Solar Power Satellites

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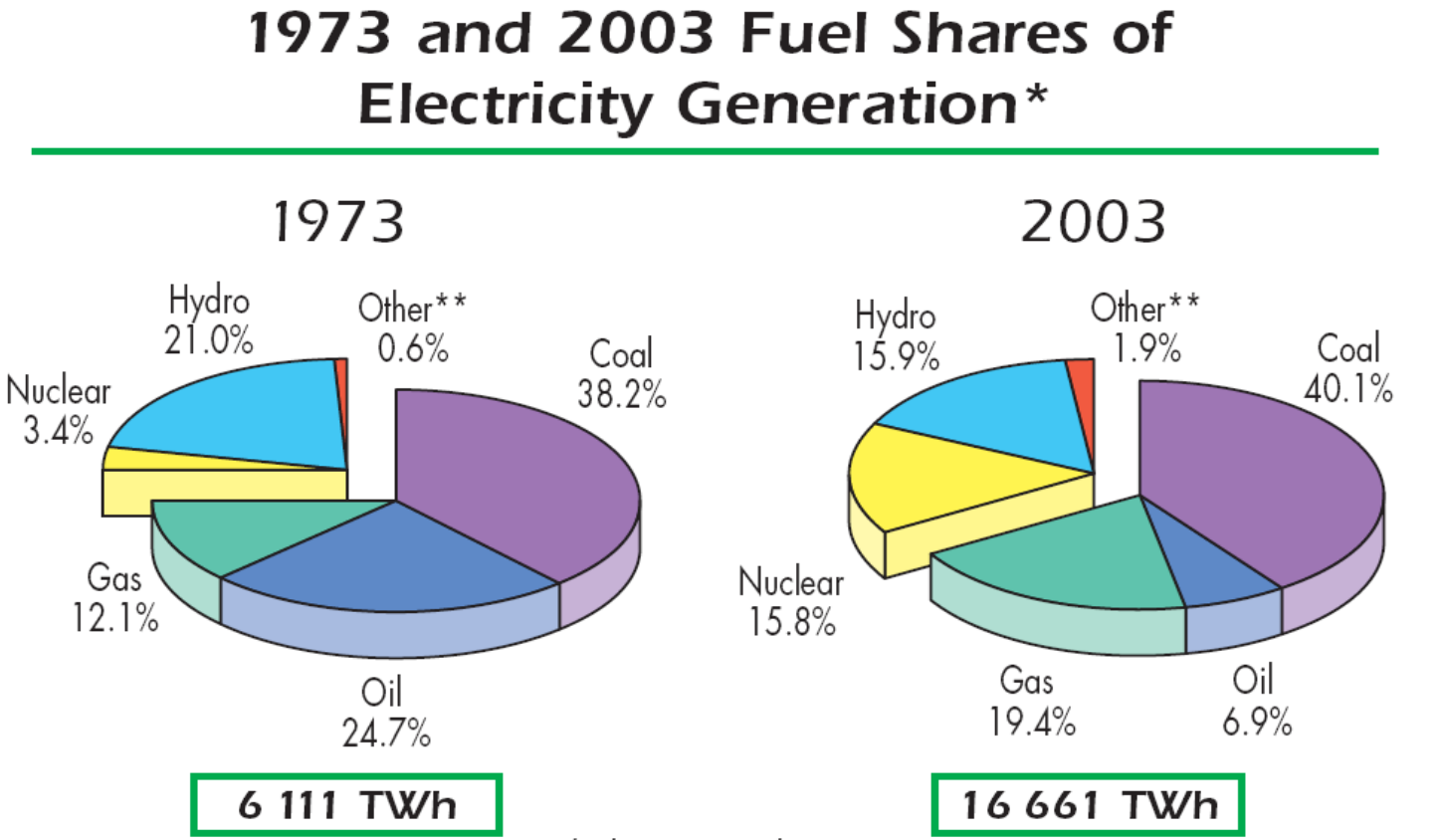
Outline of Talk

- (Houston, we have a problem:) Energy in 21st Century
- Solar Power Systems – ground & space
- Reference SPS
- SPS: Pros and Cons
- Required Protection for Other Spectrum Users

