Solar Electric Propulsion Mission Architectures

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Solar Electric Propulsion Mission Architectures

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Abstract

This presentation reviews Solar Electric Propulsion (SEP) Mission Architectures with a slant towards power system technologies and challenges. The low-mass, high-performance attributes of SEP systems have attracted spacecraft designers and mission planners alike and have led to a myriad of proposed Earth orbiting and planetary exploration missions. These SEP missions are discussed—from the earliest missions in the 1960’s, to first demonstrate electric thrusters, to the multi-megawatt missions envisioned many decades hence. The technical challenges and benefits of applying high-voltage arrays, thin film and low-intensity, low-temperature (LILT) photovoltaics, gossamer structure solar arrays, thruster articulating systems and microsat systems to SEP spacecraft power system designs are addressed. The overarching conclusion from this review is that SEP systems enhance, and many times enable, a wide class of space missions.
SEP attractive for missions
- High Isp, mass savings

SEP Mission Review
- Past- Present – Future
  - Robotic
  - Human
- Technologies, Challenges & Benefits
  - Power Systems
  - Structures

Introduction

First Russian SEP Missions in 1964
- Yantar-1 / Ion thruster, Zond-2 / 6 PPTs (Mars Flyby)

First US SEP Mission 1968: ATS-4
- 20-W, 5-cm Cs Ion Thrusters, 300-W PVA

In The Beginning…
- Primary EP
- Reduced cell count, concentrator PV

DS-1: 1998

- Express-A #2/3: Induced plasma at PVA in GEO - 2000

GeoComsat EP

NASA/TM—2003-212456 3
Waste Gas Management, Reboost

4x500-W, 0.33 N, 100-500 sec Isp

Options: 10-kW HET (shown), 5-kW Arcjet
- Array shadowing/clearance, sputtering, PPU placement

ISS – 2001 EP Reboost Study
ISS – ED Tether Reboost (MSFC)

- Downward Deployed
  - Commercial spacecraft bus
  - 7 km long tether
  - Uses ISS Power
  - Significant cg shift
  - Ingress/Egress Interference

- Upward Deployed

Geomagnetosphere Science (Microsats)
High-Power EP Tech Demo
- 10 kW HET & VASIMR Thrusters
- 9-month, LEO to GEO spiral transfer

Balance s/c mass, rad dose, geoscience

RTD

1500 kg initial wet mass
ISS Inspector - PowerSphere

- PPTs, photography, microscopy
  - 1000’s sorties, precision control

ISS Inspector -- PowerSphere

Aerospace/AFRL

Water Electrolysis Thruster – “WET”

- Unitized PEM EL/FC, H2/O2 Prop
- Non-hazardous, low pressure fuel
Mars Sample Return (JSC)

- Shuttle launched/retrieved
- 10 kW Xe Ion Thrusters, Xe resistojet ACS
- 20 kg canister returned LMO->LEO

Mars ComSat (GSFC)

- 6-12 kW Ion/Hall EP plus Chem Prop.
- Enabled launch on Delta 7925
- Enabled Mars Orbit Maneuvering – KOZ Issue
- Enables Missions By Use of Smaller LV
- Faster Trips Times than All EP

SEP-Chem Missions

- 20 kW EP (1-AU) / Chem, 200-W at Jupiter
- PVA Challenges: radiation, LILT, pointing

Europa Orbiter (JPL)
HES, Multijunction Solar Cells

PV Array Performance: Venus to Jupiter
3-5 Cells

Heliocentric Distance (AU)
Temperature (C)

"1-Au Normalized" Performance

Wing Peak Power
Cell Vmp

1-MW EP LEO->HEEPO
Chem TMI Burn

80 MT Stage
80 MT Payload

Challenges:
- Thin Film PV
- Rad Harness
- High voltage
- Structures

Human Mars – 2020’s
- **400 kW Ion EP**: LEO to L1
- 30 MT Stage
- 30 MT Payload

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**Human Gateway-HPM-OASIS**

**AEC-Able Design**: SRTM Heritage

- Thruster palette
- Outboard joints
- Outboard Mast
- Deployable Mast
- Deployed
- Stowed
- Open truss canister
- Root Joint
- Root Truss

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Show LaRC SEP view.mov

LaRC/RASC

NASA/TM—2003-212456
Thin-Film Photovoltaics

- High efficiency (15-20%)
- Low mass substrates (0.1-0.2 kg/m²)
- Encapsulated for High Voltage Operations
- Low cost

Radiation Hardness

- Thin Film PV
- Entech SLA
High Voltage PVAs (D2)

- D2HET Program Plasma Testing / Modeling
- AEC-Able SquareRigger
- ILC-Dover NGST Sunshield

Gossamer Structures
The Future? Space Solar Power

- 200 kW HET per node; 20 MT LEO->GEO, ACS

Or The Future? “SolarBird”

Power generation satellite group

Mitsubishi Microwave beam directed at the Earth
SEP systems enhance, and many times enable, a wide class of space missions.
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