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OUT OF THIS WORLD: THE NEW FIELD OF SPACE ARCHITECTURE

HOWE AND SHERWOOD, EDITORS

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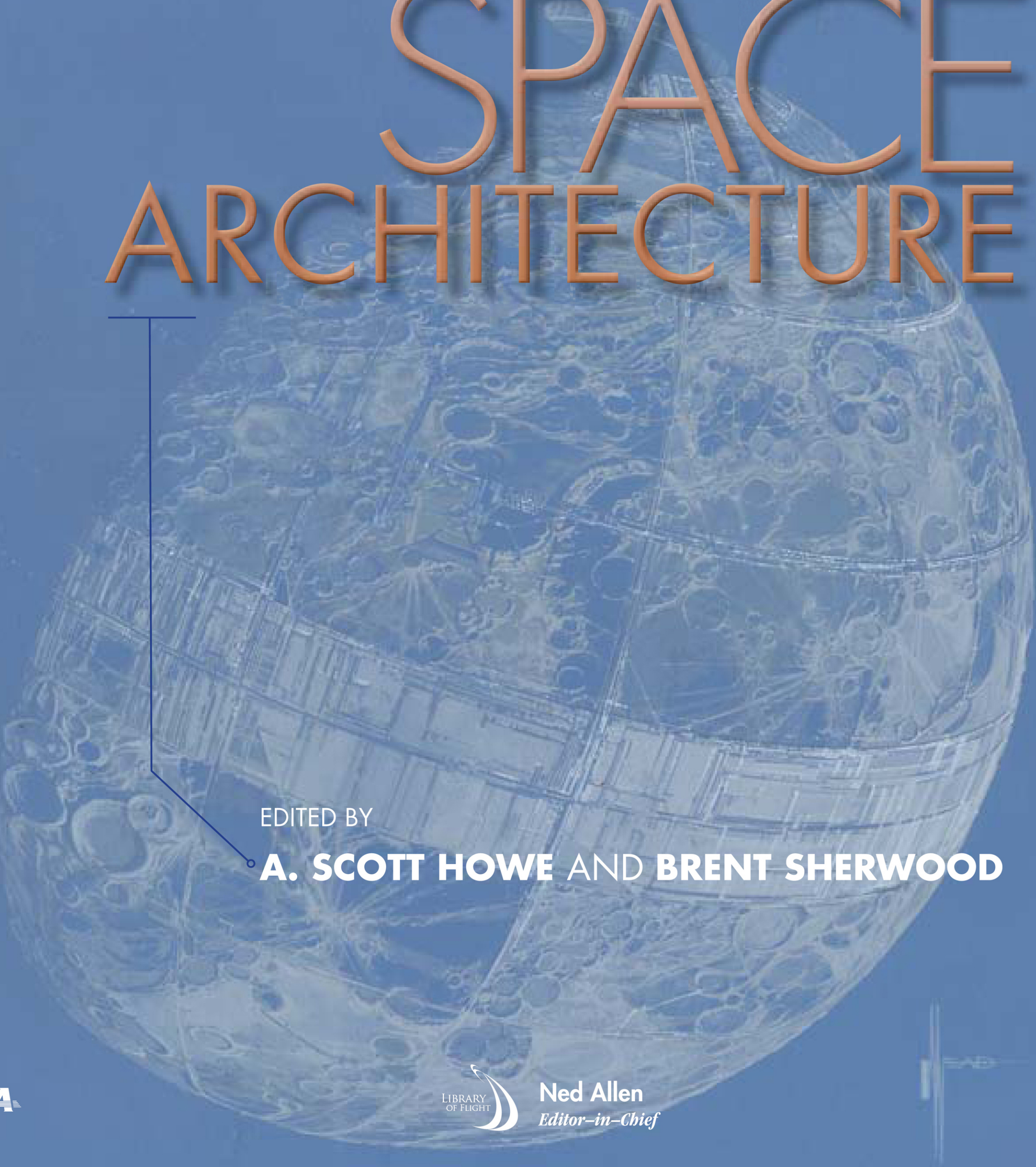

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space architecture for the mother ship: bringing it home

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INTRODUCTION

SINCE THE BEGINNING OF THE SPACE AGE in the late 1950s, an understanding has grown of our planet as an extraordinary cradle of life in the vast, dark universe. But we also are learning to see the limits of the Earth system, the fragility of our atmosphere, and the influence human population has on this closed-loop system that receives its driving energy from the sun.

Yet we exploit our planet with unappeasable hunger: the wealthiest 20% of people account for 86% of the world's total private consumption. If every person alive today consumed at the rate of an average person in the United States, three more planets would be required to fulfill the demand. This by itself is alarming. Even more appalling is that despite the accelerating accumulation of wealth in industrial societies, and despite real-time news distribution and high-speed transportation by airplanes and trains, it nonetheless seems unachievable to prevent people dying from hunger or lack of clean water. The State of the World report concludes balancing population growth vs poverty as our number-one challenge (Starke 2003). Almost a quarter of the planet's population, 1.2billion people, are classified by the World Bank as living in "absolute poverty," defined as living on less than 1 U.S. dollar a day (World Bank 2008).

