

GelSight Mobile



User Manual

Version 2.0

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1 Introduction

1.1 About this Manual

The purpose of this manual is to provide a description of the GelSight Mobile System and to describe the best practices for using GelSight Technology. While this manual provides a detailed introduction to the GelSight System, please contact our product support team if you have any additional questions. Our team can be reached via email at support@gelsight.com.

This manual is dedicated to the GelSight Mobile System equipped with the 0.5X or 1.0X lens having the following Part Numbers:

- Model 0.5X: MB2-0501, MB2-0502, MB-0503, MB2-0065
- Model 1.0X: MB2-1001, MB2-1002, MB-1003

1.2 About GelSight, Inc.

GelSight, Inc. was founded in 2011 and specializes in systems for high-resolution imaging, measurement and tactile sensing using GelSight Technology. GelSight Technology is a unique imaging system that uses an elastomeric sensor. The technology was invented at the Massachusetts Institute of Technology and is licensed for commercialization by GelSight, Inc. GelSight, Inc. is based in the Boston area and has a distribution network covering North America, Europe, Israel, Brazil, South Korea and China.

The unique component of the GelSight System is an elastomeric sensor with a painted membrane on one side. This sensor is informally called: the gel, gel pad or gel cartridge, depending on its form factor. When pressed against any rigid surface, the gel conforms to the surface topography to reveal detailed features as small as one micrometer. The fact that GelSight Technology can image surface details of any material regardless of its optical properties is a unique advantage that leads to robust, fast, and portable measurement solutions with applications in surface metrology and robotic tactile sensing.

GelSight products bring competitive solutions to non-destructive testing and quality control in the manufacturing and maintenance of high-value products in the aerospace, automotive, and consumer electronics industries. The fully digital information provided by GelSight Systems makes the results compatible with industrial organizations based on the Internet of Things and Industry 4.0 concepts.

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CE CONFORMITY



The GelSight Mobile Probe complies with the following European Directives:

- Directive 2014/53/EU

Electromagnetic Compatibility



The GelSight Mobile Probe described in this manual has been tested and found to comply with Part 15 of the FCC rules and withISED Canada license-exempt RSS standard(s), which state that:

Operation is subject to the following two conditions:

- This device may not cause harmful interference, and
- This device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.

You are cautioned that any changes or modifications not expressly approved in this manual could void your authority to operate this equipment under above jurisdictions. The shielded interface cable recommended in this manual must be used with this equipment in order to comply with the limits for a computing device pursuant to Subpart J of Part 15 of FCC Rules.

RoHS AND REACH CONFORMITY



The GelSight Mobile Probe complies with the RoHS and REACH European Directives.

- Directives 2002/95/EC amended by 2011/65/EU

Restriction of Hazardous Substances in Electrical and Electronic Equipment - RoHS 2

- Directive EC 1907/2006

Registration, Evaluation, Authorization and Restriction of Chemicals - REACH

WEEE CONFORMITY



The GelSight Mobile Probe complies with the WEEE European Directive.

- Directive 2002/96/EC amended by 2003/108/EU

Waste Electrical and Electronic Equipment - WEEE

2 GelSight Mobile

2.1 What is GelSight Mobile?

GelSight Mobile is a high-resolution 3D measurement system that can quantify microscale surface geometry regardless of the optical properties of the material. This unique capability comes from the GelSight Sensor, or gel, which filters out the optical properties of the surface to provide fast and precise 3D measurements of optically challenging surfaces, such as metals, glass, and composites. Combined with computer vision techniques, the GelSight Mobile System can accurately measure down to micron scale critical features and defects such as scratches, dents, radii of curvature, gaps, and offsets.

The GelSight Mobile 0.5X System consists of a handheld probe with a capture field of view of 17.0 mm x 14.2 mm (0.66" x 0.56") connected to the USB 3.0 port of a Windows 10 Microsoft Surface Pro tablet or Windows 10 laptop (see *Figure 1*). The GelSight Mobile probe is powered directly via the USB 3.0 port on the tablet or laptop.

The GelSight Mobile 1.0X probe has a field of view of 8.5 mm x 7.1 mm (0.33" x 0.28") and is provided as a system with the same tablet or laptop.

The operating software of the system is called GSMobile and it allows for easy and repeatable measurements such as scratches, dents, radii of curvature, gaps, and offsets.

The system is delivered in a dedicated hard case for convenient transportation and protection of the system.

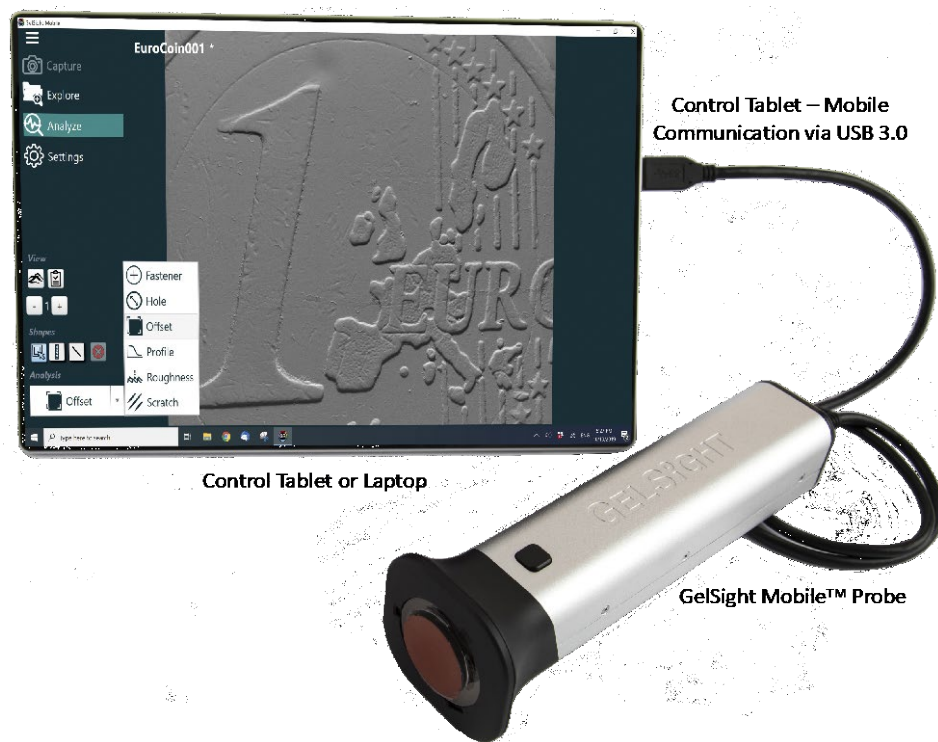


FIGURE 1: GELSIGHT MOBILE SYSTEM

2.2 General Principle

The GelSight Technology is based on the optical properties of a membrane on an elastomeric sensor which allows an imaging system to capture snapshots of the surface in contact with the membrane using controlled illumination. The GelSight Mobile System captures six (6) photos of the same object with different illumination angles in a very short time (see capture of the specimen in Figure 2). Next, a custom-developed 3D reconstruction algorithm calculates the slope and x-y position of every geometrical detail on the surface (see Figure 3 for the 3D rendering of the surface). The color map represents the altitude for each pixel of the domain. Unlike stereo imaging systems using multiple cameras, the GelSight Mobile System uses *photometric stereo*, a 3D measurement technique based on a single camera and multiple lights. This configuration allows for a simple handheld device that measures 3D surface detail within seconds.

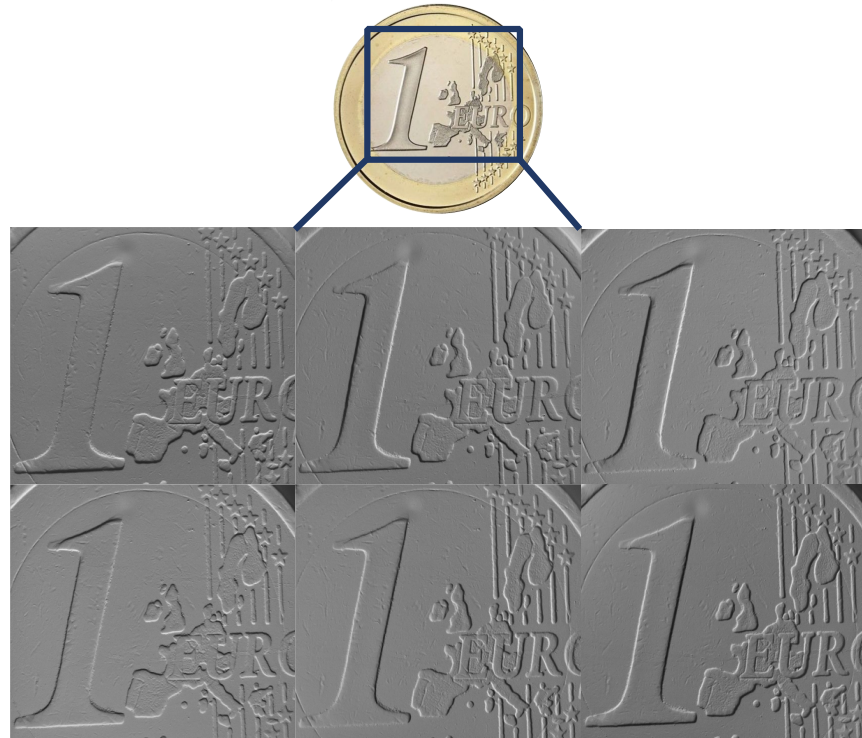


FIGURE 2: CAPTURE OF A SPECIMEN WITH 6 DIFFERENT ILLUMINATION ANGLES

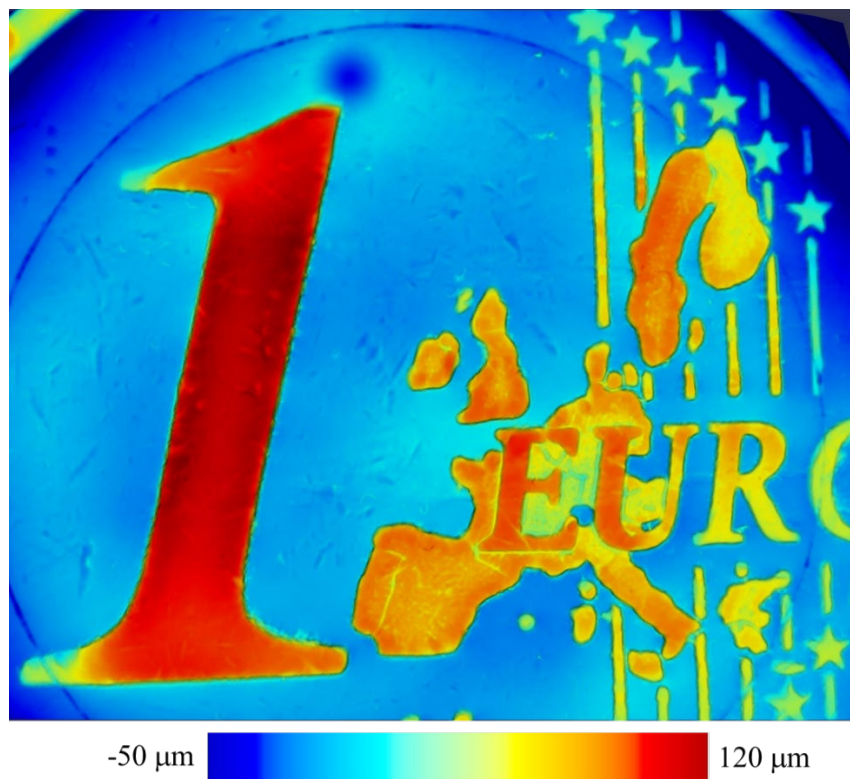


FIGURE 3: 3D RENDERING OF THE SPECIMEN

3 General Description of the Product

3.1 Description of the GelSight Mobile System

The GelSight Mobile System comes with the following components (see Figure 4):

- The Mobile Probe
- The Gel Cartridge
- A Windows 10 Tablet or Laptop
- The GSMobile Software
- A USB 3 Cable
- A 2mm Screwdriver for focusing the camera
- A Calibration Kit with a Flat Glass, a Ball Grid Array (BGA) cap, and a GelSight G500 calibration plate delivered with a certificate of conformity (As of the GelSight Mobile System V2.0, the G500 replaces the Rubert R513 Precision Reference Specimen.)
- A Hard Case with customized compartments



Mobile probe



Gel Cartridge



Windows 10 Tablet
or Laptop



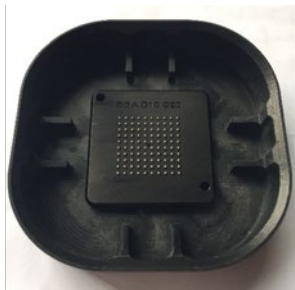
2mm hex drive



USB 3.0 cable



Hard Case



BGA D10 S20 target



Flat Glass target



GelSight G-500

FIGURE 4: GELSIGHT MOBILE SYSTEM

3.2 Description of the GelSight Mobile Probe

GENERAL

The GelSight Mobile Probe has been designed and developed by GelSight, Inc. It is a portable instrument providing autonomy and flexibility for the user. Its robust design and the choice of materials make it perfectly suited to challenging operational environments like a factory floor or maintenance facilities.



FIGURE 5: GELSIGHT MOBILE PROBE

MECHANICAL ARCHITECTURE

The GelSight Mobile Probe has a robust and reliable mechanical design (presented in Figure 6). The Principal Mechanical Functions are:

- To ensure the optical alignment from the reflective membrane to the camera to avoid any bias or deformation of the optical information across the field of view
- To maintain the gel cartridge in a precise position relative to the optical axis
- To propose an easy and ergonomic grip of the probe by the user.

The Mechanical Design uses rigid parts that are not subject to particular mechanical or thermal constraints.

Most of the Mechanical Components are made of anodized aluminum which ensures a corrosion resistant, durable, and aesthetic finish to the product.

All the screws are thread-locked, which guarantees a strong and robust assembly of the unit, thus avoiding FOD (Foreign Object Damage).

To guarantee electrical continuity between different components, anodization masking techniques are used according to the definition specified on the drawings of the components.

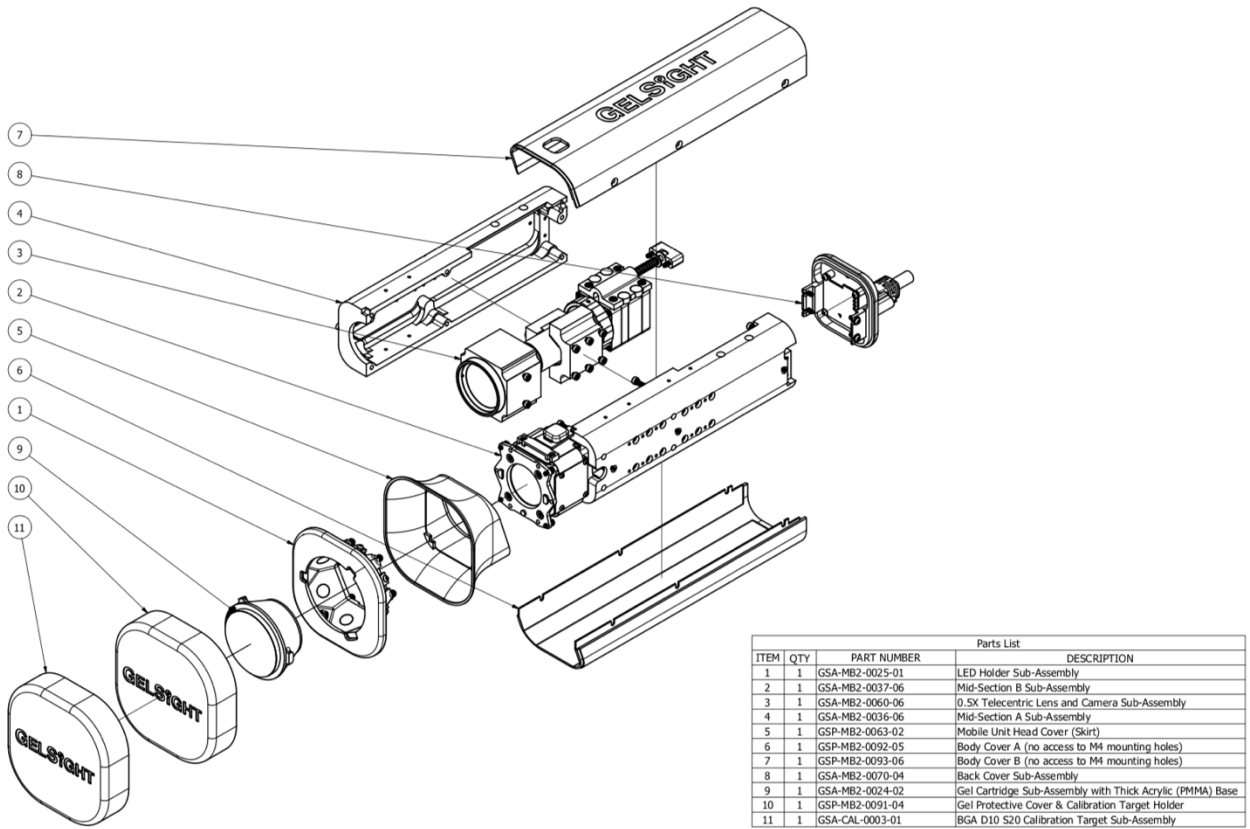


FIGURE 6: MECHANICAL DESIGN OF THE GelSIGHT MOBILE PROBE

THE GEL CARTRIDGE

GENERAL

The Gel Cartridge (Figure 7) represents a key component of the GelSight Mobile System. Its optical properties enable the system’s unique measurement capabilities. It is made up of an acrylic base, an elastomeric gel (either a thermo plastic elastomer (TPE) or silicone), and a painted membrane.

Acrylic Base:

This structure homogeneously diffuses the light used to illuminate the surface being measured. It also provides the mechanical structure necessary to align the Gel Cartridge with the imaging system, while also allowing the user to apply downward pressure to the elastomeric gel during a measurement.

Elastomeric Gel:

This unique, optically transparent material precisely conforms to the three-dimensional structures of any surface it is pressed against, enabling the imaging system to capture those structures.

Painted Membrane:

When this thin layer of optically reflective material is pressed against the measurement surface by the gel, it creates a consistent surface for imaging. This is what enables the GelSight Mobile System to measure surfaces accurately regardless of their reflective properties.

Each Gel Cartridge has its own serial number comprised of 9 characters (2 groups of 4 characters separated by a hyphen).

GelSight offers 2 different types of gel membranes:

- 1) High Friction Gel (ref. GEL-MB01) can be recognized by its shiny aspect and tacky membrane. This gel is well suited for measuring surfaces that are shallow, rough, or scratched.
- **Do Not Use High Friction Gel** on concave surfaces or on surfaces presenting cavities or hollow structures. Using High Friction Gel on these types of surfaces traps air between the gel and the surface, causing inaccuracies in the scan.
- 2) Low Friction Gel (ref GEL-MB02) can be recognized by its matte aspect and soft membrane. This gel has been developed to measure deep scratches and rougher surfaces such as cavities or porosities. The presence of microspheres at the surface of the membrane allows air to be evacuated through the micro channels enabling an accurate scan of the surface. (see the example in section 1.30).

GEL HEALTH

The Gel Cartridge is a consumable, and so will need to be replaced periodically. Its useful life is affected by two primary factors:

1. Number of uses: The Gel Health indicator in the software counts the number of times a cartridge has been used and uses a color code (described in the section on [Capture Mode](#)) as a guide to help organizations decide on the overall health of the gel. They are not a rule. There are many variables involved that affect the health (and ultimately the accuracy) of the gel, including: the abrasiveness of the surfaces being scanned, the working environment, cleanliness, care used when handling, etc.
Therefore, *as a general practice*, we suggest that gels are healthy and will capture accurately when still green (under 200 uses). Between 200 and 300 uses, in the yellow zone, may not provide an acceptable range of repeatability, so we recommend you recalibrate the cartridge or replace it. When gel use count reaches 300 and the color code turns red, regardless of how the gel is used, we recommend replacing with a fresh gel.
See also the section on [Special operation - precautions](#).
2. Lifetime: The Gel Cartridges have a lifetime of 12 months from the date of manufacture. This 'use by' date is posted on the cartridge packaging.

Regardless of type, the Gel Cartridge should be checked on a regular basis. This can be done directly by:

- Taking a capture of the flat glass and verifying the absence of damages or incrustated particles
- Checking the validity of calibration described in [Settings Mode, Section 1.19](#). (Note that, while all users can validate an existing calibration, only an Administrator-level user can perform a calibration.)

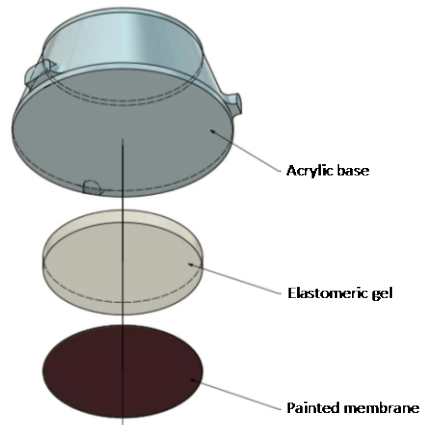


FIGURE 7: SCHEMATIC VIEW OF THE GELSIGHT MOBILE GEL CARTRIDGE

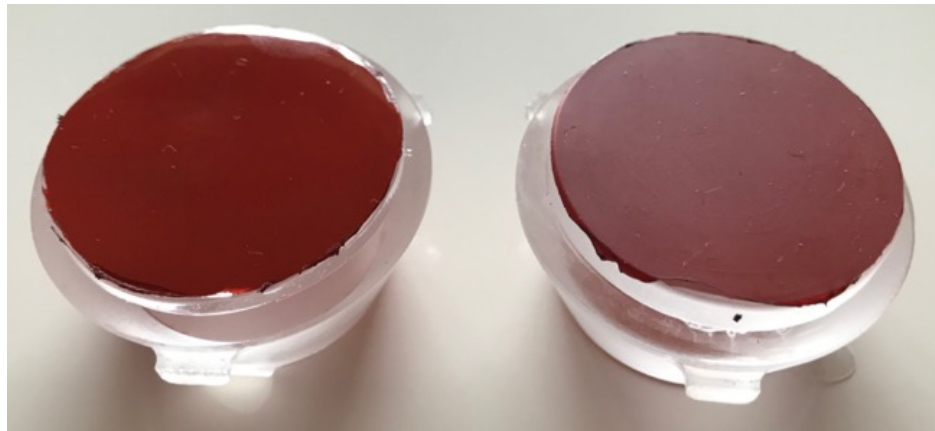


FIGURE 8: STANDARD GELSIGHT GEL CARTRIDGES

GEL-MBO1: HIGH FRICTION TPE GEL (SHINY ASPECT ON THE LEFT) - GEL-MBO2: LOW FRICTION TPE GEL (MATTE ASPECT ON THE RIGHT)

INSTALLATION OF THE CARTRIDGE

The Gel Cartridge is designed with three tabs that fit into matching slots on the Probe. There is a single large tab that fits in one location, guaranteeing that the Gel Cartridge is always in the same position and with the same focal distance with respect to the camera.

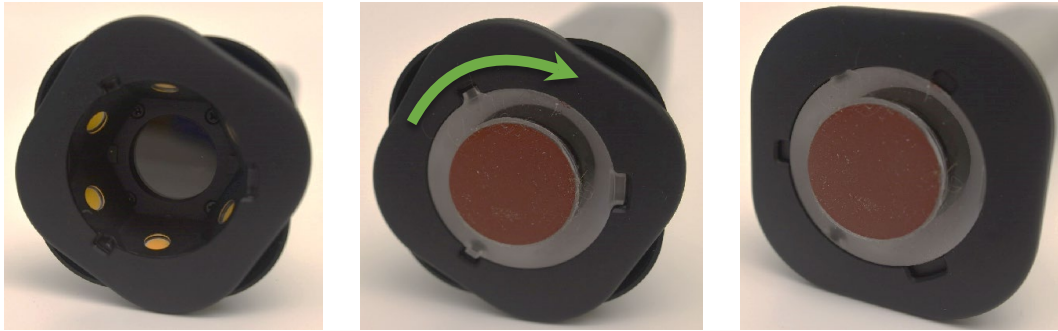


FIGURE 9: INSTALLATION OF THE GEL CARTRIDGE

To install the cartridge, follow these steps: (see Figure 9)

- Turn the locking ring counterclockwise to expose the slots in the LED holder
- Insert the cartridge and turn the locking ring clockwise
- The cartridge is now securely installed in the GelSight Mobile Probe
- Take care to avoid touching the membrane or the transparent back side of the acrylic disk when installing (or removing) the cartridge.

Note: Reverse these steps to remove the cartridge.

POWER SUPPLY

The GelSight Mobile Probe is powered by the tablet or laptop through the USB 3.0 connection (5 V DC, 900 mA max).

The power consumption of the Ximea MC050MG-SY camera is typically 2.85W. The power consumption of the LED of the Probe Lighting System is low. Overall power consumption is less than 3.5W.

