Advanced Output Center

FARO Scanning Guide

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Lesson 1:
Scanner Hardware

This lesson introduces you to the scanner hardware, scanner components, and scanner setup and maintenance.

To proficiently work with the scanner hardware, you need be familiar with:

- Transport case contents
- Scanner components
- LEDs
- Safety
- Maintenance and care
- Setting up

Hardware and Components

Each scanner solution may vary slightly, depending on the model and the accessories you purchased.

Focus^{3D} X 330

The Focus^{3D} X 330 is shipped inside a black transport case, which has wheels and an extendable handle.

Focus^{3D} X 330 Transport Case Contents

The Focus^{3D} X 330 is shipped with the following:

1. Transport case
2. Transport cover
3. PowerBlock battery
4. Power cable
5. PoweDock battery charger
6. USB flashdrive
7. SD card case
8. Focus3D X330

Under the transport cover:

9. External power supply
10. Car adapter power supply

Scanner Components

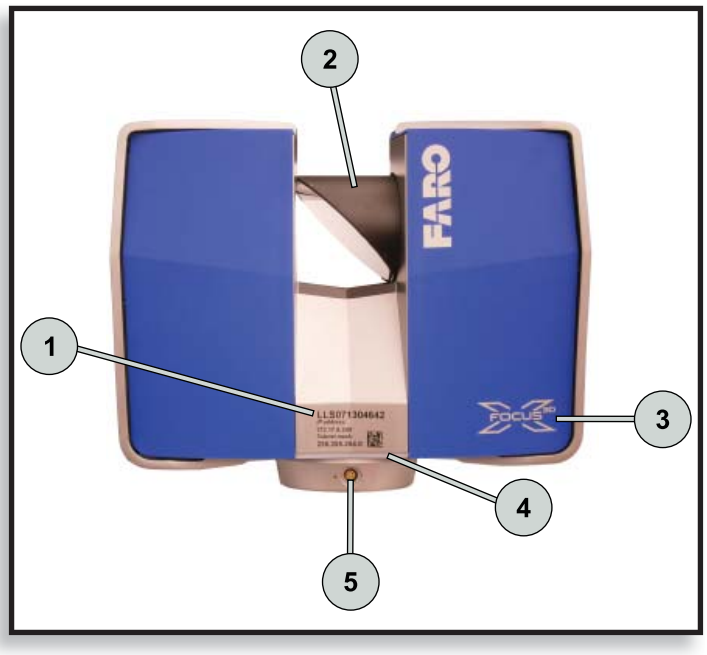
There are five scanner component locations:

- Front
- Back
- Touch-screen side
- Battery side
- Bottom

Front

The front of the scanner is the side with the power inlet.

Focus^{3D} X 330 Front



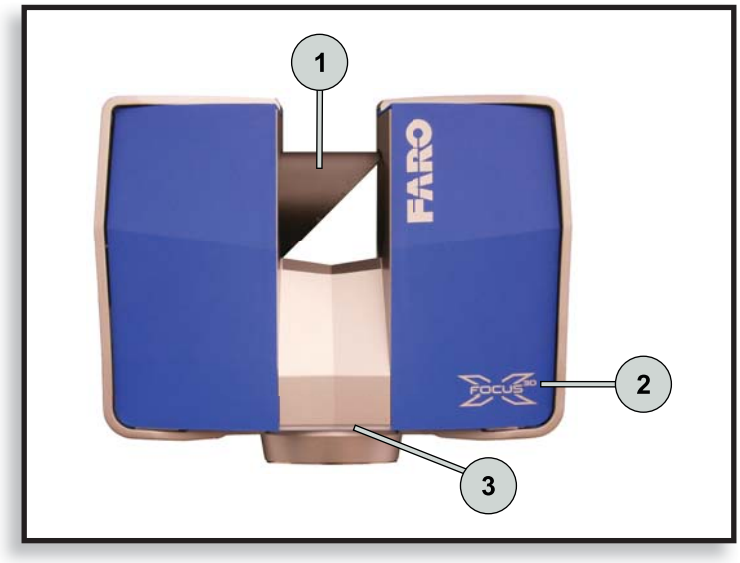
The following components are located on the front of the scanner:

1. Serial number
2. Mirror
3. Scanner logo
4. Light-emitting diode (LED)
5. Power inlet

Back

The back of the scanner is the side without the power inlet.

Focus^{3D} X 330 Back



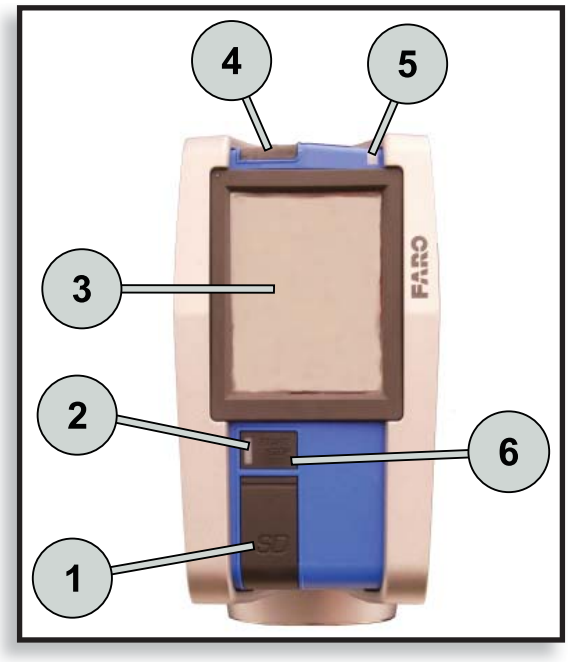
The following components are located on the back of the scanner:

1. Mirror
2. Scanner logo
3. LED

Touch-Screen Side

The touch-screen side of the scanner is the side with the touch screen, the Start/Stop button, and the SD card slot.

Focus^{3D} X 330 Touch-Screen Side



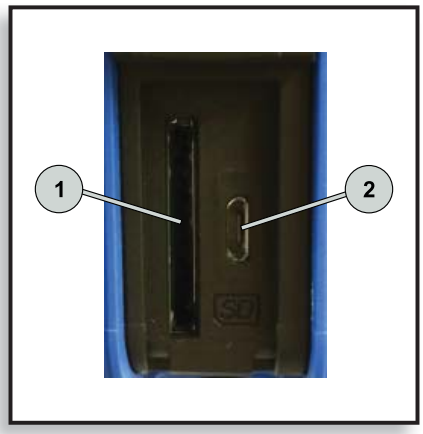
The following components are located on the touch-screen side of the scanner:

1. SD memory card slot cover
2. LED
3. Touch screen
4. Power button
5. LED
6. **Start/Stop** button

SD Card Slot Cover

There are two inlets under the SD card slot cover.

Focus^{3D} X 330 SD Card Slot



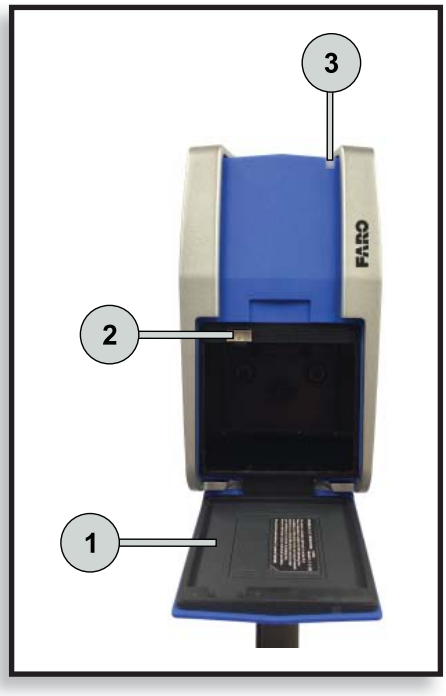
The following are located under the SD card slot cover:

1. SD card slot
2. Micro USB port (for service only)

Battery Side

The battery side of the scanner is the side with the battery compartment.

Focus^{3D} X 330 Battery Side



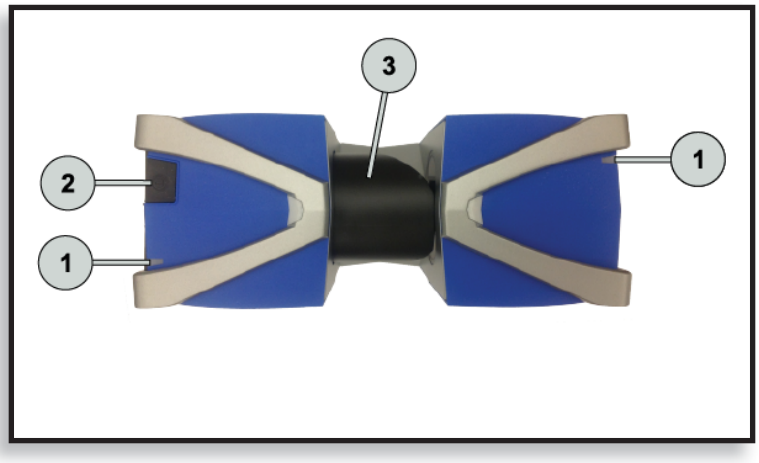
The following components are located on the battery side of the scanner:

1. Battery compartment cover
2. Battery fastener
3. LED

Top

The power button is located on the top of the scanner.

Focus^{3D} X 330 Top



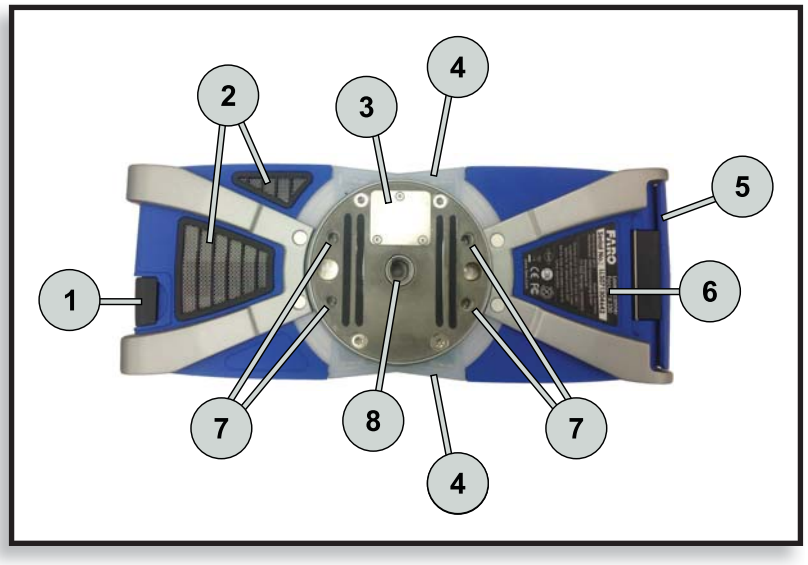
The following components are located on the top of the scanner:

1. LEDs
2. Power button
3. Mirror

Bottom

The bottom of the scanner is used for mounting and service.

Focus^{3D} X 330 Bottom



The following components are located on the bottom of the scanner:

1. SD card slot cover
2. Cooling vents
3. Automation interface cover
4. LEDs
5. Battery cover
6. Serial number
7. M5 threaded holes
8. 3/8-inch threaded hole

LEDs

The LEDs use the following colors to show the status of the scanner:

- Blinking blue – The scanner is booting up or shutting down, pictures are being taken, or the battery is charging when the scanner is off.
- Steady blue – The scanner is ready to scan.
- Blinking red – The scanner is scanning and the laser is on.
- Steady orange – An error occurred.

Setting Up

Setup of the scanner includes:

- Setting up the tripod.
- Mounting the scanner.
- Supplying power to the scanner.
- Starting up the scanner.
- Clearing scan data.

Power Supply

Power can be supplied to the scanner with the external power supply unit or the battery.

External Power Supply Unit

When installing the external power supply unit, be sure to secure the unit to relieve pressure on the unit's cord. You can use the tripod hook, Velcro, or another system.

External Power Supply Unit

When inserting the power plug, line up the red dot on the plug with the red dot next to the power inlet.

Power Plug and Inlet

Battery

The battery can be charged in the scanner or in the PowerDock battery charger, which is an optional accessory. The scanner needs to be plugged in, but does not need to be on, to charge the battery.

If the scanner is off, the LEDs will illuminate blinking blue while the battery is charging. If the scanner is on, you can monitor the battery's power level using the scanner interface by tapping **Manage** > **General Settings** > **Power Management**.

When fully charged, the battery lasts 4 to 6 hours. Generally, it takes about 4 hours to charge the battery in the scanner and about 1 hour to charge the battery in the PowerDock charger.

The battery will lose power over time, even when not in use. Recharge the battery before use.

When installing the battery, hold the battery so the PowerBlock regulatory information is on top and the battery contacts are facing toward the scanner. Push the battery into the battery compartment until it clicks into place.

Battery

Starting Up

To turn the scanner on, press the power button on the top. It will take a few minutes to start up. As the scanner starts up, the LEDs illuminate blinking blue. When the scanner is ready to scan, the LEDs illuminate steady blue.

Shutting Down

To shut down the scanner, use the touch screen and tap **Manage** > **Shut down Scanner** or quickly press and release the power button. The LEDs illuminate blinking blue while the scanner is shutting down.

Do not remove the power supply (or battery) during the shutdown process – doing so may damage the scanner or result in loss of data.

Troubleshooting

If the scanner stops responding, press and hold the power button for four to five seconds.

Power Button

SD Card

The SD card is used to store captured scan data. It is also used to store scan information, settings, and parameters; this collection of data is called a **Snapshot**. The SD card is also used to install scanner software updates.

You can find information about software updates on FARO's website (www.faro.com).

Clearing Scan Data

Before beginning a scan project you may want to remove all data from the SD card and the scanner.

To format the SD card in the scanner:

1. Insert the SD card.
2. Tap **Manage** > **Service** > **SD Card** > **Format**.

After formatting, remove all project files from the scanner.

To remove project files from the scanner:

1. Tap **Manage** > **Projects**.
2. Tap each project and tap **Delete**.

Safety

It is important to adhere to all safety procedures when using the scanner. These safety procedures will help protect you and your scanner during scan operations.

Electrical Safety

Follow these electrical safety guidelines:

- Do not open the scanner housing. Dangerously high voltages are used in the scanner. Only qualified service personnel should open the housing.
- Never insert objects into the openings in the housing, as they may cause short circuits, electrical shock, or fire.
- Use only the FARO-recommended power supply and battery. Ensure that the specifications of the power converter are appropriate for the available electrical voltage. If you do not know the electrical voltage, consult your local power company.
- To avoid electrical shock, use the scanner only in dry environments.

Eye Safety

The Focus^{3D} X 130 and X 330 contain Class 1 lasers. Class 1 lasers, which are used in devices such as laser printers, are eye-safe.

Maintenance and Care

It is important to adhere to all maintenance and care procedures. These procedures will help keep your scanner in good working condition.

Storage

When storing the scanner for an extended period of time, remove the battery. Store the scanner in the transport case to protect it from environmental hazards, such as dust. Store the scanner and all scanner equipment in a low-humidity environment with a stable temperature.

Home Screen

When you turn the scanner on, the **Home** screen appears.

Home Screen

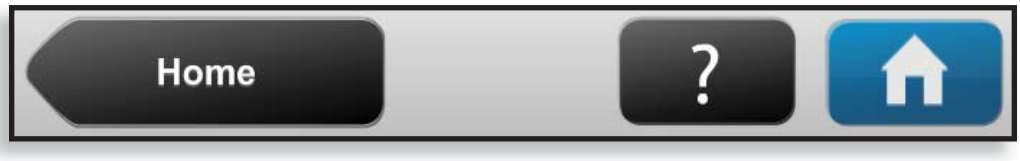
The **Home** screen contains the following:

1. Navigation bar
2. Status bar
3. Information drop-down box
4. **Start Scan** button
5. Menu

Navigation Bar

The navigation bar contains a button that takes you to the previous screen, the **Help** button, and the **Home** button. The navigation bar also displays errors if they occur.

Navigation Bar



Status Bar

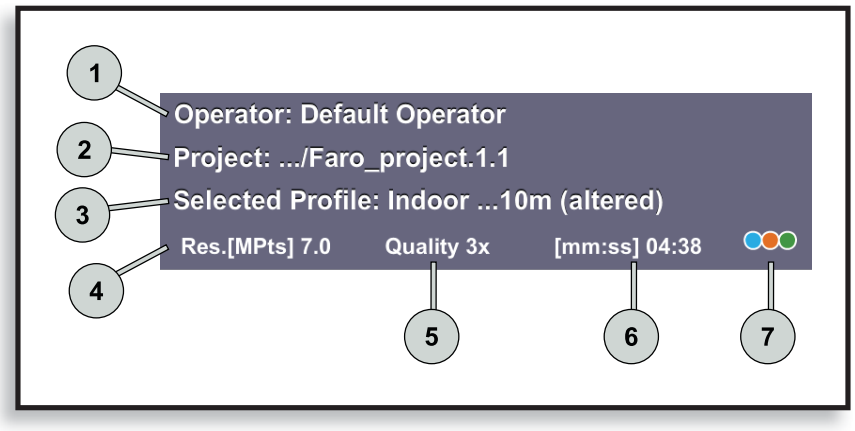
The status bar shows the name of the currently displayed screen or the scan progress, whether the scanner is broadcasting, battery status, and time.

Status Bar

Information Drop-Down Box

Tapping the arrow under the navigation bar opens the information drop-down box, which displays details about scanner settings and parameters.

