27 – Lunar Healthcare System

SUMMARY

Initial crew will be selected for peak health and so the healthcare system will focus on potential emergencies. But, as older, private settlers arrive, a broader set of healthcare services will be necessary. The key will be to anticipate the need beforehand and then to push forward healthcare providers, facilities, equipment and medications to ensure that all is available when needed.

A well-organized healthcare system could not only ensure healthcare provision but could proactively prevent dental, medical, and psychological conditions. Public health approaches could also eliminate many infectious diseases from off-Earth settlements.

OVERVIEW

The best approach to addressing the initial medical challenges on the Moon would be to prevent it where possible. This includes proper screening and selection of initial crew to ensure that they are unlikely to experience medical conditions that the facilities are not prepared for. It could also involve regular, voluntary screening and tracking to ensure that problems are picked up earlier when they are more easily treated.

There will be different phases of development with different healthcare needs. The key to ensuring that a growing base has the right healthcare providers, equipment, facilities, and medications is to, as much as possible, anticipate when the need is likely going to arise and then push forward those things to meet the need before they become necessary. The same holds true for equipment, facilities, and medications. Among the international astronauts and early, healthy, private settlers should be those healthcare providers willing to serve their fellow residents freely as part of their contribution to the growing base / settlement. AI and increasingly capable humanoid robots will provide some of the healthcare labor needed.

A unified healthcare system, including a unified, very efficient, and proactive healthcare IT system is described. It would seek to be the

central nervous system of a highly capable healthcare system and so could demonstrate to those on Earth how such an excellent and cost-effective healthcare system could look like.

Consideration needs to be put into meeting the healthcare needs of remote EVAs, outposts, and new bases to ensure that likely medical conditions can be adequately addressed. An emergency medical response system would need to be established to identify situations that need rapid response whether within a facility or during an EVA. This could include having a medical Mission Control, having qualified people and/or teleoperated humanoid robots locally available, and the Moon-wide capability for a suborbital response team able to fly from a polar international base to anywhere on the Moon within 20 minutes.

PREVENTION

Crew Selection

As described in Chapters 12-16, it is anticipated that there will be phases of lunar exploration and development. It will start with extremely healthy professional astronauts with few medical conditions. There is already an Aerospace Medicine system in place that can detect and exclude from the astronaut corps those who will pose a medical risk to mission success.

But as private settlers pay for their ticket and start arriving on the Moon, many (most?) of those will be older individuals who have lived long enough to have saved up enough money such that they can afford to move to the Moon. And with age comes and accumulation of health conditions. This is why this book breaks the private settler phase into two parts (early and later). Private settlers who have a history of cardiovascular disease, insulin-dependent diabetes, medication-controlled seizures, or any number of other risky medical conditions should not be out, far away from medical facilities at the International Lunar Base lest they experience a medical incident that the lunar healthcare system is not yet ready to respond to. But it is during the early private settler phase that the final touches of a healthcare system would be put in place. Then, as later, less healthy settlers arrive, there will be facilities and response systems similar to what we have on Earth. So, for private settlers there will need to be a selection process to divide them into the early versus later group.

Preventive Healthcare System

Dentistry is particularly good with regular cleanings and checks to help detect and prevent cavities. Early treatment can prevent small problems from becoming big problems. Really good medical systems are similarly proactive in managing patient's conditions. As branches of humanity begin fresh starts on the Moon and Mars, it would do well for us to think about the healthcare systems that we want to see established. Indeed, if the Moon could demonstrate (and even make available for free) a very well-designed healthcare system then this could be one of the many blessings that lunar development could provide to the people of Earth.

For starters, one's personal health is something that belongs to the individual and doesn't belong to the "system". But a good system should be available should the individual wish to take advantage of it. And as on Earth, the privacy of health information should be strictly maintained.

What would a comprehensively preventive healthcare system look like on the Moon? It would be unified, comprehensive, and would be able to detect and help manage healthcare actions. As one small example, a resident's bathroom scale could be connected to the system and routinely monitored to see how the patient's weight is going. Automated analysis of information could trigger automated and/or AI health education and prompts to help the individual take actions optimized for their health.

