Mechanisms: deployments, actuators and reliability

Essential answer

Mechanisms: deployments, actuators and reliability. The question to solve is: Why can a simple hinge become critical to the whole mission? N for force, N·m for torque, degrees or radians for angle, cycles for life under a defined profile. The rest of the course turns that idea into an auditable line of reasoning: explicit units, stated assumptions, reproducible calculations, order-of-magnitude checks and interpretation limits. A result is useful only when the reader can explain what it measures, where every input came from and which engineering decision it can support.

Reasoning map

1. 1 — The concrete scene
2. 2 — Essential words, explained before using them
3. 3 — See the architecture before calculating
4. 4 — Formulas, only when they answer a question
5. 5 — What units and margins mean

Parts performing movement or locking.

Transition from compact to operational configuration.

Before calculating

Quantity:	Mechanisms: deployments, actuators and reliability
Check:	units + order of magnitude + assumptions
Decision:	state what the result actually supports

Mechanisms: deployments, actuators and reliability

Parts performing movement or locking.

Transition from compact to operational configuration.

Rotational effect of force, in N·m.

Gap between parts affecting jamming and accuracy.

One failure is enough to lose the function.

3 — See the architecture before calculating

Survive launch without unwanted motion.

Spring, motor or actuator provides torque.

Sensor proves position is reached.

4 — Formulas, only when they answer a question

How to read it : tau equals force times lever arm

For perpendicular force; real torque depends on geometry and friction.

5 — What units and margins mean

N for force, N·m for torque, degrees or radians for angle, cycles for life under a defined profile.

6 — Three concrete demonstrations, calculated step by step

30 N at 0.20 m.

Resistance 4 N·m → excess 2 N·m

Open command sent, end switch inactive.

Command sent ≠ position proven

Do not continue hazardous sequence.

200 test cycles for 20 mission cycles.

Load profile must remain representative.

7 — Deepening: what the simplified diagram hides

Active reading

Sections:	3 — See the architecture before calculating ; 4 — Formulas, only when they answer a question
Verification:	A value is usable only with its unit and calculation boundary.
Exercise:	change one assumption and predict the direction of change before recalculating

Mechanisms: deployments, actuators and reliability

Vacuum, lubrication and materials change friction and wear.

Clearances and resisting torque change with expansion.

Simplicity, margin and testing compensate for limited statistics.

End switches, encoders and motor current give different evidence.

A mechanism adds capability but also complexity and sometimes a single point.

8 — Application to an Earth-Mars spacecraft

9 — Reference dossier: what a real project must still consider

Motors, gears, springs, hinges, latches, cables, bearings and sensors can form a spacecraft mechanism. It must work after launch vibration, vacuum, extreme temperature and sometimes months of storage. One-shot deployments gain confidence from simplicity, margins, material control and representative testing rather than in-flight statistics.

Moving surfaces depend on friction, wear and lubrication. Vacuum can make terrestrial lubricants unsuitable, while Mars dust adds abrasion and contamination. Material pairs, coatings, compatible lubricants, clearances, cleaning and inspection therefore matter.

A joint that moves at room temperature can bind when cold or become loose when hot. Analysis covers manufacturing tolerances, temperature, wear and alignment. Actuators need enough torque margin without damaging hardware at stops.

A solar-array or antenna deployment may happen only once. Designers must plan for false sensors, motor overcurrent and partial deployment, and recovery logic is part of the mechanism system, not merely software.

Limit switches, encoders, motor current and cameras each provide different evidence. Each can be ambiguous on its own, so combining them improves diagnosis, especially when a Mars crew must decide whether physical intervention is safe.

NASA notes that mechanisms add capability and complexity and can introduce single-point-failure risk. System design should ask whether a minimum mission is possible without the mechanism, whether independent paths exist or whether a fixed architecture can eliminate motion entirely.

Surface equipment may be repairable, increasing the value of accessible fasteners, standard parts, lifting tools and documentation. EVA dexterity and contamination still constrain what can be done outside, so repair tasks should be allocated between external work and pressurised workshops.

Active reading

Sections:	8 — Application to an Earth-Mars spacecraft ; 9 — Reference dossier: what a real project must still consider
Verification:	A value is usable only with its unit and calculation boundary.
Exercise:	change one assumption and predict the direction of change before recalculating

Mechanisms: deployments, actuators and reliability

10 — Common traps and bad intuitions

Confusing command and actual motion.

Adding mechanism without addressing single-point risk.

A spacecraft mechanism may have only one chance to move

Deploying an array, opening a cover or pointing an antenna looks simple on Earth, but mechanisms must survive launch, vacuum, temperature cycles and long inactivity. Lubrication, clearances, thermal expansion, contamination and cold welding all affect reliability.

Actuators must be matched to required torque, speed, end stops and locking. The system also needs independent evidence that motion completed; two identical limit switches can still share the same mechanical or wiring failure.

Reliability often favors simplicity, such as springs and passive latches, but long-lived infrastructure may need repeated operation and maintenance. The right architecture depends on cycle count and the consequence of failure.

11 — Guided exercises

Question : What question comes before choosing hardware?

Question : Why is a nominal result insufficient?

12 — What to remember

Explain the topic in simple words before symbols.

Connect at least four interfaces with other subsystems.

Redo the three numerical examples without reasoning gaps.

13 — NASA sources for further study

NASA - 2026 State-of-the-Art: Structures, Materials, and Mechanisms

NASA - 2026 State-of-the-Art: Integration, Launch, Deployment and Orbital Transport

Active reading

Sections:	10 — Common traps and bad intuitions ; A spacecraft mechanism may have only one chance to move
Verification:	NASA - 2026 State-of-the-Art: Structures, Materials, and Mechanisms | NASA - 2026 State-of-the-Art: Integration, Launch, Deployment and Orbital Transp | NASA Systems Engineering Handbook
Exercise:	change one assumption and predict the direction of change before recalculating