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# Development of High-Specific Power CIGS Thin-Film Solar Cells for Space Applications

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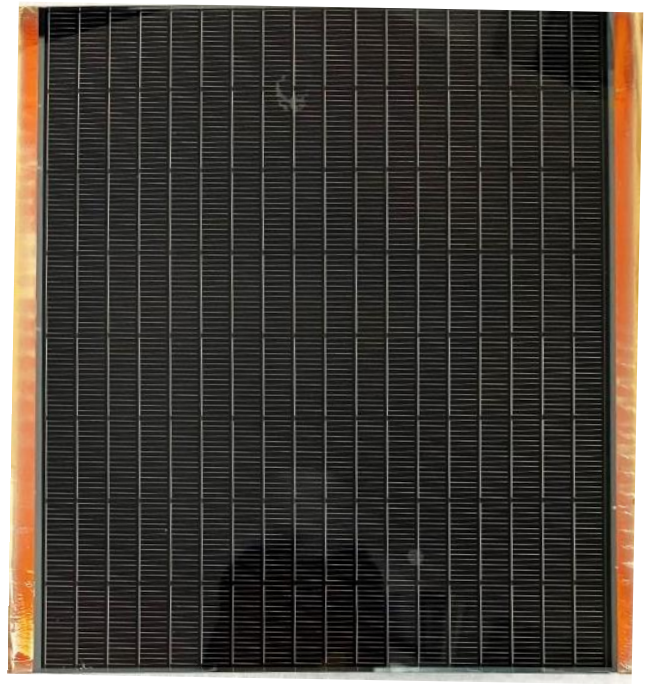
idemitsu

# Outline

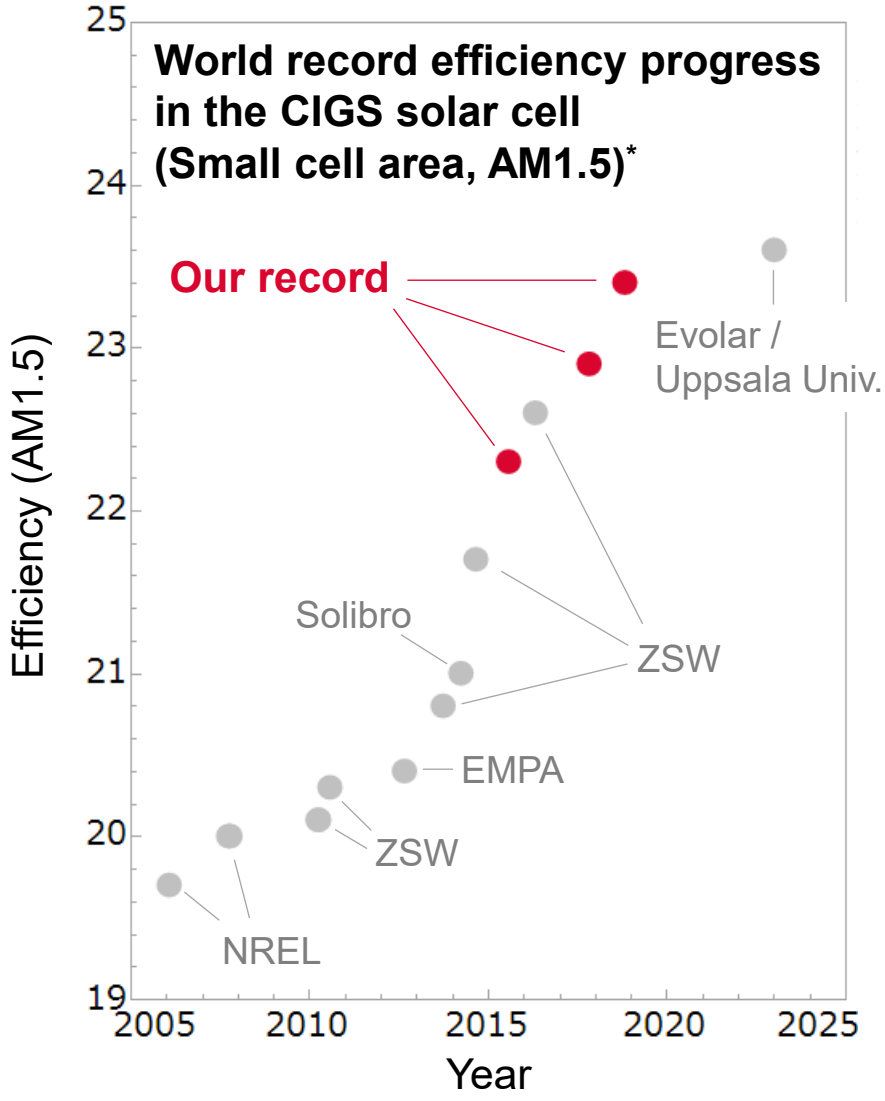
1. **Idemitsu and CIGS — who we are**
   *GW-scale terrestrial heritage and pivot to space*
2. **Why CIGS for space**
   *Three pillars: radiation tolerance, weight, mass-producibility*
3. **Radiation tolerance and self-healing**
   *New HLS dynamics confirmed down to 45 ºC*
4. **In-orbit demonstrations**
   *Heritage and new BOTAN flight result*
5. **Power-to-weight on Ultra-Thin Glass**
   *17.2% on 0.4 mm UTG, lightweight encapsulation*
6. **Path to market**
   *Bench plant, JAXA fund, Source Energy*