Information Drop-Down Box



The information drop-down box displays:

1. **Operator** – Displays the most recent operator name.
2. **Project** – Displays the most recent project name. If the project has a parent project, the name is preceded by **.../**.
3. **Selected Pro le**
4. **Res.[MPts]** – Resolution (Megapoints)
5. **Quality**
6. **[hh:mm:ss]** – Scan duration
7. Color mode – Indicates if **Scan with Color** is on or off.

Start Scan Button

The **Start Scan** button starts a scan. When a scan is in progress, the **Stop Scan** button appears.

Start Scan and Stop Scan Buttons

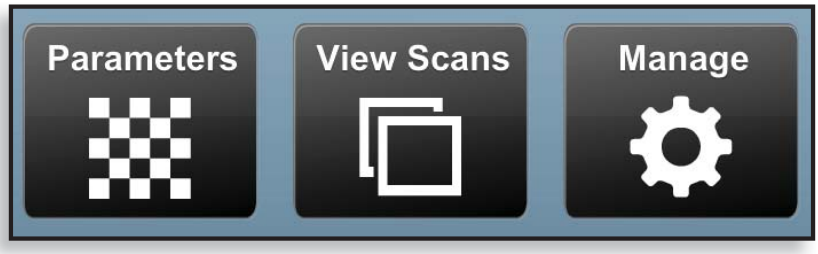
Menu

All features of the scanner interface are accessed from the menu.

The menu contains the following buttons:

- **Parameters** – Specify the settings for each scan.
- **View Scans** – View the scans on the SD card.
- **Manage** – Create and modify projects, change scanner settings, service the scanner, and more.

Menu



General Interface Elements

As you use the scanner interface, you will use several different general interface elements.

Icons and Buttons

Icon/Button	Function
	Home
	Help
	Scroll Up
	Scroll Down
	On
	Off
	Selected
	Delete
	Duplicate
	Increase
	Decrease
	Slider

Icon/Button	Function
	**Backspace**
	**Zoom In**
	**Zoom Out**
	**Reset Size** – This only appears when you are zoomed in on a scan preview.
	**New**
	**Open**
	**Previous Scan**
	**Next Scan**
	**Move Up or Down**
	**Move Left or Right**
	**Warning**
	**Error**
	**Parent Project**
	**Project**

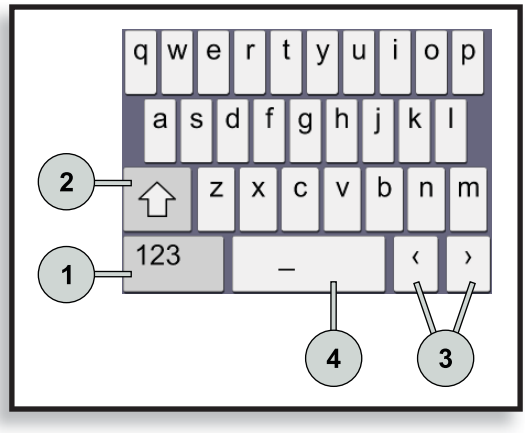
On-Screen Keyboard

When you tap a field to enter information, an on-screen keyboard appears that allows you to enter information.

The on-screen keyboard contains the following:

1. Numbers and special characters
2. Shift
3. Move cursor
4. Space (or underscore when spaces are not allowed)

On-Screen Keyboard



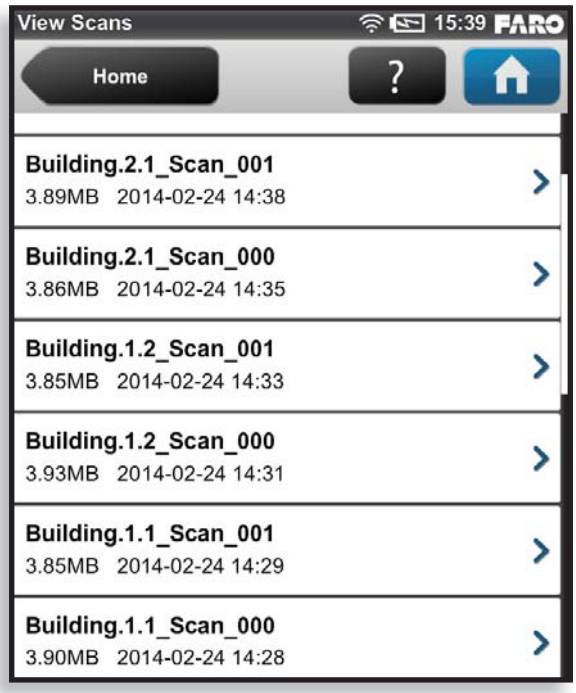
When you touch a letter on the on-screen keyboard, that letter and the letters on either side will appear enlarged. You can rock your finger from one side to the other to select any of the three letters. The selected letter is darker blue than the other two, and is entered into the text field when you remove your finger.

Project File Structure

A project is an organized collection of scans that are related to each other. To facilitate organization, a project can consist of a project name, parent folders, child folders and subfolders.

Scan projects are often composed of several subprojects. For example, a scan of the interior of a multi-floor building can be organized into subprojects – one subproject for each level of the building. Each of these subprojects can be organized into subprojects representing each room on each floor of the building.

Project Folder



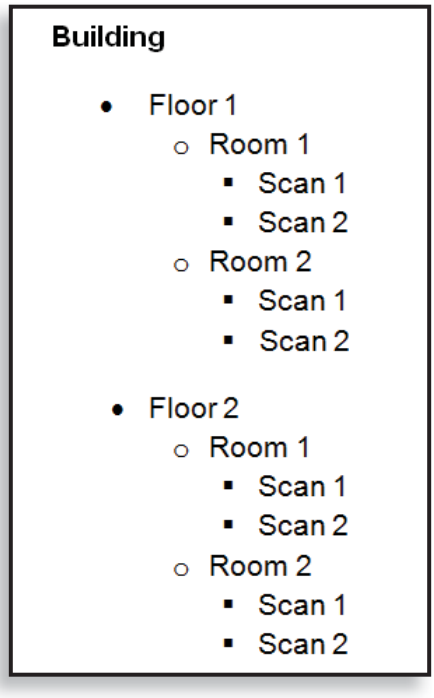
Project Naming

Naming projects appropropriately aids in strategic organization. Give each scanning project, and folders within the project, names with meaning. For example, the case or job number, the client name or number, street location, or other easily identifiable designations. This will prove helpful particularly when working in SCENE or other software.

Conceptual File Structure

Conceptually, the organization of the file structure for a multi-floor building might look like this:

Conceptual File Structure



Scanner File Structure

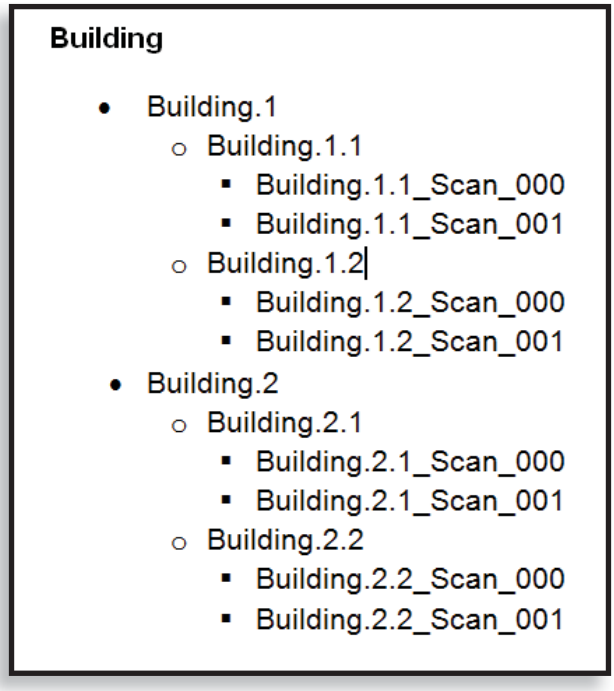
The easiest way to create this file structure on the scanner is to add subprojects and let the scanner automatically name each subproject and each scan. The scanner's automatic naming uses consecutive numbers, periods, and underscores.

When using **Add**, the scanner automatically creates a subproject with the same name as the original project, appended with a period and a number. Each subsequent subproject will be automatically appended with consecutive numbers.

The highest-level project is called a **Parent Project**.

If you create the file structure using the scanner's automatic naming, the previous list looks like this:

Scanner File Structure



When you view the file structure on the scanner (by tapping **Manage** > **Projects**), you can see the main (**Parent**) project is **Building**, the first-level subproject (Floor 1) is **Building.1**, and the second-level subprojects (Room 1 and Room 2) are **Building 1.1** and **Building 1.2**.

To view subprojects on the scanner, select the project that contains the subprojects.

Manage > Projects

When you view the scans (by tapping **View Scans**), you can see that each scan is also numbered consecutively, beginning with 0. When the scanner automatically numbers scans, it uses three digits. So, if the initial scan number is 0, the name of the first scan ends with **000**.

The **View Scans** screen sorts scans with the most recently captured scans at the top.

View Scans

For each project and subproject, you can enter and customize the following project information:

- **Project Name** – Project names cannot contain spaces or special characters (!, @, #, $, %, ect.) and must be no longer than 40 characters.
- **Parent Project** – Parent projects contain subprojects. You can tap on this field to assign a parent project to a subproject.
- **Customer** – Record a customer's name.

- **File Base Name** – Enter a file base name. Each scan is saved with a name that begins with the file base name and ends in consecutive numbers. The **File Base Name** (scan base name) determines the names of the scans. You cannot rename scans in SCENE, so be sure to enter an appropriate **File Base Name** when setting up your project.
- **Initial Scan No.** – The first scan is saved with this number, and each successive scan is numbered consecutively.
- **Additional Info** – Record notes and additional information.
- **Latitude** – Enter the approximate latitude (±10 degrees) of the scan. Enter the latitude using decimal degrees.

To open a project and edit project information:

- Tap **Manage** > **Projects**. Tap the blue arrow next to the project name you want to open. Tap a field to edit as needed.

If you do not create a project on the scanner, then scans will be automatically placed in the **Default_Project** folder.

Duplicating a Project

You can also create a new project or subproject by duplicating an existing project or subproject and editing the fields.

To duplicate a scan project:

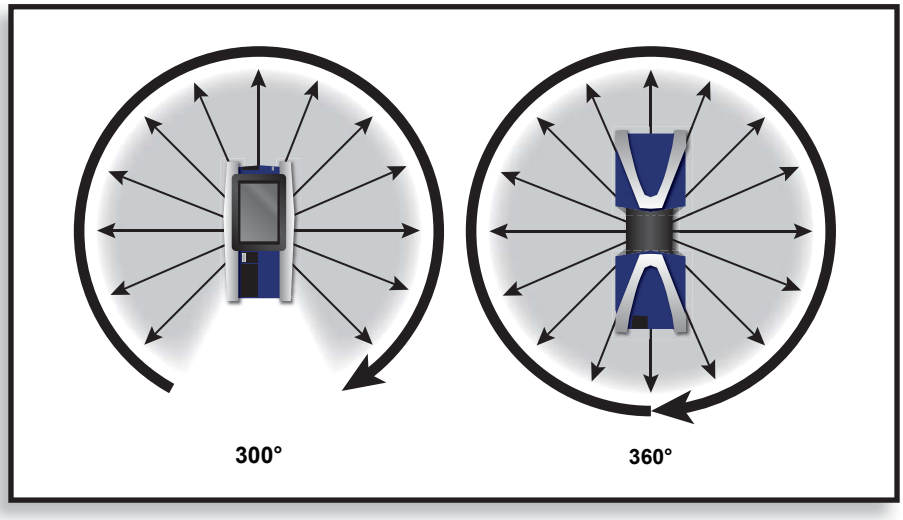
1. Tap **Manage** > **Projects**.
2. Tap the project you want to duplicate.
3. Tap **Duplicate**.

   A new project is created and the project name is automatically preceded by **Copy_of_**.

4. Edit each field as needed.

The mirror rotates around a horizontal axis, and the scanner rotates around a vertical axis. The scanner captures a 300-degree view around the horizontal axis (the tripod mount obscures a small area directly below the scanner) and a 360-degree view around the vertical axis.

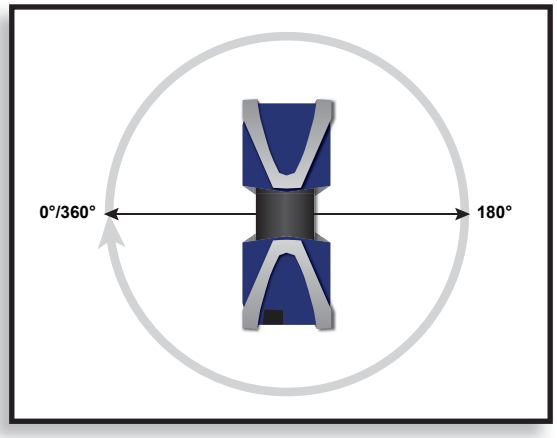
Horizontal and Vertical Axes



The start/stop point is where the scan starts and stops on the horizontal axis. The start/stop point of the scanner is located at the center of the scanner, in line with the power inlet and perpendicular to the front of scanner.

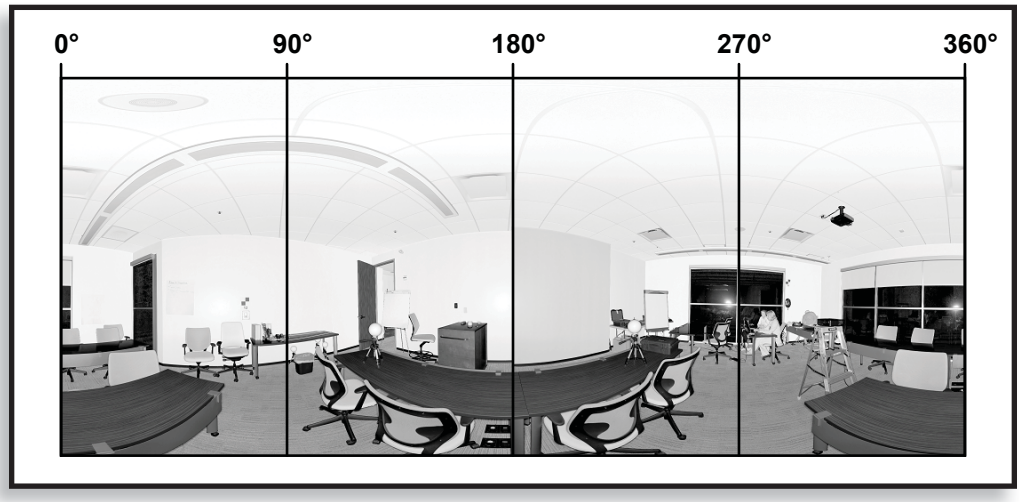
Because the laser light is emitted both in front of and behind the scanner, it only has to rotate 180 degrees to capture a 360-degree scan.

Start/Stop Point



The preview that is displayed on the scanner's touch screen is a flattened (planar) view of the three-dimensional data. The left edge (0°) of the preview is adjacent to the right edge (360°).

Scanner Preview

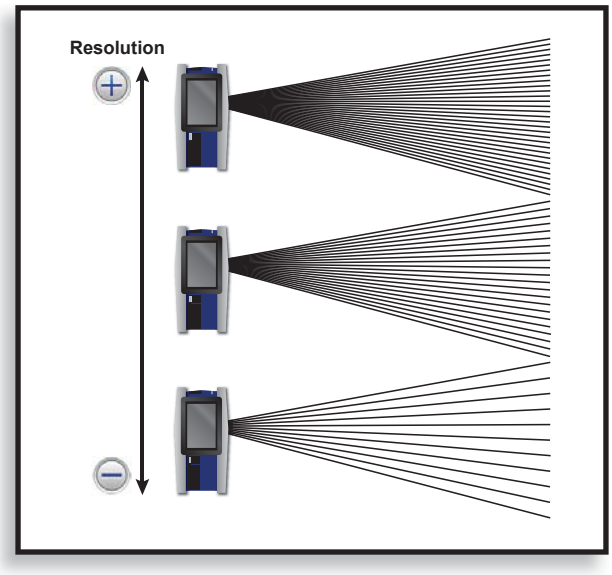


Point Distance

Because the laser light is sent from a single point (the center of the mirror), the distance between the captured scan points increases with distance from the scanner. This distance, called point distance, is also referred to as point density.

Point Distance is determined by the **Resolution** setting; the higher the **Resolution** setting, the smaller the point distance and the higher the **Resolution** setting, the larger the point distance.

Point Distance



Common Scan Parameters

Scan **Parameters** are used by the scanner when recording scan data. You can set these parameters to ensure you have enough scan data to meet project requirements, are working within any time constraints, and are able to successfully register scans together.

