9.

Survival by Design

Oil Crisis, the Middle East, and the Quest for Lunar Settlements

Pamela Karimi

Strategies for Survival in Arid Lands

Stretching from the Atlantic Ocean to the Central Asian plateau, the region of the Middle East and North Africa (MENA) is largely dominated by arid lands which have brought about distinct forms of societal organization, political order, and manmade settlements. The struggles for survival in the desert demanded the invention of complex forms of sustainable design or constant seasonal migration. These taxing living conditions led many to proceed to abolish this way of living on the cusp of the region's entry into the modern world. Historians have argued that arid lands often gave colonial and pseudo-colonial powers a ploy to justify their occupation of the deserts (including those of the MENA region) in ecological terms.[1] Colonial powers frequently viewed deserts as devastated areas in need of renewal and repair. The failure of the native population to sustain fertile areas and to make the best of the natural resources available to them was, for example, highlighted in the aftermath of the Second World War when the US Department of the Interior brought aid to the Middle East through such public programs as the Point IV and Tennessee Valley Authority as well as private interests such as the Development and Resources Corporation (with ties to government bodies such as the Khuzestan Water and Power Authority led by David Lilienthal). These public and private entities would soon build dams across the region's major rivers (Fig. 9.1), thereby disrupting centuries-old sustainable local methods of careful water management such as the *qanat*, or underground tunnel system, which brought infiltrated groundwater and spring water to the Earth's surface using only gravitational force.

Megan Black explains that such hierarchies of technical ability laid the foundations for an ideology that would gain prominence in all US-led initiatives, including the Point IV program's concept of "resource

primitivism," which held that "primitive people misunderstood and undervalued their own resources and needed constant supervision."[2] Black continues: "Resource primitivism revived the age-old colonial logic that insisted 'primitive' people failed to value and tend land properly and should therefore be dispossessed of it."[3] By the mid-twentieth century, such environmentally tuned architecture as the basket homes of Iraq's marshlands and the wind towers of the Gulf states and Iran were on the verge of extinction (Fig. 9.2). This gradual disappearance affected the region's environmental management negatively. For example, as evidenced by the Khuzestan Development Program's reports, now housed in Princeton University Library's special collections, the modern irrigation canals that replaced the ancient *qanat* system (Fig. 9.3) completely interrupted older canals and cut access to water for many small villages.[4]

The idea that local design and culture were not sufficient for modern life was internalized by the native populations and is best captured in their imaginative writings, including one of Iran's earliest works of science fiction. In *Rostam in the Twenty-Second Century* (1934), penned by Abdolhussein Sanati Zadeh Kermani (1896–1973), the iconic conqueror from the eleventh-century Persian epic the *Shahnameh* returns to life. Rostam's character was probably inspired by the American science fiction protagonist Buck Rogers: a space hero created by Philip Francis Nowlan (1888–1940) in the 1928 pulp novella *Armageddon 2419* AD, who later appeared in a comic strip, radio show, and television series. *The Adventures of Buck Rogers* became an important part of global popular culture, spawning many similar science fiction stories. Unlike Buck Rogers and other heroes of American science fiction, however, Rostam finds it difficult to comprehend and manage the tools of modern technology.[5] He is portrayed as an embarrassingly emotional man who cannot comprehend the significance of civilized life in the twenty-second century (Fig. 9.4). More importantly, the whole novel adopts a racist and particularly anti-Semitic tone by rendering the Jewish people as intellectually flawed, especially compared to their white European counterparts. In the preface, Iran's renowned intellectual and the pioneer of modern Persian fiction, Mohammad-Ali Jamalzadeh (1892–1997), encourages readers to further their knowledge of their standing as a civilization in the modern world. Included in Jamalzadeh's suggested list of supplementary readings

Fig. 9.1 (left) Dez Dam, Andimeshk, Khuzestan province, Iran, 1963

Fig. 9.2 (opposite, above) Traditional ice storage house with wind catchers for cooling in Yazd, Iran, 2007

Fig. 9.3 (opposite, below) S.H. Rashedi, aerial view of the qanat system in Bam, Kerman province, Iran, 2014


همینکه چشمان رستم و زنکیانو را بستند هر دو نفر را در طیاره نشانیده
و تاکید نمودند که از باز نمودن چشمانشان خودداری نمایند

جانکاس از عقب موتورسیکلت چندین میله فولادی که برویهم تا شده بود
در آورده و برای نشستن رستم جائی تهیه نموده و رستم را بترك خود نشانید
صداوتق توتق موتورسیکلت بلندشد وبجانب نقطه‌ای که تا گردان جانکاس
و زنکیانو ایستاده بودند بسرعت روان گردید

در این شهر یکنفر باسیمای کرفته و عبوس دیده نیمشود و همه خوش
بین خوش حال و خون گرم‌اند همه خوشگل ووجیه و خوش اندام‌اند
هر کسی وظیفه دارد که اعمال یومیه خودرا یادداشت نماید ایدآل همه
این است هرچیزی را بحد کمال برسانند

بجز دریاچه‌های مملو از گاز غلیظ و کوههای بسیار مرتفع بدشکل
چیزی نمیدید و چنان بوحشت افتاد که بهتر آن دانست زنجیری را که
جانکاس نشانش داده بود بکشد و بخوابد

by French and German authors is a book by the eugenicist Henri Decugis (1874–1947).[6] In this way, Iranians are told to rethink their identity as a nation—to reevaluate their perceived stagnancy in order to cope better with the modern world. Iranians in the 1930s would have been astonished to learn that just a few decades later their very own methods of design and life would become a model for envisioning the future of humanity. This became particularly evident in the years leading up to the notorious energy crisis of the early 1970s. First in science fiction and then in actual scientific investigations, the inclination to look into the Middle Eastern desert blossomed much earlier than the 1970s, and particularly with the start of the Cold War.

