Satellite Technology (20EC81)

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Unit-III (A)
Power System

Presented by

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Power Supply Subsystem

- Power supply subsystem
  - Generates
  - Stores
  - Controls
  - Distributes
- Electrical power to other subsystems on board the satellite platform.

Power Supply Subsystem

- The electrical power needs of a satellite depend upon the intended mission of the spacecraft and the payloads that it carries along with it in order to carry out the mission objectives.
- The power requirement can vary from a few hundreds of watts to tens of kilowatts.

Types of Power systems

- Although power systems for satellite applications have been developed based on the use of
  - solar energy
  - chemical energy
  - nuclear energy
- The solar energy driven power systems are undoubtedly the favorite and are the most commonly used ones.

Solar power system

- This is due to the abundance of mostly uninterrupted solar energy available in the space environment, and the use of photon energy in solar radiation.

Heat Generators

- The power systems known as heat generators make use of heat energy in solar radiation to generate electricity.
- A parabolic dish of mirrors reflects heat energy of solar radiation through a boiler, which in turn feeds a generator, thus converting solar energy into electrical power.

Solar Panels

- The major components of a solar power system are the solar panels
- The solar cell is the basic element of Panel.
- Rechargeable batteries, battery chargers with inbuilt controllers, regulators and inverters to generate various d.c and a.c voltages required by various subsystems.

Solar Panels

- The solar panel is nothing but a series and parallel connection of a large number of solar cells.
- The voltage output and the current delivering capability of an individual solar cell are very small for it to be of any use as an electrical power input to any satellite subsystem.

Solar Panels

- The series-parallel arrangement is employed to get the desired output voltage with the required power delivery capability.
- A large surface area is therefore needed in order to produce the required amount of power.
- Need for large solar panels must be balanced against the need for the entire satellite to be as small and light weight as possible.

Solar Panels

- Panels may be rotated to expose to Sun
- More the exposure more the power Generated
- But Efficiency reduces as temperature increases
- Flat panels vs Cylindrical panels

Principle of Operation of a Solar Cell

- basic solar cell is based on the photovoltaic effect.
- In photovoltaic effect, there is generation of an open circuit voltage across a P–N junction when it is exposed to light
- This open circuit voltage leads to flow of electric current through a load resistance connected across it