The three most commonly used **Parameters** are:

- **Resolution**
- **Quality**
- **Scan with Color**

Resolution and Quality

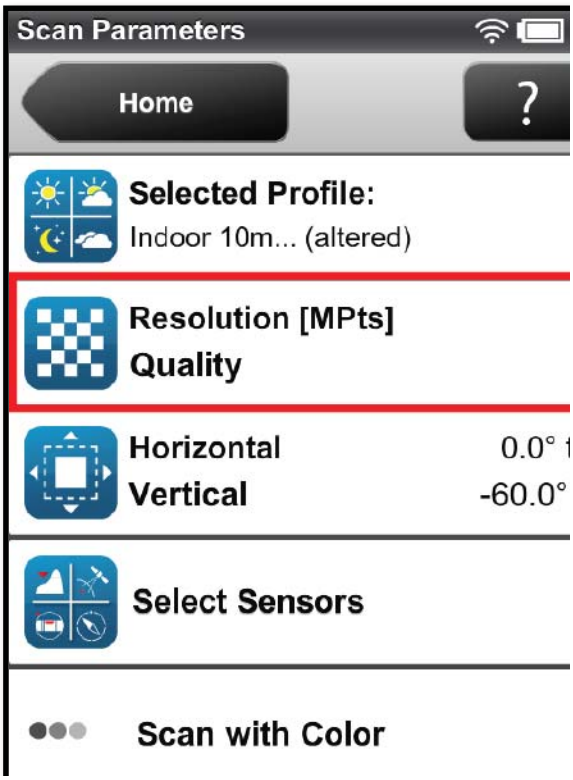
Resolution and **Quality** are the most important scan parameters because they affect the level of detail captured, the scan duration, and the ability to register scans properly.

The **Resolution** setting determines the density of scan points. The higher the **Resolution** setting, the sharper the image and the greater the fineness of detail.

The **Quality** setting determines how long the scanner takes to measure a point and the length of time a point is sampled. The higher the **Quality** setting, the less noise, or number of extraneous unwanted points, in a scan.

To adjust the **Resolution** and **Quality** settings, from the **Home** screen, tap **Parameters** > **Resolution [MPts] Quality**.

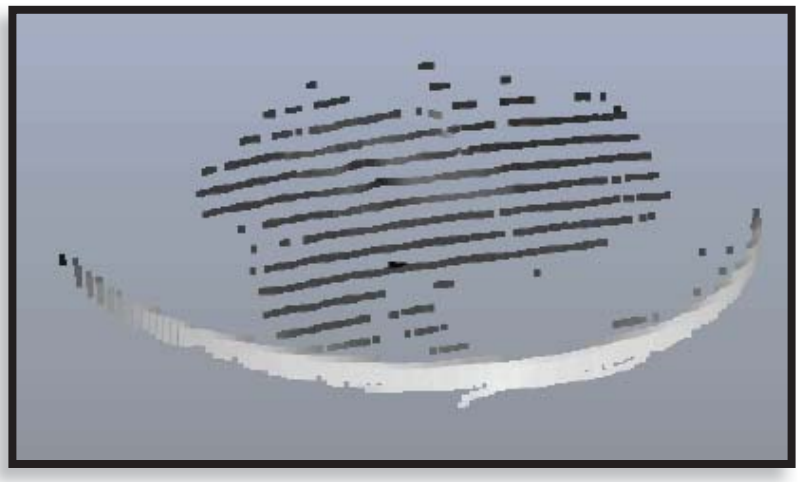
Resolution



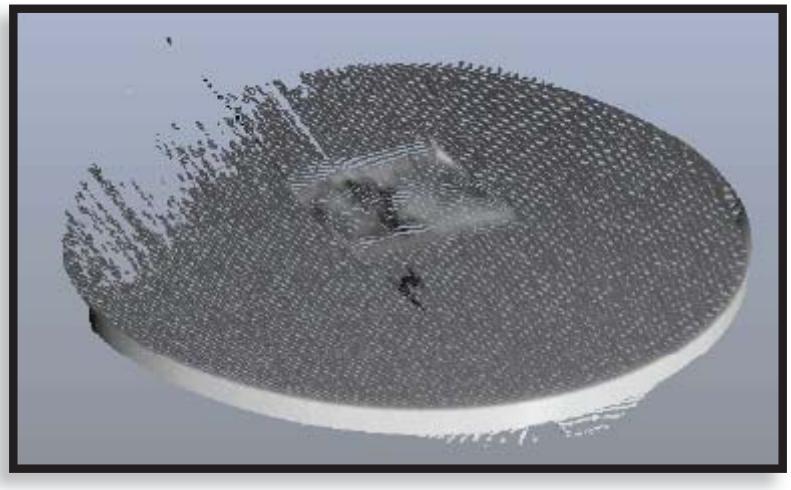
Resolution

The **Resolution** setting determines the point distance, which, in turn, determines the level of detail.

Tabletop (Low Resolution)



Tabletop (High Resolution)



Increasing the **Resolution** setting increases the number of points captured and decreases the point distance. Decreasing the **Resolution** setting decreases the number of points captured and increases the point distance.

You can adjust the **Resolution** setting to capture more points on distant objects. For example, with a **Resolution** setting of **1/8**, the point distance 10 meters from the scanner is 12.272 millimeters (~0.5 inch). Increasing

the **Resolution** setting to **1/2** reduces the point distance to 3.068 millimeters (~0.1 inch).

Choose a **Resolution** setting based on the level of detail needed, the distance to the object of interest, and the distance to the targets. **Resolution** is shown as a fraction and ranges from **1/1** to **1/32**.

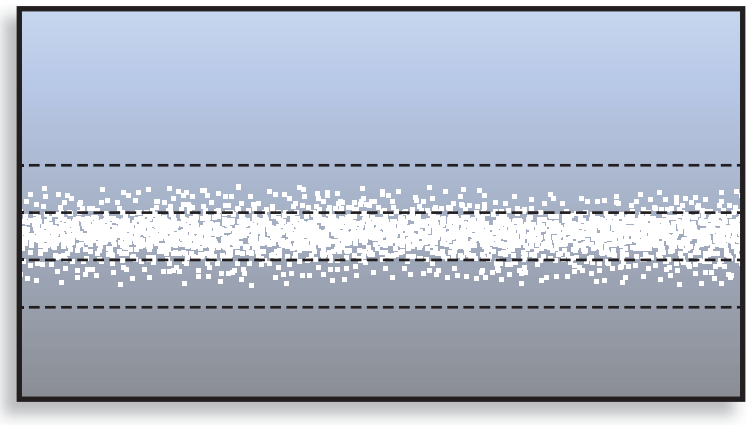
Generally, follow these guidelines:

- **1/1** or **1/2** – Objects and small areas
- **1/4** or **1/5** – Outdoors and large, indoor spaces
- **1/8** or **1/10** – Indoors and small, outdoor spaces

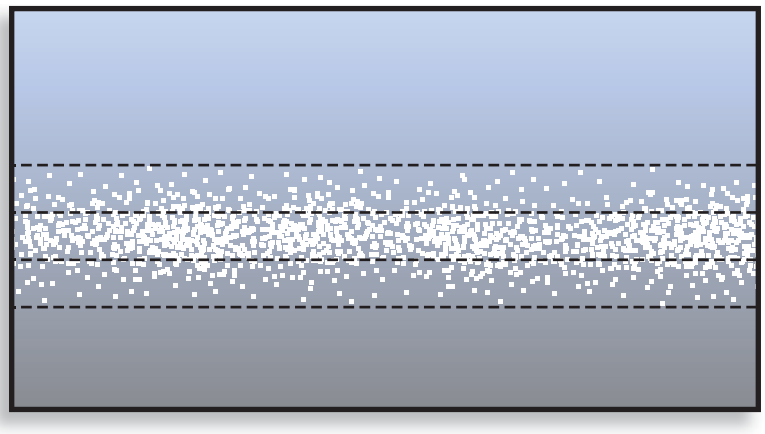
Quality

With a higher **Quality** setting, the scanner captures points that are more concentrated on objects in the scan area. The **Quality** setting affects the rate of measurement, the level of noise reduction, and the range of the scanner.

Plane Cross-Section (High Quality)



Plane Cross-Section (Low Quality)



Increasing the **Quality** setting decreases the rate of measurement. That is, it increases the amount of time the scanner takes to capture each scan point, taking multiple measurements to confirm the data and then averaging the result.

The **Quality** setting also employs noise reduction, an algorithm used to determine whether differences in scan points are an accurate representation of detail, or noise (extraneous unwanted points). The algorithm compares scan points within a specific distance of one another and determines if the difference is within the tolerance specified by the **Quality** setting. If it is not, then the scan point is removed. This may result in a greater point distance (lower point density).

Choose a **Quality** setting based on environmental conditions. Increase the **Quality** setting in adverse scanning conditions, and decrease it if conditions are good, time is a factor, or error tolerances are larger. The **Quality** setting is shown as a number followed by an x. The **Quality** settings that are available depend on the selected **Resolution** setting.

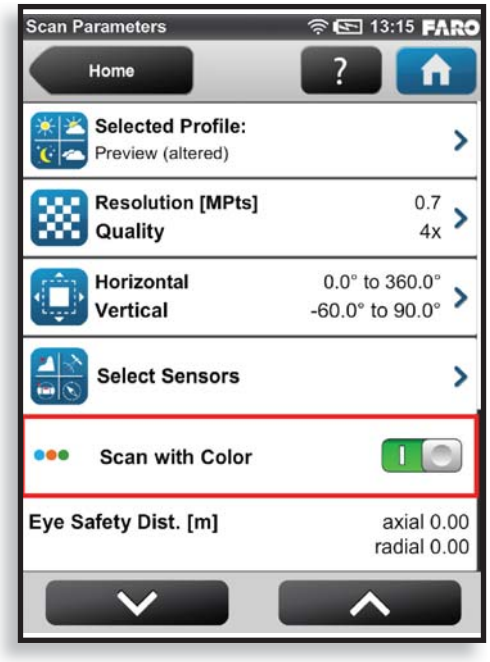
Generally, follow these guidelines:

- **2x** – Optimal conditions and when time is a concern
- **3x** – Indoors, and outdoors with overcast conditions
- **4x** – Outdoors in sunny conditions when range is needed, or in inclement weather

Scan with Color

When **Scan with Color** is on, the scanner takes color photographs of the scan area after capturing the scan data. The scanner makes an additional rotation and captures approximately 85 photographs per scan. The color information can be applied to the scan data in SCENE.

Scan with Color



Applied Color

Scan Profiles

Resolution and **Quality** settings, detail scan settings, the color setting, and other settings can be saved as a scan **Pro le**.

To select a profile, from the **Home** screen, tap **Parameters** > **Selected Pro le**.

There are up to seven predefined scan **Pro les** (depending on the scanner model):

- **Indoor ...10m** – Use indoors when the distance between the scanner and the object of interest is less than 10 meters.
- **Indoor 10m...** – Use indoors when the distance between the scanner and the object of interest is greater than 10 meters.
- **Outdoor ...20m** – Use outdoors when the distance between the scanner and the object of interest is less than 20 meters.
- **Outdoor 20...** – Use outdoors when the distance between the scanner and the object of interest is greater than 20 meters.
- **Preview** – Use to quickly capture a low-resolution scan.
- **Object HD** – Use to capture a high-resolution scan.
- **Outdoor: Far Distances** – Use outdoors, when the distance between the scanner and the object of interest is greater than 20 meters, and when it is acceptable for points closer to the scanner to be less accurately measured.

If you select a predefined profile and modify it, the profile name is appended with **(altered)**. For example, if you select **Indoor 10m...**, and then disable **Scan with Color**, the profile name is displayed as **Indoor 10m... (altered)**.

Scan Profiles

Profile Name	Resolution Setting	Quality Setting	Scan with Color	Sensors
Indoor ...10m	1/8	3x	On	On
Indoor 10m...	1/5	4x	On	On
Outdoor ...20m	1/5	4x	On	On
Outdoor 20...	1/4	4x	On	On
Preview	1/16	4x	Off	Off
Object HD	1/2	6x	On	On
Outdoor: Far Distances*	1/4	4x	On	On
*This profile is the same as **Outdoor 20...**, but with the **Far Distances Optimization** turned on. **Far Distances Optimization** increases the quality of points captured farther than 20 meters from the scanner, and may decrease the accuracy of points captured within 20 meters.				

To reset a predefined profile to the default settings:

1. From the **Home** screen, tap **Parameters** > **Selected Pro le**.
2. Tap any predefined profile other than the altered profile, so that it is highlighted.
3. Tap the first predefined profile.

Custom Scan Profiles

You can also create custom scan profiles.

To create a custom scan profile:

1. From the **Home** screen, tap **Manage** > **Pro les**.
2. Tap **Add** or **Duplicate**.
3. Tap each field to edit the settings.
4. Tap **Home**.

For each profile, you can enter and customize the following project information:

- **Pro le Name** – Enter the name of the profile.
- **Resolution [MPts] Quality** – Set the **Resolution** and **Quality** settings.
- **Horizontal Vertical** – Select a scan area other than a full scan (called a detail scan).
- **Select Sensor** – Turn on or off sensors such as the inclinometer.
- **Scan with Color** – Turn on or off color photography.
- **Color Settings** – Set the exposure modes for photographs.
- **Advanced Settings** – Enable of disable various filters.

Scan Duration

The **Resolution** and **Quality** settings and **Scan with Color** are correlated with **Scan Duration**. Increasing the **Resolution** and **Quality** settings increases the **Scan Duration**, and decreasing the settings decreases the **Scan Duration**. Using **Scan with Color** adds time to the **Scan Duration**.

When determining **Scan Duration**, use the **Resolution / Quality** screen; do not use the **Information Drop-Down Box**.

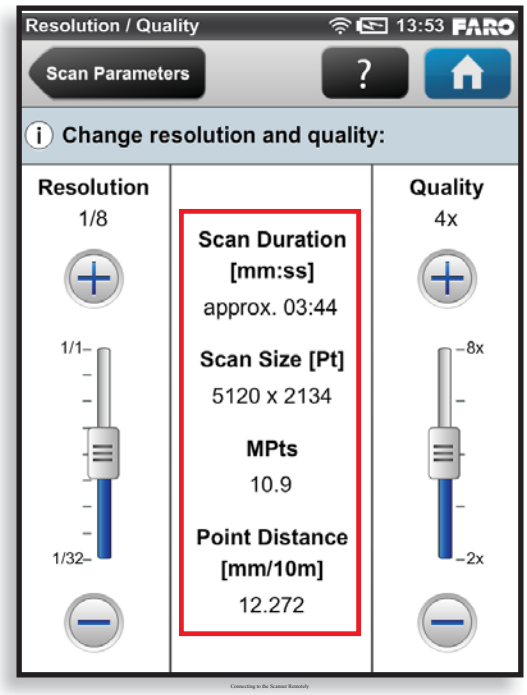
Troubleshooting

When the **Scan Duration** is greater than an hour, seconds are not displayed; the format changes from **mm:ss** to **hh:mm**.

As the **Resolution** setting is changed, the following also change:

- **Scan Size** – Number of scan points in each row and column of scan data
- **MPts** – Total number of scan points in megapoints
- **Point Distance** – Distance between scan points, shown either as the point distance in millimeters at 10 meters from the scanner (**[mm/10m]**) or the point distance in inches at 30 feet from the scanner (**[in/30ft]**).

Resolution/Quality



Connecting to the Scanner Remotely

As you discuss the scanner software, you can connect to the scanner using a Wireless Local Area Network (WLAN) so you can demonstrate features and commands, as well as Activities.

To connect remotely to the scanner:

1. Using the scanner:
   A. Tap **Manage** > **General Settings** > **WLAN**.
   B. Verify **WLAN Status** is turned on.

      The scanner **IP Address, Port** number, and **Encryption Key** are listed on the **WLAN** screen.

   C. Using your computer:
   A. At the bottom right of your computer screen, click the Network icon.
      I. From the list of wireless devices, select the scanner, and click **Connect**.
      II. The scanner name is the scanner serial number, which is on the front of the scanner, above the power inlet.

         When prompted for an encryption key, enter the encryption key for the scanner (for example ***0123456789,*** if no preferences have been changed from the original defaults**).**

   B. Open an internet browser.
      I. In the internet browser's address field, enter ***http://***, followed by the internet protocol (IP) address of the scanner, followed by the **Port** number (for example, ***http://192.168.111.2:8400***).

         If your browser does not support Flash, this function may not work

Lesson 1: Scanning Considerations

This lesson introduces the many factors can affect a scan project, which should be considered before starting to scan. Understanding these factors before you start planning a project can save time and money.

These factors include:

- Site conditions
- Project requirements
- Registration

Site Conditions

Site conditions can vary greatly, based on location, vehicular and pedestrian traffic, weather, and other circumstances.

Consider site conditions, such as:

- Potential hazards – Some sites may contain hazards, such as at a building site or in a high-traffic area.
- Terrain – The terrain can affect target arrangements and scanner positions, as well as accessibility.
- Window of opportunity – Some situations may require you to scan within a specific time frame, such as when there are fewer pedestrians in a public area.
- Reflectivity – Shiny, highly reflective surfaces are difficult to scan. Darker objects reflect less light. To compensate for high reflectivity, you can reduce distance, increase angle, use an anti-glare coating, and increase the **Quality** setting.
- Movement – The scanner and the object of interest must not move in relation to one another. To prevent movement, you can make sure the tripod is stable and avoid vibration and wind.

- Obstructions – People or vehicles moving in front of the scanner can obscure the object being scanned. To avoid and compensate for obstructions, you can scan during low traffic, block off the scan area, and crop out obstructions in SCENE.
- Temperature – The ambient temperature should be between 41 and 104°F (5 and 40°C). To ensure the temperature is safe for scanning, you can turn the cooling fan on or off and scan only when the ambient temperature is optimal. Abrupt temperature changes can also cause condensation inside the scanner. To avoid this, you can place the scanner in an airtight plastic bag so that moisture condenses on the bag as the scanner adjusts to the new temperature.
- Other weather conditions – Fog, rain, dust, snow, and other environmental conditions can affect both the scanner and the captured data. To protect the scanner, you can cover the scanner with a shelter or plastic. It is best to avoid scanning until conditions have improved.

