 Lo Jung-pang, "Decline," p. 151, n. 4; and "Ships," p. 3. Despite the controversy surrounding the size of the ships, there does not seem to be much argument against the figure of 62 treasure ships or the figures of 27,000-28,000 people on them.

enough to the complements of the ships mentioned by Gong Zhen and in the *Shilu*, even the largest of these (1,462 tons) does not come close to 16,000 tons of capacity (corresponding to the 20,000 tons displacement that Xin estimates for the ships in the *Ming shi*).

In addition to these scattered references to the number of men on board Zheng He's ships, the *Shilu* also contain information about the types and quantities of ships either ordered by the emperor or constructed under imperial order at various times during the period. There are twenty-two entries dating from the time of Zheng He documenting the orders for or construction of such ships. Not all of them were for use on Zheng He's expeditions – some were ocean-going grain transports and others may have been military ships. Nor do these entries record all the ships that were ordered or constructed in China during those twenty-eight years. Even the 250 mentioned by Yan Congjian are not recorded in the *Shilu*, for example, and the 61 mentioned in the edict for the seventh voyage are also omitted.[56] There were many regular standing orders for canal boats and military vessels not recorded here, and of course the *Shilu* does not mention the myriad smaller ships used by the common people or the government for fishing, ferrying, and other aspects of daily life.

While not comprehensive in this sense, these *Shilu* entries contain important information about the ships, such as the numbers that were ordered or completed, the region or regions that supplied them, and the kinds of ship they were – grain transports or other types. I have listed this information by date in the table below, along with the *Shilu* references, and have indicated whether the *Shilu* says the ships were "converted" (*gaizao* 改造) or simply "built" (*zao*). The common practice seems to have been to convert ocean-going transport ships (*haiyun chuan* 海運船) to other types of ship – although it is difficult to tell which type they were converted into unless their purpose is explicitly stated in the entry. The purpose is given only in one case – that of the 249 ships constructed in 1407 – and these are the only converted ships that we can say for certain were part of Zheng He's fleet. Some grain transports may also have been converted into military ships.[57]

[56] This edict, dated 25 May 1430, orders Zheng He to sail to the Western Oceans with 61 "large and small ships" (*da xiao xiang* 大小舡). The text of the edict is included at the beginning of Gong Zhen's account, *Xiyang fanguo zhi*.

[57] Lo says that the converted ships were used for embassies to distant places, in other words, for the expeditions. See his "Ships," p. 5. It is possible that when military ships were taken on Zheng He's voyages, this left the provinces in need of ships for self-defence. The military aspects of the voyages have been underplayed.

Numbers of Ships Ordered or Constructed according to the *Shilu*: 1403–1419

Date	Number	Name of ship	Place(s)	Reference
25 May 1403	137	*haichuan*	Fujian	5th month, *xinsi*, 20A:2b, p. 356
4 Sept 1403	200	*haiyun chuan* (converted)	Zhejiang, Huguang, Jiangxi, Suzhou, and other prefectural guards	8th month, *guihai*, 22:4a-4b, pp. 411-412
1 Nov 1403	188	*haiyun chuan*	Huguang, Zhejiang, and Jiangxi	10th month, *xinyou*, 24.6b, p. 442
1 March 1404	50	*haichuan*	capital guard (Nanjing)	1st month, *renxu*, 27:4b, p. 498
2 March 1404	5	*haichuan*	Fujian	1st month, *guihai*, 27:4b, p. 498
18 July 1405	1,180	*haizhou*	Zhejiang and other regional commanders	6th month, *bingxu*, 43.3b, p. 686
7 Nov 1405	80	*haiyun chuan* (converted)	Zhejiang, Jiangxi, Huguang, and Zhili, Anqing and other prefectures	10th month, *mouyin*, 47:3b, p. 722
26 Nov 1405	13	*haiyun chuan* (converted)	Zhejiang, Jiangxi, Huguang	11th month, *dingyou*, 48:2a, p. 731
19 Nov 1406	88	*haiyun chuan*	Zhejiang, Jiangxi, Huguang, and Zhili, Huizhou, Anqing, Taiping, Zhenjiang, Suzhou and other prefectures	10th month, *yiwei*, 60.1b, p. 866
5 Oct 1407	249	*haiyun chuan* (converted)	(no place mentioned) commander Wang Hao 汪浩	9th month, *yimao*, 71:1b, p. 988
6 Dec 1407	16	*haiyun chuan* (converted)	Zhejiang, Huguang, Jiangxi	11th month, *dingsi*, 73.1b-2a, pp. 1014-1015
14 Feb 1408	48	treasure ships	Ministry of Works	1st month, *dingmao*, 75:2b, p. 1032
25 March 1408	33	*haiyun chuan* (converted)	Jinxiang and other guard stations in Zhejiang	2nd month, *dingwei*, 76:3a, p. 1039
23 Nov 1408	58	*haiyun chuan*	Jiangxi, Zhejiang, Huguang, and Zhili, Susong	11th month, *gengxu*, 85:1b, p. 1128
30 Nov 1409	35	*haichuan*	Jiangxi, Huguang, Zhejiang, and Suzhou and other prefectural guards	10th month, *renxu*, 97.4a, p. 1285
14 Jan 1410	5	*haichuan*	Yangzhou and other guard stations	12th month, *dingwei*, 99:1a, p. 1295
30 Oct 1411	48	*haichuan*	Linshan, Guanhai, Dinghai, Ningbo, Changguo and other guard stations in Zhejiang	10th month, *xinchou*, 120.2a-2b, pp. 1515-1516
2 Nov 1412	130	*haiyun chuan*	Zhejiang, Huguang, Jiangxi and Zhenjiang and other prefectural guards	9th month, *gengchen*, 133:3b, p. 1634

24 Dec 1412	61	ocean-wind ships	Yangzhou and other guard stations	11th month, *renyin*, 134:3b-4a, pp. 1640-1641
19 Oct 1413	61	ocean-wind ships (converted)	Jiangxi, Huguang, Zhejiang and Zhenjiang, and other prefectural guards	10th month, *xinchou*, 143:2b, p. 1706
1 May 1415	—	*haichuan*	—	3rd month, *gengshen*, 162:3b-4a, pp. 1840-1841
2 Oct 1419	41	treasure ships	—	9th month, *yimao*, 216:1b, p. 2156

In addition to the 249 ships in 1407, converted "in preparation for sending embassies to the … Western Oceans," only three other sets of ships in these entries were definitely used on Zheng He's expeditions. These are the five ocean-going ships built in 1404, which the *Shilu* states explicitly were ordered because envoys would soon be sent abroad to the same "Western Oceans"; the 48 "treasure ships" in 1408; and the 41 "treasure ships" in 1419. Thus we have a total of 343 ships that were built for Zheng He's voyages.[58] Of these, the 249 in 1407 were the converted ones. As for the other converted ships – 188 in 1403, 80 in early November 1405, 13 in late November 1405, 16 in December 1407, 33 in 1408, and 61 in 1413 – it is tempting to think that these too were used on the voyages. This would give us 630 converted ships used on the voyages. However, because only the 249 are expressly stated to have been for the voyages, we cannot draw this conclusion.[59]

Conversion of existing ships would have been much more economical in material and effort than construction from scratch. Moreover, the fact that it was possible to convert the 249 ships into vessels for Zheng He's use suggests that at least some of the expedition ships were roughly the same size as the ocean-going grain transports. Four additional entries refer to the construction of *haiyun chuan*, or ocean-going grain transport ships, but we have no evidence to document their use on the voyages. Seven further entries are for ships vaguely termed *haichuan* (ocean-going ships), only one of which – the five ships in 1404 already mentioned – is associated with the voyages. The exceptionally large order of 1,180 *haizhou* 海舟 issued in 1405 is puzzling, since we are not told the purpose of

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[58] These references are to: Yongle 2, 1st month, 21st day, *guihai* (2 March 1404); Yongle 5 (1407), 9th month, 5th day, *yimao* (5 October 1407); Yongle 6 (1408), 1st month, 18th day, *dingmao* (14 February 1408); and Yongle 17 (1419), 9th month, 13th day, *yimao* (2 October 1419), in *Ming Taizong shilu* 明太宗實錄, *j.* 27, p. 4b, p. 498; *j.* 71, p. 1b, p. 988; *j.* 75, p. 2b, p. 1032; and *j.* 216, p. 1b, p. 2156, respectively.

[59] It has been suggested that these were the same as the 250 ships said by the *Shuyu zhouzi lu* to have been built in 1403. However, they cannot be the same because the 1407 ships were converted from *haiyun chuan* while the others were built from scratch. Lo is quite certain that they were for the voyages. He says: "Between 1405 and 1408, nearly 400 transports were converted to embassy ships for voyages to distant lands" (Lo, "Ships," p. 5).

these ships, but intriguing nonetheless. Two other orders use the term *haifeng chuan* 海風船 (ocean-wind ships), but nothing is known about them beyond the obvious – that they must have been "ocean-going" ships. One set of these ships was built from scratch and the other converted. If we add the 343 ships identified for use by Zheng He's maritime expeditions to the 250 ships noted by Yan Congjian to have been constructed for the first voyage, and the 61 mentioned in the edict for the seventh voyage, we obtain a total of 654 ships that seem to have been constructed for the voyages according to the *Shilu*.

