Long Flex PCB Interconnects for deployable spacecraft solar arrays.

A Technical perspective for high-reliability power systems

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Wiring is no longer just connectivity

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CONNECTING TECHNOLOGY

Introduction

The increasing power demands of modern spacecraft - driven by high-throughput communications, electric propulsion, and onboard processing - are pushing solar array architectures toward larger, more mechanically complex deployable structures. At the same time, mass budgets, packaging constraints, and reliability requirements remain uncompromising.

In this environment, the interconnect architecture becomes more of a focus. It directly affects reliability of deployment, electrical performance, structural integration, manufacturability, and, most importantly, overall mission success. Long flex PCB interconnects are increasingly being adopted as a high-reliability alternative to conventional wire harnesses in spacecraft solar arrays

By replacing discrete wiring with engineered flexible printed circuits, long flex PCBs provide a deterministic, scalable, and mass-efficient solution for folded and roll-out solar array systems.

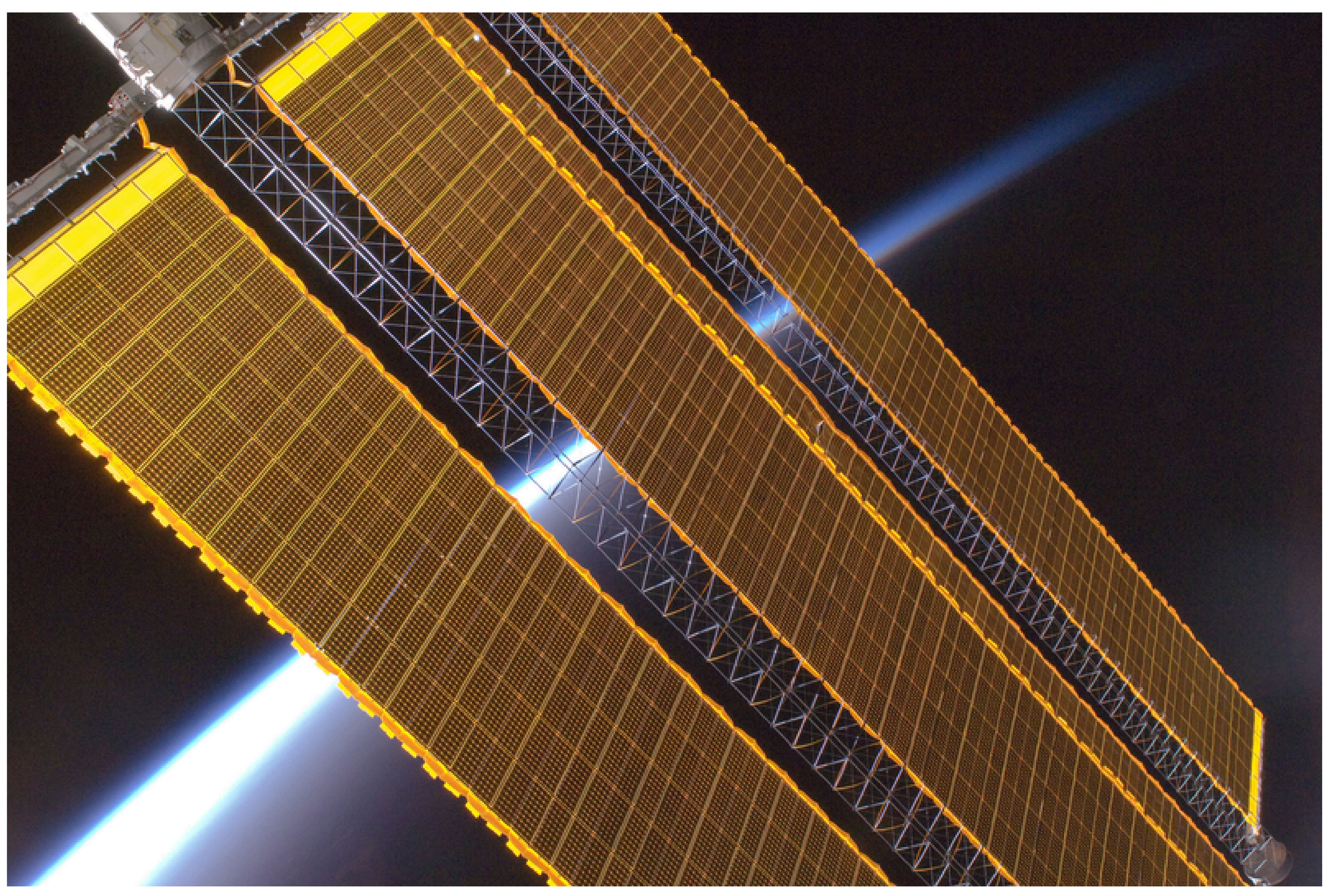


Image source: NASA - A solar panel array of the International Space Station (Expedition 17 crew, August 2008)

Why traditional harnesses fall short

The interconnects traditionally used for solar arrays are most commonly discrete wire harnesses. This is often routed across panel hinges and structural interfaces, and while this approach is tried and tested, there are several potential disadvantages for deployable space systems.

