How silicon technology can modify the PVA landscape ?

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AGENDA

A. Silicon for Space Heritage & Potential

B. Low cost silicon cells radiation hardness

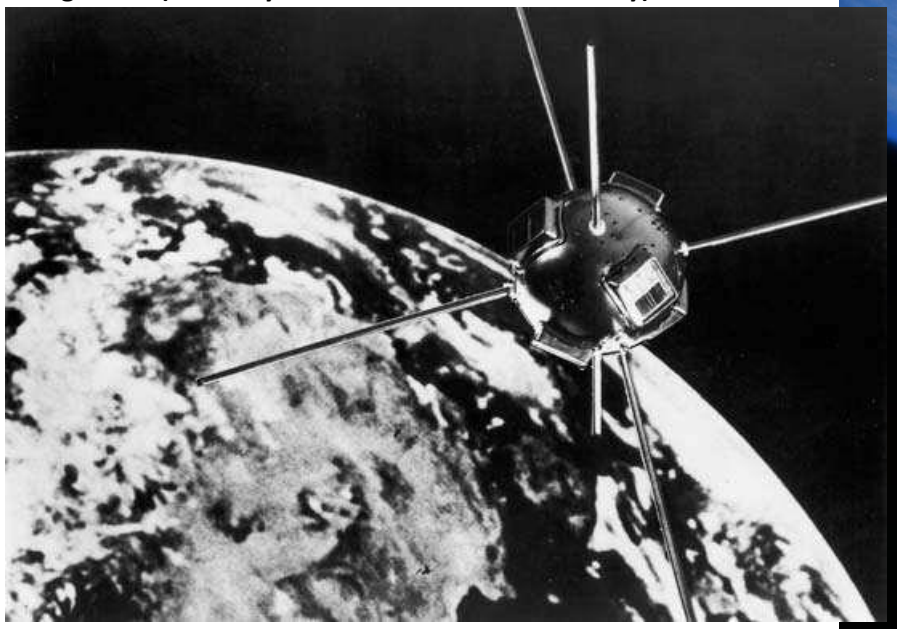
C. Low cost silicon PVA thermal cycling

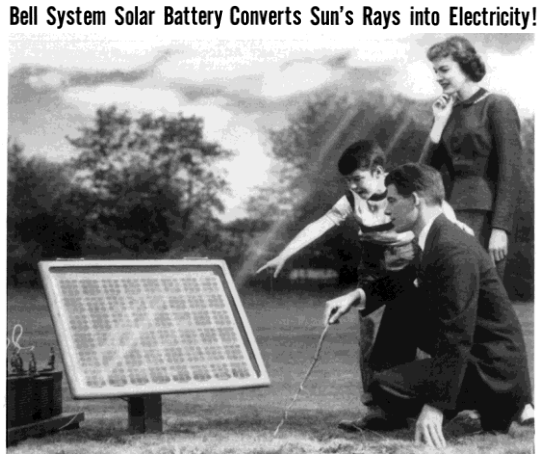
D. Conclusions & perspectives

SI4SPACE HERITAGE

- Since the 1st photovoltaic array in 1954, silicon technology has powered satellites for ~ 50 yrs

Vanguard 1 (Courtesy of Naval Research Laboratory)



