Surface mobility: rovers, cargo, routes and rescue

Guiding question

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

Course map

The real phenomenon → Vocabulary and problem boundary → Course-specific system view → Mathematical relationship and reading the symbols → Worked calculations and interpretation

1 — The real phenomenon

Mobility connects habitat, landing zones, resources, science and construction sites. Energy endurance, payload, speed, redundancy, communications, navigation, recovery capability and return conditions must all be sized. A fast vehicle that cannot be rescued is not a robust system.
The guiding question is: How do we turn a rover into a reliable part of a Mars logistics system? Reasoning starts with the physical or operational function before introducing the mathematical relationship. The goal is not to accumulate terminology, but to know which quantity changes, why it changes and what becomes hazardous when it leaves its domain. For "Surface mobility: rovers, cargo, routes and rescue", the first task here is therefore to identify the mechanism specific to this subject before searching for an equation or reference value.

2 — Vocabulary and problem boundary

In "Surface mobility: rovers, cargo, routes and rescue", distinguish the phenomenon, available measurement, any command, the margin and the success criterion. The calculation boundary states what is included and excluded; without that boundary, a percentage, mass or time may be mathematically correct but wrong as an engineering conclusion. For "Surface mobility: rovers, cargo, routes and rescue", the chosen boundary also states what would otherwise be double-counted or omitted from a mission budget.
distance, network flow, power, pressurized volume, travel time, interface state and backup capacity
broken line, blocked logistics route, isolated zone, incompatible interface or backup capacity concentrated in the same location
layout mockups, segmented-network testing, rover campaigns and reconfiguration exercises

Equation - evidence - decision

$E_{trajet} = e_{km} \times d$

Failure to test: The reference failure is not a vague "broken component." For "Surface mobility: rovers, cargo, routes and rescue", test in particular broken line, blocked logistics route, isolated zone, incompatible interface or backup capacity concentrated in the same location. Diagnosis asks which symptoms appear first, which are only consequences and which action preserves the most options.

Surface mobility: rovers, cargo, routes and rescue

3 — Course-specific system view

This lesson does not reuse one generic picture for every subject. The system view follows cause → measured quantity → decision or physical response → limit for “Surface mobility: rovers, cargo, routes and rescue”. The English text remains fully equivalent while large translated illustrations are intentionally deferred until their dedicated artwork is supplied. For “Surface mobility: rovers, cargo, routes and rescue”, the system view must expose inputs, outputs, measured quantity and the consequence of drift without relying on a generic module diagram.

4 — Mathematical relationship and reading the symbols

Read aloud : trip energy equals energy use per kilometer times distance.

Before substituting numbers, write the unit of every term, state whether the relationship is a physical law, approximation or project indicator, and check dimensional consistency. This is especially important here because “Surface mobility: rovers, cargo, routes and rescue” combines quantities that do not all have the same evidence status. For “Surface mobility: rovers, cargo, routes and rescue”, this relationship is chosen because of the phenomenon under study; a different dominant quantity would require a different equation or model.

5 — Worked calculations and interpretation

1.8 kWh/km × 24 km = 43.2 kWh

60 kWh available − 43.2 kWh = 16.8 kWh

6 trips × 450 kg = 2,700 kg transported

1. 1. Energy 1.8 kWh/km × 24 km = 43.2 kWh Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Surface mobility: rovers, cargo, routes and rescue”.
2. 2. Return margin 60 kWh available − 43.2 kWh = 16.8 kWh Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Surface mobility: rovers, cargo, routes and rescue”.
3. 3. Cargo 6 trips × 450 kg = 2,700 kg transported Interpretation: this result is used only after comparison with units, margin and the scenario boundary for “Surface mobility: rovers, cargo, routes and rescue”.

6 — What the formula does not contain

Operational table

Phenomena / sections:	3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation
Relationship to revisit:	E_trajet = e_km × d
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 3 — Course-specific system view ; 4 — Mathematical relationship and reading the symbols ; 5 — Worked calculations and interpretation. State one measured quantity, one margin and one possible decision.

Surface mobility: rovers, cargo, routes and rescue

The relationship “E_trajet = e_km × d” does not by itself contain all of “Surface mobility: rovers, cargo, routes and rescue”. It does not automatically tell us whether a sensor is valid, a structure is aging, a resource is accessible, a command arrives in time or a secondary failure removes margin. The example 1.8 kWh/km × 24 km = 43.2 kWh therefore remains a local calculation rather than a complete architecture.

To make the model useful, explicitly add the quantities that dominate this subject: distance, network flow, power, pressurized volume, travel time, interface state and backup capacity. We can then ask which variation truly changes the result, which is negligible and which forces an architectural change. For “Surface mobility: rovers, cargo, routes and rescue”, this model limitation states exactly what a correct calculation still cannot establish about the real system.

7 — Instrumentation, observability and data quality

For “Surface mobility: rovers, cargo, routes and rescue”, observability relies on distance, network flow, power, pressurized volume, travel time, interface state and backup capacity. Each datum has a unit, acquisition rate, uncertainty, timestamp and validity domain. A value arriving without context can be more dangerous than no measurement because it creates unjustified confidence.