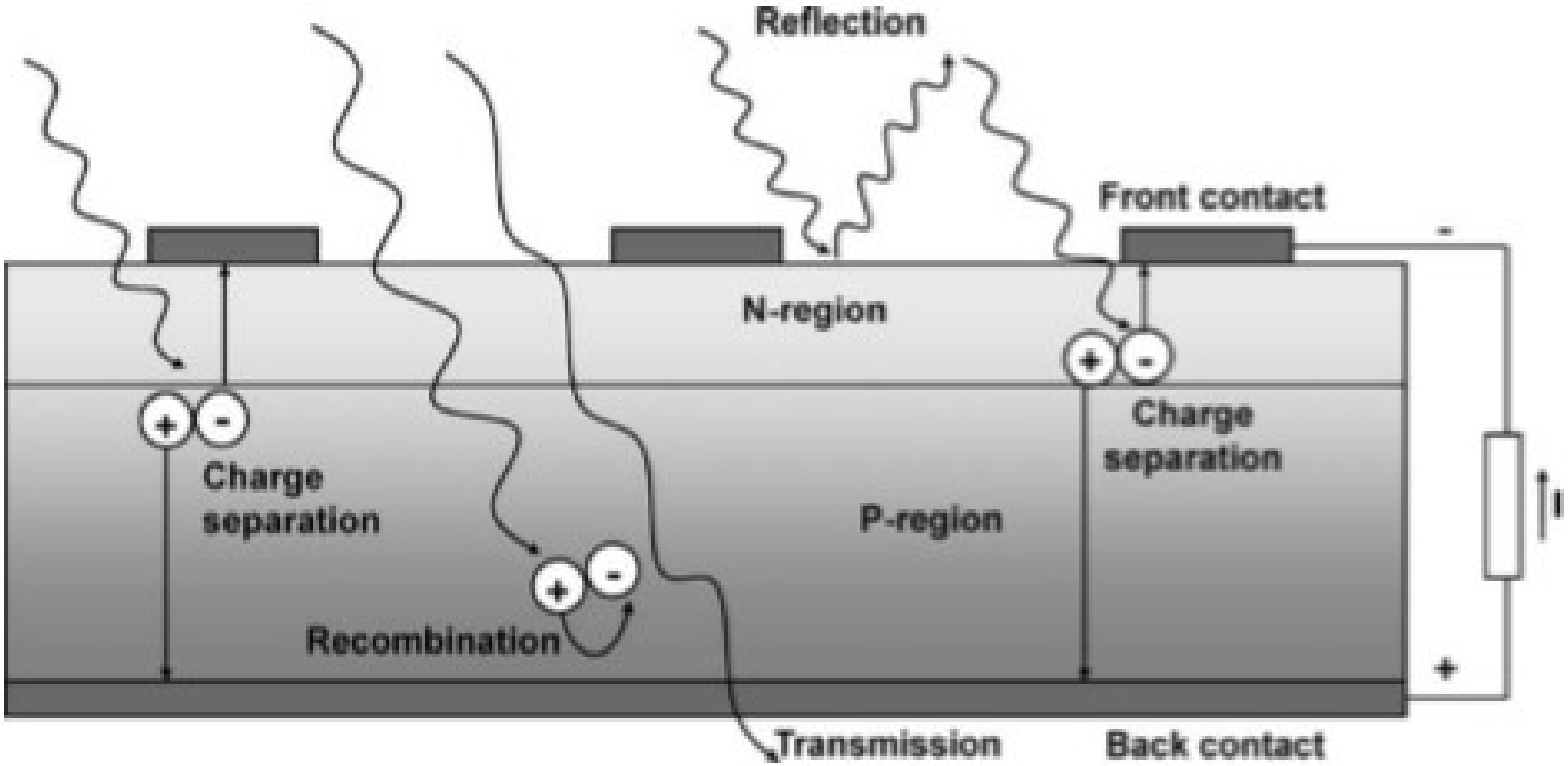
Principle of Operation of a Solar Cell

- It is evident from the figure that the impinging photon energy leads to the generation of electron–holepairs.
- The electron-hole pairs either recombine and vanish or start to drift in the opposite directions, with electrons moving towards the N-layer and holes moving towards the P-layer.

