Economic Imperative of Space Exploration and Settlement

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This essay addresses the economic imperative for creating a self-sustaining space-based economy. For a space architecture to be economically viable it must create wealth. Wealth is the total of all the assets of an economic unit that generate current income or have the potential to generate future income. Therefore, it is imperative that for a viable space-based economy to exist it must generate income and have the potential to generate future income.

Expansion of humanity into new ecospheres has been driven by many different needs and wants, however one of the main driving forces has been the creation and acquisition of wealth. In modern terms when we talk about wealth and income they are measured in units of money but in historic terms they were measured in how well a family lived. Wealth meant food, shelter, things to meet basic human needs and the implements needed for survival. A person with land and the equipment/manpower to produce had wealth. Income was measured in how well that asset(s) could provide for a family over time. Even people who expanded into new ecospheres for other reasons, such as avoiding persecution, still attempted to acquire wealth as defined in their time. Ultimately, the expansion of the human race is inexorably tied to the acquisition of wealth.

In general discussions space can be defined as everything that is not on Earth. From an economic point of view and the discussion of wealth acquisition this provides an arena so large as to be indescribable, whether in prose or mathematics. To do any type of meaningful examination a smaller unit has to be selected.

For this essay the economic unit that will be explored is space within the confines of the Sol solar system, primarily areas off celestial bodies. More specifically, space-based assets such as stations, satellites, or any other items not on or in a celestial body. The selection of unit boundaries is based on shared physical conditions within the unit which are significantly different than those found on or in a celestial body. This is analogous to basing an economic unit on a geographical location.

The space economic unit's environment includes:

- Micro-gravity often referred to as zero-g
- Extremely hostile environment to both living organisms and inert materials
- Extreme temperatures
- Unknown quantity of natural resources
- Energy in the form of solar radiation (light)
- Nothing to anchor structures. Everything free floats in orbit or is traveling from one area to another
- Inimical to human life

For an economic unit to produce sustainable income it must be able to provide something of value that is wanted or needed. The defined space economic unit will derive its value from location, its physical environment and minerals.

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One of the ways income is generated is through production of items that are wanted by buyers. The items produced can include everything from basic mined/refined minerals to complex manufactured items such as computers to food. All items require some level of effort to create and have buyers willing to pay/trade for them.

Profit is the difference between what it costs to make, deliver and sell an item and the price paid by the buyer. Profit determines the sustainability of income. Production of an item will cease if the makers of the item cannot make a profit or at least break even. While market forces influence demand and price, costs are driven by the production process.

The production process is a process that adds value to an item. The mining and refining of minerals add value to the extracted minerals. At each step of the process, the value of the mineral increases. The production of computers is also a value-added process. The creation of each component and the final assembly adds value to the product. Ultimately, the economic viability of the space unit will depend on the demand of products and the value-added in the manufacturing process.

Food production in the economic unit is subject to the same market forces as any other produced item. The final manufacturing/production cost, including transportation, must be cheaper than the price for a profit to be made. Driving forces for price will be the same as those that drive the price of food in terrestrial markets and include type, flavor, freshness and availability.

PRODUCTION (Value Added)

Definition of Value Added: the amount by which the value of an article is increased at each stage of its production, exclusive of initial costs.

The purpose of production is to add value to a finished product. Mining materials, refining them, creating components from them and ultimately assembling the components into a finished product has value added at each stage in the form of materials and labor. The final products value is determined by the market while profit is determined by the costs incurred for each phase of manufacturing versus the final price.

The market determines the value of an item by meeting a need and/or desire. The demand for that product is determined by the willingness of consumers to purchase it at a given price. An item that meets a need better than its competition may be able to charge a higher price than an inferior product. Consumers are also willing to pay higher prices if they can gain status by owning it.

For a company to make a profit from space manufacturing they must be able to build something that meets a need, has a lower cost to manufacture than what the market will pay and meet a consumer demand. The best way to accomplish this feat is to use the space environment to the advantage of production, i.e. produce items that are affected by the environment resulting in superior quality, products that can only be made in space or have an advantage due to location.

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COSTS

All products involve costs to produce them. Labor, materials, energy and transportation are a way to categorize costs. Each of these categories have a unique challenge in space.

Labor

Labor is a necessary ingredient in a value-added operation. This could be people onsite doing the work or overseeing/maintaining equipment to tele-operators. The process defines the amount and type of labor as well as where the labor will be located.

As stated earlier, the space environment is extremely hostile to humans. Unlike Earth, there is no food, breathable atmosphere, suitable shelter and or gravity. Everything that can be found on Earth in abundance is currently missing in space. For humans to exist and thrive in space, these items must be present.

The very basics of a livable space will have to include an atmospheric processor to maintain a breathable atmosphere, shelter from the hostile environment which includes radiation, extreme heat/cold, and meteoric impacts along with places to work, sleep, eat and provide personal hygiene.

Material

Material can range from raw minerals mined on site or manufactured products for assembly into a larger product. The material can come from a celestial body or from a space born asset. Costs are determined by location and type of operation. Mining ice on an asteroid has a different cost then mining ice on the moon. A circuit board manufactured in space will have a different cost then one made on Earth.

Energy

Energy is a prime ingredient in a value-added process. It can take many forms including heat, electricity, kinetic and combustion. The energy could come from nuclear power plants (fusion/fission), solar panels, a gravity well, and/or chemical reaction. The type is determined by the value-added process and the associated costs.

