Cruden motion simulators for vehicle development and testing

Increasing numbers of automotive OEM departments, their suppliers and automotive research institutes are working with Cruden to significantly reduce vehicle development cost and time.

Cruden 6-DOF, driver in the loop, motion-based simulators are trusted for their realism and accuracy, and relied upon to deliver unlimited repeatable virtual vehicle testing.

Simulators for various automotive applications

Traditionally, the use of driving simulators has been limited to large OEMs and research institutes. Extremely powerful PC hardware has driven the development of accessible software tools for simulation to new levels. Now, simulators play a significant role in automotive engineering, at departmental level and across geographies, at automotive suppliers, academic organizations and OEMs.

Virtual vehicles can truly be used as test mules long before the first prototypes are built. For the subjective assessment of new developments, or when a driver plays a vital role in the control loop, driving simulators are a valuable step between desktop simulation and actual prototypes.

Cruden has recognized the potential of driving simulators since the late 1990s and has developed an extensive software suite that either integrates with existing engineering environments or serves as a starting point for newcomers. Simulators by Cruden are well known for their flexibility, durability and performance. Over 100 motion based simulators have been installed and are being used for various automotive applications:

- **Vehicle dynamics**
- **Autonomous driving**
- **Ride & comfort**
- **Driver training**
- **HMI**
- **ADAS**
- **NVH**
- **Audio**

What to buy?

When acquiring a simulator, there are many questions. While there is no "one size fits all" solution, the engineering application will decide the configuration, motion system, top platform and other fundamental components. Next, the budget, timing, facility and the level of customer experience with DIL simulators are important factors to consider.

Cruden technology is flexible, meaning an array of different simulators can be put together for different applications. Our experts will help you choose the right solution for your situation.

Cruden backs up its installations with maintenance, support and consultancy contracts, according to customer requirements. This can vary from responding to occasional phone and email queries, to providing remote online support, maintenance visits and full support and consultancy contracts.

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Products: standard or customized

Cruden makes standard as well as bespoke simulators to customer specification. Below are three standard simulators that are commonly specified for the automotive market.

A646-D3C

Base product for automotive applications

Compact, affordable and flexible, it ships in one piece and fits in a space of 5.5 m x 5 m x 3.5 m. Customers can be up and running within approximately three to four months.
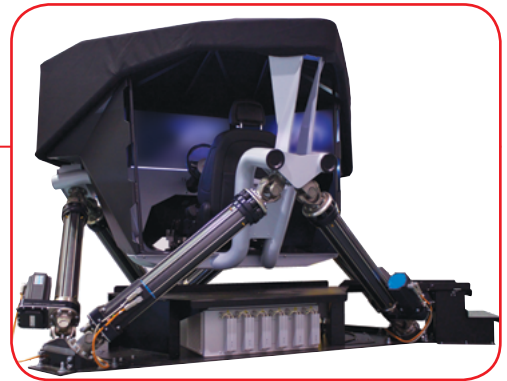
Hardware
- 6-DOF, 640 motion base with control loading
- 3x 42" displays
- Recessed top frame with passenger car seat, steering wheel and pedals
- Canopy

Software
- Panthera
- ePhyse (external vehicle model integration)
- Data logging
- Content: skid pad and highway
- Spectator view
- CSVM in-house vehicle model available as an option.

Typical applications
- Vehicle dynamics
- Autonomous driving
- Driver training
- HMI
- ADAS

A646-N3

Simulator with on-board projection and screen

A compact solution for when a mock-up or partial vehicle is required and more advanced visuals. Fits into a space of 8 m x 7 m x 5.5 m.

Hardware
- 6-DOF, 640 motion base with control loading
- On-board carbon fibre screen with a viewing angle of 180°
- Top frame with interface on which a mock up or partial vehicle can be mounted
- Interchangeable Driver Cell (IDC) optional (see page 4).

Software
- Panthera
- ePhyse (external vehicle model integration)
- Data logging
- Content: skid pad and highway
- Spectator view
- CSVM in-house vehicle model available as an option.

Typical applications
- Vehicle dynamics
- Autonomous driving
- Driver training
- ADAS
- NVH
- Audio
- HMI

A646-F5

High immersion simulator with off-board projection and screen

This system requires a 9 m x 6.5 m x 5 m simulator room and has an 8 m diameter, 210° viewing angle screen.