The Future Is a Desert

Invoked by visionaries and science fiction authors, the desert-savvy architectural heritage, design culture, and raw resources of the Middle East were critically influential for the three decades that came to be known as the "Environmental Age" (1960s–80s).[7] During the Cold War, many imaginary and futuristic outer-space settlements were envisaged in desertlike locations, most notably the arid parts of the MENA region. The MENA desert with its resources is often seen as an image of the future of humanity in the face of a catastrophe. These very arid lands had already proven their value to Europeans on the cusp of the Industrial Revolution at a time of growing awareness of the lack of natural resources within the European continent. The portions of the world that became subject to European occupation lived "through the ecological catastrophe brought about by European colonialism and its repercussions."[8] The social and political realities of the colonial past, which continue to affect us to this day, thus came to shape the imagination of those who envisaged the future of the world amid a lack of resources on Earth, even in the course of a probable apocalypse, and a likely consequent massive migration to other planets. Notably, Ray Bradbury's *The Martian Chronicles* (1950) depicted desert landscapes with a thin atmosphere which humans could breathe. The images that accompanied these tales, whether in print form or through moving pictures, were inspired by the built environment, desert landscapes, rare natural resources, and even the MENA people themselves (albeit often through sensationalized and imprecise representations).[9]

Fig. 9.4 Pages from Abdolhussein Sanati Zadeh Kermani's Rostam dar Gharn-e BistoDovvom [Rostam in the Twenty Second Century] (Tehran: Khandaniha Press, 1952), featuring the irrational Rostam and utopian life in the Western hemisphere. University of Utah Libraries

Similar to these landscapes that were subject to colonialism in the nineteenth and early twentieth centuries, the projected imaginary landscapes in science fiction are destined to be colonized. *The Martian Chronicles* invokes themes of colonization and the end of civilizations, which recur throughout the text. The indigenous golden-eyed and brown-skinned Martian peoples are portrayed as an advanced culture with telepathic abilities who have tamed the planet's deserts. The lives of the Martians are disrupted by the arrival of humans seeking to colonize. A double extinction bookends the novel—a pandemic among the Martians and a nuclear holocaust on Earth—both directly caused by humans. Early on, a dialog between two of the Martian characters presages the looming genocides and the envisaged shape of that as a (Middle Eastern) desert:

> "You'll be all right tomorrow," he said. She did not look up at him; she looked only at the empty desert and the very bright stars coming out now on the black sky, and far away there was a sound of wind rising and . . . waters stirring cold in the

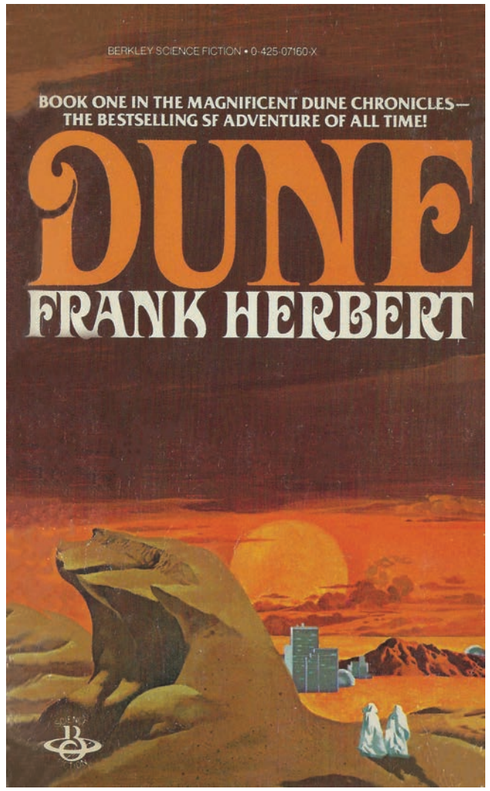


Fig. 9.5 Cover of *Dune* by Frank Herbert (1965), Chilton Books edition, *c.* 1982

> long canals. She shut her eyes, trembling. "Yes," she said. "I'll be all right tomorrow."[10]

The desert world Altair IV was also depicted in film as the eponymous *Forbidden Planet* (1956). Once more, the future is a desert; and the extinction of an advanced civilization and the settler colonial mindset is central to the film's plot. The Krell, who inhabited Altair IV for millions of years, had developed technology far beyond humanity's abilities, capable of manipulating matter on the atomic scale with the power of their minds by tapping a machine powered by "9200 nuclear reactors" that spanned "8000 cubic miles." Yet, in a Freudian twist, the Krell went extinct when their own technology released their "monsters of the id."

Another arid land that served as a science fiction backdrop is that of Frank Herbert's novel *Dune* (1965), and its film and TV series adaptations (Fig. 9.5). Although each motion picture version projects a slightly different vision of the future, they all remain committed to the main narrative arc of the book, which is overtly centered on the desert cultures of the MENA region. Despite being arid and inhospitable, the desert planet Arrakis is the sole source of the priceless "spice" that enables space exploration. The "spice" thus serves as the interstellar equivalent of petroleum, which fuels Earthbound transport, commerce, and military power. Just as petroleum fuels conflicts on Earth, so too does "spice" give rise to conflicts among the powerful Houses of the Imperium in the Dune universe, a place in the very distant future of our own universe. Remarkably, the director of the 2021 film version, Denis Villeneuve, shot many of his scenes in Jordan's Wadi Rum, standing in for Arrakis—the same canyons of rock and sand where David Lean shot iconic scenes for *Lawrence of Arabia* (1962). In both *Dune* and *Lawrence of Arabia*, the protagonist is none other than a white savior. The star of the *Dune* plot, Paul Atreides, is a white man, who is

fabricated as a savior and given Arabic honorifics and messianic titles, such as Lisan al Gaib and Mahdi. The novel describes the Fremen people as descendants of the Zensunni Wanderers, whose belief system Herbert modeled after both Zen Buddhism and Sunni Islam; in Dune they follow the divine Buddallah. The Zensunni religion endows water itself with a mystical quality: "Bless the Maker and all His Water. Bless the coming and going of Him, May His passing cleanse the world. May He keep the world for his people."[11] Reference to the design culture of the Middle Eastern desert is also accentuated in Herbert's text. For example, to survive in the waterless environment, the Fremen natives depend on a "stillsuit," which is designed to preserve the body's moisture—perhaps one can imagine that the suit is a more sophisticated form of traditional Arabian desert costumes such as the *qamis*.