This configuration allows a fully autonomous portable system to perform measurements on the shop floor, production lines or directly in the field, for controls or during maintenance operation.

In normal conditions, the GelSight Mobile Probe can be powered by the tablet's battery for approximately 2 hours.

Note: You can conserve the life of the battery in the tablet or laptop by turning the probe's lights off when they are not being used. Switch off the LEDs by clicking on the Live View Button (on the left side of the Capture window in Figure 43.) Click the Live View button again to switch them back on.

The components of the GelSight Mobile Probe are illustrated below in

Figure 10 and identified in Table 1.

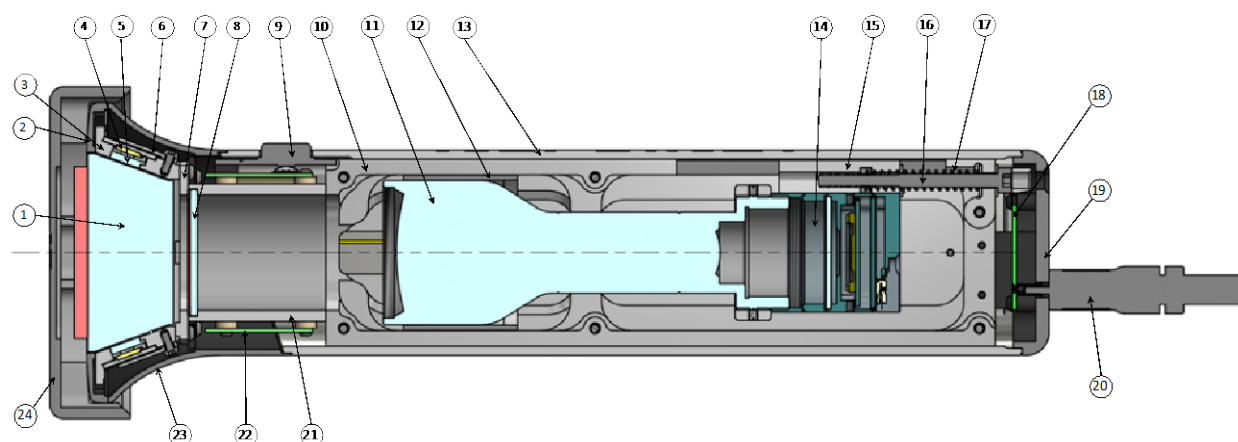


FIGURE 10: GELSIGHT MOBILE PROBE

Item	Description	Item	Description
1	Gel Cartridge with acrylic base	13	Body Cover
2	Locking Ring	14	Ximea 5 MPixel Camera
3	LED Holder	15	Camera Focus Adjustment Plate
4	LED Cap	16	Camera Focus Adjustment Screw
5	LED	17	Camera Focus Adjustment Spring
6	LED Mounting Cap	18	PCB Power Breakout
7	Locking Ring Spring	19	Back Cover
8	Protective Glass	20	USB 3.0 Cable ref. CBL-U3-3M0
9	Tactile Button	21	Mid -Section Body B
10	Mid-section Body A (1/2)	22	PCB LED, Tactile Button Control
11	Telecentric Optic Lens	23	Head Cover
12	Lens Mounting Spring	24	Protective Cap

TABLE 1: PRINCIPLE ELEMENTS OF THE GELSIGHT MOBILE PROBE

OPTICAL PATH

The gel's membrane reflects the light coming from the LEDs through the acrylic base and the elastomeric gel. Due to the opacity of the membrane, the GelSight Mobile System is not sensitive to external light sources or potential specular reflection of the controlled surface. The light is then redirected to the high frame-rate camera through a telecentric lens, which provides orthographic projection of the subject on the sensor of the camera.

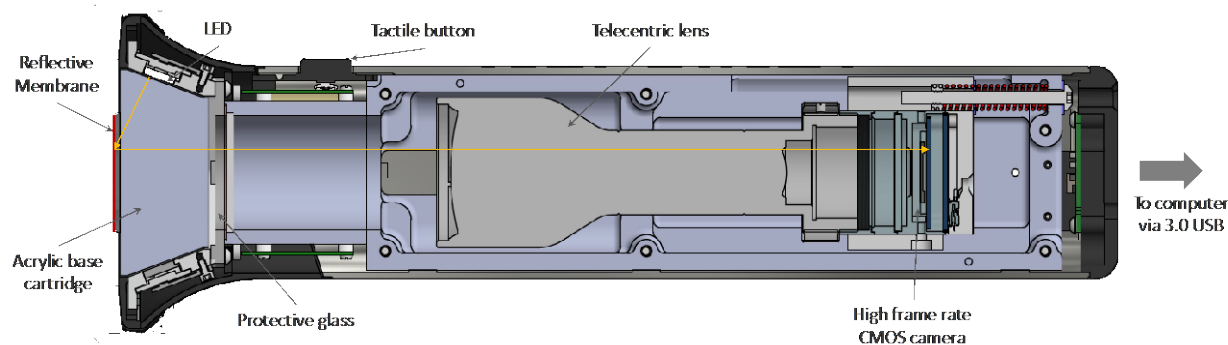


FIGURE 11: GENERAL PRINCIPLE OF THE GELSIGHT MOBILE PROBE

4 Technical Specification

The main technical characteristics of the GelSight Mobile Probe for the standard option are described here:

4.1 Dimension and Weight

- Model 0.5X: 6.6 x 6.6 x 21.5cm, 600g (2.6 x 2.6 x 8.46", 1.32 lbs)
- Model 1.0X: 6.6 x 6.6 x 21.5cm, 600g (2.6 x 2.6 x 8.46", 1.32 lbs)

4.2 Field of View:

- Model 0.5X: 17.0 x 14.2 mm (0.67 x 0.56")
- Model 1.0X: 8.5 x 7.09 mm (0.33 x 0.28")

4.3 Resolution in x-y plane: 5 MP camera (2464 x 2056)

- Model 0.5X: 6.9 microns (0.27 thou)
- Model 1.0X: 3.45 microns (0.13 thou)

4.4 Accuracy

IN THE X-Y DIRECTIONS

The Spatial Resolution in the X-Y plane is approximately 4 microns (0.00016 inches) for the Model 0.5X and 2 microns (0.00008 inches) for the Model 1.0X.

To determine the accuracy of the probe in the X-Y direction, GelSight used a certified test specimen with holes having diameters of 400, 600 and 800 microns. Each hole was measured 20 times by the same operator. The mean diameter obtained for each hole was compared to the actual value as certified by an independent laboratory, enabling the calculation of a global uncertainty in the X-Y direction (see Table 2). Measurements exhibit a global uncertainty between 0.23% and 0.34% for the range 400 to 800 microns.

Actual	Mean	Standard Deviation	Global uncertainty
396.2	395.9	1.4	1.0 (0.25%)
602.0	602.2	2.2	1.4 (0.23%)

	800.1	802.5	1.6	2.7 (0.34%)
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TABLE 2: MEASUREMENT RESULTS FOR CERTIFIED HOLE DIAMETERS (ALL QUANTITIES IN μM)

IN THE Z DIRECTION

To evaluate the accuracy of the system in the Z direction, GelSight performed a series of measurements on a certified test specimen with ten grooves having depths between 9 and 90 microns. This is known as the GelSight Groove Specimen, part number RSP-GT01. In this study, we measured each groove ten times, which led to a total of 100 measurements. We repeated this full measurement set on seven different days for a total of 700 measurements.

A statistical analysis of these measurements allows us to define a conservative error bound for scratch depth measurements at $4\text{ }\mu\text{m} + (4\%) * Z$, where Z is the nominal depth of the groove. Additional experiments are required to support a smaller error bound.



FIGURE 12: GROOVE DEPTH REFERENCE SPECIMEN RSP-GT01

It is worth mentioning that a single Gel Cartridge was used for the entire study. It was calibrated only once at the beginning of the study, using the standard calibration procedure in the GelSight Mobile software.

4.5 Calibration

Only Administrator-level users can perform calibrations.

GELSIGHT 500 CALIBRATION PLATE

As of GelSight Mobile System V2.0, we use the GelSight 500 calibration plate for Z direction accuracy. This target has a single, precisely-measured 500-micron groove, housed in a cap to make scanning easier. For more details, refer to How to Use the GelSight G-500 Calibration Plate.

RUBERT 513E REFERENCE SPECIMEN

Note: The Rubert 513E reference specimen is still available for use in GSMobile System V 2.0. We include its legacy description:



FIGURE 13: RUBERT 513E CALIBRATION TARGET

The Rubert R513E specimen has been delivered with numerous GelSight systems. Like the GelSight G-500 groove plate, the Rubert R513E specimen can be used as a calibration target. The R513E comprises 4 calibrated grooves (30, 200, 500 and 1000 microns) and is delivered with a Certificate of Calibration. We recommend using the 500 micron groove as a reference during the calibration protocol because it can provide calibration data that is valid for a wide range of depth measurements.

4.6 Repeatability and Reproducibility

To determine the repeatability and reproducibility of the GelSight Mobile System, a three-operator gage R&R study was conducted. The ten grooves of the specimen RSP-GT01 were measured three times each by three different operators. A single Gel Cartridge and calibration were used for the entire set of 90 measurements.

The results were exported from the GelSight Mobile software and entered into Minitab. A tolerance of 30 μm was used so that the statistical results could be displayed as both a percentage of the study variance and percent tolerance. Note that the choice of a 30 μm tolerance is arbitrary and usually depends on a customer specification for the process being evaluated. The statistical results for the GRR study are shown in the table below.

Source	StdDev (μm) (SD)	Study Vr (μm) (6 $\times$ SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	1.3346	8.008	5.34	26.69

TABLE 3: GAGE REPEATABILITY AND REPRODUCIBILITY ANALYSIS OF VARIANCE USING MINITAB SOFTWARE. THE PROCESS TOLERANCE WAS SET TO 30 μm FOR THE ANALYSIS.

4.7 Surfaces and Materials

Due to the reflective membrane of the elastomeric sensor, the GelSight Mobile System can measure rigid surfaces regardless of their optical properties. The materials can be transparent, highly reflective, translucent or opaque, such as metals, composites, glass, plastics, fabrics, leather, diamonds, wood, human skin, and more. There is a possibility that deformation may occur when measuring non-rigid

surfaces. For these cases, it is possible to use a softer gel. It is often possible to compensate for any low-frequency deviations of the shape using post-processing techniques in software.

However, the surfaces need to be clean and dry. No particles or liquids, such as solvents or oils, should be on the surface being measured since they may deteriorate the membrane.

4.8 Environment

- Optimal Ambient Temperature of Operation: 10 to +25°C (50 to 77°F)
- Ambient Temperature of Operation: 0 to +45°C (32 to 113°F)
- Ambient Temperature of Storage and Transportation: -20 to +60°C (-4 to 140°F)
- Relative Humidity, Non-Condensing (RH): 80%

4.9 Aspect Ratio Geometry Limitation

Since contact between the membrane and a surface is an absolute requirement for the GelSight Technology, only features with an aspect ratio (ratio between height and width) limited to 1.0 can be captured. For higher aspect ratios, the gel may not be in contact with the entire surface of the walls of the feature.

Due to the intrinsic design of the illumination system, shapes with vertical walls or steep slopes may not receive the necessary illumination to precisely reconstruct the 3D surface. Walls having an angle greater than 50° with regards to the horizontal will not be properly characterized (Figure 14).

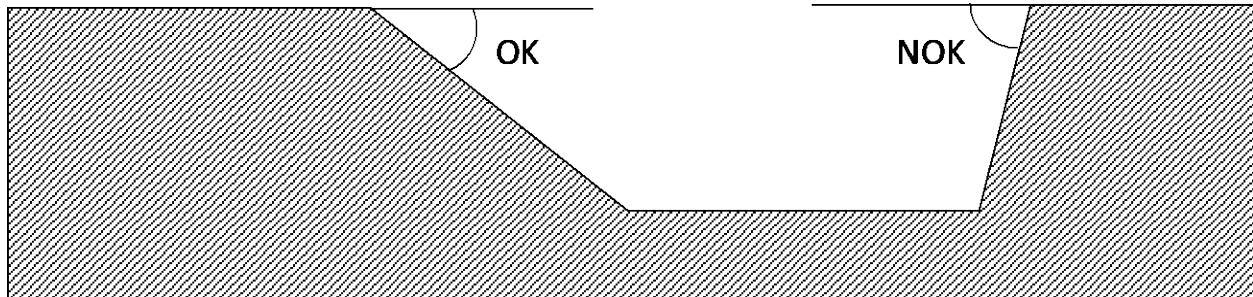


FIGURE 14: VERTICAL WALL LIMITS

5 GSMobile Software

GSMobile is a software application that supports all of GelSight, Inc.'s hardware systems, including the GelSight Mobile Probe. The software provides workflows for image capture (scanning), calibration, 3D reconstruction, and a variety of post-processing and analytical operations.

5.1 System and Storage Requirements

GSMobile has been developed to run on Windows 10 platforms and typically runs on a Microsoft Surface Pro tablet equipped with Intel Core i5 and 8GB of RAM or a laptop with the equivalent performances.

A capture with 3D reconstruction requires approximately 58 Mbytes, which means a 128 GBytes SSD can store more than 2,000 measurements.

5.2 Installation

To upgrade GS Mobile on a computer that has already had a previous version of the software installed, download and install the GelSight Mobile Software Package Installer (and executable file approximately 60Mbytes). It can be found at this link:

<https://gelsight.com/software-updates/>

Read and Agree to the License Agreement.

Run the Installer.

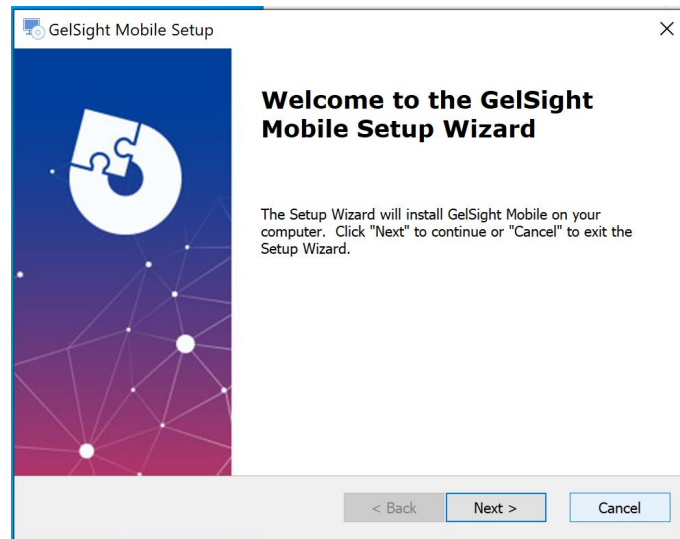


FIGURE 15: GELSIGHT GS MOBILE WINDOWS INSTALLATION - 1

Select the Install Location (Figure 16). You can leave the default location or change it to your own folder.

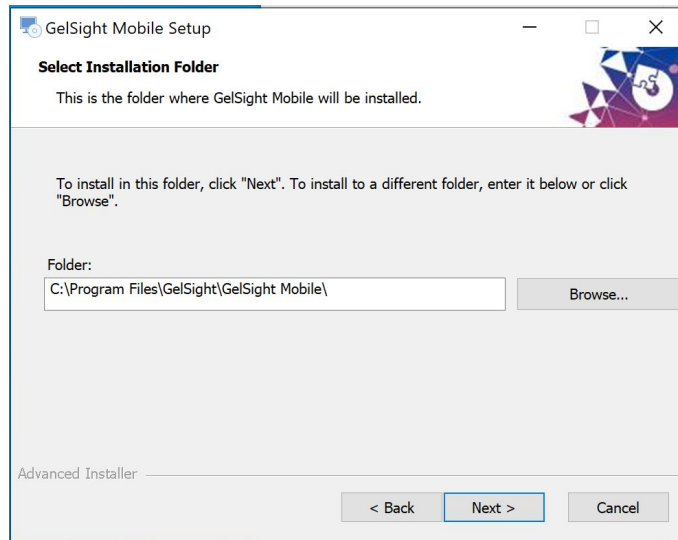


FIGURE 16: GELSIGHT GS MOBILE WINDOWS INSTALLATION - 2

The GSMobile Installer should start installing and copying files in the selected folder (Figure 17).

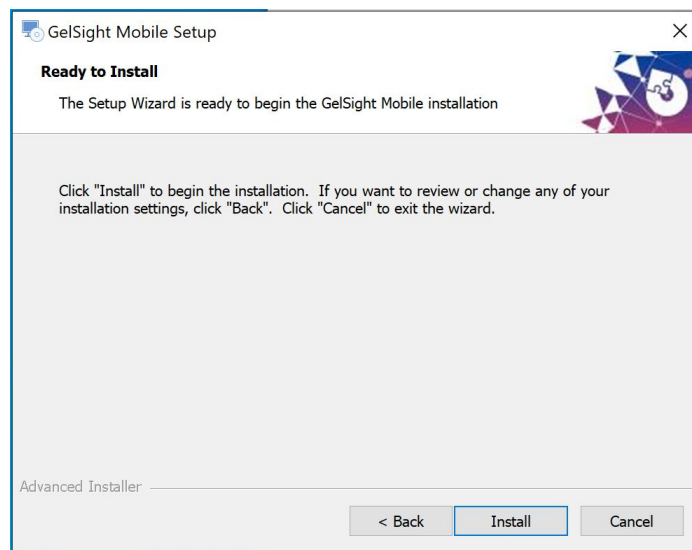


FIGURE 17: GELSIGHT GS MOBILE WINDOWS INSTALLATION - 3

The Installation is now successfully completed (Figure 18).

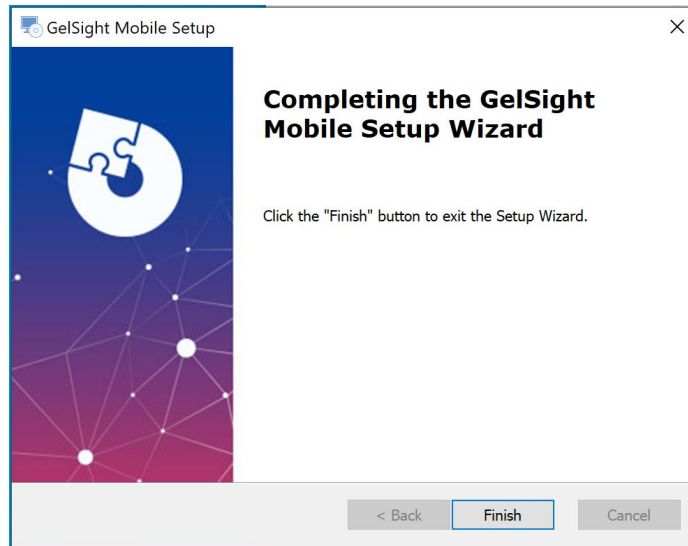


FIGURE 18: GELSIGHT GS MOBILE WINDOWS INSTALLATION – 4

If this is the first time GS Mobile is being installed onto the computer, in addition to installing the GS Mobile software you also need to install the camera drivers. They can be found at:

https://www.ximea.com/support/wiki/apis/XIMEA_Windows_Software_Package

Select the "XIMEA Windows Software Package Stable Installer" and run it.

5.3 Starting with GSMobile – Settings

Double-click on the GSMobile icon on the desktop of your tablet or laptop (Figure 19).



FIGURE 19: GS MOBILE ICON ON THE TABLET OR LAPTOP DESKTOP

After Launching GSMobile the Main Menu is displayed (Figure 20).

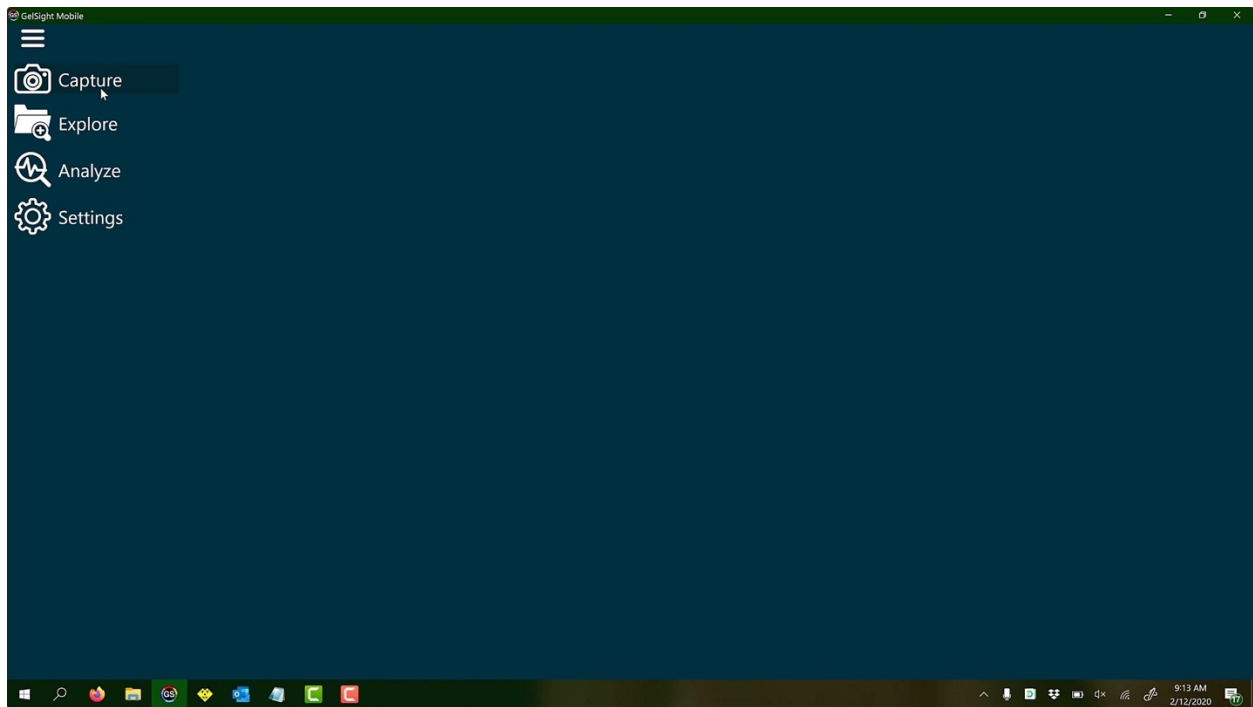


FIGURE 20: GSMOBILE MAIN MENU

5.4 Settings Mode

SETTINGS - SYSTEM

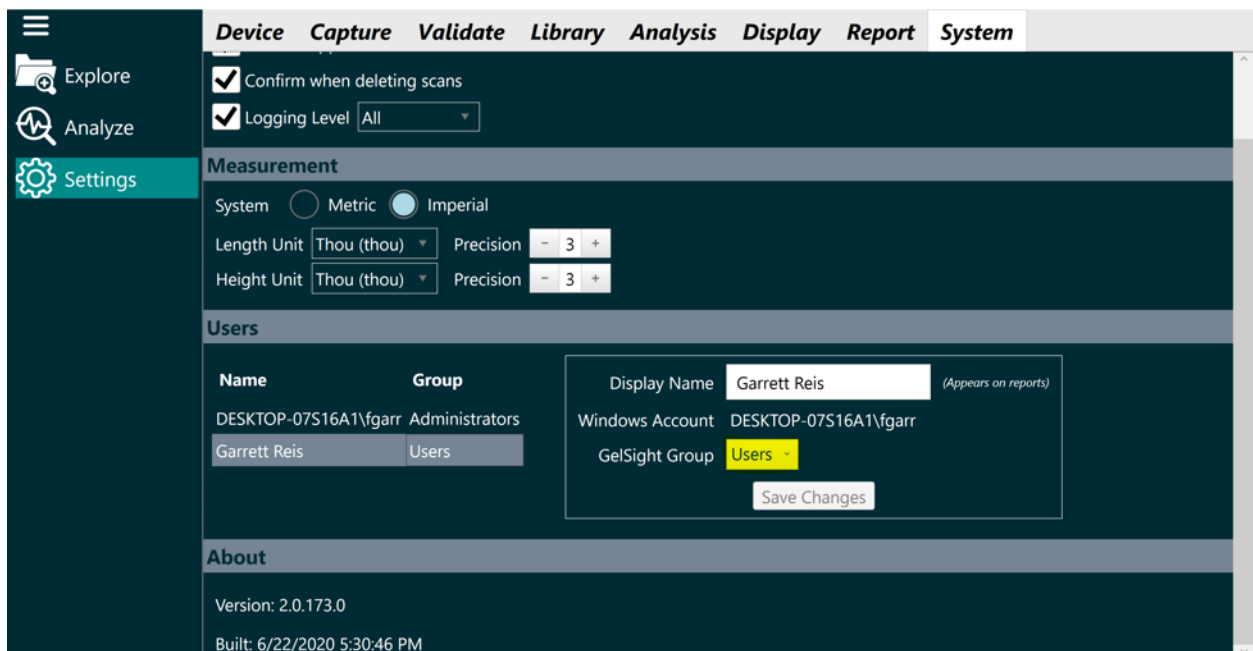


FIGURE 21: SETTINGS – SYSTEM

The user can customize features and settings of GSMobile by selecting the Settings Icon in the Main Menu. However, the privileges for what can and cannot be changed depends on the type of user.

