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The Lessons of Varsovian's Reconnaissance

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"The path made by a Leader is tread on sand;
his track is seen for others to follow
only as one footstep follows another.
For if he stands still, the trail is erased;
its footprints washed away by the changing tide."

--- Domitius Lucullan, 195 AD

I want to tell you a story about advanced missions, planning for advanced missions, and the technology that enables advanced missions. I want to illustrate what is required of a technology for it to be truly enabling. We pride ourselves on our technical capabilities; we have detailed knowledge of the devices and systems we could build for those missions; how they work, how soon we might be able to develop them, the degree of technical risk involved. We know better than most people how mission requirements influence the development of new technologies. Sometimes, however, we fail to appreciate the economic requirements that enable the mission in the first place.

We believe that today we have the enabling technology which could bring about a new age of exploration and discovery. For the first time in human history we possess the physical means of leaving our own world and traveling to new worlds. New worlds out there waiting to be explored, waiting for the crunch of human footsteps, waiting to give us new discoveries and surprises.

We believe we have the technology -- today, right now -- to begin this new age of exploration, but since the costs are so great, and we are not able to prove beforehand the extent of the benefits that might accrue to pursuing these adventures, we cannot justify the risk and expense. Therefore, we falter at the challenge.

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At this point we should remember that there was a previous age of discovery and exploration when men left their known world behind and discovered a new one. This did not happen as soon as it could have. It took place well after the Renaissance began, a thousand years after the fall of Rome.

Curiously enough, the ancients had available to them the science and technology that would have enabled that age of discovery. Beginning with the Greeks the dark curtain of superstition was already parting, giving way to scientific understanding based on observation and measurement. By the time of the Roman Empire, everyone knew the world was round -- and by the end of the second century AD they could locate the parts of the world they knew with maps of surprising geometric fidelity, by means of astronomical observations.

In fact, the scientific knowledge, and the accompanying technology and organizational skills that the Romans mastered allowed them to gain military and political dominance of western civilization for hundreds of years. Their resulting economic strength sustained regular contact and trade with the rest of the known world including the eastern civilizations in India and China. Their knowledge about the world was not entirely accurate, but it was sufficient for them to know, for example, that the Orient could be found by going west. Their technology, even though limited compared to that of 15th century Europe, was capable of taken them there.

Of all ancient peoples the Romans had developed the discipline and organization necessary to carry out missions of exploration. More than any other society before them they had mastered the art of complex organization -- they had learned to bureaucratize; that is, to split up a large effort into smaller more easily manageable tasks and recombine the results into a unified cohesive whole.

If the Romans were capable of preceding Columbus, why didn't they? Let us imagine for a moment that we could go back in time and stand there, on the waterfront at Ostia, that ancient port city on the mouth of the river Tiber, gateway to Imperial Rome. . . .

The crumbling stone pier juts out into the harbor towards the breakwall. On late summer afternoons like this one the breeze blows onshore, carrying with it the pungent aromas of the Mediterranean, the shriek of gulls that wheel and dip in wide circles over the harbor. The harbor is crowded with vessels of every kind; from huge war galleys with multiple banks of oars that stroke the water in confident, well-coordinated, wingbeat-like sweeps, to lighters and tenders scurrying among the larger ships like beetles. And sailing vessels too: mostly merchantmen who are tied up at the docks or riding at anchor near the harbor mouth, waiting for evening, when the wind will shift direction from onshore to an offshore breeze and carry them out to sea.

A few paces away from us staring out to sea is a very distinguished looking figure (fig. 1), his arms folded behind him at parade rest. His cape is scarlet, trimmed with ermine. He wears the silver breastplate of a Proconsul. His retinue is huddled some distance behind him; muttering to themselves, casting worried glances over in his direction. Their master is not in a good mood. He is scowling; his jaw is set with hard lines around his mouth. Lucius Marcellus Varsovian is not a happy man. He has driven his chariot hard all the back from the capitol after being handed one of the few defeats in his career. To compound his frustration, insult has been added to injury -- the westbound courier already cleared the harbor earlier during the day, so he is unable to obtain passage home on a military galley. The first leg of the long voyage to Spain will have to be on a merchant vessel, a sailing ship. He is not accustomed to having to wait for the wind to change and he is furious.

The senate refused to back him again. Too bad -- his proposal was bold and imaginative. It could have resulted in a fresh infusion of new riches to the Empire. Possibly, it could have restored the Empire's declining fortunes, bringing a new sense of purpose and ending the petty squabbling and infighting that was now going on. He had proposed an expedition; a sea voyage from Spain westward across the Great Western Ocean, to find a more direct way to China than the long overland route traveled by the caravans. A direct sea route could put all the wealth of China within reach of Rome. With a sea route this wealth could flow, not by a trickle on the backs of a few pack animals, but by the shipload. But they refused him again. How could they be so short-sighted as to reject such a modest proposal, and one which had such a potentially great payoff? All he had asked for was some men and a few ships. . . . .

At this point you might be tempted to characterize Lucius Marcellus Varsovian as a visionary, a man ahead of his time. That would be a mistake. The ancients (Table I) have known the world was round ever since Aristotle's time; from the calculations of the astronomers

Eratosthanes and Hipparchus they have a pretty good idea of its size. By the second century AD, they had even learned how to make maps that were geometrically accurate, using astronomical observations to locate position.

And Lucius Marcellus Varsovian is not a dreamer. He is not interested in exploration or discovery, or opening a sea route for commerce. He wants to take his armies to China and plunder their cities!

The riches of the Orient have tantalized him for a long time. His knowledge of China is more tangible than just fables because there is regular contact and trade in the third century. In earlier times the emporer Marcus Aurelius had sent emissaries to the Han court in Peking; their reports told of large cities linked by a network of good roads, heavily populated but not heavily fortified. The richest ones were furthest east, located on a wide coastal plain that ended with an ocean. The reports also indicated that the Chinese empire was more a loose confederation of fiefdoms than an empire; although every warlord had his own army, there was no national army nor the political cohesiveness to sustain one -- it had never been necessary because they were so well isolated.

Distance and geography have kept the two empires apart. The caravan route to China is a tortuous overland journey which permits a limited exchange of communication, trade goods and culture but so far has prevented the more direct form of cultural intercourse that Lucius Marcellus Varsovian is contemplating. From Asia Minor it winds through the foothills east of Persia and through the mountain passes of Afghanistan; over narrow trails where men and animals must travel single file, easy prey for an ambush. Once over the mountains, the route traces its way across the mongolian steppe; an easier march here, but by then the presence of a large army would be known, and the Chinese emporer would have plenty of time to rally his warlords and prepare defenses. The last thing Lucius Marcellus wants is to fight an extended battle halfway across the plains of Mongolia; by the time he reached his targets the troops would be worn out.

A long overland march simply will not work. Varsovian knows this all too well-- as a young centurion in Atticus' disasterous Afghan campaign, he was one of the few who had made it back across the Khyber Pass alive.

But a sea route would change everything. Like his contemporaries Lucius Marcellus is mainly a land soldier, but he is not entirely unappreciative of sea power. He understands the surprise value of an amphibious assault, having used this tactic successfully to crush the Berber rebellion in Mauretania. Ferrying his troops along the coast just out of sight of land until nightfall, then turning towards the beach, he came ashore at dawn and drove swiftly inland before they could rally their tribes, cutting off their main encampment and capturing their chief; who was subsequently drawn and quartered.