If each fleet contained as many as 250 ships, which was the figure cited by Yan Congjian for the first voyage, or even 100, as indicated in the Changle inscription, why is the total number of ships constructed for the voyages as high as 654? A likely explanation seems to be that the fleet had to be replaced several times during the 28-year period of the voyages. Wooden ships of this era were regularly repaired and replaced, and we have three 16th century sources that discuss how often this was done: *Nanchuan ji* 南船紀 of 1542 by Shen Qi 沈啟, the *Longjiang chuanchang zhi* 龍江船廠志 (*Treatise of the Longjiang Shipyard*) of 1553 by Li Zhaoxiang 李照祥 (fl. 1537–1553), and the *Caochuan ji* 漕船記 (*Record of Canal Boats*) of 1527 (revised and published in 1544), by Xi Shu 席書 (1461–1527) and Zhu Jiaxiang 朱家相 (*jinshi* 1538). Although these three treatises were all written approximately 100 years after the last of Zheng He's voyages sailed home to port, they still all predate the novel. Despite treating different types of ship, they all give roughly the same schedule for the repair and replacement of vessels. As a rule, ships were repaired every three to five or years, and completely rebuilt (*gaizao*) after ten years.[60] Although we do not know if Zheng He's ships also had a life-span of only ten years, it is probably safe to assume that similar rules applied to them, given that they were probably built of the same materials as these 16th-century ships.[61]

Because the expeditions extended over a period of almost thirty years, the fleet must have been rebuilt at least twice after its initial construction. The ten-year rule would have meant that after their initial construction in 1403, they had to be rebuilt in 1413, and again in 1423. There would have been no point in rebuilding them in 1433 because the returning expedition of that year was the last one. However, if we look at the schedule of the arrival and return of Zheng He's seven voyages, these dates do not make sense. Particularly the 1423 overhaul

[60] The Longjiang shipyard treatise says that they had to be repaired once every five years and rebuilt every ten; the canal boat treatise says they were taken in for minor repairs after three years, major repairs after six, and given a complete overhaul after ten. Luo Chuandong 羅傳棟 says that they had to be rehauled after only five years in Jiangnan. See his *Changjiang hangyun shi: Gudai bufen* 長江航運史: 古代部分 (Beijing 1991), p. 401. *Longjiang chuanchang zhi*, *j.* 1, pp. 5a, 6b; Lo, "Ships," p. 7. *Caochuan ji*, *j.* 3, p. 26a. In fact, the canal boat treatise says that a ship should be taken in for a complete rehaul after nine years (*Caochuan ji*, *j.* 3, p. 26a).

[61] Because the ships found in archaeological sites from Song and Yuan periods were built of the same types of wood as those described in the 16th-century treatises, it does not seem likely that there was a major change in materials in the early 15th century.

does not seem right, because the sixth expedition had just returned the previous year, and there was a nine-year hiatus before the seventh set sail in 1431.[62] The fleet would surely have needed rebuilding before the seventh, probably around 1430. In fact we have the imperial edict dated in that year, ordering the construction of the 61 “large and small ships.” Therefore, it makes sense that, in order to devise a plausible repair schedule, we need to see it against the backdrop of the arrivals and departures of the seven expeditions, as well as the evidence of ship orders recorded in the *Shilu*. After the initial construction in 1403–1405, the fleet of 250 ships was probably replenished with the 249 converted ships ordered in 1407. However, these would not have been ready until the third expedition (1409–1411). The 48 *baochuan* and 33 converted grain transports built in 1408 would also have been ready for that voyage, but they may have been used for the side expeditions to Bengal, Brunei, the Philippines, and other such destinations, which were being launched at about the same time.[63] This supply may have been enough to get them through the fourth voyage (1413–1415), since the 61 *haifeng chuan*, whose conversion was ordered in 1413, may not have been ready by that trip; the latter were probably not used until the fifth voyage (1417–1419). The 41 treasure ships built in 1419 must have been for the sixth voyage (1421–1422). This voyage was followed by the nine-year gap mentioned above. If these dates for construction and conversion are correct, they suggest that the ships for the voyages needed to be replaced more frequently than other ships, and may have been replaced four or more times. Hence the number 654 does not seem far-fetched. The need for more frequent replacement of these ships may have been due to the wear-and-tear of such long journeys on the high seas and the losses suffered on the voyages.[64]

The pattern of ship construction and conversion presents a rather confusing picture in the context of changes that were occurring at the time in the government’s grain transport policy. Emperor Yongle’s decision to move the capital to Beijing necessitated the complete renovation of the river and canal system for the transport of grain and other items from the south to the north. During the Hongwu period, while the capital was at Nanjing, transport to the north had consisted primarily of grain and supplies for the troops in Liaodong. This was accomplished by sea, continuing the practice of the Yuan. However, many shipments were lost, and this method was costly and inefficient. Looking ahead to the huge quantities of food and materials that would need to be transported when the capital moved to Beijing, Emperor Yongle put the Minister of Works Song Li 宋禮 in charge of renovating the northern section of the canal (the Huitong canal 會通河)

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62 Of course the emperor did not know there would be this hiatus, and in fact planned a seventh expedition for 1424, so the fleet may still have been rebuilt in 1423.

63 See my article “The Giraffe of Bengal: A Medieval Encounter in Ming China,” *Medieval History Journal* 7 (January–June 2004) 1, pp. 1-37.

64 We do not know how many ships were lost in shipwrecks, as this information does not seem to have been recorded consistently.

in 1411, a feat he accomplished within 100 days. Gradually more and more grain was transported by canal, and because of the plan's success, ocean transport of grain was officially stopped in 1415.[65]

Given these trends, one would expect ocean-going grain transports to have been built in substantial quantities before 1411, but to taper off after that. This would be a logical time for them to be converted into ships for other uses. It is thus puzzling why the conversion of ocean-going transport ships for other purposes is recorded in the *Shilu* as early as 1403, 1405, 1407, and 1408, when grain transport to northern regions was carried out almost exclusively by sea. It is also puzzling why the government built 200 ocean-going transport ships in September 1403, but then converted 188 of the same type for another purpose in November of that year. Similarly, why did the authorities convert 33 ocean-going transport ships in March 1408, and then build another 58 in November of the same year? The only explanation I can offer is that there were extensive demands on the shipbuilding industry at the time, necessitating a certain amount of juggling of ships to fill various needs. In addition to ocean-going ships and canal ships for grain transport, China had to maintain a fleet of military ships as well, in order to defend the coast against pirates. A further anomaly occurred after 1411. One would expect the authorities to stop building ocean-going grain transports after that date, and to divert the existing ones to other purposes. However, in November of 1412 an order was issued for the construction of 130 more grain transports. This was perhaps because the joint river and ocean transport policy (*he hai jian yun* 河海兼運), though winding down, was still in effect until 1415, and therefore ocean-going grain transport ships were still needed. Despite these apparent inconsistencies, there are points of congruity with the grain transport policy, such as the construction of 200 *haiyun chuan* in 1403, 88 in 1406, and 58 in 1408. After the 1412 order for ships, the shipbuilding record is consistent with the grain transport policy in that there are no *Shilu* references to the construction of *haiyun chuan* after the official termination of ocean-going grain transports in 1415. It seems that energies were poured into canal-boat building after this time.[66]

There is surprising similarity in the numbers of treasure ships ordered for the various individual voyages. There are two orders for treasure ships numbering 48 and 41, two for 61 ocean-wind ships (perhaps only one of which was for treasure ships), the 62 for the first voyage in the *Ming shi*, and 61 mentioned in the edict of 1430. They thus seem to have ranged from 41 to 62 treasure ships; smaller ships must have made up the rest of the fleet. There is also consistency in the total number of people who travelled on the various individual voyages – usually between 27,000 and 28,000. These consistencies make calculations for the aver-

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65 Elvin, *Ming Tribute Grain System*, p. 9.

66 A new phase of shallow-bottomed canal boat building began after 1415, and by 1450 the number of such craft in the fleet of canal boats was fixed at 11,770 (Elvin, *Ming Tribute Grain System*, p. 9).

age number of men per ship possible. Interestingly, Gong Zhen's estimate of 200-300 men per ship works out perfectly if we use the figure of 100 ships that he gives for the seventh voyage. Although some of the ships would have been larger and some smaller than the average, it is doubtful that the largest would have been ten times the average, the necessary number to reach 8,000 men, the likely complement of a 20,000 ton ship according to Xin.

For a long time it seemed that the only illustrations closely associated with Zheng He's voyages were those found in what J.V.G. Mills called the Mao Kun 茅坤 map.[67] This is the map included as the last chapter of Mao Yuanyi's 茅元儀 (1594–1641) collection of documents on military matters entitled *Wubei zhi* 武備志 (Treatise on Military Preparedness), printed in 1621 and presented to the throne in 1628.[68] Although the connection between this map and Zheng He's voyages is somewhat tenuous, based on the hypothesis that it was in the collection of Mao Yuanyi's grandfather Mao Kun (1511–1601) who was conversant in coastal military matters, Mills, Joseph Needham, and others were convinced of its association with Zheng He's voyages, speculating that it may have been a discarded draft or copy of one of the sailing charts used on the expeditions.[69] At the end of the map, following the forty folios that depict Zheng He's route from Nanjing to the Arabian peninsula and East Africa, are four "stellar diagrams," each with an illustration of a ship in the centre surrounded by images of guiding stars and constellations placed as they should look in relation to the ship when sailing on a particular course to a particular destination. Each depicts a difficult segment of the route where there were large expanses of ocean to cross and it was important to set the direction of the ship exactly right (see Illustrations on pp. 41f.).[70] Instructions on how to sail in these regions and the altitudes of the stars accompany the illustrations.[71] Each of the four diagrams depicts a three-masted, deep-bottomed ship in the style of the *fuchuan* 福船 or Fujian-style ship with a deep draught, as opposed to the *shachuan* 沙船 or "sand-ship" (the Jiangsu-style flat-bottomed ship).[72]

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[67] Although this work is after 1597, it is thought to have come from the library of Mao Yuanyi's grandfather, Mao Kun (1511–1601, *jinshi* 1538) who had been actively involved in the defense of the Chinese coast against pirates and was thus in possession of many materials relating to military defense.

[68] Mao Yuanyi, *Wubei zhi* (fasc. of 1621 edition), *j*. 240, in *Zhongguo bingshu jicheng* 中國兵書集成 (Beijing 1989), vols. 27-36. The map is in vol. 36, on pp. 10388-10431 of this collection.

[69] Mills, *Ma Huan*, p. 239.

[70] These segments of the route were between the west coast of India and Hormuz, and between Ceylon and Sumatra. See Mills, *Ma Huan*, pp. 335-346.

[71] Mills, *Ma Huan*, pp. 335-346.

