

Mars logistics, inventory, spares and critical stock

Manage shortages before they occur: consumption, spare parts, traceability, packaging, stock levels, obsolescence and resupply decisions under interplanetary delay.

Before you begin — Prerequisites: modules 00–34 as relevant. Every important symbol is defined at first use.

Mastery objectives

- connect principles to architecture or operational decisions
- repeat simple calculations and verify units and assumptions
- identify degraded modes, interfaces and uncertainty
- produce a verifiable procedure or plan

1. On Mars inventory is a survival system

An item that exists but cannot be found is almost equivalent to an item that is absent. Every critical consumable and spare needs identity, quantity, location, condition, expiration where relevant and compatibility. The base must know not only what it owns but what is actually usable.

2. Predictable consumption and unpredictable failures

Drinking-water treatment consumables or routine filters have relatively predictable usage. Failures of boards, motors or valves are probabilistic. Logistics must combine deterministic consumption forecasts with probabilistic spare requirements.

3. Reorder points under interplanetary delay

On Earth an order may arrive in days. On Mars a resupply opportunity can depend on a launch window and months of transit. Reorder thresholds must include consumption during lead time, variability, margin and the possibility that the next cargo mission is lost.

4. Commonality and standardization

Two systems using the same fan, bearing or connector reduce the number of stock items. Standardization can also create common-mode failure. Useful commonality must therefore be balanced against the risk that one defect affects the entire fleet.

5. Packaging, volume and second life

Packaging consumes launch volume and later becomes waste or material. Containers designed for reuse as furniture, radiation shielding, storage or feedstock reduce functionally lost mass.

6. Obsolescence and configuration

A physically compatible part may be incompatible with software or a later system revision. Inventory must preserve versions, batches, serial numbers and configuration history. Logistics therefore becomes part of configuration management.

7. Classifying items by criticality and recovery time

Two parts with the same mass may require completely different logistics policies. A unique life-support pump and a standard computing tablet do not have the same stockout consequence or recovery time. Classification should combine functional criticality, probability of demand, time required to repair or manufacture, resupply delay from Earth and the existence of substitutes. Items capable of stopping a life-critical function form a special class whose inventory thresholds must remain visible to operations. This prioritization prevents mass from being wasted on easy-to-replace items while a lightweight but irreplaceable component is underprotected.

8. Packaging, storage and ageing: a spare can fail without ever being used

Stored hardware is not physically static. Polymers, batteries, lubricants, seals, medicines and some electronic components age. Dust, thermal cycles, controlled habitat humidity and radiation can affect shelf life. Inventory records therefore need lot, date, storage conditions, expiry or service life, periodic inspection and exact location. Sensitive items may require rotation so older stock is used first and replaced by later logistics deliveries. An autonomous base must know not only what it owns, but whether each resource remains genuinely usable.

9. Obsolescence and configuration: knowing which part fits which version

A fleet that evolves for ten years will not remain perfectly homogeneous. A converter, circuit board or seal may exist in several revisions that are not interchangeable. Inventory must therefore be linked to actual equipment configuration: serial number, hardware revision, firmware, compatibility and local modification history. Parts commonality is powerful only when it is real. When a new revision replaces an older one, the crew must decide whether existing stock remains usable, requires requalification or has become obsolete. Logistics therefore connects directly to configuration management.

10. Worked example: reorder point

A filter is consumed at 2 units/month. Reliable resupply is estimated 10 months after the decision and the base requires a margin of 6 units. A simple reorder point is $2 \times 10 + 6 = 26$ filters. If stock falls to 25, the decision is already late under this model.

Deeper engineering: calculate spares under a Martian recovery delay

An Earth reorder point usually assumes a supplier can replenish inventory within a known lead time. Mars adds a discontinuity: a part requested today may have to wait for a launch opportunity, interplanetary transit, unloading and local qualification. For some items the real recovery time can therefore be hundreds of days. NASA studies of supportability and long-duration logistics address exactly this problem of mass, spares and maintenance far from Earth. [NASA NTRS — Spares Logistics](#)

Worked example. A critical filter is consumed on average every 18 days. The team adopts a conservative 420-day recovery time between the replenishment decision and actual local availability. Mean demand during that interval is $420 \div 18 \approx 23.3$ filters. Adding a safety stock of eight filters for variability, loss and degradation gives a reorder point of about $23.3 + 8 = 31.3$, rounded to 32 filters. Waiting until only five remain would already be far too late.

The simple calculation assumes regular consumption. A real policy must distinguish consumables, randomly failing parts, repairable items and components the local workshop can manufacture. A heavy part that can be printed on Mars may have less logistics value than a tiny sensor that cannot be produced locally. Inventory records therefore need criticality, recovery time, substitution options, configuration compatibility and local manufacturing capability. [NASA NTRS — Logistics Reduction Technologies](#)

11. Progressive exercise

For five components with different failure rates, decide which deserve a complete spare, a repair kit or only local-manufacturing drawings. Justify the choices using mass, criticality and lead time.

Reasoned correction

The prompt does not supply the five failure rates or masses, so there is no unique numerical ranking. A correct solution first builds a table containing mission failure probability, consequence of loss, spare mass, repair time, resupply delay and local manufacturability. As an example, a light controller whose loss stops ECLSS deserves a complete spare; a heavy but serviceable pump may justify seals, bearings and a motor as a repair kit; a non-critical metal bracket that can be measured and machined locally may require only qualified drawings and feedstock. A rare mission-killing failure can therefore rank above a frequent failure with an easy workaround.