# Idemitsu and CIGS

Idemitsu has been developing, manufacturing, and selling CIGS solar cells and panels through our wholly owned subsidiary, **Solar Frontier.**

1978: Launched R&D of solar cells.
1993: Launched R&D of **CIGS** solar cells.
2007: Start of **commercial production (20 MW).**
2011: Started operation of our **900 MW-scale solar panel plant.**
2020: Cumulative shipments of CIGS solar panels **reached 6 GW.**
2020: Idemitsu launched R&D of **CIGS solar cells for space use.**
2022: Solar Frontier ends production of terrestrial CIGS solar panels.
2025: Final Investment Decision to establish
**a bench plant for space CIGS mass-production validation.**




*Based on NLR's Best Research-Cell Efficiency Chart

# Why CIGS for Space — Three Pillars

The space solar market is growing fast. Our CIGS uniquely offers all three at once:

**Pillar 1**

## Ultra Radiation-Hard

### Self-healing CIGS

Self-healing crystal recovers from radiation damage under heat and light. Outperforms 3J-GaAs at high fluence
— ideal for HLEO, MEO, GEO, and beyond.

**Pillar 2**

## Light Weight

### > 440 W/kg target

High radiation tolerance enables thin or no coverglass, and ultra-thin glass substrate. Comparable to or exceeding GaAs-CIC at end-of-life.