Project Requirements

Project requirements are determined by your client, the situation, the scan data you need to capture, and the intended use of the scan data.

When planning your project, consider project requirements, such as:

- Project type – Project types can include construction and architecture, cultural heritage, forensics, gaming and animation, factory specifications, reverse engineering, and more. The type of project will help determine the level of detail, object or area of interest, time constraints, and more.
- Project location – The project location can affect weather, accessibility, amount of traffic, lighting, and other site conditions.
- Confidentiality – In several industries, confidentiality can be an important project requirement, and can affect how data is captured and shared and the type of metadata that is recorded.
- Cultural sensitivity – Some scan projects require cultural sensitivity, in which the people and places involved in the scan project may have specific requirements in terms of how the project is conducted.
- Time constraints – Time constraints are almost always a factor in project requirements, and can be imposed by the project schedule,

site conditions, and other factors. Careful planning can ensure that your project proceeds in accordance with the time constraints.

- Verifying accuracy – In many situations, it is important to verify the accuracy of the scanner.

Verifying Accuracy

You can verify the accuracy of the scanner and scan data by using scale objects in your scans. Scale objects are objects in the scan area with known lengths that can be used as reference objects and compared to captured scan data to verify the accuracy of the data. Scale objects are objects such as rulers, yardsticks, or any accepted standard measurement indicator. Features within the scan area with known, verifiable lengths, such as windows and doors, can also be used as scale objects.

See Appendix 2 for more information on verifying the accuracy of captured scan data.

Registration

In most situations, multiple scans will need to be registered into a single project point cloud. Registration is also referred to as placing scans, and involves aligning multiple individual scans onto a single coordinate system. Understanding how registration works and planning ahead are essential to successful registration.

Lesson 2: Registration

This lesson explains the basic concept of registration. Understanding registration allows you to plan scan projects to ensure efficiency and success.

While some scan projects require only a single scan, creating a three-dimensional image requires multiple scans. Each scan must be positioned accurately relative to all of the other scans.

The American Society for Testing and Materials (ASTM) defines registration as "the process of determining and applying to two or more datasets the transformations that locate each dataset in a common coordinate system so that the datasets are aligned relative to each other" (ASTM International, Standard Terminology for Three-Dimensional (3D) Imaging Systems. Publication No. E2544-11a).

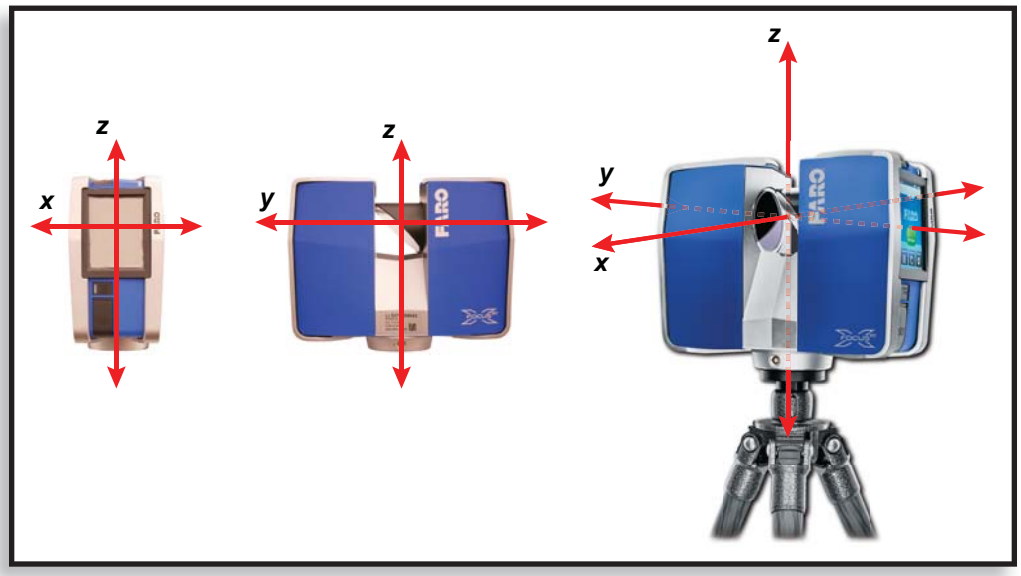
There are several important concepts related to registration, including:

- Coordinate systems
- Common reference objects
- Sensor data
- Reference scans

Coordinate Systems

The scanner saves each scan within its internal Cartesian coordinate system. The origin of each scan is located in the center of the scanner's mirror.

Scanner Coordinate System



A single scan, when viewed from the scanner location, looks complete.

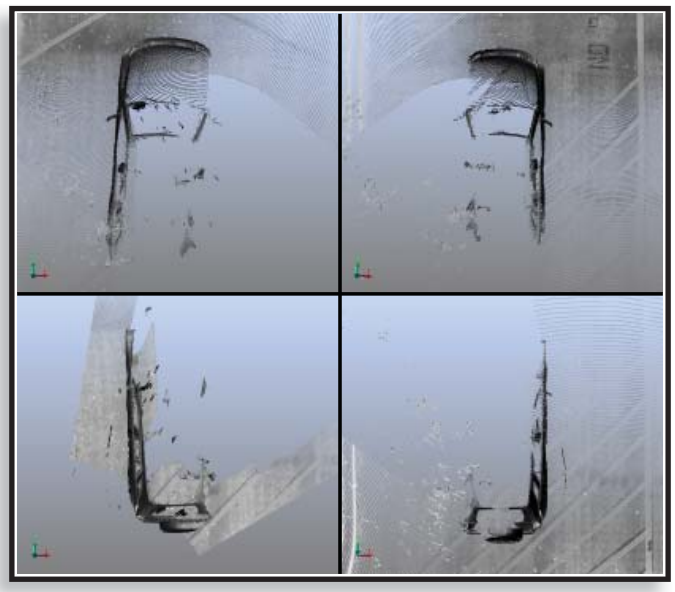
Single Scan (Viewed from the Scanner Position)

However, when viewed from above, the image is incomplete.

Single Scan (Viewed from Above)

To create a complete, three-dimensional image, you need multiple scans.

Multiple Individual Scans



Registration aligns multiple scans on a single coordinate system so each scan is positioned correctly in relation to the other scans.

Multiple Registered Scans

Common Reference Objects

Common reference objects are objects common to two or more scans. Common reference objects are used to align the scans during registration.

There are two main types of common reference objects:

- Artificial common reference objects (targets)
- Natural common reference objects

Artificial Common Reference Object (Checkerboard)

Artificial Common Reference Objects (Targets)

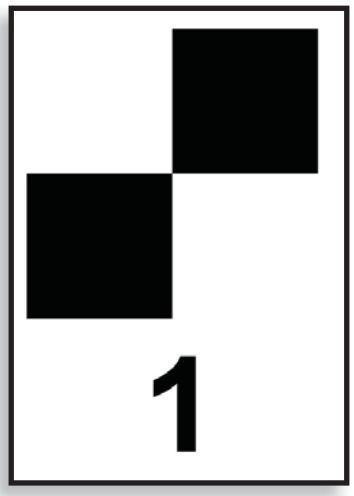
Artificial common reference objects, called targets, are objects strategically placed in the scan area. These are particularly useful, because SCENE automatically detects targets and uses them during registration.

Common types of targets include:

- Checkerboards – Flat, paper targets that can be printed in various sizes. The advantages of checkerboards are they are portable and disposable, and can be printed in various sizes. They also require fewer scan points to be recognized in SCENE, and can be placed farther from the scanner. The disadvantage is they must be angled toward the scanner.
- Spheres – Three-dimensional, white spheres that come in various sizes. The advantage of spheres is that they can be placed at any angle to the scanner. The disadvantage is that they require more scan points to be recognized in SCENE.

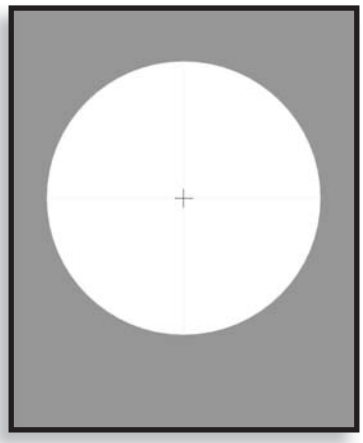
You can use a combination of target types.

Checkerboard



Sphere

Circular Flat Target



Checkerboards

Checkerboards can be printed as they are needed, and are inexpensive. They can also be printed in a larger size, which allows you to place them farther from the scanner and still be recognized as checkerboards.

You can number checkerboards, which makes it easy to identify which checkerboards correspond to one another.

When SCENE identifies a checkerboard, it determines a contrast mean point, which is a single point where the two black squares meet. Because of this, you can place checkerboards on tripods and rotate them as you move the scanner to maintain an angle perpendicular to the scanner, which makes them easier for the software to recognize.

Be sure to print checkerboard targets with laser printers, rather than inkjet printers, because the reflectivity of checkerboards printed with inkjet printers can cause problems. Laminating checkerboards can also cause problems due to reflectivity. If you do laminate checkerboards, be sure to use a matte laminate and test the targets before use.

Spheres

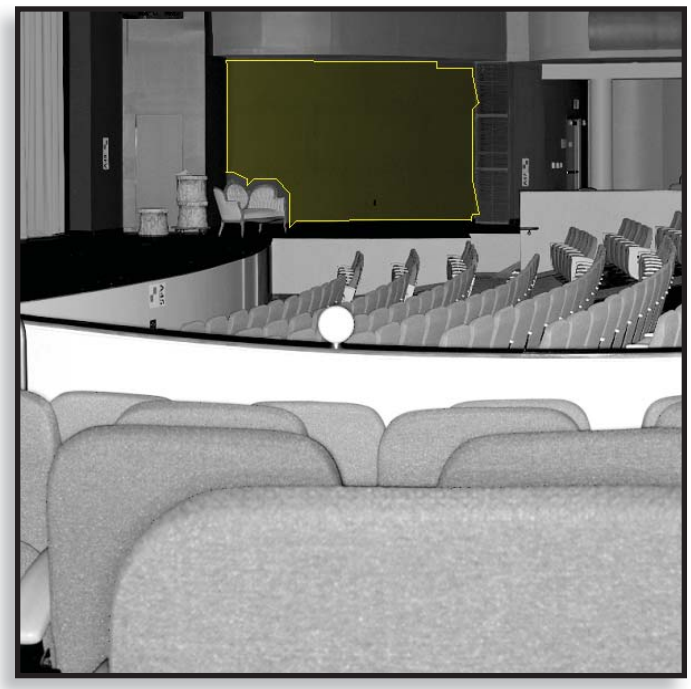
Spheres are useful because they can be placed at any angle to the scanner. Because several scan points are used to identify a sphere, they can also be placed farther away from the scanner.

SuperSpheres are larger spheres that can also be placed farther from the scanner.

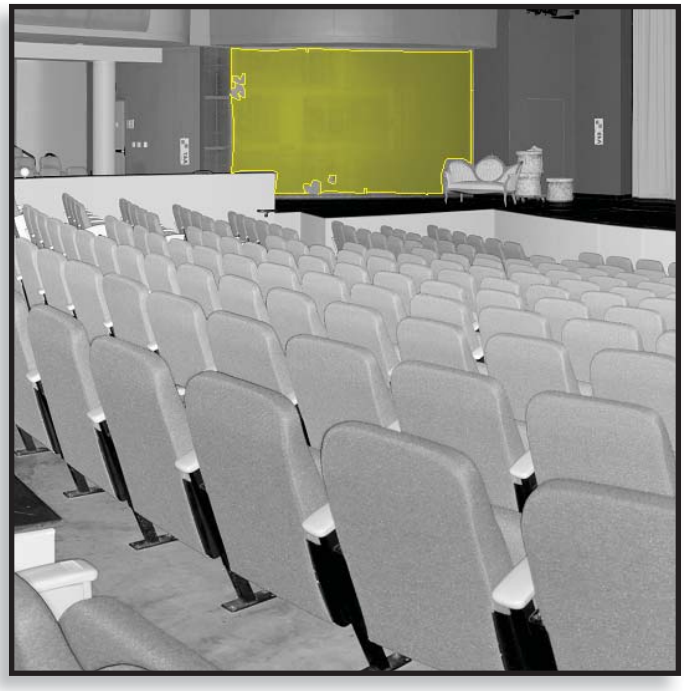
Natural Common Reference Objects

Natural common reference objects are geometric objects, such as points, planes, and lines, that occur on features in the scan area. A feature such as a wall, for example, can be identified as the same plane in two or more scans and used as a common reference object during registration.

Natural Common Reference Object (Plane in Scan 1)



Natural Common Reference Object (Plane in Scan 2)



Correspondence

A correspondence is the relationship between the same common reference object in multiple scans. To register scans, you need to be able to identify the same object in two or more scans. SCENE uses these objects, (common reference objects), to create correspondences.

Sensor Data

Sensor data can also be used during registration. The sensors provide positional information about the scans relative to one another, and relative to external data, depending on the sensor and the scanner settings.

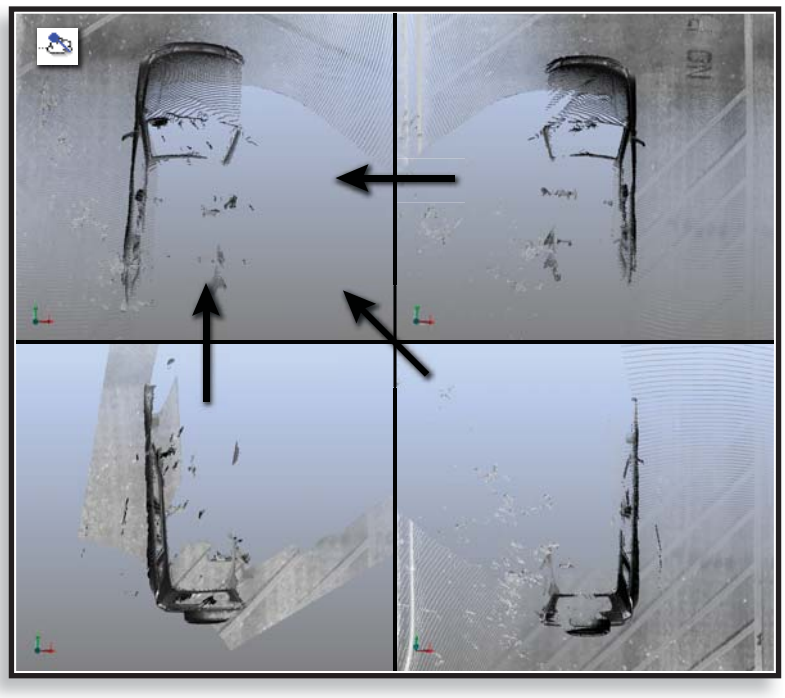
The sensor data that can be used during registration includes:

- Inclinometer
- Compass
- Altimeter
- GPS

Reference Scans

During registration, SCENE aligns all scans to a single scan, called a **Reference Scan**. All of the scans included in the registration are aligned to the coordinates of the **Reference Scan**. In addition, the sensor data, such as the **Altimeter** data, for all scans is factored into the registration relative to the sensor data of the **Reference Scan**.

Reference Scan (Top Left)



By default, SCENE usually selects the first scan in a scan project as the **Reference Scan**. You can also manually select the **Reference Scan**.

To manually set the **Reference Scan**:

1. In the **Structure** window, right-click on the scan.
2. Click **Operations** > **Registration** > **Reference Scan**.

You can also manually set the **Reference Scan** by opening the **Properties** dialog box and, on the **Scan** tab, selecting **Reference Scan**.

Lesson 3:
Scanner Positions

This lesson explains the importance of scanner positions and the steps for planning scanner positions. Positioning the scanner correctly leads to capturing all required scan data in the most efficient manner possible.

There are several factors to consider when selecting scanner positions, including:

- Number of scanner positions
- Distance from the object or area of interest
- Line of sight
- Angle to the object of interest
- Bisecting
- Target arrangements

The primary concern when selecting scanner positions is capturing the object of interest.

Number of Scanner Positions

Each project will differ in the project requirements and constraints, and the number of scanner positions will depend on these factors, as well as on site and environmental conditions. With careful planning, you can minimize the number of scanner positions needed to adequately capture the object or area of interest.

The most important factor to consider when determining the number of scanner positions is overlapping scan areas. Each scan area must overlap with one or more other scan areas to ensure successful registration.

