thereafter. In the early 1960s, the Wisconson Solar Energy Center researched the performance of solar cells under concentrated sunlight. They showed that cells could operate at intensities of several hundred times normal sunlight [7]. The critical issues proved to be (1) reducing series resistance to enable efficient handling of the large currents involved and (2) maintaining low-enough cell temperature. Much of the improvement in concentrating systems since these early days has come from reducing the negative impact of these two factors. The Wisconson group went on to design a working 50-W system using a parabolic dish concentrator, thereby demonstrating the feasibility of the concept [8].

In 1965, Eugene Ralph, then with the Heliotek Division of Textron (later Spectrolab), proposed several approaches to concentrating systems, from low-concentration reflective cones to high-concentration heliostat fields. He clearly articulated the vision that concentrating PV systems might one day supply large amounts of terrestrial power [9]. At a time when flat-plate systems cost hundreds of dollars per watt, Ralph projected that megawatt-sized systems could be built in the future for less than $1.00/W. Interestingly, this is $5.40/W in current dollars, which is about what current concentrator systems would cost in megawatt production quantities.[5]

Despite these early efforts, not much happened in the development of practical concentrating systems until the energy crisis of 1973 renewed concerns about the availability and depletion of fossil fuels.

11.3.1 The Sandia National Laboratories Concentrator Program (1976 to 1993)

One of the US Government's responses to the issues raised by the 1973 oil crisis was to upgrade the status and funding of energy research, first, through the National Science Foundation's Research Applied to National Needs program, then through the Energy Research and Development Administration (a renamed and remissioned Atomic Energy Commission), and finally through the DOE, which was created in 1977. From the beginning, concentrators played a significant role in the mission to develop cost-effective PV power. Sponsored research began in 1976 and included university research at Arizona State University headed by Professor Charles Bacus, plus a variety of industrial laboratories. Sandia National Laboratories in Albuquerque, New Mexico, became the lead agency for managing the concentrator program. The first Project Integration Meeting was held in 1978 [10]. Already 19 subcontractors were under contract to develop cells and systems, and they reported their plans and progress. DOE established a goal of having commercial systems available in 1981 at $2.00/W. This proved wildly optimistic, but was in a grand tradition with other wildly optimistic projections about PV cost reductions. In fact, in constant dollars, this goal was achieved about 20 years later.[6]

[5] Unfortunately, this is only marginally less than the cost of today's flat-plate systems, and is still too expensive for large-scale power production. Another factor of three-cost reduction is needed. In later sections, this chapter discusses possible avenues for realizing this cost reduction; however, the reader should keep in mind that concentrator manufacturers are able to achieve these prices at rather small, almost prototype production volumes, whereas flat-plate modules are now produced in automated factories producing up to 100 MW/year.

[6] $2.00/W is $5.60/W in 2001 dollars, about what today's concentrators and flat-plate systems cost in large installations.