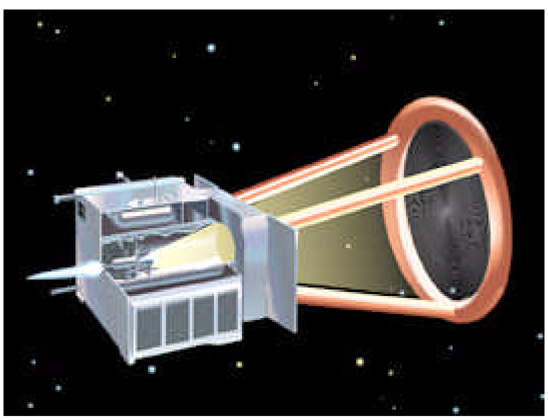
Refractive Secondary Solar Concentrator Being Designed and Developed

As the need for achieving super high temperatures (2000 K and above) in solar heat receivers has developed so has the need for secondary concentrators. These concentrators refocus the already highly concentrated solar energy provided by a primary solar collector, thereby significantly reducing the light entrance aperture of the heat receiver and the resulting infrared radiation heat loss from the receiver cavity. Although a significant amount of research and development has been done on nonimaging hollow reflective concentrators, there has been no other research or development to date on solid, single-crystal, refractive concentrators that can operate at temperatures above 2000 K.

The NASA Lewis Research Center recently initiated the development of single-crystal, optically clear, refractive secondary concentrators that, combined with a flux extractor, offer a number of significant advantages over the more conventional, hollow, reflective concentrators at elevated temperatures. Such concentrators could potentially provide higher throughput (efficiency), require no special cooling device, block heat receiver material boiloff from the receiver cavity, provide for flux tailoring in the cavity via the extractor, and potentially reduce infrared heat loss via an infrared block coating.

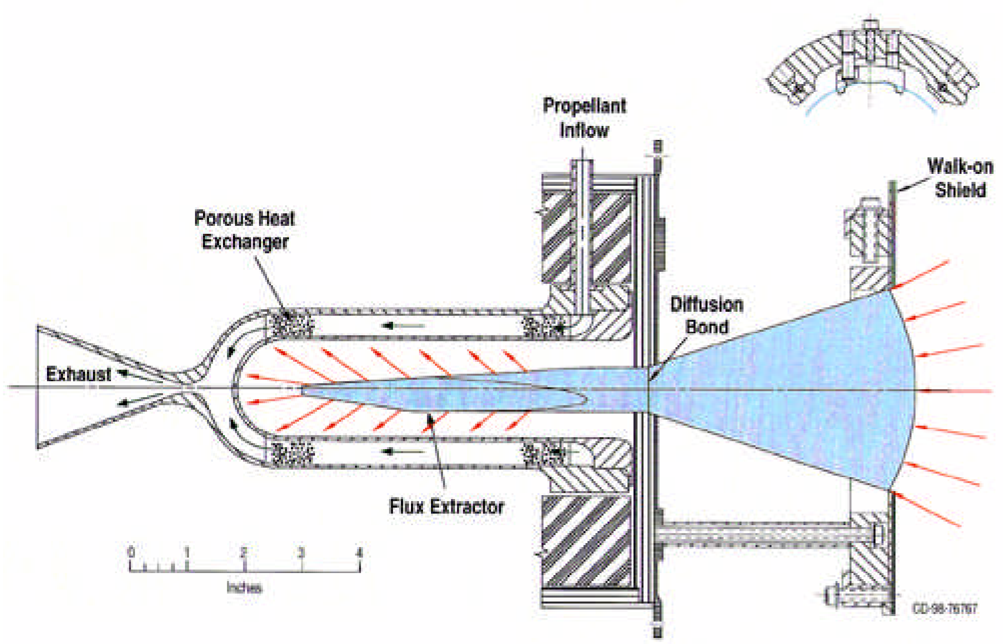
The many technical challenges of designing and fabricating high-temperature refractive secondary concentrators and flux extractors include identifying optical materials that can survive the environment (high-temperature, vacuum and/or hydrogen atmosphere), developing coatings for enhanced optical and thermal performance, and developing crystal joining techniques and hardware that can survive launch loads.