Hardware
- 6-DOF, 640 motion base with control loading
- 5 projectors
- Top frame with interface on which a mock up, partial or full vehicle can be mounted
- Interchangeable Driver Cell (IDC) optional (see page 4).

Software
- Panthera
- ePhyse (external vehicle model integration)
- Data logging
- Content: skid pad and highway
- Spectator view
- CSVM in-house vehicle model available as an option.

Typical applications
- Vehicle dynamics
- Autonomous driving
- Driver training
- ADAS
- NVH
- Audio
- HMI

Hardware

Cruden's driving simulators are built around motion systems with direct drive force feedback steering systems. From there, a choice of standard top platforms is available, but custom configurations can also be specified by the customer using Cruden's technology building blocks.

Motion base

Cruden uses various motion bases for its simulators. Its standard industrial 6-DOF systems – with either 400 or 640 mm actuator stroke – are used in professional automotive, motorsport and military applications around the world.

The hexapod platform is a renowned and excellent solution for motion systems:
- The parallel kinematic structure and closed-loop system make it very stiff.
- Excellent high dynamic behaviour.
- No accumulation of positions errors, as with cascaded structures.
- Small package with a simple mechanical design, using six identical actuators.
- No moving cables and cable chains.

## Control loading / Force feedback

Cruden uses a direct drive force feedback steering system. It is a purposely designed multi-turn actuator for high-speed steering wheel applications. The nominal maximum torque is 20 Nm, peak torque is 30 Nm. The maximum velocity is 4500 deg/s.
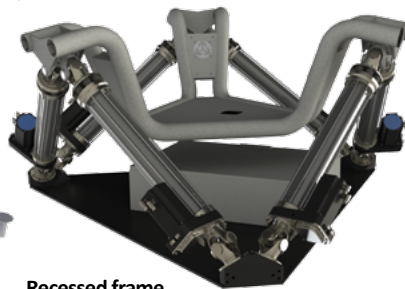

Top platform

Cruden standard simulators come with either a recessed-seating frame or interface frame on which a mock-up, cockpit or partial/complete vehicle can be mounted.

The Interchangeable Driver Cell (IDC) option allows for different mock-ups to be fixed to the top platform, with a changeover time of only 30 minutes.
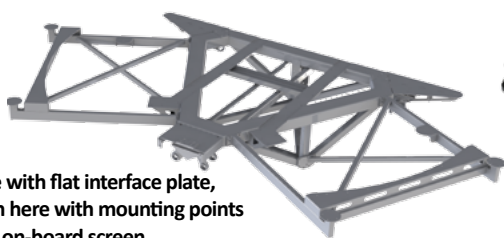
Frame with flat interface plate, shown here with mounting points for an on-board screen.

Recessed frame

Interchangeable Driver Cell (IDC) platform

FREQUENCY RESPONSE

The bandwidth (-3 dB point) of Cruden's motion bases exceeds 20 Hz in all 6-DOF. The bandwidth for heave and rotational degrees of freedom goes beyond 40 Hz.
The control loader bandwidth exceeds 50 Hz.

LATENCY

Full round-trip latency (from driver input to visual change from full white to full black) is just below 30 ms of which 19 ms is due to the projectors.
For motion (heave, roll, pitch and yaw) it is 10 ms. Surge and sway are below 20 ms.
The end-to-end latency from the driver generating an input to the driver receiving feedback on the control loading is only 7 ms.
Audio latency is as low as 8 ms.

Vehicle components

Cruden has many years' experience integrating complete or partial vehicles, mock-ups, cockpits and original vehicle components e.g. shifting devices, pedal boxes, steering wheels or complete dashboards. Company know-how of CAN-bus and other automotive protocols enables interfacing with virtually all automotive hardware and software.

Add-ons such as an active brake pedal, seat belt loaders and vibration devices create a fit-for-purpose engineering tool. Cruden has a standard canopy to improve the immersiveness of its recessed low-seating platform.

Display and audio

Cruden makes systems with integrated TFT displays as well as on- and off-board projection systems with both mono and stereo projection using various technologies available on the market (Infitec, active shutter glasses and more). All simulators come with digital audio.

