

A Dynamic Path to Flight – Sunpower and the Advanced Stirling Converter (ASC-F). J. Collins¹, W. A. Wong², K. Wilson², Eddie Smith³, and M.A. Dunlap⁵, ^{1,3,4,5}Sunpower, Inc., 1055 E. State Street - Suite D, Athens, Ohio 45701. ¹collins@sunpower.com, ³wilson@sunpower.com, ⁴smith@sunpower.com, ⁵dunlap@sunpower.com, ²NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, OH 44135, ²wayne.a.wong@nasa.gov,

Introduction: Sunpower, Inc. was founded in 1974 in Athens, Ohio with the goal of developing “Better Machines for a Better World” based on founder William Beale’s invention - the Free Piston Stirling Engine (FPSE). Fast-forward nearly 40 years to the Advanced Stirling Converter (ASC). The ASC was initially developed under contract to NASA Glenn Research Center (GRC) as a technology development project and has ultimately been adopted by NASA as the power conversion technology for the Advanced Stirling Radioisotope Generator (ASRG). With the continued support of NASA GRC and system integrator, Lockheed Martin Space Systems Company (LMSSC), the ASC and ASRG are poised to be integrated into two of three candidate missions in the Discovery 12 program. To meet the challenge of being the first dynamic Radioisotope Power System (RPS) selected for flight, Sunpower has undergone a transformation from a purely Research and Development (R&D) company to a qualified space flight hardware vendor

Sunpower’s Evolution To Flight Provider: Sunpower’s first 25-30 years were built upon innovation and R&D with a goal of commercializing FPSEs. In the last 10 years a focus has been added to commercialize Free-piston Stirling Cryocoolers through Sunpower’s onsite cryocooler manufacturing. Early ASC developmental units drew from Sunpower’s past with innovation yielding an enabling technology for NASA while cryocooler manufacturing introduced a more advanced level of inspection and quality assurance best practices.

In 2008, along with additional requirements being levied on the ASC-E2 project in preparation for flight, Sunpower established a formal Quality Assurance (QA) department with its first dedicated employee. Sunpower QA is an integral part of the ASC-F project and now features eight dedicated employees, dedicated inspection equipment, and mature processes. Sunpower has passed a total of three NASA GRC and Lockheed Martin Quality Audits resulting in Sunpower holding approved space hardware supplier status with LMSSC.

Sunpower engineering supporting the ASC-F project has expanded to add specialization to core Stirling design and operation expertise. Engineering staff have been recruited specifically for experience in Materials

and Processing, aerospace project management, aerospace production, GD&T, manufacturing, and analysis.

The technician resource pool has been expanded and cross-trained on Sunpower specific tasks as well as new capabilities such as clean room protocol. Additionally staff have received specialized training to NASA and aerospace industry standards on specialized processes such as soldering, potting, inspection, and brazing.

In July 2011, Sunpower completed construction and began operations in a new facility in Athens, OH. The entire company has been relocated. A significant driving force for the relocation effort was the ASC project successes and evolving requirements. New capabilities such as regenerator fabrication, clean room operation, soldering and potting in compliance with NASA standards, and control of heater head and displacer fabrication have been added to Sunpower’s competencies as a result of new requirements either through technology transfer from NASA GRC or in order to meet requirements. A significant portion of the new facility is dedicated to ASC production which has increased capacity and throughput. A clean room has been erected to meet Planetary Protection and Cleanliness requirements. Contributing to the need for a new facility is Sunpower’s growth (partially associated with ASC success) essentially doubling in personnel in the last 4 years.

ASC-F Design Status: Sunpower’s primary task in design efforts has been to build upon and supplement existing design documentation from previous ASC builds. This effort included analyses to meet flight requirements, updating and expanding drawings and processing documentation. Sunpower has developed capabilities to update existing ASC design documents to meet flight standards in areas including geometric tolerancing and dimensioning, separation of work instructions from engineering requirements, etc. A joint Configuration Control Board (CCB), co-chaired by LMSSC and NASA GRC and including Sunpower and DOE membership, was chartered in late 2010 and is responsible for review and approval of a single set of configuration controlled design documentation for use in the ASC-E3 and ASC-F builds. In January 2011, the first flight Issued drawing in Sunpower history was approved.

Sunpower has focused significant effort on qualifying processes to flight standards. Sunpower, with guidance from LMSSC and support from the ASC-E3 project, has qualified special processes and qualified new capabilities and is in production of long lead procurements making use of those processes.

The ASRG completed Preliminary Design Review (PDR) efforts in January 2011 and will complete Final Design Review (FDR) closeout in February 2012. Manufacturing Readiness Review (MRR) is slated for 1st quarter 2012.

ASC-F Production Status: Sunpower will build test and deliver eight ASCs under the flight contract. Two convertors will be slated for a Qualification generator. Four will be designated for the two flight generators. The final two are designated spares for the flight generators.

ASC-F fabrication is in parallel with many ASC-E3 activities. However, the ASC-E3 schedule has been set such that the first two pair of ASC-E3s serve as pathfinders for design changes, processing changes, and lessons learned from the ASC-E2 build and for new processes and working environments resulting from the clean room. This provides a significant risk reduction to the flight convertors.

Sunpower initiated fabrication of the longest lead procurements in late 2010. A series of long lead production reviews (LLPRs) have served as reviews of design documentation, design analyses, special processes, and process flow. Necessitated by the program schedule, successful completion of the LLPRs permits Sunpower to begin procurement and fabrication of components prior to FDR completion. The longest lead components (critical path) are slated for delivery to Sunpower during first quarter 2012.

LLPRs have been held for nearly all ASC components, and procurement/fabrication has begun on most of the components. The non-critical components will be procured and delivered to match the production schedule. First run of the first flight unit is schedule for mid-2012. The first flight convertors are scheduled for delivery to LMSSC late in 2012. The final convertors are scheduled for delivery late in 2013.