mPower TECHNOLOGY

AFFORDABLE, SCALABLE POWER FOR LARGE-SCALE LEO CONSTELLATIONS

AN MPOWER TECHNOLOGY WHITE PAPER

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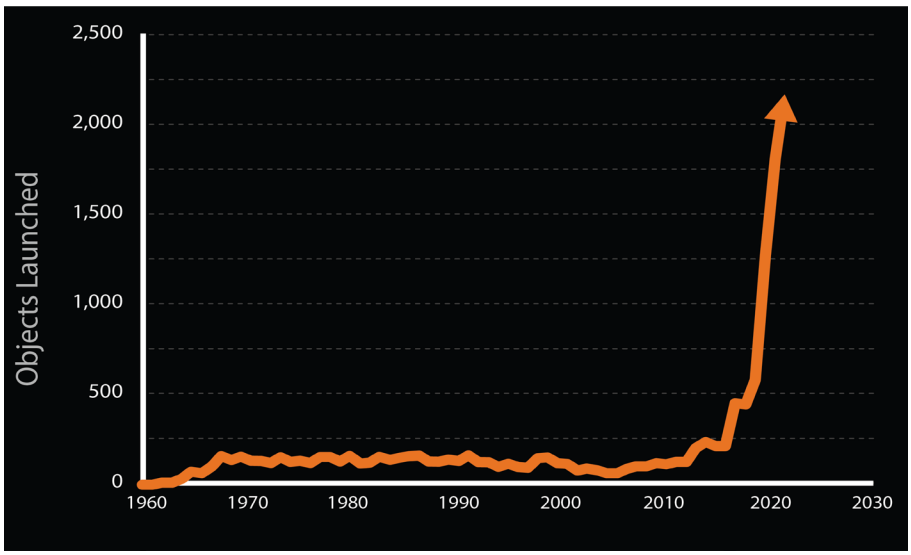
THE RISE OF LEO CONSTELLATIONS

Low-Earth orbit (LEO) constellations are large networks of satellites that orbit closer to the Earth's surface thereby offering several advantages over traditional geosynchronous satellites, including lower latency, higher data rates, and global coverage. They can enable a wide range of applications including notably ubiquitous broadband communications, high-resolution Earth observation, and a variety of military and surveillance missions. They also can support "edge computing" in space to minimize the amount of data that must be transmitted down to Earth.

LEO constellations have experienced significant growth in recent years, driven in part by the dramatic reduction in launch costs led by SpaceX and others. Recoverable, low-cost commercial launch vehicles have exponentially reduced the cost of putting a satellite into orbit.

As a result, numerous constellations are being planned, built and launched including SpaceX Starlink, OneWeb, Rivada Networks, Amazon Kuiper, AST SpaceMobile, Telesat Lightspeed, Lynk Global, IRIS2, and countless others. Moreover, several sovereign nations are now planning their own constellations for reliable and secure communications. Each constellation is composed of several hundred to upwards of 10,000 satellites. These constellations taken together are expected to dramatically increase the number of satellites launched to space as seen below:



Space 2.0 programs are growing exponentially due to rapidly declining launch costs

AFFORDABLE, SCALABLE POWER – A KEY ENABLER FOR LARGE-SCALE LEO CONSTELLATIONS

This dramatic growth is necessarily forcing a massive rethink of how satellites are built and launched. Electronics needed for controlling and monitoring satellites have been miniaturized and require far less power than ever before. At the same time, the computing power onboard a satellite has increased by orders of magnitude.

Despite these tremendous advances, there is one crucial building block that has remained stubbornly stuck in the past – power. Power for these satellites has been largely provided by the same solar technology for decades: GaAs-based solar cells, otherwise known as III-V cells. This 40-year-old technology has dominated the market since the 1990's but has two fundamental problems when it comes to LEO constellations.

First, III-V cells are simply too expensive, particularly for these proliferated, large-scale constellations. After the payload, the most expensive system on a satellite is its power generation and management systems. Multijunction III-V solar panels have historically cost upwards of $200/watt. More recently, they have declined in price, but are still far too high for today's large-scale constellations that require multiple megawatts of power.

