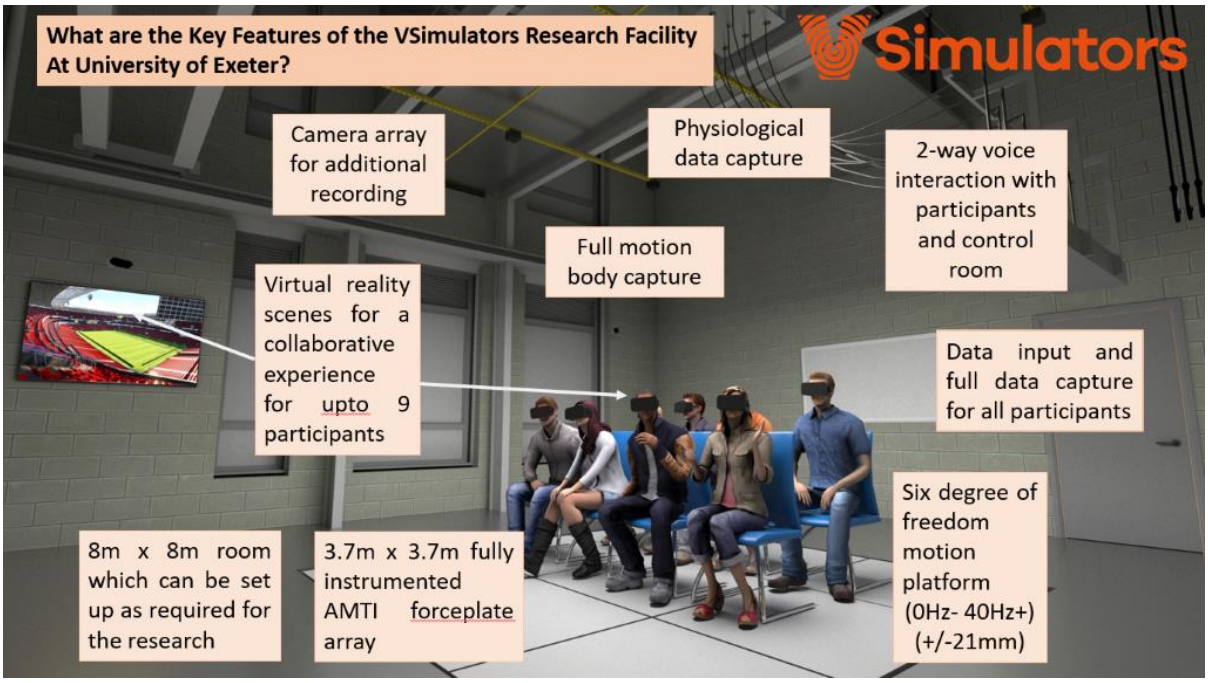
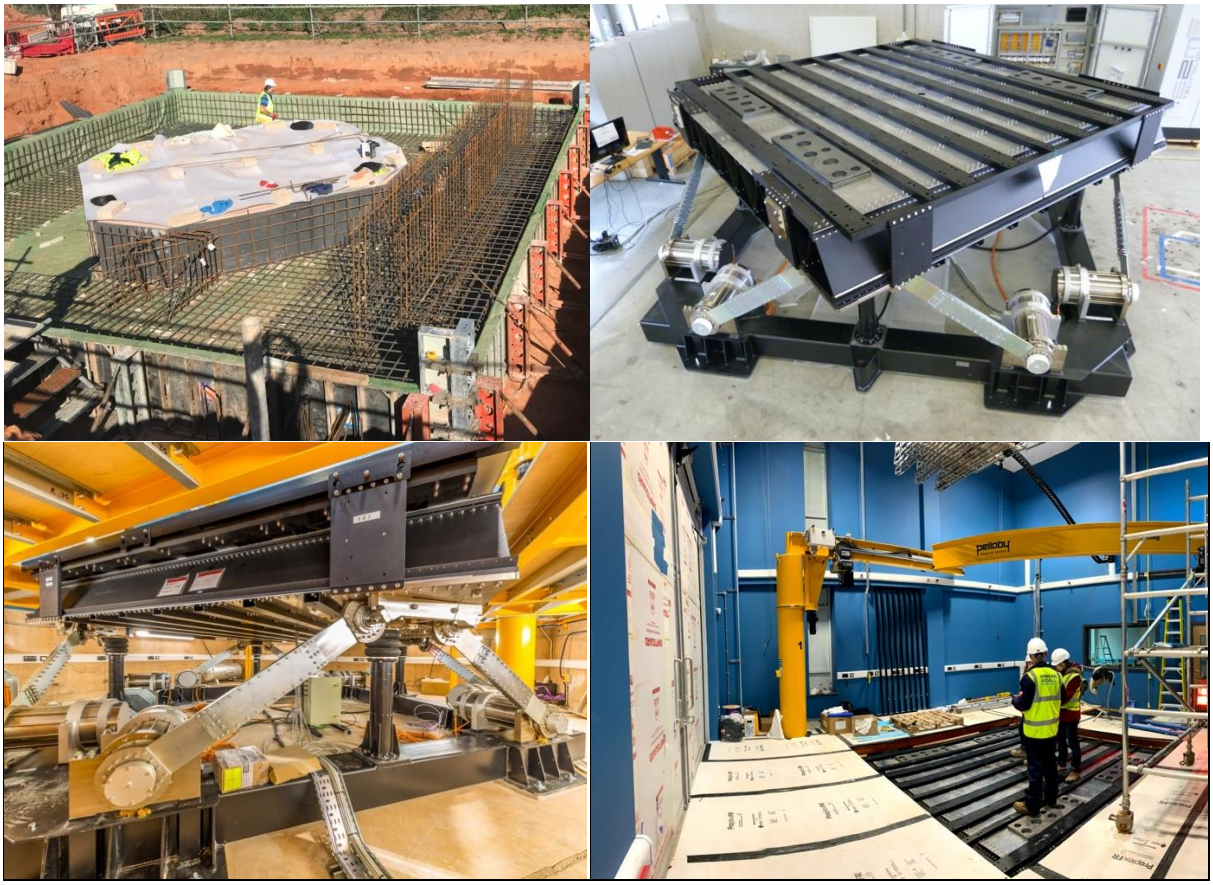
Technical Specification – VSimulators at University of Exeter