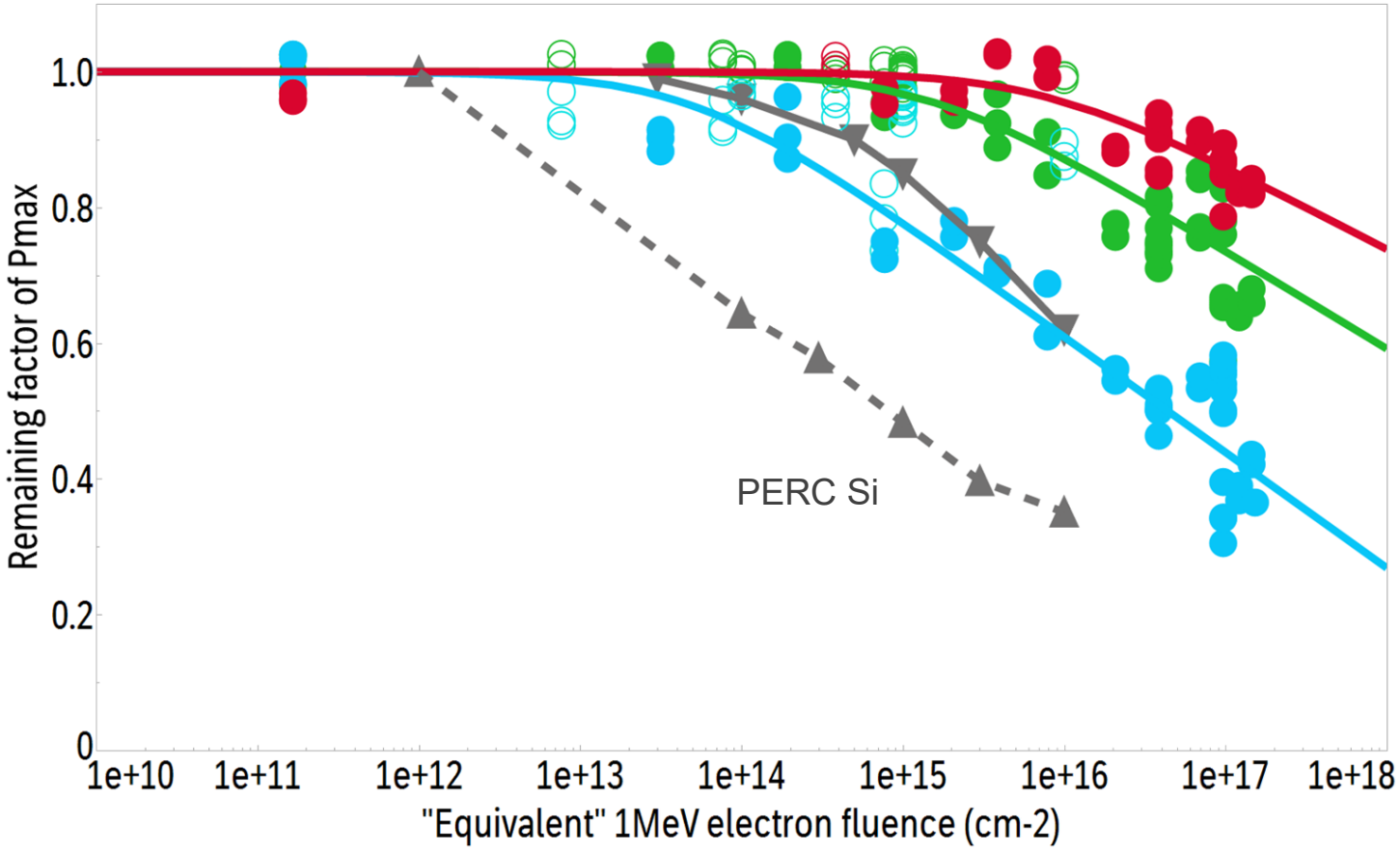
**Pillar 3**

## Mass-Producible

### GW-scale heritage

Solar Frontier's terrestrial 900 MW plant proved CIGS can be made at scale, with reasonable cost. We bring that production DNA to space.

# Radiation Tolerance: CIGS vs PERC Si vs 3J-GaAs




**NIEL scaling:** $\Phi' = \Phi \times \mathrm{NIEL}(E) / \mathrm{NIEL}(1\ \mathrm{MeV}\ e^-)$ via SR-NIEL-7 calculator
**Light anneal:** 65 ºC, metal-halide ~60 mW/cm², open-circuit.

CIGS Light anneal >1,000 hr
CIGS Light anneal >100 hr
CIGS as-irradiated
▲ PERC Si
▼ 3J-GaAs

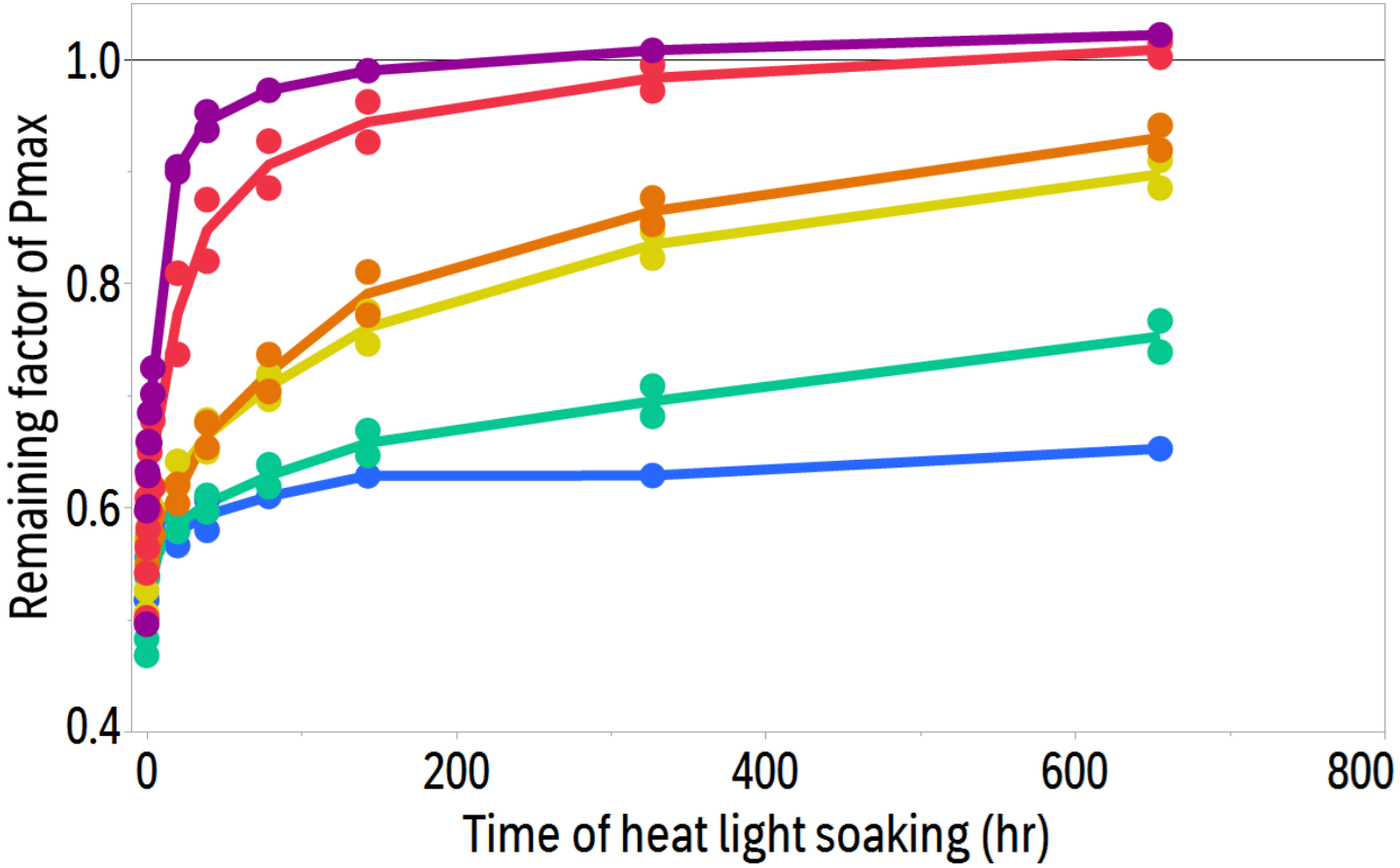
**> 0.95**

$P_{max}$ retention after 1 x $10^{16}$ e/cm²
(unshielded CIGS, after Light anneal)