Thanks to Mike Davis and URSI Commissions

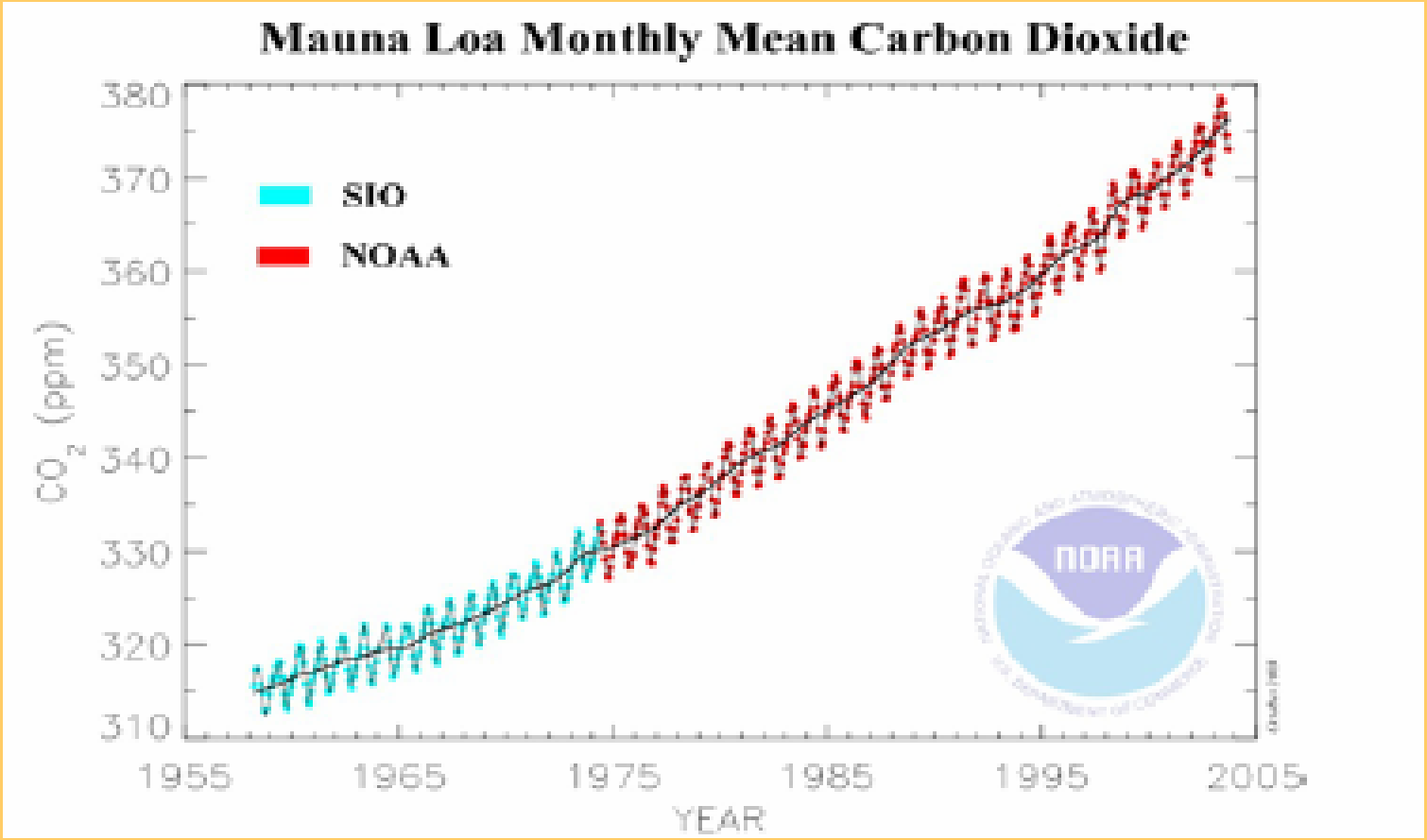
Average Electricity Generation

Increased from 0.7 to 1.9 TW over 30 Years,
Increasing 3.4% per Year -> **5.2 TW in 2033**