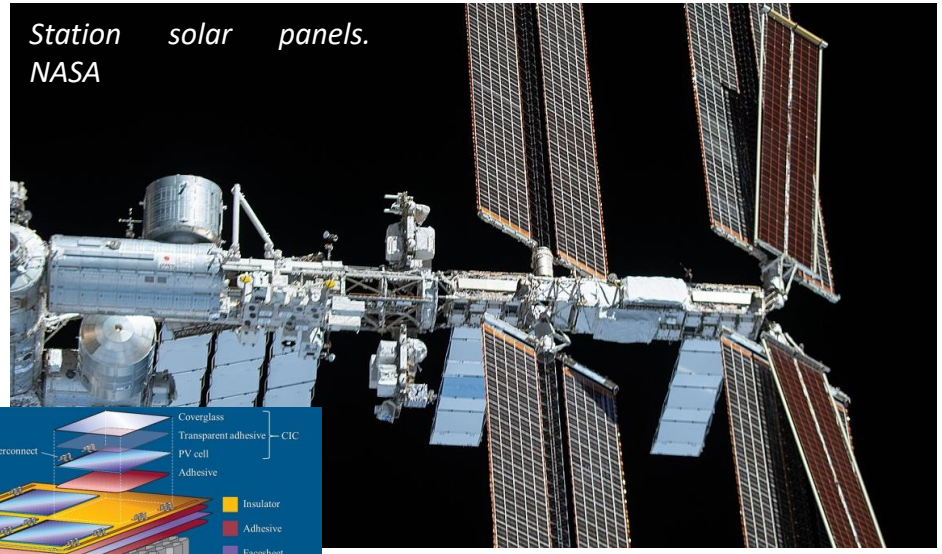


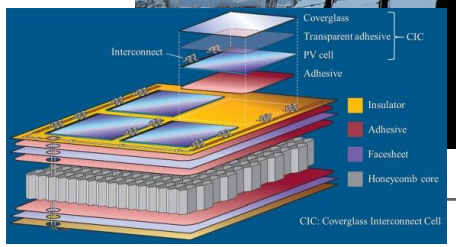
- ISS is powered by 2500 m² of Si arrays with 84 to 120 kW, based on MWT Al-BSF 60µm 8x8 cm solar cells reaching ~14% Efficiency (Silicon K6700B - Spectrolab)

Station solar panels. ESA

SI4SPACE POTENTIAL

- **Since 2000's, III-V became the dominant space PV technology, for their perf. premium**

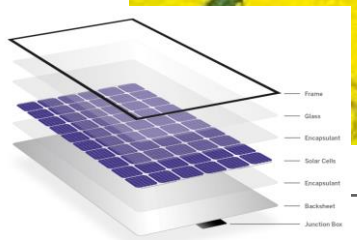




III-V space PV

Production capacity	< 1MW/yr.
AM0 BOL efficiency	30-32%
Cells Cost	~ 100 €/W
PVA Mass	0.5 – 3 kg/m^2

- **Since 2000's, terrestrial Si PV went through major industrial & technological evolutions**

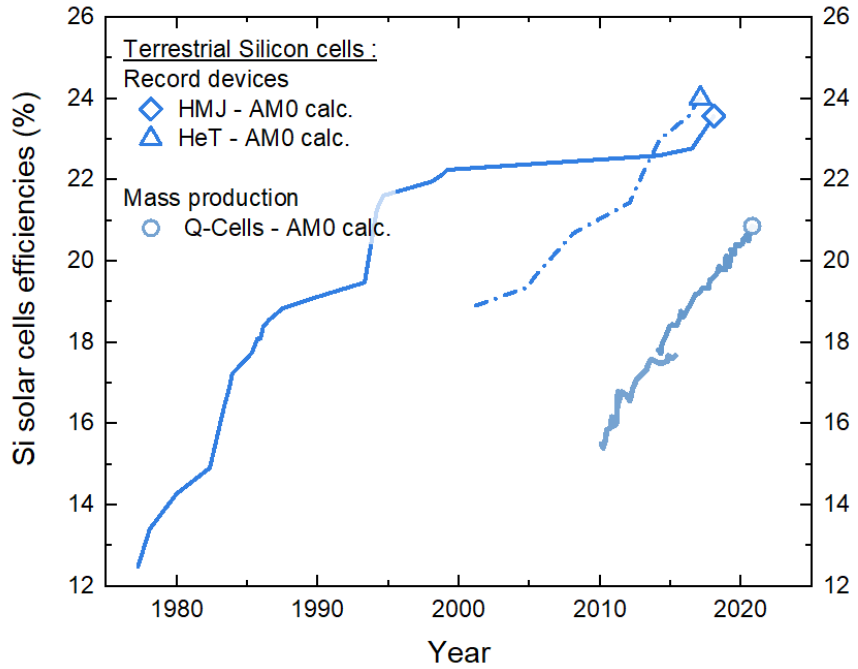


Si terrestrial PV

Production capacity	**140 GW in 2020**
AM0 BOL efficiency	19-20%
Cells Cost	**~ 0.1 €/W**
PVA Mass	10-12 kg/m^2