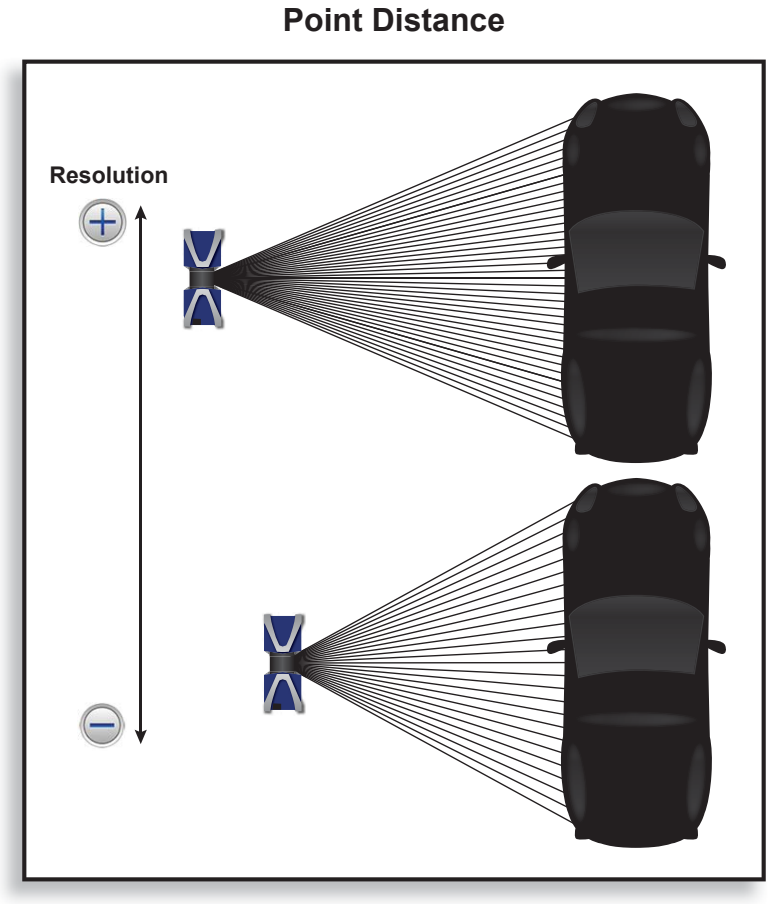
Distance from the Object or Area of Interest

The maximum allowable distance between the scanner and the object of interest depends on the desired level of detail, time constraints, site conditions, and other factors.

The primary factor when determining distance from the scanner is **Point Distance**.

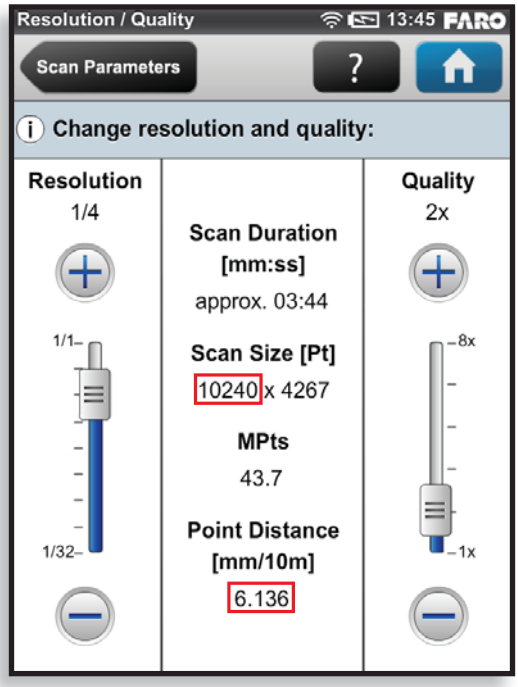
Increasing the **Resolution** setting decreases the **Point Distance** (increasing the point density), which allows the scanner to be positioned farther from the object or area of interest, and increases the **Scan Duration**.

Decreasing the **Resolution** setting increases the **Point Distance** (decreasing the point density), which requires the scanner to be positioned closer to the object or area of interest, and decreases the **Scan Duration**.



You can calculate the point distance using the horizontal resolution on the **Resolution / Quality** screen.

Resolution / Quality Screen



Point Distance Formula

$$\text{Point Distance (m)} = \frac{2\pi d}{r}$$

r = Horizontal Resolution
d = Distance (m)

$$\frac{2 \times 3.14159 \times 10}{10240} =$$

$$\frac{62.8318}{10240} =$$

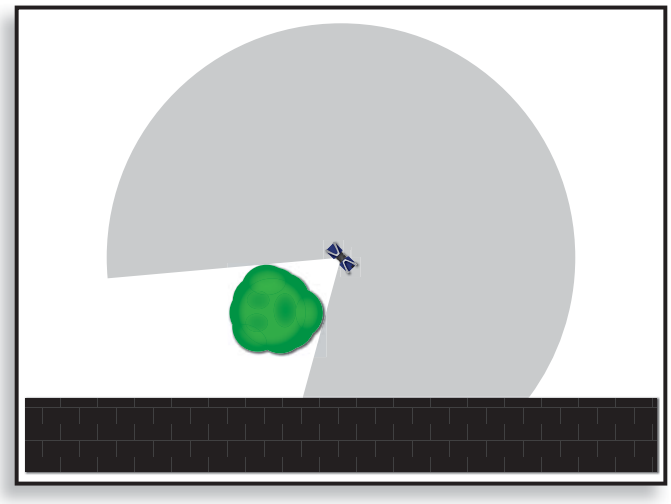
$$0.0061359$$

$$0.00613 \text{ m} = 6.13 \text{ mm}$$

Line of Sight

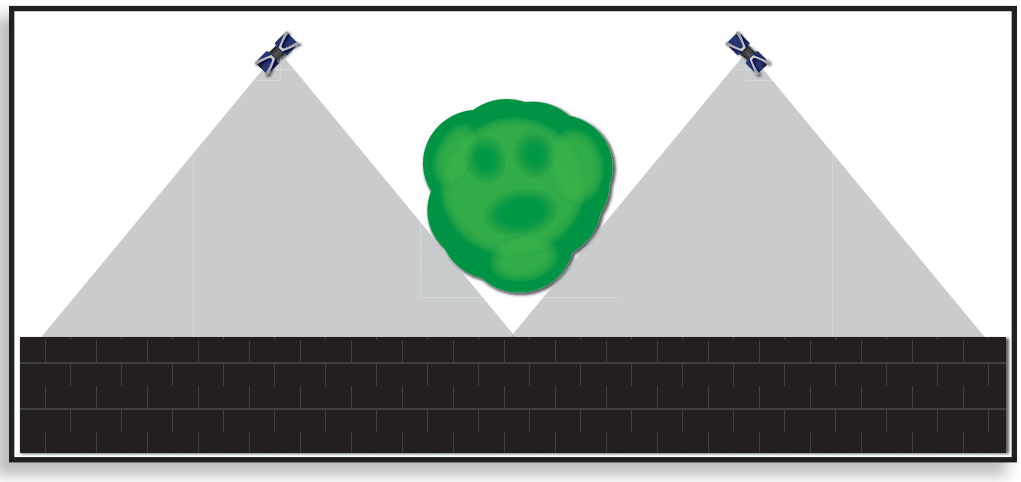
The line of sight to the object of interest is the most important factor in capturing scan data. You may have to capture multiple scans to work around obstructions, such as trees and cars.

Line of Sight

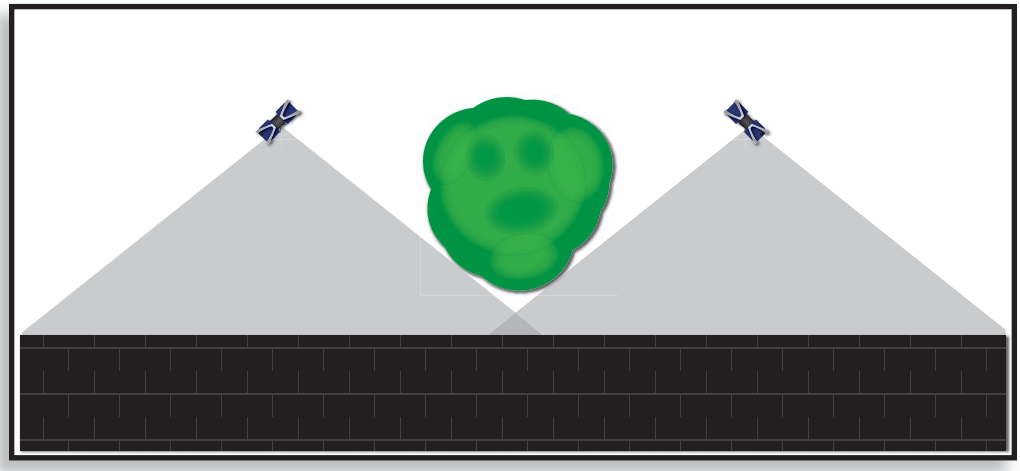


Select scanner positions to ensure that two or more scans have overlapping areas in which common reference objects can be identified.

Line of Sight – Without Overlap



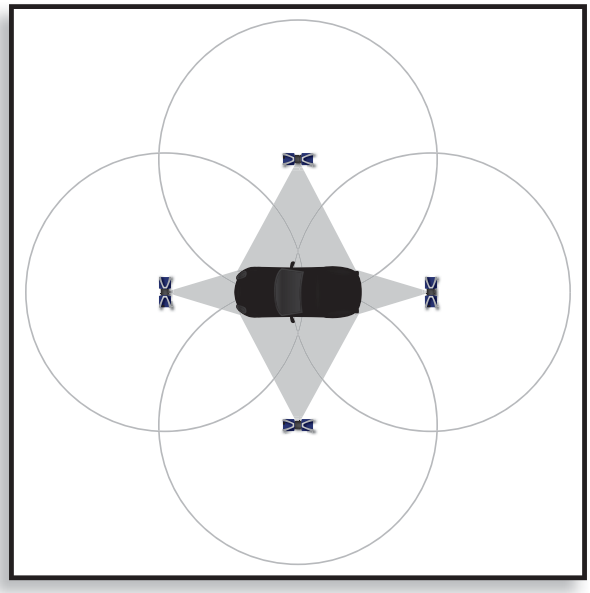
Line of Sight – With Overlap



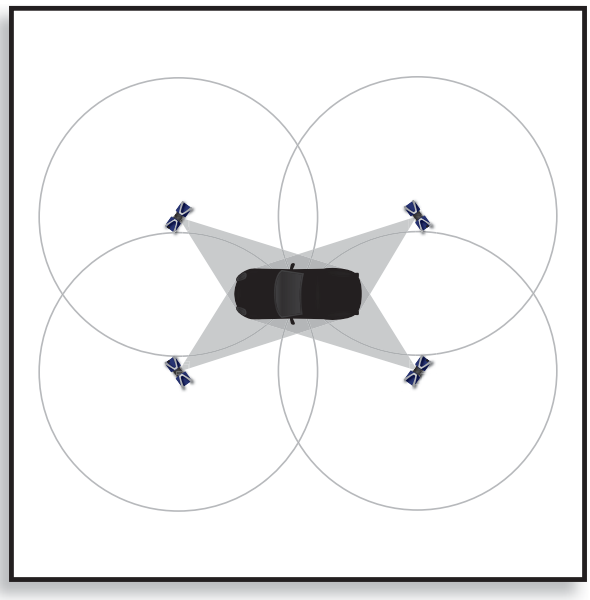
Angle to the Object or Area of Interest

Multiple scans captured from different angles provide the most complete three-dimensional image. Selecting proper angles can reduce the number of required scans. Position the scanner at angles to the object of interest that will give you the best line of sight for capturing the necessary details and ensuring that scans contain overlapping areas.

Angle – Without Overlap



Angle – With Overlap



Angles can be adjusted both horizontally and vertically; consider capturing some scans from higher and/or lower scan positions.

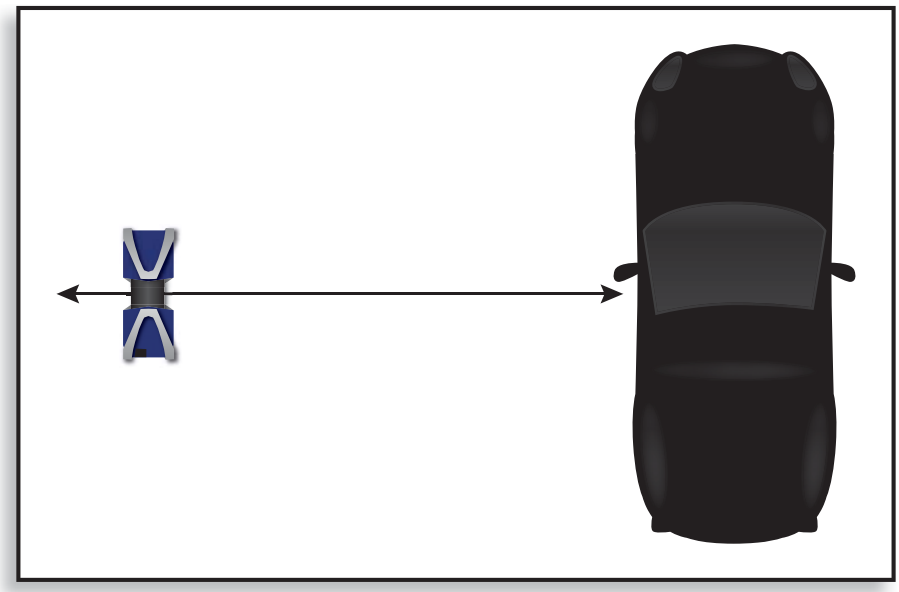
Bisecting

Bisecting refers to positioning the scanner so the start-stop point splits an object in the scan data.

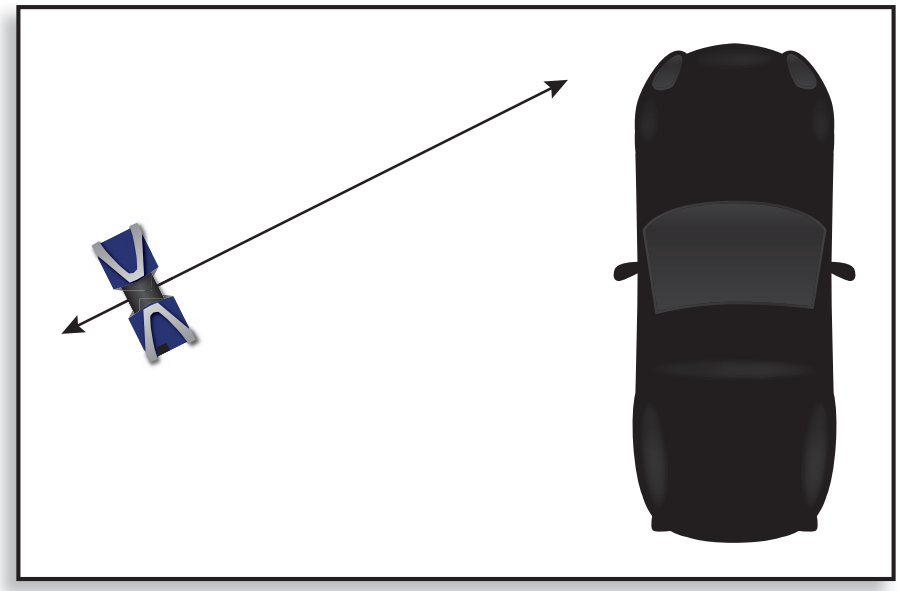
Do not position the scanner so that the start/stop point is on the object of interest. If the entire scan area is of interest, position the scanner so the start/stop point is on the area with the least amount of detail, such as a flat wall.

The start/stop point of the scanner is along the scanner's *x* axis, in line with the power inlet.

Bisecting the Object of Interest



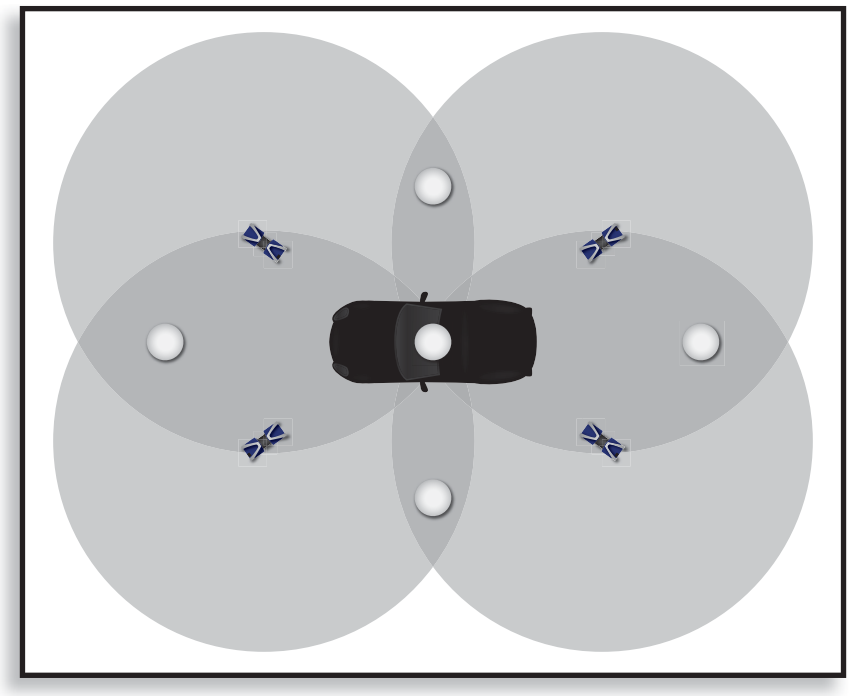
Angled to Avoid Bisecting the Object of Interest



Target Arrangements

Even if you plan on using targetless registration, it is recommended that you use targets in your scan project to give you more options for ensuring successful registration. Position the scanner so targets can be arranged in overlapping scan areas.

Targets Arranged in Overlapping Areas



Lesson 4:
Target Arrangements

This lesson explains the importance of target arrangements, which include target placement and target mounting. Arranging and mounting targets carefully ensures you are able to register scans successfully.

The arrangement of the targets in relation to one another and in relation to the scanner position is critical to the registration process. If the targets are not arranged properly, then registration cannot be done automatically, and will have to be done using other methods.

There are several guidelines you should follow to ensure successful registration. Planning ahead and arranging the targets carefully will save time and prevent problems during registration.

Factors to consider when arranging targets include:

- Number of targets
- Distance from the scanner
- Line of sight
- Unique patterns
- Spacing
- Angle to the scanner
- Bisecting
- Mounting

Number of Targets

Mathematically, at least three common reference objects are required for registration. If sensor data, such as **Inclinometer** data, is used, then only two targets are required.

