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Innovative Conceptual Study of an Ultra-Lightweight, Large-Scale Solar Array for Lunar-Orbiting SPS

Tanaka laboratory

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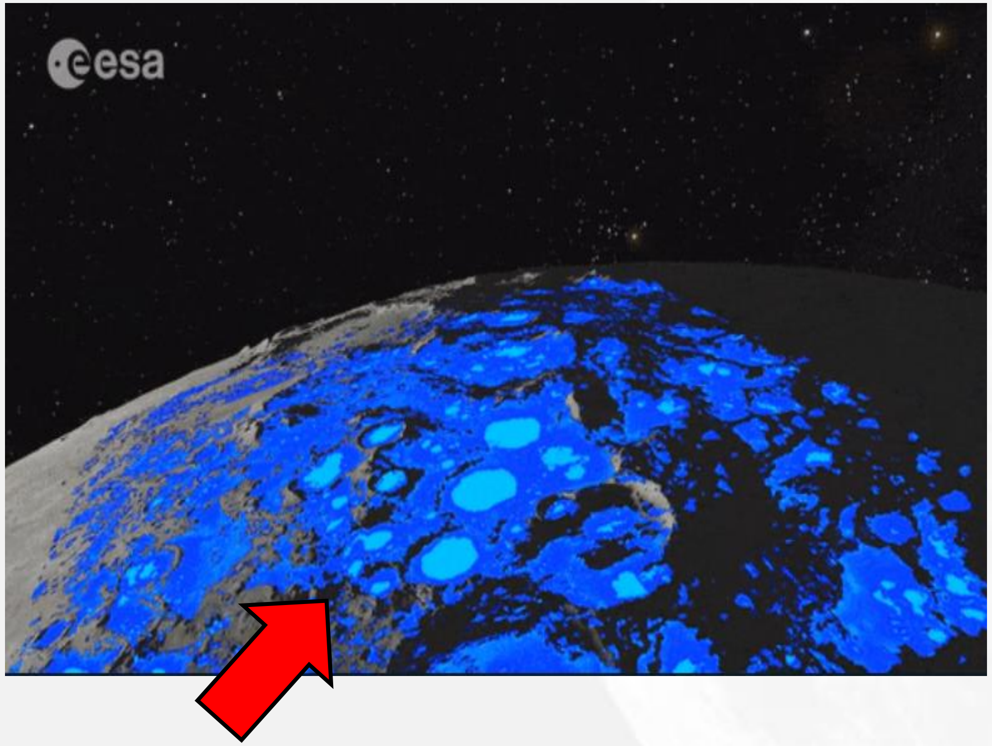
✓ Background – Interest in Lunar Resources

Lunar exploration is accelerating !



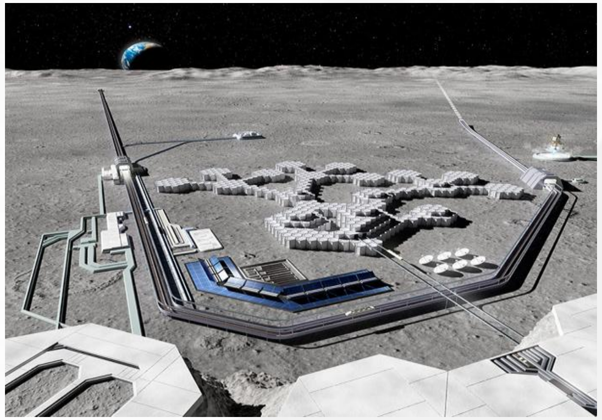
Water Resources

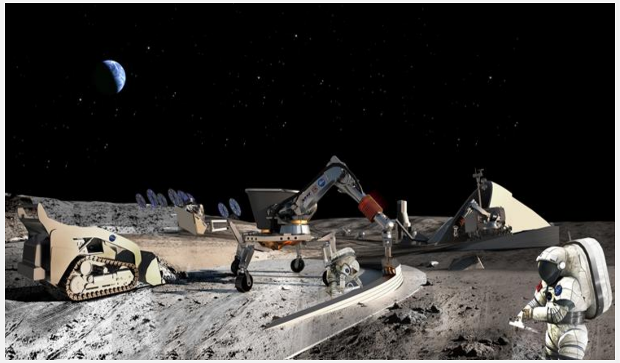
Water Resources are believed to exist at the lunar **South Pole**.