Hardware technical details

- VSimulators chamber, 8m x 8m
    - 3.7m x 3.7m motion platform
        - 6-axis motion: surge (x), sway (y), heave (z), roll (x), pitch (y), yaw (z)
        - Octopod configuration with 8 electrically driven motors
        - Payload: 1000kg excluding force plates
        - Frequency range (nominal): 0.5 - 40 Hz
        - Individual axis displacement range : +/- 21 mm
        - The motion platform is designed for high fidelity reproduction of motion signals at the upper and lower limits of vibration in civil structures operating in linear range of their behaviour. Lower levels of motion are at the limits of human perception, higher levels will be uncomfortable (but still safe) to humans
        - The motion platform can reproduce motion recorded in real world conditions, principally structural vibrations in floors, footbridges and football stadia
        - The motion platform is secured onto a 50 tonne concrete block to minimise vibration transmission between motion platform and environment
    - Force plate array, comprising motion platform surface
        - Nine AMTI BP12001200 force plates, each 8.9kN capacity, 390Hz natural frequency
        - Nine AMTI GEN-5 signal conditioning/amplifiers
        - 1kHz sample rate
    - Motion capture
        - 16 Optitrack prime 13 cameras
        - Resolution for tracking at 0.8mm in 4 metre square space
        - Software: Optitrack Motive 2.1.1. final
        - Real-time full-body motion capture camera system for one or more occupants, using Optitrack body suits and markers
        - 100Hz sample rate
    - Virtual reality headsets
        - Nine HTC Vive-pro tethered Head-mounted displays (HMDs)
        - Allows unconstrained motion of up to nine people on the motion platform.
    - Accelerometers, on motion platform soffit corners
        - Four JA-70S triaxial force balance servo accelerometers, 1kHz sample rate
    - Harness
        - For safety for one individual, TBA
    - Treadmill
        - Bespoke design, for single person, instrumented, TBA
- Control room
    - Where the experimental protocols, scenes, data capture is controlled and managed. In addition, there is a viewing area to watch the experiment in the chamber.
- Workshop
    - Adjacent to the platform to enable the build and delivery of scenery or additional equipment to support the design of experiments and use of the facilities.
- Showers/lockers
    - These are available to human experiment participants.
- Briefing room
    - This provides a space to locate participant volunteers between experiments and for commercial or academic use linked to projects within the VSimulators facility.