*CIGS retains > 80% even at 1 ×$10^{17}$ e/cm² — well beyond the PERC Si degradation curve.*

**→ Strong fit for HLEO, MEO, GEO, and high-radiation orbits.**

# Self-Healing Dynamics Down to 45 °C




**Sample temperature**

- 85 ºC
- 75 ºC
- 65 ºC
- 55 ºC
- 45 ºC
- 35 ºC

**Proton irradiation:** 1 MeV, 1x10¹³ cm⁻², dark.
**Light annealing:** metal-halide lamp ~60 mW/cm², open-circuit

**KEY FINDING**

**Recovery confirmed at 45 ºC and above**

→ Self-healing at typical orbital temperatures

→ No active heating required

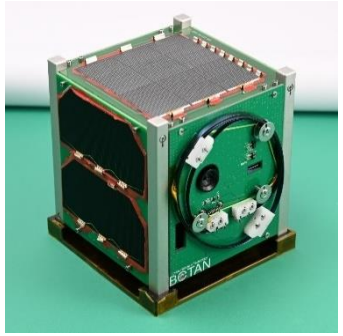
→ Expands viable mission profiles

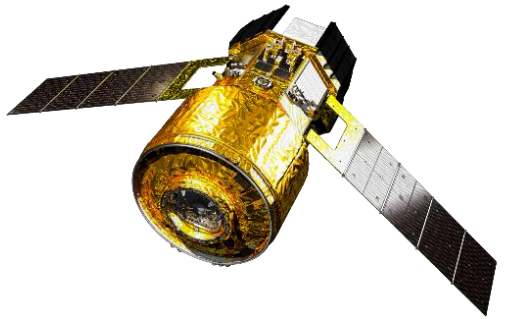
# Our space demonstration heritage and plan

*From 2002 to 2027 — continuous flight heritage and active demonstration program*

| Spacecraft | MDS-1 | XI-V | BOTAN | HTV-X1 | MOMIJI | Ten-Koh 3 |
|---|---|---|---|---|---|---|
| **Operation** | JAXA | Univ. Tokyo | Chiba Inst. Tech. | JAXA | Chiba Inst. Tech. | Nihon Univ. |
| **Launch Year** | 2002<br>Finished | 2005<br>Finished | **2025**<br>Finished | **2025**<br>Ongoing | 2026<br>(Plan) | 2027<br>(Plan) |
| **Orbit** | GTO | LEO | LEO | LEO | LEO | LEO |
| **Satellite size** | 2.7m$^3$ | 1U | 1U | ISS supply vehicle | 2U | 3U |

Cubesat “BOTAN”
(Chiba Inst. Tech.)