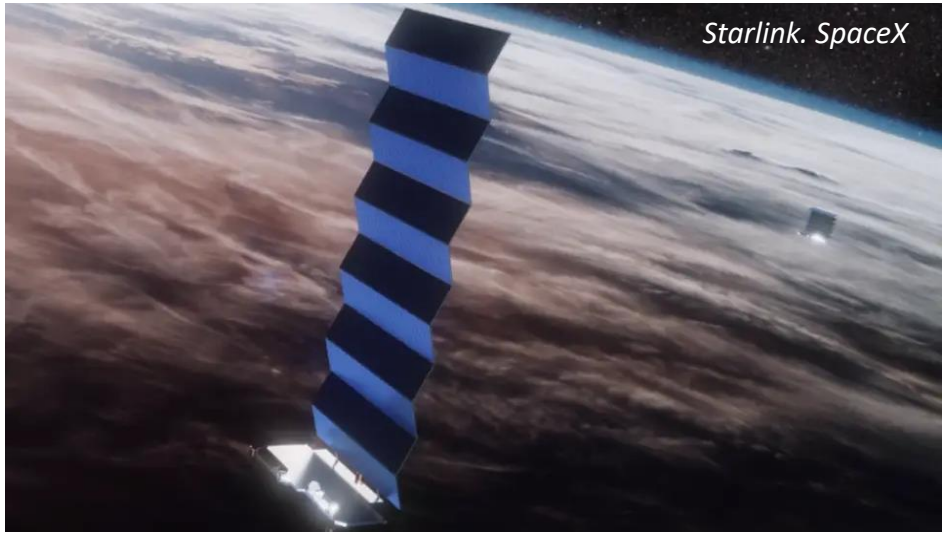
SI4SPACE POTENTIAL

- **Continuous Si cells efficiency (BOL) improvements (Lab & Industry)**



- **Si terrestrial trends/roadmaps convergence with Si space needs:**
  - High eff. on p-type, Thickness reduction, Ga doping, CTM ratio & design optimization, etc.

- **New Space & emergence of LEO constellations opens up Si opportunities again.**



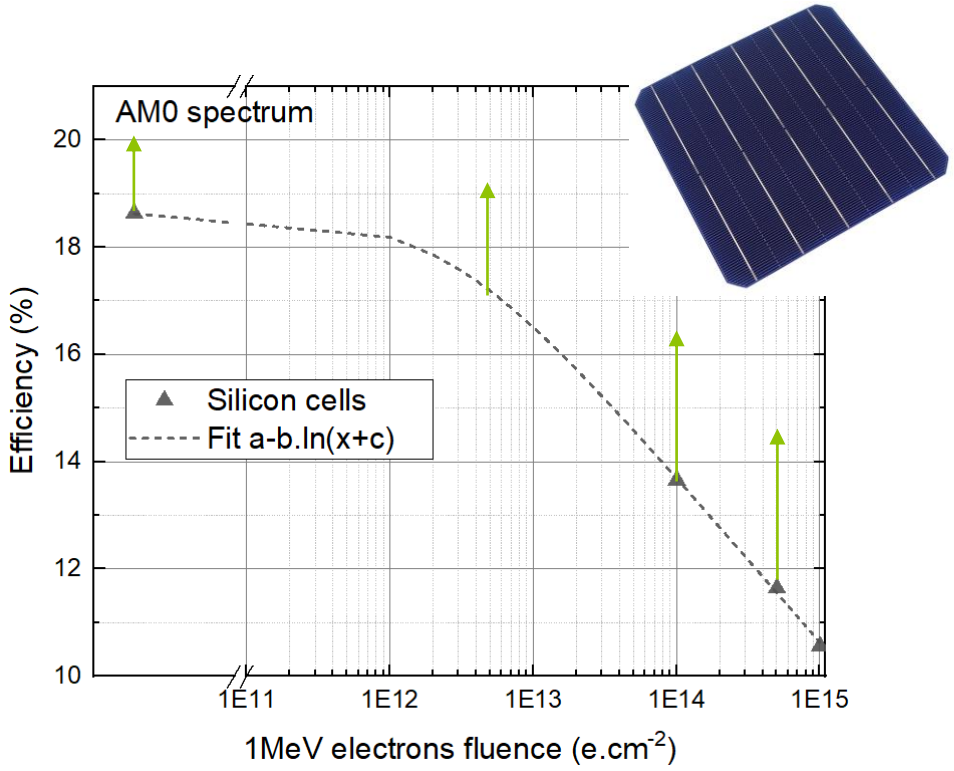
→ **New perf./cost compromises possible**
- Shorter missions, moderate env. constraints
- Redondancy of constellation architecture

