Living Off the Land in Space

LIVING OFF THE LAND IN SPACE

Green Roads to the Cosmos

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FOREWORD

Two scientists and an artist have collaborated to produce this book, which is both scientifically authoritative and artistically inspiring. Les Johnson, a physicist by education, managed in-space propulsion research for about a decade at NASA's Marshall Space Flight Center in Huntsville, Alabama, and is now the manager of that Center's space science programs and projects office. Dr Gregory Matloff, a member of the International Academy of Astronautics and a Fellow of the British Interplanetary Society, has published many technical papers and two books on these topics and has consulted for NASA. C Bangs has shown her space-related art in many international settings; her work enlightens the visionary drive in humanity towards cosmic exploration.

As well as qualifying as an instruction manual for scientists and engineers, this book should appeal to far-sighted minds who feel that the new millennium will hopefully see the expansion of humanity beyond the edges of the solar system. It is hoped that this book will inspire astronomical researchers currently seeking Earth-like worlds circling nearby stars. In centuries to come, these worlds may well serve as new homes for humanity.

Although not science fiction, this is a visionary book. Already, researchers in the SETI (Search for Extraterrestrial Intelligence) community have greatly expanded their search for alien radio transmissions. The time may well come when deep-space exploration and SETI will join forces to permit humanity to join a wider galactic community.

Dr Claudio Maccone
Co-Vice-Chair, SETI Permanent Study Group,
International Academy of Astronautics

ACKNOWLEDGMENTS

Many people contributed to the research described in this book. The cited technical and popular references outline their efforts.

Artist C Bangs collaged digital photographs, created and scanned her drawings and internet imagery to produce cover and chapter frontispiece art. All planetary and spacecraft images are from NASA websites; all star fields and galactic images are from the Hubble Space Telescope websites.

The image of the Conestoga Wagon collaged into the Chapter 1 frontispiece is used with the courtesy of the Detroit Michigan Historical Museum.

A photograph of a steam locomotive is incorporated in the Chapter 12 frontispiece. We thank Dipl.-Ing. Tobias B. Kohler of Graz, Austria, for his permission to use this image.

The frontispieces for Chapters 4 and 11 are derived from an aerocapture poster produced by the In-Space Propulsion Research Group at NASA Marshall Space Flight Center. C Bangs participated in the creation of this poster during her summer 2004 tenure as a NASA Faculty Fellow.

During the summer of 2003, C Bangs participated in the creation of another In-Space Propulsion Research Group poster project at NASA Marshall that combines elements of ancient planetary mythology and modern space technology. This poster is used as the frontispiece for Chapter 21.

In 2001, C Bangs was funded by NASA Marshall to create the prototype Rainbow Holographic interstellar message plaque described in Chapter 14. Some of the six multiplexed two- and three-dimensional images on that plaque are incorporated in that chapter's frontispiece.

The poetry and folksong segments used to introduce each chapter come from several sources. These include Louis Untermeyer, *A Treasury of Great Poems*, Simon & Schuster, New York (1942) and Walt Whitman, *Leaves of*

Grass, ed. E. Holloway, International Collectors Library, Garden City, New York (Doubleday copyright 1926)

We are also grateful to our colleague Dr Claudio Maccone for consenting to write the Foreword to this volume. The efforts of our publisher, Clive Horwood, are also appreciated, as are the contributions of the editorial staff of Praxis and Copernicus Publishing Companies. Special thanks go to Praxis editors Arthur Foulser and Alex Whyte and to Harry Blom and Christopher Coughlin of the New York Springer office.

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INTRODUCTION

CITIZENS OF THE COSMOS

Full fathom five thy father lies:;
Of his bones are coral made;
Those are pearls that were his eyes;
Nothing of him that doth fade
But doth suffer a sea-change
Into something rich and strange.

William Shakespeare, from *The Tempest*

A PERSON younger than 40 or so can be forgiven for imagining that space travel has always been with us. Those a bit older, who matured in the heady days of humanity's first hesitant steps into the cosmic abyss, are fortunate enough to have witnessed the drama.

In less than half a century we have collectively altered. No longer are we a two-dimensional planet-dwelling folk, forever bound by the vagaries of soil, ocean, wind, and rain. We have climbed above the clouds, tasted the vacuum of low Earth orbit (LEO). Some of us have lived above the atmosphere for a

year or longer; a few dozen have orbited our planet's solitary natural satellite or disturbed its dusty surface with their bootprints. On their fiery return to Earth, the pioneering astronauts of these Apollo expeditions returned rocky samples of the lunar surface to terrestrial laboratories.

