Requirements & Solutions to Power Needs in Space

Near Earth Missions

Unmanned Missions to Solar System

Manned Missions to Solar System

Unmanned Missions Out of the Solar System

Needs

Nuclear

Solar

Chemical

Beamed
Reasons That Solar Power May Not Be Appropriate For Specific Space Missions

1) Too far from the Sun to make use of solar power

2) In a space radiation environment too harsh to allow sustained use of solar cells (e.g., very near to the Sun)

3) Landing near a planet’s poles, where the illumination is insufficient

4) In night environments with time frames beyond practical battery capacity

5) On a dust- or cloud-enshrouded world, or in a subsurface application, where the use of solar power is impractical or impossible
Near Earth Missions
Requiring Space Power

Civilian
- Broadcast Satellites
- Commercial Air Traffic Radar
- Space Shuttle
- Space Station

Military
- Monitoring, Control, and Tracking
- Strategic Defense Initiative
  - Station Keeping
  - Alert Mode
  - Burst Mode
POWER REQUIREMENTS FOR SPACE BASED RADAR
Monitoring, Control and Tracking

Prime Power (kWe)

Military Missiles and Aircraft
Commercial Air Traffic
Treaty Verification Crises & Sea Traffic
Sea Traffic Topographical Weather

(Resolution) X (Area Coverage) X (Number & Duration of Observations)
# of Satellites
**Iridium**

- 66 Satellites, Motorola  
  (46 now up and rest in 1998)

- Communicate anywhere in the world by hand held phone

- Operational ≈1998

- 5 year life, 432 mile orbit

- 30 $M each, 2 $B total

- 500 $W_e$ per satellite

- 689 kg/satellite

- 33 kW$_e$ total system  
  (289 MW$_{eh}$/year)
International Space Station

- Total requirement - 105 kWₑ continuous (Russian MIR ==> 30 kWₑ)
- Two independent solar power supplies
  - U. S. = 76 kWₑ
  - Russian = 29 kWₑ
- 120 V DC for US and 28 VDC for Russian system
- American array is 108.6 ft by 240 ft
  (≈ 26,000 ft², 54% of football field)
- Mass ≈ 0.64 lb/ft², 16,640 lbs, 7.56 tonnes
- Power density ≈ 100 kg/kWₑ
- Plus 24 batteries for US system (solar eclipse)- NiH,
  US only: 370 lb (168 kg), life= 6.5 y
- Plus coolant to keep batteries at 0-10 °C
# Military Power Needs in Space

## Space Surveillance

- **Passive Infrared** 20 kW  
- **Computers** 50 kW  
- **Laser Radar**  
  - (Track) 50 kW  
  - (Image) 3,000 kW

## Space Radar

- 5 MW

## Orbital Transfer Vehicle

- 17 MW

## Weapons Platforms

- **Kinetic Energy Kill** 100 kW  
- **Free Electron Lasers** up to 300 MW  
- **Neutral Particle Beam** up to 500 MW  
- **Electromagnetic Launchers** up to 500 MW
There Are Three Levels of Power Required For SDI Applications

<table>
<thead>
<tr>
<th>Mode</th>
<th>Time of Operation</th>
<th>Power, MWe</th>
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<tbody>
<tr>
<td>Housekeeping</td>
<td>Continuous-7y</td>
<td>0.1</td>
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<tr>
<td>Alert</td>
<td>Up to 1 y</td>
<td>10</td>
</tr>
<tr>
<td>Burst</td>
<td>Up to 30 mins.</td>
<td>Up to 1000 MWe</td>
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Figure 2. Forecasted Military Power Needs Regimes
Figure 3. Forecasted Power System Wt. Vs Power & Energy Req.
Power Needs for Exploration of the Moon/Mars

