ELECTRIC PROPULSION AND POWER

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Electric propulsion programs are in progress in Europe, Japan, the USA, and the USSR. About a half dozen space tests of electric propulsion have been performed by the USA and the USSR has published results of over a dozen space experiments. In the near future many space tests of electric propulsion are firmly planned by Japan (pulsed plasma, MPD, ion thruster); West Germany (ion thruster); and the USA (pulsed plasma, ion thruster).

Due to time constraints it is impossible to present aspects of all ongoing electric propulsion programs and for brevity only the NASA electric propulsion program will be discussed herein.

ELECTRIC PROPULSION PROGRAM

OBJECTIVE

- IDENTIFY, PROVIDE, AND TRANSFER THE TECHNOLOGY FOR ELECTRIC PROPULSION SYSTEMS FOR ON-ORBIT AND TRANSPORTATION PROPULSION FOR EARTH-ORBITAL AND PLANETARY MISSIONS

Electric propulsion converts electrical energy into directed momentum or fields which can be used for propulsion functions.

Electric propulsion offers the benefits of operation at values of specific impulse an order of magnitude or more greater than theoretically possible with chemical propulsion. This feature grossly reduces the propellant requirements for transportation and on-orbit propulsion functions which can result in enabled mission capability or significant reductions in mission costs. To date, emphasis has been on space propulsion devices. Recently, however, some efforts have been directed at electric propulsion concepts to augment Earth-to-orbit propulsion.

ELECTRIC PROPULSION SYSTEMS

FUNCTION

TRANSFORM ELECTRICAL ENERGY

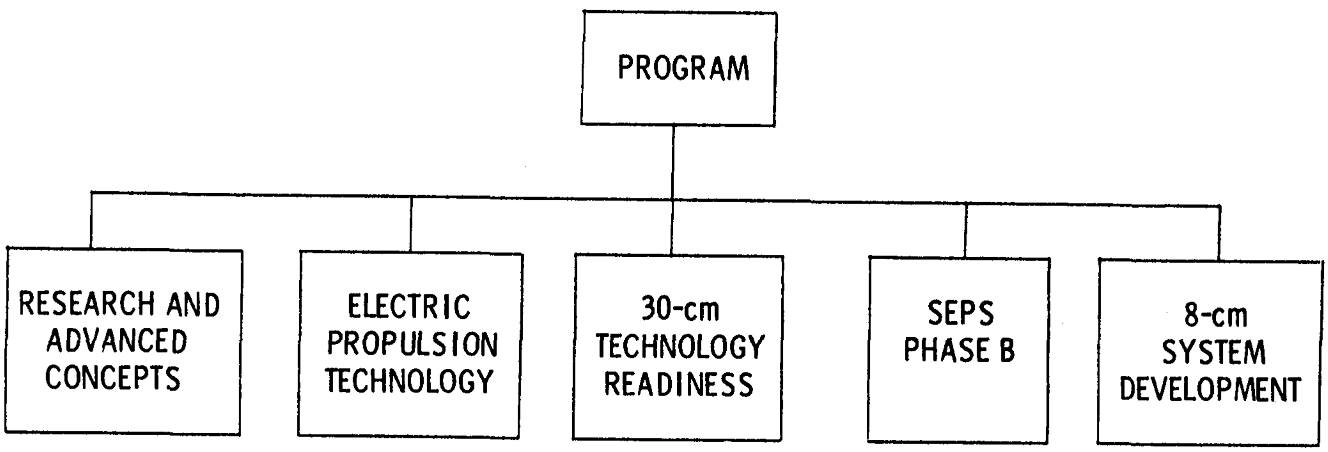
INTO DIRECTED MOMENTUM OR FORCE

FOR ON-ORBIT OR TRANSPORTATION PROPULSION FUNCTIONS

The NASA electric propulsion program encompasses R&D efforts on several concepts and range from basic research to final development and flight test.

The research and advanced concept efforts are presented in a subsequent discussion. A brief summary of the status of the various elements of the NASA electric propulsion program will be given on the following charts.

