Offroad Simulator - User Manual

English (US)

This manual describes the documented simulator build supplied with it. Use the matching manual and Physical models document from your Steam or Web distribution; older packages can have different controls and settings.

Offroad Simulator is a configurable vehicle and cold-gas flight simulator for Windows. Choose the exhibition course, the independent obstacle and RCS course, or the speed test circuit, drive a generic off-road vehicle, compare drivetrain and suspension setups, change individual tire pressures and vehicle loading, experiment with braking assists, and use optional reaction control system (RCS) equipment for short flights and aerial rolls. The simulator provides exterior and cabin cameras, adjustable daylight and volumetric weather, controller vibration, optional USB steering wheel and pedal support, and CSV telemetry recording.

This manual explains normal operation, the complete keyboard and Xbox 360 controller mappings, and every control in the configuration panel. Settings and examples use the units displayed by the simulator, including metric units. Defaults describe a fresh full installation without saved preferences; your saved configuration may use different values.

For the governing equations, physical assumptions, numerical methods, and model limitations, see the companion Physical models document.

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1. Installation, access, and language

1.1 Starting the simulator

For an installed Web copy, run the simulator from its installed shortcut or installation folder. The installer can install the Microsoft Visual C++ x64 prerequisite if it is missing. Registration takes place inside the simulator.

For a standalone Windows package, retain the entire delivered folder and launch `OffroadSimulator.exe` from its top level. Moving only the executable separates it from the content and runtime files it needs. In a development checkout, the equivalent packaged launcher is `Packaged/Windows/OffroadSimulator.exe`.

The welcome screen presents the background, title, and capability descriptions in sequence. Wait until the continue prompt appears, then press a fresh keyboard key, click the mouse, or press a digital Xbox 360 controller button. Inputs before the prompt are ignored. Moving a stick alone does not continue. The presentation fades into track selection. Choose **Exhibition course**, **Obstacles and RCS course**, or **Speed test circuit**, then confirm the choice to load that map. The vehicle and its sound start only with the selected track. The selector itself contains no driving vehicle or track environment.

Use the mouse, arrow keys/WASD, controller D-pad, or left stick to choose a track. **Enter**, **Space**, or controller **A** confirms; **Esc/B** returns to welcome. The static route previews describe all three tracks without loading their worlds. Opening the selector always requires a fresh confirmation input; continuing past welcome does not automatically start a track.

Use **Alt+F4** or the window close button to exit. During driving, **Esc** displays a reminder of the settings and exit shortcuts; it does not quit the application.

1.2 Full access and demonstration mode

Access mode	Available operation
Steam edition	Full simulator capabilities. The separate Web registration form is not used.
Registered Web edition	Full simulator capabilities after activation on the licensed PC.
Unregistered Web demonstration	Ten minutes of driving per session, default vehicle settings, a finite RCS sample, language selection, and HUD visibility controls. Advanced configuration is locked.

The demonstration has RCS installed with 100 kg of usable air and no recharge. Vehicle recovery preserves the air and auxiliary energy already remaining in that demonstration session. Changing track also retains the remaining air and auxiliary energy. The ten-minute allowance belongs to the session, not each map: loading another track does not restart it. The countdown stops while settings are open, RCS flight is paused, or selection/loading is in progress. When the session time expires, the simulator returns to the welcome screen.

The detailed configuration reference in this manual describes full access. A demonstration panel displays only its available controls, **Change track**, and a button to return to the welcome screen for registration.

1.3 Registering the Web edition

At the unregistered welcome screen, wait for the prompt and press **R** to open registration. Use another key or a controller button to enter the demonstration instead. On the course, **R** has the separate vehicle recovery function.

Enter the following in the registration form:

Form control	How to use it
Full name	Enter the first and last name associated with the purchase.
Registration email	Enter the exact registration identifier you received. Preserve an appended suffix such as `_2` or `_3` when present.
Registration code	Paste the supplied code. The entry is masked on screen.
Register	Submit the information. Initial activation requires an Internet connection. **Enter** also submits when a request is not already in progress.
Cancel	Close registration and return to the welcome screen. **Esc** has the same effect.
Status message	Reports validation, connection, activation, or local saving results. Correct the reported issue before resubmitting.

A Web license is permanent for one PC. After successful activation, subsequent launches validate the local license without requiring an online activation each time. Reinstalling or uninstalling the game preserves the personal preferences and local license. If the license is already activated on another PC or the PC has changed, request manual recovery from the publisher. The registration screen reports this condition; changing vehicle settings cannot resolve it.

1.4 Selecting English or Spanish

On the course, press **Tab** or **Start** on the Xbox 360 controller to open settings. Choose **English (US)** or **Español** at the top. The selection immediately updates the interface, HUD, notices, course signs, and recovery names, and saves automatically. English (US) is the initial language.

CSV column names and configuration keys keep their machine-readable names in either language. Changing language does not change the measurement units.

2. Your first drive

1. Connect the Xbox 360 controller before driving, or use the keyboard. Connect any optional USB wheel and pedals before launching the application.
2. Continue past welcome, select a track, and confirm. The vehicle starts stopped at that track's start position, with the engine running and the transmission in **N**, meaning neutral.
3. Hold the service brake: **LT** on the controller or **S** on the keyboard.
4. Press **RB** or **E** once to select first gear. Release the brake and gradually apply **RT**, or press **W**.
5. Steer with the left stick or **A/D**. Start slowly and follow the course markings.
6. Use **LT/S** to slow down. Hold **A** on the controller or **Space** on the keyboard for the parking brake while driving.

7. Press **B/C** to switch between exterior and cabin views. Use the right stick or mouse to look around.
8. Stop before opening **Tab/Start** to change physical settings. Use **Save configuration** when you want the changes to survive a restart.

Automatic transmission is enabled initially. Selecting first gear starts automatic forward shifting; you do not need to shift through all six forward gears manually. To reverse, stop, release the throttle, and press **LB/Q** through first and neutral into **R**. Apply the throttle to move backward. **S/LT** remains the brake; it does not automatically select reverse.

The keyboard **N** key changes daylight. It is not a direct neutral selector. Select neutral using the sequential gear controls.

3. Complete control reference

3.1 Controller names and input priority

The controller reference uses an **Xbox 360 controller** in XInput mode. **LB/RB** are the shoulder buttons, **LT/RT** are the analog triggers, **L3/R3** mean clicking the left/right stick, and **Start/Back** are the center buttons. Some interface help uses the newer names **Menu/View** for Start/Back.

Keyboard and controller driving inputs can be used together. Keyboard steering overrides the left stick while held, and the strongest service brake input is used. An enabled, correctly calibrated USB wheel profile takes priority for ground steering and throttle; keyboard/controller braking remains available. A missing required wheel axis activates braking until the profile is repaired or disabled.

In RCS flight, a connected XInput controller supplies collective, roll, and pitch from **RT and the left stick**. For the keyboard-only flight controls in section 3.4, disconnect the XInput controller. Keyboard toggles, recovery, and lateral commands remain available with a controller connected.

3.2 Driving controls

Action	Xbox 360 controller	Keyboard	Operation
Throttle	RT	W	Progressive on RT; full demand while W is held. Requires a selected gear for ground propulsion.
Service brake	LT	S	Progressive on LT; full demand while S is held. Operates in forward and reverse.
Steer left/right	Left stick left/right	A / D	Returns toward center when released, using the configured steering response.
Parking brake	Hold A	Hold Space	Hold to apply; release to remove. This is a separate brake demand without ABS modulation.
Upshift	Press RB	Press E	One sequential step toward the next forward gear; selects first from neutral.
Downshift	Press LB	Press Q	One sequential step toward a lower gear, neutral, or reverse; selects reverse from neutral when permitted.

Action	Xbox 360 controller	Keyboard	Operation
Disengage digital clutch	Hold X, or L3 with RCS installed and flight assigned to X	Hold Left Shift	Used for fully manual transmission. Release to engage the clutch. See the binding rules below.
Analog clutch, when enabled	Push right stick upward	No separate analog keyboard input	Upward travel progressively disengages the clutch. Centered or downward stick leaves it engaged. This mode replaces the digital clutch path while a controller is connected.
Start a stopped engine	D-pad up	I	Starts or restarts the engine. It is not an engine on/off toggle.
Toggle 4x2/4x4	D-pad left	F	Requires the conditions for transfer changes. Returns to the selected Rear/Front preference when 4x4 is disabled. Unavailable as a driving shortcut while flight is active.
Select driven axle in 4x2	Use settings	Use settings	Tab/Start > DRIVETRAIN > Driven axle in 4x2. Choose Rear or Front while stopped and with 4x4 disabled; see section 4.2.
Toggle high/low range	D-pad right	L	Requires stopping and disengaging the transmission. Unavailable as a driving shortcut while flight is active.
Toggle headlights and associated vehicle lights	D-pad down	H	Also controls the amber front lights, blue wheel lights, and position lighting.
Toggle hill start assist	Use settings	J	Enables or disables the timed hill hold function.
Toggle hill descent control	Use settings	K	Enables or disables the descent controller; its operating conditions still apply.
Recover vehicle	Y while driving	R, or Y while driving	Moves to a safe recovery on the active track and resets the trial state. The basic track uses its start; exhibition and obstacle courses use their nearest safe point. In flight, Y starts/cancels automatic roll instead.

Clutch and flight button sharing: without RCS installed, **X** is the digital clutch button. With RCS installed and the default **X** flight binding, the digital clutch moves to **L3**. Selecting **L3** as the flight button moves the clutch back to **X**. **G** always remains the keyboard flight toggle. **R3** is reserved for camera reset.

3.3 Camera, interface, lighting, and recording

Action	Xbox 360 controller	Keyboard / mouse	Operation
Open/close configuration	Start	Tab	Opens the scrollable panel. Start/Tab closes it even after interacting with controls.
Close configuration	Start	Esc or Tab	Returns to driving. Closing does not automatically save all settings.

Action	Xbox 360 controller	Keyboard / mouse	Operation
Select and adjust panel controls	Standard interface focus where available	Mouse click, drag, scroll, or type in numeric boxes	The mouse provides access to the complete panel, including device lists and calibration.
Exterior/cabin camera	B	C	Toggles the active view without changing the vehicle's motion.
Orbit exterior camera	Right stick	Move mouse	The exterior view keeps a level horizon through vehicle roll and pitch and follows vehicle yaw. The chosen orbit persists when you release the input.
Look around cabin	Right stick	Move mouse	Adjusts the view within the cabin's look limits. The cabin itself follows body attitude.
Exterior camera zoom	No dedicated controller binding	Mouse wheel	Forward zooms in; backward zooms out, in 0.25 m steps. Requested distance is limited to 2.5-30 m.
Reset camera view	Click R3	No dedicated keyboard binding	Restores the initial exterior orbit and distance and centers the cabin view. It does not recover or move the vehicle.
Advance time by three hours	Back	U	Wraps after midnight and disables continuous day/night cycling.
Switch between night and daytime	Use settings	N	Selects 23:00 when currently daytime, or 15:00 when currently night; disables continuous cycling.
Start/stop telemetry recording	Use settings	T	Opens a new CSV file or closes the active one. The recording indicator confirms that recording is active.
Exit application	No dedicated controller binding	Alt+F4	Closes the simulator. The window close button also works.

Moving the mouse upward lowers the exterior camera. Horizontal mouse movement rotates the orbit horizontally. The mouse remains usable while a controller is connected. Obstacles can shorten the actual exterior camera distance; it extends smoothly again when clearance returns. Zoom and orbit are session preferences.

When analog clutch is enabled in driving mode, right-stick vertical movement is assigned to the clutch and does not also change camera elevation. Horizontal camera movement remains available. In flight, the right stick resumes its normal camera role.

3.4 RCS flight controls

Install RCS before using flight controls in a full session. The demonstration supplies its own fixed RCS sample.

Action	Xbox 360 controller	Keyboard-only flight	Operation
Enable/disable flight	Press X, or L3 if selected	G	To enable, release RT and lateral controls first. Keyboard collective must be at zero.

Action	Xbox 360 controller	Keyboard-only flight	Operation
Increase vertical collective	Squeeze RT farther	Hold Space	RT sets collective directly. Space increases a stored collective value at about 80 percentage points per second.
Reduce vertical collective	Release RT progressively	Hold Left Ctrl	Left Ctrl reduces the stored value at about 100 percentage points per second.
Maintain collective command	Hold RT position	Release Space and Left Ctrl	Keyboard collective remains at its last value; releasing Space does not cut thrust. Neither input provides altitude hold.
Roll left/right	Left stick left/right	A / D	Redistributes vertical nozzle thrust from side to side.
Pitch nose up/down	Left stick down/up by default	S / W by default	Redistributes front/rear vertical thrust. **Invert stick pitch** reverses the pitch direction, including the keyboard command.
Lateral translation left/right	Hold D-pad left/right	Hold Left Arrow / Right Arrow	Commands the lateral nozzles. Holding both directions cancels the lateral command.
Permit lateral use of landing reserve	Hold RB with lateral input	Hold V with lateral input	Allows discretionary lateral jets to use reserved air.
Start/cancel automatic left roll	Y	Y	With flight active and manual thrust/attitude/lateral controls neutral, starts the eleven-phase maneuver. Press again to cancel.
Recover immediately	Use keyboard R	R	Explicitly ends flight and starts a recovery trial. Y is not recovery while flying.
Switch camera / reset view	B / R3	C / mouse adjustment	Camera operation remains available during flight.
Open configuration	Start	Tab	Pauses the world during active RCS flight.

Keyboard overlap during flight: A/D and W/S become attitude commands; Space becomes collective increase. Space does not apply the keyboard parking brake in flight. S also remains a service brake input when there is wheel contact, so W/S flight input can affect braking at touchdown. On the controller, **LT** and **A** remain the service and parking brakes; shifts, ground steering, and engine propulsion are disengaged during flight.

To hand control back to the drivetrain, disable flight and release the thrust and lateral inputs. The system requires neutral inputs at the transition before accepting driving demands.

4. Driving and vehicle operation

4.1 Transmission and engine

The gearbox has reverse, neutral, and six forward gears. A new normal session or recovery begins in neutral with the engine running. Neutral disconnects wheel propulsion even if RPM rises with the throttle.