[72] Jin Qiupeng 金秋鵬, "Qijin faxian zuizao de Zheng He xia Xiyang chuandui tuxiang ziliao – *Tianfeijing* juanshou chatu" 迄今發現最早的鄭和下西洋船隊圖像資料 — 《天妃經》卷首插圖 (The Earliest Hitherto Discovered Illustration of Zheng He Going to the South Seas in the *Sūtra on the Celestial Spouse*), *Zhongguo keji shiliao* 中國科技史料 21 (2000) 1, pp. 61-64.

As recently as the 1980s some scholars still thought that Zheng He's ships were likely to have been *shachuan* rather than *fuchuan*, despite the obvious point that deep-bottomed ships would fare much better on the high seas than shallow ones.[73] However, it now seems that scholars in general accept that the ships were *fuchuan*.[74] In 1997 Jin Qiupeng 金秋鵬 made an important discovery of another set of illustrations that adds weight to the view that they were *fuchuan*. These are in a modern collection of Chinese art reproductions, one particular volume of which features illustrations used in printed books. They are illustrations of a religious text, *Taishang shuo Tianfei jiu kuling ying jing* 太上說天妃救苦靈應經, which tells of the rescue of sailors by the Heavenly Spouse (*Tianfei* 天妃), the goddess to whom Zheng He and his entourage prayed for safe voyages (see Illustrations on p. 43). Contemporaneous with the voyages, the text is dated Yongle 18 (1420).[75] These illustrations, which Jin calls "the earliest hitherto discovered illustrations of Zheng He's ships," show deep-water, three-masted ships, similar to those in the stellar diagrams of the Mao Kun map. While it is questionable whether illustrations in a religious text can serve as solid evidence for such technical details as the size of ships, they may reflect the image of the ships that was in people's minds, and thus may tend to support the argument that Zheng He's ships were three-masted *fuchuan* rather than *shachuan*.[76] The impression one gets from the image is of ships of a modest rather than colossal size.

Jin Qiupeng also notes that scholars are beginning to question whether Zheng He's ships were all built in Nanjing, as it was previously assumed. Some of the ships may have been built in Fujian. We know from the Quanzhou ship that there was a long tradition of shipbuilding for overseas trade in Fujian,[77] and we know from the *Shilu* table above that ships for the voyages were built in various places,

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Gradually the theory that Zheng He's ships were *shachuan*, which was still held in the 1980s, has been supplanted by the view that they were *fuchuan*.

73 This point is backed up now by archaeological discoveries of long-distance sailing ships of the *fuchuan* style such as the Song dynasty Quanzhou ship. See, for instance, the discussion of Xi Longfei 席龍飛, *Zhongguo zaochuan shi* 中國造船史 (Wuhan 1999), p. 160.

74 Xi Longfei, *Zhongguo zaochuan shi*, p. 267.

75 The catalogue entry for the illustration tells us that its publication was financed by Sheng Hui 勝慧, a monk who sailed on one of the voyages.

76 See his "Cong Baochuanchang duogan de jianding tuilun Zheng He baochuan" 從寶船廠舵杆的鑑定推論鄭和寶船, *Wenwu* 文物 (1962/3), pp. 35-40. Jin Qiupeng, "Qijin faxian," pp. 61-64. There is a Yongle 18 copy of a work entitled *Taishang shuo Tianfei jiu ku ling jian jing* 太上說天妃救苦靈驗經 at the Beijing Library, which may be the same work; Jin had not seen it when he wrote his article. Wang Bomin 王伯敏 (ed.), *Zhongguo meishu quanji* 中國美術全集: *Huihua bian* 繪畫編: *Banhua juan* 版畫卷 [M] (Shanghai 1988), Illustration No. 30, pp. 32-33.

77 Donald H. Keith and Christian J. Buys, "New Light on Medieval Chinese Seagoing Ship Construction," *International Journal of Nautical Archaeology and Underwater Exploration* 10 (1981) 2, pp. 119-132, esp. p. 131.

not just in Nanjing. It is possible that after sailing to Changle Zheng He's fleet acquired deep-bottomed ships made in Fujian.[78]

Dated one hundred years after Zheng He, but still before 1597, the two shipyard treatises, *Nanchuan ji* and *Longjiang chuanchang zhi* also contain illustrations of ships and many details that shed light on this discussion.[79] The second chapter of the Longjiang treatise includes illustrations of all twenty-four types of ship that were being built at the shipyard in 1553 when the treatise was written, with the dimensions of each ship given in a panel above its illustration. Because these treatises were written more than 120 years after Zheng He's final expedition returned home to port, after substantial reductions had occurred in size due to economic considerations as well as official bans on large ships and on overseas trade and contact, and because the ships built at this shipyard were primarily for inland water transport, these ships were much smaller than those probably used on the voyages. Moreover, little or no resemblance to Zheng He's ships can be claimed. Notably, when we come to the page in the treatise on ocean-going ships (*haichuan* 海船), the illustration is only a bare, sketchy outline, with no details filled in (see Illustration on p. 40 below). This is in contrast to the illustrations of the other ships in the treatise, which display individual characteristics such as types of sail, deck, and decoration. In the top register of the page on the *haichuan*, where for other ships the details of the ship's length, beam, and depth are provided, we have only the words, "There is no information about the dimensions" (*chidu wukao* 尺度無考).[80] From this statement some scholars have concluded that by 1553 all knowledge about Zheng He's "treasure ships" (*baochuan* 寶船) had been lost, and the technology forgotten. However, something – perhaps a vague recollection of a shipwright from an earlier generation or an item of ship lore that still survived – must have made the illustrator depict a ship with four masts, a deep draught, and a particular style of rudder. It seems likely that Zheng He's treasure ships were of this style, though it is unjustified to leap too confidently to that conclusion.

Considerable detail is given about the ships that are covered in *Longjiang chuanchang zhi*. In addition to their length, width, and height, as noted above, we are also told the amount of the various materials (including wood) that were needed to construct them, and the number of man-days needed for construction and repair. The largest ship for which such details are given is 400 *liao*. Two ship types are designated by this size, a combat ship 8.95 *zhang* in length and a

78 Jin Qiupeng, "Qijin faxian," pp. 61-64.

79 For a study of the Longjiang treatise, see Hans Lothar Scheuring, *Die Drachenfluß-Werft von Nanking: Das* Lung-chiang ch'uan-ch'ang chih*, eine Ming-zeitliche Quelle zur Geschichte des chinesischen Schiffbaus*. Heidelberger Schriften zur Ostasienkunde, Bd. 9 (Frankfurt a.M. 1987). Caution should be exercised here, however, because as Scheuring points out (pp. 104-124), Zheng He's ships were not built in the Longjiang shipyard but in a separate treasure-ship shipyard (*baochuan chang*) directly on the Yangzi river.

80 *Longjiang chuanchang zhi*, 2:36a.

patrol ship of 8.8 *zhang*, both approximately 91 ft long.[81] *Nanchuan ji* also has 400-*liao* combat and patrol boats, both 8.6 *zhang* long, but this is not the largest ship recorded in this work. There is also an entry for a 1,000-*liao* ocean-going ship (*haichuan*). Unfortunately its dimensions are not given, but curiously the amounts of the different types of wood that were used for its construction are specified, and it is thus possible to calculate its rough dimensions by comparing the materials necessary to build it with those specified for the 400-*liao* ships in the same work. An initial comparison of these two quantities reveals that the 400-*liao* ships required 63 percent of the amount of wood required for 1,000-*liao* ships. If this percentage is applied to the dimensions of the 400-*liao* ship, we can estimate that the 1,000-*liao* ship may have been about 143 ft long.

A more scientific method of calculating the dimensions of a ship of the early Ming from its size expressed in *liao* has been devised by André Wegener Sleeswyk, who suggests that the length, width, and depth of the ship, all figured in *chi* (Chinese feet), multiplied together and then raised to the power of 2/3 yields the number of *liao*, which he asserts is not a measurement of capacity but a measurement of loaded displacement (the weight of the ship, including all the rigging, plus the weight of the cargo). Using this formula he finds that the dimensions of a 2,000-*liao* ship would be 200 *chi* long, 36 *chi* wide, and 12.5 *chi* deep, and those of a 1,500-*liao* ship would be 175 *chi* long, 30 *chi* wide, and 11 *chi* deep.[82] My rough calculation for the length of the 1,000-*liao* ship does not appear to be greatly different from this, since one *chi* is only slightly larger than an English foot.[83] Under the 1,000-*liao* ship, *Nanchuan ji* says that this ship takes after the Yuan dynasty grain transport ship (*haiyun chuan*), which continued to be used in the Ming. It was the type of ship that Emperor Hongwu used for sending provisions to Liaodong, and also the type that Emperor Yongle used for transporting provisions to the capital.[84] It is also the same size as that mentioned by Song Li in his calculation, and we know that some of these were converted into ships for Zheng He's voyages. Thus we can probably say that some of Zheng He's ships were approximately 150 ft long, some 175, and some 200.

Most studies of Zheng He's ships discuss vessels from earlier periods in China's history as a basis for speculating about the size and nature of the Ming ships. This is understandable, since we have so little information about the treasure ships themselves. However, information about previous ships needs to be used cautiously and can give rise to a number of problems. I do not have space to undertake a thorough discussion here, but it is important to point out some of the problems that may be encountered in making such comparisons and to mention some of the conclusions that can be drawn. For a detailed discussion of earlier

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81 See *Longjiang chuanchang zhi*, *j.* 2, pp. 17b and 23 a-b.

82 Sleeswyk, "*Liao* and Displacement," p. 9.

83 One *chi* is equal to 1.02 ft.

84 *Nanchuan ji*, *j.* 1, pp. 79b-80a.

ships, I refer the reader to Xi Longfei's 席龍飛 history of Chinese shipbuilding (*Zhongguo zaochuan shi* 中國造船史), which covers the subject quite thoroughly.

