SPS OVERVIEW: REQUIREMENTS, ALTERNATIVES, AND REFERENCE SYSTEM

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Any major new source of energy should satisfy several requirements. It should be non-depletable with a large positive energy payback over its useful life, capable of base-load operation and have no fundamental constraint on capacity. It should be compatible with power grids, economically competitive and environmentally acceptable. It should not make excessive use of critical resources, and should be capable of development with reasonable cost, time and risk. The SPS appears to be capable of meeting all of these requirements.

Several power generation options were considered, including silicon, gallium arsenide and thin film photovoltaics, solar/Brayton and solar/Rankine cycle thermal engines, solar/thermionic and nuclear/Brayton. Of these, the last two were rejected early because of large mass penalties relative to the other systems. The helium Brayton and potassium Rankine systems are nearly competitive in mass and cost with the photovoltaic options, but the Brayton cycle achieves competitive mass only at very high turbine inlet temperatures which require advanced ceramic materials not appropriate for reference system use. The potassium Rankine cycle is an acceptable alternative to photovoltaic systems, but was not selected as the reference system because of turbomachinery and radiator maintenance questions and difficulty of construction relative to the photovoltaics.

Some thin film photovoltaic systems may be competitive if sufficiently high efficiencies can be achieved; some present resource problems. The candidate reference systems were thus reduced to silicon and gallium arsenide. A sunlight concentration ratio (CR) of 2 reduces the cost and weight of a gallium arsenide system but is not effective for silicon. Gallium arsenide at CR2 is substantially lighter than silicon at CR1, but presents technology and availability problems. Pending resolution of these questions, both systems are retained as reference systems.

For RF generation, the klystron is preferred to the amplitron because of higher gain, lower noise and higher output per tube. The magnetron appears interesting but has not been investigated in depth. Solid-state RF generators offer several advantages; they are discussed in a subsequent paper. A slotted waveguide array is the preferred type of radiating element based on high efficiency, simplicity and few unknowns. The waveguides are assembled into 10 m x 10 m subarrays for minimum mechanical and electronic complexity.

A wide variety of transmitter power density tapers has been studied. A ten-step 10 dB Gaussian taper has been selected for the reference system as a good compromise between peak power density, sidelobe levels and mechanical complexity. The reference system employs a retrodirective phase control system, although ground command and hybrid systems are promising alternatives.

The reference rectenna consists of dipole receiving elements and Schottky barrier diodes on panels normal to the microwave beam, with power distribution and conditioning equipment for the required interfaces with the power grid. Other concepts, such as waveguides or parabolic concentrators, may offer advantages but appear to be too costly.

A reference set of efficiencies has been defined that represents reasonable goals for each step in the power conversion-transmission-reception chain (see figure 1). These efficiencies imply a power density limit of 21 kW/m^2 at the transmitter which, together with a limit of 23 mW/cm^2 at the ionosphere and the reference antenna taper, leads to a maximum power of 5 GW per microwave link delivered to the power grid. This is the value selected for the reference system. There is recent evidence that 23 mW/cm^2 may be conservative; if so, the maximum power per link could be increased.

A geostationary orbit, with zero eccentricity and inclination, is preferred on an overall basis, although a few other orbits offer some specific features that could prove to be advantageous. Solar radiation pressure is the dominant perturbative force, requiring on the order of 50 tonnes of propellant per year if eccentricity is to be held at zero. By differential thrusting, this orbit-keeping impulse can also be applied to altitude control, which would otherwise require nearly as much propellant itself.

A major consideration in selection of the reference configuration (figure 2) was ease of construction. The scale of the program mandates the highest possible degree of automation in the construction process; this in turn places a premium on highly regular configurations that can be constructed with a small number of frequently repeated operations. Ease of construction was, for example, one consideration in the selection of an end-mounted, rather than central, antenna.

The reference system is constructed in synchronous orbit using material transported from low earth orbit by electric orbit transfer vehicles. Construction in low orbit of sections of the satellite with subsequent self-powered transfer to synchronous orbit for assembly is an alternate approach.