Design strategies for survival in the desert are likewise portrayed in other cinematic representations of life in the face of the scarcity of natural resources. Remarkably, thoughtful methods of capitalizing on scarce natural resources on other planets are often visually cued in film through Middle Eastern desert landscapes. Perhaps most famously, this phenomenon was captured in the Tunisian Berber village that became Tatooine, the iconic backdrop for the original *Star Wars* film (1977), and a venue for extracting water from the existing, albeit limited, air humidity. Borrowing heavily from Herbert (among others), the director George Lucas set the film's opening scenes on a critically dry desert planet. Lucas's debt to Herbert is perhaps made clearest in the original treatment, in which the famous droids R2-D2 and C-3PO of the film version are not yet incarnate, and in their stead we have two "bureaucrats":

> The two terrified, bickering bureaucrats crash land . . . while trying to flee the battle of the space fortress. They accidentally discover a small container of the priceless "aura spice" and are rummaging around the rocks pushing and pulling each other trying to find more when they are discovered by Luke Skywalker and taken to his camp.[12]

While this subplot never made it beyond the treatment, we learn in the films that the Rhett Butleresque starship captain Han Solo made his living running spice. Additionally, settlers must rely upon "moisture farming" to extract water from the arid atmosphere. The desert also has its own mysterious native tribe of "Sandpeople." Like the Fremen, the Sandpeople are portrayed as fierce warriors who are capable of living with minimal technology on the high desert. Desert planets reappear later in the series, in the worlds of Geonosis and Jakku, which echo Tattoine's blasted ecosphere.

Thus, to reiterate, the production of all these futuristic tales with the central theme of the (MENA) desert paralleled American interest in the raw resources of the Middle East. Recall, for instance, that *Dune* is a novel about the future of humans on other planets, but it is one that captures the environmental policies of the Cold War and the sociopolitical atmosphere of the postcolonial world (the book was released three years after the Algerian liberation). Imperial and colonial ambitions and science fiction are directly related because "both are concerned with issues of travel, migration, alterity, colonization, empire, and power."[13] Set in motion by colonial ambitions, survival design strategies in the deserts of the Middle East played an important role in mainstream popular culture in the United States, particularly during the early 1970s oil crisis, which necessitated a way to avoid reliance on fossil fuels. However, such strategies were dismissed by major actors within the scientific community. Early accounts of scientific space exploration attested to this point, as the following section reveals.

Escaping Oil Crisis

The early history of space exploration is inextricably linked to the geopolitical context of the peak of the Cold War. The United States and the Soviet Union had both harnessed the destructive force of nuclear energy. The US-led Manhattan Project culminated in the first atomic weapon in 1945. In parallel, the Soviet Union pursued a weapon of its own. Stalin appointed Igor Kurchatov to lead the Soviet bomb effort in the closed town of Arzamas-16 (formerly Sarov) on the Volga River. The Soviets successfully tested their first atomic weapon on August 29, 1949. The fallout from the test was soon discovered by the US, setting off the Cold War. Both sides dived full bore into the development of a weapon of almost unlimited destructive power—the hydrogen bomb, or "Super" as it was known. By 1953, the world had two powers, each capable of delivering hydrogen weapons anywhere on the globe via airplane.

In a few short years, both sides leapfrogged from bomber to missile deployment of nuclear weapons. In the Soviet Union, Sergei Korolëv (1907–1966) led the development of the R-7, the very first missile with the capability to deploy a nuclear warhead anywhere on the planet—or to launch a satellite into space. On August 21, 1957, the R-7 was successfully launched from Kazakhstan's Baikonur Cosmodrome—sporting a payload of a mock nuclear warhead. When the Soviet Union launched the first artificial satellite atop an R-7 just forty-four days later, there was no doubt in the minds of the millions of Westerners tuning in to Sputnik's radio transmitter that the rhythmic pulses they heard could mean only one thing—the ability of the Soviet Union to deliver a nuclear warhead to their front doorstep. On August 14, 1958, then-senator John F. Kennedy spoke on the US Senate floor of the "missile gap" between the Soviet Union and the US:

> We are rapidly approaching that dangerous period which General Gavin and others have called the "gap"; or the "missile-lag period"—a period, in the words of General Gavin, "in which our own offensive and defensive missile capabilities will lag so far behind those of the Soviets as to place us in a position of great peril."[14]

Thus, the stage was set for the Cold War showdown to escalate from the surface of the Earth into the cold reaches of space. The confluence of a series of epochal events in the 1960s and early 1970s created the conditions which led scientists, engineers, and architects to lay down bold plans for explorations of the Moon and beyond. These events were set into motion by many factors, but chiefly by the Soviet Vostok–Soyuz and American Mercury–Gemini–Apollo NASA missions, which commenced with the launch of the first human into space in 1961 and culminated in the landing of humans on the Moon in 1969. In less than a decade, the space frontier had been opened for human exploration. The technical and scientific infrastructure required to mount these missions was vast, encompassing everything from the launch vehicles to the computers, radar arrays, and biomedical technology needed to support manned space pursuits. Importantly, these early advances preceded the semiconductor revolution of the early 1970s, so that the Soviet and NASA programs had to carry out the basic research and develop much of this technology specifically for space exploration, rather than look to pre-existing commercial solutions in industry, and they did so at significant cost.

To create this vast infrastructure and foster manned spaceflight, Soviet and American space programs were lavishly supported. At its peak in 1966, NASA spending constituted 4.41 percent of the federal budget. By contrast, NASA's recent budget is less than one-half of one percent of the federal budget. Naturally, this pre-existing space-industrial complex sought to outdo the golden era of the Apollo lunar landings. Yet, as lavish as these government-supported space programs were, permanent lunar outposts would have required much larger expenditure—expenditure that was becoming increasingly infeasible as the US became more deeply embroiled in Vietnam and Cambodia. A commercially viable incentive was required to provide a plausible revenue stream to help offset the enormous cost. Such an impetus came in 1973, when the Yom Kippur War motivated the Organization of Arab Petroleum Exporting Countries (OAPEC) to embargo their oil exports, culminating in the oil crisis of 1973, which saw the price of oil increase fourfold in less than a year. The rocketing cost of oil sparked the first major interest in renewable energy, including a 1973 plan by the Democratic US congressman Morris King Udall (1922–1998) to eliminate the use of fossil fuels by 2000.[15]