On the other hand, we are flying to space, and in so doing realizing how valuable life's most basic resources are. To launch 1 kg of water into low Earth orbit costs about €20k. In contemplating human missions to Mars, transporting all supplies for two years appears impractical. Systems would have to be developed to recycle air and water, and perhaps food, and to conserve energy. The end state of such development is eventually a closed-loop system powered by the sun: a microcosm of our "mother ship" Earth.

COWBOYS, SPACEMEN, AND PROSUMERS

Kenneth Boulding (1966) stresses the need to change from a "cowboy economy" to a "spaceman economy." He describes the cowboy economy as an open system with plenty of world. Its measure of success is high throughput. The spaceman economy is a more closed system in a narrow world. Its measure of success is quality and complexity of stock (i.e., human bodies and minds).

One of the key problems in developing countries is lack of infrastructure and high costs to introduce it. Industrial societies rely on costly infrastructure to bring fresh water, electricity, heating, and telecommunications directly into apartments and houses and to remove waste seemingly easily. However, there is no such thing as a municipal water supplier in a spaceship. On a spaceship, the concept of waste is redundant; instead, there are resources in different states of processing (just like in a natural system). Low-energy and lightweight systems are needed to keep the systems going, make potable water from liquid waste, and make food using solid waste. Such systems do not yet fully exist, but much research is heading in this direction. Eventually this technology will enable spaceships to become independent of Earth-based resupply.

This technology will be costly initially, but the spin-off will address one of the largest markets of the world: private housing. The Fraunhofer Institute (2004) forecasts a strong, growing market for autonomous systems in private housing, with people investing in independence from municipal infrastructure and ever-growing prices for water, waste and energy. (Note: throughout this chapter, the

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word "autonomous" specifically denotes such independence from societal infrastructure.) This competitive market would make the systems cheap and eventually enable developing countries to leapfrog the whole process of investing in and maintaining expensive centralized infrastructure. A remarkable example of such a technology jump is the mobile phone, which is currently spreading successfully in developing countries. Obviating the construction of landlines, cell phones are proliferating currently in rural areas of China, Ghana, and India.

The underlying thesis of this analysis is that once we can think in terms of decentralized, autonomous, solar-powered, recycling space systems, we can imagine such technology jumps for terrestrial applications. Once we imagine them, they become more likely to happen. The oft-heard argument that technology is too expensive and that there is no money in developing-world markets, has been dramatically disproved by examples like the motorbike and mobile phone. And the need is real: we live in a time when despite unprecedented amounts of money being available, we have not figured out how to help the world's poor lead a decent life.

Promising crossover fields from space technology to development aid include 1) mobility and communication; 2) closed-loop autonomous systems; and 3) *in situ* resource utilization (ISRU). These are elaborated and illustrated by examples given in what follows. Recent projects show enormous potential for such development. The company Architecture and Vision has proposed several projects suggesting implementation of space technology in developing countries. Unfortunately many architects left this field after the 1960s when frustration developed that design and architecture could not "change the world." Whereas the earlier belief that it could might have been naive, our task as architects and engineers is to try staying current with advanced technology and implementing it into dignified housing for human beings under given environmental, economic, and social conditions. Whether in space, Europe, or Africa, this challenge is largely invariant.

In Alvin Toffler's "Third Wave" society (Toffler 1980), highly infrastructure-dependent consumers eventually become self-producing and independent "prosumers" who help to produce and maintain a clean and healthy environment as they consume. Through easy access to communication they can identify ad hoc business opportunities, using information to offset material resource needs as in the mobile phone example.

MOBILITY AND COMMUNICATION

Communication can be described as mobility of information. Mobility of hardware and software is a key to information and knowledge. Most developing countries are severely deprived of such mobility. Long distances must be covered by foot every day, to work, to get water, and to visit relatives and friends. Transportation and access to information, Internet, or even telephone are quite limited. Compared to the Western world's access to knowledge and information, these cultures are literally disconnected. However, the abundance of technology and some consequences of globalization open possibilities for poor nations and even individuals to leapfrog development.

Digital Divide

Increasingly the world divides not only into rich and poor, but into those who have access to information technologies and those who do not. The term "digital divide" came into regular usage in the mid-1990s (Wikipedia 2008), when the Internet began wide distribution into Western households. To cross this divide, Massachusetts Institute of Technology (MIT) Media Lab launched a research initiative to develop a "$100 laptop" now named the XO-1, a technology that could revolutionize how we educate the world's children. To achieve this goal, a new, nonprofit association, One Laptop per Child, was created. "If you take any world problem, any issue on the planet, the solution to that problem certainly includes education," says Nicholas Negroponte, the initiator of the project (Bullis 2005). He learned from previous work with schools in Senegal, Costa Rica, India, and other countries that simply providing access to a computer is key to leveraging a child's innate creativity and curiosity. "Even in the developing parts of the world, kids take to computers like fish to water," Negroponte notes.

