Onboard computer and data: compute, store, command and telemeter

Essential answer

Onboard computer and data: compute, store, command and telemeter. The question to solve is: What does the spacecraft computer actually do when nobody is typing? It receives telemetry, executes commands, timestamps events, manages data buses, runs GNC algorithms, stores data and supports fault detection. Some functions are real-time while others are not. Computing architecture therefore assigns priorities, processors, memory and networks according to timing and failure consequences. 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

Sensors produce measurements; software time-tags and processes them, commands actuators, stores data and prepares telemetry.

Computing, acquisition and command electronics.

Before calculating

Quantity:	Onboard computer and data: compute, store, command and telemeter
Check:	units + order of magnitude + assumptions
Decision:	state what the result actually supports

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2 — Essential words, explained before using them

Computing, acquisition and command electronics.

Command sent to the vehicle.

Network exchanging data among units.

Monitor detecting a hung computer.

3 — See the architecture before calculating

Identify, calibrate and time-tag a value.

Filter, navigate, control or compress.

Apply the order to the correct unit in the correct state.

Keep what cannot be sent immediately.

4 — Formulas, only when they answer a question

How to read it : data equals rate times time

R in bit/s times t in s gives bits.

How to read it : one byte equals eight bits

Check conversion between link rate and storage.

5 — What units and margins mean

bit, byte, bit/s, kbit/s, Mbit/s, MB/GB with stated convention.

6 — Three concrete demonstrations, calculated step by step

2 Mbit/s for 30 min.

900 MB at 3 Mbit/s.

20 sensors, 16 bits at 100 Hz.

7 — Deepening: what the simplified diagram hides

Centralisation simplifies some functions but concentrates dependencies.

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

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Without coherent time tagging, fusion and diagnosis become difficult.

Volatile and non-volatile storage play different restart roles.

Bit flips and upsets require mitigation and recovery.

Logs must allow failure reconstruction.

8 — Application to an Earth-Mars spacecraft

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

It receives telemetry, executes commands, timestamps events, manages data buses, runs GNC algorithms, stores data and supports fault detection. Some functions are real-time while others are not. Computing architecture therefore assigns priorities, processors, memory and networks according to timing and failure consequences.

RAM is fast but usually loses content without power. Non-volatile memory preserves code, parameters and recovery data. Long missions must protect reference software images and safe configurations. Radiation-induced bit errors are mitigated with error correction, scrubbing, redundancy and controlled reboot strategies.

Sensors, actuators and computers exchange data through links and protocols. Rate, latency, determinism, topology and fault tolerance matter. A faster bus is not automatically better if it adds complexity or power. Network failure can make healthy equipment unreachable.

Measurements cannot be fused correctly when timestamps are wrong. Clock drift can affect navigation, communications, sequencing and anomaly reconstruction. Vehicles therefore maintain and distribute time references while accounting for onboard, ground-reception and propagation times.

Energetic particles can temporarily flip bits or disturb circuits without permanent destruction. The system combines suitable parts, shielding, redundancy, voting, corrected memory, watchdogs and reconfiguration. The goal is not zero errors but recovery or safe behaviour when errors occur.

Structured logs record events, key values, mode changes, resets and bus messages. Logging itself must be managed so memory and communications are not overwhelmed. Good observability lets engineers reconstruct the causal chain of an anomaly.

Local controllers can reduce wiring and isolate faults but complicate synchronisation, software updates and diagnosis. Mars maintenance must also preserve configuration files, programming tools, firmware versions and replacement compatibility. Avionics therefore has a digital logistics chain as well as hardware.

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

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10 — Common traps and bad intuitions

Thinking more CPU fixes poor architecture.

Logging much but not the right variables.

The onboard computer turns sensor data into traceable decisions

Flight computers receive telemetry and commands, execute flight software, drive actuators and preserve data under constrained resources. Data buses must deliver bandwidth, timing and fault behavior; high peak rate is useless if a critical command can be delayed unpredictably.

Memory carries different criticality levels. Validated software, configuration tables and fault history need stronger protection than disposable science products. Radiation-driven bit errors may require ECC, scrubbing, redundancy and rollback logic.

Telemetry is also a human interface. Too little data hides faults; too much saturates channels and operators. Parameters are selected so engineers can reconstruct system state and test competing diagnostic hypotheses.

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.

13 — NASA sources for further study

NASA - 2026 State-of-the-Art: Small Spacecraft Avionics

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

Active reading

Sections:	10 — Common traps and bad intuitions ; The onboard computer turns sensor data into traceable decisions
Verification:	NASA - 2026 State-of-the-Art: Small Spacecraft Avionics | 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