SPACE BIOLOGY

The Human Factors in Space Flight

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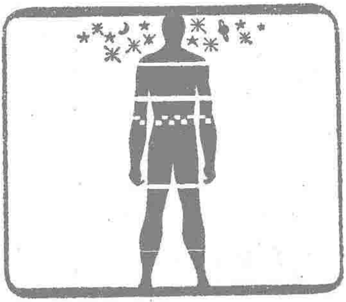

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Foreword

As MAN projects himself into the strange environment of the universe beyond the life-supporting atmosphere of his native planet, he will encounter physical and psychological forces alien to his experience. The success of his personal conquest of these extraterrestrial regions will depend in large measure upon his ability to identify these hazards and to neutralize them with protective devices. Space biology, in this pioneer generation of man's exploration of the limitless vertical frontier, is generally confined in definition to the study of these human factors of space flight. This limited use of the term is incorporated into the title and content of this volume.

This is not a textbook of space biology, in the sense of offering only a description of present knowledge concerning the physiological aspects of manned space flight. Instead it is an historical survey of research accomplishments from the earliest times which have led to our present state of sophistication in this revolutionary field. In addition to presenting the highlights of our present understanding of space-flight problems, ranging from waste disposal to weightlessness, it seeks to offer some indication of the steps by which we have reached our current level of accomplishment. More than this, it attempts to identify the individual scientists, both in the United States and abroad, who have made important contributions to this progress.

The authors take pleasure in acknowledging that many of these scientists have made direct contributions to this book. Three in particular deserve special thanks for their willingness to answer innumerable questions and to discuss in detail important developments related to their fields of specialized research. These individuals are Colonel John Paul Stapp, chief of the Aerospace Medical Laboratory at Wright Air Development Division; Lieutenant Colonel David G. Simons, now at the United States Air Force School of Aviation Medicine; and Dr. Harald J. von Beckh, Technical Advisor to the chief of the Aeromedical Field Laboratory at the Air Force Missile Development Center. Many others in the nation's universities, industry, branches of the military service and other government agencies—as well as their counterparts in other countries—who have been encountered in their laboratories or at various national and international symposia, have also helped in a similar manner. Although it is impossible to mention all by name in this brief foreword, they are identified as sources of information in the footnotes of each chapter.

We must also publicly confess our monumental debt to our wives, Virginia Bushnell and Jane Hanrahan—not only for their typing and proof-reading services, but for their toleration of the strange behavior often associated with the pangs of authorship.

James Stephen Hanrahan
David Bushnell

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PART ONE

Introduction

The Whim and the Wherewithal

MAN is beginning to venture forth into interplanetary space. Already material projections of his creativity have preceded him. Artificial satellites circumnavigate the earth. A man-made vehicle has impacted on the moon. Space probes have reached far outward and are now in perpetual orbit around the sun. Various agencies are planning to place instrumentation on Venus and Mars. And man will not be far behind.

Before living man can penetrate the hazardous vastness of space, many complex problems of space biology must be solved. But much has already been accomplished toward understanding the nature of these hazards and toward perfecting the protective devices which will neutralize the dangers. Space biology became a serious field of experimental research more than a dozen years ago, and the roots of these studies drift far back through time. The history of this scientific and technological endeavor is one of the boldest and most fruitful chapters in the story of human intellectual evolution.

Until man was actually faced with the possibility of space flight, there was slight practical justification for space biology. And before man could prepare to challenge the physical and mental forces to be encountered in space, two developments were required: the desire and the ability. The desire itself is age-old; it antedates recorded history. But the technical ability is new-found. Although the first significant achievements leading toward this ultimate accomplishment date from at least the seventeenth century, it was not until midpoint in the twentieth century that flight beyond the limits of the earth's atmosphere came within man's practical reach. And as the major powers of the world rush to win a foothold in the vastness of space, the human factors of space flight have become a field of intensive scientific research.