The XO-1 (Figure 1) is designed to be much lower cost (market price is about $200 U.S.) and much longer lived than typical laptops. It uses flash memory instead of a hard drive, runs the Linux operating system, and uses the Sugar user interface. Mobile ad hoc networking based on the 802.11s wireless mesh network protocol allows students to collaborate on activities and share Internet access from one connection. The wireless networking has much greater range than typical consumer laptops. For use at home and where power is not available, the XO-1 can be solar or foot powered. It comes with at least two of three options: crank, pedal, or pull-cord. Children could have a second battery for group charging at school while using their laptop in class (OLPC 2008).

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FIGURE 1 XO laptop (courtesy of fuseproject).

FIGURE 2 Already today India has more cellular phone connections than landlines (courtesy of Hunger Project).

Children could take a computer with them wherever they go, learning languages, math, science, geography, and economics as well as playing games and chatting online with friends. They could draw and compose music. Negroponte's original plan was aggressive: to produce 100 to 150 million laptops by 2007. By mid-2008, 667,000 orders were confirmed. Uruguay was the first country to purchase a full order: 100,000 laptops in October 2007. With another 200,000 laptops Uruguay can cover all public school children between 6 and 12 years old. Also participating in the project are Afghanistan, Cambodia, Ethiopia, Colombia, Haiti, Mexico, Mongolia, Papua New Guinea, Peru, Rwanda, and the United States of America.

Negroponte's emphasis on education is visionary. Although its impact on developing nations might occur only over the long term, we should not underestimate people's inventiveness once technology is easily accessible. Yet *The Economist* (2005a) sees the digital divide not as a problem in itself, but a symptom of deeper, more important divides: income, development, and literacy. Fewer people in poor countries own computers and have access to the Internet simply because they are too poor, are illiterate, or have other more pressing concerns such as food, healthcare, and security. So even if it were possible to cause a computer to appear in every household on Earth, this would not necessarily achieve very much: a computer is not useful if you have no food or cannot read.

Leapfrogging the Digital Divide

One interesting effect of digital technology (and improved batteries to make devices long-running) is that it not only quickly opens the gap between the people who have access and those who do not, but it also provides the means to leapfrog that gap. India has the second-largest mobile phone market in the world (Hindu Business Line 2008) (Figure 2). This means the turnover is already fast underway.

But technology can also have immediate effects on the economic prosperity of even poor people. Evidence suggests mobile-phone technology has the greatest impact on development. Mobile phones raise long-term growth rates, their impact is twice as big in developing nations as in developed ones, and an extra 10 phones per 100 people in a typical developing country increases GDP growth by 0.6 percentage points (*Economist* 2005b).

When it comes to mobile phones, there is no need for intervention or funding from the United Nations (UN) even the world's poorest people are already rushing to embrace mobile phones because their economic benefits are so apparent. Mobile phones do not rely on a permanent electricity supply and can be used by people who cannot read or write. Phones are widely shared and rented out by the call, for example, by "telephone ladies" in Bangladeshi villages. One person in a village buys a mobile phone, perhaps using a microcredit loan. Others then rent it out by the minute; the small profit margin enables its owner to pay back the loan and make a living. When the phone rings, its owner carries it to the home of the person being called, who then takes the call. Other entrepreneurs are "text message interpreters," sending and receiving text messages (which are generally cheaper than voice calls) on behalf of their customers, who might be illiterate. So although the number of phones per 100 people is low by rich-world standards, they still make a big difference. As in industrial societies, children are very open to, and quickly adapt, new technologies (Figure 3).

FIGURE 3 African boy with mobile phone dummy built of clay (courtesy of *The Economist*).

Farmers and fishermen use mobile phones to call several markets to work out the best price for their produce. Small businesses use them to shop around for supplies. Mobile phones are used to make cashless payments in Zambia and several other African countries. In Argentina, poor people who live by searching household trash for valuables use mobile phones to have an advantage over competitors. Again, mobile phones have a dramatic impact despite their low per-capita numbers: by reducing transaction costs, broadening trade networks, and reducing the need to travel (of particular value for people looking for work). So it is no surprise that people in poor countries spend a larger proportion of their income on telecommunications than those in rich countries.

The digital divide that really matters, then, is between those with access to a mobile network and those without. The good news is this gap is closing fast. The UN set a goal of 50% access by 2015, but a new report from the World Bank notes that 77% of the world's population already lives within range of a mobile network (*Economist* 2005b).

Mobile HIV/AIDS Health Clinic

Education, communications, and health have been described as the key factors to help developing nations. They have to go together: experience shows distribution of medicines or condoms without providing long-term education does not lead to improvements. The tragedy AIDS has introduced into Africa shows there is urgent need for combining education, communication, and health.

The facts speak for themselves (UNAIDS 2007):

- *Global*: Sixty-five million people worldwide are infected with HIV, of whom 25 million have died. In 2000, approximately 5.3M people were newly infected with HIV, and 600,000 of them were children. A child is orphaned because of AIDS every 14 seconds—one-third of these is younger than five. Ninety-five percent of those infected with HIV live in the Global South.
- *Africa*: Sub-Saharan Africa is home to over 25 million cases, about 70% of the world's total. Fifty-five percent of the HIV-positive people in sub-Saharan Africa are women. Six of seven HIV-positive children in Africa are girls. In eight African countries, over 15% of adults are infected. Around a third of today's 15-year-old Africans will die of AIDS.
- *South Africa*: With over five million infected people, it has the largest number of people living with HIV/AIDS in the world. One of four South African women between ages 20 and 29 is infected with the virus.