ELECTRIC PROPULSION PROGRAM



ELECTRIC PROPULSION PROGRAM

- ENCOMPASSES:
  - R&D EFFORTS ON SEVERAL CONCEPTS
  - EFFORTS FROM BASIC RESEARCH TO FLIGHT TESTS
- ION THRUSTER SYSTEMS ARE THE MOST MATURE EP CONCEPT IN THE USA

Two 8cm mercury ion thrusters will be flown on the Air Force P80-1 satellite which will be launched from the Shuttle into a 740Km altitude polar orbit. One thruster will be placed on the zenith side and the other on a surface which is alternately the ram or wake side. The zenith thruster will demonstrate the propulsion functions required for seven years north-south stationkeeping of a 1000 Kg geosynchronous satellite. The thrusters will be operated simultaneously and in various modes to duplicate conditions expected on an operational system. Diagnostics are arranged about each thruster to refine ground based data on the particle effluents from the 8cm thrusters.

Successful culmination of this space test should provide adequate confidence in the hardware to allow for user application of the 8cm ion thruster system.

ION THRUSTER SYSTEMS

8-cm MERCURY

PROPULSION FUNCTION	CHARACTERISTICS	STATUS
• ON-ORBIT FOR EARTH ORBITAL MISSIONS	• ONE MLB • 175 W • 2800 SEC.	• IN FINAL DEVELOPMENT FOR SPACE TEST ON AF P80-1 SATELLITE • FLIGHT HARDWARE IN FAB. PHASE

NASA has been engaged for several years in a program to provide technology readiness of the 30cm mercury thruster system by the end in 1980. The 30cm thruster system was developed primarily for planetary transportation. In the technology readiness effort the thruster has been developed and its lifetime verified by a series of long term tests. The field and particle interfaces of the thruster are also being defined. Other critical technology, such as power conditioning circuits and elements, are also under development and their basic design will be verified in tests with thrusters.

Recently two Phase B system studies were initiated in industry to define Solar Electric Propulsion Systems (SEPS) capable of a number of missions. It is anticipated that these studies will result in overall SEPS approaches and provide sufficient definition to allow initiation of a final development program for SEPS.

ION THRUSTER SYSTEMS

BASELINE 30-cm MERCURY

PROPULSION FUNCTION	CHARACTERISTICS	STATUS
• TRANSPORTATION FOR PLANETARY MISSIONS	• 8-30 MLB • 0.75-3 kW • 2200-3000 sec.	• CRITICAL SYSTEM TECHNOLOGY READINESS TO BE ACHIEVED IN 1980 • PHASE B SYSTEM STUDIES UNDERWAY (MANAGED BY MSFC)

Advanced mercury thruster systems are under development for transportation and on-orbit propulsion for Earth orbital missions and transportation for planetary Nuclear Electric Propulsion Systems. For these applications, increase in thrust and thrust to power ratio provide strong performance and cost benefits. In addition, due to the nearly constant power, strong simplifications can be made in power processing. Tests are underway which indicate long lifetimes are available at increased thrusts and that significant reductions (~3X) in thrust system specific mass, and power to thrust (~2X) ratio are possible with advanced mercury ion thruster systems.

ION THRUSTER SYSTEMS

ADVANCED MERCURY

PROPULSION FUNCTION	CHARACTERISTICS	STATUS
• TRANSPORTATION FOR PLANETARY AND EARTH ORBITAL MISSIONS	• INCREASED THRUST & THRUST/POWER • SIMPLIFIED PPU REQS.	• THRUSTS TO ~ 0.1 LB DEMONSTRATED • SPECIFIC IMPULSES DOWN TO ~ 1500 sec. DEMONSTRATED • 500 HOUR LIFE TEST PERFORMED AT ~ 50 MLB • REDUCED POWER PROCESSOR REQS. DEMONSTRATED
• ON-ORBIT PROPULSION	• INCREASED THRUST & THRUST/POWER • SIMPLIFIED PPU & COMMAND/CONTROL REQS.	• THRUSTS TO 4 MLB DEMONSTRATED

Inert gas thruster systems are of interest for Earth orbital missions for several reasons:

1) The fact that the inert gases do not condense offers some strong performance benefits. These include the ability to start up the thruster system in a few seconds and the possibility of eliminating many power supplies;
2) The integration of thruster systems will become an increasingly important issue as the Earth orbital space systems increase in size and complexity. Inert gases are more benign than any other candidate propellants which should ease the integration of propulsion systems with the space systems;
3) Inert gases, due to their light atomic masses, inherently operate at higher values of specific impulse than mercury. Future Earth orbital missions are likely to include heavier space systems, last longer, and include more on-board power than present systems. All of these traits strongly drive propulsion systems in the direction of increased specific impulse;
4) For Earth orbital mission models which include many large space systems, the availability and potential environmental impact of mercury will probably preclude its use as a transportation, or perhaps on-orbit, propellant.