Acquisition of water resources

⬇ use as…

Source of drinking water, oxygen, rocket fuel for <u>lunar base construction</u> and <u>human exploration</u>





✓ Background – Energy Problem

Problems of Solar Power Generation on the Lunar Surface

1. Long lunar nights

On the lunar surface, the night lasts for about 14 days out of a 28-day cycle.
As a result, it is difficult to generate enough power.

➡ **Require** a stable energy supply system

2. Areas where power generation is not possible

The area near the South Pole is permanently shadowed.
As a result, generating solar power is **impossible**.

➡ **Require** a system that can transmit energy directly

✓ Background – Lunar SPS

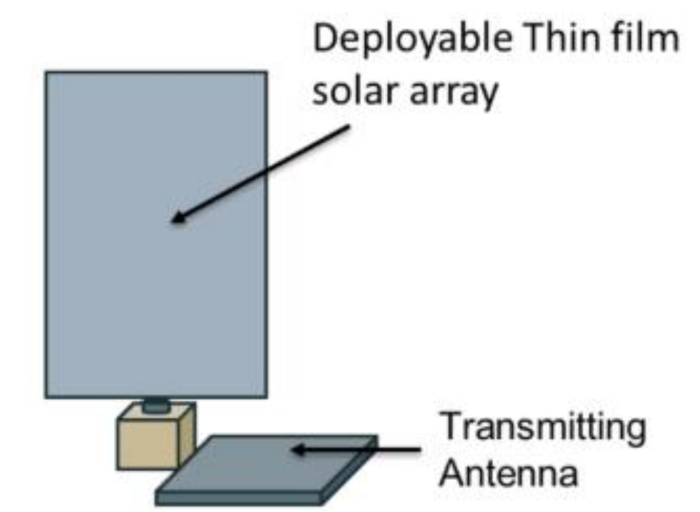
Lunar SPS is a satellite that can convert generated **electrical energy** into **radio waves** and transmit it to the lunar surface.

1. Stable Power Supply

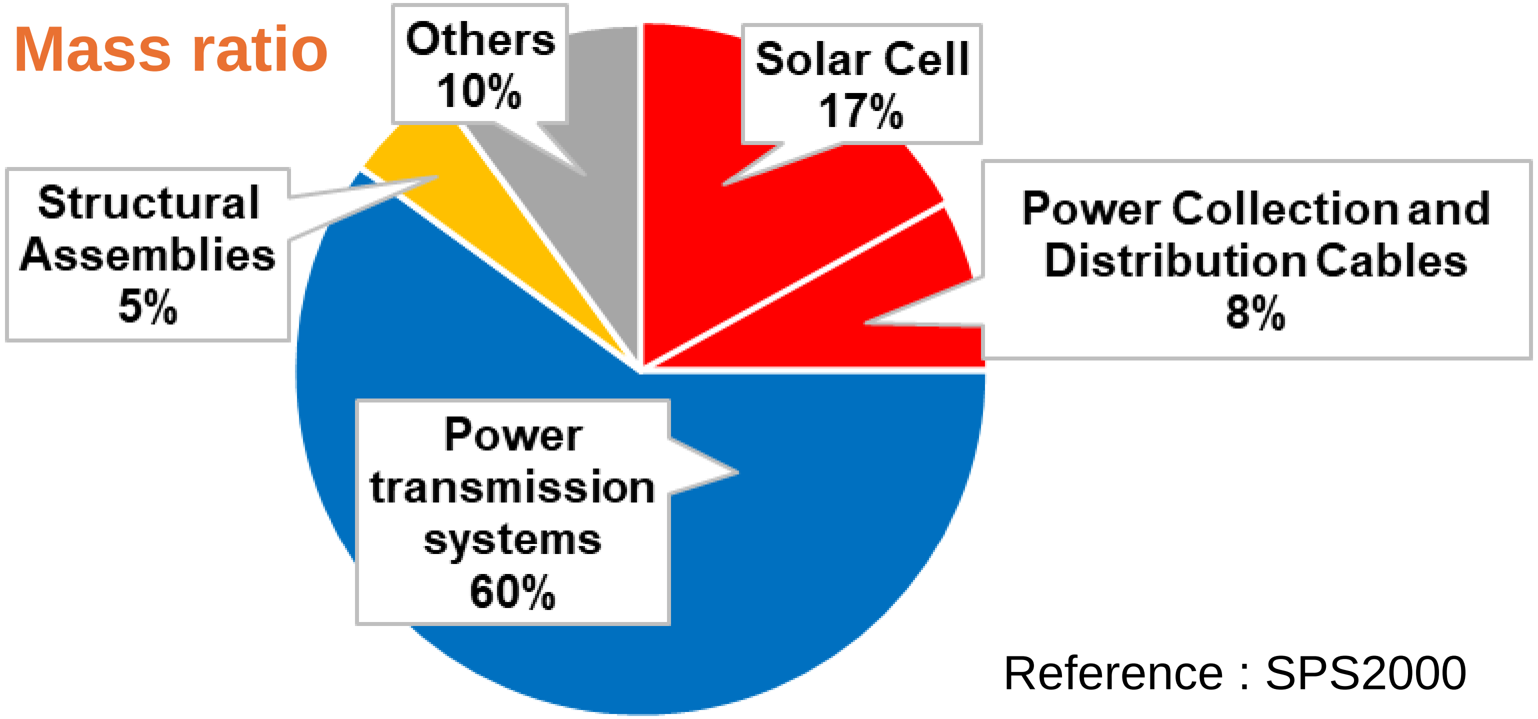
Capable of supplying power regardless of day or night