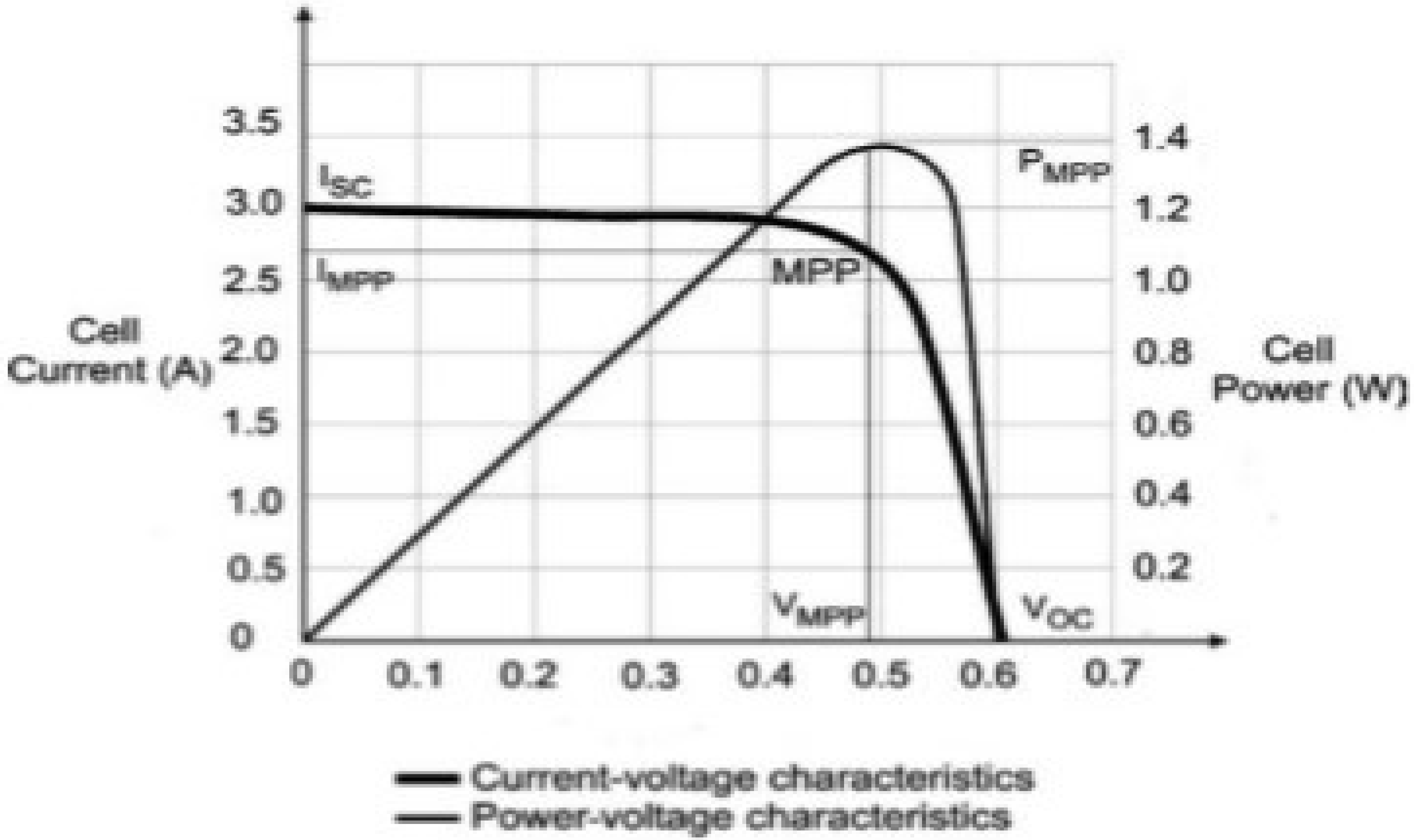
Principle of Operation of a Solar Cell

- This accumulation of positive and negative charge carriers constitutes the open circuit voltage.
- This voltage can cause a current to flow through an external load.