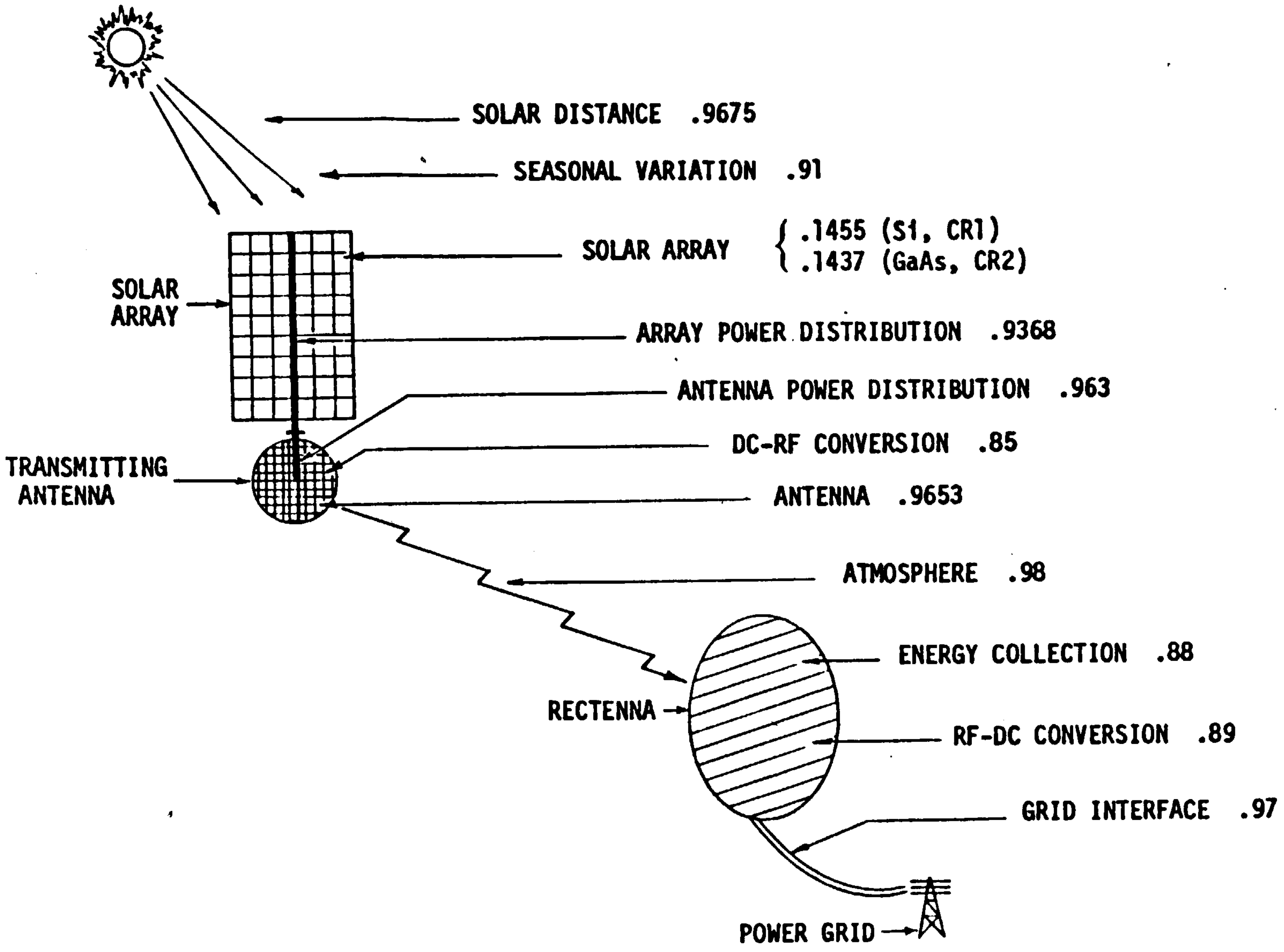

Figure 1. Reference Efficiency Chain

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