

Field science, sampling and planetary protection

Learn how to turn a Martian rock or sample into traceable science: context, protocol, contamination control, chain of custody, storage and planetary-protection decisions.

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. A sample without context loses much of its scientific value

A rock removed from its setting cannot tell its whole story. Field scientists must record position, orientation, geologic unit, neighboring features, imagery and relationships between layers. Documentation is therefore part of the sample rather than an optional note.

2. State a hypothesis before collecting

Collecting everywhere quickly produces more material than can be analysed. A good campaign begins with a question: relative age, hydrated minerals, depositional origin or alteration history. The reason for choosing each sample should be explainable in relation to the hypothesis.

3. Contamination: separate what came from Mars from what we brought

Tools, gloves, lubricants, habitats and crew can carry terrestrial molecules and organisms. For biosignature studies even tiny contamination may become scientifically important. Cleaning procedures, blanks and contact records must make it possible to reconstruct the handling history.

4. Chain of custody and unique identity

Every sample needs a unique identifier linked to metadata, handlers, containers and storage changes. An incomplete chain of custody is not merely administrative; it can make it impossible to establish whether a chemical signature came from the field or from later handling.

5. Subsampling and preservation

A valuable sample should not be destroyed by the first analysis. Fractions can be allocated to mineralogy, chemistry, organics, microbiology or long-term archive. Temperature, pressure and container atmosphere can themselves alter some materials.

6. Planetary protection in both directions

Planetary protection seeks to limit contamination of other worlds by Earth organisms and, for some returned materials, to prevent uncontrolled release before characterization. A human base makes scientific separation more difficult because the crew itself is a large biological contamination source, requiring dedicated zones and procedures.

7. Field geology is decision-making under time constraints

A Mars field excursion cannot be an unconstrained walk. The crew has a budget of time, energy, EVA consumables, communications and sample-carrying capacity. Traverse planning therefore ranks objectives before departure: mandatory observations, desirable samples, opportunistic measurements and abort criteria. A visually spectacular outcrop may be less valuable than a sequence of ordinary points that preserve stratigraphic context. Field scientists must continually trade local detail against regional interpretation. The scientific value of a sample depends as much on its documented context as on its chemical composition.

8. Blanks, witnesses and provenance: detecting contamination instead of assuming absence

A strong scientific chain of custody includes controls that reveal what the mission itself adds to a sample. A contamination blank can expose a clean witness to the same handling environment without collecting the target material, helping identify dust, molecules or microorganisms introduced by gloves, containers or work areas. Material witnesses and handling logs then support retrospective analysis. This discipline is essential when organic or biological measurements might be interpreted as evidence of Martian history. A good protocol never promises 'zero contamination'; it measures, limits and attributes the contamination that actually occurs.

9. Preserving the future value of a sample

A sample may eventually be examined with instruments that did not exist when it was collected. Preservation strategy should therefore avoid consuming or altering all available material. Temperature, pressure, container atmosphere, vibration, radiation and storage time can change minerals, ices or organic compounds. Teams need to record the history of every container, preserve aliquots when appropriate and document every opening. This turns a rock into a traceable scientific object and allows a future laboratory to distinguish Martian signal from storage effects and terrestrial contamination.

10. Worked example: sampling allocation

A 120 m outcrop contains four visible units and a team has 18 tubes. Reserve 2 tubes for blanks/controls and 4 for unexpected opportunities. Twelve planned tubes remain, averaging 3 per unit. The average should not be applied mechanically; a more variable unit may deserve more samples.

Deeper engineering: build a sampling plan that preserves evidence

Collecting more material does not automatically improve science. A good plan allocates a limited number or mass of samples among hypotheses, controls, duplicates and reserves for future instruments. Planetary protection adds another requirement: document the paths by which terrestrial contamination could reach the sample. Provenance, chain of custody and blanks therefore become part of the measurement itself. [JPL — Planetary Protection](#)

Worked example. A field team has 24 tubes and decides to reserve 20% for duplicates or future analysis. $24 \times 0.20 = 4.8$, rounded to 5 reserved tubes. Nineteen remain. If three geological units must receive at least four tubes each, the minimum consumes $3 \times 4 = 12$ tubes, leaving seven tubes for the most discriminating targets. The arithmetic does not choose rocks for the geologist; it exposes the cost of a strategy and prevents the team from discovering too late that some categories can no longer be represented.