2. Flexible Selection of transmission targets

By placing rectennas, wireless power transmission is possible anywhere.



Mass ratio



Reference : SPS2000

We focus on Power Generation System

✓ What is our project?

Research Objective

Building a Lunar SPS through **multiple launches** is **costly.**

↓

To enable realization with **a single launch**, both **lightweight design** and **deployment methods** will be considered to reduce **transportation costs**.

Research Content

Propose **Ultra-Lightweight structures** and **Deployment methods**.

- **Thin-Film Solar Cell**
- **Power Collection and Distribution Cables**

↓ **Weight reduction**

Acquisition of high Specific Power

- **Panel fold**
- **Miura fold**

↓ **Comparison**

Selection of a safe and stowage efficiecy deployment method

✓ Selection of Thin-Film Solar Cell and Design Goal

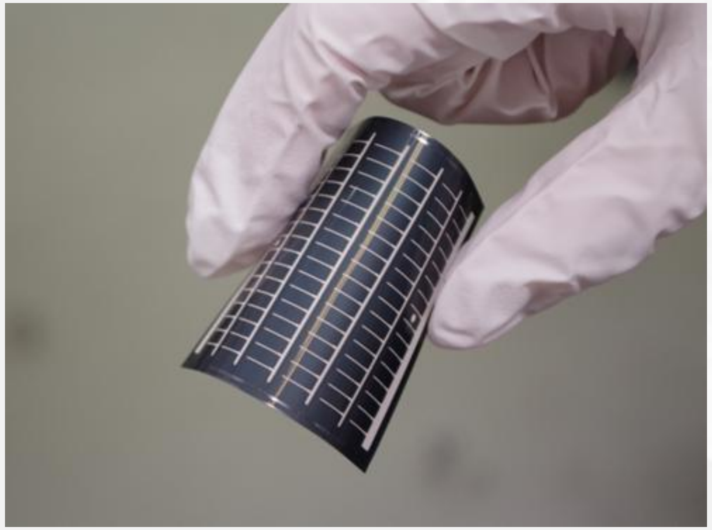
Conventional Power Generation

ISS Solar Array：**30 W/kg**
⇒ Thin-Film Solar Cells indispensable (lightweight, flexible, foldable)