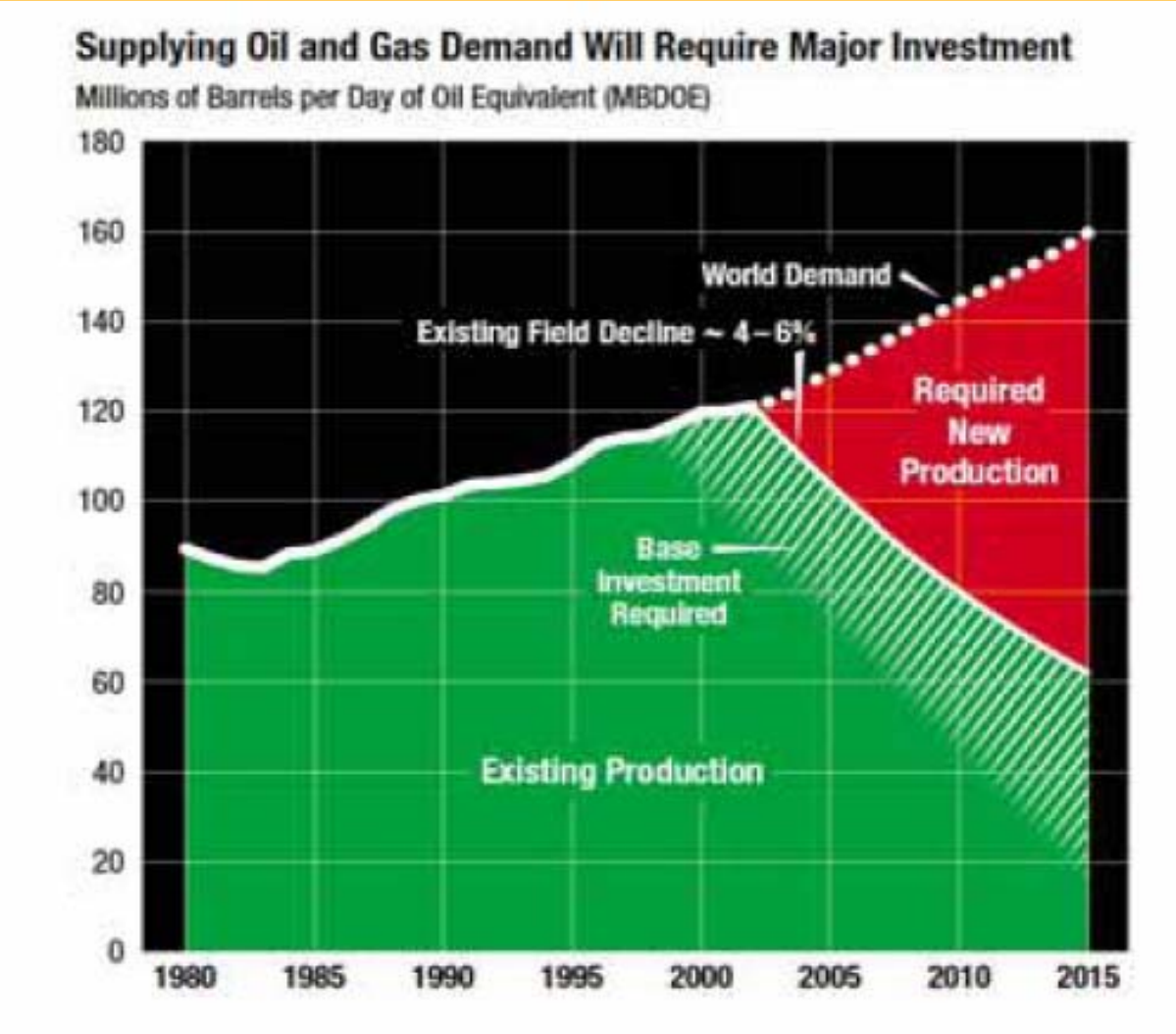


International Energy Agency, Key World Energy Statistics

CO_2 is Increasing too!



