Supplementary Information for:

LARK: A Low-Cost, Accurate, Occlusion-Resilient, Kalman Filter-Assisted Tracking System for Image-Guided Surgery

George Sideris, Justin Cree, Andrew Stirling, Mamadou Ly, Étienne Léger, D. Louis Collins

Contents

1 Supplementary Note 1: Landmark Registration

Landmark registration aligns a set of measured 3-D points with their corresponding ground-truth (GT) points to determine the rigid transformation between two coordinate systems. This method is central to IGS, where precise alignment ensures that surgical instruments and patient anatomy share a consistent spatial frame of reference.

We employ a point–based registration strategy using the Orthogonal Procrustes method [39]. The aim is to find a rotation matrix $S \in SO(3)$ and a translation vector $d \in \mathbb{R}^3$ that minimise the difference between corresponding points in the measured and GT sets. Suppose N_f fiducial points are available. The Fiducial Registration Error (FRE) is the root-mean-square distance between corresponding fiducials after alignment:

$$\text{FRE} = \sqrt{\frac{1}{N_f} \sum_{i=1}^{N_f} \left\| x_i^{\text{GT}} - \left(S\, x_i^{\text{meas}} + d \right) \right\|^2} \tag{1}$$

To determine S and d, the measured and GT point sets are first translated so that their centroids lie at the origin. Denote those centroids by $\bar{x}^{\text{meas}}$ and $\bar{x}^{\text{GT}}$. After centring, the covariance matrix is

$$G = \sum_{i=1}^{N_f} (x_i^{\text{meas}} - \bar{x}^{\text{meas}})(x_i^{\text{GT}} - \bar{x}^{\text{GT}})^\top . \tag{2}$$

Applying Singular Value Decomposition (SVD) to G,

$$G = U\, \Sigma\, V^\top ,$$

the optimal rotation is

$$S = V\, U^\top .$$

If $\det(S) < 0$ the final column of V is negated to prevent a reflection. The translation that relates the two centroids is

$$d = \bar{x}^{\text{GT}} - S\, \bar{x}^{\text{meas}} .$$

With S and d fixed by the fiducials, we validate the transformation on a separate set of N_t target points. The Target Registration Error (TRE) is

$$\text{TRE} = \sqrt{\frac{1}{N_t} \sum_{j=1}^{N_t} \left\| y_j^{\text{GT}} - \left(S\, y_j^{\text{meas}} + d \right) \right\|^2} . \tag{3}$$

The same transformation can be applied to a measured trajectory $\{p_1^{\text{meas}}, \ldots, p_{N_p}^{\text{meas}}\}$ to obtain

$$p_i^{\text{trans}} = S\, p_i^{\text{meas}} + d, \qquad i = 1, \ldots, N_p .$$

For each transformed point p_i^{trans} we locate its nearest neighbour q_i^{GT} in the GT trajectory T^{GT}:

$$q_i^{\mathrm{GT}} \;=\; \mathop{}_{q\in T^{\mathrm{GT}}}\big\|p_i^{\mathrm{trans}} - q\big\|.$$

The trajectory TRE is then

$$\mathrm{TRE}_{\mathrm{traj}} \;=\; \sqrt{\frac{1}{N_p}\sum_{i=1}^{N_p}\big\|p_i^{\mathrm{trans}} - q_i^{\mathrm{GT}}\big\|^2}.$$

Nearest-neighbour matching compensates for any temporal offset between the measured and GT trajectories, ensuring that spatial correspondence is preserved even when the two are sampled at different rates.

2 Supplementary Note 2: Noise Profiling

To compare the performance of our adaptive Kalman filter with a constant velocity Kalman filter using static covariance matrices, we first conduct a noise profiling procedure. The procedure allows us to estimate the static measurement noise covariance matrices R_i for each camera and the process noise covariance matrix Q for the non-adaptive filter.

The noise profiling involves collecting a series of pose measurements while the surgical instrument is held stationary at L distinct workspace locations indexed by $\ell = 1, \ldots, L$. At every location we record $T = 30$ consecutive pose estimates from each active camera $i \in \{1, \ldots, N\}$. The sample variance of those poses gives the location–specific measurement covariance

$$R_{\ell,i} = \mathrm{Var}\Big(y_{\tau,i} \;\big|\; \tau = 1, \ldots, T\Big), \tag{4}$$

where $y_{\tau,i}$ is the pose returned by camera i on frame τ while the instrument is fixed at location ℓ.

We then compute the average measurement noise covariance for each camera across all sampled positions:

$$\bar{R}_i \;=\; \frac{1}{L}\sum_{\ell=1}^{L} R_{\ell,i}, \tag{5}$$

which serves as the static measurement noise covariance matrix for camera i in the non-adaptive Kalman filter.

To formulate the static process noise covariance matrix Q, we calculate the average of the $\bar{R}_i$ matrices across all cameras:

$$Q \;=\; \frac{1}{N}\sum_{i=1}^{N} \bar{R}_i, \tag{6}$$

where N is the total number of cameras. This approach ensures that Q reflects the average noise characteristics across the entire system.

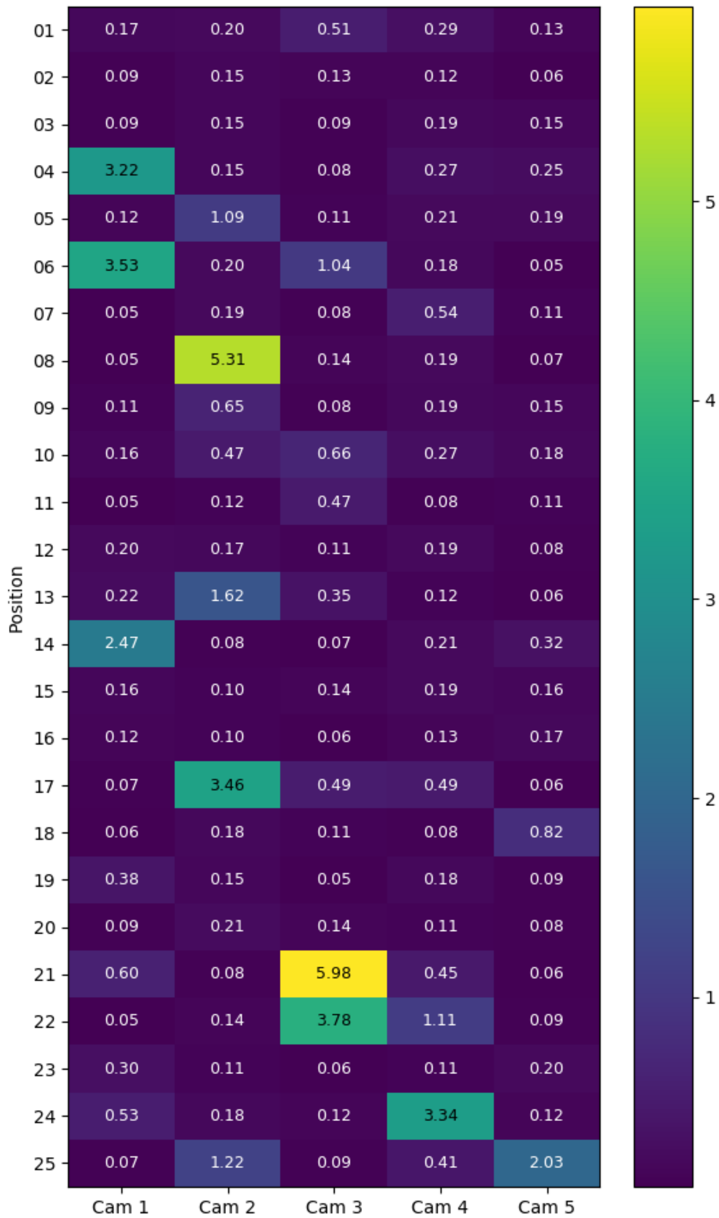
Beyond tuning the static covariance matrices for the non-adaptive Kalman filter, this procedure provides valuable insights into the spatial distribution of measurement noise within the workspace. By analyzing the norms of the covariance matrices $R_{\ell,i}$, we generate heatmaps illustrating the noise profile for each camera at different positions. The Frobenius norm of each $R_{\ell,i}$ matrix is computed as

$$\big\|R_{\ell,i}\big\|_F \;=\; \sqrt{\mathrm{Tr}\big(R_{\ell,i}R_{\ell,i}^{\top}\big)}. \tag{7}$$

This norm provides a single scalar value to represent the overall noise level for each camera at each position. Supplementary Figure 1 shows the spatial distribution of noise across all measured positions for one of our experimental trials.

By employing this noise profiling procedure, we ensure that the static Kalman filter is optimally configured for our experimental conditions, providing a fair baseline for comparison with our adaptive Kalman filter. Moreover, the insights gained can guide adjustments to lighting, camera placement, and calibration to enhance measurement precision. In the OR, technicians can swiftly perform this procedure prior to surgery to ensure camera setups meet precision requirements, minimizing tracking variability.

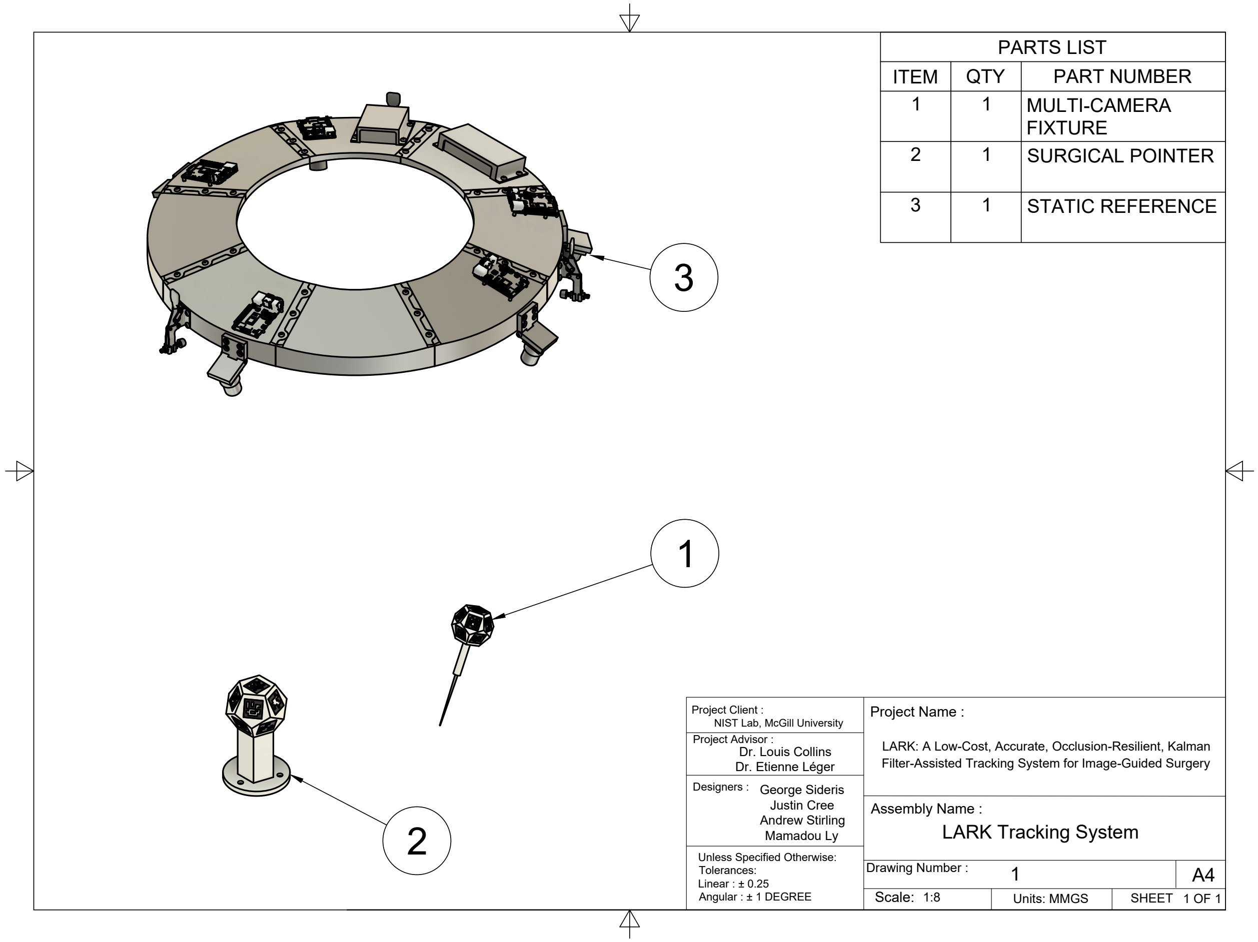
3 Supplementary Figures 1-26:



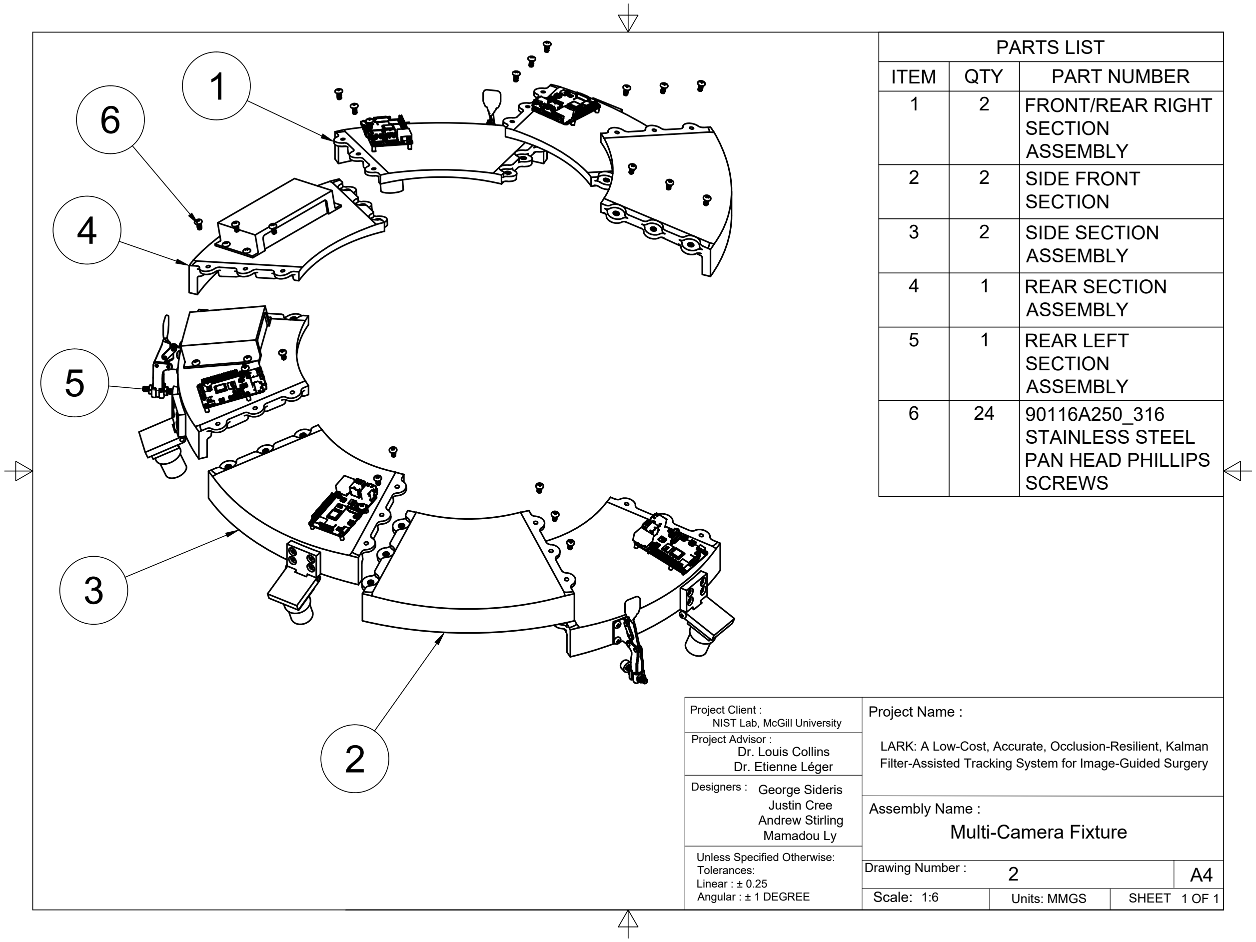
Supplementary Figure 1: Spatial distribution of the norm of the measurement noise covariance matrices $R_{\ell,i}$ for each camera across all measured positions.

P/N	Part Name	Sub Assy	DWG #	OTS or Manufactured	Supplier	Supplier Part ID	Web Link to Product	Quantity	Total Cost ($CAD)	Delivery Time	Raw Material	Manufacturer	Manufacturing Time	Manufacturing Cost	Notes
1	Instrument Handle	Surgical Pointer	4	3D-Printed	N/A	N/A	N/A	1	21.40	N/A	PLA Plastic	Ultimaker S5	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (5.35x10^5 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
2	Static Reference	N/A	5	3D-Printed	N/A	N/A	N/A	1	46.40	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (1.16x10^6 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
3	Camera Mount	Camera	7	3D-Printed	N/A	N/A	N/A	5	8.58	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (42917 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
4	Fixture Section Rear	Rear Section	10	3D-Printed	N/A	N/A	N/A	1	16.16	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (4.04x10^5 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
5	Fixture Section Front/Rear Right	Front/Rear Right Section	11, 12	3D-Printed	N/A	N/A	N/A	2	32.32	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (4.04x10^5 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
6	Fixture Section Rear Left	Rear Left Section	13, 14	3D-Printed	N/A	N/A	N/A	1	16.16	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (4.04x10^5 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
7	Fixture Section Side Front	Side Front Section	15	3D-Printed	N/A	N/A	N/A	2	32.32	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (4.04x10^5 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
8	Fixture Section Side	Side Section	16, 17	3D-Printed	N/A	N/A	N/A	2	32.32	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (4.04x10^5 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
9	USB Power Supply Cover	Rear Left Section	18	3D-Printed	N/A	N/A	N/A	1	0.13	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (3134 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
10	Ethernet Switch Cover	Rear Section	19	3D-Printed	N/A	N/A	N/A	1	0.13	N/A	PLA Plastic	Group X using NIST lab printer (Lab has sufficient PLA stock)	8 Business Days	N/A	Total Cost: Estimated by multiplying part volume (3134 mm^3) with PLA price rate ($0.04 CAD/cm^3). Mfg Time: It takes 1 day to print 2 distinct parts (e.g. one fixture section and one camera mount on the same print), it will take 8 business days to 3D-print all 16 parts.
11	Raspberry Pi Model 4/1GB	Front/Rear Right Section, Side Section, Rear Left Section	N/A	OTS	PiShop	1GB-9002	https://www.pishop.ca/product/raspberry-pi-4-model-b-1gb/	5	244.75	1 Business Day	N/A	N/A	N/A	N/A	Alternative if out of stock: https://www.canakit.com/raspberry-pi-4.html
12	Raspberry Pi Global Shutter Camera	Camera	N/A	OTS	PiShop	2103-1	https://www.pishop.ca/product/raspberry-pi-global-shutter-	5	350.00	1 Business Day	N/A	N/A	N/A	N/A	
13	Arducam CS-Mount 6mm Lens	Camera	N/A	OTS	Uctronics	LN040	https://www.uctronics.com/lens/cs-mount-lens/arducam-lens-for-raspberry-pi-high-	5	161.29	4-7 Business Days	N/A	N/A	N/A	N/A	
14	D-Link 8 Port Gigabit Ethernet Switch	Rear Left Section	N/A	OTS	Amazon	DGS-108GL	https://www.amazon.ca/dp/B08W3RYNSR/?coliid=I1K0CR86BY0ZEJ&colid=RNBD9HX9	1	34.99	1 Business Day	N/A	N/A	N/A	N/A	
15	ALITOVE 5V 15A Power Supply Adapter	Rear Section	N/A	OTS	Amazon	ALT-0515	https://www.amazon.ca/ALITOVE-Transformer-Converter-5-5x2-1mm-100V-	1	33.99	2 Business Days	N/A	N/A	N/A	N/A	Alternative USB Power Supply: https://www.amazon.ca/Anker-Family-Sized-Desktop-Charger-Technology/dp/B00QTIQ21I/ref=asc_df_B00QTIQ21I/?tag=googlemobshop-20&linkCode=df0&hvadid=312701813721&hvpos&hvnetw=g&hvrand=16718876108775184369&hvpon
16	300V AC/300V DC Terminal Block	Rear Section	N/A	OTS	McMaster	7527K54	https://www.mcmaster.com/7527K54/	1	12.02	1 Business Day	N/A	N/A	N/A	N/A	
17	M2.5 x 0.8 mm + 5 mm Thread Length Male-Female Brass Hex PCB Motherboard Spacer Standoff	Camera	N/A	OTS	Amazon	a19111800ux0458	https://www.amazon.ca/uxcell-M2-5x8mm-Male-Female-Motherboard-	40	16.99	2-4 Weeks	Brass	N/A	N/A	N/A	Purchase 1 pkgs of 100 units.
18	Heat-Set Inserts for Plastic Brass, M2.5 x 0.45 mm, 5.9 mm Installed Length	Front/Rear Right Section, Side Section, Rear Left Section, Camera	N/A	OTS	McMaster	94459A439	https://www.mcmaster.com/94459A439/	40	25.59	1 Business Day	Brass	N/A	N/A	N/A	Purchase 2 pkgs of 25 units.
19	Brass Tapered Heat-Set Inserts for Plastic M5 x 0.8 mm Thread Size, 6.7 mm Installed Length	All Ring Section Assemblies	N/A	OTS	McMaster	94180A361	https://www.mcmaster.com/94180A361/	70	42.12	1 Business Day	Brass	N/A	N/A	N/A	Purchase 2 pkgs of 50 units.
20	316 Stainless Steel Pan Head Phillips Screws M2.5 x 0.45 mm Thread, 6mm Long	Front/Rear Right Section, Side Section, Rear Left Section, Camera	N/A	OTS	McMaster	90116A110	https://www.mcmaster.com/90116A110/	40	14.95	1 Business Day	Stainless Steel	N/A	N/A	N/A	Purchase 1 pkg of 100 units.
21	316 Stainless Steel Pan Head Phillips Screws M5 x 0.80 mm Thread, 8mm Long	All Ring Section Assemblies	N/A	OTS	McMaster	90116A248	https://www.mcmaster.com/90116A248/	20	16.11	1 Business Day	Stainless Steel	N/A	N/A	N/A	Purchase 1 pkg of 25 units.
22	316 Stainless Steel Pan Head Phillips Screws M5 x 0.80 mm Thread, 10mm Long	All Ring Section Assemblies	N/A	OTS	McMaster	90116A250	https://www.mcmaster.com/90116A250/	50	16.70	1 Business Day	Stainless Steel	N/A	N/A	N/A	Purchase 1 pkg of 50 units.
23	304 Stainless Steel Pan Head Phillips Screws M5 x 0.80 mm Thread, 40mm Long	Camera Mount	N/A	OTS	Amazon	B0DBQRW8T1	https://www.amazon.ca/uxcell-M5-0-8x40-Phillips-Fasteners-	5	14.94	2 Business Days	Stainless Steel	N/A	N/A	N/A	Purchase 1 pkg of 20 units.
24	Low-Profile Hold-Down Toggle Clamp Open Arm, Steel, 360 lbs. Holding Capacity	Front/Rear Right Section, Rear Left Section	N/A	OTS	McMaster	5128A85	https://www.mcmaster.com/5128A85/	3	64.11	1 Business Day	Steel	N/A	N/A	N/A	
25	Boye 10" Aluminum Single Point Knitting Needles, Size 9	Pointer	N/A	OTS	Amazon	B000QHFD5Y	https://www.amazon.ca/10-Inch-Aluminum-Single-Knitting-	1	6.11	1 Business Day	Aluminum	N/A	N/A	N/A	Purchase 1 pkg of 2 units.
								Total Before Tax ($CAD)	1260.58					**Reference for PLA rate:**	OVERTURE, "Filament 1.75mm pla 3d printer filament, dimensional accuracy +/- 0.02 mm, 1 kg spool, 1.75 mm, pla black 3d printing material." https://www.amazon.ca/Filament-Dimensional-Accuracy-Printing-Material/dp/B08JTVQ116/. Accessed: 2023-12-01.
								Total After Tax ($CAD)	1449.67						