With **Automatic transmission with torque converter** enabled, select first to drive forward. The converter allows progressive launch and the gearbox changes forward gears according to RPM and throttle. You can still issue sequential gear commands. Reverse remains a deliberate selection; brake to a stop, downshift through neutral, select reverse, and apply throttle. Changes into or out of reverse are rejected if longitudinal speed is 0.8 m/s or higher, about 2.9 km/h. Stopping fully is the clearest procedure.

For assisted manual driving, stop, disable automatic transmission, and leave **Manual transmission clutch assist** enabled. Select gears sequentially; the assistance modulates clutch engagement for launching.

For fully manual driving, disable both automatic transmission and clutch assist. Hold Left Shift or the applicable controller clutch button, select first, apply modest throttle, and release the clutch progressively if using an analog input. Before each shift, disengage the clutch. A shift is rejected unless clutch engagement is below 15%. The engine can stall if the clutch is engaged at insufficient RPM. Disengage it and press I or D-pad up to restart. A separate calibrated USB clutch pedal can provide progressive engagement.

In the cabin, the steering wheel follows the modeled road-wheel steering and steering ratio. The two instrument needles show speed and engine RPM, and gauge illumination follows the engine's running state. These visual instruments complement the numerical HUD; they are not separate controls.

4.2 Traction, range, and differentials

The default 4x2 mode drives the rear axle. Open **Tab/Start > DRIVETRAIN > Driven axle in 4x2** to select **Rear** or **Front**. In Spanish the control is **Tren motriz en 4x2**, with **Trasero** and **Delantero**. The selected axle receives propulsion and engine braking; the steering and rear parking brake keep their normal controls. The selector is disabled in 4x4 and retains its preference for the next return to 4x2. Use **Save configuration** to retain the choice between sessions. Older configurations and an absent or invalid axle preference default to Rear.

The HUD shows **4x2 R** for Rear and **4x2 F** for Front in English, or **4x2 T/D** in Spanish. **Four-wheel drive** supplies both axles with a base 50/50 split and a bounded coupling torque that opposes differences between their mean wheel speeds. The effective axle torques can therefore differ from 50/50. **Low range** multiplies the selected gear ratio to trade wheel speed for wheel torque. Low range is useful for slow obstacles and is required by hill descent control.

Open differentials allow the two wheels on an axle to turn at different speeds. On split traction or with one wheel lightly supported, that can limit useful drive at the other wheel. Front and rear locks reduce the speed difference on their respective axles. Limited-slip differentials provide a softer torque-biasing alternative. Locks can resist turning on high-grip surfaces; compare them at low speed on the articulation and split-traction sectors.

Requested change	Conditions
Change driven axle in 4x2	Disable 4x4. Total speed at most 0.15 m/s, body angular speed at most 0.15 rad/s, throttle at most 5%, and front/rear mean wheel speeds synchronized within 2 rad/s. Select neutral or disengage the clutch; holding the service brake is accepted in automatic mode.
Toggle 4x4	Release throttle to 5% or less, reduce total vehicle speed to 0.5 m/s or less, and let front/rear mean wheel speeds synchronize within 2 rad/s before engaging.

Requested change	Conditions
Engage front or rear lock	Release throttle, reduce total speed to 0.5 m/s or less, and let the two wheel speeds on that axle synchronize within 2 rad/s.
Release a differential lock	Does not have the engagement speed/synchronization restriction.
Change high/low range or automatic/manual transmission type	Total speed at most 0.15 m/s and body angular speed at most 0.15 rad/s. Release throttle, and select neutral or disengage the clutch. Holding the service brake is accepted for the disengagement condition in automatic mode.
Connect/disconnect an anti-roll bar	Throttle at most 5%, total speed at most 1 m/s (3.6 km/h), and body angular speed at most 0.3 rad/s. Engagement changes progressively over 0.35 s.
Change physical values, loads, tire dimensions/pressures, or most numeric vehicle settings	Total speed at most 0.15 m/s and body angular speed at most 0.15 rad/s. Wait for the vehicle to settle.

ABS, EBD, hill-assist switches, limited-slip selection, clutch assist, and the descent speed target can be adjusted without resetting the driving state. A rejected setting leaves the previous accepted value in place and produces an explanatory notice. Wheelspin can prevent engagement even when the body appears stationary.

Accepted mode changes preserve gear, engine state, wheel motion, temperature, wear, elapsed simulation time, and the open telemetry recording. Changing a physical dimension or travel limit can require the suspension to settle to a new equilibrium.

4.3 Braking and slopes

The service brake is progressive with LT or a calibrated brake pedal and full demand with S. Hydraulic application/release times soften the pressure response. EBD adjusts front/rear distribution using axle support. ABS reduces and restores brake pressure independently per wheel above 2 m/s, about 7.2 km/h. ABS does not create extra tire grip.

Brake energy heats the rotors. With default settings, fade begins at 350 °C and reaches its maximum reduction at 700 °C, where the modeled service brake factor is 35%. Tires have their own temperature model; tire temperature and brake temperature are separate readings. Let the brakes cool between repeated comparisons.

The parking brake is applied while its control is held. It adds a separate braking torque without ABS modulation. Service braking and hydraulic hill assists activate the stop lights; parking brake input alone does not activate the stop lamps.

H or D-pad down switches the front/roof driving lights, eight amber grille markers, four blue wheel-area lights, and rear position-light state together. The blue lamps are attached to the body/fenders; they illuminate the wheel areas while the suspension and steering move independently. Service braking brightens the rear stop-light strip even when the driving lights are off. There are no separate normal-play switches for each individual lamp group.

Hill start assist: enable the switch or press J. On a slope steeper than 3°, stop with more than 25% service brake and at least two loaded wheel contacts. Releasing the pedal retains brake pressure for the configured duration, initially two seconds. It releases earlier when sufficient uphill drive torque is

available or the support conditions no longer hold. The function can hold while the vehicle faces either way on the slope. Use the parking brake for a longer stop.

Hill descent control: select low range and a non-neutral gear, enable the switch or press K, and approach the downhill section slowly. Release the throttle, service brake, and parking brake. With sufficient support and a downhill slope, the controller requests wheel braking toward the selected speed, initially 2 m/s (7.2 km/h). It can regulate forward or reverse descent. Engagement requires speed below 12 m/s; if already active it can continue braking above that speed. Applying a pedal or parking brake overrides its automatic demand. Low grip, brake fade, or insufficient support can prevent the target from being reached.

4.4 Tires, suspension, and load

Individual tire sliders set cold gauge pressure. The live pressure changes with tire temperature. Pressure affects carcass stiffness, loaded radius, longitudinal/lateral response, and rolling resistance. The contact model considers tire width and rounded shoulders when meeting low edges, steps, and supporting scene surfaces.

The vehicle has independently tunable front and rear articulated axle suspensions. Springs establish support and sag, compression damping resists shortening, rebound damping resists extension, and travel limits define available movement. Anti-roll bars couple opposite sides of an axle; disconnecting them permits more articulation at the cost of roll resistance.

Driver, passenger, cargo, roof load, and fuel are equivalent added masses at different positions. They change total sprung mass, center of gravity, load distribution, and inertia. Roof load raises the center of gravity; lateral cargo offset changes left/right balance. These settings do not add visible occupants or cargo, and the fuel mass is not consumed as you drive. RCS equipment, residual gas, and usable air also contribute mass when installed; expelled air reduces that mass.

Tire temperatures and wear evolve during a trial. There is no separate tire replacement action in the panel. A deliberate vehicle recovery starts a fresh vehicle state for repeatable comparisons.

4.5 Opening settings and losing focus

In ground driving, opening configuration removes throttle, disengages the clutch input, and applies the service brake while ground physics continues. Stop on a stable surface before tuning. Opening settings is not a general freeze of the vehicle or environment.

During RCS flight, opening settings, losing application focus, or disconnecting a controller used for flight pauses the world, gas consumption, and flight effects. Close the panel or restore focus and release thrust/lateral inputs before resuming. Reconnect the controller after a flight disconnect, or use G to disable flight and return to keyboard driving. Keyboard collective is reset by the pause, so increase it again deliberately after resuming.

5. RCS flight and automatic roll

5.1 Equipment and resources

RCS means reaction control system. The installation has four vertical and four lateral cold-gas nozzles attached to the vehicle body. The four vertical nozzles provide lift and roll/pitch moments; paired lateral nozzles provide sideways force. All use one finite air supply. The vehicle can continue translating with its existing momentum during flight.

In a fresh full installation, RCS begins uninstalled. Stop, open Tab, enable **Install RCS equipment (vehicle stopped)**, and select **Save RCS settings** or **Save configuration**. Installation changes the physical mass and the controller clutch/flight sharing. Uninstalling removes the modeled equipment and its gas mass and disarms flight.

Base settings are 100 kg usable air, 80 kg equivalent equipment mass plus residual gas, 10,000 N per vertical nozzle, 2,000 N per lateral nozzle, 300 bar full pressure, and 30 kWh auxiliary energy. Values are generic simulation parameters. Increasing a capacity does not fill the additional space; applying or saving settings never grants new air or battery energy.

5.2 Manual takeoff, attitude, and landing

1. Begin on an open area with overhead and sideways clearance. Inspect the air, pressure, and **Hover** reading on the RCS HUD.
2. Release RT and the D-pad, or reduce keyboard collective to zero and release the arrow keys. Press X/G, or the configured L3 flight button.
3. Increase collective gradually. When upright, collective above the current hover estimate accelerates upward; below it accelerates downward. **No margin** means the current supply cannot support hover in that attitude and configuration.
4. Use small roll and pitch inputs. They redistribute lift; full side input closes the opposite vertical bank. Actual angular motion depends on nozzle forces, their lever arms, and the vehicle's inertia.
5. Center the attitude controls before the rotation grows too far. Optional damping can brake roll/pitch rate while the controls are centered and thrust is available. It does not command a level attitude.
6. Hold lateral input for a sideways impulse. Release to stop the jets; use opposite thrust to reduce the acquired sideways velocity. There is no automatic lateral position hold.
7. Reduce collective to descend, then increase it early enough to reduce the downward speed before touchdown. Watch world vertical speed and terrain clearance as well as body attitude.
8. After settling onto the wheels, disable flight to restore drivetrain propulsion and permit recharge.

Vertical thrust is directed toward the vehicle roof. Tilting diverts some of that force sideways; inverted vertical thrust points toward the ground. Collective is a thrust command, not a height or vertical-speed command. Releasing RT closes the commanded vertical jets, while releasing Space merely stops increasing keyboard collective. Use Left Ctrl to reduce keyboard collective.

Roll and pitch are direct thrust-distribution inputs, not target angular velocities. The configured flow ceiling, valve opening response, pressure, and remaining air limit the actual result. Diagonal commands keep roll priority; pitch is reduced when there is insufficient valve headroom. Full attitude commands can reduce total available lift even if collective remains high.

5.3 Reserve and recharge

The default landing reserve is 25% of usable capacity. At or below that level, manual discretionary lateral thrust is blocked unless you hold RB/V. Collective remains available. Reserve is an allocation rule, not a guarantee that an existing descent or rotation can be stopped.

To refill, enable **Auto recharge while grounded and disarmed**, disable flight, and keep the vehicle supported on its wheels. Refill pauses when the world is paused and stops when flight is enabled or wheel support is lost.

Refill mode	Behavior
Fast test refill	Enabled by default. Fills empty to full in five active simulation seconds, adjustable from one to five. A partial refill takes proportionally less time. Does not consume or replenish auxiliary battery energy.
Physical compressor	Used when fast refill is disabled. Consumes the finite auxiliary energy supply. Power, efficiency, current pressure, and ambient conditions determine the refill rate; the base 30 kW system takes minutes. It cannot continue when energy is exhausted or compressor power is zero.

In a full session, recovery or a fresh session initializes air and auxiliary energy to the configured capacities. Saving, installing/uninstalling, changing capacities, and starting an automatic roll do not refill them. In the demonstration, recovery preserves the remaining RCS resources and recharge is unavailable. **Changing track preserves remaining air and auxiliary energy in both access modes**; it is separate from a deliberate recovery/refill trial.

5.4 Automatic left roll

With RCS installed, enable flight, then release RT, the left stick, and lateral controls. For keyboard flight, lower collective to zero with Left Ctrl before releasing the keys. Press **Y** to request automatic takeoff, a full left roll, and a controlled landing.

The pilot checks available air, lift, pressure, mass flow, and rotational authority before starting. The base 100 kg supply is generally insufficient for this full profile; the HUD reports its estimated air requirement after rejection. Use **Usable air (kg)** while stopped to choose a larger supply, then allow recharge or perform a full-session recovery before trying again. A larger configured capacity alone does not create additional air. Added load or a modified RCS setup changes the requirement.

Slopes, uneven or partial support, an airborne start, and existing forward or reverse motion are supported. The takeoff phase physically prepares attitude and clearance; the landing phase follows the local surface. Horizontal coasting is preserved. The maneuver does not stop the vehicle horizontally to take off or finish.

The English HUD bank names are **VL** (vertical left), **VR** (vertical right), **LL** (lateral left), and **LR** (lateral right). Each bank contains a front and rear nozzle. These identify nozzle banks, not the direction in which the gas is seen traveling.

Phase	Commanded banks	Purpose
1	VL + VR	Prepare takeoff attitude, climb, and establish clearance.
2	VR	Initiate the left roll.
3	VR + LL	Add lateral-bank assistance.

Phase	Commanded banks	Purpose
4	VR + LL	Continue through the first quarter.
5	LL	Continue rotation with the vertical banks off.
6	All off	Pass the inverted interval on a ballistic trajectory.
7	LR	Apply opposite lateral-bank assistance.
8	LR + VL	Begin braking rotation.
9	LR + VL	Continue rotational braking.
10	VL	Complete the rotational braking stage.
11	VL + VR	Modulate thrust for the landing.

Transitions follow measured attitude, rotation, clearance, and braking needs. The phases are not a fixed-duration animation and actual force can be below the commanded level. The automatic pilot can use landing reserve for its maneuver.

Press Y again, or apply manual collective, roll/pitch, or lateral input, to cancel and take manual control. X/G disables flight. R recovers immediately. Contact before completing the turn or exceeding twelve active simulation seconds interrupts the pilot with a notice. Completion requires sufficiently stable support and attitude; it does not guarantee success with arbitrary loads, air supply, obstacles, or initial velocities.