Mini-project

Build a 200-item base inventory: criticality, consumption, reorder threshold, common parts, expiration, local manufacturing, storage and periodic physical audit.

On Mars, inventory is stored time: every spare part is a decision made before the failure

Logistics on Mars is governed by delay. A missing filter, seal, bearing or reagent cannot usually be replaced by placing an order for next-day delivery. The settlement must survive until the next feasible shipment or create a substitute locally. Inventory is therefore not warehouse administration; it is a physical buffer against the interplanetary supply chain.

Not all stock behaves the same way. Food portions, cleaning chemicals and filters can have relatively predictable consumption. Pumps, electronic modules and pressure regulators fail stochastically. Some parts age on the shelf through battery degradation, lubricant separation, seal hardening, corrosion or expiry of sterile packaging. A useful inventory model separates consumption, failure probability, lead time, shelf life, commonality and consequence of stockout.

Standardization is a powerful logistics tool. If ten systems use the same qualified valve, one spare pool can support all ten. If each system uses a unique valve, every interface demands its own stock. Yet commonality also creates common-cause risk: a manufacturing defect in one shared part family can affect many systems. Standardization must therefore be paired with batch traceability and, for the most critical functions, consideration of diverse alternatives.

Configuration control is inseparable from inventory. A physical spare may fit mechanically while being incompatible with the installed software, connector revision or pressure rating. The store must know not only “how many valves” but exactly which part number, revision, approved substitutes and system configurations each item supports.

Four logistics ideas that determine whether a stockpile is actually useful

Criticality

Criticality describes the consequence if an item is unavailable when needed. A low-cost O-ring can be more critical than an expensive scientific instrument if its absence disables a life-support function.

Lead time

Lead time is the interval between recognizing a need and having a usable replacement in hand. On Mars it can include waiting for a launch window, transit, landing, inspection and local transport.

Commonality

Commonality is the deliberate use of the same part, tool, interface or consumable across multiple systems. It can reduce spare diversity and training burden while increasing dependence on a shared design.

Approved substitution

A substitute is not merely something that seems to fit. Approved substitution records the conditions under which another part or material is technically compatible, qualified and safe for a specific function.

Calculation laboratory

Formula 1 — reorder point for a predictable consumable

Canonical quantitative mini-lessons

This block is the module quantitative reference; exercise values are pedagogical and must be replaced by mission data before any real decision.

Reorder point

$$R_{\text{order}} = d_{\text{use}} \times L_{\text{lead}} + S_{\text{safety}}$$

1 — Concrete question

What does “ $R_{\text{order}} = d_{\text{use}} \times L_{\text{lead}} + S_{\text{safety}}$ ” compute in “Reorder point”?

2 — Intuition without symbols

The reorder point must cover expected use during lead time plus an explicit reserve.

3 — Quantities

R_{order} : inventory level that triggers replenishment [unité de stock]; d_{use} : average consumption [unité/j];

L_{lead} : replenishment lead time [j]; S_{safety} : safety stock [unité]

4 — Formula

$$R_{\text{order}} = d_{\text{use}} \times L_{\text{lead}} + S_{\text{safety}}$$

5 — Read aloud

Read “ $R_{\text{order}} = d_{\text{use}} \times L_{\text{lead}} + S_{\text{safety}}$ ” by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

R_{order} : inventory level that triggers replenishment [unité de stock]; d_{use} : average consumption [unité/j];

L_{lead} : replenishment lead time [j]; S_{safety} : safety stock [unité]

7 — Pronunciation

Say subscripts, powers, parentheses and Greek letters explicitly so the relation can be reconstructed without seeing the page.

8 — Units

R_{order} [unité de stock]; d_{use} [unité/j]; L_{lead} [j]; S_{safety} [unité]

9 — Convention

Keep the same frame, time basis, system boundary and sign convention throughout the substitution.

10 — Why this operation

The relation turns the system mechanism into a quantity that can be checked by numerical substitution.

11 — Assumptions

All inputs must be coherent in unit, frame, duration and scenario.

12 — Independent check

A second method or inverse relation should recover the same order of magnitude.

13 — Numerical case

With $d_{\text{use}} = 2$ unité/j, $L_{\text{lead}} = 10$ j, $S_{\text{safety}} = 6$ unité: $R_{\text{order}} = 2 \times 10 + 6 = 26$ unités.

14 — Why the calculation works

The relation turns the system mechanism into a quantity that can be checked by numerical substitution.

15 — Verification

A second method or inverse relation should recover the same order of magnitude.

16 — Mental estimate

Estimating before calculation helps detect sign, unit or factor errors.

17 — Interpretation

Trigger before crossing this level, not when inventory merely looks almost empty.

18 — What the result does not prove

The calculation proves neither that inputs are exact nor that the model remains valid outside the declared scenario; both require separate evidence.

19 — Sensitivity

Varying one input at a time reveals which variable drives the decision most strongly.

20 — Guided and autonomous exercises

Guided exercise. Recalculate this scenario: With $d_{\text{use}} = 2.5 \text{ unité/j}$, $L_{\text{lead}} = 180 \text{ j}$, $S_{\text{safety}} = 90 \text{ unité}$:
 $R_{\text{order}} = 2.5 \times 180 + 90$?