TIMING

Push to the Front of the Line

It will be critical to ensure that healthcare providers, equipment, facilities, and medications are available when they are needed at every phase of lunar development. Fortunately, this won't be as difficult as it might first appear.

Take for example the healthcare providers. For even very healthy astronauts, we may expect an incident needing emergency medical intervention including pulmonary expertise. Since those skills will be a high priority, the one physician in the Initial Permanent Crew should probably be both fully trained in these fields and highly experienced. And they should be trained in additional skills that we anticipate needing and be backed up by immediate access to specialists on Earth. For things like nurse midwife, we won't need that expertise until quite a bit later and

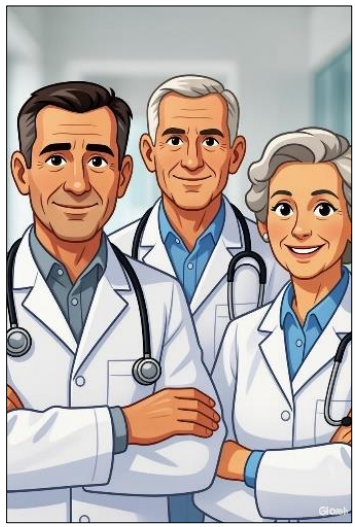
only after the artificial gravity prescription (see Chapter 24) has determined that having off-Earth children can be done safely. For things like an endocrinologist needed to treat residents with diabetes, they should be pushed to the front of the line but only prior to when we expect that they will be needed (i.e. during the early settlement phase). The same hold true for equipment, facilities, and medications.

Anticipating Needs

It is possible, but would require a lot of work, to formally anticipate what the healthcare needs will be at each phase of base growth. Before very large, inflatable specialty habs start being delivered by a fleet of Starships, some new healthcare organization with the expertise needs to take upon themselves the work of developing a plan for meeting the healthcare needs of a growing base. I presented at the Mars Society Conference on this topic. Scan the QR code to the right to watch that presentation.

Mostly Free Care

Trained, experienced, and expert healthcare professionals certainly deserve appropriate compensation consistent with what they have to offer in the marketplace. But it seems as though the Initial Lunar Base will probably operate differently than private healthcare systems on Earth. As described in these pages, the initial, expensive seats on the Starship fleet will be purchases with those with the deepest pockets (i.e. large countries) so we can anticipate governmental exploration and base phase followed by private settlers. The private settlers will skew older, including retired individuals who will likely want to play their part in the historic establishment of humanity's first permanent foothold beyond Earth. They will likely consider it a privilege to freely contribute their time and expertise for the wellbeing of their fellow settlers.



Retired volunteers.

AI and increasingly capable robots will also be able to provide aspects of healthcare for a relatively low cost. All told, extensive healthcare will be able to be provided at a reasonable cost to governmental and private

residents without "breaking the bank". Much later, as the per-seat price comes down and if/when individuals are born off Earth, then the healthcare system may start charging more for services but by that point AI and robotics may be so advanced that all bets are off.

Nursing Homes

Just because private settlers will tend to be older doesn't mean that we are starting a literal nursing home on the Moon. No granny will be pushing her walker to take her place in a Starship.

But older people will get even older and so there will come a time when actual nursing homes will become a thing if those individuals don't return to Earth first. Individuals needing nursing care need a lot of attention. Hopefully, by the time that point comes, nursing home personnel will be greatly augmented by robots capable of providing much of the needed care. Although not the equivalent of the human touch, they will be an essential part of the healthcare team.

CONTEXTS

Astronaut Phases

During the astronaut phases (Artemis, ILEP, & government ILB), governments will select their astronauts the way they have been selected up to now. These are amazing specimens of humans, highly fit physically, and (generally) mentally fit as well. They will not bring much in the way of chronic diseases needing treatment but, theoretically, may need treatment for certain emergencies and injuries. So, that is going to require a certain type of medical care availability. With time, those health astronauts may begin to develop problems resulting from the reduced gravity environment. This may be a bit of a real-time learning process where studies begin to reveal statistics on what the issues are and what healthcare is needed to address the conditions.