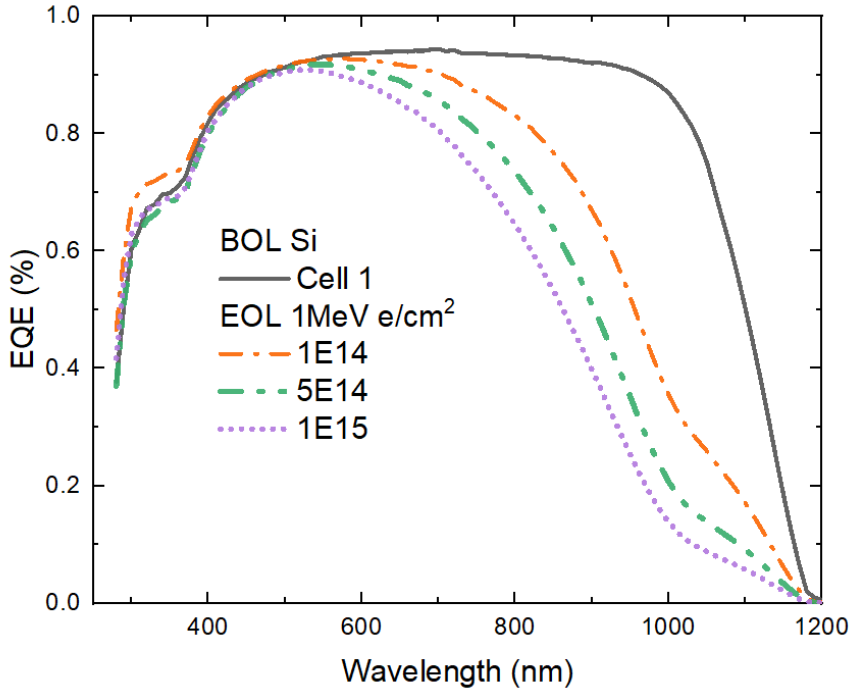
→ **Foreseen PV needs beyond III-V prod. capacities**

M.A. Green et al., PiP **30**, 3 (2022) | NREL Best Research-Cell Efficiency Chart | F. Fertig et al., IEEE JPV **12**, 22 (2022)