Consistency is checked with at least one independent piece of information when the function is critical. A trend, physical balance or second measurement principle helps distinguish a real system change from a drifting sensor. For “Surface mobility: rovers, cargo, routes and rescue”, the selected instrumentation must distinguish a real physical change from sensor drift or a bad state estimate.

8 — Phenomenon-specific failures and recovery

The reference failure is not a vague “broken component.” For “Surface mobility: rovers, cargo, routes and rescue”, test in particular broken line, blocked logistics route, isolated zone, incompatible interface or backup capacity concentrated in the same location. Diagnosis asks which symptoms appear first, which are only consequences and which action preserves the most options.

The degraded mode must be defined before failure: minimum function, allowable duration, consumed stock, crew action, abort condition and return-to-nominal criterion. That sequence is topic-specific and cannot be replaced by one universal paragraph about redundancy. For “Surface mobility: rovers, cargo, routes and rescue”, the degraded mode is defined around the minimum function specific to this subject, with an abort threshold and a return-to-nominal condition.

Operational table

Phenomena / sections:	7 — Instrumentation, observability and data quality ; 8 — Phenomenon-specific failures and recovery
Relationship to revisit:	E_trajet = e_km × d
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 7 — Instrumentation, observability and data quality ; 8 — Phenomenon-specific failures and recovery. State one measured quantity, one margin and one possible decision.

Surface mobility: rovers, cargo, routes and rescue

9 — NASA / reference case

The operational case is treated as a production or service chain: input resource, machine, intermediate storage, quality control, maintenance and final user. NASA ISRU, autonomy and manufacturing work helps separate a technology demonstration from a truly available Mars industrial capability.

The case is used only within what it actually demonstrates. Flight measurement, human-system standard, component test and architecture study are different kinds of evidence; the text therefore states what is observed, calculated, simulated or still prospective. For “Surface mobility: rovers, cargo, routes and rescue”, the cited NASA case is used as targeted evidence for this phenomenon and is never turned into one universal Mars architecture.

10 — Architecture trade

A good solution for “Surface mobility: rovers, cargo, routes and rescue” does not maximize one metric. Compare nominal performance, mass, energy, simplicity, maintenance, crew time, common dependencies and recoverability. An option that improves 60 kWh available − 43.2 kWh = 16.8 kWh can still be rejected if it makes failure detection or repair much harder.

The trade is recorded together with its assumptions. If environment data, mass or mission cadence changes, we know which conclusions must be recomputed instead of silently preserving an obsolete choice. For “Surface mobility: rovers, cargo, routes and rescue”, the trade is evaluated against the interfaces actually touched by this subject rather than a generic list of desirable qualities.

11 — Demonstration, testing and success criteria

The evidence strategy for “Surface mobility: rovers, cargo, routes and rescue” combines layout mockups, segmented-network testing, rover campaigns and reconfiguration exercises. Every test records exact hardware, software, configuration, environment, tolerances and success criterion. A successful demonstration outside the mission domain does not replace qualification inside it.

Evidence grows by levels: analytical relationship, simulation, component, subsystem, integrated system, duration and failure. This hierarchy prevents one spectacular test from being presented as validation of the whole mission. For “Surface mobility: rovers, cargo, routes and rescue”, demonstration must reproduce the constraints that make this phenomenon difficult; a spectacular test outside the mission domain is insufficient.

Operational table

Phenomena / sections:	9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria
Relationship to revisit:	$E_{trajet} = e_{km} \times d$
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 9 — NASA / reference case ; 10 — Architecture trade ; 11 — Demonstration, testing and success criteria. State one measured quantity, one margin and one possible decision.

Surface mobility: rovers, cargo, routes and rescue

12 — Decision exercise

Situation: revisit “Surface mobility: rovers, cargo, routes and rescue” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable.

Situation: revisit “Surface mobility: rovers, cargo, routes and rescue” with a 20% increase in the most penalizing quantity from the first worked example while one measurement or backup path is unavailable.
Expected answer: recompute the relationship, identify remaining margin, check whether observability is still adequate, and decide whether degraded operation remains acceptable. Multiplying by 1.2 is not enough if the variation also changes interfaces or limits.

13 — What to retain without over-generalizing

14 — Topic-specific primary sources

These references directly document the phenomenon, technology or human constraint addressed in this lesson. They do not by themselves define an official Mars architecture. For “Surface mobility: rovers, cargo, routes and rescue”, the bibliography is deliberately targeted to this page so that readers can trace each claim back to the relevant primary document.

Topic-specific primary sources

NASA NTRS — Autonomous Systems & Robotics for Surface Infrastructure - https://ntrs.nasa.gov/citations/20210024326

NASA NTRS — Human Exploration of Mars: Preliminary Lists of Crew Tasks - https://ntrs.nasa.gov/citations/20190001401

NASA TechPort — NASA Platform for Autonomous Systems - https://techport.nasa.gov/projects/94884

Operational table

Phenomena / sections:	12 — Decision exercise ; 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources
Relationship to revisit:	$E_{trajet} = e_{km} \times d$
Expected decision:	measure → compare with margin → choose nominal, degraded or stop

Check before continuing

Explain without rereading: 12 — Decision exercise ; 13 — What to retain without over-generalizing ; 14 — Topic-specific primary sources. State one measured quantity, one margin and one possible decision.