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MOTION SYSTEMS

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This chapter describes some of the requirements for your motion capture space. Some of the information relates to the permanent set up, the rest will be useful whether you are working in a permanent space or on location.

The area you use will depend on many factors including:

• The space available – the capture space

• The Vicon system you have purchased

• The type of motion capture you wish to perform

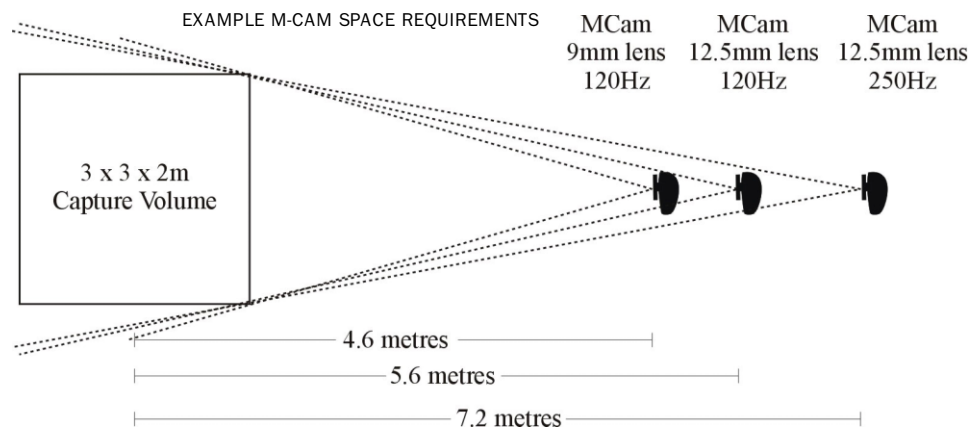• Whether you wish to capture analogue data such as Force Plate, EMG or audio.

This chapter presents a few guidelines for setting up your capture space in order to get the best results.
Our engineers will be on hand the first time the system is installed. This guide will be useful, however, whenever you extend, upgrade, or move the system to a new location.

The capture space
How big should the capture space be?
The space required can be calculated based on the size of the volume you wish to capture, the speed at which you plan to capture and the number of cameras you have in your system. The diagram below can be used to help you estimate the space required.

EXAMPLE M-CAM SPACE REQUIREMENTS

| MCam 9mm lens 120Hz | MCam 12.5mm lens 120Hz | MCam 12.5mm lens 250Hz |

3 x 3 x 2m
Capture Volume

4.6 metres
5.6 metres
7.2 metres

For example if you wanted to capture your data in a 3 meter by 3 meter by 2 meter volume using MCams with 12.5mm lenses, capturing at 120Hz, you would need a room approximately 12 meters square. If you had 9mm lenses you could do the same in a 10 meters square room. Please contact your Vicon sales person or Customer Support Engineer prior to planning you new location for exact specifications and considerations.

The floor and the ceiling

If you are performing gait analysis you may consider installing a raised floor. This allows for the inclusion of force plates and provides space for cables and for storage of Camera Interface Units.

Gait laboratories unable to install false floors will need to either provide a pit for the installation of force plates or provide a raised walkway. Force plate manufacturers will be able to advise on installation of the plates including building considerations.

The floor should be dull to prevent reflections. If it is a surface that may be polished then you should advise cleaning staff not to do so.

The ceiling should be made of a similarly non-reflective material such as the tiled suspended ceilings often found in offices. The ceiling height should be at least 3m above the floor – though this may need to be higher if you are to capture movements such as climbing stairs or jumping. If you are to fix your cameras to a suspended rig then consult your building maintenance engineers to ensure the ceiling is strong enough to support the rig safely and without vibration from other parts of the building. Excessive vibration can lead to capture problems if it is significant enough to move camera positions by a millimetre or more. Once positioned for a particular capture volume the cameras should not move. If the cameras do move then the system will have to be re-calibrated.

Walls

If the cameras are to be mounted on the walls then they should not vibrate as a result of movements within the capture space or elsewhere in the building.

Wall and floor colours

Although the colour is not particularly important the finish should be non-reflective – matte or satin.

Windows and Doors

If there are windows present then they should have curtains or blinds to block out direct sunlight. We advise using backed curtains.

Electrical circuits

In a permanent capture space, doors should, if possible, be recessed with a curtain in front to minimise the interference during capture.

Electricity supply

Lighting

To minimise the effect of any switching surges we recommend that the circuit for the Vicon System is separate from other electrical equipment, such as lighting, fans and heating.

Conduits and electrical outlets

Fluorescent lighting is recommended and normal levels of lighting may be used

without affecting system performance. Spotlights should not be used and any incandescent lights should be able to be switched off and leave a reasonable lighting level in the studio. It may also be useful to be able to dim lighting levels around computer screens to reduce glare.

If you have a permanent location you may consider the use of inbuilt conduits for the Vicon system cables. It is better to install conduits after the optimum camera positions have been established and then place them close to each camera, leading to the location of the Vicon computer and Datastation system. If you have a false floor installation then the under floor space may be used for cables.

The number and position of electrical outlets will depend on additional equipment to be used. You should, however, ensure that there are enough close to the location of the computer and Datastation. The numbers of outlets required are typically:

Each PC/Workstation	Usually 2
Vicon Datastation	1
Force Plate Amplifiers	1 for each amplifier
EMG Amplifier	1 for each unit
Spare	As needed

Cables – safety
The Datastation and any analogue equipment should be plugged into the same power circuit. This is most easily done by the use of a high quality surge protector or battery back-up plugged into a single wall outlet. This helps to reduce 50 or 60Hz noise in analogue channels.

Network considerations
In a capture space without permanent camera fixtures you should ensure cables are positioned away from the capture volume and in such a way that the possibility of damage occurring due to people tripping or pulling them in minimised, if necessary by taping them to the floor.

Computer network
We recommend a dedicated network connection between the Workstation and Datastation. This means that if you want your Workstation PC to connect to your local area network then you should install a second network card to communicate directly with that network.

In the simplest connection the Datastation and the Workstation PC communicate through a single 100 Base-T crossover cable (supplied by Vicon Motion Systems). If you need cabling longer than that supplied with your system then it must comply with Category 5 performance. The two systems communicate via a TCP/IP Ethernet connection.

Workstation is installed as part of the Vicon Suite of products. For the software to function you must have a valid Dongle plugged into the parallel port of your computer. This Dongle should be delivered with the install CD as part of your Vicon system. Note that in order to install the Dongle drivers during the installation process you must have Administrator rights on your computer.

• Place the installation CD in your CD ROM drive

If you have Autorun enabled then one of two things will happen: with the Entertainment Software Suite the installation will begin, offering common and custom installation options; with the Science & Engineering Software Suite, a document in Rich Text Format, InstallationNotes.rtf, will be launched. This includes instructions for the installation (including upgrades) and up to date news on the version of Workstation you have purchased. If Autorun is not enabled then you may find this file by browsing the Install CD with Windows Explorer.