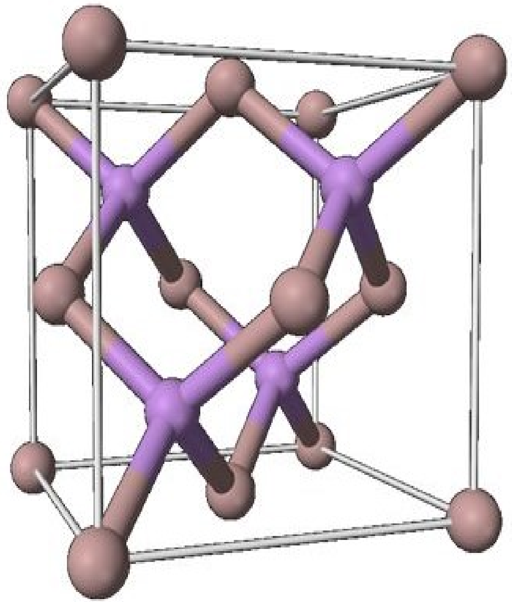
Solar Panels



I-V & P–V characteristics



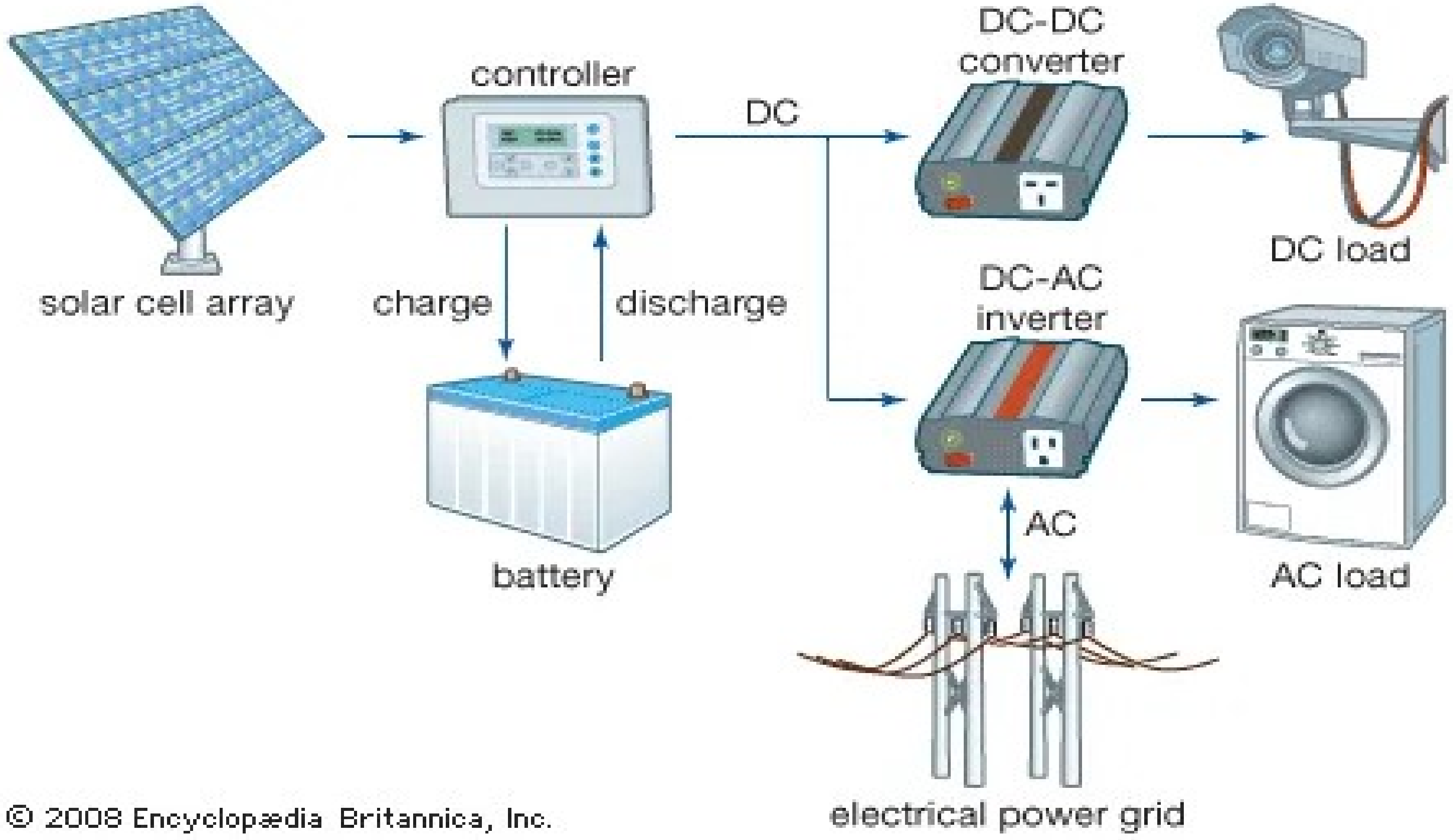
Gallium Arsenide (GaAs)