One reason why it can be useful to investigate earlier traditions of shipbuilding is because naval architecture tends to evolve slowly and conservatively over time, building on its own foundations and following its own traditions. Examining ships from earlier periods can also help determine whether China had the technical capability and know-how necessary to build ships of a certain size. However, there are certain pitfalls that need to be avoided. For instance, some scholars assume that if China *could* build a ship of a certain size, she *did* build it, and also *used* it on these voyages. They thus jump too quickly from the possible to the actual. Although there may be extreme examples of unusually large ships, this is quite different from constructing an entire fleet of them and sailing them overseas. Another assumption often made is that if China was able to build ships of a certain size in the past, she could build even larger ones in the future. When we are told that ships in the Song were 2,000 or even 5,000 *liao*, there is often an implication that ships in the Ming must have been double, triple, or even ten times that size. This is forgetting that at any point in the past shipbuilders may have come up against the natural limit to the size of a wooden ship. (This limit is discussed below.) A third assumption is that if China possessed certain requisite secondary technologies, such as ways of lowering large ships into water, this can somehow bolster the argument that such large ships existed.[85] Again we need to make the distinction between the possible and the actual. For these reasons I feel that whenever one uses non treasure ships to speculate about treasure ships one needs to exercise caution. This applies not only to discussions of historical Chinese ships, but also modern Chinese ships, historical and modern Western ships, and even contemporary (i.e. Ming) Chinese ships used for a different purpose, such as grain transport ships.

By the same token, there are certain things we can learn from non treasure ships. From earlier Chinese ships we can learn about the types of wood and other materials that were used to build ships, styles of construction and design, types of rudders, masts, anchors, and so forth. Studies of earlier ships can also give us an idea of the standard proportions between parts of the ships: length to width, for example, or length of ship to length or number of masts. For instance, when Xu Jing wrote that his six *kezhou* 客舟 ships were 10 *zhang* long and 2.5 *zhang* in the beam,[86] we can see that they had a length-to-width ratio of 4 to 1, compared to the 2.4-to-1 ratio of the treasure ships described in the *Ming shi* and the novel. We can also use the dimensions of ships described in the historical records or revealed in archaeological discoveries to devise and check formulas for calculating

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[85] For example, Zhou Shide notes that China had the means for sliding large ships into water along slippery ramps. See Zhou Shide, "Cong Baochuanchang duogan de jianding tuilun Zheng He baochuan," pp. 36-37.

[86] Xu Jing, *Xuanhe fengshi gaoli tujing* (1124; Taipei 1974, facsimile reprint), *j*. 34, p. 5a.

displacement and other specifications. Xu Jing says that his *kezhou* is 2,000 *hu*, which is equivalent to 2,000 *liao*.[87] If one applies Sleeswyk's formula to the dimensions Xu Jing provides, it comes quite close to 2,000 *liao*, thus substantiating this formula.[88] In turn, we can use these formulas to check whether other measurements are accurate. While the *kezhou* in Xu Jing's work seems to be a practical size, his statement that the dimensions and other aspects of the *shenzhou* 神舟 are all three times larger seems highly questionable.[89] Sleeswyk's formula confirms that there is something wrong with this statement. If its dimensions are all three times larger, its loaded displacement works out to eight times larger or 16,000 *liao* using Sleeswyk's formula. Moreover, although the original complement of the *kezhou* was 60 men, and that too is now tripled to 180 men, this vastly alters the ratio of the number of men per *liao* in the *shenzhou*.[90] Sleeswyk's formula thus confirms my suspicion that something is wrong with the statement about the *shenzhou*.

There have been a number of archaeological discoveries of Chinese ships both in or near Chinese waters and in other parts of the world. What is found in marine archaeology tends to be quite arbitrary and not necessarily respresentative of what existed, but all the ships that have been found have been quite small, none larger than 105 ft long. Most of those found in Chinese waters have been shallow-bottomed canal boats, military ships, or grain transport ships, dating from the Song, Yuan, and Ming periods. The only one of a type comparable to Zheng He's ships is the ocean-going *fuchuan* found at Quanzhou, which measured roughly 98 ft (30 m) in length, and had a displacement of 494 tons.[91] When Sleeswyk's formula is applied to this ship it yields a loaded displacement of 1,000 *liao*, quite a sensible figure. The ships that have been discovered in Southeast

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87 Xu Jing, *Xuanhe fengshi gaoli tujing*, *j*. 34, p. 5a.

88 Sleeswyk uses the dimensions for the ships treated in the *Longjiang chuanchang zhi*, as translated by Scheuring, to calculate their loaded displacement expressed in *liao*. In his formula one multiplies ship length, width, and depth (expressed in Chinese feet or *chi*) together, and then raises the answer to the power of 2/3. In the case of the *kezhou*, this is 100 x 30 x 25, and yields 1,778 *liao*. If one uses Xin Yuan'ou's formula for calculating tons of displacement, the answer comes to 752 tons, which is close to the 800 tons displacement that, according to Xin, corresponds to the 500 tons capacity, equivalent to 2,000 *liao*. Xin Yuan'ou, "Guanyu Zheng He baochuan chidu de jishu fenxi," p. 8.

89 Xu Jing, *Xuanhe fengshi gaoli tujing*, *j*. 34, p. 6b.

90 From one man for every 33 *liao* in the *kezhou*, which is already three times higher than normal, it becomes one man for every 89 *liao* in the *shenzhou*, or nine times higher than normal, and thus quite outrageous.

91 For detailed descriptions of these ships, see Xi Longfei, *Zhongguo zaochuan shi*, pp. 138-139, 152-173, 194-219, and 248-258. It is also discussed in Xi Longfei and D.W. Chalmers, "The Rise and Decline of Chinese Shipbuilding in the Middle Ages," *International Journal of Maritime Engineering* (Part A2, 2004). An archaeological report was done by Jeremy Green, and is published in "The Song Dynasty Shipwreck at Quanzhou, Fujian Province, People's Republic of China," *International Journal of Nautical Archaeology and Underwater Exploration* 12 (1983) 3, pp. 253-261.

Asian waters have also been rather small, between 60 and 90 ft long.[92] Even though none of these ships comes close to the scale of the ships described in the *Ming shi* or the novel, this does not prove that ships of this size did not exist. Yet, until a much larger find is made, marine archaeologist Gould is correct in asserting that "Nothing in the archaeological record so far provides direct evidence for anything like the Ming Dynasty's treasure ships".[93]

In 1957, it seemed that an important breakthrough had occurred with the discovery of an enormous rudder post in the treasure-ship shipyard. It was 36.2 ft (11.07 m) long and 1.25 ft (46 cm) diameter. The rudder itself was not found, but the slots on the post into which the rudder once fitted were still visible. These slots indicate that the rudder was probably 19.7 ft (6 m) broad. Assuming that Zheng He's ships were *shachuan*, Zhou Shide argued that this rudder had a ratio of 7 to 6 in length (along the water line) to breadth. This was the ratio for the rudders of large *shachuan* in Jiangsu province. He then calculated that the rudder must have been 19.7 ft by 23 ft (6 by 7 m), which works out to an area of 452 sq ft (42 sq m). With this rudder area, Zhou Shide then used the formula AS = LT to calculate the length of the ship to which it originally belonged, which he surmised to have been a treasure ship.[94] He concluded that the treasure ships must have been 480 ft (146.3 m) or 536 ft (163.4 m) long, not only confirming but by some calculations, exceeding the length given in the *Ming shi*.[95]

As Xin Yuan'ou points out, despite its astounding size, the rudder post was still too small for the size of ship mentioned in the *Ming shi*.[96] There are three problems with Zhou's calculations. First, although we know the breadth of the rudder, we do not know its length. Therefore, its area is speculative. Second, it is probably a mistake to assume that the proportions for a rudder on a Jiangsu *sha-*

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92 These are the Nanyang ship, Longquan wreck, and the Royal Nanhai. See Sten Sjostrand, "Discovering Asia's Ceramic Development over Half a Millennium – Through Shipwrecks of the 14th to 19th Centuries," prepared for the 'Maritime archaeology Malaysia' exhibition, November 2001, Muzium Negara, Kuala Lumpur, Malaysia http://www.maritimeasia.ws/exhib01/pages/index. html [accessed 4 April 2005]). The most comprehensive discussion of shipwrecks of this period is Geoff Wade, "The Pre-Modern East Asian Maritime Realm: An Overview of European-Language Studies," Asia Research Institute, Working Paper Series, National University of Singapore, ARI Working Paper No. 16, December 2003, published on the following website: http: //www.ari.nus.edu.sg/docs/wps/wps03_016.pdf [accessed 4 April 2005].

93 Gould, *Archaeology and the Social History of Ships*, p. 197.

94 In this formula, A is a coefficient of 40-50, S is the area of the rudder, L is the length of the ship, and T is the draught of the ship.

95 He calculated this on the basis of "the usual Chinese 7/6 length-breadth proportions for the rudder blade" (Needham, *Science and Civilisation in China*. Vol. 4, Pt. 3, p. 481). Needham says that Zhou Shide was using *huai* units (1.12 ft), not the usual Ming units; 538 ft. and 600 ft. our measure respectively (p. 482, note a). There are two possible figures because he is using different assumptions about draught.

96 Sleeswyk points to Zhou Shide's "rather questionable procedure of extrapolation," and asserts that a rudderpost of this size probably belonged to a ship of 203 ft (62 m) in length. See his "*Liao* and Displacement," pp. 4 and 11.

chuan (a flat-bottomed boat built to sail on inland waterways) would be the same as for one of Zheng He's ocean-going treasure ships, which was probably a *fu-chuan*. In the two cases where we have archaeological evidence of rudders unearthed along with the remains of ships, one is of a triangular shape rather than rectangular, which makes the applicability of the 7/6 ratio difficult to gauge, and the other has a different ratio. The latter is the Yuan Penglai ship, which has a rudder of 5.7 ft (1.75 m) long along the waterline and 14.1 ft (4.3 m) broad, yielding a ratio of 1 to 2.46 (quite different from the ratio of 7 to 6).[97] The third problem with Zhou's argument is that he does not seem to be using the correct formula. If we plug all the details of the Penglai ship into the formula, we obtain a rudder area of 1.39 sq m, whereas the actual rudder area is 7.525 sq m. Similarly, the formula yields a rudder area of 0.299 sq m for the triangular rudder of the Song dynasty Tianjin ship, whereas the actual area was 2.223 sq m. It thus appears that there is something wrong with Zhou Shide's formula.

