Technical Systems Validation

Jason Long, Ph.D.
Cincinnati Children's Hospital Medical Center

Cincinnati Children's™
changing the outcome together

Technical Systems of Interest

- Video-based motion capture systems
- Force plates
- EMG systems
- Pedobarograph systems

Cincinnati Children's
changing the outcome together

Disclosure / Disclaimers

- I am a GCMAS Representative on the Board of Directors of the Commission for Motion Laboratory Accreditation, Inc. (CMLA)
- I am presenting today in my role as Director of the Cincinnati Children's Motion Analysis Lab.
- None of the following approaches/examples should be interpreted as mandatory or best practice.
  - *cmlainc.org/Resources – Quality Assurance Presentation*
- Companies and commercially available items are mentioned in this presentation. They are provided only as examples; no endorsement is implied.

Cincinnati Children's™
changing the outcome together

Terminology

- Calibration
  - A comparison of measured values delivered by a test device against those of a calibration standard
- Accuracy (Validity)
  - The degree of closeness of measurements of a quantity to that quantity's true value
- Precision (Repeatability)
  - The degree to which repeated measurements under unchanged conditions show the same results

Cincinnati Children's™
changing the outcome together

ACCURACY AND PRECISION

ARE NOT THE SAME THING

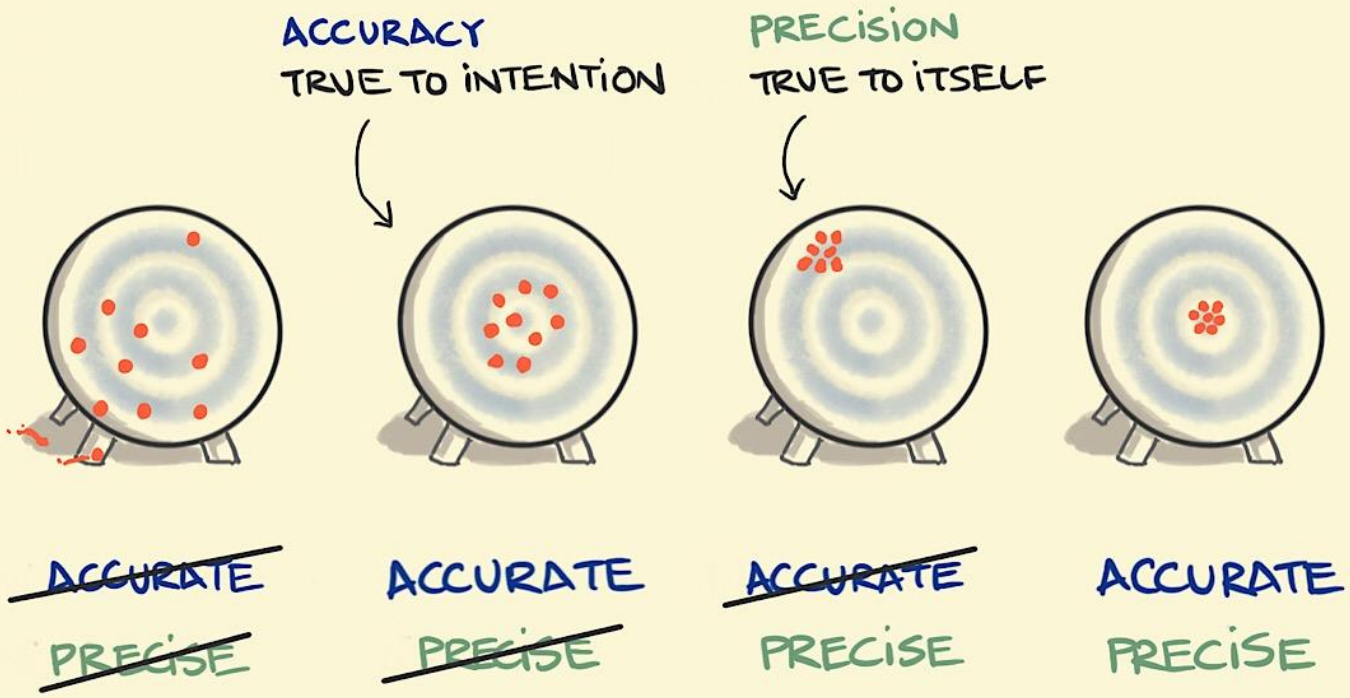


Image: Sketchplanations.com

Cincinnati Children's
changing the outcome together

Motion Capture System

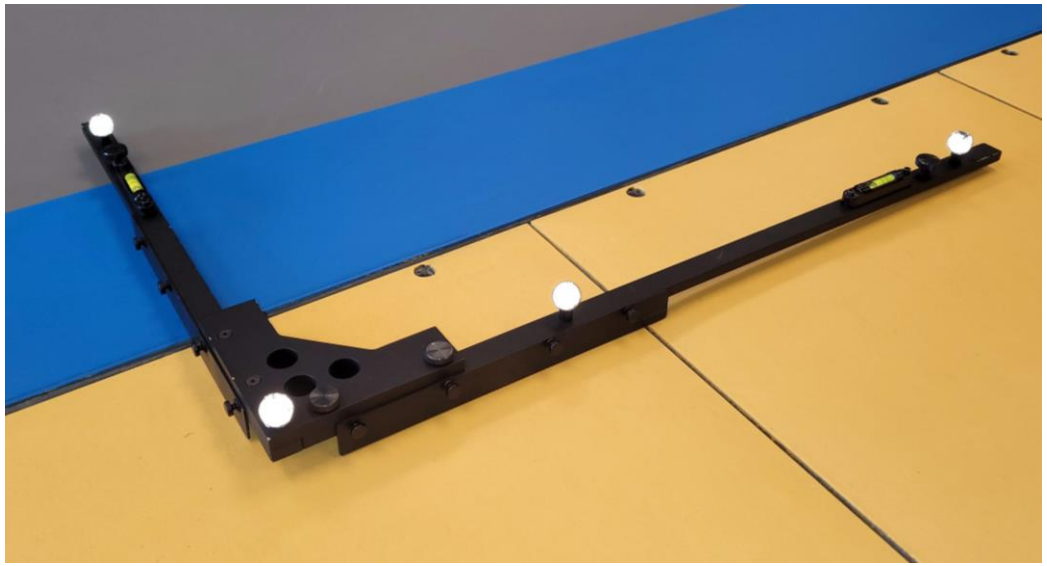
Cincinnati Children's
changing the outcome together

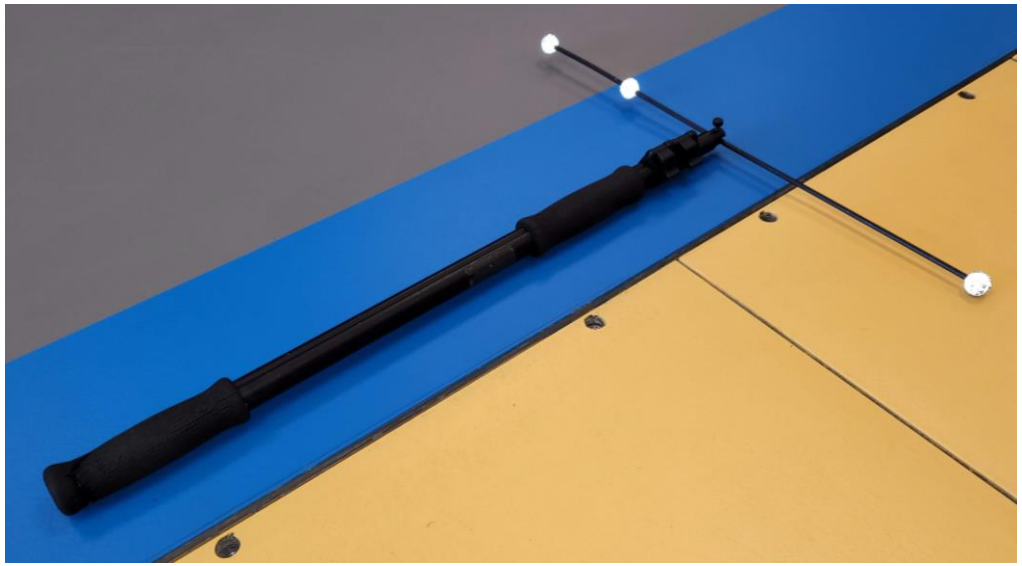
Video-Based Motion Capture System

- Calibration
  - Establishes the position and orientation of each camera around/within the capture volume
  - Establishes transformation matrix(ces) by which 3D marker positions can be calculated from 2D camera data
  - Generally performed immediately prior to data collection, and following any adjustment to cameras
  - Each camera system manufacturer has system-specific processes for camera calibration
- Accuracy and Precision
  - Repeated measurement of markers at known positions and/or distances

