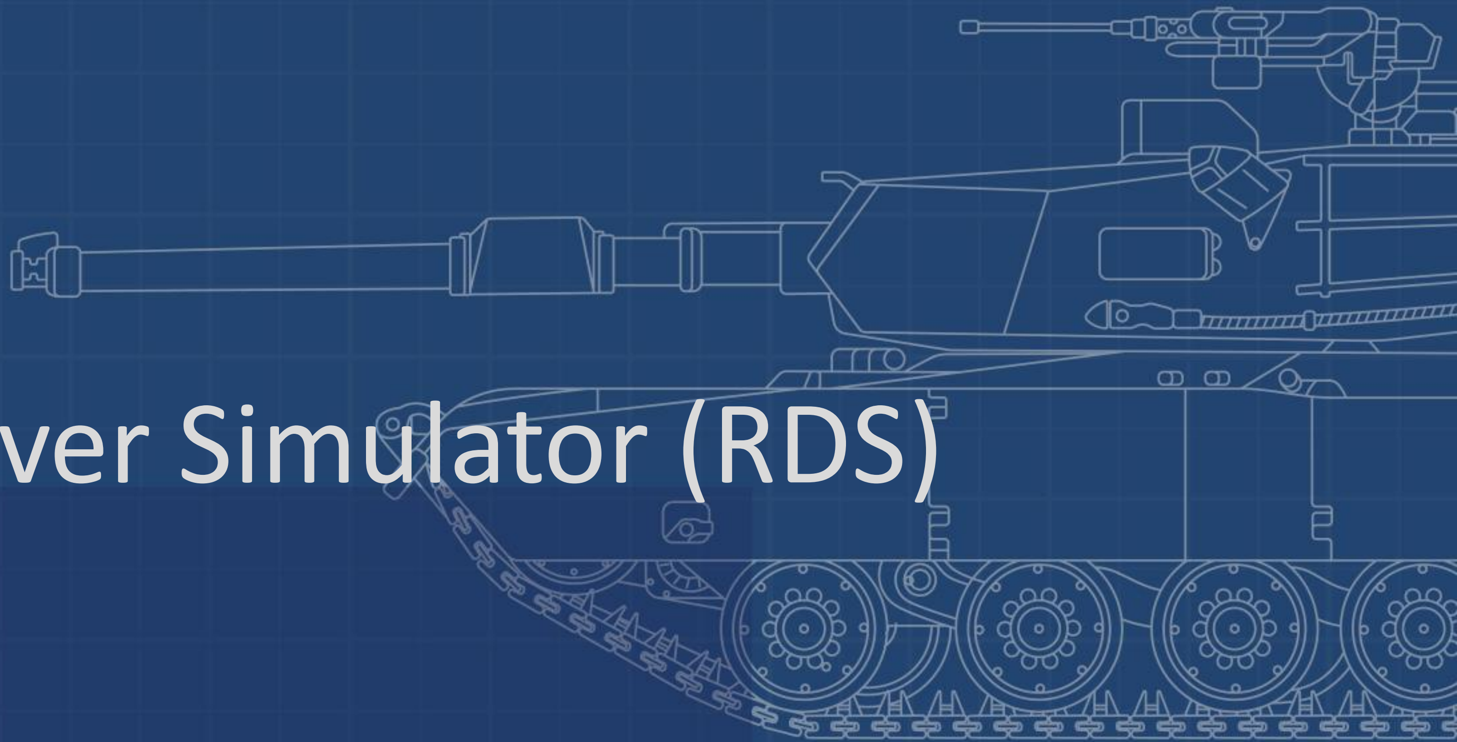
UNIVERSAL MOTION SIMULATION

RECONFIGURABLE, HIGH-FIDELITY
MOTION SIMULATION FOR
DYNAMIC, IMMERSIVE TRAINING

MAK One Integration

Reconfigurable Driver Simulator (RDS)



Presentation to MAK User Group, I/ITSEC 2023

Ben Goodman, Nov ’23

MAK One integration with RDS

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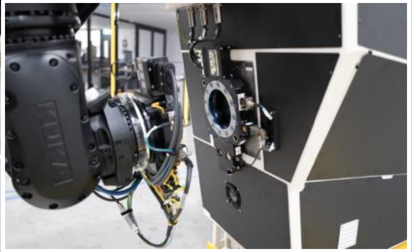
Reconfigurable Driver Simulator

RDS overview



Overview

The Reconfigurable Driver Simulator (RDS) is a highly dynamic motion platform featuring a 6 Degree of Freedom (DOF) robotic motion platform, rapidly interchangeable cabins, haptically enabled controls, immersive simulation environments, and advanced motion control.

