Earth-Mars team: planning science, maintenance and autonomy over several days

Guiding question

Concrete → interfaces → measurement → calculation → failure → recovery.

Course map

The real phenomenon → Vocabulary and problem boundary → Course-specific system view → Mathematical relationship and reading the symbols → Worked calculations and interpretation

1 — The real phenomenon

Earth has many specialists and deep analysis tools; Mars has real-time situational awareness and the ability to act. An asynchronous organization uses objective-based plans, data packages, synchronization windows and delegated decisions. Science, maintenance and safety priorities are balanced over a multi-day horizon.
The guiding question is: How do we divide work between Earth specialists and the local crew without creating a permanent queue? Reasoning starts with the physical or operational function before introducing the mathematical relationship. The goal is not to accumulate terminology, but to know which quantity changes, why it changes and what becomes hazardous when it leaves its domain. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, the first task here is therefore to identify the mechanism specific to this subject before searching for an equation or reference value.

2 — Vocabulary and problem boundary

In “Earth-Mars team: planning science, maintenance and autonomy over several days”, distinguish the phenomenon, available measurement, any command, the margin and the success criterion. The calculation boundary states what is included and excluded; without that boundary, a percentage, mass or time may be mathematically correct but wrong as an engineering conclusion. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, the chosen boundary also states what would otherwise be double-counted or omitted from a mission budget.
decision authority, available information, communications delay, workload, alarms, configuration and action status
ambiguous direction, stale information, alarm cascade, incomplete handover or authority conflict
crew simulations, real-time procedure runs, communications loss, handover exercises and debriefs

Equation - evidence - decision

Capacité = heures_équipage + heures_robot

Failure to test: The reference failure is not a vague “broken component.” For “Earth-Mars team: planning science, maintenance and autonomy over several days”, test in particular ambiguous direction, stale information, alarm cascade, incomplete handover or authority conflict. Diagnosis asks which symptoms appear first, which are only consequences and which action preserves the most options.

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3 — Course-specific system view

This lesson does not reuse one generic picture for every subject. The system view follows cause → measured quantity → decision or physical response → limit for “Earth-Mars team: planning science, maintenance and autonomy over several days”. The English text remains fully equivalent while large translated illustrations are intentionally deferred until their dedicated artwork is supplied. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, the system view must expose inputs, outputs, measured quantity and the consequence of drift without relying on a generic module diagram.

4 — Mathematical relationship and reading the symbols

Read aloud : planned operational capacity can add crew and robot hours only when tasks are truly substitutable.

Before substituting numbers, write the unit of every term, state whether the relationship is a physical law, approximation or project indicator, and check dimensional consistency. This is especially important here because “Earth-Mars team: planning science, maintenance and autonomy over several days” combines quantities that do not all have the same evidence status. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, this relationship is chosen because of the phenomenon under study; a different dominant quantity would require a different equation or model.

5 — Worked calculations and interpretation

24 crew h + 18 robot h = 42 h gross capacity, to be qualified

12 required h out of 42 h = 28.6% of gross capacity

theoretical 30 h remain before contingencies and non-substitutable work

Guardrail: adding “crew hours” and “robot hours” is valid only when tasks are genuinely substitutable or converted into the same unit of output. Otherwise the two capacities must remain in separate budgets.

1. 1. Plan 24 crew h + 18 robot h = 42 h gross capacity, to be qualified Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Earth-Mars team: planning science, maintenance and autonomy over several days”.

2. 2. Maintenance 12 required h out of 42 h = 28.6% of gross capacity Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Earth-Mars team: planning science, maintenance and autonomy over several days”.

3. 3. Science theoretical 30 h remain before contingencies and non-substitutable work Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Earth-Mars team:

Operational table

Phenomena / sections:	3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation
Relationship to revisit:	Capacité = heures_équipage + heures_robot
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation. State one measured quantity, one margin and one possible decision.

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6 — What the formula does not contain

The relationship “Capacité = heures_équipage + heures_robot” does not by itself contain all of “Earth-Mars team: planning science, maintenance and autonomy over several days”. It does not automatically tell us whether a sensor is valid, a structure is aging, a resource is accessible, a command arrives in time or a secondary failure removes margin. The example 24 crew h + 18 robot h = 42 h gross capacity, to be qualified therefore remains a local calculation rather than a complete architecture.

To make the model useful, explicitly add the quantities that dominate this subject: decision authority, available information, communications delay, workload, alarms, configuration and action status. We can then ask which variation truly changes the result, which is negligible and which forces an architectural change. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, this model limitation states exactly what a correct calculation still cannot establish about the real system.

7 — Instrumentation, observability and data quality

For “Earth-Mars team: planning science, maintenance and autonomy over several days”, observability relies on decision authority, available information, communications delay, workload, alarms, configuration and action status. Each datum has a unit, acquisition rate, uncertainty, timestamp and validity domain. A value arriving without context can be more dangerous than no measurement because it creates unjustified confidence.

