USC ASTE-523 -- Spring, 2023
The Design of Low-Cost, Space Missions
A Near-Term, Income-Generating, Lunar Settlement

Homework Set #4 -- Due 2/16/23

ANSWERS

This course is concerned with colonizing the Moon. However, one of the bigger topics in the colonization arena is whether to colonize the Moon or Mars. The first question is effectively a short survey of the people in the class. For Mars, the trip times and stay times are largely fixed by the syndoic period between the Earth and Mars -- i.e., you have to start and return when the planets are lined up so your target will be there when you get there. (There's no good way for you to hang around and wait for Mars or the Earth to show up, especially if they've already passed.) That's not a major problem for the Moon. I can go to the Moon and return almost any time. Of course, I would typically prefer to be on the Moon during the daylight for whatever location I'm at. Here's some basic data:

Mars tours:	
Tourist total round trip time	970 days (2.66 yrs)
Stay time on Mars	454 days (1.24 yrs)
Working on Mars:	
Probable minimum tour of duty	6.9 yrs
Moon tours:	
Tourist total round trip time	14 days or 36 days
Stay time on the Moon	7 days or 29 days
Working on the Moon:	
Probable minimum tour of duty	3 yrs (could vary)

For working on the Moon or Mars, we assume that you would take your spouse and kids with you and that communications back to Earth was quick and easy. (Not quite so quick for Mars. The time from when you say "Hi" to when they say "Hi" back varies from 10 min to an hour and a half, depending on where Mars and the Earth are in their orbit.) Answer all of the questions as though someone else were paying for the cost of the trip.

1. Your gender?
   Are you married?
   Do you have kids?
   Would you visit the Moon as a tourist? (1=No to 5=Yes)
   Would you visit Mars as a tourist? (1=No to 5= Yes)
   Would you consider getting a job on the Moon? (1=No to 5= Yes)
   Would you consider getting a job on Mars? (1=No to 5= Yes)
   Any comments on either trip?

   There is no right or wrong answer here. We are trying to collect people's opinions and ideas which we'll summarize it for the class.

2. In today's space business, small businesses appear to have an advantage in terms of reducing mission cost. Explain why they have an advantage in space, but don't appear to have a similar advantage in producing low cost automobiles. Do you believe that this advantage will extend to building settlements on the Moon? Why or why not.

Advantages of small businesses in space:
- Tend to be innovative in their approach
- Rapid decision-making
- Cost is always critical
- Don't have large infrastructure to support or to get in the way
- Don't have expensive facilities that need funding
- Don't have expensive R&D support activity that drives up cost

Why don't they have an advantage in car production:
- Can't afford large manufacturing facility and assembly lines
- Don't have capital to create economies of scale
  (special tooling, large factories)
- Don't have large R&D staff to create new, low-cost approaches

For building lunar settlements, it's likely to be more neutral. (Any answer for this part is OK, so long as it is well explained.)

Three advantages of small business are that they are still innovative and rapid in their response and the lunar settlement can be broken down into potentially many small pieces. However, the settlement as a whole is a large activity that allows large business to take advantage of their larger R&D staff and capital.

3. The environment on the surface of the Moon is remarkably brisk with nighttime temperatures falling to about 100K (–280°F). Mars is not quite as cold, but is a much harsher thermal environment. Explain why. How might you design or operate hardware to withstand the cold lunar environment at low cost?

Because Mars has an atmosphere, cooling can occur as on Earth by conduction, convection, and radiation. In addition, winds can provide very rapid cooling. The Moon has no atmosphere and, therefore, no winds or convection. The regolith (surface) material is a very poor conductor of heat, so that the only practical cooling comes from radiation which is much more controlable than convection cooling. You could put material in a container with a reflective inner surface to minimize radiative cooling or bury material a few feet underground during the night. Inside an external layer of regolith, the temperature range will be very modest.