USERS AND ADMINISTRATORS

There are two types of users defined for the GelSight Mobile System V2.0: Regular users and Administration-level users, aka Administrators.

Important: The Gelsight Mobile software must be installed by someone with Windows Administrator privileges within the organization. (This is a Windows requirement.) Also, the first Windows administrator for an organization who installs – and runs -- the GSMobile system automatically becomes a GelSight administrator. Therefore, if a Windows administrator installs GSMobile on a laptop or tablet but hands it off to a regular user *without running it first*, there will be no designated GelSight Administrator.

If a customer does not have access to an administrator Windows account when first installing the software, the GSMobile system will display a warning suggesting the software be installed by the organization's IT department.

All additional windows user accounts will automatically be assigned as “users” within the GS Mobile Software.

Here is a list of what regular users and Administrators can and cannot do.

Regular users can:

- View existing scans
- Capture new scans
- Delete scans they have just captured in capture view (but **not** older scans in the library)
- Analyze existing scans (i.e. add analysis routines to them)
- Generate reports

Regular users *cannot*:

- Change measurement system settings, i.e., switch between metric and imperial units.
- Access the “camera ideal default” setting on the Settings>System window.
- Adjust scan clean up settings.

Administrators can do everything regular users can do. They can access all functions within the GSMobile software, including calibration and their corresponding protocols and settings, plus:

- Calibrate
- Tune an existing calibration
- Select an older calibration for the current device
- Set the user group of other users (although not for themselves)
- Delete and rename any scan in the library
- Add a new Gel
- Completely reconfigure the device (for example, if it was mistakenly first entered as a 0.5x but is really a 1.0x, administrators can make that change)

- Change to a different, existing gel for the current device (which will automatically select the last calibration for that gel on that device)

GSMobile administrators can assign other user accounts as either “user” or “administrator.” This can be done by selecting a user account and selecting from the “GelSight Group” drop down menu. The “display name” can also be changed here and will carry over to all future reports created by this user. That makes it possible to identify users and their measurements when multiple operators are using the device.

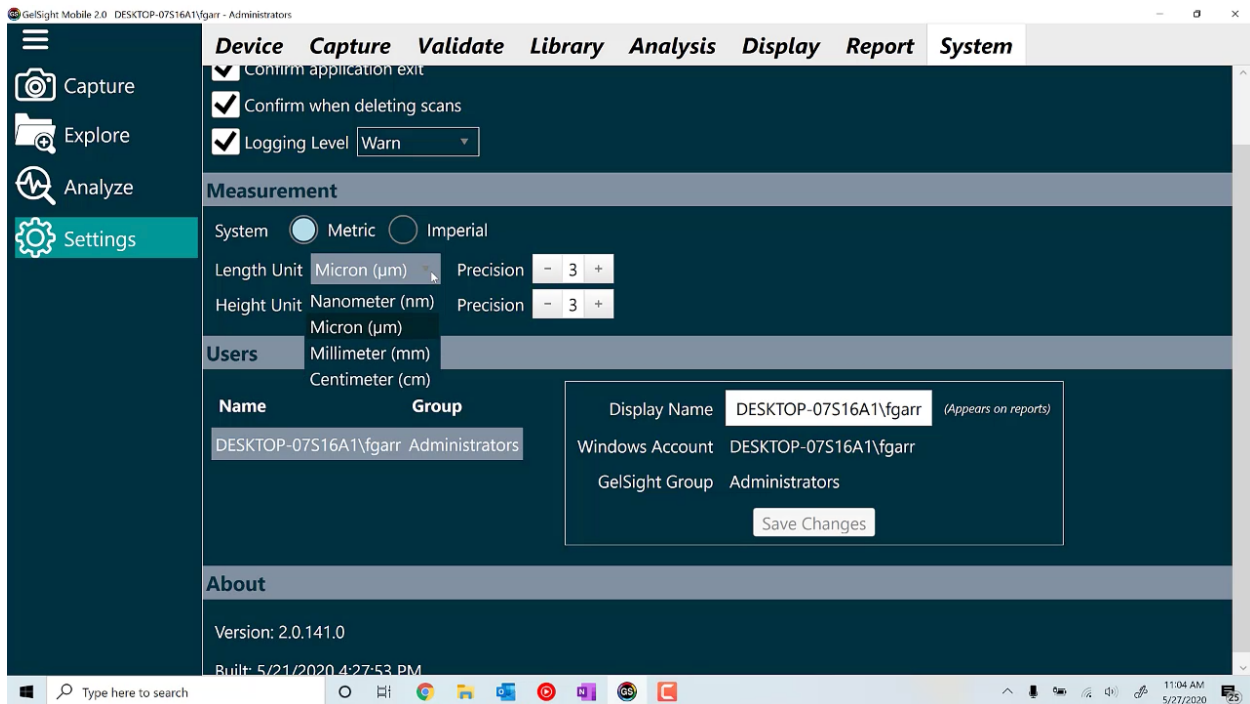


FIGURE 22: SELECTION OF THE UNITS

Use the System tab to choose whether to use the Imperial or Metric (International Standard) measurement system and, for each system, the preferred units of measurement for the horizontal (x-y) and vertical (z) directions:

- Metric System: nm, μm , mm, cm
- Imperial System: μin , thou, in

Note: After you have performed an analysis of a scan, you can re-enter Settings Mode, select the System tab, and switch to a different unit of measure. The GSMobile system will update the associated measurement data automatically.

You can also determine how you want the system to behave at certain times, for example, you can opt to have the operator prompted for confirmation when deleting scans or exiting the system.

SETTINGS – DEVICE

The screenshot shows the 'SETTINGS – DEVICE' screen with a sidebar menu on the left containing 'Capture', 'Explore', 'Analyze', and 'Settings' (highlighted). The main area has tabs for 'Device', 'Capture', 'Validate', 'Library', 'Analysis', 'Display', 'Report', and 'System'. The 'Device' tab is active, showing fields for 'Type' (GelSight Mobile 0.5X), 'Serial Number' (922002), 'Shutter (ms)' (0.604), 'Current Gel' (Z97D-3A73), and 'Status' (Uncalibrated). A 'Calibration' section includes 'Calibrate' and 'Select' buttons. Below this is a table for 'BGA Target' with columns for 'Name', 'Type', and 'Serial Number'. A 'Groove Target' section shows 'Rubert 513 500' and 'PUD5' with 'Add' and 'Edit' buttons. A 'Max Deviation' field is set to 2.0%. An 'Edit Groove Target' dialog is open, showing fields for 'Type' (GelSight CAL-G500), 'Name' (GelSight CAL-G500), 'Serial' (A103), 'Verified?' (checked), and 'Depth' (495.963 μm).

FIGURE 23: SETTINGS – DEVICE

Use the Settings>Device tab to select and edit calibration targets. You can also select an existing Gel Cartridge as well as add a new cartridge to the probe.

The 'Select a gel cartridge' dialog shows a table with columns 'Name', 'Last Calibration', and '# of Uses'. It lists two cartridges: Z51W-TZ3F (5/27/2020 9:16 AM, 128) and Z971-3H86 (5/26/2020 11:28 AM, 6). A note states: 'Any gel cartridge assigned to this device will be unassigned from any other device currently using it'. 'OK' and 'Cancel' buttons are at the bottom.

Name	Last Calibration	# of Uses
Z51W-TZ3F	5/27/2020 9:16 AM	128
Z971-3H86	5/26/2020 11:28 AM	6

The 'Add New Gel Cartridge for this Device' dialog prompts the user to 'Enter the serial number inscribed on the gel cartridge'. It includes a text input field, a 'OK' button, and a 'Cancel' button. A small image of a gel cartridge with the serial number 'ABCD-1234' is shown on the right.

FIGURE 24: SELECT AND ADD NEW GEL CARTRIDGES

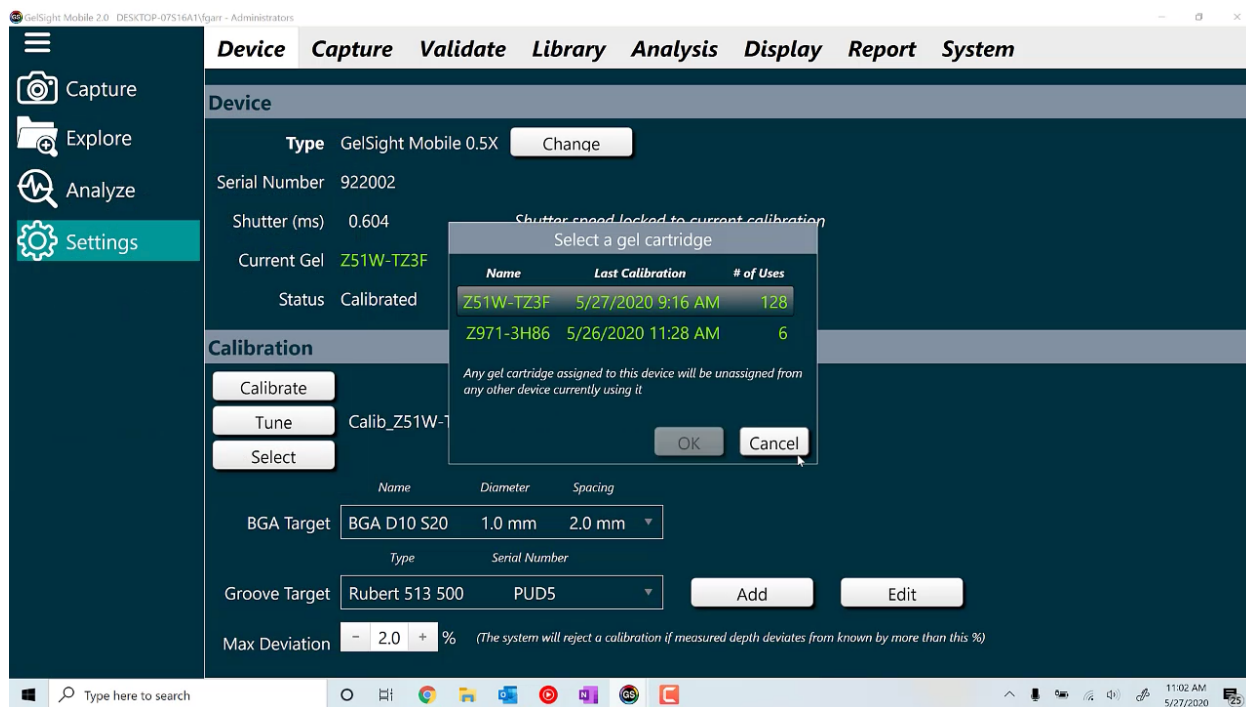


FIGURE 25: DEVICE TAB - SELECT A GEL CARTRIDGE

SETTINGS — VALIDATE

The GelSight Validation Protocol is still being evaluated and is not available yet.

SETTINGS - REPORT

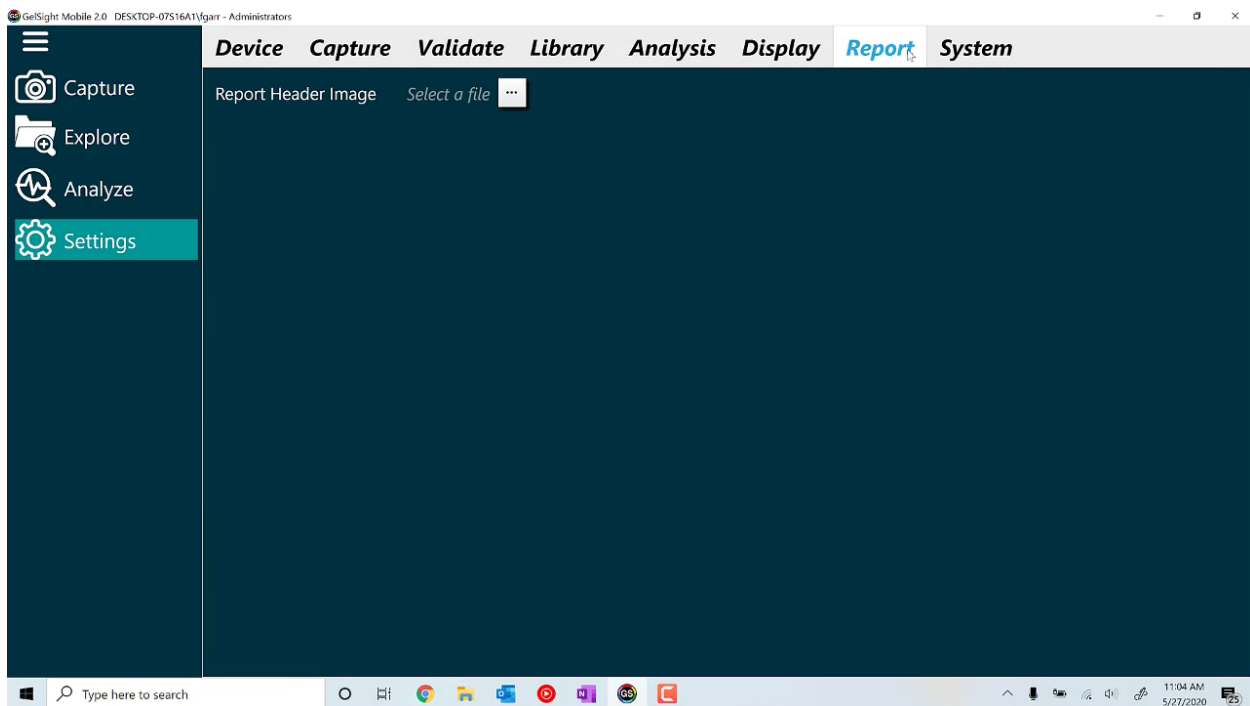


FIGURE 26: SETTINGS - REPORT

You can add a customer-uploaded image, for example, a logo, to be included on report files. Select a file with the [...] button and navigate to the image.

SETTINGS — LIBRARY

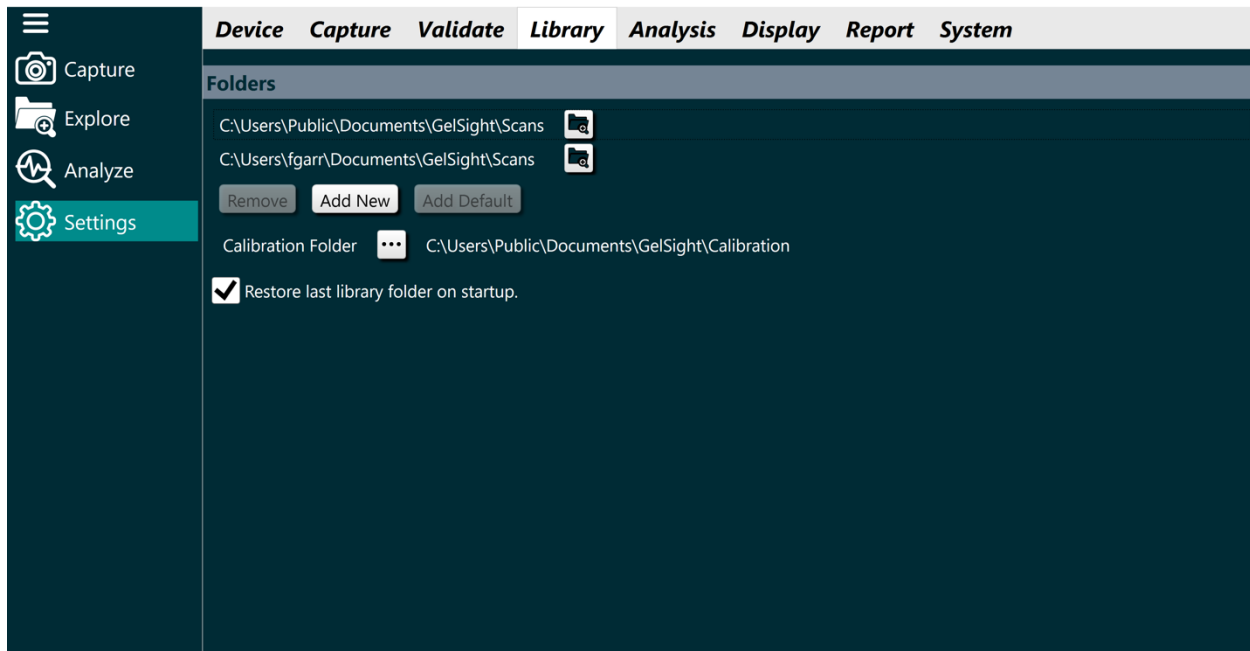


FIGURE 27: SETTINGS – LIBRARY

GSMobile utilizes the classic Windows 10 file structure and file hierarchy. File and data management depend on the user organization. You can select an existing library by clicking on its folder.

You can add a new root library path with the Add New button.

If two operators are using the same tablet or laptop but have different user profiles, both will be able to share the same scans and calibrations because the default root path is in the public documents folder, specifically, C:\Users\Public\Documents\Gelsight\Calibration.

Administration-level users can use the Add Default button to add a new default library path.

SETTINGS – ANALYSIS

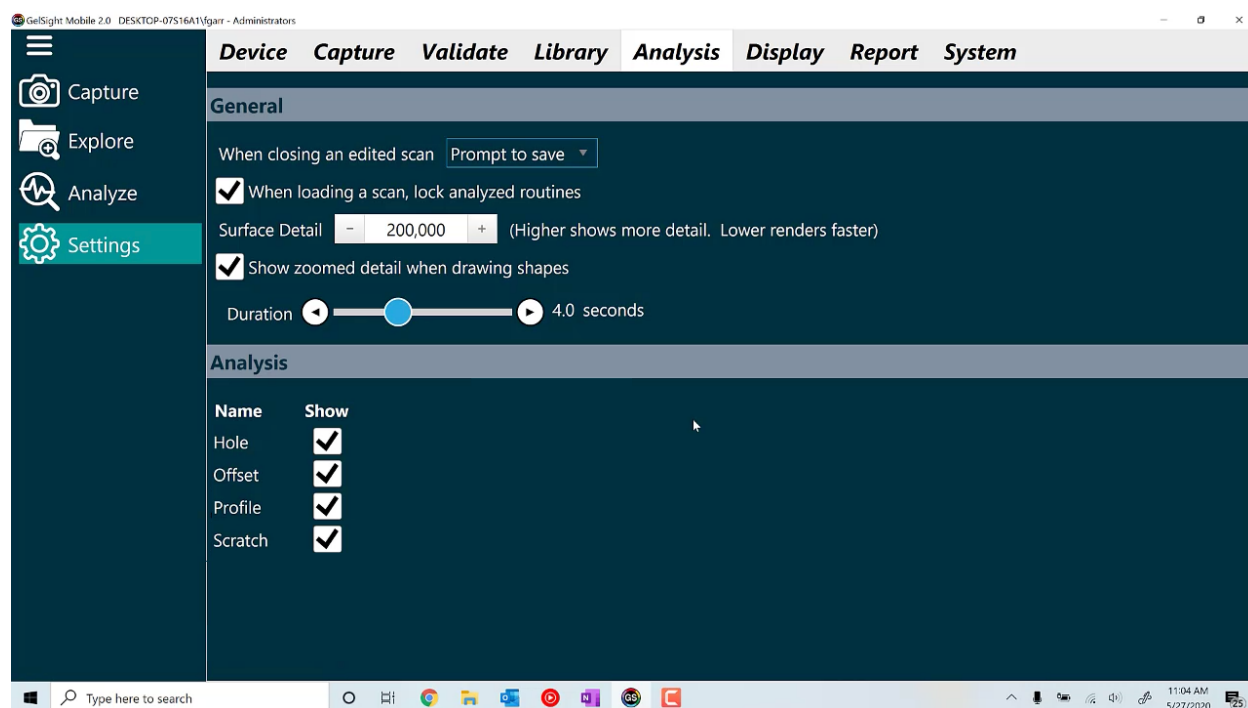


FIGURE 28: SETTINGS – ANALYSIS

Use the Analysis tab to choose how to interact with the system when performing analyses. You can:

- choose how to be prompted to save an edited scan
- decide whether analyses should be locked when loading a scan
- select the level of surface detail the view displays during analysis
- decide whether to zoom in on the area of analysis when using graphic tools to draw the shapes you use in analysis.

SETTINGS – DISPLAY

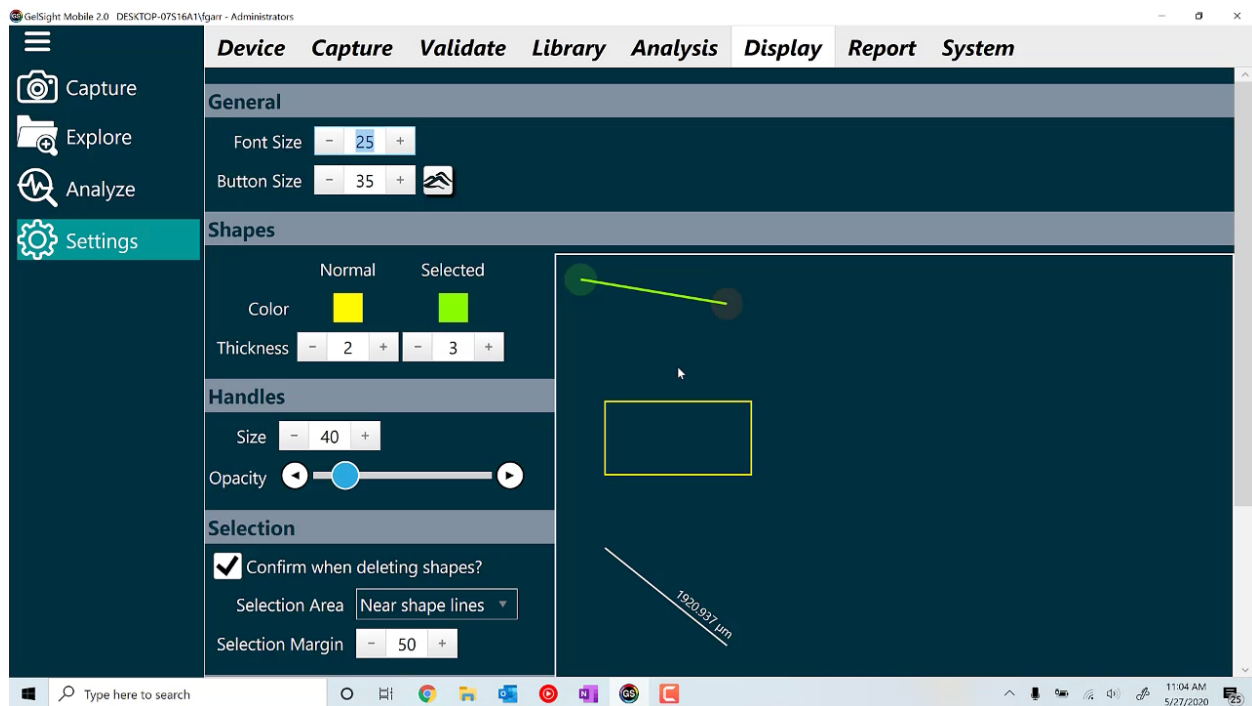


FIGURE 29: SETTINGS – DISPLAY: GRAPHIC TOOL PARAMETER SETTING

When you're analyzing a capture, you'll use different graphic tools (lines, circles, polygons, ruler). You can define their characteristics, including line thickness, color, handle size, etc., on this Display tab.

SETTINGS – CAPTURE

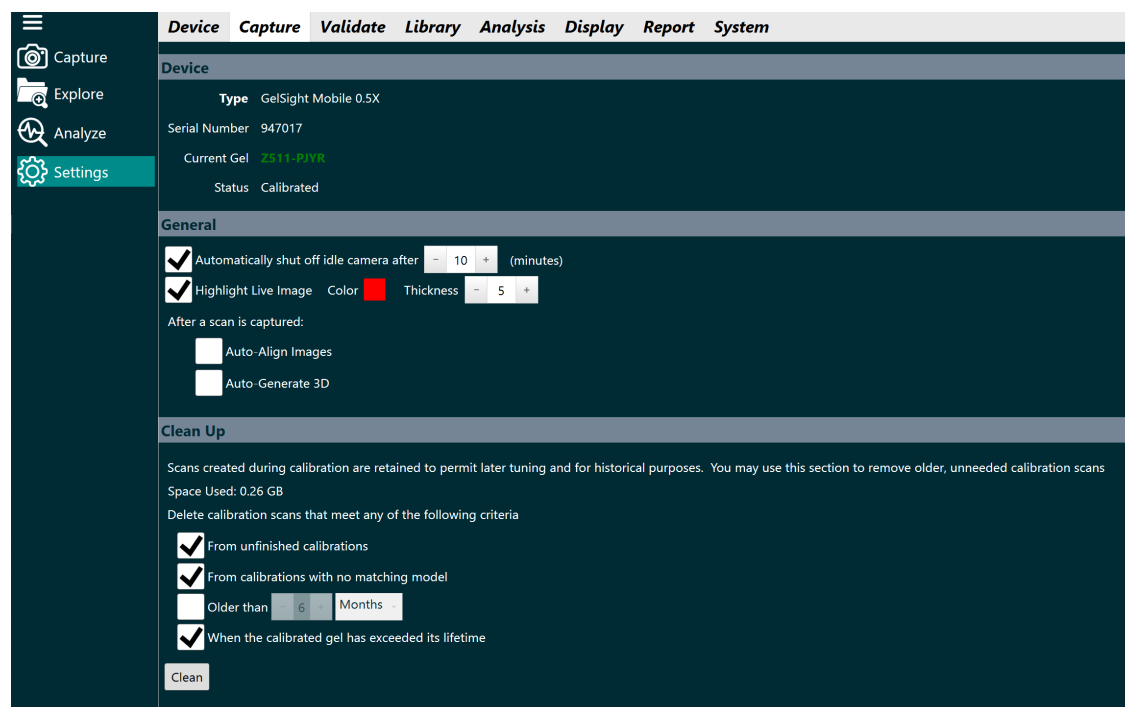


FIGURE 30: SETTINGS – CAPTURE

The GelSight Mobile Probe should be plugged into the USB 3.0 port of the tablet or laptop. The GSMobile system will detect the probe automatically. The user only needs to select the type of probe, whether the Mobile 0.5X or the Mobile 1X, the first time it's plugged in. (If the user chooses the wrong device when plugging it in the very first time, the Administrator can change it.)