Lunar Exploration

<table>
<thead>
<tr>
<th>Year</th>
<th>Crew</th>
<th>Duration-months</th>
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<tbody>
<tr>
<td>1995-2000</td>
<td>Robotic</td>
<td>-----</td>
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<tr>
<td>2000-2006</td>
<td>3-6</td>
<td>3-6</td>
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<tr>
<td>2007-2014</td>
<td>9-15</td>
<td>6-12</td>
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<tr>
<td>2015-2025</td>
<td>18-24</td>
<td>12</td>
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Mars Exploration

<table>
<thead>
<tr>
<th>Year</th>
<th>Crew</th>
<th>Duration-months</th>
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<tbody>
<tr>
<td>1992-2003</td>
<td>Robotic</td>
<td>-----</td>
</tr>
<tr>
<td>2019</td>
<td>3-6</td>
<td>1-2 (stay)</td>
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<tr>
<td>UNMANNED PRECURSOR</td>
<td>MANNED OUTPOST</td>
<td>INTERIM BASE</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>2 KWe</td>
<td>100 KWe</td>
<td>500 KWe</td>
</tr>
</tbody>
</table>

- ORBITER
- ROVER
- SAMPLE RETURN
- FARSIDE COMSAT

- HABITAT (6 CREW)
- LABORATORY
- SCIENCE EXPTS
- LOX PILOT PLANT
- SITE PREP
- ROVERS/TRAILERS
- LANDER/ASCENT VEHICLE

- HABITAT (15 CREW)
- ADD'L LABS
- EXTENDED SCIENCE
- IN-SITU RESOURCES PLANT
- CELSS RESEARCH
- SURFACE SURVEYS
- MINING
- LOX PRODUCTION
- MATL'S PILOT PLANT
- REUSABLE LEM CARGO VEHICLE

- HABITAT (24 CREW)
- RESEARCH FACILITIES
- SUSTAINED SCIENCE
- INCREASED LOX PRODUCTION
- METALS PRODUCTION
- MANUFACTURING
- CERAMICS PRODUCTION
- FOOD PRODUCTION
- PRODUCT EXPORT
- MASS DRIVER
MARS BASE POWER TIMELINE PROFILE - STEADY GROWTH

POWER (kWe)

YEAR (20__)
Proposal-Capture Worldwide Direct Broadcast HDTV Market

• Market Value 9-20 $B/Sat-y

• 5 GEO Satellites for Global Coverage

• Each with a 100 kW\textsubscript{e} power supply for a Ku Band Transmitter

• Presently Hughes uses a 6-8 kW\textsubscript{e} solar powered GEO satellite ($600M) for conventional TV

• Cost to Service Provider /Y for each subscriber
  
  Fiber/Cable > $101/Y  
  Direct Broadcast Satellite \approx $2.52/Y

• 100 kW\textsubscript{e} ==> 150 Channels of HDTV @ 3 Gbits/s
Mass Requirements For Space Power

System Power (kW)

System Specific mass (kg/kW)

RTG's

Photovoltaic

Reactor

After Edenburn
Mass Requirements for Space Station

Power System Mass for 100 kW<sub>e</sub>

**Solar** ........300 kg/kW<sub>e</sub>

- 30 tonnes for Solar Panels
  - Multiple shuttle launches (≈ 30 tonne total launch capability)
  - In orbit assembly
  - Large array size (1,000 m<sup>2</sup>)
  - Transport to GEO only 6 tonnes capability
  - Batteries needed for “dark” periods

**Nuclear** ...... 30 kg/kW<sub>e</sub>

- 3 tonnes for nuclear
  - Reentry possibility
  - Political questions
Cost Considerations

- Historical Space Solar Power System Costs (30 reviews)
  - are $10,000-$12,500 per installed watt for DoD Applications
  - are $4,000 per installed Watt for Commercial applications

- Space Nuclear Power Costs are $1,000-$2,000 per installed Watt
  - For Solar ………100 kW\textsubscript{e} => $400-1,000 M
    (ISS is $20,000$/W\textsubscript{e})

- For Nuclear ……100 kWe => $100-$200 M
FIGURE AAA