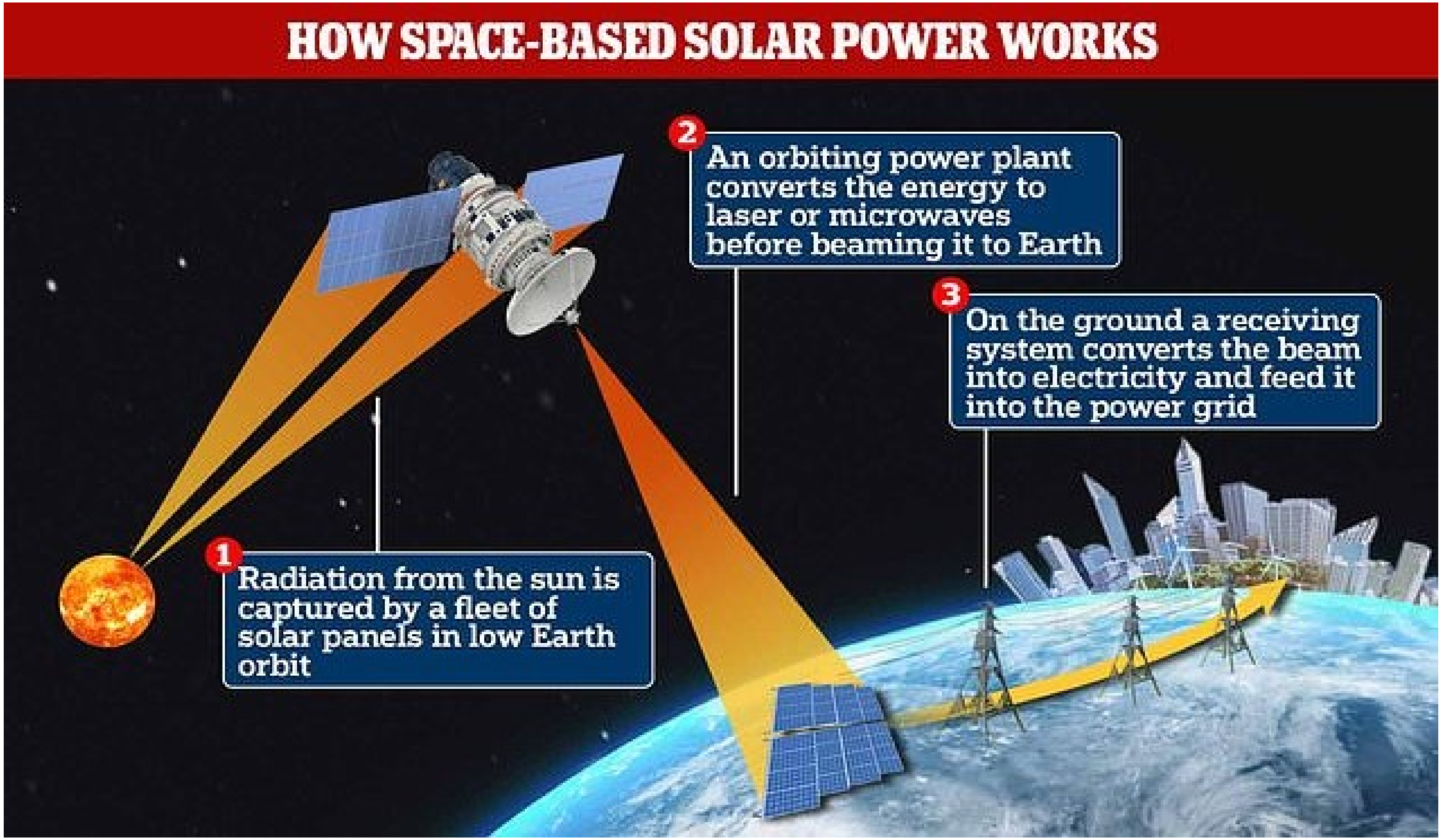
GaAs's advantages over silicon in semiconductor use

- High electron mobility (~8x Silicon)
- Significant reduction in signal noise
- High power transmission
- High breakdown voltages
- Direct bandgap