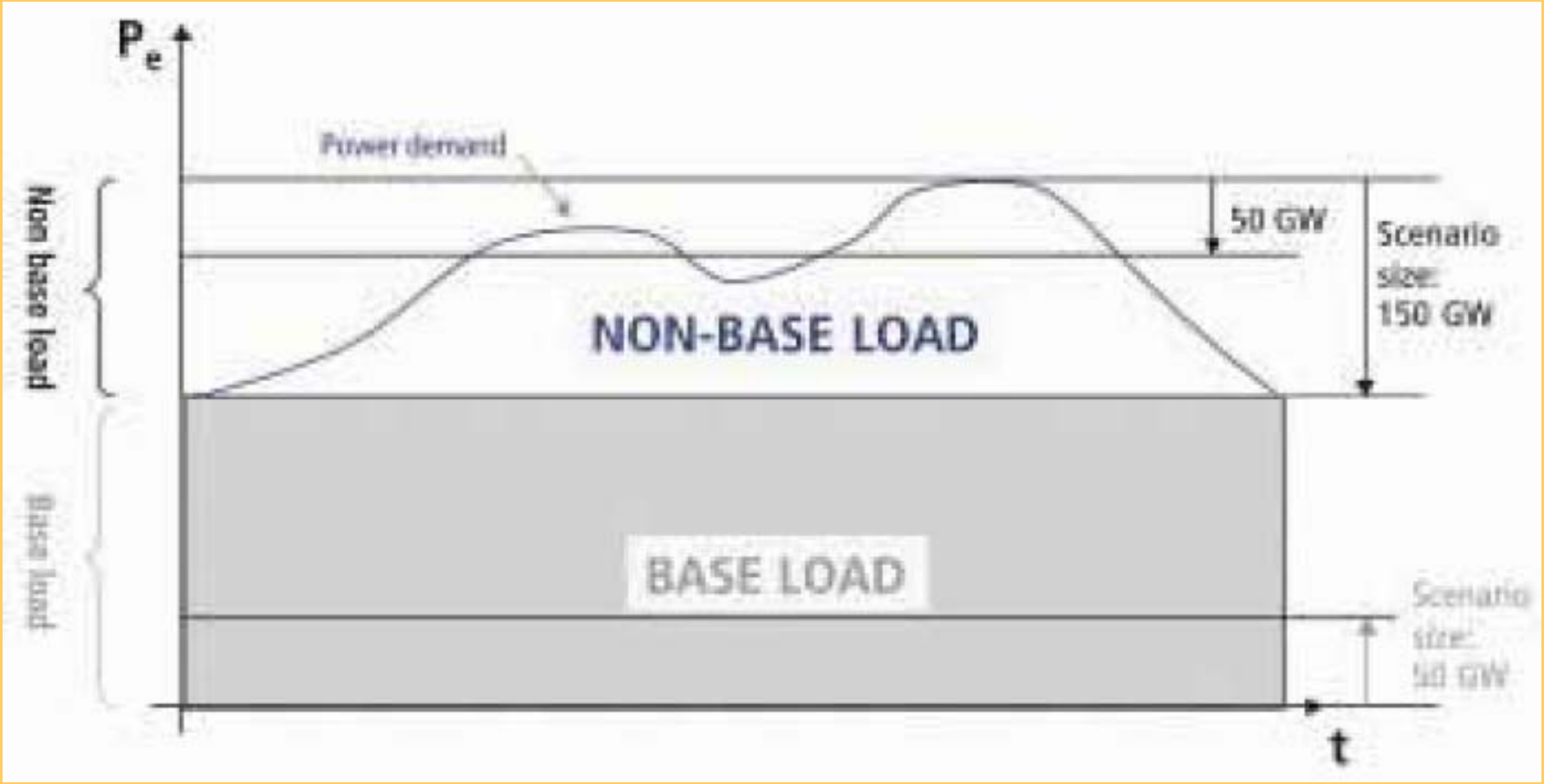
And Oil and Gas are Depleting!