As a result of wounds received in this campaign, he was sent to Alexandria to recuperate, where he spent a rather quiet period in his career reaquainting himself with the classical education of his youth. He had been a frequent visitor to the Great Library, and saw there a map of the world (fig. 2) published by the astronomer Claudius Ptolomy, the first conical projection based on astronomical observations and the most accurate map of its time. On this map, the eastern part of China and the west coast of Spain were opposite -- opposite sides of the world. Intrigued, he had studied the "syntaxis" which explained how the map had been made; how astronomy could tell you the size of the world and where you were located on it. The map showed that the eastern part of China, where the richest cities were, appeared furthest away from the west coast of Spain (where he had been born) but if that map were wrapped around a globe according to the method explained in the book (fig. 3), the east coast of China and the west coast of Spain would actually have to be facing each other, separated only by an undetermined stretch of ocean. This distance, according to his calculations and depending on the accuracy of the astronomical measurements, would be somewhere between 1500 and 2000 leagues. He couldn't fully understand all of the explanations which led to this result, but they made sense to him and, unlike the scholars who discussed it at length, he was quick to grasp its military significance. If that stretch of ocean could be crossed, the richest part of China might be directly accessible to his armies.

Could this ocean be crossed? 1500 to 2000 leagues of open ocean was a formidable distance. But not an insurmountable distance. Roughly equal the Empire's dimensions from western Spain to eastern Persia, it was less than the sea distance navigated routinely by galleys from Britain to Asia Minor. What if he could muster his legions at the port of Gades on the west coast of Spain, load his troops and their catapults into ships and head directly west? In summertime the sea would be calm. For navigation they could follow the setting sun, or use lodestone. An accurate landfall wouldn't be needed -- it would be hard to miss the Chinese coast.

Compared to the perils of an overland march, a sea voyage would be short and uneventful. After a few weeks cooped up in their ships, his troops would be restive and spoiling for a fight, eager to attack. And a seaborne invasion would not be expected. From an eastern beachhead an invasion force of only a few thousand troops could easily sweep across the wide coastal plain unopposed; the cities would be easy prey for his seasoned legions and their siege engines. Even if the Chinese emperor were able to rally his minions and prepare a counterattack, that would take time. Time to allow him an orderly retreat back to his ships, laden with the spoils of war.

He could return to Rome in triumph. Perhaps become the next emperor. Lucius Marcellus had a rough understanding of the relationships between economic growth and military strength. By the third century Rome had conquered, absorbed and digested all of the western world; there were no new civilizations nearby left to conquer. The empire was in decline -- his legions were not engaged in conquest any more, bringing home plunder. Instead they were relegated to maintaining order on the frontier, collecting taxes and putting down rebellions. There was no real challenge.

On the other hand, the distant Orient and its fabled cities would provide a worthy target for his legions. Why waste well-disciplined troops on the frontier skirmishing with barbarians when their skills are so much more profitably used against civilised people? Why burn down a few rude huts in some squalid village, when to the east there are magnificent cities waiting to be sacked? And what satisfaction is there ravishing unwashed savages dressed in animal skins with stringy yellow hair and long fingernails when, to the east, there are palaces to be looted -- filled with voluptuous princesses, succulent concubines draped in silk and jewels, their bodies bathed in perfumes and spices . . .

But -- before his armies could embark; before the ships could clear the harbor, he would have to have some more information. How far to the China coast? Where were the best places for landing? Where could an invasion force land unopposed, or better yet, undetected? The calculations indicated that his target should lie 1500 to 2000 leagues west of Spain, but this was only an estimate. An invasion would be reasonable if the distance were better known, but he couldn't commit hundreds of ships and thousands of men to a one-way voyage into the sunset without some assurance that the Great Western Sea was navigable, and the China coast on the other side. The first mission of the campaign would therefore have to be a voyage of exploration, not conquest. Or, in the mind of Lucius Marcellus Varsovian -- a reconnaissance.

That was the mission: to cross the Great Western Ocean and reconnoiter the China coastline preparatory to mounting an invasion. The audacity of this mission, and the ingenious way he used the limited technology of his time to ensure that it could succeed, demonstrates the extent to which the art of mission planning was raised by his genius. It serves as an example to mission planners everywhere who must base their plans for the future upon the technological capabilities of the present.

What kind of ship could cross that distance? A sailing vessel would seem the logical choice. By Varsovian's time they were routinely sailed beyond the Mediterranean up and down the west coasts of Europe and Africa. The sturdy little merchantmen (fig. 4) which carried Rome's trade to the four corners of the empire were seaworthy and reasonably fast in a favorable wind: broad, beamy, bluff-bowed, the Roman trademark was a single large square sail, loose-footed and placed well forward for stability downwind in rough seas. Their shallow draft enabled them to be sailed to shore; most were small and light enough that they could be dragged right up onto the beach. Their Greek and Phonecian design heritage reflected conditions on the Mediterranean; generally pleasant but often unpredictable weather with sudden storms. Hugging the coastline and making forward progress as long as the wind was behind them, they could steer for shore whenever the wind turned against them or a storm threatened, and wait there until better conditions prevailed.

However, that strategy, so effective along the well-settled Mediterranean, would not work out in the open ocean. And the qualities which made their ships so suited for sailing under these conditions made them unable to hold a course more than a few points off the wind. They would not work for this expedition. If the wind were to blow steadily eastward, they would never get there. If it blew steadily west they wouldn't make it back.

A more reliable form of propulsion would have to be used. Oars, with the built-in reliability of hundreds of rowers straining their backs in unison, would be the propulsion system of choice. Being a military man Varsovian was well acquainted with them -- from the common galley to the Emporer's festival barge, all of Rome's official business moved to the beat of oars. And there was no better type of oared vessel for crossing oceans than the galley, which ferried the empire's officers, administration and military might, and other business which could not wait -- for if sails propelled Rome's commerce, it was oars which moved her ships of state. Military requirements could not be subject to the caprice of nature. When the army had to move, it couldn't wait for the wind to change. With a galley, navigation was straightforward; one could steer a direct course to the destination, and arrival could be predicted with some certainty. That meant a naval action could be planned out beforehand, and the mission planner had the freedom to set course and schedule according to the timetable of the mission. These capabilities suited the methodical romans well. Like no other society before them they took full advantage of the organizational and schedular opportunities: in their galleys, roman legions traversed the Mediteranean with impunity, extending their line of march out into the Mediterranean in any direction as if it were a parade ground.

But the reliablility of straining backs comes at a price: the men who pull the oars must be fed and watered. This places a severe operational limitation on the amount of time the galley can stay at sea. For short voyages that is not a problem. A warship can sustain high performance for the entire length of its mission; because it is out for less than a day, and its crew does their eating and drinking ashore. For longer voyages however food and water must be carried on board. Space is limited on any ship; but a galley is more severely restricted because such a large fraction of the available space is taken up by its crew. The amount of supplies that can be fitted into the remaining space, together with the rate at which the supplies are consumed, determines how how many days at sea the ship can operate.

Compared with the distances commonly traveled by military vessels across the empire, Varsovian's requirement was unprecedented. A trireme, with its slender hull crammed with rowers for high performance, could achieve perhaps three days traveling at 11 knots. The quinquireme, a much larger warship, could last about a week, but it could sustain only about 7 knots. That was enough to cross the Mediterranean nonstop from Italy to North Africa, but not enough for a voyage beyond the Pillars of Hercules. A sailing vessel could last much longer between provisionings, of course, but that was because they require fewer crew to operate; sometimes that capability is needed to wait out periods of calm, or bad weather on some lonely beach.

To row across the ocean, Varsovian would need a ship that compromised crew size and speed for carrying capacity. His ship had to maximize the range he could travel before his onboard supplies were exhausted. There were many choices to make and they all conflicted --

a.) You can carry plenty of rowers or plenty of supplies, but not both.

b.) Large ships carry more supplies than small ones but a larger crew is needed.

c.) Large crews row faster; but that reduces the amount of food and water you can carry and consumes it at a faster rate.

d.) Faster speed reduces the number of days in transit, but greatly increases the rate at which supplies are consumed. The harder they row, the faster they go. But the consumption rate goes up even faster.

e.) On the other hand, reducing crew effort does not necessarily reduce consumption -- even if they don't row at all, they still eat.