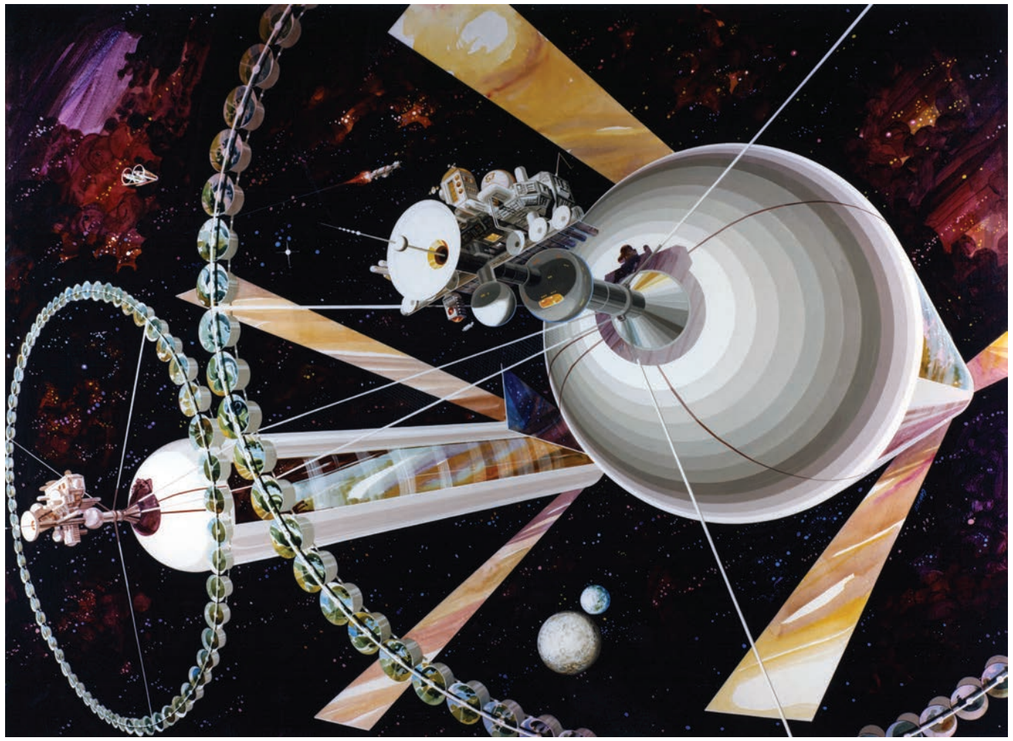


Fig. 9.6 Rick Guidice, illustration of Gerard O'Neill orbital settlements, better known as O'Neill cylinders, 1975

Anticipating ever-increasing petroleum costs, the Princeton physicist Gerard O'Neill (1927–1992) advanced his plan to develop massive space colonies by constructing mile-long artificial cylinders in Earth orbit. The primary commercial purpose for these vast enterprises was to be the generation and transmission of solar energy back to Earth. The materials for "O'Neill cylinders" were ultimately to be brought in from asteroids in orbits beyond Mars (Fig. 9.6). In the wake of the 1973 oil crisis, O'Neill was influenced by

environmental sensibilities, taking his cue from another scientist, Peter Glaser (1923–2014), who wrote fervently about the use of satellites in Earth orbit to gather solar energy. Under Glaser's plan, the solar energy gathered by the satellites would then be beamed back to Earth in intense microwave beams. Picking up on this concept of solar energy generation, O'Neill realized that his proposed space colonies would be solar energy collectors par excellence.[16] Yet despite these additional efforts, O'Neill's concepts ultimately lacked a solid economic foundation, particularly after the oil crisis eased and ground-based sustainable energy became more common.

Whether backed up by scientific claims or by the pop culture of the Apollo era, most ambitious plans for lunar settlements turned out be economically unviable. They were also "haunted," architectural historian Felicity Scott argues, "by the legacy of settler colonialism and its violent and inequitable modes of governance."[17] On one occasion Gerard proclaimed: "In contrast to our experience with expanding civilizations on Earth, in space colonization there would be no destruction of indigenous primitive populations; nothing corresponding to the Indian wars of 19th century America."[18]

Earth Architecture and Regolith Outposts

It is against this backdrop of the tremendously lavish, costly, and primarily orbital settlements that the ideas of the Iranian-American architect Nader Khalili (1936–2008) for more modest lunar structures stand out (Fig. 9.9). In the 1970s, Khalili abandoned his lucrative design business in Los Angeles to return home for a five-year research odyssey amid Iran's vernacular settlements. Soon after, Khalili embarked on a new design project. Using clay, water, and fire, he invented the Geltaftan system, a renewed approach to conventional methods of kiln firing (Fig. 9.7). After extensive trial and error, he sought to improve upon the structural weaknesses of existing adobe architecture by enhancing its resistance to earthquakes. Khalili's work in Iran resulted in a series of building projects (including sandbag shelters) that were made cheaply and ecologically and were particularly apt for the immediate and temporary accommodation of refugees or disaster victims (Fig. 9.8).

However, by the architect's own account, in the political atmosphere of the late 1970s and early 1980s, the world was more fascinated by the future than by the present. So Khalili translated his humanitarian "Earth architecture" into shelters for lunar surfaces. In October 1984, at a NASA-sponsored symposium on the future of lunar outposts, Khalili proposed a method for constructing lunar base structures in situ by using unprocessed or minimally processed lunar regolith (a blanket of unconsolidated, heterogeneous superficial deposits covering terrestrial planets and moons). Titled "Magma, Ceramic, and Fused Adobe Structures Generated in Situ," Khalili's paper envisioned melting the lunar regolith at high temperatures of 900–1200°C to produce magma. In a later iteration of the paper published in 1989, Khalili considered several renewable energy sources, including solar and nuclear, possibly converted into microwaves for the actual melt.[19] The viscous magma would flow through molds to form rib members for shell structures. The packing material between these structural rib members would also be produced directly by sintering the lunar regolith to just below the melting point. The process of sintering allows the glass and silicate particles comprising the regolith to become fused into a compact solid. In the absence of

Fig. 9.7 (opposite, above) Nader Khalili's Geltaftan method in action in a village in the Tehran province, Iran, 1983

Fig. 9.8 (opposite, below) Nader Khalili, prototype for sandbag shelters under construction in Ahvaz, Iran, 1995

