LASER POWER TRANSMISSION FOR SPACE POWER AND PROPULSION

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SUMMARY

A review is being made of the state of development of major components and subsystems required for ground-to-space, space-to-space, or space-to-ground laser power transmission for electric or thermal power or propulsion. System characteristics are being evaluated from an applications viewpoint, and major problem areas are being identified. The objective is to identify a rewarding first application of lasers for space power and propulsion. An evolution of laser power transmission capabilities over the next 20 years is projected. Supporting technology requirements are to be identified, priorities set, and continued developments coordinated with other government agencies. This paper is an early status report of this work.

INTRODUCTION

A myriad of proposals have been made on the use of lasers in future space systems. Each shows the characteristics and advantages of such systems. It has been difficult to make an economic case for space-to-space power transmission for electric or thermal power generation as compared with conventional power systems on each satellite. Results appear more promising for laser propulsion. The possibility has been suggested that laser power transmission for propulsion may justify the laser system major components, which in turn could allow the laser energy electric or thermal power conversion system to be more competitive. It is expected that DOD work in this area will reduce the non-recurring and recurring costs of NASA-proposed systems, but the degree cannot be quantified until a better definition of the NASA program is available.

PRIOR WORK

Prior work at NASA Centers, in industry, and at universities has addressed both major components and potential system application. NASA centers involved in lasers for power transmission have principally been Lewis, Ames, JPL, and Langley. The Lewis work is phasing out, and MSFC is picking up parts of this work. Industry participation has included LMSC, AVCO, BDM, Math Sciences Northwest, Westinghouse, Ball Brothers, and others. Universities involved are Washington, California, Pennsylvania, Pacific, Ohio State, Stanford, MIT, and others.

APPLICATIONS

Systems work at Lewis and their contracts with LMSC and others have addressed laser power transmission both for use in generating electricity on multiple receiving satellites and for use in an orbit-raising propulsion system at the receiving end. This work used a space-located laser and relay system. AVCO has proposed a GW ground-based laser for booster operation and for ground-to-GEO transfer. The University of Washington has proposed space-based lasers and adaptive optic relays for aircraft propulsion. Ball Brothers, BDM, Schaffer Associates and others have proposed a GEO-to-ground transmission by laser power instead of by microwave as presently being used in the satellite power system studies.

MAJOR TROUBLE SPOTS FROM APPLICATIONS VIEWPOINT

- Laser
  - Low ($\leq$100 K) heat rejection temperature
  - Complex and high-power laser supporting subsystems
  - Low-efficiency use of solar energy (for space located)
  - Hazards of a pointing error
- Laser energy collection and conversion
  - Large and heavy heat rejection radiators for heat engines
  - Conventional photovoltaics response not matched by current high-power laser output spectrum
  - High-energy density required for thermal electronic laser energy conversion (TELEC)
- Laser propulsion
  - Acquisition and tracking over wide range of laser-propulsion unit altitudes and ranges
- Laser transmission for electric or thermal energy use at receiving satellite
  - Economics dictate multiple use of source laser
  - Noncontinuous transmission requires high-charge-rate storage system on receiving satellite
  - Unless laser power source benefits in scaling to its large power capacity, in location, or other factors, its power source will be $\sim$5 times or more larger than the total of conventional dedicated satellite power systems.