Sustainable Energy Sources

- Solar -- Terrestrial and Space
- Geothermal
- Wind
- Hydro, Tidal Energy, Ocean Thermal
- Biomass
  - Absorbs as much CO_2 as it produces
- (Nuclear)

Peak and Base Loads



Solar Power

- **Ground-based**
  - Reasonably matched to peak oad
  - Requires *storage* to support base load
- **Solar Power Satellites**
  - Geosynchronous orbit (Glaser 1968)
  - Microwave power transfer to rectenna
  - Available 24/7 for base load
  - Requires advance in launch weight/$ and more!

History

SPS 1979 (DoE/NASA ref system): 40-60 satellites; Geosynch orbit; 2.45 GHz (CW)

1981 Thompson paper: OOB emission; noise on oscillator; thermal radiation; rectenna;

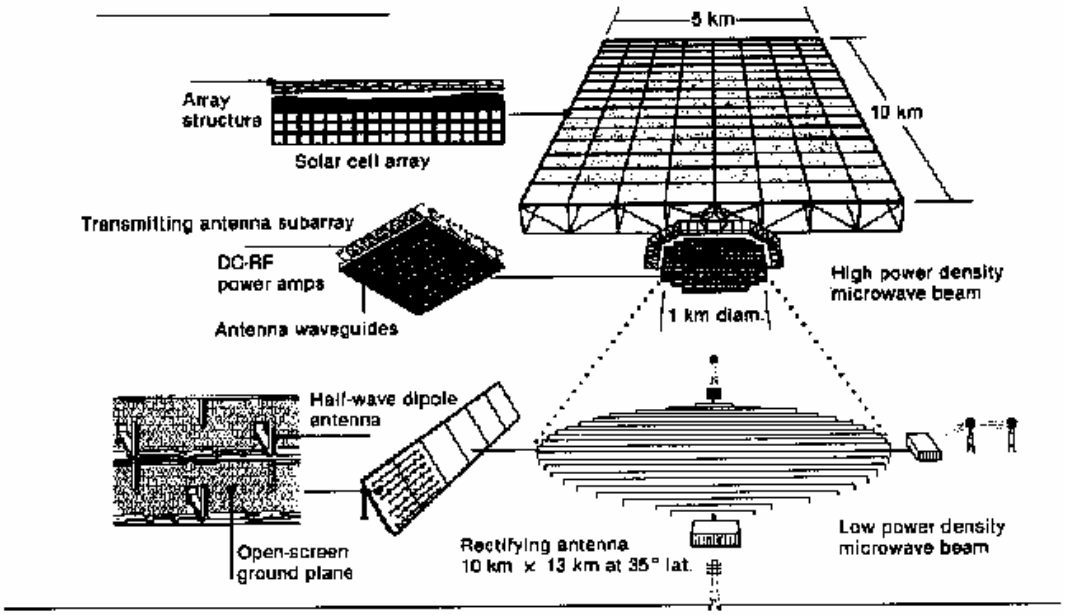
1981 NRC study – soso statement wrt RAS; none wrt EESS

SPS 2000 (Japan); others – new technology; 5.x GHz? LEO?

2002 NRC study
http://www.nap.edu/openbook/0309075971/html/

2005 URSI doc:
http://vsop.mtk.nao.ac.jp/URSI/documents/Whitepaper0509.pdf

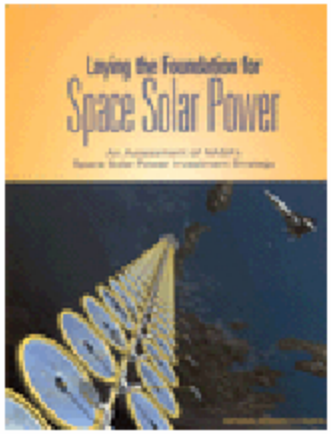
Solar Power Satellite Reference Design



SOURCE: C. C. Kraft, "The Solar Power Satellite Concept," NASA publication No. JSCp 14898, July 1979.