5.5 Gas appearance and sound

Gas jets and short-lived clouds respond to actual nozzle output. Existing clouds retain motion when the vehicle turns and dissipate after a jet closes. With ground interaction enabled, the visual gas expands over reached ground and obstacle surfaces. The clouds scatter available light, including the blue wheel lights; they have no self-emission. This represents cold-gas condensation.

Appearance controls change density, width, reach, lifetime, turbulence, and visual quality independently of thrust, gas consumption, and physical vehicle forces. Hiding gas does not turn off the RCS. Pausing freezes the visible clouds; recovery clears the trail. Engine and RCS sounds respond to engine operation and gas flow.

6. Tracks and vehicle recovery

Choose a track after welcome, or open **Tab/Start > Change track** during a session. All tracks use the same vehicle controls and physical model. A track change closes the current CSV, stops the old vehicle and sounds, and loads a new vehicle stopped at the destination start in neutral. It retains the currently accepted vehicle/RCS setup, appearance, glass, controller profile, and remaining air and auxiliary energy, including setup changes that have not been saved to disk. Position, speed, tire/brake trial state, flight/automatic roll, and contact caches do not travel.

- **Exhibition course:** the original connected obstacle route, including its sectors, bridges, lower crossings, varied grip and lighting.

- **Obstacles and RCS course:** an independent compact course combining varied rigid surfaces, rollers, steps, narrow passages, S-curves, loops, layered crossings and an elevated 10 m RCS crossing, within an approximately 86.21 × 98.02 m road footprint. Ordinary lanes are 4.4 m wide, matching the exhibition course; the narrow challenge retains a 3 m lane with approach/departure transitions. Eight ground-level sector signs, the sector HUD and illuminated edge markers identify the route. Boards associated with raised road sectors have been removed. External rocks and road barriers are limited to quantities similar to the exhibition course, with no curve direction boards or guardrails. It uses its own recovery locations, geometry and environment settings.
- **Speed test circuit (N3):** an independent closed circuit of approximately 433.33 m inside an 86.41 × 99.52 m design rectangle (8,599.5232 m²). Its 8.8 m wide road occupies approximately 83.8 × 99.3 m. Four main 53 m straights connect through three 12.5 m centerline-radius hairpins and an outer return with two 25 m radius quarter-circles and a 25 m straight. Dirt and asphalt provide different acceleration and braking conditions; the slippery sector has been removed. Curves bank inward by up to 6 degrees with smooth 12 m entry and exit transitions. Straights and all six recovery locations remain level; brake before the hairpins. The same infinite apron, large concrete light columns and illuminated edge markers preserve the established course style, with twelve active night floodlights. Six sectors identify the route, without exhibition obstacles, bridges or route crossings. The stable track identifier remains `basic-test`.

All three courses retain an infinite analytic apron and their own safe recovery locations internally; **R** recovers the vehicle in the active course and the settings panel does not list destination teleports. The rectangular N3 design envelope bounds its marked circuit, while the surrounding ground remains driveable. The RCS crossing interrupts the elevated driving surface; it is not an invisible road across the gap. Attempting a crossing still requires sufficient installed thrust, usable air and appropriate pilot inputs. Auxiliary energy supplies the compressor when recharging is available; thrust itself uses the stored compressed air.

The obstacle course has 16 connected sectors: start, a bank of fixed transverse rollers, compacted earth, a narrow passage, gravel and small stones, alternating blocks and steps, a connected underpass, an RCS platform climb, the gap approach, the RCS gap, landing platform, gravel descent, mixed grip, wet surface and separated rock blocks, transverse bridge climb, transverse bridge, and return curves. The RCS gap is 10 m long in a 4.4 m wide lane elevated 6 m above the apron. Safe recoveries exist before and after it; the open gap itself is not a recovery point. Compacted-earth and gravel labels describe the configured rigid surfaces rather than deformable ground. Approach the RCS gap with a full standard tank and about 30 km/h of forward speed. Enter flight mode before the edge, use vertical thrust to clear the missing deck, then reduce thrust to land on the far platform. The crossing uses the normal RCS controls and consumes tank air.

Each track retains its own clock, day/night cycle and weather. The speed test circuit initially uses clear weather at 15:00 without clock cycling; the obstacle course also starts at 15:00 with its cycle disabled and uses its own weather preferences. Changing track saves the departing environment; returning restores that track's settings. A previous shared environment configuration is migrated only to the exhibition when its track-specific file is absent.

The compacted-earth, gravel, blocks and return sectors contain curves rather than only straight test strips. The mixed-grip route winds below an elevated loop, creating additional overpasses alongside the principal bridge. The straight after the entrance curve of sector 7 alternates its bank to the left and right by up to about 14 degrees. Enter slowly and make smooth steering corrections; the road levels out around the underpass. Sector 13 keeps its mixed-grip wet surface through the first half, then changes

to 33 large faceted rock blocks arranged in eleven rows of three, with small open gaps. Crawl through this second zone and place the wheels carefully; the gaps expose the ground-level apron rather than an invisible deck. Before entering the blocks, stop and select four-wheel drive and low range. Advance slowly, apply the throttle gently and ease it when wheelspin persists, rather than holding high engine speed while progress stops. Choose wheel paths on the blocks away from the joints. Passage depends on vehicle loading, tires, grip and pilot inputs; this setup does not guarantee a crossing for every configuration.

Eight ground-level sector signs remain at sectors 1-7 and 13; raised-road sector boards and the tall RCS-gap boards have been removed. The HUD continues to identify all 16 sectors. The narrow-passage barriers include the same striped bases as the exhibition course, anchored to the apron under their feet, and elevated roads reuse its T-shaped supports. Edge markers follow the road edge and overall grade; they remain level across the lane over local obstacle relief. The start line remains without the floating start caption. Ground-level and elevated lanes can share an overhead view while offering different support heights; a nearby crossing is not an automatic transfer between them.

The exhibition course is a connected route with different profiles and grip surfaces, elevated bridges, and lower crossings. Direction markings and signs identify the route. The title HUD reports the active track and nearby sector.

Course floodlights switch on automatically at night and switch off in daylight. Edge markers and illuminated guidance help identify the route; vehicle lights remain useful in darker areas and can be controlled independently of the clock. You can leave the marked route for the surrounding apron and return, while obstacles, posts, and bridge structures retain their local collisions.

The exhibition and obstacle courses each enable fifteen of their 30 column-mounted floodlights for the current night-lighting trial. N3 enables twelve floodlights. The concrete columns and fixture housings use the same style across the courses. The enabled lights use 60-degree full outer beams. On the exhibition course this narrows the previous 75-degree beam to leave darker gaps. A 48-degree full inner core keeps the previous core-to-beam ratio and a soft edge. The exhibition lights retain their previous aim, peak output and range; its other lenses no longer glow at night. N3 positions and aims its twelve columns for its own route. Pools of light around curves, obstacles and bridge approaches alternate with darker areas where the vehicle headlights help with navigation. Bridge decks, rocks and other solid objects still cast shadows.

The following are the exhibition sectors and lower crossings to explore by driving. They are not selectable destinations in the settings panel.

Exhibition sector / crossing	What to explore
Start and opening turns	Launching, braking, steering response, and baseline handling.
Approach ramp	Clearance, climb torque, low range, and hill start assist.
S-bend undulations	Pitch response and front/rear damping over changing elevation.
Alternating rollers	Alternating wheel support and axle response.
Beveled steps	Tire radius, pressure, shoulder contact, and slow approach control.
Smooth-surface turns	Reduced-grip cornering, slip, and brake control.
Side slope	Body roll, center of gravity, and lateral load distribution.

Exhibition sector / crossing	What to explore
Twin precision tracks	Wheel placement and maintaining alignment on separated tracks.
Curved slalom	Steering progression, load transfer, and directional changes.
Rock garden	Tire contact on irregular low obstacles and careful wheel placement.
Axle articulation	Suspension travel, anti-roll bars, and traction with unequal support.
Diagonal bumps	Combined roll/pitch inputs and opposite-wheel loading.
Alternating wedges	Changing axle articulation and damping balance.
Precision gate	Low-speed positioning and camera use.
Split traction	Differential behavior and braking where left/right grip differs.
Crest and descent	Cresting, available travel, brake heating, and descent control.
Fine washboard	Repeated small inputs, tire compliance, and damping.
Hairpins and links	Tight connecting turns and approach alignment.
North bridge	Elevated route and approach/departure control.
Central bridge	Elevated route above the central lower crossings.
South bridge	Elevated route and its connection back toward the loop.
Central serpentine	Repeated steering transitions.
Final double S-bend	Combined directional changes near the end of the lower route.
North underpass	Approach the lower route beneath the north bridge area.
Central underpass	Approach the lower route beneath the central bridge area.
South underpass	Approach the lower route beneath the south bridge area.

R, or controller **Y** while driving, selects the nearest safe recovery belonging to the active course. N3 supplies six recovery locations, one for each sector. No recovery sends the vehicle into a different track.

Recovery places the vehicle upright in the destination's intended direction, stops its body motion, disarms flight, resets the engine/wheel/suspension trial state, and selects neutral. Tire/brake heat, wear, and motion peaks restart. Configuration values are retained. Full-access RCS resources reset to their configured capacities; demonstration resources are retained. An open CSV continues, with simulation time restarting, so stop and restart recording if you want separate trial files.

7. Reading the HUD

7.1 Panel meanings

HUD panel	Information and interpretation
Title, location and time	The active track, nearby sector, and the simulated clock. Location is a sector indication, not a requirement to remain on a prescribed line.
Speed and drivetrain	Speed in km/h, selected gear, automatic/manual mode, RPM bar, engine torque in Nm, engine power in kW, 4x2 R/F (Spanish T/D) or 4x4, high/low range, and engine running/stopped state. The large speed magnitude does not distinguish reverse; check the gear. Torque/power are engine-side readings before drivetrain losses.
Brakes and assists	Service brake pressure percentage, the hottest wheel brake temperature, the number of wheels with active ABS modulation, and active hill hold/descent or standby status.
Tire contact	FL/FR/RL/RR identify front left/front right/rear left/rear right. Each wheel shows current tire pressure, temperature, normal load in kN, and slip percentage. The panel also reports the active input connection. An unsupported wheel has no useful normal load even if it is spinning.
XYZ acceleration	Signed local chassis acceleration in g and m/s², short peak markers, world vertical acceleration, and world vertical speed. See section 7.2.
RCS power and thrust	Actual combined front+rear nozzle thrust for VL, VR, LL, and LR, in kN and as a percentage of installed nominal thrust. This panel requires installed RCS. The percentage is actual force, not trigger position or electrical power.
RCS status and resources	Flight/driving/pause state, usable air and capacity, tank pressure, auxiliary energy, hover estimate, vertical speed, recharge/reserve notices, and automatic roll progress or rejection. This panel requires installed RCS.
Controls help	Context-sensitive driving or flight reminders, camera shortcuts, and access to configuration.

All eight visibility preferences begin enabled and save automatically. Some driving panels are hidden while the configuration panel is open. Hiding every HUD panel does not disable Tab/Start. Notices, the CSV recording indicator, numerical fault messages, and the demo countdown remain independent of these visibility switches.

7.2 Acceleration and thrust instruments

Local axes move with the chassis: **+X is forward**, **+Y is right**, and **+Z points toward the roof**. A positive local X value indicates acceleration toward the nose; negative X indicates acceleration toward the rear. Body rotation changes how world acceleration projects onto these axes.

These instruments measure kinematic acceleration from changes in world velocity. Rest is approximately **0 g**. Free-fall world Z is approximately **-1 g**. Constant-speed ascent or descent can have near-zero acceleration even with significant vertical speed. This display is not an accelerometer that

reports 1 g while resting.

The bars span ±2 g; numerical values can exceed that scale. Peak indicators retain recent signed peaks for 1.25 seconds. World Z and **Vz** help separate actual upward/downward motion from the chassis' local attitude. Paused flight retains the last reading and labels it as paused. Recovery clears the derivative history and peaks to avoid treating a teleport as a physical acceleration.

RCS bars show actual bank force. Pressure loss, shared flow limits, empty air, or closed valves can produce a lower force than a high collective command suggests. A bank at 100% means its installed nominal thrust is being delivered, not that the vehicle can hover in its current attitude.

Values close enough to round to zero display plain `0`. Examples are 0.005 g at two-decimal precision and 0.05 m/s at one-decimal precision. This formatting does not modify simulation or CSV values.

8. Complete configuration panel reference

Open the panel with **Tab** or Xbox 360 **Start**. Use the mouse wheel to scroll its right-hand column. Click checkboxes, drag sliders, expand folded sections, and use the numeric boxes where provided. Numeric boxes support typing as well as dragging/spin adjustment; ordinary sliders do not provide a separate text entry field.

Changes normally apply as you make them. There is no general Apply button and closing the panel does not discard changes. **Save configuration** persists vehicle, RCS, appearance, environment, and input profiles. **Save graphics settings** separately persists anti-aliasing/upscaling and scene detail. Dedicated save buttons persist only their named group. Language and HUD visibility save automatically. The controls below are described in panel order, including collapsed groups and the final action buttons.

Range endpoints are the values offered by the panel. Cross-dependent validation can narrow the accepted result, particularly for RCS pressures. Exact stored defaults can have more precision than a slider label displays.

8.1 Language

Control	Detailed behavior
English (US)	Selects US English immediately and saves the language independently of vehicle settings. The selected button is highlighted.
Español	Selects Spanish immediately, refreshes course signs and interface labels, and saves independently.
Language save message	Confirms the saved language or reports a saving problem. It is an information display, not another setting.

8.2 HUD PANELS

Each checkbox controls only the named instrument group and saves immediately. These controls are available in the demonstration too.

