Failure with no spare: manufacture, inspect and requalify a local part

Guiding question

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

Course map

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

1 — Mission brief

Decide whether a Mars-made part can return to critical service.
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 « Failure with no spare: manufacture, inspect and requalify a local part ».

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 « Failure with no spare: manufacture, inspect and requalify a local part ».
Local manufacture of a critical part begins with functional requirements, not the printer. The student defines loads, interfaces, temperature, possible sealing requirements, service duration and consequences of failure. This dossier determines which characteristics must be reproduced and which may be changed. Copying only Earth geometry without understanding function can produce a dimensionally correct part that is mechanically unacceptable.

Equation - evidence - decision

marge = limite_admissible - charge_max

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 « Failure with no spare: manufacture, inspect and requalify a local part ».

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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 « Failure with no spare: manufacture, inspect and requalify a local part ».

Manufacturing data include feedstock, process history, build orientation, machine parameters and lot identity. Fifteen percent extra material does not compensate for uncertain properties. The student separates mass margin from strength margin, then selects coupons or specimens that verify the process before the critical part is loaded. Traceability becomes part of the manufactured object.

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 « Failure with no spare: manufacture, inspect and requalify a local part ».

5 — Starting calculations

Marge mécanique 18 kN - 12 kN = 6 kN Interpret the result inside the global budget before making a decision.

Temps fabrication 7 h + 3 h inspection + 2 h test = 12 h Interpret the result inside the global budget before making a decision.

Matière 4,8 kg × 1,15 = 5,52 kg with 15% material margin Interpret the result inside the global budget before making a decision.

6 — Mass, power and time budget

Operational table

Phenomena / sections:	3 — Data and assumptions ; 4 — Governing relationship ; 5 — Starting calculations
Relationship to revisit:	marge = limite_admissible - charge_max
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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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 « Failure with no spare: manufacture, inspect and requalify a local part ».

Inspection combines several levels. Dimensional measurement, surface examination, available nondestructive evaluation and functional testing detect different defects. The student builds an evidence chain that matches Martian equipment. If a control method normally available on Earth is missing, the allowed operating envelope must shrink, testing must increase, or the part may simply be unqualifiable for that function.

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 « Failure with no spare: manufacture, inspect and requalify a local part ».

The scenario's 18 kN minus 12 kN gives a 6 kN load margin, but it must be tied to a defined load case and safety factor. The student also checks failure modes not represented by maximum load: fatigue, wear, temperature, buckling, leakage or local defects. A part can pass one static proof test and still be unsuitable for hundreds of cycles.

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 « Failure with no spare: manufacture, inspect and requalify a local part ».

Operational table

Phenomena / sections:	7 — Navigation, communications and state knowledge ; 8 — Survival and human factors
Relationship to revisit:	marge = limite_admissible - charge_max
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.

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The twelve-hour fabrication-and-test duration belongs in the operational timeline. Manufacturing, inspection and proof testing consume machines, energy and people, and a second attempt may be necessary. The student compares this duration with how long the failed system can remain in degraded mode. Technical manufacturability does not guarantee the repair arrives before operational margin is exhausted.

9 — Mission-specific injected incident

The locally manufactured critical part passes dimensional inspection but material properties show dispersion; the student must choose a proof test, load limit and in-service monitoring period. For this mission, the criterion is applied explicitly to « Failure with no spare: manufacture, inspect and requalify a local part ».

For AM-16.10, the answer must show which quantities in “Failure with no spare: manufacture, inspect and requalify a local part” are recomputed, which assumptions cease to be valid and which action remains reversible before consuming an irreversible reserve.

If measured material properties are dispersed, the student does not select the best value. The cause is investigated, sampling expanded, process modified or allowable load reduced. Conditional requalification states operating limits, authorized duration and additional inspections. This turns local printing into an engineering process rather than an improvised replacement.

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 « Failure with no spare: manufacture, inspect and requalify a local part ».

Operational table

Phenomena / sections:	9 — Mission-specific injected incident ; ; 10 — Decision and justification
Relationship to revisit:	marge = limite_admissible - charge_max
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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The final dossier preserves the exact part configuration, material data, inspection results, proof evidence, limits and authority that accepted its use. A later revision receives a different identifier. This discipline lets the base learn from repairs instead of accumulating 'almost identical' parts whose history is no longer known.

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 « Failure with no spare: manufacture, inspect and requalify a local part ».

13 — Reference sources

Topic-specific primary sources

NASA TechPort — In-Space Manufacturing Portfolio - https://techport.nasa.gov/projects/11874

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

NASA NTRS — NASA Methodology for Physics-of-Failure-Based Reliability - https://ntrs.nasa.gov/citations/20230004376

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

Operational table

Phenomena / sections:	11 — Required deliverables ; 12 — Assessment rubric ; 13 — Reference sources
Relationship to revisit:	marge = limite_admissible - charge_max
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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.