Supplementary Figure 2: Bill of Materials for LARK Tracking System.



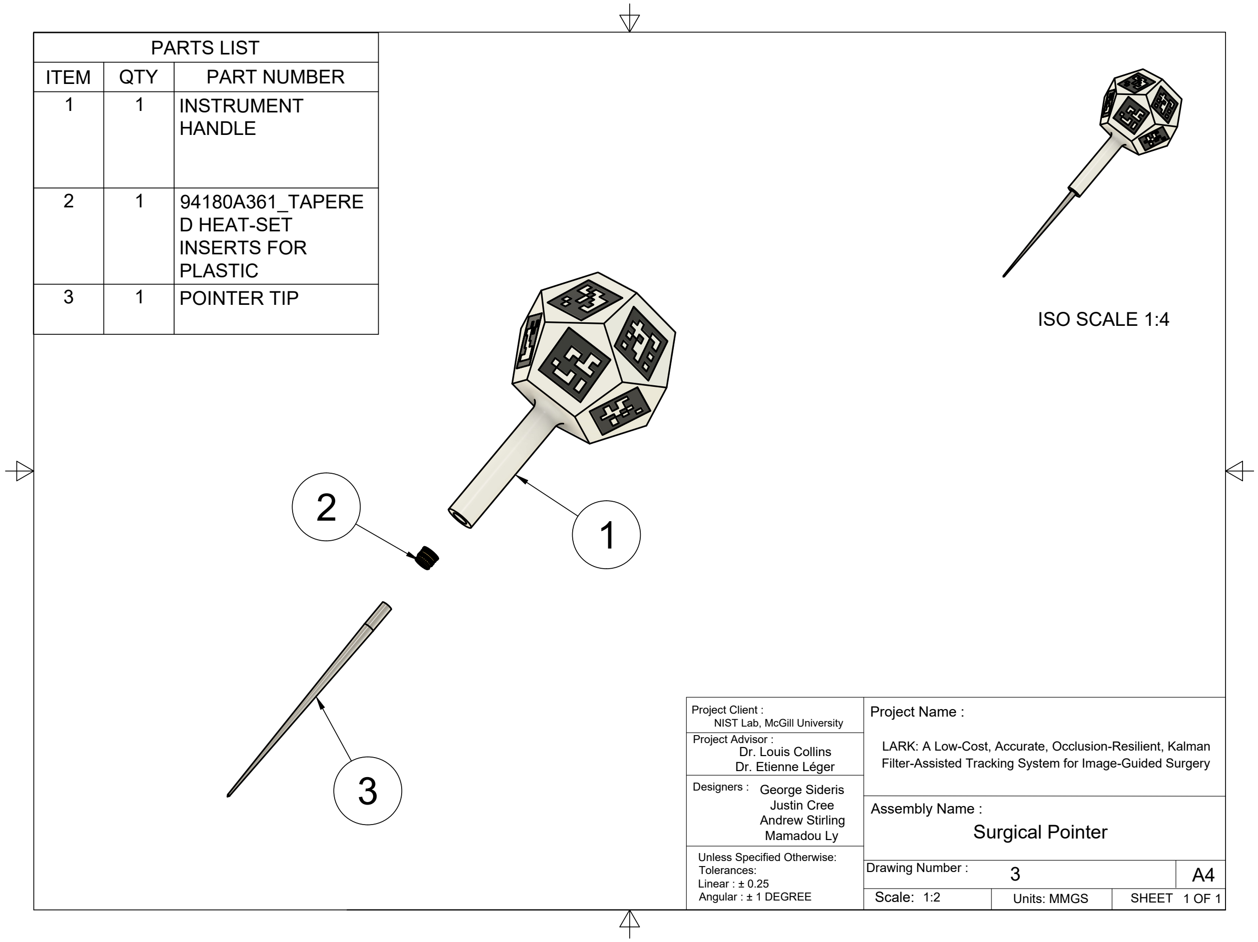
Supplementary Figure 3: LARK Tracking System Assembly Drawing.



PARTS LIST

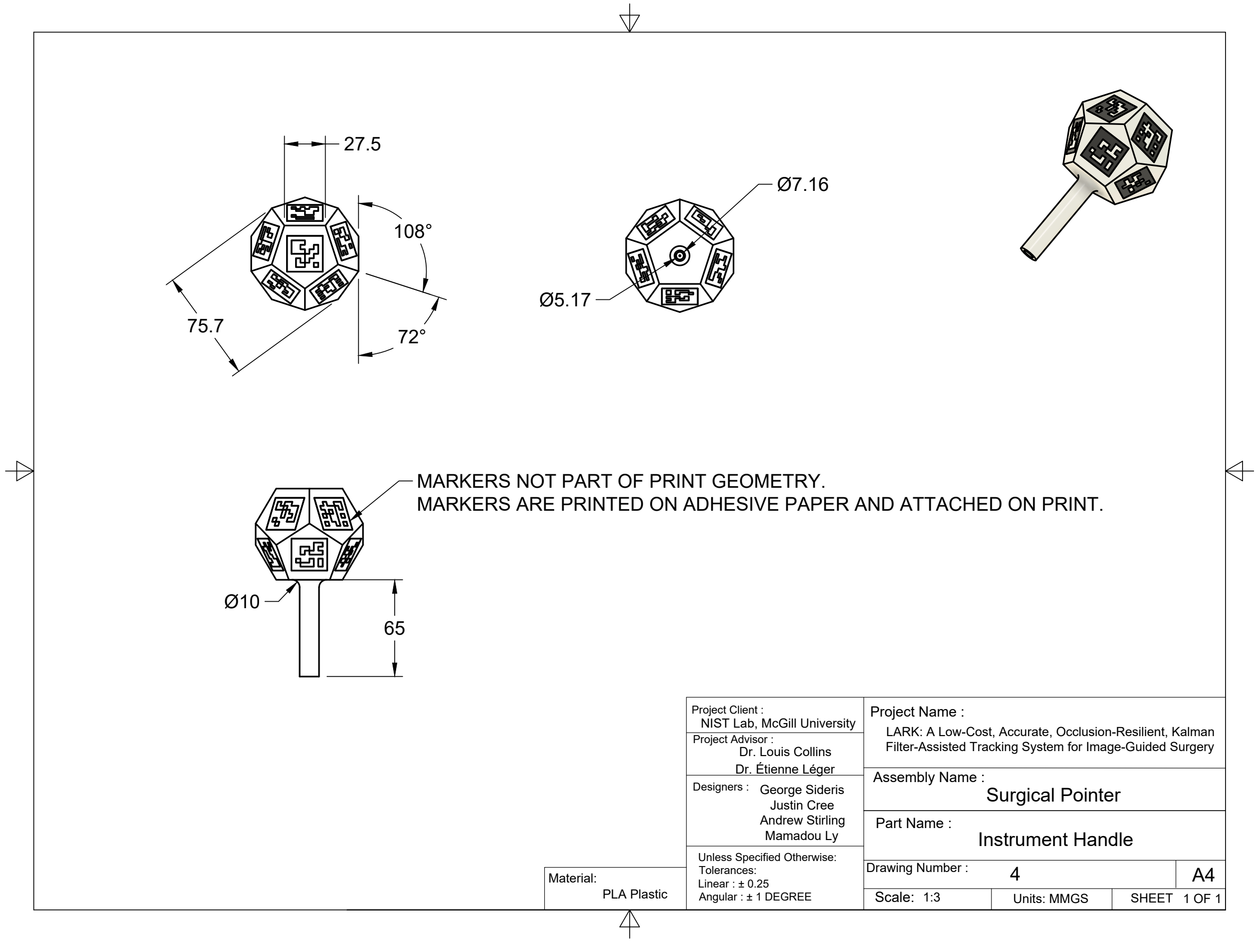
ITEM	QTY	PART NUMBER
1	2	FRONT/REAR RIGHT SECTION ASSEMBLY
2	2	SIDE FRONT SECTION
3	2	SIDE SECTION ASSEMBLY
4	1	REAR SECTION ASSEMBLY
5	1	REAR LEFT SECTION ASSEMBLY
6	24	90116A250_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS

Supplementary Figure 4: Multi-Camera Fixture Assembly Drawing.