Checkbox	Default	Detailed behavior
Title, location and time	On	Shows/hides the active track name, current area, and simulated clock.
Speed and drivetrain	On	Shows/hides the speed, gear, RPM, torque, power, traction/range, and engine-state group.
Brakes and assists	On	Shows/hides brake pressure, maximum brake temperature, ABS activity, and hill-assist status.
Tire contact	On	Shows/hides all four tire readings and input connection status.
XYZ acceleration	On	Shows/hides local acceleration, peaks, and world vertical motion. Hiding it leaves the separate RCS thrust preference intact.
RCS power and thrust	On	Shows/hides the actual four-bank thrust instruments when RCS is installed.
RCS status and resources	On	Shows/hides flight state, air, pressure, energy, hover estimate, and roll status when RCS is installed.
Controls help	On	Shows/hides the context-sensitive shortcut reference.
HUD save message	Informational	Reports that panel visibility saves automatically, or reports a write failure. Tab remains usable if every panel is hidden.

8.3 GRAPHICS AND ANTI-ALIASING and SCENE DETAIL

These groups appear after HUD PANELS when you open **Tab** or Xbox 360 **Start**. They are available in both the demonstration and full editions. Changes apply immediately; use **Save graphics settings** to retain the anti-aliasing and scene-detail selections independently of vehicle configuration.

Control / mode	Choices or default	Detailed behavior
Automatic	Default anti-aliasing/upscaling mode	On supported hardware, selects DLAA at up to 2,073,600 output pixels (1920 × 1080) and DLSS Quality above that pixel count. Uses Native TSR when the selected NVIDIA mode is unavailable.
Native TSR	Native input resolution, 100%	Uses Unreal Engine's temporal super resolution at the output resolution. It remains available when NVIDIA DLSS is unsupported.
NVIDIA DLAA	Native input resolution, 100%	Uses NVIDIA deep-learning anti-aliasing without reducing input resolution. Requires supported NVIDIA RTX hardware and a compatible driver.
DLSS Quality / DLSS Balanced / DLSS Performance	Input scale supplied by the NVIDIA SDK; the status line shows the current percentage	Reconstructs the selected output resolution from a smaller rendered image. Unsupported choices are disabled. A lower input resolution can reduce GPU rendering cost; it cannot guarantee more frames per second when CPU or simulation work is the limiting factor.
Active mode and resolution	Read-only status	Shows the active mode, input dimensions, output dimensions, and input percentage. A fallback notice explains when Native TSR replaces an unavailable NVIDIA mode.

Control / mode	Choices or default	Detailed behavior
Scene detail	Essential / Detailed / Full; Full by default	Essential uses the simpler scene geometry. Detailed adds bevels, three Electric Dreams photogrammetry rock variants, surface variation, and visible wear. Full also displays fasteners and support plates. The original collision and tire-support geometry remains active in every level.
Save graphics settings	Button	Saves anti-aliasing/upscaling and scene detail together in Configuration/Graphics.json. The status line confirms success or reports a write failure. Use this button in addition to any vehicle/environment save you need.

All levels use ground-texture variation that reduces repetition and distant detail, with separate finishes for painted bridge steel, matte sign faces, and galvanized signposts. Detailed and Full also use continuous concrete texturing on the lighting columns and their bases, with broader, distance-filtered yellow/black beacon stripes. Fine chips, worn edges, and fasteners are visual details and do not create additional tire or body contacts. Visible surface wear does not advance physical tire wear or change grip.

Switching Epic/Cinematic quality retains the selected anti-aliasing mode. Resizing the game window updates input/output sizing and reevaluates Automatic. There are no independent display-resolution or fullscreen selectors in this panel. NVIDIA frame generation and Ray Reconstruction are not enabled.

8.4 RCS - COLD GAS FLIGHT

Control	Range / default	Detailed behavior
Install RCS equipment (vehicle stopped)	Off / On; Off	Adds/removes the equivalent equipment and gas mass and enables the RCS system. Requires stopping and low body rotation. Installation changes and flight-button changes disarm flight and require neutral input.
RCS status display	Informational	Reports installed state, flight state, usable/maximum air, pressure, energy, recharge mode/status, hover estimate, pitch allocation, and automatic roll state. Use this display to diagnose conditions before takeoff.
Flight/clutch control reminder	Informational	Shows the current X/L3 assignment and the alternate clutch button, plus the main thrust/attitude/lateral controls.
Enable flight (release RT) / Disable flight	Button	Toggles flight without needing the controller flight button. Activation requires low collective and released lateral controls. Enabling from an open menu leaves the world paused until the panel is closed and inputs are neutral.
Damp rotation when the stick is centered	Off / On; On	Uses differential nozzle thrust to oppose roll/pitch rotation when the effective attitude input is centered. It needs available thrust and does not provide automatic leveling or altitude hold.
Auto recharge while grounded and disarmed	Off / On; On	Permits refill only with wheel support, flight disabled, and jets closed. Turning it off prevents both fast refill and compressor refill.
Fast test refill (no battery use)	Off / On; On	Selects the virtual test air supply. Turning it off selects the physical energy-limited compressor if auto recharge remains enabled.

Control	Range / default	Detailed behavior
Fast refill: empty to full (s)	1-5 s; 5 s	Sets the full refill time for fast mode. A half-empty tank needs approximately half this duration. It does not control compressor-mode refill time.
Usable air (kg)	1-300 kg; 100 kg	Sets usable capacity above residual cutoff gas. More capacity increases available flight impulse after refilling but also adds gas mass when filled. Increasing it does not fill the added capacity. Requires stopping.
Thrust per vertical nozzle (N)	1,000-25,000 N; 10,000 N	Sets each of the four vertical nozzles' nominal thrust. Actual thrust is limited by collective, valve response, pressure, shared flow, and remaining air. Requires stopping.
Pitch authority (%)	0-200%; 100%	Scales pitch control. Zero disables commanded pitch. With compensation enabled, 100% targets pitch acceleration comparable to the roll reference for the same collective and stick input. Higher authority can saturate the available valves; it does not increase installed nozzle power.
Compensate pitch for inertia and saturation	Off / On; On	Uses actual inertia and nozzle geometry to allocate pitch. Roll retains priority during diagonal commands. With this off, pitch authority scales the direct front/rear stick distribution.
Save RCS settings	Button	Writes RCS physical/control preferences to Rcs.json. Current air, energy, and flight state are preserved. Also saves changes made in the advanced RCS group below.

Pitch authority, compensation, damping, recharge mode/timing, pitch inversion, and flight-button selection can change without the physical-equipment stop gate. Equipment, thrust, capacities, pressures, and the other resource/physical values require total speed at most 0.15 m/s and angular speed at most 0.15 rad/s. For predictable experiments, disarm and settle on the ground before changing them.

8.5 RCS gas appearance

Expand **RCS gas appearance** to reveal this independent visual group. These controls do not alter the RCS forces, air use, or auxiliary energy.

Control	Range / default	Detailed behavior
Show RCS jets and clouds	Off / On; On	Shows/hides gas rendering. Nozzle physics continue even with this off.
Expansion over ground and obstacles	Off / On; On	Enables surface-contact gas clouds and their expansion along reached surfaces. It is a visual response, not extra vehicle thrust or a physical blast force on objects.
Density	0.10-4.00; 2.00	Changes the optical density of the gas. Higher settings make scattering more visible under available lighting.
Width	0.50-2.00; 1.00	Scales jet and cloud width. It does not change nozzle geometry or flow.
Jet reach (m)	1.00-6.00 m; 4.00 m	Sets the visible jet's reach and the visual surface-contact search distance. It does not extend a physical force beam.

Control	Range / default	Detailed behavior
Airborne dissipation (s)	0.20-0.80 s; 0.45 s	Sets the maximum lifetime scale of free-air clouds. Actual individual cloud lifetimes vary slightly below the setting. Higher values retain a longer trail.
Ground dissipation (s)	0.30-1.20 s; 0.70 s	Sets the corresponding lifetime scale for clouds spreading over a surface.
Turbulence	0.00-1.00; 0.70	Adjusts visual irregularity and movement in the gas. It does not add turbulence forces to the vehicle.
Quality: Low / Balanced / High (change)	Three choices; Balanced	Click to cycle quality. Increases cloud budget and rendering/contact sampling detail. Active cloud budgets are 16, 36, and 48 respectively. This setting is separate from fog/dust quality and Epic/Cinematic graphics.
Save RCS appearance	Button	Writes RcsVisuals.json independently of RCS physics and vehicle settings.
Appearance save message	Informational	Reports saving/loading results for this group.

8.6 RCS tank, compressor, and controls

Expand **RCS tank, compressor, and controls**. Its preferences use **Save RCS settings** or the global **Save configuration** button.

Control	Panel range / default	Detailed behavior
Invert stick pitch	Off / On; Off	Reverses the pitch command from the left stick and keyboard W/S. It does not invert roll or the camera.
Thrust per lateral nozzle (N)	100-6,000 N; 2,000 N	Sets each lateral nozzle's nominal force. The shared flow and remaining air still apply. Lateral nozzles can translate and create moments because they act away from the center of mass.
Equivalent equipment mass (kg)	20-600 kg; 80 kg	Sets dry equipment mass. Residual gas and usable air are additional. Higher mass affects suspension loading, inertia, lift needs, and roll feasibility.
Full tank pressure (bar absolute)	50-400 bar; 300 bar	Sets pressure at full usable capacity. Changes the pressure available over the usable-air range and the residual gas needed by the tank model.
Cutoff pressure (bar)	2-100 bar; 20 bar	Sets the lower usable-pressure limit. Validation also limits it to 40% of full pressure, so a low full-pressure setting can reduce the accepted maximum.
Minimum regulated pressure (bar)	3-160 bar; 40 bar	Pressure above which the model can deliver regulated nominal thrust. Below it, force falls toward zero at cutoff. Validation keeps it at least 1 bar above cutoff and no higher than full pressure.
Equivalent exhaust velocity (m/s)	200-750 m/s; 500 m/s	Sets impulse delivered per mass of expelled gas. At the same thrust, a higher value uses less air and raises the total thrust supported by a given mass-flow ceiling. It is a generic equivalent parameter.

Control	Panel range / default	Detailed behavior
Valve opening response (s)	0.005-0.150 s; 0.025 s	Sets the opening response time. Smaller values respond more quickly; commanded closure cuts the valve target/output rather than waiting through a matching closing delay.
Maximum shared mass flow (kg/s)	5-250 kg/s; 100 kg/s	Limits total gas use across all eight nozzles. When combined requests exceed it, their actual forces are reduced together. Increasing only nozzle ratings may therefore produce no extra total thrust.
Landing reserve fraction	0.00-0.60; 0.25	Fraction of usable capacity reserved from normal manual lateral use. For example, 0.25 is 25%. RB/V overrides the lateral restriction; collective remains available in reserve.
Compressor power (kW)	0-500 kW; 30 kW	Sets physical-compressor electrical input power. Higher values can refill faster while using energy faster. Zero disables physical refill. Fast test refill bypasses this value.
Compressor efficiency	0.10-0.90; 0.50	Sets modeled compression efficiency. Higher values require less auxiliary energy per added mass at the same conditions. It has no battery effect in fast refill mode.
Auxiliary energy capacity (kWh)	0.01-100 kWh; 30 kWh	Sets the finite compressor energy capacity. Increasing it does not recharge current energy. A full-session recovery or fresh session initializes the configured supply.
Centered stick damping (1/s)	1-15 s^{-1}; 6 s^{-1}	Sets rotational damping strength when centered-stick damping is enabled. Higher values request stronger rate reduction, within available nozzle authority. It is not a target roll rate.
Flight button: X / L3 (change)	X or L3; X	Click to alternate the controller flight toggle. The other button becomes the digital clutch. G remains flight on the keyboard and R3 remains camera reset. A binding change disarms flight.
Automatic roll / refill guidance	Informational	Reminds you of Y, manual cancellation, resource preservation, and the distinction between fast refill and the compressor. Use the live HUD for the actual start rejection and air estimate.

Keep full, cutoff, and regulated pressures in a sensible increasing relationship. If a requested pressure appears to move to another value, validation has accepted the compatible value. The tank uses absolute pressure; tire pressure sliders use gauge pressure.

8.7 SCENE AND ENVIRONMENT

Control	Range / default	Detailed behavior
Time of day	00:00-24:00, wrapping to 00:00; 15:00	Sets sun/moon and scene-lighting time. Moving the slider turns continuous cycling off so the chosen time remains fixed.
Continuous day/night cycle	Off / On; Off	Advances simulated time while the world runs. Turn it off for a fixed-lighting comparison.
Simulated day length	2-120 real minutes; 20	Sets the active-simulation time for a full 24-hour cycle. Smaller values make the clock and daylight change faster. It matters while the cycle is enabled.
Vehicle headlights	Off / On; On at session start	Controls the vehicle's headlight/associated lighting state, equivalent to H or D-pad down. This on/off state is not stored by Save environment or Save configuration.

Use **Save environment** or **Save configuration** to preserve hour, cycle enable, and day length. Time advance shortcuts and the Night/Day action buttons disable continuous cycling.

8.8 VEHICLE GLASS

Control	Range / default	Detailed behavior
Glass light transmission	0-100%; 50%, in 1% panel steps	Controls light transmission for the windshield, rear glass, and side windows. Zero is dark; 100% is clear. Reflections remain, so perceived brightness also depends on lighting and exposure. This is a material transmission value rather than a guaranteed image brightness percentage.
Save configuration	Button	This is the global save action placed near the glass control. It saves all supported configuration groups, not just the glass value.

Restore default vehicle returns glass transmission to 50% along with the default vehicle parameters. Save afterward to preserve the restored preference.

8.9 ENVIRONMENT PRESETS, FOG, DUST GUSTS, and VOLUMETRIC QUALITY

Environment presets replace both weather-effect groups with a predefined setup. They reset the weather values and weather quality to the preset's starting configuration, so apply a preset before fine-tuning individual sliders. They do not select the clock hour or vehicle headlights.

Preset button	Detailed behavior
Clear	Disables environmental fog and windblown dust. It is useful for unobstructed handling comparisons.
Light mist	Enables the light base fog and disables dust.
Dense fog	Enables fog with density 0.12, reference height 2 m, and ground concentration 0.30; disables dust.
Windblown dust	Disables environmental fog and enables stronger dust: intensity 0.65, interval 7 s, duration 16 s, size 6 m, and wind speed 3.5 m/s.

Fresh weather defaults have both fog and dust enabled. Selecting a preset is a deliberate replacement of that combination. You can then enable either effect independently to create your own combination.