To install the software:
• Select Start | Run on the Windows task bar

• Using the Browse button on the Run dialog locate and select the file setup.exe in the root of the CD

• Click Open

• Click OK

Follow the instructions of the InstallShield wizard to complete the installation of the software components you have purchased.

Common options include:
• Vicon Workstation Software

• Vicon BodyBuilder Software

• Vicon PlugIn SDK

• Vicon Real-Time SDK

Additional Science & Engineering Software Suite options include:
• Vicon Polygon Software

• Eclipse Data Management

Additional Entertainment Software Suite options include:

- Vicon Workstation Software

- Vicon BodyBuilder Software

- Vicon Mobius

- Vicon RT Viewer

- Utilities

- CG PlugIns

- CG Real-Time PlugIns

- Datastation Software

The first step in setting up the hardware will be to connect the Workstation PC and the Datastation. This is done via an Ethernet network connection. Once you have established communication between the Workstation and the Datastation you can continue with the remaining connections.

Checklist

Before starting to connect your system you should have unpacked and checked your inventory. You may need additional networking hardware

Network connections

All Vicon Datastations are supplied with network connection capability. This will either be through an RJ45 network connector socket located near the serial port or with a standard Network Interface Card (NIC) located on the back of the Datastation. You must ensure that the Workstation PC has a suitable network card installed. The system uses a 10/100 Base-T Ethernet network link.

To make a direct connection between the PC and the Datastation:
• Connect the network card of the PC to the network connector of the Datastation using the crossover cable in your accessories kit

To connect via a hub, switch or your Local Area Network:
• Using the straight thru cable, supplied with your accessories kit, connect the Datastation to the network hub, switch or nearest network point

• Similarly, connect the PC to the network

• Start the PC and allow to boot correctly

• Start the Datastation and allow to boot correctly

You will need to have TCP/IP installed as a network protocol on the Workstation PC. If it is not already installed you may need to consult your computer's operating system manual or your Network Administrator for assistance. The Workstation PC and Datastation should ideally use private Class A, B or C address ranges. These are reserved for internal networks and will not clash with registered Internet addresses. If you need to connect you Workstation PC to another network we recommend installing a second network card. Vicon Datastations are usually shipped with an IP Address 192.168.0.10.An appropriate IP address for the network card that will connect the Workstation to the Datastation would be 192.168.0.11, with a Subnet Mask of 255.255.255.0.

Checking the connection

The simplest way to check that the Workstation PC and the Datastation can communicate is to 'Ping' the Datastation from a command prompt and trying to establish a connection using the Workstation software.

Using 'Ping':

• Open up a Command Prompt window from the Windows Start menu

• Type: Ping <IP Address of Datastation>

If the connection is present the response will indicate you have received a reply from the IP address you tested.

If the connection is not present the reply will be "Request timed out". In this case check physical connections of cables and IP addresses.

Connecting the cameras

Schematic of the basic
system cable
connections
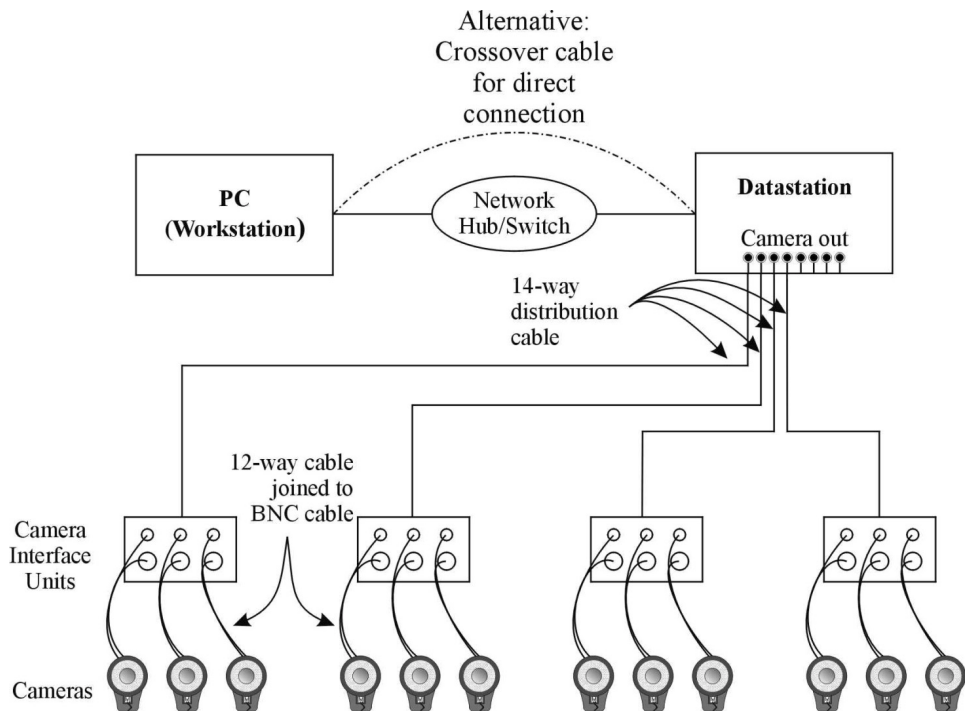
Datastation to Camera Interface Unit

The cable connecting the Datastation to the Camera Interface Unit is a standard 20m distribution cable with 14-pin connectors on each end. Using these cables connect the Camera Out sockets on the Datastation to the socket labelled Datastation In on the Camera Interface Unit. The connectors are identical and so the cable may be used either way. Note that the connectors on the Datastation are identical in type but are in different positions.

14-WAY CAMERA OUT AND
DATASTATION IN SOCKET

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Location of connectors on Datastation

System	Location of connector	Label	Comments
624/V8i	Front panel	Cameras are numbered left to right (1–3, 4–6 etc.), although numbers are not displayed on the case.	The system may not support the full complement of cameras. A green LED indicates activated connectors.
612	Rear Panel	Connectors are labelled "CAM 1–3", CAM 4–6" etc.	The system may not support the full complement of cameras. The channels available will depend on the number you have purchased.
460/V6	Rear Panel	Connectors are labelled "CAM 1–3", "CAM 4–6".	All camera connectors are active.

Camera Interface Unit to Camera

Some example systems and their connector locations are listed below:

Camera to Strobe

The front panel of the MCam Camera Interface Unit has three pairs of connectors, labelled CAM 1, CAM 2 and CAM 3. The 10m cables comprise a 12-way cable to pass power and synchronisation signals to the camera and a 10m BNC cable to take video signals from the camera to the Camera Interface Unit. These cables are easily recognised as they are joined as a pair with just the ends separate for ease of connection. Again, the connectors are identical so that they may be used either way. On the back of the MCam you will find a BNC and 12-pin Lemo connection like those on the Camera Interface Units. The other end of each camera cable connects here. To connect the Lemo connectors make sure the red dots on both of the connections line up.

M2Cam systems use only the 12-way cable and so there will be no BNC cable or connections.