Our robotic emissaries, less concerned with the requirements of life support, have ventured further afield. They have flown by, circled, or landed upon every solar-system planet save tiny, frigid Pluto (which is not actually a planet). Probes from Earth have touched down upon hellish Venus, roved the frozen deserts of Mars in searches for life and water, entered the atmosphere of giant Jupiter, and successfully reached the surface of Saturn's giant moon, Titan. Many other small solar-system bodies—asteroids, comets, and planetary satellites—have been explored by these small ships from Earth. Carrying engraved messages, four of them have actually departed from the solar system to endlessly cruise the galactic void as the first starships from Terra. Stationed above our planet's turbulent atmosphere, sophisticated space telescopes sensitive to many regions of the electromagnetic spectrum have extended our intellectual reach by billions of light-years, and searched billions of years into the past.

But as well as exploring, astronauts and robots have begun to lay the framework and infrastructure for an extraterrestrial economy. Already, most long-distance communication is routed through geosynchronous communication satellites permanently stationed about 35,000 kilometers above the equator. Other spacecraft monitor weather and climate and help to record our planet's extensive, but finite resources. It's difficult to get lost anywhere on our planet, when one's location can be easily ascertained by routinely tapping into the global-position satellite network.

Perhaps our dreams of cosmic flight began with observations of birds and other living fliers. Although there are legends of ancient people experimenting with kites and hang gliders, the first successful device to carry humans above the Earth's surface was the hot-air balloon. Only a century or so after the Montgolfier brothers' first balloon ascent above the French countryside, other inventors such as the German Count Zeppelin learned how to put reciprocating engines on board lighter-than-air aircraft and control their flight through the sky.

But although these early sky ships were cumbersome and slow, the hydrogen gas that replaced hot air had a nasty tendency to react explosively with atmospheric oxygen.

In the first quarter of the twentieth century, heavier-than-air aircraft began to replace the lumbering giants. Initially driven by propellers, early airplanes proved to be safer, faster and more economical than the giant Zeppelins.

The Second World War was a watershed in the development of powered flight both within and above the atmosphere. The jet engine was developed as a replacement to the propeller; and both the speed and cruising altitude of commercial and military aircraft increased as a consequence of this development. Before 1950, aircraft had exceeded Mach 1, the sound barrier, and achieved operational altitudes in the lower stratosphere.

Another reaction motor, the rocket, saw its first large-scale application during the Second World War. Some of these rocket-propelled ballistic missiles crossed the 60-kilometer threshold to space as they arched toward their distant targets.

The computer also emerged as a computational tool in that period, with some crude automatic devices being used to control the trajectories of early cruise missiles.

At the end of that conflict, the energy of the atom was unleashed destructively. The Faustian bargain of nuclear energy may still prove to be a *blessing* by unlocking vast energy reserves for human applications, or as a *curse*, as it may yet destroy us.

After the conclusion of the Second World War, the victorious powers realized the potential of combining the rocket, computer, and nuclear warhead. Conceptually, a general could arrive at work in the morning and, before his morning coffee break, could push a button and launch a fleet of nuclear-tipped, computer-guided ballistic missiles towards an opposing country. By lunchtime, he could have caused the death of one hundred million people.

The Space Race of the 1960s was neither a quest for knowledge nor an attempt to expand the frontiers of terrestrial life. Plainly and simply, it was an effort by the superpowers—the USA and the USSR—to gain the high ground militarily and impress the developing world with their technological superiority.

The USSR jumped to an early lead in the Space Race with multiple accomplishments, including the first orbital spacecraft (Sputnik 1, in 1957) and the first human-occupied spacecraft (Vostok 1, which carried Yuri Gagarin into orbit in 1961).

Playing catch-up and hoping to regain technological supremacy, America aimed for the Moon, which orbits the Earth at an average distance of 384,000 km. Apollo 8 orbited the Moon in 1968, and Apollo 11 followed with the first piloted Moon landing in 1969.

Although subsequent Apollo missions, especially the final three flights (Apollos 15–17), would return much scientific data about our planet's natural satellite, many people lost interest in the space program after the success of the first lunar expeditions. Clearly, the quest for national

prestige had fueled the early Space Age, not the search for scientific data or the desire to open new frontiers.