The solution was to find a galley with moderate crew size and extra cargo capacity, and a cruising speed that took minimum rowing effort to sustain. Fortunately his experience suggested a compromise solution -- the common troop galley (fig. 5) which had served him so well in the Mauretanian campaign. A medium size vessel of about 40 tons displacement, there were hundreds of them in use throughout the empire; used to ferry the army to wherever there was trouble. Designed to carry a cohort of 100 fully armed troops and their officers, it was rowed by another 100 men pulling on the oars and it also carried a lugsail rig for periods of favorable wind. The troop galley was something of a compromise -- For economy, sails could be used when the wind was favorable; for reliability and for periods of unfavorable wind, there were the oars. With moderate effort a galley of this design could be rowed continuously at four or five knots, enough to cover thirty to forty leagues per day. These galleys were not as fast as a warship, but they could stay at sea for a much longer period. With its wider hull and smaller crew, it normally carried enough food and fresh water for voyages of about ten days. Varsovian would modify this vessel by removing the troop accomodations and putting in more supplies, essentially replacing the 100 fully armed troops with provisions for his rowers. Based on the weight and available volume alowed by this modification, he could lay in enough extra provisions for an estimated 54 days of travel; a little less than two months at sea.

Varsovian calculated that if the ship could average thirty seven leagues per day (assuming assistance from favorable winds no more than half the time), 54 days of continuous travel could cover 2160 leagues. Which would be enough to cross the Great Western Ocean if Ptolomy was right.

However, crossing the Great Western Ocean nonstop would still not be enough range to accomplish the mission. His mission was not a one way voyage. If he got there -- if he really found the coast -- he wouldn't be able to count on a friendly port or fresh provisions. In fact, he might just have to turn around in empty ocean and head home.

He would have to plan for a two way voyage. Westward across that distance to China, or at least as far as China should be; then eastward across that distance back to Gades. 1500-2000 leagues westward, then 1500-2000 leagues back. Twice the distance across the Great Western Ocean from Spain to China. This created a thorny problem of course. The 2000 plus leagues of range he had managed to squeeze out of his troop galleys was a one-way range. But the 2000 leagues of range he actually needed was the round trip range, more commonly known as "distance to point of no return" to where half the supplies are exhausted. Rowing westwards from Gades, they would reach the point of no return (fig. 6) only twenty-seven days into the voyage, a little over 1000 leagues. If he was willing to gamble with his expedition and keep going -- a one way voyage might possibly land them on the Chinese coast and, with a little bit of luck, they might find a secluded harbor where they could foray ashore for food and water. The risks, however, jeapordized the sucess of the mission. What if they never sighted land? If a direct sea route to China was truly out of reach, that would be dissappointing but nonetheless valuable information. But it would be worse to make a successful landfall, only to be butchered on shore by the local cavalry while trying to hustle a few supplies. . . .

The only way his reconaissance mission could be a success was to ensure that they could return home with the information. Besides, knowing you can return generally enhances crew morale! He would have to find a way to stretch his range to twice the 2000 or so leagues he had so far obtained, with ships that were already at the limits of their range. It was a problem which would have caused a lesser man to give up.

But the consumate planner Varsovian managed to solve this problem as well. He determined a way to accomplish this by organizing the mission in a way which nearly doubled the range of his ships. He did it by augmenting the expedition with additional vessels, and using them to replenish the other ships at carefully timed intervals.

A fleet of thirty two galleys would be required. They would all leave the port of Gades together on the Ides of June, rowing westward (fig. 7). Eighteen days later however, after one third of the food and water had been exhausted, the fleet would split into two groups. His ships would pair off with one another in mid-ocean and, within each pair, supplies would be transferred from one ship to the other. The ship receiving the supplies would be fully reloaded and would continue the voyage westward as illustrated in fig. 8. The donor vessel, with just enough inventory left to make a return trip, would turn east and head for home. As a result, the expedition would gain an additional 54 days of operating time beyond the 18 that had already been used, and stretch their round trip range an extra 360 leagues beyond the original point of no return.

Twelve days later, or thirty days into the voyage, this maneuver would take place again. Of the sixteen ships that had continued to row westward, eight of them would relenquish a fraction of their supplies to their sister ships and then turn home, leaving eight ships to continue the voyage (fig. 9). Again, the westbound ships would be fully replenished; the eastbound ships would head back with exactly enough food and water for the return trip, since it was in fact the same amount that they had consumed on the outbound leg. 240 more leagues of range would be gained.

Six days later, 1440 leagues west of Gades, the fleet would divide itself once more (fig. 10). Four galleys rowing westward, four galleys rowing back. And, if land were not sighted within another six days, or forty-two days from home port, the remaining ships could pair off once again, leaving two galleys to venture onwards (fig. 11). The expedition would have covered 1680 leagues of open ocean at this point; a round trip distance much further than any individual galley could have gone, and close to the estimated distance from Spain to China. They would have another four days to push further before the remaining galleys would have to reduce their numbers again.

Forty six days from home port, eighteen hundred and forty leagues beyond the Pillars of Hercules; if land had still not been sighted yet, there was still margin for an additional four days of exploration. The expedition could split itself up one last time (fig. 12), sending the last galley west for another 160 leagues. The final round trip range that resulted would be two thousand leages. Figure 13 summarizes the mission stages, their separation points, the fractional gain in operating time and range obtained with each stage.

Varsovian's plan was the first known use of staging to boost the range. This approach had major strengths. He could obtain the endurance he needed from ships whose capabilities were limited. It allowed him to navigate a round trip distance which would have been otherwise impossible. His plan not only extended the range of the expedition to almost double that of any individual ship, but at the same time guaranteed that every ship in the expedition could return. And it guaranteed that, with portions of his fleet dropping out and returning home as the various mission stages were exhausted, news of the expedition's progress could be reported home at regular intervals. At each staging point he could choose which ships should continue and which should return; ensuring himself only the soundest ships and strongest crews to continue the voyage. Failed or weakened elements could be removed to the rear; these would not have to make the return voyage alone.

Best of all, the plan allowed for contingencies--there was plenty of margin for error. If his range estimate was wrong; if he was unable to make landfall for any reason, or if the China coastline proved to be inhospitable he could still complete the mission with reasonabe confidence that all his galleys could return safely. His plan not only extended the range, it did so in a way which maximized his chances for success while minimizing the risk to his ships and crew.

According to this plan, time at sea could be stretched to one hundred days, almost double the range of any individual galley. The expedition could travel westward for a full fifty days before it would have to turn around and go home. Fifty days gave two thousand leagues -- and if Ptolomy's estimate for distance were correct, landfall should be made sometime within that period.

Unfortunately, Varsovian's plan could not anticipate the most difficult phase of the mission where risks are usually the greatest: presentation of his proposal to the Emporer and assembled senate (fig. 14). The review began encouragingly enough; everyone agreed that the conquest of China would be a giant step forward. The Emperor had listened to his plan carefully, had liked it, had endorsed it. Some of the senators had supported it, for it appeared to be a reasonable plan. Before the army could invade, a reconaissance mission was needed. It was logical, it minimized the risk, and the technology develolpments required to enable the mission were modest.

But the plan was very expensive. In fact, the costs were enormous; instead of a simple scouting foray this expedition (summarized by stages in Table II) had the dimensions of a full scale campaign -- thirty-two troopships and four thousand men, just to carry out a scouting mission to see if China was really on the other side of the ocean!

