Rotating LEO Resorts as Training Wheels for Space Settlements

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Abstract

This paper and presentation suggest that rotating resorts in LEO are a natural step toward realistic space settlements. They allow early resolution of key issues about human health in low gravity, at far lower cost and risk than bases on the Moon and Mars. Tourists may stay a few weeks, but most staff will stay >1 year. They will be the test subjects for health and countermeasures in sustained Moon & Mars gravity. Such resorts can determine whether and how we can live in Moon or Mars gravity in good enough health, and whether reproduction is normal. They also allow iterative tests of highly automated low-g farming and other circular economy concepts, at far lower costs and risks than feasible on the Moon or Mars.

A slowly rotating asymmetrical dumbbell can provide Moon and Mars gravity at the two ends and ~0g near the hub. If a resort is in Equatorial LEO (ELEO), launch and reentry can be done on any orbit, with flight times under 2 hours. This allows bus-like seat spacing and may allow launch costs low enough to enable large-scale ELEO tourism.

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Some key questions we must answer to design viable space settlements

1. How much gravity do adult humans need for health? (Please see the bibliography.)
2. How much gravity do humans need for healthy reproduction and child development?
3. What diet, med, & exercise countermeasures do we need for good health at reduced gravities?
4. What crop mixes work well in low g, & what do we need for highly automated low-g farming?
5. How much "circular economy" is practical on scales of LEO resorts to initial settlements?
6. How much supply mass from Earth will we need per person-year, over the first ~10 years?

Key implications of different settlement locations

1. Delivering people or supplies to any settlement beyond LEO will cost ~10X more than to LEO.
2. Celestial resources are nearly infinite, but also nearly infinitely spread out. This matters!
3. Equatorial LEO (ELEO) needs equatorial launch sites, but allows launch & reentry on any orbit.
4. You can't see most of earth from ELEO, but LEO comsats could put hi-res Earth views online.
5. ~1 cm of radiation shielding is enough in ELEO, but beyond LEO you need meters of shielding.
6. On demand trips to & from ELEO take hours; for the Moon, days; and for Mars, 0.6-2.8 years.
7. Few-hour rides to & from ELEO resorts can be more like bus than RV rides, with lower prices.
8. Artificial gravity makes outside views rotate, except with de-spun modules or video displays.
9. Artificial gravity causes different sensations than rotating rooms. We must test AG in orbit!

Scenario for a LEO resort that uses artificial gravity (=AG)

1. The resort is a rotating asymmetrical dumbbell that provides Moon & Mars gravity at the ends.
2. Spin rate & facility length are based on relevant crew spin tests in LEO, not rotating room tests.
3. Inboard nodes provide zero-g and low-g, for docking and for tourists to try freefall & low-g.
4. Most tourists may stay for 1-4 weeks, but most of the resort staff will stay a year or more.
5. Low g may ease visitors' 2-3 day adaptation to 0g. And many may prefer low g to 0g.
6. Staff monitoring will correlate health with activity, diet, gravity levels, countermeasures, etc.
7. Launches deliver tourists often enough that most stays overlap; this can improve operations.
8. The resort can also host low-g research and service any co-orbiting microgravity facilities.
9. Spent stages and waste can be recycled onsite or stored for a later coplanar settlement.

Space settlement payoffs from an AG LEO resort

1. An AG resort can quantify the appeal of living with easy access to a range of gravity levels.
2. Staff health data can tell us whether sustained Moon or Mars gravity are enough for health.
3. If Moon and/or Mars gravity allow good health, the resort can refine needed countermeasures.
4. If we need >Mars gravity, we will know that our future will be in rotating free-space settlements.
5. A resort can also determine the health implications of retiring at various reduced gravity levels.

