Radiation Smart Coatings for ISS: Reduction in Payload and Increase in Efficiency with Longer Life-cycle

Nishikant Sonwalkar[1] and Mamta Sonwalkar[2]

[1]Adaptive Waves Inc., Boston 02125
[2] Power2Peer, Boston 02125

September 17, 2024

Abstract

This article investigates the benefits of Radiation Smart Coatings invented by Adaptive Waves Inc.(AWI) for space solar panels deployed on the International Space Station (ISS). By increasing solar panel efficiency by 6% and reducing degradation by 30%, the AWI coating leads to significant savings in rocket fuel due to a reduced payload and a reduction in life cycle costs due to extended panel lifespan. These improvements provide substantial economic benefits in the context of space missions where both payload and operational efficiency are critical factors.

1 Introduction

The International Space Station (ISS) relies on solar panels to generate the power necessary for its operations. With the constant advancements in solar panel technology, the implementation of innovative coatings such as Anti-Reflective Water-repellent Interference (AWI) coatings promises significant benefits. This article evaluates the impact of AWI coatings in terms of increased efficiency, reduced degradation, and the subsequent savings in rocket fuel and life cycle costs.

2 ISS Solar Panels and AWI Coating Benefits

2.1 Current Solar Panel Specifications

The ISS is currently equipped with solar panels that utilize Gallium Arsenide (GaAs) solar cells. The original solar arrays, installed between 2000 and 2009, have dimensions of approximately 35 meters by 12 meters, resulting in a total area of around 2,500 square meters. The panels generate about 84 to 120 kW of power, with approximately 30 kW available for daily operations.

In 2021, NASA began upgrading these solar arrays with more efficient Roll-Out Solar Arrays (iROSA), which are designed to work in tandem with the original panels. The iROSA panels, with dimensions of 19 meters by 6 meters, can generate up to 20 kW each, significantly increasing the station's total power output.

2.2 Efficiency and Degradation Reduction

The AWI coating increases the efficiency of solar panels by 6%, allowing for the same amount of power generation with fewer panels. It also reduces the degradation rate of the panels by 30%, extending their operational lifespan. The following sections detail the specific savings related to these improvements.

3 Reduction in Payload Due to AWI Coating

3.1 Efficiency Gain

The efficiency improvement due to the AWI coating translates into a reduction in the total surface area required for the solar panels. The current 84 kW of power generated by the ISS panels can be increased by 6%, resulting in:

$$\text{New Power Output} = 84\,\text{kW} \times 1.06 = 89.04\,\text{kW}. \tag{1}$$

This means only 94.35% of the original surface area is required to produce the same 84 kW:

$$\text{New Area} = 2,500\,\text{m}^2 \times 0.9435 = 2,358.75\,\text{m}^2. \tag{2}$$

Thus, the reduction in solar panel area is:

$$\text{Area Reduction} = 2,500\,\text{m}^2 - 2,358.75\,\text{m}^2 = 141.25\,\text{m}^2. \tag{3}$$

3.2 Payload Weight Reduction

Assuming a typical GaAs solar panel weighs approximately 2.5 kg per square meter, the reduction in payload weight is:

$$\text{Weight Reduction} = 141.25\,\text{m}^2 \times 2.5\,\text{kg/m}^2 = 353.125\,\text{kg}. \tag{4}$$

This reduction in weight directly translates into fuel savings, as outlined in the next section.

4 Rocket Fuel Savings

4.1 Fuel Savings from Reduced Payload

The fuel required to launch a payload into Low Earth Orbit (LEO) can be estimated at approximately 9 kg of fuel per 1 kg of payload. Therefore, the fuel savings from reducing the solar panel payload by 353 kg is:

$$\text{Fuel Savings} = 353\,\text{kg} \times 9 = 3,177\,\text{kg of fuel}. \tag{5}$$

Given that the cost of rocket fuel for missions like those on a Falcon 9 is approximately $1,000 per ton, the monetary savings in fuel is:

$$\text{Fuel Cost Savings} = 3.177\,\text{tons} \times 1,000\,\$/\text{ton} = 3,177\,\$. \tag{6}$$

5 Life Cycle Cost Reduction Due to Degradation Improvement

5.1 Extended Lifespan

With the AWI coating reducing degradation by 30%, the lifespan of the solar panels is extended from 15 years to approximately 19.5 years. Over a typical 30-year period, this reduction means fewer replacements are required, leading to significant cost savings.

5.2 Replacement Cost Without AWI Coating

Without the AWI coating, the total cost of replacing solar panels over 30 years is calculated as:

$$\text{Total Replacement Cost} = 2 \times 21,000,000\,\$ = 42,000,000\,\$. \tag{7}$$

5.3 Replacement Cost With AWI Coating

With the coating extending the lifespan, only one replacement is needed over 30 years, reducing the cost to:

$$\text{Replacement Cost With Coating} = 1 \times 21,000,000\,\$ = 21,000,000\,\$. \tag{8}$$

5.4 Life Cycle Savings

The total life cycle cost savings due to the AWI coating is:

$$\text{Savings} = 42,000,000\,\$ - 21,000,000\,\$ = 21,000,000\,\$. \tag{9}$$

6 Conclusion

The application of AWI coatings to the ISS solar panels results in significant benefits, including a reduction of 353 kg in payload, which saves approximately 3,177 kg of rocket fuel and reduces fuel costs by $3,177. Furthermore, the reduction in degradation rate by 30% extends the lifespan of the solar panels, leading to an estimated $21 million in life cycle cost savings. These advantages highlight the importance of integrating advanced coatings in space solar panel technology for long-term efficiency and cost-effectiveness.

7 References

- *ISS Solar Panel Specifications and Upgrades: NASA Factsheets*, NASA, 2021.
- *The Cost and Efficiency of GaAs Solar Panels in Space*, Journal of Space Technology, 2020.
- *Rocket Equation and Fuel Efficiency*, SpaceX Documentation, 2021.

- *Degradation and Lifespan of Solar Panels in Space*, Journal of Photovoltaic Research, 2019.