The strobe of the MCam should be mounted on the front of the camera unit and held in place by the magnetic strip. The strobe is connected to the camera by a short flying lead permanently attached to the strobe. Plug this Lemo connector into the socket on the front of the MCam.

Camera numbers

Once the cameras are connected they are assigned a number by virtue of their connections. For example, cameras 1,2 and 3 are connected to the Camera Interface Unit that is then connected to the first Camera Out socket on the Datastation. By the same logic camera 5 is connected to the number 2 connector (middle) on the Camera Interface Unit that is connected to the second Camera Out socket on the Datastation.

Check the system

When the connections are complete and the Datastation is turned on the strobes will be receiving power. When using visible light strobes this is recognised because the red strobe LEDs will be illuminated. When using infra-red strobes you will only be able to tell that they are receiving power by the power on indicator, a green LED near the top of the strobe ring.

Calibration objects

Before using Workstation to capture data you need to define the System Configuration. This tells Workstation software about the hardware you are using.

System configuration

The System Configuration dialog is where you specify your system type, its IP address and other hardware, for example analogue boards. If you have more than one system or you change the setup regularly you can define and name different configurations.

The System
Configuration dialog
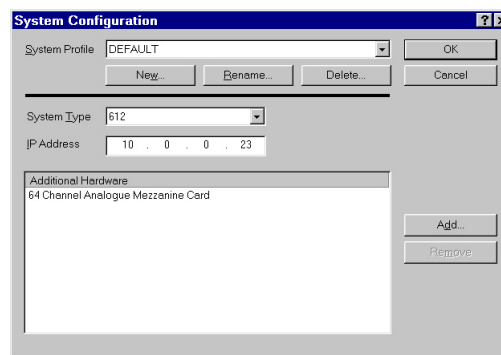
To create a new System Configuration:
• Select System | System Configuration

• Click New

• Enter a name for the configuration and Click OK to close the Profile Name dialog

• Select you system from the System Type drop down list

• Enter the Datastation IP address as displayed on the front panel of the Datastation itself

If you have analogue cards installed in your Datastation then these should be listed under Additional Hardware. If they are not:
• Click Add

• Select the type of additional hardware from the list

• Click Add

• Click OK to close the System Configuration dialog

Video setup

Video setup is where you specify the mode and type of camera that you have connected to your system. Each camera type may operate in several modes.

To open the Video Setup dialog:
- Select System | Video Setup

There are two drop down lists:
- Select Camera Type

- Select Mode

The camera mode specifies both the scan and video rate. Progressive scans each line of video from top to bottom in sequence. Interlaced scans odd numbered lines in one pass and even numbered lines in the next pass. When using MCams the interlaced option is only used for diagnostic purposes.

Video rate defines the sampling frequency of the cameras. It is recommended that you use a rate that will reproduce the motion accurately. Although high capture rates provide more samples per second, this will increase the amount of data you need to process and store. With the MCam we recommend capturing at 120Hz for most human movements.

Analogue Setup
Details on setting up for analogue data capture are covered in Capturing Analogue Data.

Applying system settings
Vicon stores data in a strict hierarchy, controlled by the Eclipse data management application. This allows you to control every aspect of your data. As part of this, unique system settings can be applied at different levels in this hierarchy. For example, camera mode could be set different for a single session than that for the entire system. Therefore, whenever you change system settings you must be careful to note at which level of the hierarchy they are being applied.

Some system setup dialogs (accessed from the System menu) include a pane labelled Applies To. This allows you to choose the level of the hierarchy to which the settings will be applied; it depends on where you are in the hierarchy when you open the dialog. If you are in the top or second level of the hierarchy then the settings will become the system defaults. If you have a session open but not a trial then the settings apply to the session. You can, however, choose to make the settings the system defaults by selecting the check box that appears in the panel. If you have a trial open then the settings will apply to the trial, though you can choose to apply them to the whole session.

Video Setup 'Applies To' option

Current location in the database:	Settings apply to:	'Apply To' Option available:
Top or second level in the database	System defaults	None
Session	Session	System defaults
Trial	Trial	Session

Once you have set up the studio you will need to consider the capture volume itself, the arrangement of cameras and camera settings. The steps include:

- Marking the boundaries of the capture volume on the floor

- Arranging cameras

- Checking that each camera can view as much of the capture volume as possible

- Checking the camera and strobe settings

Marking out the capture area

The capture volume is three-dimensional but in practice is more readily viewed by its boundaries marked out on the floor. This gives you a guide for the positioning of the cameras, and your subjects a guide as to where they can move.

The area should be as central to your capture space as possible to maximise the volume you are able to capture.

For most human movements good results are obtained by placing cameras above the maximum height of any marker you wish to capture and pointing down. The area marked out should be at the bottom of each camera's field of view. For example if the subject will be jumping then cameras would need to be higher than the highest head or hand markers at the peak of the jump.

Camera 2 (above Camera 1 Field of View)   Camera 1

Camera 1 Field of View

Placement of cameras on high tripods ensures good visibility and avoids possible problems caused by having strobes in the field of view
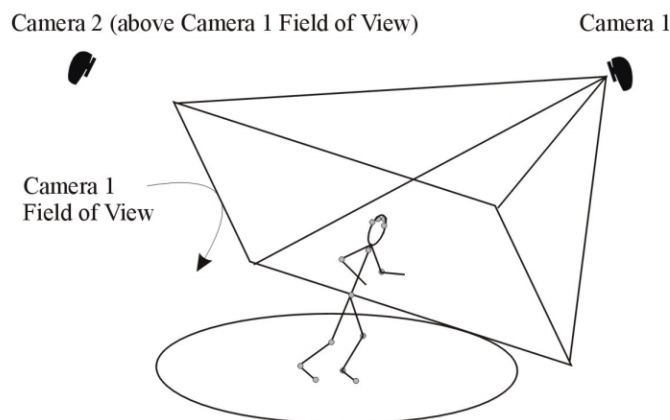
Cameras placed in this manner reduce the likelihood of a marker passing in front of the image of another cameras strobe. Even though this is usually the optimal arrangement it is still, possible to calibrate and capture with other strobes in another cameras view.

Using the Live Monitor to set up cameras

To help in positioning your cameras you can use the Live Monitor. This feature, in Workstation, allows you to view what each camera will capture.

This is useful for initial inspection of your setup, to check that each camera can view the capture volume, to look for spurious light sources and to optimise essential camera settings. The Live Monitor is opened from the System menu.