The plan must then be tied to metadata. A tube without position, orientation, images, stratigraphic context and handling history can lose much of its value. Perseverance therefore documents cached samples closely. A future human crew may be able to collect far more material, but the quality of the evidence package associated with each sample will remain decisive. [NASA — Mars Rock Samples](#)

11. Progressive exercise

Build a field record for a fictional sample: coordinates, image, horizon, texture, tool, operator, container, time, tested hypothesis and contamination risk. Identify which missing fields would make interpretation difficult.

Reasoned correction

Example field record: sample M37-01; rover-recorded coordinates and elevation; three pre-sampling photographs with scale; horizon described as a light layer beneath a dark slab; fine texture with millimetre inclusions; sterilized tool no. 2; named operator; sealed container C-014; local and UTC time; tested hypothesis “late aqueous deposit”; contamination note “no outer-glove contact, witness tool negative.” Missing coordinates, context imagery, time, tool/container identity or contamination history sharply reduces interpretability because later investigators can no longer reconstruct the geological setting or distinguish a natural signal from introduced material.

Mini-project

Plan a six-hour scientific EVA to collect eight samples from three geologic units while preserving safety margin, contamination controls, photographic documentation and chain of custody.

Science is only as trustworthy as the sample history

A Martian sample can be scientifically valuable because of its exact context: where it was found, which layer it came from, what was nearby and what touched it before analysis. Once that context is lost, a rock may remain interesting but can no longer answer the same questions. Field science therefore begins before collection with mapping, imaging, instrument calibration and a sampling plan that records provenance as carefully as the material itself.

Planetary protection adds another layer. A human settlement carries Earth organisms, organic compounds, lubricants, plastics and combustion products. Those materials can contaminate a sample and create a false biological signal. At the same time, samples from special regions or subsurface environments may require containment decisions until their hazard is understood. Science operations must therefore separate forward contamination, sample cleanliness and crew safety rather than treating all contamination as one problem.

The strongest field programme uses controls. Blank containers, witness plates, duplicate samples and known reference materials help reveal contamination introduced by tools, packaging or instruments. A surprising detection becomes much more credible when the team can show that the blank remained clean, the instrument calibration was valid and the chain of custody was unbroken.

Four concepts that turn a collected rock into defensible evidence

Provenance

Provenance is the documented origin and contextual history of a sample. It includes location, depth or stratigraphic position, orientation, neighbouring materials and the circumstances of collection.

Chain of custody

Chain of custody records who or what controlled the sample through collection, transfer, storage and analysis. It makes it possible to reconstruct handling and identify where contamination or mix-up could have occurred.

Blank

A blank is a control that should contain none of the target material. If the blank produces a signal, the team has evidence that contamination or analytical background may be contributing to the result.

Forward contamination

Forward contamination is transfer of Earth-origin biological or organic material to another planetary body. For Mars science, it can compromise the interpretation of life-detection or habitability evidence.

Formula 1 — field time budget per sampling station

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.

Sample allocation by zone

$$n_{\text{zone}} = n_{\text{total}} \times w_{\text{zone}}$$

1 — Concrete question

What does “ $n_{\text{zone}} = n_{\text{total}} \times w_{\text{zone}}$ ” compute in “Sample allocation by zone”?

2 — Intuition without symbols

Weighted allocation distributes a limited sample count according to scientific importance decided in advance.

3 — Quantities

n_{zone} : allocated samples [sample]; n_{total} : total samples [sample]; w_{zone} : zone weight [sans dimension]

4 — Formula

$$n_{\text{zone}} = n_{\text{total}} \times w_{\text{zone}}$$

5 — Read aloud

Read “ $n_{\text{zone}} = n_{\text{total}} \times w_{\text{zone}}$ ” by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

n_{zone} : allocated samples [sample]; n_{total} : total samples [sample]; w_{zone} : zone weight [sans dimension]

7 — Pronunciation

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

8 — Units

n_{zone} [sample]; n_{total} [sample]; w_{zone} [sans dimension]

9 — Convention

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

10 — Why this operation

Multiplication converts a rate, fraction or specific quantity into a total.

11 — Assumptions

Factors must belong to the same scenario and their units must combine correctly.

12 — Independent check

Dividing the result by a non-zero factor should recover the product of the others.

13 — Numerical case

With $n_{\text{total}} = 40$ sample, $w_{\text{zone}} = 0.25$ sans dimension: $n_{\text{zone}} = 40 \times 0.25 = 10$ sample.

14 — Why the calculation works

Multiplication converts a rate, fraction or specific quantity into a total.

15 — Verification

Dividing the result by a non-zero factor should recover the product of the others.