ELECTRIC POWER FROM ORBIT: A Critique of a Satellite Power System

A Report Prepared by the
Committee on Satellite Power Systems



Laying the Foundation for Space Solar Power: An Assessment of NASA's Space Solar Power Investment Strategy

Committee for the Assessment of NASA's Space Solar Power Investment Strategy, Aeronautics and Space Engineering Board, National Research Council

ISBN: 0-309-07597-1, 94 pages, 8 1/2 x 11, (2001)

2005 Oct 17

SPS 2000 LEO

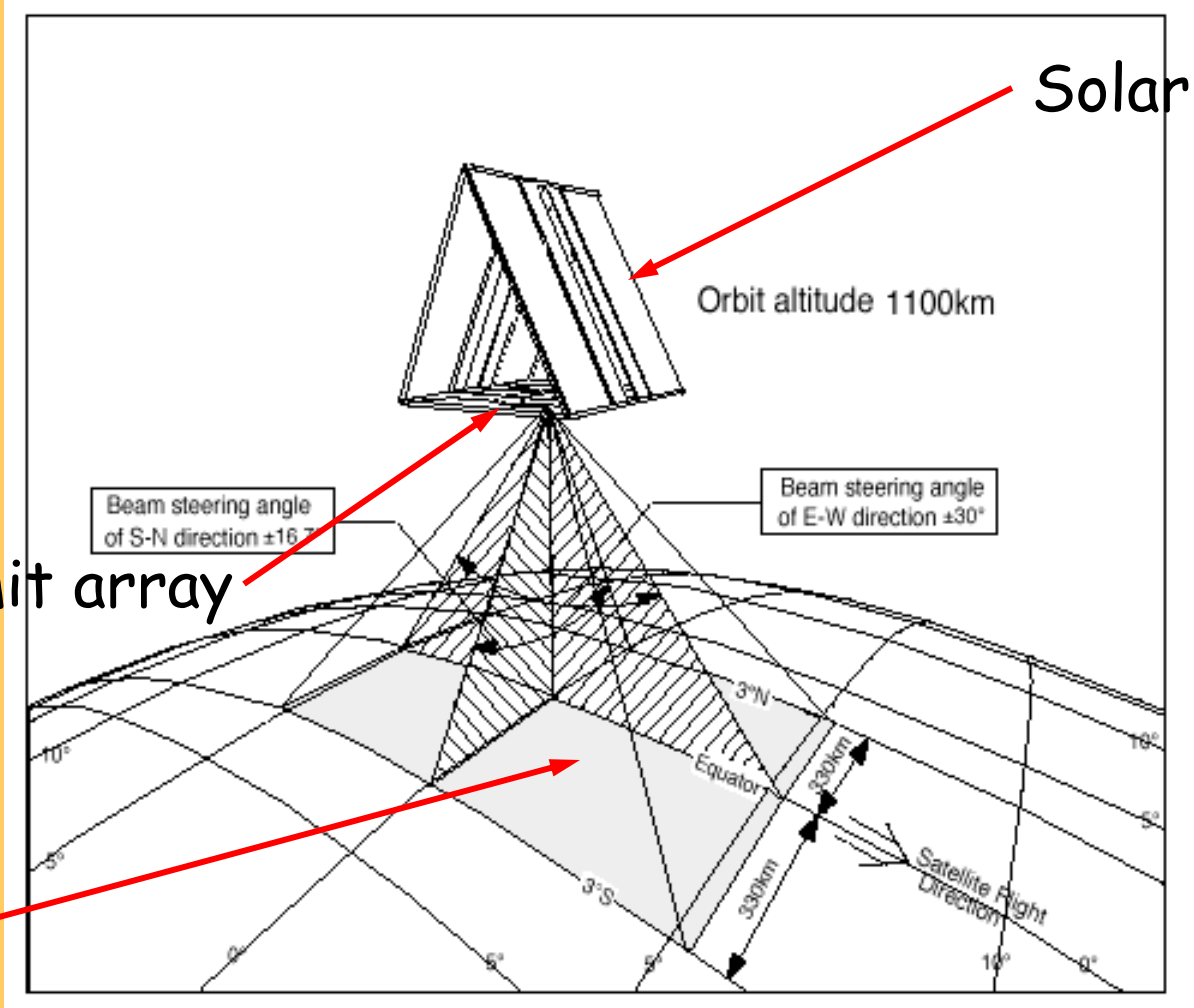


Fig. 2. Microwave beam scanning control.

