SSP Implementation: GEO vs. LEO

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GEO Orbit SBSP

Cost?
Maintenance?
Environmental?

Solar storm?
Installation and Launching Costs

**GEO**: 35786 km (22300 Mile)

**International Space Station**: 278 km (173 mi) and 460 km (286 mi)
GEO Orbit Congestion → Limited Units

Source: The European Space Agency
Coverage Closer to the Equator

Geostationary orbit

12 hours after

24 hours after
LEO?
LEO Implementation: Direct Transmission

- Lower altitudes → lower power loss
- Lower transmission power per unit
- Higher reliability
- Lower cost of launching
- Complex?
- Handoff Process
- Synchronization
- Routing if a cluster is not in ground station field of view
LEO Implementation: Direct Transmission

Multi-Satellite Synchronization?

- Different Doppler
- Different distance to ground
Follower – Leader Option

PCBS visibility zone / cone

Follower Satellite
Leader Satellite
Follower-Leader Option

Synchronization may not be required if each spacecraft orbit in formation is carefully designed.

But how about conversion loss?
- RF to DC
- DC to RF
MEO-LEO (Tethered Option)

Solar Power Harvesting Units (SOPHU)

Ionosphere
Atmosphere

Orbital Control
Situation Awareness
Power Distribution
High Gain Comm.
Power Relaying
Security
Reliability

Transmission Line Structures (TLS)

LEO Satellite
Ground PCBS

The Earth
Ci1es in the Equator Transmission Line Needed
Captured Power

- Transmission frequency: 5GHz
- The power harvested by solar cells: 1400W/m²

<table>
<thead>
<tr>
<th>TX Antenna Aperture</th>
<th>Area (Km²)</th>
<th>$P_t$(dB)</th>
<th>Captured Power GEO</th>
<th>5000Km</th>
<th>1000Km</th>
</tr>
</thead>
<tbody>
<tr>
<td>500m (88dBi)</td>
<td>4</td>
<td>98</td>
<td>100 MW</td>
<td>1 TW</td>
<td>3 TW</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>91</td>
<td>20 MW</td>
<td>200 GW</td>
<td>600 GW</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>71</td>
<td>200 KW</td>
<td>2 GW</td>
<td>6 GW</td>
</tr>
<tr>
<td>250m (82dBi)</td>
<td>0.01</td>
<td>71</td>
<td>33 KW</td>
<td>340 MW</td>
<td>1 GW</td>
</tr>
</tbody>
</table>

$L_{Direct} = 32.45 + 20\log(d_{Km}) + 20\log(f_{MHz}) + L_{Ion} + L_{Atm} + L_{Ecl} \rightarrow$ Eclipse Loss

Ionosphere Loss
Atmospheric Loss
<table>
<thead>
<tr>
<th></th>
<th>GEO</th>
<th>LEO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distribution</strong></td>
<td>Central</td>
<td>Distributed</td>
</tr>
<tr>
<td><strong>Accessibility</strong></td>
<td>Near Equator</td>
<td>Everywhere (Orbit Design)</td>
</tr>
<tr>
<td><strong>Efficiency (Power)</strong></td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Cost/Kwatt</strong></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Hazard</strong></td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Signal Processing</strong></td>
<td>Simpler</td>
<td>Complex</td>
</tr>
<tr>
<td>Cost</td>
<td>LEO</td>
<td>GEO</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Launch</td>
<td>• Launch cost is a significant portion;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Several launches will be needed;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• The launch to lower orbits is much lower than to the GEO;</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Lower Launch cost</strong></td>
<td><strong>Higher Launch cost</strong></td>
</tr>
<tr>
<td>Ground Stations</td>
<td>• Several smaller units are needed</td>
<td>One huge unit is needed</td>
</tr>
<tr>
<td></td>
<td>• All units are identical,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Production cost per unit is lower</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Lower Ground Station Cost</strong></td>
<td><strong>Higher Ground Station Cost</strong></td>
</tr>
<tr>
<td>Ground Power distribution</td>
<td>No distribution is needed</td>
<td>Distribution is needed</td>
</tr>
<tr>
<td></td>
<td><strong>Not applicable</strong></td>
<td><strong>Significant Cost</strong></td>
</tr>
<tr>
<td>With Tether</td>
<td>• Several studies tethers have been conducted.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Commercially available.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Technology is available</strong></td>
<td><strong>Not applicable</strong></td>
</tr>
<tr>
<td>Satellite</td>
<td>Several small identical units; lower production cost per unit;</td>
<td>One huge unit</td>
</tr>
<tr>
<td></td>
<td>Similar harvesting area to GEO</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Lower cost</strong></td>
<td><strong>Higher cost</strong></td>
</tr>
</tbody>
</table>
Research Areas

1. Analysis and comparison of already proposed techniques:
   a. Expected Efficiency;
   b. Expected Cost;
   c. Expected Space Needed on The Ground;
   d. Expected Reliability;
   e. Expected Durability;

2. The best techniques for absorbing solar energy in the space?
   a. Forming the Structure of Satellites;
   b. Designing the best Orbit;
   c. Solar Sensors;

3. Energy Transfer from the atmosphere to the earth surface (Wireless; Laser; Cable)
   a. Wireless Transmission Scheme (Modulation, Beam-forming)
   b. RF – Optical Systems?
   c. Antenna structures (Number of Antennas, Antenna Design)
   d. Selecting the transmission parameters
Research Areas

4. **Ground Receivers**
   a. The Ground Antenna Structure (Size, Distribution, etc);
   b. Passive or Active Receiver?
   c. High Aperture Antenna Beam-forming

5. **Energy Conversion** (How energy should be converted to the City Electricity?)
   Whether Rectantennas are the best options?

6. **Channel Modeling**
   The effect of Ionosphere on the RF Signal and Ionosphere based on their power;

7. **Environmental Effects**
   The Effect of High Energy Laser or RF signal on Ionosphere;

8. **Cyber Systems**
   a. The Control Process of the Whole Structure;
   b. Directing power from one satellite to another;
References


Thank you

Question?