The cost alone of modifying thirty-two troop galleys was no small amount of money. Of course, shipyards from Venicia to Tarantum would be busy for months -- for the amount of business it represented Varsovian had obtained some political support from families of the shipbuilders who had furnished the fleet that carried Julius Caesar to his conquest of Britain. They festooned the outer halls with banners that proclaimed:

"Rome needs the Expedition"

"It's time we raised our oars again"

But when the total costs of the mission were presented (Table III), the opposition gave way to a clamor -- most people could not understand going to the expense of outfitting thirty-two ships for a voyage that would actually be completed by one, two, or at the most four ships.

"Isn't your proposal just a little bit gold-plated?" asked Caius Flattus Flavius, the ranking senator on the floor.

"Yes it is gold-plated." replied Lucius Marcellus, "gold-plating is the only way we can do this mission when it really needs to be gold, but we can't afford it . . . ."

With thirty-two galleys under stroke, the operating costs were outrageous. Consider the anticipated charges for provisioning the ships, food, wine, fresh water and casking; not to mention wages for the crew-- they would all have to be volunteers.

The opposition was vocal, and the criticisms were hard to answer. How could these enormous expenditures be justified? Varsovian's proposal violated the limits which govern every enterprise involving public monies: Where expenditure is great, great risk is not tolerated. Where risk is great, great expenditure is not tolerated.

"A publicity stunt" some said. "Lucius Marcellus wants to take the army on a boat ride to China?" With riots at home and rebellions abroad, there's no way to justify committing all those troops to some wild expedition. Besides, Varsovian could not guarantee that the expedition would succeed. He couldn't prove that the results of the expedition would pay back its cost. Could he show any tangible benefit? Certainly not within the next fiscal year. . .

"What are they gonna do when that last galley finally gets there; conquer all of China with only one cohort?" -- snorted Caius Crassus.

"If you're gonna go that way with all those ships, why don't you just keep going and invade the place while you're at it -- it wouldn't be that much more expensive than the fiasco you have proposed!"

For several hours of testimony the debate raged on. No decision was reached, but they agreed to appoint a committee to study Varsovian's proposed plan further; subject it to a cost/benefit tradeoff analysis to see if it could be re-optimized within a reduced range of performance parameters and budget constraints. It was at that point that Varsovian had turned on his heel and marched out of the senate chamber in disgust. In the end, they had voted to table the issue until a more decisive mandate could be established.

So why didn't they do it? Why didn't they go, when they were so strong and capable -- why didn't they seize the opportunity, to resume their unbroken string of conquests, conquests that had expanded their empire and made them great? Setting out to finally conquer all of the known world and, in doing so, encounter the unknown civilizations of the Maya, the Toltec, the Incas instead? What juxtaposition of history might have resulted, how would it have changed? What riches might have been preserved had those ancient cultures of the New World been consolidated under the bond of a greater Roman Empire, instead of being burned in the fires of the Inquisition?

Why didn't they? The answer is a little too simple and a little too close because, to know the answer to that question we do not have to look back any further than the present time, and we don't have to look at anyone further back than ourselves.

Sometimes having the enabling technology is not enough. It is because an enabling technology must be enabling in more than just the physical sense;

physically capable of rendering the mission. It must also be enabling in the economic sense, rendering the costs and risks of the mission reasonable . Reasonable cost means that the cost can be justified on the basis of benefits that are immediately anticipated. The previous voyages and discovery and exploration were more than bold ventures into the unknown. They were ventures with an economic purpose. To find a cheaper route to the Indies in order to facilitate a trade that was already thriving; to claim and survey new lands that had been discovered, to go search for easy riches. The king would not dip into his treasury and finance an expedition unless he could anticipate a cut of the profits. And reasonable risk means the immediate benefit anticipated by that risk taker must be high enough to make the payoff outweigh the risk. No pioneer would take chances to benefit only his unborn grandchildren -- a new world belonging to future generations is not enough motivation to risk losing your scalp in the present one!

Yes, we have the technology that makes it physically possible to venture out beyond our known world to new worlds. Our combustion driven rockets could take us wherever we want to go in the solar system. It would not be impossible to make them large enough to carry men and their life support. But while the chemical rocket propulsion technology developed to date has undeniably made interplanetary travel possible, it has certainly not enabled the mission yet. The combustion driven Mars spaceship must be the size of an aircraft carrier and it carries the price tag of a major military campaign -- hard to sell when the known benefits of this mission are so intangible.

However we are developing more energetic means of power and propulsion for our spaceships. Some of them, such as electric propulsion and nuclear rockets, are driven by the atom. The electric propulsion technology, and the nuclear power sources being developed in our laboratory could reduce the size of our Mars spaceship by orders of magnitude. That might make the price of our expedition more reasonable.

Lowering the price of the mission, making it more reasonable is where we play our part. We space power technologists may get frusturated sometimes because the benefits of our work are not immediately obvious to everyone, and nobody ever wants to pay for it. How often the mission planner reminds us that "better is the enemy of good". But we can take comfort in the fact that the advanced technology we are working on now will someday become the economically enabling technology for those future missions. Every advancement we make towards smaller, lighter, more powerful and energetic spacecraft serves to reduce the cost and risk of these adventures we are dreaming about. As progress continues, the dream will come ever closer to reality.

Let's look back one more time at Lucius Marcellus Varsovian standing on the pier. Bitter, disillusioned, cynical, he stares out to the sea dancing on the horizon past the breakwall. His eyes pierce the afternoon sunlight but they are blinded by bitterness and dissappointment. How will the Empire survive if it cannot be bold enough to mount even this modest expedition? When men and nations no longer dare to dream, what can the future hold?

But as he stands there staring out to sea, he fails to see a most marvelous thing taking place right in front of him. A graceful arab dhow, (fig. 15) with its lateen rig and deep keel; her sharp prow and delicate forefoot biting cleanly into the water, is threading its way out of the harbor close-hauled, beating upwind towards the breakwall opening and the open water beyond.

There is much more work to do before we venture out as explorers and colonists!

THE ANCIENTS

Pythagoras	(550 BC) First to offer scientific arguments that the world was round.
Aristotle	(350 BC) Proved convincingly, and to everyone's satisfaction, that the world was not only round but also the true center of the universe.
Eratosthanes	(240 BC) First accurate estimate of earth's size, based on solar observations.
Hipparchus	(120 BC) Discovered earth's precession; published first accurate astronomical tables predicting eclipses, positions of stars and planets throughout the year. First to systematically use trigonometric principles, he refined, based on astronomical observations, earlier estimates of the sizes, distances to sun, earth, and moon.
Claudius Ptolomy	(140 AD) Last and most authoritative of the classical Greek astronomers. Compiled and codified the body of Greek thought (including Hipparchus) on astronomy, earth sciences in thirteen volumes ("The Syntaxis"). Published first dimensionally accurate (conical projection) map of the known world; but underestimated size of earth by 30%.

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TABLE I.

EXPEDITION TO THE ORIENT ACROSS THE WESTERN SEA

GRADUS	Primus	Sec.	Tertius	Quartus	Quint.	Sextus	TOTAL
Number of Galleys Each Stage	XVI	VIII	IV	II	I	I	XXXII
Number of Days at Sea	XXXVI	LX	LXXII	LXXXIV	XCII	C	
OPERATING EXPENSES	(mille sestertium)						
WAGES oarsmen	$\overline{IV}$DCCXC	$\overline{III}$CMXC	MMCD	MCD	DCC	DCCXXX	$\overline{XIV}$CLXXX
officers	MDCCCLX	MDLX	CMXX	DXL	CCXC	CCCXX	VCDL
CONSUMEABLES							
meat	MCXI	CMXII	DLVI	CCCXX	CLXXXI	CXCV	$\overline{III}$CCLXXV
bread	DLXVI	CDLXIX	CCCLXXXI	CLXIV	XC	CIX	MDCLXXX
goat butter	LXXIV	LXIV	XXXV	XXVI	X	XII	CCXXI
black olives	XLII	XXXIII	XXII	XIV	XII	XIV	CXXXVIII
grapes	CXL	CXXII	LXIII	XLIX	XIX	XIX	CDXII
zucchini	LXXXIV	LXXIX	XLVII	XXI	XII	XX	CCLXIII
pasta	CCXXII	CLXXXI	CXI	LXVIII	XLVI	XLV	DCLXXIII
water (incl. casking)	CCXL	CCXIV	CXIII	LXIX	XXIX	XXXI	DCCVI
wine	CCCXII	CCLVI	CX	XCIX	LII	LVI	DCCCLXXXV

TABLE II.

