Water–oxygen–power campaign: operate a small industrial plant

Guiding question

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

Course map

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

1 — Mission brief

Connect ice extraction, purification, electrolysis, storage and power with maintenance.
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 « Water–oxygen–power campaign: operate a small industrial plant ».

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 « Water–oxygen–power campaign: operate a small industrial plant ».
The water–oxygen–power plant is a process chain. Extraction is useless if purification sets a lower throughput; purification is useless if storage is saturated; electrolysis cannot operate when energy is unavailable. The map therefore shows intermediate inventories and maximum capacities at each stage. Overall output is set by the bottleneck, not by the fastest machine considered in isolation.

Equation - evidence - decision

m_produit = débit × temps × rendement

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 « Water–oxygen–power campaign: operate a small industrial plant ».

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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 « Water–oxygen–power campaign: operate a small industrial plant ».

Ice-quality assumptions matter. A gross extraction rate of 120 kg/day does not automatically become 120 kg/day of usable water. The student distinguishes excavated mass, recoverable fraction, purification losses and quality required for each use. Water for electrolysis, drinking and cleaning may require different controls, and rejects must remain in the mass balance rather than disappearing mathematically.

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 « Water–oxygen–power campaign: operate a small industrial plant ».

5 — Starting calculations

Eau nette 120 kg/j × 0,85 = 102 kg/j Interpret the result inside the global budget before making a decision.

Oxygène scénario 20 kg water × 0,888 ≈ 17,8 kg O_2 theoretical before losses Interpret the result inside the global budget before making a decision.

Énergie 45 kW × 8 h = 360 kWh 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 « Water–oxygen–power campaign: operate a small industrial plant ».

Operational table

Phenomena / sections:	3 — Data and assumptions ; 4 — Governing relationship ; 5 — Starting calculations
Relationship to revisit:	m_produit = débit × temps × rendement
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 energy budget is scheduled by operating window. A 45 kW load for eight hours represents 360 kWh, but production may be shifted if solar generation, storage or other base loads change. The student creates an operating schedule that protects vital functions, avoids simultaneous peaks and uses water or oxygen storage as operational buffers.

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 « Water–oxygen–power campaign: operate a small industrial plant ».

Product quality is a state variable just like flow rate. Conductivity, contamination, pressure, temperature or purity are measured at defined points in the chain. The student states which measurements permit transfer into clean storage, which cause recirculation and which require shutdown. This prevents a bad batch or failed sensor from propagating contamination through the entire plant.

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 « Water–oxygen–power campaign: operate a small industrial plant ».

Maintenance is built into industrial cadence. Filters, seals, pumps and dust-exposed surfaces do not have infinite availability. The plan reserves hours, spares and buffer inventory so that one line can stop without immediately removing a life-critical resource. Autonomy is as much the ability to stop production safely as the ability to reach high nominal throughput.

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:	m_produit = débit × temps × rendement
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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Extracted ice contains more impurities than expected and purification flow falls; oxygen production and water storage must be replanned against available power. For this mission, the criterion is applied explicitly to « Water–oxygen–power campaign: operate a small industrial plant ».

For AM-16.06, the answer must show which quantities in “Water–oxygen–power campaign: operate a small industrial plant” are recomputed, which assumptions cease to be valid and which action remains reversible before consuming an irreversible reserve.

When impurities reduce purification throughput, the first step is to measure the new bottleneck. The student may reduce extraction, extend processing time, activate a second train or draw from buffer storage. Each response must protect water and oxygen margin while respecting available power. The plan states the threshold at which non-vital industrial production is stopped.

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 « Water–oxygen–power campaign: operate a small industrial plant ».

The final deliverable is a multi-sol production table: incoming material, qualified water, oxygen output, energy used, safety inventory and maintenance hours. An 'unexplained' column should remain zero or be justified. This discipline converts a process demonstration into industrial operations in which every kilogram and kilowatt-hour has a traceable destination.

11 — Required deliverables

Operational table

Phenomena / sections:	; 10 — Decision and justification ; 11 — Required deliverables
Relationship to revisit:	m_produit = débit × temps × rendement
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 « Water–oxygen–power campaign: operate a small industrial plant ».

13 — Reference sources

Topic-specific primary sources

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

NASA NTRS — Integration of ISRU into Lunar/Mars Exploration - https://ntrs.nasa.gov/citations/20100021362

NASA NTRS — Advanced Exploration Systems Life Support Systems Project Overview - https://ntrs.nasa.gov/citations/20210015025

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

Operational table

Phenomena / sections:	12 — Assessment rubric ; 13 — Reference sources ; Topic-specific primary sources
Relationship to revisit:	m_produit = débit × temps × rendement
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.