Motion platform hardware



Motion platform: clockwise from top left: 50 tonne concrete foundation; factory acceptance at E2M, Amsterdam; installation in Exeter; view from basement level

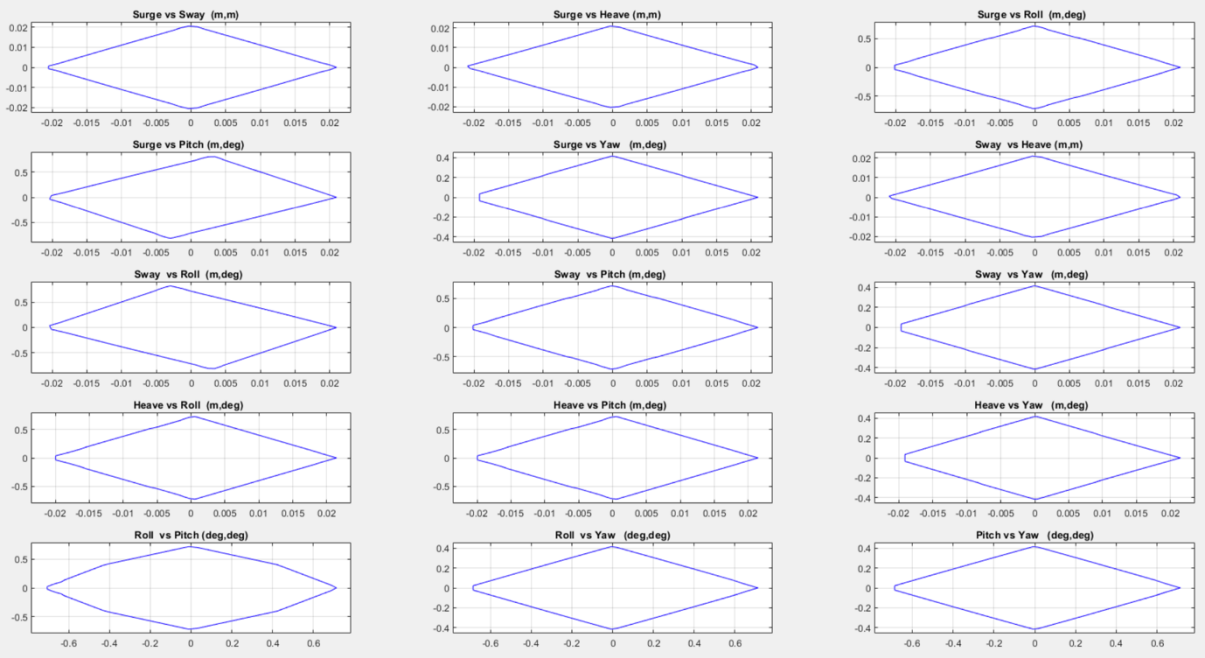
Motion platform performance -excursion limits

Control laws govern the design platform motion to avoid mechanical limitations, as follows:

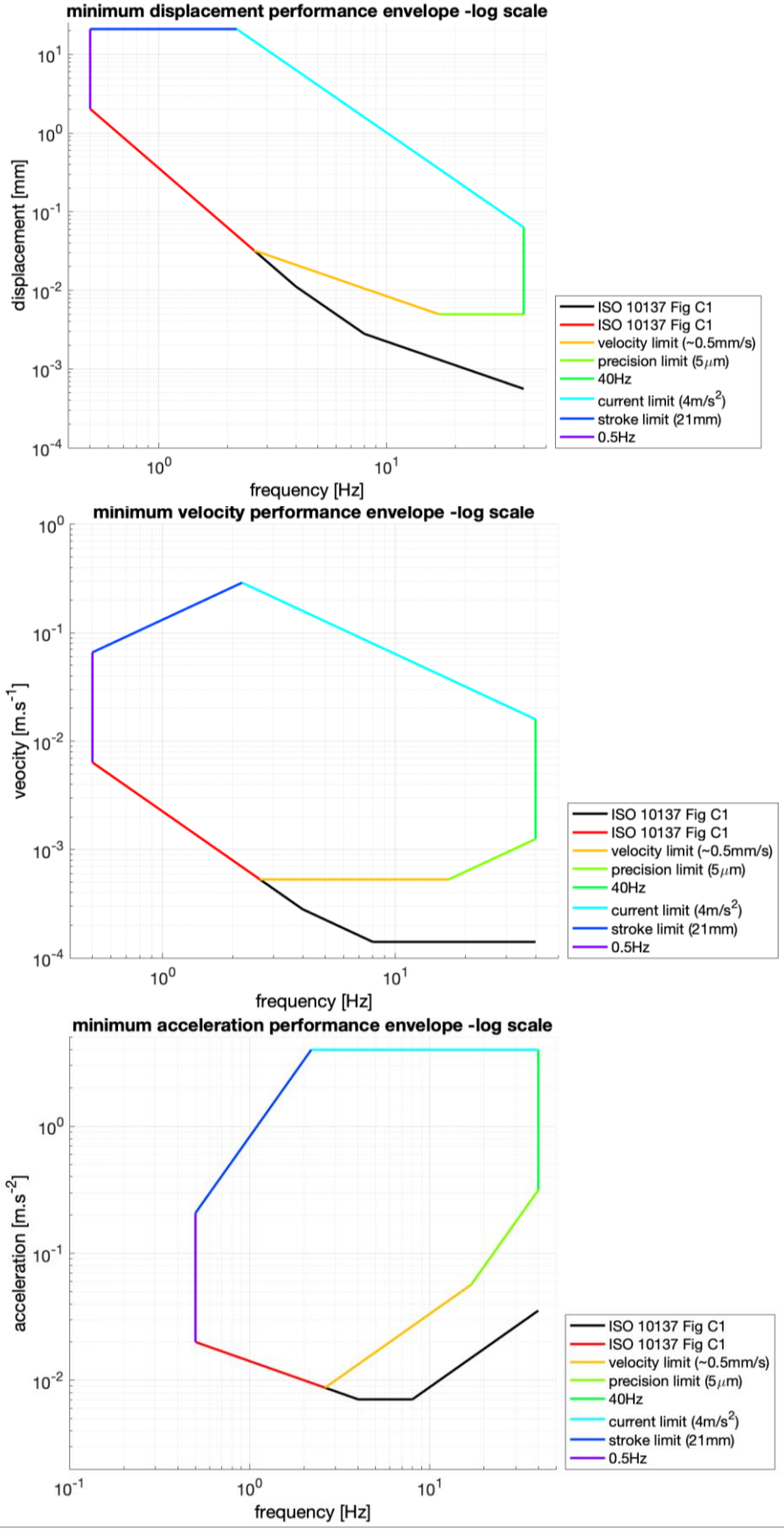
	Excursions single DOF			Velocity		Acceleration	
Surge	-0.021	0.021	m	0.3	m/s	2	m/s2
Sway	-0.021	0.021	m	0.3	m/s	2	m/s2
Heave	-0.021	0.021	m	0.3	m/s	2	m/s2
Roll	-0.7	0.7	deg	10	deg/s	80	deg/s2
Pitch	-0.7	0.7	deg	10	deg/s	80	deg/s2
Yaw	-0.4	0.4	deg	7	deg/s	80	deg/s2

Acceleration of 4m/s^2 is achievable with supplied motors, subject to control laws.