FOG contains its enable checkbox and the collapsed **Fog settings** group:

Control	Range / default	Detailed behavior
Enable environmental fog	Off / On; On	Shows/hides the global environmental fog. It does not disable the separate dust clouds. Density zero also removes visible global fog.
Density	0.000-0.200; 0.003	Sets optical fog density. Increasing it reduces visibility and strengthens scattering under suitable lighting.
Reference height (m)	-2-20 m; 0 m	Sets the fog layer's height reference in the scene. Raising it changes where dense fog sits relative to the course.

Control	Range / default	Detailed behavior
Concentration near the ground	0.10-4.00; 0.60	Controls height falloff. Higher values concentrate fog more tightly near its reference level; smaller values spread it farther vertically.
Tint: cool (0) / warm (1)	0.00-1.00; 0.35	Interpolates the fog scattering tint from cool bluish to warm. Lighting still affects the final appearance.

DUST GUSTS contains its enable checkbox and the collapsed **Dust and wind settings** group:

Control	Range / default	Detailed behavior
Enable windblown dust	Off / On; On	Enables moving atmospheric dust gusts. Switching it off clears the active dust volumes.
Intensity (0 to 1)	0.00-1.00; 0.35	Scales cloud density. Zero removes visible dust while retaining the other preference values.
Gust interval (s)	2-40 s; 12 s	Sets the approximate spacing between gust births. Timing varies slightly around the value. Short intervals can create overlapping gusts.
Gust duration (s)	4-30 s; 14 s	Sets how long a gust develops and fades. Longer duration increases persistence and possible overlap.
Cloud size (m)	1.5-10 m; 5 m	Sets the base size of the clustered volumes; each gust expands over its life. It is not a hard visibility-distance limit.
Center height (m)	0.2-6 m; 1.2 m	Positions the cloud center relative to the sampled ground near its spawn area. Larger values lift the dust layer.
Wind direction (degrees)	0-360°; 35°	Sets the world direction toward which dust travels: 0° is +X, 90° is +Y, 180° is -X, and 270° is -Y. It is not relative to vehicle heading and is not a weather report's wind-from bearing.
Wind speed (m/s)	0-12 m/s; 3 m/s	Sets dust advection speed. Zero stops the main wind translation while the gust can still grow, fade, and show turbulence.
Turbulence (0 to 1)	0.00-1.00; 0.45	Adds irregular lateral/vertical cloud motion. This atmospheric dust setting does not apply aerodynamic gust forces to the vehicle.

Shared control	Choices / default	Detailed behavior
Volumetric quality	Performance / Balanced / High; Balanced	Shared fog/dust rendering resolution. Higher quality provides finer volumetric detail at greater rendering cost. It is independent of RCS gas appearance quality.
Save environment	Button	Writes hour, day length, cycle, and all fog/dust/volumetric preferences to the active track's Environment.json. It does not save vehicle, RCS, wheel profiles, or the headlights switch.
Environment save message	Informational	Reports whether environment settings were saved and will load on the next launch.

WHEEL DUST provides an independent **Enable wheel dust** switch (On by default) and **Wheel dust intensity** (0-1; default 0.65). Moving, supported wheels raise short-lived clouds on sand, gravel and dry rock. Wet surfaces, metal and clean pavement do not emit dry dust. The clouds stay in world space, follow the wind, and scatter the available scene light. They do not change traction, suspension, soil, vehicle forces or RCS consumption. Save environment to retain these preferences. Performance / Balanced / High limit active wheel clouds to 8 / 16 / 24; volumetric rendering is disabled in clear conditions when no wheel clouds remain.

The vehicle body uses highly polished turquoise metal with a clear coat. Rubber and trim retain a rougher finish. Lumen evaluates lighting at reflection hits, including the front layer of glass; indirect diffuse lighting remains cached. These rendering changes preserve the physical model and the Epic/Cinematic controls.

8.10 DRIVETRAIN

Observe the change conditions in section 4.2. Use **Save configuration** to retain this group.

Control	Range / default	Detailed behavior
Automatic transmission with torque converter	Off / On; On	Enables converter launch and automatic forward shifts. Turning it off enables the manual gearbox; clutch assist is controlled separately. Changing transmission type requires stopping and neutral/disengagement or the automatic brake condition.
Manual transmission clutch assist	Off / On; On	Automatically modulates clutch engagement in manual mode. Disable for direct digital, analog-stick, or calibrated pedal clutch control. It does not turn automatic shifting on.
Four-wheel drive	Off / On; Off	Off drives the selected 4x2 axle (Rear by default); On couples front/rear drive. Both engagement and disengagement require low speed and released throttle; engagement also needs wheel synchronization.
Driven axle in 4x2	Rear / Front; Rear	Selects which axle receives drive and engine braking in 4x2. Disabled in 4x4, retaining the stored preference. Requires stopping, released throttle, unloaded transmission and synchronized axle means.
Low range	Off / On; Off	Adds the configured low-range multiplier. Changing range requires stopping and transmission disengagement. It is required for hill descent regulation.
Front differential lock	Off / On; Off	Couples the front axle's left/right wheel speeds through the modeled lock. Engagement requires low speed, released throttle, and synchronized front wheels.
Rear differential lock	Off / On; Off	Applies the same lock behavior to the rear axle, with the corresponding rear-wheel engagement check.
Limited-slip differentials	Off / On; Off	Adds speed-sensitive torque bias in unlocked differentials. It is a partial alternative to locking, not a traction-control brake system.
Peak torque (Nm)	100-650 Nm; 360 Nm	Scales the engine torque curve. It is peak capability, not constant delivered torque; RPM, throttle, losses, and clutch/converter state still matter. Requires stopping.
Final drive ratio	2.50-5.50; 3.73	Multiplies every gear. A larger number increases wheel torque and engine speed for a given road speed while reducing road speed at a given RPM. Requires stopping.

Control	Range / default	Detailed behavior
Low range ratio	1.50-4.00; 2.48	Sets the extra reduction applied only with Low range enabled. Larger values favor slow control and wheel torque. Changing the numeric value requires stopping.

8.11 BRAKES AND HILL ASSISTS

Control	Range / default	Detailed behavior
Per-wheel ABS	Off / On; On	Modulates each wheel's service pressure to reduce locking above 2 m/s. It does not modulate the separate parking brake.
Electronic brakeforce distribution (EBD)	Off / On; On	Adjusts front/rear service brake distribution with current axle support. Turning it off uses the configured base front bias directly.
Hill start assist (J)	Off / On; On	Enables the timed slope hold after a braked stop with sufficient loaded wheel support. J toggles the same preference.
Hill descent control (K)	Off / On; Off	Enables downhill speed regulation when low range, a gear, a sufficient slope, contact, and released pedals permit it. K toggles the same preference.
Hill hold duration (s)	0.50-4.00 s; 2.00 s	Sets maximum retained-pressure time after brake release. Adequate drive torque or loss of conditions can release it sooner. Requires stopping to change.
Descent speed (m/s)	0.80-5.00 m/s; 2.00 m/s	Sets the downhill speed target, equivalent to 2.88-18 km/h. It can be adjusted without resetting the vehicle; available grip/braking still limits regulation.
Rated brake torque (Nm)	1,000-4,000 Nm; 2,600 Nm	Sets the nominal brake torque scale before pressure, front/rear distribution, ABS, and thermal fade are applied. Requires stopping.
Base front brake bias	0.50-0.80; 0.64	Sets the baseline front share: 0.64 means 64% front and 36% rear. EBD modifies that share according to support when enabled. Requires stopping.
Pressure application time (s)	0.02-0.30 s; 0.07 s	Sets how quickly hydraulic pressure approaches increasing demand. Smaller values feel sharper; larger values build more gradually. This is a response time constant, not a fixed delay before any braking. Requires stopping.
Pressure release time (s)	0.02-0.30 s; 0.05 s	Sets how quickly pressure follows a lower demand. Smaller values release more quickly. It is separate from ABS modulation and the hill-hold release logic. Requires stopping.
Brake fade onset (°C)	150-500 °C; 350 °C	Sets the rotor temperature where modeled thermal effectiveness starts to fall. Requires stopping.
Full brake fade temperature (°C)	550-1,000 °C; 700 °C	Sets the temperature where the maximum modeled loss is reached. Maximum fade leaves 35% of the nominal thermal factor, rather than reducing it to zero. Requires stopping; validation maintains separation from fade onset.

8.12 TIRES

All changes in this group require stopping. Pressure is independent per wheel; the dimensions and nominal stiffness apply to all four tires.

Control	Range / default	Detailed behavior
Front left (bar)	0.80-3.50 bar; 2.20 bar	Sets the front-left tire's cold gauge pressure. Compare with its live HUD pressure after heating. Lower pressure increases compliance and changes the loaded radius and tire response.
Front right (bar)	0.80-3.50 bar; 2.20 bar	Sets the front-right cold gauge pressure independently. A left/right mismatch can produce different support and response.
Rear left (bar)	0.80-3.50 bar; 2.20 bar	Sets the rear-left cold gauge pressure independently, useful for rear-axle load and traction comparisons.
Rear right (bar)	0.80-3.50 bar; 2.20 bar	Sets the rear-right cold gauge pressure independently. Use matching rear values for a symmetric baseline.
Unloaded radius (m)	0.300-0.600 m; 0.435 m	Sets the unloaded radius of every tire. Changes visible wheel dimensions and the protective collision geometry. Larger radius changes clearance and the effective distance/torque relationship at the road. Loaded radius is smaller under deflection.
Width (m)	0.180-0.400 m; 0.265 m	Sets tire width, affecting the modeled footprint and contact on edges, as well as the visible tires and rims. It is not a simple grip multiplier.
Rated vertical stiffness (N/m)	100,000-400,000 N/m; 200,000 N/m	Sets the nominal carcass stiffness before pressure effects. Higher values reduce tire deflection for a comparable load and can make small obstacles feel sharper.

The HUD reports the current temperature-dependent pressure rather than merely repeating the cold slider. Lower pressure does not guarantee better grip on every surface, load, or speed. Use the same starting tire temperature and recovery state when comparing settings.

8.13 CHASSIS AND SUSPENSION

Control	Range / default	Detailed behavior
Base sprung mass (kg)	800-3,500 kg; 1,850 kg	Sets the body/base mass carried by the suspension, excluding the added occupants, cargo, roof load, fuel, RCS masses, and unsprung axle masses. Increasing it increases sag and changes inertia and acceleration.
Half of each axle's mass (kg)	20-100 kg; 47.5 kg	Sets one half of each axle's equivalent unsprung mass. Each axle therefore has twice the value, and both axles together have four times it: 190 kg at the default. It affects how the axles respond to road inputs.
Base center of gravity height offset (m)	-0.40 to +0.20 m; -0.22 m	Sets the base mass's vertical center relative to the chassis reference, not its absolute height above the ground. Raising it increases the base mass's leverage in roll/pitch. Added loads determine the final combined center of gravity.

These physical changes require a settled stop. Use the live mass and CG display in **DISTRIBUTED LOAD** to see the combined result.

8.14 FRONT SUSPENSION

These settings apply to the front axle. All numeric changes require a settled stop. The connection checkbox has the separate low-speed condition described in section 4.2.

Control	Range / default	Detailed behavior
Spring rate per side (N/m)	20,000-100,000 N/m; 43,000 N/m	Front spring stiffness on each side. Higher values reduce sag and resist front compression; lower values allow more movement under the same force.
Compression damping (Ns/m)	1,000-8,000 Ns/m; 2,800 Ns/m	Resists front suspension shortening. More damping slows rapid compression but can transmit sharper loads into the chassis. It does not add static spring support.
Rebound damping (Ns/m)	1,000-10,000 Ns/m; 4,200 Ns/m	Resists front suspension extension. More damping slows rebound and wheel return after an obstacle; too much can delay regaining support over repeated bumps.
Reference length (m)	0.30-0.65 m; 0.46 m	Sets the front suspension's reference geometry/length. Changing it alters the body-to-axle relationship and resulting equilibrium ride height, alongside spring sag.
Compression travel (m)	0.15-0.28 m; 0.23 m	Sets available front compression travel relative to the reference. More travel allows additional bump movement before the compression limit.
Droop travel (m)	0.04-0.18 m; 0.12 m	Sets available front extension travel. More droop can help the wheels maintain contact when the axle articulates or the body rises.
Anti-roll bar rate (N/m)	0-30,000 N/m; 9,000 N/m	Sets front left/right coupling strength while the bar is connected. Zero removes its elastic coupling even if the checkbox remains on.
Anti-roll bar connected	Off / On; On	Connects/disconnects the front bar with a 0.35 s transition. Disconnection permits more independent left/right articulation and less front roll resistance.
Axle roll inertia (kg m²)	20-180 kg m²; 55 kg m²	Sets resistance to angular acceleration of the front axle itself. It changes transient articulation; it is different from spring or bar stiffness.
Radius arm length (m)	0.85-1.40 m; 0.95 m	Sets the front axle locating-arm geometry. It changes the path and orientation of the axle as suspension heave and roll vary.

8.15 REAR SUSPENSION

The rear group is independent of the front group. Matching front/rear numbers is a useful baseline, but a loaded rear axle can benefit from a different setup.

Control	Range / default	Detailed behavior
Spring rate per side (N/m)	20,000-100,000 N/m; 43,000 N/m	Rear spring stiffness per side. More stiffness supports rear additions with less sag; less stiffness allows greater rear compression for the same load.
Compression damping (Ns/m)	1,000-8,000 Ns/m; 2,800 Ns/m	Resists rear suspension shortening and controls the speed of rear compression after an input.
Rebound damping (Ns/m)	1,000-10,000 Ns/m; 4,200 Ns/m	Resists rear extension after an obstacle or load release. It affects how quickly the rear wheels follow the next surface.
Reference length (m)	0.30-0.65 m; 0.46 m	Sets rear reference geometry/length and influences rear ride height with the chosen spring and load.

Control	Range / default	Detailed behavior
Compression travel (m)	0.15-0.28 m; 0.23 m	Sets rear bump travel before the compression limit.
Droop travel (m)	0.04-0.18 m; 0.12 m	Sets rear extension travel before the droop limit.
Anti-roll bar rate (N/m)	0-30,000 N/m; 9,000 N/m	Sets rear left/right spring coupling while its bar is connected. Changing front/rear bar balance changes how roll resistance is shared.
Anti-roll bar connected	Off / On; On	Connects/disconnects the rear bar progressively. Requires released throttle, total speed at most 1 m/s, and low body rotation.
Axle roll inertia (kg m²)	20-180 kg m²; 55 kg m²	Sets the rear axle's resistance to roll acceleration and changes its transient response independently of the front axle.
Radius arm length (m)	0.85-1.40 m; 0.95 m	Sets rear locating-arm geometry and the rear axle's motion path during suspension movement.

