BLANKET TECHNOLOGY WORKSHOP REPORT

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The solar array blanket, defined as a substrate covered with interconnected and glassed solar cells, but excluding the necessary support structure, deployment, and orientation devices, cannot be considered as a completely independent element of technology. Particularly in larger array designs, the interactions between the blanket and the structure that is used to package, deploy, support and, if necessary restow it, can be significant design drivers. Systems constraints such as spacecraft configuration, size and payload requirements also may influence blanket design. Thus it is extremely difficult to assign a blanket specific power goal without some knowledge of the mission class that will utilize it.

The three main mission classes considered were low Earth orbital (LEO), intermediate, or LEO to GEO transfer, and geosynchronous (GEO). Although interplanetary missions could be considered to be a separate class, their requirements, primarily power per unit mass, are generally close enough to geosynchronous missions to allow this mission class to be included within the third type. Examination of the critical elements of each class coupled with considerations of the shuttle capabilities was used to define the type of blanket technology most likely required to support missions that will be flown starting in 1990.

There are three user groups currently operating in the space environment; NASA, the military, and the communications satellite industry. NASA has interests in all three mission classes, as does the military to some degree, while the third group is primarily interested in geosynchronous orbits. All three user groups indicate the need for increasing array power levels, rising from the present 1-3 kW to upwards of 25 kW.

LOW EARTH ORBITAL REQUIREMENTS

Technology capable of satisfying the immediate forecasted needs for the Earth orbital applications does exist in the form of the SEP type array. Thus the question of standardizing this technology was considered. It was the general consensus that the requirements placed on the array by mission planners and spacecraft system designers will mandate continual modifications, minor and major, which will tend to prevent any high degree of array standardization.

The larger power systems, planned for the future, must of necessity be less expensive than smaller arrays which can cost in excess of 1000 dollars per watt EOL. Concern over the growing cost of photovoltaic arrays was expressed. Although the array typically makes up a very small fraction ($\leq$5 percent) of the total mission cost, the steady increase in cost may make photovoltaics less attractive for future missions and thus make it easier for alternative power sources to compete. The SEP array cost does not appear to be a major concern at this time, but cost of power will become very important as array requirements exceed 100 kW. Since LEO power costs are determined by life cycle considerations, it is very important that the operating lifetime of LEO arrays be maximized. Technology to guarantee a minimum lifetime of 5 years is critical, while 10 year operation is highly desirable.

A key conern in this area is the question of orbital "drag," which becomes more important as the size of the array increases. To reduce this problem, higher efficiency cells which will reduce array size for a given power level, will be necessary, as will be in-orbit partial or full restowage capability.

The shuttle launch capability for LEO applications does not place significant mass constraints on arrays. However, the shuttle launch cost is determined by the amount of shuttle bay volume taken up by the mission. Thus more attention must be paid to properly packaging arrays and blankets rather than to reducing their mass.

INTERMEDIATE OR TRANSFER ORBIT REQUIREMENTS

Intermediate orbits (>500 km) which are used predominantly by military satellites place a critical requirement on radiation resistance. Equivalent 1 MeV fluences exceeding $1x10^{16}$ e/cm^2 would be experienced by the blanket. Radiation resistance is also required in order to consider using low thrust propulsion systems to boost payloads from LEO to GEO. Efforts to significantly reduced the amount of degradation presently observed in silicon solar cells is encouraged. The superior radiation resistance predicted for gallium arsenide argues for its consideration for these orbits. The alternative approach is to develop blankets capable of surviving the temperatures necessary to anneal the electrical degradation caused by the radiation environment.

GEOSYNCHRONOUS ORBIT REQUIREMENTS

There was a unanimous agreement that geosynchronous orbit requirements are the main driver for blanket technology. Shuttle costs and the IUS launch capability place a premium on lowering the array mass. There will always be pressure to reduce array mass in order to increase the satellite's "traffic" (communication channels, etc.) potential. The IUS is designed to launch ~2300 kg into GEO. Except for a few unique situations, the mass allowance for the solar array will be constrained to ~150 kg.

Power levels of 25 kW and up will be required for space platforms and space based radar. This leads to the conclusion that arrays possessing a beginning-of-life specific power of ~200 W/kg could be required. Translating the array specific power to a blanket specific power cannot be easily done since structural and systems requirements must be considered. Generally, the fraction of the array mass resulting from the structure becomes smaller as the array size increases. Thus, the overall specific power of the array would likely be greater for a large array (>10 kW) than a smaller array (~1 kW) even though the same specific power blanket was used for both.

A set of technology requirements necessary to support a 1990 launch was established. From previous experience, it was determined that these goals would have to be accomplished by 1985. It was determined that a 300 W/kg blanket (BOL) including bus mass, could be achieved by 1985 without the need for a major "breakthrough" in blanket technology. This will require that by

1985 silicon solar cells 50-60 μm thick with an AMO efficiency of 14 percent are in production. New and innovative processes for assembling and laying down very thin cells must have been reduced to practice. The present method of covering solar cells will have to be replaced. Possible alternatives suggested were thin (25-50 μm) integral covers or organic encapsulants. The approach to interconnecting must be modified to accomodate welding of extremely thin interconnects. To reduce the mass of the bus system it will be necessary to operate blankets near 200 volts. This led to a discussion concerning array space charging effects and plasma interactions. It was agreed that this was a potential major problem, and further, that very little is actually understood in this area. It was strongly recommended that space experiments aimed at providing information on the effects of plasma leakage on blanket performance be instituted once the shuttle is operational. In addition, as advanced blankets are developed, they should be flight tested as quickly as possible, preferably on an annual basis.

1990 REQUIREMENTS

It was conceded that blanket specific power must probably reach 400 W/kg EOL (1×10^{16} e/cm^2) to assure that arrays can satisfy the requirements for advanced geosynchronous missions. The members felt that revolutionary rather than evolutionary developments would be necessary. For example, the solar cells employed in this advanced blanket would have to be 15 to 16 percent efficient (EOL) at operating temperature. The cell's mass would have to be equivalent to no more than 50 μm of silicon. Obviously, advanced encapsulants or covers would be required. Although low mass blankets imply minimum back surface radiation shielding, the trade-offs seem to indicate that reduced shielding does result in improved EOL specific power in the cases studied to date. Further reductions in harness mass will be required, thus making even higher array operating voltages, in the order of 1000 V, necessary. Although not discussed in any great detail, concepts such as concentration and more efficient optical coupling, which would reduce the blanket operating temperature, were deemed appropriate areas for development. It was not possible to accurately forecast when advanced blankets ($\geq$400 W/kg EOL) would be available, but it was agreed that work aimed at developing this technology should begin immediately.