particle irradiation damage [35]. The performance of these cells degrades significantly (often exceeding a 50% loss) in very high-radiation environments such as experienced near Jupiter or in MEO. The relatively large temperature coefficient of silicon cells also results in large reductions in efficiency at high temperatures [26].

There have been many enhancements to silicon cells over the years to improve their efficiency and make them more suitable to space utilization. Textured front surfaces for better light absorption, extremely thin cells with back surface reflectors for internal light trapping, and passivated cell surfaces to reduce losses due to recombination effects are just a few examples and are discussed in more detail in Chapters 7 and 8. Currently, high-efficiency Si (HES) cells approaching 17% AM0 efficiency in production lots are available from several producers. The advantage of the HES cell to that of a III-V lies in their relatively lower cost and lower material density. However, silicon solar cells are less tolerant of the radiation environment of space.

10.4 III-V SOLAR CELLS

The efficiency of space solar cells achieved dramatic improvements as the focus shifted from Si toward GaAs and III-V semiconductor systems. The 1.43 eV direct band gap is nearly ideal for solar conversion (see Figure 10.1). By 1980 several types of III-V cells had been tested in space, with a 16% GaAs solar cell being developed by 1984 and a 18.5% efficient GaAs/Ge solar cell developed by 1989. It was also found that the GaAs cells had significantly better radiation resistance than Si cells. GaAs cells with efficiencies in excess of 80% of their theoretical maximum were routinely available commercially by 1998. Single-junction GaAs on Ge cells are currently commercially available with an AM0 efficiency of 19% and V_{OC} of 0.9 V. III-V solar cells for space applications are currently grown on Ge wafers because of the lower cost and higher mechanical strength over GaAs wafers.

Investigations on further efficiency improvement toward the end of the 20th century turned toward the development of multiple-junction cells and concentrator cells. Much of the development of "multijunction" GaAs-based photovoltaics was supported by a cooperative program funded by the Air Force Manufacturing Technology (ManTech) program and Space Vehicles Directorate, the Space Missile Center, and NASA [36]. This work resulted in the development of a "dual-junction" cell that incorporates a high band gap GaInP cell grown on a GaAs low band gap cell. The 1.85-eV GaInP converts short wavelength photons and the GaAs converts the lower energy photons. Commercially available dual-junction GaInP/GaAs cells have an AM0 efficiency of 22% with a V_{OC} of 2.06 V. See Chapter 9 for a complete discussion of this type of solar cell.

The highest-efficiency solar cells currently available for space use are triple-junction cells consisting of GaInP, GaAs, and Ge. They are grown in series of connected layers and have been produced with a 26.9% efficiency with a V_{OC} of 2.26 V in production lots, with laboratory cells of 29% (see Figure 10.8). Emcore, Inc., Tecstar, Inc., and SpectroLab, Inc., currently produce cells that are commercially available in the 25 to 27% range. Hughes Space and Communications Company's HS601 and HS702 spacecraft currently use MJ technology as do most other contractors for their high-performance spacecraft.