ION THRUSTER SYSTEMS

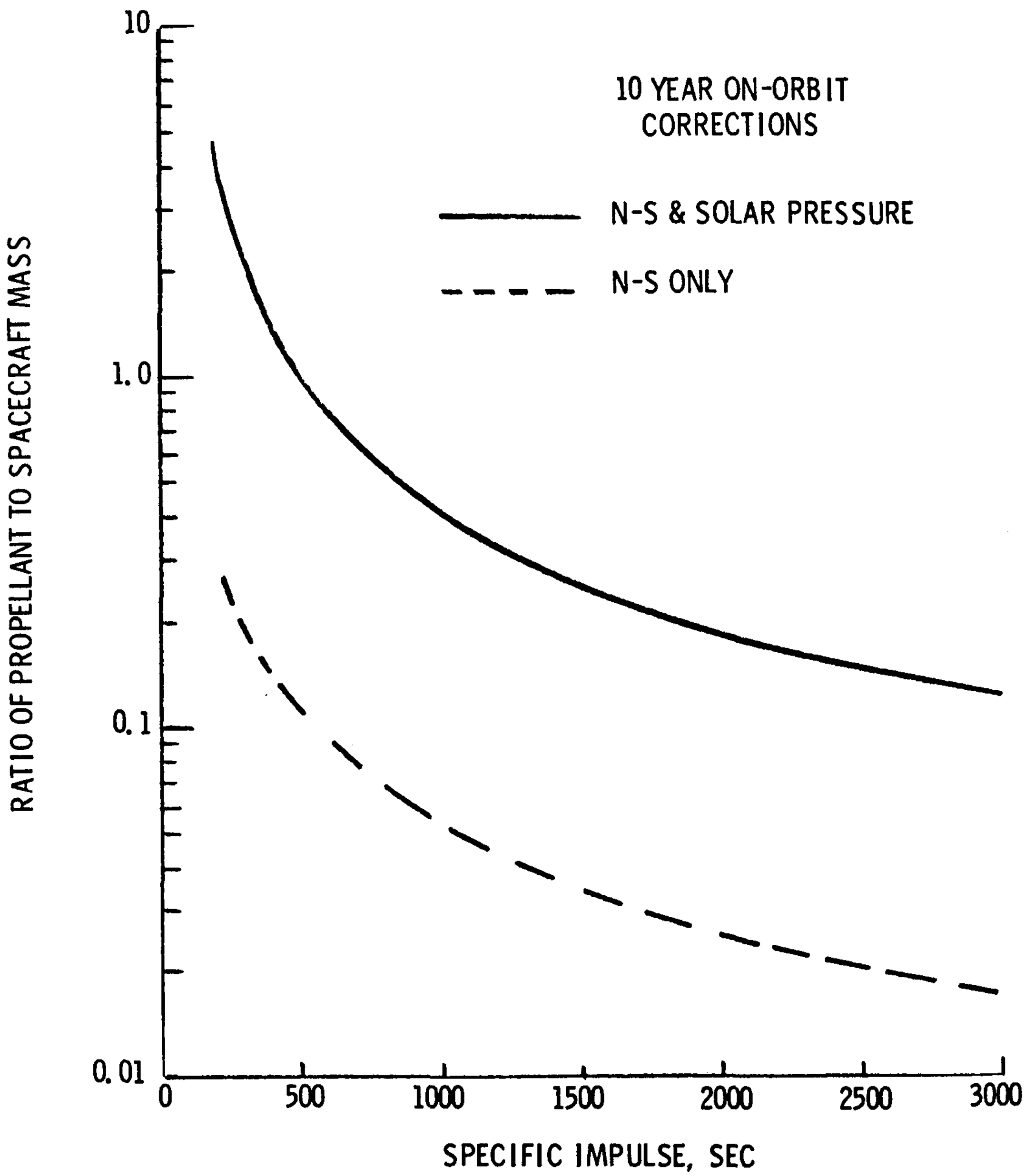
INERT GAS

PROPULSION FUNCTION	CHARACTERISTICS	STATUS
• TRANSPORTATION AND ON ORBIT FOR EARTH-ORBITAL MISSIONS	TBD	• RESEARCH PROGRAM IN PROGRESS FOR 4 YRS • PROGRAM ENTERING PRELIMINARY DEVELOPMENT PHASE