Using more than three targets is recommended in case one or more are not adequately visible, and to allow the registration to be refined, or made more accurate.

However, using too many targets can add confusion and make it difficult to identify which targets correspond to one another.

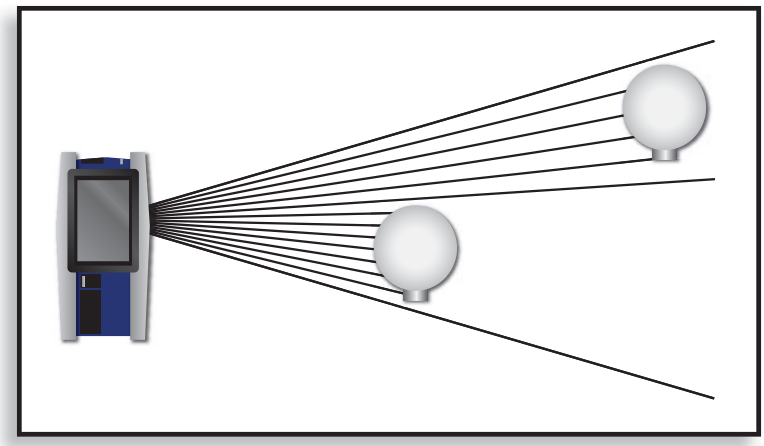
Distance from the Scanner

The distance that a target can be placed from the scanner depends on many factors. Light, moisture, and dust can reduce the scanner's range. Adjusting the **Quality** setting can help compensate for these conditions, but also increases the **Scan Duration**.

The two factors that most affect distance are the **Resolution** setting and the size of the target. For example, when using checkerboard targets printed on letter-size paper and a **Resolution** setting of 1/4, the targets should not be placed more than 50 feet from the scanner.

The **Resolution** setting affects maximum distance because it determines the **Point Distance**. Because the **Point Distance** increases with distance from the scanner, placing a target too far from the scanner can result in too few points captured on the target.

Point Distance



Increasing the **Resolution** setting and the size of the target increases the number of points captured on the target. Increasing the **Resolution** setting also increases the **Scan Duration**; it may be better to place the target closer to the scanner.

For example, given a **Quality** setting of 4x, **Scan with Color** off, and a 140-mm-diameter sphere, the following maximum distances are generally recommended:

- **Resolution** setting: 1/16, maximum distance: 15 feet
- **Resolution** setting: 1/1, maximum distance: 232 feet

Maximum Distance

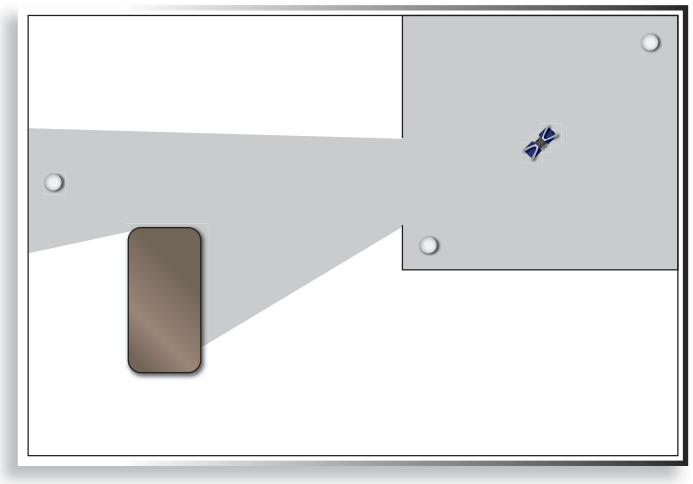
Resolution Setting	Point Distance		Maximum Distance	
	in. at 30 ft	mm at 10 m	ft	m
1/16	0.884	24.54	15	4.5
1/10	0.552	15.34	25	7.5
1/8	0.442	12.27	32	10
1/5	0.276	7.67	39	12
1/4	0.221	6.14	63	19
1/2	0.110	3.07	129	39
1/1	0.055	1.53	232	70.5

Line of Sight

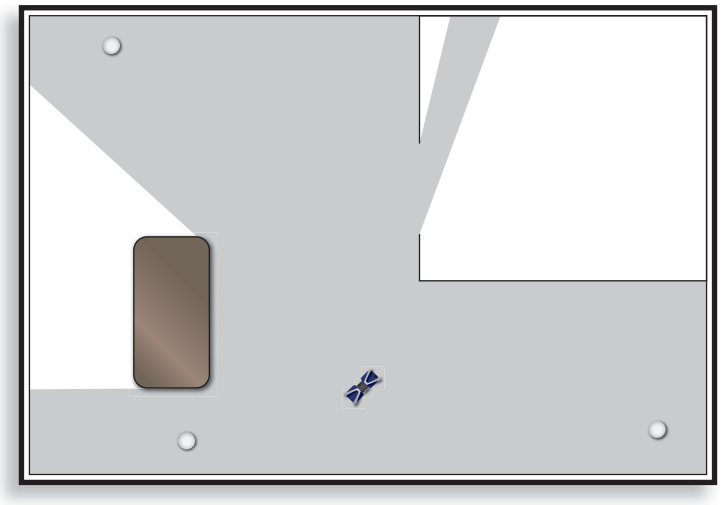
Arrange targets so that there is a clear line of sight from the scanner to the targets, and ensure that each target is visible from more than one scanner position.

For example, if a room requires two scans, then arranging the targets with a good line of sight to each scanner position may not ensure that each target is visible from both scanner positions. It is important to take both scanner positions into consideration.

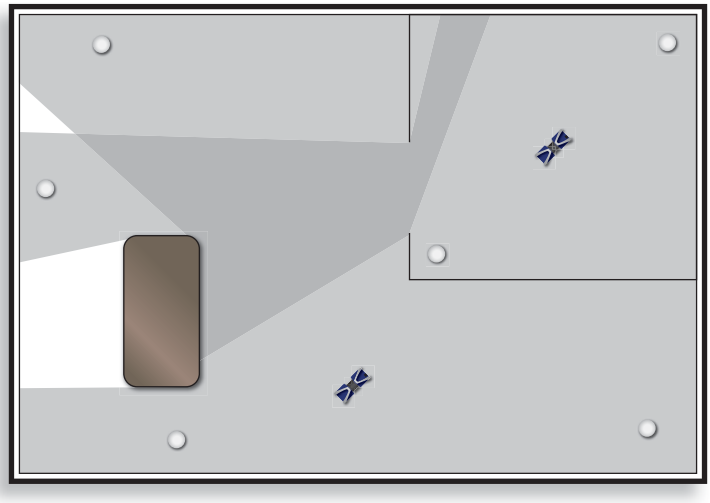
Good Line of Sight – First Scan



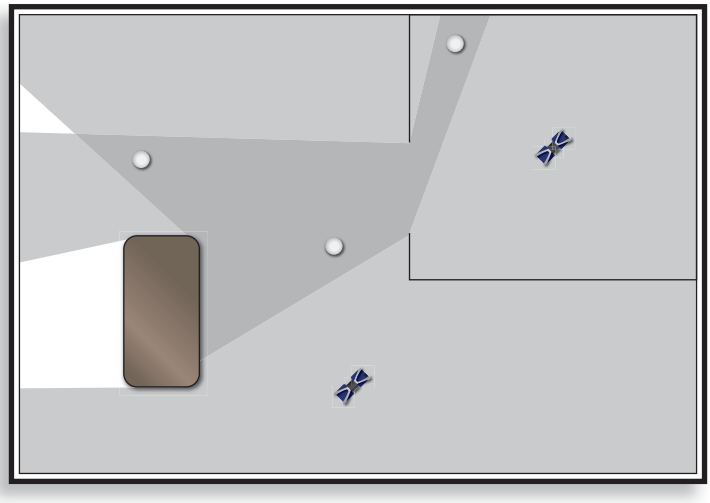
Good Line of Sight – Second Scan



Poor Line of Sight – Both Scans



Good Line of Sight – Both Scans

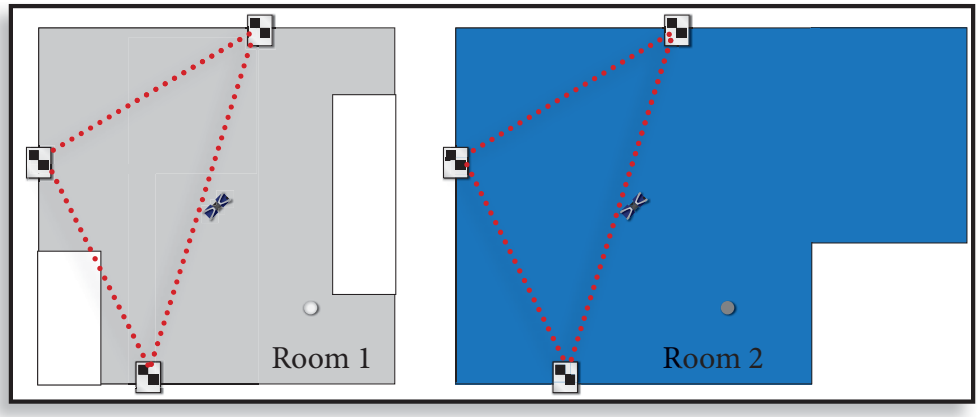


Unique Patterns

If targets are arranged in similar patterns, SCENE will detect the similarity and align the patterns.

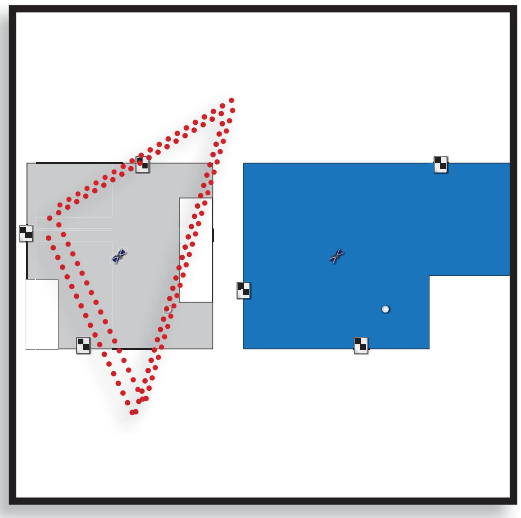
Arrange groups of targets in unique patterns.

Two Rooms With Similar Patterns



Similar Patterns Aligned

SCENE will interpret the two different rooms as the same due to the similar pattern arrangement.

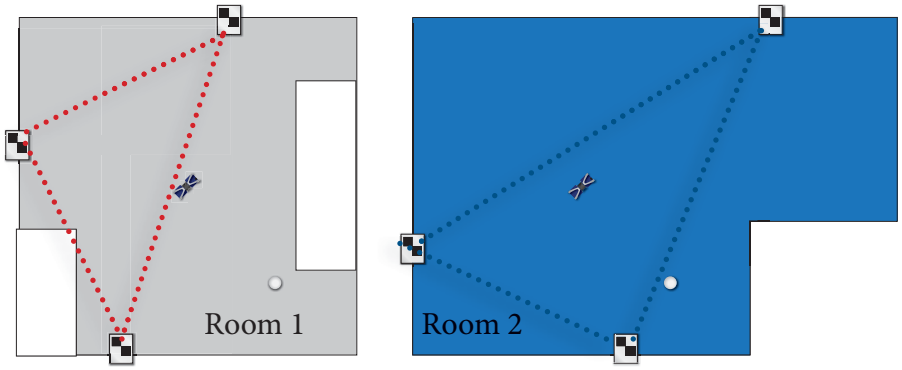


Alignment Error

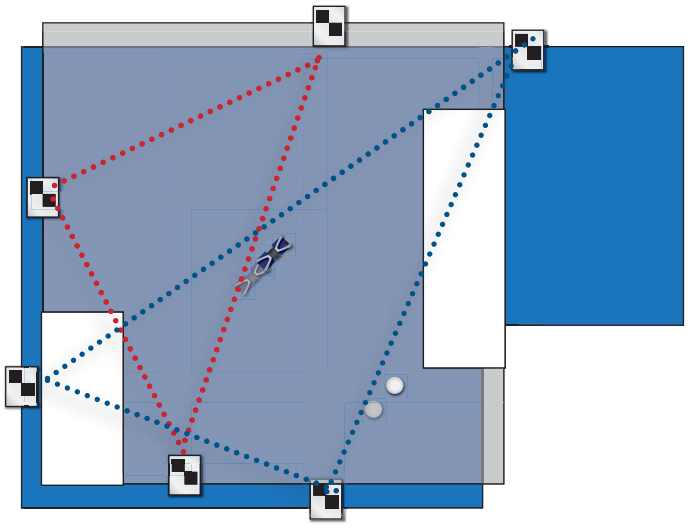
Two Rooms with Unique Patterns

Unique Patterns Aligned

Note the patterns do not overlap, so SCENE will correctly interpret them as individual scans.



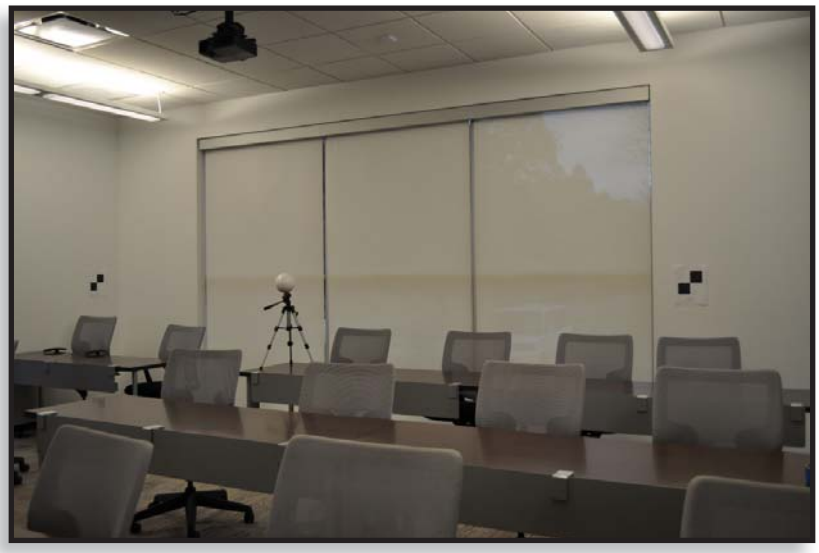
Rooms differentiated;
no alignment error



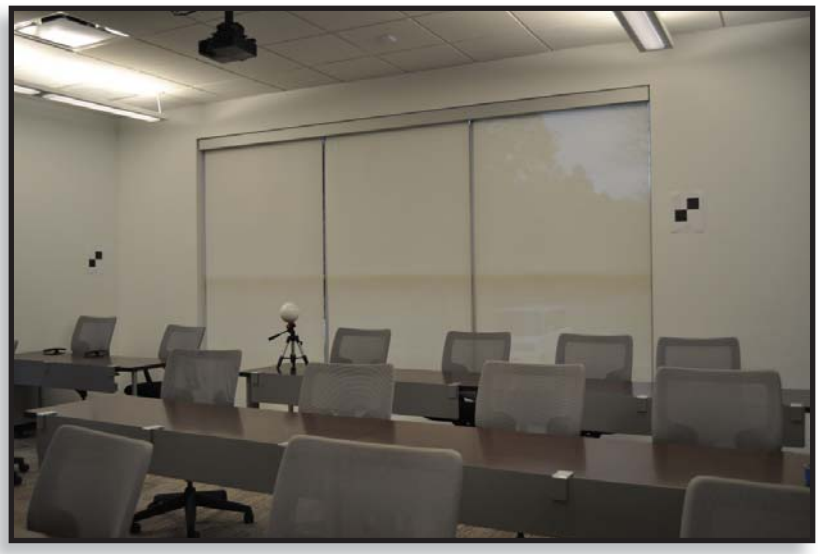
Height

Ensure that the targets are arranged in unique patterns in three dimensions by varying the height of the targets. You can vary the height using surfaces in the scan area, such as tabletops, or by other means, such as tripods.

Similar Patterns – Height



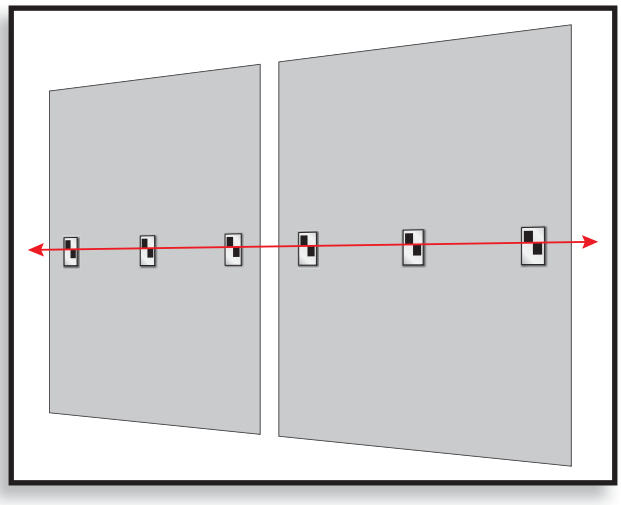
Unique Patterns – Height



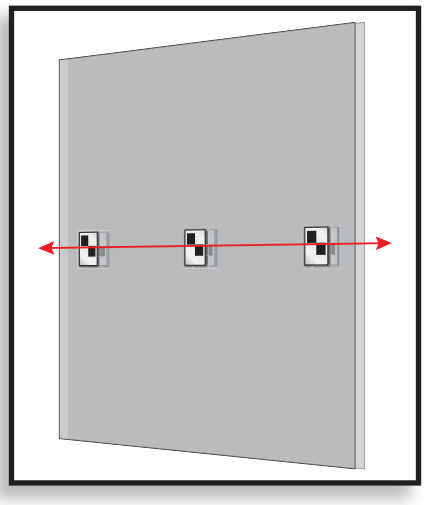
Straight-Line Pattern

When creating unique target arrangements, be sure not to arrange targets in a straight line. When targets are placed in a straight line, the line acts as an axis during registration. The scans can align around the axis in an infinite number of ways.

