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Sustainability in Space: Implementation of Circular Economy and Material Efficiency Strategies in Space Missions

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Abstract : The ultimate aim of space exploration has been centralized around the possibility of life on other planets in the solar system. This aim is driven by the detrimental effects that climate change could potentially have on human survival on Earth in the future. This drives humans to search for feasible solutions to increase environmental and economical sustainability on Earth and to evaluate and explore the ability of human survival on other planets such as Mars. To do that, frequent space missions are required to meet the ambitious human goals. This means that reliable and affordable access to space is required, which could be largely achieved through the use of reusable spacecrafts. Therefore, materials and resources must be used wisely to meet the increasing demand. Space missions are currently extremely expensive to operate. However, reusing materials hence spacecrafts, can potentially reduce overall mission costs as well as the negative impact on both space and Earth environments. This is because reusing materials leads to less waste generated per mission, and therefore fewer landfill sites are required. Reusing materials reduces resource consumption, material production, and the need for processing new and replacement spacecraft and launch vehicle parts. Consequently, this will ease and facilitate human access to outer space as it will reduce the demand for scarce resources, which will boost material efficiency in the space industry. Material efficiency expresses the extent to which resources are consumed in the production cycle and how the waste produced by the industrial process is minimized. The strategies proposed in this paper to boost material efficiency in the space sector are the introduction of key performance indicators that are able to measure material efficiency as well as the introduction of clearly defined policies and legislation that can be easily implemented within the general practices in the space industry. Another strategy to improve material efficiency is by amplifying energy and resource efficiency through reusing materials. The circularity of various spacecraft materials such as Kevlar, steel, and aluminum alloys could be maximized through reusing them directly or after galvanizing them with another layer of material to act as a protective coat. This research paper has an aim to investigate and discuss how to improve material efficiency in space missions considering circular economy concepts so that space and Earth become more economically and environmentally sustainable. The circular economy is a transition from a make-use-waste linear model to a closed-loop socio-economic model, which is regenerative and restorative in nature. The implementation of a circular economy will reduce waste and pollution through maximizing material efficiency, ensuring that businesses can thrive and sustain. Further research into the extent to which reusable launch vehicles reduce space mission costs have been discussed, along with the environmental and economic implications it could have on the space sector and the environment. This has been examined through research and in-depth literature review of published reports, books, scientific articles, and journals. Keywords such as material efficiency, circular economy, reusable launch vehicles and spacecraft materials were used to search for relevant literature.

Keywords : circular economy, key performance indicator, material efficiency, reusable launch vehicles, spacecraft materials
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