A hunt in the library for formulas relating rudder size to size of ship turned up one in an introductory textbook on naval architecture that closely resembles Zhou Shide's formula. The problem is that it is for the rudder of a modern steel ship.[98] The textbook specifically states that it is for "a rudder working directly behind a propeller," and the illustrations are clearly of a steel, engine-driven ship.[99] It does not seem wise to apply such a formula to the dimensions of a 15th-century wooden sailing ship. Not only does Zhou Shide's formula seem inappropriate, but there is also a problem with his methodology. One cannot speculate about the area of the rudder from the length of its rudder post alone, let alone about the size of the entire ship from that original speculation. Thus we cannot rely on his conclusion that the discovery of the rudder post confirms the dimensions recorded in the *Ming shi*. If, on the other hand, one uses the Quanzhou ship's dimensions to determine the proportion of rudder post length to length of ship, and applies that proportion to the rudder post found at the Longjiang shipyard, one finds that it fits a ship that is about 150 ft long. This result adds to the evidence we already have for ships of between 100 and 200 ft long on Zheng He's expeditions.

From the archaeological discoveries of ships of the Song, Yuan, and Ming period we can tell the types of wood that were used for ships before and up to the

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97 On the Penglai ship, see Xi Longfei, *Zhongguo zaochuan shi*, pp. 209-217.

98 I am grateful to Dr Raymond Mercier for helping me find this formula and for advising me on the scientific aspects of this article, but take full responsibility for any errors I have made.

99 Zhou Shide's formula, AS = LT, is probably a simplified version of the formula given in the textbook: Ap = LT/100 [1 + 25 (B/L)2]. In Zhou's formula, S is the area of the rudder, L is the length of the ship, T is the draught, and A is the coefficient, which he says is usually 40-50 in coastal ocean-going ships. In the textbook, Ap is the projected area of the rudder, LT is length times draught, and B/L is beam (width) divided by length (cf. Thomas C. Gillmer and Bruce Johnson, *Introduction to Naval Architecture* [London 1982], pp. 275-276). If one works out Zhou's formula using the specifications of the Song ship and using a value of 45 for A, one ends up with the equation 100.35 = 17.98, which is clearly incorrect. Using Gillmer and Johnson's formula, the result is: 2.23 = 0.427. In both cases, the rudder area is about five times larger in proportion to the length of the ship than is the case in a modern steel ship.

time of Zheng He. The Song dynasty Quanzhou ship's hull was made of Chinese fir (*shanmu* 杉木), pine (*songmu* 松木), and cedar (*nanmu* 楠木), with certain other parts made of camphor (*zhangmu* 樟木).[100] The Yuan Penglai ship had a *longgu* of pine and camphor, settings for the masts and rudder out of cedar, a hull of fir, and supports of camphor. A Ming ship discovered at Ningbo was built mostly of Chinese fir, with the bulkheads made of camphor.[101] The same types of wood, along with elm (*yumu* 榆木) for the rudder, are mentioned in the two shipyard treatises as components of the ships built in the Longjiang shipyard, with detailed amounts of the various woods given for each type of ship. It is thus possible to know how much wood was necessary to build ships of particular sizes, and perhaps therefore to calculate how much would have been required to construct treasure ships of the size indicated in the *Ming shi*. If this could be known, we could ask whether China's forests could have supported construction of so many huge ships, and whether it would have put a strain on forests or infrastructure. If it had strained China's resources, one would expect some sign of this in the historical sources; the presence or absence of such evidence may therefore help us decide whether the ships were that big.

Despite the details given in the shipyard treatises, it is quite difficult to know exactly how much wood was used for shipbuilding. The amounts of some woods when used for planks are expressed in *zhang*, while for other uses they are expressed in numbers of timbers. When they are expressed in timbers we do not know how tall the timbers were. For the planks it is specified whether they are in single, double or triple thickness, but it is difficult to tell how much wood is meant in some cases.[102] The subject therefore requires more study before any conclusions can be drawn.

A possible short-cut to an estimate of the amount of wood necessary for the treasure ships is to use the rules of thumb used for the British "Ships-of-the-Line" in the 17th to 19th centuries. Detailed information is available on this subject, giving the amounts and species of wood required to build eleven out of the thirteen ship types.[103] Information about other Western ships is also available. According to one source, the construction of the "Vasa," an 180-ft, three-masted Swedish sailing ship built in 1628, required approximately 1,000 oak trees as well as smaller quantities of wood of other species.[104] The three largest ships of

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[100] Li Guoqing, "Archaeological Evidence for the use of 'chu-nam' on the 13th century Quanzhou Ship, Fujian Province, China" *International Journal of Nautical Archaeology and Underwater Exploration* 18 (1989) 4, pp. 277-283, esp. p. 277; Xi Longfei, *Zhongguo zaochuan shi*, p. 162. Xi and Chalmers also discuss the types of wood used for ships, see "Rise and Decline."

[101] Xi Longfei, *Zhongguo zaochuan shi*, pp. 215 and 255.

[102] For example, see the amount of cedar needed to build a 200-*liao* combat ship, in *Longjiang chuanchang zhi*, *j.* 7, p. 36b.

[103] John Edye, *Calculations relating to the equipment, displacement, etc. of ships and vessels of war* (London 1832).

[104] This figure is based on shipyard records for the "Vasa," which sank in the same year it was built, and was discovered underwater, 95 percent intact, in 1961. It had a displacement of 1,200

the Ships-of-the-Line, with lengths of 205 ft (62.5 m), 196 ft (59.8 m), and 176 ft (53.6 m) respectively, had loaded displacements of 4,588, 3,570, and 2,997 tons, requiring 5,880, 4,339, and 3,600 loads of wood. The average number of loads of wood per ton displacement works out to 1.23 for the three largest sizes, with each load equivalent to approximately one tree.[105] Using this information, we can calculate that a single ship of 20,000 tons would have required approximately 24,600 trees, while a fleet of 62 would have needed 1,525,200 trees. Because Zheng He's fleet had to be rebuilt three or four times, it consumed at least 4,575,600 and perhaps up to six million trees. The fleets would also have included smaller ships to bring the total up to 100-250 ships, and this would have required still more wood. Another way of calculating the amount of wood necessary for the fleet is to add the number of ships we know were built for the voyages from scratch – five in 1404, 48 in 1408, 41 in 1419, 61 in 1430 (the edict) and 62 mentioned in the *Ming shi*, or a total of 217 treasure ships – and multiply this number by the number of trees needed per ship. This calculation gives us 5,338,200 trees, a figure close enough to our estimate of six million to suggest that it is not a wild exaggeration. Would the construction of so many large ships have had the same devastating effect on China's forests as the age of sail had on European forests? This question requires a deeper knowledge of the size of China's forests in the 15th century than is available at present.

How much of a burden would cutting and transporting this amount of wood have placed on China's forest industry and infrastructure? In addition to ships for the maritime expeditions, other types of ship were being built at the same time, making further demands on China's forests. Ocean-going grain transports were constructed until 1412, and canal ships were also built in numbers that increased after 1411. Military ships were needed to defend China's coast from pirates. Given the high demand for wood for shipbuilding of various kinds, one would expect to find references in the historical sources to vast quantities of wood being harvested and transported to the shipyards for construction. However, only a few scattered references bear upon this subject. Most of the references to the harvesting of wood concern another of Yongle's ambitious projects: the construction of palaces in Beijing in preparation for his movement of the capital to that city. As early as 1406, Yongle announced that construction on the new palaces was about to begin.[106] He sent five of his top officials to various provinces to supervise lum-

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tons and accommodated 445 people, including seamen and soldiers. Peter H. Spectre and David Larkin, *Wooden Ship: The Art, History and Revival of Wooden Boatbuilding* (Boston 1991), pp. 161-171.

105 Referring primarily to oak, Albion says that the "load" was fifty cubic feet, and that "Roughly, the average oak of timber size contained about a load of timber, and made nearly a ton of shipping," *Forests and Sea Power*, p. 9. Sometimes information in other sources is contradictory. For instance, one source says that the 18th-century "Seventy-four" (a third-rater) required 2,000 trees. Spectre and Larkin, *Wooden Ship*, p. 179.

106 Construction on the new capital began in 1407. Major palace buildings were finished in 1417–1421. The announcement that it would become primary capital was issued in October 1420, and

ber operations: Minister of Works Song Li was sent to Sichuan, Vice Minister Gu Bu 古朴 to Jiangxi, Shi Kui 師逵 and Jin Jun 金純 to Huguang, Vice Censor-in-Chief Liu Guan 劉觀 to Zhejiang, and Assistant Censor-in-Chief Shi Zhongcheng 史仲成 to Shanxi.[107] Song Li was sent to Sichuan again for this purpose in 1412.[108] In this year, lumbering became a corvee duty, primarily in Sichuan and Huguang, an indication of its importance to government policy at the time.[109] After his work on the canal was finished in 1415, Song Li resumed the supervision of lumbering activity in Sichuan (1415).[110] According to the *Ming shi*, he was summoned back to the east coast in 1419 "in order to build foreign ships" (*zao fan zhou* 造番舟), a confusing phrase, but it probably refers to building ships for Zheng He's voyages. He may have been involved in the construction of the 41 treasure ships that were built that year.[111] After Yongle's death in 1424, Emperor Renzong 仁宗 (r. 1424–1425) halted the lumber industry corvee, but it was reinstated again during the first year of Xuande 宣德 (1425) when timbers were required to repair one of Nanjing's palaces. At that time officials were sent to oversee lumbering activities in Huguang.[112] The impression conveyed in the histories is that most of this wood-harvesting activity was for palace construction rather than for shipbuilding. If the exhaustion of natural and human resources for the purpose of palace construction is mentioned in the records, why would it not be mentioned for ship construction?

