

N82 22745

by Francis L. Pugh
IBM Federal Systems Division
Westlake Village, CA

and A.I. Gordon
Space Operations & Satellite Systems Division, Rockwell International
Seal Beach, CA

A projection of the electrical energy demands over the next 30 to 50 years, coupled with reasonable assessments of known or developable energy sources, indicates that a shortage of electrical energy will occur about the turn of the century. Recognizing the criticality of such a shortage, the Department of Energy (DOE) is currently evaluating alternative power generation concepts. One of these candidate concepts is the Satellite Power System (Figure 1).

The power levels considered during the evaluation of the various satellite systems have ranged from 5 to 10 GW. It is apparent that, with this power level, both the satellite and the rectenna must be very large and encompass a large number of complex operational system activities.

Major elements of the Satellite Power System (SPS) consist of a power satellite placed in a geosynchronous equatorial orbit, and a dedicated ground receiving station (GRS) located at a selected site within the continental United States. The nominal power output of the SPS is established at 5 gigawatts (5 million kilowatts) although, because of various system constraints or losses, it may actually produce between 4 and 5 gigawatts.

The GRS and utility interfaces are designed to emulate existing power generation sources, such as present hydroelectric, thermal, or nuclear plants. The fact that the electrical power is first converted from solar sources in space is irrelevant in this approach. The rectenna receiving panels, which cover 30 to 40 square miles, are treated as if they are merely another type of power source.

The SPS has at least three distinct time phases of operations. These are (1) test and evaluation (T&E), (2) initial operational capability (IOC) including startup, and (3) final operational capability (FOC). As the SPS capability passes through these phases, there will be an evolutionary change from semi-automated control and validation to a more automated system.

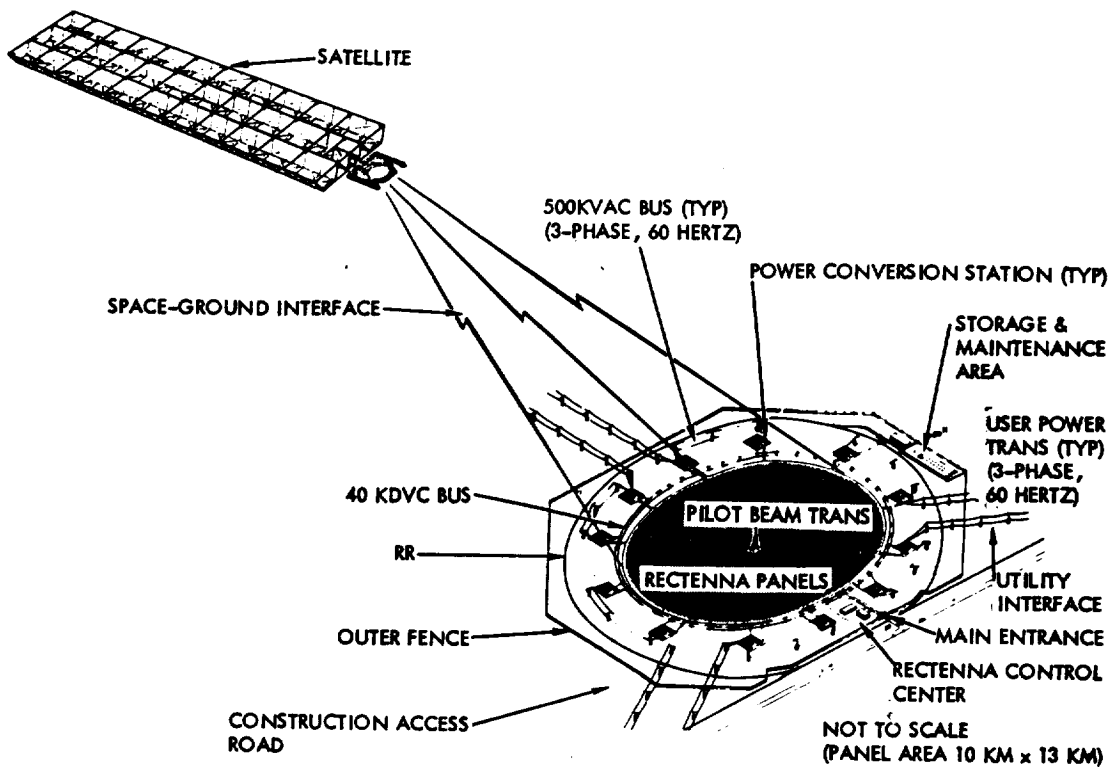


Figure 1. Satellite Power System

This functional analysis is constrained to startup and nominal operations because of the limited study time and because of the limited subsystem and system data available. The satellite functions identified and evaluated primarily address the major subsystems to generate and transfer the energy obtained during the primary satellite mission.

The startup phase will be used to illustrate the basic activities that may occur during any one of the three operational phases.

Startup control functions for satellite power production and transmission are sequenced automatically by the spaceborne and ground computers. An example of the antenna startup sequence and related control issues is shown in Figures 2 and 3. This analysis identified concerns regarding activation, stabilization, and control response times.