These shocking statistics led the nonprofit organization "Architecture for Humanity" to launch an international competition for a mobile HIV/AIDS clinic for Africa. Architecture and Vision proposed a clinic that would be built up on a standard 2.55-m-wide truck (Figures 4 and 5). The deployable roof is equipped with solar cells, which allow constant charging of batteries and fuel cells. Preferably the

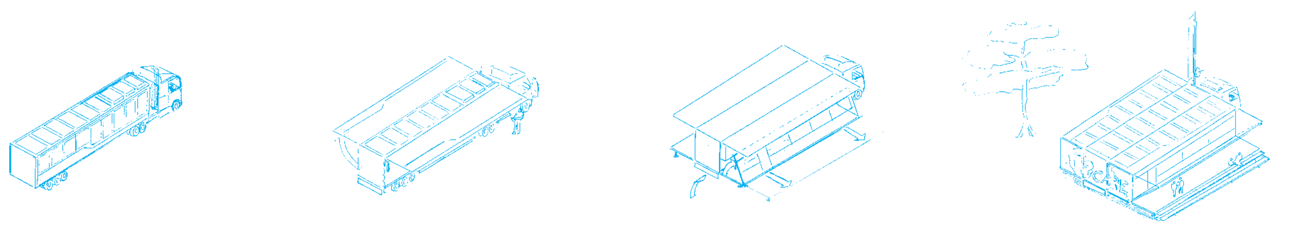

FIGURE 4 Mobile health clinic travels compactly on a truck and can be deployed at desired location (courtesy of Architecture and Vision).

FIGURE 5 Mobile health clinic comes fitted onto a standard truck (courtesy of Architecture and Vision).

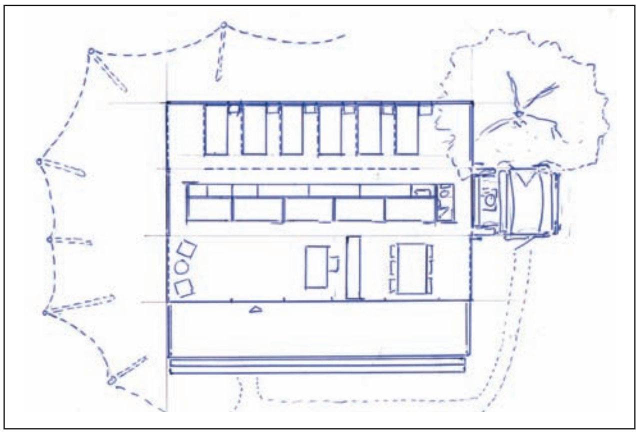

FIGURE 6 Plan of deployed clinic. The space created by unfolding the container can be extended by additional canvas structures (courtesy of Architecture and Vision).

truck would be operated by a hybrid engine to promote alternative energy use in developing nations. Figure 4 shows how the Health Clinic is set up. The container's side walls fold up to form the roof. In the same way floor panels are folded down. An extra outdoor veranda is provided as well. A flagpole provides visibility from afar. A central core contains the storage, facilities, water supply, and toilet needed for a doctor, a nurse, and up to six bed-ridden patients (Figure 6). Six beds can be set up in the part separated by the central storage unit. The side adjacent to the veranda serves as reception and consultation room. The veranda has a double function: first, it protects activities from sunlight and rain and offers a shaded entrance; second, it serves as a stage to perform educational plays informing people about AIDS prevention (Figure 7).

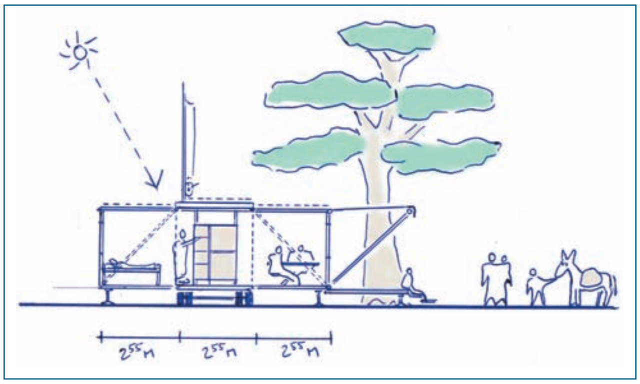

FIGURE 7 Clinic has two fold-out sides: one provides patient beds, and the other reception and consultancy. Veranda is a shading device and stage for presentations, lectures, or educational plays (courtesy of Architecture and Vision).

FIGURE 8 Six-meter-diameter vacuum chamber in Houston where NASA has tested autonomous life-support systems for up to 90 days (courtesy of NASA).

CLOSED-LOOP AUTONOMOUS SYSTEMS

Today spaceflight is still dependent on resupply from Earth. The International Space Station (ISS) is resupplied by progress and automatic transfer vehicle (ATV) capsules, which bring consumables like water, food, and oxygen and are filled with waste for burnup during reentry into Earth's atmosphere. To go far beyond Earth orbit, increasing loop closure will be necessary.