Other settlement tasks AG LEO resorts can address

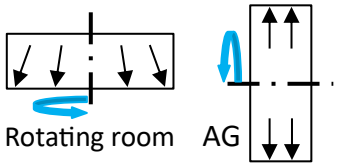
1. Increasing the spin or lengthening the resort can provide higher gravity levels, up to a full 1g.
2. An animal lab (zoo?) can test mammal reproductive issues relevant to human reproduction.
3. Resorts can test crops, automation techniques, and processing crops into food for resort use.
4. They can refine other circular economy techniques, to reduce supplies needed from Earth.
5. They can also store stages & waste that settlements will find more useful than celestial ores.

Thesis: If you want viable space settlements, start with an AG resort in LEO or ELEO.

Appendix A. Why can't we use rotating room tests to select the AG spin rate?

In 1960, Graybiel et al. tested six young soldiers in a rotating room over 2 days. The room was round, windowless, 15 feet in diameter, and rotated about a vertical axis at 1.71 to 10 rpm. Some soldiers reported mild general malaise, nausea, or headaches even at 1.71 rpm. One vomited at 2.21 rpm. Increases to 3.82 and 5.44 rpm raised the response frequency and severity. But most subjects did eventually fully adapt, even to spin rates up to 5.44 rpm.

Graybiel noted that his tests had a different spin axis from AG, and that that may be significant. It is. As shown at right, felt gravity nearly aligns with the spin axis in rotating rooms. But in AG, the felt gravity is at right angles to the spin axis. The sensed Coriolis forces are very different.



More importantly, in a rotating room, the forces stay the same when you turn around, so it is easy to adapt. But in AG, the forces you feel reverse direction each time you turn around. So you can't adapt as easily, if at all. We don't know. We really must test people in true AG, in orbit. But halving the spin rate requires a 4X longer spin radius. The best shape for AG resorts may be the longest affordable dumbbell. To learn more, please read www.thespacereview.com/article/4905/1.

Appendix B. How much can we reduce tourist launch costs to an ELEO resort?

The Mercury capsule weighed ~1 tonne. Gemini, Apollo, and Soyuz weighed ~2 tonnes per seat, and Crew Dragon about the same, if using all 7 seats. (So far, they have carried only 2-4 people.) Mass/seat growth is due to longer and more challenging flights that include docking. But capsules have also grown to use available booster capacity, without redesign for maximum seat count.

We can do better, especially if free flight time is just a few hours. The quickest docking of Crew Dragon to ISS was 14.7 hours after launch. But Gemini 11 docked to its Agena just 94 minutes after launch. ELEO always allows quick docking and landing, since the orbit stays over the launch and landing site. If you can't dock to a resort in a few hours, reenter and re-launch after problems are fixed. Few-hour flights can also use batteries & evaporative cooling to reduce weight & cost.

Short missions also allow far closer seating. Not everyone needs or wants to pay for roomy seats. Seating can be even closer if tourists need not wear IVA pressure suits and helmets. Most tourists may not want to wear them, or ride in any vehicle that has reason to need them.

Competition will also help drive seat prices down. I don't know how low prices may get, but they may get low enough for serious AG tourism in ELEO. And that's a step toward space settlement.

Appendix C. Can spent stages and facility waste be more valuable than celestial ores?

Space resorts and settlements may both buy spent rocket stages delivered to them, for habitable space or many other uses. Stages modified to allow better and easier use will get higher prices.

And if settlers on the Moon or Mars find an ore with the same elements as their waste flow, they will use it to expand their settlement, even if the processing is hard. Settlement waste even has several advantages over such ores: we don't even have to find, mine, or transport them; we know its chemical forms; and a mostly-circular local economy can adapt waste to be easier to process.

The most useful advantage of spent stages & waste vs. celestial ores is that the processing can be the same everywhere. Celestial ores will often need new hardware and tricks for effective local use. Local ores may be needed to make a profit, but waste will be better for most sustainment.

Finally, the further settlements get from Earth, in time or deltaV, the more Earth supplies will cost. Then the economy must get ever more circular, to reduce future supply costs. But the first space settlement might best be in ELEO, where profit can come from credible services rather than ores.

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