Numeric rear adjustments require the same settled stop as front adjustments. A shorter new travel limit can constrain the current suspension position; allow the vehicle to settle before evaluating the result.

8.16 DISTRIBUTED LOAD

Every load change requires stopping. These are physical equivalent masses; the controls do not spawn visible people, cargo, or fuel containers.

Control	Range / default	Detailed behavior
Driver (kg)	0-120 kg; 0 kg	Adds mass at the left front seating location, above the base CG reference. It changes left/right balance and the combined center of gravity.
Passenger (kg)	0-120 kg; 0 kg	Adds mass at the opposite front seating location. Equal driver/passenger masses help restore lateral symmetry.
Rear cargo (kg)	0-500 kg; 0 kg	Adds mass behind the center of the chassis. It increases rear support demand and alters pitch/roll inertia.
Lateral cargo offset (m)	-0.65 to +0.65 m; 0 m	Moves the rear cargo's modeled center left/right: negative is left and positive is right. It has no effect when Rear cargo is zero.
Roof load (kg)	0-200 kg; 0 kg	Adds relatively high mass toward the rear part of the roof. It raises the combined CG and changes roll/pitch inertia and flight requirements.
Fuel (kg)	0-90 kg; 0 kg	Adds equivalent mass low and toward the rear. This mass remains constant through driving; there is no fuel consumption/refueling subsystem.
Sprung mass / CG / current front-rear load display	Informational	Shows combined sprung mass, local CG X/Y/Z in meters, and current front/rear normal support in newtons. The support values are instantaneous, so motion and terrain can change them even with unchanged mass.
Bar operating reminder	Informational	Reminds you of the released-throttle and low-speed requirement for bar connection changes.

Combined sprung mass includes RCS equipment and gas when installed. The front/rear support display includes the actual wheel support response, rather than simply a static percentage of the displayed sprung mass. Total equivalent vehicle mass also includes the two unsprung axles.

8.17 STEERING

Control	Range / default	Detailed behavior
Maximum steering angle (degrees)	20-42°; 34°	Sets the road-wheel steering-angle scale. More angle allows tighter low-speed turning but makes a given normalized demand stronger.
Controller dead zone	0.000-0.300; 0.045	Removes small stick input around center and rescales the remaining travel. This shared stick normalization also affects controller camera axes and RCS attitude input; it is distinct from trigger and USB-axis dead zones.
Steering smoothing (s; higher = more gradual)	0.04-0.30 s; 0.10 s	Sets gradual steering response for keyboard/controller demand. Higher values soften changes and return-to-center response. A calibrated USB wheel uses direct steering instead of this stick dynamics path.
Stick curve (higher = finer control near center)	1.00-2.50; 1.35	Shapes controller ground steering after the dead zone. A larger exponent reduces sensitivity near center while retaining full lock. Keyboard A/D remains full demand; RCS attitude input is not shaped by this ground-steering exponent.

These numeric vehicle settings require a settled stop to change. A larger dead zone can eliminate drift but also removes small intentional input; use the smallest value that centers reliably.

8.18 Xbox 360 controller vibration and triggers

The controller vibration/trigger block applies to the Xbox 360 controller through XInput. The preferences are stored with the driving-device profile. Use **Save configuration** to retain them.

Control	Range / default	Detailed behavior
XInput controller vibration	Off / On; On	Enables the two controller rumble channels. The signal combines contact roughness, tire slip, and ABS activity; it is not torque feedback from a steering wheel.
Vibration strength	0.00-1.00; 0.50	Scales the permitted rumble output. Zero silences vibration even if its checkbox remains enabled.
Trigger dead zone	0.000-0.200; 0.025	Discards small RT/LT input near release and rescales the remaining travel. Also affects RT collective in RCS flight, which uses the throttle trigger curve.
RT throttle curve	0.50-2.50; 1.00	Exponent for RT demand after the dead zone. Above 1 gives finer control near release; below 1 gives a stronger early response. Applies to ground throttle and controller flight collective.
LT brake curve	0.50-2.50; 1.30	Exponent for LT braking. Above 1 makes early travel gentler while retaining full brake demand at full trigger.

Control	Range / default	Detailed behavior
Analog-trigger guidance	Informational	Use analog triggers for progressive control. XInput rumble has two channels; there are no separate trigger-motor controls in this panel.

Vibration stops when settings are open, focus is lost, the controller disconnects, or the application closes. A ready USB wheel profile uses wheel feedback instead of controller rumble for driving feedback.

8.19 USB wheel and pedals (optional)

Expand this group to access device assignments, calibration, shift buttons, and torque feedback. The simulator detects the DirectInput device list at launch. Connect devices before starting; restart to discover newly attached hardware.

General control	Default	Detailed behavior
Device/status message	Informational	Reports available/active hardware or a missing required axis. If a required input is absent or uncalibrated with the profile enabled, throttle is cut and the service brake is applied.
Use steering wheel and pedals profile	Off	Enables the calibrated hardware path for steering, throttle, brake, and optionally clutch. Leave it off until calibration is valid. Disable it to return to ordinary keyboard/controller driving.
Separate clutch pedal	Off	Requires and uses the configured CLUTCH axis when enabled. When off, digital or analog-stick clutch input remains the fallback. Disable manual clutch assist if you want the pedal to control engagement directly.

There are four independently assigned input roles:

Role	Required when	Valid output after calibration
STEERING	Wheel profile enabled	Approximately -1 at full left, 0 centered, +1 at full right.
THROTTLE	Wheel profile enabled	0 released to 1 fully pressed.
BRAKE	Wheel profile enabled	0 released to 1 fully pressed. The strongest keyboard/controller/pedal service brake demand is used.
CLUTCH	Wheel profile and Separate clutch pedal enabled	0 released to 1 fully pressed in the calibration display; the driving clutch is engaged at release and disengaged when pressed.

Each role has its own complete set of the following controls. STEERING uses three calibration buttons; each pedal uses two.

Per-role control	Range / initial state	Detailed behavior
Select device	Detected device list; None initially	Select the device that supplies this role. The same device can supply several roles, or each pedal role can use a separate USB unit. **None** clears the assignment. A saved unavailable device is shown as disconnected. Changing the device invalidates the role's calibration.

Per-role control	Range / initial state	Detailed behavior
Axis	X, Y, Z, Rx, Ry, Rz, Slider 0, Slider 1	Select the moving axis on that device. Their indices are 0-7 in this order. Initial role indices are steering 0, throttle 1, brake 2, clutch 3, but those indices are not a calibration. Changing the axis invalidates its calibration.
Reading / output / calibration status	Informational	Raw reading is the current device value; output is the normalized result. The status distinguishes valid calibration from missing endpoints or missing readings. Values continue updating in the menu for calibration.
Left	STEERING only	With the physical wheel at full left, click to record the left endpoint.
Center	STEERING only	Center the physical wheel, then click to record its neutral point. The recorded center must lie between the two endpoints.
Right	STEERING only	With the physical wheel at full right, click to record the right endpoint.
Released	THROTTLE, BRAKE, CLUTCH	Release that pedal fully, then click to record its rest value.
Fully pressed	THROTTLE, BRAKE, CLUTCH	Press that pedal fully, then click to record the opposite endpoint. Endpoints can be numerically reversed, but must be distinct.
Invert axis	Off / On; Off for each role	Reverses the normalized role output. Use the live output to confirm the result; a pedal already calibrated correctly from release to full press normally needs no inversion.
Dead zone	0.000-0.300; 0.020 for each role	Removes a small steering-center region or small pedal demand near release, then rescales the remaining input. This is independent of XInput stick/trigger dead zones.

The following controls appear after the four input roles:

Control	Range / default	Detailed behavior
Upshift button	0-127; 4	Sets the sequential upshift button on the selected steering device. Indices start at zero; a driver showing one-based labels can differ by one.
Downshift button	0-127; 5	Sets sequential downshift on that same steering device. Press/release for individual shifts. Avoid assigning both directions to the same physical button.
Physical steering wheel rotation (degrees)	180-1,440°; 900°	Declares full lock-to-lock physical travel for steering ratio and feedback-rate calculations. It does not reprogram the device driver's rotation limit. Calibrated endpoints still define full normalized steering travel. Set it to the actual usable wheel travel.
Torque force feedback on a compatible wheel	Off / On; Off	Enables modeled steering torque only for a compatible motorized DirectInput driving wheel with an actuator axis and constant-force support. It does not turn a non-motorized controller into a torque-feedback device.

Control	Range / default	Detailed behavior
Invert force feedback direction	Off / On; Off	Reverses the torque command direction. Check direction on the actual wheel at low strength and low speed.
Torque strength (maximum 0.70)	0.00-0.70; 0.35	Scales normalized torque output. It is not a measured torque in Nm and does not calibrate the wheel's motor. Start low when checking a new wheel.
Torque rate of change	0.50-5.00; 2.00	Limits torque-command change per second. Lower settings make transitions gentler; higher settings respond faster. Capability/contact loss bypasses the ramp and removes force immediately.
Profile save guidance	Informational	Reminds you that **Save configuration** preserves device assignments, calibration, buttons, vibration, curves, and force feedback. Calibration changes alone are not automatically saved.

The wheel profile controls ground driving, not a separate flight-stick assignment system. For RCS use the Xbox 360 controller or keyboard flight mappings. Force feedback combines a reduced front-tire aligning effort, wheel-motion damping, and suspension irregularity. Output is cut on menu opening, focus loss, device disconnection, loss of sufficient front support, disabling, or exit. Constant-force effects expire if updates stop for about 100 ms.

8.20 CONTROLLER AND GRAPHICS

Control	Range / default	Detailed behavior
Analog clutch on right stick vertical axis	Off / On; Off	In driving mode with an Xbox 360 controller connected, upward right-stick travel progressively disengages the clutch. It replaces the digital clutch input path and reserves vertical camera movement for the clutch. Horizontal camera control remains. In flight, the stick controls the camera normally. Save configuration stores this preference.

The Epic/Cinematic quality buttons appear in the final course/actions block below this heading rather than as sliders beside the clutch checkbox. Anti-aliasing/upscaling and scene detail have their own earlier groups and save button, described in section 8.3.

8.21 ENVIRONMENT AND RECOVERY and final action buttons

Button	Detailed behavior
Night: 23:00	Sets 23:00 and disables continuous day/night cycling. Save environment or Save configuration to retain the time preference.
Day: 12:00	Sets noon and disables continuous cycling. This differs from the N keyboard shortcut's 15:00 daytime selection.
Change track	Saves this track's environment, closes CSV recording, and returns to selection while retaining the session setup, remaining RCS resources, and demo time.

Button	Detailed behavior
Epic quality	Applies Epic rendering scalability, the default graphics profile, then reapplies the selected anti-aliasing/upscaling mode. Native TSR and DLAA use 100% input resolution; DLSS modes use the NVIDIA SDK's input scale. Fog/dust preferences retain their own volumetric settings.
Cinematic quality	Applies the higher Cinematic rendering scalability, then reapplies the selected anti-aliasing/upscaling mode. Rendering cost can increase; this does not alter physics settings.
Save configuration	Saves vehicle and glass settings, RCS settings, RCS appearance, environment, and controller/wheel profiles. The same global action is also present near the glass slider. It does not save a driving-session checkpoint.
Restore default vehicle	Attempts to apply the base vehicle parameter set and returns glass transmission to 50%. Stop and settle first so physical changes can be accepted. It leaves the separate RCS, appearance, weather, device profile, language, and HUD preferences in their own groups. It does not perform a vehicle recovery. Save to retain the restored vehicle values.
Start or stop CSV recording	Starts a new telemetry CSV or closes the current file. It is equivalent to T. Settings changes and recovery do not automatically create a separate file.
Return to driving	Closes the panel. Changes already applied remain active; unsaved groups need an explicit save to survive restart. In paused flight, release thrust/lateral inputs to resume.

Epic/Cinematic selections are session graphics actions; the simulator's configuration save does not write their selection. Camera orbit/zoom and the headlights on/off state are also not saved by that action.

8.22 Demonstration-only panel controls

The demonstration shows the language buttons, the eight HUD visibility checkboxes, the anti-aliasing/upscaling and scene-detail groups with **Save graphics settings**, information about advanced configuration and its non-refillable RCS sample, **Change track**, and these actions:

Button	Detailed behavior
Return to driving	Closes the demonstration panel and resumes the driving session or the flight-resume procedure.
Return to welcome to register	Ends the driving session and opens the welcome screen. Wait for the input prompt, then use R to open the registration form.

9. Calibrating a USB steering wheel and pedals

1. Close the simulator, connect the wheel/pedals, and finish any setup required by their Windows driver. Start the simulator again so its startup device list includes them.
2. Stop the vehicle and open **Tab > USB wheel and pedals (optional)**. Keep **Use steering wheel and pedals profile** off during the initial assignments.
3. Under STEERING, select the wheel device and move the wheel while trying the appropriate axis. Confirm that the raw reading changes.
4. Turn fully left and click **Left**. Center the wheel and click **Center**. Turn fully right and click **Right**. The endpoints must be sufficiently different, and the center must lie between them.

5. Confirm normalized steering is approximately -1 left, 0 centered, and +1 right. Use **Invert axis** only if required. Add only enough dead zone to eliminate center jitter.
6. Under THROTTLE, choose the device/axis, release the pedal and click **Released**, then fully depress it and click **Fully pressed**. Confirm output rises from 0 to 1. Repeat independently under BRAKE.
7. If using a clutch pedal, perform the same two-point calibration under CLUTCH and enable **Separate clutch pedal**. Disable manual clutch assist when testing direct clutch engagement.
8. Assign sequential shift button indices from the steering device and set its actual full lock-to-lock rotation.
9. Enable **Use steering wheel and pedals profile**. If a missing-axis message appears and the brake is held automatically, repair that assignment/calibration or disable the profile.
10. Test at low speed. Keyboard S and controller LT can still request braking. Verify steering direction, pedal release, and clutch operation before testing difficult obstacles.
11. If the wheel supports torque feedback, enable it at a low strength and check its direction and behavior on the actual hardware. Adjust inversion and rate of change as needed.
12. Choose **Save configuration**. Close and reopen the simulator when you want to verify persistent assignments and calibration.

