U.S. DEPARTMENT of ENERGY | Office of Critical Minerals and Energy Innovation

Integrated Energy Systems Office

2026 IESO Space Photovoltaics Workshop: Findings and Participant Recommendations

Technical Priorities for Next-Generation Space Photovoltaics

1. Executive Summary

The United States Department of Energy (DOE) Integrated Energy Systems Office (IESO) Space Photovoltaics (PV) Workshop convened 78 participants in Washington, D.C. on June 2, 2026: 37% from solar and space industries, 45% from Federal agencies and national laboratories, and 18% from academia. Participants identified barriers to scaling the next generation of space PV and proposed research and development (R&D) targets and recommended actions for the community.

The targets and actions in this report reflect recommendations of workshop participants and do not constitute commitments or the opinions of DOE.

Satellites, powered by PV cells, are fundamental to national defense, global communications, weather forecasting, navigation, and a growing on-orbit economy. Workshop participants expect demand for space power to grow faster than domestic production can scale and faster than qualification pathways can adapt. Proven III–V technologies (which use semiconductors combining chemical elements from Group III and Group V of the periodic table) offer high energy conversion efficiency and radiation tolerance but remain costly and dependent on specialized equipment and concentrated supplies of gallium (Ga), germanium (Ge), and other components. Lower-cost silicon (Si), perovskites, and other thin films offer potential advantages in cost, scale, and mass but require mission-relevant reliability data and qualification pathways. Participants therefore identified three main barriers: technology reliability, domestic manufacturing and supply-chain resilience, and appropriate testing and qualification.

To overcome these barriers, participants identified three core opportunities for R&D:

- **Advance PV performance and reliability.** Participants prioritized R&D to advance a portfolio of PV technologies and establish mission-relevant reliability. Participants proposed cross-cutting 2035 targets: PV arrays that simultaneously deliver at least 200 watts per kilogram (W/kg) of

specific power, retain at least 70% of beginning-of-life power at end of life for a defined mission profile, and cost less than $10 per watt at a defined array boundary. Reaching these targets requires both steady improvement of existing Si and III–V-based cells and higher-risk research on thin-film and perovskite-based multijunction cells, including predictive understanding of in-orbit degradation, recovery, and combined-stressor effects.

- **Rebuild the U.S. supply chain and manufacturing base.** Participants identified a clear need to reduce the material intensity of critical minerals such as Ga and Ge; strengthen their supply chains; expand U.S. manufacturing capacity for Si, III–V, and thin-film cells, substrates, and module components; and develop domestic manufacturing equipment capability. Participants noted continued terrestrial PV R&D and manufacturing as a key enabler in strengthening domestic manufacturing and supply chains for space PV.
- **Modernize testing and qualification.** Participants recommended mission- and technology-specific protocols, combined-stressor ground testing, regular low-cost flight opportunities, and shared data. Orbit-specific environmental profiles and market analysis would inform these activities.

2. Workshop Design

The workshop used a two-stage process. In the morning, tables of mixed-expertise participants identified and ranked R&D gaps across technology and performance; manufacturing and supply chains; and testing, qualification, and data. Each table placed its highest-priority gap on an impact-versus-feasibility matrix. In the afternoon, participants regrouped by technology: III–V, silicon, and thin-film/perovskite PV. They then translated the priority gaps into current baselines, 2035 targets, and recommended actions. This report synthesizes the barriers to scaling space PV, technical targets, and R&D and community actions proposed during the workshop.

3. Background: The Three Barriers to Scaling Space PV

Workshop participants expect both satellite count and power demand to increase substantially over the next decade; several participants cited a potential two- to threefold increase in power requirements per satellite.