Video-Based Motion Capture System

- Calibration Example: MAC Raptor system (Cortex interface)
  - L-frame and wand

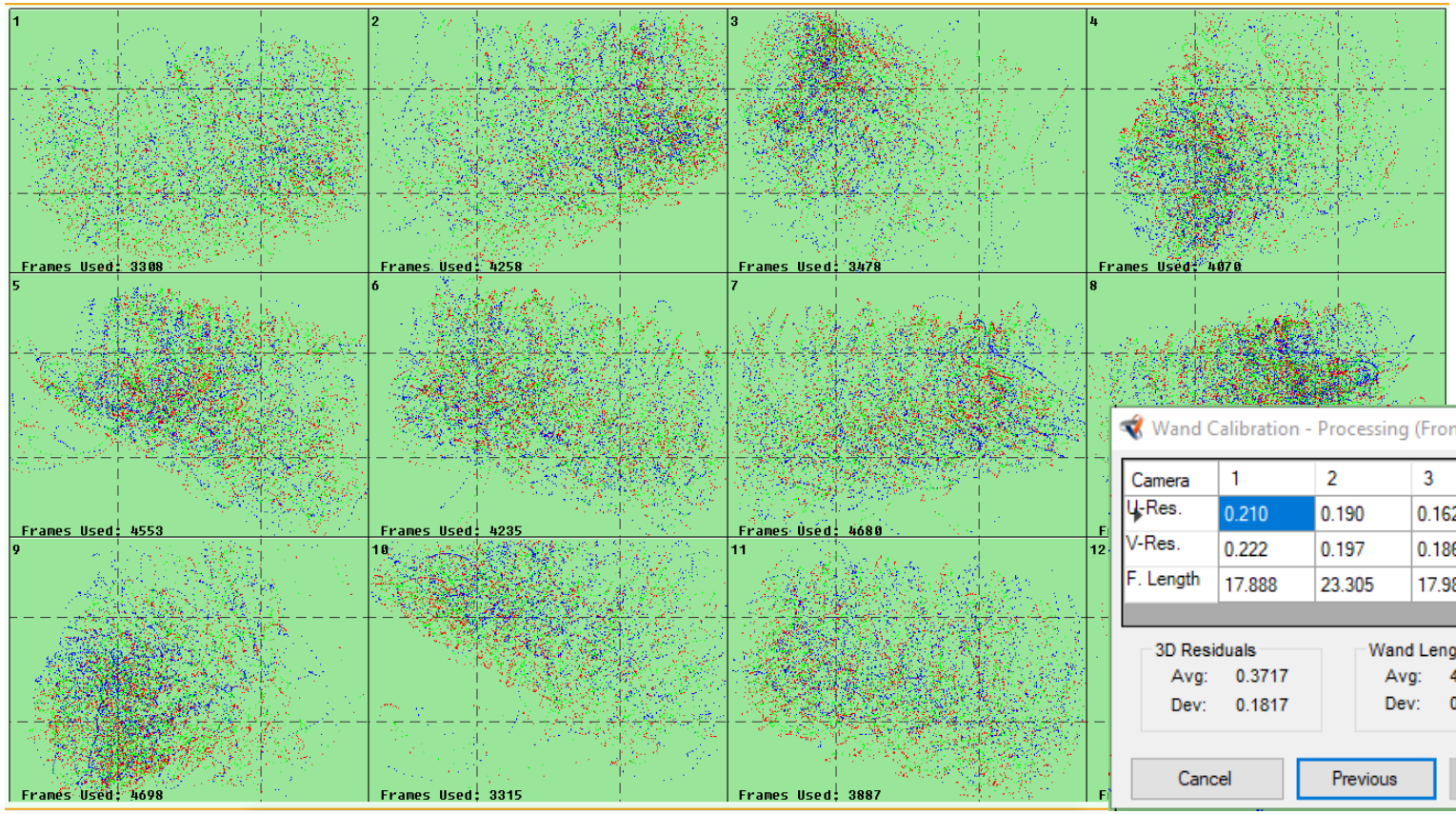


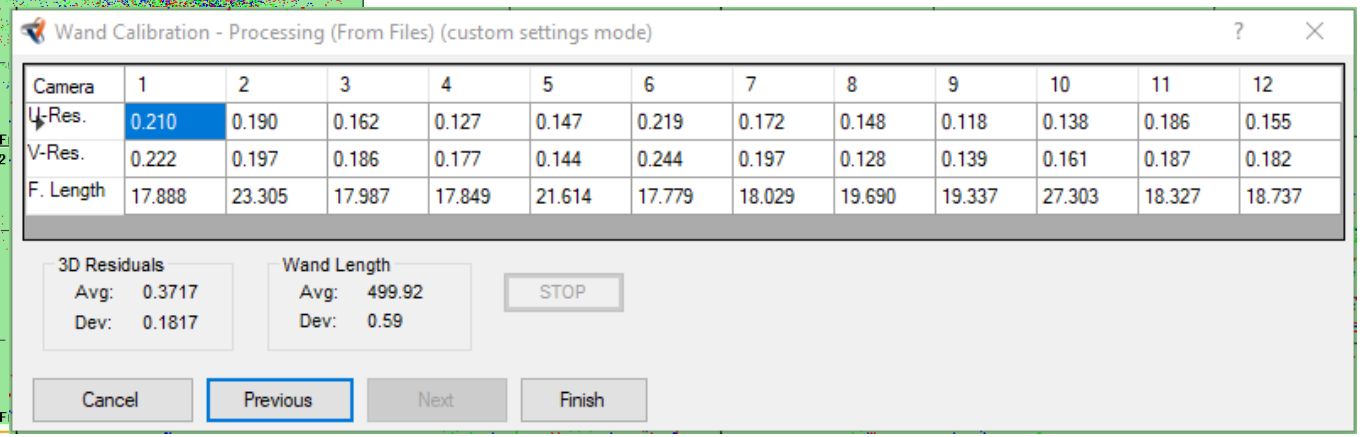


Cincinnati Children's
changing the outcome together

Video-Based Motion Capture System

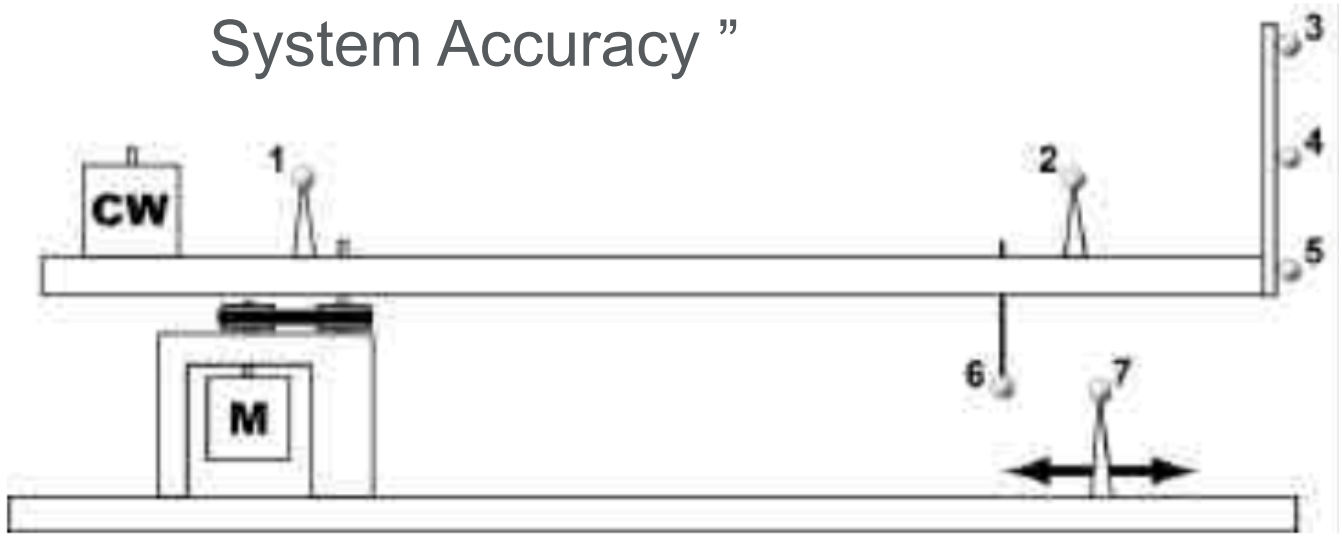
- Calibration Example: MAC Raptor system (Cortex interface)
  - Calibration residuals





Video-Based Motion Capture System

- Accuracy / Precision Example: SAMSA device
  - "Standard Assessment of Motion System Accuracy "



GAIT & CLINICAL GCMAS MOVEMENT ANALYSIS SOCIETY

About ▾ | Councils ▾ | Students ▾ | Patients & Families | Memberships ▾

Standards Council

The GCMAS Standards Council has proposed a protocol for quantifying the accuracy of a motion analysis system (i.e., how accurate the system is at locating markers). This Standard Assessment of Motion System Accuracy protocol (SAMSA) is intended to test video-based systems that employ reflective markers, though it is possible that it could be used to test systems with active markers as well.

SAMSA uses a simple device based on a earlier design used by Jim Richards to compare motion systems [1]. This device consists of a beam fitted with markers and rotated at 60 RPM by a motor. The protocol is designed to test the ability of a motion system to (1) track moving markers; (2) resolve markers using a subset of the cameras; and (3) resolve markers that pass close to one another during a trial. The protocol has been tested in the laboratories of seven Standards Committee members and the results have been used to formulate an accuracy standard in the form of acceptable error thresholds. This testing and the error thresholds were presented at the 2007 GCMAS Meeting in Springfield; please refer to this abstract for further details [2]. A manuscript detailing these findings is currently in preparation.

GCMAS Members Interested In Testing Their Own Labs Using This Protocol Have Two Options:

1. Build your own SAMSA device using the plans available on this website.
2. Borrow a SAMSA device that belongs to GCMAS and is available to members on a first-come, first-served basis. There is no cost to members for this service; all that is required is that you take no more than one week to complete your testing and that you pay to ship the device to the next lab in line when your testing is complete. Contact the Standards Committee here.