Several research programs are moving in this direction including space-simulation chamber experiments at the NASA Johnson Space Center (JSC) (Figure 8). The primary goal of the Lunar-Mars Life Support Test Project (LMLSTP) conducted from 1995 through 1997

FIGURE 9 Plants provide oxygen, clean the water, and yield food. They also support crew psychological health and will become an important element of deep-space missions (courtesy of NASA).

at JSC was to test an integrated, closed-loop system that employed biological and physicochemical techniques for water recycling, waste processing, and air revitalization for human habitation. Conditions of isolation and confinement enable studies of human factors, medical sciences (both physiology and psychology), and crew training (see Chapter 25). Study results provide a wealth of data important for long-duration space missions and extreme environments here on Earth. The longest simulation in the JSC study was by a crew of four for 90 days, using wheat to revitalize the air and a bioreactor for water recycling, which used microbes to clean the water. An incinerator was used in the solid-waste processing system to turn crew fecal matter into ash and gaseous carbon-dioxide products for uptake by the wheat (NASA 2004).

Bioregenerative life-support systems will have to become more lightweight, power-efficient, and reliable in the future to be incorporated as critical systems for long-duration space missions. The deep-space astronaut of the future will likely be a "bionaut" as well, living in balance with controlled plant, animal, and microbial systems in very confined spaces (Figure 9).

The traditional farm on Earth has been fairly autonomous (as defined in this chapter) based on ISRU: firewood from the forest and food and materials from crops and animals. With the growth of cities and the buildup of modern infrastructure, this model has declined. Most buildings are fully dependent on utilities supplying water, electricity, and heating energy. With the first oil crisis in the 1970s, better insulation and solar energy started to reduce the energy demand of houses. Continued sharply rising costs for energy, water, and waste management, as well as homeowner desire to become more independent, will open a large market for autonomous systems in western societies. In 2004, the Fraunhofer Institute predicted a substantially growing market for passive houses over the succeeding 15 years (Fraunhofer Institute for Solar Energy 2004).

However, a more dramatic beneficiary of such systems would be the developing world, which lacks the sophisticated infrastructure of the first world. According to UN reports, 1.1 billion people do not have direct access to drinking water, and 2.4 billion do not have access to basic sanitation (UN/WWAP 2003). Developing countries often do not have the means for extensive infrastructure. Mobile and low-energy water recovery systems can help improve this situation and possibly allow a technology jump as happened with the mobile phone. Analogous to the mobile-phone market, the large housing market in wealthy countries could help motivate a cheap mass product for the future based on currently expensive technology.

The UN also estimates 50% of the world's drinking water is transported on women's heads. Sixty percent of these carriers are more likely children (Figures 10 and 11). In many countries it is the women's and

FIGURE 10 A girl helping her sick grandmother to carry water in Changara district, Tete province, in March 2004 (© UNICEF/MOZA0239/G.Pirozzi).

FIGURE 11 Boy and a young girl on their way to carry water in Gondola, Manica, March 2004 (© UNICEF/ MOZA0521/G.Pirozzi).

children's tasks to collect water from sources often up to two hours walking distance away. According to the World Health Organization, in the Sudan the energy used to tote water from rivers and other water sources accounts for one-third of a woman's daily calorie intake (Starke 2003).

The facts again speak for themselves (WaterAid 2008):

- Roughly one-sixth of the world's population, 1.1 billion people, are without access to safe water. About two-fifths of the world's population, 2.4 billion people, are without access to adequate sanitation.
- There are 2.2 million people in developing countries, most of them children, are dying each year from diseases associated with lack of access to safe drinking water, inadequate sanitation, and poor hygiene. Six-thousand children are dying every day from these causes, equivalent to 20 jumbo jets crashing every day.
- Half of the world's hospital beds are occupied by patients suffering from water-borne diseases. Two-hundred million people in 74 countries are infected with schistosomiasis; 20 million suffer severe consequences. A 77% reduction of incidence is achievable through well-designed water and sanitation interventions alone.
- The average walking distance for women in Africa and Asia to walk to collect water is 6 km. The weight they carry on their heads is equivalent to your airport luggage allowance (20 kg).
- The average person in the developing world uses 10 liters of water a day. The average person in the United Kingdom uses 135 liters.

Eco-Unit

The Architecture and Vision Eco-Unit responds to the water situation by providing a communal unit for water collection, water recovery, hygiene, and controlled disposal of human wastes, as would a spaceship (Figure 12). Water is collected over the roof or from a nearby water source. Solar cells and biogas created by human waste provide power to recover both potable water and grey water for the toilet.

The roof shape is inclined to collect water when it rains and provide a good angle for the solar cells. The box has a 2.5-m transportation width and is deployed with inflatable walls after installation, providing the most economic use of space for transportation and local use. Its construction uses a mix of hard and soft materials. The design conception derives from current aerospace technologies, although materials will be more conventional and cheap. Hard materials include wood and protected cardboard. From the hard core a soft inflatable section can be deployed, which minimizes volume for transportation to the site.