Detailed guided correction — open after trying

With $d_{\text{use}} = 2.5 \text{ unité/j}$, $L_{\text{lead}} = 180 \text{ j}$, $S_{\text{safety}} = 90 \text{ unité}$: $R_{\text{order}} = 2.5 \times 180 + 90 = 540 \text{ unités}$. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $d_{\text{use}} = 1.8 \text{ unité/j}$, $L_{\text{lead}} = 210 \text{ j}$, $S_{\text{safety}} = 100 \text{ unité}$: $R_{\text{order}} = 1.8 \times 210 + 100$?

Autonomous correction — open after trying

With $d_{\text{use}} = 1.8 \text{ unité/j}$, $L_{\text{lead}} = 210 \text{ j}$, $S_{\text{safety}} = 100 \text{ unité}$: $R_{\text{order}} = 1.8 \times 210 + 100 = 478 \text{ unités}$. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

Trigger before crossing this level, not when inventory merely looks almost empty.

Days of cover

$$D_{\text{cover}} = Q_{\text{stock}} / d_{\text{use}}$$

1 — Concrete question

What does “ $D_{\text{cover}} = Q_{\text{stock}} / d_{\text{use}}$ ” compute in “Days of cover”?

2 — Intuition without symbols

Coverage translates stock into operational time at the assumed usage rate.

3 — Quantities

D_{cover} : duration covered by stock [j]; Q_{stock} : available stock [unité]; d_{use} : average consumption [unité/j]

4 — Formula

$$D_{\text{cover}} = Q_{\text{stock}} / d_{\text{use}}$$

5 — Read aloud

Read “ $D_{\text{cover}} = Q_{\text{stock}} / d_{\text{use}}$ ” by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

D_{cover} : duration covered by stock [j]; Q_{stock} : available stock [unité]; d_{use} : average consumption [unité/j]

7 — Pronunciation

Say subscripts, powers, parentheses and Greek letters explicitly so the relation can be reconstructed without seeing the page.

8 — Units

D_{cover} [j]; Q_{stock} [unité]; d_{use} [unité/j]

9 — Convention

Keep the same frame, time basis, system boundary and sign convention throughout the substitution.

10 — Why this operation

Division relates a quantity to a coherent capacity, duration or reference.

11 — Assumptions

Numerator and denominator must describe the same scenario and the denominator must remain positive.

12 — Independent check

Multiplying the result by the denominator should reconstruct the numerator.

13 — Numerical case

With $Q_{\text{stock}} = 360$ unité, $d_{\text{use}} = 2.5$ unité/j: $D_{\text{cover}} = 360 / 2.5 = 144$ j.

14 — Why the calculation works

Division relates a quantity to a coherent capacity, duration or reference.

15 — Verification

Multiplying the result by the denominator should reconstruct the numerator.

16 — Mental estimate

Comparing numerator and denominator scales predicts the result.

17 — Interpretation

Compare coverage with the next credible replenishment and retain margin.

18 — What the result does not prove

The calculation proves neither that inputs are exact nor that the model remains valid outside the declared scenario; both require separate evidence.

19 — Sensitivity

The result rises with the numerator and falls as the denominator rises.

20 — Guided and autonomous exercises

Guided exercise. Recalculate this scenario: With $Q_{\text{stock}} = 525$ unité, $d_{\text{use}} = 3$ unité/j: $D_{\text{cover}} = 525 / 3$?

Detailed guided correction — open after trying

With $Q_{\text{stock}} = 525$ unité, $d_{\text{use}} = 3$ unité/j: $D_{\text{cover}} = 525 / 3 = 175$ j. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $Q_{\text{stock}} = 96$ unité, $d_{\text{use}} = 1.2$ unité/j: $D_{\text{cover}} = 96 / 1.2$?

Autonomous correction — open after trying

With $Q_{\text{stock}} = 96$ unité, $d_{\text{use}} = 1.2$ unité/j: $D_{\text{cover}} = 96 / 1.2 = 80$ j. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

Compare coverage with the next credible replenishment and retain margin.

Margin above reserved stock

$$M_{\text{stock}} = Q_{\text{stock}} - Q_{\text{reserve}}$$

1 — Concrete question

What does " $M_{\text{stock}} = Q_{\text{stock}} - Q_{\text{reserve}}$ " compute in "Margin above reserved stock"?

2 — Intuition without symbols

Total inventory can look comfortable even when part of it is already committed to a critical scenario.

3 — Quantities

M_{stock} : truly uncommitted stock [unité]; Q_{stock} : total available stock [unité]; Q_{reserve} : stock reserved for critical scenarios [unité]

4 — Formula

$$M_{\text{stock}} = Q_{\text{stock}} - Q_{\text{reserve}}$$

5 — Read aloud

Read " $M_{\text{stock}} = Q_{\text{stock}} - Q_{\text{reserve}}$ " by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

M_stock: truly uncommitted stock [unité]; Q_stock: total available stock [unité]; Q_reserve: stock reserved for critical scenarios [unité]

7 — Pronunciation

Say subscripts, powers, parentheses and Greek letters explicitly so the relation can be reconstructed without seeing the page.