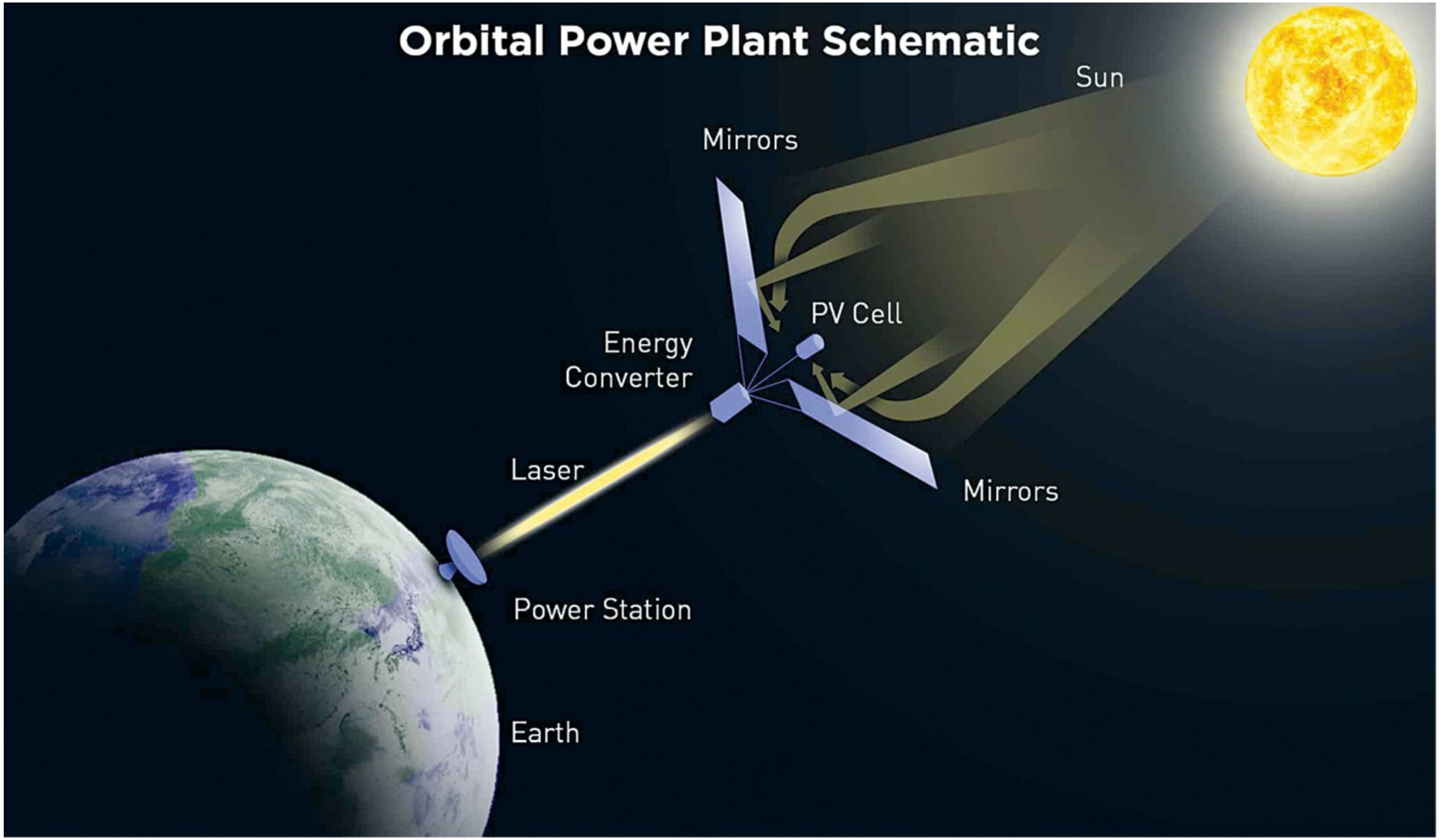
Solar Panels

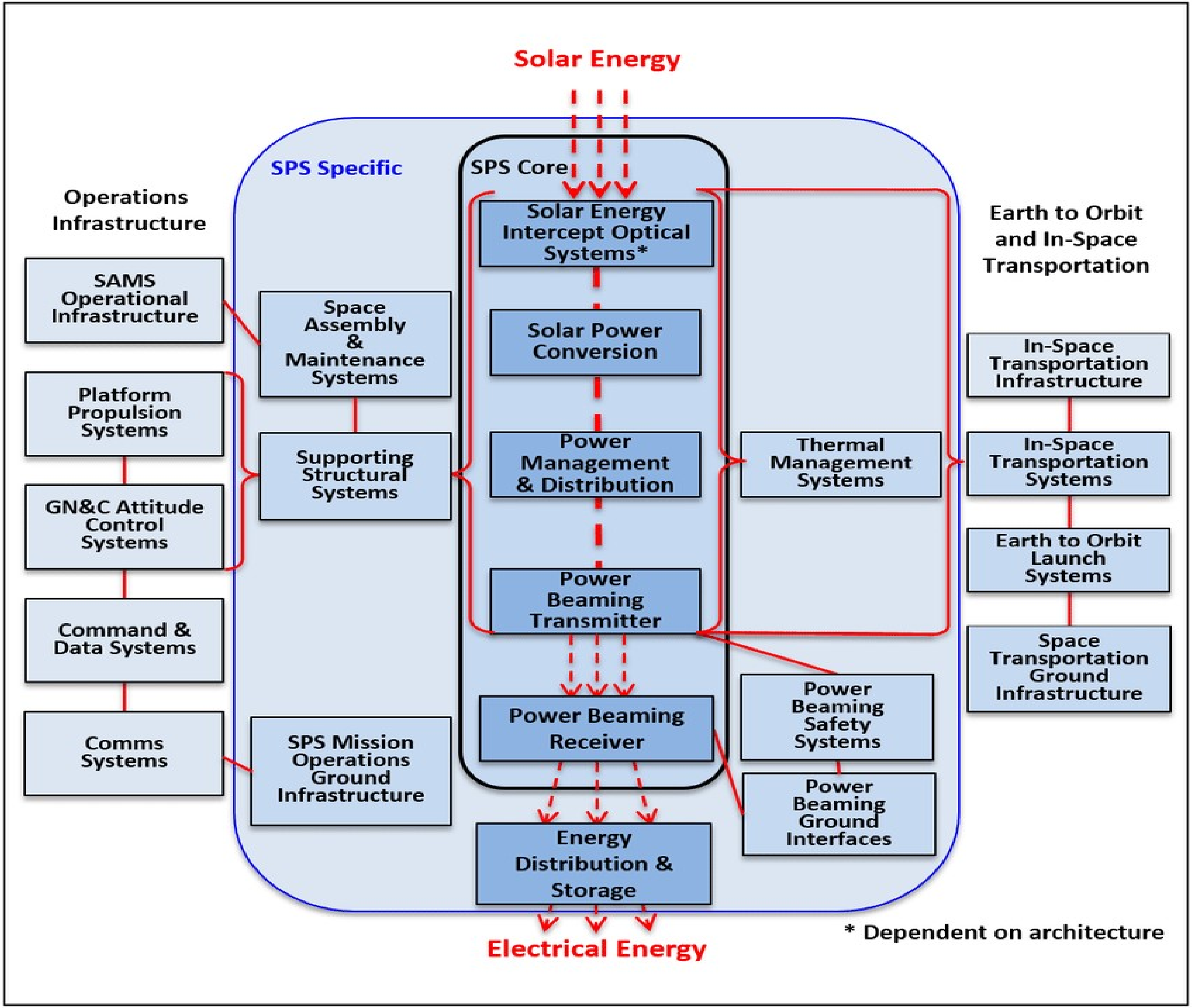


Solar power system



Solar power system




Solar Energy
SPS Specific
SPS Core
Operations Infrastructure
Earth to Orbit and In-Space Transportation
Solar Energy Intercept Optical Systems*
SAMS Operational Infrastructure
Space Assembly & Maintenance Systems
Solar Power Conversion
In-Space Transportation Infrastructure
Platform Propulsion Systems
Supporting Structural Systems
Power Management & Distribution
Thermal Management Systems
In-Space Transportation Systems
GN&C Attitude Control Systems
Earth to Orbit Launch Systems
Power Beaming Transmitter
Command & Data Systems
Space Transportation Ground Infrastructure
Power Beaming Safety Systems
Power Beaming Receiver
Comms Systems
SPS Mission Operations Ground Infrastructure
Power Beaming Ground Interfaces
Energy Distribution & Storage
* Dependent on architecture
Electrical Energy

Characteristics

- The solar cell generates its maximum power at a certain voltage.
- The power–voltage curve has a point of maximum power, called the maximum power point (MPP).
- The cell voltage and the corresponding current at the maximum power point are less than the open circuit voltage and the short circuit current respectively.

Efficiency

- Solar efficiency is the ratio of the maximum electrical solar cell power to the radiant power incident on the solar cell area.
- The efficiency figure for some crystalline solar cells is in excess of 20%.

Si & Ga-As

- The most commonly used semiconductor material for making solar cells is Silicon(Si).
- Both crystalline and amorphous silicon are used for the purpose.
- Another promising material for making solar cells is Gallium Arsenide(Ga-As).
- Gallium arsenide solar cells, when perfected, will be lightweight and more efficient.