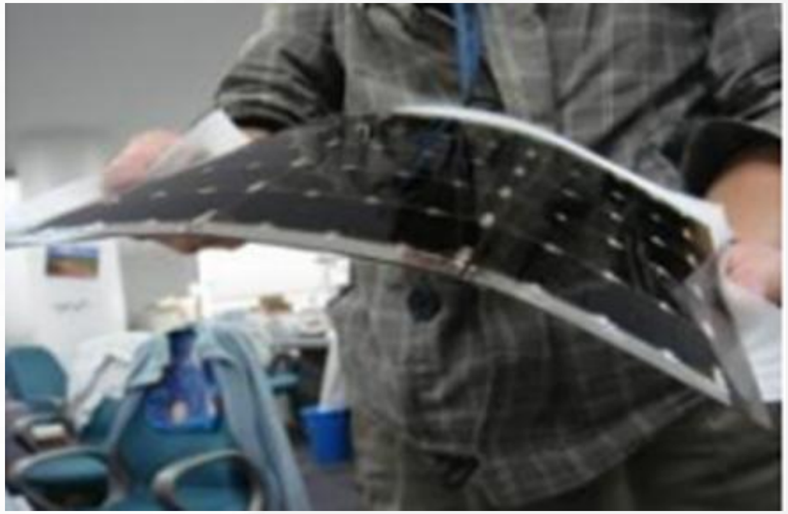
Solar Array Wing of ISS

Candidate Thin-Film Solar Cells

- **CIGS：** High reliability, strong radiation resistance
- **3J-GaAs：** Triple-junction, conversion efficiency ～30%



CIGS



3J-GaAs

Comparison of Specific Power

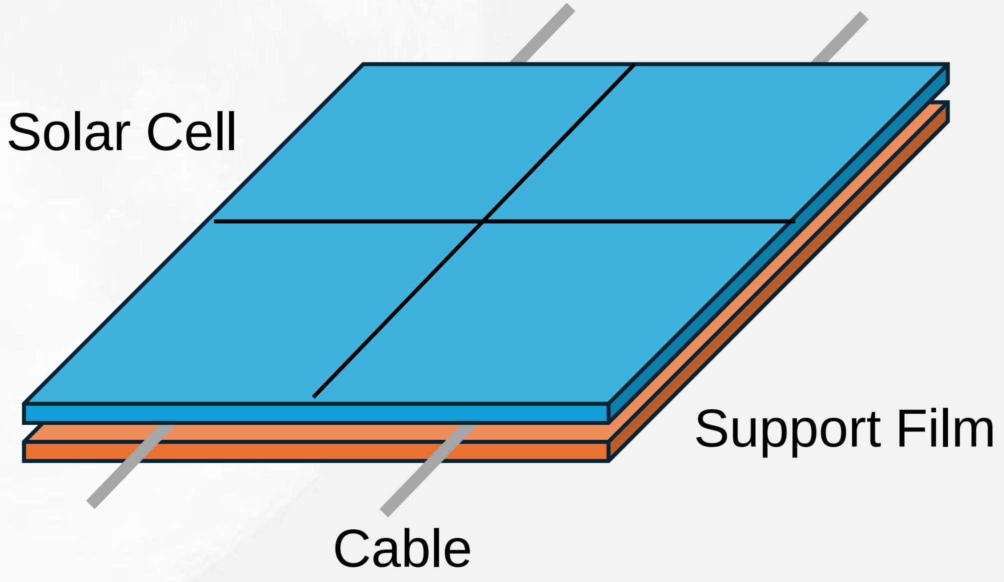
CIGS：922 W/kg ＞ 3J-GaAs：510 W/kg

Power Generation System (200 kW)