A separate USB pedal set is supported; throttle, brake, and clutch can each reference their own device. Assignments use device identity, not just the displayed name. Replacing a device or changing the selected axis requires new calibration. Discovering a newly connected device requires restarting the application even if the old device list is still visible.

10. Saving, restoring, and personal files

10.1 What each save action stores

Action	Stored preferences	What it does to the active trial
Select language	Language.json	Updates text immediately.
Change a HUD checkbox	Hud.json	Updates visibility immediately.
Save configuration	Vehicle.json, Rcs.json, RcsVisuals.json, the active track's Environment.json, DrivingDevices.json	Preserves current preferences; does not recover the vehicle or refill resources.
Save RCS settings	Rcs.json	Preserves tank/equipment/control preferences; leaves current air and energy as they are.
Save RCS appearance	RcsVisuals.json	Preserves gas rendering preferences independently of physical RCS settings.
Save environment	Tracks/{track-id}/Environment.json	Preserves the active track's clock/cycle and weather preferences.
Change track	Saves the departing track's Environment.json	Preserves current setup/resources within the session; closes CSV and resets driving state at the new start.

Action	Stored preferences	What it does to the active trial
Save graphics settings	Graphics.json	Preserves anti-aliasing/upscaling and scene detail; leaves the physical trial state and Epic/Cinematic selection unchanged.
Restore default vehicle	No automatic save	Changes the in-memory base vehicle values and glass transmission; save afterward if wanted.
Vehicle recovery	No automatic preference save	Resets the trial state at a recovery destination using current accepted settings.

Most slider and checkbox changes remain only in memory until their relevant save action is used. Exiting without saving can therefore restore the previous saved preferences next time. Closing the menu does not undo changes within the current session. Track changes also preserve current in-memory vehicle settings; environment settings are saved automatically when leaving a track.

Saved preferences are not saved progress. They do not retain vehicle position, gear, wheel motion, tire wear/heat, brake temperature, remaining RCS air/energy, automatic roll progress, camera orbit/zoom, or an active CSV file. A new session starts a new trial using the stored setup. Travel between tracks within the same session retains the current setup and air/energy in memory; it does not create a disk checkpoint or retain each track's vehicle position. Headlight state and Epic/Cinematic button selection are not fields written by Save configuration. Anti-aliasing/upscaling and scene detail persist through the separate Save graphics settings action.

10.2 File locations

For a normal packaged Windows session, personal data is under `%LOCALAPPDATA%/OffroadSimulator/Saved`. You can paste that location into Windows File Explorer. A development/editor session uses the project's own `Saved` directory unless launched with an isolated data path.

Relative location under Saved	Purpose
Configuration/Vehicle.json	Vehicle physical parameters, modes including the Rear/Front 4x2 axle preference, cold tire pressures, analog clutch preference, and glass transmission.
Configuration/Rcs.json	RCS installation, equipment/tank/compressor parameters, reserve, recharge, pitch, damping, and flight button.
Configuration/RcsVisuals.json	Gas visibility, ground interaction, density, size, lifetimes, turbulence, and visual quality.
Configuration/Tracks/exhibition/Environment.json	Exhibition hour, cycle, day length, fog, dust, wind and volumetric quality.
Configuration/Tracks/obstacle-course/Environment.json	Independent obstacle-course clock, cycle and weather preferences.
Configuration/Tracks/basic-test/Environment.json	Independent N3 speed-circuit clock and weather preferences.
Configuration/Environment.json	Legacy shared environment, retained for compatibility and read only for first-time exhibition migration.

Relative location under Saved	Purpose
Configuration/Graphics.json	Requested anti-aliasing/upscaling mode and scene-detail level. An unsupported saved NVIDIA mode uses Native TSR on the current PC.
Configuration/DrivingDevices.json	Controller vibration/trigger curves, USB role assignments/calibration, shift buttons, wheel rotation, and torque feedback.
Configuration/Language.json	Language preference.
Configuration/Hud.json	Independent panel visibility preferences.
Telemetry/	User-started CSV recordings.
Logs/	Runtime logs useful when investigating a reported error.

The local activation license is managed separately from these tuning files. A backup of Vehicle.json or a copied game folder does not transfer a one-PC activation.

10.3 Backups and restoring a setup

Before a long experiment, stop, save the relevant configuration, close the simulator, and copy the desired configuration files into a separately named backup folder. To restore that setup later, close the simulator, preserve the current files in another backup, and put the saved copies back in their original configuration locations. Restart to load them.

Use the panel for ordinary adjustments. If you edit JSON manually, close the simulator first, retain valid JSON syntax and complete arrays, and keep a backup. Unsupported or invalid values can be clamped or replaced by defaults; an unreadable file produces a notice and uses fallback values. Loading an older supported file supplies missing newer preferences. `TwoWheelDriveAxle` is stored as the case-sensitive string `Rear` or `Front` in Vehicle.json; a missing field, unknown string, or wrong JSON type uses `Rear`. `FourWheelDrive=true` drives both axles while retaining that preference. The legacy shared environment file is retained; its first-time exhibition migration writes a separate track-specific copy.

Changing a capacity can reduce the current remaining resource to the new maximum; increasing it does not increase what remains. Restoring settings from disk on a fresh launch initializes a new trial rather than resuming the saved resource balance.

11. Recording and interpreting telemetry

Press **T**, or select **Start or stop CSV recording**, to start recording. An on-screen **REC** indicator confirms it. Press again to close the file. Each recording name includes the track identifier and a UTC timestamp. Existing files are not intentionally overwritten. Every row includes a `track_id` column. Changing track closes the current recording; press T again in the destination to start a separate file.

Files use CSV with a header, UTF-8 BOM, and CRLF line endings. Open them in a spreadsheet or analysis tool that accepts comma separators and dot decimal values. The regular user CSV writes approximately every 0.1 seconds, subject to frame timing. This is distinct from the higher-frequency physics update and from developer diagnostic traces.

11.1 Measurement groups

CSV group	Fields and meaning
Basic vehicle	`time_s`, signed longitudinal `speed_mps`, `rpm`, engine `torque_Nm`, engine `power_kW`, `gear`, and world `x_m/y_m/z_m`. Gear is -1 for reverse, 0 for neutral, and 1-6 forward.
Per-wheel contact	FL/FR/RL/RR prefixes with normal load, slip, current pressure, tire temperature, compression, surface identifier, soil sink, and footprint.
Per-wheel suspension	Compression rate, spring/damper/bar assembly force, and local wheel-center coordinates. The spring force field is an assembly/seat force, not the complete vector chassis reaction including every constraint/stop.
Axles	Front/rear heave, roll, heave/roll rates, bar engagement, bar force, and constraint error. Angles are in radians where labeled `rad`; rates are their corresponding per-second rates.
Load and attitude	Combined sprung mass, local CG, front/rear normal support, and body roll/pitch.
Braking	Pressure demand/response, effective front share, grade, assist demand, hill hold state/time remaining, and descent active state.
Per-wheel brakes	Rotor temperature, fade factor, ABS pressure fraction, ABS activity, and applied brake torque.
Feedback	Normalized wheel torque command and low/high controller rumble commands. These are software commands, not measured wheel motor torque. `sim_*` channels are for simulated peripheral diagnostic trials.
RCS state and resources	Armed/pause state, collective/attitude/lateral commands, usable air, pressure, auxiliary energy, cumulative consumed/recharged air, cumulative energy use, impulse, mass flow, charging state, and compressor power.
RCS forces	Combined force/torque values, vertical speed, eight actual nozzle forces, fast-refill mode, and each nozzle's target and valve state.
Track and drivetrain	`track_id`; `four_wheel_drive` is 0 for 4x2 or 1 for 4x4; `two_wheel_drive_axle` is the retained `Rear`/`Front` preference. `FL_drive_torque_Nm`, `FR_drive_torque_Nm`, `RL_drive_torque_Nm`, and `RR_drive_torque_Nm` are the signed wheel-side drive/differential torques.

The drivetrain fields are appended after `track_id`, preserving the earlier column order. In 4x4, `two_wheel_drive_axle` records the retained 4x2 preference, not the actual 4x4 torque distribution.

The standard user CSV contains RCS force and vertical-speed fields. The XYZ acceleration bars and held peaks are HUD instruments; they are not added as a separate XYZ acceleration/peak block to the regular user CSV. To estimate acceleration from regular recordings, use time and signed speed carefully, considering that changing vehicle heading makes a scalar speed derivative different from a full world/local vector acceleration. Separate developer motion traces are not created by pressing T.

11.2 Reading values correctly

- `speed_mps` is chassis-forward velocity projection. A moving vehicle can have sideways or vertical velocity not represented by that scalar. The HUD's large speed shows its magnitude in km/h.
- Slip is a signed dimensionless ratio; multiply by 100 for percent. Spinning a lightly loaded wheel does not imply strong traction.

- Wheel-side drive torque is different from the engine `torque_Nm` reading: it includes the gear reduction, transmission losses, axle allocation, and left/right differential reaction. Negative wheel torque can represent reverse propulsion or back-driving; use gear and wheel motion to interpret it. A locked or limited-slip non-driven axle can show equal and opposite coupling torques even though it receives no net engine input.
- Brake pressure, ABS pressure, fade, bar engagement, and normalized commands are generally fractions, not percentages unless the field explicitly says otherwise.
- RCS thrust is force in N, while bank HUDs use kN. Do not compare engine kW directly to nozzle kN as though they were the same quantity.
- Nozzles 0/1 are front left/right vertical, 2/3 rear left/right vertical, 4/5 front left/right lateral, and 6/7 rear left/right lateral.
- Surface identifiers preserve the model's numeric convention: 0 concrete, 1 gravel, 2 wet, 3 rock, 4 sand, 5 mud, 6 timber, 7 polished, 8 steel, 9 rubber, 10 ramp, 11 asphalt. The courses assign rigid geometry and material properties by sector; a defined material identifier does not by itself add another selectable terrain or map. N3 uses rigid compacted-earth gravel and asphalt; its former polished low-grip sector has been removed. Surface labels do not imply persistent soil deformation.
- Legacy soil-related columns can remain zero on the present solid-surface course. Their presence is not a promise of deformable soil or persistent ruts in this scenario.
- Ordinary settings/mode changes preserve the open recording and simulation time. Recovery preserves the open file but resets trial time and dynamic state. Changing track closes the file and requires a new recording. Use a new file per recovered trial when comparing runs.

Use **Save configuration** to preserve the setup separately from its CSV. Telemetry is a measurement record, not a complete setup snapshot or a replay file.

12. Suggested experiments

Use a saved baseline, the same recovery destination, and a new CSV for each trial. Change one variable at a time and compare similar entry speed, direction, tire/brake starting temperature, and driving inputs. Save the experimental setup under a backup name before replacing your baseline.

12.1 4x2, 4x4, limited slip, and locks

1. Recover at **Axle articulation** or **Split traction** with the base vehicle.
2. Select **Rear** under **Driven axle in 4x2** and drive the obstacle slowly with open differentials, observing wheel load and slip.
3. Recover, stop, select neutral, release throttle, and choose **Front**. Repeat with the same setup and driving inputs.
4. Recover and repeat with 4x4, then with limited slip, then with the appropriate axle lock. Make engagement changes with released throttle and stopped/synchronized wheels.
5. Compare progress, spinning unloaded wheels, turning resistance, and the recorded load/slip and per-wheel drive-torque values. Record the selected 4x2 axle as part of each baseline.

12.2 Pressure and tire dimensions

1. Use **Beveled steps** or **Fine washboard** at a consistent low speed.

2. Compare all four cold pressures at 2.2 bar against a lower symmetric pressure, keeping the dimensions unchanged.
3. In separate trials compare radius or width, allowing the vehicle to settle after applying changes.
4. Observe loaded contact, body motion, slip, and temperature. Avoid interpreting a single change in camera motion as a complete tire-performance result.

12.3 Suspension articulation and damping

1. Recover at **Axle articulation** with both bars connected.
2. Repeat with the front bar disconnected, rear disconnected, then both disconnected.
3. Observe support retained by each wheel and body roll. Change connection only with the permitted low speed and released throttle.
4. Restore the bars and compare compression or rebound damping individually over **S-bend undulations**. Separate spring support changes from damping-rate changes.

12.4 Load placement

Compare a rear cargo addition with a roof load addition, preserving the same base setup. Watch combined mass, CG, front/rear load, body roll, and the RCS hover estimate if installed. In another trial, offset rear cargo laterally and compare the side-slope response. Recover before each measured attempt so dynamic history is comparable.

12.5 Braking, ABS, and descent

Record repeated stops from a similar speed with ABS/EBD enabled, then change one assist at a time. Inspect wheel slip, brake pressure, ABS activity, and heat. Use a consistent starting temperature. To test hill descent, select low range and a gear at **Crest and descent**, enable K, release the pedals, and compare a few descent targets while watching whether the HUD says the assist is actually active.

12.6 Manual flight and gas resources

1. Install RCS, recover in full access to initialize the configured resources, and begin with fast refill enabled.
2. Practice a small upright takeoff and landing with minimal attitude input. Learn how collective relative to Hover changes acceleration, not height directly.
3. Compare centered-stick damping on/off during a small roll input, with enough clearance and air to recover manually.
4. Disable flight and observe fast refill. Then turn fast refill off and observe physical compressor power and auxiliary energy usage in a separate trial.
5. Change visual gas settings independently and confirm that their appearance changes do not change the force/resource readings.

12.7 Automatic roll

Use a full-access session with suitable clearance. Set a usable capacity that exceeds the displayed roll estimate after accounting for your mass and thrust setup; allow the added capacity to refill or deliberately recover. Arm flight, neutralize manual controls, and press Y. Watch the phase and force

bars. Compare a stationary start with gentle existing coasting only after learning the cancellation and recovery controls. Completion still depends on the physical conditions.