Since 1972, no human has ventured more than a few hundred kilometers from Earth's surface. Several hundred humans have experienced the weightless environment on board the reusable American space shuttle, Russian Salyut, and Mir space stations and, most recently, the international space station (ISS).

The space-launch fraternity is also expanding. China has demonstrated a capability to launch humans to LEO that rivals that of the USA and Russia. Heavy- and medium-lift launch vehicles are in routine operation in Europe, India, and Japan. Many other nations will soon have the capability to orbit small or mid-sized satellites. And the X-Prize competition demonstrated that suborbital space, at least, is not off limits to private astronauts.

With so many players in this cosmic game, humanity seems poised to expand its reach once again beyond LEO. But what are the motivations that could trigger this expansion when it begins?

The very human desire to soar like the birds, which motivated early aviation pioneers, does not seem applicable in the case of expanding into a vacuum far above the reach of any avian. In an era of one super power, the desire for enhanced national prestige also seems to be an inappropriate trigger for human cosmic expansion.

But business now has a global reach. In the quest to make a profit, private "space liners" will soon apply the technology of Rutan's Space Ship 1 to allow space tourists a few minutes of weightlessness and a glimpse of black skies above the distant Earth for a cost of "only" a few hundred thousand dollars. Some day, as technology improves, these costs will come down and typical citizens of the developed world will easily acquire astronaut wings. Ultimately, this quest for profit may even encourage the development of orbital hotels and the reusable, single-stage-to-orbit ferries they will require. But because of the huge capital costs and time scales involved, few venture capitalists will ante up the huge sums required to begin the economic development of the solar system.

What may be needed is a collaboration between government and private interests. Enlightened governments' interests in solar-system settlement might be two-fold: obtaining the resources of the solar system and insuring national survival.

Less than one-billionth of the light emitted by our Sun actually strikes the Earth. One way of maintaining our planet's high-energy lifestyle in the post-fossil-fuel era is to construct large solar energy collectors in space, using space resources. Using microwave technology, this energy could be beamed back to receivers on Earth's surface.

At approximate intervals of a century, cosmic objects capable of destroying a city impact the Earth. A recent impact in Tunguska, Siberia, in 1908 resulted in an explosion with the energy equivalent of a 20-megaton hydrogen bomb. That's more than enough energy to level a large city and kill 10 million people! Fortunately, the Tunguska object impacted a wilderness.

About 65 million years ago, a much larger space object struck in what is now the Yucatan, Mexico. Most terrestrial species, including the dinosaurs, were wiped out or adversely affected in this event.

Enlightened governments, with an interest in self-preservation, could direct their astronomical resources to accurately track the trajectories of near-Earth objects (NEOs) that might some day threaten the Earth. A task for the military establishments of a consortium of such nations might be the development and maintenance of techniques that could divert Earth impactors.

And while the military is diverting threatening asteroid and comet fragments, entrepreneurs could mine these objects for useful materials, in cooperation with the governmental space programs. The material resources of NEOs could be used to construct solar-power stations to supply terrestrial energy needs and large space habitats to house the space workers (and their families) who are engaged in NEO diversion and mining, and the construction of solar-power stations.

There are terrestrial precedents for such private and public cooperation on the frontier. The settlement of the North American west by private individuals and corporations, for example, was greatly hastened by the construction of transcontinental railroads using public funds.

The breakout into the solar system will be grand and majestic. Unlike previous territorial expansions, it will be a truly international endeavor. Fortunes will be made on this new frontier and lives will be lost; but, from the perspective of the far future, the most important result will be the expansion of the terrestrial biosphere into the celestial realm. Ultimately, Gaia's children will inherit the sky, altered by the new environment to become true citizens of the cosmos.

FURTHER READING

For an exciting journalistic treatment of the Space Race, consult J. Barbour, *Footprints on the Moon* (American Book-Stratford Press, 1969). Early robotic exploration of the outer solar system is reviewed by M.

Washburn, in *Distant Encounters* (Harcourt, Brace, Jovanovich, New York, 1983). In the *Soviet Manned Space Programme* (Salamander, New York, 1988), Philip Clark reviews the Russian space stations through the development of Mir. Prospects for space solar power and asteroid mining are reviewed by John S. Lewis, in *Mining The Sky* (Addison Wesley, New York, 1996).

1

THE OLD FRONTIER

I will arise and go now, and go to Innisfree
And a small cabin build there, of clay and wattles made;
Nine bean rows will I have there, a hive for the honey bee,
And live alone in the bee-loud glade.