Space Battery System

- Batteries store electricity in the form of chemical energy and are invariably used together with solar energy driven electrical power generators to meet the uninterrupted electrical power requirements of the satellite.
- They are never used as the sole medium of supplying the electrical power needs of the satellite.

Space Battery System

- The batteries used here are rechargeable batteries that are charged during the period when solar radiation is falling on the satellite.
- During the periods of eclipse when solar radiation fails to reach the satellite, the batteries supply electrical power to the satellite.
- Batteries are also used during the launch phase, before the solar panels are deployed.

Space Battery System

- The choice of the right battery technology for a given satellite mission is governed by various factors.
  – the frequency of use
  – magnitude of load
  – depth of discharge.
- Generally, fewer cycles of use and less charge demanded on each cycle lead to a longer battery life

Space Battery System

- The choice of battery technology is closely related to the satellite orbit.
- Batteries used on board LEO satellites encounter much larger number of charge/discharge cycles as compared to batteries onboard GEO satellites.
- LEOsatelliteshaveanorbital period of the order of 100 min and the eclipse period is 30–40min per orbit.

Space Battery System

- For GEO satellites, the orbital period is 24 hours and the eclipse duration varies from 0 to a maximum of 72 min during equinoxes.
- Battery capacity is highly dependent on the temperature. As an example, the nickel metal hydride (NiMH) battery has a maximum capacity between the operating temperature of 10 to 15◦C and its capacity decreases at a rate of 1Ah/◦C outside this range.

Space Battery System

Battery Types

- Commonly used batteries onboard satellites are
  - Nickel–Cadmium (NiCd)
  - Nickel Metal hydride (NiMH)
  - Nickel–Hydrogen (NiH_2) batteries.
  - Lithium Ion Batteries

Battery Types

- Small satellites in LEO mostly employ nickel–cadmium batteries.
- Nickel–hydrogen batteries are slowly replacing these because of their higher specific energy and longer life expectancy.
- Currently, GEO satellites mostly employ nickel–hydrogen batteries.
- Lithium ion batteries is the future and can be used on LEO, MEO and GEO satellites.

Energy Specifications

- NiCd batteries: 20–30 W h/kg
- NiMH and NiH2 batteries: 35–55 W h/kg
- Li Ion batteries: 70–110 Wh/kg

Ni-Cd Batteries

- They can offer high currents at a constant voltageof1.2V.
- Are highly prone to what is called the ‘memory effect’.
- Memory effect means that if a battery is only partially discharged before recharging repeatedly, it can forget that it can be further discharged. If not prevented, it can reduce the battery’s lifetime.

Ni-Cd

- This battery's problem is toxicity of cadmium, as a result of which it needs to be recycled or disposed of properly.
- Also, nickel–cadmium batteries have a lower energy per mass ratio as compared to nickel metal hydride and nickel–hydrogen batteries

Ni-MH Batteries

- The nickel metal hydride batteries are cadmium-free replacements of nickel–cadmium batteries.
- The anode of the battery is made of a hydrogen storage metal alloy of nickeloxide.
- Also, these batteries are less affected by the memory effect as compared to nickel–cadmium batteries.

Ni-H2 Batteries

- The nickel-Hydrogen battery combines the technologies of batteries and fuel cells.
- battery uses nickel hydroxide as the cathode as in the nickel–cadmium cell.
- Like the hydrogen–oxygen fuel cell, the battery uses hydrogen as the active element in the anode.

Ni-H2 Batteries

- Its resistance to repeated deep discharge and tolerance for overcharge makes it the chosen battery in many aerospace applications, especially for GSO and LEO satellites.
- Its disadvantages include its high cost and low volumetric energy density. Nickel-hydrogen batteries are being used on both LEO and GEO satellites

Li-Ion Batteries

- Lithium ion batteries produce the same energy as nickel metal hydride batteries but weigh approximately 30% less.
- These batteries do not suffer from the memory effect unlike their Ni-Cd & Ni-MH.
- These batteries require special handling as lithium ignites very easily.
- They can be used for LEO, MEO as well as GEO satellites.

Thank You