4. A particularly insidious problem for the cost of government space system programs is a time lag between mission phases caused by the decision making process (evaluate phase J before proceeding with phase K), the funding process (Congressional appropriations and flow-down), or simply bureaucratic inertia. Explain why this drives up cost and why it is particularly damaging within small organizations. Give four approaches for trying to solve this problem.

Why it drives up cost:
People put on overhead, or laid off -- may or may not choose to return
Cost of coming up to speed again
Cost of hiring and training new people
Schedule delay for coming back up to speed costs $$
Loss of morale costs $$ and makes people less committed to success
For small company, may be no option but to lay off people or close the company

What to do about it:
Recognize the nature of the problem and deal with it as a specific management requirement
Require decision making be done on time
Do decision making in parallel (rather than in series) with ongoing work
Make contracts run for 15 months at a time, to avoid layoffs due to annual delays
Make contract boundaries well after fiscal boundaries to allow for decision making
Slow activity if delay is imminent to avoid a funding cliff
Motivate management and contracting organizations to avoid breaks
USE A COMMERCIAL PROGRAM RATHER THAN A GOVERNMENT ONE

5. In your own words, explain both the advantages and disadvantages of using industrial, non-space-qualified hardware inside a space settlement on the Moon.

Advantages:
- Low cost
- Immediately available
- Much wider range of parts available
- Has already been through extensive use testing
- Manuals and help available on the web
- May get free hardware or software plus help from a manufacturer that wants free adverstising

Disadvantages:
- May be heavier than you would like
- May have larger performance range (therefore require larger margins)

6. We are proposing a major paradigm change for space hardware by using normal commercial hardware inside a settlement on the surface of the Moon. Give 5 examples of products or services (not necessarily space-related) which have undergone a major paradigm change since ~1990 resulting in dramatic cost reductions per unit of performance. For each, briefly explain what has brought about the change.

Examples:

Item	Cause
Long distance phone service	GEO communications satellites
Long distance phone service	Phone via internet
Computers	Introduction of tablets, smartphones
Communications	Internet

Telephones	Cell phones
Zoom meetings	Comm software
Messaging	iPhones
Major appliances	"Smart technology"
Air Travel	Economies of scale
Calculators	Digital electronics
Watches	Digital electronics
Small cameras	Plastics + manufacturing
Small cameras	Cameras in cell phones
Package delivery	Competition, air transportation
Digital photography	Digital electronics, cellphones
Color printers	Digital electronics
Music players	Digital electronics, cellphones
Location services	GPS
Books	E-books
Encyclopedias	Internet
Watches	iwatch
Games	Video games
Toys	"Smart technology"
Movies	Video on demand
???	iphones, tablets (didn't exist earlier)

7. In your own words, explain the principle differences in terms of cost between the Traditional Lunar Habitat, the O'Neill Lunar Settlement, and the O'Neill Space Colony. Why are these differences so large?

The main reason for the very high cost of the TLH is that everything in the habitat is designed and built specifically for it and is imported from the Earth. In the OLS, we use ordinary commercial equipment for most of our equipment and build from lunar material those things which are both large and particularly simple, such as desks, chairs, tables and typical furniture. We also build the rooms themselves. The OSC uses much the same furniture and equipment as the OLS, but is huge in size and costs a great deal to build and furnish because of its size.

8. Explain why living in a large O'Neill enclosure on the Moon will dramatically reduce the time, cost, and challenge of lunar business, science, and living.

The biggest reason is that it will allow us to use normal, everyday Earth equiment on the Moon. I don't have to create it, reinvent it, or test it. We jusst set it up and use it. The equipment does not need to be refineed, perfected, or tested. It doesn't even have to work right the first time. If we go to Sam's Used Lunar Computers and get something that's cheap but doesn't work well, we order one from Costco and have it delivered at the end of the week. If someone wants a bowl of pea soup, we open the can, heat the soup on a normal stove, and give it to them. The TV he's watching while eating the soup came from Home Depot and plugs into a 110V outlet on the wall.