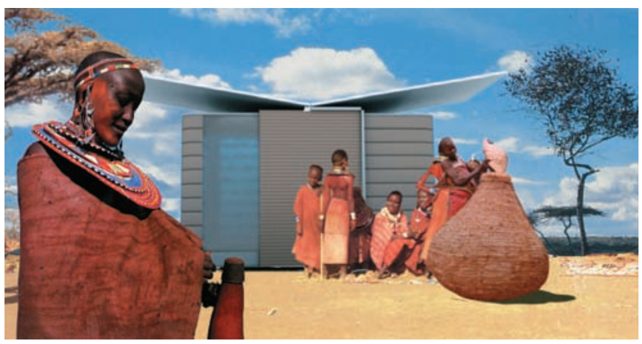

FIGURE 12 Mobile Eco-Unit powered by solar energy could provide safe sanitation for a local village community (courtesy of Architecture and Vision).

Eco-Unit technology would be adaptable, meaning it could be high tech and expensive or low tech and inexpensive, and so implementation in poor countries would be possible. The main problem is not the technology, but its implementation and the education of people to use it correctly. For most villages in poor countries, large-scale infrastructure for fresh water and waste water recovery is much too expensive. The Eco-Unit concept offers a decentralized approach that would avoid infrastructure and downstream health costs and immediately provide better living conditions for people. It would especially relieve women and children in developing countries from the unergonomic burden of carrying water.

FIGURE 13 Introduction of *in situ* biogas not only relieves people from buying expensive firewood, but yields a clean, soot-free kitchen (courtesy of Ashden Awards for Sustainable Energy/Martin Wright; www.ashdenawards.org).

Technology Jump: From the Middle Ages into Modern Times

Often new technologies are around for a considerable time before their exponential adoption begins. The challenge is how to identify the promising ones early and control the parameters necessary for their commercial introduction. Successful new technologies are mostly connected to considerable improvement of the quality of life. For example, the Frankfurt Kitchen introduced in 1929 was heavily criticized in the beginning, but became a game-changer that saved women a lot of time and allowed them to become more independent. Often the introduction of technology, even if quite low tech, can solve many problems simultaneously. Once the introduction is completed, many people ask why it was not done long before.

A good example for such a technology jump can be found in Nepal, where the majority of people still cook over open fires on the kitchen floor. Firewood is getting rare and more expensive as Nepal suffers from severe deforestation. The introduction of biogas into households starts solving many problems with simple, low-tech, decentralized technology. Many people in rural areas have one or two cows. Feces of men and animals are collected in a concrete biogas tank, which provides enough gas for clean, soot-free cooking (Figure 13). The tank residue is excellent fertilizer (Figure 14). Taking into account the costs of wood, the biogas system pays for itself within two years. Part of its successful introduction is the use of micro-finance-style loans (Ashden 2005). This example raises the question, "Why hasn't this been done

FIGURE 14 Biogas production technology is low tech. Residue from the concrete tank yields fertilizer (courtesy of Ashden Awards for Sustainable Energy/Martin Wright; www.ashdenawards.org).

earlier?" Sufficient wood supply? No financing for farmers? The technology, and the possibility to apply it cheaply, had been around for over 30 years.

IN SITU RESOURCE UTILIZATION

In situ resource utilization (ISRU) is a very old concept that has shaped cultures and buildings over centuries (Figure 15). The industrial revolution introduced an increasing independence from local energy and resources. Transportation became cheap. Globalization economics creates the absurd situation in which an apple from the neighborhood can be more expensive than one imported from Argentina or elsewhere. The high degree of infrastructure and logistics has even made us forget the value of local resources. This value has begun to be reestablished from an unlikely direction: technology development for human planetary exploration. ISRU techniques are being developed in laboratories to extract oxygen propellant from lunar regolith and methane propellant using carbon dioxide in the Martian atmosphere. Such technologies are economically enabling for advanced missions. But they also sharpen our sense of how to use even small amounts of local resources to best benefit, which is a real "spaceman" mentality as defined earlier. Spaceman technological thinking brings control over the environment back into the hands of people, yielding a powerful resource.

One of the most complex challenges for long-duration human spaceflight is radiation protection, as discussed throughout this volume. Current shielding concepts require bulk mass, which is why use of local regolith has been proposed (Figure 16).

FIGURE 15 Swiss mountain hut built from stones found on the site (courtesy of Book SolarPower).

FIGURE 16 Nader Kahlil's sand-based domes at Cal Earth Institute suggest a building method for planet surfaces using their local resources (courtesy of Cal Earth Institute).

Christopher Alexander, the father of architecture pattern language, defined the leapfrog opportunity by using local resources 10 years ago, perhaps knowingly. In a 1996 lecture (Gupta 2004), he commented to a group of software programmers in San Jose that

> In traditional society where lay people either built or laid out their own houses, their own streets, and so on, the adaptation was natural. It occurred successfully because it was in the hands of the people that were directly using the buildings and streets. So, with the help of the shared pattern languages, which existed in traditional society, people were able to generate a complete living structure.
>
> In our own time, the production of environment has gone out of the hands of people who use the environment. So, one of the efforts of the pattern language was not merely to try and identify structural features which would make the environment positive or nurturing, but also to do it in a fashion which could be in everybody's hands, so that the whole thing would effectively then generate itself.