The incumbent high-performance PV technology for space is a triple-junction III–V solar cell grown on a Ge substrate. Three stacked sub-cells of decreasing bandgap (the minimum energy needed to absorb light and generate electricity)—gallium indium phosphide (GaInP, bandgap of ~1.9 electron-volts (eV)), indium gallium arsenide or gallium arsenide ((In)GaAs, ~1.4 eV), and the Ge substrate itself (~0.66 eV)—each captures a different part of the solar spectrum. They are grown by metalorganic vapor-phase epitaxy (MOVPE), a process in which gaseous chemical precursors react on a heated surface to build thin, highly ordered semiconductor crystal layers that are lattice-matched with the layers below and are connected in series through tunnel junctions, which allow electrical current to pass efficiently between the sub-cells. These cells deliver about 30% beginning-of-life (BOL) efficiency under air mass zero (AM0) illumination and provide the radiation tolerance required for many long-duration missions [1]. Production is concentrated among a small group of established manufacturers including Spectrolab (Boeing), SolAero (Rocket Lab), Azur Space (5N Plus), and Sharp [2].

This picture has shifted with the build-out of large low Earth orbit (LEO) communications constellations. The largest, SpaceX's Starlink, adopted low-cost Si panels accepting lower efficiency to avoid the expense of III–V at large satellite-constellation volumes, compensating for the lower efficiency (with the best space Si cells at 17.4% AM0 BOL efficiency [3]) by deploying much larger panels. One industry estimate places total installed orbital solar capacity at roughly 100 MW and SpaceX at about 90% of that total [4]. Because Starlink uses silicon, this estimate suggests that silicon accounts for most of the installed orbital PV capacity.

Metal-halide perovskite PV is another option promising rapid scalability and low cost. Because its light-absorbing layer is only a few hundred nanometers thick and can be printed onto ultralight flexible substrates, it offers a power-to-mass ratio far above any incumbent. Ultra-thin perovskite cells have demonstrated roughly 20–30 kW/kg at the bare-cell level [5], [6]. For comparison at the cell level, MicroLink reported more than 3 kW/kg for a three-junction III–V cell under AM0 conditions [7], [8]. These cell-level figures demonstrate the potential of thin-film cells and should not be compared directly with packaged-cell, panel, or array specific power. The long-term operational and radiation stability remains a principal barrier to flight use.

The workshop discussions pointed to three linked barriers: limited mission-relevant reliability evidence for lower-cost technologies; concentrated, import-dependent supply chains for critical materials and components; and qualification approaches that participants viewed as too slow or insufficiently tailored to some missions and emerging technologies.

- **Reliability of lower-cost alternatives.** Lower-cost silicon and halide-perovskite technologies have less standardized evidence for long-term performance under combined space stressors, including proton and electron irradiation, thermal cycling, vacuum, ultraviolet-rich AM0 illumination, atomic oxygen, and micrometeoroids. Terrestrial-derived silicon architectures now have operational experience at constellation scale, but they do not have the same standardized qualification record as heritage space silicon or III–V products. Perovskite behavior under combined, mission-relevant space stressors is not yet well understood.

- **A fragile critical-materials supply chain.** III–V cells depend on gallium, recovered as a by-product of aluminum refining, and germanium, recovered from zinc refining, and the supply chains for these two materials are highly concentrated and import-dependent. U.S. Geological Survey (USGS) reports more than 50% net import reliance for germanium [9], although domestic recovery and refining capacity is expanding (e.g., Ge substrates are finished in the U.S. by the semiconductor manufacturer 5N Plus but only from imported and recycled feedstock). For gallium, USGS reports 100% U.S. net import reliance; China accounts for about 99% of global primary low-purity Ga production [10]. Teledyne reports that around 80% of the space-qualified cerium-doped cover glass used on Western satellites to protect PV cells from radiation, especially in medium Earth orbit (MEO) and geostationary Earth orbit (GEO) environments, comes from its site in Wales [11]. Export controls and concentrated supply have increased price volatility and procurement risk for gallium and germanium [9], [10], propagating supply risk directly into space PV cell and module production.