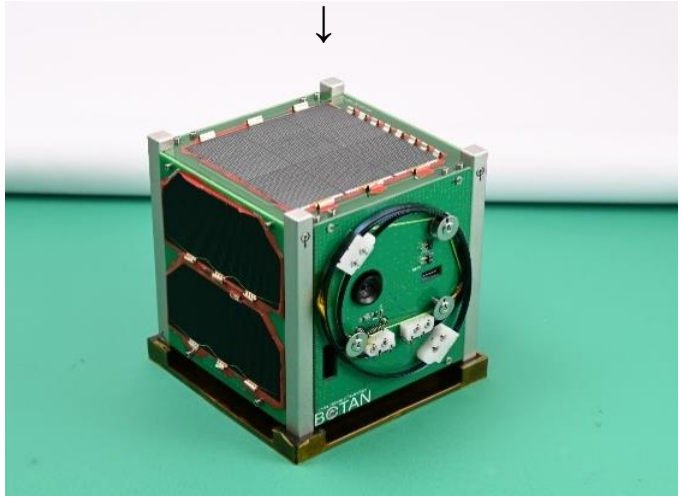


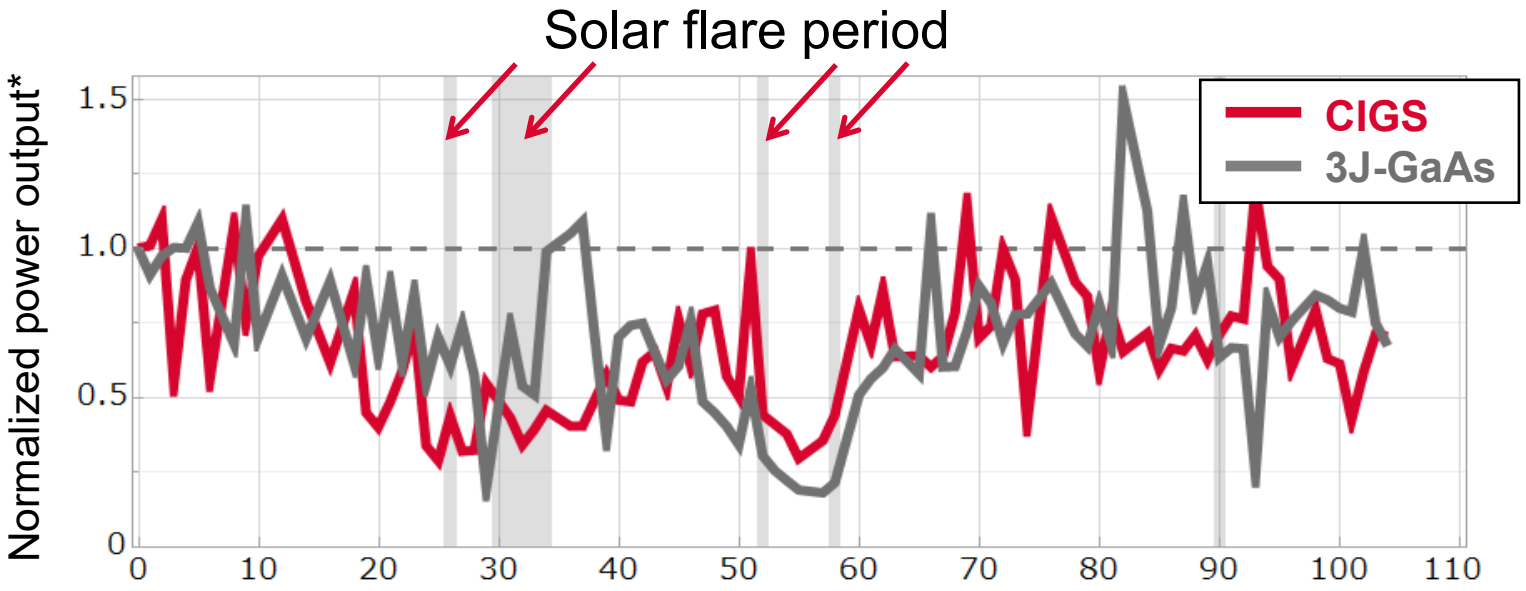
HTV-X (JAXA)

# Demonstration results from the CubeSat “BOTAN”

Our CIGS (No cover-glass)




*Chiba Institute of Technology "BOTAN" (1U cubesat)*




*Daily averaged power output (Day 1 = 1.0). Shaded bands = solar flare events.

**MISSION SUMMARY**

**Cell:** Idemitsu CIGS, ~54 cm²
metal substrate, no coverglass
**Carrier:** 1U cubesat, body-mounted,
released from ISS Kibo
**Period:** 2025/10/10 – 2026/02/27 (140 days)
**Compared with:** **3J**-GaAs cell on the same sat.

**140**

**days operational**

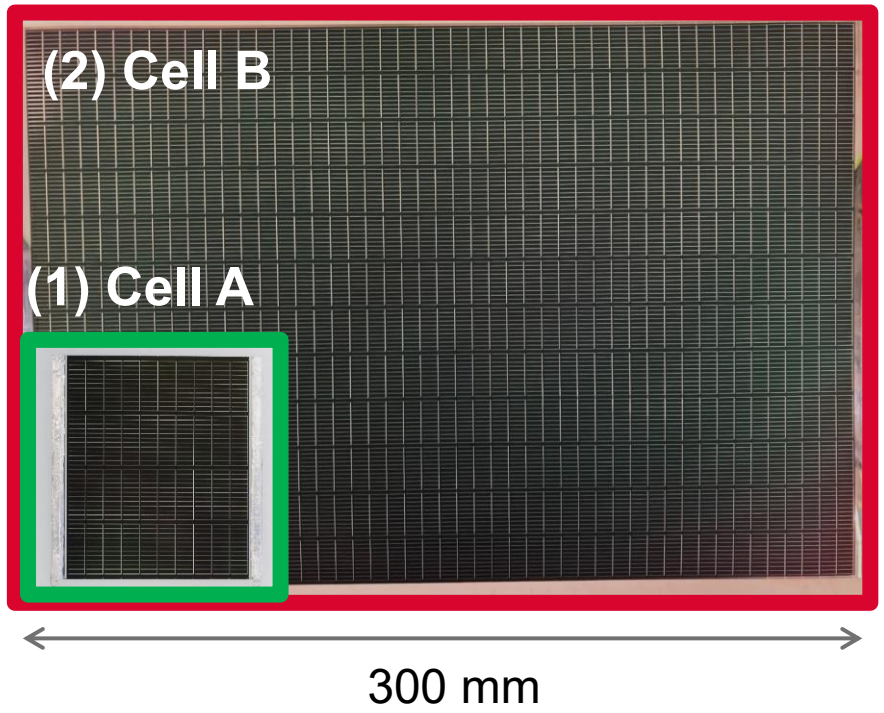
*full mission duration*

**X-class**

**solar flare survived without cover-glass**

# Light Weight: CIGS on Ultra-Thin Glass

*Substrate evolution from terrestrial 1.8 mm glass to space-grade 0.4 mm — and below.*