Multi-degree of freedom excursions. Excursions are per degree of freedom; in combination individual axis excursions will be limited by control laws as follows



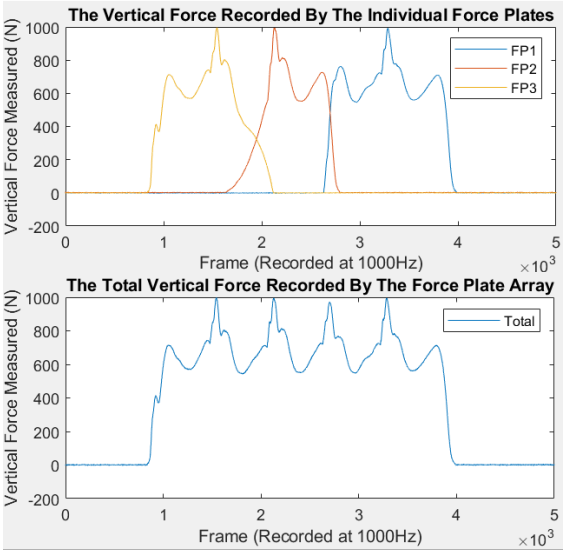
Motion platform performance -frequency range, assuming 4m/s^2 acceleration limit

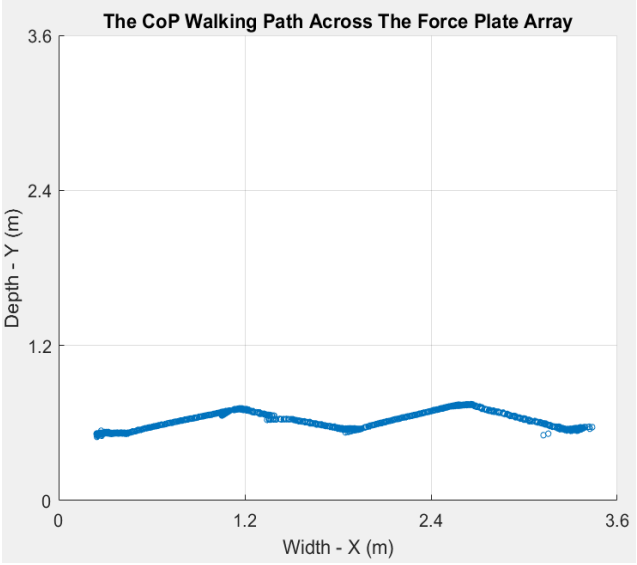


Motion below 0.5Hz and above left-projected orange line may be achievable

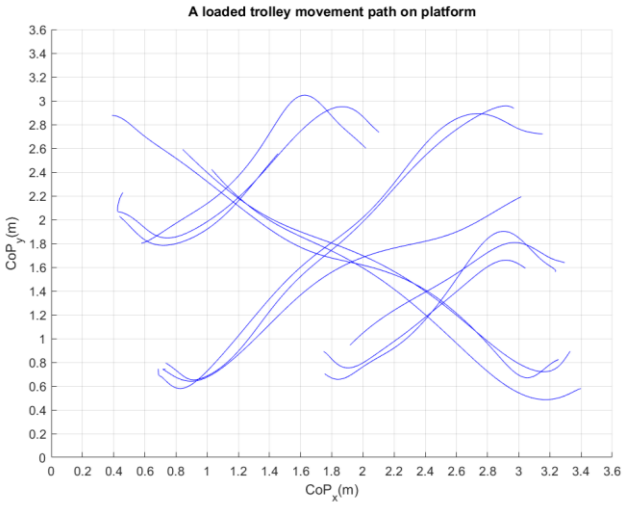
Force plate performance: footfall tracking, vertical force and centre of pressure