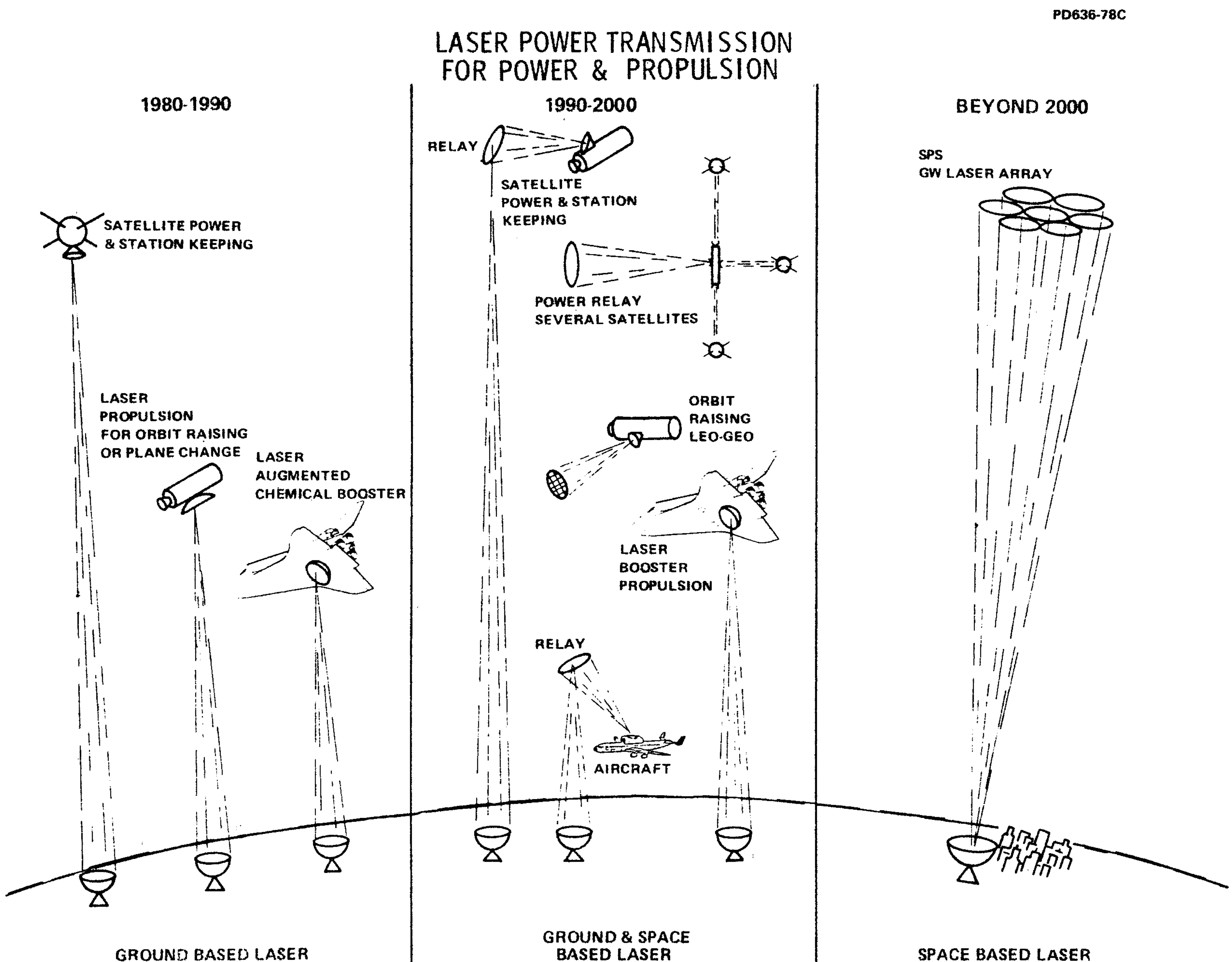
PROPOSED DEVELOPMENT SCENARIO

Figure 1 illustrates a development and implementation program for the next 20 years. Ground-based lasers are proposed for the first applications. The reasons are that a minimum of space-based laser problems would have to be solved. Emphasis would be concentrated on the receiving and conversion equipment. It is anticipated that large amounts of DOD-sponsored technology would be exploited. Many of the adaptive optics problems encountered to make atmospheric transmission without too much beam divergence would be common to later requirements of the space-based relay system. Early ground deployment would not have to address the hazards of a loss of pointing as far as ground damage is concerned. Safety of operations could be demonstrated.

Between 1990-2000, space-based laser relays could be deployed to redirect the ground-based laser beam to the desired point of application. Later in the decade, low- and medium-power space-based laser systems would be deployed. The lightweight optics systems would be qualified in the previously deployed laser relays, and the laser power system and heat rejection systems would receive the required emphasis. If a large deviation from DOD-type lasers was required, the change and economics could more credibly be justified from previous applications experience with ground-based systems.

Post-2000 deployment of space-based GW laser systems is projected. Earlier deployment of GW laser booster systems is projected. NASA planned future activities are

- Electron storage ring laser
- Solar pumped laser
- Laser-to-electric energy conversion
- Laser-augmented chemical propulsion
- Laser propulsion
- Visible lasers
- System studies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LASER POWER TRANSMISSION
FOR POWER & PROPULSION
1980-1990
1990-2000
BEYOND 2000
SATELLITE POWER
& STATION KEEPING
LASER
PROPULSION
FOR ORBIT RAISING
OR PLANE CHANGE
LASER
AUGMENTED
CHEMICAL BOOSTER
RELAY
SATELLITE
POWER & STATION
KEEPING
POWER RELAY
SEVERAL SATELLITES
ORBIT
RAISING
LEO-GEO
LASER
BOOSTER
PROPULSION
RELAY
AIRCRAFT
SPS
GW LASER ARRAY
GROUND BASED LASER
GROUND & SPACE
BASED LASER
SPACE BASED LASER

Figure 1.