long-term proposed space science missions and assessed the adequacy of SOA solar cell and array technologies [16]. At present, while low-cost thin-film cells are just beginning to present a viable space power option [$\sim$10% air mass zero (AM0) efficiency for small-area cells], the best space solar cells are triple-junction III-V cells with an AM0 efficiency around 27%, and conventional arrays have reached a specific power of around 70 W/kg. These arrays meet the needs of many near-Earth missions but fail to meet some critical NASA Office of Space Science (OSS) mission needs in three ways. These are (1) missions that utilize solar electric propulsion (SEP) and require much higher specific power (150–200 W/kg), (2) missions that involve harsh environments [low solar intensity/low temperature, high solar intensities (HIHT), high-radiation exposure, and Mars environments], and (3) Sun–Earth connection missions that require electrostatically clean arrays that do not allow the array voltage to contact and thereby distort the plasma environment of the array. The entire surface of an electrostatically clean array is maintained at approximately the same potential as the spacecraft structure.

Work is in progress at several U.S. National Labs, universities, and solar cell companies to develop four-junction III-V cells with 30 to 35% efficiency and/or low-cost thin-film cells with large-scale efficiencies greater than 12%. This work is supported mainly by NASA, AFRL, and DOE [National Renewable Energy Lab (NREL)]. Unfortunately, no significant programs are presently under way to develop solar cells that can function efficiently in harsh environments. The majority of the ongoing work on advanced arrays is focused on developing flexible thin-film arrays. A limited amount of work is in progress on the development of concentrator arrays and electrostatically clean arrays. Table 10.2 compares space solar power (SSP) drivers and current SOA technology.

10.2.1 The Space Environment

All solar cells that are developed for use in space must take into consideration the unique aspects of the space environment. The spectral illumination that is available in space is not filtered by our atmosphere and thus is different from what is experienced on Earth. Space solar cells are designed and tested under an Air Mass Zero (AM0) spectrum (see Figure 16.1). A more complete discussion of air mass (AM) can be found in Chapters 16 and 20.

In the terrestrial PV world, cost is still the driver in PV development, and this has generated interest in several thin-film material systems (i.e. amorphous silicon, $CuInGaSe_2$, CdTe). The smaller material costs and higher production potential for thin-film arrays may well drive PV modules below current costs. The current National Photovoltaics Goal is the development of a 20% thin-film cell. The problem is more complicated for space applications since these cells must also be developed on a lightweight flexible substrate that can withstand the rigors of the space environment. This suggests that a minimum of 15% AM0 efficiency will be needed to be competitive with current satellite power systems. The current benchmark for the space PV world are commercially available multijunction III-V cells of GaInP/GaAs/Ge described further in Chapter 9. Table 10.3 lists the current status of cell efficiencies measured under standard conditions (AM1.5 global) as well as extraterrestrial (AM0) spectra.

The major types of radiation damage in solar cells that are of interest to designers are ionization and atomic displacement due to high-energy electrons and protons