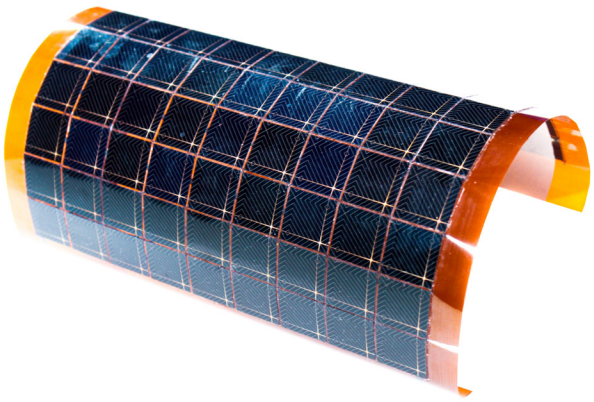
Second, there is simply not enough global supply to meet the huge demand from these constellations. Each of the larger constellations alone would nearly exhaust global supply capacity of III-V solar cells, and expanding capacity would mean adding expensive, highly specialized reactors that require massive capital investments and time to ramp production volumes. Given the unpredictability and market timing for these constellations, these investments are not easily justified and processing tools/materials required for the much higher production volumes for III-V cells are neither immediately available nor easily scalable. With the expected surge in the number of satellites, the need for an effective, scalable, and affordable solar cell technology is more crucial than ever.

Clearly a new solution is needed, one that meets the changing needs of the space market. Enter mPower's DragonSCALES™, a vastly less-expensive, high-performance alternative to current III-V technology.

DRAGONSCALES - THE NEXT GENERATION OF SPACE POWER

DragonSCALES consist of a completely flexible, interconnected mesh of high-efficiency silicon photovoltaic (PV) cells. Laser-singulated silicon solar cell die are connected in series and parallel on a pre-printed copper flex circuit. They are assembled using existing high-volume fabrication processes from the microelectronics industry to meet customized applications requirements. The result is space-grade solar modules that are three to five times less expensive than III-V solutions and available in virtually unlimited supply. But it doesn't stop there. DragonSCALES cells also present a long list of compelling performance benefits for today's space missions when compared with III-V and other silicon-based solutions:

DragonSCALES™



1. THE DRAGONSCALES MATRIX

The interconnected design of DragonSCALES means that modules have smaller fault containment regions and are more tolerant to damage from micrometeorites. Unlike traditional silicon (Si) modules that require all-series connections, the parallel connection in DragonSCALES modules reduces the impact of individual cell failure, thereby enhancing overall system reliability. This is a crucial advantage for LEO constellations where system robustness is of paramount importance. Additionally, they can support a design that mitigates the need for additional wiring and bypass diodes. Finally, it also means they are more shade tolerant and less sensitive to voltage mismatches.

2. WEIGHT AND VOLUME MATTER

Since silicon is half the density of GaAs, DragonSCALES cells are significantly lighter than traditional III-V cells. In addition, since they are flexible, they require less supporting structural materials than both GaAs III-V and other Si-based solutions. It also means they can dramatically reduce the required stowage volume in a launch vehicle with the right design. DragonSCALES enables solutions that are best in class in terms of power-to-weight and power-to-volume ratios. This is critical for space missions, where the balance between system weight and power generation is a vital aspect of the design.

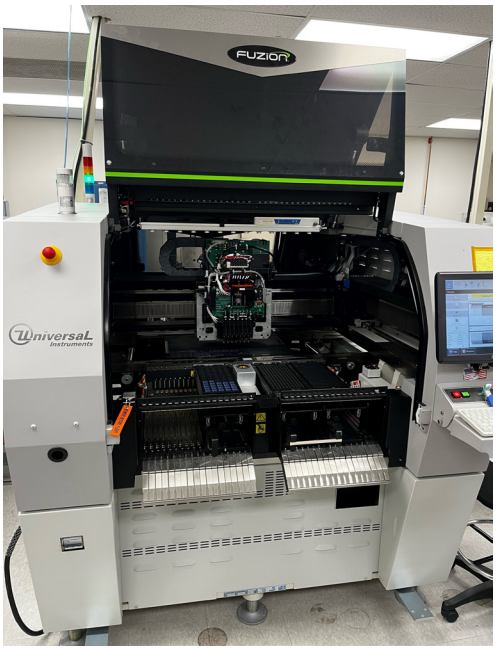
3. PROTECTION FOR RADIATION, ESD and ATOMIC OXYGEN

LEO constellations must operate over several years in incredibly harsh operating environments. With the right design, DragonSCALES cells can offer higher radiation resilience and even enhanced radiation recovery for the demanding radiation environments of LEO missions. With passive annealing and nominal operating temperatures, DragonSCALES can provide steady state performance close to beginning of life (BOL) power throughout the mission and into end of life (EOL). Even for higher orbits above ~1100km, DragonSCALES cells provide a radiation recovery advantage over other Si solutions given their unique design and fabrication.