These include, but are not limited to, higher mass and volume due to insulation, shielding, connectors, and strain relief. They also entail an increased part count, which adds complexity, maintenance and assembly time. Routing across hinge lines and moving interfaces can be difficult, and multiple electrical discontinuities can create failure points under vibration and thermal cycling. In addition, harness layout tolerances can introduce greater variability in electrical performance.

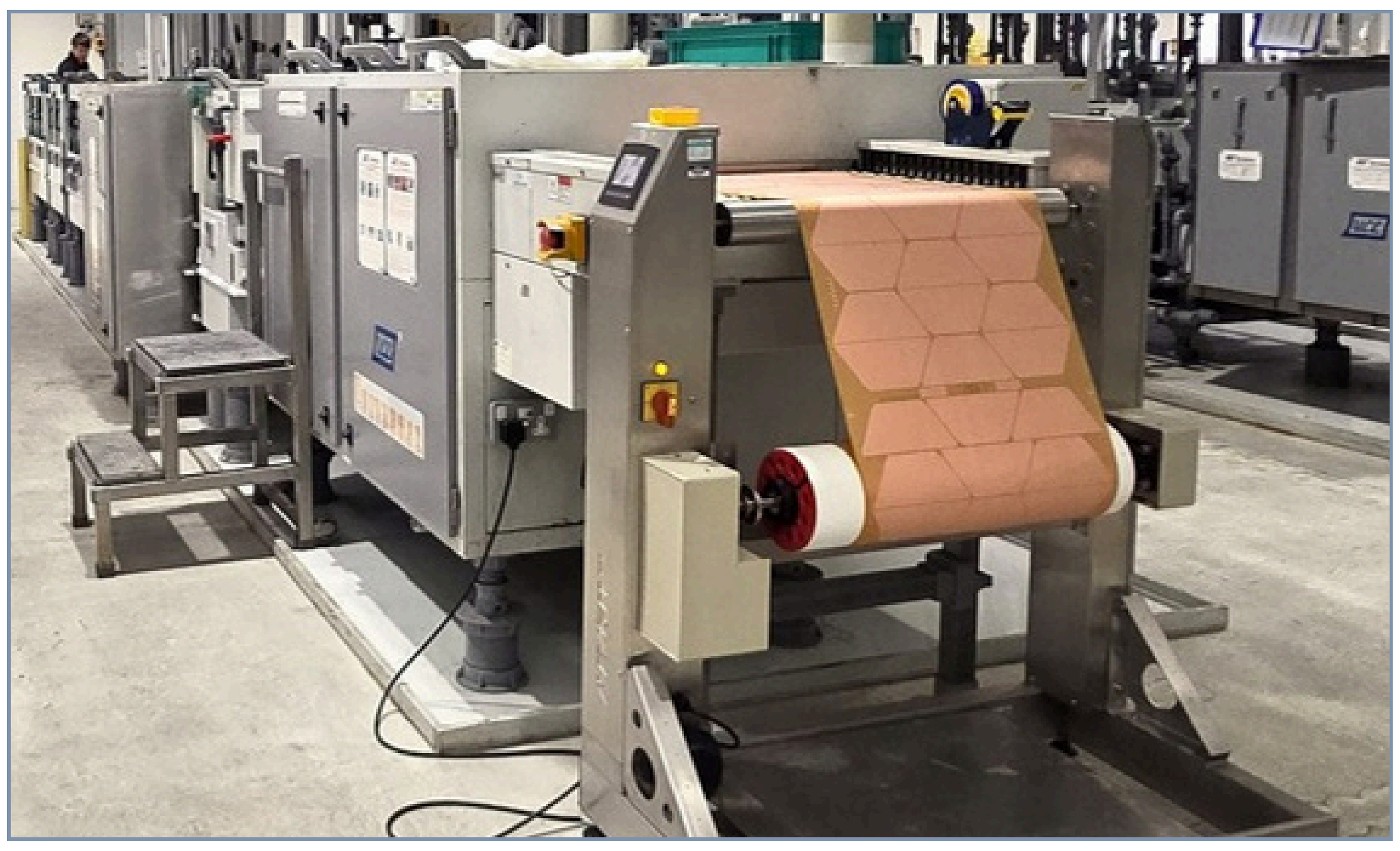
Limitations such as these can increase integration risk, reduce repeatability, and make spacecraft production more difficult to scale when looked at from a systems engineering perspective.