16 — Mental estimate

Estimating each factor separately quickly predicts product scale.

17 — Interpretation

Document weights before collection to avoid adjusting them after seeing results.

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

A relative change in one factor transfers directly to the product when the others stay fixed.

20 — Guided and autonomous exercises

Guided exercise. Recalculate this scenario: With $n_{\text{total}} = 60$ sample, $w_{\text{zone}} = 0.3$ sans dimension: $n_{\text{zone}} = 60 \times 0.3$?

[Detailed guided correction — open after trying](#)

With $n_{\text{total}} = 60$ sample, $w_{\text{zone}} = 0.3$ sans dimension: $n_{\text{zone}} = 60 \times 0.3 = 18$ sample. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $n_{\text{total}} = 100$ sample, $w_{\text{zone}} = 0.15$ sans dimension: $n_{\text{zone}} = 100 \times 0.15$?

Autonomous correction — open after trying

With $n_{\text{total}} = 100$ sample, $w_{\text{zone}} = 0.15$ sans dimension: $n_{\text{zone}} = 100 \times 0.15 = 15$ sample. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

Document weights before collection to avoid adjusting them after seeing results.

Contamination fraction

$f_{\text{cont}} = n_{\text{cont}} / n_{\text{total}}$

1 — Concrete question

What does “ $f_{\text{cont}} = n_{\text{cont}} / n_{\text{total}}$ ” compute in “Contamination fraction”?

2 — Intuition without symbols

Contamination fraction quantifies observed frequency of a cleanliness problem in the evaluated lot.

3 — Quantities

f_{cont} : contaminated fraction [sans dimension]; n_{cont} : contaminated samples [sample]; n_{total} : examined samples [sample]

4 — Formula

$f_{\text{cont}} = n_{\text{cont}} / n_{\text{total}}$

5 — Read aloud

Read “ $f_{\text{cont}} = n_{\text{cont}} / n_{\text{total}}$ ” by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

f_{cont} : contaminated fraction [sans dimension]; n_{cont} : contaminated samples [sample]; n_{total} : examined samples [sample]

7 — Pronunciation

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

8 — Units

f_{cont} [sans dimension]; n_{cont} [sample]; n_{total} [sample]

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 $n_{\text{cont}} = 2$ sample, $n_{\text{total}} = 50$ sample: $f_{\text{cont}} = 2 / 50 = 0.04$.

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

Suspend contamination-sensitive interpretation when this fraction exceeds the protocol threshold.

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 $n_{\text{cont}} = 1$ sample, $n_{\text{total}} = 20$ sample: $f_{\text{cont}} = 1 / 20$?

Detailed guided correction — open after trying

With $n_{\text{cont}} = 1$ sample, $n_{\text{total}} = 20$ sample: $f_{\text{cont}} = 1 / 20 = 0.05$. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $n_{\text{cont}} = 5$ sample, $n_{\text{total}} = 100$ sample: $f_{\text{cont}} = 5 / 100$?

Autonomous correction — open after trying

With $n_{\text{cont}} = 5$ sample, $n_{\text{total}} = 100$ sample: $f_{\text{cont}} = 5 / 100 = 0.05$. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

Suspend contamination-sensitive interpretation when this fraction exceeds the protocol threshold.

Chain-of-custody completeness

$C_{\text{custody}} = n_{\text{logged}} / n_{\text{transfers}}$

1 — Concrete question

What does “ $C_{\text{custody}} = n_{\text{logged}} / n_{\text{transfers}}$ ” compute in “Chain-of-custody completeness”?

2 — Intuition without symbols

Every transfer should leave a record; completeness measures the documented share.

3 — Quantities

C_{custody} : traceability completeness [sans dimension]; n_{logged} : logged transfers [transfer]; $n_{\text{transfers}}$: total transfers [transfer]

4 — Formula

$C_{\text{custody}} = n_{\text{logged}} / n_{\text{transfers}}$

5 — Read aloud

Read “ $C_{\text{custody}} = n_{\text{logged}} / n_{\text{transfers}}$ ” by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

C_{custody} : traceability completeness [sans dimension]; n_{logged} : logged transfers [transfer]; $n_{\text{transfers}}$: total transfers [transfer]

7 — Pronunciation

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

8 — Units

C_{custody} [sans dimension]; n_{logged} [transfer]; $n_{\text{transfers}}$ [transfer]

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 $n_{\text{logged}} = 18$ transfer, $n_{\text{transfers}} = 18$ transfer: $C_{\text{custody}} = 18 / 18 = 1$.