Fig. 9.9 Nader Khalili during his explorations in the deserts of Iran, *c.* 1976

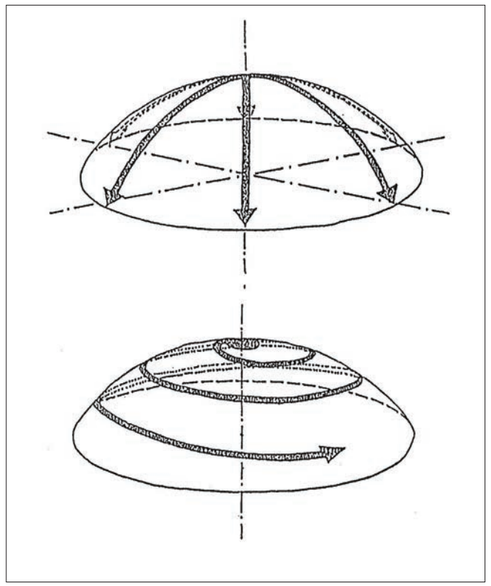
an atmosphere, all lunar settlements would require a minimum of two meters of compacted regolith to protect against long-term exposure to cosmic rays. Khalili noted that this sintered regolith packing material would provide a sufficient safety buffer in less space than packed regolith. The melting and sintering of the lunar regolith which Khalili envisioned have been explored in depth in the years since.[20]

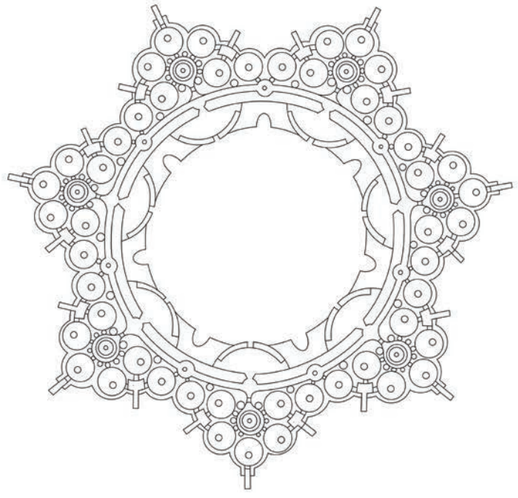
Khalili also proposed that magma could be "thrown" on a centrifugally gyrating platform. Careful regulation of heat applied to the melt would allow for the lunar material to be shaped into any form desired, "such as ducts, panels, pipes, shafts, tunnel rings, and curb modules," while working to economical and technical advantage by using primarily local resources.[21] The resulting components could be brought together into a grand regolith settlement in the form of a circular structure with radiating apses, resembling the floor plans of Persian adobe ice-storage houses or pigeon towers, which appear in the 1989 article in the form of a drawing of the "giant potter's wheel" and mockups of shell structures (Fig. 9.10). Likewise, Khalili's "Plan for Crater Base with Habitation and Workspace for 70 People," a circular structure with radiating apses, calls to mind the floor plans of Persian pigeon towers (Fig. 9.11). Also included in the article is an architectural detail from the nineteenth-century Borujerdi House in Kashan, Iran by the master builder Ali Maryam (Fig. 9.12). Khalili suggests the form of this particular structure as a jumping-off point for casting similar forms in situ with generated magma "either by utilizing existing lunar contours in proximity to the complex, or by forming mounds of lunar soil to desired interior spaces." In particular, Khalili underscores the significance of the "free form" of such structures that could be sculpted effortlessly, "breaking the barriers of the purely geometrical spaces." These free forms, in Khalili's assessment, could "approach hyperbolic, paraboloid shell structures without reinforcing tensile members." Additionally, such forms "could withstand low-gravity forces if . . . fused monolithically and formed in shorter spans, and when their structural membranes are working in conjunction with other geometrical forms."[22]

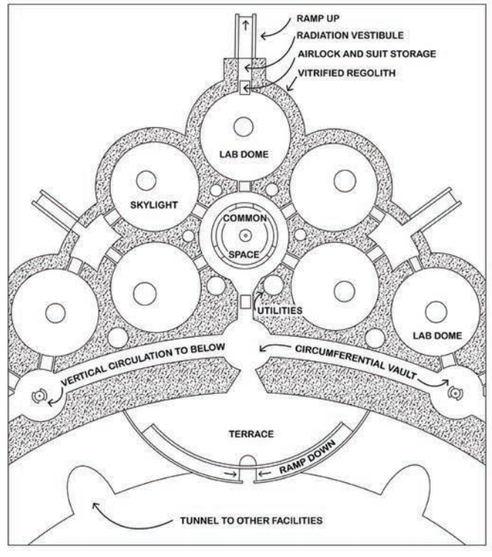
Fig. 9.10 (opposite, above left) Magma creates double-curvature shell structures as it flows along meridians or in spiral troughs, with regolith mound form to be excavated after completion and packed over structure for shielding. Drawing by Pedram Karimi after Nader Khalili, 1989

Fig. 9.11 (opposite, below, left and right) Nader Khalili's plan for habitation and workspace on the lunar surface. Drawing by Pedram Karimi after Nader Khalili, 1989

Fig. 9.12 (opposite, above right) Natural lunar contours sculpted using magma flows to create shielded light scoops and radiation vestibule. Drawing by Pedram Karimi after Nader Khalili, 1989







Khalili's proposed project is far from a romanticized or even nationalistic urge apropos of his homeland, Iran. Perhaps the most prescient suggestion in Khalili's 1989 paper was the proposal to use terrestrial lava tubes as a model to learn from and to prototype his concepts for lunar settlements. These tubes are created by the flow of lava underground. When the lava leaves, a natural cave is left behind. He suggested that the Craters of the Moon National Monument in Idaho could be studied to understand how these initially rocky and lifeless geological formations gradually produce agricultural soil over time, and eventually provide the foothold for plant life to grow. Khalili understood that the same processes could inform settlements both on the Moon and on Mars, allowing future inhabitants to pursue agriculture within these settings. While Martian lava tubes were first observed by the Viking orbiter in 1972,[23] lunar lava tubes were only discovered shortly after Khalili's passing, in 2009.[24] Lava tubes on the Moon and Mars, some the size of small cities owing to the weaker gravities of those worlds compared to that of the Earth, have since become the focus of intense interest as potential sites for the first human settlements.[25] The Resilient Extra-Terrestrial Habitats (RETH) Institute, a project jointly pursued by NASA, Harvard University, Purdue University, the University of Connecticut, and the University of Texas San Antonio, for example, is actively tracking this research direction.[26]