## Achievements on UTG

**17.2%**
on 0.4 mm UTG (Cell A)

**14.2%**
**on < 0.2 mm large UTG** (Cell B)

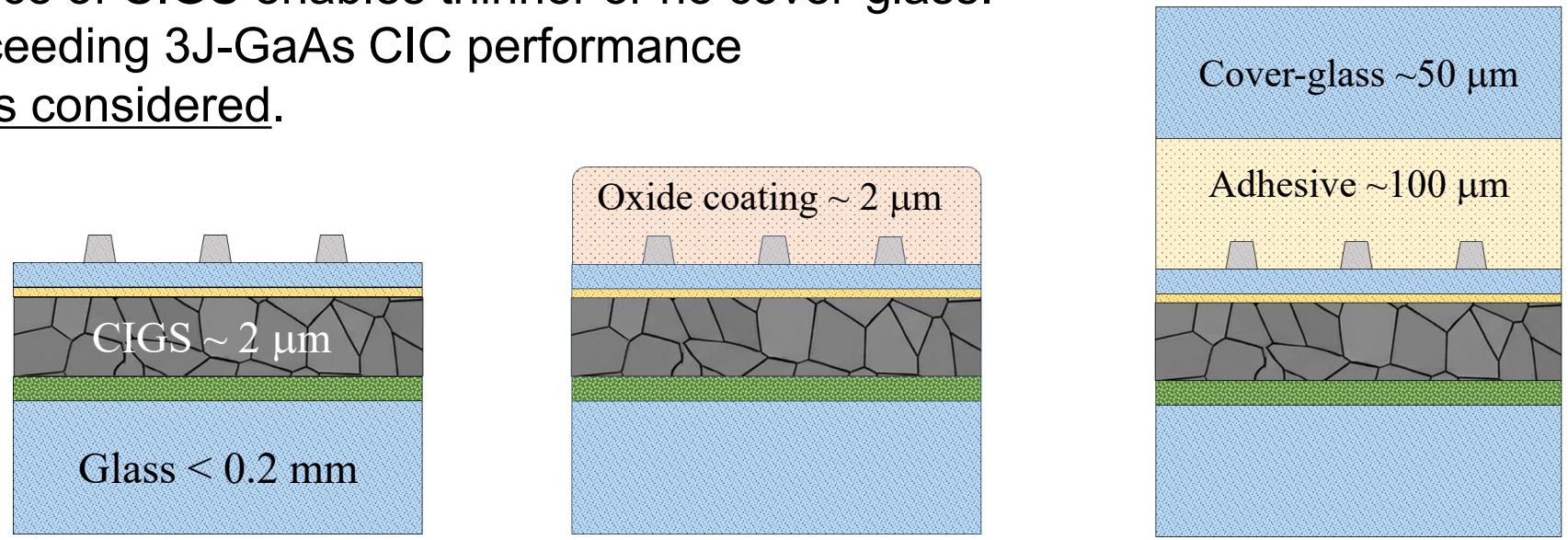
**< 0.5**
kg/m$^2$
*substrate areal mass (vs 4.5 for terrestrial)*

**> 500 cm$^2$**
current cell size
*Monolithically series-connected*

**A 17%-class space cell from a proven terrestrial production lineage.**

# Power-to-weight ratio of our CIGS

High radiation tolerance of CIGS enables thinner or no cover-glass.
Comparable to or exceeding 3J-GaAs CIC performance
when encapsulation is considered.