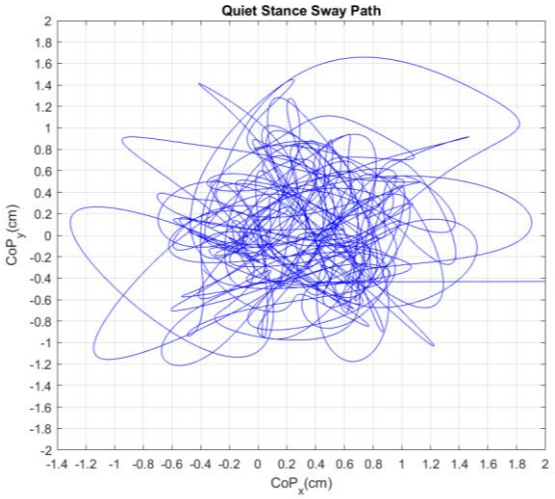
AMTI GEN-5 returns three force and moment values for each force plate, from which force time history and centre of pressure (CoP) trajectory may be determined.





Time history and CoP trajectory for walking across three force plates

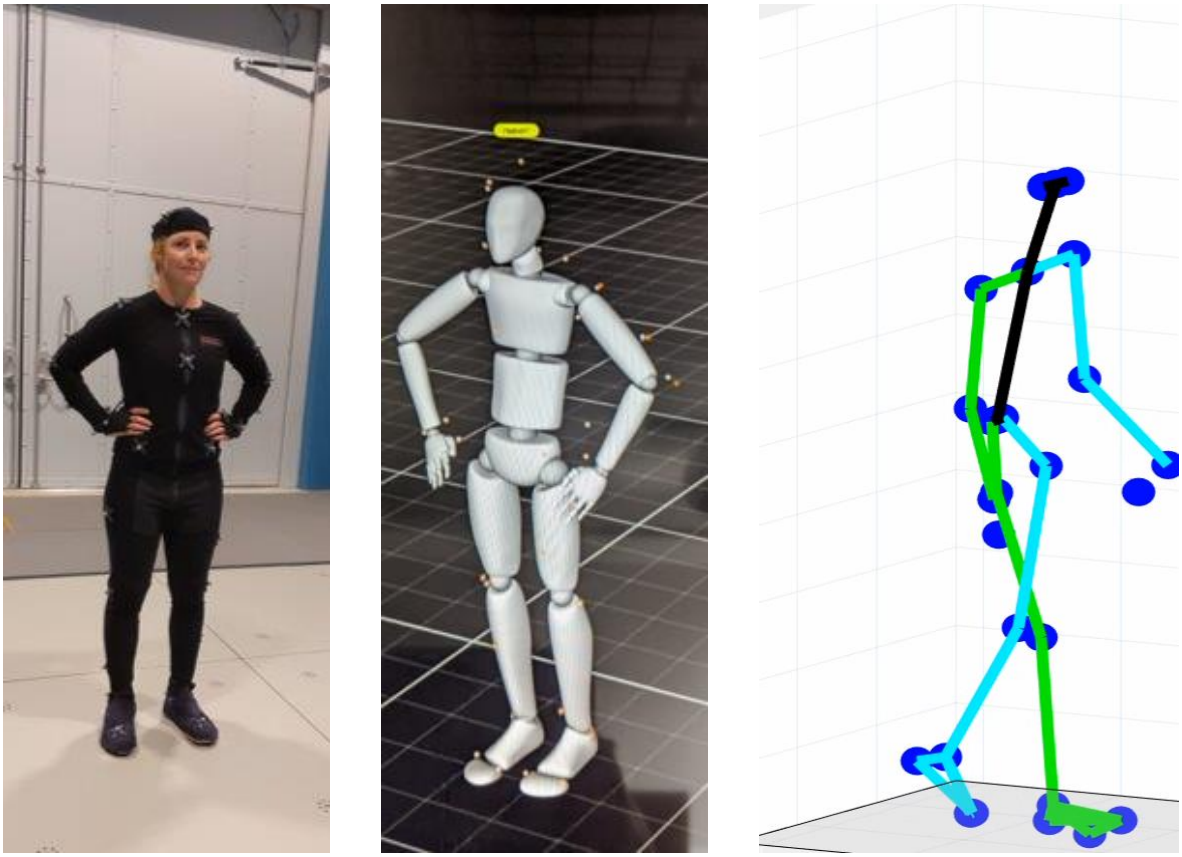




CoP trajectories for loaded trolley towed across platform (left) and for person remaining nominally stationary on the spot (right).