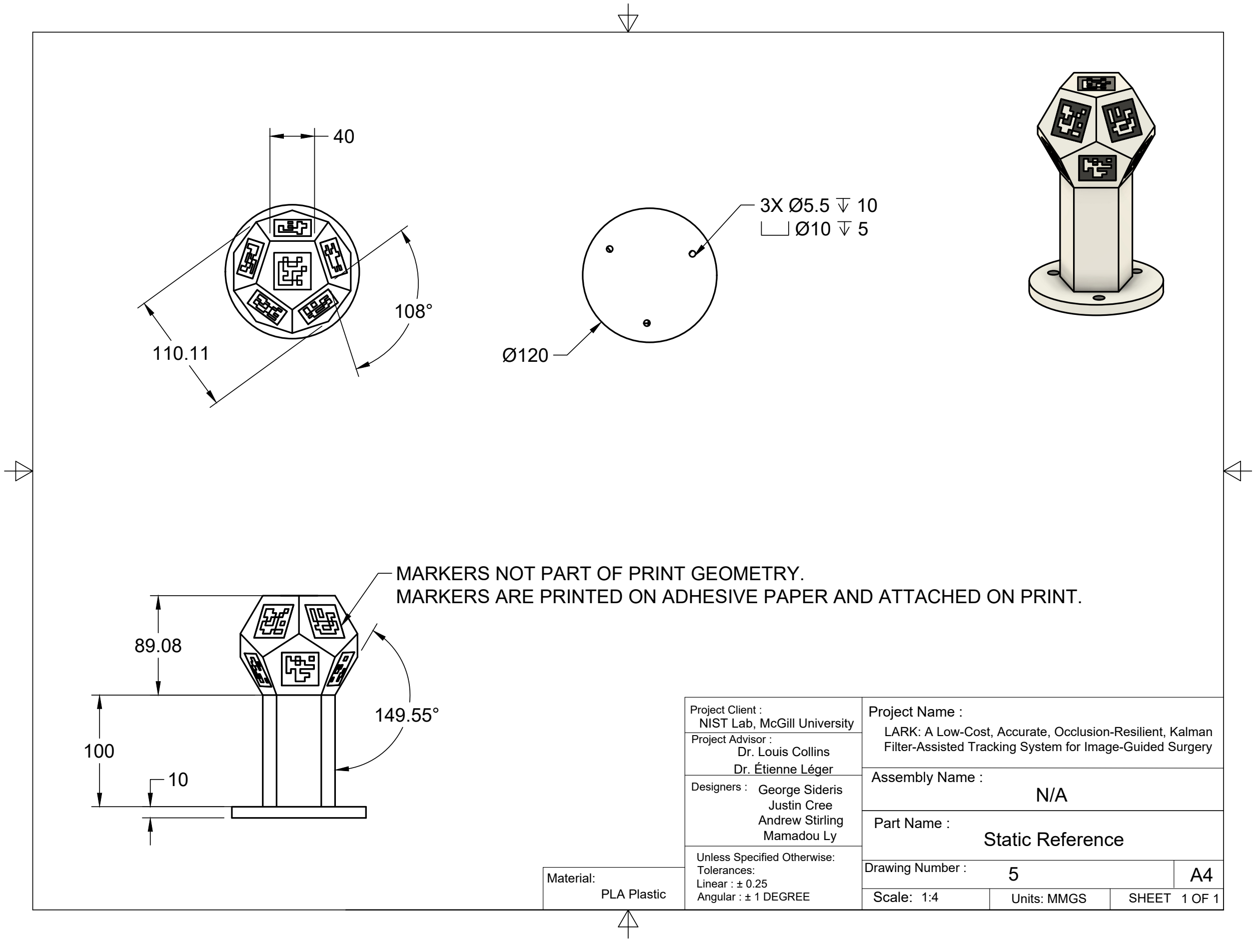


PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	INSTRUMENT HANDLE
2	1	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC
3	1	POINTER TIP

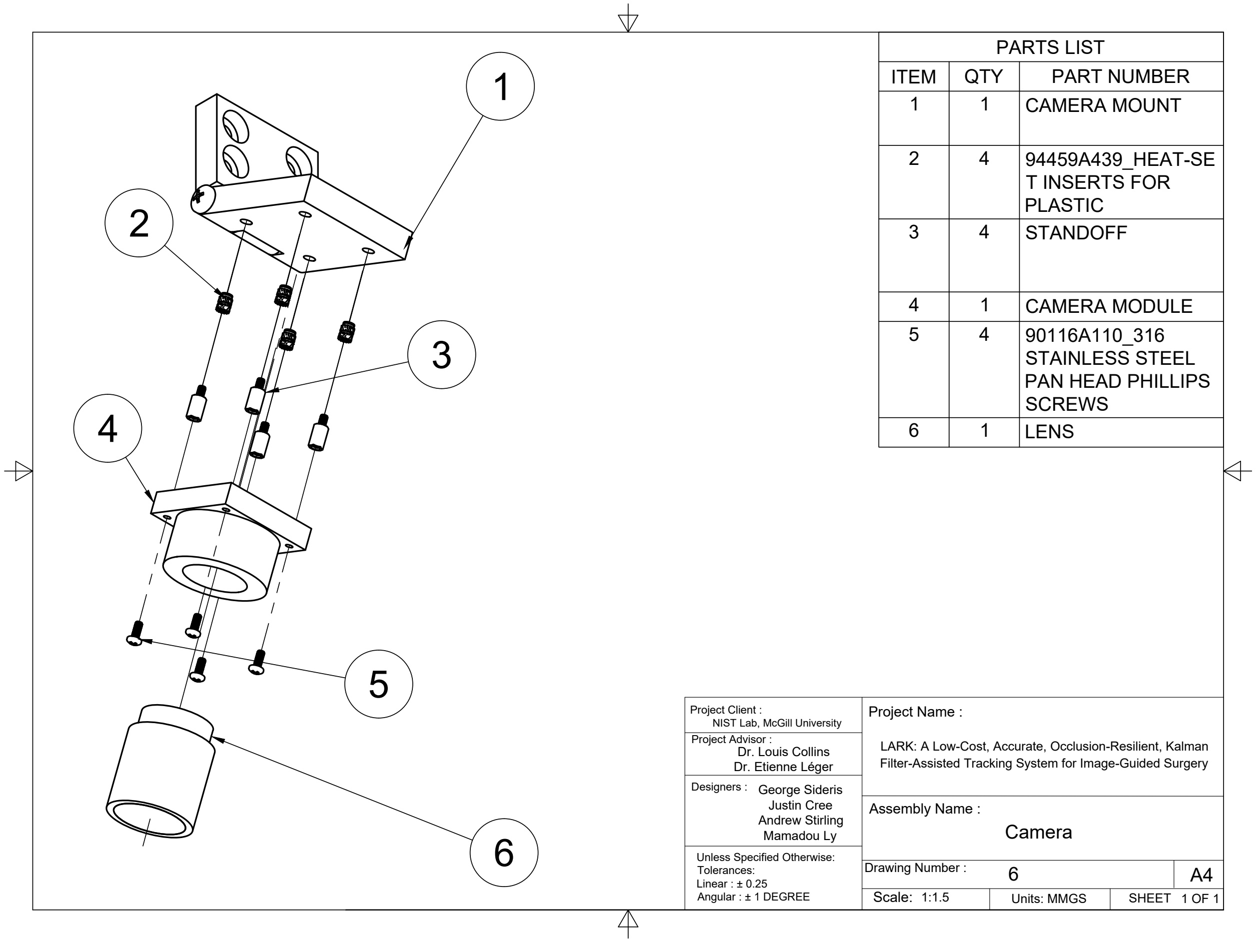
Supplementary Figure 5: Surgical Pointer Assembly Drawing.



Supplementary Figure 6: Instrument Handle Technical Drawing.



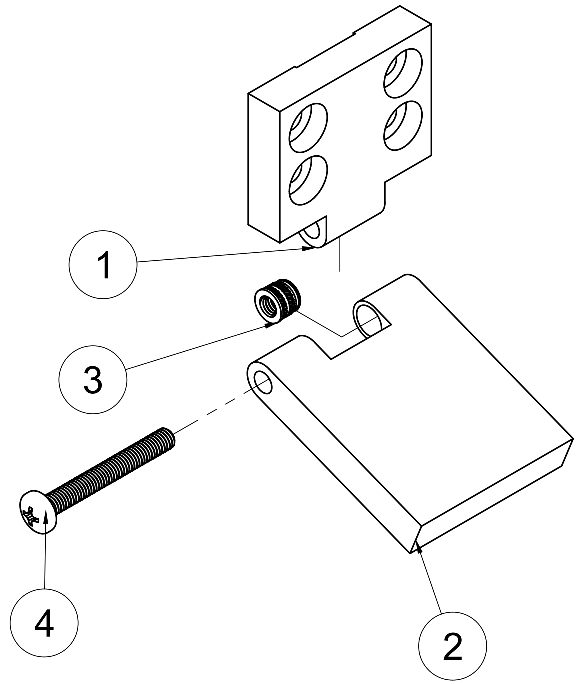
Supplementary Figure 7: Static Reference Technical Drawing.



PARTS LIST

ITEM	QTY	PART NUMBER
1	1	CAMERA MOUNT
2	4	94459A439_HEAT-SET INSERTS FOR PLASTIC
3	4	STANDOFF
4	1	CAMERA MODULE
5	4	90116A110_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS
6	1	LENS

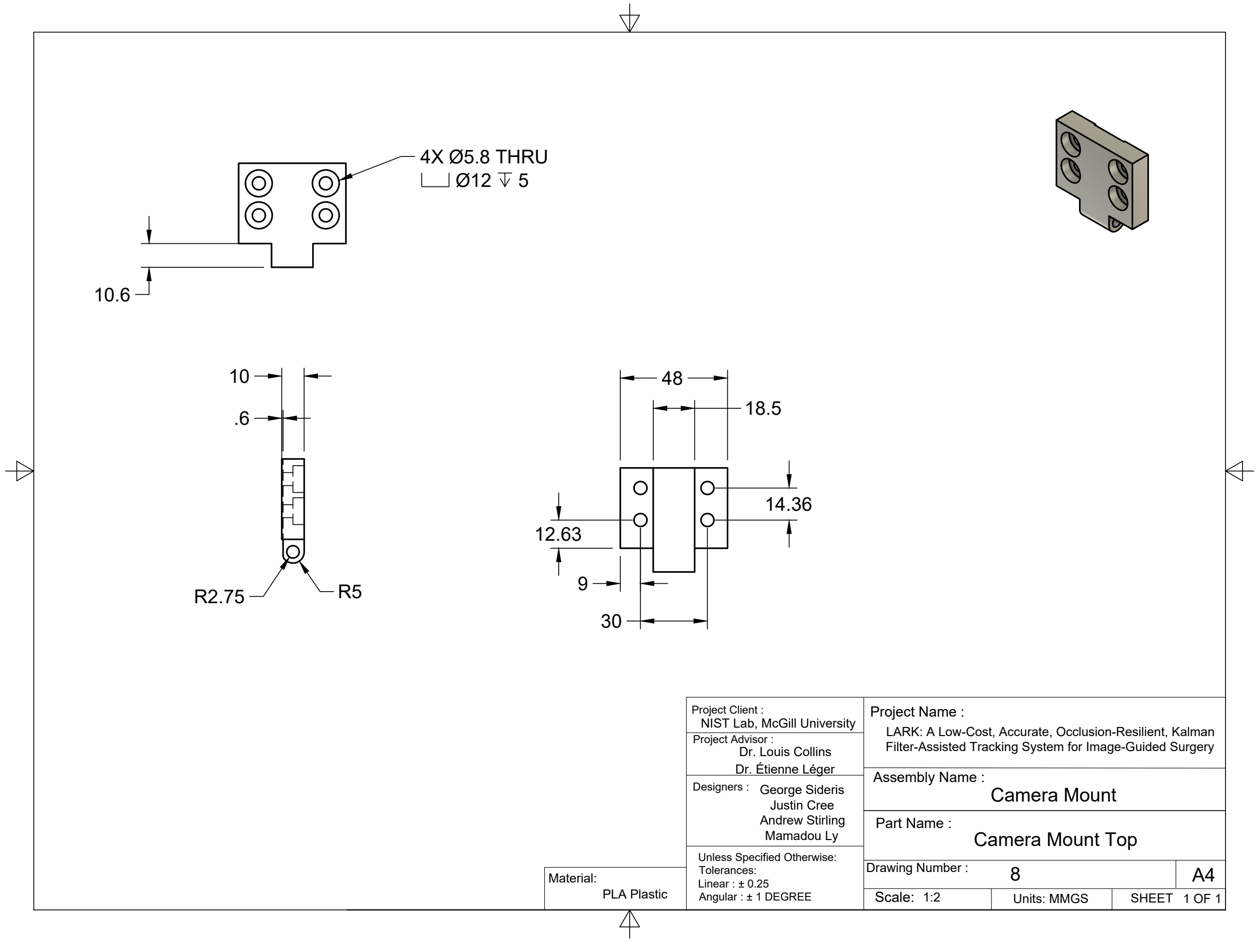
Supplementary Figure 8: Camera Assembly Drawing.