Solar thermal propulsion system for Shooting Star Experiment.

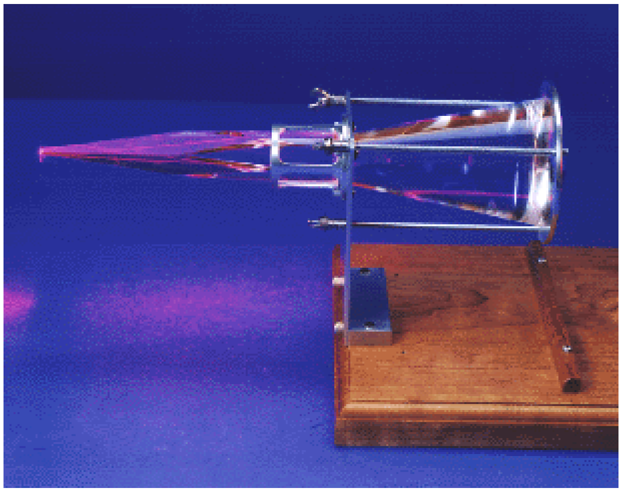
As a result of development work begun by NASA Lewis and Analex Corporation personnel in May 1996, a refractive secondary concentrator was baselined by the NASA Marshall Space Flight Center for their Shooting Star Experiment (SSE), which is to be placed in orbit by the shuttle in early 2000. This experiment will demonstrate all the technologies associated with a solar thermal propulsion system. The artist's rendering of the SSE (preceding illustration) shows the primary sun collector lens deployed from

NASA Goddard Space Flight Center's Spartan "free flyer" space platform. The solar thermal propulsion engine and secondary concentrator are located inside the Spartan platform.



Solar thermal engine for Shooting Star Experiment with refractive secondary concentrator.

The schematic shows a conceptual design of the engine and secondary concentrator. The secondary concentrator will be constructed of single-crystal zirconia, sapphire, or yttrium-aluminum-garnet (YAG), with the selection being made after extensive testing of all three materials. The engine, which will be constructed of rhenium, is designed for use with hydrogen propellant at temperatures approaching 2500 K but will use nitrogen propellant in the SSE. The propellant will enter the engine, flow through a rhenium-foam-filled annulus around the receiver cavity, be heated to temperatures approaching 2000 K, and expand through the nozzle, increasing the specific impulse over that of the cold gas. The following figure graphically demonstrates how a beam of light refracts and reflects in the concentrator and then enters the extractor where it is broken up into many rays of light that ultimately exit the extractor in a predicted distribution pattern.



Beam trace through refractive secondary concentrator.

Lewis' Secondary Concentrator Design Team developed the analytical tools needed for the optical design of a refractive secondary concentrator. A zirconia secondary concentrator and flux extractor were successfully fabricated for testing in 1998. Lewis is continuing to investigate materials and coatings that could extend the capabilities of these concentrators for various NASA and Air Force missions.

Bibliography

Soules, J.A., et al.: Design and Fabrication of a Dielectric Total Internal Reflecting Solar Concentrator and Associated Flux Extractor for Extreme High Temperature (2500K) Applications. NASA CR-204145. Presented at SPIE International Nonimaging Symposium, San Diego, CA, July 27-29, 1997.

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Programs/Projects: ISS, space shuttles, SSE, space transportation, high-temperature solar applications (e.g., solar thermoelectric, solar thermionics, solar dynamics, and solar ovens

Special recognition: A paper describing this research was nominated as one of the two most significant papers presented at the 1997 SPIE International Nonimaging Symposium.