DISTRIBUTE POWER TO KLYSTRONS

- CLOSE ANTENNA RING BRUSH SWITCHGEARS
- POWER UP CENTRAL CONVERTERS
 - 5 OUTPUT VOLTAGES TO KLYSTRONS
 - 60+ KW POWER TO EACH
- CLOSE 5-POLE SWITCHGEARS TO PRIMARY/SECONDARY BUSES
- PLACE REDUNDANT SWITCHGEARS ON STANDBY
- SEQUENTIALLY CLOSE 5-POLE SWITCHGEARS TO:
 - MECHANICAL MODULES
 - POWER MODULES (INDIVIDUAL KLYSTRONS)
- STABILIZE POWER TRANSMISSION TO EARTH
- MAINTAIN BATTERIES 100% CHARGED
- ECLIPSES: OPEN MAIN POWER BUSES
 - SHUT DOWN POWER MODULES/ENERGIZE BATTERY BUS
 - MAINTAIN KLYSTRON TEMPERATURES
 - UPDATE ORBIT PREDICTIONS AND SCHEDULES
 - MAINTAIN RETRO-ELECTRONICS ON STANDBY

Figure 2. Satellite Operations – Startup (Antenna)

ACTIVATION & STABILIZATION TIMES

• REPETITIVE STATIONKEEPING & BORESIGHT OPERATIONS

- STATUS & CONTROL SEQUENCING THROUGH 100,000+ POINTS
- THERMAL STABILIZATION OF KLYSTRONS
- INITIATION & STABILIZATION OF FINE POINTING

STARTUP TIME SEQUENCES COULD BECOME VERY LONG

POSSIBLE IMPACT TO SPS CONTROL RESPONSE REQUIREMENTS

- STARTUP/SHUTDOWN DUE TO ECLIPSES
- EMERGENCY RESPONSES AND RECOVERY
- RESPONSE TO UTILITY POWER LOADINGS

Figure 3. Startup Control Issues

ORIGINAL PAGE IS
OF POOR QUALITY.

The ground control center does not play a direct role unless the onboard control system fails. In this event, direct ground control would be limited to performing emergency shutdown using separate and redundant control links in critical systems' areas.

The rectenna control center (Figure 4) would monitor startup sequencing to provide any necessary ground support to the satellite. This includes antenna boresighting, pilot beam control and initiation of power reception, conversion, and distribution to the utility customer interfaces. Special coordination functions may be needed from the ground center to avoid power surges and to provide load leveling. Emergency shutdown of satellite operations also may be required if a major ground system failure occurs.

During the operational phase the satellite and GRS have reached stabilized power conversion and transmission to the utility network. The rectenna control center will receive periodic updates of scheduled power requirements from the utility area control center (Figure 5). These load schedules are translated by the ground center into satellite power output schedules which take into account RF transmission, rectenna conversion, dc-to-dc/ac conversion efficiencies, and related factors. This scheduling facilitates matching of generated power to load levels.

If for some reason the entire utility network or a dedicated customer drops off the line, the SPS power output may be shut down, adjusted, or switched to other loads. The ground center must accommodate these and other contingencies such as problems in rectenna dc-to-dc/ac conversion and distribution. Emergency shutdowns or load adjustments require authenticated commands, rather than enabling messages, to be transmitted to the satellite.