Advanced technology can provide new solutions for the simple problems of developing countries. One example is the LifeStraw by Torben Vestergaard Frandsen, a 25-cm-long, plastic pipe filter that turns dirty water into clean, potable water (Figures 17 and 18). Sucked-up water meets two textile filters that remove particles including even clusters of bacteria. Then the water enters a chamber of iodine-impregnated beads, where bacteria, viruses, and parasites are killed. The second chamber is a void space, where the iodine

FIGURE 17 LifeStraw uses textile filters to make water safe for drinking on the go (courtesy of Vestergaard Frandsen).

FIGURE 18 LifeStraw is likely to be one of the inventions with a very high impact on the situation in developing countries (courtesy of Vestergaard Frandsen).

can maintain its killing effect. The last chamber contains granulated active carbon that removes most of the bad smell of iodine and parasites that have not been taken by the prefilter or killed by the iodine. LifeStraw lasts for one person's annual needs of clean water and costs $5. The costs of a water treatment plant and infrastructure would be far higher and probably still not reach all people. Nobody needs to die from diseases originating from unsafe water resources.

FIGURE 19 Desert Seal is a space technology transfer project that uses local energies to cool a tent in desert regions (courtesy of Céline Laurière).

Another example is Desert Seal, a tent for hot, arid climates that uses local energies for cooling itself (Figure 19). The tent resulted from a study by Architecture and Vision for the European Space Agency (ESA), investigating use of space technologies for inflatable tents in hot regions (European Space Agency 2005).

Desert Seal is designed specifically for hot, arid environments where the air becomes considerably cooler higher above the Earth's surface. During the day, temperatures can easily go above 60°C at ground level, but remain 40°C lower just 2–3 m above the ground (Figure 20). Traditional Persian buildings already use this effect (Figure 21), and camels are evolved to benefit from this effect with their high legs and long neck (Figure 22).

During the day, an electric fan in the top of the tent, 2.26 m above the ground, constantly blows cooler air inside, thus reducing the temperature

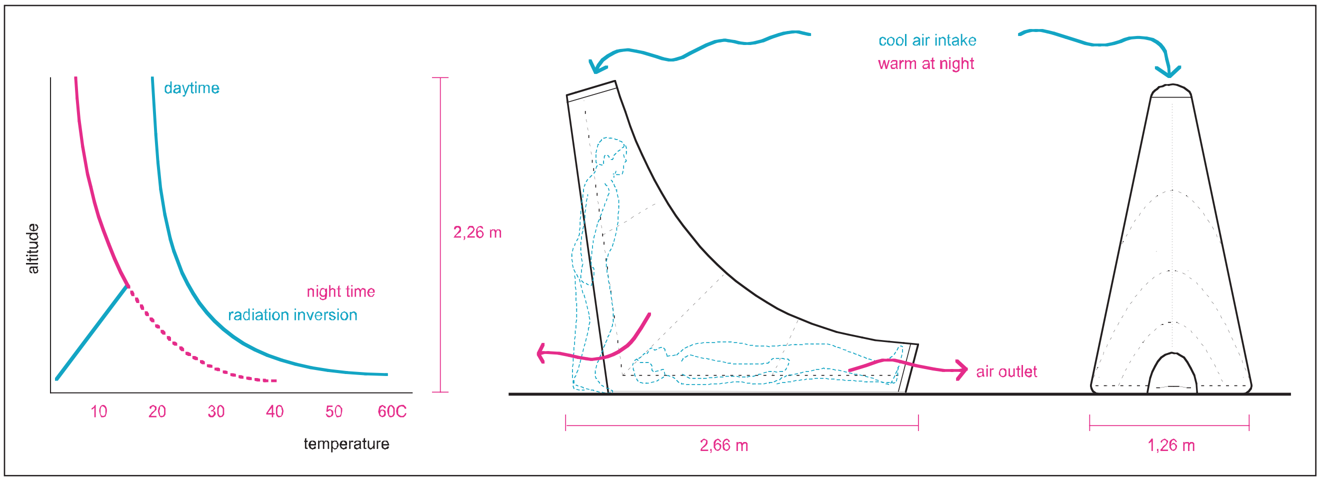

FIGURE 20 Desert Seal makes use of desert temperature profile. Cooler air is blown into the tent from the top by a solar-powered electric fan (courtesy of Architecture and Vision).

FIGURE 21 Wind scoop tower in the historical district of Dubai (courtesy of Architecture and Vision).

FIGURE 23 Desert Seal heat-reflecting silver-coated awning and flexible solar array to power the fan (courtesy of Céline Laurière).

