Top 20 Rules for University Rover Challenge Success

The most important function of your rover is to convert time and mass into points. Everything that follows is in service of that single idea. These rules distill what we looked for while judging the INCOSE Foundation's systems engineering award at this year's University Rover Challenge, read against the 2026 URC requirements: a winning rover is a disciplined system-of-systems in which communications, mobility, perception, manipulation, the base station, and — above all — the operators are engineered together.

Foundations — If These Fail, Nothing Else Matters

1. ***The first step in winning is not losing.*** Do not get disqualified. Read every line of the rule set and treat the deadlines as gating milestones: registration (Oct 29), PDR (Dec 3), the competitive SAR (Feb 27) that down-selects to 36 teams, the communications submission (Apr 24), and the Rover Expense Report (May 20). A brilliant rover that misses a deliverable, busts the $24,000 budget, or fails weigh-in never converts a single second of mission time into points.

2. ***Communication is king — if you can't talk to the rover, it's a statue.*** The link is the spine of the entire system-of-systems. Plan for the 900 MHz sub-band shuffle (900-Low/Mid/High, 8 MHz max) the schedule will impose, and design the Delivery Mission link knowing line-of-sight is not guaranteed for more than half the course out to 1 km. Repeaters, directional antennas, and a drone relay are all on the table; a dropped link mid-task is a statue holding your points hostage.

3. ***Robust mobility is necessary — if it doesn't move, it's a statue.*** MDRS terrain runs from flat sand to gravel, boulder fields, vertical drops, and steep, loosely consolidated slopes out to 1 km. Mobility must survive all of it while carrying every deployable except the drone out of the start gate. Suspension, traction, and ground clearance are not where you save mass; a high-centered rover scores exactly nothing on Delivery.

4. ***Operator vision and situational awareness are everything.*** Operators in the C2 station cannot see the course — they fly entirely on your cameras. Camera count, placement, and orientation are a first-order design decision, not an afterthought. You need driving views, hazard views, and arm/task views, and you need to know which one matters in each moment of each mission. Spend a few dollars on coverage you will only occasionally need: a cheap wide-angle fisheye looking down under the chassis lets operators see a rock wedged in a wheel or debris caught in the drivetrain on those boulder-field traverses — the difference

between a ten-second course correction and a mission-ending intervention you never saw coming.

Fine Manipulation — See the Task, Then Do It

5. ***Task vision quality wins the fine-manipulation missions.*** Equipment Servicing demands you read a USB-C slot framed by 1 cm ArUco markers, hit a specific keyboard for autonomous typing, and seat a cache in a tight drawer. None of that happens on a blurry, badly-lit, poorly-placed camera. Dedicate optics, focus, and lighting to the end-effector's working volume — and remember you are outdoors. Full sun, a passing cloud, or the rover's own shadow falling across the lander can blow out highlights or crush detail into darkness and make a task camera useless at the worst moment. A high-dynamic-range sensor and/or on-board task lighting keeps the working area legible regardless of where the sun is and what the rover's own body is shadowing.

6. ***Never underestimate the need for fine motor skills.*** Servicing tasks are unforgiving: turn a quarter-turn valve, undo a latch, push a cam-lock hose fitting, flip switches, seat a sample tube. Grippers must grasp features up to 7.5 cm and apply controlled, repeatable force. Coarse, twitchy manipulators turn nominal tasks into long, frustrating, point-bleeding ordeals.

Flying the Rover — The Link and the Operators

7. ***Bandwidth is life — learn to throttle.*** When the link narrows — and on the far half of the Delivery course it will — you must shed load gracefully: drop video frame rate or resolution, prioritize the one camera that matters, and keep critical command-and-telemetry channels open. A system that floods its own pipe and chokes off control has defeated itself.

8. ***Use every scrap of feedback the rover can give you.*** Motor currents, accelerometers, GNSS, temperatures, link metrics — every heartbeat and telemetry stream helps operators understand the rover's true state and diagnose trouble before it becomes an intervention. Each intervention costs 20% of the mission, and the penalties stack, so the cheapest fix is the one your telemetry lets you avoid entirely.

9. ***Help your operators — design the human into the loop.*** Thoughtful UI, passive guidance, alignment lasers, stereo vision, and semi-automated routines ("return arm to known pose," "re-center steering") all reduce operator workload and error. The ArUco markers on posts and the lander are invitations to build computer-vision aids; the human and the autonomy should each do what they do best.