There are various possible explanations for the absence of references to the procuring of wood for shipbuilding in the records. First, not all the ships used on Zheng He's voyages were built from scratch. Second, the usual practice in shipbuilding was to use local woods as much as possible in order to minimise trans-

the conversion to the new capital was scheduled for 2 February 1421. See Edward L. Farmer, *Early Ming Government: The Evolution of Dual Capitals*. Harvard East Asian Monographs, 66 (Cambridge, Mass. 1976).

107 *Ming shi*, *j*. 6, p. 83; *j*. 18, p. 1995. The cutting of wood in Huguang was suspended in the first year of Xuande, or 1425 (*Ming shi*, *j*. 9, p. 117), but resumed again in Zhengde 正德 9 (1514) (*Mingshi*, *j*. 16, p. 207). The Ministry of Works stopped engaging in the lumber industry in Xuande 5 (1430) (*Ming shi*, *j*. 9, p. 121).

108 *Ming shi*, "Shihuo zhi" 食貨志 6, *j*. 82, p. 1995.

109 This "compulsory military service for harvesting wood" (*caimu zhi yi* 採木之役) was instituted because of the need for wood to build the new palace in Beijing rather than to build ships. See the final chapter on food and commodities, "Shihuo zhi" 6 in the *Ming shi*, *j*. 82, p. 1995.

110 *Ming shi*, *j*. 153, 4203-4205, esp. 4205; *Ming Taizong shilu*, Yongle 20, 7th month, *yihai*, *j*. 250, pp. 4b-5a, pp. 2336-2337.

111 *Ming Taizong shilu*, Yongle 17, 9th month, *yimao* (2 October 1419), 216:1b, p. 2156; *Ming shi*, "Biography of Song Li," *j*. 153, p. 4205); Lee, "Sung Li," pp. 1224-1225.

112 These officials were Huang Zongzai 黄宗載 and Wu Tingyong 吳廷用. *Ming shi*, "Shihuo zhi" 6, *j*. 82, p. 1995. This order was cancelled because of a drought, and a similar effort was also thwarted because of the expense.

portation costs.[113] Wood was probably harvested from the forests near the shipyards first, and this activity would have been carried out on a local level without being recorded in the dynastic histories or court records. The provinces that supplied the ships, according to the *Shilu* – Fujian, Zhejiang, Huguang, Jiangxi, and Zhili – are all conveniently located near main river transport routes on which wood could be transported from its sources.[114] Third, palace-building may have required species of wood that were rarer and more exotic than those required for ships, therefore more effort may have been needed to obtain it. Certain parts of ships required particularly tall timbers or strong types of wood but these may not have been needed in large quantities. According to Lo Jung-pang, only trees from the hills of Southwest China were tall enough for some purposes, such as making masts.[115] Some of the rarer woods like teak (*tielimu* 鐵力木, 鐵梨木, or 鐵栗木) may have come from southern tropical regions, Japan, or even Southeast Asia. However, the bulk of the materials were probably readily available near the shipyards, at least during the period of the voyages. So far I have not been able to establish a clear link between shipbuilding and the consumption of China's forests during the time of Zheng He.[116]

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113 Xi Longfei comments on the use of local wood in ships dating from the Song period (*Zhongguo zaochuan shi*, p. 154). We know that harvesting wood from a long distance was expensive: "Logs were floated down rivers at considerable expense and labour" (Lo, "Ships," p. 8). Speaking of obtaining wood for repairing palaces, Emperor Xuande once advised, "If there are any large timbers in Nanjing they should be used. If there aren't then go elsewhere to get them" (Xuande 1, 2nd month, *renchen* [5 April 1426], *Ming Xuanzong shilu* 明宣宗實錄, *j*. 4, p. 9a, p. 389). At the beginning of the Ming, looking ahead to the need for ships to defend the Ming empire's shores, Emperor Hongwu planted certain types of trees in the capital region to alleviate the burden on the people to supply them. These trees were not the major wood-supplying trees, but those providing other products such as paints and varnishes (*you qi* 油漆), rope, and so forth. He ordered that 500,000 paulownia (*tong* 桐), palm (*zong* 棕), and lacquer trees be planted outside the Zhaoyang gate in order to provide these items for public use. See Fu Weilin 傅維鱗 (d. 1667), *Ming shu* 明書, in *Congshu jicheng* (1936), pp. 3929-3958; and Luo Chuandong 羅傳棟 (ed.), *Changjiang haiyun shi* 長江航運史 (Beijing 1991), p. 395. See also *Hongwu jingcheng tuzhi* 洪武京城圖志, quoted in Zheng and Zheng, *Zheng He xia Xiyang ziliao huibian*, vol. 1, p. 211. Jacques Gernet's description of Hongwu's preparation for shipbuilding creates a somewhat different impression. See his *A History of Chinese Civilization*, trans. by J.R. Foster (Cambridge 1982), p. 391.

114 There is room for more research here into the various prefectures, districts, and provinces mentioned in the *Shilu* entries to determine whether they are areas where the species of wood used for shipbuilding grew. Concerning Jiangxi, Shen Xingjing 沈興敬, in *Jiangxi neihe hangyun shi* 江西內河航運史 (Beijing 1991), p. 104, tells us that before the completion of the Huitong canal, Jiangxi produced ships for the sea transport of grain and for Zheng He's expeditions, whereas after the canal was finished it was ordered to build shallow-bottomed boats for the canals. However, when one looks at the gazetteers on which this statement is based, they do not say anything about Zheng He's expeditions but only about *haiyun chuan* and canal boats. It is not entirely clear that we can say for sure that *haiyun chuan* included Zheng He's ships. The gazetteers refer to the information *Shilu*, so it seems that this is our best source of information.

115 Lo, "Ships," p. 8.

116 Shipbuilding is listed as one of the industries that placed demands on China's forests in late im-

In the category called "wood" (*mucai* 木材) of the section of the Longjiang shipyard treatise on materials used for shipbuilding, the type of wood that heads the list of materials required is not *shanmu*, but *chuanshan* 川杉, that is, Chinese fir from Sichuan.[117] Whether this is a species only grown in Sichuan, or one that originated from Sichuan but is grown elsewhere, is not clear. If it is the former, this implies that the wood used in the largest quantity for shipbuilding had to come all the way from Sichuan. It is possible that during this period of intense usage of wood for various purposes (to build ships for the expeditions, for military use, for canal transport, and to build the new palace), local Chinese fir was gradually being used up and that by the time the shipbuilding treatises were written it had to be sought in Sichuan. Lo Jung-pang mentions that a shortage in the supply of Sichuan fir first appeared in 1466, and that cedar was substituted.[118] The Longjiang shipyard treatise tells of a similar case. Li Zhaoxiang reports that in Jiajing 7 (1529) he was asked personally to refurbish five of the "yellow" imperial ships (*huang chuan* 黄船) that normally stood in readiness for the emperor in the capital region. The three ships made of cedar needed only to be re-caulked, while the two made of Sichuan fir needed completely rebuilding (*gaizao*). Li noted that the Ministry of Works sent officials in all directions to try to buy Sichuan fir, but none was available. They finally obtained an imperial order authorising the use of cedar instead of fir for these two ships because of the urgent need.[119] From this account we can tell that there was a shortage of Sichuan fir in 1529, that cedar was a higher quality wood and lasted longer than fir, and that cedar was probably more expensive than fir, hence the need to obtain imperial permission to use it instead of Sichuan fir. The latter hypothesis is corroborated in the Longjiang treatise where it is shown that one *chi* of cedar three *chi* in circumference cost 9 *fen* 分 9 li 釐 (0.99 *qian* 錢), while one *chi* of fir of the same circumference cost 5 *fen* 1 *li* (0.51 *qian*). Cedar was thus nearly twice as expensive as fir in 1553.[120]

While we have no conclusive evidence about the effect of shipbuilding on China's forests during the time of the voyages, we know that the large number of ships built during the Yuan period, had a devastating effect on China's forests. Xi Longfei quotes from a song that apparently circulated during the Yuan, lamenting the great damage done to the forests on account of shipbuilding:

> The myriad trees in the thick forest are all chopped down,
> There is no place in the dark-blue mountains that does not mourn.
> When you arrive with your axes on the side of the creek,

perial China in Mark Elvin and Liu Ts'ui-jung (eds.), *Sediments of Time: Environment and Society in Chinese History* (Cambridge 1998), p. 249. They are speaking of a slightly later time.

117 *Longjiang chuanchang zhi*, *j.* 5, p. 11b.

118 Lo, "Ships," p. 8.

119 *Longjiang chuanchang zhi*, *j.* 1, pp. 7a-7b.

120 *Longjiang chuanchang zhi*, j. 5, pp. 7a and 8a.

Can you not leave one tall pine to which the birds can return?[121]
萬木森森截盡時, 青山無處不傷悲
斧斤若到耶溪上, 留個長松啼了歸

Perhaps the same was true for the time during the voyages, but I cannot yet corroborate this.

Several histories of Western wooden sailing ships mention there being a natural limit to the size of ships in the age of sail. The reason for this was partly that "the strength required of a hull increases more rapidly with size than its displacement,"[122] and partly that certain key parts of the ship need to have the tensile, longitudinal strength of a single tree, for which the maximum size was probably 80-100 ft (24-30 m).[123] John Charnock, in his *History of Naval Architecture* published in 1802, quotes a "Naval Memoir" by a Mr Willet saying, "The size of our ships seems now to have reached its ultimatum, for nature itself in some measure fixes its limits … Timber, the growth of nature as much as man, cannot be made to grow longer."[124] In *The Story of the Ship*, Charles Gibson says, "Although the wooden sailing ship became both faster and larger, there were limits to its growth. Beyond a certain size (in length about 300 feet) a wooden ship is structurally unsafe."[125] Robert Albion, author of *Forests and Sea Power* concerning the supply of wood for the English Ships-of-the-Line, notes that despite the fierce competition among the various European powers during the age of the sailing ship to produce bigger, better, and more efficient ships, there was a surprisingly slow increase in size. He attributes this "static condition … of naval architecture … partly to conservatism, but even more to those large and crooked timbers."[126] To him, the "largest ship that could sail well and fight well under nearly all conditions" was the "Seventy-four" of the British navy, one of the 18th-century Ships-of-the-Line. This was the third largest in the series, 176 ft

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121 Xi Longfei, *Zhongguo zaochuan shi*, p. 185, quoting from Wu Weilan 吳葳蘭, "Yuandai de zaochuan shiye" 元代的造船事業, in *Zhongguo zaochuan gongcheng xuehui chengli sishi zhounian lunwen ji* 中國造船工程學會成立四十周年論文集 3 (1983), p. 6. These ships were built first to secure the defeat of the Southern Song and then to launch the two naval expeditions against Japan in 1274 and 1281. According to Xi Longfei, 16,900 ships were built between 1270 and 1292.