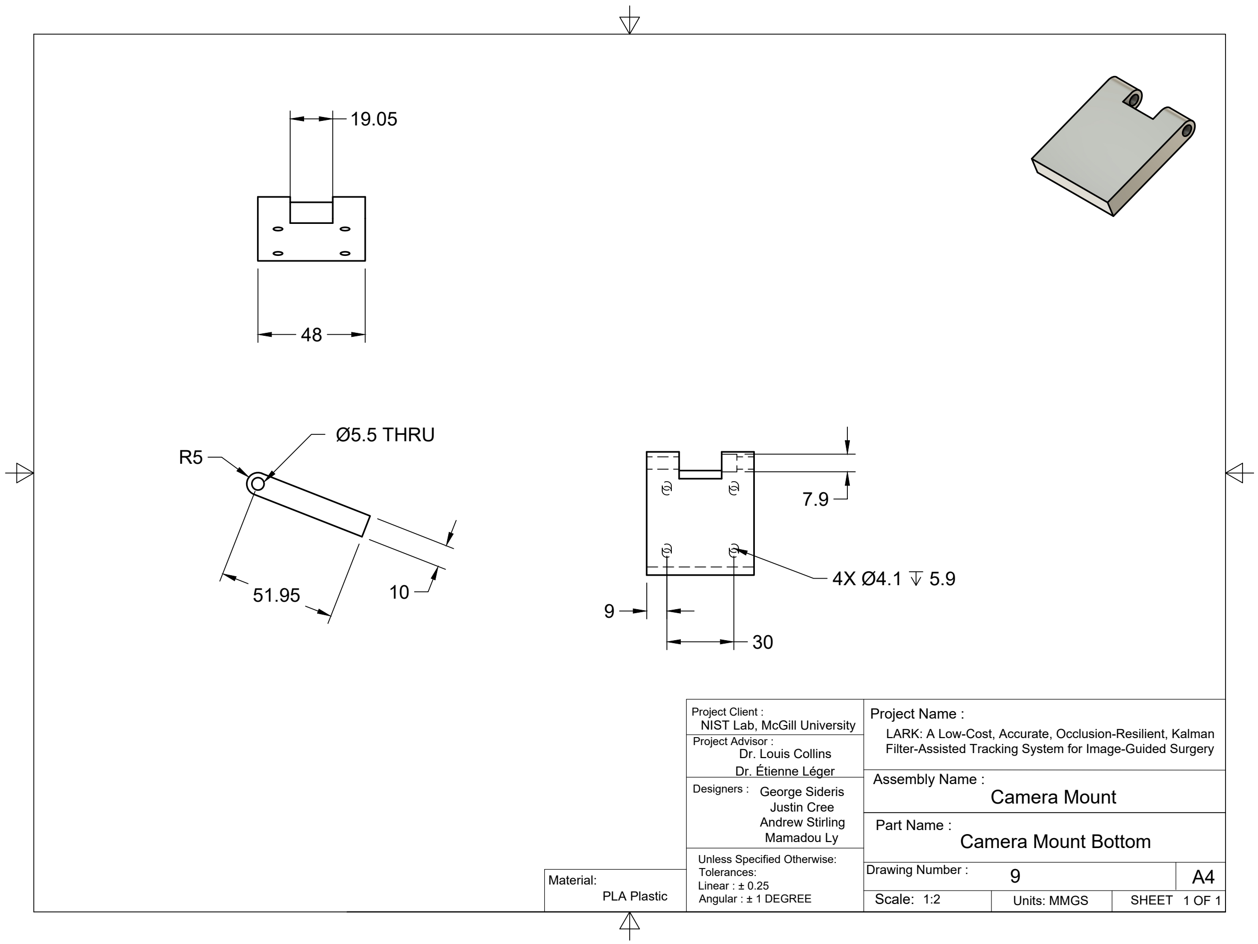
PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	CAMERA MOUNT TOP
2	1	CAMERA MOUNT BOTTOM
3	1	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC
4	1	90116A270_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS

Project Client : NIST Lab, McGill University	Project Name : LARK: A Low-Cost, Accurate, Occlusion-Resilient, Kalman Filter-Assisted Tracking System for Image-Guided Surgery
Project Advisor : Dr. Louis Collins, Dr. Etienne Léger	
Designers : George Sideris, Justin Cree, Andrew Stirling, Mamadou Ly	Assembly Name : Camera Mount
Unless Specified Otherwise: Tolerances: Linear : ± 0.25, Angular : ± 1 DEGREE	Drawing Number : 7 — A4
	Scale: 1:1 — Units: MMGS — SHEET 1 OF 1

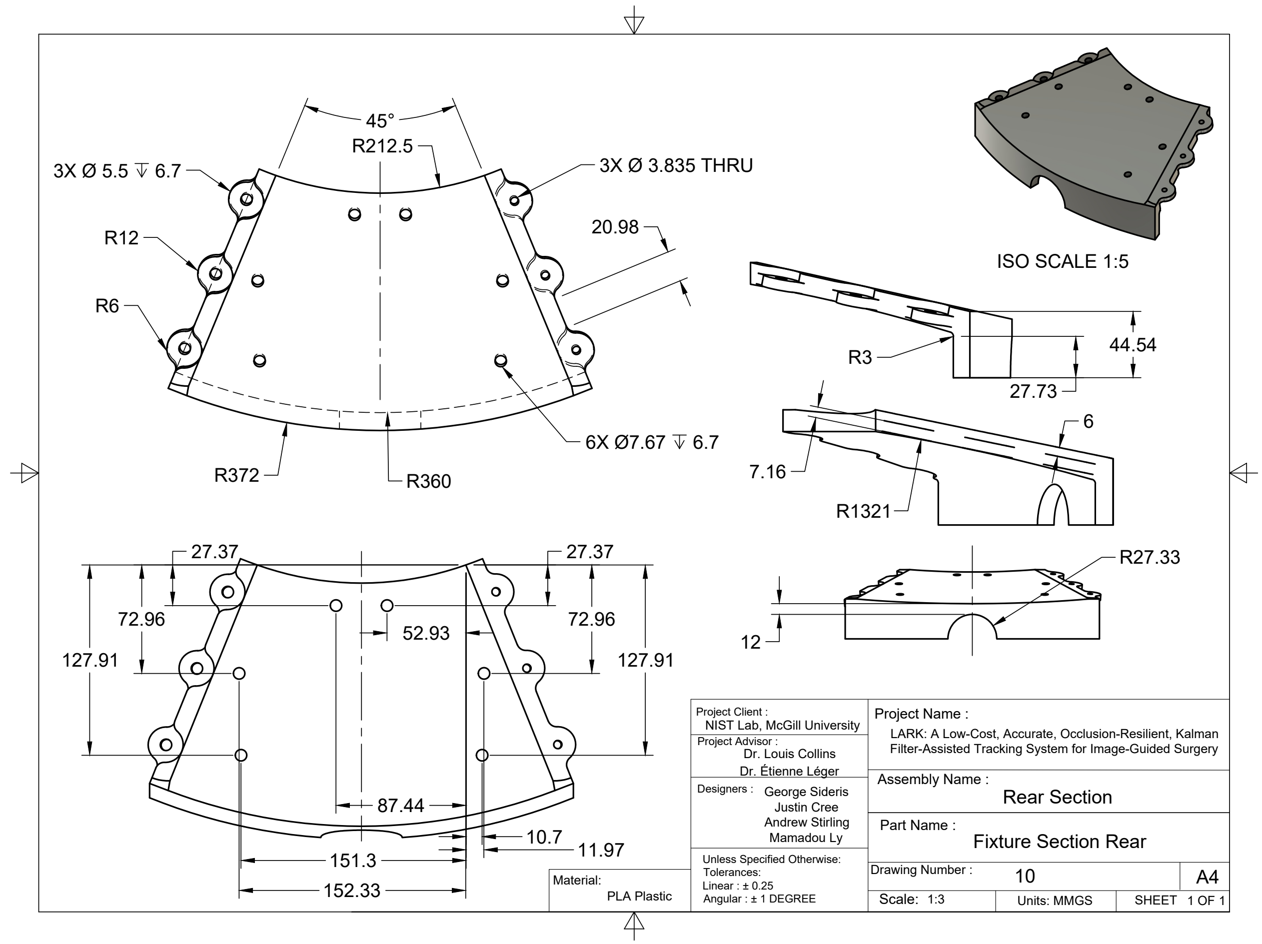
Supplementary Figure 9: Camera Mount Assembly Drawing.



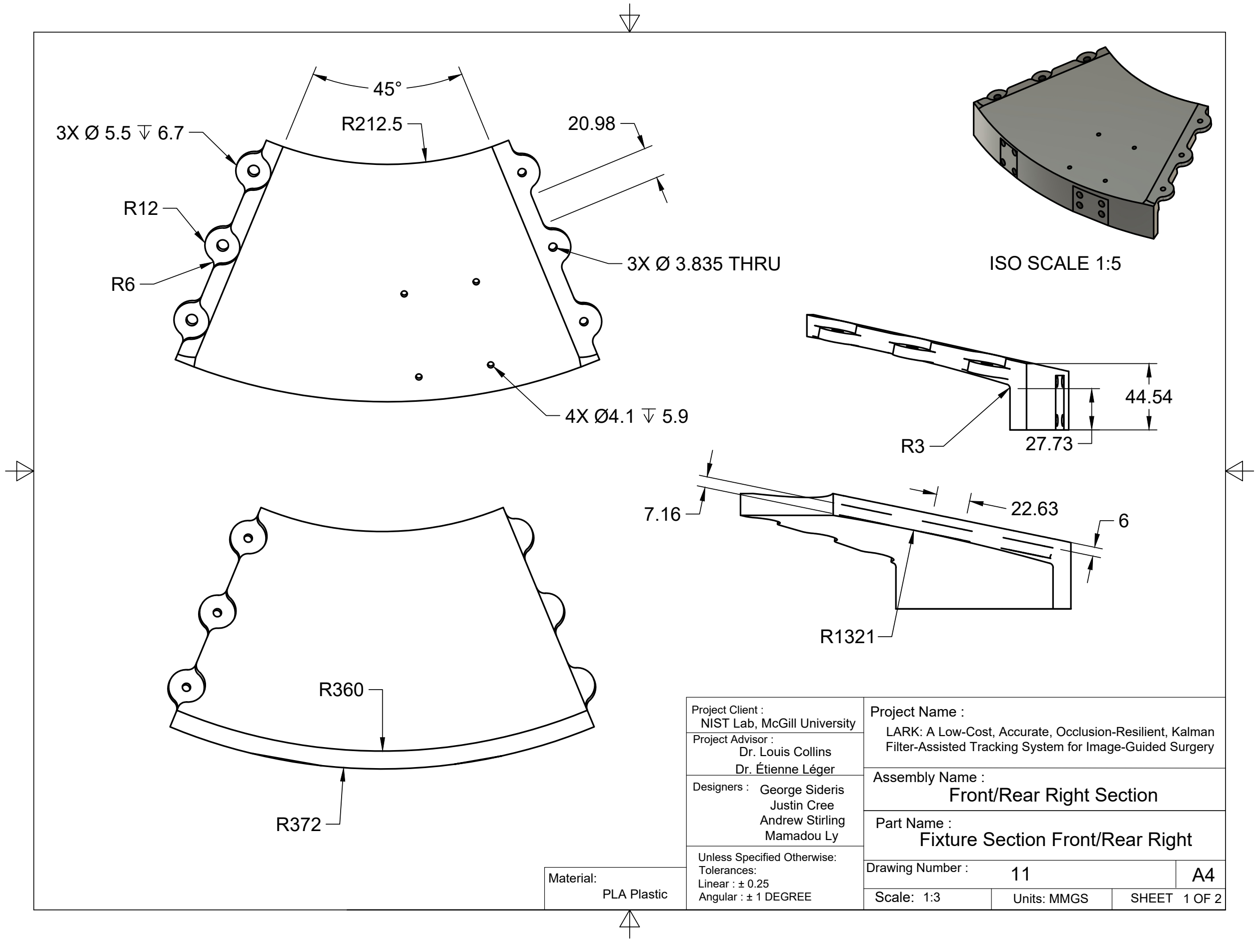
Supplementary Figure 10: Camera Mount Top Technical Drawing.