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 sample with an unexplained custody break should be downgraded or isolated.

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 $n_{\text{logged}} = 23$ transfer, $n_{\text{transfers}} = 25$ transfer: $C_{\text{custody}} = 23 / 25$?

Detailed guided correction — open after trying

With $n_{\text{logged}} = 23$ transfer, $n_{\text{transfers}} = 25$ transfer: $C_{\text{custody}} = 23 / 25 = 0.92$. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $n_{\text{logged}} = 9$ transfer, $n_{\text{transfers}} = 10$ transfer: $C_{\text{custody}} = 9 / 10$?

Autonomous correction — open after trying

With $n_{\text{logged}} = 9$ transfer, $n_{\text{transfers}} = 10$ transfer: $C_{\text{custody}} = 9 / 10 = 0.9$. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

A sample with an unexplained custody break should be downgraded or isolated.

Sampling rate

$r_{\text{sample}} = n_{\text{samples}} / t_{\text{field}}$

1 — Concrete question

What does " $r_{\text{sample}} = n_{\text{samples}} / t_{\text{field}}$ " compute in "Sampling rate"?

2 — Intuition without symbols

Sampling rate links collected sample count to actual field time consumed.

3 — Quantities

r_{sample} : sampling rate [sample/h]; n_{samples} : collected samples [sample]; t_{field} : field time [h]

4 — Formula

$r_{\text{sample}} = n_{\text{samples}} / t_{\text{field}}$

5 — Read aloud

Read " $r_{\text{sample}} = n_{\text{samples}} / t_{\text{field}}$ " by naming every operation, subscript and grouping explicitly.

6 — Symbols and meaning

r_{sample} : sampling rate [sample/h]; n_{samples} : collected samples [sample]; t_{field} : field time [h]

7 — Pronunciation

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

8 — Units

r_{sample} [sample/h]; n_{samples} [sample]; t_{field} [h]

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 $n_{\text{samples}} = 12$ sample, $t_{\text{field}} = 4$ h: $r_{\text{sample}} = 12 / 4 = 3$ sample/h.

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
Do not increase rate at the expense of context, photography, sterility or documentation.
- 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 $n_{\text{samples}} = 20$ sample, $t_{\text{field}} = 5$ h: $r_{\text{sample}} = 20 / 5$?

Detailed guided correction — open after trying

With $n_{\text{samples}} = 20$ sample, $t_{\text{field}} = 5$ h: $r_{\text{sample}} = 20 / 5 = 4$ sample/h. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $n_{\text{samples}} = 9$ sample, $t_{\text{field}} = 3$ h: $r_{\text{sample}} = 9 / 3$?

Autonomous correction — open after trying

With $n_{\text{samples}} = 9$ sample, $t_{\text{field}} = 3$ h: $r_{\text{sample}} = 9 / 3 = 3$ sample/h. The decision must then be checked against the module margins and assumptions.

- 21 — Mission decision
Do not increase rate at the expense of context, photography, sterility or documentation.

Positive-blank fraction

$f_{\text{blank}} = n_{\text{positive_blanks}} / n_{\text{blanks}}$

- 1 — Concrete question
What does " $f_{\text{blank}} = n_{\text{positive_blanks}} / n_{\text{blanks}}$ " compute in "Positive-blank fraction"?
- 2 — Intuition without symbols
Blanks reveal procedural contamination that could otherwise be mistaken for a Martian signal.
- 3 — Quantities
 f_{blank} : positive-blank fraction [sans dimension]; $n_{\text{positive_blanks}}$: positive blanks [blank]; n_{blanks} : analyzed blanks [blank]
- 4 — Formula
 $f_{\text{blank}} = n_{\text{positive_blanks}} / n_{\text{blanks}}$
- 5 — Read aloud
Read " $f_{\text{blank}} = n_{\text{positive_blanks}} / n_{\text{blanks}}$ " by naming every operation, subscript and grouping explicitly.
- 6 — Symbols and meaning
 f_{blank} : positive-blank fraction [sans dimension]; $n_{\text{positive_blanks}}$: positive blanks [blank]; n_{blanks} : analyzed blanks [blank]
- 7 — Pronunciation
Say subscripts, powers, parentheses and Greek letters explicitly so the relation can be reconstructed without seeing the page.
- 8 — Units
 f_{blank} [sans dimension]; $n_{\text{positive_blanks}}$ [blank]; n_{blanks} [blank]
- 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 $n_{\text{positive_blanks}} = 1$ blank, $n_{\text{blanks}} = 20$ blank: $f_{\text{blank}} = 1 / 20 = 0.05$.