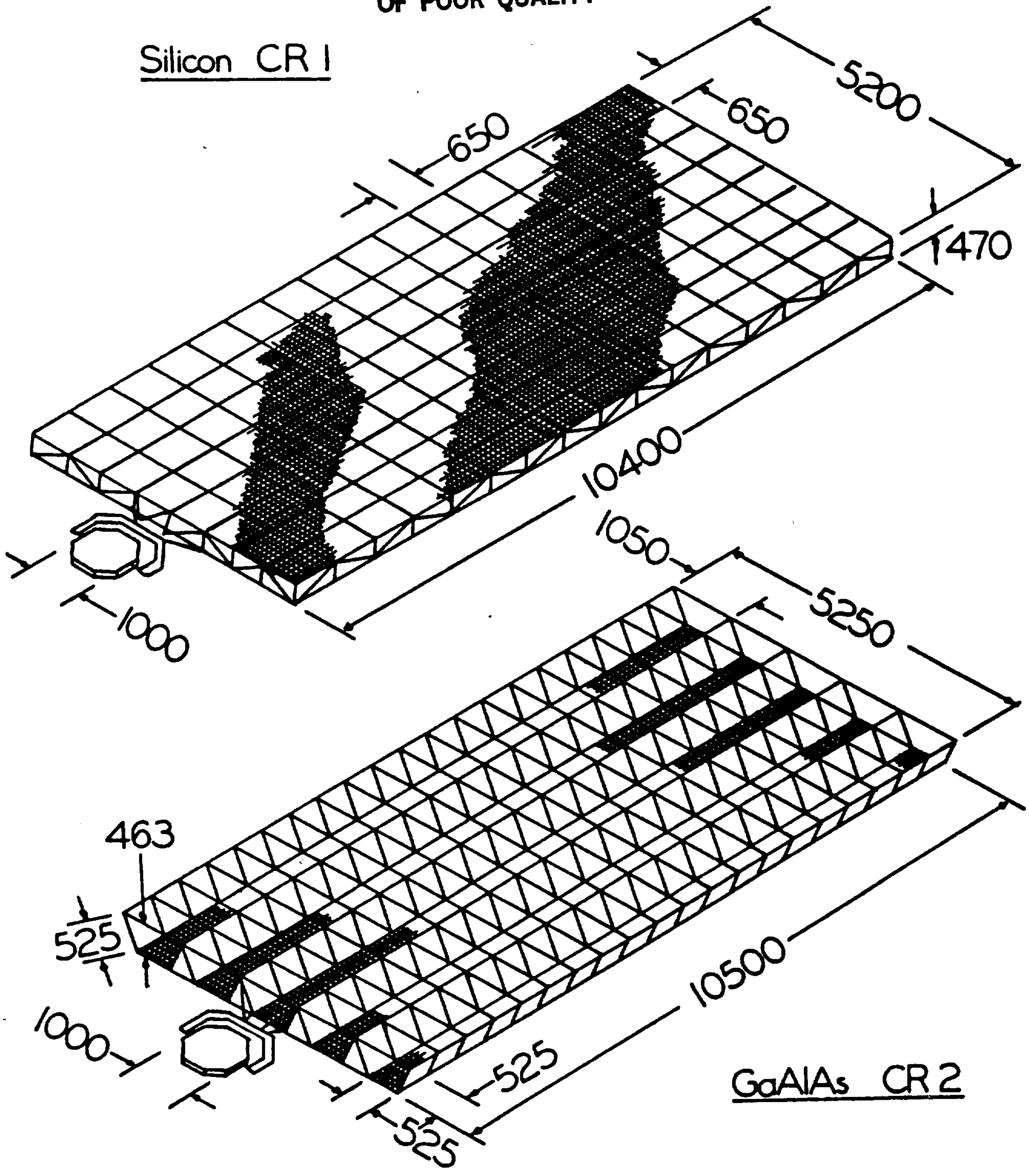

Dimensions in meters

Figure 2. Reference Configurations