Key Features

- Large range of motion
- Rapid Reconfiguration in <10 min
- Advanced Washout Algorithm for highly-realistic motion
- Ab initio to advanced driver training scenarios

Primary Sub-systems

1. Instructor Operating Station
   ➲ VR-Forces
2. Modular Vehicle Cabin
   ➲ VR-Engage
3. Motion Platform

Reconfigurable Driver Simulator

Benefits for driver training, from beginner to advanced

The value of a *high-fidelity* driving simulator

Realism to support Learning Objectives

- Faithful motion cues are critical when performing difficult tasks with limited vision.
- For *ab initio* training teaches a new driver precise control.
- For more advanced training, can teach near limits of a vehicle, and avoid costly and dangerous accidents.

Higher 'Simulation Efficiency' leads to better overall training outcomes

- Increased comfort and reduced motion sickness allows more time in Simulator and fewer distractions from learning outcomes
- Allows a greater proportion of training to be in simulator rather than real platform, greatly reducing cost

The benefits of reconfigurability

- Reduced incremental cost to add new vehicle types
- Smaller overall footprint, through re-use of core motion platform
- Plug-n-Play - all the vehicle-specific characteristics on the cabin.
- Fast change-over allows more flexible logistics and scheduling, higher platform utilisation, for a suite of simulators when supporting multiple vehicles

(In addition to the general benefits of training with simulators)

UMS (Pre)History

Deakin University research and collaboration with the Australian Army

2006 - 2017

- Institute for Intelligent Systems Research and Innovation (IISRI) began exploring anthropomorphic robot arms for use in simulators
- Inspired by ‘robo-coasters’, Max Planck Institute and Flight-Simulators
- At the time, Army were planning to acquire many new vehicle platforms, and build a new Simulation Centre to house them. Reconfigurability was an important consideration, as was size and motion fidelity

IISRI built a prototype simulator for the M1A1 Abrams.

- Used mainly VR-Vantage and an early version of Vortex
- Demonstrated to Australian Army through a series of trials in 2017.
- Feedback was extremely positive.

UMS was formed as an independent company to commercialise the Research and deliver a production system to Army.

UMS History

I/ITSEC and the birth of UMS… and possibly of VR-Engage

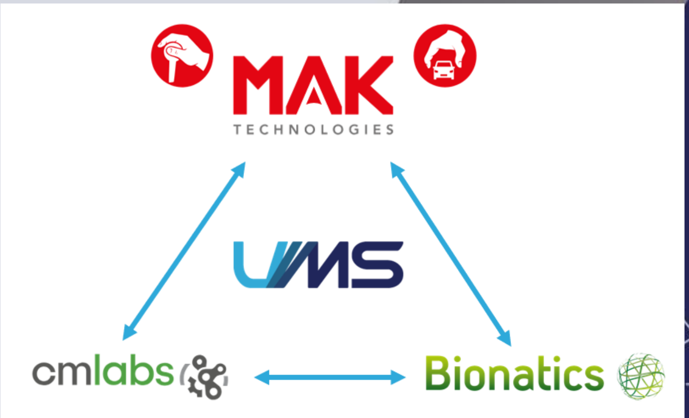
The UMS Software Architecture has built on VR-Engage from the beginning, but the story goes deeper…

Around 2014/15 Kyle Nelson, our founding CTO, started investigating a high-fidelity *off-road* driving simulator.

- ✓ First step was highly realistic physics – CM-Labs Vortex Studio was selected
- ✓ Second was a detailed and performant terrain – Bionatics Blueberry3D procedural terrain server was chosen
- i Third was a platform providing IG and Simulation Engine to tie it all together

Discussions at I/ITSEC, between Kyle, Len and Michel led to a close collaboration

- IISRI, and later UMS, worked with engineers at MAK to beta-test and stabilise the integrations.
- B-Design3D were later added as terrain design partners



The RDS was built on this new software architecture, with a then-brand-new VR-Engage as part of the foundational platform.

