Challenge of Developing Circular Economy in Human Space Flight

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Current human space program such as International Space Station (ISS) relies on re-supply items which are launched and delivered from Earth. Due to this linear economy or system, various types of issues exists. One example is inefficient material transportation. Each re-supply mission requires rockets, spacecrafts, and re-supply items and more than 95% of the total mass are discarded every time. One of the bottlenecks in space activities is escaping from Earth's gravity, or more precisely, escaping from Earth atmosphere’ resistance. Rockets are used to overcome this barrier, but they are extremely inefficient, with about 6% of their mass being the structure, 93% is fuel, and only 1% is the spacecraft including re-supply items. Next issue is the shortage risk of re-supplies. This could happen due to launch failures or spacecraft malfunctions that were scheduled to transport supplies to the International Space Station. Waste is another issue and as they can only be discarded less than once a month, when cargo spacecrafts departs ISS and be burnt during Earth atmosphere’s re-entry, they sometimes causes uncomfortable odors as well as occupying ISS’ s stowage area. One more issue to be mentioned is the amount of time and astronaut and ground team ‘s resources consumed for planning and unloading/loading supply and re-entry/return items. As there are only couple of opportunities of re-supply and disposal each year, it requires huge amount of time and human resources for planning and managing the items. If we could recycle items used in space, we would be able to reduce the burden on astronauts and the team on the ground and use the same resources for other value creation.

In order to make human space program sustainable, it is necessary to develop and establish a circular economy or system. The question is, what needs to be done and what are the gaps to realize it? Ideally speaking, we should transport natural capitals from Earth and create the same eco-system at the destination. Natural capital that cannot be initially obtained locally will have to be transported from Earth. Prof. Yamashiki is working on a concept named “Core Biome Complex" with other professors and experts to identify the minimum element and amount of natural capital, i.e. “selected core biome”.

Efforts are already been made on ISS. Here we’d like to focus on essential elements for survivability which are air, water, and food. Approximately 91.8% of the air has been recycled even though 8.2% of it is leaking every year. Highly pressurized Oxygen tanks are periodically launched and used to maintain the pressure and volume. Approximately 93% of water, including astronauts’ sweat and urine is collected and recycled and NASA is aiming to recycle 98% of it in the future. Food completely relies on resupplies.

Given the fact that we will likely not be able to recycle air and water 100%, and as we know that it would not be easy to re-supply air and water if we are traveling to Mars and beyond, we would need natural capital to maintain the amount of supplies for nominal operation as well as cases when technical recycling system fails. We would also need natural capital to support technical recycling as we would need a biological recycling system including decomposers to develop food recycling.

In summary, it can be said that in order to establish a circular economy for sustainable human space program, we should continue our efforts to develop a technical recycling system, and in addition to that, we would need to figure out the minimum element and amount of natural capital to be used as a reserve as well as a part of biological recycling. In addition, it is also important to remember that those recycling

system should be designed to avoid waste and pollution, and corresponding regulations or standards should be developed as well.

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