8 — Units

M_stock [unité]; Q_stock [unité]; Q_reserve [unité]

9 — Convention

Keep the same frame, time basis, system boundary and sign convention throughout the substitution.

10 — Why this operation

Subtraction isolates a margin or difference between comparable states.

11 — Assumptions

Terms must share the same frame and unit.

12 — Independent check

Adding the margin back to the subtracted term should reconstruct the initial state.

13 — Numerical case

With Q_stock = 120 unité, Q_reserve = 45 unité: M_stock = 120 - 45 = 75 unités.

14 — Why the calculation works

Subtraction isolates a margin or difference between comparable states.

15 — Verification

Adding the margin back to the subtracted term should reconstruct the initial state.

16 — Mental estimate

Comparing the two terms predicts the sign before calculation.

17 — Interpretation

Plan routine operations only against genuinely uncommitted margin.

18 — What the result does not prove

The calculation proves neither that inputs are exact nor that the model remains valid outside the declared scenario; both require separate evidence.

19 — Sensitivity

The result moves directly when either term changes.

20 — Guided and autonomous exercises

Guided exercise. Recalculate this scenario: With Q_stock = 80 unité, Q_reserve = 60 unité: M_stock = 80 - 60 ?

Detailed guided correction — open after trying

With Q_stock = 80 unité, Q_reserve = 60 unité: M_stock = 80 - 60 = 20 unités. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With Q_stock = 310 unité, Q_reserve = 250 unité: M_stock = 310 - 250 ?

Autonomous correction — open after trying

With Q_stock = 310 unité, Q_reserve = 250 unité: M_stock = 310 - 250 = 60 unités. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

Plan routine operations only against genuinely uncommitted margin.

Spare endurance

$t_{\text{spares}} = N_{\text{spares}} / \lambda_{\text{use}}$

1 — Concrete question

What does " $t_{\text{spares}} = N_{\text{spares}} / \lambda_{\text{use}}$ " compute in "Spare endurance"?

2 — Intuition without symbols

A spare count becomes operationally meaningful only relative to the rate at which spares are actually consumed.

3 — Quantities

t_{spares} : mean duration covered [j]; N_{spares} : number of spares available [pièces]; λ_{use} : mean consumption or failure rate [pièces/j]

4 — Formula

$$t_{\text{spares}} = N_{\text{spares}} / \lambda_{\text{use}}$$

5 — Read aloud

Read " $t_{\text{spares}} = N_{\text{spares}} / \lambda_{\text{use}}$ " by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

t_{spares} : mean duration covered [j]; N_{spares} : number of spares available [pièces]; λ_{use} : mean consumption or failure rate [pièces/j]

7 — Pronunciation

Say subscripts, powers, parentheses and Greek letters explicitly so the relation can be reconstructed without seeing the page.

8 — Units

t_{spares} [j]; N_{spares} [pièces]; λ_{use} [pièces/j]

9 — Convention

Keep the same frame, time basis, system boundary and sign convention throughout the substitution.

10 — Why this operation

Division relates a quantity to a coherent capacity, duration or reference.

11 — Assumptions

Numerator and denominator must describe the same scenario and the denominator must remain positive.

12 — Independent check

Multiplying the result by the denominator should reconstruct the numerator.

13 — Numerical case

With $N_{\text{spares}} = 12$ pièces, $\lambda_{\text{use}} = 0.04$ pièces/j: $t_{\text{spares}} = 12 / 0.04 = 300$ j.

14 — Why the calculation works

Division relates a quantity to a coherent capacity, duration or reference.

15 — Verification

Multiplying the result by the denominator should reconstruct the numerator.

16 — Mental estimate

Comparing numerator and denominator scales predicts the result.

17 — Interpretation

If calculated endurance is shorter than recovery time, increase stock or reduce consumption rate.

18 — What the result does not prove

The calculation proves neither that inputs are exact nor that the model remains valid outside the declared scenario; both require separate evidence.

19 — Sensitivity

The result rises with the numerator and falls as the denominator rises.

20 — Guided and autonomous exercises

Guided exercise. Recalculate this scenario: With $N_{\text{spares}} = 8$ pièces, $\lambda_{\text{use}} = 0.025$ pièces/j: $t_{\text{spares}} = 8 / 0.025$?

Detailed guided correction — open after trying

With $N_{\text{spares}} = 8$ pièces, $\lambda_{\text{use}} = 0.025$ pièces/j: $t_{\text{spares}} = 8 / 0.025 = 320$ j. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $N_{\text{spares}} = 20$ pièces, $\lambda_{\text{use}} = 0.05$ pièces/j: $t_{\text{spares}} = 20 / 0.05$?

Autonomous correction — open after trying

With $N_{\text{spares}} = 20$ pièces, $\lambda_{\text{use}} = 0.05$ pièces/j: $t_{\text{spares}} = 20 / 0.05 = 400$ j. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

If calculated endurance is shorter than recovery time, increase stock or reduce consumption rate.

Inventory accuracy

$$A_{\text{inv}} = N_{\text{correct}} / N_{\text{checked}}$$

1 — Concrete question

What does “ $A_{\text{inv}} = N_{\text{correct}} / N_{\text{checked}}$ ” compute in “Inventory accuracy”?

2 — Intuition without symbols

Reliable logistics depends on inventory records matching what is physically available.