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ORIGINAL PAGE IS
OF POOR QUALITY

IMPERIAL TREASURY EXPENDITURE

EXPEDITION TO THE ORIENT ACROSS THE WESTERN SEA

FIXED COSTS

Conversion of 32 troopships to extended range configuration	$\overline{LXXVIII}$CXLIV

OPERATING EXPENSE

WAGES	
oarsmen	$\overline{XIV}$CLXXX
officers	$\overline{V}$CDL

CONSUMEABLES	
meat	$\overline{III}$CCLXXV
bread	MDCLXXX
goat butter	CCXXI
black olives	CXXXVIII
grapes	CDXII
zucchini	CCLXIII
pasta	DCLXXIII
water (incl. casking)	DCCVI
wine	DCCCLXXXV

TOTALS	(mille sestertium)
Fixed Cost	$\overline{LXXVIII}$CXLIV
Operating Expense	$\overline{XXVII}$DCCCIII
material	$\overline{XLVII}$CCCXXV
burden	$\overline{XI}$DCCCXXXI
labor	$\overline{LXXXVIII}$DCCXXXIV
overhead	$\overline{XXXV}$CXCIV
G + A	$\overline{LXXXIX}$CCXCIX
cost of money	$\overline{VII}$DLXXIV
fee	$\overline{LVII}$CMXLIII
Grand Total	$\overline{CDXLIV}$CCXXVII

TABLE III.

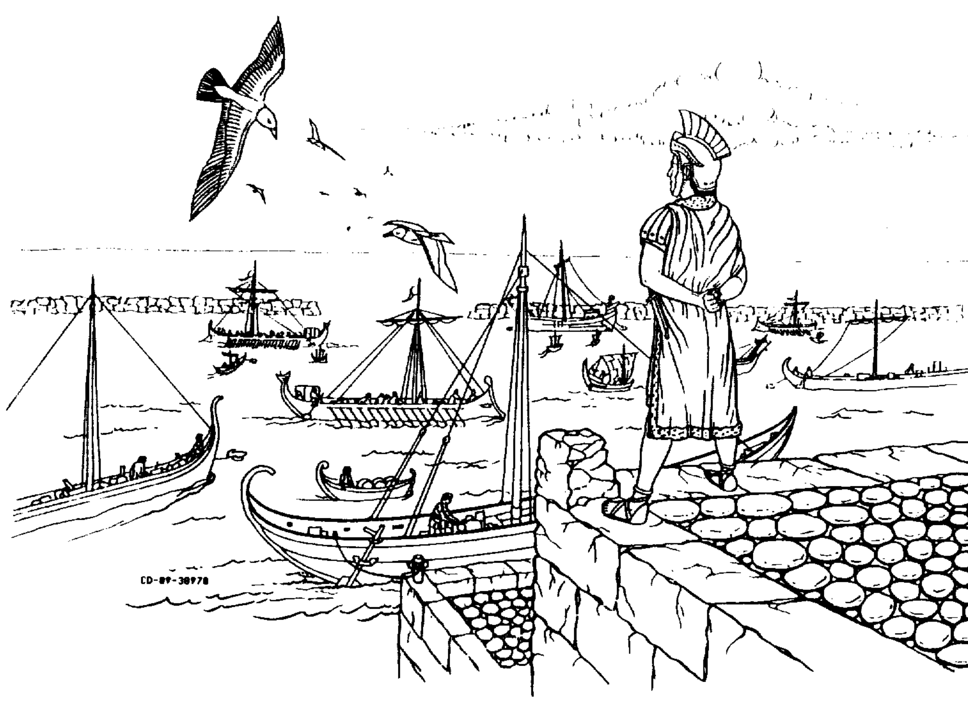

FIGURE 1.

PTOLEMY'S MAP OF THE WORLD

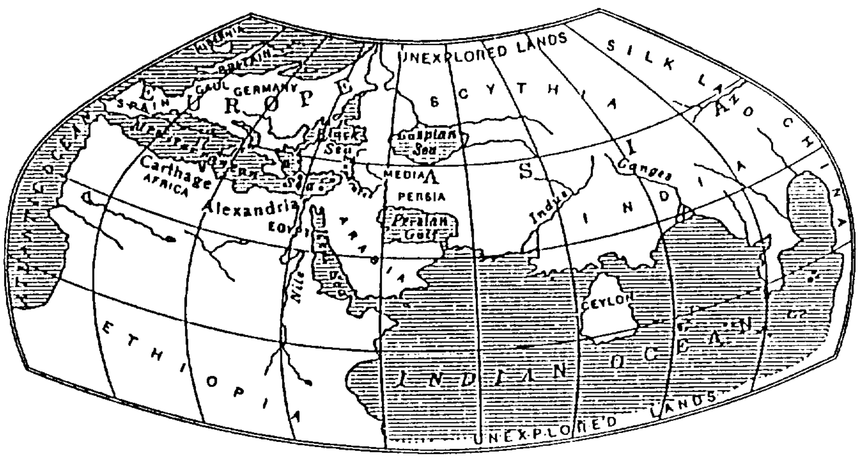

FIGURE 2.

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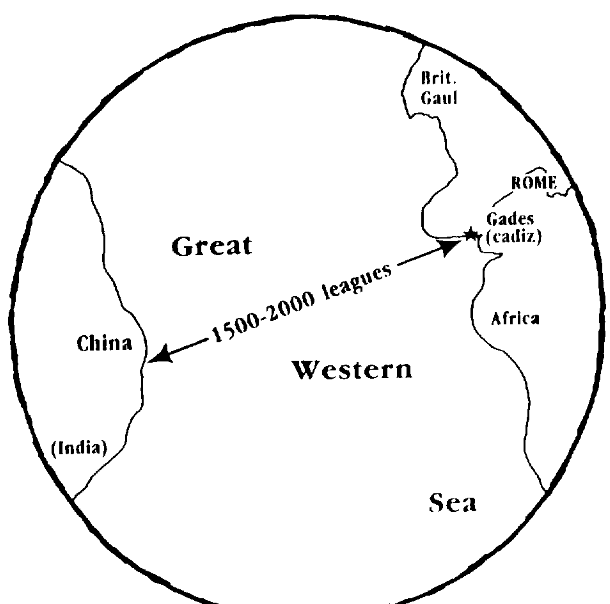

FIGURE 3.