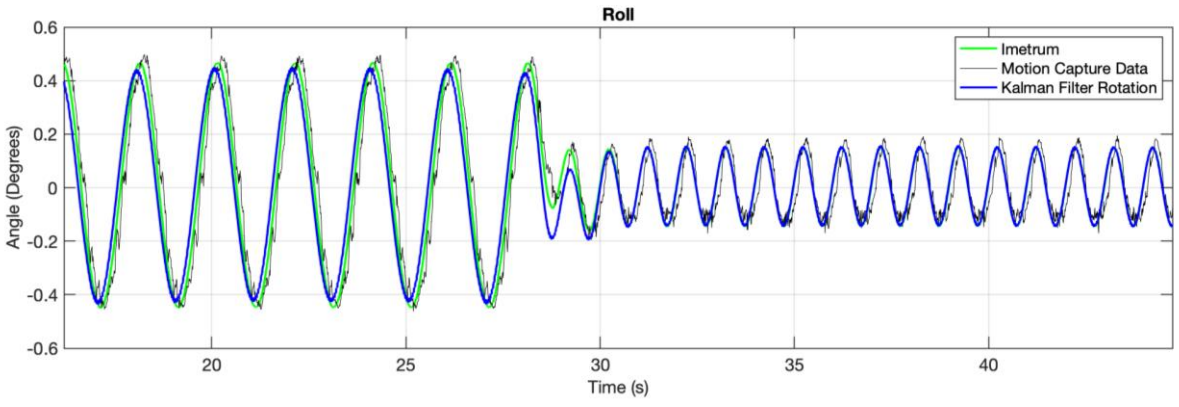
Motion capture

Passive markers can be attached as arrays or points and tracked using Optitrack Motive software. Active markers are used to integrate VR into platform motion and for positional tracking of headsets.



Motion capture: body suit, markers, Motive view and avatar reconstruction

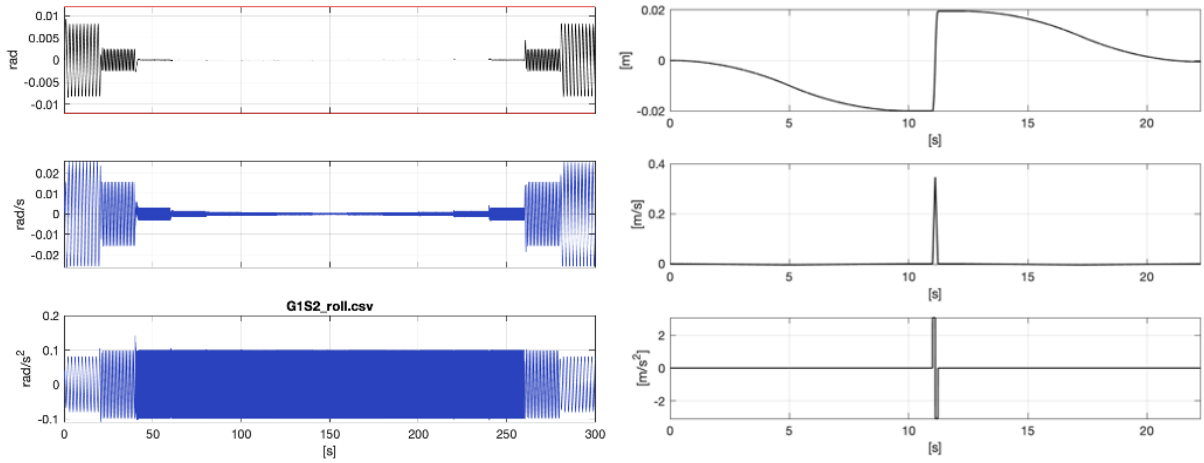
Motion capture system (black line) was cross-checked against gold-standard Imetrum vision system (green line) and high-grade IMU (Kalman filter, blue line) 0.2° is equivalent to 6mm movement at tracked location.