Camera 1
Field of View

Live
Monitor
view
(Workstation)

Capture Volume boundary
marked out with markers

Placing markers around the boundary of the capture volume allows you to check that each camera can see enough of the volume.
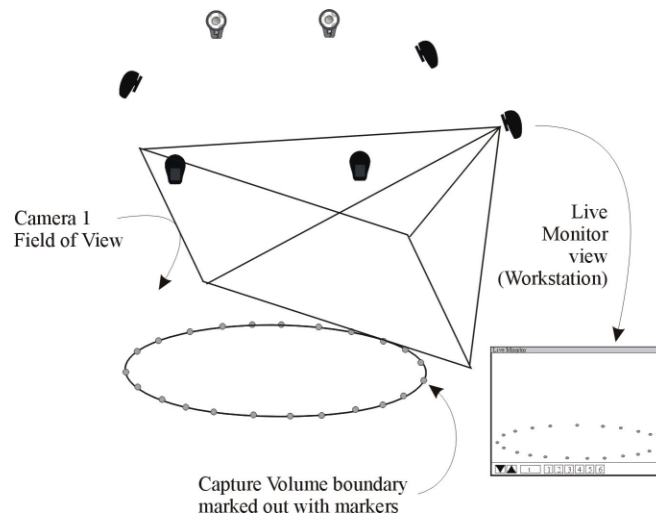
Because the cameras are intended to view only reflective markers you can use these to temporarily mark out the boundaries of the volume on the floor. You should use the same size markers that will be used for your motion capture session.

Opening the Live Monitor

Start by opening the Live Monitor window available in Workstation. To do this you need to have your system (i.e., Workstation, Datastation and cameras) connected:

• Start the Workstation application

• Select System | Live Monitor to start a link and open the Live Monitor window

The Live Monitor window shows the view through selected cameras.

Checking the capture volume

To verify that each camera can see as much of the capture volume as possible:

• Select each camera in turn and check the view

Initially you are looking to see whether the camera is positioned and oriented for the maximum view. You should see dots matching the layout of markers on

the floor. If you do not see markers possible reasons are:

- The camera is not aimed at the volume correctly

- The system is not connected and linked

- Strobe intensities are too low

- Camera sensitivity is not high enough

- Camera aperture is not open sufficiently

Check each of these in turn.

The camera is not aimed at the volume correctly
Ensure that the camera is pointed in the direction of the marked out volume.

The system is not connected and linked
When the system is connected the Datastation display will show the text "Connected" and the Workstation Status Bar will indicate "Link established with Datastation". If the system is not connected correctly, refer to Connecting The Hardware, above.

Strobe intensities are too low
The strobe intensity is controlled using the Camera Control Bar, seen to the right of the Workstation window when the Live Monitor is open. The slider labelled Strobe Int. controls the amount of light emitted by the strobes. Note that this controls the light of all strobes simultaneously. For camera positioning set the intensity to 9.5.

Camera sensitivity is not high enough
The sensitivity of each camera to light is controlled using the Cam Sens slider on the camera Control Bar. This affects only the selected camera. As such each camera can have unique camera sensitivity. For camera positioning set the Camera Sensitivity to approximately 5.

Camera aperture is not open sufficiently
If you are still not seeing the markers in the Live Monitor you will need to check the camera's aperture setting. The aperture ring is a dial on the lens itself. It is typically labelled with numbers from 16 to 1.4. The label C indicates that the aperture is completely closed and 1.4, in this example is completely open. With the camera sensitivity set to 5, move the ring to open the aperture until you can see markers in the Live Monitor.

If, at this stage if you still cannot see markers contact your Vicon Technical Support Engineer.

Remember that you are aiming to capture a volume and so the markers you see should be near the bottom of the window. Also remember that the final result is

the combination of all camera views, so if one camera cannot see a certain part of the volume very well then others may compensate, i.e., it is not necessary to get every camera perfect for the whole volume.

• Check the height of the volume

Ask a colleague to walk around the volume holding the calibration wand at head height – or higher if your moves involve jumping or walking up above floor height. The wand uses 50mm markers so these may appear brighter. Instead you could create a height test wand with smaller markers, or have your colleague don a headband with markers attached. They should walk around the outer edge of the volume, as this is the area most sensitive to losing data due to poor camera positioning.

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Calibration is probably the most important individual step of the preparation process. Calibration allows the software to calculate the relative location and orientation of all the cameras. When your movements have been recorded the reconstruction process uses these measurements to calculate the accurate movements of the markers through space. This process is different from subject calibration (described in The Essentials of Motion Capture).

There are two main steps to system calibration:

Static calibration
This calculates the origin or centre of the capture volume and determines the orientation of the 3D Workspace.

Dynamic calibration
This involves movement of a calibration wand throughout the whole volume and allows the system to calculate the relative positions and orientations of the cameras. It also linearises the cameras.

Calibration objects

Regardless of the capture volume size the calibration process is the same – though you may choose to use different size calibration objects. In this example it is assumed that you are preparing a full body capture session and are therefore using the L-Frame for static calibration and the 500mm wand for dynamic calibration.

The standard wand is a metal rod with two 50mm reflective spheres attached 500mm part. The L frame is made from two metal rods fixed at 90∞. One arm has three reflective spheres attached, the other just one. The clinical variant differs from the standard large volume in that it is designed to be accurately aligned with force plates (where the edge of the corner piece, forming the origin of the capture volume, will align accurately with the edge of the force plate). These devices will be delivered as separate extension arms that need to be assembled. Details are given in Vicon Hardware (Motion Capture with the Vicon System).

Calibration procedure

To perform the calibration:

• Place the L-Frame on the floor in the centre of the capture volume

• Select System | Live Monitors

• Check that each camera is viewing only the four markers on the L-Frame

If you can see more than just the L-Frame markers, possible sources are; markers left in the camera view, reflections from other reflective material (e.g., high gloss flooring or shiny metal objects) or direct sunlight. You need to

eliminate all of these sources of reflection before you can calibrate. To remove these sources you can physically remove them, cover them or if this is impractical reduce camera sensitivities. Once they have been removed you can continue with the system calibration:

• Select System |Calibrate Cameras to open the Calibrate Cameras dialog

• Ensure that all of the cameras are selected, even if it lists more cameras than you know you have connected to the system

• Under Reference Object ensure that the correct Calibration Reference Object file (e.g., example.cro) is selected and that the appropriate name of your calibration object is specified

If you are unsure which calibration objects you have, refer to the diagram in Vicon Hardware.

• In the Calibration panel ensure that Capture is set to "all new data"

• Click Calibrate

The Data Capture – Calibration (Static) dialog opens. When you are ready:
• Click Start

The software collects 20 frames of static data and then displays the Data Capture – Calibration (Dynamic) dialog. Be careful, as it is very easy to accidentally start the dynamic calibration portion at this stage before the L-Frame has been removed.

• Remove the L-frame from the volume and ensure that it is not visible to any of the cameras

• Have an assistant stand in the volume with the wand

• Click Start to start collecting data

The system will begin collecting data. The wand should be waved so that all positions in the volume are covered in all orientations. It is important to get a variety of wand positions during this process. The duration of the wand wave should be long enough that the volume is sufficiently covered. There is no fixed way to wave the wand. One technique is described under Waving the wand, below.

Maintaining one orientation of the wand may yield satisfactory residuals, but this does not give the system good data. Wand calibrations with just vertical or just horizontal wand positions should be avoided.

• When you think sufficient data has been collected click Stop
Vicon now performs its calculations and then the Calibrate Cameras dialog

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reopens, displaying new residual values.

