
Reproducing a T-72 / T-90 Crew Training Environment Without a Live Platform

A hybrid physical and VR approach to transferable armoured crew training

CLIENT	National armoured forces training establishment (name withheld)
DOMAIN	Crew training simulation, hybrid physical and VR
CLASSIFICATION	Public release. Client and platform-sensitive data excluded

At a Glance

Challenge	Crews trained on T-72/T-90 platforms had too little seat time, repeated drills were costly, and key failure scenarios could not be rehearsed safely on a live vehicle.
Approach	A hybrid system: physical crew-station mock-ups with instrumented controls, combined with VR visuals, a vehicle dynamics model, fault injection, and an instructor station.
Design principle	Fidelity was allocated where it changes trained behaviour (controls, layout, procedure, faults) rather than maximised everywhere.
Success measure	Transfer of training: how trainees perform on their first live-vehicle session, not how the simulator looks.
Outcome	Early and repetitive training moved off the live platform. Live time was reserved for later stages. Limitations in motion cues and physical stress remain and are documented.

Figures in this document shown as [highlighted brackets] are placeholders to be replaced with measured project data before release.

1 Context

The client operates armoured crew training on T-72 and T-90 family platforms. Their pipeline depended heavily on access to live vehicles, which produced three recurring problems:

- **Availability.** Vehicles were shared between operational units and training, so crews often received less seat time than the syllabus assumed.
- **Cost per repetition.** Fuel, ammunition, track and engine wear, range time, and support staff made each exercise expensive, which discouraged repeating a drill until it was mastered.
- **Limits on what could be trained.** Emergency procedures, degraded-mode operation, and fire or fault drills cannot be safely or economically induced on a live tank.

The client did not want to replace live training. The aim was to move the early and repetitive stages off the live platform so that vehicle time is spent where it adds the most value.

2 Problem Statement

Build a training environment in which a crew can learn and rehearse procedures that transfer to the real vehicle, with no live tank involved.

Definition of success

The requirement was transfer of training, not visual realism. A simulator that looks impressive but teaches the wrong muscle memory is worse than none. Success was defined by whether a trainee who had used the system performed measurably better on their first live-vehicle session.

3 Constraints

Constraint	Effect on design
Information security	The system runs fully offline on an isolated network. No cloud dependency and no external telemetry.
Limited access to the live platform	Fidelity data came from client-supplied documentation, supervised measurement sessions, and instructor interviews, not unrestricted instrumentation.
Mixed trainee experience	The system had to serve first-time trainees and experienced crews rehearsing emergency drills.
Motion-sickness risk	Long VR sessions in a vehicle-like space can cause discomfort, which limited the use of motion and head-tracked rendering.
Maintainability	The client's technical staff, not the vendor, needed to handle routine maintenance and scenario authoring.

4 Approach: Hybrid Physical and Virtual

A pure-VR concept was tested early and set aside. A headset with hand controllers can teach spatial orientation and procedure sequence, but it cannot teach what depends on touch: where a lever sits relative to the trainee's knee, how much force a hatch handle needs, how a cramped compartment limits movement. These are the things trainees get wrong on first contact with the real vehicle.

The adopted architecture separates what hardware does best from what software does best.

Physical layer	Virtual layer
Crew-station mock-ups (driver, commander, gunner) built to match real compartment geometry. Real or faithfully reproduced controls: levers, pedals, switches, hatch mechanisms, seating positions. Force and travel characteristics tuned against measurements and instructor feedback, not only visual similarity. Instrumented controls, so every input is captured by the software.	VR headsets for the external view, vision devices, and the surrounding environment. A vehicle dynamics model driving terrain response, engine and transmission behaviour, and fault states. An instructor station for scenario control, fault injection, observation, and after-action review.

The physical layer carries what VR cannot (touch, reach, posture). The virtual layer carries what hardware cannot (terrain, variety, repeatable faults, safe failure).

System architecture (functional view)