Consistency is checked with at least one independent piece of information when the function is critical. A trend, physical balance or second measurement principle helps distinguish a real system change from a drifting sensor. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, the selected instrumentation must distinguish a real physical change from sensor drift or a bad state estimate.

8 — Phenomenon-specific failures and recovery

The reference failure is not a vague “broken component.” For “Earth-Mars team: planning science, maintenance and autonomy over several days”, test in particular ambiguous direction, stale information, alarm cascade, incomplete handover or authority conflict. Diagnosis asks which symptoms appear first, which are only consequences and which action preserves the most options.

The degraded mode must be defined before failure: minimum function, allowable duration, consumed stock, crew action, abort condition and return-to-nominal criterion. That sequence is topic-specific and cannot be replaced by one universal paragraph about redundancy. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, the degraded mode is defined around the minimum function

Operational table

Phenomena / sections:	6 — What the formula does not contain ; 7 — Instrumentation, observability and data quality ; 8 — Phenomenon-specific failures and recovery
Relationship to revisit:	Capacité = heures_équipage + heures_robot
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 6 — What the formula does not contain ; 7 — Instrumentation, observability and data quality ; 8 — Phenomenon-specific failures and recovery. State one measured quantity, one margin and one possible decision.

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9 — NASA / reference case

Human-system standards, CHAPEA and communications-delay research provide reality checks. They show why a distant crew must decide locally, preserve a shared state, manage fatigue and errors, and use Earth as depth of expertise rather than an instantaneous remote control.

The case is used only within what it actually demonstrates. Flight measurement, human-system standard, component test and architecture study are different kinds of evidence; the text therefore states what is observed, calculated, simulated or still prospective. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, the cited NASA case is used as targeted evidence for this phenomenon and is never turned into one universal Mars architecture.

10 — Architecture trade

A good solution for “Earth-Mars team: planning science, maintenance and autonomy over several days” does not maximize one metric. Compare nominal performance, mass, energy, simplicity, maintenance, crew time, common dependencies and recoverability. An option that improves 12 required h out of 42 h = 28.6% of gross capacity can still be rejected if it makes failure detection or repair much harder.

The trade is recorded together with its assumptions. If environment data, mass or mission cadence changes, we know which conclusions must be recomputed instead of silently preserving an obsolete choice. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, the trade is evaluated against the interfaces actually touched by this subject rather than a generic list of desirable qualities.

11 — Demonstration, testing and success criteria

The evidence strategy for “Earth-Mars team: planning science, maintenance and autonomy over several days” combines crew simulations, real-time procedure runs, communications loss, handover exercises and debriefs. Every test records exact hardware, software, configuration, environment, tolerances and success criterion. A successful demonstration outside the mission domain does not replace qualification inside it.

Evidence grows by levels: analytical relationship, simulation, component, subsystem, integrated system, duration and failure. This hierarchy prevents one spectacular test from being presented as validation of the whole mission. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, demonstration must reproduce the constraints that make this phenomenon difficult; a spectacular test outside the mission domain is insufficient.

12 — Decision exercise

Operational table

Phenomena / sections:	9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria
Relationship to revisit:	Capacité = heures_équipage + heures_robot
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria. State one measured quantity, one margin and one possible decision.

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Situation: revisit “Earth-Mars team: planning science, maintenance and autonomy over several days” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable.

Situation: revisit “Earth-Mars team: planning science, maintenance and autonomy over several days” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable. Expected answer: recompute the relationship, identify remaining margin, check whether observability is still adequate, and decide whether degraded operation remains acceptable. Multiplying by 1.2 is not enough if the variation also changes interfaces or limits.

13 — What to retain without over-generalizing

14 — Topic-specific primary sources

These references directly document the phenomenon, technology or human constraint addressed in this lesson. They do not by themselves define an official Mars architecture. For “Earth-Mars team: planning science, maintenance and autonomy over several days”, the bibliography is deliberately targeted to this page so that readers can trace each claim back to the relevant primary document.

Topic-specific primary sources

NASA NTRS — Overview of Crew Operations for Transit to Mars - https://ntrs.nasa.gov/citations/20230012629

NASA NTRS — Assessment of the State of Communication Delay Research - https://ntrs.nasa.gov/citations/20250003885

NASA NTRS — Space Flight Resource Management for ISS Operations - https://ntrs.nasa.gov/citations/20110010923

Operational table

Phenomena / sections:	13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources ; Topic-specific primary sources
Relationship to revisit:	Capacité = heures_équipage + heures_robot
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources ; Topic-specific primary sources. State one measured quantity, one margin and one possible decision.