Then, the Serial Number of the Device and the Shutter speed automatically populate (Figure 32).

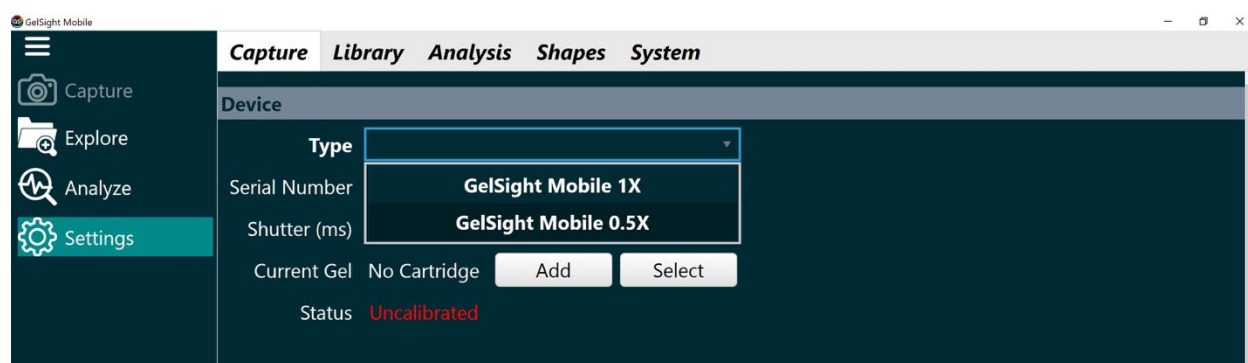


FIGURE 31: SELECTION OF THE GELSIGHT MOBILE TYPE (0.5X OR 1.0X)

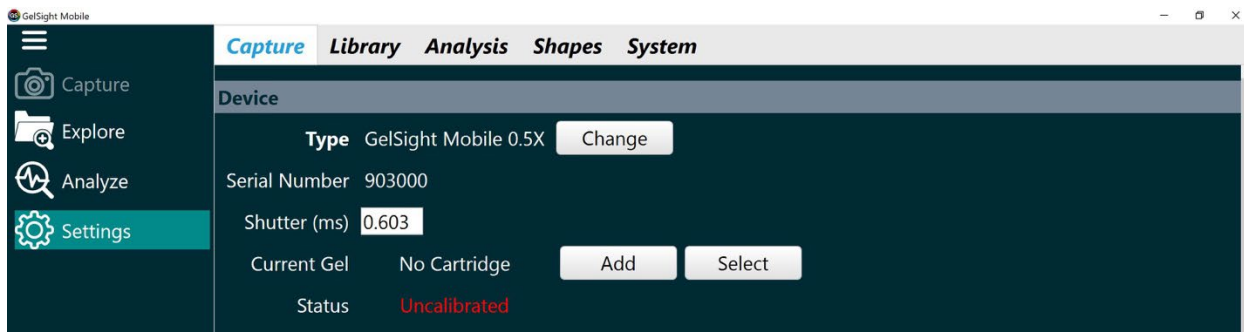


FIGURE 32: GELSIGHT MOBILE PROBE CONNECTED

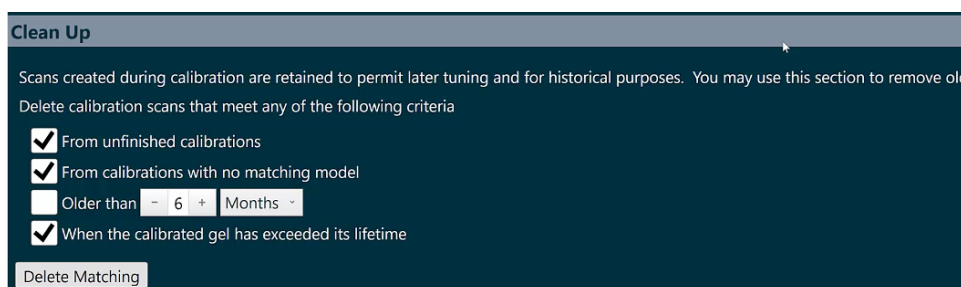


FIGURE 33: SETTINGS - CAPTURE CLEAN UP

The GSMobile System's calibration process produces several scans with large files. These files, which are byproducts of the calibration process, are rarely needed afterwards. Administrators will occasionally want to delete these files to free up space on the tablet or laptop. The Clean Up section in Settings > Capture enables administrators to manually delete old calibration scans that meet certain criteria, for example: scans of a certain age, scans from a gel that has exceeded its lifetime, and so on.

Deleting scans this way from GSMobile moves them to the Windows recycle bin. It does not remove them entirely from the tablet/laptop; they can be recovered from the Recycle bin in the standard fashion.

SHUTTER SPEED SELECTION

Shutter Speed is a key parameter since it directly determines the quantity of light seen by the camera. Despite the fact that the shutter speed is set to default (at 0.602), Administrator-level users only can modify shutter speed during calibration depending on the exposure quality of the images. Recommended values for the Shutter Speed are between:

- 0.45 to 0.8 msec for the GelSight Mobile 0.5X
- 3 to 5 msec for the GelSight Mobile 1.0X.

The Shutter Speed (in milliseconds) should be set to avoid overexposure or underexposure. Figure 34: Examples of Scan with Different Shutter Speeds (0.5X Mobile) shows the influence of the shutter speed on the scan on a calibration target BGA D05 S10 (captured with a GelSight Mobile 0.5X). From left to right the Shutter Setting is 0.4 ms, 0.6 ms, and 0.8 ms, demonstrating underexposure, correct exposure and overexposure, respectively.

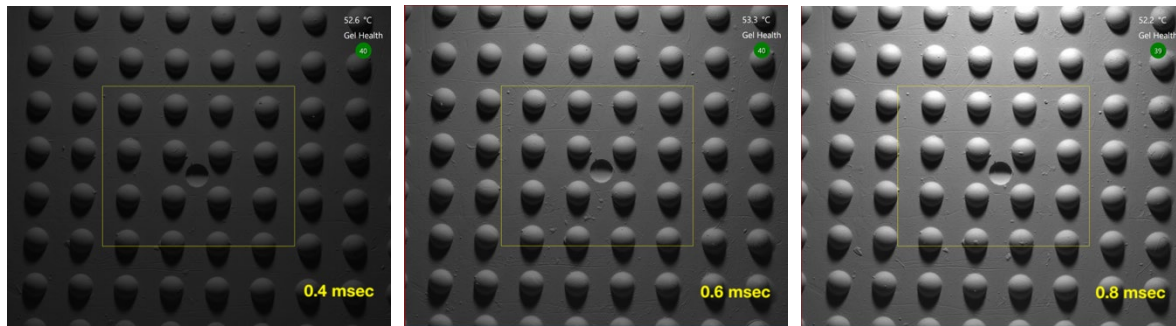


FIGURE 34: EXAMPLES OF SCAN WITH DIFFERENT SHUTTER SPEEDS (0.5X MOBILE)

GEL CARTRIDGE CALIBRATION

Note: For the GelSight Mobile Probe's data to be accurate for calibration (or measurements), its camera must warm up first. Therefore the application will not allow any captures until the temperature of the camera in Capture Mode reads as greater than 30° Celsius. It should take the probe less than fifteen minutes to warm up.

The temperature information is indicated in the upper right corner of the screen in Capture Mode.

ASSOCIATION OF THE CARTRIDGE

A Gel Cartridge needs to be calibrated to the Mobile System. This is absolutely necessary before doing any capture and analysis. GSMobile will need a set of calibrations to be able to reconstruct the 3D surface acquired during a capture.

To calibrate a Gel Cartridge, the User can:

- 1- Select a Cartridge which has already been calibrated with the current Mobile System
- 2- Choose a New Cartridge and calibrate it

In the First Case, the User has to select the serial number of the Gel Cartridge they want to use (Figure 35). Then, the last Set of Calibrations obtained with the Gel Cartridge will be used. In the example of Figure 35, the Gel Cartridge with the serial number Z806-TPE3, the Set of Calibration done on 11/18/2019 at 1:44PM is used.

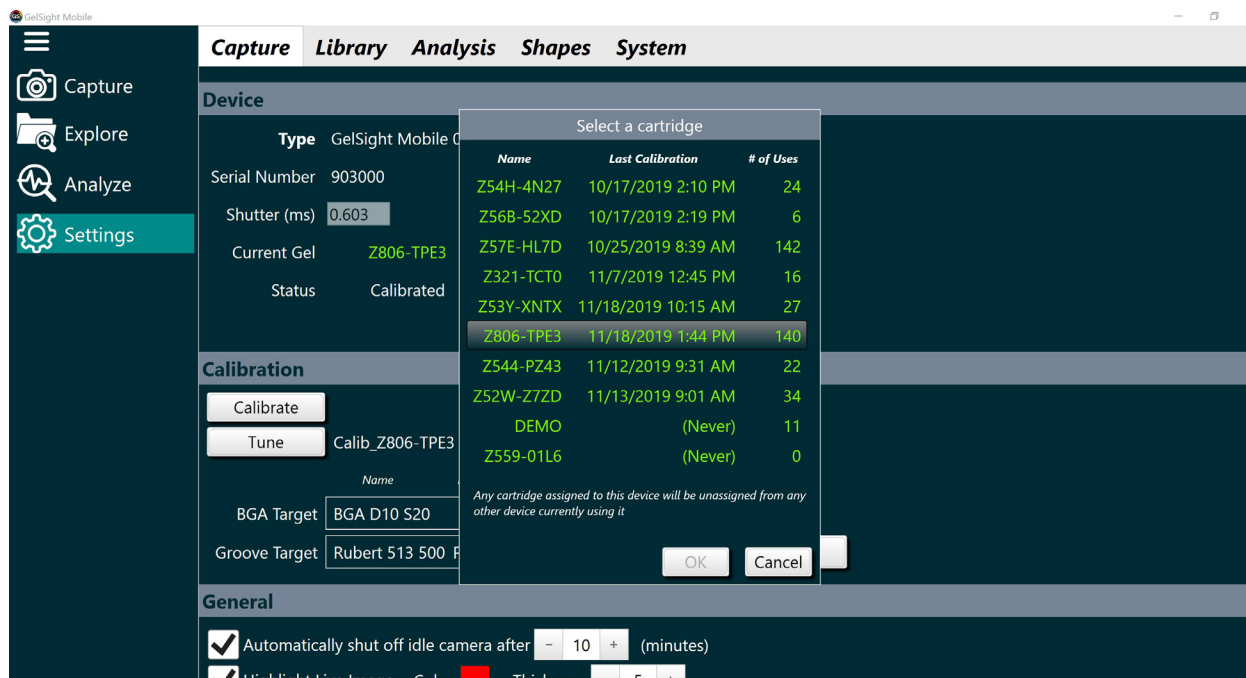


FIGURE 35: SELECTION OF A CALIBRATED GEL CARTRIDGE

For each Gel Cartridge, the number of scans done with the current system is mentioned. This information allows the user to evaluate the remaining potential of the Gel Cartridge.

In Capture Mode, the number of uses for the currently installed gel is displayed in the upper right of the Capture Window. In addition, a color code (green, yellow, red) tells the user how many times the Gel Cartridge has been used:

The Gel Health dots are color coded:

- Green = 0 - 199 captures
- Yellow = 200 – 299 captures
- Red = 300 + captures

ENTERING THE GELSIGHT G500 (OR RUBERT 513E) AND BGA CHARACTERISTICS

Before calibrating the very first Gel Cartridge, the Administration-level user needs to enter the characteristics of the GelSight G500 calibration plate (or Rubert 513E) and BGA targets.

HOW TO USE THE GELSIGHT G-500 CALIBRATION PLATE

As of GSMoblie 2.0, the GelSight G500 calibration plate is a new groove target for use in calibration. It has only one 500 micron groove and is housed inside a cap, which makes scanning easier.



FIGURE 36: GELSIGHT G500 CALIBRATION PLATE

The screenshot shows the GELSIGHT Mobile application interface. The left sidebar contains icons for Calibrate, Explore, Analyze, and Settings. The main screen is divided into tabs: Device, Capture, Validate, Library, Analysis, Display, Report, and System. The 'Device' tab is active, showing the following information:

- Type:** GelSight Mobile 0.5X (with a 'Change' button)
- Serial Number:** 922002
- Shutter (ms):** 0.604
- Current Gel:** Z97D-3A73
- Status:** Uncalibrated

The 'Calibration' section includes a 'Calibrate' button and a 'Select' button. Below this, there are two tables for selecting targets:

Name	Distance
BGA Target	BGA D10 S20 1.0 mm 2.0 mm

Type	Serial Number
Groove Target	Rubert 513 500 PUD5

Below the tables, there is an 'Add' button and an 'Edit' button. At the bottom, the 'Max Deviation' is set to 2.0 %.

The 'Edit Groove Target' dialog is open, showing the following fields:

- Type:** GelSight CAL-G500
- Name:** GelSight CAL-G500
- Serial:** A103
- Verified?:** ☒
- Depth:** 495.963 μm

The dialog has 'OK' and 'Cancel' buttons.

FIGURE 37: SELECTING THE GELSIGHT G500

Enter the G500's serial number in the Settings>Device tab and the specific depth of the groove as listed in its Certificate of Calibration.

RUBERT 513E TARGET

Note: As of GSMobile V2.0, the GelSight G500 calibration plate is supplied with the system, but users who have the Rubert 513E Target can continue to use this specimen to calibrate their system.



FIGURE 38: RUBERT 513E TARGET

For Rubert R513E Target, the user enters its Serial Number, the Selected Groove used for the Calibration (200 or 500 microns), and the Measured Depth of the Groove given by the Certificate of Conformity delivered with the system.

BGA TARGET REFERENCE

For BGA Target Reference, the user must enter the following:

- BGA D10 S20 for the 0.5X Mobile Device
- BGA D05 S10 for the 1.0X Mobile Device

CALIBRATION OF A GEL CARTRIDGE

Only Administrator-level users can calibrate a new Gel Cartridge.

When a new Gel Cartridge is selected, click on the Add Button to enter the serial number of the new Gel Cartridge, then click Calibrate.

Calibration of a Measurement System is a key process to verify and to maintain the Instrument Accuracy. It generally involves a calibrated target which is provided with a Certificate of Calibration from a Qualified Metrology Laboratory.

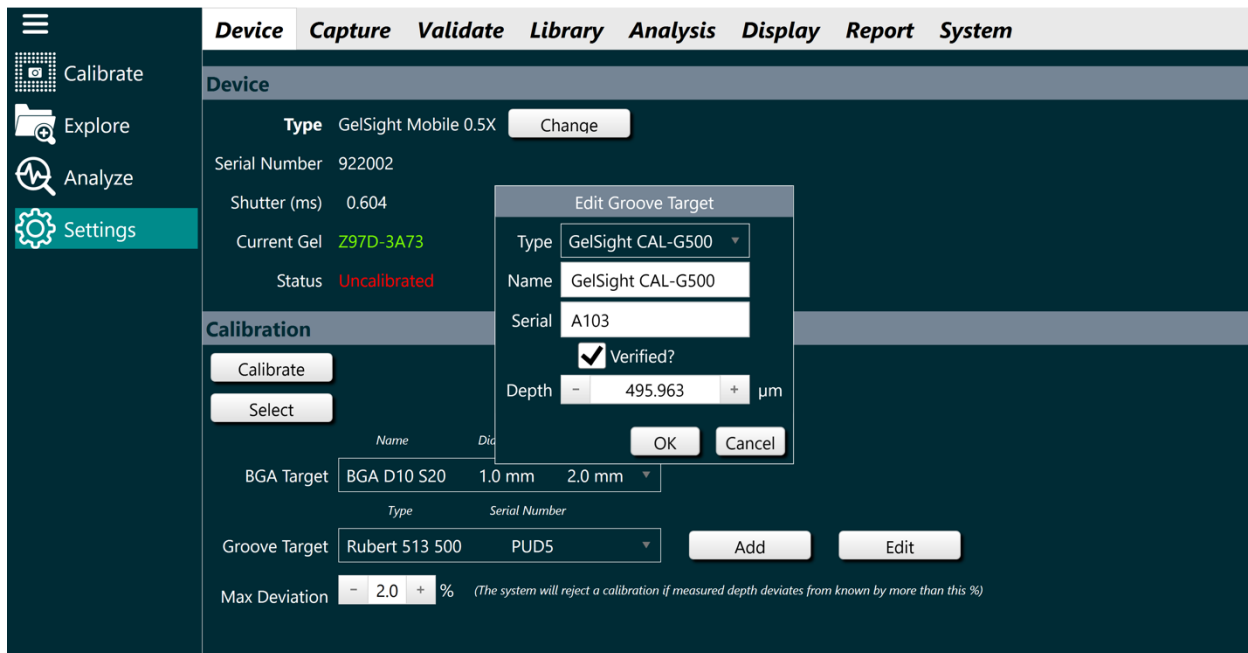


FIGURE 39: ENTERING THE GELSIGHT G500 CHARACTERISTICS

The GelSight Mobile Calibration Protocol involves 3 different specimens: One flat glass as a reference plane, a Ball Grid Array (BGA) with Calibrated Spheres (1mm diameter $\pm 2.5 \mu\text{m}$ for the BGA D10 S20) and a GelSight G500 calibration plate with one calibrated groove 500 microns deep, delivered with a Certificate of Calibration.

Note that the [Rubert 513E Target](#) can also be used for calibration.

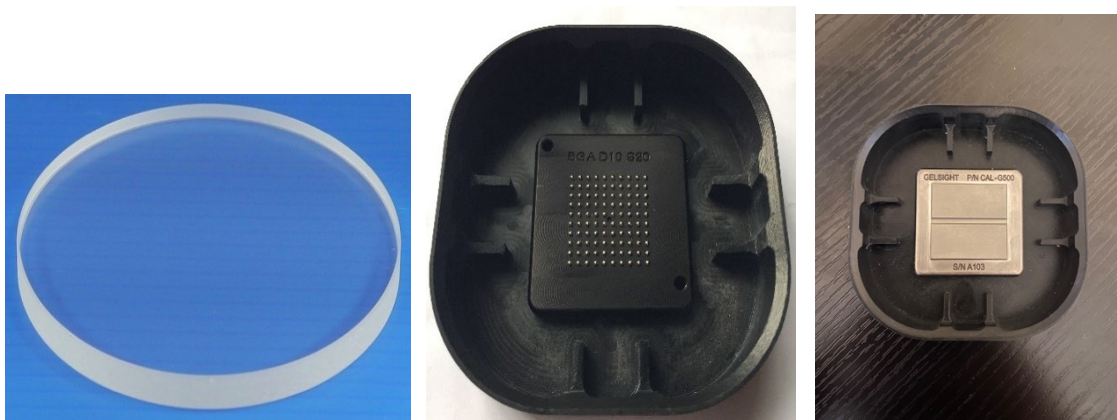


FIGURE 40: SPECIMENS USED DURING THE CALIBRATION PROTOCOL – FROM LEFT TO RIGHT: FLAT GLASS, BGA, GELSIGHT G500

The user needs to follow the different steps of the calibration protocol in the GSMobile app. The first steps of calibration consist of capturing scans for:

- the Flat Glass (1 scan)
- 4 different positions of the BGA Specimen (by rotating the cap by 90° each time) – (4 scans)
- one scan of the GelSight G500 Calibration plate (or one scan of the Rubert R513E Groove Target (200 or 500 micron).

The flat glass capture provides a uniform light illumination, allowing the creation of a Plane of Reference.

For the 4 BGA Captures, GS Mobile detects each individual sphere and digitally generates a 1mm diameter circle around each of them. Then, for each pixel inside the circle, GS capture measures the illumination level necessary for the determination of the height in the Z direction.

Finally, a last capture is taken from the calibrated feature of the GelSight G500 or from the Rubert 513E Specimen. In this example, the Rubert 513E's 500 microns groove has been chosen to calibrate the system.

When done with your captures, click on the Calibrate Box (Figure 42: Different steps of the acquisition protocol-7).

From these captures, the software automatically computes a Set of Calibrations which is absolutely necessary to generate the 3D surface from the 6 images of a Capture and to Perform Quantitative Measurements with a Known and Guaranteed Accuracy.

The Computation of the Calibration Model lasts around 90 seconds and comprises the following steps:

- Creating Flat Field Model
- Adjusting Images
- Optimizing Parameters
- Creating Stereo Model
- Model Created, Finishing

At the end of the calibration, the user can accept the calibration model or recalibrate the Gel Cartridge by tuning the Angular Bias Parameter.

The Angular Bias Parameter expressed in % modifies the nominal section of reference of the calibrated balls of the BGA used in the computation of the calibration model. Angular Bias is used to stretch or compress the measurement in the vertical direction mainly.

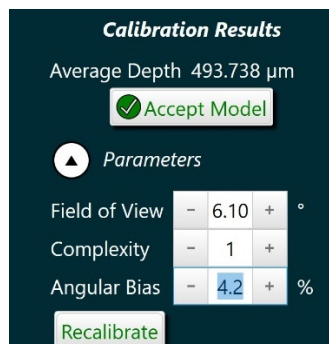


FIGURE 41: CALIBRATION PARAMETERS MENU

An increase of the Angular Bias Parameter will reduce the calculated Average Depth and vice versa. If you choose to recalibrate the Gel Cartridge, we recommend increasing or decreasing Angular Bias in steps of 10%.

Finally, the calibration model is composed of 2 files with the extension .yaml and .png and are stored under C:\Users\Public\Documents\GelSight\Calibration.

It is worthwhile to mention that the user also has the possibility to modify the Field of View Parameter which is optimized to reduce the low frequency effect due to the compactness of the illumination system.

Additional information is given in [Field of View](#) and [Angular Bias Parameters](#).



FIGURE 42: DIFFERENT STEPS OF THE ACQUISITION PROTOCOL. THE GROOVE SCANS ARE OF THE RUBERT 513E TARGET.

Note: We recommend that, when scanning the BGA, the hole in the center should produce a shadow that covers between 25 and 50% of the hole's surface.

5.5 Capture Mode

After setting the parameters of GSMobile and having calibrated a Gel Cartridge, you are ready to capture 3D surfaces scans in Capture Mode.

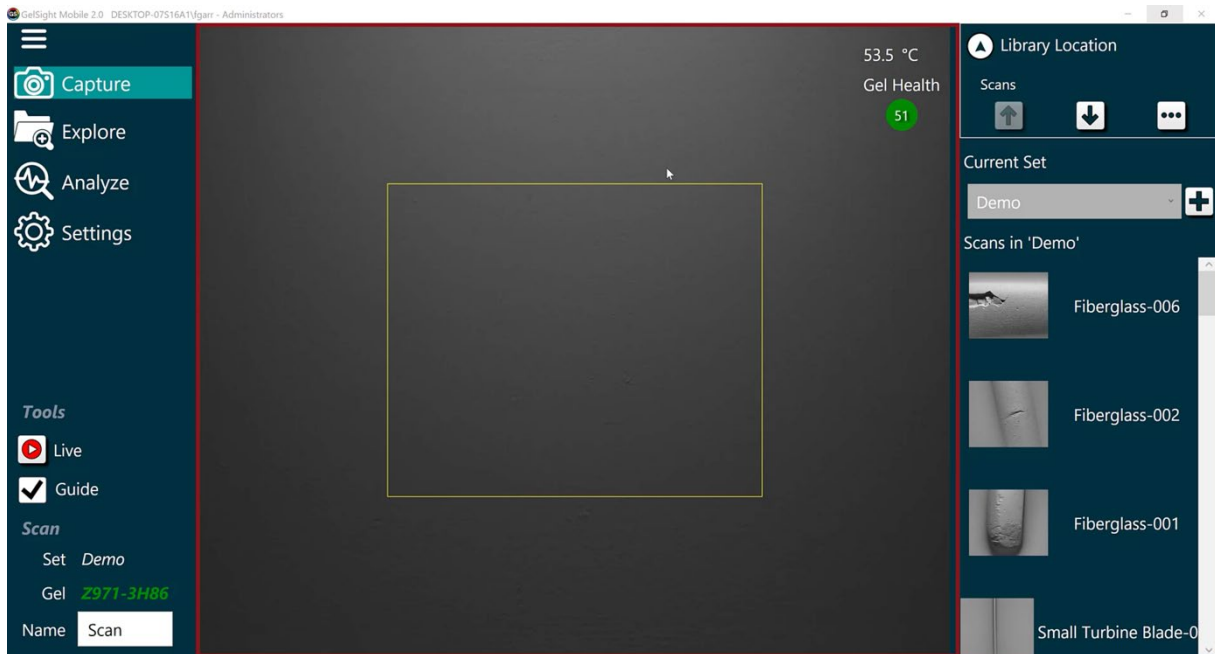


FIGURE 43: CAPTURE MODE

NAMING SCANS

When starting with GSMobile, the system assigns the default prefix, “scan” to new captures. You can change the name by clicking on the Name dropdown box in the lower left of the Capture screen and entering alphanumeric characters. For example, you could change the name to something more descriptive like “Pipe” or “Piston Scratch.”