LOW COST SILICON CELLS RADIATION HARDNESS

- Typical LEO equivalent dose: 1MeV 1^E14 to 1^E15 e/cm²

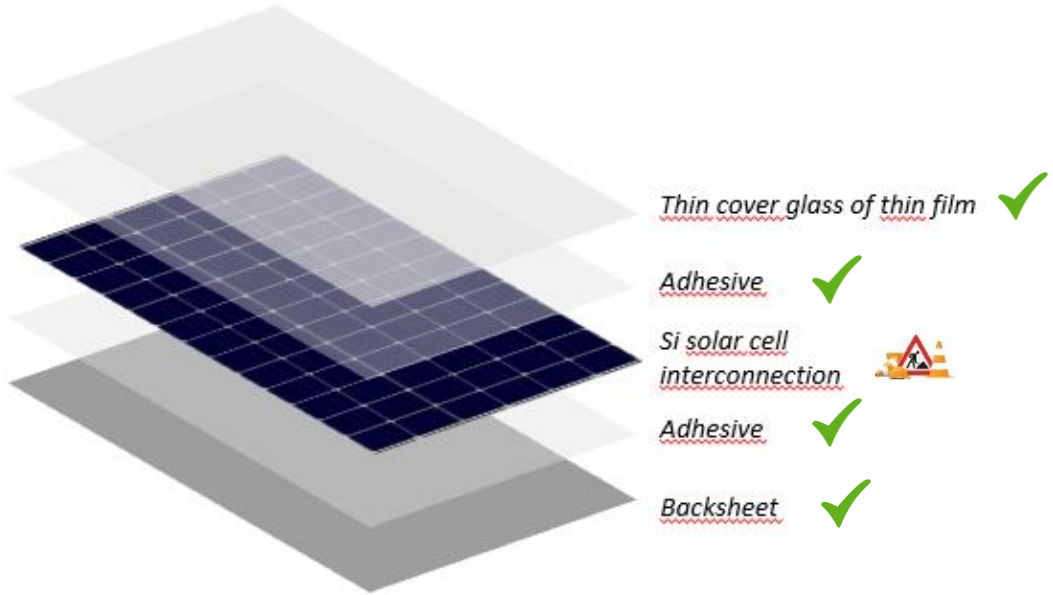


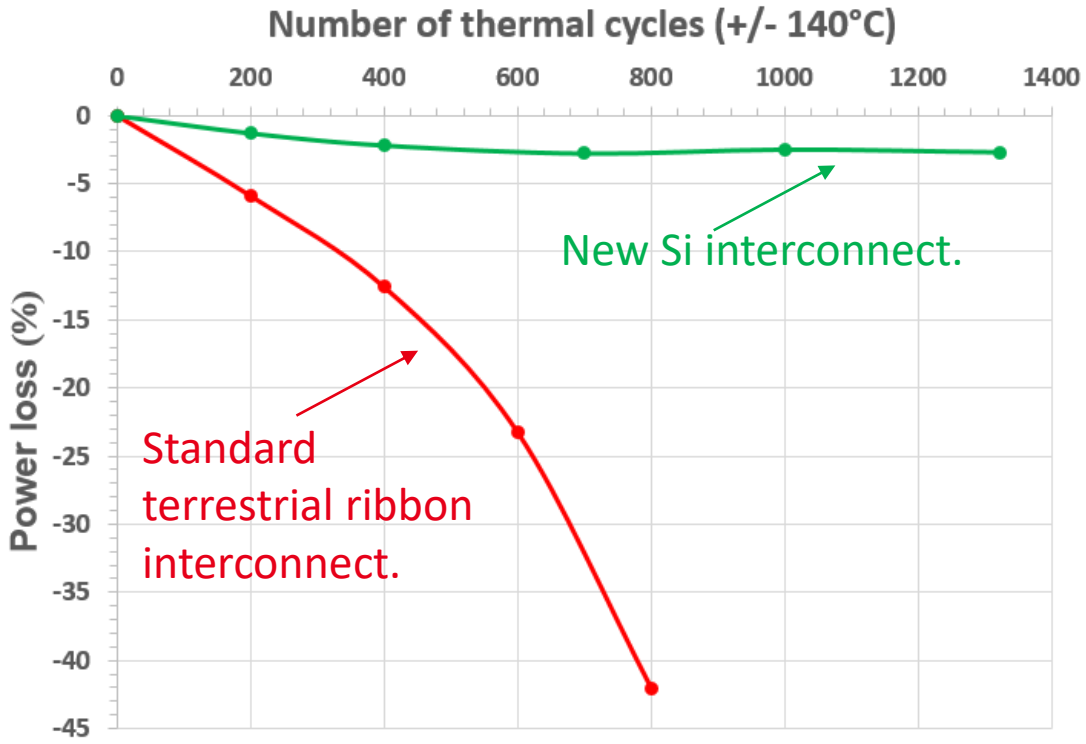


→ 10-14% EOL efficiency with today's terrestrial Si cells
Potential of higher EOL performances in near futur

LOW COST SILICON PVA THERMAL CYCLING

- Typical LEO thermal cycling: +/-100°C, 10 – 40 cycles/day, > 50 000 cycles for 10 years





- Selected COTS components are compatible with LEO thermal cycling

New Si cell interconnection solution
→ Significant thermal cycling improvement

CONCLUSIONS & PERSPECTIVES

- **Evolution of terrestrial Si PV and recent space market developments calls for new Si space story**
  - Si x2 less performant (EOL) but hundreds time cheaper than III-V
  - Large volume & industrial maturity, compatible with foreseen space PV demand
  - Convergence of terrestrial cell/array design vs space needs

- **Promising low cost Si cells & array testing**
  - PERC Si cells with 10-14% EOL AM0 efficien
  - Standard Si terrestrial array fails with space
  - Selected COTS components & new intercon

Space Si PV challenges:

- EOL efficiency ↗ (cells & array)
- Mass budget ↘ (array & mechanism)
- Validation of ~ 50 000 thermal cycles

- **Si won't replace III-V but can power specific market segments (e.g. constellations)**
  - Moderate radiation doses (< $1^{E}15$ 1MeV e^{-}/cm^{2})
  - Moderate thermal amplitude & mission duration (< +/- 140°C)
  - Moderate power needs (<4 kW)

Thank you for your attention

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