UMS Today

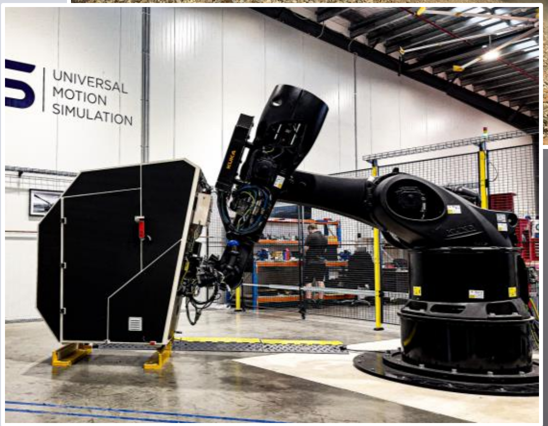
The journey so far

☑ Completed core development of RDS at end of 2021

- Production branch uses VR-Forces v4.7, VR-Engage v1.4 and Blueberry3D Terrain Server v4.2
- Delivered 6 complete RDS systems to the new O'Donnell centre at Puckapunyal (in Australia) in Oct'23 – System Acceptance in Jan'24

Future development

- Migrate to MAK One (5.03/2.03) and adopt the MAK-Earth terrain server
- Add new types of obstacles and more complex collisions with both objects and terrain
- Introduce new vehicle types: the M1A2 SEPv3 Abrams, M1150 Assault Breacher Vehicle (ABV), Hanwha K21 Redback IFV.
- Deployment planned for Q3'25



Simulators for driving Military vehicles

Building a high-fidelity, motion-enabled driving simulator

Platform motion becomes increasingly important as task difficulty increases and field of view is restricted.

The quality of a driving simulator is judged on:

- *Feeling* of the wheels or tracks travelling over the ground – ground contours, slip, texture, etc….
- *Feeling* of driving over or through obstacles – touch of the wheels, vehicle balance, etc…
- *Realism* - synchronisation of visual, audio and motion cues to build the right skills and habits.
- Training scenarios that deliver learning outcomes.

Also important:

- Haptic Controls that feel real, in the right place, to build muscle memory.
- Capability to train in ways that aren't practical in a real vehicle, including difficult conditions or near vehicle-limits.

Simulators for driving Military vehicles

Building a high-fidelity, motion-enabled driving simulator

Challenging requirements

- Highly detailed terrain geometry and a variety of different surface material properties
- Accurate Physics model – for realistic vehicle motion
- Visual details – for user's view near the ground (i.e. not looking down from above)
- Performance implications of highly-detail 3D assets
- Faithful motion cues to learn "seat of the pants" driving and precise vehicle control
- Tight synchronisation of visual and motion cues to eliminate/minimise simulator motion sickness

Platform motion becomes increasingly important as task difficulty increases and in the absence of a good, wide field of view.

Driver Input ➲ VR-Engage ➲ Vortex ➲ Accel and Velocity data ➲ Washout Algorithm ➲ Robot Motion