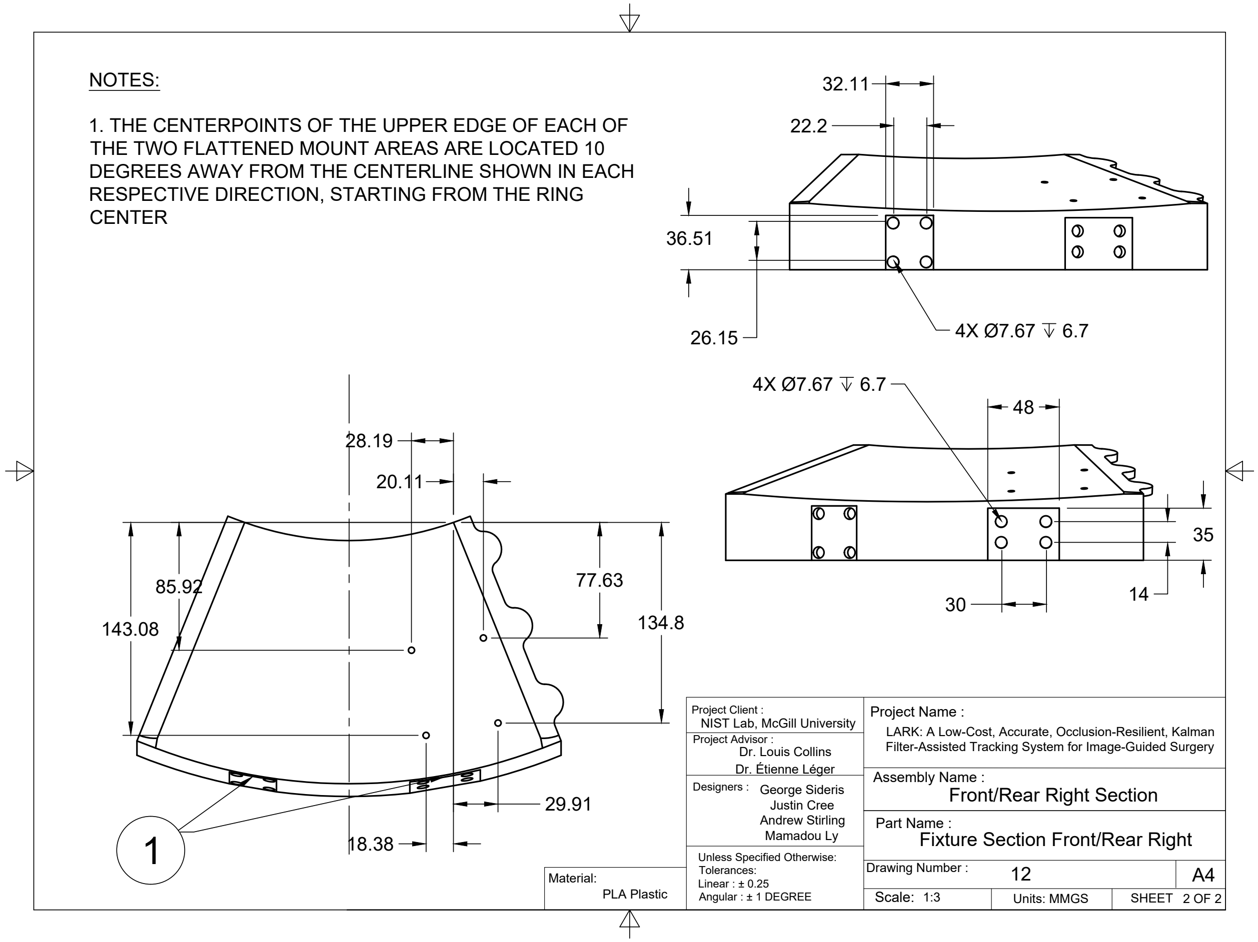
Supplementary Figure 11: Camera Mount Bottom Technical Drawing.



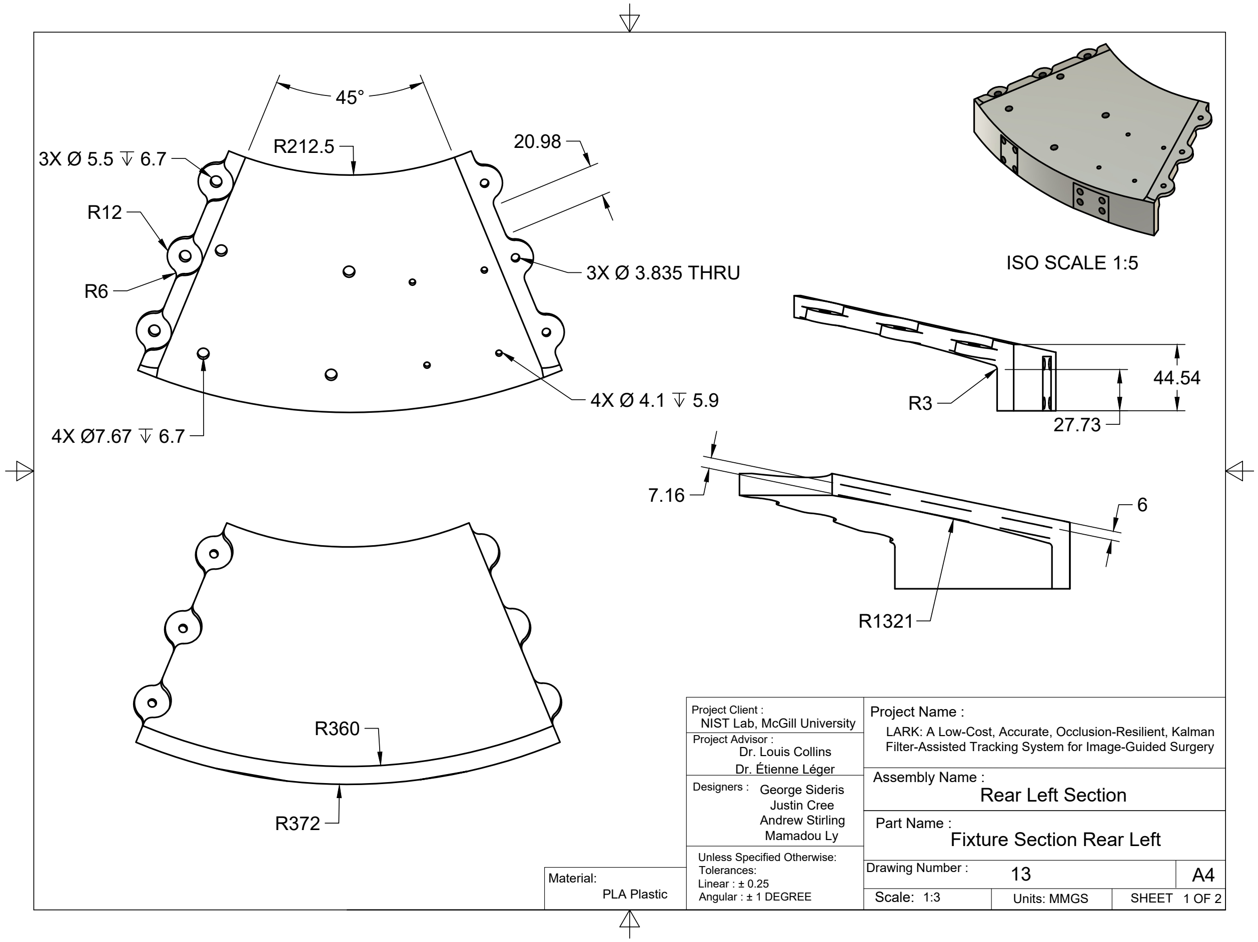
Supplementary Figure 12: Fixture Section Rear Technical Drawing.



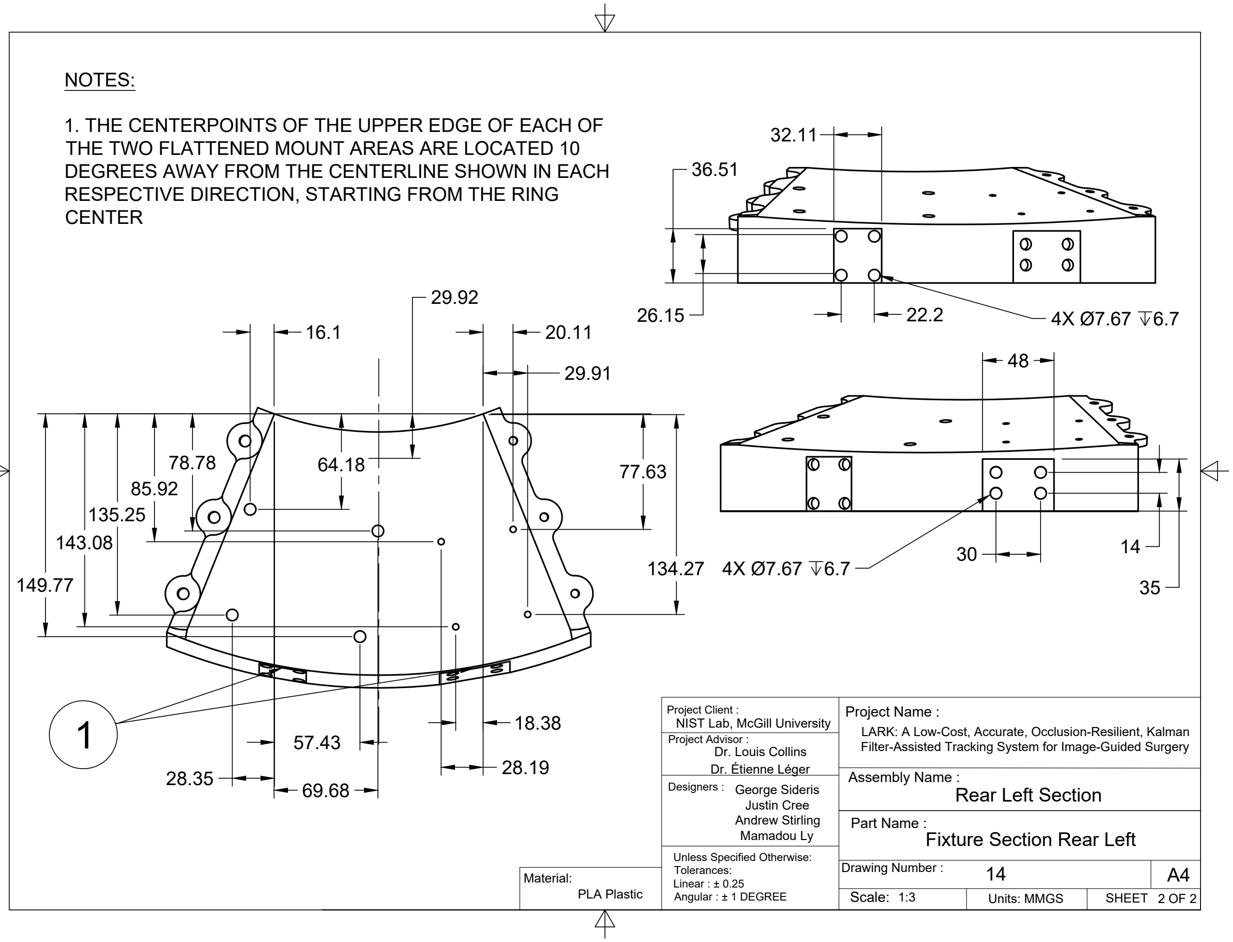
Supplementary Figure 13: Fixture Section Front/Rear Right (1/2) Technical Drawing.