12.8 Lighting and visibility

Disable the day/night cycle, select a fixed time, and compare Clear, Light mist, Dense fog, and Windblown dust. Turn H on/off and adjust glass transmission while observing both cabin and exterior views. Keep Epic/Cinematic, anti-aliasing/upscaling, output size, and scene detail fixed when comparing weather appearance. The wheel-dust switch is independent of the fog and windblown-dust switches. Change one rendering group at a time when evaluating its cost.

13. Troubleshooting

Symptom	What to check
The welcome screen ignores input	Wait until the continue prompt appears, then release and press a fresh digital input. Stick motion alone does not continue.
R opens registration instead of recovery	You are at the unregistered welcome screen. R is registration there and recovery on the course.
Advanced settings are absent	The Web copy is in demonstration mode. Use the panel's return-to-welcome action and register from the welcome screen. Steam/full registered access exposes the complete panel.
The engine revs but the vehicle will not move	Check N, a held brake/clutch, flight mode, or an enabled but invalid USB profile. Select a gear and disable flight with neutral thrust inputs.
Reverse will not engage	Stop fully, release the throttle, then downshift through first and neutral. A moving reverse transition can be rejected.
Manual shifting is ignored	With clutch assist disabled, disengage the clutch sufficiently. Check the analog clutch setting or separate pedal if a digital key appears ineffective. Allow the short shift interval between presses.
The engine stopped	In fully manual mode, disengage the clutch and press I or D-pad up. Reduce clutch load during the next launch.
A slider or checkbox moves back	The requested change was rejected or clamped. Read the notice. Stop/settle, release throttle, select neutral, or let wheelspin end as required. RCS pressure relationships can narrow a requested value.
4x4/lock will not engage at rest	Check wheelspin and synchronization as well as body motion and throttle. The body can be stationary while wheel speeds differ.
Driven axle in 4x2 is disabled or reverts	Disable 4x4 first. Stop and settle, release throttle, select neutral or disengage the clutch, and let front/rear wheel-speed means synchronize. Holding the service brake is accepted for unloading an automatic transmission. Read the rejection notice; save after the choice is accepted.
J or K is enabled but the assist says standby	The support, slope, speed, gear/range, or pedal conditions are not satisfied. Descent needs low range and a non-neutral gear; pedal input overrides it.

Symptom	What to check
Hill descent exceeds its target	Check traction, contact, brake temperature/fade, and entry speed. The controller requests wheel braking and cannot anchor the chassis to the slope.
The vehicle settles or changes attitude in settings	Ground physics continues with brake applied. Tune from a stable stopped position. Flight menu behavior is a separate world pause.
X no longer disengages the clutch	Installing RCS with flight on X moves the digital clutch to L3. Selecting L3 flight moves the clutch back to X. Analog clutch can also replace digital clutch operation.
Right-stick vertical look is unavailable	Analog clutch is enabled while driving. Use the mouse for looking or disable the option; flight restores the stick's camera role.
R3 does not recover the vehicle	R3 resets only the camera. Use R, or Y while driving, for recovery.
Y does not recover the vehicle	Flight is enabled, so Y starts/cancels automatic roll. R always provides recovery on the course.
Flight refuses to arm	Install RCS, release RT and both lateral directions, and reduce keyboard collective to zero. Read the notice.
Keyboard Space/WASD do not control flight as expected	A connected XInput controller supplies collective and attitude. Disconnect it for keyboard-only flight. Also remember Space increases a stored collective value rather than acting as a momentary thrust switch.
Thrust continues after releasing Space	Keyboard collective stays at its last value. Hold Left Ctrl to reduce it; G disarms flight.
RCS is armed but cannot climb	Check Hover/no-margin, orientation, remaining air, pressure, mass, nozzle rating, and shared mass flow. Attitude inputs can reduce lift; increasing only one limit may not increase available thrust.
Lateral jets stop while vertical thrust remains	The landing reserve threshold has been reached. Prioritize landing or deliberately hold RB/V to permit lateral reserve use.
RCS will not recharge	Disable flight, rest on the wheels, enable auto recharge, and unpause. In compressor mode also check nonzero power and remaining auxiliary energy. The demonstration cannot recharge.
Raising capacity does not increase the remaining air/energy	Capacity changes do not refill resources. Recharge air or use a deliberate full-session recovery/fresh session to initialize capacities.
Y roll is rejected	Neutralize collective, stick, and lateral commands; read the estimated air or thrust rejection. Recharge and check capacity, mass, nozzle power, pressure, and flow.
Roll stops partway through	Manual input/Y can cancel. Early contact or a maneuver timeout can also interrupt the pilot. Read the notice, take manual control if appropriate, or recover.
Flight remains paused after closing settings	Restore focus, release thrust/lateral inputs, and reconnect the controller if it disconnected. G can disable flight for return to keyboard driving.

Symptom	What to check
Gas is difficult to see	Check its visibility checkbox, actual nozzle force, scene lighting, density, and camera angle. Cold gas does not illuminate itself.
A wheel or pedals are missing from the list	Connect them before launch and restart. Confirm their Windows driver exposes suitable DirectInput axes.
The wheel profile holds the brake on	A required device, axis, or calibration is missing/invalid. Repair it or disable the profile to use keyboard/controller input.
Wheel or pedal output is reversed	Verify recorded endpoints first, then use the role's Invert axis control if needed. Check the live normalized output.
There is no torque feedback	Confirm a compatible motorized constant-force wheel, valid steering/profile, enabled feedback, sufficient front contact, focus, closed menu, and nonzero gain. Controller rumble is a separate feature.
Settings disappear after restart	Use the save button for that group. Only language and HUD visibility save automatically. Read any save failure notice and check the user-data directory's write permissions.
Headlights, zoom, or Epic/Cinematic quality do not restore	These are session actions outside the values saved by Save configuration. Reapply them after launch.
Anti-aliasing/upscaling or scene detail does not restore	Click Save graphics settings and check its success/error line. Save configuration and Save environment do not save Graphics.json.
DLAA/DLSS is disabled or a saved NVIDIA mode uses Native TSR	The current GPU or driver does not support that mode. Read the active-mode/fallback status. Native TSR remains available.
All HUD panels disappeared	Open Tab/Start and re-enable the desired HUD PANELS checkboxes.
A recording restarts its time in the middle	A recovery reset the trial while the CSV remained open. Start a separate file after each recovery for clean comparisons.
XYZ acceleration columns are missing from the CSV	The regular T recording contains its listed driving/RCS fields; the XYZ/peak block is a HUD instrument. It is separate from developer motion traces.
Rendering becomes slow	Try Epic rather than Cinematic, DLSS Quality/Balanced/Performance on supported hardware, a lower scene-detail level, Performance fog/dust quality, lower RCS appearance quality, or disable visible weather/gas effects individually. Lowering GPU cost will not necessarily increase frame rate when CPU/simulation work is limiting. These choices preserve the selected physics parameters.
A numerical fault notice appears	Stop the trial, preserve the CSV and log if recording, note the setup that triggered it, and recover. Restore a known setup before repeating.

Symptom	What to check
Web activation fails	Recheck the exact name, identifier/suffix, code, Internet connection, and status message. A license already on another PC needs publisher recovery. A local save error requires fixing the reported saving problem and retrying on the same PC.

14. Advanced vehicle file settings

The panel covers ordinary tuning. Vehicle.json also supports the following physical fields that do not have dedicated sliders in the panel. They are optional for advanced experiments and are not extra keyboard bindings. Close the application and back up the file before editing; restart to load the result. Save a configuration from the panel first to obtain a complete file with the correct key names and arrays.

Ranges below are accepted by the vehicle settings validator. These fields use exact case. Do not confuse engine/road-wheel quantities with controller settings. Avoid replacing an entire file with only a few fields when you intend to preserve the existing setup.

Key	Accepted range / default	Meaning
`Wheelbase`	2.0-4.0 m; 2.90 m	Front/rear axle spacing. Changes axle locations, related vehicle geometry, load distribution leverage, and nozzle/body fitting.
`Track`	1.3-2.4 m; 1.68 m	Lateral wheel-center spacing. Changes support geometry, related visible dimensions, and roll leverage.
`WheelInertia`	1-8 kg m²; 2.7 kg m²	Equivalent rotational inertia per wheel. Affects wheel acceleration and coupling to the drivetrain.
`TireDamping`	100-1,000 Ns/m; 350 Ns/m	Carcass compression-rate damping, separate from suspension compression/rebound damping.
`LongitudinalStiffness`	30,000-160,000; 90,000	Longitudinal brush-model force stiffness scale per unit slip before the traction limit.
`LateralStiffness`	30,000-160,000; 78,000	Lateral brush-model force stiffness scale before the combined grip limit.
`RelaxationLength`	0.05-0.60 m; 0.22 m	Distance scale for the buildup of tire slip response. Longer values make the response more gradual.
`EngineInertia`	0.15-1.00 kg m²; 0.32 kg m²	Resistance to engine speed changes under combustion, losses, and clutch/converter torque.
`IdleRpm`	650-1,200 RPM; 850 RPM	Engine idle target used by the idle assistance.
`MaxRpm`	4,000-7,500 RPM; 5,800 RPM	Engine speed at which combustion throttle is cut by the modeled limiter.
`Gears`	Six entries, each 0.4-5.0	Forward ratio array, first through sixth. Defaults are 4.16, 2.37, 1.56, 1.15, 0.86, 0.67. Keep exactly six entries.
`ReverseRatio`	2.0-5.0; 3.8	Reverse reduction magnitude before final drive and optional low range.
`Efficiency`	0.70-1.00; 0.92	Equivalent transmission efficiency used for drive losses.

Key	Accepted range / default	Meaning
`ClutchCapacity`	300-1,000 Nm; 650 Nm	Maximum modeled engine-side clutch/converter transfer torque scale. Increasing engine torque alone can exceed the available transmission coupling.
`BrakeHeatCapacity`	8,000-40,000 J/K; 18,000 J/K	Equivalent rotor heat capacity per wheel. Larger values heat and cool more slowly for the same energy flows.
`BrakeCooling`	10-100 W/K; 35 W/K	Base brake cooling coefficient, with an additional speed-dependent contribution.
`DragArea`	0.4-1.8 m²; 0.95 m²	Effective aerodynamic drag area used by the body drag model.
`AmbientC`	-10 to 45 °C; 20 °C	Thermal ambient reference for tire pressure/temperature, brake cooling, and compressor calculations. This is not a visible weather temperature slider.
`SteeringRate`	0.3-4.0 rad/s; 1.8 rad/s	Steering-rate limit used with the gradual keyboard/controller steering response. A calibrated wheel uses the direct path.

The other saved vehicle keys correspond to the panel controls already described. `TwoWheelDriveAxle` stores `Rear` or `Front` for the 4x2 selector; `FourWheelDrive` independently enables 4x4. `PressureBar` stores four cold pressure entries in FL, FR, RL, RR order. `AnalogClutch` and `GlassLightTransmission` preserve their named preferences, with glass stored as a 0-1 fraction. Runtime RCS mass is managed from Rcs.json and current gas; do not add it to base sprung mass unless you deliberately want an additional equivalent load.

The panel provides X/L3 flight selection. An older saved R3 flight assignment falls back to X because R3 is reserved for camera reset. Use the panel's current supported choices rather than relying on an obsolete button value.

15. Units, terminology, and simulation scope

Term / unit	Meaning
N / kN	Force; 1 kN = 1,000 N. Normal load and nozzle thrust are forces.
Nm	Torque. Engine torque, brake torque, and moments are different quantities even when they share this unit.
kW / kWh	Power / stored energy. One is a rate and the other an amount. RCS compressor power consumes auxiliary energy over time.
m/s / km/h	Speed. Multiply m/s by 3.6 to obtain km/h.
g / m/s²	Acceleration units; 1 g is treated as 9.81 m/s².
bar	Pressure. Tire sliders are cold gauge pressure; RCS tank pressures are absolute in the gas model.
N/m / Ns/m	Spring stiffness / damping. Stiffness relates force to displacement; damping relates force to motion rate.
kg m²	Moment of inertia, resistance to angular acceleration. It is not an added mass in kilograms.
Roll / pitch / yaw	Rotation around the vehicle's forward/right/up axes. Roll leans the sides, pitch raises/lowers the nose, and yaw changes heading.

Term / unit	Meaning
Sprung / unsprung mass	Mass carried by the suspension / equivalent axle masses moving with wheel support.
CG	Combined center of gravity in chassis coordinates. Load placement and RCS resources can move it.
Collective	Overall vertical RCS thrust demand before attitude redistribution and physical limits.
Armed / disarmed	Flight input routing enabled / driving routing enabled. Disarmed RCS can recharge when the other conditions permit.
Hover estimate	Current collective estimate needed to oppose gravity with the available setup and attitude. It is an instrument, not an autopilot mode.

The simulator uses a reduced physical vehicle model coupled to the scene's rigid-body dynamics. It represents drivetrain behavior, articulated axles, elastic tire contact with width and rounded shoulders, load transfer, thermal trends, slip, wear, braking assists, and finite-resource cold-gas flight. It is intended for interactive experimentation with generic parameters, not as a calibrated prediction for a particular production vehicle, tire, or real RCS installation.

The selectable tracks are the connected exhibition course, the independent obstacle and RCS course, and the speed test circuit. The model's retained surface/telemetry identifiers do not add a terrain editor or persistent soil deformation to these tracks. Weather wind moves visual dust; it is not a tunable vehicle crosswind-force system. Visual gas interaction is also distinct from applying physical gas-blast forces to obstacles. Local test results identify their actual executable, inputs and measured outcomes; a successful RCS trial does not guarantee a crossing for arbitrary vehicle mass, tank state or pilot commands.

Body details such as the winch, protective fittings, doors, and rear hitch are part of the vehicle model; this control set does not provide winch operation, door-opening controls, trailer coupling, or a separate damage-repair simulation. Fuel load is an equivalent mass, not a consumable tank. The panel does not contain independent audio-volume, input-remapping, resolution, or fullscreen controls; graphics actions include Epic/Cinematic quality, anti-aliasing/upscaling and scene detail.

For useful comparisons, combine the instruments with repeatable setup, entry conditions, and actual driving observations. Physical wheel torque direction, controller vibration, and peripheral feel must be checked with the connected hardware. A setting accepted by the panel is a valid input to the model, not a guarantee of stable handling or a successful aerial maneuver under every condition.