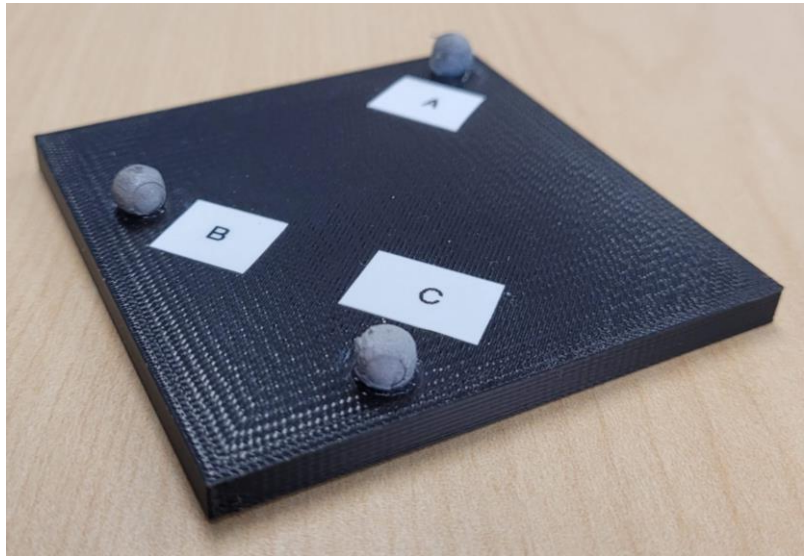
www.gcmas.org/standards

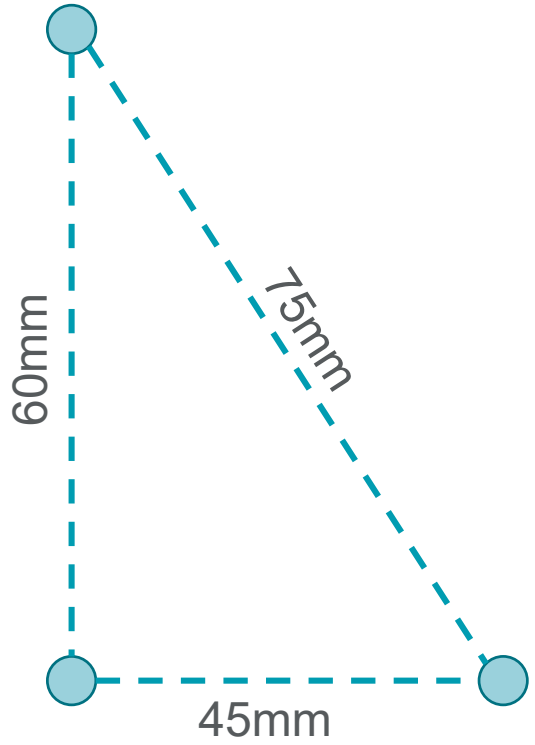
Piazza SJ, Chou L-S, Denniston NL, McMulkin ML, Quigley EJ, Richards JG, Schwartz MS. A proposed standard for assessing the marker-location accuracy of video-based motion analysis systems. Proceedings of the 12th Annual GCMAS, Springfield, MA, 2007.