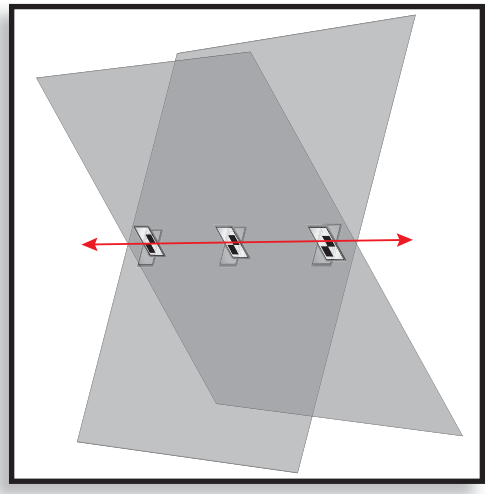
Straight-Line Pattern



Straight-Line Pattern Aligned



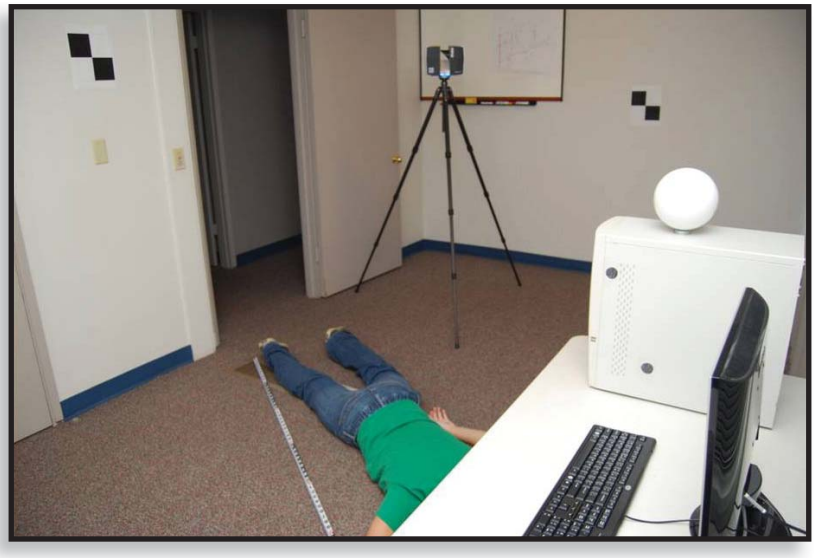
Straight-Line Pattern Aligned (Axis)



Target Types

Another way to ensure that each arrangement of targets is unique is to use more than one type of target. Using both spheres and checkerboards makes it easier to distinguish one arrangement from another.

Multiple Target Types

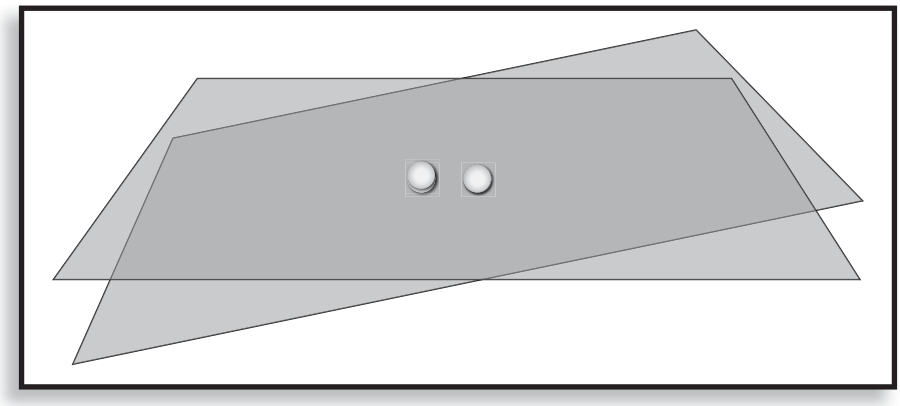


Spacing

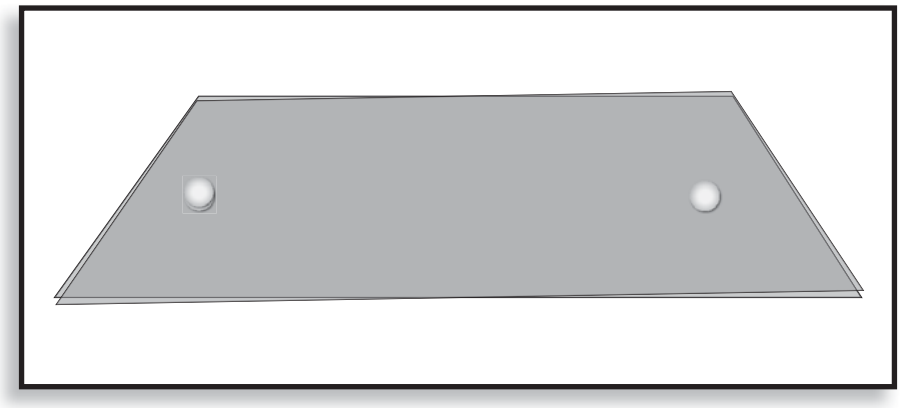
Targets should be spaced as far apart as possible within the overlapping scan areas.

Spacing out the targets reduces angular error.

Target Spacing (Poor Arrangement)



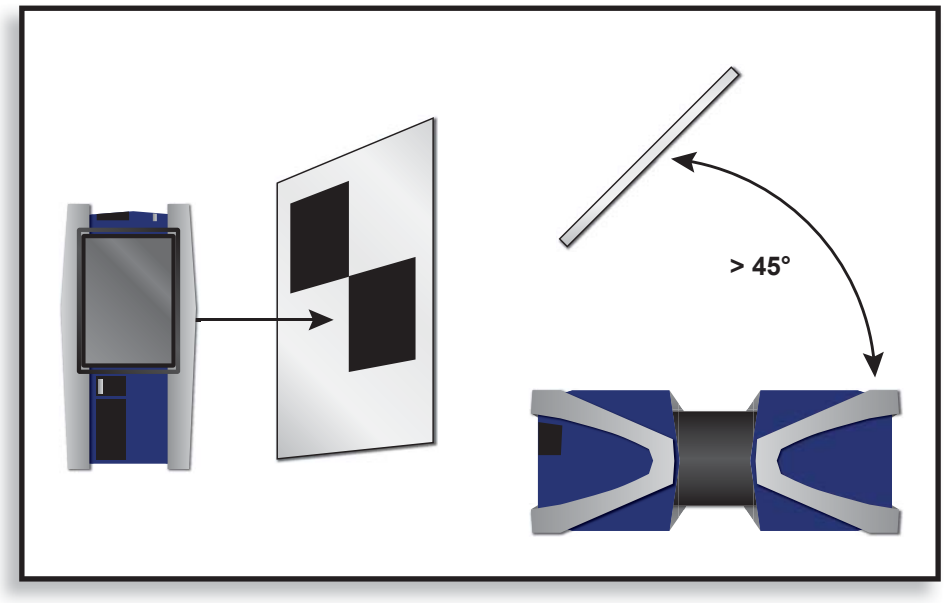
Target Spacing (Good Arrangement)



Angle to the Scanner

When using checkerboards, arrange them so they are facing the scanner. SCENE may not recognize a checkerboard mounted at an angle greater than 45 degrees.

Target Angle to the Scanner

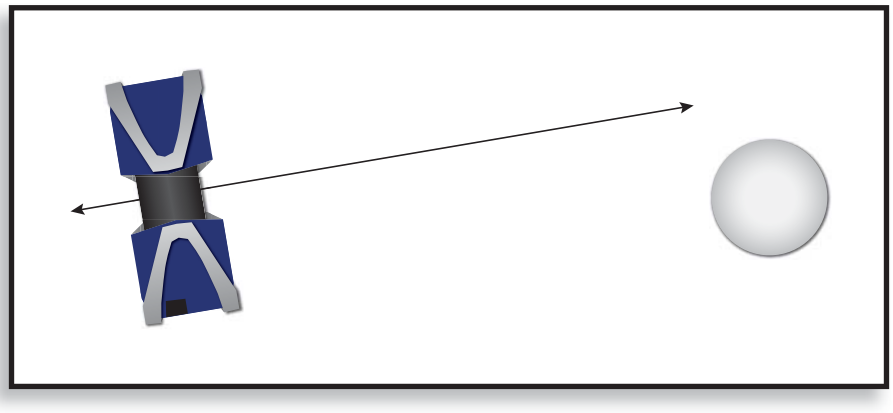


Bisecting

Arranging targets at the start/stop point of the scan is called bisecting the target, and may prevent the target from being recognized in SCENE. Be sure to place targets completely within the scan area, and not at the start/stop point.

Bisecting the Target

Angled to Avoid Bisecting the Target



Mounting Targets

In addition to mounting targets on objects and features that exist in the scan area, targets can be mounted using:

- Magnets
- Tripods
- Metal washers
- Cones

When mounting targets, keep the following guidelines in mind:

- Avoid obstructions.
- Mount checkerboards securely on flat surfaces.
- Do not mount targets on movable objects; if an object can be moved, it probably will be moved.
- Do not mount spheres with flat magnets on rounded surfaces because they can wobble.

Lesson 5:
Scanning Strategies

This lesson explains some of the basic scanning strategies that can be used, depending on site conditions and other factors that affect your scan project. Understanding and practicing scanning strategies allows you to adapt the elements of each strategy to individual scan projects.

There are several different strategies that can be used to maximize the efficiency of a scan project. Which strategy you select depends on the size of the project, whether you will be using targets, the number of targets you have, and other factors.

There are three general types of strategies:

- Centralized – Involves placing either the object of interest, the targets, or the first scan in the center of the scan area.
- Traversing – Involves moving targets from one scan area to another, and linking adjacent scans with targets arranged in the overlapping scan areas.
- Detail with an Overview – Involves capturing a low-resolution overview scan of the entire area, and then scanning a smaller area at a higher resolution.
- Targetless – Use sensor data, ensure at least 30 percent overlap, and capture scans consecutively.

Scanning strategies can be combined and altered for each scan project.

Centralized Strategies

Centralized strategies involve placing either the object of interest, the targets, or the reference scan in the center of the scan area.

Use Centralized strategies when the object or area of interest is small enough that you can arrange all of the targets before you begin scanning.

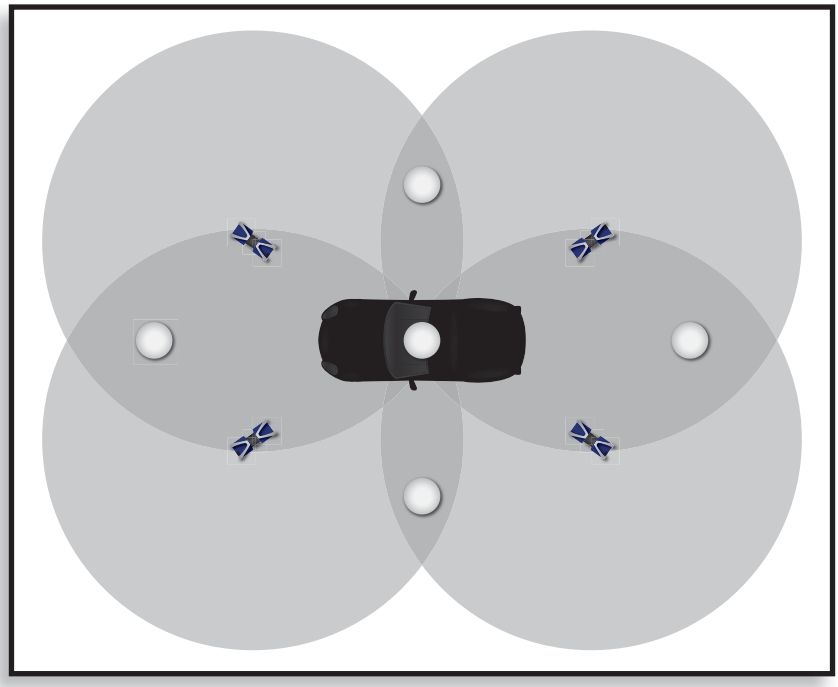
Central Object of Interest

The Central Object of Interest strategy involves arranging targets and positioning the scanner around the object of interest.

Because the object of interest is centralized, the scanner has a clear line of sight to most, if not all, of the targets.

Do not place the targets directly between the scanner and the object of interest, to avoid creating an obstruction. Because the scanner captures 360 degrees, the targets can be placed to the side of and behind the scanner positions. Spacing out the targets this way will help ensure accuracy during registration.

Central Object of Interest Strategy



Central Targets

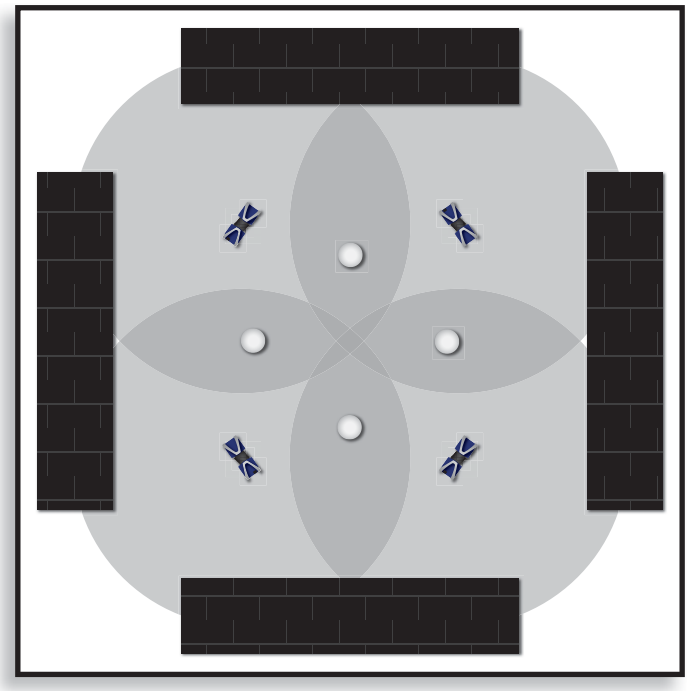
The Central Targets strategy involves arranging targets in the center of the scan area and positioning the scanner around the targets.

With this scanning strategy, all of the scans are registered using the same group of targets.

The Central Targets strategy can be used when you have a limited number of targets.

A disadvantage to using the Central Targets strategy is that the targets are arranged close together, which is not recommended for registration.

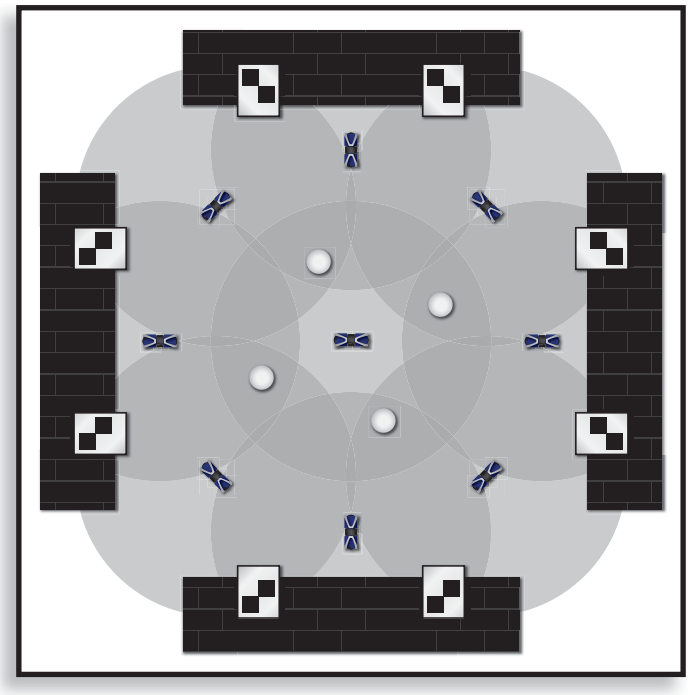
Central Targets Strategy



Central Reference Scan

The Central Reference Scan strategy involves capturing a central reference scan and arranging targets and positioning the scanner around the initial reference scan.

Central Reference Scan Strategy



Traversing Strategies

Traversing strategies involve moving targets from one scan area to another, and linking adjacent scans with targets arranged in the overlapping scan areas.

Use Traversing strategies when the object or area of interest is large enough that you cannot place all of the targets before you begin scanning, and must move targets from scan area to scan area.

When using traversing strategies, targets are arranged and moved in groups.