Khalili's sustainable and ecologically minded proposal stood in stark contrast to those set forth at the same panel by contemporaneous construction experts. Noteworthy is a project proposed by a representative from the Portland Cement Company for setting up a cement factory on the Moon to build three-story office buildings.[27] Deeply rooted in a colonial mindset, the company could not have been a more intense contrast with Khalili's vision. Khalili described his dislike of the company's proposal in these terms:

> For the last ten years I have been involved in research, design and construction of buildings made with earth and fire. I have tried to take my building system to the poor countries of the world, where the earth and manpower is plenty. But everywhere I go I see that the Portland Cement Company people are ahead of me and are setting up plans and selling concrete blocks. And here once again I see that they want to beat me to the moon.[28]

Once again, Khalili upholds the desire to contribute to humanity, rather than proposing (or, rather, marketing) a mere profit-making enterprise, as did the Portland Cement Company. Indeed, by all accounts, Khalili's humble yet effective proposal was ahead of its time for proposed space settlements; it was certainly in sharp contrast to the US government-led initiatives and the other major pseudo-colonial development projects mentioned earlier.

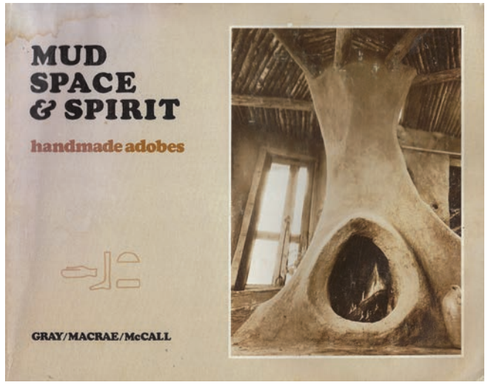
The Many Nuances of "Soft" Design

Khalili's thinking was very much in line with the alternative design projects developed from the countercultural movements in the US and elsewhere in the Western hemisphere. Let us recall specifically the energy-efficient design proposals that were abundantly depicted in popular, user-friendly books, such as *Mud, Space & Spirit: Handmade Adobes* (1976), in which the authors promoted DIY-style constructions out of mud, including grotto-like abodes and pit houses, inspired mainly by Native American desert architecture of the Southwest (Fig. 9.13).[29]

Beyond the field of architecture, concepts of sustainable and ecological design inspired by desert settlements (in the Middle East or elsewhere) were abundantly featured on the pages of important, albeit

alternative, American publications. Take, for example, the 1978 issue of *Co-Evolution Quarterly*, titled "Soft-Tech" and published by the *Whole Earth Catalog*. It was co-edited by the catalog's own editor Stewart Brand (b. 1938) along with industrial designer and a student of Buckminster Fuller's, Jay Baldwin (1933–2018). According to Steward Brand, the term "soft" was inspired by Amory B. Lovins's breakthrough book *Soft Energy Paths* (1977).[30] In lieu of "hard" technologies of nuclear power and environmentally perilous fossil fuels, Lovins promoted "soft" energy forms "such as solar energy, wind and biomass conversion—the use of crop, wood, and other organic waste and, where suitable, perhaps also an ecologically balanced growth of trees and shrubs for conversion to liquid and gaseous fuels."[31] "Soft-Tech" further addressed design and technologies or materials that can physically change states in

Fig. 9.13 Wayne McCall, cover design for Virginia Gray and Alan Macrae's *Mud, Space & Spirit: Handmade Adobes*, Capra Press, 1976



response to varying environmental conditions.[32] The *Co-Evolution Quarterly* special issue takes the concept one step further by presenting "soft" in terms of traditional "soft" building materials such as mud or straw-mud and natural settlements with no industrial intervention. For example, "Soft-Tech" features cool, underground grotto-like settlements like those found in the desert climates of the Middle East. The visual emphasis is on southern Europe (such as Sicily), southern California, and the American Southwest.[33] Accordingly, the front cover features a high-pressure water wheel—an early eco-friendly development in gardening—framed by naghshbandi, a form of sinuating lines and floral patterns used in Iranian book illustrations (Fig. 9.14). Thus, references to desert architecture and Middle Eastern traditions are plentiful but understated and elusive, both in the volume's outward appearance and in its content.

This vast and important body of literature on environmentally sound forms of energy consumption and materials is not the only scenario against which Khalili proposed his project to NASA. More importantly, Khalili's ideas were formed against a backdrop of highly celebrated alternative architectural achievements, including the 1970s work by the Cosanti Foundation initiated by Italian architect Paolo Soleri (1919–2013) in the Arizona desert, which became a testing ground for Soleri's progressive concept of "arcology," a portmanteau of "architecture" and "ecology."[34] Although Soleri's interest in soft, elastic, and moldable materials such as clay and sand ultimately gave rise to soaring, obdurate concrete buildings, the goal was to minimize the carbon footprint. Even though Soleri's creations were solid and massive, as architectural historian Larry Basbea tells us, "his buildings were not static"; "they were understood rather as evolutionary waypoints, architecture in a state not of being but of becoming."[35] Some observers have even attributed the shape of Soler's creations to "sci-fi

futurism, Italian hillside towns and Middle Eastern villages."[36] Interestingly, Khalili and his students participated in Soleri's ceramics workshops in Arcosanti—an Arizona subdivision of the Cosanti Foundation.[37] However, while Soleri's vision became what the critics appropriately saw as predominantly sculptural, handmade, and even decorative, Khalili's focus remained on the function of the "soft" spaces he created.[38]

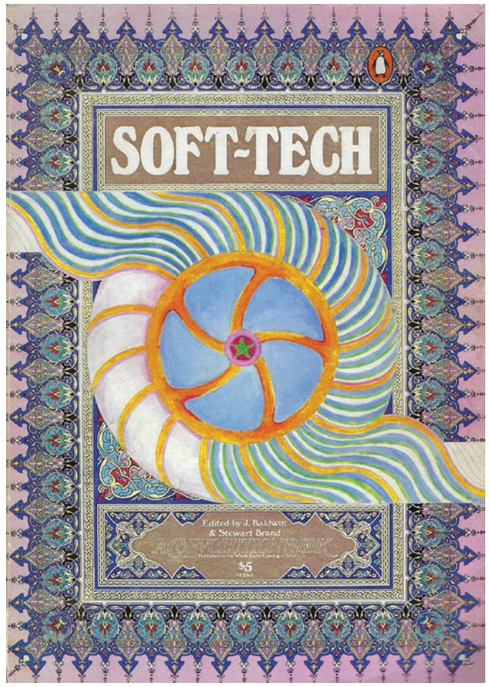


Fig. 9.14 Greenman Cooperative, cover design for Jay Baldwin and Stewart Brand's *Soft-Tech: A Co-Evolution Book*, Penguin Books, 1978