Additionally, DragonSCALES' unique design allows for individual encapsulation of 2cm by 2cm die in radiation-resistant glass which becomes fully encapsulated and isolated from the environment. Electrostatic discharge (ESD) and atomic oxygen (AO) concerns are mitigated via this fully encapsulated design.

4. BUILT FOR SCALE

The DragonSCALES design enables automation at the module, panel, and array level of manufacturing, increasing quality control, reducing infant mortality and streamlining testing processes. DragonSCALES panels are simple to integrate and come "deployment ready", removing the majority of time-consuming and expensive-touch labor. DragonSCALES eliminates round wire assembly, diode boards, backside boards and feedthrough holes. This enables faster production rates, lower costs, and higher product uniformity compared to other solar technologies.



mPower Technology high-volume production line

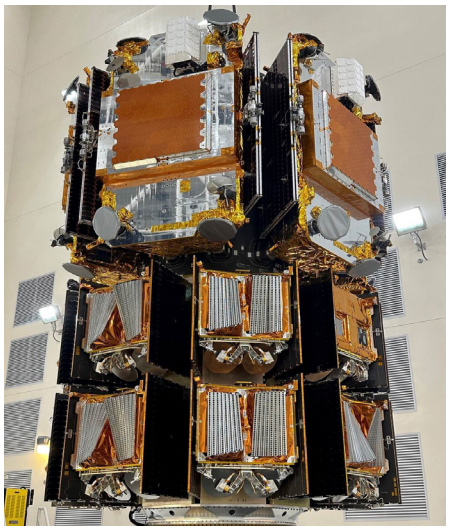
5. CLOSING THE EFFICIENCY GAP

The terrestrial PV industry invests billions of dollars each year to increase the efficiency of Si cells for residential and commercial rooftops and other large-scale markets. With its modular architecture, DragonSCALES is uniquely positioned to leverage these new, higher efficiency silicon-based cells (e.g., heterojunction cells, perovskites on silicon) as they become available. These higher-performing emerging silicon cells can be readily dropped into the qualified DragonSCALES assembly, reducing time to market and providing an immediate efficiency boost that closes the gap with GaAs cells. DragonSCALES further closes the efficiency gap with III-V through its superior packing factor. Because DragonSCALES cells are smaller and completely customizable, they can achieve higher packing factors (~95%+) by more completely filling a usable area. Practically speaking, this translates to an additional realized "efficiency" boost.

6. TIMING IS EVERYTHING

Unlike other Si-based solutions, DragonSCALES is ready to support large scale LEO constellations NOW, not years from now. High-volume manufacturing at both the module and panel level have been designed and implemented with proven manufacturing partners leveraging high-volume, automated processes and tools. Moreover, DragonSCALES has been thoroughly proven on the ground in numerous thermal, radiation and other qualification tests, and also in LEO orbit on several missions including with OneWeb for the Gen-2 design and with Lynk Global. DragonSCALES is in the process of further program level qualifications with most US and EU primes for large scale, "proliferated" LEO constellations. available solar power solutions that are reliable, scalable, and easy to integrate.

OneWeb Launch 19 JoeySat Payload Adapter including DragonSCALES demonstrator - Launched May 20, 2023 Vandenberg AFB on SpaceX Falcon 9



CONCLUSION

Emerging large-scale LEO constellations will require affordable, readily available solar power solutions that are reliable, scalable, and easy to integrate. DragonSCALES offers the perfect solution and is ready for high-scale production today. By leveraging the economies of scale from the silicon PV and microelectronics market, DragonSCALES can readily and cost-effectively meet the tidal wave of demand from the LEO constellation market. Further, its unique architecture provides additional advantages for LEO constellations over other solar technologies, including III-V and other Si-based solutions.

With over $25 million in engineering and development work and years of rigorous testing, mPower Technology's solar solutions are ready to power the next generation of LEO constellations.