Profitable Condominium Development Using Self-Replicating O'Neill Colonies

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Space Resources Are Abundant:
Return on investment exceeding 50 to 1 is projected using conservative assumptions, entirely from the sale of homes built from off-Earth materials and solar energy. An initial city of 1,000 condos housing 10,000 workers is constructed from Lunar materials over a ten year period for $20 billion. It is copied annually ten times, creating one million condos valued at $1 trillion. New workers buy in to the space cities for $100,000 each plus transportation costs, receiving pay in fast-growing equity in future condos. A flourishing secondary economy will provide interior decorating, medical care, bicycles, restaurants, etc. After 20 years, the space settlers will own the living spaces and industrial base, and will continue the annual doubling construction as long as it is profitable to do so, trading among ourselves for all the factors of life.

Inductive Proof:
Assume true for K. Show true for K plus 1. Generalize (by setting K equal to K plus 1; repeat). Remember to go back and show true for the initial K. Assume true for one self-sufficient city in space, built from sunlight and ore. Show true for cloning the city and all infrastructure. Extend to a million or a billion condos. Go back and figure out how to pay for the first city.

Assumptions:
1. Ten annual investments of $2 billion each
2. $5 billion for Moon Mining facility at the South Pole
3. $5 billion for large space station to house construction workers
4. $5 billion for the initial space processing factory
5. $5 billion for five drones to capture asteroids and return them to Earth orbit

2010—first O'Neill city completed with one million tons of ore from the Moon
2011—second city, factory, and drone completed
2012-2020 completion of remaining one million condos in one thousand communities
2020: Payback of Earth investors: $1 trillion
2021: Workers duplicate everything for themselves—the second million condos

Feasibility Analysis:
Before optimizing for obvious cost savings for the above model, it is helpful to note the elements of feasibility demonstrated by recent human activities. The International Space Station is a single condo capable of housing 10 workers. It can be duplicated using the same plans, docking scheme, launch capacity, training facilities, etc. The second ISS could be linked to the first by a strut, and the two can be rotated to simulate gravity, creating a "barbell" design for long-term living. Each barbell can be duplicated using the same designs and resources, until (after 10 doublings) one thousand condos have been constructed. The Apollo astronauts returned ore from the Moon. Additional trips could lift tons of ore to space for processing. The simple laboratory experiments on the space shuttle and various space stations could be expanded to process I-beams, cables, glass, and concrete from the ore. The Eros docking and scientific mission could be modified to re-direct small asteroids to Earth orbit, increasing the available materials without limit. Cheap access to space will come with increased traffic and improvement trends until the United Shuttle makes routine flights to LEO. Thus, each aspect of the Space Condos model is feasible. This paper focuses on improvements in the scalability of the steps and the profitability of the business model.

The Water Cannon:
It is believed that the South Pole of Earth's Moon contains substantial hydrogen, either as water ice or as solar wind trapped at the bottom of permanently dark craters. Lunar ore contains a large amount of oxygen, which reacts explosively with hydrogen to form water and liberated energy. A long tube made from rocket upper stages or concrete braced along crater walls could guide one-ton barrels of ore to escape velocity. An engineering comparison is needed between ore ships, mass drivers, and water cannon to determine construction costs, maintainability, capacity, accuracy, and other attributes for moving ore to space. Initial loads would contain iron wrapped in concrete. More advanced methods of mining, separation, and pre-processing could increase the raw materials menu without changing the basic delivery methods. A system of one or more tubes firing one-ton barrels

every 30 seconds would place one million tons into space in one year. Tugs could retrieve the ore, perhaps from L-2, and guide them to the factory for processing. Perhaps 20 workers will be needed at the Moon Mine for several years, until ore from asteroids and comets floods the market.

Construction Shack and LEO Transfer Station:
Each city holds up to 10,000 people, brought up from Earth in weekly loads of 200. For best use of supershuttle transports and orientation facilities, the initial construction shack will be converted to a low-Earth-orbit transfer station upon completion of the first city. Future doublings of the traffic will require additional transfer facilities.

Factory:
The elements on Earth are identical to the elements in space, so, in theory at least, anything we have here can be made in space. Until the replicator is commercially available the best assumption is that the heavy structural components will be made in space and the advanced designs (semiconductors and pharmaceuticals) will be made on Earth. The simplest model calls for iron processed with solar heat to be molded into building materials, including larger and more efficient factories. This bootstrapping and research and development approach will enhance current knowledge of space-based industrial processing, including glass, aluminum, concrete, I-beams, cable, vapor-deposition balloon-structures, tethers, foam metals, etc. Easy tasks will be pursued initially, with slag stored nearby, until additional processing skills are available. Using "every part of the pig except the oink", materials will be fully consumed. The factory output will provide the ability to build more factories, drones, cities, supershuttles, transfer facilities, volatiles storage, and other structures and products. Each standard factory will be capable of processing at least two million tons of ore per year.

Drones:
Captured asteroids and comets will quickly flood the market for ore, replacing the Moon as the source of unlimited materials for growth. Various methods of diverting the asteroid (or portion thereof) have been suggested, including mass drivers, ion drives, solar sails, bombs, chemical fuels, etc. I am fond of using beamed energy to power a "space needle", which sets up an elevator on a rotating asteroid and hurls ore off the end every rotation. You might assign to your students in orbital mechanics the problem of timing the separations so that the main body AND the ejected mass both are captured by the near-Earth factory tugs, while timing the market for elements of fluctuating value, and optimizing against competing teams for maximum profit. Aerobraking is permitted as long as no political science or law students are in your class!