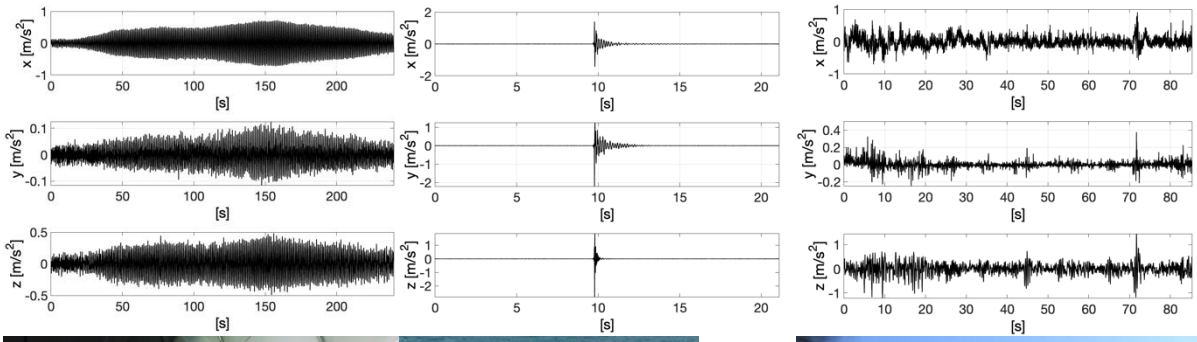
Optitrack motion tracking fidelity.

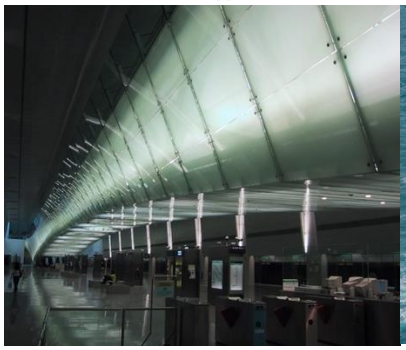
Motion platform signal generation and replay

Drive signals are provided typically as acceleration signals, integrated to displacement and velocity for the control software. Two synthetic examples designed to explore ranges of translational and rotational motion used in pilot studies are:



Signals recorded in real world conditions include:





Footbridge (SLE)

Lighthouse (storm wave impact)

Train

Virtual reality and scene control

Up to nine users can co-operate in virtual environments, subject to operating guidance on social distancing. Stock scenes for football stadium, footbridge and office are available. Users can create additional scenes and incorporate 360° using software interfaces.

EVE VR factory acceptance testing at Holovis; stock VR scenes.

Data Feeds

Force plate, platform acceleration and motion capture data are synchronised via EVE software are available as CSV files when motion is generated within a scene. These data can be provided to the user.

Input data in the form of MATLAB files observing motion platform performance are to be provided by the user.

Sensors

Additional sensors, provided by the user, can be used e.g. body-worn inertial measurement units (IMUs), for heart rate, blood pressure, eye tracking, and galvanic skin responses. These will require separate data acquisition systems that need to be manually synchronised with EVE data acquisition.

Analysis of Data/Research Collaboration/Commercial use

VSimulators@Exeter provides the opportunity to draw together a collaborative community of structural engineers, architects, vibration specialists, civil engineers, biomechanists, physiotherapists, sports scientists, data scientists, computer scientists, specialists in creative media and immersive reality, psychologists and other disciplines, to create new inter-disciplinary knowledge and help solve human factors and other human-centred research challenges.

Data generated by EVE or user-supplied sensors are not analysed by VSimulators@Exeter staff.