Some knowledge of the evolution of man's desire for interplanetary flight and of the development of his sciences and technology to the point where this is now possible is needed for an understanding of the new age of human history into which the world is moving. Each of these major prerequisites reached its necessary present stage through a series of historical steps. The early scientific and technological developments are a part of the recorded history of science and the practical arts. In later chapters there will be frequent reference to many of these early technical contributions. The evolution of the activating motivation, however, is less well documented and is worthy of brief consideration here.

The antiquity of man's desire to enlarge his personal cosmic environment and to escape the confines of the earth is impossible to ascertain. With the dawn of literature of any description, the concept is already well established. A recent book-promotion brochure was probably entirely correct when it referred poetically to man emerging from the cave to begin his journey to the stars.[1] The development of this desire, phase by phase, has been marked by major turning points in human intellectual evolution. This development of an idea is of particular importance for the final achievement of manned space flight, for it encouraged much of the technological advance required.

Marjorie Hope Nicolson, who for five years offered an English literature course at Smith College on "Science and Imagination" and continued her active exploration of the theme of cosmic travel at Columbia University, has brilliantly traced the development of this desire as reflected in the literature available to English readers of the seventeenth and eighteenth centuries.[2] Other individuals have brought parts of this history down to the present and have filled some of the gaps of the earlier story with examples from the literature of other languages. It is clear that throughout history, as recorded in any language, man has yearned for the stars as a young child reaches for the moon.

Because science and technology are always strongly influenced by prevailing social, religious, economic and political circumstances,[3] it is not possible to ignore completely any consideration of mythology, superstitious beliefs or religion. Speculations of this nature, however, have contributed comparatively little to the historical development of the determination to conquer space, and will be considered only as they have stimulated purposeful thought on the subject.

The first serious phase of man's desire for space flight was hampered by ignorance of basic astronomical and meteorological facts. Ancient thinkers had no reason to believe that the atmosphere did not extend upward to the stars, and so it seemed reasonable to contemplate using large birds, winged chariots, golden arrows and similar devices as vehicles for interplanetary travel. It was not until the sixteenth and seventeenth centuries that European scientists began to suspect the limitations of the atmosphere, although natives of the American highlands and of central Asia had long been aware of the adverse effects of great heights. In 1590 the Jesuit padre José de Acosta published his conviction that the thinning atmosphere had been responsible for his affliction in the Andes. Early in the same century Leonardo da Vinci and others undertook Alpine expeditions to observe the mysterious climate at high altitude, as well as for other aesthetic and scientific reasons.[4] But the thinning of the atmosphere was not confirmed scientifically until 1648, when Périer ascended the Puy-de-Dôme in Auvergne with a primitive Torricelli-type barometer and verified Blaise Pascal's deduction that atmospheric substance and pressure decreased with altitude.[5] As late as 1875 the balloonists J. E. Crocé-Spinelli and H. T. Sivel were martyrs in exploring altitude physiology as a field of scientific investigation.[6]

Ancient speculation on space travel which did not consider problems of space biology was yet practical within its own context, and forms an interesting part of the prehistory of astronautics. It was as realistic, in a sense, as the belief, after the famous *Man-High* balloon flights of 1957, that radiation hazards would probably not prove a serious obstacle to space flight[7]—a theory exploded a few months later when the Explorer satellites disclosed the existence of the Van Allen radiation belts.[8]

The earliest anthropological or historical evidence of modern man discovered to date is that of a *Homo sapiens* species already widely dispersed over a great part of the world.[9] And it is from many widely separated sources that the earliest extant traces of astronautical thought appear. Early Babylonian literature, transmitted to us by Persian intermediaries, includes this sort of speculation.[10] Winged anthropomorphic statuary and legends from early civilizations attest to the desire which caused the earth-weary Psalmist to cry "Oh that I had wings like a dove!" and which motivated the ancient Chinese emperor Shun to attempt flight and, with interesting foresight, dabble with the equivalent of parachutes.[11] Solomon, who historically led Israel to the height of its greatness and studded Jerusalem with a temple and public buildings, unhistorically is said to have given the Queen of Sheba "a vessel whence she could traverse the air," which he had made by the wisdom God had given him.[12]