FIGURE 22 Desert Seal tent collects cooler air at higher levels (courtesy of Architecture and Vision).

inside. The fan is powered by batteries charged by flexible solar panels mounted outside the tent (Figure 23). During the night, the desert ground radiates heat to the dark sky and quickly reaches temperatures below 0∫C. Because air acts as a good insulator, at higher levels it stays considerably warmer. The fan on top, now running on batteries, blows warmer air into the tent. The tent consists of an air-beam structure made of polyethylene-coated material. It has an awning of silver-coated, high-strength textile to reflect heat and provide protection from direct sunshine. The L-shaped tent allows upright entry and minimizes aerodynamic loading.

CONCLUSION AND CALL TO ACTION

The space age created the concept of Earth as our mother ship. The concept leads to understanding our planet as an interdependent system of life and matter, technology as a tool for interacting with the planet and its crew, and the value each crew member adds to the whole mission.

The space age also yields technologies we can use to maintain and protect the mother ship and to provide higher living standards for the third world. The case studies presented in this chapter illustrate the tremendous potential for creative use of modern technologies to help developing countries. As technology becomes ubiquitous and cheaper, old preconceptions—for examples that technology cannot help poor people because it is too expensive—must and can be overcome.

The mobility of knowledge (computer), communications (mobile phone), and health services (mobile clinic) can positively affect individual lives. Closed-loop systems and intelligent use and recovery of local resources can make people more independent and yield free time for self-organization, education, and working to improve quality of life. Modern lightweight and low-energy technologies can unlock the potential of using resources locally and individually, as with LifeStraw. Large, centralized infrastructure is not only expensive, but also it hinders self-organization. Monsoon and earthquake disasters demonstrate that centralized infrastructure, once destroyed, yields more dire postdisaster disruption. The more decentralized the provision of basic needs, the less vulnerable the population becomes.

Space architects are uniquely positioned to participate in the development of approaches for solving tough problems of human spaceflight, to integrate those solutions into comfortable, attractive, safe, and productive human environments for space missions, and then to see how those solutions can be adapted to benefit indigent populations and compromised environments on Earth. In many cases, we already have technologies and capacity to solve very practical yet devastating problems. The architect's most fundamental motivation—to use good design to improve the world—has never been needed more.

References

Ashden (2005), "NEPAL - Biogas Sector Partnership," The Ashden Awards for Sustainable Energy, http://www.ashdenawards.org/finalist05_1.html [Retrieved 17 Aug. 2005].

Boulding, K. E. (1966), *The Economics of the Coming Spaceship Earth*, Sixth Resources for the Future Forum on Environmental Quality in a Growing Economy, Washington, D.C., March 8.

Bullis K. (2005),"A Hundred-Dollar Laptop for Hungry Minds," *Technology Review*, Vol. 28, Sept. http://www.techreview.com/articles/05/09/wo/wo_092805bullis.asp. [retrieved 16 Jan. 2005]

Economist (2005a), "Calling Across the Divide," *The Economist*, 374 Issue 8417, March 12, p. 74.

Economist (2005b), "The Real Digital Divide," *The Economist*, 374 Issue 8417, March 12.

European Environment Agency (2004), "Impacts of Europe's Changing Climate: An Indicator-Based Assessment," EEA Rep. No 2/2004), Office for Official Publications of the European Communities, Luxembourg.

European Space Agency (2005), "Space Concepts Improve Life in the Desert, http://www.esa.int/esaCP/SEM0TB6Y3EE_index_0.html [retrieved 20 Oct. 2005].

Fraunhofer Ins. for Solar Energy (2004), "Enormous Potential for Passive and Lowest-Energy Houses," Press Release 06/04, Fraunhofer, Freiburg.

Gupta, R. (2004), "Switching Sides—Leapfrog Nations—Emerging Technology in the New Developing World," http://www.worldchanging.com/archives/001408.html, [retrieved 14 Dec. 2005].

NASA (2004), "ALS: Lunar Mars Life Support Test Project, http://advlifesupport.jsc.nasa.gov/lmlstp.html [retrieved 14 Dec. 2005].

OLPC (2008), "Laptop: a Learning Tool Created Expressly for the Children in Developing Nations," One Laptop Per Child, July 20.

Starke, L. (ed.) (2003), "State of the World 2003: Worldwatch Institute Report on Progress Toward a Sustainable Society," W.W. Norton Com., New York.

Toffler, A. (1980), *The Third Wave*, William Morrow and Co., Inc., New York.

UNAIDS (2007), *AIDS Epidemic Update December 2007*, UNAIDS, Geneva.

UN/WWAP (2003), *Water for People, Water for Life: The United Nations World Water Development Report,* United Nations/World Water Assessment Program, UNESCO (United Nations Educational, Scientific and Cultural Organization) and Berghahn Books, Paris.

WaterAid (2008), "Statistics, Facts About Water, Sanitation, Hygiene and WaterAid's Work," http://www.wateraid.org/uk/what_we_do/statistics/default.asp [retrieved 18 July 2008].

Wikipedia (2008), "Digital Divide," *Wikipedia, The Free Encyclopedia*, July 14, http://en.wikipedia.org/w/index.php?title=Digital_divide&oldid=225687168 [retrieved 20 July 2008].

World Bank (2008), *Global Economic Prospects 2008: Technology Diffusion in the Developing World*, The World Bank, Washington, D.C.