CIGS Solar Cell, Support Film, Power Collection and Distribution Cables

Considering mass

Target Specific Power：500 W/kg

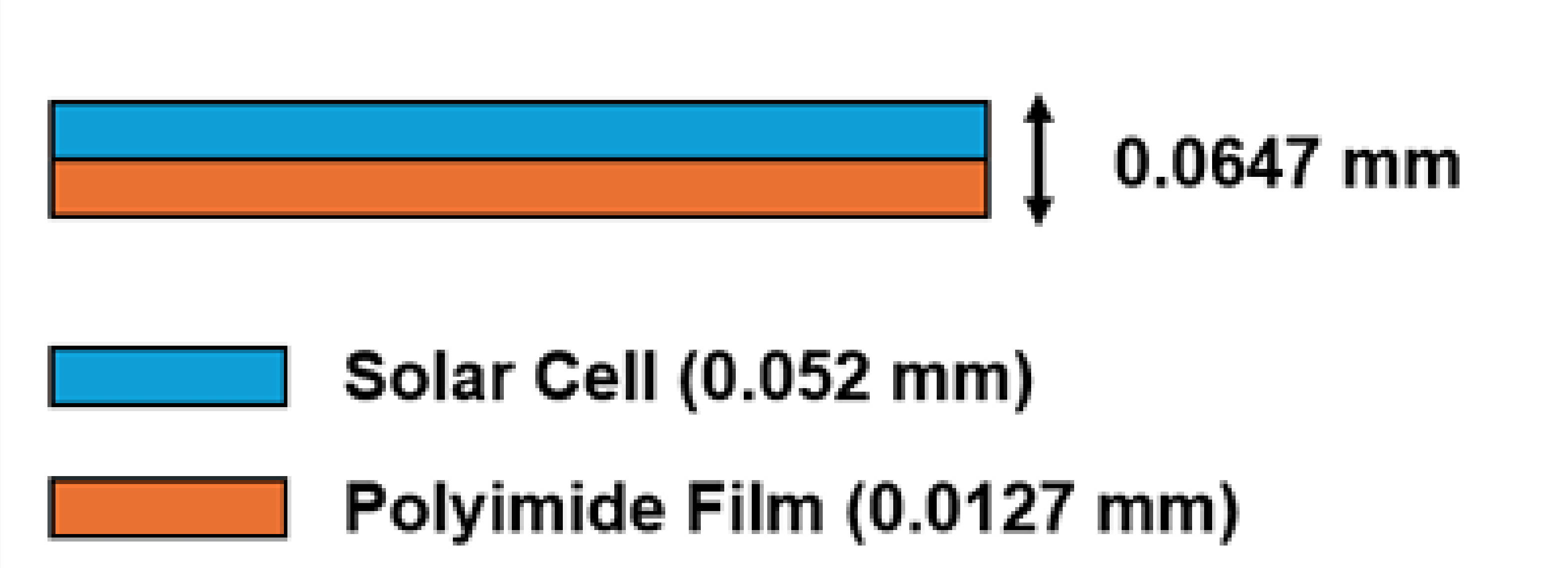


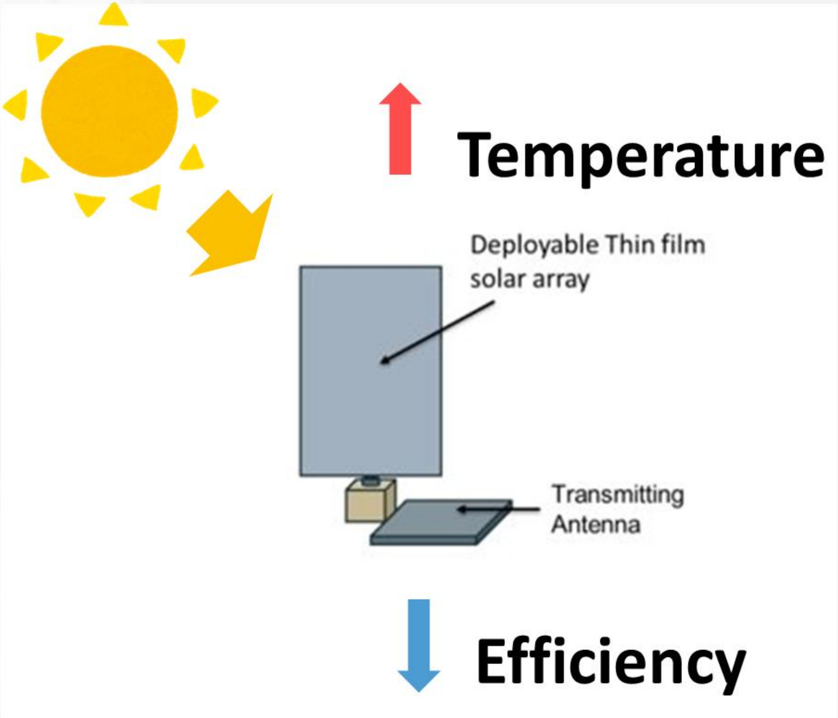
✓ Thermal Analysis and Determination of Array Size

Solar cell efficiency decreases as surface temperature increases.