Five hundred years later Anaxagoras, who brought Ionian philosophy to Athens and who remained there some 30 years to teach pupils such as Pericles, Euripides and possibly Socrates, reached the daring pre-telescope conclusion that the moon was a body much like the earth, with plains and ravines, and was inhabited.[13] He also sought to depose the god Helios by maintaining that the sun was a physical entity, probably a burning stone.[14] Charged with impiety and banished from Athens for life, he nevertheless left behind a more rational concept of cosmology and has continued to stimulate thought down to modern times concerning the physical and social environment that will be encountered on heavenly bodies by visiting earthlings.

The intellectual genius of Greece permitted an Anaxagoras to develop a rational concept of the physical nature of planets and stars. It produced an Anaximandros who conceived of man as the product of an organic evolution which originated in simple form and developed a creature who came up from the ooze to stand erect upon land.[15] It stimulated a Democritus to range mentally from the atomic theory of the structure of matter to a vast concept of a universe in which worlds collided—worlds which might or might not have water and flora and fauna.[16] It developed a Plato who could perversely speculate upon political theory or play with myths of souls rising and falling through heavenly regions.[17] It conceived an Aristotle who defined a sharp division between earth and heaven, who had the first glimmerings of an understanding of gravity, who insisted upon the necessity of studying the stars, but who could not admit of the concept of space travel at all.[18] Ultimately, some centuries later, a flickering of this genius produced a Lucian, the leading figure of the revival of Greek literature which flourished under the Roman Empire. And it was with the so-called *True History* of Lucian, composed in the third century of the modern era, that a tale of supernatural travel to other worlds was first fully developed and implanted in true literature.[19]

From that moment on, through Roman times to the present, tales of interplanetary or intergalactic travel have stimulated man's desire. More than this, they have encouraged him to expand his scientific knowledge and to enlarge his technology to the point that the National Aeronautics and Space Administration is already carefully preparing the first true astronauts to penetrate space in Project Mercury.[20] But before modern science and technology could accept as valid a concept so staggering, a long evolution of human desire to explore other worlds followed a long trail through a maze of fanciful stories, gradually acquiring greater validity as the fiction became more scientific, becoming more practical as new technologies developed.

Lucian, a serious philosopher and prolific writer upon matters philosophical, was the first to compose a full story of extraterrestrial adventure. He was bolder in imagination than Diodorus of Sicily, who three centuries before had told of Abaris and his flight around the world on a golden arrow; or than Cicero, who used a dream to provide the elevation necessary for a view of the entire universe; or than Plutarch, who pondered the moon and the possibility of life existing there.[21] Lucian ranged far through space and encountered near-human life in remote regions of the universe. He sought rational explanations of the problems involved in such a journey, and established a pattern followed by writers of later centuries.[22]

Even on far-flung frontiers of civilization during the so-called Dark Ages, man sought to add a third dimension to his existence. The legends of Britain, for example, tell of a ninth-century king named Bladud who flew on feathered wings. Elmer of Malmesbury was another who would take leave of the earth's surface, and John Damian, abbot of Tungland, would fly from Sterling Castle to France. All of these tales had important effects, for they continued to excite imagination through the writings of Geoffrey of Monmouth, John Stow, Michael Drayton, John Taylor, John Milton, John Lesly, and William Dunbar.[23] But none of them seems to have matched the intellectual boldness of Lucian. It was not until the great period of fifteenth-century geographical exploration and the overseas expansion of western Europe, beginning with the work of Portugal's Henry the Navigator, that men again seemed to have the imagination to leap off mentally into the unknown with the courage of Polynesian seafarers.