Private Settler Phases

As mentioned before, the early private settler phase will select for healthy individuals, but they may develop chronic conditions sooner than younger astronauts. And settlers in the later phase will require the whole gamut of care minus any significant conditions that would better be treated on Earth.

Remote Locations

But the context is not just the health of the residents. Rather, remote outposts or newly started bases will have special healthcare needs that will need to be planned for. It may be that some selection will need to be made to ensure that a new location will not have likely healthcare needs beyond what is available at that location. It may also be that, as they do on Earth, residents will need to travel to receive treatment. This may be to a large international base or even to take the three-day trip back to Earth. But the goal is to make the Moon as medically independent from Earth as early as possible.

HEALTHCARE PROVIDERS

Physicians and Mid-level Providers

In the early phases and in remote locations, there may need to be highly trained, exceptional physicians. For example, the physician among the Initial Permanent Crew may best be a dual-boarded, ER and Pulmonary/ICU physician maybe even with emergency surgical skills additionally trained in other potential conditions. This person could be among the best of the best (aka "right stuff").

As the base grows, a logical sequence of specialists would be pushed to the front of the line to ensure that the expected skills are available. Consultants and telemedicine should also be available. Gynecology would be a relatively early need, but their obstetrics training could wait until pregnancies occur among residents (after the artificial gravity studies on pregnant animals).

Especially as the private settler phases occur, mid-level providers could fill out the ranks of the medical staff.

Nurses and Allied Health

As a physician, I can tend to focus on physician specialties. But, obviously, at the same time we need to ensure that there are nurses with experience in the various nursing fields as well as the allied health professionals such as the various therapists. Pharmacists will be needed in all phases but especially during the later crew phase when people start bringing a wide variety of chronic medical conditions.

Dentistry

Preventing dental problems.

We can try screening and early detection but prevent what we can, people will certainly develop dental conditions that will need treatment. Given that a dental emergency could occur during any phase and chronic dental conditions will need care, we will need our dentists as an important part of the healthcare system.

Mental Health

Practically everyone has at least some mental issues of at various levels and as the selection practices relax especially with the later private settler phase, mental health will assume a larger part of the healthcare system. Counselling can be provided locally, remotely using telemedicine, or AI.

Given the special safety environment of habitats in a vacuum, we need to make sure that a suicidal or delusional resident can't seriously harm others.

LUNAR RESCUE SYSTEM

Mission Control

Given the global, sometimes simultaneous exploratory missions of the ILEP described in this book, we should give thought to how those activities will be overseen by Mission Control. Whether that would be an extension of NASA, an international consortium, or a private company (e.g. former mission control experts) is an interesting question. Either way, when a medical or logistics emergency develops anywhere on the Moon there needs to be a coordinated plan to respond to that emergency in a way that adequately meets the need whatever it might be.

Mission Control will need to be constantly maintaining oversight of EVAs so that the moment there is a problem, they will know the nature of the problem and rapidly respond appropriately. Part of that rescue system will be to ensure that the components of the rescue system are ready to respond on a moment's notice and that assets are in place, at the right place when needed.

Self-Rescue

Lunar expeditions may wish to have more than one vehicle. In this way, if one breaks down or if there is a medical incident (e.g. cracked visor) the other half of the crew could respond immediately. One could also have a robot as a team member that would be able to suffer much more trauma and still be functional compared with human crew. Telerobots on vehicles could also be pre-positioned prior to the landing of international explorers and they could follow the crew. In this way, the landing could be observed and responded to and any incident could have an immediate, teleoperated response.