- 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 non-zero rate requires identifying the source before any sensitive claim.
- 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 $n_{\text{positive_blanks}} = 0$ blank, $n_{\text{blanks}} = 10$ blank: $f_{\text{blank}} = 0 / 10$?

Detailed guided correction — open after trying

With $n_{\text{positive_blanks}} = 0$ blank, $n_{\text{blanks}} = 10$ blank: $f_{\text{blank}} = 0 / 10 = 0$. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $n_{\text{positive_blanks}} = 2$ blank, $n_{\text{blanks}} = 25$ blank: $f_{\text{blank}} = 2 / 25$?

Autonomous correction — open after trying

With $n_{\text{positive_blanks}} = 2$ blank, $n_{\text{blanks}} = 25$ blank: $f_{\text{blank}} = 2 / 25 = 0.08$. The decision must then be checked against the module margins and assumptions.

- 21 — Mission decision
A non-zero rate requires identifying the source before any sensitive claim.

Preserved sample mass

$$M_{\text{preserved}} = M_{\text{collected}} \times \eta_{\text{pres}}$$

- 1 — Concrete question
What does “ $M_{\text{preserved}} = M_{\text{collected}} \times \eta_{\text{pres}}$ ” compute in “Preserved sample mass”?
- 2 — Intuition without symbols
Mass actually available for future analyses depends on what survives preservation and immediate allocations.
- 3 — Quantities
 $M_{\text{preserved}}$: preserved mass [g]; $M_{\text{collected}}$: collected mass [g]; η_{pres} : preserved fraction [sans dimension]
- 4 — Formula
 $M_{\text{preserved}} = M_{\text{collected}} \times \eta_{\text{pres}}$
- 5 — Read aloud
Read “ $M_{\text{preserved}} = M_{\text{collected}} \times \eta_{\text{pres}}$ ” by naming every operation, subscript and grouping explicitly.
- 6 — Symbols and meaning
 $M_{\text{preserved}}$: preserved mass [g]; $M_{\text{collected}}$: collected mass [g]; η_{pres} : preserved fraction [sans dimension]
- 7 — Pronunciation
Say subscripts, powers, parentheses and Greek letters explicitly so the relation can be reconstructed without seeing the page.
- 8 — Units
 $M_{\text{preserved}}$ [g]; $M_{\text{collected}}$ [g]; η_{pres} [sans dimension]
- 9 — Convention
Keep the same frame, time basis, system boundary and sign convention throughout the substitution.
- 10 — Why this operation
Multiplication converts a rate, fraction or specific quantity into a total.
- 11 — Assumptions
Factors must belong to the same scenario and their units must combine correctly.

12 — Independent check

Dividing the result by a non-zero factor should recover the product of the others.

13 — Numerical case

With $M_{\text{collected}} = 500$ g, $\eta_{\text{pres}} = 0.8$ sans dimension: $M_{\text{preserved}} = 500 \times 0.8 = 400$ g.

14 — Why the calculation works

Multiplication converts a rate, fraction or specific quantity into a total.

15 — Verification

Dividing the result by a non-zero factor should recover the product of the others.

16 — Mental estimate

Estimating each factor separately quickly predicts product scale.

17 — Interpretation

Explicitly reserve a fraction for future instruments and scientific questions.

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

A relative change in one factor transfers directly to the product when the others stay fixed.

20 — Guided and autonomous exercises

Guided exercise. Recalculate this scenario: With $M_{\text{collected}} = 300$ g, $\eta_{\text{pres}} = 0.9$ sans dimension: $M_{\text{preserved}} = 300 \times 0.9$?

Detailed guided correction — open after trying

With $M_{\text{collected}} = 300$ g, $\eta_{\text{pres}} = 0.9$ sans dimension: $M_{\text{preserved}} = 300 \times 0.9 = 270$ g. The decision must then be checked against the module margins and assumptions.

Autonomous exercise. Recalculate this scenario: With $M_{\text{collected}} = 1000$ g, $\eta_{\text{pres}} = 0.75$ sans dimension: $M_{\text{preserved}} = 1000 \times 0.75$?

Autonomous correction — open after trying

With $M_{\text{collected}} = 1000$ g, $\eta_{\text{pres}} = 0.75$ sans dimension: $M_{\text{preserved}} = 1000 \times 0.75 = 750$ g. The decision must then be checked against the module margins and assumptions.

21 — Mission decision

Explicitly reserve a fraction for future instruments and scientific questions.