3 — Quantities

A_{inv} : fraction of correctly recorded items [sans dimension]; N_{correct} : correctly recorded items [articles];

N_{checked} : checked items [articles]

4 — Formula

$$A_{\text{inv}} = N_{\text{correct}} / N_{\text{checked}}$$

5 — Read aloud

Read “ $A_{\text{inv}} = N_{\text{correct}} / N_{\text{checked}}$ ” by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

A_{inv} : fraction of correctly recorded items [sans dimension]; N_{correct} : correctly recorded items [articles];

N_{checked} : checked items [articles]

7 — Pronunciation

Say subscripts, powers, parentheses and Greek letters explicitly so the relation can be reconstructed without seeing the page.

8 — Units

A_{inv} [sans dimension]; N_{correct} [articles]; N_{checked} [articles]

9 — Convention

Keep the same frame, time basis, system boundary and sign convention throughout the substitution.

10 — Why this operation

Division relates a quantity to a coherent capacity, duration or reference.

11 — Assumptions

Numerator and denominator must describe the same scenario and the denominator must remain positive.

12 — Independent check

Multiplying the result by the denominator should reconstruct the numerator.

13 — Numerical case

With $N_{\text{correct}} = 198$ articles, $N_{\text{checked}} = 200$ articles: $A_{\text{inv}} = 198 / 200 = 0.99$.

14 — Why the calculation works

Division relates a quantity to a coherent capacity, duration or reference.

15 — Verification

Multiplying the result by the denominator should reconstruct the numerator.

16 — Mental estimate

Comparing numerator and denominator scales predicts the result.

17 — Interpretation

Below the mission threshold, run corrective inventory before trusting system quantities.

18 — What the result does not prove

The calculation proves neither that inputs are exact nor that the model remains valid outside the declared scenario; both require separate evidence.

19 — Sensitivity

The result rises with the numerator and falls as the denominator rises.

20 — Guided and autonomous exercises

Guided exercise. Recalculate this scenario: With $N_{\text{correct}} = 470$ articles, $N_{\text{checked}} = 500$ articles: $A_{\text{inv}} = 470 / 500$?

Detailed guided correction — open after trying

With $N_{\text{correct}} = 470$ articles, $N_{\text{checked}} = 500$ articles: $A_{\text{inv}} = 470 / 500 = 0.94$. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $N_{\text{correct}} = 95$ articles, $N_{\text{checked}} = 100$ articles: $A_{\text{inv}} = 95 / 100$?

Autonomous correction — open after trying

With $N_{\text{correct}} = 95$ articles, $N_{\text{checked}} = 100$ articles: $A_{\text{inv}} = 95 / 100 = 0.95$. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

Below the mission threshold, run corrective inventory before trusting system quantities.

Critical request fill rate

$F_{\text{critical}} = N_{\text{filled}} / N_{\text{requests}}$

1 — Concrete question

What does " $F_{\text{critical}} = N_{\text{filled}} / N_{\text{requests}}$ " compute in "Critical request fill rate"?

2 — Intuition without symbols

Fill rate measures whether the logistics system actually supplies critical items when requested.

3 — Quantities

F_{critical} : fraction of critical requests filled [sans dimension]; N_{filled} : critical requests filled [demandes];

N_{requests} : total critical requests [demandes]

4 — Formula

$F_{\text{critical}} = N_{\text{filled}} / N_{\text{requests}}$

5 — Read aloud

Read " $F_{\text{critical}} = N_{\text{filled}} / N_{\text{requests}}$ " by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

F_{critical} : fraction of critical requests filled [sans dimension]; N_{filled} : critical requests filled [demandes];

N_{requests} : total critical requests [demandes]

7 — Pronunciation

Say subscripts, powers, parentheses and Greek letters explicitly so the relation can be reconstructed without seeing the page.

8 — Units

F_{critical} [sans dimension]; N_{filled} [demandes]; N_{requests} [demandes]

9 — Convention

Keep the same frame, time basis, system boundary and sign convention throughout the substitution.

10 — Why this operation

Division relates a quantity to a coherent capacity, duration or reference.

11 — Assumptions

Numerator and denominator must describe the same scenario and the denominator must remain positive.

12 — Independent check

Multiplying the result by the denominator should reconstruct the numerator.

13 — Numerical case

With $N_{\text{filled}} = 48$ demandes, $N_{\text{requests}} = 50$ demandes: $F_{\text{critical}} = 48 / 50 = 0.96$.

14 — Why the calculation works

Division relates a quantity to a coherent capacity, duration or reference.

15 — Verification

Multiplying the result by the denominator should reconstruct the numerator.

16 — Mental estimate

Comparing numerator and denominator scales predicts the result.

17 — Interpretation

A high value does not remove the need to analyze every unfilled request and its severity.

18 — What the result does not prove

The calculation proves neither that inputs are exact nor that the model remains valid outside the declared scenario; both require separate evidence.

19 — Sensitivity

The result rises with the numerator and falls as the denominator rises.

20 — Guided and autonomous exercises

Guided exercise. Recalculate this scenario: With $N_{\text{filled}} = 72$ demandes, $N_{\text{requests}} = 80$ demandes: $F_{\text{critical}} = 72 / 80$?

