Almost every type of concentrating technology was explored during this period, including reflective dishes (Boeing), reflective troughs (Acurex, GE), point-focus Fresnel lenses (RCA, Varian, Motorola, Martin Marietta), linear Fresnel lenses (E-Systems), luminescent concentrators (Owens-Illinois), compound parabolic concentrators (Sun Trac, University of Chicago), and small heliostat fields with a central receiver (AAI). Silicon cell research was conducted at Purdue University, Arizona State University, RCA, GE, Applied Solar Energy Corporation, Spectrolab, and Motorola. Gallium arsenide cells were also researched at Varian, Hughes, The Research Triangle Institute, and Rockwell International. In addition to these outside contractors, Sandia conducted in-house research on cells, lenses, and systems. A dynamic research program was created that was coordinated and documented through annual review meetings.

In 1978, DOE initiated a program to test concentrator concepts called the *Photovoltaic Concentrator Applications Experiments*. Seventeen projects ranging in size from 20 to 500 kW were awarded Phase I contracts to do feasibility studies. These projects to a large extent covered the gamut of possible system options. Eight concepts were awarded continuing funding to build prototype systems. By 1980, system efficiencies for these prototypes ranged from 5% for the reflective trough systems to 10% for point-focus Fresnel systems, and 12% for linear Fresnel systems [11].

Early experience indicated that reflective approaches were much more problematic and difficult compared with Fresnel lenses, mainly due to flux uniformity issues [12]. This, along with funding constraints, led Sandia to focus on Fresnel lens systems for continued development. Flux uniformity remains a critical factor to be considered in all concentrator system designs.[7]

Two system approaches survived the cut and were deployed in large (for the time) demonstration projects. These were the point-focus Fresnel modules of Martin Marietta (later Intersol) and the line-focus Fresnel approach of Entech.

11.3.2 The Martin Marietta Point-focus Fresnel System

Martin Marietta participated throughout the Sandia program developing a series of point-focus Fresnel modules and systems.[8] First-generation units had four lenses per housing. The housing was made of injection molded plastic and each lens was 30 cm × 30 cm. The cells were round and of approximately 6-cm diameter (having been made from 2.25-inch diameter wafers), resulting in a concentration ratio of 33X, rather low for a point-focus system. These modules demonstrated efficiencies in the 9 to 10% range, placing the concept at the upper end of efficiencies at that time (1978). Figure 11.6 shows the overall design concept. The large extruded aluminum heat sink doubled as the structural mounting support. First-generation modules were deployed in two significant demonstration projects as discussed in the section describing the Sandia National Laboratories Concentrator Program.

[7] The reader will note that in a line-focus system in which the cells are connected in series along the focus, the source current will be limited by that of the cell receiving the least illumination. Minor flux nonuniformities thus have a serious impact on overall efficiency.

[8] In 1984, this work was "spun out" of Martin Marietta to a start-up dedicated to commercializing the technology by the name of Intersol.