APPLICATIONS

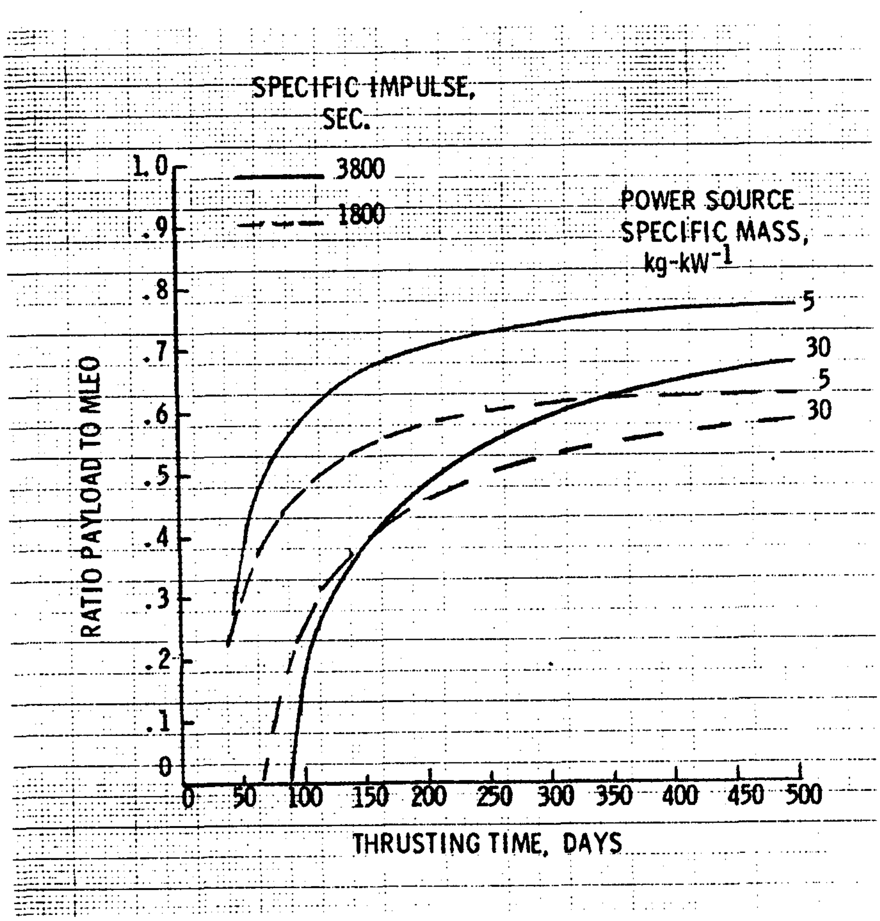
- PROPULSION REQUIREMENTS FOR LSS MAY DIVERGE SHARPLY FROM PRIOR EXPERIENCE
  - GREATLY INCREASED ON-ORBIT & TRANSPORTATION PROPULSION ENERGIES
  - NEW ON-ORBIT & TRANSPORTATION PROPULSION REQUIREMENTS
  - NEW MISSION STRATEGIES

This figure shows the ratio of propellant, required for geosynchronous on-orbit propulsion, to spacecraft mass as a function of specific impulse. The dotted curve is appropriate for dense spacecraft typical of those in use today. The effect of solar pressure increases directly with the ratio of system surface area to mass and that ratio is expected to be very much higher for future LSS than for present systems. The solid curve shows the propellant to mass ratio for a geosynchronous satellite with the characteristics of the Space Based Radar. It is seen that for systems with lightweight structure the on-orbit propellant requirements become very large and can exceed by factors the spacecraft mass for specific impulses less than about 500 seconds.



EFFECT OF SOLAR PRESSURE ON ON-ORBIT PROPULSION (SBR GEOMETRY)

The figure shows the ratio of non-power payload to total mass required in Low Earth Orbit (LEO) for a geosynchronous orbit (GEO) transfer using state-of-art mercury ion thrusters. In addition to the non-power payload, the electric propulsion thrust system and the power system are also delivered to GEO and are available for various uses on-orbit. Dependent on the specific impulse and specific power source increases, it is seen that GEO transfers are possible in less than 50 days. The non-power payload rises rapidly with trip time from a zero value to an asymptotic value dependent only on the specific impulse in the limit of very long trip times. The figure also shows that the non-power payload can become a large fraction of the total mass required in LEO. This feature can grossly reduce the Earth to orbit propulsion requirements for LSS at GEO.



APPLICATIONS

o EARLY DEFINITION OF GENERIC LSS PROPULSION REQUIREMENTS CAN ALLOW APPROPRIATE RESPONSES IN ELECTRIC PROPULSION TECHNOLOGY DIRECTIONS