- **Outdated qualification standards.** The American Institute of Aeronautics and Astronautics (AIAA) S-111A standard provides qualification and quality requirements for space solar cells [12], while S-112A standard covers electrical components used on space solar panels [13]. Workshop participants described the current standards as too rigid and costly for some short-duration LEO missions and insufficiently tailored to emerging technologies and combined-stressor degradation for specific missions. Participants reported that current qualification practices do not consistently reproduce coupled in-orbit stressors or incorporate timely feedback from flight data.

4. Workshop Findings and Recommendations

The workshop recommendations center on three parallel efforts:

- Advance PV performance and reliability through targeted R&D.
- Rebuild the U.S. supply chain and manufacturing base.
- Modernize testing and qualification.

One of the most consistently emphasized near-term needs was regular, low-cost flight testing to generate data, build flight heritage, and calibrate ground test models to rapidly de-risk and qualify new space PV technologies.

4.1 Advance PV Performance and Reliability

Three PV technology families are central to the near-term space PV portfolio: silicon, III–V, and perovskite/other thin films. Participants recommended advancing them in parallel rather than selecting a single winner.

Across the workshop, participants proposed a range of quantitative measures for future space solar arrays. To provide a concise cross-technology summary, this report focuses on four metrics that recurred in the workshop record and are useful for evaluating performance, durability, scalability, and cost. The following values represent a synthesis of workshop input rather than formally agreed targets for every technology or mission:

- Deployed-array specific power: > 200 W/kg
- Deployed-array areal power, AM0 at the end of life (EOL): > 200 W/m^2
- EOL power retention: at least 70% of BOL power for a defined orbit, mission duration, and environmental profile
- Cost: < $10/W at a defined hardware boundary

Metric boundaries. Space PV performance and cost can be reported at four levels of assembly: the bare *cell*; the *CIC* (cell-interconnect-cover glass), which adds the interconnects and protective cover glass; the *panel* (or blanket, in flexible designs), which integrates and wires multiple CICs onto a supporting substrate; and the *array* (or wing), which also includes structural and deployment hardware. Values reported at these different levels are not directly comparable. Adding packaging, interconnection, wiring, and deployment hardware generally lowers specific power and raises cost per watt, while also enabling protection, integration, and deployment. The workshop records did not consistently specify key reporting parameters: hardware boundary; illumination spectrum, whether AM0 or air mass 1.5 global (AM1.5G), the standard terrestrial reference spectrum for nonconcentrating PV testing; BOL or EOL condition; orbit and mission duration; production volume; and dollar year. In preparing this report, the values were cross-checked across session records and published literature and aligned to a common hardware boundary and set of conditions where the available information allowed. Values that could not be normalized without additional assumptions are identified as preliminary. Table 1 in Section 5 puts the selected targets in the context of published baselines.

Across all three PV cell technologies, the most critical research frontier is developing a predictive understanding of how cells age in orbit, specifically regarding radiation damage and recovery. Participants recommended including mechanical modeling of long-term degradation, such as creep-level finite-element analysis, alongside radiation and thermal models. Validated models could reduce reliance on broad heritage margins by allowing designers to evaluate degradation for a defined mission and orbit. Cell R&D also needs a systems-level understanding at the satellite and array level, so that satellite-level drivers and requirements inform cell targets and future development priorities.

In addition to advancing Si, III–V, perovskite, and thin-film PV technologies, the workshop community recommended funding exploratory studies of far-horizon, high-risk/high-payoff space PV technologies.

R&D Priorities for Si PV

Participants expected LEO power demand to grow substantially and identified silicon as a likely high-volume option because it can leverage terrestrial PV R&D, suppliers, equipment, workforce, and manufacturing scale. They therefore identified continued strength in U.S. terrestrial PV R&D and manufacturing as a key enabler for space PV growth.

