Crewed transit: close air, water, power and maintenance budgets

Guiding question

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

Course map

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

1 — Mission brief

Verify that life-support loops can sustain the transit duration with failures and 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 « Crewed transit: close air, water, power and maintenance budgets ».

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 « Crewed transit: close air, water, power and maintenance budgets ».
During crewed transit, water, energy and maintenance form a coupled system. Degraded water recovery increases makeup drawn from storage; an intermittent pump increases maintenance demand; extra interventions can disturb sleep and crew availability. The student therefore represents these cross-effects instead of treating three budgets independently.
The degraded mode succeeds only if it remains sustainable until repair or redundant hardware restores capability.

Equation - evidence - decision

stock_net = besoin × durée × (1 - récupération)

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 « Crewed transit: close air, water, power and maintenance budgets ».

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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 « Crewed transit: close air, water, power and maintenance budgets ».

Scenario inputs must be converted into trends. A daily use rate or recovery loss is useful only when it supports an estimate of time to threshold. The student calculates nominal, degraded and pessimistic horizons and distinguishes water physically present from water actually accessible, because contamination, a stuck valve or an isolated tank can make part of the inventory unavailable.

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 « Crewed transit: close air, water, power and maintenance budgets ».

5 — Starting calculations

Perte eau scénario 24 L/j × 180 j × 0,02 = 86,4 L Interpret the result inside the global budget before making a decision.

Énergie ECLSS 3,8 kW × 24 h = 91,2 kWh/j Interpret the result inside the global budget before making a decision.

Temps maintenance 2,5 h/sem × 26 sem = 65 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 « Crewed transit: close air, water, power and maintenance budgets ».

Operational table

Phenomena / sections:	3 — Data and assumptions ; 4 — Governing relationship ; 5 — Starting calculations
Relationship to revisit:	stock_net = besoin × durée × (1 - récupération)
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 separates instantaneous power from daily energy. Running 3.8 kW for 24 hours gives a daily energy requirement but does not prove that peak power can be supplied. The student identifies simultaneous equipment, shed-able loads and functions that cannot be interrupted, such as critical ventilation, computing, thermal control or medical support.

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 « Crewed transit: close air, water, power and maintenance budgets ».

State monitoring relies on measurements that can be cross-checked: flow, pressure, humidity, conductivity, motor current, temperature and inventory consumption. An intermittent pump may be detected before total failure if trends are observed. The course asks which variables should trigger alarms, which support diagnosis and which are mainly useful for later analysis on Earth.

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 « Crewed transit: close air, water, power and maintenance budgets ».

Human time is also a limited resource. Sixty-five planned maintenance hours cannot simply be added to the crew schedule without checking rest periods, science and critical operations. The student builds a crew-hour budget and defines a threshold at which technical degradation also becomes a human-performance risk. Keeping hardware alive by creating chronic fatigue is not a stable solution.

Operational table

Phenomena / sections:	7 — Navigation, communications and state knowledge ; 8 — Survival and human factors
Relationship to revisit:	stock_net = besoin × durée × (1 - récupération)
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. State one measured quantity, one margin and one possible decision.

Crewed transit: close air, water, power and maintenance budgets

9 — Mission-specific injected incident

On transit day 95, water recovery drops and a pump becomes intermittent; makeup water, maintenance effort and allowable repair delay must be recomputed. For this mission, the criterion is applied explicitly to « Crewed transit: close air, water, power and maintenance budgets ».

For AM-16.03, the answer must show which quantities in "Crewed transit: close air, water, power and maintenance budgets" are recomputed, which assumptions cease to be valid and which action remains reversible before consuming an irreversible reserve.

When water recovery drops on transit day 95, the decision must occur before storage reaches a critical threshold. The student compares at least three responses: increase makeup, temporarily reduce selected uses, and repair or transfer to a redundant chain. Each option costs different amounts of water, power, crew time and risk. The selected strategy states remaining margin and the condition that would force another change.

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 « Crewed transit: close air, water, power and maintenance budgets ».

The final dossier includes a 180-day timeline with checkpoints. At each checkpoint the student records water inventory, available energy, accumulated maintenance and open anomalies. The timeline exposes slow drift before it becomes an emergency and demonstrates why interplanetary survival depends on observation and maintainability as much as nominal hardware performance.

Operational table

Phenomena / sections:	9 — Mission-specific injected incident ; ; 10 — Decision and justification
Relationship to revisit:	stock_net = besoin × durée × (1 - récupération)
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 9 — Mission-specific injected incident ; ; 10 — Decision and justification. State one measured quantity, one margin and one possible decision.

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11 — Required deliverables

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 « Crewed transit: close air, water, power and maintenance budgets ».

13 — Reference sources

Topic-specific primary sources

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

NASA — ISS Water Recovery Milestone - https://www.nasa.gov/missions/station/iss-research/nasa-achieves-water-recovery-milestone-on-international-space-station/

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

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

Operational table

Phenomena / sections:	11 — Required deliverables ; 12 — Assessment rubric ; 13 — Reference sources
Relationship to revisit:	stock_net = besoin × durée × (1 - récupération)
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 11 — Required deliverables ; 12 — Assessment rubric ; 13 — Reference sources. State one measured quantity, one margin and one possible decision.