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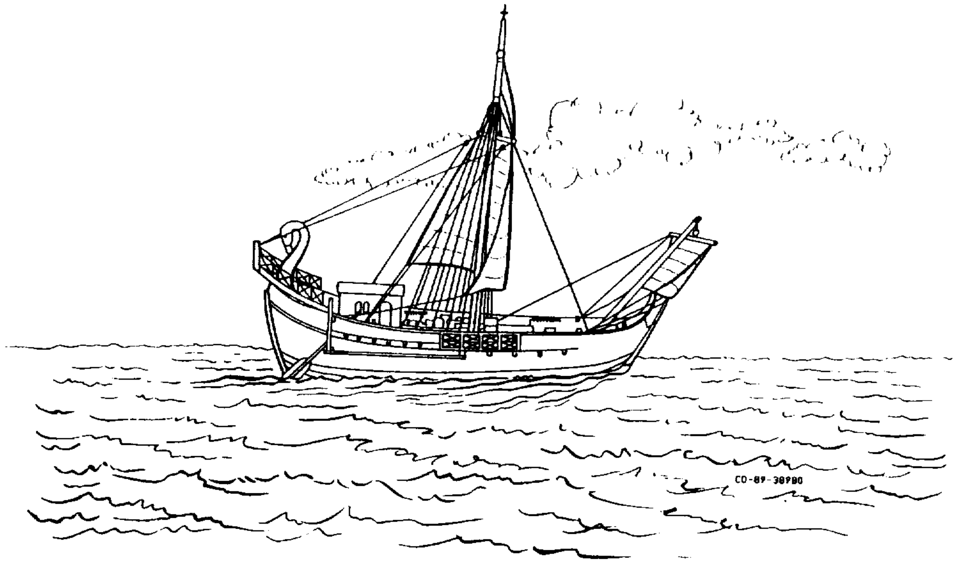
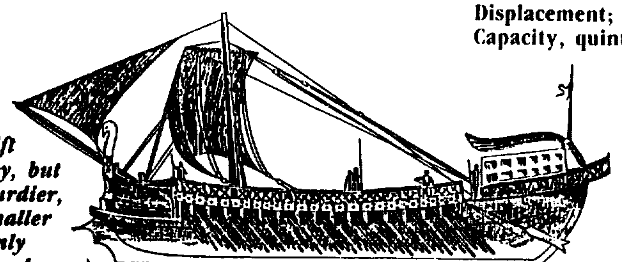


FIGURE 4.

ROMAN TROOP GALLEY

Length overall, feet: CXL
Beam, ft: XXI
Displacement; tons: CXX
Capacity, quintals: MCM



Not a swift war galley, but wider, sturdier, with a smaller cohort (only one hundred oars). Not as fast, but able to stay at sea much longer.

SPEED
nominal cruise 4-5 kt.
maximum sustained 7 kt.
dash 8 kt.

PROPULSION: sail or oars depending on wind direction (assume half time each mode).

ENDURANCE
continuous cruise 54 days

COHORT, officers: XII
oarsmen: XCVI

RANGE
nominal one way 2160 leagues (1 leagues = 3 mi.)
round trip 1080 " "

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FIGURE 5.

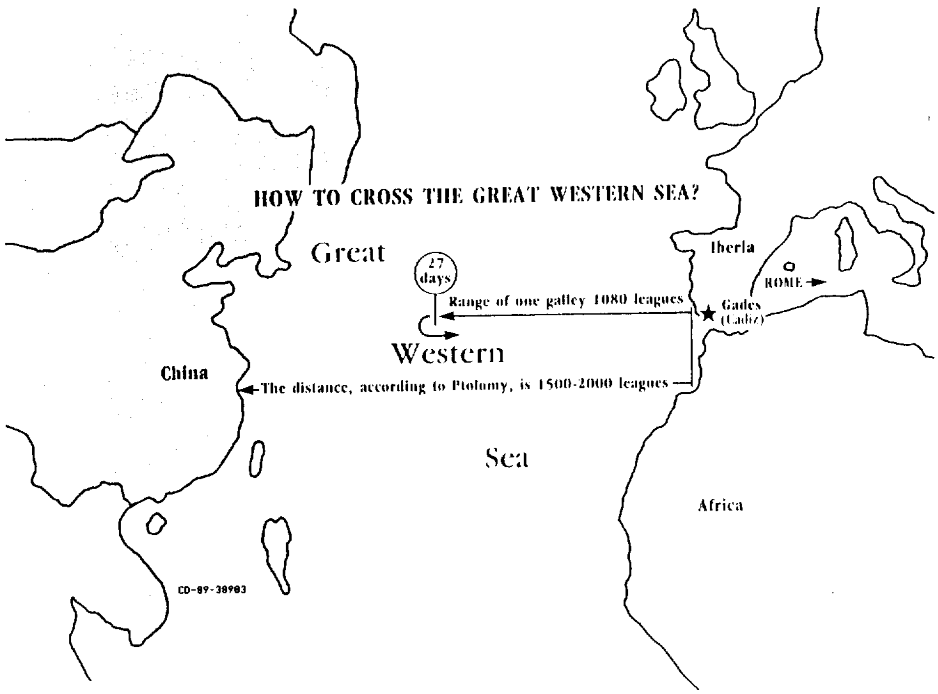

FIGURE 6.

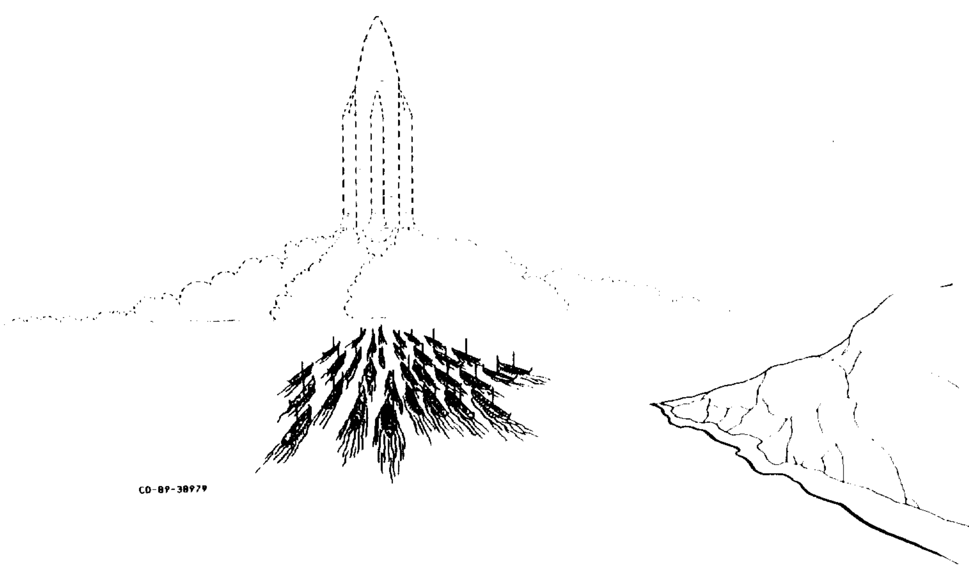

FIGURE 7.

18 DAYS INTO VOYAGE
720 LEAGUES WEST

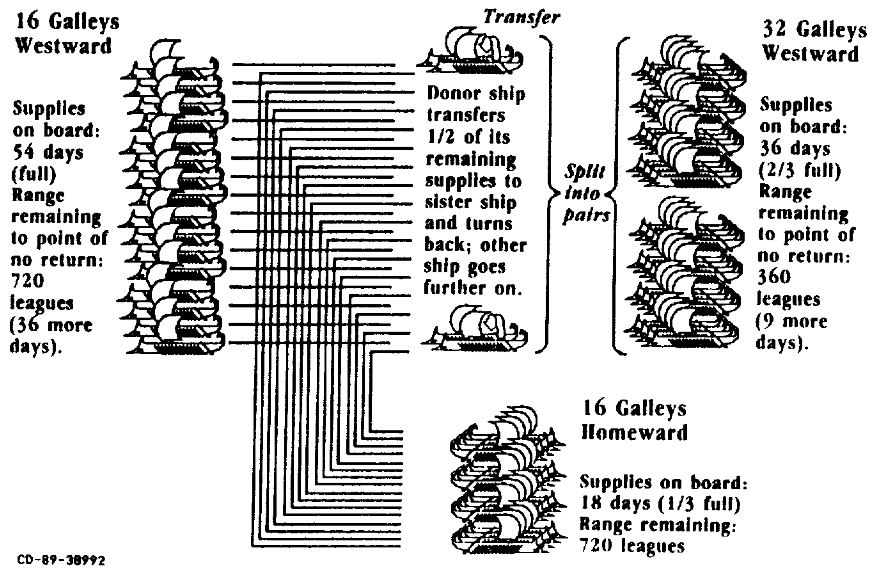

FIGURE 8.