● Analysis

Analyze Solar Array temperature → Calculate required area



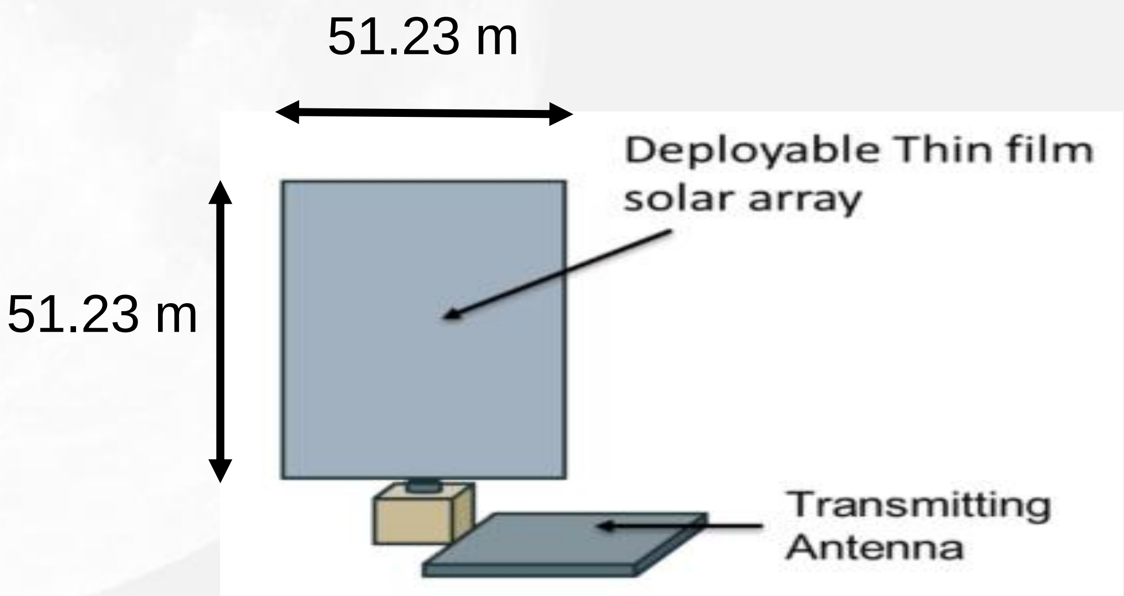


✓ Thermal Analysis and Determination of Array Size

● Conditions

Pointing direction	Sun-pointing
Solar radiation	1,367 W/m^2
Orbit	Apoapsis：1000 km Periapsis：100 km
Orbital period	9895 s