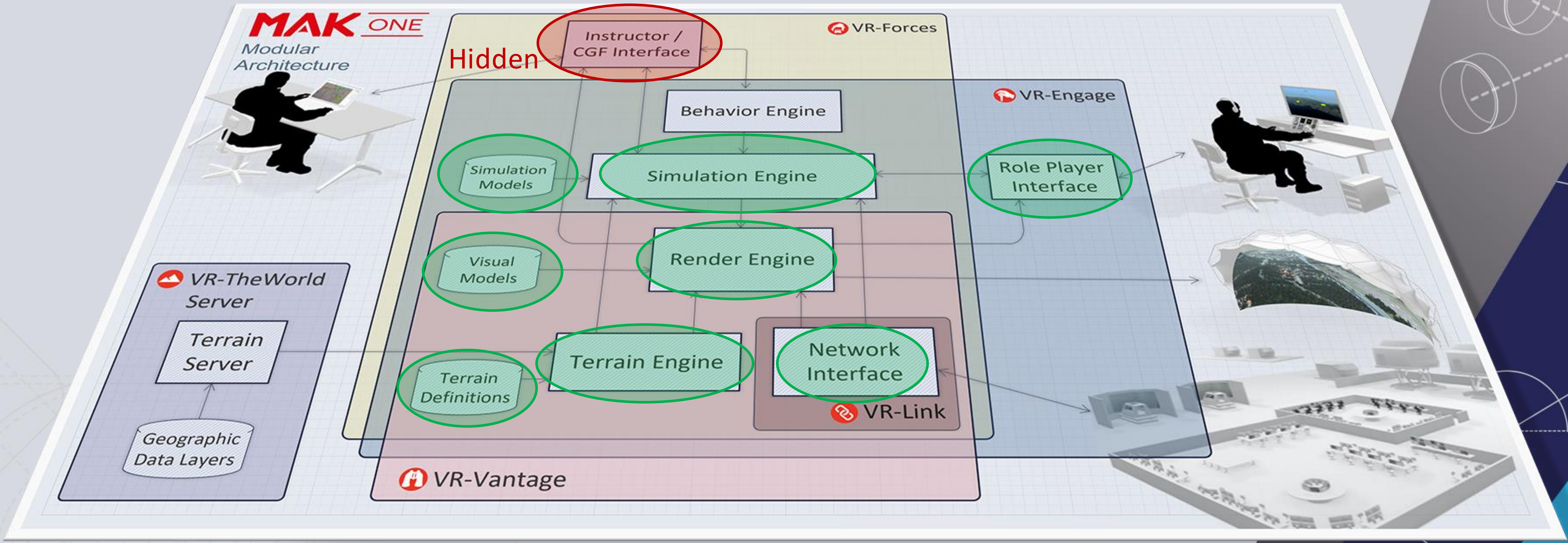
⇧ ----⇧ Terrain, MAK-Earth & Vehicle physics

Simulation and Integrations

MAK One Technology Stack

High level view of how MAK One helps RDS make high-fidelity ground simulation possible

Sources: MAK ONE, MAKtv



Very High-Fidelity Terrains

Obstacles and Ground Level Details

Realistic off-road driving relies on high-fidelity ground features:

- Terrain needs to *look* convincing at ground level
- Driving needs to *feel* convincing - Vortex physics engine models the interactions between wheels/tracks and the terrain polygons.

Considerations

- Performance: Size, Area, Level of Detail (LoD), etc…
- Quality and variety of terrain surface material properties and vegetation information

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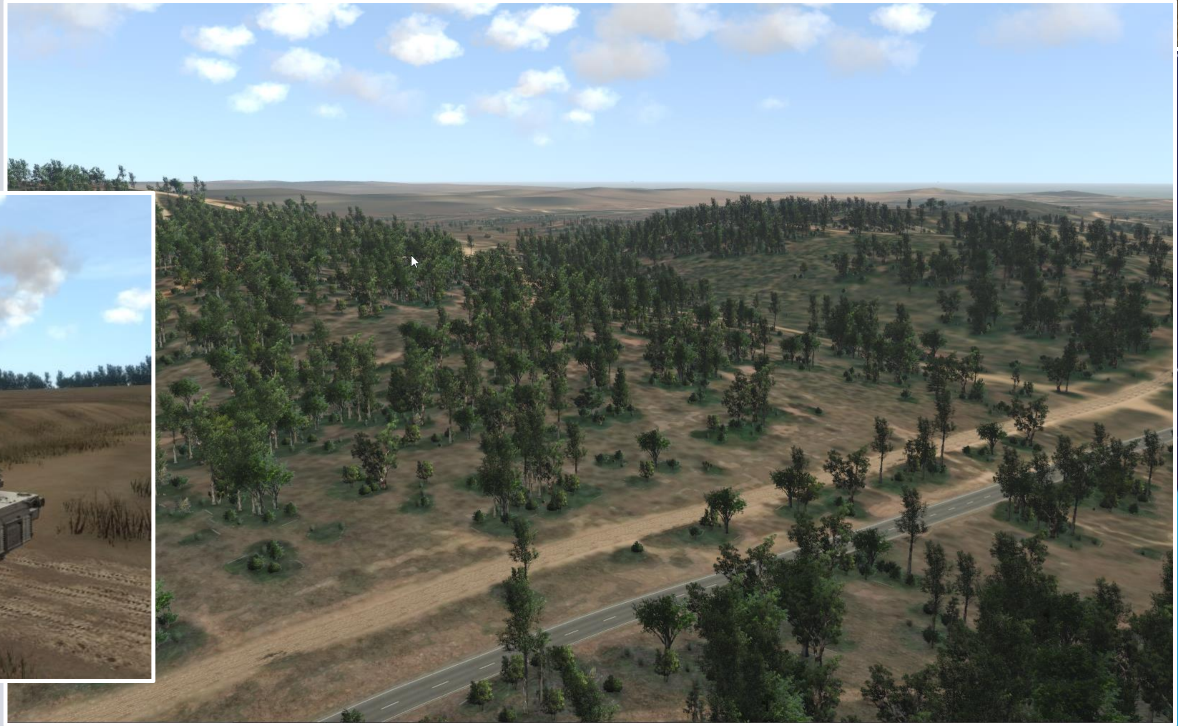
Very High-Fidelity Terrains