122 Sleeswyk, "*Liao* and Displacement," p. 5.

123 Robert Albion notes that in Western ships, certain parts of the ship required logs of exceptional size and shape, and a shortage of these logs could force shipyards to curtail their shipbuilding and retard the development of naval architecture. See Robert Greenhalgh Albion, *Forests and Sea Power: The Timber Problem of the Royal Navy, 1652–1862* (Cambridge, Mass. 1926), p. 5. There is some disagreement among experts on this point.

124 John Charnock (1756–1807), *An History of Marine Architecture*, 3 vols. (London 1800–1802), vol. 3, p. 234.

125 Charles E. Gibson, *The Story of the Ship from the Earliest Days to the Present* (London 1958), p. 145. This length is equivalent to 91.44 m. Sleeswyk says that a safer length was 250 ft for seagoing ships; see "*Liao* and Displacement," p. 3.

126 Albion, *Forests and Sea Power*, p. 5.

(53.6 m) long and 48.2 ft (14.7 m) in the beam. It had 1,741 tons burden, 2,997 tons displacement (loaded), and carried 600-650 men.[127] Joseph Needham spoke of "the practical upper limit for wooden-hulled sailing ships," and noted an 8th-century Chinese saying, quoted in a 12th-century work, that "Water won't carry 10,000," meaning that it is impossible for ships to be bigger than a capacity of 8,000-9,000 piculs (562-635 tons).[128]

Western ships pushed up against this limit throughout the 17th and 18th centuries, occasionally exceeding it, with disastrous consequences. Speaking of wooden battleships of the mid- to late-nineteenth century and wooden motorships of World War I, both of which surpassed 5,000 tons, Gould says:

> The longest of these ships, the Mersey-class frigates, were unsuccessful, and one, HMS Orlando, showed signs of structural failure after an 1863 voyage to the United States. The Orlando was scrapped in 1871 and the Mersey soon after. But the Mersey-class frigates and the largest of the wooden battleships, the 121-gun Victoria class, required internal iron strapping to support the hull, as did many other ships of this kind.[129]

According to Albion, the French "tried to go beyond the natural limits in 1792, only to produce a ship that was notoriously flimsy," the *Commerce de Marseilles*.[130] Technological achievements finally enabled Westerners to break through the timber barrier, beginning with Robert Seppings' introduction in the early 1800s of triangular braces that were bolted to the inside of the ship's ribs to strengthen it longitudinally.[131] This innovation, as well as several others, resulted from a number of years' work as a naval architect; they did not happen overnight. Yet even this was only a minor improvement. The most dramatic breakthrough in the size of ships was due to a major leap in technology: the use of the steam engine and steel hulls after 1860.

It seems that China would have required a comparable breakthrough to have built and successfully sailed a fleet of ships 450 ft long in the 15th century. However, it is unclear when she would have had time to make these technological breakthroughs. As Xin says, from Yongle's first order for the construction of ships for the voyages in 1403 to their departure from Chinese shores in 1405 it was only a matter of months, surely not enough time to make such advances. It would have been difficult even if this had been the main focus of attention, but it

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[127] Albion, *Forests and Sea Power*, p. 4. The dimensions are compiled from various tables in Edye, *Calculations*. This ship had a complement of one man per 2.7-2.9 tons burden, a ratio that is not far from Song Li's rule. The name "Seventy-four" refers to the number of guns on the ship.

[128] Wang Dang 王讜, *Tang yulin* 唐語林, ca. 1107, ed. by Zhou Xunchu 周勳初, *Tang Yulin jiaozheng* 唐語林校證 (Beijing 1987), p. 727: *shui bu zai wan* 水不載萬. Describing conditions in the 8th century, the passage is translated in Needham, *Science and Civilisation in China*. Vol. 4, Pt. 3, pp. 451-452.

[129] Gould, *Archaeology and the Social History of Ships*, p. 198.

[130] Albion, *Forests and Sea Power*, p. 6.

[131] *Ibid*., pp. 393-394.

was not. After usurping the throne, Yongle had to consolidate his rule on many fronts. If there had been such major technological advances, they would presumably have turned up in the archaeological or written record. However, we have no evidence of any such technological developments. Although a lack of evidence does not prove that something did not exist, it puts the burden of proof on those who wish to assert that it did.

In conclusion, the claims that Zheng He's ships were 450 ft long are, first, difficult to substantiate, and second, problematic. One reason why they are problematic is that they seem to defy the physical laws that govern the behaviour of all wooden sailing ships – Chinese, Western, or other – on the high seas. These laws may come to us via Western investigations, and one has to be careful about applying Western guidelines to Chinese conditions. However, in this case the guidelines are at least in part the result of universal principles of marine science, engineering and naval architecture. Ships of the proposed size would have required extraordinary amounts of materials and complex infrastructural management but the historical records are strangely silent on this matter. Moreover, such enormous ships might not have been sound. Although we do not know how many of Zheng He's fleet were lost at sea, numerous eunuchs came and went on multiple voyages, as did Ma Huan and Fei Xin. Therefore Zheng He's ships must have been sound enough to transport them back home with a certain degree of reliability and predictability. All indications are that exaggeration has been at work in the accounts that mention the ships' enormous size, though we still are not absolutely sure of the exact mechanism by which it took place.

A ship of about 200-250 ft would make much more sense than the 450 ft one. Such a ship would be large enough to transport the required number of people and amount of supplies and treasures. Although this was the maximum size of wooden ships in the West, this is not the reason why we should accept it as an optimum size. Gong Zhen's evidence is perhaps the soundest – his statement that there were 200-300 men on the ships. This number of men could not have managed a ship of 20,000 tons, but would have been quite adept at handling ships of a smaller size, such as the Razee Corvette, a Ship-of-the-Line manned by 205-220 men, or the Fifth Rate (46-gun) ship with a complement of 280-300 men. The Razee Corvette was 145 ft long, and 38.5 ft in the beam with a burden of 944 tons and a displacement of 1,280 tons. The Fifth Rate was over 150 ft long and 40 ft in the beam with a capacity of 1,063 tons burden and a displacement of 2,154 tons.[132] Ships that are too large also have certain disadvantages, foremost among which is a loss of maneuverability. This lesson was learned by the Spanish Armada.

When people speak of the size of Zheng He's ships, they are usually referring to the largest ones, whose size is still unknown. Perhaps the most telling state-

[132] John Edye, *Calculations* (pages unnumbered).

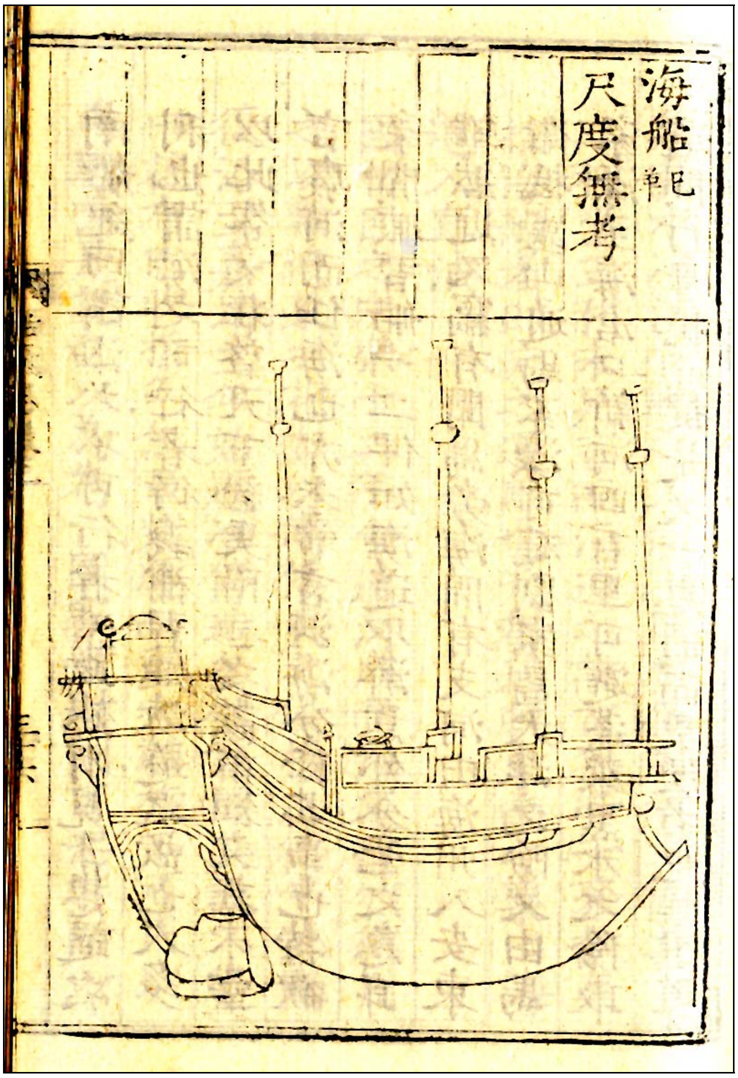
ment about what can be known is Li Zhaoxiang's succinct comment in the Longjiang shipyard treatise that there is no information about the size of the *haichuan*. If Li Zhaoxiang, after two years as superintendent of a shipyard in the same city where the treasure ships were probably built, and while writing such a highly detailed and comprehensive treatise on the shipyard and shipbuilding, could give no information about such ships so soon after the voyages, how can we know more about them 600 years later, without conclusive archaeological evidence? Of course I am ready to be surprised by the discovery of a 450 ft ship, but so far I have been unable to substantiate the gigantic size of Zheng He's vessels. This does not mean that we know nothing about them. I hope this article has shown that we know quite a bit about some of his ships, and more can be learned by further study of the texts and other evidence at hand.