Cincinnati Children's™
changing the outcome together

Video-Based Motion Capture System

- Accuracy / Precision Example: 3D-printed plate





Cincinnati Children's
changing the outcome together

Force Plates

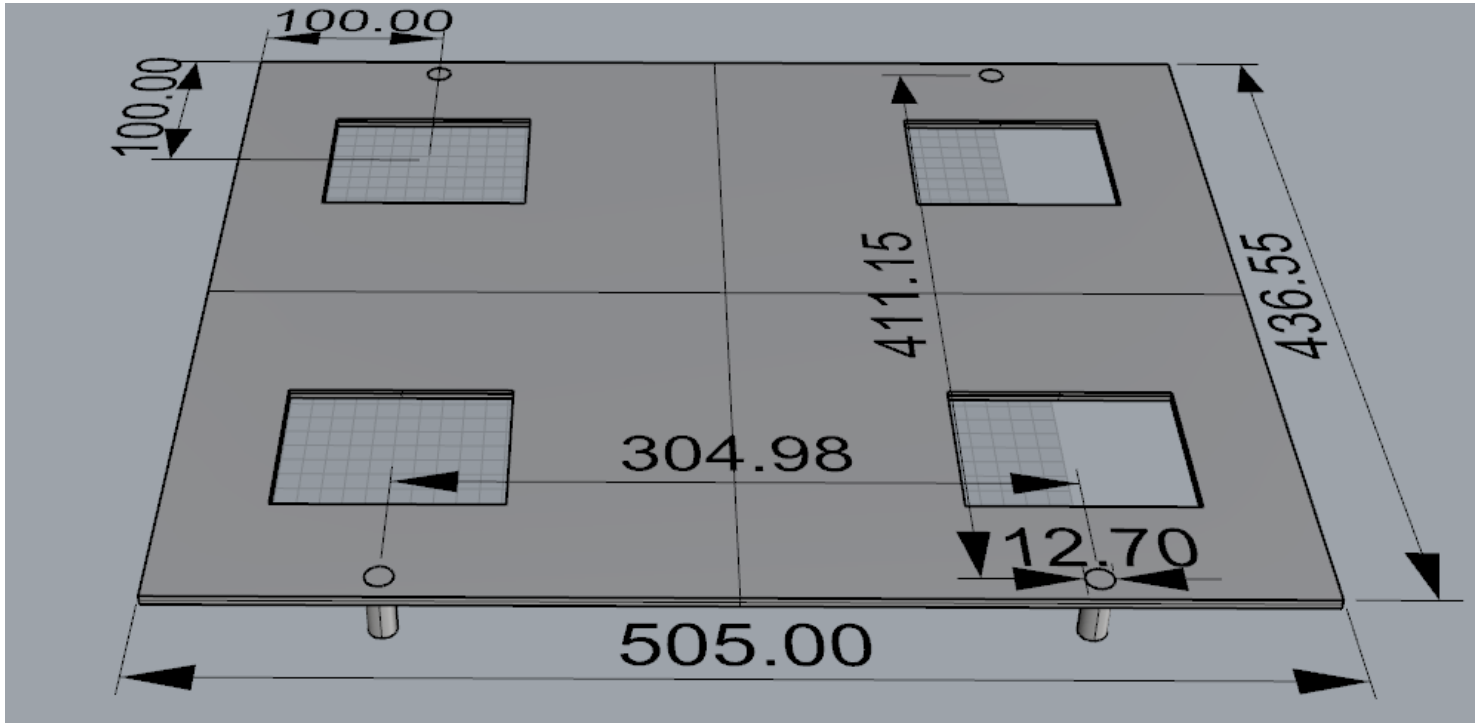
Cincinnati Children's
changing the outcome together

Force Plates

- Calibration
  - Establishes a transformation matrix by which measured voltages can be converted to imposed forces and moments
  - Generally performed by manufacturer at factory, with no onsite methods of calibration available
- Accuracy and Precision
  - Repeated measurement of known loads placed at known positions

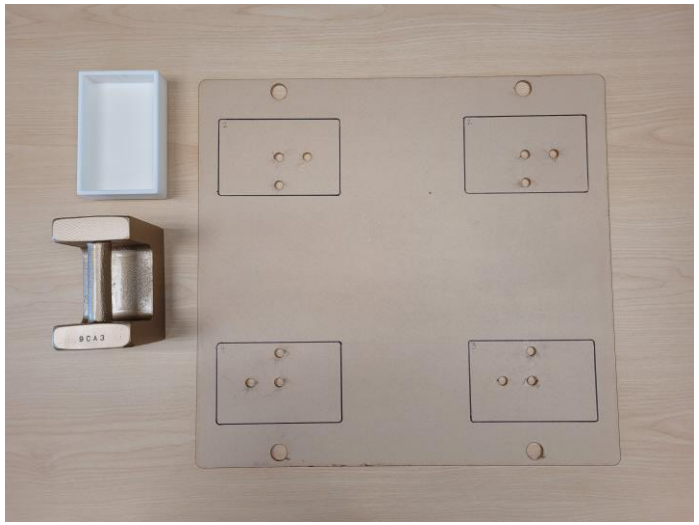
Force Plates

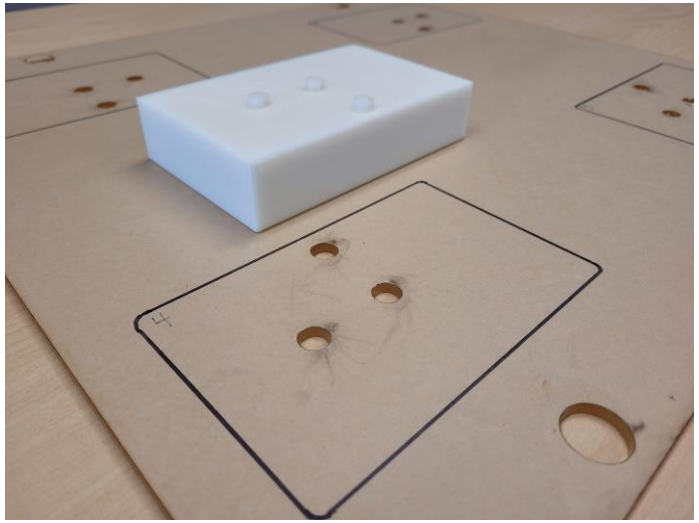
- Accuracy / Precision Example: fixture plate w/3D printed lock