And I shall have some peace there, for peace comes dropping slow,
Dropping from the veils of the morning to where the cricket sings;
There midnight's all a glimmer, and noon a purple glow,
And evening full of the linnet's wings.

William Butler Yeats, from *The Lake Isle of Innisfree*

THROUGH their million-year history, humans and their hominid progenitor species have been anything but static. Perhaps because of a desire to escape their fellows, perhaps because of a desire for peace, or perhaps for reasons we will never know, our earliest ancestors migrated from an "Eden" in Central Africa to populate Eurasia and Australia. More recently, perhaps 13,000 years ago, the remote descendents of these early pioneers crossed an Ice Age land bridge between Siberia and Alaska to begin the human occupation of the New World.

All pre-human and most human territorial expansions occurred before the development of written record-keeping, so it is difficult today to estimate the ratio of successful to failed expansions. But analogies can still be drawn from the archeological record.

PALEOLITHIC MIGRATIONS

Approximately one million years ago during the Old Stone Age (Paleolithic era), bands of *Homo erectus*, the first hominids capable of long-distance bipedal locomotion, trekked across arid terrain connecting Africa and Asia. It may have been population pressure, environmental change, or some unknown factor that sparked the migration of these first, pre-human pioneers.

No longer could these migrants depend upon the mild climate and abundant food supplies of tropical Africa. It was necessary for them to learn various skills enabling survival in unfamiliar environments.

As they climbed the slopes of various mountain ranges, our ancestors would have noticed a distinct decrease in ambient temperature. Even their ample supply of body hair was not enough. Some genius rose to the occasion and noted that skins of slaughtered animals could be used as heat-retaining body covers. Another nameless protohuman observed that natural fires could be maintained by adding wood and leaves and used to cook food and provide heat.

For the success of these early migrations, it was necessary to use the skins of local animals as clothing and to utilize local resources to maintain fires. *Homo erectus* would not have gotten very far if he had to return to Olduvai Gorge in Kenya every time a fire ran down or an animal skin wore out.

The out-of-Africa territorial expansion of *Homo erectus* bands was likely limited by the extent of the Eurasian landmass. It was an early human of our species, *Homo sapiens*, who discovered a method of expanding beyond the Asian continent.

If you consult a map of present-day southeast Asia, hundreds of kilometers separate Australia from major islands of the Indonesian archipelago. But at various geological times sea levels were lower and the water barrier between Asia and Australia was less daunting.

About 60,000 years ago, some brilliant human must have pondered this reduced waterway and noted that logs and natural rafts could survive ocean voyages. Trees could be cut and joined together with vines to form natural rafts. In periods of calm seas and clear skies, people could float (or perhaps

row) across the narrow seas. In this way, the ancestors of the Aboriginal People spread their culture to Australia and New Guinea.

No historians or scientists witnessed this historic migration, but it could not have succeeded unless the migrants quickly learned to use local trees and vines to prepare their island-hopping rafts.

The final Paleolithic migration, and one of the most significant, was the peopling of the New World. Earlier than 13,000 years ago, small bands of humans crossed an Ice Age land bridge from Siberia to Alaska. Perhaps supplemented by a few Europeans who had migrated westward across the Arctic ice sheet, the descendants of these migrants fully occupied North and South America within a few millennia of their arrival. As sixteenth-century European explorers and settlers were to learn, the Native Americans developed cultures that were superbly adapted to the environments they encountered.

Neolithic and Bronze Age Migrants

Around 6,000 BC, a new era of human development, The New Stone Age or Neolithic begins. Human capabilities altered as people began to replace a free-roving, hunter–gatherer existence with settled town life. Architecture improved, as did animal husbandry and agriculture.

In the Mediterranean basin, keen observers must have noted how large nautical birds, such as swans, can utilize their feathers as sails and be pushed by the wind against a river's current. The Nile river boats, some of which have been preserved in tombs, would be instrumental in uniting Egypt into a national entity.

Before the invention of writing, some of these crude craft were used to explore the islands closest to Egypt—Crete and the other Cyclodic isles. Perhaps using craft not unlike those described in the biblical legend of Noah and the Sumerian epic of Gilgemesh, early civilized humans began to island hop across the Mediterranean.