Landscape and trees

Teach a trainee to select a path through/over/around landscape features.
Learn to navigate through trees, choosing a path and avoiding collisions (and damage).

- Types of trees should be geo-typical, collision zones for trees appropriate to the vehicle. For example, Tanks don't stop if they hit a shrub
- Light, shadow and detail are all important for a new driver to learn effective path selection and precise vehicle control



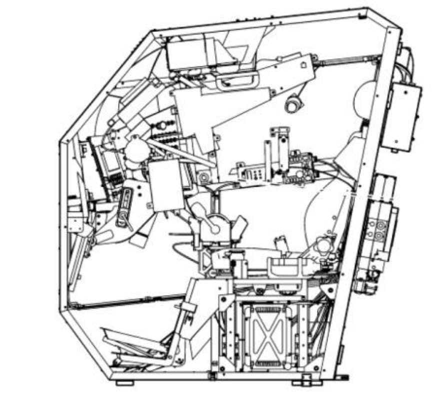
Vehicle Replication

Haptic controls in a Vehicle-specific cabin

VR-Engage running locally on cabin computer to minimise latency

Control of the (virtual) vehicle

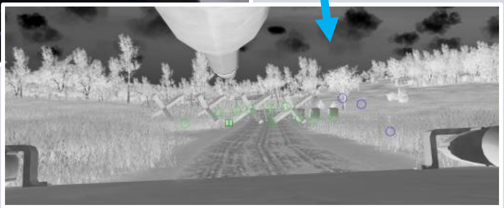
- Steering-wheel with force-feedback, pedals, gears – all integrated with Vortex Physics Engine to control the trainee's vehicle
- Speed, heading, steering angle, etc are displayed to the Trainee Driver on a replica dashboard



VR-Engage

Visualisation

- IR and night-vision using SensorFX
- 3 periscopes
- External cameras
- 'Hatch-open' wide field of view