• If the Calibration Residuals are satisfactory (see below), click Accept

Note that if you calibrate the system on your own you should place the wand on the floor in the centre of the volume, start the dynamic calibration in Workstation and then walk into the volume and proceed with the wand wave. When you have finished, place the wand on the floor again before leaving the volume. Finally stop the calibration in Workstation.

Recalibrating the system

A calibration is only valid for the arrangement of cameras for which it was done. This means that if a camera moves, for any reason, you must recalibrate the system. In general you should calibrate before each capture session. In cases where cameras are fixed permanently, for example in wall mounts, then this may not be necessary. However, since the calibration process is quick and simple it is good practice to calibrate often.

In critical situations it is also good practice to calibrate the system after the capture session is complete. This second calibration can then be applied to any of the data in the session should any of the cameras have moved, for example by accident.

To apply a calibration to an open trial:

• Select System | Set Calibration

The Set Camera Calibration dialog lists calibrations (by time) created for the current session and archived. Use the radio buttons to select a list of calibrations or click Other to locate other calibrations.

• Select the calibration you wish to apply and click OK

How good is the calibration?

The key to success in using the Vicon system is good calibration and therefore you need to be able to recognise just how good the calibration has been. This is largely a matter of experience but the following questions and answers will help you.

Following calibration the following parameters are displayed in the Calibrate Cameras dialog:

Residual for each Camera

A residual is a measure of the accuracy of a single camera . They are larger the greater the distance of the camera from the capture volume and are measured in millimetres.

Mean Residual (std dev.)

The Mean Residual is the mathematical mean of the individual residuals. The standard deviation is shown in parentheses.

Residual Range (high – low)
The range is the difference between the highest and lowest residual values. The high and low values are displayed in parentheses.

Wand Visibility
The wand is considered to be visible to a camera if both wand markers are in that camera's field of view. The Wand Visibility is a measure of this for all cameras throughout the dynamic calibration. That is, a value of 100% means that both markers are visible in all cameras in every frame.

Static Reproducibility
Static reproducibility is the root mean square error of the L Frame co-ordinates as calculated compared to the .cro file scaled to the size of the L-Frame. This is most useful in clinical or engineering laboratories where you wish to measure of the goodness of location of additional equipment such as force plates in the workspace. It is of less importance without a lab reference to compare to. Indeed if the L-Frame is bent or distorted you can get low residuals but a high static reproducibility

It is the root mean square of the distance between two rays; the first being that from the centre of the strobe ring to the centroid of the marker and the second being the reflected ray from the marker to the camera lens.

For a Clinical L-Frame used with force plates the static reproducibility should be less than 1%.

What are acceptable residual values?
Residuals should be less than 0.1% of the distance from the camera to the centre of the capture volume. For example in a capture space of dimensions 10_10_3 meters, using MCams with 12.5mm lenses you would expect residuals in the range 1 to 4mm.

What affects residual values?
Consistency between residual values is also important. Cameras with the same lenses, the same distance from the capture volume would be expected to have similar residuals. If one camera has a value that is significantly different from all the others then there may be a problem with that camera. Other factors include noise – extraneous reflections or flickering light from elsewhere in the capture space. This may be on the person performing the calibration and wand waving, lights or reflective material elsewhere. Try checking the Live Monitors for additional sources of light.

What about very large residuals?
Residual values much higher than those given here may indicate a problem. Residuals in the thousands suggest that you have not covered a sufficient amount of the capture volume or do not have sufficient wand visibility. Mathematically it means that the calibration algorithm failed to converge to a meaningful result.

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Will cameras seeing other strobes affect the calibration?

A strobe in view of the camera will not affect the calibration as long as it does not appear to be flickering. If there is too much light or not enough, the strobe will appear to flicker in the camera view. The dynamic portion of the calibration recognizes movement. Flickering will be detected as movement and result in a failed calibration.

Failed calibrations

A calibration has failed if you observe either high residual values or dashes where the value should be displayed. The calibration may fail for some or all of the cameras.

In either case the first step should be to attempt to calibrate the system again. If this fails in the same manner then go to the Live Monitor and check for extraneous reflections. Make sure also that the person waving the wand does not have any reflective material on them, for example, shiny jewellery or reflective material on their shoes.

Also check the wand visibility. If this is low (under 50%) then you need to improve the wand wave. Please refer to the waving guidelines below.

Waving the wand

There is no particular wand waving technique you should follow. You should, however, use the suggestions below as a guideline.

• Allow the cameras to view the wand in multiple orientations, e.g., horizontal and vertical

• Fill the capture volume completely

• Medium pace of movement

• Do not point the wand directly at any camera

An example wand waving technique is:

Start on the outside of the volume, facing inwards. Wave the wand in a vertical figure of eight in front of you whilst moving around the outside of the volume. After a circuit move inwards and continue spiralling in to the centre. Finish by crouching in the centre, waving the wand in circles near the floor and spiralling up to head height.

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The Vicon system has been designed to capture the three-dimensional movement of specialised reflective markers. To enable motion capture you need to attach these markers to your subject. The example below describes the use of reflective markers for full body human motion capture.

Markers can be attached at any time during setup, although you should avoid having sets of markers lying around the capture area when you are trying to calibrate the system. Routinely you will attach markers away from the main capture volume at any time during preparation.

What are markers?

Markers are the spheres that reflect light from the strobe back into the camera. Markers come in various shapes and sizes, for example:

- 3mm hemispheres or 4mm spheres for facial and hand capture

- 9 or 14mm spheres for full body capture

- 12 or 20mm soft markers for capture when performing moves involving contact

- 25, 35 and 50mm spheres for capturing movements in very large volumes

What should the subject wear?

As the motion capture process captures the movement of markers rather than the body to which they are attached, the clothes worn by the subject can influence the results obtained. For example, if they are attached to loose clothing then the data will be that of the clothing rather than the person wearing it.

In most cases you will be looking to capture the movement of the underlying skeleton. In the clinical environment markers will be attached to anatomical, bony landmarks. As such we would recommend minimal clothing to allow attachment of markers directly to the skin, e.g., shorts for men and shorts and sports top for women.

In animation environments we recommend the use of lycra body suits that may be supplied with some systems. You can order specialised body suits directly from Vicon Motion Systems.

Humans move differently when wearing shoes compared with bare feet. In clinical or sports science labs you will probably be aware of whether your subject should wear shoes or not. Animation studios will need to consider whether their CG characters will be wearing shoes in order to obtain realistic motion capture. If they are wearing shoes take some care to note how the shoes bend and attach markers to reflect that movement

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How to attach markers

Ideally, once a marker is attached to the subject it should not fall off or move. To ensure that this is the case you should take care to securely attach markers to the subject. When selecting the correct approach, much will depend on the clothing worn by the subject and the types of moves you are capturing. There are a number of different techniques that have been successfully used. The following list is merely a starting point to develop the best approach for you.