30 DAYS INTO VOYAGE
1200 LEAGUES WEST

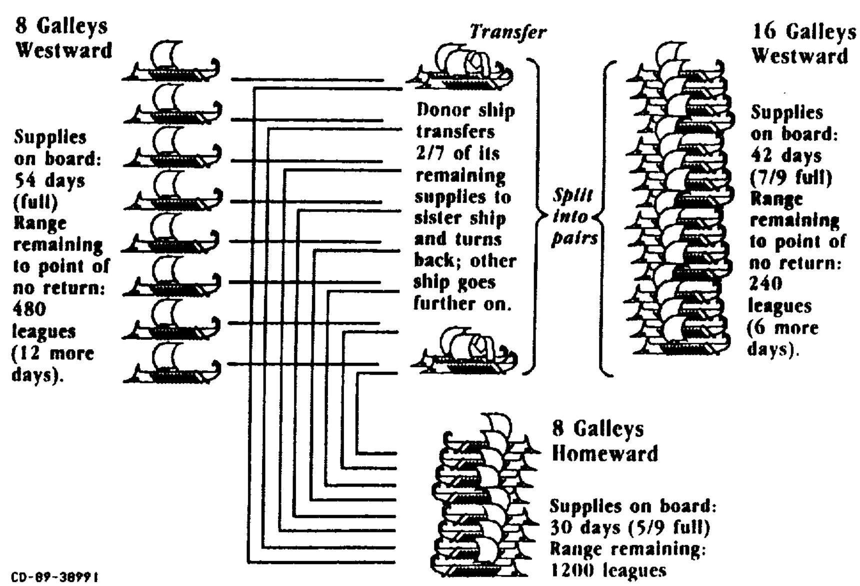

FIGURE 9.

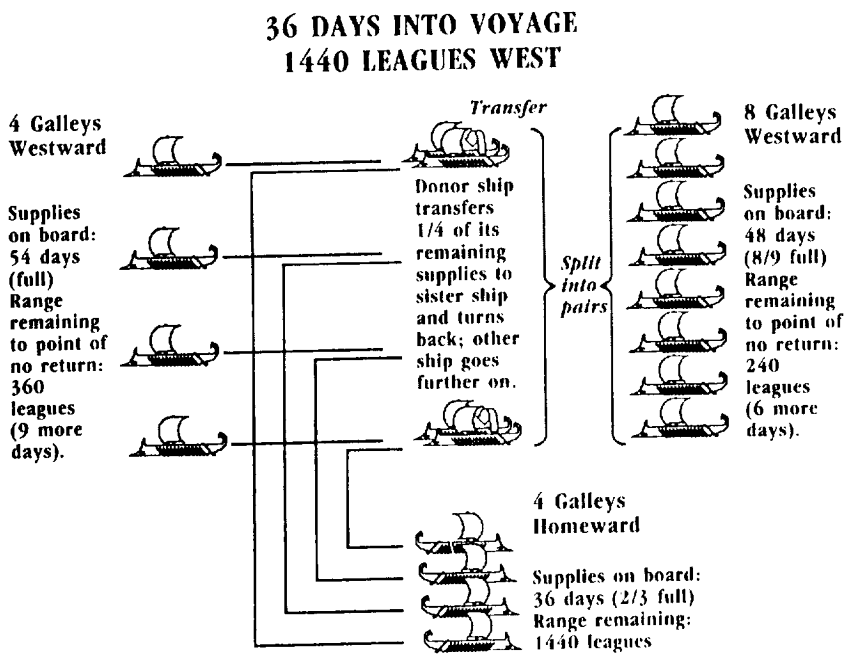

FIGURE 10.

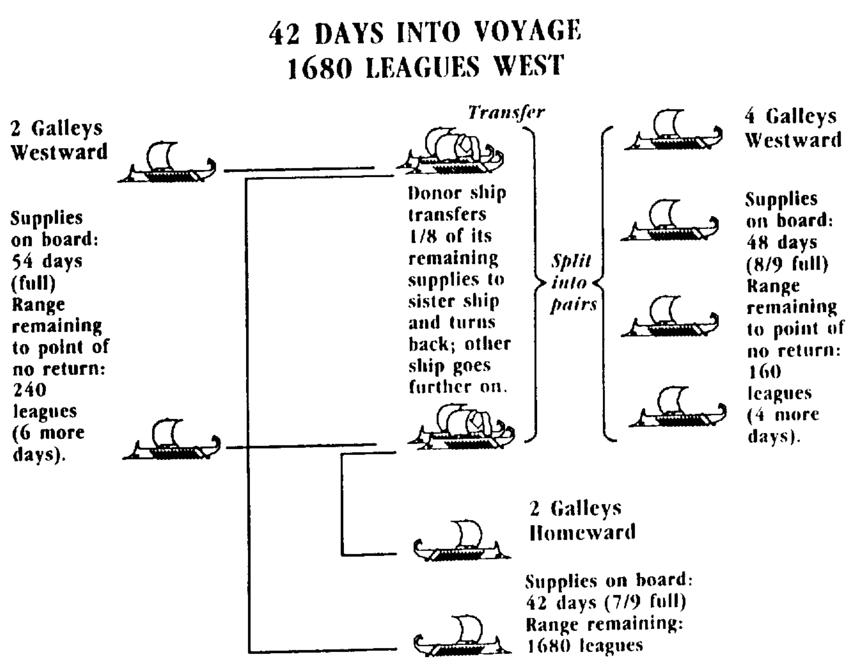

FIGURE 11.

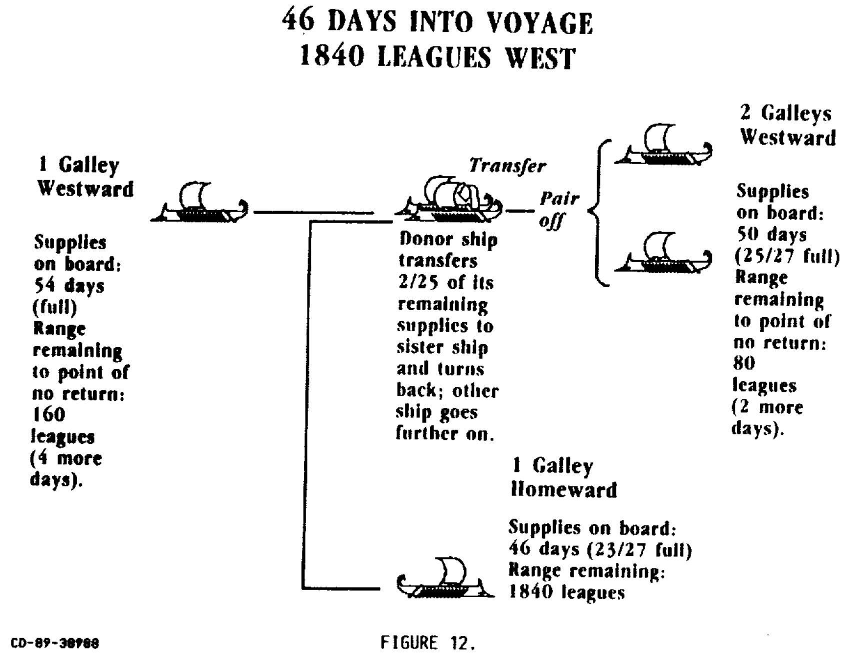

FIGURE 12.