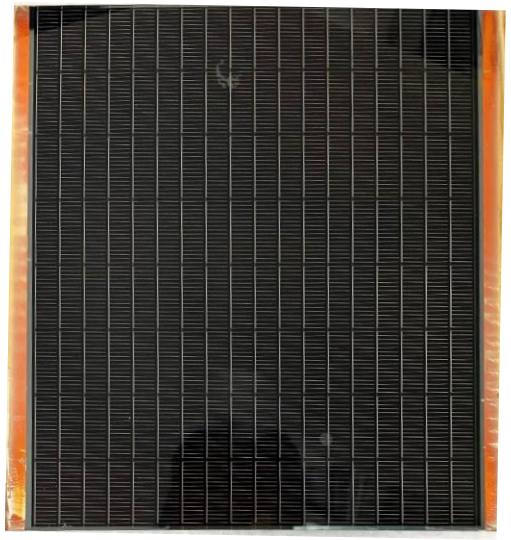


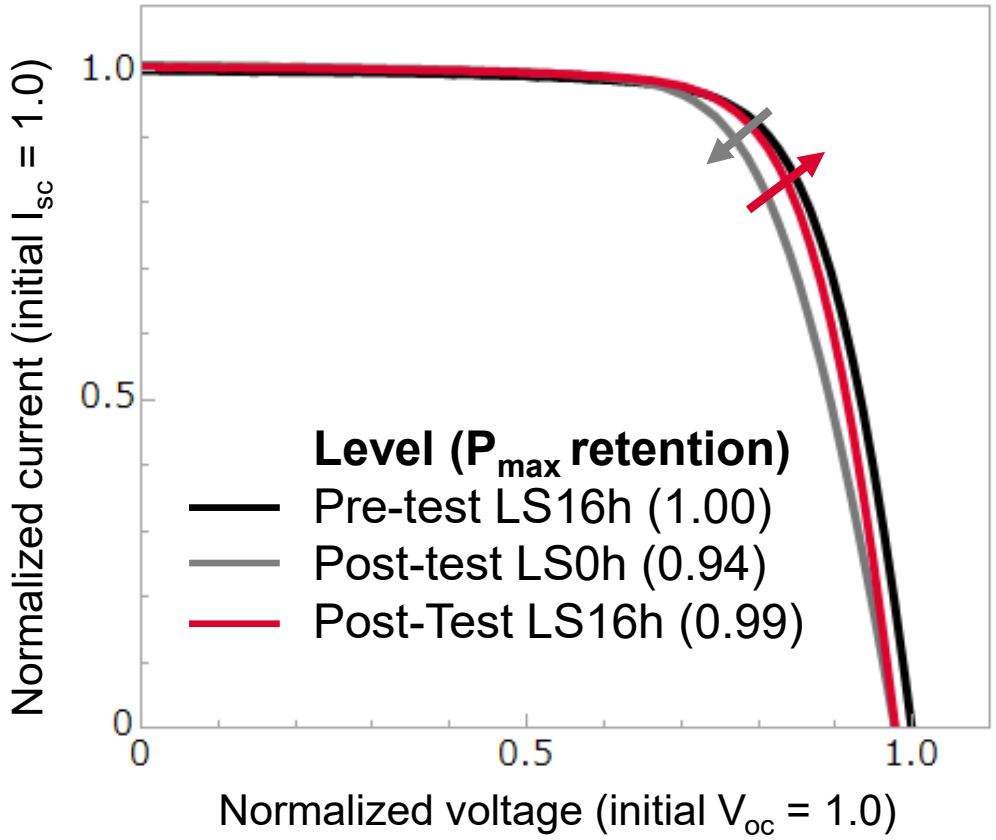

| | Bare | Oxide coating | Cover-glass |
|---|---|---|---|
| **Power-to-weight ratio (W/kg, AM0-17%)** | **450** | **444** | **309** |
| **Total weight (g/cell*)** | ~ 34 | ~ 35 | ~ 50 |
| **Thermal emissivity (%)** | ~ 50% | 75~80% | > 80% |

*Cell size : 260 mm x 270 mm (Candidate standard size at our future bench plant)

# Thermal cycle test results for the CIC structure

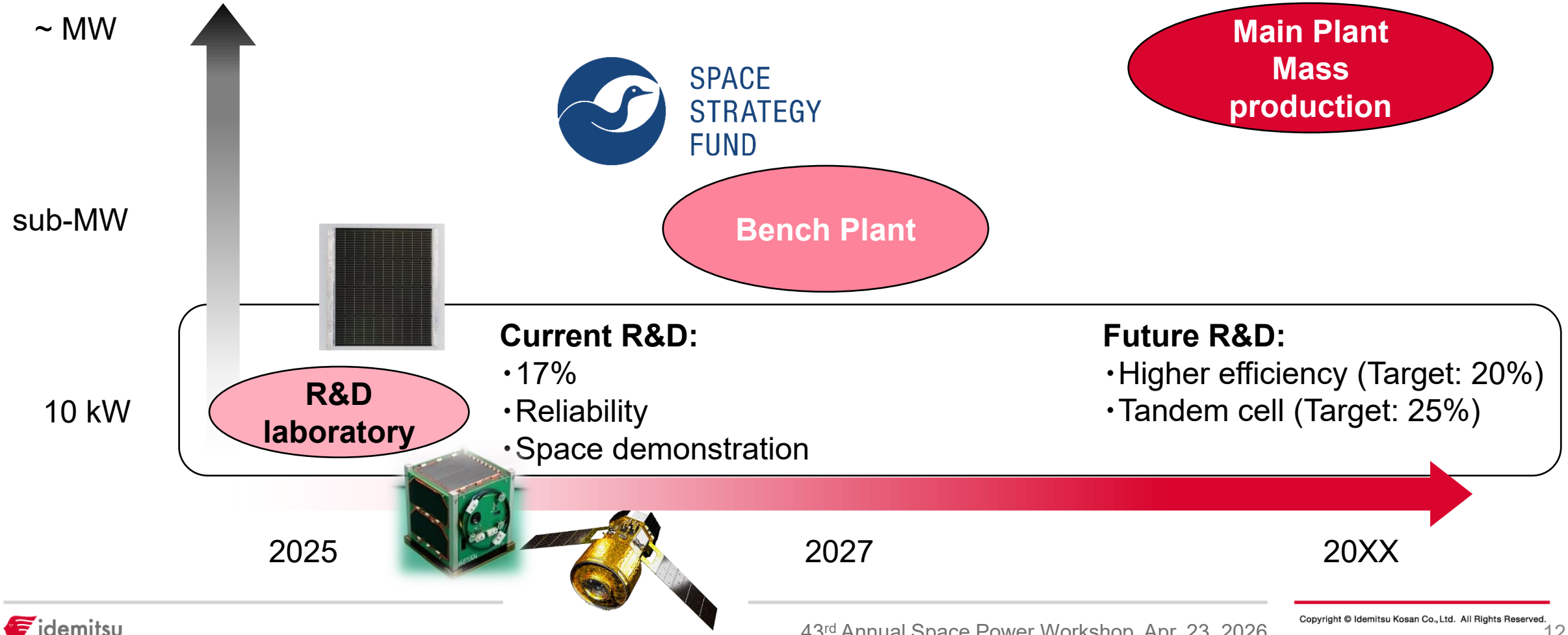
Thermal cycling performed on a CIC structure (cover glass / silicone adhesive / CIGS on 0.4 mm UTG).
No cracking or delamination observed; ~99% performance retention after light soaking.
(-120 °C/+120 °C at ~7 min/cycle, 1313 cycle)