Vicon double sided tape

The use of double sided tape is the most common way of attaching markers. The tape is very good at adhering to the skin and is recommended for hands, the face and other exposed parts. It is suitable for most other marker locations when action is not too vigorous. It is not so good if the skin gets very wet with sweat or on clothing. The tape supplied with your accessories kit is hypoallergenic.

Gaffer / Duct / Gum tape

These types of tape offer a stronger adhesion and are suitable for attachment to clothes and shoes in particular. Note that it can be affected by moisture. These should not be used to attach directly to the skin.

Spirit Gum / Toupée tape

These are less affected by moisture and can be used to attach markers directly to the skin.

Velcro

This is the most secure method of attachment to clothing. If you are going to use the same performers for a large number of capture sessions, we recommend that you get body suits made with soft Velcro patches sewn on at the correct locations for markers. Permanent Velcro patches should be sized much larger than the marker base (perhaps 3"x3") so that some latitude is allowed for final marker placement. Each marker can be attached to the same point using the opposite hook Velcro pieces. As humans are of different shapes, you will need to consider getting a range of different sizes of bodysuit. You can also order specialised body suits directly from Vicon. These allow the direct attachment of the hook side of Velcro.

Sweatbands

A headband, with the markers secured by screwing the bases through the material, is the most suitable and comfortable for your head markers. Wrist bands are also useful in holding extender rods in place for positioning wrist markers.

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Where to place markers
Correct positioning of the markers on your subject is key in achieving good motion capture. Although you could place the markers anywhere, bear in mind that you are usually aiming to capture the movement of the underlying skeleton.

Where to attach markers
As such, markers should be placed at specific and easily identified anatomical locations.

The figure below shows an example of where to position markers for a full body capture

Front and rear views for the example marker placement. Note the asymmetry in upper arm, forearm, thigh and shin marker.
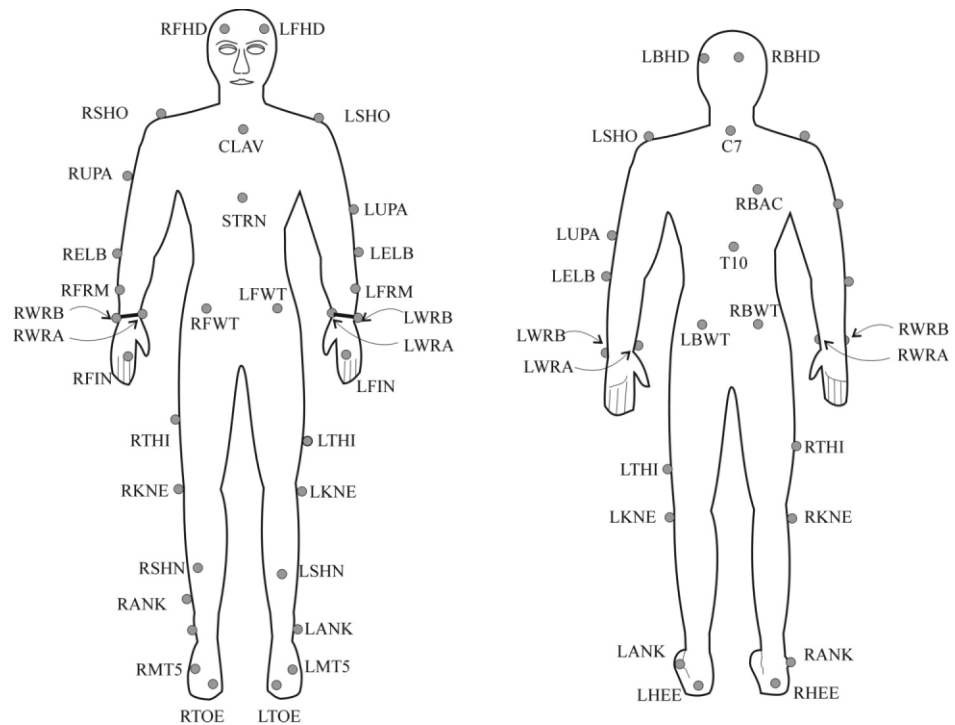
The names of the markers are called labels. These labels are listed in a file called the Marker Set and are associated with the markers in the Workstation application. Marker sets are described in greater detail in the Reference section.

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The table below lists the labels used in the HumanRTkm.mkr marker set supplied with your system; the PlugInGait.mkr marker set for clinical gait analysis is detailed in the PlugIn Gait documentation.

The positions of markers listed below are approximate marker positions that will be suitable for some applications. For exact marker placement please refer to the specifications of the desired model, visualisation or analysis package.

Example marker definitions

Marker Label	Definition	Position
LFHD	Left front head	Left temple
RFHD	Right front head	Right temple
LBHD	Left back head	Left back of head
RBHD	Right back head	Right back head
C7	Seventh cervical vertebrae	Base of the neck
T10	Tenth thoracic vertebrae	Centre mid-back
CLAV	Clavicle	Top of the breast bone
STRN	Sternum	Base of the breast bone
RBAC	Right back	Centre of the right shoulder blade
LSHO	Left shoulder	Placed on the bony prominence on top of the left shoulder
LUPA	Left upper arm	Placed on the outside of the upper arm
LELB	Left elbow	Placed on the bony prominence on the outside of the elbow joint
LFRM	Left forearm	Placed on the outside of the lower arm
LWRA	Left wrist	Extended from the thumb side using a wrist bar
LWRB	Left wrist	Extended from the little finger side using a wrist bar

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LFIN	Left finger	Placed just below the middle knuckle on the left hand
RSHO	Right shoulder	Placed on the bony prominence on top of the right shoulder
RUPA	Right upper arm	Placed on the outside of the upper arm
RELB	Right elbow	Placed on the bony prominence on the outside of the elbow joint
RFRM	Right forearm	Placed on the outside of the lower arm
RWRA	Right wrist bar thumb side	Extended from the thumb side using a wrist bar
RWRB	Right wrist bar pinkie side	Extended from the little finger side using a wrist bar
RFIN	Right finger	Placed just below the middle knuckle on the right hand
LFWT	Left Front Waist	Left Front Waist
RFWT	Right Front Waist	Right Front Waist
LBWT	Left back Waist	Left back Waist
RBWT	Right back Waist	Right back Waist
LTHI	Left thigh	Placed on the outside of the thigh below hand swing
LKNE	Left knee	Placed on the outside of the knee joint
LSHN	Left shin	Placed on the outside of the lower leg
LANK	Left ankle	Placed on the bony prominence on the outside of the ankle
LHEE	Left heel	Placed on the back of the foot
LMT5	Left 5th metatarsal	Placed on the outside of the foot at the base of the little toe

LTOE	Left toe	Placed on the tip of the big toe
RTHI	Right thigh	Placed on the outside of the thigh below hand swing
RKNE	Right knee	Placed on the outside of the knee joint
RSHN	Right shin	Placed on the outside of the lower leg
RANK	Right ankle	Placed on the bony prominence on the outside of the ankle
RHEE	Right heel	Placed on the back of the foot
RMT5	Right 5th metatarsal	Placed on the outside of the foot at the base of the little toe
RTOE	Right toe	Placed on the tip of the big toe

These markers can also be grouped, according to the segments of the body.