10. ***You need a coach and a flowchart.*** Under a 15-minute setup clock and tight mission timers, operators bog down and leave points on the table. A non-driving coach watching the clock plus a task-by-task decision flowchart keeps the crew

moving, deciding when to attempt, when to skip, and when to abort — turning hesitation back into scored points.

11. ***Operators are part of the system — give them time to practice.*** Hardware capability is only realized through skilled operation. Operators need real seat time on representative tasks to build the muscle memory that converts the 15-minute setup and tight mission clocks into points. An under-practiced crew will never extract what the rover can actually do.

Designing for Failure — Robustness in the Field

12. ***Research your COTS parts — then use them to the fullest.*** Commercial components inform your custom design and often outperform it. Know their real capabilities: motor braking, for instance, keeps a parked rover from rolling downhill on a slope — don't design that feature out. Understanding the COTS envelope tells you where to spend custom engineering and where to simply buy reliability.
13. ***A disconnected interface kills capability.*** Vibration over boulder fields finds every loose connector and unsecured wire. Loctite, strain relief, disciplined cable routing, and robust connector choices remove failure modes before they remove your score. The most common field failure is not a clever subsystem breaking — it is a humble connection shaking loose.
14. ***Obstacle avoidance matters — use sensors wisely.*** In Autonomous Navigation the later objects sit in boulder fields requiring genuine autonomous avoidance. Build exclusion zones around targets: there is no reason to drive over a navigation tag or the very object you are trying to detect. Sensible perception keeps the rover safe and keeps hard-won targets intact.
15. ***Aim for graceful degradation.*** When something fails — and something will — it should fail soft. A dead drive motor should free-wheel, not lock a wheel and beach the rover. Redundancy, fail-safe defaults, and degraded-mode plans let a wounded rover keep scoring instead of becoming a statue in the field.

The Environment, and Proving It Works

16. ***The environment is not your friend.*** MDRS brings 100°F heat, blowing dust, wind, and the occasional light rain. Each one attacks connectors, sensors, optics, and cooling. Seal what must stay clean, shade what overheats, and assume dust will find every gap. The conditions are part of the requirements, not an excuse.
17. ***Test in representative conditions — it is imperative.*** Terrain, heat, and dust expose the interdependencies a clean lab hides. As Baldwin & Clark put it in Design Rules, integration and testing identify and resolve unknown interdependencies. Note that on-site testing is barred at MDRS — so do it beforehand on representative ground (Factory Butte and similar OHV areas), not for the first time on the clock.

18. ***Work out your troubleshooting procedures before the issues arise.*** The desert is the worst place to invent a recovery plan. Pre-write and rehearse procedures for link loss, frozen arm, GNSS dropout, and stuck mobility, including who becomes a runner — remembering that anyone who leaves the C2 station to intervene cannot return to operate that mission. Practiced procedures beat improvisation every time.

The Whole System and Its Budgets

19. ***The base station is part of your system — give it equal attention.*** The C2 station, antenna, computers, displays, and controllers all count against your $24,000 budget and all determine whether you can fly the mission. A flaky base station, a marginal antenna, or a cluttered operator layout fails the whole system as surely as a broken wheel. Bring your 25 m of cable and engineer the ground segment deliberately.

20. ***Use every bit of your mass limit.*** The deployed limit is 50 kg per mission and 70 kg across all fielded parts. Every kilogram you leave on the table could have bought redundancy, an extra camera, a sturdier arm, or a better antenna. Mass is a budget — spend it deliberately on capability rather than surrendering it by accident.

Resources & Getting Help

You are not on your own. INCOSE has professional and student chapters all over the world, and they are genuinely happy to help student teams — with mentoring, design reviews, and a sounding board for the systems-engineering thinking these rules are built on. Reach out to your local chapter; the systems-engineering community wants you to succeed.

Two free, authoritative references are worth keeping open while you design:

- The **Systems Engineering Body of Knowledge (SEBoK)** — a living, community-maintained guide to SE practice, free online at sebokwiki.org.
- The **NASA Systems Engineering Handbook** (NASA/SP-2016-6105 Rev 2) — a free, practical treatment of SE across a project life cycle, available at nasa.gov/reference/systems-engineering-handbook.

For systems-engineering events and a monthly Historical Corner full of SE successes and failures worth learning from, see michigan.incose.org/news.

Credits

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