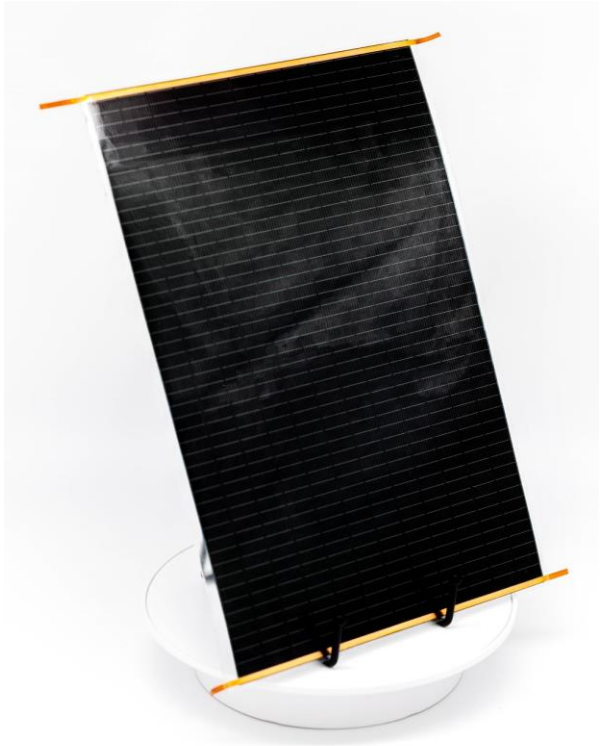

# Next phase toward market entry

Idemitsu has made a final investment decision (FID) to establish
**a bench plant for space CIGS mass-production validation.**
Our project has also been selected for **JAXA's Space Strategy Fund.**



# Strategic Partnership with Source Energy

SOURCE ENERGY COMPANY



**BUSINESSWIRE · NOVEMBER 6, 2025**

**Idemitsu Kosan and Source Energy Company Announce Strategic Collaboration to Co-Create Next-Generation Solar Array Products for Space Market**

**TOKYO & LONGMONT, Colo. —** Idemitsu Kosan Co., Ltd. and Source Energy Company today announced a strategic collaboration to co-develop and deliver next-generation energy solutions for the high-LEO and MEO markets. This collaboration will combine Idemitsu's proven CIGS solar cell technology with Source Energy's family of advanced solar modules and deployable arrays for satellites and spacecraft.

*idemitsu.com/jp/news/2025/251106.pdf · businesswire.com*

# Path to Market and Summary

## Roadmap to mass production

| 2025 | 2027 | 20XX |
|---|---|---|
| **R&D Laboratory** | **Bench Plant** | **Main Plant** |
| **10 kW** | **sub-MW** | **~ MW** |
| 17% efficiency, reliability, space demonstration | Mass-prod. tech. validation. JAXA fund selected. | Full mass production for the space market |

## Strategic enablers

SPACE STRATEGY FUND

**JAXA's Space Strategy Fund**
Accelerates demonstration and mass-prod. tech development.

SOURCE ENERGY COMPANY

Co-developing next-gen modules and arrays for high-LEO and MEO markets.

**TAKE-AWAYS** · 17.2% on UTG · 45 ºC self-healing · Cubesat flight · 99% x 1,313 cycles
· Decision to establish a bench plant