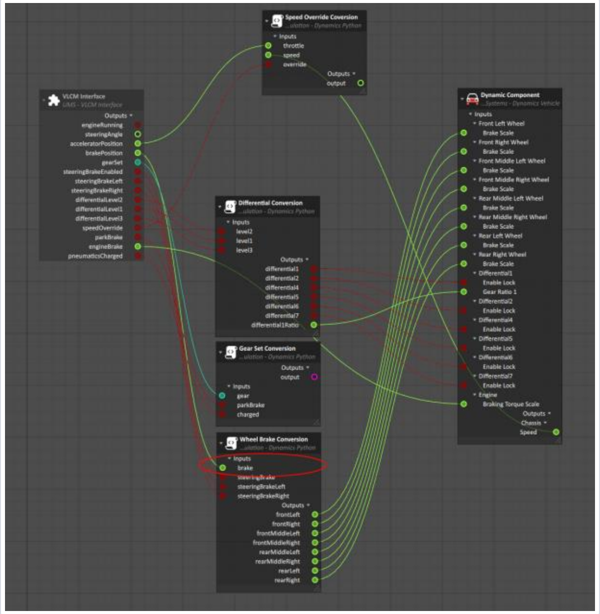


Vehicle Replication

Vortex Model Tuning

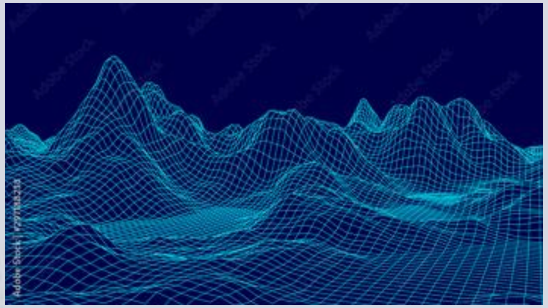
Inputs

1. Vehicle OEM data
2. Instrumented driving
3. Training requirements
4. etc…



Tuning

- In purely virtual world
- On full system with motion
- On different terrain surfaces
- At various speeds
- Special operations, e.g. Pivot-steer



Verification and Validation

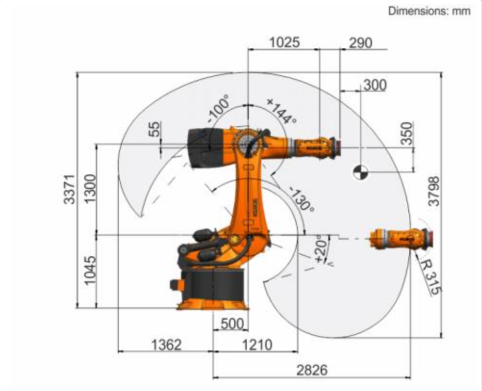
1. Specific performance requirements
2. Testing in CM-Labs Vortex Studio
3. Subjective input from SME drivers
4. etc…

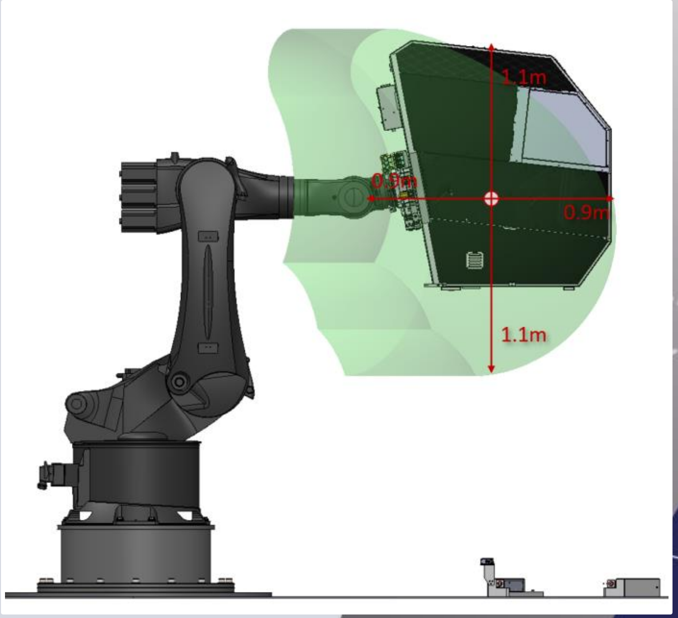
Result: realistic and dynamic driving

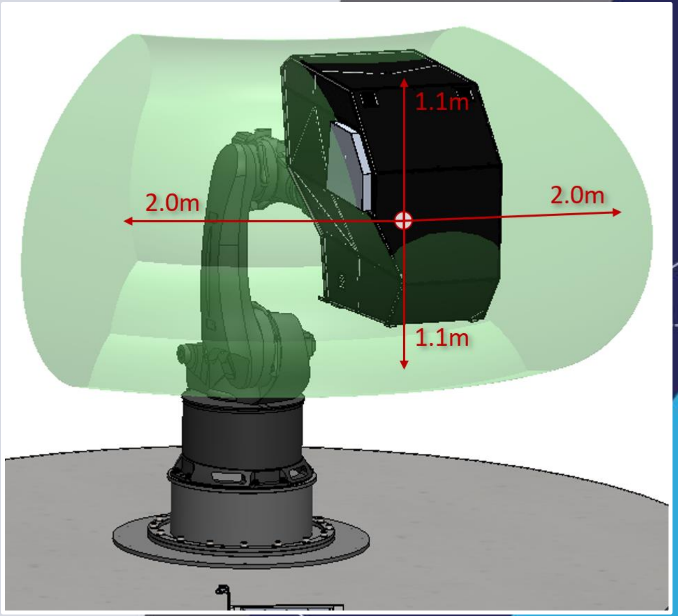
M1 Abrams - mobility and speed demo - YouTube

Robot Motion

Virtual physics to real-world motion







Advanced motion-cueing algorithms replicate the sensation of the vehicle motion, as experienced by the trainee's vestibular system.