As the Bronze Age dawned with advances in literacy and mathematics, some of the colonists from North Africa and West Asia began to contribute to the art of ship design. Long before the Classical era, keel-equipped ships, originally invented in Minoan Crete, completed the exploration of the Mediterranean Sea. Certainly before 1,000 BC, humans had crossed the English Channel and ventured into the Atlantic.

Once again, native materials must have been extensively used by these explorers and settlers. Their expansion would have been greatly limited if a

ship had to return to Tyre, Memphis, Ur, or Knossos every time a sail required mending.

Although the keel was a major innovation, it would provide less-than-adequate stability for an early sailing ship attempting to traverse the stormy Pacific. Several thousand years ago, a genius in New Zealand must have realized that greater stability in rough seas would result if several canoes were lashed together side-by-side to produce the first catamaran.

Over the course of several millennia, the pre-literate Polynesian people used these craft to island hop across the vast Pacific Ocean, sometimes navigating between tiny islands separated by thousands of miles of open sea. Navigation instructions for these epic journeys were passed on in the form of memorized epic poems. Everywhere they ventured, the Polynesians learned to develop and exploit the local environments in their island habitats.

Historical Migrations

During the Iron Age, in the fifth century BC, Greek scholars including Thucydides and Herodotus produced the first written histories. Accurate record-keeping subsequent to this development resulted in better knowledge of human territorial expansion during and after the Classical era.

This was the time of the first great empires—the Athenian, Persian, Hellenistic, and Roman. Colonies of existing city states were no longer established only by private individuals; government also played a role.

One model for historical human territorial expansion was established around 900 BC. Recovering from the Aegean Dark Age, Dorian and Ionian Greeks began to expand from their homelands into southern Italy and Asia Minor. What resulted was a "city-hopping" type of expansion in which migrants would first establish a city state mirroring the ideals of their distant home and then, in turn, send out expeditions to establish new colonies. Naples was established in this manner, as a colony of Cumae around 600 BC. Many Greek-established towns around the Black Sea evolved to become major cities of Russia and neighboring countries.

Human population was increasing in this period, and technology was advancing. Unfortunately, this technological advance manifested itself in warfare. Colonies of rival empires engaged in constant battle, in some cases for centuries.

People living in the modern west are used to thinking of progress as a constant upward march, but this is not an accurate historical perspective.

Attempted territorial expansions have not always succeeded. Because of advances in written record-keeping, we know a great deal about historical expansions that failed, as well as those that succeeded.

One notable failure was the expansion of Norse culture starting around 800 AD. The Vikings were a warlike people who preyed upon other cultures they encountered. Viking longboats, equipped with flexible keels, oars and sail, were superbly adapted to the treacherous North Atlantic.

By 930, the Vikings had spread far from their Norwegian origin~~,~~ to occupy Iceland. In 986, they reached Greenland. Around 1000 AD, it is thought that Viking ships had sailed to Baffin Island, Labrador and to their New World colony called Vinland.

But over the next few centuries, the Viking tide retreated. Perhaps their failure was due to climatic change or perhaps it was do to violent competition within Viking society. Certainly, the violent reaction of Native North Americans to Viking predations played a role in the demise of Norse America. Another possible contribution to their failure is Viking dependence upon pillage and trade, as opposed to the development of indigenous industries utilizing local resources.

A few centuries later, history witnessed on of the great "what might have beens" of all time. In the early fifteenth century, Ming Dynasty China constructed a huge fleet of enormous ocean-going junks and used these vessels to visit ports throughout Asia and Africa

With the support of Ming Emperor Yung-Lo, the Moslem eunuch admiral Zheng Ho used these junks—some of which measured 130 meters bow-to-stern and had crews of 500 men—to show the flag in Asian and African waters and ship novelties home to the court. Unfortunately, policy changed upon the death of the emperor; the fleet was recalled and the junks rotted at their piers. Although Imperial China certainly had the technology to spread its culture around the globe, the will for such an endeavor was lacking.

It was left to fifteenth-century European powers with much fewer resources than Imperial China at their disposal, notably Portugal and Spain, to initiate the Age of Discovery. Using the newly developed caravels, Portuguese navigators were encouraged by Prince Henry the Navigator to explore, fish, and trade farther from home. Some have speculated that the comparative scarcity of resources in tiny Portugal led to these explorations around Africa and to the far ports of exotic India.