Participants identified the following Si R&D priorities:

- **Advance radiation-hardened silicon PV to greater than 23% AM0 BOL efficiency at 50–60 micrometers cell thickness for high-volume manufacturing, leveraging terrestrial technology to:**
    - Ensure sustained, long-term support for Si PV R&D and facilitate collaboration between academic, national lab, and industry stakeholders to accelerate innovation and workforce development.
    - Identify and adapt terrestrial Si PV materials and components for space applications, including contacts, frontsheets, backsheets, and encapsulants.
    - Evaluate lower-cost, higher-mass terrestrial-derived designs where mission-level trade studies show that the cost and production benefits outweigh the mass penalty.
- **Improve Si PV power retained at EOL by investing in radiation degradation research to:**
    - Establish radiation-tolerance baselines for modern cell architectures because historical data may not be directly representative of current commercial technologies.

- Optimize the trade-off between radiation resistance and photocurrent by reducing cell thickness to 50–60 micrometers (μm).
- Develop active radiation-hardening strategies using dopants, impurities, thermal or ultraviolet (UV) annealing, or blackbody radiation engineering.

- **Qualify critical components** by standardizing and qualifying interconnects to withstand combined stressors in space and during launch, e.g., long-term thermal cycling from −155°C to +155°C.

One silicon breakout group proposed 330 watts per square meter (W/m^2) BOL and greater than 230 W/m^2 EOL at the array level, together with qualification toward a 10-year LEO mission. Another stated a baseline cost of a Si panel of $7/W and proposed panel cost targets of approximately $3/W near-term and $2/W by 2035. These values are included to preserve the participant-proposed benchmarks and indicate the intended scale of progress. However, no supporting published sources were identified, and key assumptions, including AM0 conditions, hardware boundaries, production volume, and dollar year, were not documented; the values should therefore be verified and refined before being used as formal baselines or targets.

R&D Priorities for III–V PV

Current III–V cells meet many cell-level efficiency and radiation-tolerance needs, but the broader system does not yet meet the workshop's cost and scale targets. The constrained supply of Ga and Ge directly limits how many III–V cells can be made and keeps production costs high.

Participants identified the following III–V PV R&D priority:

- **Develop III–V fabrication using less Ga and Ge** by developing alternative substrates, wafer reuse, and growth methods that significantly reduce raw material consumption during epitaxy. The literature documents up to five gallium arsenide (GaAs) substrate reuse cycles with repolishing [14] and one demonstrated direct reuse cycle without repolishing [15]. Participants proposed a target of more than five reuse cycles without repolishing at 95% yield.

R&D Priorities for Perovskite and Multijunction Thin-Film PV

Participants proposed a cell-level specific power target above 500 W/kg for perovskite-based single- and multijunction cells. However, deploying them requires significant advances in cell- and module-level reliability science, backed by ground and flight validation to prove their durability in actual space environments.

Participants identified the following perovskite and thin-film R&D priorities:

- **Advance multi-stressor degradation science** by investigating the combined effects of light, heat, thermal cycling, and radiation on perovskite cells and panels.

- **Establish space-relevant baselines** by developing a common reporting protocol for AM0 BOL and mission-relevant EOL performance in addition to terrestrial AM1.5G reporting.

- **Build predictive mission-life models** by measuring activation energies, wake-up and metastability kinetics, post-eclipse recovery, and low-temperature behavior down to -110 °C to support predictive mission-life models and shorten the learning cycles.
- **Accelerate reliability validation** by establishing space-relevant qualification protocols and defining technical readiness criteria for perovskite and thin-film cells and modules.

4.2 Rebuild the U.S. Supply Chain and Manufacturing Base

Scaling domestic space PV will require coordinated progress in terrestrial-derived silicon, critical-mineral resilience, and specialized III–V and perovskite manufacturing. Participants identified high capital requirements, low production volumes, and concentrated material supply as barriers between laboratory innovation and qualified production.

