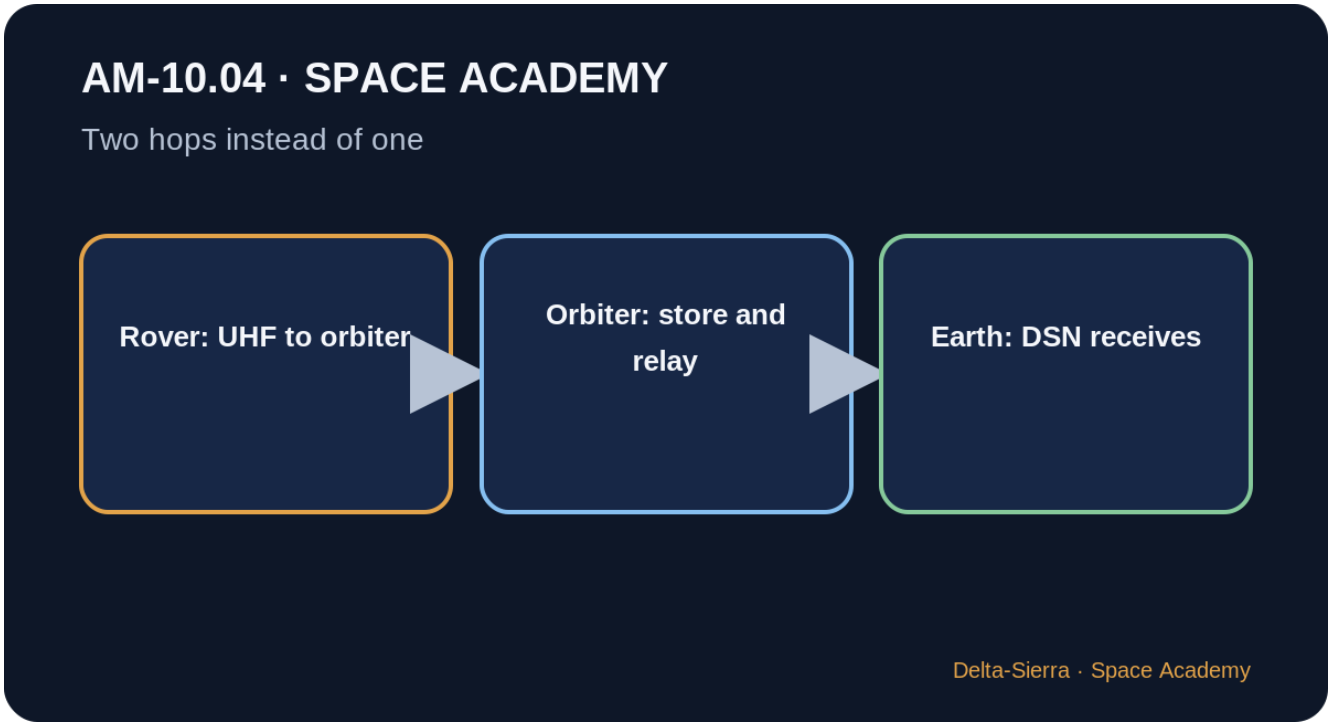
AM-10.04 — Mars relay network: UHF to the orbiter, X-band to Earth

Why does a Mars rover send most science data to an orbiter instead of pointing directly at Earth?



A fast local link to an orbiter avoids asking the small rover to carry the entire interplanetary communication burden alone.

1 - Understand the scene

A rover has limited power, a relatively small antenna, and spends roughly half each Martian day without direct line of sight to Earth because Mars rotates. An orbiter periodically passes only hundreds or thousands of kilometres away. It is much easier to send data quickly to that orbiter and let the orbiter use larger power and antenna capability for Earth transmission.

NASA describes the Mars Relay Network as international infrastructure. In 2026, after NASA declared MAVEN ended on June 3, the NASA Science page lists four spacecraft in the relay network. The membership changes as missions age, so a durable architecture must plan replacement and redundancy.

2 - Essential vocabulary

Relay - Equipment that receives data and retransmits it to another destination.

UHF - Ultra High Frequency, used for short-range rover-to-orbiter links around Mars.

X-band - Microwave band commonly used for deep-space communication.

Direct-to-Earth - Link where a surface vehicle communicates directly with Earth without an orbital relay.

Relay pass / session - Time window when rover and orbiter have line of sight and schedule a data exchange.

DSN - NASA Deep Space Network of large ground antennas communicating with distant missions.