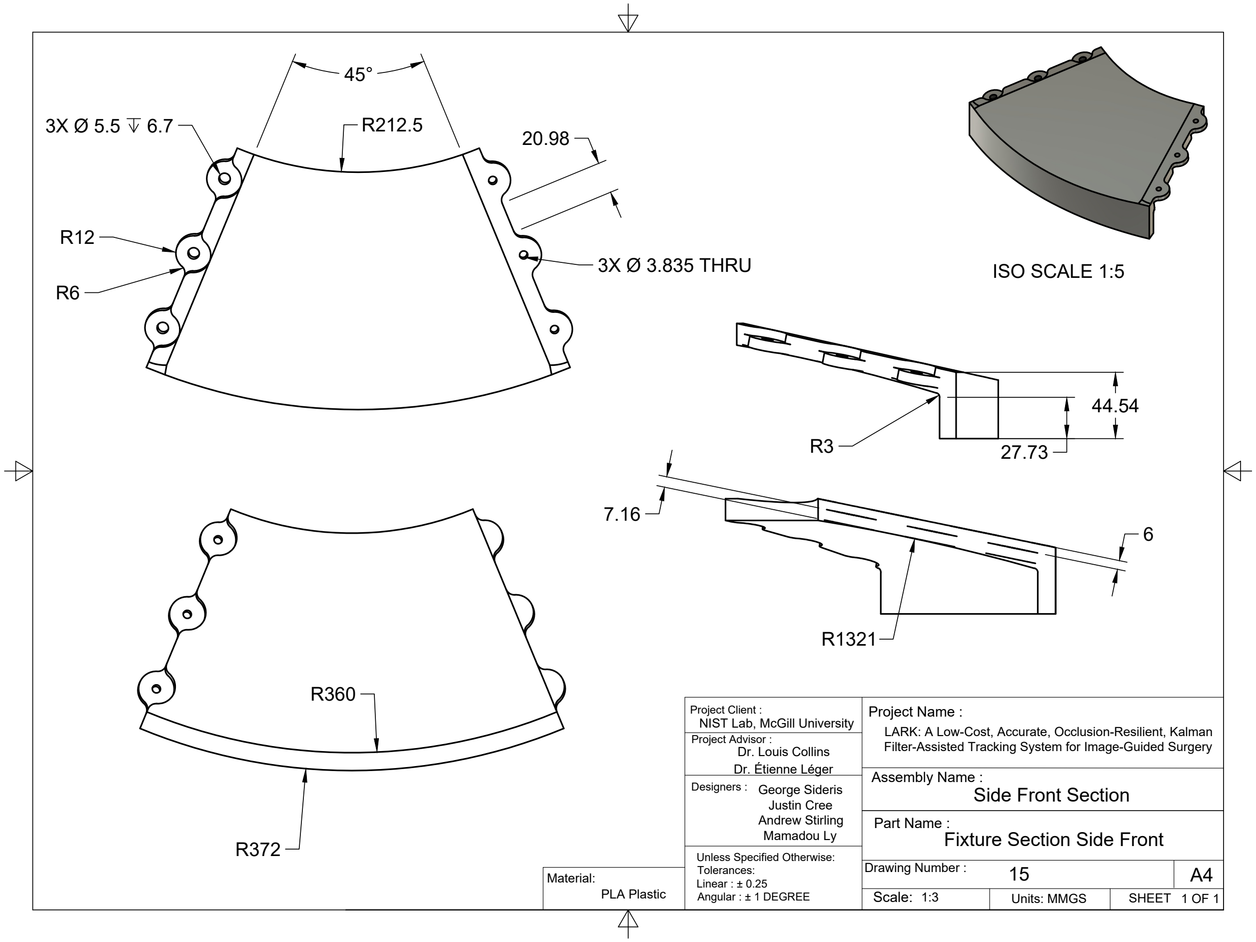
Supplementary Figure 14: Fixture Section Front/Rear Right (2/2) Technical Drawing.



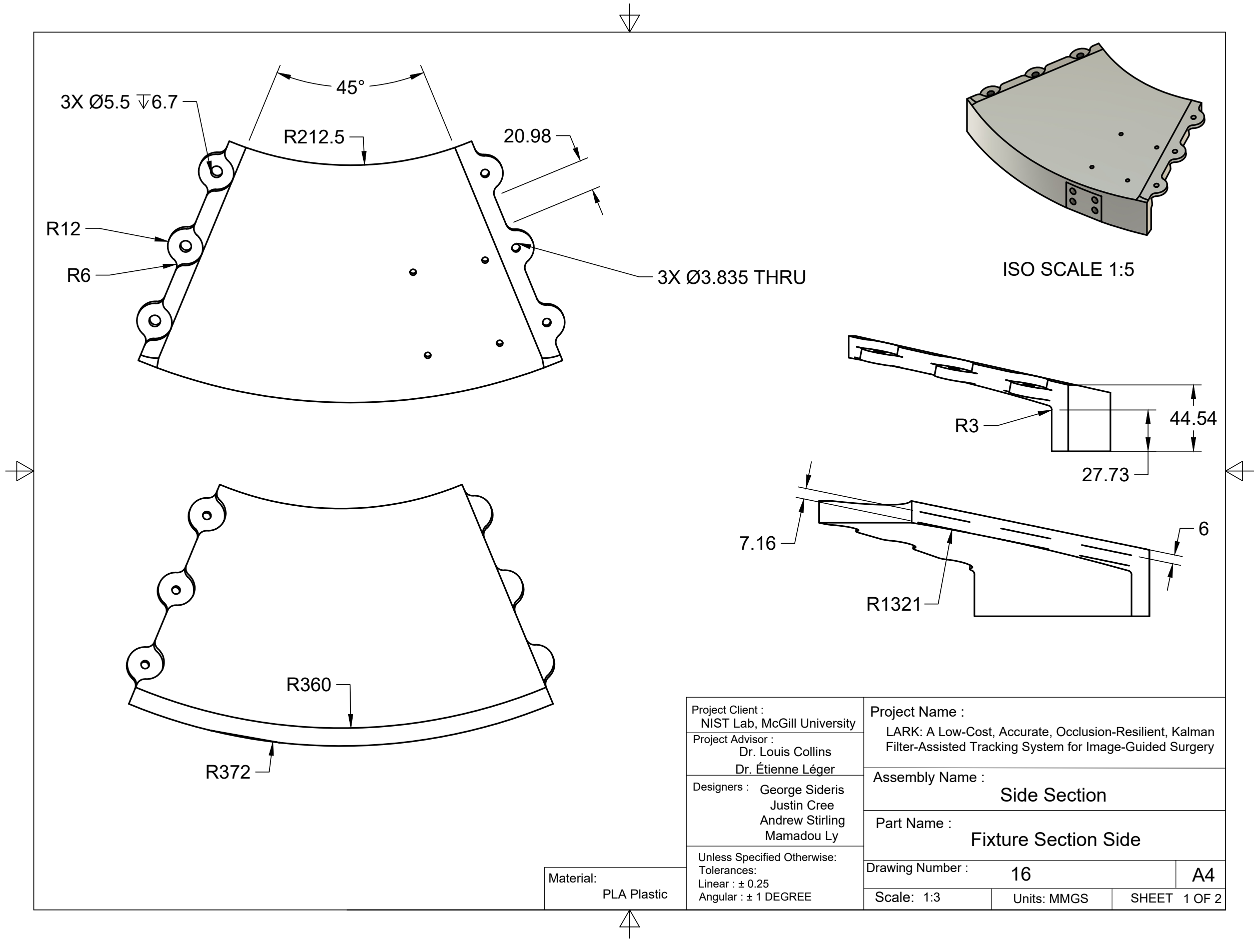
Supplementary Figure 15: Fixture Section Rear Left (1/2) Technical Drawing.



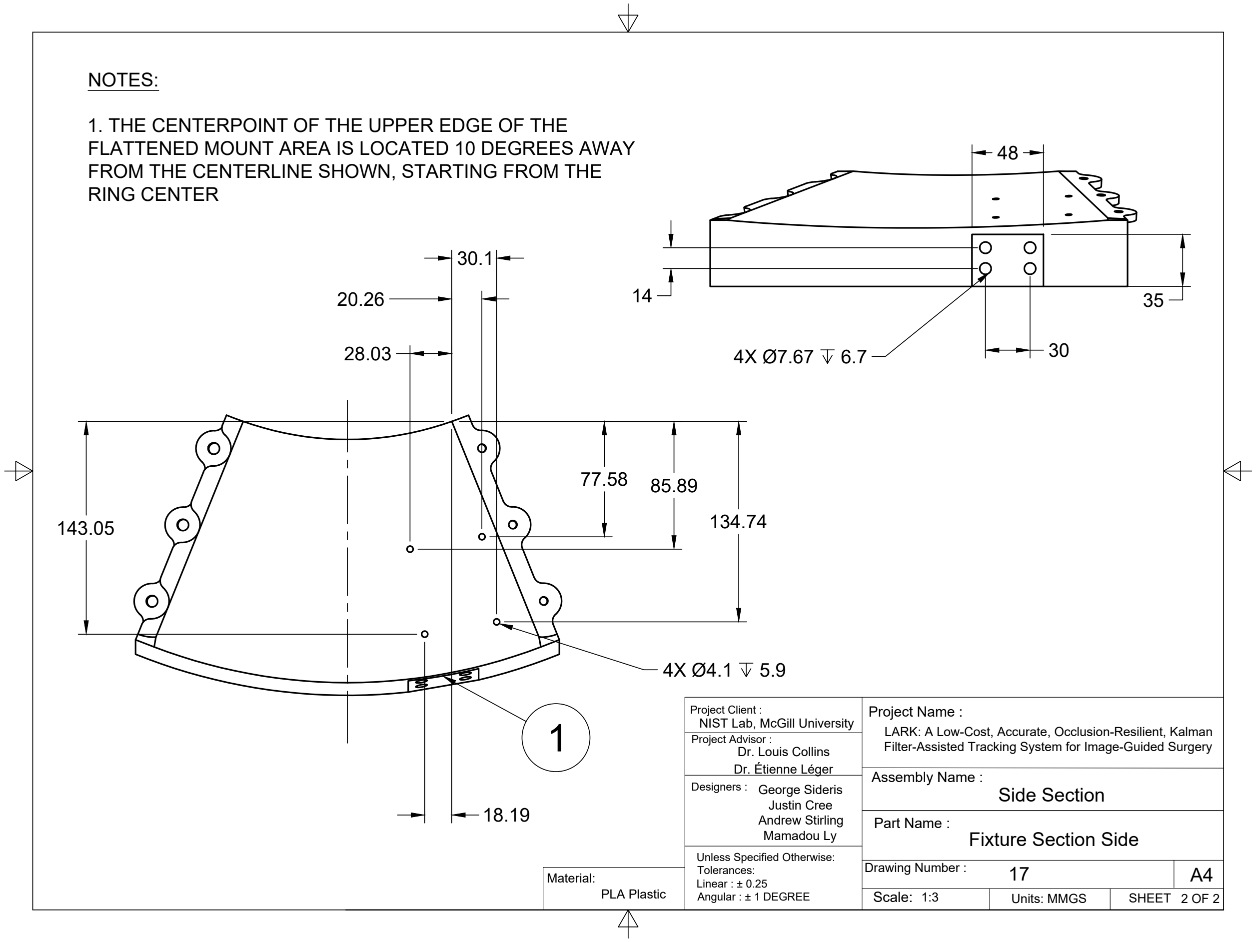
Supplementary Figure 16: Fixture Section Rear Left (2/2) Technical Drawing.