Participants identified the following priority actions:

Leverage the Terrestrial PV Foundation to Scale Space PV

Participants identified continued strength in U.S. terrestrial PV R&D, manufacturing, suppliers, equipment, and workforce as a key enabler for affordable space PV scale:

- **Establish a 100 MW/yr domestic space PV manufacturing target** by leveraging relevant suppliers, equipment, workforce, and manufacturing know-how from the U.S. terrestrial module industry, whose nameplate capacity reached 65.5 GW/yr in 2025 [16].
- **Elevate Si PV research and workforce development** by coordinating shared roadmaps and building a highly skilled pipeline of space PV technicians and engineers.
- **Establish standardized process design kits** by standardizing cell and material families to enable companies and researchers to seamlessly validate and transition laboratory-scale cell designs into larger-scale, commercial fabrication lines (a "lab-to-fab" model).

Secure Critical Minerals

Gallium and germanium supply chains are concentrated and import dependent. Participants recommended that R&D aim to:

- **Map the supply chain** by conducting a comprehensive national space PV supply-chain survey to identify and address bottlenecks, dependencies, and cost risks for raw materials.
- **Reduce material intensity** by investing in R&D for substrate alternatives, wafer reuse, ultra-thin layers, and greater use of silicon PV cells where mission appropriate.
- **Secure supply** by expanding domestic recovery and recycling, considering offtake agreements, and evaluating domestic processing and extraction where technically and economically feasible.

Rebuild Domestic Manufacturing Capacity

Domestic space-grade cell production is concentrated among a small number of vendors. Participants identified a funding and infrastructure gap between laboratory pilot lines and qualified production and suggested the following actions to address this gap:

III–V Compound Semiconductor Capacity

Participants suggested that R&D aim to:

- **Assess and repurpose U.S. compound-semiconductor foundries** by assessing whether underutilized domestic compound-semiconductor infrastructure could produce a space-qualified multijunction product at approximately 30% AM0 BOL efficiency and whether this would enable flexible, turnkey processing lines that can scale up or idle dynamically based on national security needs or market demand.

- **Scale wafer reuse technology** by accelerating development of high-yield substrate peeling and reuse methods (targeting reuse beyond five times with no repolishing) to dramatically lower the bill-of-materials cost of expensive III–V cells.

- **Develop high-throughput growth technologies** by evaluating and scaling high-throughput epitaxial growth methods such as Dynamic Hydride Vapor-Phase Epitaxy (D-HVPE). D-HVPE has demonstrated GaAs growth rates above 300 micrometers per hour and cell efficiencies above 25% under AM1.5G [17]; these results support evaluation of D-HVPE as a higher-throughput alternative to conventional MOVPE.

- **Secure domestic component manufacturing** by encouraging domestic sourcing of critical array components, including protective cover glass, specialized space adhesives, raw materials, manufacturing equipment, and trained manufacturing technicians.

Perovskite and Thin-Film Capacity

Participants suggested that R&D aim to:

- **Establish a domestic perovskite equipment and manufacturing base** by establishing U.S.-based metal-halide perovskite manufacturing and equipment capabilities early, while the technology and supply chain are still developing, to retain domestic know-how and reduce future supply dependence.

- **Conduct integration-focused R&D** by launching a dedicated, collaborative research program focused specifically on the unique packaging, metallization, and array-level integration challenges of perovskite-based PV cells.

- **Create a pilot "lab-to-fab" validation pipeline** by establishing a shared pilot-scale facility where researchers and startups can validate laboratory-scale cell processes using standardized manufacturing protocols before scaling them to commercial fabrication lines. This pipeline would help bridge the early-stage funding gap by lowering scale-up costs and generating the validation data needed to attract follow-on investment.

4.3 Modernize Testing and Qualification

Participants identified the time, cost, and limited capacity of testing and qualification as major near-term barriers for new, lower-cost technologies. They described current requirements as insufficiently tailored to mission duration, orbit, and technology.

Participants' recommendations on testing and qualification included the following:

- **Develop mission- and technology-specific test standards** by setting up flexible, mission- and technology-specific qualification pathways that complement or update heritage standards and are matched to the target orbit and mission lifetime. Use coordinated round-robin campaigns, in which national laboratories, industry, and academia test comparable samples using common protocols for radiation, thermal, UV, and other stressors. Combine the results with shared flight telemetry to establish and refine these pathways.

