

Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth

Guiding question

Concrete → flows → sensors → calculation → failure → refuge.

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

A Mars mission must prevent, diagnose and treat medical problems with limited resources and communications delay. Autonomy involves crew skills, imaging, laboratory capability, medications, sterility, consumables, procedures and decision support. The medical system must be designed from risk scenarios, not by arbitrarily accumulating equipment. The guiding question is: How do you provide care when rapid evacuation and real-time specialist support no longer exist? 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, the chosen boundary also states what would otherwise be double-counted or omitted from a mission budget. energy intake, protein, micronutrients, stored mass, crop yield, medical parameters and care time deficiency, crop loss, degraded pharmacy, uncertain diagnosis or unavailable medical resource storage tests, controlled plant growth, medical simulations and rationing scenarios

Equation - evidence - decision

autonomie = stock / consommation ; marge = (stock – besoin)/besoin

Failure to test: The reference failure is not a vague “broken component.” For “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, test in particular deficiency, crop loss, degraded pharmacy, uncertain diagnosis or unavailable medical resource. 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”. The English text remains fully equivalent while large translated illustrations are intentionally deferred until their dedicated artwork is supplied. For “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, 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 : consumable endurance can be estimated as stock divided by use; margin compares stock with requirement.

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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth” combines quantities that do not all have the same evidence status. For “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, 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

240 doses / 2 doses/day = 120 days if use were constant

150 required, 210 available → $(210-150)/150 = 40\%$ margin

12 min one way + 12 min back = at least 24 min for one simple exchange, excluding human response time

1. 1. Medication 240 doses / 2 doses/day = 120 days if use were constant Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”.

2. 2. Consumable margin 150 required, 210 available → $(210-150)/150 = 40\%$ margin Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”.

3. 3. Consult delay 12 min one way + 12 min back = at least 24 min for one simple exchange, excluding human response time Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”.

Operational table

Phenomena / sections: 3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation

Relationship to revisit: autonomie = stock / consommation ; marge = (stock – besoin)/besoin

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 “autonomie = stock / consommation ; marge = (stock – besoin)/besoin” does not by itself contain all of “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”. 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 240 doses / 2 doses/day = 120 days if use were constant therefore remains a local calculation rather than a complete architecture.

To make the model useful, explicitly add the quantities that dominate this subject: energy intake, protein, micronutrients, stored mass, crop yield, medical parameters and care time. We can then ask which variation truly changes the result, which is negligible and which forces an architectural change. For “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, this model limitation states exactly what a correct calculation still cannot establish about the real system.

7 — Instrumentation, observability and data quality

For “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, observability relies on energy intake, protein, micronutrients, stored mass, crop yield, medical parameters and care time. 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, test in particular deficiency, crop loss, degraded pharmacy, uncertain diagnosis or unavailable medical resource. 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, the degraded mode is defined around the minimum function specific

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:	autonomie = stock / consommation ; marge = (stock – besoin)/besoin
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

The reference case is selected from ECLSS, NASA-STD-3001 or human-analog evidence according to the topic. The goal is not to copy the ISS onto Mars, but to identify what has been demonstrated, what is environment-dependent and what still requires qualification for a mission without rapid resupply.

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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth” does not maximize one metric. Compare nominal performance, mass, energy, simplicity, maintenance, crew time, common dependencies and recoverability. An option that improves 150 required, 210 available → $(210-150)/150 = 40\%$ margin 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth” combines storage tests, controlled plant growth, medical simulations and rationing scenarios. 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, demonstration must reproduce the constraints that make this phenomenon difficult; a spectacular test outside the mission domain is insufficient.

Operational table

Phenomena / sections:	9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria
Relationship to revisit:	autonomie = stock / consommation ; marge = (stock – besoin)/besoin
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.

Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth**12 — Decision exercise**

Situation: revisit “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable.

Situation: revisit “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth” 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 “Autonomous medicine: diagnostics, pharmacy, treatment and decisions far from Earth”, 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 — NASA-STD-3001 Health and Medical Care - <https://www.nasa.gov/reference/3-0-health-and-medical-care/>

NASA — Spaceflight Human-System Standard, Volume 2 - <https://www.nasa.gov/reference/nasa-std-3001v2/>

NASA — CHAPEA Mission 2 - <https://www.nasa.gov/humans-in-space/chapea/chapea-mission-2/>

Operational table

Phenomena / sections:	12 — Decision exercise ; 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources
Relationship to revisit:	$\text{autonomie} = \text{stock} / \text{consommation}$; $\text{marge} = (\text{stock} - \text{besoin}) / \text{besoin}$
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 12 — Decision exercise ; 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources. State one measured quantity, one margin and one possible decision.