鄭和寶船尺寸考

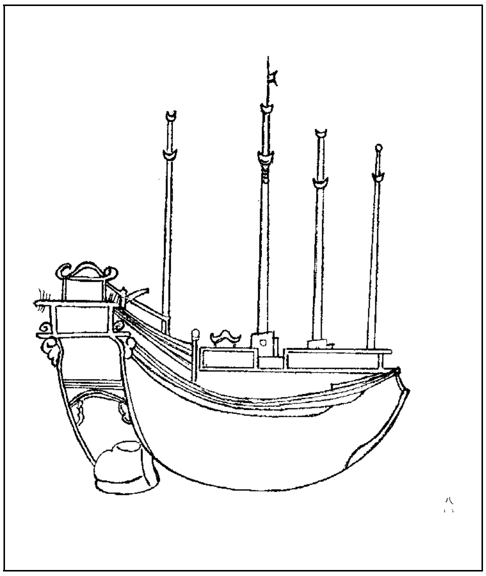
程思麗

本文就鄭和寶船的尺寸問題所引發的爭議進行了考證，即鄭和寶船尺寸是否如《明史》中所記載的 44 丈長、18 丈寬 (447 英尺長、183 英尺寬)。作者首先考察了文獻資料，其中包括石碑文、第一手記錄、《明實錄》、官方和非官方史料、圖片和造船廠史誌等。鑒於近年的相關研究推論《明史》中記載的鄭和寶船尺寸可能出自於羅懋登 1597 年出版的一本小說，本文遂將文獻考察終點放在 1597 年以前。除此之外，作者研究了在中國和朝鮮海域挖掘出失事船隻的考古證據，特別對在南京船廠遺址發現的一隻 11 米長的船舵所做的考古解釋進行了研究。作者還就諸多將鄭和寶船和其他船隻、包括中國不同歷史時期的船隻以及其他國家的船隻進行的比較研究提出了質疑。本文不僅涉及船隻尺寸、承載量和排水量， 還涉及航行所需的船員數量和船上補給，可以用來造船的木材量，以及如此木材需求對當時中國林業的影響等問題。這些疑問又引出對其他問題的思考，如鄭和航海所建造船隻的總量，這些船隻是新建還是改造自其他船隻，還有船隻的檢修時限，從中可以推測出在鄭和持續 28 年海洋遠征中船隻需要重造的頻率。本文考證的結果支持了上海交通大學造船工程教授辛元歐的推斷， 即鄭和寶船約有 450 英尺長的可能性很小，並認爲它們大約接近 200 至 250 英尺長。

Illustrations

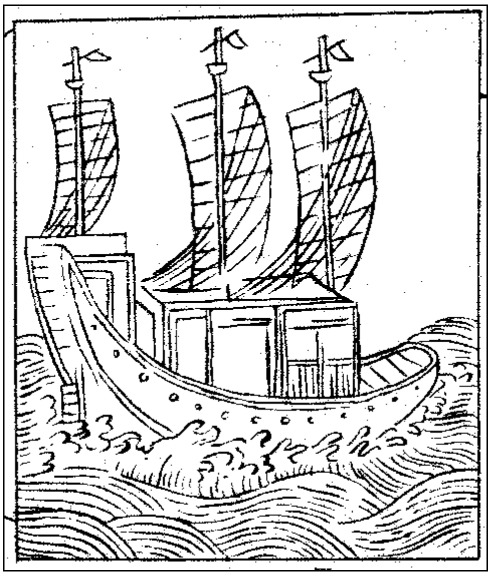


Li Zhaoxiang's 李照祥 (fl. 1537–1553) *Treatise of the Longjiang Shipyard* [*Longjiang chuanchang zhi* 龍江船廠志] of 1553. Illustr. from *Xuanlantang congshu xuji* 玄覽堂叢書續集, vol. 117, facsimile ed., *j*. 2, p. 36a.

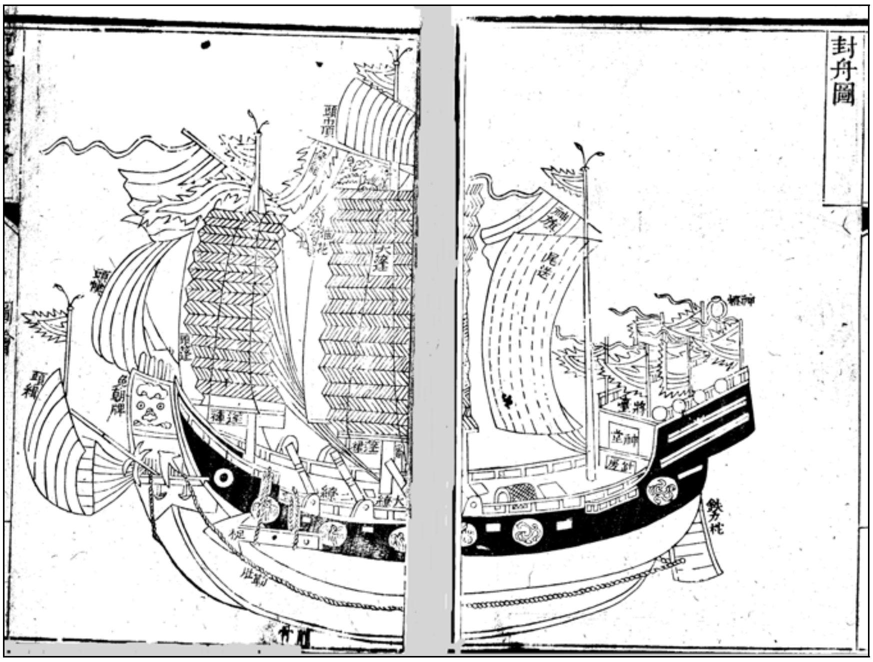


Li Zhaoxiang's 李照祥 (fl. 1537–1553) *Treatise of the Longjiang Shipyard* [*Longjiang chuanchang zhi* 龍江船廠志] of 1553. Modern edition of this work edited by Wang Lianggong 王亮功 (Nanjing: Jiangsu guji, 1999).

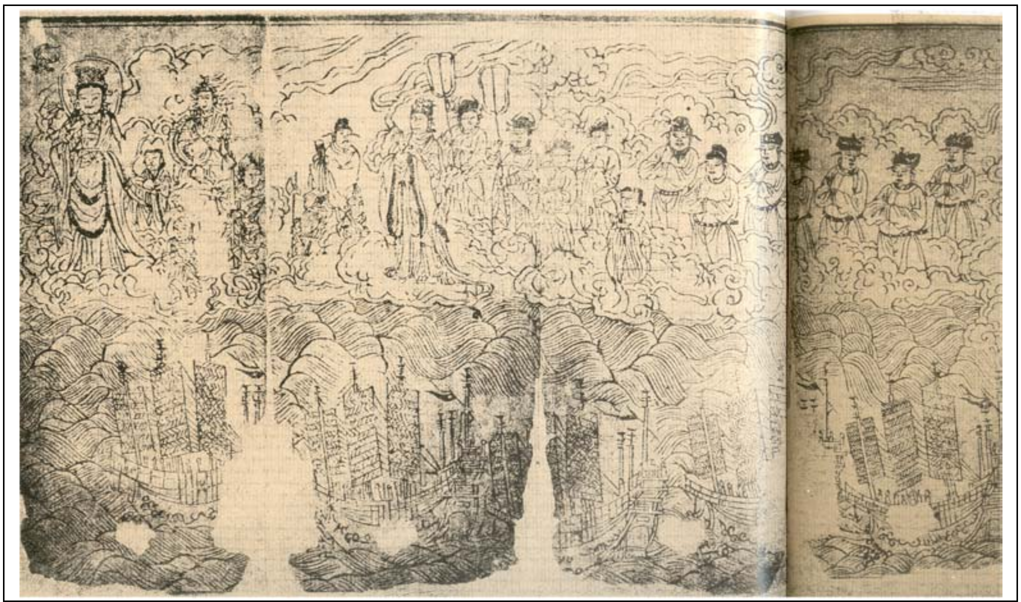
Mao Yuanyi 茅元儀, *Wubei zhi* 武備志 (facsimile of 1621 ed.), *j*. 240, in *Zhongguo bingshu jicheng* 中國兵書集成 (Beijing: Jiefang jun, 1989), vols. 27-36. The stellar diagram is in vol. 36, on p. 10431 of this collection.



Mao Yuanyi 茅元儀, *Wubei zhi* 武備志 (facsimile of 1621 ed.), *j*. 240. Modern edition, without characters: Haijun haiyang cehui yanjiu suo 海軍海洋測繪研究所, *Xin bian Zheng He hang hai tuji* 新編鄭和航海圖集 (Beijing: Renmin jiaotong, 1988).



Zhou Huang's 周煌, *Liuqiu guozhi lüe* 琉球國志略 (1759), pp. 33b-34a.
Cf. also Needham, *Science and Civilisation in China*. Vol. 4, Pt. 3, figure 939, p. 405.



Tianfei. From Wang Bomin 王伯敏 (ed.), *Zhongguo meishu quanji* 中國美術全集: ***Huihua bian*** 繪畫編: *Banhua juan* 版畫卷 [M] (Shanghai 1988), Illustration No. 30, pp. 32-33.

Tianfei. From Wang Bomin 王伯敏 (ed.), *Zhongguo meishu quanji* 中國美術全集: ***Huihua bian*** 繪畫編: *Banhua juan* 版畫卷 [M] (Shanghai 1988), Illustration No. 30, pp. 32-33.