Transportation

Transportation will be unique as compared to terrestrial transport. On a body such as earth, transportation costs are measured in distance. X amount of miles/kilometers equal Y cost in fuel, maintenance and deprecation of the vehicle. However, in space the cost will be calculated in the change of velocity.

Moving items to, around, or from space requires a change in velocity. Going from one orbit to another requires a change in velocity. To leave Earth (or any celestial body) requires the vehicle to gain even more velocity. The larger the celestial body the greater the required velocity. Returning is the same process but in reverse. A vehicle must reduce its velocity.

The change in velocity (delta V) requires energy. It can be in the form of fuel, electricity, gravity or even conversion of potential to kinetic however, all energy has a cost. The more delta V you need the greater the cost. Mass is also part of the cost equation. The greater the mass, the

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more energy is needed to create delta V which increases cost. Hence mass is directly proportional to the cost of movement to, around or returning from space.

Assets in strategic places can reduce the cost of delta V by reducing the mass of the object to be moved or by using energy that costs less per unit. The type and amount of savings will be determined by location and market. Just as it is on earth, profit is created by being able to produce a product and deliver it to the market for less than the selling price. Long-term profit provides sustainable income which generates wealth.

The type and placement of infrastructure in space will be determined by the markets served. For the infrastructure to be effective it must provide convenient/cost effective access to the materials and markets. The type and placement of infrastructure will change over time as the market changes. Initially the infrastructure may support mainly outbound traffic in the form of exploration missions and small amounts of manufacturing but as the market matures the infrastructure would need to support traffic in both directions and greater volumes of production. Just as it is on Earth, space-based infrastructure will change over time to support both mature and developing markets. It will be modified, moved, demolished and abandoned as the market dictates.

Each market has its own needs and must be examined separately.

MARKETS

To have a sustainable economic unit, wealth must be created. Production of goods is an excellent method to create wealth, but the items produced within the economic unit must meet a demand not currently satisfied by other production. The demand not being met could be quantity, quality, type, need, price and/or apparent worth. The goods must also be produced and sold at a profit. The best way to do this is to use the economic unit's assets to an advantage. An example would be producing goods within a country (economic unit) to avoid tariffs, excessive transportation costs, labor issues, etc. For a space based economic unit the environment and location are the assets.

The harsh conditions found in space can be used for an advantage in production. The amount of wealth creation will depend on how effective the space environment can be used to produce a given good. The more that the production of goods is dependent on the space environment, the greater the value of that production to the space environment. If an item, which is in demand, can only be produced in microgravity then its worth is greater to the space economic unit then some other product that can be produced in a less hostile environment. The greater economic worth results in higher probability of wealth generation.

The number and type of known products that could be produced utilizing the space environment is far greater then what is discussed in this paper. History has also shown that when humans enter a new environment we tend to use that environment in new ways and to develop new unique products. In other words, it would be difficult to impossible to create a comprehensive list of goods that can and will be produced in space. Instead some of the known markets that will benefit from the space environment will be covered.

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Health

Proteins and internal organs can be grown in a microgravity environment. The production of proteins benefits from crystallization via random diffusion. This results in a more orderly crystal with fewer impurities. Initially these proteins will be used for study but eventually they will lead to new drugs and unique treatments that can only be produced in microgravity.

Cells grown on Earth result in flat shapes that do not function as they do in the body. Cells grown in microgravity result in 3D structures that have the same function as inside the body. This could lead to organ transplants that use organs grown from the recipients' tissues. Eliminating the possibility of rejection and relieving the need for antirejection drugs and therapies.

Future advances in stem cell research combined with microgravity could result in the ability to replace (almost) any part of the body. Creating a new way to treat injury, disease and age.

Raw Materials

Raw minerals would be mined from celestial bodies (outside the defined economic unit) however, refining and processing could occur with the space economic unit especially if it occurs near the extraction point so that transport costs are reduced. Purifying the material at the mining site ensures that more of the transported mass is the sellable. This reduces the overall cost per pound for transport.

Material processing

Crystal based materials have different properties when created in space. An example would be a boule used in computer chip manufacture. A boule created in space would have a more uniform structure creating a better base for computer chips. Over the years, material science experiments have been done in space resulting in interesting materials. As we gain more knowledge in space processing new materials will emerge that could potentially change entire industries. Super conductors, both electrical and optical, are two of the possible outcomes, creating massive upheavals of many different industries.

Consumables

While the space environment is not conducive to food production, transportation costs moving food from a planetary site to space could be exorbitant. Producing food outside of a gravity well requires less delta V to transport it to space based consumers. Just as on Earth, producing food closer to consumers reduces transportation costs, the difference is that the cost in space is not measured in distance but in delta V.

Production, storage and distribution of fuel (energy) outside a gravity well reduces the cost of transportation. The greater the delta V that is required to move fuel to the consumer, the more of the fuel is used for distribution and lower the profit. Income is maximized by lowering the cost of goods including the cost of transport.

Production, storage and distribution of breathable atmosphere is subject to similar economics as fuel production.

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SUMMARY

Just as with any economic unit, the space economic unit is complex and diverse but has enormous potential and does not exist in a (economic) vacuum. Initial demand for products produced in space will be driven by the economies of Earth and then other celestial bodies. Eventually space based demand will become a major driver of the space economy. Which is integral to the colonization of space.

As the economic unit becomes belter defined, more people will attempt to use it to acquire wealth. Early adopters have a greater chance of maximizing their returns but ultimately it will be the people and organizations that learn how to maximize the economic unit's environment that will be the big winners.

In the end, the person or company who is willing take advantage of this new frontier could become the first trillionaire.

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