The system automatically appends the number -001 to the name you gave the scan. If you were to continue with more scans, the system would keep the same name and continue to increment the number, therefore: Pipe-002, Pipe-003, etc.

5.6 Capturing a Scan

Once the [shutter speed is set](#), the name of the scan defined, and the Live View Button is on, the system is ready to capture a surface scan.

Press the gel on a surface. Once a clear image appears on the screen, push the button on the probe (see Figure 10). When the User releases the button, six (6) images will be captured successively in a very short time.

Using the six captured images, GSMobile automatically generates a 3D model of the scanned surface. This operation lasts around fifteen (15) seconds during which the User can continue to do other captures in parallel.

In order to save battery life, switch off the LEDs by clicking on the Live View Button (on the left side of the Capture window). Another click on the Live View Button will switch on the LEDs. To resume capturing, click on the Live View Button to turn the LEDs back on.

NAVIGATING FOLDERS IN CAPTURE MODE

The upper right pane of the Capture window contains icons used to edit and navigate through your scan folders. This is another way of accessing folders while not in Explore Mode.

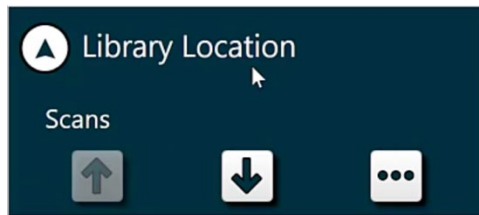


FIGURE 44: LIBRARY/FOLDER NAVIGATION ICONS

Use this icon  to hide or display the file navigation icons.

Use the up and down arrows to move to higher and lower levels of folders and subfolders.

Use the  icon to display the root library folder within the GSMobile software, where you can change to another library or manage folders (edit, delete, rename, etc.) as you would within Windows Explorer. Changes made there will be reflected here within the GSMobile software.

Scan and calibration folders are located in C:\Users\Public Documents\GelSight.

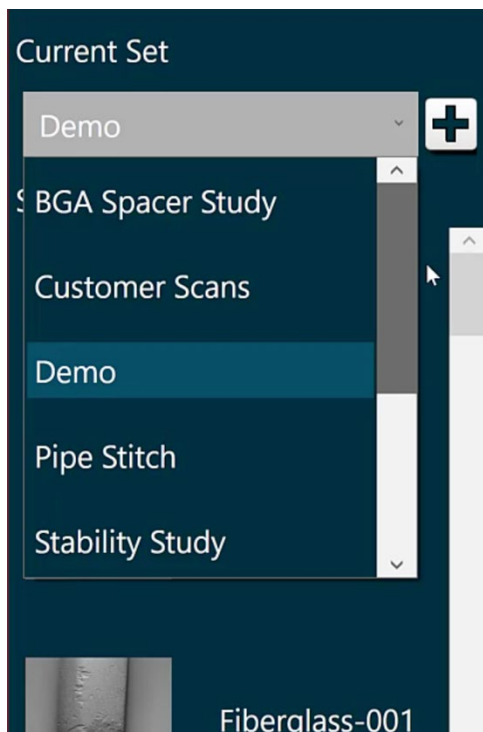


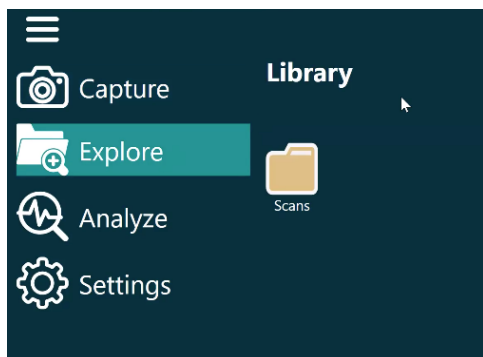
FIGURE 45: DROPDOWN MENU

Use the dropdown menu to select the scan folders from within the currently selected library folder.

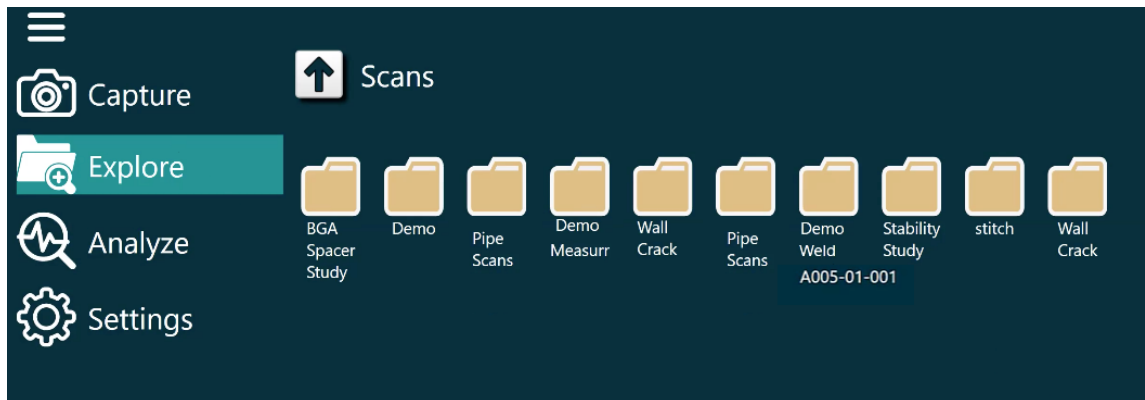
Use the plus icon to create folders within folders.

5.7 Explore Mode

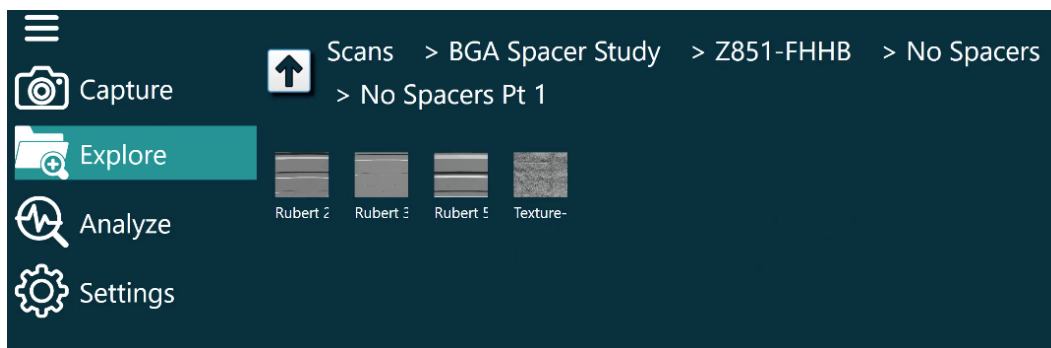
When you click on **Explore** in the main menu, you access the library (C:\Users\Public\Documents\Gelsight\Scans) where the GSMobile scans are stored.



Click on the Scans folder to see your scan files and your file organization. Click on a folder to access its folders.



The up arrow takes you up one level of folders, in this example, to the baseline Scans folder. You can select folders to drill down to the scans themselves, which display as thumbnails.



In Explore Mode, you can grow or shrink the size of the scan thumbnails using the zoom slider:

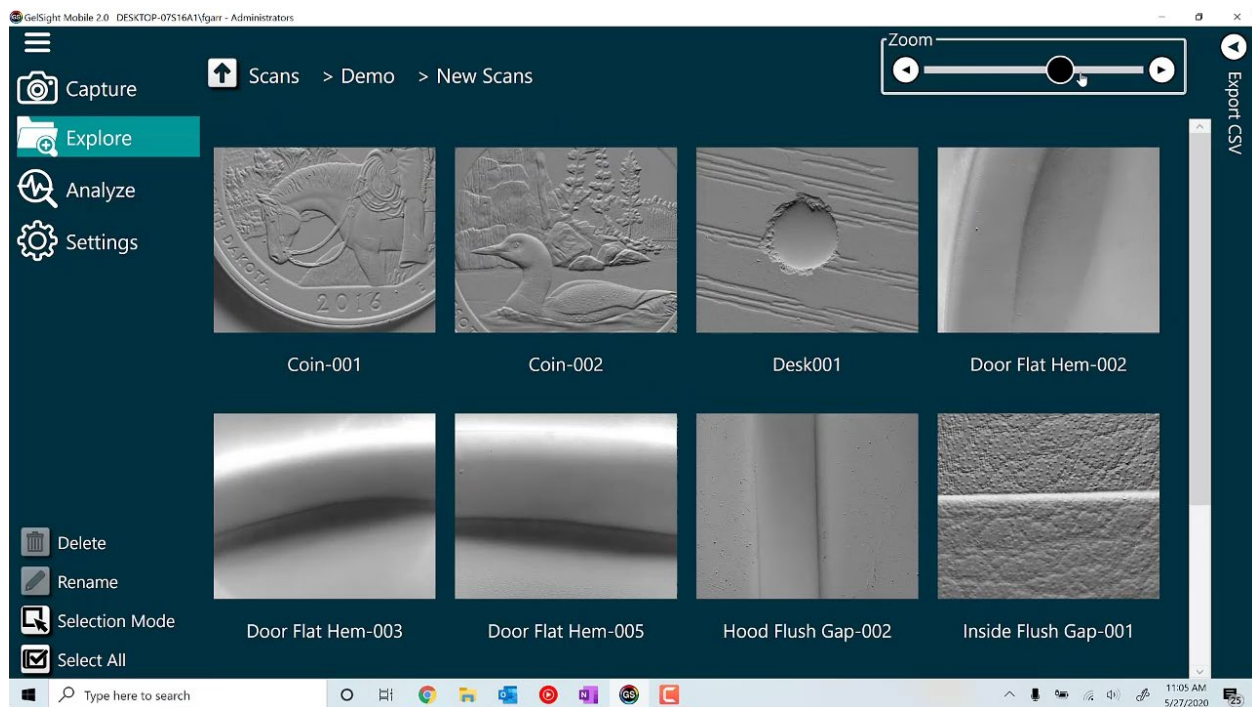


FIGURE 46: ZOOMED IN VIEW OF SCANS

EXPLORE MODE – HOW TO SELECT SCANS

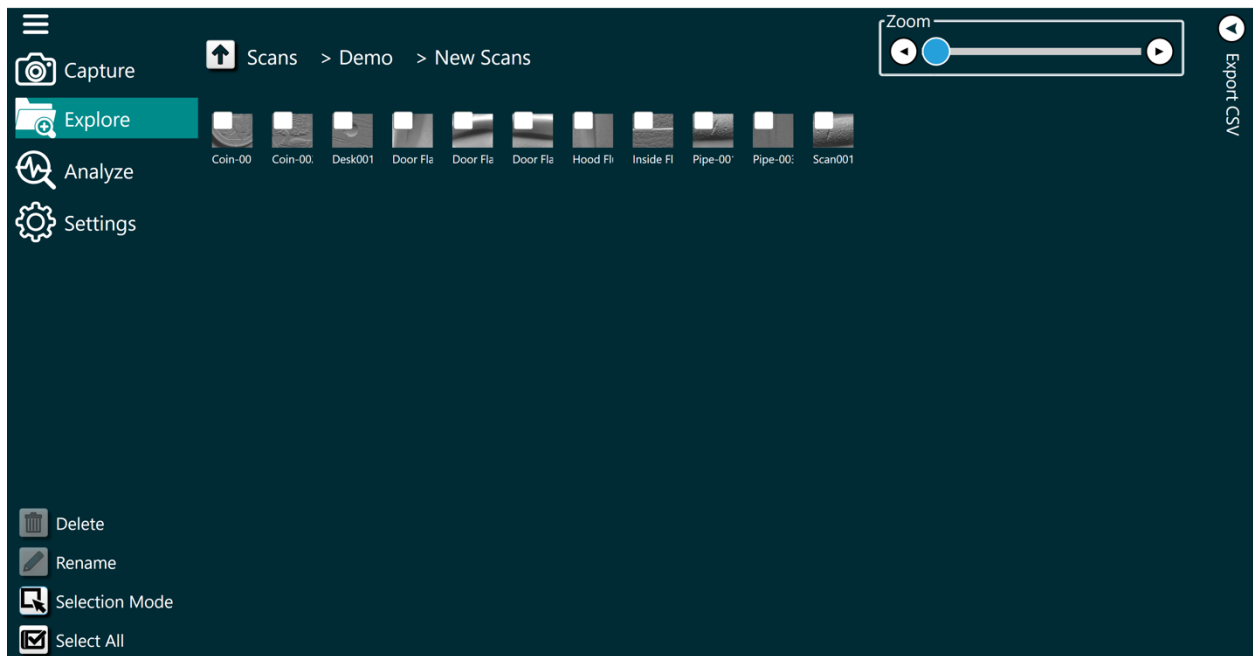


FIGURE 47: EXPLORE MODE – HOW TO SELECT

To select scans for analysis only, you would click on the desired scan and the system takes you directly to Analyze Mode. But to select scans for organizational purposes, for example, for file management, or to delete, rename, or export files, you need to be in Selection Mode.

Click the Selection Mode button in the lower left of the screen. The Explore window displays a checkbox for each scan within the currently selected folder.

Check the boxes of individual scans to select them or click the Select All button to select all the scans at once.

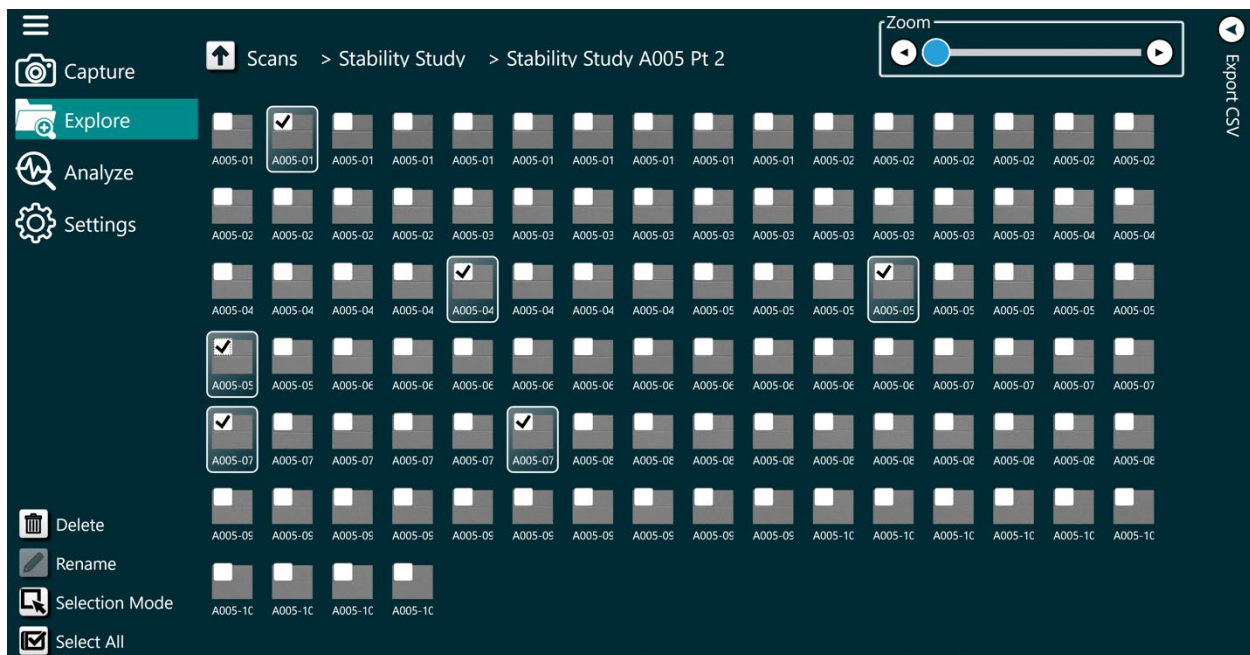


FIGURE 48: SELECTION MODE - INDIVIDUAL SCANS SELECTED

Once an individual scan is selected, you can rename or delete it. Or you can delete all scans that are checked.

EXPORT CSV FUNCTION

The Export CSV function, available in Explore mode, enables you to export scan analysis data in a CSV (comma-separated values) format, for example, to an Excel spreadsheet.

While in selection mode, select the scans whose data you want to export, then click the Export CSV icon on the right side of the window to display a dropdown of export options.

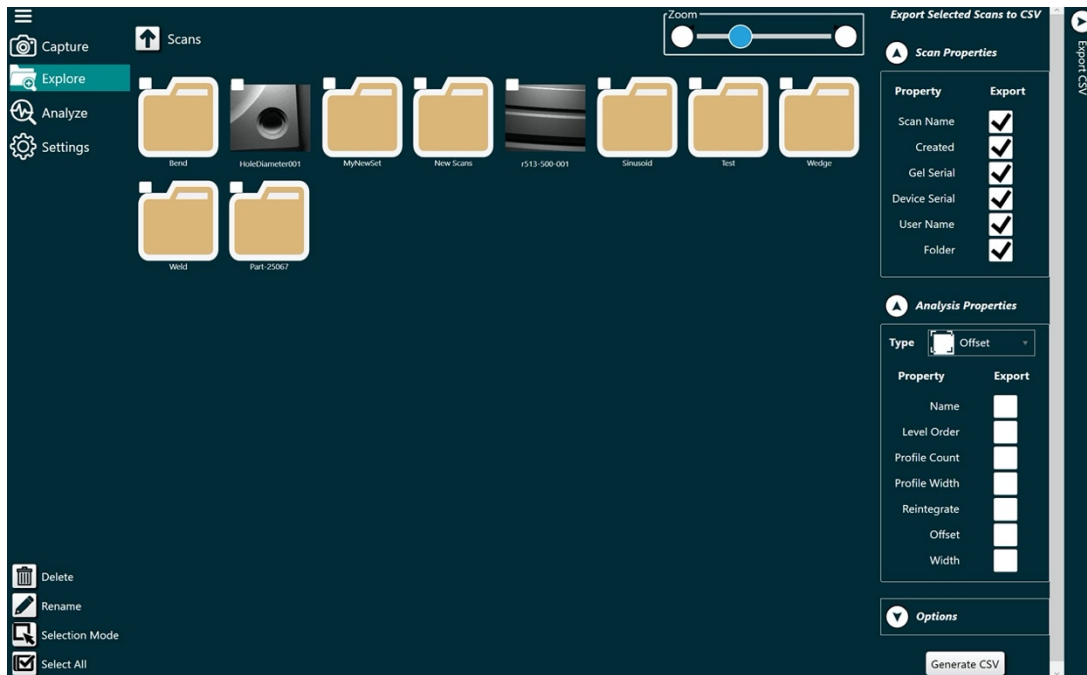


FIGURE 49: THE EXPORT CSV FUNCTION

You can choose which data to be included in the Excel spreadsheet by checking the boxes in two lists: Scan Properties and Analysis Properties. These will be the column names in the resulting CSV file.

Use the Scan Properties list to select the identifying characteristics of the scans you want to export:

- **Scan Name** – the name the operator has given the scan
- **Created** – the date the scan was created
- **Gel Serial** – the serial number of the gel used to create the scan
- **Device Serial** – the serial number of the GelSight probe used
- **User Name** – the ID of the operator who created the scan
- **Folder** – the name of the folder where the scan data is stored.

The Analysis Properties list enables you to export the results of your analysis from scans that have been completed and saved. (You can only export data from saved analyses.)

Select which type of analysis (Offset, Scratch, etc.) to export from the **Type** dropdown box. Here are the data export value options for an Offset analysis, for example:

Analysis Properties

Type Offset ▼

Property	Export
Name	☐
Level Order	☐
Profile Count	☐
Profile Width	☐
Reintegrate	☐

You can select from the parameters that are visible on the particular analysis screen. The Export Function will export all the data measurement files—all of the offset values within each selected scan – to a CSV file.

Use the **Options** list to choose how the data is displayed:

Options

Length Unit Micron ▼

☐ Delimit With Tabs

☐ Write HeaderRow

- **Length Unit** – Choose from the dropdown box the length unit in which the data will be displayed. The metric options, shown in this example, are nanometer, micron, millimeter, and centimeter (nm, μm , mm, cm). You can also choose from imperial measurement options: μin , thou, in.
- **Delimit With Tabs** – Used to format the spreadsheet file. This separates each exported datapoint into different columns on the spreadsheet.
- **Write Header Row** – Adds the property titles to the spreadsheet. For example, “Offset” would be the column title and the results would be listed in cells below that.

When you have made your selections concerning what scan properties and datapoints to export and how the data is to be displayed, press the **Generate CSV** button Generate CSV.

The system takes you to the root folder called **Output CSV File**, where you can save the CSV file.

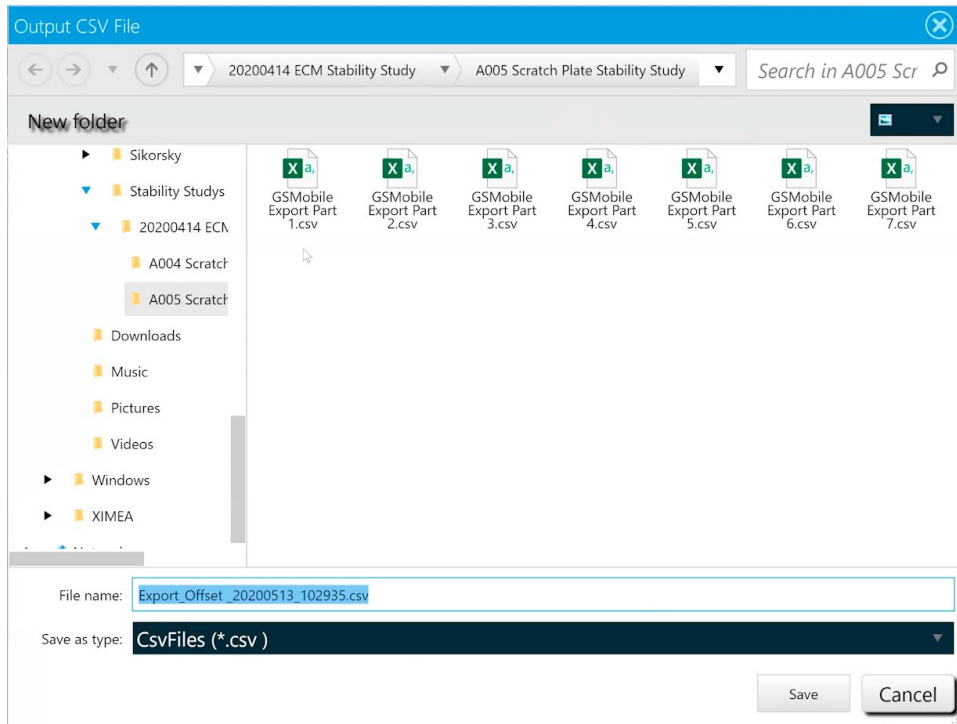


FIGURE 50: OUTPUT CSV FILE FOLDER

	A	B	C	D
1	Scan Name	Gel Serial	Set	Offset
2	A005-01-001	011V-4BZH	Stability Study A005	86.23177707
3	A005-01-002	011V-4BZH	Stability Study A005	87.15871692
4	A005-01-003	011V-4BZH	Stability Study A005	83.27522581
5	A005-01-004	011V-4BZH	Stability Study A005	86.11615304
6	A005-01-005	011V-4BZH	Stability Study A005	83.96872242
7	A005-01-006	011V-4BZH	Stability Study A005	88.19976546
8	A005-01-007	011V-4BZH	Stability Study A005	83.504517
9	A005-01-008	011V-4BZH	Stability Study A005	86.19301635
10	A005-01-009	011V-4BZH	Stability Study A005	84.14608144
11	A005-01-010	011V-4BZH	Stability Study A005	86.32796077
12	A005-02-001	011V-4BZH	Stability Study A005	76.30187233
13	A005-02-002	011V-4BZH	Stability Study A005	74.32913438
14	A005-02-003	011V-4BZH	Stability Study A005	74.77063952
15	A005-02-004	011V-4BZH	Stability Study A005	77.96101674
16	A005-02-005	011V-4BZH	Stability Study A005	80.46479431
17	A005-02-006	011V-4BZH	Stability Study A005	80.075971
18	A005-02-007	011V-4BZH	Stability Study A005	76.63208722

FIGURE 51: SAMPLE EXPORTED DATA IN EXCEL SPREADSHEET

5.8 Analyze Mode

GENERAL

The GelSight Mobile System efficiently measures very detailed surface features like: scratches, dents, pits, offsets between surfaces. These functions (Hole, Offset, Profile, Scratch) are available in the Analysis Panel of GSMobile. Here are the details for each function.