Head Four markers are used, left and right front, left and right back. These are most easily attached using a head band.

Chest C7
C7 is the seventh and most prominent vertebra, felt at the base of the neck when the chin is rested on the chest. If the subject has long hair then it should be tied up so as not to obscure this marker.

T10
T10 is the tenth thoracic vertebra. Approximately in the centre of the spine, more or less at the same height as the lower end of the breast bone.

STRN
STRN is the sternum. Attach the marker to the lower end of the breast bone. If the subject is female the marker may be moved upward until clear of the breasts. It should be placed on skin or clothing which moves with the ribcage rather than the breasts.

CLAV
CLAV is the clavicle, placed centrally, between the collar bones, just below the throat.

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RBAC

RBAC is used to create asymmetry in the marker set because there is no equivalent left side marker.

Arms ### LSHO/RSHO

SHO is the shoulder marker. It should be placed on a point that remains visible, e.g., on the bony knob of the collar bone – called the Acromion.

LELB/RELB

ELB is the elbow marker and should be placed on the outside of the elbow joint.

LWRA/RWRA and LWRB/RWRB

In order to define the rotation of the forearm you need to two independent markers on the wrist. This is achieved using a wrist bar with a marker at each end. These can be manufactured using the accessories kit and a sweatband. The important things to remember are:

- The bar should be just above the wrist joint

- Care must be taken so that the band does not move around the wrist during movement

In terms of markers, WRA is on the thumb side and WRB is on the side of the little finger.

LFIN/RFIN

The finger marker is attached to the skin between the knuckles of the index and middle finger.

Marker sets for the whole hand are described under Small Volume Capture, in Advanced Techniques.

Pelvis The front markers should be placed on the bony prominence of the pelvis. The back ones just outside the dimples found in the small of the back. All four should be at the same height.

Legs ### LTHI/RTHI

The thigh markers are asymmetrical markers. They are often used to aid the autolabeller in defining body asymmetry, by placing one on the front in the middle of the thigh of either the left or right leg.

Knee RKNE and LKNE are placed on the outside of knee, level with the middle of the kneecap.

LANK/RANK

RANK and LANK are placed on or close to the prominent bone on the outside of the ankle.

Feet LHEE/RHEE
LHEE and RHEE attach to the back of the heel.

LMT5/RMT5
The fifth metatarsal, MT5, is the bone nearest the little toe. The marker is placed on the top of the foot above this bone.

LTOE/RTOE
The toe markers are placed on top of the foot at the end of the big toe.

Asymmetrical Markers Although most markers are placed in specific anatomical positions a number are used to produce asymmetrical marker patterns. The Autolabel feature in Workstation works by recognising patterns of markers. Therefore this asymmetry helps the autolabeller to distinguish between the left and right sides of the body. For example you should position the left upper arm marker, LUPA, at a significantly different height on the upper arm than the right upper arm marker, RUPA.

The following markers should be placed asymmetrically on the subjects:

• LUPA and RUPA

• LFRM and RFRM

• LTHI and RTHI

• LSHN and RSHN

When capturing more than one subject the autolabeller has the additional task of distinguishing between the two subjects. To help this identification you can place the asymmetrical markers at different positions on the two subjects. Capturing multiple subjects is described under Advanced Techniques.

Using some sample data included with the installation you can now take a look around the Workstation interface.

Starting Workstation

You can start Workstation in any of the following ways:

• From the Windows Start menu

• Select Start | Run and locate the Workstation.exe file in the main Workstation subfolder of the Vicon folder under

• Create a shortcut on the desktop by dragging the Workstation.exe file onto the desktop

• Create a shortcut on the Start menu by dragging this file onto the Start button

Opening a database

When you start Workstation for the first time you will be presented with the Open Database dialog.

If the sample database, Examples, is listed in the central box you can access the sample files as follows:

• Click Example

• Click Open

If this file is not listed use the Browse button to find the file Examples.enf. This will be in the location …\Vicon\User Data\Examples\Workstation. Select the file and click Open. Finally:

Click Open in the Open Database dialog.
You should now see the Eclipse Data Directory

The Eclipse Data
Directory
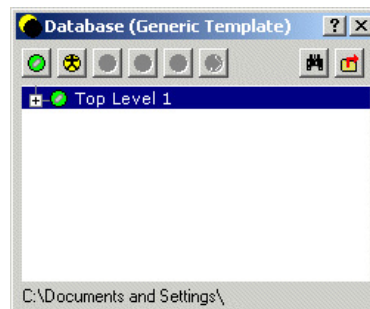
Viewing the Eclipse Data Directory

The Eclipse Data Directory allows easy access to all of the data used by the Vicon system. It will be displayed every time you start Workstation. If you prefer you can switch off this facility by clearing the Open Data Browser Window check

box in the User Preferences Dialog (File | User Preferences... menu item)

At other times you open the window either by:
• Selecting Data Directory from the View menu

• Clicking the Eclipse icon

• Pressing F2

The Eclipse Data Directory window opens automatically when you close a trial. The Eclipse Data Directory displays the file system and works in a similar manner to Windows Explorer. The difference is that different levels (called nodes) display different types of data and there is a rigid hierarchy of levels.

The first time you use the Eclipse Data Directory you should see the window similar to the diagram below.

To view the hierarchy:
• Click the plus (+) sign to the left of the top level icon

• Continue clicking the plus signs to expand the nodes until you have the following view:

The Eclipse Data Directory expanded to four levels.
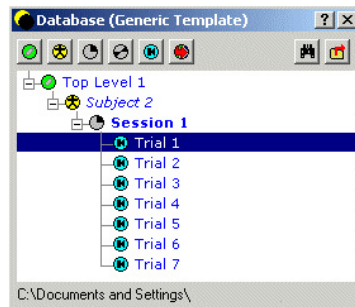
The icons to the left of the names indicate the level of classification. You can label these according to your own preferences but the defaults for Science and Engineering and Entertainment Eclipse Data Templates are shown in the next Table

Nomenclature and
icons for Generic,
Science/Engineering
and Entertainment data
templates.

Generic Database	Science and Engineering		Entertainment (V series)	
Top Level	Patient Classification	🟢	Project	🟢
Subject	Patient	☢	Capture Day	☢
Session	Session	◔	Session	◔
Sub-session	Sub-session	◕	Sub-session	◕
Trial	Trial	◉	Trial	▣
Polygon Report	Polygon Report	🔴	Not available	

The meanings of these classifications will be described in detail under Managing Vicon Data, in The Essentials of Motion Capture.

A Trial is the name given to the data capture process and the group of files in which the data is stored. The other levels or nodes are different ways of organising your data. These can be thought of as being similar to folders in the Windows file system, though the difference is that they contain different kinds of data and the data hierarchy is strictly maintained. For example you can move data around using the Data directory, but you can only ever put Trial data in a Session or Sub-session, and a session in a capture day or patient level. Expanding the window you will see other information is also displayed as shown in the figure below.