Supershuttles:
I have long wanted to buy a ticket to space. Cheap access to space depends on a reliable market for launches and nothing else. Many existing and proposed designs will greatly lower the cost to space, improve safety, and add flexibility to the limited methods now in use. My suggestion is that the orbiting factories construct airframes from foam metals, de-orbit them for parachuting straight down, and outfit them with avionics and other complex parts on Earth. This solution scales with the growth of cities in space, improves structures (stronger, lighter, and constantly improving with experience), and reduces costs. Each city will need one supershuttle making a weekly round trip to LEO in order to bring up the workers, so the number of ships must double each year. It may be that the same craft will serve as tugs and space taxis/buses, given their strength, size, cheapness, and hybrid Earth/space construction methods.

Secondary Economy:
Rich construction workers will demand ever-improving goods and services. Many services will stay on Earth during the set-up period and be communicated to the machines and screens of the construction shack. Soon the neighbors of the construction workers will create a thriving economy within each city and among the cities, covering everything from precious metals (for gold plating your aquarium) to sushi bars (for celebrating your patent filings). My model assumes modest gains in productivity per worker, entirely absorbed in secondary businesses and the introduction of non-working residents (old, young, stay-at-home, and retired). Initially 50% work in construction and 50% work in other jobs; eventually 25% construction, 25% secondary economy, and 50% dependents. For example, a condo that held 10 workers in four bedrooms on rotating shifts in the early years might end up with a doctor, a factory automation manager, their two kids, and a robotic expresso bar on the front porch. Think "Manhattan" in the early years and "Montana" in the more expansive build-out scenarios.

Asteroid Belt:
Someone is going to wonder why we bring rocks to near-Earth when we can "plant seeds" in the Asteroid Belt. Moving one complete city to the Belt will create an easier doubling location, with two exceptions: the journey from Earth or near-Earth to the Belt will be long and slow; and the solar furnaces will need larger reflectors.

Other Revenue:
This paper examines ONLY condo sales to pay for space settlements, and finds that the revenue from that alone justifies the project. Other revenues will of course be sought, and may yield substantial profits. Solar power satellites are hard for a California Governor to seize, but can provide customers with a lot of clean electricity; platinum and other precious metals are available in astronomical quantities; and specialty products from crystals to pharmaceuticals will be offered. My favorite revenue "sweetener" is to sell artificial food flavorings developed in space—years of blue-green algae will inspire the scientists to achieve greatness in taste. However, like the Mayflower settlers, the funding for space will come from buy-ins that enable workers to make fortunes in space. The sunlight is free, the ore is free for the taking, and the initial designs can be copied ad infinitum without payment TO EARTH for anything, after the initial city and factory complex is purchased.

Risks:
Investment risks can be laid off in common ways, like diversification (one percent of your pension fund in fast-growing space assets); liquid markets (mortgage exchanges, real estate title brokers, publicly traded shares, and convertibility of Earth currencies for space currencies). Delays are costly so redundant paths are described, including five independent drones and multiple water cannon on the Moon; multiple cities each building factories, drones, supershuttles, and more cities; multiple spacelines carrying ticketed passengers; multiple transfer stations in LEO; multiple owners maximizing profits. The multi-tenant governance form is preferred to the political form, so the success of apartment buildings and shopping centers will be applied to space cities. Once the fertility process is set in motion, it is hard to envision economic reversals sufficient to stop it! The initial costs may be challenged as cheaper than NASA experience, but investors habitually outperform governmental approaches for cost-effectiveness. Decentralized markets are best for coordinating complex projects, so the Moon Mining corporation will sell ore to the Condo Construction corporation, and the fourth city will sell doorknobs to the third city.

Return on Investment:
Key variables in the Space Condos model are: initial costs and timeline for physical set-up; construction doubling rate; and market demand for space condos.

As long as the human race is motivated by better living conditions, the market for condos will be self-generating, due to the productivity of the self-replication model and cost effectiveness of exploiting available ore and free sunlight. By pre-selling condos under construction, the cash-flow analysis shows short time periods for capital at-risk, flexible market structures for financing growth, diversified secondary investment opportunities, and dynamic support for further growth and investment. That is, workers prosper after they buy in to the productive assets; space is naturally the low-cost producer of living facilities; new towns attract ambitious families; and multiple communities attract multiple sponsors. It is anticipated that asteroidal ore will quickly flood the market for materials, and the improvements in construction automation and techniques will quickly reduce the work requirements to a bare minimum, so most of the effort of building great cities will be in entrepreneurial support ventures.

Economic Insight:
Kenneth Boulding described the three factors of production as energy, materials, and know-how. If I have an ice cream cone and I give it to you, I don't have it anymore. If I teach you how to make ice cream, we both know how. The traditional factors of production, land, labor, and capital, are inappropriate for either the Earth's economy or the resources of space. The Boulding model describes the reason for the huge increase in wealth in the last one hundred years—we have more know-how!

The economic worldviews of tribes divide into scarcity or abundance. Are we facing shrinking hunting grounds and encroaching neighbors? We must arm and fight! Only through sacrifice, discipline, patriotism, and initiative can we hope to prevail against the dangerous neighbors who want to exterminate us. That's the scarcity paradigm that dominates political discourse and most economics texts. Are we facing unlimited abundance? Make love, not war. That's the abundance paradigm that emphasizes trade, learning, cooperation, risk, and tolerance.