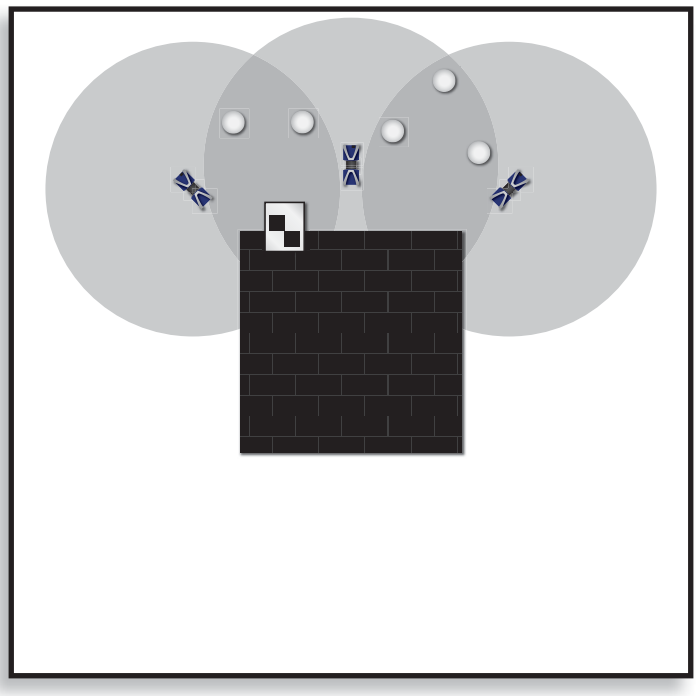
Open Traverse

The Open Traverse strategy involves linking each scan to the previous scan by moving targets.

It is best to begin by planning target arrangements and scanner positions for the first three scans. First, identify the overlapping scan areas, based on the maximum distance, as determined by the **Resolution** setting. For example, an outdoor scan, with a **Resolution** setting of 1/4 will have a maximum distance of approximately 63 feet, or 19.3 meters.

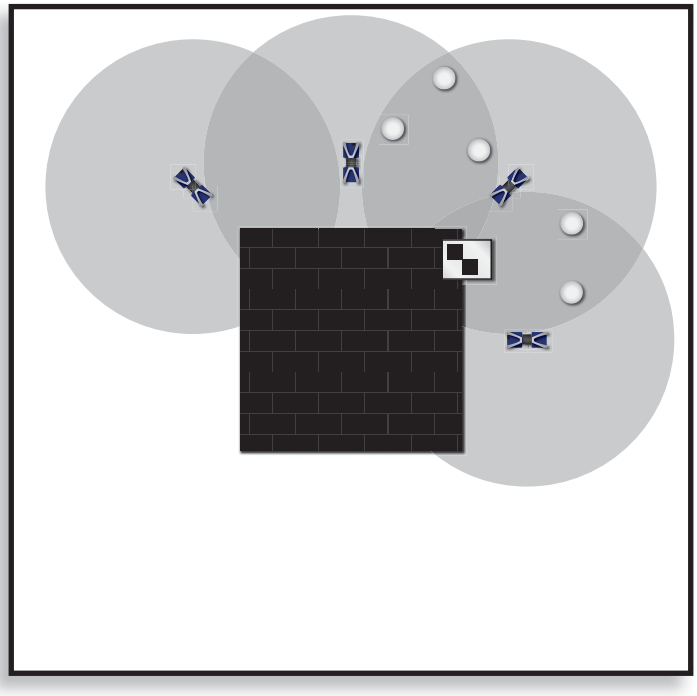
Then arrange the first two groups of targets within the overlapping scan areas. Capture the first and second scans.

Open Traverse Strategy – First Three Scans



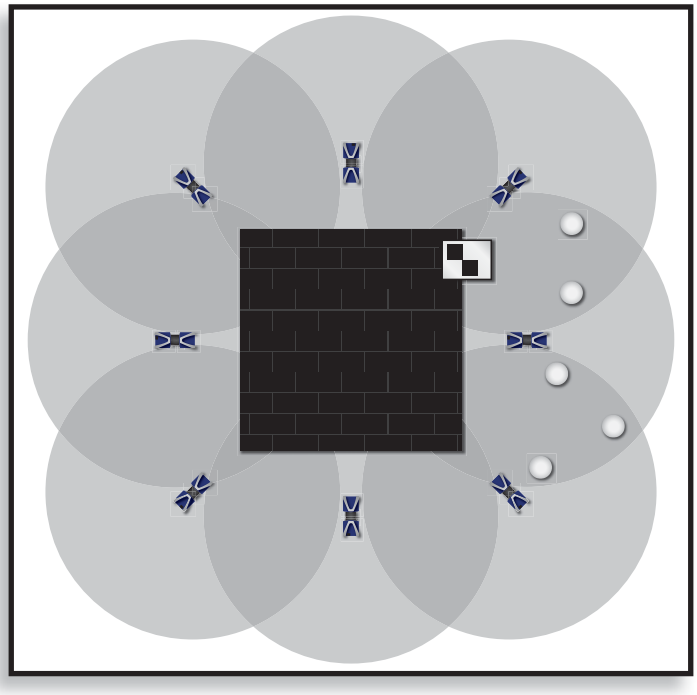
Before capturing the third scan, identify the overlapping areas between the third and fourth scans, and move the first group of targets to that area. **Do not** move the second group of targets, which is between the second and third scans.

Open Traverse Strategy – Fourth Scan



Capture the fourth scan. Continue identifying overlapping scan areas and moving the groups of targets as needed.

Open Traverse Strategy – All Scans

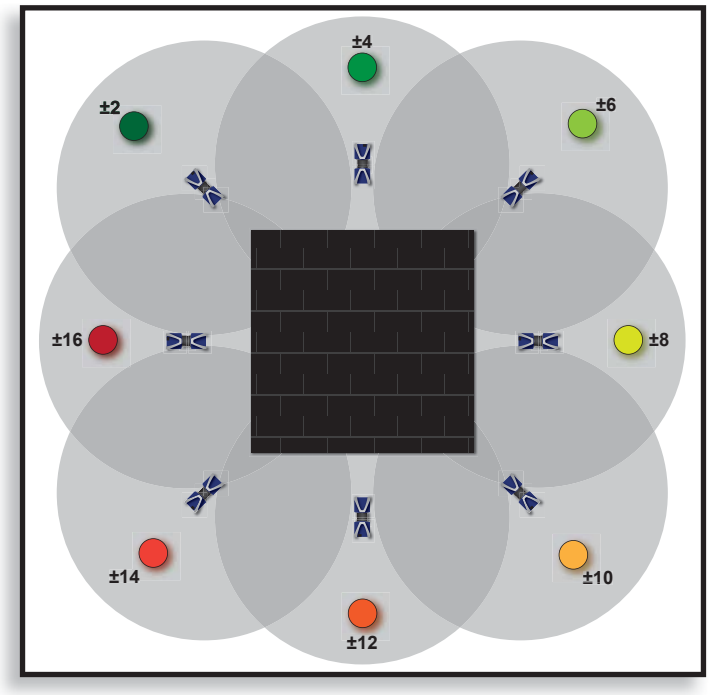


Error

During registration, SCENE designates the first scan as the reference scan, and all subsequent scans are aligned to this reference scan. Each scan position contains a small amount of error (±2 mm), and this error accumulates with each subsequent scan.

While the first scan has an error of ±2, the second scan has an error of ±4, the third scan has an error of ±6, and so on. This can lead to a significant amount of error after several scans.

Open Traverse Strategy – Error



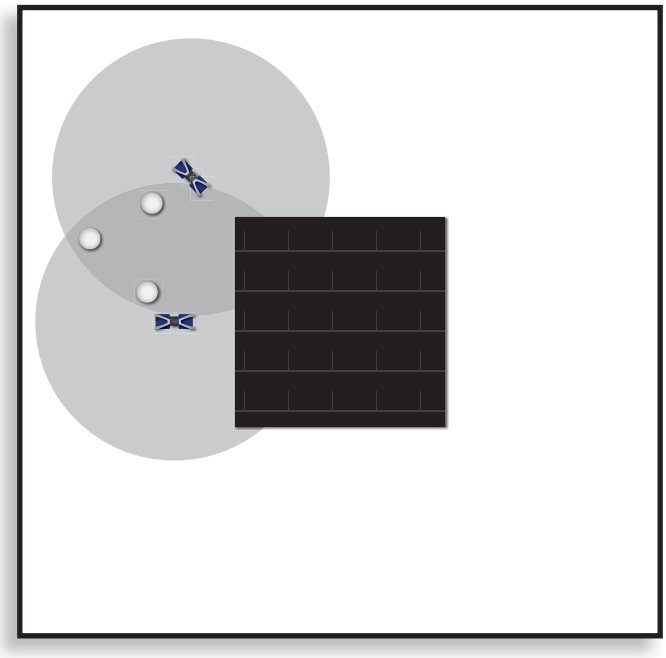
The accumulation of error can be mitigated by using the Closed Traverse strategy.

Closed Traverse

The Closed Traverse (or Closed Loop) strategy involves adding an additional step to the Open Traverse strategy and linking the first and last scans.

To begin, identify the overlapping scan areas between the first scan and the last scan. Arrange a group of targets in that area.

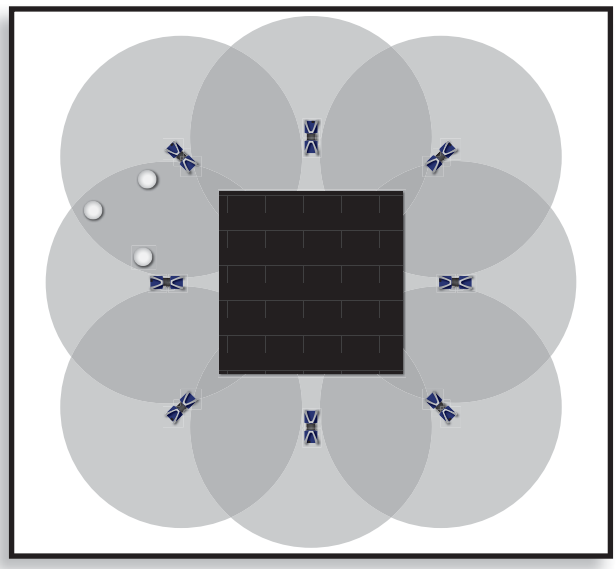
Closed Traverse Strategy – First and Last Scan



This group of targets will remain in place until you have completed the final scan in the Closed Traverse strategy.

Then plan target arrangements and scanner positions for the first three scans. Continue with the Traversing strategy.

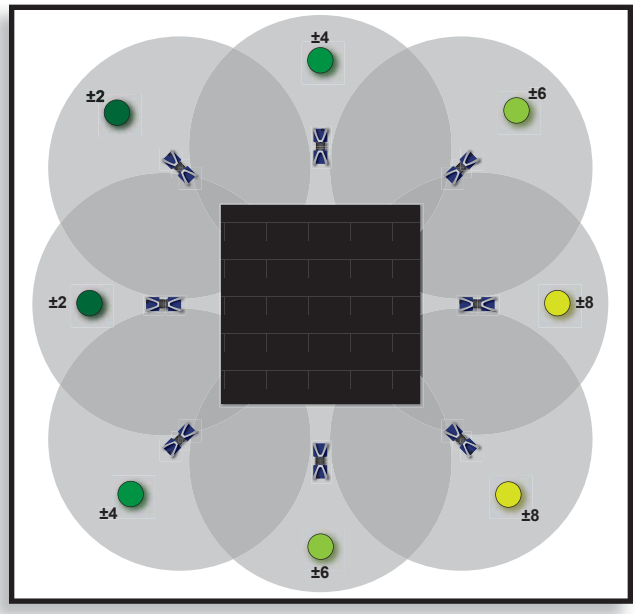
Closed Traverse Strategy – All Scans



Error

Linking the first and last scans reduces the error for all of the scans.

Closed Traverse Strategy – Error



Targetless Strategy

To ensure there is enough overlap between scans, you will need to take more scans than for **Target Based** registration. While this adds time to the scan project, the fact that you don't need to arrange and move targets also saves time.

It is best to use a linear approach and locate each subsequent scanner position adjacent to the previous scan position.

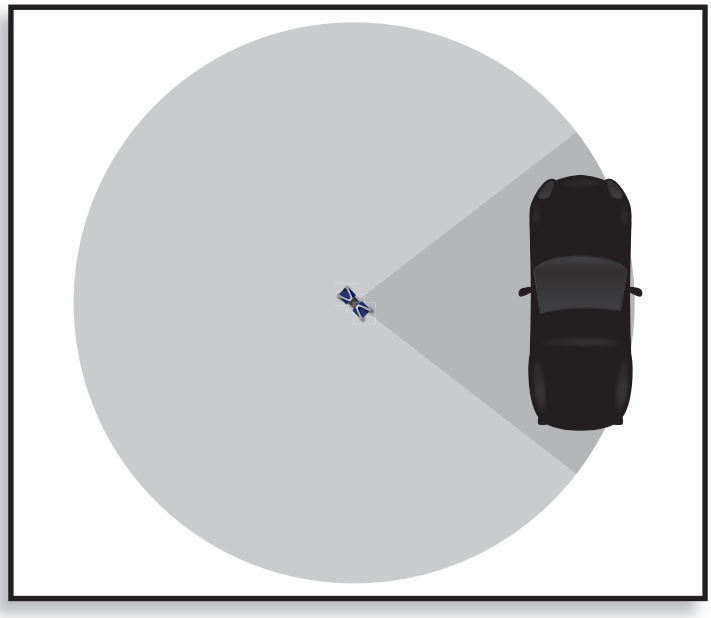
Targetless registration requires at least 30 percent overlap between scans. To ensure adequate overlap, locate each subsequent scanner position within range of the previous scanner position.

Detail with an Overview Strategy

The Detail with an Overview strategy involves capturing a low-resolution overview scan of an entire area, and then scanning a smaller area at a higher resolution.

Use this strategy when a smaller, high-resolution scan needs to be captured within a larger context.

Detail with an Overview Strategy



This strategy will be discussed in more detail later in the training.

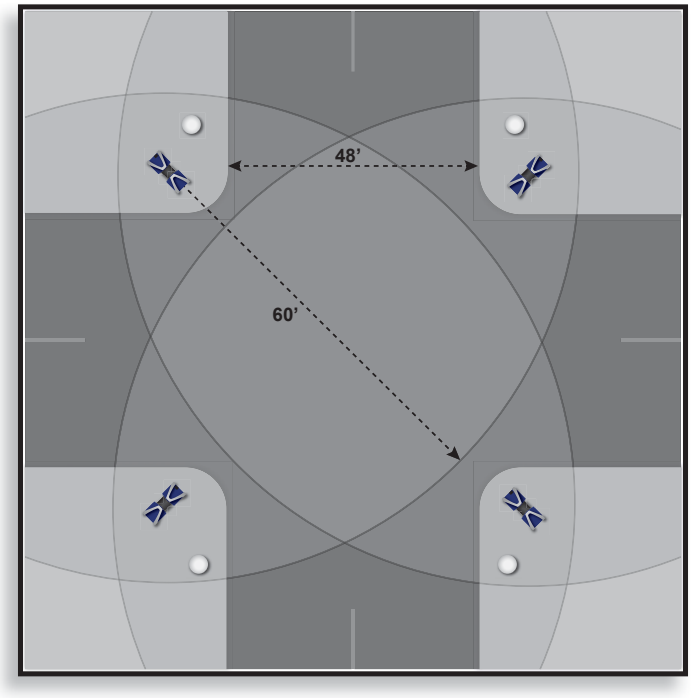
Examples

Seeing real-world examples of different scanning strategies can help you decide what strategies might work for you.

Intersection Example 1

This is a simple layout because each target is visible from every scanner position. However, it is made more complicated by the fact that the crew must stay out of the road. The four targets are placed in overlapping areas on the sidewalk. In addition to the spherical targets used here, you can also attach checkerboard targets to streetlights, signs, and other objects in the scan area.

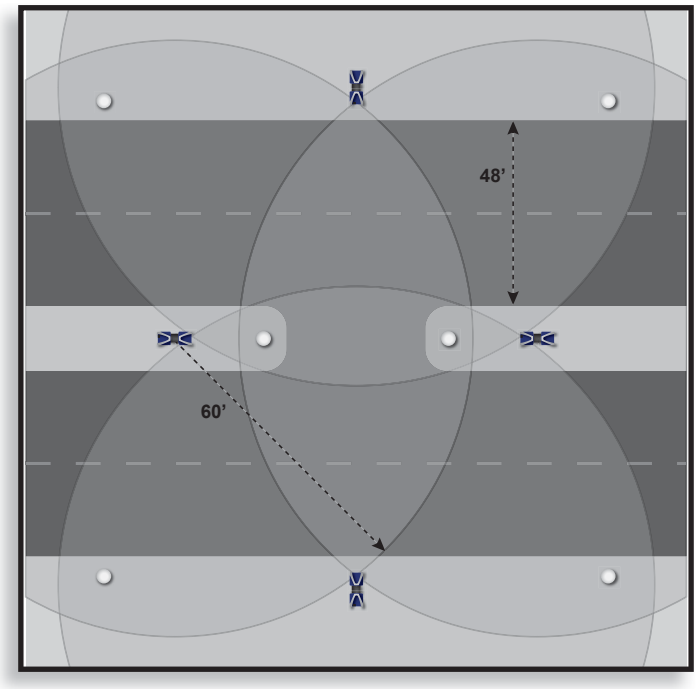
Intersection Example 1



Intersection Example 2

In this example, a higher **Resolution** setting is required to adequately capture the targets. Another option, which would allow a faster scan with a lower **Resolution** setting, is to use larger targets.

Intersection Example 2



Site Sketches

During project planning, site sketches can help you select proper target arrangements, as well as scanner positions. Site sketches can also be used during registration to clarify how scans relate to one another.

Site Sketch