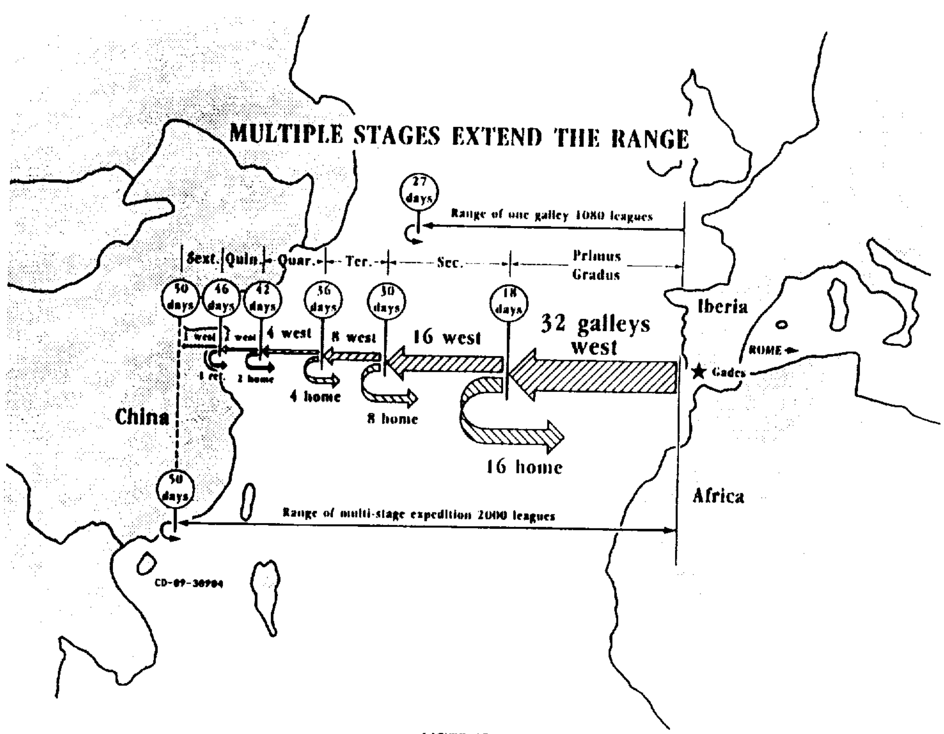

FIGURE 13.

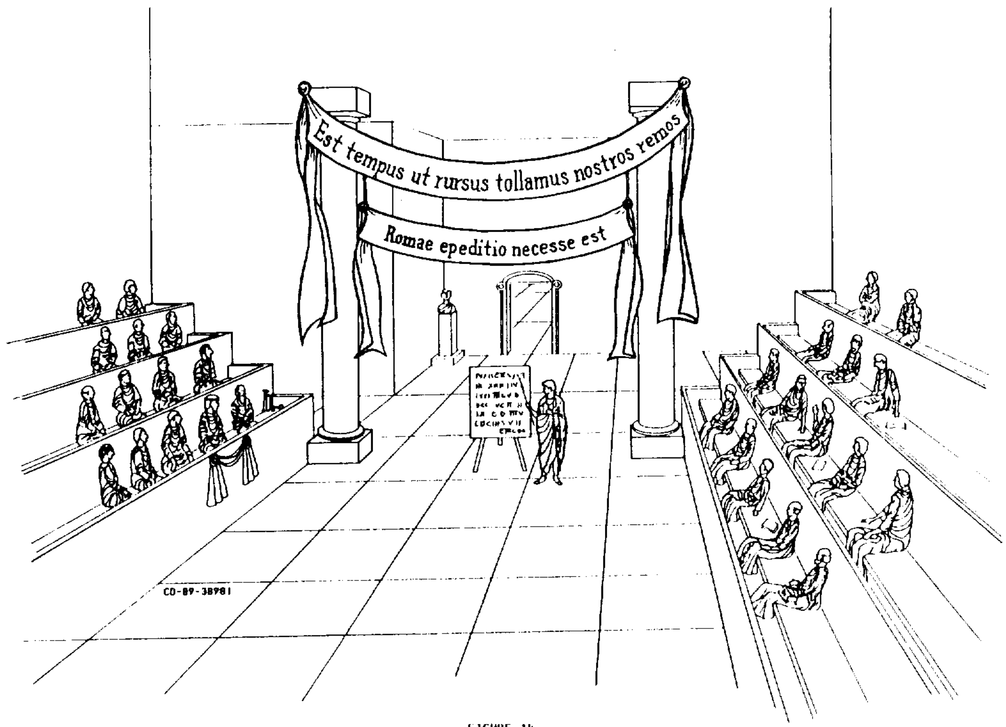

FIGURE 14.

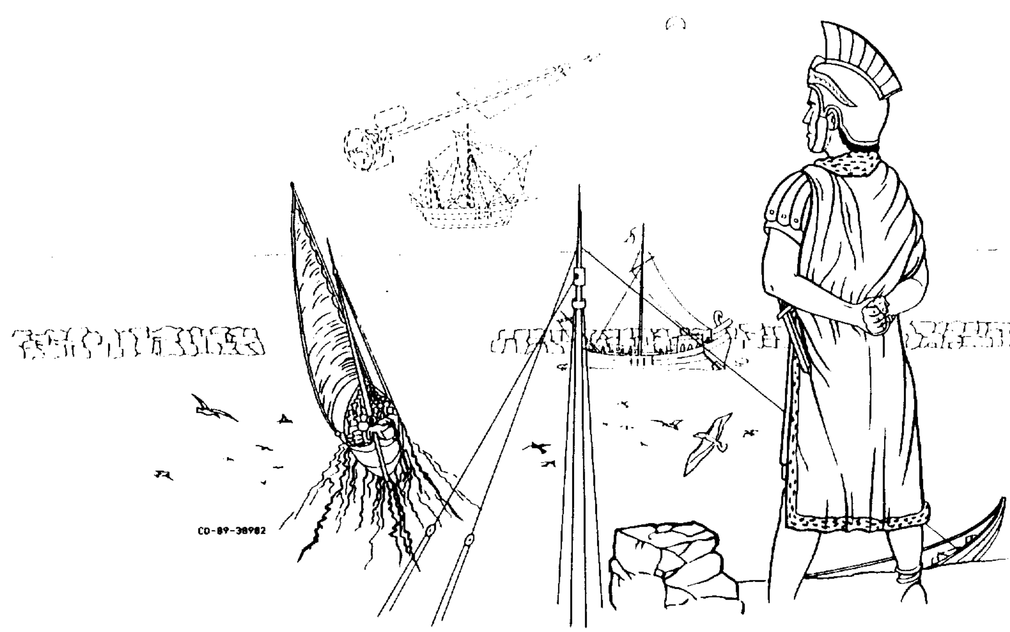

FIGURE 15.

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15. Supplementary Notes

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16. Abstract

This paper illustrates the role played by advanced technology with respect to the anticipated era of discovery and exploration (in space): how bold new exploration initiatives may or may not be enabled. Enabling technology makes the mission feasible. To be truly enabling, however, the technology must not only render the proposed mission technically feasible, but also make it viable economically; that is, low enough in cost (relative to the economy supporting it) that urgent national need is not required for justification, low enough that risks can be programmatically tolerated. An allegorical parallel is drawn to the Roman Empire of the second century AD, shown to have posessed by that time the necessary knowledge, motivation, means, and technical capability of mounting, through the use of innovative mission planning, an initiative similar to Columbus' voyage. They failed to do so; not because they lacked the vision, but because their technology was not advanced enough to make it an acceptable proposition economically. Speculation, based on the historical perspective, is made on the outcome of contemporary plans for future exploration showing how they will be subjected to the same historical forces, within limits imposed by the state of technology development, that shaped the timing of that previous era of discovery and exploration.

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