The User can choose from different view modes (3D, 2D, Report) and graphic tools such as: rectangle, line, circle, polygon, ruler:

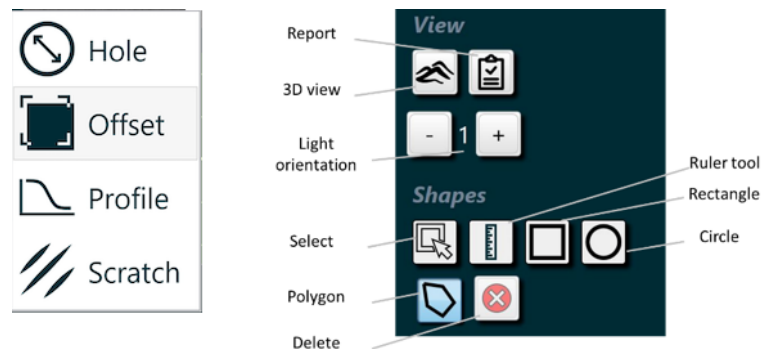


FIGURE 52: FUNCTIONS, VIEWS AND SHAPES TOOL AVAILABLE UNDER ANALYSIS MODE

HOLE FUNCTION

GSMobile allows for easy and direct measurement of hole diameters and their related circularity. In the Analysis menu, select the Hole function.

The process is automated, so the system finds the hole automatically and performs its analysis.

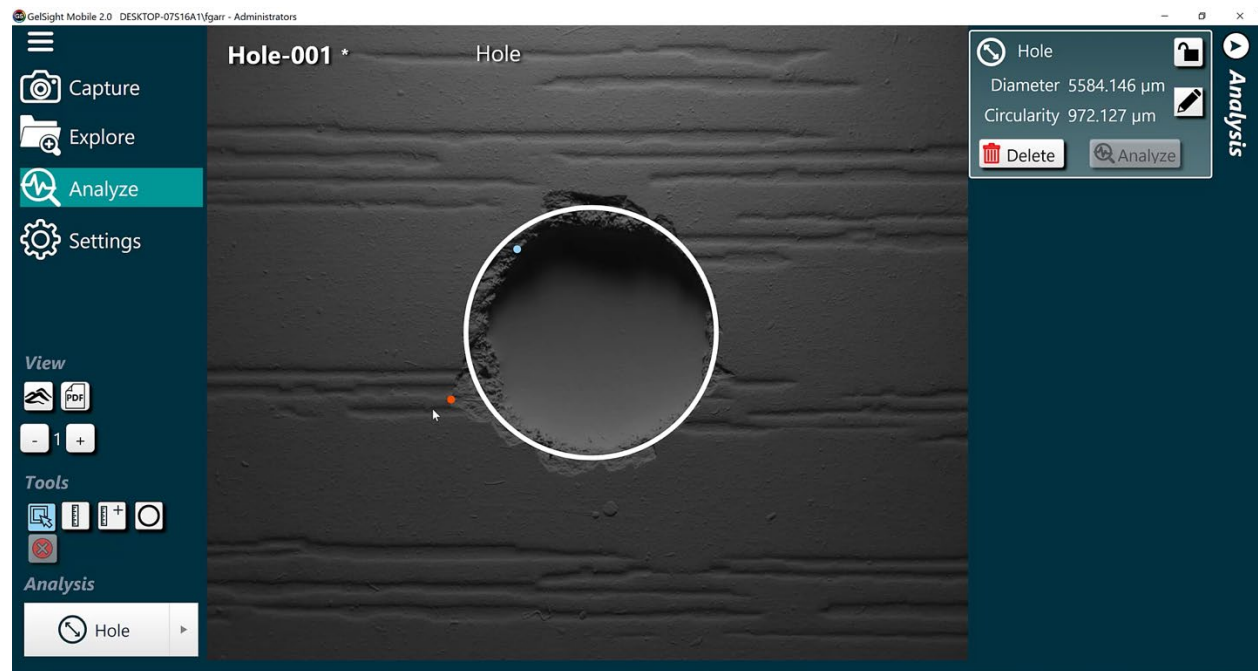


FIGURE 53: HOLE ANALYSIS

The system finds the perimeter of the hole, displays its diameter and circularity, and displays the location of the minimum (blue dot) and maximum (red dot) points of the diameter. As in this example of an imperfectly circular hole, the min and max points may not be located on the perimeter circle itself.

OFFSET FUNCTION

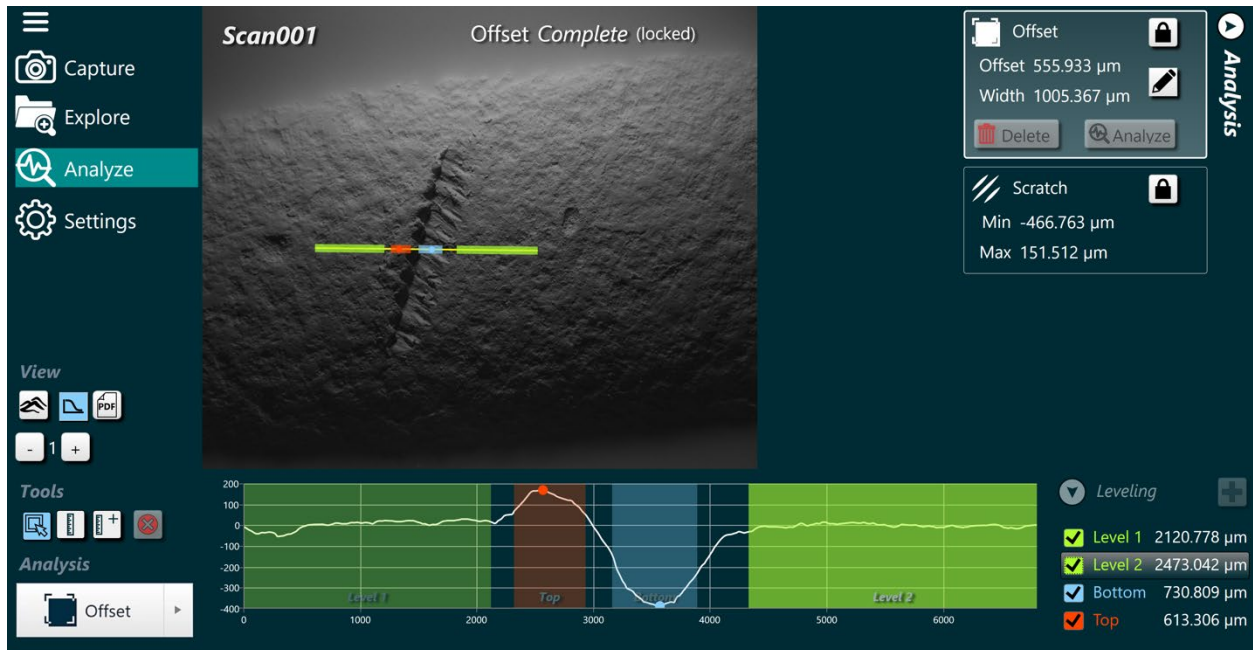


FIGURE 54: OFFSET FUNCTION

The offset function is used to measure the height difference between 2 different zones of a profile. It works similarly to the Profile Function, except that 2 additional distinct zones must be defined by the User. This corresponds to the red and blue areas. For the leveling function, the User can move the boundaries of these zones by simply moving the edges of the image on the tablet's touch screen.

These two (2) regions correspond to the locations of the domain where an averaged z height will be calculated. Once the two (2) zones are well defined, the value of the offset which is the difference between these two (2) altitudes, is given at the top of the screen (here $556 \mu\text{m}$).

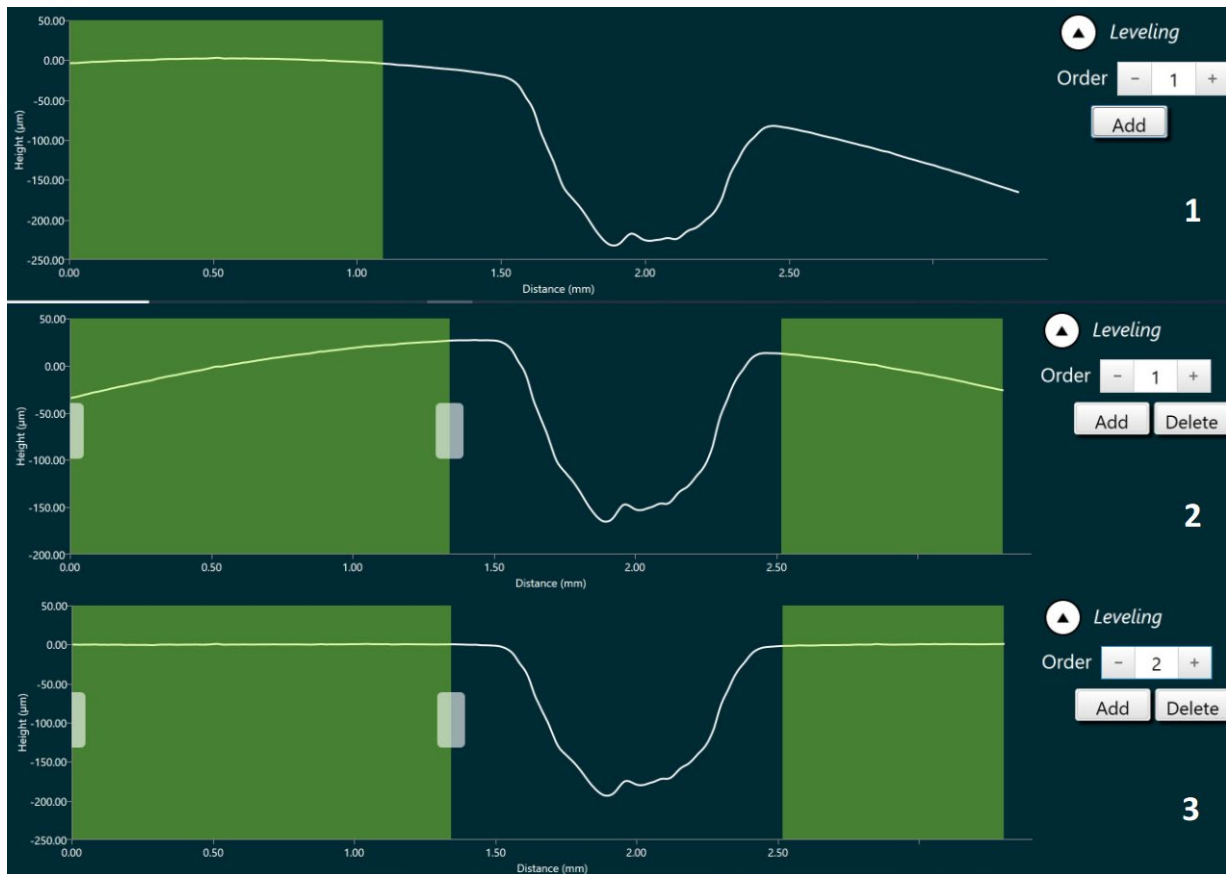


FIGURE 55: UTILIZING THE LEVELING TOOL

The Leveling Function has two functions: 1) It levels the profile by considering the global shape of the surface to be measured. 2) It also takes into account the probe's position during the image capture. In this case, a 1st leveling zone is defined by GSMobile (Figure 54-1). The User can change the boundaries of the level zone by moving the cursor on each side of the leveling zone. A 2nd leveling zone can be added by clicking on the Add box (Figure 54-2). Then, the User can disregard the cylindrical shape of the measured component by selecting the polynomial order of the leveling function. Here the 2nd order is chosen (Figure 54-3).

For a flat surface, a 1st order levelling adapts to level the profile.

PROFILE FUNCTION

Select Profile from the Analysis Menu.

The profile function allows the User to directly access the z altitude along a User Selectable Line. Figure 56 shows the profile across a dent on a cylindrical pipe. After plotting a line across the dent, the User has direct access to the z profile along the plotted line (green and red circle being the starting and ending points respectively). In this example, one can see the profile of the dent but also the global cylindrical shape on the part (here a pipe). In this kind of configuration, it may be difficult to directly extract the relevant information the User wants and a levelling of the overall shape would be helpful.

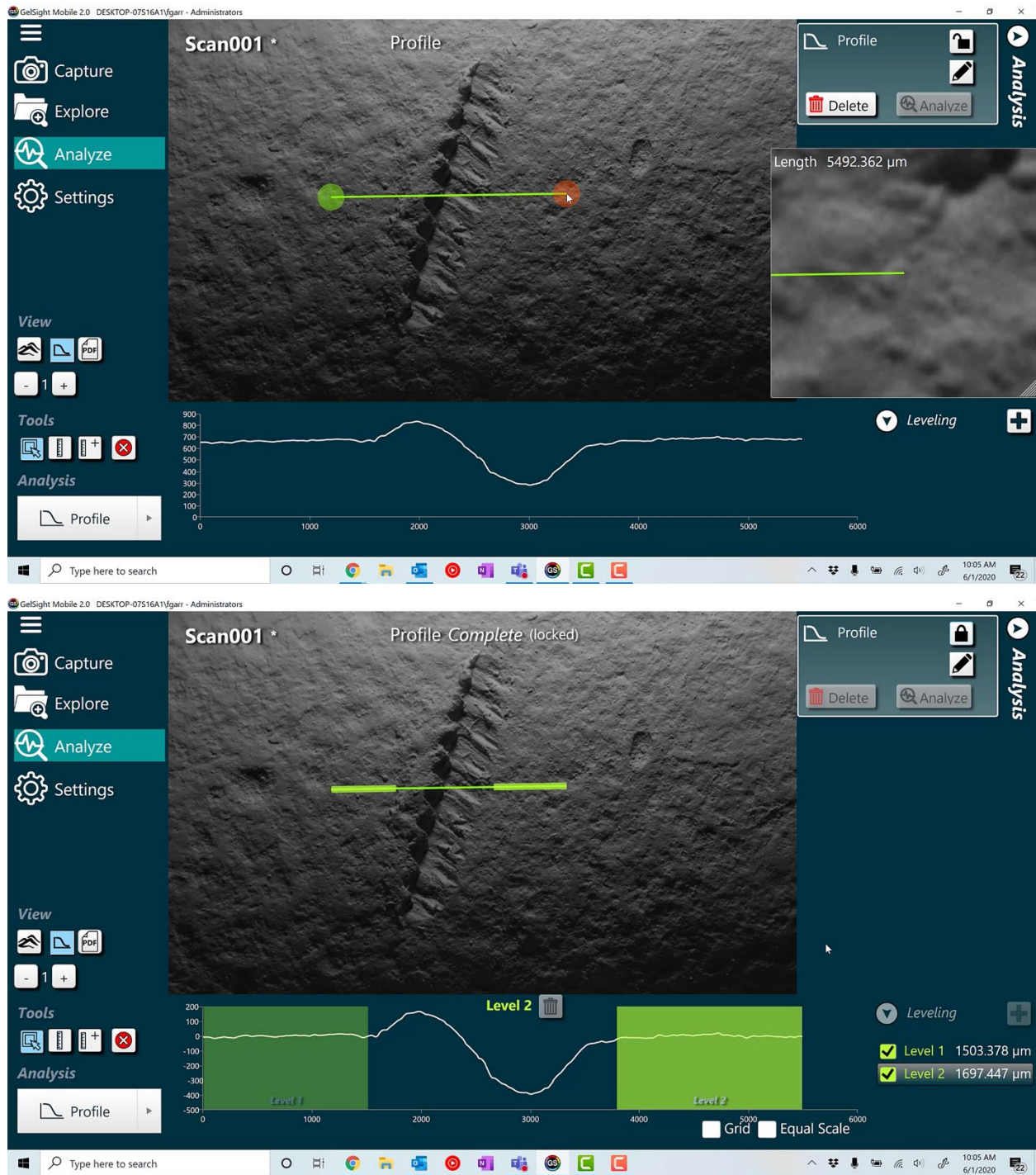


FIGURE 56: PROFILE FUNCTION

In this case, it is very easy to determine the lowest point of the profile of the dent.

In the Tools panel (left side of the window), the User can zoom in or out of the image or to select the light channel allowing the visualization of the Capture according to the angle of lighting (see Figure 54).

GRID AND EQUAL SCALE

Check the **Grid** checkbox to show the display of the profile grid.

Check the **Equal Scale** checkbox to fit the ranges of the axes to the available screen space. That ensures the measurement distance per pixel is the same for both axes, as shown in this example:

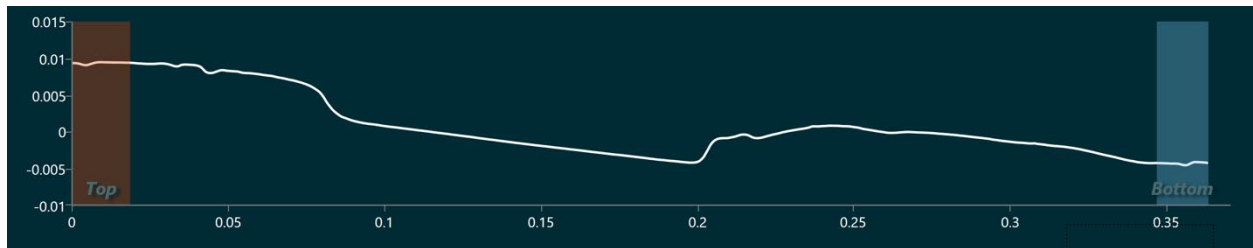


FIGURE 57: WITHOUT EQUAL SCALE

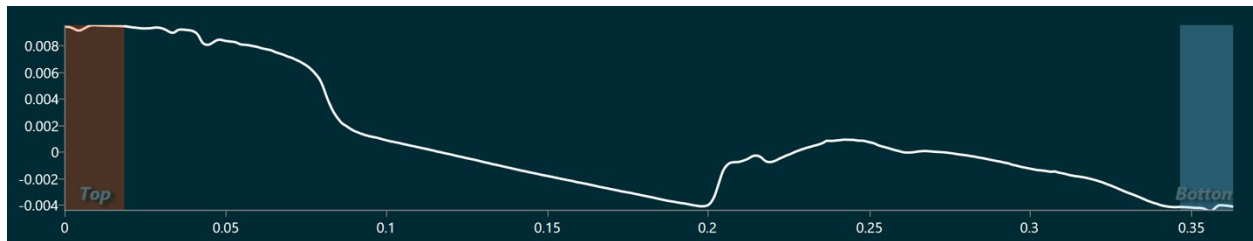


FIGURE 58: WITH EQUAL SCALE

SCRATCH FUNCTION

To characterize a scratch, the user wants to know the deepest point of the scratch and its position.

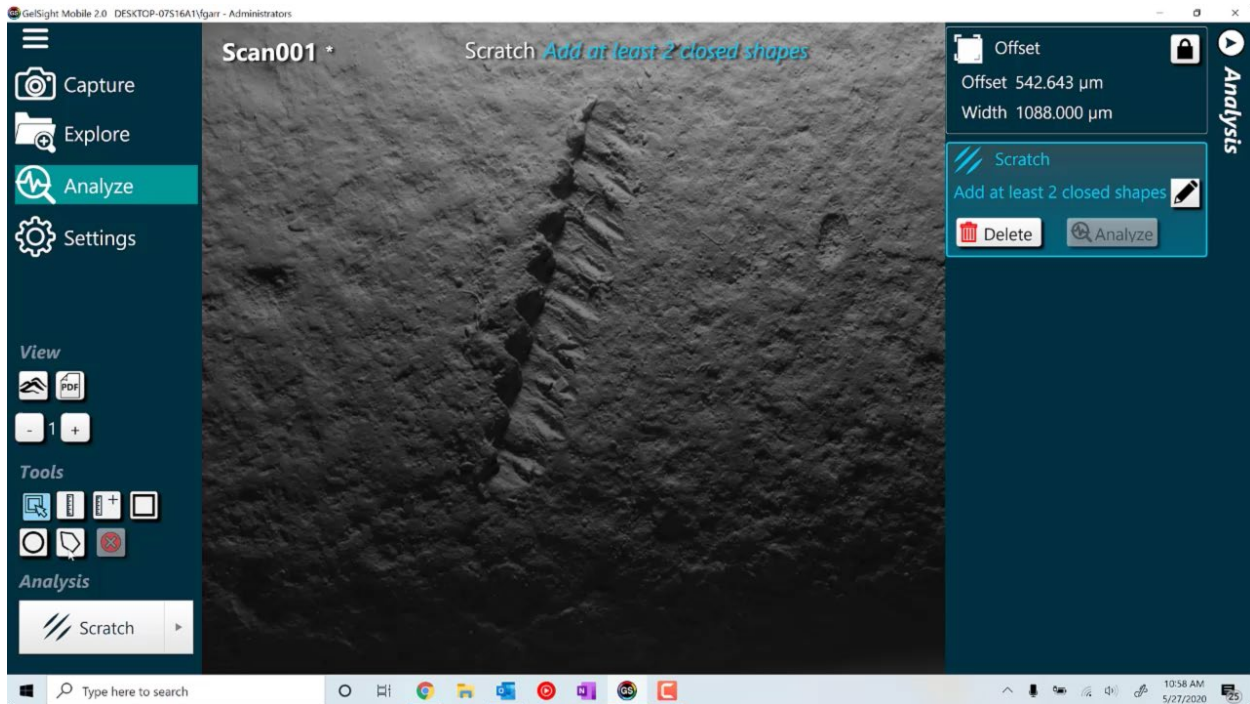


FIGURE 59: SCRATCH FUNCTION

The Scratch Function determines the deepest and highest point of a selected area. To characterize a scratch, draw two (2) polygons:

1. Draw the first polygon to isolate the scratch.
2. Draw a second polygon that contains the 1st polygon and is approximately 3 to 4 times larger than the area of the 1st polygon). The GSMobile system will compare the second area to the area that encloses the scratch. It will use this 2nd area to erase the scratch by reconstructing the surface using a polynomial function. The Scratch function will determine the minimum and maximum altitudes of the 1st polygon including the scratch with respect to this surface of reference.