Starting question

How much EVA or rover time should be reserved for one complete sampling station rather than only for grabbing the specimen?

Read aloud

Say: "station time equals context time plus collection time plus documentation time plus cleaning time."

Symbols, pronunciation and meaning

Each term represents a different operation: contextual observation, physical collection, records/labels, and contamination-control or tool-cleaning work.

Units

All time terms must use the same unit, usually minutes. Their sum is station duration.

Origin and status of values

Durations come from field trials, analogue exercises or a declared planning assumption. They should reflect suit, glove, rover and communication constraints.

Why this operation

The activities occur sequentially or consume separate crew capacity, so adding them captures the full operational burden of a scientifically defensible station.

Substitution and calculation

If context = 12 min, collection = 8 min, documentation = 6 min and cleaning = 4 min, total = 30 min per station.

Calculator entry

Enter $12 + 8 + 6 + 4$. Keep each component visible so later process improvements can target the dominant term.

Mental estimate

Four tasks each take several minutes, so a total around half an hour is reasonable.

Independent check

Subtract each component from the 30 min total and confirm the remainder equals the sum of the other three.

Physical or operational interpretation

If a plan allocates only ten minutes per site, it may force the team to sacrifice provenance or contamination control even though the sample itself can be physically collected.

Plain-English translation

This station requires about thirty minutes to collect a sample with its supporting scientific evidence under the stated assumptions.

Variation / sensitivity

Reducing cleaning time by two minutes saves only two minutes; choosing fewer higher-value sites may save more than rushing every site.

Limit / assumption

Tasks can overlap between crew members and some sites require much longer imaging or subsurface access. The equation is a planning decomposition, not a universal sampling duration.

Formula 2 — sampling capacity within an EVA time allocation

Starting question

How many complete sampling stations fit inside the time actually allocated to science?

Read aloud

Read: “station count equals the whole number of available-time divided by time per station.”

Symbols, pronunciation and meaning

$T_{\text{available}}$ is science time remaining after travel and reserves; t_{station} is time required for one complete station.

Units

Both times use the same unit. The quotient is a count and is rounded down because a partial station may not deliver complete evidence.

Origin and status of values

Available time comes from the EVA timeline after mandatory margins; station time should come from representative field trials or the previous calculation.

Why this operation

Division asks how many equal station durations fit in the allowed block. Rounding down preserves schedule feasibility.

Substitution and calculation

With 170 min of science time and 30 min per station: $170 / 30 = 5.67$, so plan at most five complete stations with 20 min remaining.

Calculator entry

Type $170 \div 30$ and then take the integer below the result for conservative station count.

Mental estimate

Six stations would require 180 min, which already exceeds 170, so five is the only feasible whole number.

Independent check

Multiply five stations by 30 min = 150 min; subtract from 170 and recover 20 min remaining.

Physical or operational interpretation

The remainder can absorb site variability, tool cleaning or an especially valuable observation instead of forcing an overrun.

Plain-English translation

The allocated block supports five complete thirty-minute stations, not six.

Variation / sensitivity

If station time falls to 25 min, six stations fit in 150 min and twenty minutes still remain; procedure efficiency can change science return.

Limit / assumption

Travel, unexpected terrain, crew fatigue and discoveries can invalidate equal station times. A real EVA also retains safety return margin that should not be consumed by science targets.

Mission reasoning: protect context, contamination controls and scientific choice

Survey before touching

Initial imaging and remote measurements preserve a view of the site before tools disturb it. This is especially important for layered deposits, fragile crusts or possible biological textures. A sample bag can preserve material; it cannot recreate the original geometry after the outcrop has been broken.

Use controls that travel with the sample process

A blank or witness material should experience relevant parts of the same handling environment as the sample. Otherwise it may fail to reveal contamination introduced by a glove, tool, container or laboratory atmosphere. Controls are strongest when they are planned into the sampling chain instead of added after a surprising result appears.

Separate sample priority from collection order

The highest scientific priority may not be the first accessible rock. Field teams should use a decision framework based on context, uniqueness, instrument observations, time and contamination state. This prevents the schedule from turning into a simple sequence of “collect whatever is closest.”

Preserve evidence through custody transfers

Every handoff—astronaut to rover rack, rover to airlock, airlock to laboratory—creates a chance for label error or contamination. Unique identifiers, sealed containers, time records and custody acknowledgement reduce that risk. Digital records should be backed by physically robust labels that survive dust and handling.