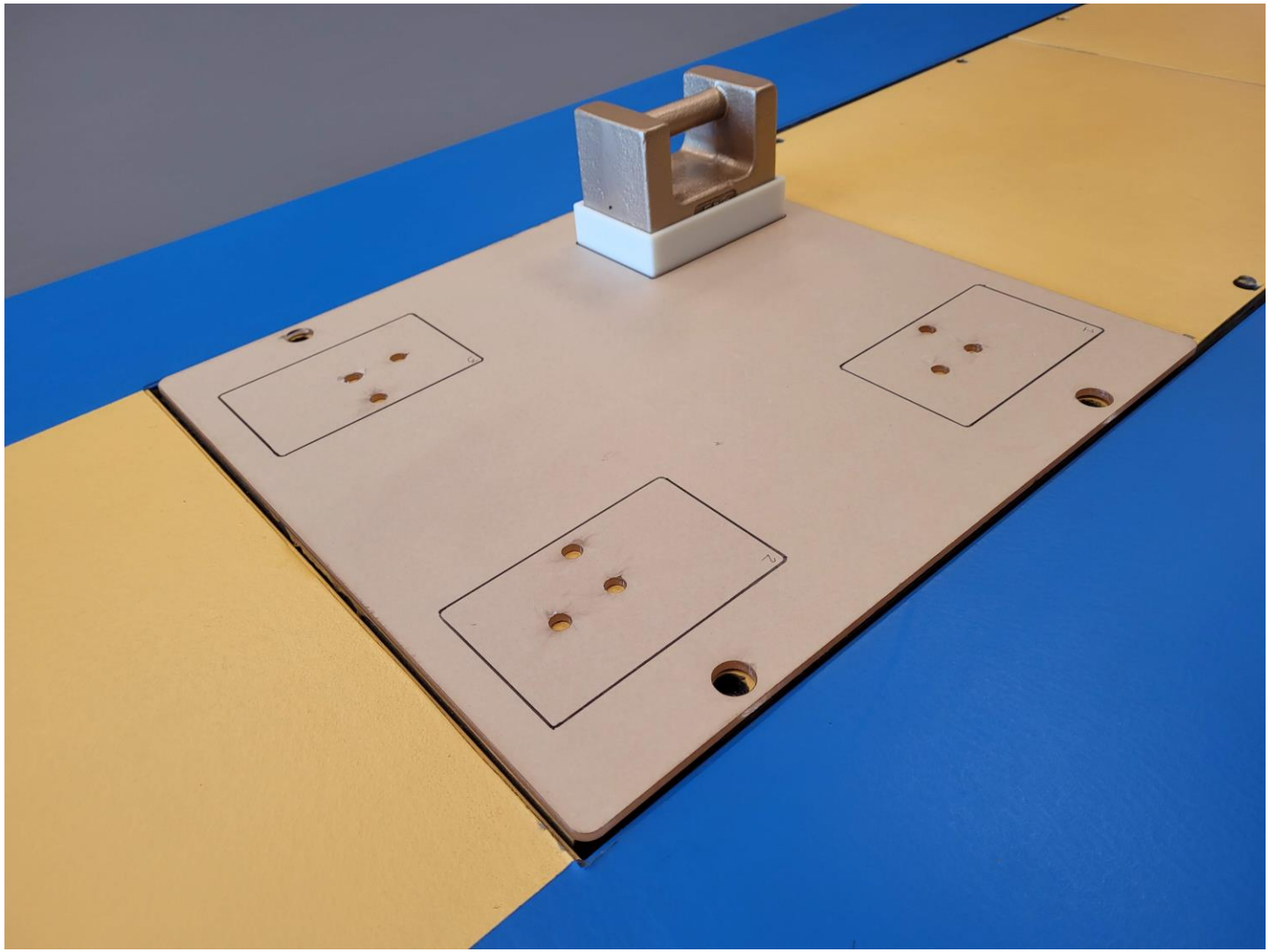


Cincinnati Children's
changing the outcome together

Force Plates







Motion Capture System / Force Plates

- Motion Capture / Force Plate Sync
  - Measure alignment between motion capture reference frame and force plate reference frame
    - Geospatial alignment
    - Temporal alignment
    - *Holden, Selbie, and Stanhope. "A proposed test to support the clinical movement analysis laboratory accreditation process." GAIPOS 17(3). 2003.*

motion-labs.com

Cincinnati Children's
changing the outcome together

Pedobarograph System

Cincinnati Children's
changing the outcome together

Pedobarograph System

- Calibration
  - Establishes the capability of each sensel to measure imposed vertical load
  - Generally performed by manufacturer at factory
    - e.g. Pressurized bladder that loads a large area uniformly
- Accuracy and Precision
  - Repeated measurement of known loads placed across known regions