Detailed guided correction — open after trying

With $N_{\text{filled}} = 72$ demandes, $N_{\text{requests}} = 80$ demandes: $F_{\text{critical}} = 72 / 80 = 0.9$. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $N_{\text{filled}} = 99$ demandes, $N_{\text{requests}} = 100$ demandes: $F_{\text{critical}} = 99 / 100$?

Autonomous correction — open after trying

With $N_{\text{filled}} = 99$ demandes, $N_{\text{requests}} = 100$ demandes: $F_{\text{critical}} = 99 / 100 = 0.99$. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

A high value does not remove the need to analyze every unfilled request and its severity.

Starting question

When should the settlement trigger replenishment of a consumable so stock lasts through the supply delay?

Read aloud

Read: "reorder point equals demand rate times lead time plus safety stock."

Symbols, pronunciation and meaning

R is the inventory level that triggers action; d is average demand per unit time; L is replenishment lead time; S is additional safety stock.

Units

If demand is kilograms per day and lead time is days, $d \times L$ is kilograms. S and R must use the same inventory unit.

Origin and status of values

Demand comes from consumption records or a declared scenario. Lead time must include the whole recovery chain, not only cruise time. Safety stock is a policy choice based on uncertainty and consequence.

Why this operation

Multiplication converts the consumption rate into expected quantity consumed during the lead time. Adding S protects against demand or schedule variation.

Substitution and calculation

For 2.5 kg/day, a 180-day lead time and 90 kg safety stock: $R = 2.5 \times 180 + 90 = 450 + 90 = 540$ kg.

Calculator entry

Enter $2.5 \times 180 + 90$. Keep lead time and demand in matching day units.

Mental estimate

Two and a half kilograms for about two hundred days is roughly 500 kg, so 540 kg including margin is plausible.

Independent check

Subtract safety stock: $540 - 90 = 450$ kg. Divide by 180 days and recover 2.5 kg/day.

Physical or operational interpretation

When available stock falls to about 540 kg, the settlement should initiate the approved replenishment path under these assumptions.

Plain-English translation

The trigger is intentionally much higher than near-empty because Mars replenishment arrives slowly.

Variation / sensitivity

If lead time grows to 240 days, the same policy raises R to 690 kg. Longer logistics delay directly increases required stock.

Limit / assumption

This formula assumes relatively stable consumption. Random failures, shelf-life losses and launch-window discontinuities need different treatment or additional margins.

Formula 2 — days of cover for a consumable

Starting question

How long will the remaining usable quantity last at the current consumption rate?

Read aloud

Read: “days of cover equals usable quantity divided by daily demand.”

Symbols, pronunciation and meaning

Q is usable inventory after quarantine or expiry; d is consumption per day; D_{cover} is time until depletion if conditions remain constant.

Units

With Q in kilograms and d in kilograms per day, the kilogram units cancel and the result is days.

Origin and status of values

Use physically usable stock, not database quantity alone. Consumption should reflect the current crew and operating mode.

Why this operation

Division asks how many daily demand blocks fit inside the remaining quantity.

Substitution and calculation

If 360 kg remain and use is 2.5 kg/day, $D = 360 / 2.5 = 144$ days.

Calculator entry

Enter $360 \div 2.5$. Record whether emergency rationing or alternate supply streams are excluded.

Mental estimate

At about 2.5 kg/day, 250 kg gives 100 days; another 110 kg adds roughly 44 days, so 144 is plausible.

Independent check

Multiply 144 days by 2.5 kg/day and recover 360 kg.

Physical or operational interpretation

Days of cover is easier for operations teams to compare directly with shipment milestones and contingency durations.

Plain-English translation

The stock supports about 144 days at the stated rate.

Variation / sensitivity

Reducing use to 2.0 kg/day extends cover to 180 days, showing the value of controlled conservation during delay.

Limit / assumption

The result changes immediately if demand changes or part of the inventory becomes unusable. It is not a guarantee of future availability.

Mission reasoning: manage inventory by recovery time and consequence

Classify stockouts by mission consequence

Inventory reviews should distinguish items whose absence is inconvenient from those that remove redundancy, end an EVA capability or threaten life support. This supports rationing and shipment priority before the warehouse becomes crowded with low-consequence stock.

Track usable quantity, not only database quantity

A sealed package can be expired, damaged, contaminated, out of calibration or incompatible with the current configuration. Physical cycle counts should verify identity, condition and location. Quarantined material must not silently inflate the apparent reserve.

Use repair and cannibalization as planned logistics modes

A failed assembly may provide motors, connectors or sensors for another repair. Cannibalization is safer when interfaces, inspection criteria and configuration records already exist. Improvised scavenging without traceability can spread hidden damage.

Design packaging for a second life

Interplanetary packaging consumes mass and volume. Where safe, containers can become bins, shielding, structural panels or clean storage. This must be planned early because material selection, contamination and dimensions determine whether reuse is realistic.

Control obsolescence before it becomes an emergency

Electronics and software evolve faster than a Mars settlement can replace every asset. The inventory system should identify last-buy decisions, alternative parts, firmware compatibility and test equipment needed to sustain older hardware.

Separate commonality from common-cause exposure

One shared part family can reduce stock diversity, but a single defective batch can then affect many systems. Critical common parts should retain lot traceability and, where justified, a diverse replacement path.