1. Acceleration and velocity extracted from Vortex – X, Y, Z, pitch, roll, yaw
2. Washout Algorithm calculates positions and offsets of each joint in real-time
3. Direct, closed-loop control of 6 independent joints allows very complex motion

Motion-Cueing Algorithm takes advantage of the large motion envelope to delivery sensation fidelity that exceeds traditional simulator systems.

- Ideally suited to off-road ground vehicle simulation where large, high acceleration heave motions coupled with continuous yaw rotations are experienced.
- Supports advanced "Train to Failure" scenarios

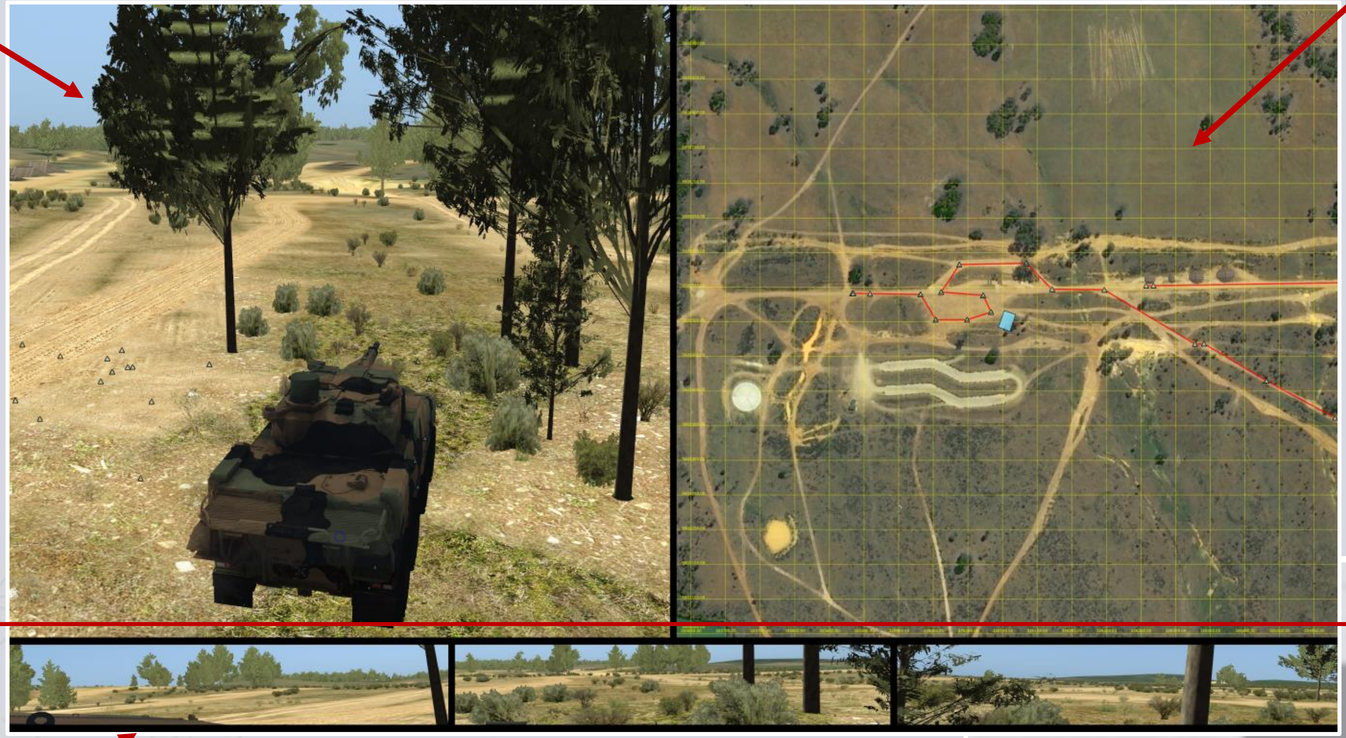
Vortex ➲ Accel and Velocity data ➲ Washout Algorithm ➲ Robot Motion