Another prime example in the corpus of ongoing activities around the time Khalili submitted his NASA project is the work of systems ecologist John P. Allen (b. 1929). Allen's deliberations with Paolo Soleri, as well as his expeditions in the deserts of Iran (he worked for the Iranian Khuzestan Project, funded by the Development and Resources Corporation), gave the impetus for Arizona's Biosphere 2, an analog for human settlements on the Moon or Mars.[39] In his autobiography Allen writes: "From the standpoint of surviving crises such as those endured by the Khuzestan Water and Power Project, I analyzed my key team, consultants, and biospherian candidates. Biosphere 2's demonstration of the close-knit bond between humanity and all nature would impact at least as many entrenched interests as had the Khuzestan Project."[40] He goes on to reflect on the ways in which spaces can act upon us. The point of reference in this assertion is an experience Allen had in the summer of 1962 with an abandoned yet intact mosque near the city of Isfahan in Iran. He mentions a characteristic which he calls "organic realism" in architecture, one that has the power to act upon and transform us. He writes of how this architecture did more with less, not by cutting quality but by increasing quality and lessening quantity:

> Spaces can enhance the potentiality of human organisms, as, for example, the way you feel your body straightening to its full height when you stand underneath the center of a Gothic ogive arch. While working on the Khuzestan Project in Iran with David Lilienthal in the summer of 1962, I . . . visited an abandoned mosque in the desert, an hour's drive from Isfahan. Not a single building was left standing near it, but the mosque itself was in very good shape and still being used for special occasions. Standing in its center, my head cocked to take in the dome, I was hurled to the floor by a smack [of realization?] to the back of my head as if from a giant hand. That was my first ah-ha! experience of *Organic Realism* in architecture.[41]

Allen's description indicates a characteristic in the brick and mortar of an old mosque at the edge of the Iranian central desert, which strikes a chord with what Khalili also saw in the desert architecture of Iran, a kind of organically grown and self-sustained architecture that can act upon us and shape our ways of life. However, unlike Khalili's vision, Biosphere 2 became synonymous with what geographer Natalie Koch calls "the spectacle of science"—a platform through which to advance the interests of institutions and to "sell" grand new schemes for the future.[42] Indeed, from its inception, the story of Biosphere 2 was but an ambitious plan that consumed enormous environmental resources and financial means in order to create an analog for life on lunar surfaces that did not function as envisioned. For one thing, Biosphere 2 was never a complete sealed environment. Additionally, the management of Biosphere 2 under John Allen was incessantly embroiled in controversy. After the project's entire expert advisory board quit in 1993, media executive and investment banker Steve Bannon (b. 1953), who later served as chief strategist in Donald J. Trump's presidential administration, became the frontrunner of the enterprise's management. A year later, Bannon removed Allen and his supporters, and embarked on a series of changes that eventually distanced the enterprise from its original mission as a self-engineered replica of Earth's ecosystem for rehearsing living conditions on lunar surfaces. Over time, Biosphere 2 became essentially an exhibition space for the general public.[43]

Decolonizing Survival Narratives

In this article I have demonstrated only a few examples among the broad vested interests of alternative designers, experimental scientists, outside-the-box thinkers, and visionaries who were directly or indirectly inspired by the logic of "organic" design in arid lands. Settler colonial imagination aside, these designers, like their science fiction writer counterparts, hoped to invent ways to save humanity by fostering more sustainable solutions both for life on Earth and for analogs on the Moon or Mars. Given all these examples, what should we make of Khalili's contributions? Why should his lesser-told story be important today? In what ways can this story help us reevaluate the way we think about the future of humanity?

As mentioned earlier, many scholars have interpreted NASA's ambitious plans, spearheaded by such pioneers as Gerard O'Neill, as settler-colonial in character.[44] In the same way, scholars have criticized North American alternative solutions as being essentially settler-colonial. Koch has argued that techno-centric "solutions" to ecological dilemmas, such as Biosphere 2, are but models of environmental injustice and settler-colonial violence which "routinely overwrite histories and presents of colonial dispossession."[45] She further argues that "the ostensibly . . . 'progressive' narratives of techno-science and environmental consciousness can nonetheless re/entrench the . . . unjust power structures of imperialism and settler colonialism."[46]

By contrast, art historian Andy Campbell has aptly argued that Khalili "counter[ed] the confabulist fantasies of his scientific colleagues with a proposal grounded in the indigenous building traditions of

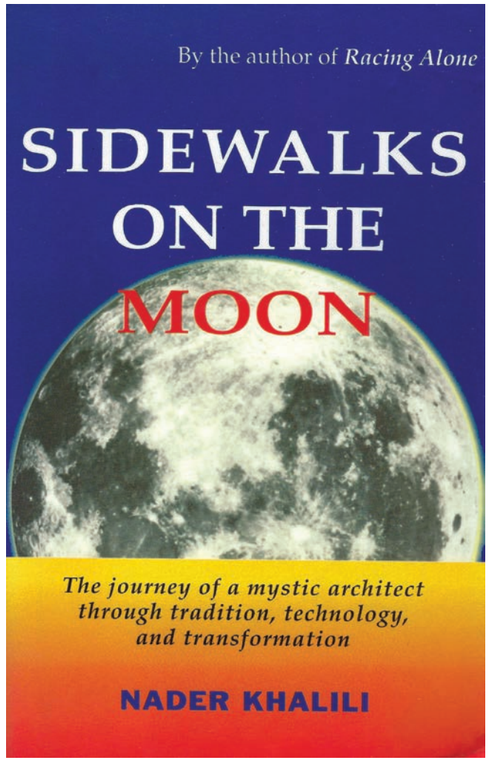


Fig. 9.15 Cover of Nader Khalili's *Sidewalks on the Moon: The Journey of a Mystic Architect through Tradition, Technology and Transformation*, Cal-Earth Press, 1994