Driven by greed and religious fervor (some would call it bigotry), Spanish Conquistadors followed Columbus to the New World in ships not derived from those of Prince Henry. Rather than settling in their new Caribbean and South American holdings, most Conquistadors sought to

make it rich and return to Seville on the backs of native American and imported African slaves. It is a good thing that these slave societies were ultimately supplanted in the New World by the somewhat freer colonies of northern European powers.

After the American Revolution, the 13 former British colonies were huddled along the eastern coast of the North American continent. Thomas Jefferson proved to be one of the most visionary US presidents when he commissioned the Lewis and Clark expedition to begin the exploration of the vast continental interior.

The 13,000-kilometer trek of the Lewis and Clark "Corps of Discovery" began near St Lewis in May 1804, crossed the continent to the Pacific and ended in September, 1806. Since weight limitations were substantial, food supplies for the 48 men in the expedition were supplemented by hunting. With the assistance of friendly Native Americans, notably Sacagawea and her French-Canadian husband Toussaint Charbonneau, members of the Corps of Discovery were able to supplement their diets with local vegetation, thereby learning how to truly "live off the land.'

The success of the Lewis and Clark preliminary continental survey led to further exploration and the westward migration of the nineteenth century. Settlement would have been considerably slowed if efficient means of transporting people and baggage westward and frontier products eastward did not exist.

One efficient transport mode was the Conestoga Wagon. These "Prairie Schooners" had boat-shaped bodies topped with white sail-like canvas bonnets. Pulled by teams of horses, mules, or oxen, they could carry as much as 7,000 kilograms and were about 3 meters in length.

These wagons were equipped with tool kits so that repairs could be made *en route*. Such a provision was essential, since the nearest repair facility might be almost a thousand kilometers distant.

Although the Conestoga Wagon was instrumental in opening the American West, transcontinental transport using this method could not keep to a timetable. Human passengers found them very uncomfortable and they were hard on the animal teams providing the motive force.

A vast improvement on the Prairie Schooner was the Transcontinental Railroad, which was completed in 1869. Surveyed by the US Army Topographic Corps, this monumental project required the support of both the Federal Government and private interests.

As the examples presented above indicate, a number of factors are required for a successful human territorial expansion. These include innovation, the ability to live off the land, a flexible ideology, and a

partnership between public and private sectors. Also necessary is at least a modicum of good luck and a good deal of determination!

FURTHER READING

An excellent, although somewhat dated treatment of early human evolution, authored by a Kenyan archeologist, is Richard E. Leakey's *Origins* (Dutton, New York, 1977), which was co-authored by Roger Lewin. Along with his father Louis and mother Mary, Richard Leakey contributed to our knowledge of hominid evolution in the Olduvai Gorge region of Kenya.

No wooden rafts used by the ancestors of the Aboriginal People to reach Australia have been preserved, but an excellent fictional portrayal of this migration is included in Stephen Baxter's science-fiction novel, *Evolution* (Ballantine, New York, 2003).

An excellent reference discussing the late prehistory and early history of humanity from 35,000 BC to the 500 AD is Jacquetta Hawkes' *The Atlas of Early Man* (St Martin's Press, New York, 1976). Of special interest is her description of how successful migrants adapted pottery styles, architecture, etc., to conform to their new environments.

Many references have examined the sea-faring contributions of the Minoan civilization in Neolithic and Bronze Age Crete. One very readable source is Rodney Castledon's *Minoans* (Routledge, New York, 1991).

Perhaps more than any other group of migrants, the Polynesians may serve as models for ultimate human expansion into the galaxy. You can read about their exploits in an article by Ben R. Finney, "Voyagers into Ocean Space," which has been published in *Interstellar Migration and the Human Experience*, edited by Ben R. Finney and Eric M. Jones (University of California Press, Berkeley, CA, 1985).

The same reference considers the expansion, and later contraction, of Viking culture in a chapter by Richard B. Lee entitled "Models of Human Colonization: !Kung, San, Greeks, and Vikings." The failure of Ming China and the success of fifteenth-century Portugal in initiating the Age of Exploration is also explored in this reference by Ben Finney, in a chapter entitled "The Prince and the Eunuch."

Many sources describe the Lewis and Clark expedition and the opening of the American West. Some of these are reviewed in a paper authored by Les Johnson, David Hardy, Ann Trausch, Gregory L. Matloff, Travis Taylor, and Kathleen Cutting, entitled "A Strategic Roadmap to Centauri." This article was published in *The Journal of the British Interplanetary Society*, vol. 58, pp. 316–325 (2005).