Logistics exercises — decide what to stock before Mars decides for you

Exercise A — Reorder trigger

A hygiene consumable is used at 1.8 kg/day. Effective replenishment lead time is 210 days and policy requires 100 kg safety stock. Calculate the reorder point.

Reveal the reasoned solution

$R = 1.8 \times 210 + 100 = 378 + 100 = 478$ kg. The order trigger is not “when nearly empty”; it is the inventory level that protects the full supply delay plus safety stock.

Exercise B — Expired reserve

The database shows 40 spare sensor cartridges, but 12 are beyond approved shelf life and 4 have damaged packaging. What is usable stock before engineering disposition?

Reveal the reasoned solution

Only 24 are immediately usable. The 16 questionable units should be quarantined until a documented engineering or medical decision extends, requalifies or rejects them. Counting them as normal stock hides risk.

Exercise C — Common pump family

Six water systems use one pump model. What benefit and risk does commonality create?

Reveal the reasoned solution

Benefit: one trained repair process and one spare pool can support six systems. Risk: a design or manufacturing defect can affect all six. Lot traceability, testing and possibly a diverse emergency pumping method reduce that common-cause exposure.

Exercise D — Cannibalization record

A rover is dismantled to obtain a motor controller for a greenhouse fan. What must configuration control record?

Reveal the reasoned solution

Record source asset and serial/revision, condition, removal history, any inspection or rework, destination system, software compatibility and the fact that the donor rover is no longer complete. Otherwise future planners may believe both assets are serviceable.

Exercise E — Days of cover

Usable stock is 525 filters and consumption is 3 filters/day. How long does it last?

Reveal the reasoned solution

$525 / 3 = 175$ days. Compare that duration with the next credible replenishment or local-production date and retain margin for damaged or contaminated units.

Exercise F — Substitution pressure

A seal of the correct diameter exists but uses a different elastomer. May the crew install it in an oxygen service line?

Reveal the reasoned solution

Not based on diameter alone. Compatibility includes pressure, temperature, oxygen service, chemical exposure, compression behaviour and qualification status. Use an approved substitute or an engineering disposition with explicit limits and verification.

Interactive beginner glossary

These terms describe how stock, time, compatibility and configuration combine into a Martian logistics system.

- inventory — Recorded set of materials, parts, tools and consumables available to support operations.
- usable stock — Inventory that is physically present, within condition limits and approved for its intended use.
- safety stock — Additional reserve held to absorb uncertainty in demand, failures or replenishment timing.
- reorder point — Inventory level at which the approved replenishment action should begin.
- lead time — Elapsed time from recognizing or ordering a need until a usable replacement is available.
- days of cover — Estimated duration that remaining usable stock will support current demand.
- critical item — Item whose unavailability creates an unacceptable safety, mission or operational consequence.
- consumable — Item that is progressively used up during normal operation and must be replenished or regenerated.
- spare part — Replacement item held to restore a failed or degraded component or assembly.
- line replaceable unit — Assembly designed to be removed and replaced as a unit during maintenance.
- shelf life — Approved storage duration during which an item is expected to remain within specified condition when stored correctly.
- expiry date — Declared date after which an item requires disposition rather than automatic normal use.
- quarantine — Controlled status that prevents uncertain material from being issued until its condition or authority is resolved.
- cycle count — Physical count and condition check of selected inventory performed without waiting for a full warehouse inventory.
- traceability — Ability to reconstruct identity, batch, history, movement and use of an item from controlled records.
- lot number — Identifier linking items produced or processed under a common manufacturing batch or condition.
- part number — Controlled identifier for a defined component design or procurement item.
- revision — Controlled version of a design, part, document, software build or interface definition.
- configuration — Defined combination of hardware, software, settings and interfaces that describes an operational state.
- approved substitute — Alternative part or material authorized for specified use under documented conditions.
- commonality — Use of the same or compatible item across multiple systems to reduce unique logistics burden.
- standardization — Deliberate adoption of common interfaces, parts or procedures to simplify operation and support.
- cannibalization — Removal of usable parts from one asset to restore another asset.

- obsolescence — Condition in which an item, technology or support source is no longer readily available or supported.
- last-time buy — Planned final procurement before a part becomes unavailable, intended to cover future support needs.
- packaging — Protective material and structure used to preserve an item during transport, storage and handling.
- storage condition — Environmental limits such as temperature, humidity, radiation or cleanliness required to preserve an item.
- stockout — Condition in which usable inventory of a required item is unavailable when needed.
- bill of materials — Structured list of components and quantities required to build or maintain an assembly.
- repairable item — Item intended to be restored to service through controlled repair rather than discarded after failure.

Operational depth: make inventory records describe reality, not hope

Connect stores to maintenance planning

The maintenance system should reserve parts for scheduled work and expose future demand. Otherwise a part can be issued to a low-priority repair today and make tomorrow's safety-critical overhaul impossible.

Audit storage environments

Temperature excursions, dust intrusion and radiation can age materials even when packages look intact. Storage sensors and inspection records help determine whether shelf-life assumptions still apply on Mars rather than copying terrestrial warehouse limits blindly.

Model whole recovery time

For a failed critical assembly, recovery time may include diagnosis, finding the spare, donning protective equipment, repair, testing and return to service. A part stored somewhere in the settlement is not equivalent to a restored function.