Persia—of which the pigeon tower is but one example. In characteristic style, Khalili spoke the academic language of his audience . . . but also pushed them toward more plainspoken arguments for a responsive architecture made from lunar regolith."[47] Indeed, Khalili continued to emphasize indigenous ecological constructions by the very people whose knowledge of such building methods had been debilitated by Western colonial powers. Instead of expanding upon the sustainable and environmentally friendly traditional methods of Middle Eastern nations, Western powers replaced them with industrial, technological, and building methods heavily contingent upon fossil fuels. Khalili ends his 1984 NASA presentation in these words:

> As a general rule, it is the use of the universal principles of the terrestrial element of the heat—the solar rays—that must be thought of at the forefront of the mediums and materials for planetary base design and construction. Adhering to the philosophy of the use of local resources, human skills, and solar energy, we can achieve our quests on the Moon, Mars, and beyond. We must learn from the accumulated human knowledge of earth-architecture, which has sheltered humans in the harshest conditions. Each person going to the Moon, regardless of his or her work, must be aware of these fundamental principles and techniques to participate in creating an indigenous architecture to form their communities, not only because of economic benefit but also because of spiritual reward. As an old Persian saying goes, "Every man and woman is born a doctor and a builder—to heal and shelter himself."[48]

Khalili, who passionately involved himself in translating and interpreting medieval Sufi worldviews and Persian poetry, especially that of Rumi, also manages to link his design concepts with his spiritual beliefs.[49] He writes:

Fig. 9.16 Building prototypes at the Cal-Earth Institute in Hesperia, California

> All heavenly bodies are like human bodies: marvels of creation in the highest forms of technology, yet filled with poetry and spirituality . . . We must sail into the cosmos not only with zero-defect spaceships, but in ones filled with inspiration, not merely carrying a data bank, but also carrying a sense of unity integrating us with our past and future aspirations. It is good to remember that what we may ultimately reach in space may be the space within.[50]

In 1994, Khalili gathered all of his thoughts about lunar settlements into a book titled *Sidewalks on the Moon: The Journey of a Mystic Architect through Tradition, Technology and Transformation* (Fig. 9.15). The title itself attests to Khalili's interests in seeking ecological wisdom, reinventing the human, and nurturing the emergence of a vibrant Earth community. Khalili's interest in framing his design based on Sufi thought, one might argue, was in line with a broader, global interest in spirituality and its latent potential for offsetting the negative effects of rapid industrialization and machine-oriented life. Both Soleri and Khalili sought what Busbea characterizes as "a desert-situated spiritual fulfillment through an ethnopsychedelic escape into other, higher, states of awareness."[51] Then again, we might situate Khalili's interest in spirituality and Sufism amid the global avant-garde design circles that frequently drew from various streams of transcendental mysticism such as Theosophy, Zen Buddhism, and Hinduism to present a counterpoint to the machine-oriented and technological ethos of industrial modernity.[52] However, at its core Khalili's search for spirituality is not a self-help strategy or a therapeutic device—characteristics that scholars have aptly acknowledged concerning some aspects of Soleri's projects in the Arizona desert or other similar initiatives by contemporaneous counter-cultural designers, such as Ant Farm and Drop City.[53] Khalili's passion for spiritualism is, quite the reverse, not grounded in his

own pursuit of recovery in the world or escape from it. Rather, his spiritual inclination is in line with his desire to bring about a more humanitarian future in light of the energy crisis, rising concerns about environmental problems, and even a conceivable apocalypse. More than a decade after Khalili's passing, at the Cal-Earth Institute he founded in California one can still meet humanitarians and activists (some with no design or art background), who come from faraway places to participate in the Institute's workshops or to join the continuing educational programs and residencies. They come to learn Khalili's building methods, and they enthusiastically take these skills back to their own disadvantaged communities (Fig. 9.16).[54]

Thus, even if not in the mainstream, Khalili's humanitarian work continues to thrive and attract the audience it aimed for. However, his ideas for building on lunar surfaces have remained to a large extent unacknowledged. Indeed, while these ideas continued to surface in his memoirs and a few scientific and architectural journals, they were never realized. In fact, Khalili's later iteration of his NASA presentation excludes any confident and brave mention of Iran. Campbell observes: "Khalili relies upon the visual and material culture of Persia without explicitly pointing to a place that was still aligned, in the minds of many US scientists, with religious fundamentalism and the hostage crisis at the US Embassy in Tehran."[55] Conversely, while O'Neill's cylinders also failed to be realized, they have continued to fascinate the popular imagination to this day, even playing a central role in recent thinking about the future of space exploration.[56]

Yet now that we have passed the fiftieth anniversary of the Apollo 11 landing, Khalili's visions are more relevant than ever. NASA, the European Space Agency, and the Russian space agency Roscosmos, as well as powerful individuals like Jeff Bezos and Elon Musk, are all pursuing the development of 3D printing technology

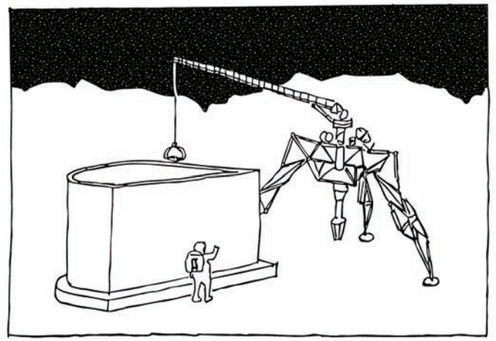


Fig. 9.17 (above) Transportable fused monolithic vertical vault constructed using Georgia Institute of Technology SKITTER Concept. Drawing by Pedram Karimi after Nader Khalili, 1989

Fig. 9.18 (opposite) Robotic construction of lunar and Martian infrastructure using 3D printing, digital rendering by NASA, 2019. Center for Rapid Automated Fabrication Technologies (Craft) at University of Southern California/NASA

to use the lunar regolith to create lunar bases, echoing Khalili's lunar building methods from decades before (Figs. 9.17 and 9.18).[57] Accordingly, a critical engagement with the history of these explorations is all the more timely now. As we "decolonize" the history of the "colonization of space," it is important to reconsider the overlooked parts of this history. It is hoped that unearthing the forgotten segments of these investigations enhances our understanding of the geopolitical role played by the Middle East in past and current environmentally friendly and self-sustained design discourses. Khalili's lunar dream for a sustained life is alive and well after all, it seems, as it was nearly four decades ago.