Cincinnati Children's
changing the outcome together

Pedobarograph System

- Accuracy / Precision Example: novel protocol

Cincinnati Children's™
changing the outcome together

EMG System

Cincinnati Children's
changing the outcome together

EMG System

- Calibration
  - Establishes the transform from voltage data collected at electrode (skin or intramuscular) to voltage data collected at the board
  - Availability of onsite methods is manufacturer-specific
- Accuracy and Precision
  - Repeated measurement of known signals (known amplitude, period, etc.) applied to electrodes

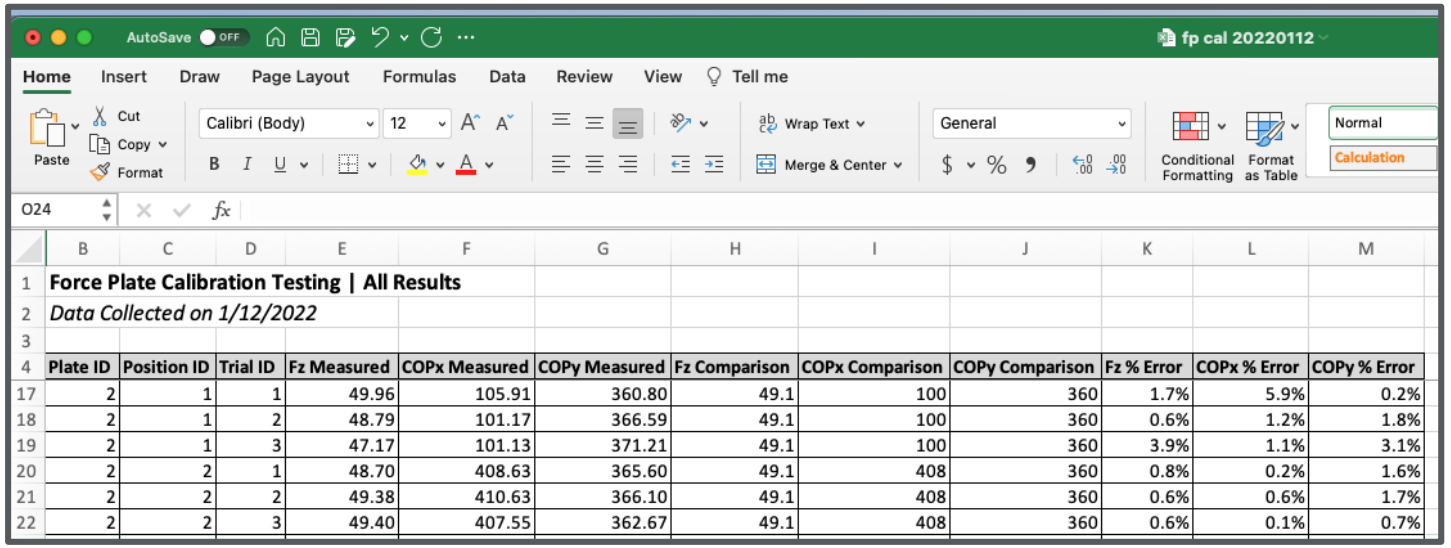
EMG System

- Accuracy / Precision Example: signal generator
  - Impose a signal of fixed frequency and amplitude at sensor, and measure output from motion capture A/D
- Device-specific challenges
  - Introduction of the signal to the sensor (geometry, material)
  - Warranty concerns

Cincinnati Children's
changing the outcome together

Documentation

- What was done?
- When was it done?
- Who did it?
- What were the results?
- What actions (if any) were taken?



	B	C	D	E	F	G	H	I	J	K	L	M
1	**Force Plate Calibration Testing | All Results**											
2	*Data Collected on 1/12/2022*											
3												
4	**Plate ID**	**Position ID**	**Trial ID**	**Fz Measured**	**COPx Measured**	**COPy Measured**	**Fz Comparison**	**COPx Comparison**	**COPy Comparison**	**Fz % Error**	**COPx % Error**	**COPy % Error**
17	2	1	1	49.96	105.91	360.80	49.1	100	360	1.7%	5.9%	0.2%
18	2	1	2	48.79	101.17	366.59	49.1	100	360	0.6%	1.2%	1.8%
19	2	1	3	47.17	101.13	371.21	49.1	100	360	3.9%	1.1%	3.1%
20	2	2	1	48.70	408.63	365.60	49.1	408	360	0.8%	0.2%	1.6%
21	2	2	2	49.38	410.63	366.10	49.1	408	360	0.6%	0.6%	1.7%
22	2	2	3	49.40	407.55	362.67	49.1	408	360	0.6%	0.1%	0.7%

Cincinnati Children's
changing the outcome together

THANK YOU