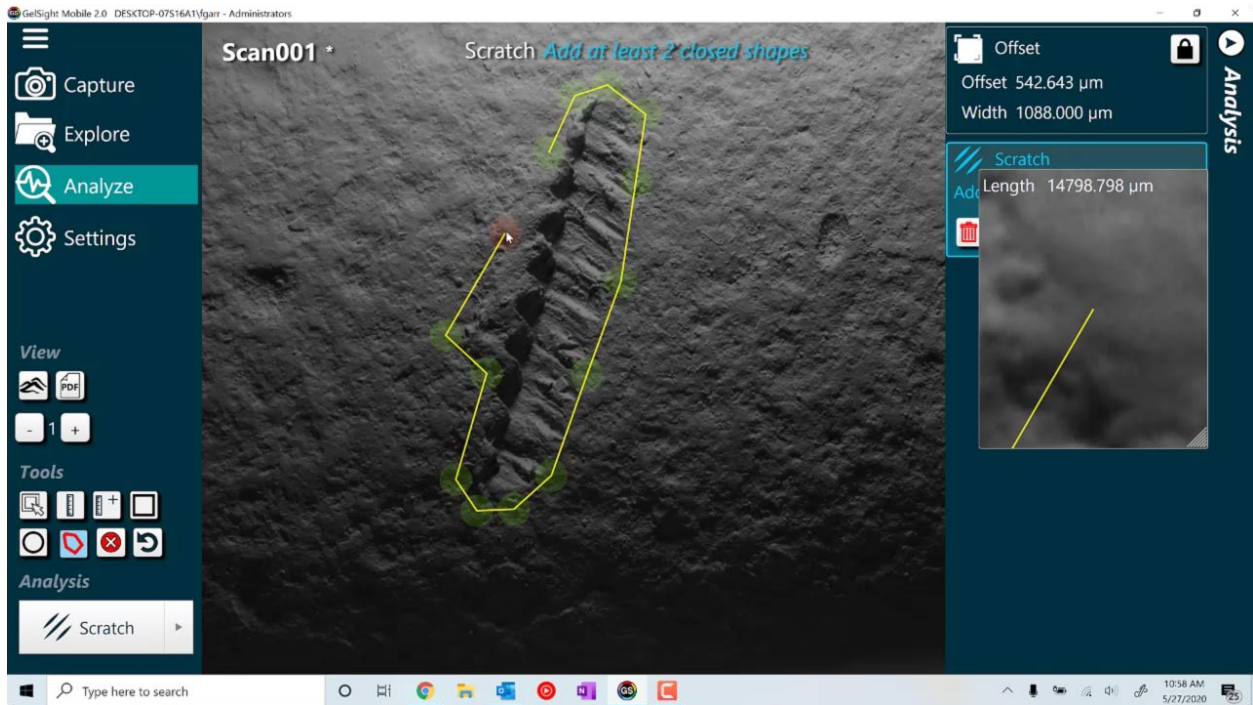


FIGURE 60: FIRST POLYGON ISOLATES THE SCRATCH

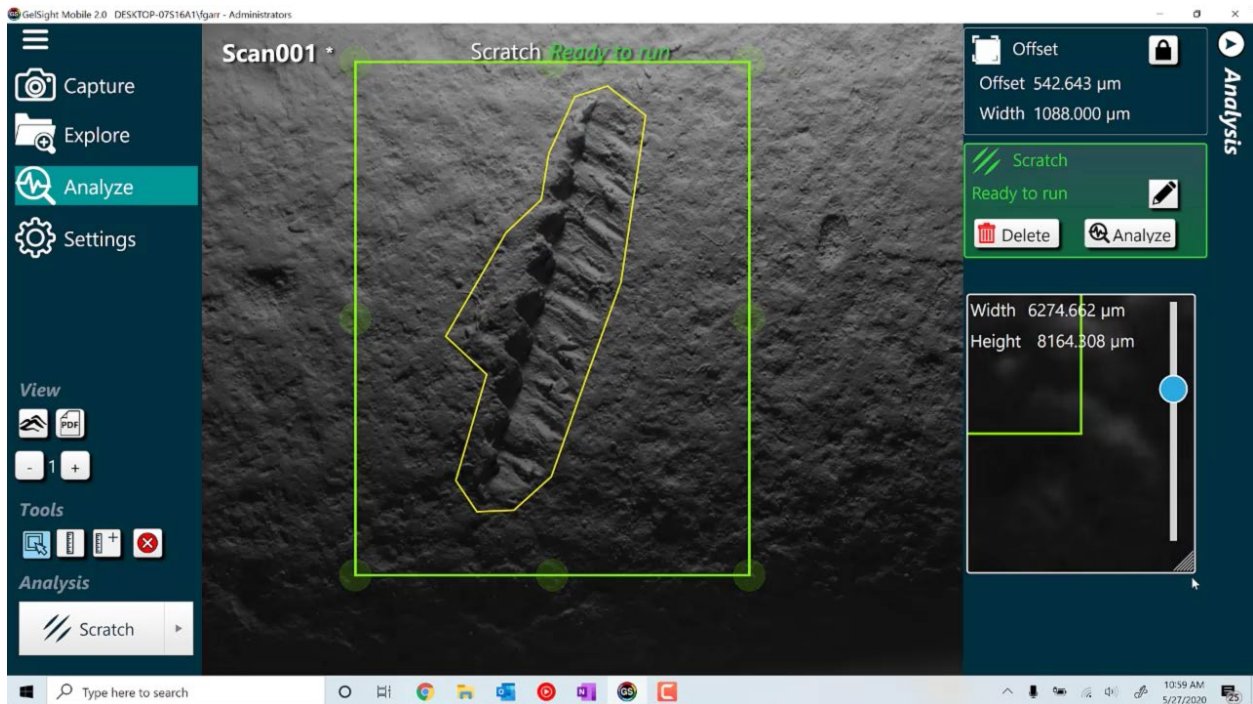


FIGURE 61: THE SECOND POLYGON DEFINES THE REFERENCE SURFACE AREA

Once the 2 polygons are created, click the Analyze button in the upper right menu.

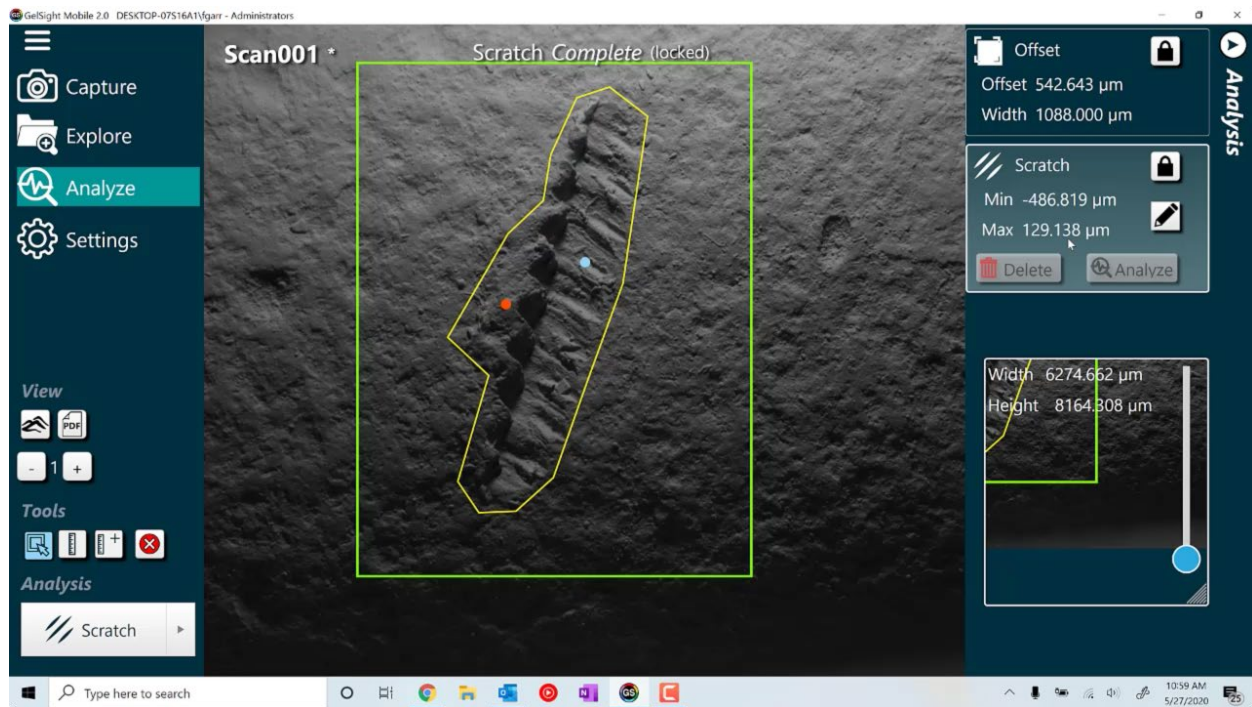


FIGURE 62: SCRATCH ANALYSIS RESULTS

The result of the Scratch Function will deliver the Min Z and Max Z of the area defined by the first polygon. The Min Z and Max Z of the scratch are also represented by the blue and red circles respectively.

Note: It is critical that both polygons contain areas where the gel came into contact with the surface and do *not* contain areas that did not come into contact with the surface.

5.9 2D Ruler Tool

The 2D ruler tool is a convenient tool to perform direct measurements in the x-y plane by simply plotting a line with a finger on the touch screen. In few seconds, you can measure very fine details (Figure 63: Utilizing the Ruler tool). The result of this direct measurement is expressed in mm or the unit you selected.

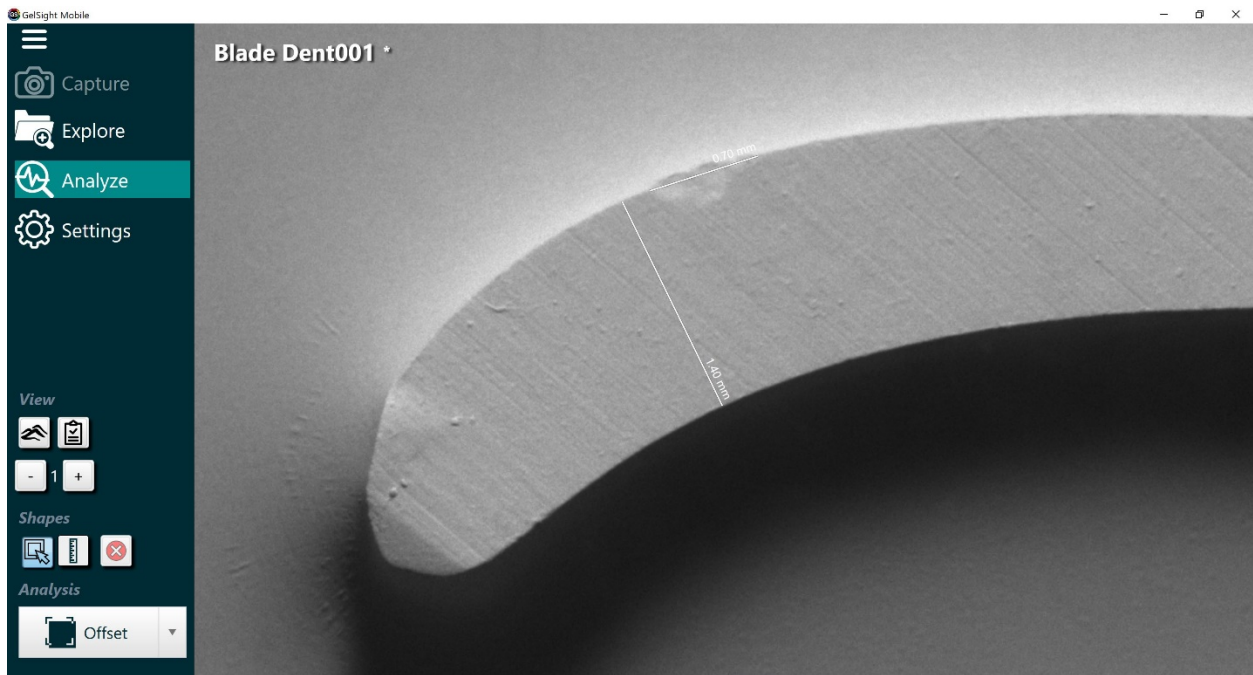


FIGURE 63: UTILIZING THE RULER TOOL

There are many more facets to the Ruler Tool:

- Draw a ruler on a scan to measure spatial distances
- Use the handle preview window to see the end of the ruler as you drag it
- Change the zoom in the handle preview window
- Change the light direction to help you see the edge. You want to choose a light direction perpendicular to the edge
- Give the ruler a name
- Force the ruler to be vertical or horizontal
- Use a global ruler (the Ruler with the plus) to make a scale marker – make a ruler, force it to be horizontal then make it a specific length like 0.25 in
- Have your named rulers in a report
- Note that if you have multiple analysis routines on the same scan, the rulers get associated with the active analysis routine and will show on that report. They will not show on the reports for other analysis routines. The global rulers will show on all reports.

5.10 3D View Mode

In Analysis mode, the 3D surface topography is available by clicking on the 3D symbol.

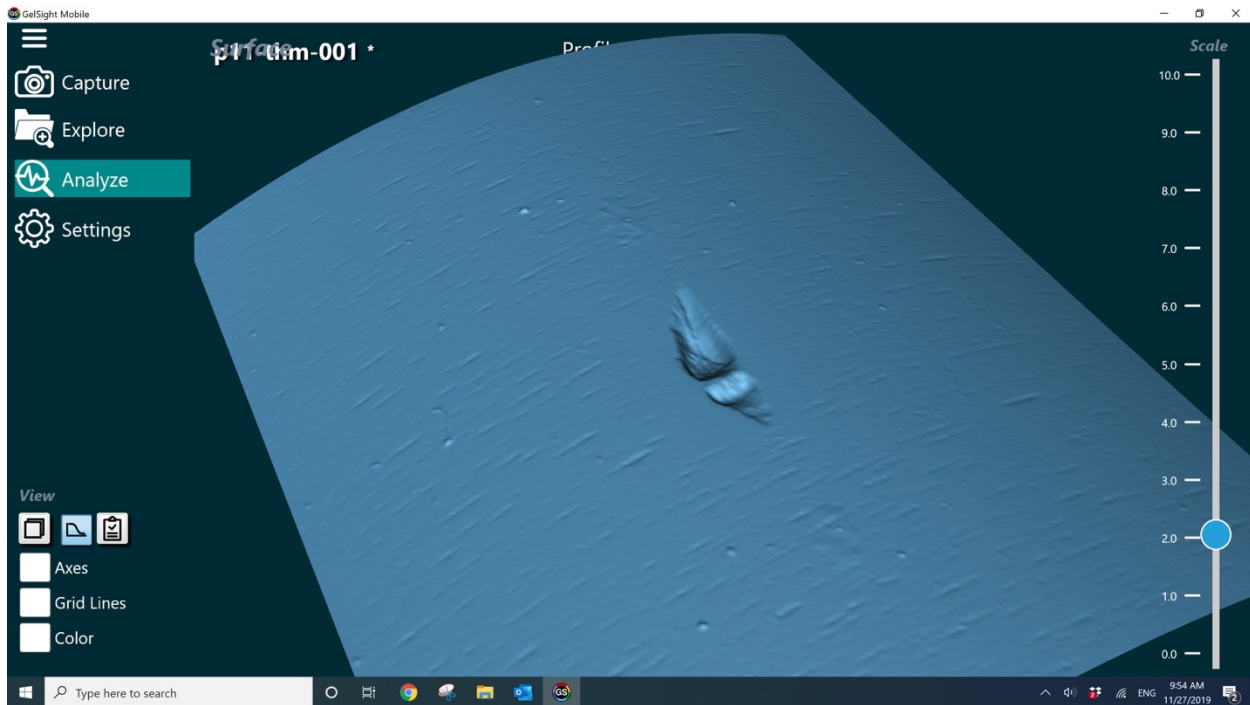


FIGURE 64: 3D RENDERING OF THE SPECIMEN

The User can enlarge, shrink or rotate the image using 1 or 2 fingers on the screen of a tablet or on the touchpad of a laptop. This allows the User to have access to very detailed information in the capture.

Axis, grid lines and color map can be selected by checking the corresponding boxes. The color map and the magnification in the z direction can be customized by the User directly on the screen (Figure 64).

5.11 Automatic Report generation

GSMobile can automatically generate a report after a measurement and/or an analysis. In Analysis mode, click on the Report button (Figure 52: Functions, Views and Shapes tool available under Analysis mode) and select the information to appear on the report.

For traceability, crucial information such as Device S/N, the Gel Cartridge S/N and the calibration set can be monitored. This enables the User to know all the parameters required during the measurement (Figure 65).

The User can print out and save to pdf format or copy the report in the clipboard.

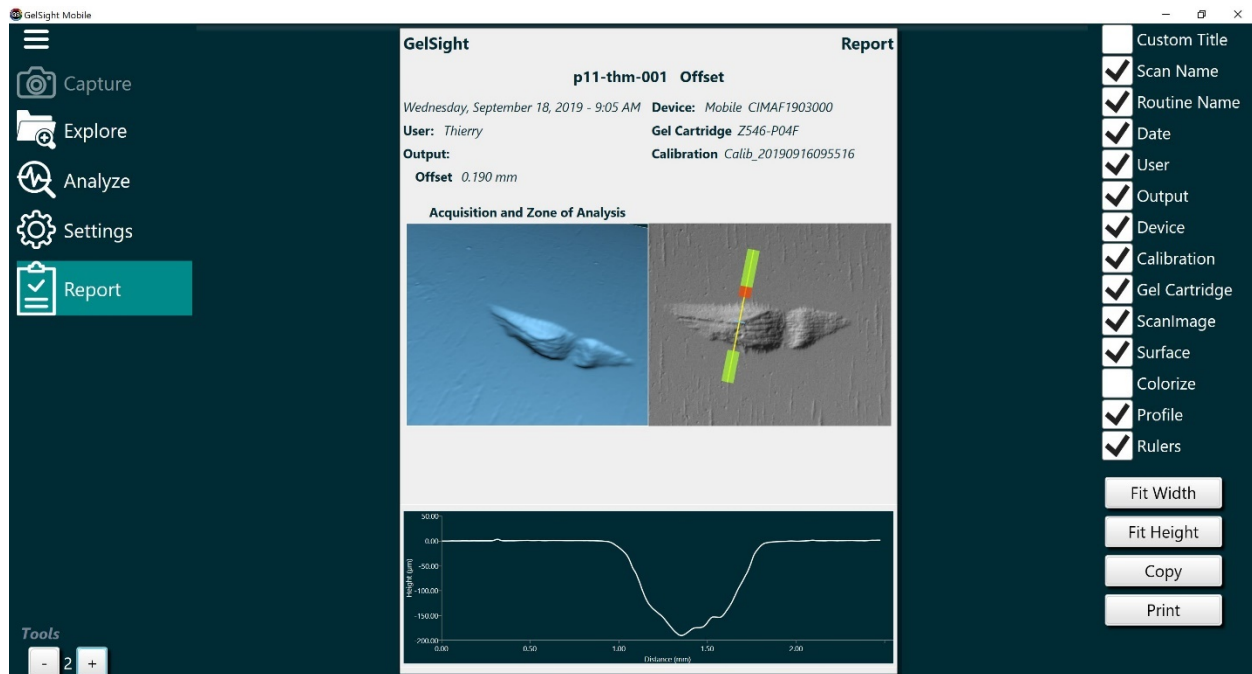


FIGURE 65: AUTOMATIC REPORT GENERATION MENU

5.12 Output files, Export files

CONVERT TO: STL FILE

GSMobile offers the capability to export files under stereo-lithography formats (.stl). Those STL files can be imported into 3rd party applications that accept STL files, for example, the majority of CAD software packages, mesh software packages, and 3D printers.

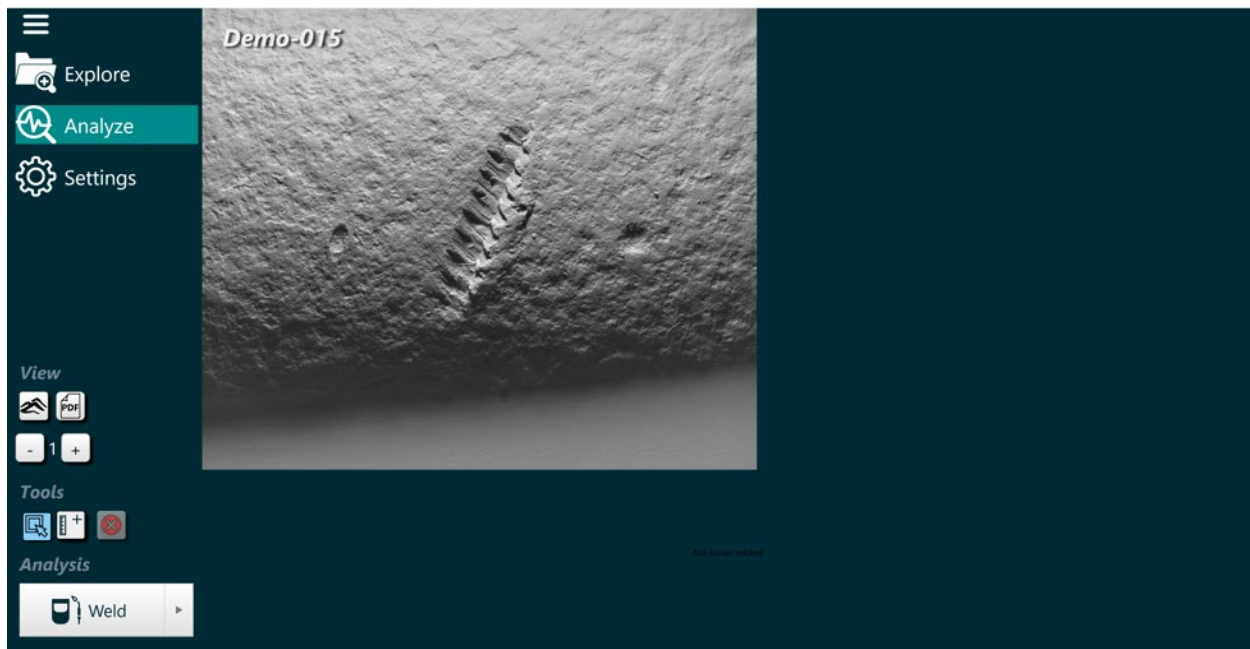


FIGURE 66: FILE TO BE EXPORTED AS STL

Before exporting an STL file, you can see a view of the 3D image by clicking on the 3D imaging view (mountains) icon  in Analysis Mode.

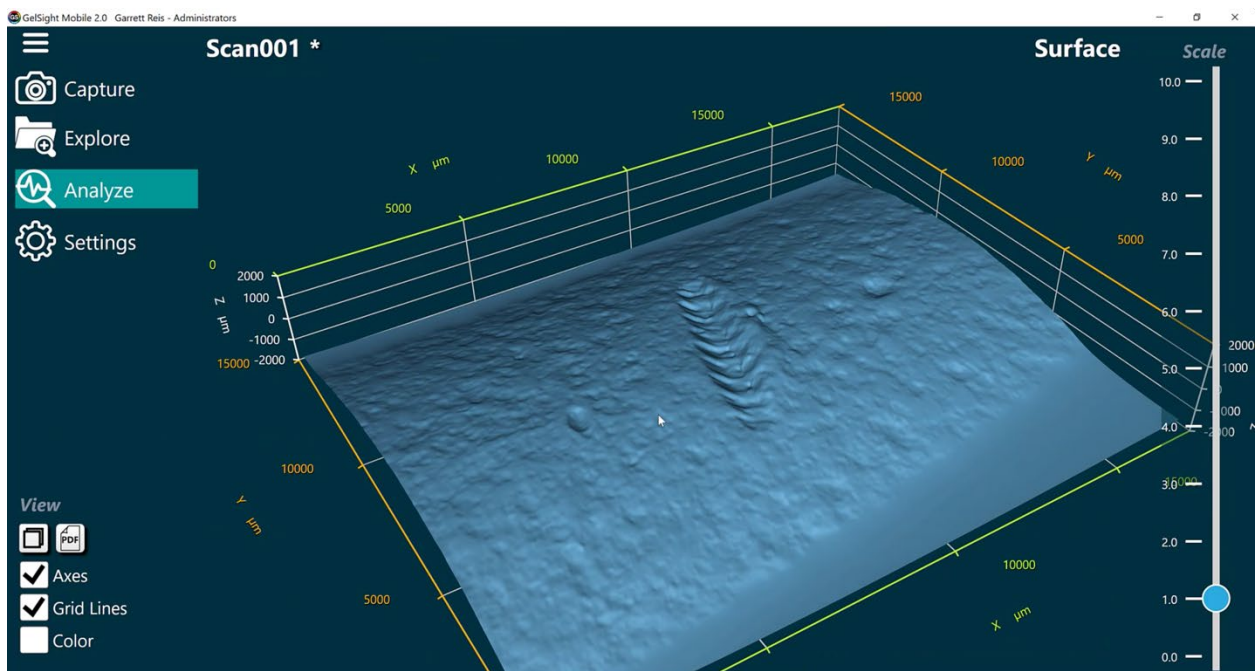


FIGURE 67: 3D IMAGE OF THE SCAN

While you can change the scale of the 3D image in this mode, as in the example below, that enhanced view will not affect the file that is exported as an STL. The STL file will remain at a scale of 100%.

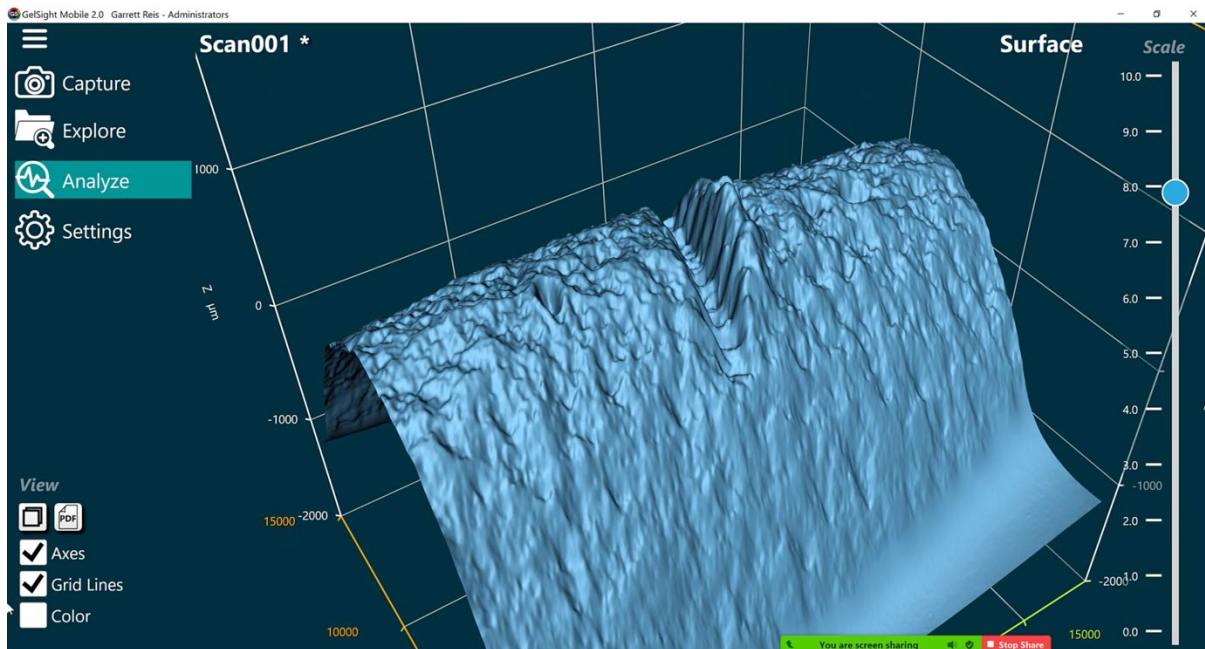


FIGURE 68: THIS ENHANCED VIEW WILL NOT CARRY OVER TO THE STL FILE

To export the STL file, you must first generate a report by selecting the PDF icon . That takes you to Report Mode.