Instructor Experience

Stealth Views and Scenario Paths (Routes)

Chase View

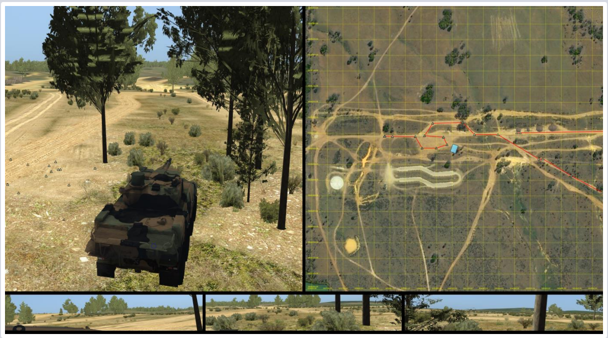
Overhead (Plan) view



Periscope views – match Driver's view

Video Monitor Screen

Operator Interface Screen



Simulation Vision Screen

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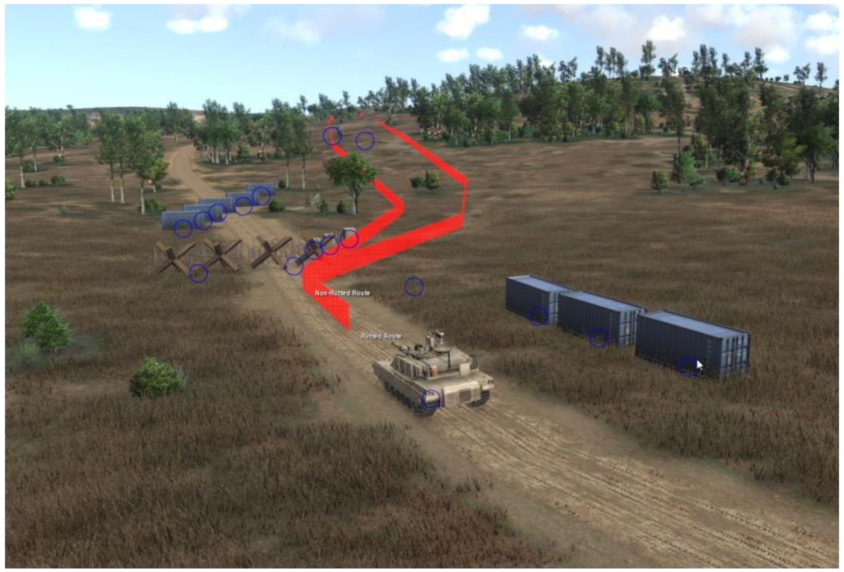
Training Scenarios

Helping the Instructor help the Trainee

“RDS Scenarios” are a hybrid of inbuilt MAK scenario, and programmatic additions post-loading.
Creative placement of roads, paths, trees and obstacles to align with Training Objectives.

Drive up the road and over a hill…

…arrive at an obstruction, go off-road and over the ridges, follow the path through the trees



The Future

AI Supported Training and Real-Time Assessment

- Improved Instructor/Student ratio
- Free instructor from repetitive and boring work, allow focus on more interesting training exercises

AI-Assisted Motion Tuning

- Replicating the *feel* of a real vehicle is challenging, and time consuming
- Leverage ML to streamline this process

Customised Scenario Editor

- Extend the in-built MAK VR-Forces scenario editing capability
- Allow training teams to produce their own scripts targeted at single-driver training, or small formations
- Build scoring and evaluation into the Scenario-authoring process
- Find the delicate balance between assisting the Instructor and constraining them

Current Contract

L400 Ph2 BOXER CRV

L907/8160 - M1A2 SEPV3 MBT, M88A2 ARV, M1150 ABV

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Future expansion

Hanwha
K9 SPH & K10 ARV

L400 Ph 3
Redback IFV

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