Planetary protection changes with the question

A geology sample used only for mineralogy may tolerate a different cleanliness level from a sample intended for trace-organic or life-detection analysis. The team should classify the science objective before collection so the contamination-control burden matches the question rather than applying one expensive standard to everything.

Field-science exercises — decide what makes a sample believable

Exercise A — Station time

A sampling station needs 15 min for context imaging, 10 min for collection, 5 min for documentation and 5 min for cleaning. How long should the timeline reserve?

Reveal the reasoned solution

The complete station requires $15 + 10 + 5 + 5 = 35$ min. Planning only ten minutes because physical collection takes ten would omit most of the evidence-preservation work.

Exercise B — EVA capacity

After travel and safety reserves, 190 min remain for science. If each complete station averages 35 min, how many full stations fit?

Reveal the reasoned solution

$190 / 35 \approx 5.43$, so five complete stations fit conservatively. Five use 175 min and leave about 15 min for variability or an additional observation, not enough for a sixth full station.

Exercise C — Dirty blank

A trace-organic analysis finds a compound in the sample and the process blank. What should the team conclude?

Reveal the reasoned solution

The detection cannot automatically be assigned to Mars. The blank shows that the sampling or analytical chain contains the compound or a source of it. The team should investigate contamination, compare concentrations and other controls, and avoid overstating the sample result.

Exercise D — Lost label

Two sealed containers are physically intact but their labels became unreadable after transfer. Why is this a major science failure?

Reveal the reasoned solution

The material may still be analyzable, but its provenance and possibly chain of custody are no longer certain. If the containers cannot be uniquely reconstructed from independent records, their ability to answer location-specific scientific questions is badly reduced.

Exercise E — High-value late discovery

A crew finds an unusual layered deposit near the end of allocated science time. What should guide the decision to stop or collect?

Reveal the reasoned solution

Use remaining EVA safety margin, scientific uniqueness, contamination state, time required for complete documentation, and whether remote observations can preserve value for a later visit. Scientific excitement does not override return rules, but rigid target count should not prevent a justified re-prioritization within safe authority.

Exercise F — Control sample choice

A team can carry either one extra science sample or one process blank on a life-detection traverse. Explain why the blank may have higher scientific value.

Reveal the reasoned solution

If the target analysis is highly contamination-sensitive, the blank provides evidence about whether any detected signal entered through tools, containers or laboratory handling. Without that control, several collected samples could all share the same ambiguous contamination source, weakening the entire dataset.

Interactive beginner glossary

These terms explain how field context and contamination controls turn material collection into reproducible planetary science.

- provenance — Documented origin and contextual history of a sample, including where and how it was found and collected.
- stratigraphy — Study of layered geological materials and their sequence, relationships and relative history.
- outcrop — Exposed bedrock or geological material visible at the surface and available for direct observation.
- sampling station — Defined field location at which contextual observations, measurements and one or more collections are performed.
- chain of custody — Record of control, transfer and handling that follows a sample from collection through storage and analysis.
- sample identifier — Unique code assigned to a sample and linked to its location, container, records and analytical history.
- field notebook — Operational scientific record containing observations, decisions, sketches, measurements and contextual information made during field work.
- context image — Photograph or other image showing a target in relation to its surroundings before or during collection.
- witness plate — Material intentionally exposed to the sampling or spacecraft environment to record contamination that could also reach samples.
- blank — Control expected to contain none of the target analyte, used to reveal background or contamination introduced by the process.
- duplicate sample — A second sample collected or prepared to evaluate spatial variability, handling effects or analytical repeatability.
- reference material — Material with known or characterized properties used to check instrument response or analytical quality.
- calibration — Process of relating instrument response to known references so measurements can be interpreted quantitatively.
- detection limit — Lowest quantity or concentration that an analytical method can reliably distinguish from background under defined conditions.
- contamination — Unwanted biological, organic, chemical or particulate material introduced into a sample, instrument or environment.
- forward contamination — Transfer of Earth-origin organisms or material to another planetary body in a way that can affect science or planetary protection.
- back contamination — Potential transfer of extraterrestrial material or hazards toward humans or Earth environments, requiring appropriate containment policy.
- planetary protection — Policies and technical practices intended to protect scientific investigations and relevant environments from harmful biological contamination.
- special region — A Mars planetary-protection concept for locations where environmental conditions may be relevant to possible terrestrial organism replication or Mars life concerns.
- sterilization — Validated process intended to destroy or remove viable microorganisms to a defined level.
- cleanliness level — Specified limit on particulate, organic, biological or other contamination for a defined item or scientific purpose.
- sample cache — Organized set of sealed samples stored for later retrieval, analysis or transfer.