	Solar Cell	Polyimide Film
Emissivity	0.53	0.55
Absorptivity	0.87	0.34



● Results

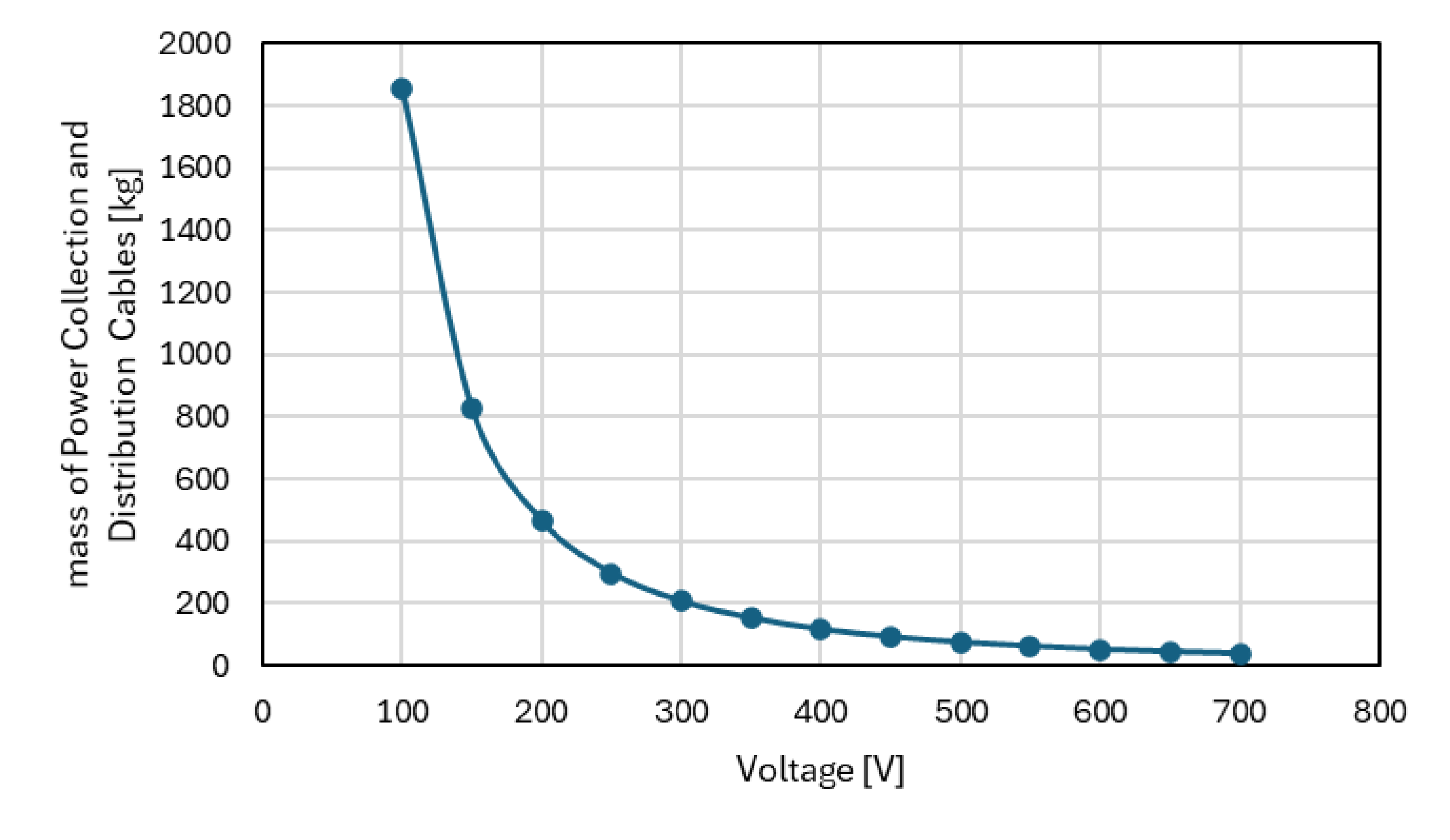
Solar cell surface temperature reached 100.45 ℃

Assuming a square

Required side length of solar array：**51.23 m**

✓ Lightweight design of power collection and distribution cables

Calculation of the mass of an **aluminum cable** as a function of applied voltage.