Explorations in Africa, the discovery of the Americas, and the definitive rediscovery of the Far East brought unknown worlds into the ken of Europeans. And shortly thereafter, Lodovico Ariosto, in his *Orlando Furioso,* sent Astolfo, inspired by a visionary suggestion of St. John the Evangelist, on a trip to the moon.[24] Even the followers of John Calvin, who vehemently opposed the concept of human flight as being contrary to God's deliberate withholding of that power,[25] added fuel to the desire by their public deliberations upon the subject.

The real turning point in the development of man's desire to penetrate the seemingly limitless regions of the universe came with an equally important turning point in the history of science. This was the scientific revolution which began about the time of Nicolaus Copernicus and the anatomist Andreas Vesalius, both of whom published their scientific bombshells in 1539. During the next two and one-half centuries the pioneers of the new revolution overturned traditional authority and established science as a methodical, inductive investigation of nature. As one historian of science, A. R. Hall, has written:

> Much more has been learnt about Nature, from the structure of matter to the physiology of man, in the last century and a half than in all preceding time. Of this there can be no doubt. But the scientific revolution ends when this vastly detailed exploration began, for it was that which made such investigation possible.[26]

The trail-blazing giants of the new science, men like Galileo Galilei and Johannes Kepler, provided solid knowledge about natural laws and distant worlds which churned man's desire to explore those remote regions. True, traditional fantasies continued to appear in print, like the earlier speculation of Francis Bacon, who wondered about the possibility of human flight by means of fowls, or that of Francis Godwin, who sent Gonsales to the moon. Miguel Cervantes referred to a flight near that orb by Torralba and his lackey Zaquiel, and the Satan of John Milton performed the last of the truly supernatural cosmic voyages. But with Galileo's confirmation of Anaxagoras' concept of lunar topography, with the heliocentric theories of Copernicus, and with Kepler's formulation of the laws of planetary motion, scientific elements began to be added to the tales. Kepler himself wrote one of the best tales of cosmic travel ever written.[27] Yet this was also the period when William Shakespeare not only struggled with the legacy of 44 spelling variations of his family surname[28] but also touched in his works upon every conceivable subject except space flight.[29]

This was the transition period between the supernatural and the scientific. John Donne, a great poet and true humanitarian (and author of a later Hemingway title), demonstrated his debt to Kepler. But Athanasius Kircher, the German Hebrew-teaching Jesuit, gave up teaching to invent the magic lantern, study hieroglyphics and archaeology, and write in Latin his *Itinerarium Extaticum,* which included a grand tour of the heavens in the old style with an angel guide. Robert Burton put to one side his contemplation of the causes, symptoms, and cures of melancholy and wrote in his *Satyre Menyspée* of a trip to the moon. Cyrano de Bergerac—who published fantasies in 1656 and 1662 on the nations and empires to be found on the moon and sun, and who also provided inspiration for Rostand's later tragedy about the person with the soul of a poet but a nose of astronomical proportions—conceived the first literary journey into space by means of rocket ship. And during this same transition period in the development of astronautical thought, John Wilkins, a founder of the Royal Society, influenced by the recent translation of Lucian's *True History* and the works of Kepler and Godwin, turned romance toward science by writing a treatise with the lengthy title: *Discovery of a New World: Or, a Discourse Tending to Prove, that it is Probable there may be another Inhabited World in the Moon.*[30]

After this period, especially after Newton published his *Principia,* the pattern was set. More than ever, man desired to incorporate the universe within his personal realm, but now he began to struggle with reality instead of pure fantasy, and to seek the means of making his age-old dream come true. With only a few backsliders, a phalanx of pseudoscientific and semiscientific writers began to pave the way to the science fiction writers and astronautical planners of today, all expressing the desire to reach beyond the confines of the earth. They even began to suspect and take into consideration some of the human-factor problems inherent in such projects. Kepler had already toyed with the problem of breathing in an airless environment, and both Kepler and Wilkins had already considered the problem of physical motion in a subgravity field.[31]