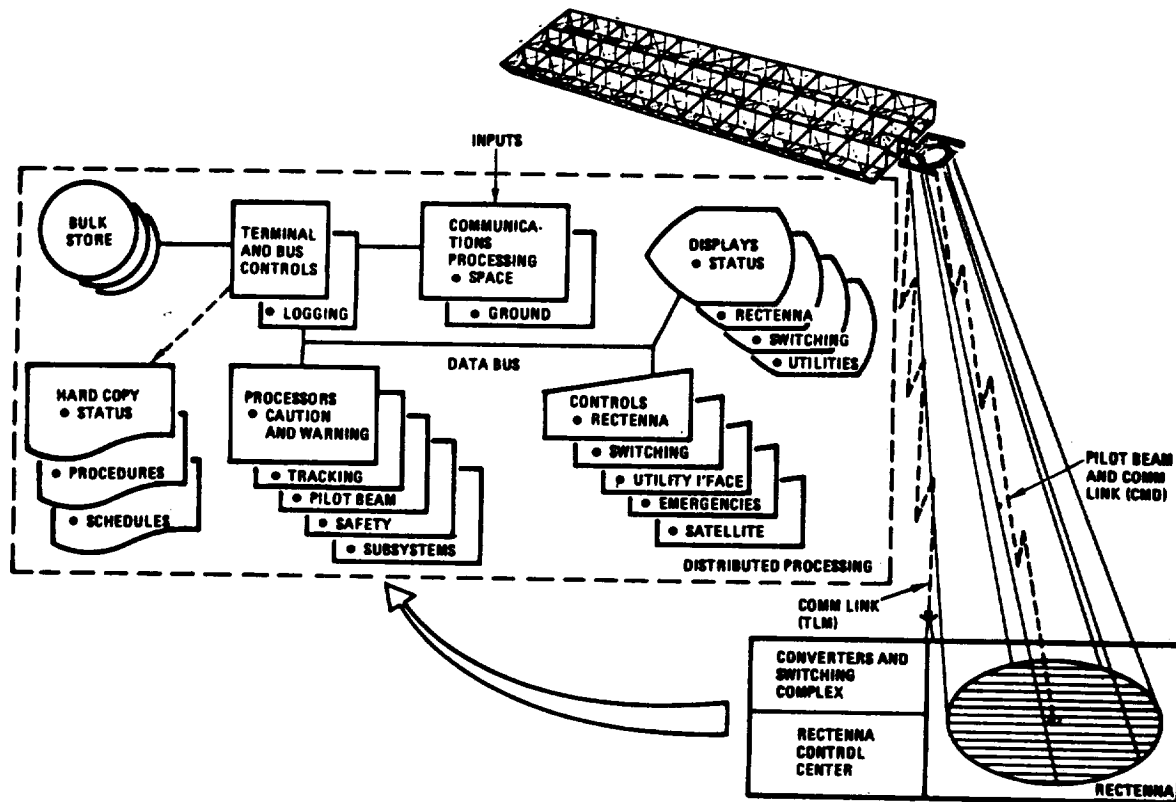


Figure 4. Rectenna Control Center Concept

ORIGINAL PAGE IS
OF POOR QUALITY

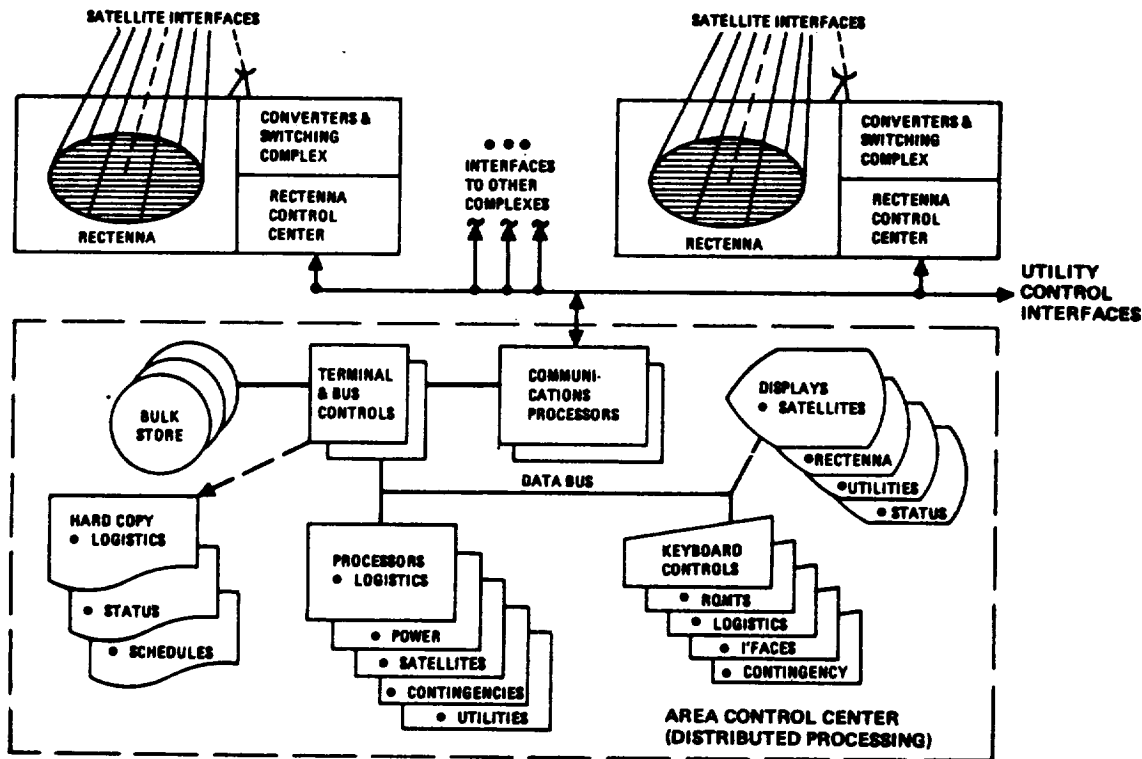


Figure 5. Area Control Center Concept

It is uncertain whether an area center is required to coordinate several rectenna sites. It may be that coordination is needed only by each rectenna with its respective utility network center. Separate rectenna and area centers might be eliminated if they could be integrated into a single location. Design trade studies are needed to investigate these possibilities.

A number of communications implications have been drawn. Continuous contact must be maintained between the satellite and ground control center. This includes bi-directional voice, data, video, and command links. In addition, the uplink pilot beams from the rectenna are crucial to acquisition and fine pointing. The high EMI environment in the near vicinity of the satellite imposes difficult conditions for communications.

From the analysis it has been concluded that there are no operational "show stoppers." The basic need is to identify in greater detail the operating characteristics and timelines of various satellite and ground system equipment with emphasis on activation and stabilization times, intervals, and sequences.