



National Aeronautics and
Space Administration



TECHNOLOGY SOLUTION

Robotics, Automation and Control

Robotic Assembly of Photovoltaic Arrays

[Adaptable automation that reduces manufacturing time and costs](#)

NASA researchers have developed a novel process for assembling thin-film solar cells into larger solar arrays. Current methods for solar array manufacturing depend on time-consuming, manual assembly of solar cells into multi-cell arrays. Print-assisted photovoltaic assembly (PAPA) is an assembly process that leverages robotic automation to build fully functional flexible thin-film solar arrays. By increasing manufacturing efficiency, PAPA's no-touch technology can reduce labor costs, decrease time-to-market, and enable assembly of large-scale solar arrays of over 500kW. This increased efficiency can help meet growing demand for large solar arrays in residential and satellite applications. Compatible with all currently available thin-film and 3D-printed solar cell materials, PAPA is capable of integrating with current and future solar cell technologies. NASA is seeking licensees that may benefit from low-cost, automated assembly of large-scale solar arrays.

BENEFITS

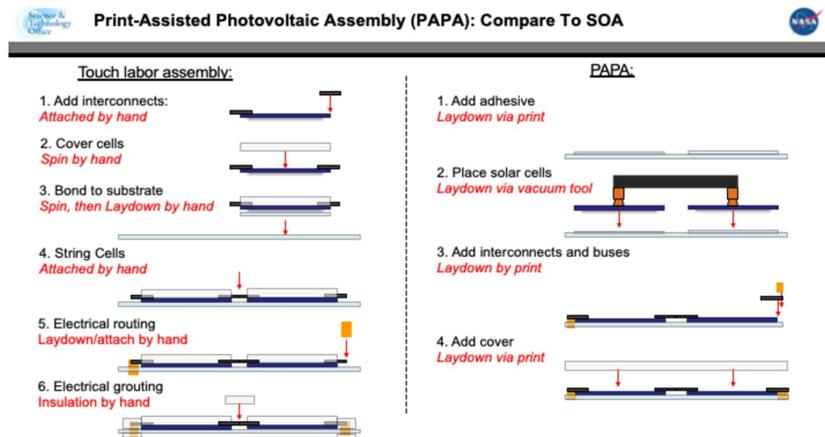
- Increases manufacturing efficiency and labor costs, resulting in savings of approximately \$300-\$400/watt
- Compatible with traditional and emerging flexible thin-film photovoltaic technology suggests immediate and sustained success solar industry
- PAPA compatibility with 3D-printed solar cells may facilitate future in-space solar array manufacturing.
- Standardization of manufacturing process reduces errors in assembly and increases product quality.
- Skilled labor for manufacturing not required, enabling assembly in non-industrial context.



THE TECHNOLOGY

NASA researchers have developed the PAPA technology to increase the efficiency of the thin-film solar array assembly process, significantly decreasing assembly time and labor costs associated with manufacturing large scale solar arrays. Traditional solar cell assembly is a labor intensive, multi-step, time-consuming process. This manual assembly will not be possible in a space environment. To enable solar array assembly in space, PAPA leverages robotic automation to distill the traditional assembly method into four fully automated steps: applying adhesive to block substrate, placing the solar cells using a vacuum tool attached to a universal robotic arm, printing the interconnects and buses to connect the cells, and applying a protective cover.

The PAPA technology is compatible with a variety of thin-film solar cells, including 3D printed cells (essential for future in-space manufacturing of arrays) and terrestrial manufacturing methods. As solar cell technologies mature, PAPA will be able to incorporate advancements into the paneling process. NASA researchers have begun to employ PAPA solar array fabrication and estimate savings of \$300-\$400/watt. For extraterrestrial assembly of solar panels the size of a football field or larger, PAPA could result in savings of approximately \$500 million; a substantial cost savings driven by standardization and efficiency in the solar array assembly process. By demonstrating increases in assembly efficiency, time and cost savings, and passing multiple environmental exposure tests, the PAPA lab prototype has completed the final phases of technology development and is ready for scale-up and commercialization.



PAPA technology increases manufacturing efficiency using a robotic-based vacuum tool to position the solar cells and automated printing to apply adhesive and perform electrical routing between cells.

APPLICATIONS

The technology has several potential applications:

- Military: unmanned aerial vehicles (UAVs), person-portable use, assembly of solar arrays in remote environments
- Space: solar arrays for satellites, assembly of large Power sails for deep space missions, solar-powered electric propulsion
- Transportation: lower cost, flexible solar arrays can enable range extension on cars, solar refrigeration units, small appliances in buses and RVs, street and traffic lights

PUBLICATIONS

Patent No: 10,930,812

-Carr, John A et al. "Initial steps towards a robotic solution for the manufacturing and assembly of thin-film space solar arrays." Flexible and Printed Electronics 8 (2023):