TFT displays

Projectors

Cruden produces its own 42" vibration isolated, industrial displays.
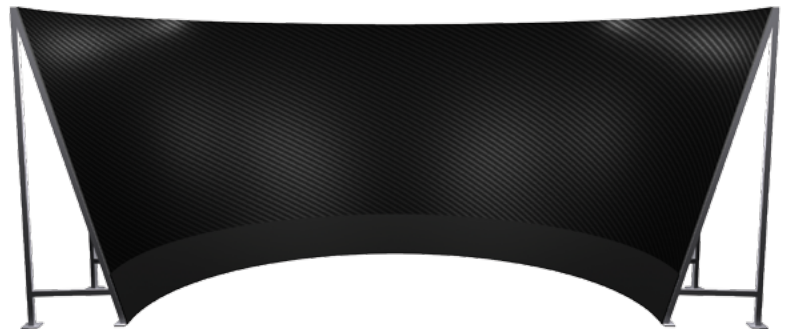
Off-board, conical screen with a diameter of 6-8 m that facilitates the use of only 3 projectors for up to 180° horizontal field of view.

PC hardware

The rendering engine and peripheral software run on high-end COTS Windows PCs. RT Linux is used to control the hardware whereas the vehicle model may reside on a variety of Real Time platforms as well as on a soft real time Windows machine.

Software

All Cruden simulators run on the Cruden software suite, consisting of Panthera, plus various add-on modules, depending on the application. Panthera integrates perfectly with existing simulator hardware and is also available as a desktop application.

Panthera

Panthera is the main simulation controller. It uses high-end physics and an excellent rendering engine. It contains controllers for different types of hardware, e.g. motion platforms, steering feedback, pedals, dashboard and a scripting engine to define and customize the simulation. Panthera easily integrates with HIL or SIL configurations as well as RCP set-ups.

Vehicle modelling / ePhyse

Either an internal or external vehicle model can be used with Cruden simulators. Panthera has a 16-DOF internal vehicle model, called iPhyse. For automotive applications, a more detailed vehicle model is typically used.

Through ePhyse Net, external vehicle model packages such as Vi-Grade, IPG CarMaker, veDYNA, CarSim, Dymola or SIMPACK can be integrated into the Cruden simulator over a network. The models run natively, in co-simulation, through their Simulink S-functions.

Alternatively, Cruden has developed its own highly detailed Simulink Vehicle Model, CSVM, which is an option on every simulator. For start-up, CSVM-Light is available.
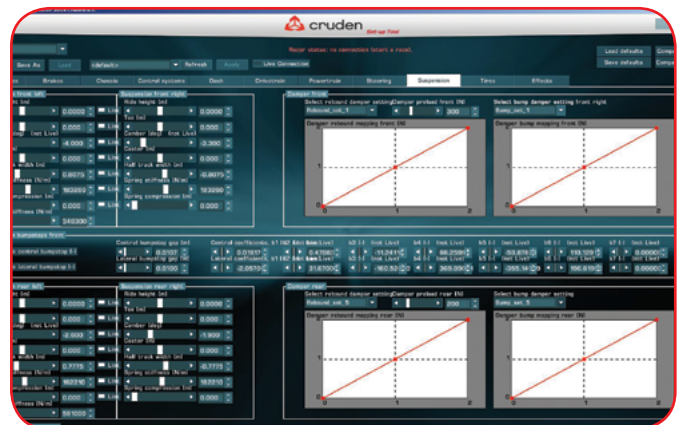
Set-up Tool

With Set-up Tool and a Cruden vehicle model, engineers can change almost all vehicle settings at runtime from a GUI. Customers with a Simulink-compatible vehicle model can also interface to Set-up Tool.

Data logging

When running a Cruden vehicle model, vehicle performance can be evaluated as the simulator runs. After the session, the data can be exported in a variety of formats. Customers can also integrate this tool in their own vehicle modeling environment.
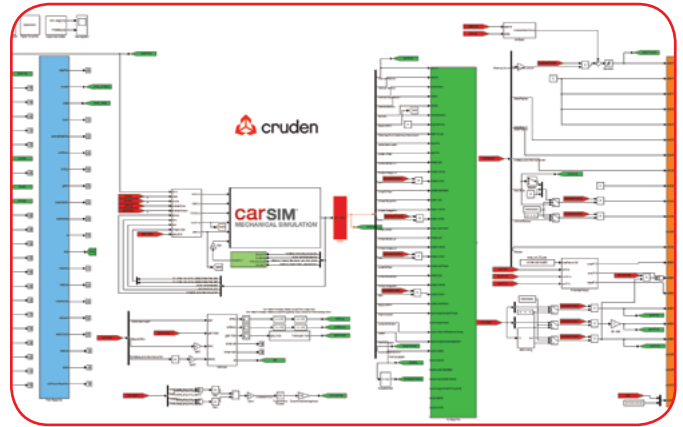
Vehicle modeling

Set-up Tool

Remote simulator operation

Content: roads, tracks, environment

Cruden creates content, ranging from skid pads, endless highways and test tracks up to full Lidar scanned public roads.