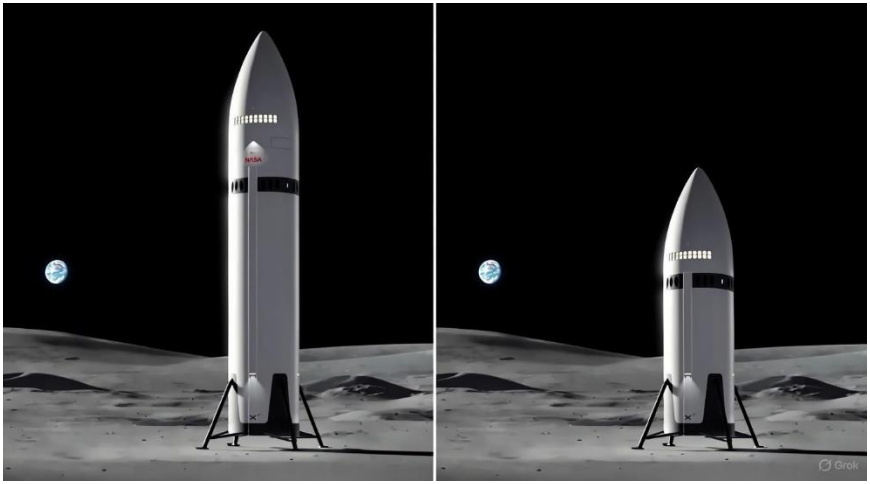
Surface Rescue

Different responses will be applicable depending upon the situation and location. If it happens within a base and the resources are available there then no global response is necessary. If it is during an EVA but there are facilities within quick driving distance then the approach response might be either a crewed, teleoperated, or automated response. For example, say that a crew vehicle has a battery malfunction, the passengers have 36 hours of life support available, and there is a waystation five hours drive away, the solution isn't to risk the lives of a team arriving by a suborbital launch from the polar base but simply to send a charged electric chassis onto which the stranded crew module could slide to and then they complete the trip.

Suborbital Rescue

But, if it is an emergency and it will take too long for surface rescue to arrive, the solution of last resort would be to launch a shortened (stubby) vehicle specifically designed to suborbitally launch from a base with telerobots or crew which would land within driving distance away from the incident, quickly deploy their own vehicle with equipment (e.g. jaws of life) and supplies and arrive at the scene as quickly as possible.

Suborbital flights from a polar base can take about 20 minutes from launch to landing. To be rapidly functional, the suborbital crew may need to already be at no more than 1/2 atm and/or use advanced suits that have good flexibility while operating at 1/2 atm.



Stubby Starship sized to be a suborbital emergency response vehicle.

PUBLIC HEALTH

Population-based Medicine

In a discussion of a lunar base, public health wouldn't normally come up in conversation. For example, that part of public health dealing with disadvantaged people groups wouldn't really apply here. But public health experts tend to excel when it comes to establishing new health systems and data acquisition, and statistical analysis. In the clinical setting they can bring expertise to population-based healthcare management applicable in the setting of a unified healthcare system.

Epidemics

When it comes to infectious disease and epidemiology, it gets quite interesting. Here is another fresh start opportunity. What infectious diseases will we have an opportunity to exclude from a lunar settlement? With proper screening, treatment, quarantine and the segmented nature of off-Earth bases/settlements, one can legitimately consider completely excluding certain organisms from every coming from Earth. Think about viruses as opposed to bacteria. Do we need any viruses for human health or can we seek to prevent them from spreading beyond Earth?

Do we need malaria on the Moon or Mars apart from a study sample? Using quarantine, can we exclude the seasonal flu? When one begins to systematically analyze which pathogens can be excluded, it becomes apparent that large sections of infectious disease can be escaped from using

proper public health measures. Now, there are things like athlete's foot whose exclusion is more easily spoken of than achieved. If an infectious agent somehow makes it to a base/settlement, public health professionals could implement protocols to fully eradicate the agent given the unique segmented nature of off-earth facilities.

Will we experience an increasing number of man-made virus pandemics on Earth? Hopefully not but we can't reasonably exclude that possibility. It should be possible to use pre-launch and upon-arrival isolation for the lunar settlement to be largely immune from that risk.