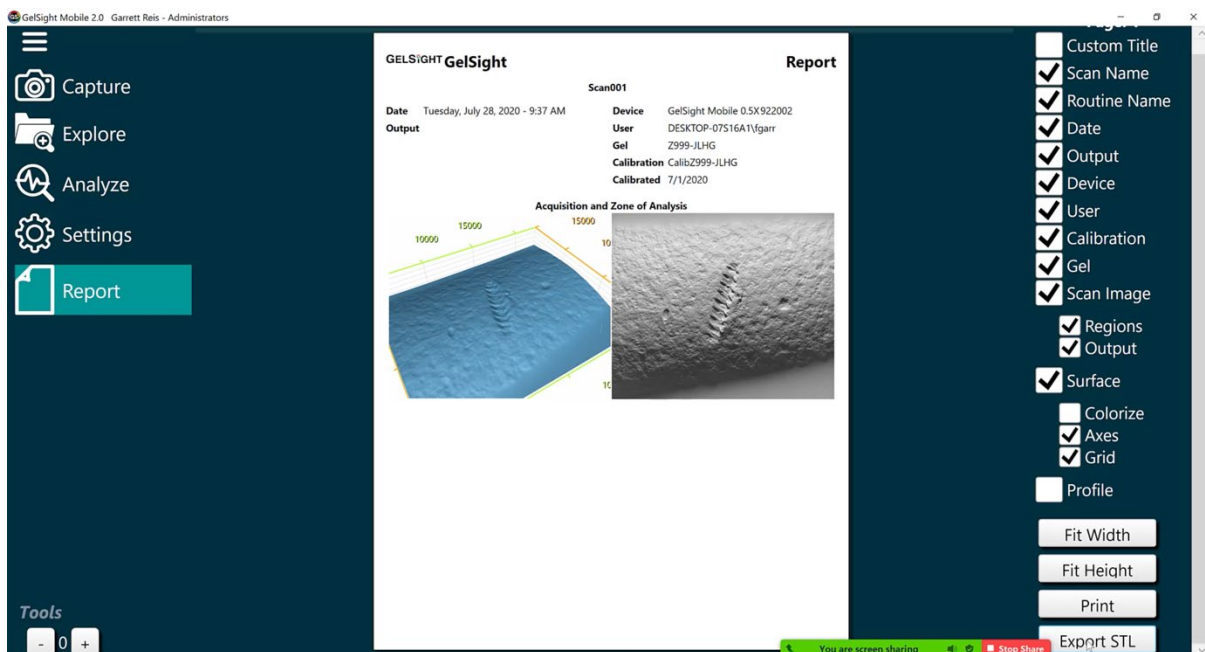


FIGURE 69: REPORT MODE

In the right panel, at the bottom of the report window, click the **Export STL** button.

Note: At present the GSMobile system does not provide confirmation when an STL export is successful.

After you've exported an STL file, you can use Windows Explorer to navigate to: C:\Users\Public\Documents\GelSight\Scans and then to the folder where this particular scan would be stored.

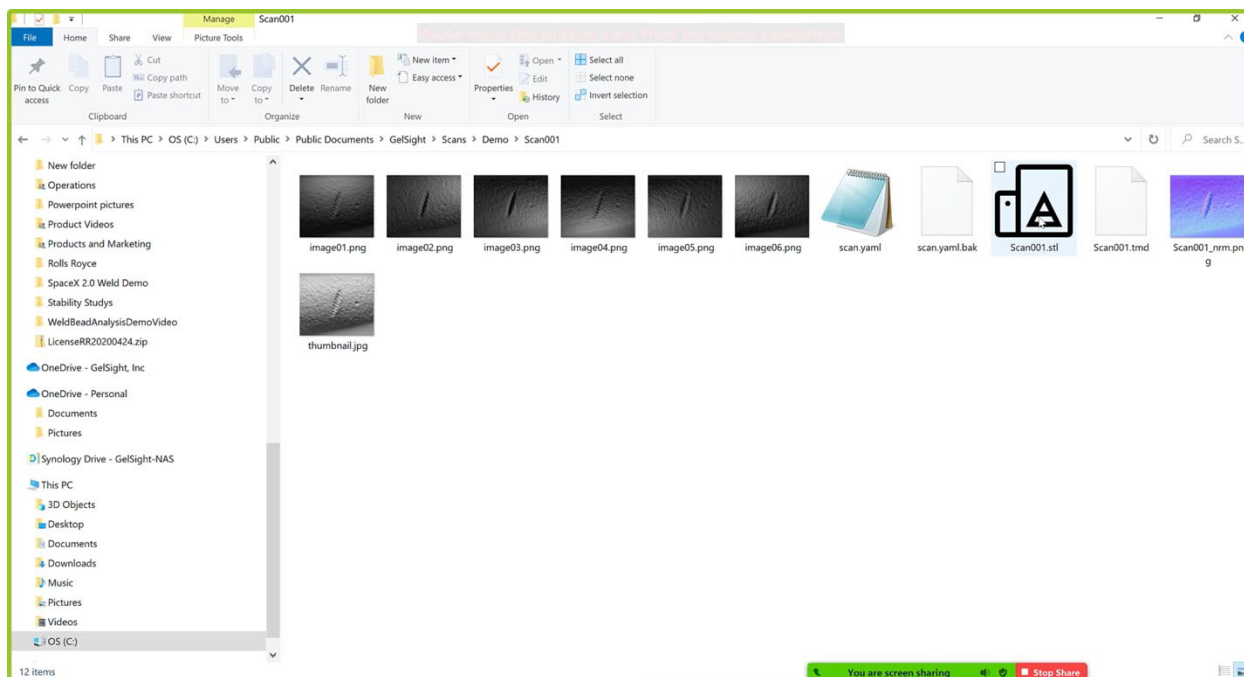


FIGURE 70: LOCATION IN EXPLORER OF NEW STL FILE

5.13 Advanced Parameters

Advanced Parameters such as Field of View and Angular Bias, are automatically set by the Automatic Calibration Protocol (see section 5.4.)

The User can choose to manually fine-tune these parameters for analysis. Generally, the automatic calibration protocol automatically determines optimized values for these parameters.

FLAT FIELD OF VIEW

The “Field of View” parameter controls surface bending, and limits the low frequency distortion inherent to the compacity of the system. Figure 71 shows the role of “Field of View” on the spread and the bend across the main diagonal of the capture on flat glass.

“Field of View” can be adjusted so that surface bending is below 0.5%. The typical value for “Field of View” is between a range of 4 to 10 degrees.

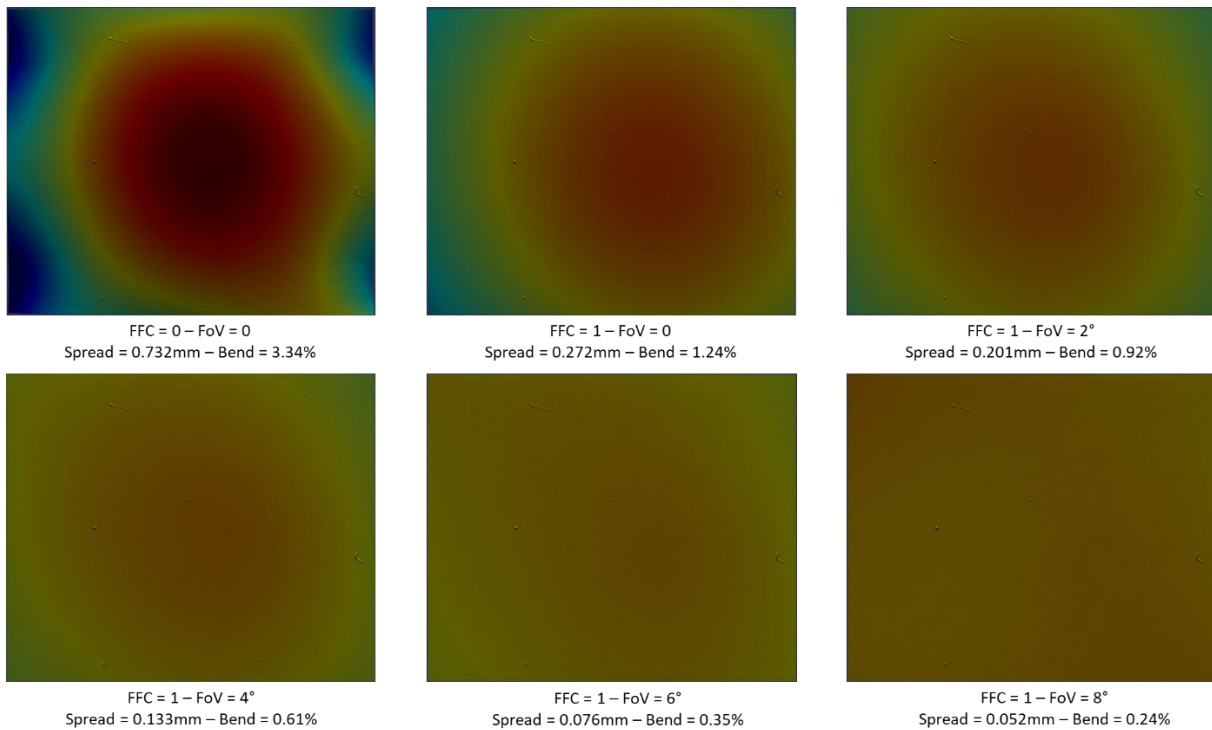


FIGURE 71: ROLE OF FLAT FIELD CORRECTION AND FIELD OF VIEW PARAMETERS ON A FLAT GLASS CAPTURE

ANGULAR BIAS

The “Angular Bias” parameter expressed in percent (%) modifies the nominal section of reference of the calibrated balls of the BGA used in the computation of the calibration model. “Angular Bias” is mainly used to stretch or compress the measurement in the vertical direction.

Typical values of “Angular Bias” are between -15% and +15% and depends on the optical properties of the gel reflective membrane.

6 Best practices

6.1 Surface Cleaning

Before each measurement, the user should clean the surface to be measured in order to remove any traces of dust, fibers or other material. Due to the high sensitivity of the gel membrane, any dust or fiber present on the surface will appear on the captures and ultimately in the 3D reconstruction. To clean the surface, classic blue painter’s tape will clean the glass.



Important Note: Never use tape to clean the Gel Cartridge. It will damage the gel's painted membrane.

6.2 Concave Surfaces and Cavities

In order for GelSight Technology to work, the gel must stay in contact with the surface that will be measured. Due to the elastomeric nature of the gel, residual air can be trapped between the gel and the surface during the measurement of hollow shapes and cavities. The User can easily detect trapped air since air pockets are visible as a blurry spot on the screen as opposed to the other parts of the image (see Figure 72). In such cases, a quantitative measurement of the scratch cannot be measured since the surface of the air pocket is part of the 3d reconstruction.

To avoid trapped air on hollow shapes such as cavities, the solution is to roll the probe while applying the gel membrane to the surface. The idea is to gently press the gel on one side and continue to apply pressure on the gel as you roll the probe. That will help push the air out of the area to be measured. (see Figure 73).

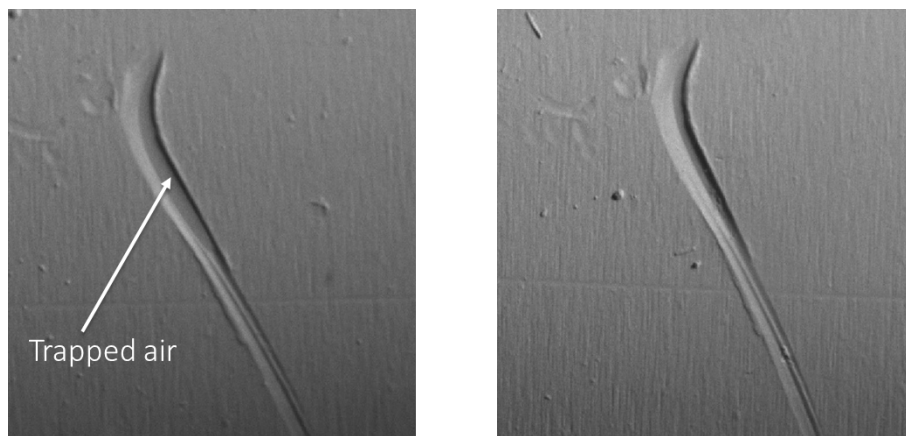


FIGURE 72: AN EXAMPLE OF TRAPPED AIR DURING THE MEASUREMENT OF A SCRATCH (LEFT: INCORRECT CAPTURE, RIGHT: CORRECT CAPTURE)



FIGURE 73: HOW TO AVOID AIR TRAPPED ON CONCAVE SURFACES

6.3 Selecting the regions for scratch measurement

An area that does not contact the Gelsight Mobile's gel surface will not show up on a measurement or an analysis. In the case of the scratch function (see section 5.8), the delimitation of the polygons used in the determination of minimum and maximum z of a selected area cannot contain areas which are not in contact with surface (see Figure 74).

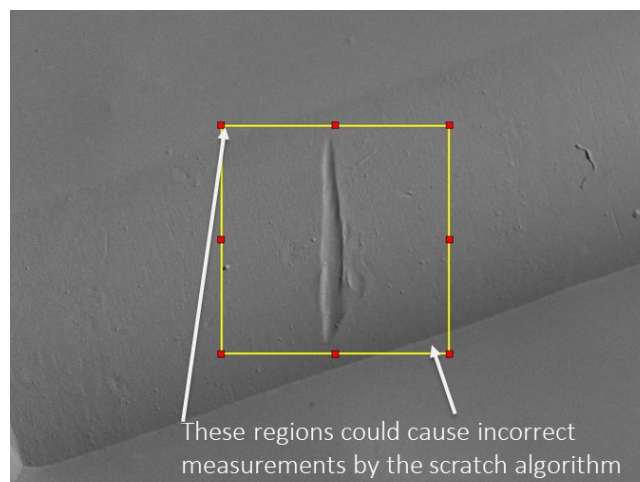


FIGURE 74: SELECTION OF REGION FOR SCRATCH MEASUREMENT

7 Maintenance Operations

- Probe Visual and internal Inspection
 - Ensure there are no apparent dents, cracks, or other damage on the aluminum frame that would inhibit the device from performing properly.
 - Gently shake the probe to ensure there are no loose parts within the casing.
 - It is not recommended that the probe be opened during routine maintenance checks.
 - If an internal problem is suspected, please contact support@gelsight.com.
- Probe Head Inspection
 - Remove gel currently being used by the device to inspect the gel loading chamber.
 - Visually inspect all 6 LED light windows for any dirt or hazing. Clean LED windows using a water damp cloth or alcohol wipe if necessary.
 - Ensure the glass plate in the center of the chamber is clean from dirt, debris, or hazing. If necessary, use an alcohol wipe to clean this surface.
 - Do not use compressed air to clean the cartridge compartment. The protective glass can be cleaned using optical quality tissue or a standard camera lens cleaning kit.
- Locking Ring Inspection
 - Ensure the gel locking ring is clean of debris and dirt. The locking ring should open and close freely.
 - Ensure the locking ring is intact and allows for the Gel Cartridge to stay in place when held at different angles. The gel should not move and there should be no shaking or loose feeling when applying pressure.
- Cleaning of Probe Outer Casing
 - Most of the external parts of the GelSight Mobile probe are made of anodized aluminum. Cleaning the GelSight Mobile probe necessitates a wipe down using a non-fiber textile or a cloth without a cleaning agent. In cases of traces on the outer casing, use a water damp cloth or alcohol wipe if necessary.
- USB Cable inspection
 - Ensure there are no apparent cracks, kinks, or bends along the USB cable that would inhibit the device from performing properly.
 - Ensure the computer port's USB connector is not damaged, and the device can be detected when connected to a computer
 - Unscrew the device from the USB connector. Ensure the threads are functioning properly and both the male/female connectors have not been warped.
- Camera Focus
 - GelSight does not expect camera focus to change over time/use. It may be necessary, though, to adjust the camera focus when using a thicker Gel Cartridge developed for specific applications.
 - Optimal camera focus can be adjusted using the provided 2mm hex drive.
 - GelSight recommends using the BGA target as a tool to ensure optimal focus.
- Calibration tools
 - As for any other metrology instrument, a formal, periodic, and documented calibration of the specimens involved in the calibration protocols is recommended. Rubert R513E and GelSight G-500 specimens have to be recalibrated by a laboratory qualified according to the ISO/IEC 17025 standard or the National Institute of Standards and Technology.

- The frequency of the recalibration of metrology instrument is generally once a year but can depend on the quality management system of each user.

8 Troubleshooting

The probe is not detected or recognized by GSMobile.

- Check the connections at the probe and at the USB 3.0 port of the tablet or laptop to make sure the probe is properly plugged in.

In Capture Mode, the LEDs do not illuminate.

- Make sure Live View is on. (Section 5.5)

In Capture Mode, the image stays frozen on the screen.

- Make sure Live View is on. (Section 5.5)

No possibility of post treatment or drawing lines or circle in View Mode.

- Verify that the height map is available and the .tmd works.

During the automatic calibration protocol, GSMobile is not able to detect a significant part of the spheres (spheres without circle).

- The BGA captures may be overexposed. Verify and fine-tune/or the value of the Shutter speed. (See [Shutter Speed Selection](#).)

During the automatic calibration protocol, GSMobile is not able to detect the center of the R513 target groove.

- The R513 groove capture may be overexposed. Verify and/or fine tune the value of the Shutter speed. (See [Shutter Speed Selection](#).)

The LED lights on the probe are flashing.

- Make sure the proper camera drivers are installed. To install the latest drivers visit https://www.ximea.com/support/wiki/apis/XIMEA_Windows_Software_Package
- Select the "XIMEA Windows Software Package Stable Installer and run it.

The images of the scans are too bright or dark.

- An administrator-level user must recalibrate the gel. Navigate to Settings > Device. Select Calibrate. Before starting the calibration, adjust the shutter speed accordingly. The default shutter speed is 0.602. To lighten up future scans, increase the shutter speed. To darken an image, lower this value. We recommend shutter speed settings between 0.45 and 0.8 ms.

The display is unclear.

- Make sure the camera is in focus. Using the provided 2mm hex drive, adjust the camera focus screw located within the back cap of the device. See [Camera Focus](#) for details.
- Be sure all stickers have been removed from the gel before inserting it into the probe head.
- Make sure the device and gel have been properly cleaned. See the [Cleaning of the Cartridge and Gel Membrane](#) and [Maintenance Operations](#) sections for details.

No device detected.

- Make sure to use a USB 3.0 port.
- Make sure the computer recognizes the device. You should be able to locate the GelSight device within the computer's "device manager" application.
- Ensure Ximea camera drivers are installed on the computer.

Failed calibration.

- Be sure to clean off all calibration artifacts of excess debris or particles. We recommend using painter tape or a traditional foam swab. Cleaning kits are also available for purchase from GelSight.
- *For Administrators only.* Ensure calibration artifacts have been entered correctly into the software:
 1. Go to Setting > Device.
 2. Make sure the BGA target selected matches the engraving within the BGA Cap (BGA D10 S20).
 3. Check to see that the correct Rubert grove or G500 plate is selected. We recommend using the 500-micron groove if the user is using a Rubert artifact.
 4. Select Edit next to the groove target dropdown menu.
 5. Ensure the verified button is checked and the depth matches the corresponding certified depth on the included certification documents.

The device keeps disconnecting.

- Make sure the device is plugged into a USB-C port. USB-A ports may cause a loose connection.
- Ensure the case on the tablet is not preventing the USB from full insertion.

There are too many particles on the Gel.

- See recommended gel cleaning instructions. *Never* use an alcohol solution to clean the gel.
- With the LED lights illuminated, inspect the gel for any tears to the red paint coating. Tears to the outer paint layer would suggest changing and calibrating a new gel.

The Offset analysis is not leveling.

- Pre-define the area of interest on the part as a flat or curved surface.
- When adding a level function within your analysis routine, ensure the correct order is selected. An order of 1 corresponds to a flat surface. An order of 2 or more corresponds to a curved or wavy surface.

The Gel does not fit snugly into the probe.

- Inspect the locking ring mechanism for any deformities.
- Ensure the locking ring does not contain any debris or dirt buildup that prevents a complete rotation of the ring.
- Ensure the protruding slots around the circumference of the gel match with the corresponding inserts on the probe head.

9 Special operation – precautions**9.1 Live View Mode**

The Handheld controller synchronizes the illumination by the LEDs and captures the image on the camera. A short button push (see Figure 10) will take 6 different images with a unique LED power per image.

A long button push will rotate the LED clockwise without image acquisition. This mode can be useful to verify the lighting of some particular features on the surface.

9.2 Camera Focus

The user may have to re-focus the camera if the camera takes a blurry image when the membrane is in contact with the surface of an object.

To adjust focus, press the gel membrane on a glass surface, use the 2mm hex drive supplied with the GelSight Mobile system and turn the focus adjustment screw through the hole on the end cap (see Figure 75). Most of the time, a few screw turns will focus the camera.



FIGURE 75: CAMERA FOCUS WITH A 2MM HEX DRIVE

9.3 Disassembling

Do not disassemble the Probe except for the eventual replacement of the USB cable.

9.4 USB 3.0 Cable Replacement

The USB 3.0 cable of the GelSight Mobile Probe is CBL-U3-3M0. There are several alternatives (USB 3.1 Gen1 cables and a sync cables, CBL-U3-1M0 / CBL-U3-3M0 / CBL-U3- 5M0, 3.14 CBL-U3-3M0-ANG and 3.15 CBL-MQ-FL-0M).

9.5 Environment – Protection Against Water and Humidity

It is important to use the GelSight Mobile system in a dry environment. Protect the probe against mechanical shock, water, caustic fluids, and dust. Operation in a wet environment with high humidity and/or mist can lower the quality of image capture.

Do not submerge the probe in water.

9.6 Mechanical Loads

Avoid mishandling the GelSight Mobile: shocks and excessive vibrations can damage your unit.

9.7 After Each Use

Remove the Gel Cartridge from the GelSight Mobile probe. Place the Gel Cartridge in its dedicated package. Put the protective cap on the GelSight Mobile probe. Place the GelSight Mobile probe in its case.

9.8 Cleaning of the Cartridge and Gel Membrane

The Gel Cartridge needs special attention since it's one of the most critical components of the GelSight Mobile probe system.

The membrane needs careful treatment.

For the Gel Cartridge with standard TPE (P/N GEL-MB01), the membrane can be cleaned using blue painter's tape.

For the Gel Cartridge with low friction TPE (P/N GEL-MB02), never use painter's blue tape or other sticky material which could permanently alter the surface of the membrane. Use brushes equipped with a fiber free foam (Figure 76: Recommended Gel Cartridge Cleaning Tools

The Flat Transparent Surface of the acrylic cartridge needs to be clean without traces of dust, fibers or other material. It can be cleaned using a cleaning wipe saturated with Isopropyl Alcohol usually used for optical devices.



FIGURE 76: RECOMMENDED GEL CARTRIDGE CLEANING TOOLS

10 Terms and Conditions

10.1 Delivery

The delivery lead time is 4 weeks after the Purchase Order is received.

10.2 Warranty

GelSight warrants to LMA that all items provided by hereunder (excluding consumable items, i.e. elastomeric cartridge) will, during the warranty period of one (1) year from reception, be free from defects in material and workmanship; of the grade and quality specified. With respect to any items that are defective as to design, workmanship or materials, GelSight will, at its own expense, either replace, repair or redesign, at its option, any defective item returned by LMA which failed during the applicable warranty period, within fourteen (14) calendar days of the date that such defective item is received by GelSight, unless otherwise agreed by LMA. If the defective item is discovered during the applicable warranty period and is returned to GelSight, GelSight will pay for the cost of transportation of the defective item to GelSight, and the cost of transportation of such item back to LMA. During the period of warranty, GelSight will provide to LMA the updates of the GelSight SDK software.

The warranties provided under this section do not cover any damage or defect of an item caused by persons other than GelSight, its agents, representatives, or contractors, resulting from misuse or abuse. Any item repaired, replaced or redesigned by GelSight shall be warranted for the original warranty period, beginning from the date that LMA received such item, excluding any period of time in which the item did not meet the Initial Specifications.

For a period of one (1) year following reception of the system, and for subsequent years subject to LMA making payments for annual maintenance, a GelSight technician will be on-site at LMA within 48 hours of receiving any service calls.

10.3 Spare Parts

GelSight will maintain a supply of spare parts for a period of five (5) years from the date of system installation.

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