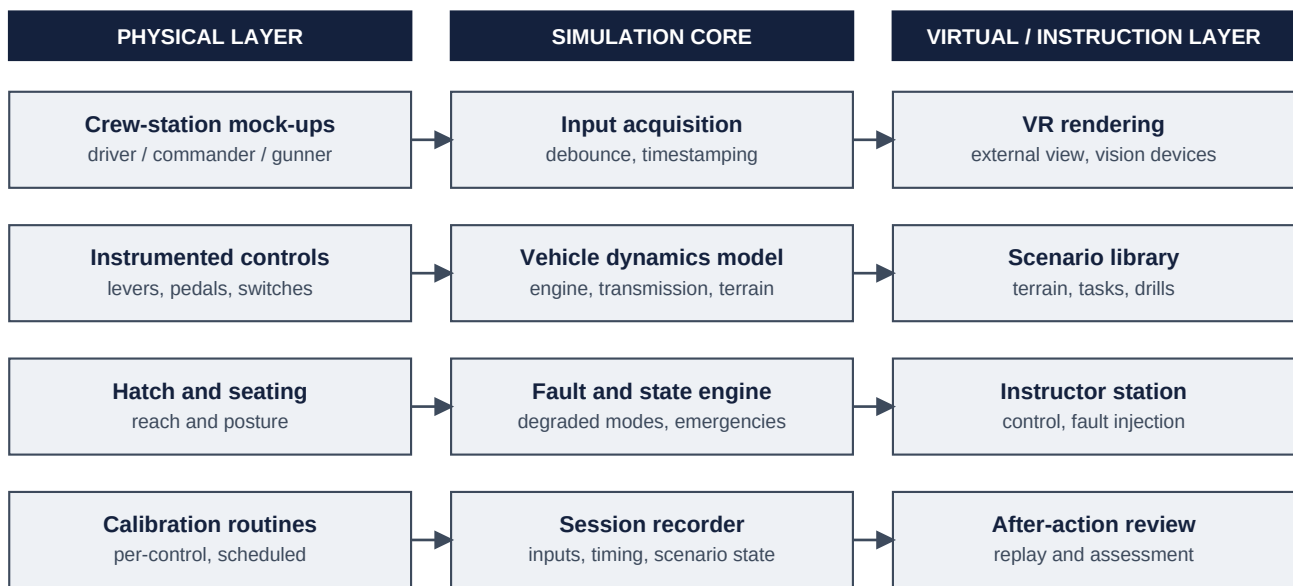


Figure 1. Functional architecture. Data flows from instrumented controls through the simulation core to the visual and instructor systems. Illustrative; component-level detail omitted.

5 Key Engineering Decisions

5.1 Fidelity was allocated, not maximised

The system was divided into elements where fidelity directly affects trained behaviour (control layout, procedure sequence, fault responses, reach and posture) and elements where it does not (cosmetic surface detail, most background scenery). Effort went to the first group. This kept cost and schedule under control and was also the correct training decision.

5.2 Latency took priority over graphical detail

In VR, end-to-end latency between head movement and displayed image matters more for comfort than texture quality. A frame-rate and latency budget was held as a hard requirement, and scene complexity was reduced where needed to meet it. Some visual detail that looked good in review was removed after trainee comfort testing.

5.3 Controls were treated as the interface contract

A disproportionate share of effort went to control hardware: sensor selection, debounce behaviour, and calibration routines. A control that registers late or inconsistently teaches trainees to compensate in ways they will have to unlearn.

5.4 Fault injection was built as a core feature

Instructors can trigger degraded states and emergency conditions during a session without preparing a vehicle. The client valued this capability most, because it allows rehearsal of scenarios crews almost never encounter in live training.

5.5 After-action review was part of the design

Every session records control inputs, timing, and scenario state. Instructors replay and assess performance against procedure instead of relying on memory. The same data supplied evidence for validation.

6 Validation Method

Fidelity claims are easy to make and hard to defend, so validation was layered.

Layer	Method	Purpose
1. Geometric verification	Compartment dimensions and control positions checked against reference measurements.	Confirm physical layout
2. Instructor review	Experienced instructors worked through standard and emergency procedures and flagged discrepancies.	Correct control feel and fault behaviour
3. Procedure comparison	Task sequences and timings compared against baseline expectations for the live platform.	Confirm procedural fidelity
4. Transfer assessment	A trainee cohort completed simulator instruction before live sessions; early live performance compared with earlier cohorts.	Measure what matters: transfer

7 Results

Quantitative outcomes (to be completed with project data)

Metric	Result
Reduction in live-vehicle hours needed to reach baseline proficiency	[X]%
Change in procedure completion time or error rate on first live session	[X]
Fault and emergency scenarios available for rehearsal (simulator vs live platform)	[N] vs [M]
Simulator availability across the training schedule	[X]%

Qualitative outcomes reported by instructors

- Trainees arrived at live sessions already familiar with layout and sequence, so live time went to higher-level skills.
- Emergency procedures were rehearsed far more often than before.
- Instructors could pause, replay, and correct in ways that are impractical in a running vehicle.

8 Limitations and What Did Not Work

A case study that lists only successes is of little use to anyone planning a similar project.

Limitation	Detail and response
Not a replacement for live training	Vibration, noise, heat, fatigue, and the physical stress of a running vehicle are only partly reproduced. The client uses the simulator for early and repetitive stages and keeps live time for the final stages.
Limited motion fidelity	Without a full motion platform, the inner ear receives no acceleration cues. Conflicting visual motion cues were reduced. Some drivers still reported mild discomfort in long sessions; session-length guidance and breaks were introduced.
Early control hardware fell short	The first generation of some controls looked right but felt wrong to experienced crews. They were redone, at a cost to schedule.
Incomplete fidelity data	Where direct measurements were unavailable, instructor judgment was used. Those elements are marked in documentation so the client knows where confidence is lower.
Limits on transfer evidence	Cohort comparisons are affected by differences between intakes and instructors. Results are a strong indication, not proof.

9 Lessons Learned

Lesson
1 Define success as transfer, then measure it. Visual quality is easy to demonstrate and a poor predictor of training value.
2 Spend on touch-critical hardware. In armoured crew stations, controls and compartment geometry matter more than scenery.
3 Involve instructors from the first week. Their corrections were more valuable than any specification received.
4 Design for the client's maintenance reality. A system only the vendor can keep running becomes unavailable.
5 State limitations plainly. Clients can plan around a stated limitation, but not around one they discover later.

10 Summary

The project moved early-stage and repetitive crew training from a scarce, expensive live platform to a controlled hybrid environment, without presenting the simulator as equal to the vehicle. The hybrid approach worked because the two layers covered each other's weaknesses, and because fidelity was spent where it changes what trainees learn. The remaining gaps, mainly motion cues, physical stress, and some data uncertainty, are known and documented, and live training covers them.

Scope and disclosure

This document describes engineering and training methodology only. Ballistic, armour, and fire-control performance data, and any information identifying the client, have been deliberately excluded.