FACILITIES AND EQUIPMENT

The International Lunar Base should initially have a medical specialty hab with sections for different healthcare functions. But, as the population of the base grows, that multi-purpose hab can be converted into a single function hab as more specialized healthcare habs arrive. Eventually, there will be an entire healthcare complex where residents can receive a wide variety of healthcare services. The order of development may be something like: multi-purpose medical facility, DentalHab, ICUHab, ClinicHab, PharmHab, HospitalHab, and later "BabyHab" if children can be safely born off Earth.

Equipment would need to precede the facilities by first being housed in multi-purpose habs until population growth justifies more specialized healthcare habs.

Remote locations such as the start of a new base may follow a similar path that the ILB followed by starting small with a multi-purpose hab and then specializing as the base grows.

MEDICATION

Shipping Costs

For off-Earth transportation costs, the rocket equation means that the cost of transport is directly related to mass. Things that are low mass such as computer chips or medications can therefore be surprisingly low cost to ship. So, for example, an 800 mg ibuprofen contains, yes, 800 mg of pure ibuprofen or just shy of a gram. A gram is 1,000th that of a kilogram. Let's say that, conservatively, when the ILB is established and growing, this is accomplished because the Starship fleet has become fully operational and with full reusability. In that context, it is estimated to

cost perhaps $850 per kilogram. So, each gram would cost $850 / 1,000 = $0.85 or less than a dollar -- not a lot. So, instead of going through the hassle of producing medication off Earth, just ship it. And at about $1 per tablet, an entire pharmacy could be shipped.

However, we don't want to waste medication and hence money, so we want to make sure that we have the right selection of medication and in the right quantity without a lot of medication exceeding its expiration date. There are computer systems that assist with "demand forecasting". This will depend upon the expected need, usage rate, how much of the meds are exceeding their expiration date, etc. It is a bit different than what pharmacies are used to dealing with but should be withing their capability to figure out. And it could be a feather in the cap of whichever pharmacy chain takes the lead in becoming the first off-Earth pharmacy.

Pharmacist in the International Lunar Base.

Certain emergencies are rare but critical meds need to be available even if they are likely to expire without being used. That's just the price that one must pay to be prepared for emergency situations.

With a three-day one-way transit to the Moon, maintaining lunar pharmacies is very doable. Far more challenging will the pharmacy on Mars where the minimal wait time will be the six months of travel and the maximum time would be the 26 months waiting for the Earth-Mars launch window to open plus the six months travel time (= 32 months), plus the radiation exposure, storage requirements, and medication expiration dates.

HEALTHCARE IT SYSTEM

Finally, as new worlds are settled, it presents an opportunity for fresh starts when it comes to measurement systems (e.g. let's leave the imperial system on Earth), logistics, electrical & electronic standards, financial, governance, and infectious diseases. Well, another fresh start opportunity may present itself in a brand-new healthcare system including a healthcare IT system.

Given the ability for large language models (LLMs) to greatly increase the speed of computer programming, perhaps we could conceive of a new, comprehensive, integrated, efficient healthcare IT system. There would be time to develop such an IT system as the bases grow and as AI continues to advance.

Especially given the limited staffing in early off-Earth bases, efficiency means extending healthcare while not consuming too much time of the base's residents. IT systems such as electronic medical records (EMRs) should not turn healthcare workers into data entry workers like is so often done. Reducing the burden of EMRs could include the application of microphones and maybe cameras in the exam room and using AI to document and suggest orders. I am aware of at least one company that is working with a major tech company to do exactly this, and I can imagine how the time of clinicians can be more focused on patient care with the AI "scribe / assistant" offloading much of the information work.

It is here proposed that the fresh start opportunity that the lunar settlement presents and the new AI tools be taken advantage of to openly develop a new, comprehensive healthcare IT system that would be broadly available at reasonable cost to enhance utilization uptake not only beyond Earth but on Earth as well.