- **Map mission-specific environmental envelopes** by characterizing radiation, thermal, UV, atomic oxygen, and other relevant conditions for LEO, MEO, GEO, cislunar (between Earth and the Moon), and lunar surface missions to anchor ground tests and predictive EOL models. Encourage environmental and other appropriate data-sharing through a common data system.

- **Create a shared space test facility** as participants reported fragmented space-testing facilities and limited radiation testing capabilities that result in long queues and test campaigns that can take 12–18 months. They proposed a shared, combined-stressor ground test facility with a target of no more than 12 months from sample intake to validated data.

- **Set regular low-cost flight tests** by establishing regular, low-cost, multi-technology flight-test opportunities—potentially quarterly as capacity and mission access allow—with sample return where practical and provide bridge resources for researchers to develop flight payloads. One group proposed an iterative protocol-development loop: model degradation, ground test common sample sets with *in situ* measurements where possible, fly matched samples, compare ground and flight outcomes, and refine the protocol. Where samples return from flight, they proposed comparing degradation mechanisms directly.

- **Develop a shared flight- and test-data registry** by establishing an open, anonymized space PV data registry so that flight and ground test telemetry can be pooled across industry, national laboratories, and academia. Shared datasets should be complete, quality-controlled, and overseen by an objective third party.

- **Perform market and technoeconomic analyses** by conducting systematic cost-benefit trade studies comparing emerging space PV technologies across various orbits, launch rates, and mission profiles to guide Federal testing priorities. Include a capability matrix matching the strengths of emergent PV technologies to mission demands and stressors.

4.4 Cross-Cutting Coordination and Funding Mechanisms

To coordinate technical work and bridge commercialization gaps, participants proposed the following organizational and funding mechanisms:

- **Space PV R&D consortium** with participants from national laboratories, industry, Federal agencies, and academia. Participants brought up the Photovoltaic Accelerator for Commercializing Technologies (PACT) [18] as a terrestrial PV example of a center that develops, validates, and documents testing protocols and supports precommercial technology testing. This consortium could define mission-dependent performance metrics, steward updated qualification standards, and operate the shared data registry (§ 4.3).

- **Milestone-driven funding tools** that accelerate the transition from laboratory research to commercial flight by leveraging a mix of public-private financial mechanisms, including:

    - Milestone-based payments that tie awards for cell efficiency improvement directly to the successful completion of certified space testing milestones.

    - Milestone-based funding that utilizes guaranteed purchase agreements and other structures that release funding when key technical milestones are met.

    - Existing DOE programs as participants suggested exploring structures modeled on existing federal programs, where technologies and projects meet applicable eligibility and program requirements, to support manufacturing scale-up.

    - Data-contribution incentives to explore milestone-based incentives for companies to contribute qualifying flight and ground test data under appropriate data-use agreements. The Solar Data Bounty Prize [19] and PV Fleet Performance Data Initiative [20] provide terrestrial examples of incentivized data contribution and fleet-scale analysis. Any space PV implementation would require separate governance for proprietary, export-controlled, and mission-sensitive data.

    - Technology prizes by considering a competitive "Go/No-Go" cash prize specifically aimed at verifying perovskite cell commercial readiness.

5. Quantitative Benchmarks and Workshop Targets

Table 1 distills the workshop's quantitative output into a concise set of metrics across PV technologies. It does not reproduce every value proposed during the breakout sessions. Metrics were selected based on their importance in the workshop record, their ability to be defined consistently, and the availability of a credible comparison baseline. Technology-specific or insufficiently defined targets are retained in the relevant technical sections.

Where possible, performance metrics are presented at the deployed-array level, capturing contributions from the cells as well as packaging, interconnection, integration, and deployment structures. Because array designs, mission conditions, and reporting conventions vary, Table 1 presents the most relevant published benchmark available or, where no comparable baseline exists, context for the scale of the workshop targets.