This transition period, when the traditional considerations of the physical world yielded to the radically new concepts concerning the nature of man and his universe, was also a period of great religious ferment. Science affected religion, and religious speculation in turn affected astronautical thought. The egocentric nature of man had survived its Copernican shift from the center of our solar system to a whirling orbit somewhat removed from the center. It had adjusted, too, to a mechanical universe in which fixed, unchanging physical laws relieved the heavenly host of the responsibility for the proper regulation of planetary and stellar motions.

The effect of these new ideas upon religion is apparent, and their direct effect upon astronautics was reinforced indirectly by spiritual speculation. Deeply religious Christian Huygens—who announced the existence of the rings of Saturn, discovered improved methods of grinding lenses, harnessed the pendulum to regulate clocks, determined acceleration due to gravity, and proposed the wave theory of light—also stated that he could not but "sometimes think that it's not improbable that the rest of the Planets have their Dress and Furniture, and perhaps their Inhabitants too as well as this Earth of ours."[32] Emanuel Swedenborg, the Swedish mathematician, scientist, philosopher, and founder of the religious sect bearing his name, wrote in his *Earths in the Universe* that there are "very many earths inhabited by man . . . thousands, yea, tens of thousands of earths, all full of inhabitants."[33]

Voltaire, high priest of the onrushing Enlightenment, that delightful period when, in theory, reason ruled, reversed the theme of Kircher's *Itinerarium Extaticum* with his satirical *Micromégas*. According to his story, a gigantic traveler from a planet of the star Sirius visited Earth in the company of a friend from Saturn. As they looked about in the midst of sophisticated mid-eighteenth-century European civilization, they commented sardonically upon existing customs and behavior.[34] Thomas D'Urbey had already adapted Godwin's *Man in the Moon* to the comic opera *Wonders in the Sun*.[35] On into the first half of the nineteenth century the theme of interplanetary or interstellar travel flowed from the pens of earth-bound men, including that of Edgar Allan Poe.[36]

About midway through the nineteenth century a major new period of astronautical thought evolved. It was signaled by the birth of both modern science fiction and serious consideration of the technical problems of space flight. Jules Verne blazed the trail for the modern extraterrestrial excursion within a seemingly scientific context, and Konstantin Eduardovich Tsiolkovsky took the first, deliberate, purely scientific step into space. Jules Verne, born the very year that the famous military rocket specialist William Congreve died,[37] sharpened his literary skill on plays and librettos. He then abandoned drama to write in rapid succession an enormously successful series of semiscientific adventures in which he foretold with astonishing correctness a number of later technological developments. The first of his astronautical romances, *From the Earth to the Moon*, was published in 1865.

Calling upon his brother-in-law, a professor of astronomy, to provide technically correct background for his story, Verne was able to include precise calculations of the trajectory and velocities involved in the takeoff and other aspects of the lunar journey.[38] The method of propulsion was bizarre—a giant cannon 900 feet long weighing 68,000 tons. But it showed that Verne understood the magnitude of initial thrust necessary to overcome the force of gravity to the extent required to reach the moon. The space vehicle itself was an aluminum projectile equipped with various emergency survival devices—a literary forerunner of the Mercury capsule to be used in the United States manned-satellite program.[39]

In 1957 a periodical devoted to furthering the conquest of space published a short article calling attention to a series of Verne's predictions which are both fantastic in their accuracy and amusing in their implications. Almost a hundred years before Vanguard I, Verne wrote of a journey into space in a vehicle weighing 20,000 pounds, launched from a site in Florida at latitude 28° N., and fired aloft by a "Baltimore Gun Club." Vanguard I, in 1957, was planned to weigh 24,000 pounds and would be launched from the Air Force Missile Test Center in Florida at latitude 28½° N. The Missile Test