A section across the
Eclipse Data Directory

To open a trial:
• Double click the text e.g., Trial 1or the adjacent trial icon

Exploring the Workstation window
The Eclipse Data Directory now closes and you will see the active Workstation window containing two smaller windows – the 3D Workspace window on the left and the Movie window on the right.

When you first open a trial such as this you will see the two windows. If no movie is present then you will only see the 3D Workspace. You can open specific types of data by double clicking the icons defined below.

Opening windows from the Data Directory

If both movie and processed data are stored in the trial, double clicking the Trial icon opens both windows. If you wish to open only one type of data then you can do this by double clicking one of the icons to the right.

	Data Type	Notes	File Extension
Ⓜ	Movie	MPEG format movies	*.mpg
Ⓐ	Analogue	e.g., from force plates	*.vad
Ⓥ	Video	Unprocessed video data, opens in monitor window	*.tvd
Ⓟ	Processed	The Vicon virtual three-dimensional motion opens in Workspace window.	*.c3d

The 3D Workspace window displays the reconstructed three-dimensional movement. This is processed data, derived from the two-dimensional data

The Time Bar is used to control all aspects of playback

recorded by each of the cameras. The movie data in this context is useful in showing what really happened during the trial capture. To observe the full trial, take a look at the Time Bar at the bottom of the Workstation window:

This is used to control all aspects of the playback – speed, direction and even some aspects of the display itself. In the centre at the bottom is a set of controls similar to those any video or compact disc player.
To view the trial:
• Click Play

You should see the captured movement playing synchronized in both the Workspace and the Movie windows.

To stop the playback:
• Click Stop

If you wish to see more detail of the action in 3D Workspace you can zoom in and out, rotate the view or move left and right, up and down. The controls are as follows:

Mouse control of the 3D Workspace

Command	Action
Zoom in	Right Mouse button, drag up
Zoom Out	Right mouse button, drag down
Rotate	Left mouse button, drag in direction of rotation
Move Left/Right	Both mouse buttons, drag left/right
Move Up/Down	Both mouse buttons, drag up/down

Note the stick figure in the 3D Workspace. This has been constructed by the Vicon software based on the labels given to the markers attached to a person moving through the capture volume. Position your mouse over the blue circles. A small pop-up will display something like C7, LFIN, or LBHD, or even LFHD-Edith. Labels are discussed above, under Attaching Markers. They associate the markers with their positions on the body, and generally relate to the skeleton rather than specific body parts – hence LFHD for Left Front Head. For your convenience the marker positions for the supplied marker sets are all defined in this manual. You can also customise or create your own marker sets for specific needs. Details of marker sets are described in the Reference section at the end of this manual.

Labelling Control Bar

To the right of the main Workstation window you will see the Labelling Control Bar, used to assign the labels to the markers. This is important for processing the data before export to other applications, such as BodyBuilder for modelling or third party animation programs. In addition the labelling process also produces the green 'stick' figure seen in the 3D Workspace. This helps in visualising the movement and verifying the labels have been assigned correctly.

Video Monitor

The Video Monitor is opened from the Window menu. It displays the original 2D video data from each camera. This window is similar to the Live Monitor but displays recorded video data rather than live video data. To open the Video Monitor:

The Video Monitor window

• Select Window | New Video Monitor

Clicking the numbered buttons at the bottom of the window displays the data from different cameras. You can also display multiple, overlaid views by holding down the <Ctrl> key when selecting an additional camera. To view a range of camera views hold down the <Shift> key while clicking the second camera button. This displays all views between the two camera buttons. To cycle through the cameras click the up and down triangles on the left. To view the motion click Play ( ) in the Time Bar.

Close the window by clicking the Close (x) in the top right hand corner.

Analogue data, such as that from force plates used in Gait Analysis is displayed in the Analogue Data window:

Analogue Data
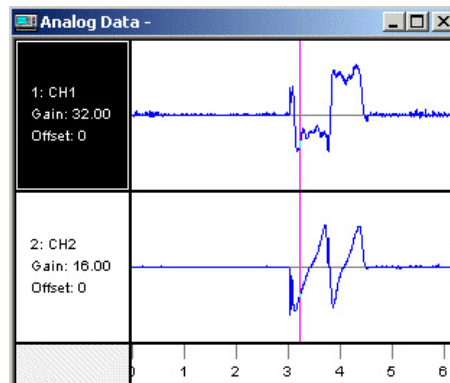
• Select Window | New Analogue Data

Each row displays a single channel of analogue data. You can expand and contract both the time and gain scales:

• Select a channel either by clicking on the channel number or by using the up and down arrows on your keyboard.

• Press G to expand the Gain

• Press T to expand the Time scale

• Press Shift + G to contract the Gain scale

• Press Shift + T to contract the time scale

• Press L or Shift + L to increase and decrease the number of channels to display in the window

Note that the Gain changes only for the currently selected channel. Time scale changes for all channels.

Continuity Chart

Continuity Charts display the continuity of marker trajectories as a function of time.

- Select Window | New Continuity Chart

A solid line represents each reconstructed trajectory. Each camera's contribution to the trajectory is displayed as a horizontal array of dots below the solid line. This shows, at a glance, which cameras are contributing to the calculated trajectory and is useful in diagnosing the causes of errors. A break in the solid line indicates the marker was not reconstructed at that point. If you choose to use the Fill Gaps feature or filter the data then the line will be unbroken, but with no dots below.

The Continuity Chart
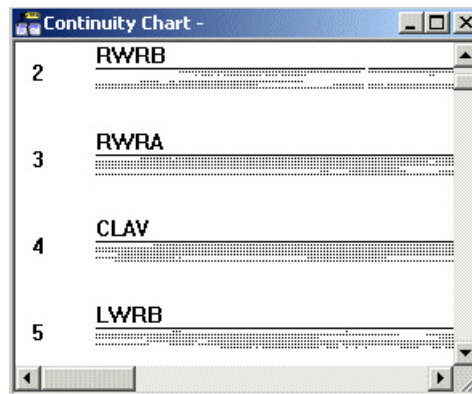
Pop up Graphs

You can view numerical data in pop up graphs. These are opened from the Graph menu, though this is only available when a 3D Workspace, Continuity Chart or Analog Data window is open. A number of options are available. To view a graph:

- Select one or more trajectories

- Select Graph | <option>

To select a trajectory, click on it with a mouse. You can select multiple trajectories by clicking them in turn. When selected they will change colour. To clear the selections click the right mouse button anywhere in the 3D Workspace. Trajectories will be unselected in the reverse order that they were selected. Some options in the graph menu require a single trajectory to be selected, some require two trajectories to be selected and some require three trajectories to be selected. If analogue data is included in the trial then you can view this without selecting any trajectories. If you do not have the correct number of trajectories selected then unavailable options will be greyed out.