- subsample — Portion taken from a larger sample for a particular analysis while preserving the remainder.
- aliquot — Measured portion of a sample or solution separated for analysis or processing.
- cross-contamination — Transfer of material from one sample, tool, container or work area into another sample or analytical process.
- site triage — Rapid field prioritization of targets so limited time is spent on the observations and samples with greatest expected scientific value.
- geologic contact — Boundary where two different rock units, layers or geological materials meet.
- in situ measurement — Measurement made at the original site without removing the target from its environmental context.
- sample integrity — Degree to which a sample retains the physical, chemical and contextual properties needed for its intended analysis.
- science return — Value of observations and samples delivered by a mission relative to the scientific questions and resources invested.

Operational depth: make every surprising result auditable

Build contamination maps

Human habitats, landing zones, rover paths and exhaust sources can create contamination gradients. Mapping those sources helps scientists choose sampling locations and interpret unexpected organics or particles. The science plan should know where the settlement itself has altered the environment.

Calibrate under field conditions

An instrument calibrated in a laboratory may respond differently after dust exposure, temperature cycling or mechanical shock. Field checks with standards and blanks help detect drift. A calibration record should identify the standard, result, time and instrument configuration used for the sample set.

Keep untouched reserve material

Not every sample should be consumed by the first available instrument. Preserving sealed reserve material allows later methods, repeat analysis or independent confirmation. This is particularly valuable when analytical technology improves faster than opportunities to revisit the same site.

Use digital records without depending on one database

Barcodes and electronic records reduce transcription error, but dust, power loss or software failure can make them unavailable. Sample identity should survive through redundant records and durable physical markings. The aim is not paper versus digital; it is recoverable provenance.

Investigate contamination as a system event

When a blank becomes positive, the response should trace tools, gloves, containers, cleaning materials, laboratory air and instrument carryover. Quietly replacing the blank does not repair the process. Contamination events deserve anomaly logic similar to engineering failures.

Let science plans evolve without breaking controls

Mars field work will discover targets planners did not anticipate. Crews need authority to re-prioritize within safety and contamination constraints, while recording why the plan changed. Flexible science is compatible with strict custody when decision records are part of the procedure.

Separate discovery mode from confirmation mode

Field exploration rewards speed and broad coverage, while confirmation of a potentially extraordinary result requires much tighter controls. The first pass may identify an unusual mineral, organic signature or texture; the second should deliberately repeat observations with blanks, alternative instruments, independent subsamples and stronger custody. This separation allows curiosity without letting the excitement of discovery lower the standard of evidence. A Mars science programme should be designed so it can escalate from reconnaissance to confirmation when the data justify it.

Plan sample storage as an analytical instrument

Temperature, pressure, radiation exposure and container atmosphere can alter volatile compounds or reactive minerals after collection. Storage therefore influences what future instruments will measure. The sample plan should specify container material, seal integrity, permitted temperature range and whether a sample must remain frozen, dry or isolated from habitat atmosphere. Preserving a sample is not simply keeping the bag closed; it is maintaining the properties needed by the intended future analysis.

Use negative results as evidence

A carefully collected sample that shows no target signal can still be scientifically valuable when detection limits, blanks and provenance are known. Negative results constrain hypotheses and can guide the next site choice. They should not be discarded simply because they are less dramatic than a positive detection.

Operational review checklist

- Record context images and location before disturbing a sampling site.
- Assign a unique identifier at collection and preserve it through every custody transfer.
- Match cleanliness and planetary-protection controls to the scientific question.
- Use blanks, witnesses or reference materials where they can reveal relevant contamination.
- Reserve time for documentation and cleaning, not only physical collection.
- Keep calibration status linked to the samples measured by each instrument.
- Separate observations, interpretations and hypotheses in field records.
- Preserve reserve sample material when future or independent analysis may add value.
- Investigate positive blanks and contamination events before trusting surprising detections.
- Never consume EVA safety margin merely to increase the number of collected samples.

Primary sources and bridges

- [JPL — Planetary Protection Mission Implementation](#)
- [NASA Science — Mars Rock Samples](#)
- [NASA Science — Mars](#)

FR ↔ EN parity matrix

Sample allocation by zone	Allocation d'échantillons par zone
Contamination fraction	Fraction contaminée
Chain-of-custody completeness	Complétude de chaîne de garde
Sampling rate	Cadence de prélèvement
Positive-blank fraction	Taux de blancs positifs
Preserved sample mass	Masse préservée