What long flex PCBs offer

Long flex PCBs can replace discrete harnesses with a continuous laminated interconnect structure. These circuits typically use conductive layers such as copper or aluminium, dielectric films such as polyimide, and adhesive or adhesiveless bonding systems.

Using Trackwise' proprietary Improved Harness TechnologyTM (IHT), it is possible to manufacture long flex PCBs extending many meters in length while retaining precise conductor geometry. Long flex PCBs are well suited to spacecraft solar array applications, as they contain one continuous conductor path with no connectors, controlled-impedance routing for power and signal reliability, integrated ground planes, and shielding for EMI and EMC performance. They also allow for engineered bend regions for repeated flexure, and rigid-flex transitions for direct attachment to electronics and panel hardware.

The ability to make the interconnect part of the deployable structure itself, rather than an external element that must be managed during integration and deployment, can also be a huge benefit.



Long flex PCB manufaturing made possible with IHT

Electrical performance benefits

From an electrical standpoint, long flex PCB interconnects offer greater predictability than harness-based designs. Controlled impedance can be maintained across the full interconnect length, supporting both power distribution and high-speed data signals.

The elimination of multiple connectors to create the appearance of length reduces insertion loss, reflections, and contact resistance variation. For high-current applications, wider conductors or parallel layers can be used to manage current density more effectively than with discrete wiring.

Thermal design can also be managed more effectively. In a vacuum, there is no convective cooling, so conductor geometry and composition selection must support both electrical efficiency and heat dissipation. For high-voltage spacecraft systems, proper stack-up design is vital to secure dielectric strength, spacing, and insulation coordination.

Electrical performance benefits

Long flex PCB interconnects are especially valuable in deployable spacecraft structures because they are designed for controlled deformation. Bend regions can be engineered with specific radii, neutral axis placement, and layer construction to reduce strain in conductive materials.

With a folded solar array, routing flex circuits across hinge lines eliminates the need for loose cables, which reduces the risk of snagging or interference during deployment. They also improve packing efficiency in the stowed configuration owing to their lower mass and volume.

In the case of roll-out solar arrays, the design requirements are even more challenging. The interconnect must tolerate continuous curvature and repeated flexing during both stowage and deployment. Long flex PCBs address this through thin, uniform constructions, high-flex materials, and continuous conductor paths.

Space qualification requirements

Space environments place extreme demands on materials and construction methods. Long flex PCB assemblies must use vacuum-compatible materials exhibiting low outgassing characteristics and comply with standards such as ECSS-Q-ST-70 and NASA outgassing requirements.

It's most common to use Polyimide-based dielectrics due to their thermal stability and radiation resistance, however, other materials can also be considered. Thermal cycling performance must also be verified, especially where coefficient of thermal expansion mismatches could create stress in the laminate structure.

Adhesiveless constructions are often preferred because of the risk of delamination over the mission life. Radiation exposure, deployment cycle testing, and physical durability testing are also essential qualification steps, especially for deep-space missions and roll-out arrays.

Integration and manufacturing advantages

Long flex PCBs simplify spacecraft assembly by consolidating multiple harnesses into a single manufactured component. This reduces part count and cost, lowers touch labour, and minimises the chance of wiring errors during integration.

Long flex PCBs also improve repeatability across builds due to the heavy reliance on automation, which is especially useful for modular spacecraft programs and higher-volume production environments. Connector interfaces can be built directly into the flex design, decreasing manual wiring operations and improving alignment.

Rigid-flex sections can also support direct mounting of interface electronics or connectors, streamlining integration even further.

Use cases in deployable arrays

Long flex PCB technology can be beneficial to both folded and roll-out solar arrays.

In folded arrays, the technology supports clean hinge-line routing, multi-panel daisy chaining, and compact stowage. Electrical continuity is maintained across articulated joints without adding extra connectors or free-hanging cables.

In roll-out arrays, the scalable interconnects offer a lightweight alternative for large-area, high-power systems. This makes it a good fit for next-generation spacecraft architectures targeting tens of kilowatts or more.

In both cases, the interconnect design becomes integral to system performance due to its influence on deployment reliability, power stability, and manufacturability.

Enabling next-generation space power systems

While spacecraft move toward higher power levels and more complex deployable structures, traditional harness architectures become harder to justify. Long flex PCB interconnects offer an attractive alternative by combining mass efficiency, electrical predictability, physical durability, and integration simplicity.

For spacecraft solar arrays, this means lower mass and volume, better electrical performance, more dependable deployment behaviour, easier manufacturing and assembly, and improved scalability related to high-level missions.

These advantages are especially relevant for GEO platforms, LEO constellations, lunar systems, and deep-space vehicles.

As deployable structures continue to evolve, the interconnect is no longer solely a support function. It is a core design element, and long flex PCB technology is helping define the next generation of high-reliability space power systems.

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