Edge blending & warping

The Panthera software has a built-in module that compensates for the distortion when projecting on an arbitrary shape surface. The compensation takes into account the position of the projectors, the shape of the projection screen as well as the dynamic position and orientation of the motion base. It also smoothly blends the edges of each area where two projections overlap.

Platform tracking

For off-board projection, Panthera tracks the motion platform position and orientation and adjusts the projected images accordingly.

SISTer

SISTer (Server for Interaction with Surfaces & Terrains) determines how the tire/road contact patch is deformed, not using a single point tire contact patch, but up to 49 query points per wheel at a frequency of 1000 Hz. This provides highly improved input to the tire model, resulting in detailed and precise forces and moments plus road-normal calculations, without additional computational costs in the vehicle model. The interaction between the vehicle model and SISTer has a latency of less than 2 ms.

INTEGRATION

Engineers value Cruden above all, because of its expertise in system integration. A simulator is a complex mechatronics system, consisting of mechanical, electrical, electronic and sometimes hydraulic components, as well as several software packages. Cruden designs the complete simulator architecture, including all the components that are integrated into a simulator.

This integration, both in the design as well as manufacturing and commissioning phase, is one of the most important and often underestimated factors.
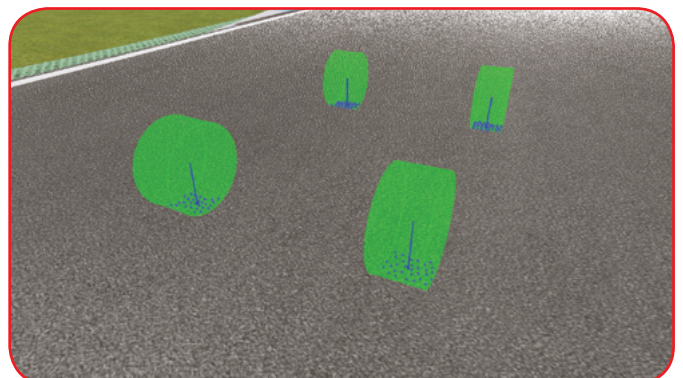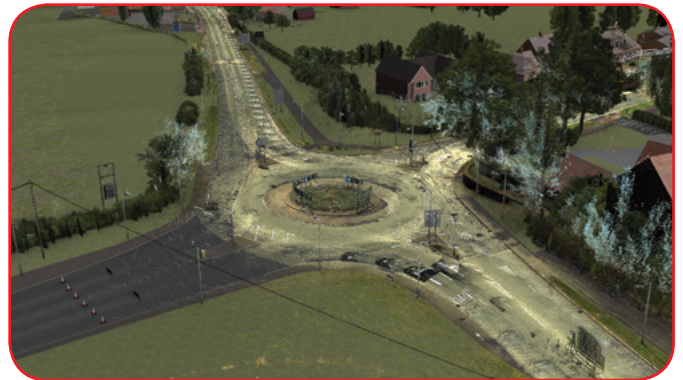
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Cruden's founders – formerly of Fokker Aircraft Company and FCS Racing Simulation – have been developing professional motion simulators since the early 1990s. The company started developing products for the aerospace industry and helped lead the technology transfer into the marine, automotive and motorsport industries.

As a result, Cruden has the world's leading experts in the complete array of technologies required for a simulator.

Cruden's team of vehicle dynamicists, software developers, mechanical engineers and project managers is based at its global headquarters in Amsterdam. The building houses all functional teams covering the mechanical design of all the company's components and systems; hardware assembly and integration; its Content & Design Studio which makes all the content for the simulated environment e.g. tracks, vehicles, cars, and scenery; the design of motion-cueing algorithms and associated software; simulator operating software and professional image generation.

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