Electrical power: generate, store, distribute and shed loads

Essential answer

Electrical power: generate, store, distribute and shed loads. The question to solve is: How can you have enough energy without lacking power at the wrong moment? Arrays, battery and distribution must simultaneously support critical loads. A large battery does not fix an undersized converter or cable. The rest of the course turns that idea into an auditable line of reasoning: explicit units, stated assumptions, reproducible calculations, order-of-magnitude checks and interpretation limits. A result is useful only when the reader can explain what it measures, where every input came from and which engineering decision it can support.

Reasoning map

1. 1 — The concrete scene
2. 2 — Essential words, explained before using them
3. 3 — See the architecture before calculating
4. 4 — Formulas, only when they answer a question
5. 5 — What units and margins mean

Arrays, battery and distribution must simultaneously support critical loads. A large battery does not fix an undersized converter or cable.

Rate of energy transfer, in watts.

Before calculating

Quantity:	Electrical power: generate, store, distribute and shed loads
Check:	units + order of magnitude + assumptions
Decision:	state what the result actually supports

Electrical power: generate, store, distribute and shed loads

2 — Essential words, explained before using them

Rate of energy transfer, in watts.

Adapts voltage or current with losses.

3 — See the architecture before calculating

Capability depends on illumination, pointing, temperature and ageing.

State of charge and available power are different concepts.

Wiring, protection and converters have limits.

Degraded mode sheds non-vital loads.

4 — Formulas, only when they answer a question

How to read it : power equals voltage times current

U in volts, I in amperes.

How to read it : energy equals power times time

For constant P, Wh is W times hours.

How to read it : loss equals current squared times resistance

Doubling current quadruples this loss.

5 — What units and margins mean

V, A, W, Wh/J and Ω. 1 Wh = 3,600 J.

6 — Three concrete demonstrations, calculated step by step

300 W for 3 h.

1,200 W on 48 V.

Capacity 2,000 W, demand 2,350 W.

7 — Deepening: what the simplified diagram hides

Capability ages and depends on temperature.

A short circuit must be isolated without blacking out the vehicle.

Active reading

Sections:	2 — Essential words, explained before using them ; 3 — See the architecture before calculating
Verification:	A value is usable only with its unit and calculation boundary.
Exercise:	change one assumption and predict the direction of change before recalculating

Electrical power: generate, store, distribute and shed loads

Ripple and transients can disturb hardware.

Peak often sizes the system more than average.

Electrical losses become heat to reject.

8 — Application to an Earth-Mars spacecraft

9 — Reference dossier: what a real project must still consider

Power is the rate at which energy is produced or consumed; energy is the accumulated amount over time. A 1,000 W load for ten seconds does not require the same battery capacity as a 200 W load for ten hours. Generation, storage and distribution therefore solve related but different problems.

A useful power budget lists each load, activity mode, efficiency, duration and priority. It separates average power, transient peak and daily energy. Critical loads must often survive load shedding, so the system needs a planned order for disconnecting non-essential consumers.

Usable capacity depends on temperature, current, state of charge, depth of discharge, ageing and cycle history. Battery management monitors cells and enforces limits. For a long mission, end-of-life capacity is more important than first-day capacity.

Sources rarely provide the exact voltage needed by every load. Converters regulate power but lose energy as heat. Protection devices isolate short circuits, and branch architecture should keep one local fault from collapsing the complete bus.

A nominal voltage does not describe ripple, noise, inrush current or transients. Motors and switching loads can disturb sensitive sensors, so grounding, filtering, wiring and sequencing are part of system design and must be tested in the integrated configuration.

Most electrical power consumed inside the spacecraft ultimately becomes heat. A more efficient converter therefore saves energy and reduces thermal load at the same time. This is a classic system-level trade rather than an isolated subsystem improvement.

Transit and surface operations have different profiles. Solar availability varies with day, season and dust, while nuclear sources have different constraints. The design must distinguish adequate average energy from guaranteed power during the worst credible period.

10 — Common traps and bad intuitions

Active reading

Sections:	8 — Application to an Earth-Mars spacecraft ; 9 — Reference dossier: what a real project must still consider
Verification:	A value is usable only with its unit and calculation boundary.
Exercise:	change one assumption and predict the direction of change before recalculating

Electrical power: generate, store, distribute and shed loads

Assuming a battery can deliver any power.

Electrical power must be budgeted by mode, not by average

Generation, storage, conversion, distribution, protection and loads form one power system. Solar arrays might provide enough energy over a day while still being unable to support a short peak without batteries. A large battery likewise cannot compensate for insufficient generation over many days.

Power in watts and energy in watt-hours must be separated. Each operating mode combines continuous and temporary loads, conversion losses and margin. End-of-life cases can be harder than beginning-of-life because solar cells and batteries degrade.

Load shedding is a safety function. When generation or storage is inadequate, non-critical users are removed first so computing, minimum thermal control, communications and recovery functions remain powered. The priority must exist before the emergency.

11 — Guided exercises

Question : What question comes before choosing hardware?

Question : Why is a nominal result insufficient?

12 — What to remember

Explain the topic in simple words before symbols.

Connect at least four interfaces with other subsystems.

Redo the three numerical examples without reasoning gaps.

Related calculator: solar + batteries

Explore load, equivalent solar hours, losses and battery-autonomy assumptions.

13 — NASA sources for further study

NASA - 2026 State-of-the-Art: Power

NASA - 2026 State-of-the-Art: Complete Spacecraft Platforms

Active reading

Sections:	Electrical power must be budgeted by mode, not by average ; 11 — Guided exercises
Verification:	NASA - 2026 State-of-the-Art: Power | NASA - 2026 State-of-the-Art: Complete Spacecraft Platforms | NASA Systems Engineering Handbook
Exercise:	change one assumption and predict the direction of change before recalculating