Final mission: grow the settlement for 500 sols despite failures

Guiding question

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

Course map

Mission brief → System map → Data and assumptions → Governing relationship → Starting calculations

1 — Mission brief

Build a growth plan that closes mass, power, maintenance, logistics, human and safety budgets.
This capstone mission requires several modules at once. An answer is complete only when it closes physical budgets, describes sensors and actions, retains margin, handles a credible failure and explains what the crew must do. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

2 — System map

Start by drawing mass, energy, information and authority flows. An arrow without a unit or owner is incomplete. The map is then used to identify common dependencies and interfaces that can propagate failure. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».
A 500-sol settlement is managed as a portfolio of capabilities rather than a list of construction projects. Power, water, pressurized volume, maintenance, mobility and spares must grow in a compatible order. Adding a habitat without expanding selected utilities can reduce overall resilience. The student therefore builds a campaign-by-campaign capability map and identifies resources that become bottlenecks as population or production grows.

Equation - evidence - decision

capacité_finale = capacité_initiale + ajouts - indisponibilités

Failure to test: Check air, water, thermal control, radiation, food, medicine and workload where relevant to this mission. The goal is to avoid a false “all good” technical calculation that forgets sleep time, suit donning or the need for a second crewmember during a critical operation. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

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3 — Data and assumptions

The supplied numbers are training-scenario data. Copy them with units, add missing assumptions and separately mark values that come from NASA sources. Any value that changes the verdict requires sensitivity analysis. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

Growth assumptions are tested across several horizons. Processing 70,000 kg over 500 sols does not prove the industrial chain can run continuously. The student introduces maintenance, planned outages, failures and demand variation, distinguishing nominal, sustainable and emergency capacity. A production target requiring 100% hardware utilization leaves no room to recover from anomalies.

4 — Governing relationship

The equation is only an entry point. It must be connected to a budget, an available measurement and a decision threshold. If units do not reduce correctly, stop before using a calculator. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

5 — Starting calculations

Puissance 60 kW + 35 kW - 12 kW indisponibles = 83 kW Interpret the result inside the global budget before making a decision.

Eau 140 kg/j × 500 sols = 70 000 kg processed Interpret the result inside the global budget before making a decision.

Maintenance 9 h/sem × 71 sem ≈ 639 h Interpret the result inside the global budget before making a decision.

6 — Mass, power and time budget

Build three separate tables. The mass budget distinguishes structure, consumables, spares and margin. The energy budget separates instantaneous power from accumulated energy. The time budget includes operations, maintenance, rest and communications delay. Positive margin in one table does not automatically compensate for a deficit in another. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

Operational table

Phenomena / sections:	3 — Data and assumptions ; 4 — Governing relationship ; 5 — Starting calculations
Relationship to revisit:	capacité_finale = capacité_initiale + ajouts - indisponibilités
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 3 — Data and assumptions ; 4 — Governing relationship ; 5 — Starting calculations. State one measured quantity, one margin and one possible decision.

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The 83 kW network after an asset loss must be compared with actual prioritized loads. The student defines service levels: survival, minimum operations, normal production and expansion. A new expansion begins only when the base can return to the previous level after a single failure. This prevents growth from gradually consuming every margin until the first major incident.

7 — Navigation, communications and state knowledge

State which variables must be known locally, which can be reconstructed later by Earth, and what accuracy each decision requires. Radio delay means safing and initial diagnosis must be possible without waiting for Earth. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

Long-term state knowledge uses reliability trends. Failure counts, repair time, spare consumption, performance drift and recurring anomalies influence the next campaign. The student therefore does not rely on one global availability number; subsystems that consume disproportionate crew hours or create common dependencies across modules are identified explicitly.

8 — Survival and human factors

Check air, water, thermal control, radiation, food, medicine and workload where relevant to this mission. The goal is to avoid a false “all good” technical calculation that forgets sleep time, suit donning or the need for a second crewmember during a critical operation. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

Human organization changes with settlement size. More hardware means more procedures, responsibilities and configuration decisions. The growth plan includes cross-training, handovers, maintenance time and change authority. A larger base understood by only one expert per system can be less resilient than a smaller base with distributed competence.

9 — Mission-specific injected incident

Operational table

Phenomena / sections:	7 — Navigation, communications and state knowledge ; 8 — Survival and human factors ; 9 — Mission-specific injected incident
Relationship to revisit:	capacité_finale = capacité_initiale + ajouts - indisponibilités
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 7 — Navigation, communications and state knowledge ; 8 — Survival and human factors ; 9 — Mission-specific injected incident. State one measured quantity, one margin and one possible decision.

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On sol 320, two major assets become unavailable while habitat expansion is underway; the growth plan must be rebaselined without eroding survival reserves or maintenance capacity. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

For AM-16.12, the answer must show which quantities in “Final mission: grow the settlement for 500 sols despite failures” are recomputed, which assumptions cease to be valid and which action remains reversible before consuming an irreversible reserve.

On sol 320 two major assets become unavailable during an expansion. The student freezes nonessential changes, reconstructs actual remaining capability and decides whether to finish, safe or temporarily abandon the work. Already spent resources do not justify continuing through sunk-cost bias. The decision compares the risk of leaving the extension incomplete with the risk of consuming the existing base's final margins.

10 — Decision and justification

End with an explicit decision: continue, delay, reconfigure, abandon an activity or enter refuge mode. Cite the three quantities controlling that decision and the remaining margin. A conclusion without a numerical or operational criterion is an opinion, not an engineering decision. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

The final dossier shows the base at sols 0, 100, 250 and 500 using the same indicators: firm power, water, refuge volume, critical inventory, maintenance capacity, mobility and open anomalies. A decision register records architecture changes. The capstone goal is to show that a robust settlement is not merely larger; it preserves margin, competence and recovery paths as it grows.

11 — Required deliverables

Operational table

Phenomena / sections:	; 10 — Decision and justification ; 11 — Required deliverables
Relationship to revisit:	capacité_finale = capacité_initiale + ajouts - indisponibilités
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: ; 10 — Decision and justification ; 11 — Required deliverables. State one measured quantity, one margin and one possible decision.

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12 — Assessment rubric

40%: calculation and unit consistency; 20%: interface treatment; 15%: margins and degraded mode; 15%: human factors and procedure; 10%: source quality and separation of data, assumptions and scenarios. For this mission, the criterion is applied explicitly to « Final mission: grow the settlement for 500 sols despite failures ».

13 — Reference sources

Topic-specific primary sources

NASA — Systems Engineering Handbook - https://www.nasa.gov/reference/systems-engineering-handbook/

NASA NTRS — Current NASA Plans for Mars In-Situ Resource Utilization - https://ntrs.nasa.gov/citations/20180002086

NASA-STD-8729.1A — Reliability and Maintainability Standard - https://standards.nasa.gov/standard/NASA/NASA-STD-87291

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

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

Operational table

Phenomena / sections:	12 — Assessment rubric ; 13 — Reference sources ; Topic-specific primary sources
Relationship to revisit:	capacité_finale = capacité_initiale + ajouts - indisponibilités
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 12 — Assessment rubric ; 13 — Reference sources ; Topic-specific primary sources. State one measured quantity, one margin and one possible decision.