Electrical Characteristics

Frequency	2.45GHz
Beam control	Retrodirective
Beam scanning angle	+30 degrees (east-west) +16.7 degrees (north-south)
Power distribution	constant
Power density	574W/m2
Max. power density on ground	0.9 mW/cm2
Input power to spacetenna	
Transmitting power	

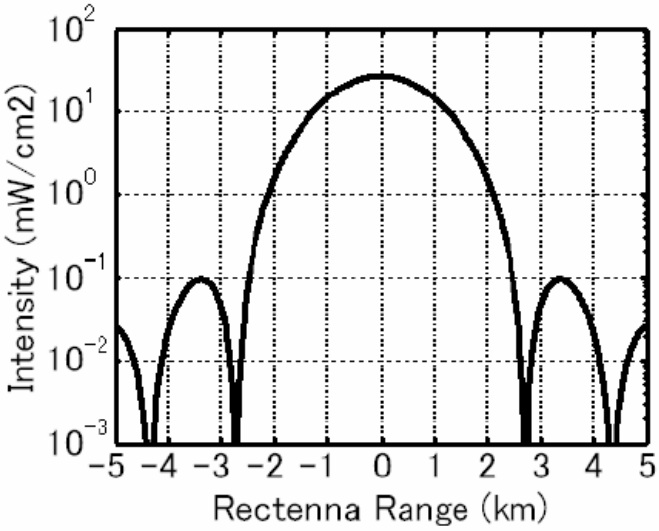


Fig. 3. Typical power density characteristics at a rectenna site (1kmϕ TX antenna with 10dB Gaussian power distribution)

Mechanical Characteristics

Shape and Dimension	132m x 132m square
Mass	134.4 ton
Number of Array module	88
Number of subarray	1936
Number of antenna elements	2,547,776 units
Number of pilot receiver	7,744 units

Solar Power Satellites

Would create an entirely new satellite construction and launch industry. A total capacity of 1 TeraWatt (TW), which is 20% of the projected 2030 global need, requires 1000 1 GigaWatt (GW) satellites, each with at least a square km of transmitter area and 10 square km of solar cells.

Solar Power Satellite Advantages

- Replaces coal and oil with unlimited solar energy.
- Provides continuous 24/7 energy supply, except during brief occultations in Spring and Fall.
- Produces only limited quantities of CO_2, during assembly and launch.

Solar Power Satellite Disadvantages

- Required protection for other uses of the spectrum is expensive and challenging.

- Requires a large reduction in launch and in-place maintenance costs to compete effectively with ground-based solar, wind, geothermal and other sustainable sources equipped with energy storage facilities. 1 TW would require one 1 GW satellite launch every two weeks for 40 years.

Solar Power Satellite Disadvantages (cont'd)

- Geosynchronous orbit is already in heavy use; could be endangered by space debris coming from such a large project.

- Solar cell lifetime is limited, with serious end of life issues: Maintaining 1 TW requires replacement/refurbishment of one satellite every two weeks forever, beginning after an assumed lifetime of 40 years.

Required Protection for Other Spectrum Users

- **ITU** Has Not Yet Allocated Spectrum for Space to Earth Power Transmission (Question 210/1).

- **RR 1.15** Industrial, scientific and medical (ISM) applications (of radio frequency energy): Operation of equipment or appliances designed to generate and use ***locally*** radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications.

Required Protection for Other Spectrum Users (cont'd)

The best reference remains:

A. R. Thompson, 1981, "Effects of a Satellite Power System on Ground-Based Radio and Radar Astronomy", *Radio Science*, vol. **16**, pp 35-45.

It describes both signal-related and thermal effects on sensitive radio observations, and references studies of effects on the night sky.

Fig. 1 Peak power from spacetenna vs radius on ground: main lobe, grating lobe (-35 dB at 440 km); random sidelobes down 60 dB at 500 km

Fig. 2: flux density vs Frequency 1-100 GHz showing thermal radiation from constellation at or above RR 769 level; harmonics of 2.45 GHz shown.

Thompson .. more

- Fig. 2: flux density vs Frequency 1-100 GHz showing thermal radiation from constellation at or above RR 769 level; harmonics of 2.45 GHz shown.