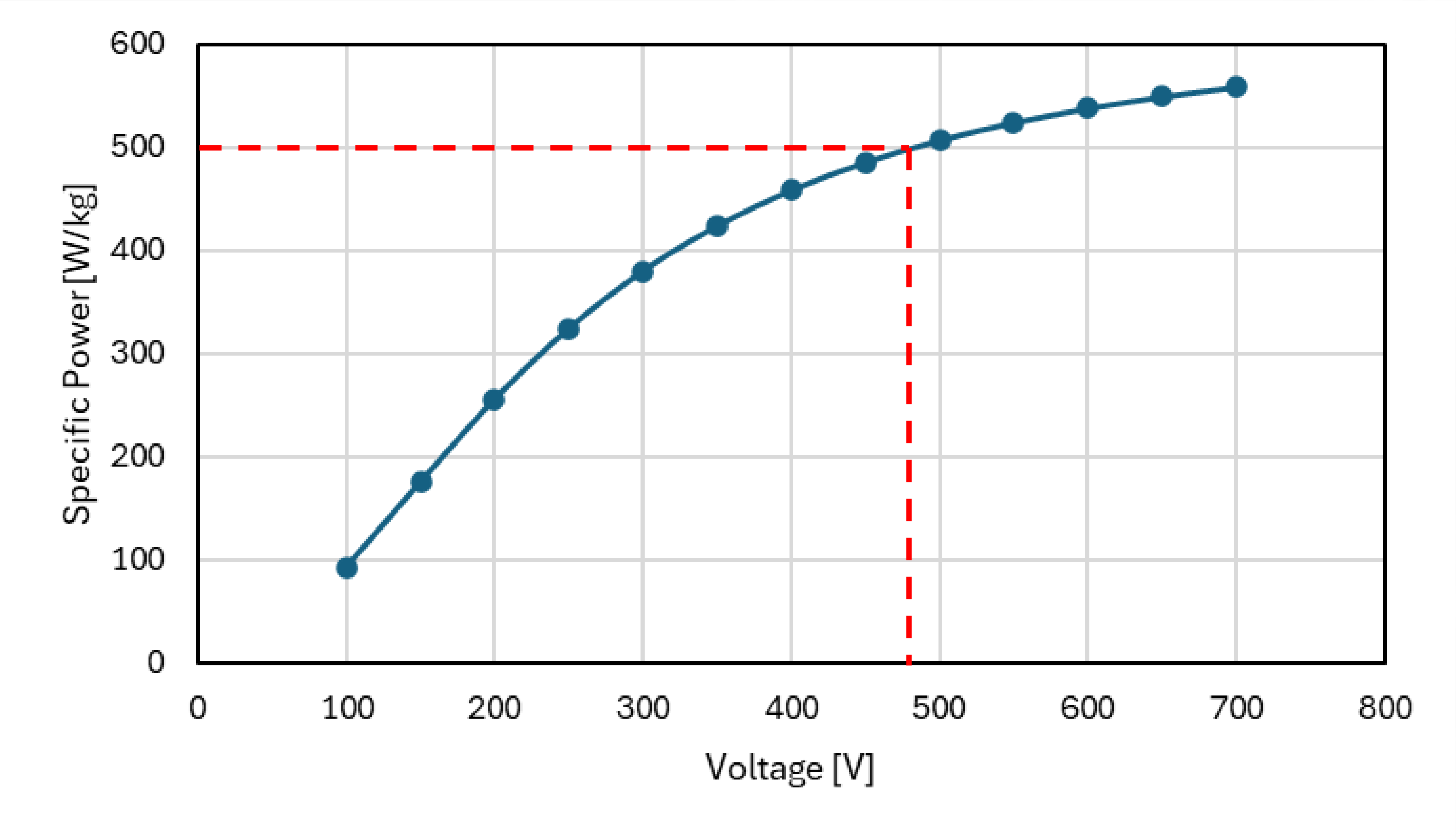


$$m_c = \frac{0.9 P \rho R L^2}{V^2}$$

m_c : mass of Power Collection and Distribution Cable [kg]
P : Power Output [W]
ρ : Density [kg/m^3]
R : Electrical Resistivity [Ω・m]
L : Cable length [m]
V : Voltage [V]
Jule loss : 10%

As the voltage increases, the mass of the cable decreases rapidly.
⇒ Weight reduction is possible

✓ Specific Power of Power Generation System



$$\alpha = \frac{P}{m_s + m_p + m_c}$$

α : Specific Power [W/kg]
P : Power Output [W]
m_s : mass of Solar Cell [kg]
m_p : mass of Polyimide Film [kg]
m_c : mass of Power Collection and Distribution Cable [kg]

	mass [kg]
m_s	273.28
m_p	47.34
m_c	79.17

It has been clarified that a voltage of at **least 484 V** is required to achieve the target specific power of **500 W/kg** and a transportation cost reduction of **$1,208,731**.

✓ Conclusion

In this study, a conceptual design of a power generation system for a Lunar SPS was conducted.

- **CIGS thin-film solar cells** were selected.
- Thermal analysis indicated that the required panel size is **51.23 m** × **51.23 m**.
- By increasing the distribution voltage to **484 V**, the cable mass was reduced, achieving the target specific power of **500 W/kg**.
- This lightweighting through higher voltage operation could potentially reduce launch costs by approximately **USD 1.2 million**.

Thank you for Listening !