Table 1. Selected Current Benchmarks and Contextual Values Compared with Participant-Recommended Targets for 2035

Metric	Current Benchmark	Participant-Recommended Target
Array specific power, BOL (W/kg)	~30 W/kg typical flown mission arrays; ~200 W/kg maximum in the National Aeronautics and Space Administration (NASA) mission dataset [21]	>200 W/kg at array level
EOL retained power (% of BOL) and mission durability	~75% after proton and ~85% after electron radiation for III–V cells [22] LEO satellite design life 5–7 yr [23];	>70% for a defined mission profile; 10 years in LEO
Array areal power, EOL (W/m^2)	~258 W/m^2 (8 kW / 31 m^2) at BOL—flown on Surface Water and Ocean Topography (SWOT) mission [24] No public EOL array baseline was identified.	>200 W/m^2 under AM0 EOL conditions
Cost ($/W; boundary stated)	~$3,500/W—flown heritage International Space Station (ISS) Si array (2000); ~$900/W—flown III–V on Dawn mission (2007) [25]. No public modern deployed Si or III–V array $/W value. ~$250–$450/W for III–V CICs; *cf.* ~$0.28–$0.39/W terrestrial Si cells [26]. Participants reported ~$7/W for a Si panel.	<$10/W at a defined array boundary
Domestic space PV manufacturing capacity	Public disclosures include >1 MWe/yr III–V cell capacity at Rocket Lab [27] and 1 MW/yr of Si module capacity at mPower [28] *cf.* U.S. terrestrial module nameplate capacity: 65.5 GW/yr in 2025 [16]	100 MW/yr, with a path toward GW scale
Decision-quality test-data turnaround	Participant-reported campaigns can take ~12–18 months.	≤12 months
Shared flight-test cadence	Participant-reported: occasional CubeSat and ISS opportunities; no recurring community-wide cadence.	Approximately quarterly, or at least four shared opportunities per year

6. A Phased Action Roadmap

Across the three priority areas, participant recommendations form a phased roadmap over the next decade: strengthen the foundation in years one through three, build shared infrastructure and scale in years three through seven, and pursue the long-term outcomes by 2035. The actions are a synthesis of workshop input and do not represent DOE or IESO commitments.

Table 2. A Phased Roadmap Consolidating the Actions Proposed by Workshop Participants

Timeframe	Key Actions
Immediate *1–3 years*	• Conduct supply-chain survey and technoeconomic analyses to guide R&D and testing priorities. *(§ 4.2, § 4.3)* • Establish beginning- and end-of-life performance baselines for space PV and advance PV reliability under combined light, heat, thermal cycling, and radiation. *(§ 4.1)* • Develop space environment profiles tailored to different orbits and lunar missions. *(§ 4.3, § 4.4)* • Develop space qualification protocols for Si and perovskite PV. *(§ 4.1, § 4.3)* • Develop space PV process design kits and standardized cell designs for pilot-scale production. *(§ 4.2)*
Mid-term *3–7 years*	• Tailor qualification standards and pathways to be mission-, orbit-, and technology-specific. *(§ 4.3)* • Establish a shared combined-stressor ground test facility, with a target of validated data within 12 months of sample intake. *(§ 4.3)* • Establish regular low-cost multi-technology flight test opportunities, with sample return where practical. *(§ 4.3)* • Scale III–V wafer reuse and high-throughput fabrication to reduce material use and production costs. *(§ 4.1, § 4.2)* • Consider establishing a space PV R&D consortium of national laboratories, Federal agencies, industry, and academia to set metrics, steward qualification standards, and manage shared data. *(§ 4.3, § 4.4)*
Long-term *by 2035*	• Strengthen domestic Ga and Ge supply chains and reduce reliance on concentrated foreign sources. *(§ 4.2)* • Scale domestic low-cost space-grade PV production to 100 megawatts per year and establish U.S.-based perovskite manufacturing capability. *(§ 4.2)* • Demonstrate and field radiation-hardened arrays for long-duration missions in low Earth orbit, near or on the Moon, and in deep space. *(§ 4.1)*

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