3 - Step-by-step mechanism

1. Rover to orbiter

Perseverance carries UHF around 400 MHz for orbiter links. NASA states rover-orbiter rates can reach about 2 Mbit/s under suitable conditions, far above the rover’s direct-to-Earth science-data capability.

2. Orbiter stores and forwards

The orbiter receives packets during a pass, stores them, then uses its deep-space link and favorable geometry to send them toward Earth.

3. Earth receives through large networks

Ground antennas including the DSN track the orbiters. The relay architecture separates the short local Mars surface-orbit link from the very long interplanetary link.

4 - Formulas and reading

volume = débit × durée

“data volume equals data rate times duration.”

A relay pass is not just an instantaneous rate; transferred volume also depends on how long the link is usable.

temps = volume / débit

“time equals volume divided by rate.”

To estimate how long it takes to empty stored data, divide data amount by useful throughput.

5 - Units and checks

Data rate uses bit/s, kbit/s, or Mbit/s. Data volume uses bits or bytes; one byte equals eight bits. Convert both quantities into compatible units before calculating.

2 Mbit/s is not 2 MB/s: eight bits make one byte, and protocols further reduce useful science-data throughput.

6 - Three demonstrations

Example 1 — Ten-minute pass

Take an ideal teaching rate of 2 Mbit/s for 10 min.

```
10 min = 600 s
volume = 2 Mbit/s × 600 s
volume = 1200 Mbit ≈ 150 MB
```

Conclusion: This is an ideal upper calculation before protocols and link variation.

Example 2 — Empty stored data

A rover has 600 Mbit to send at a useful 1.5 Mbit/s.

```
time = 600 ÷ 1.5
time = 400 s
400 s ≈ 6 min 40 s
```

Conclusion: Rate alone is not enough; a visibility window of at least this duration is also needed.

Example 3 — Slow direct Earth link

If a teaching direct link provides only 1 kbit/s for an 80 Mbit file:

```
time = 80,000 kbit ÷ 1 kbit/s
time = 80,000 s
≈ 22.2 h
```

Conclusion: This illustrates why orbital relay radically changes recoverable science volume.

7 - Deepening

The network changes over time

Orbiters age and can disappear. The loss of MAVEN reminds us that settlement infrastructure cannot treat relays as immortal; replacements must be launched before old assets fail.

Multiple partners

NASA and ESA already cooperate around Mars. A settlement architecture could extend this sharing while managing priorities, standards, and communication sovereignty.

Store to decouple

Store-and-forward lets a rover produce data without a permanent interplanetary link. The orbiter becomes a flying queue.

Relay and safety

Critical commands should not depend on a single relay. Serious architectures combine alternate paths, degraded direct Earth, multiple orbiters, and local autonomy.

8 - Why this matters for Mars

The Mars Relay Network already demonstrates the value of shared infrastructure: surface missions return more science because orbiters carry much of their data to Earth.

A Mars city would need far more than science return: maintenance, delayed telemedicine, software updates, archives, data synchronization, and fleet coordination require much larger and redundant relay capacity.

9 - Common traps

- Confusing rover-orbiter UHF rate with end-to-end rate to Earth.
- Assuming an orbiter is always visible from the rover.
- Confusing Mbit/s with MB/s.
- Assuming today’s relay network would be enough for a human settlement.
- Designing a system with no direct-Earth or backup path.

10 - Guided exercises

Question: At 1 Mbit/s for 5 min, how many ideal Mbit?

Answer: 5 min = 300 s, so volume = 1 × 300 = 300 Mbit.

Question: Why can an orbiter reach Earth better than a rover?

Answer: It generally has more power, a more capable antenna, better visibility, and can devote resources to relay.

Question: Why do four orbiters not imply perfect continuous coverage?

Answer: Their orbits, priorities, failures, geometry, and scheduled passes constrain availability; spacecraft count alone does not guarantee it.

11 - What you should explain

- Describe rover UHF → orbiter → Earth chain.
- Explain why relay increases returned data volume.

- Convert Mbit/s, seconds, and data volume in simple examples.
- Distinguish direct-to-Earth from relay.
- Explain why settlement infrastructure must be redundant and renewed.

12 - NASA / JPL sources

NASA Science - Mars Relay Network
https://science.nasa.gov/mars/mars-relay-network/

NASA Science - Mars 2020 rover components
https://science.nasa.gov/mission/mars-2020-perseverance/rover-components/

NASA - What is the Deep Space Network?
https://www.nasa.gov/directorates/somd/space-communications-navigation-program/what-is-the-deep-space-network/