Use local manufacture strategically

Local fabrication can reduce dependence on Earth for geometry, brackets, ducts and some feedstocks. It does not erase the need for qualified materials, seals, electronics or calibration standards. Logistics should explicitly identify which items can be substituted or manufactured and which cannot.

Protect stock from single events

Do not place every critical spare in one compartment vulnerable to the same fire, leak or contamination event. Distributed storage can preserve recovery capability after local damage, but location data must remain accurate so crews can find the item under emergency conditions.

Retire ghost inventory

When a component is installed, cannibalized, failed or consumed, records should change immediately. Ghost stock is especially dangerous because planning calculations can look healthy while the physical shelf is empty.

Applied logistics cases: stock, recovery and configuration

Mission case — a critical filter family approaches depletion

Suppose carbon-dioxide scrubber cartridges share a housing across several refuge and medical units. The inventory review should not ask only how many cartridges remain. It should separate installed cartridges, unopened usable stock, units held for training, quarantined packages and any cartridges reserved for a specific emergency role. Then planners compare days of cover with the next credible resupply date and with local regeneration capability. If the margin is poor, conservation may include changing replacement criteria within approved limits, reallocating lower-priority stock or accelerating a qualification test for an alternative. The decision record should explain exactly which reserve is being consumed and which future contingency becomes weaker as a result.

Mission case — a rover failure creates two logistics decisions

A failed wheel actuator can force a choice between restoring the rover immediately and preserving the only compatible spare for a second rover that performs emergency rescue. The right answer depends on fleet redundancy, terrain, remaining actuators, repairability of the failed unit and whether the damaged rover can be cannibalized later. This is why stock policy must be connected to fleet function rather than to a simple minimum quantity. One spare can be sufficient when several vehicles are interchangeable and field repair is rapid, yet dangerously insufficient when one vehicle carries a unique rescue or hauling capability. The warehouse therefore needs the operational context behind the part count.

Mission case — slow ageing changes the apparent reserve

A shelf may contain years of polymer seals, medical tubing and lubricants, but Mars storage conditions can differ from terrestrial warehouses. Low humidity, radiation, temperature cycling and packaging permeability can alter material properties even before a part is installed. A mature inventory programme samples condition, records environmental exposure and uses inspection or requalification where justified. This prevents two opposite errors: discarding perfectly usable stock merely because a calendar date passed, or trusting degraded material because the box still looks sealed. Shelf life is a controlled claim tied to storage history and acceptance evidence, not a magical property printed on a label.

Mission case — local production must enter the inventory database

If a workshop can manufacture a bracket, gasket carrier or simple duct, that capability should appear as a recovery path with feedstock, machine, tooling, inspection and lead time. Otherwise planners may either import unnecessary mass or assume local production can solve a shortage that actually depends on unavailable alloy, calibration or heat treatment. Locally produced items also need part identity and configuration status so operators know whether they are prototypes, temporary repairs or fully qualified substitutes. A Mars inventory system eventually becomes a map of possible recovery routes: Earth resupply, stored spare, repair, cannibalization, local manufacture and operational workaround, each with different time and evidence requirements.

Mission case — protect inventory data during emergencies

During a fire or depressurization, operators may move emergency stock rapidly and later discover that database locations no longer match reality. Emergency procedures should therefore include a simple post-event reconciliation step. Temporary issue, relocation and consumption can be recorded with portable labels or offline forms if the primary inventory system is unavailable. The objective is not paperwork during a crisis; it is preventing the next crisis from beginning with false assumptions about what remains. Critical reserve status should be recoverable even after network failure, and storage locations should be intelligible to a crewmember who did not participate in the original loading plan.

Mission case — logistics is also information about interfaces

A spare electronic box is useless if the replacement requires a cable, software key, special wrench or calibration adapter that was stored elsewhere and is now unavailable. For critical assemblies, the support package should identify companion consumables, tools, firmware, test equipment and procedures. This turns the bill of materials into a recovery kit rather than a list of isolated parts. The same logic applies to medical and scientific stock: a reagent may need clean containers, temperature control and a calibrated instrument. Readiness should therefore be assessed at the level of complete tasks that restore function, not at the level of individual shelf quantities alone.

Operational review checklist

- Base replenishment on full effective lead time, not cruise time alone.
- Count only usable, compatible stock in readiness calculations.
- Classify items by consequence of stockout and recovery time.
- Maintain part number, revision, lot and approved-substitution records.
- Track shelf life and storage excursions, not just quantity.
- Exploit commonality while retaining awareness of common-cause defects.
- Record cannibalization and donor-asset configuration immediately.
- Protect critical spares from one fire, leak or contamination zone.

- [Link maintenance reservations to inventory availability.](#)
- [Plan local manufacture only where materials and qualification support it.](#)

Primary sources and bridges

- [NASA NTRS — Supportability Issues for Exploration Missions](#)
- [NASA NTRS — Spares Logistics for Long-Duration Human Spaceflight](#)
- [NASA NTRS — Logistics Reduction Technologies](#)

FR ↔ EN parity matrix

Reorder point	Point de commande
Days of cover	Jours de couverture
Margin above reserved stock	Marge au-dessus du stock réservé
Spare endurance	Autonomie en pièces de rechange
Inventory accuracy	Exactitude d'inventaire
Critical request fill rate	Taux de satisfaction des demandes critiques