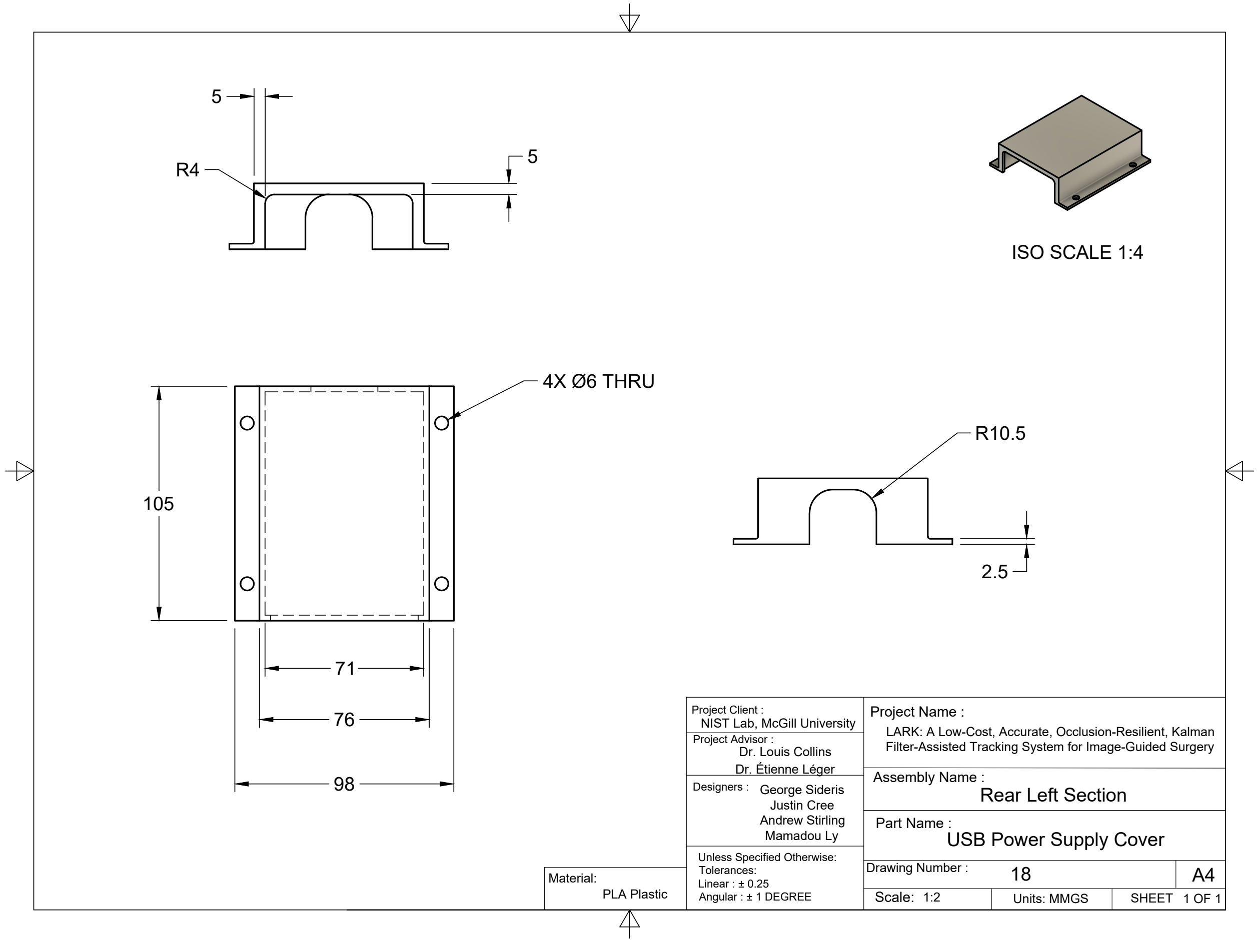
Supplementary Figure 17: Fixture Section Side Front Technical Drawing.



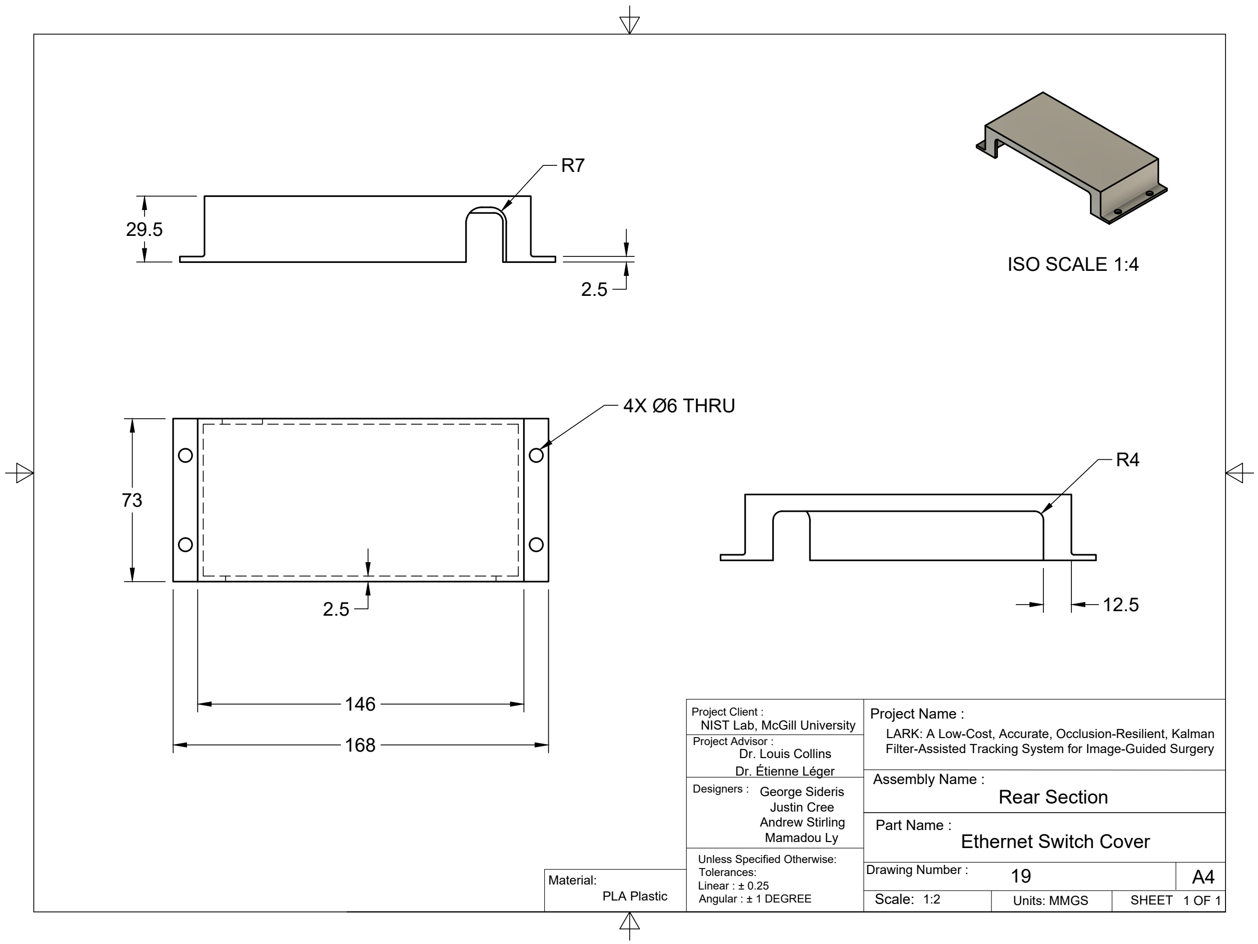
Supplementary Figure 18: Fixture Section Side (1/2) Technical Drawing.



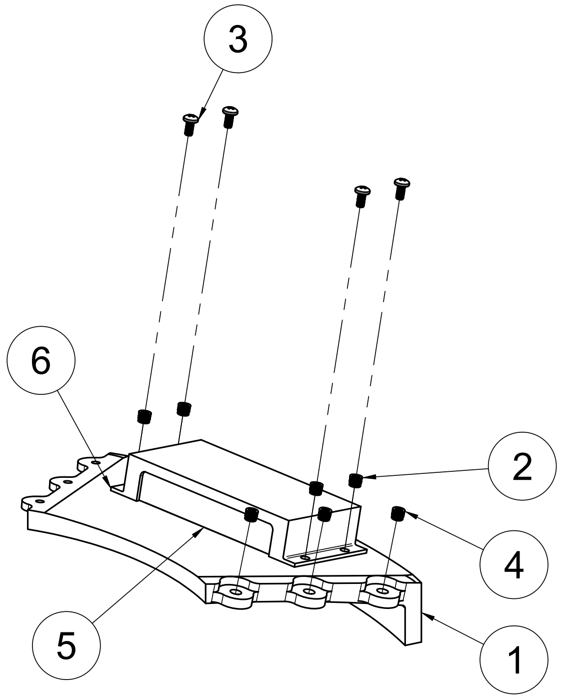
Supplementary Figure 19: Fixture Section Side (2/2) Technical Drawing.



Supplementary Figure 20: USB Power Supply Cover Technical Drawing.



Supplementary Figure 21: Ethernet Switch Cover Technical Drawing.



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	FIXTURE SECTION REAR
2	4	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC
3	4	90116A250_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS
4	3	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC (1)
5	1	ETHERNET SWITCH
6	1	ETHERNET SWITCH COVER

Project Client : NIST Lab, McGill University

Project Advisor : Dr. Louis Collins, Dr. Etienne Léger

Designers : George Sideris, Justin Cree, Andrew Stirling, Mamadou Ly

Unless Specified Otherwise:
Tolerances:
Linear : ± 0.25
Angular : ± 1 DEGREE

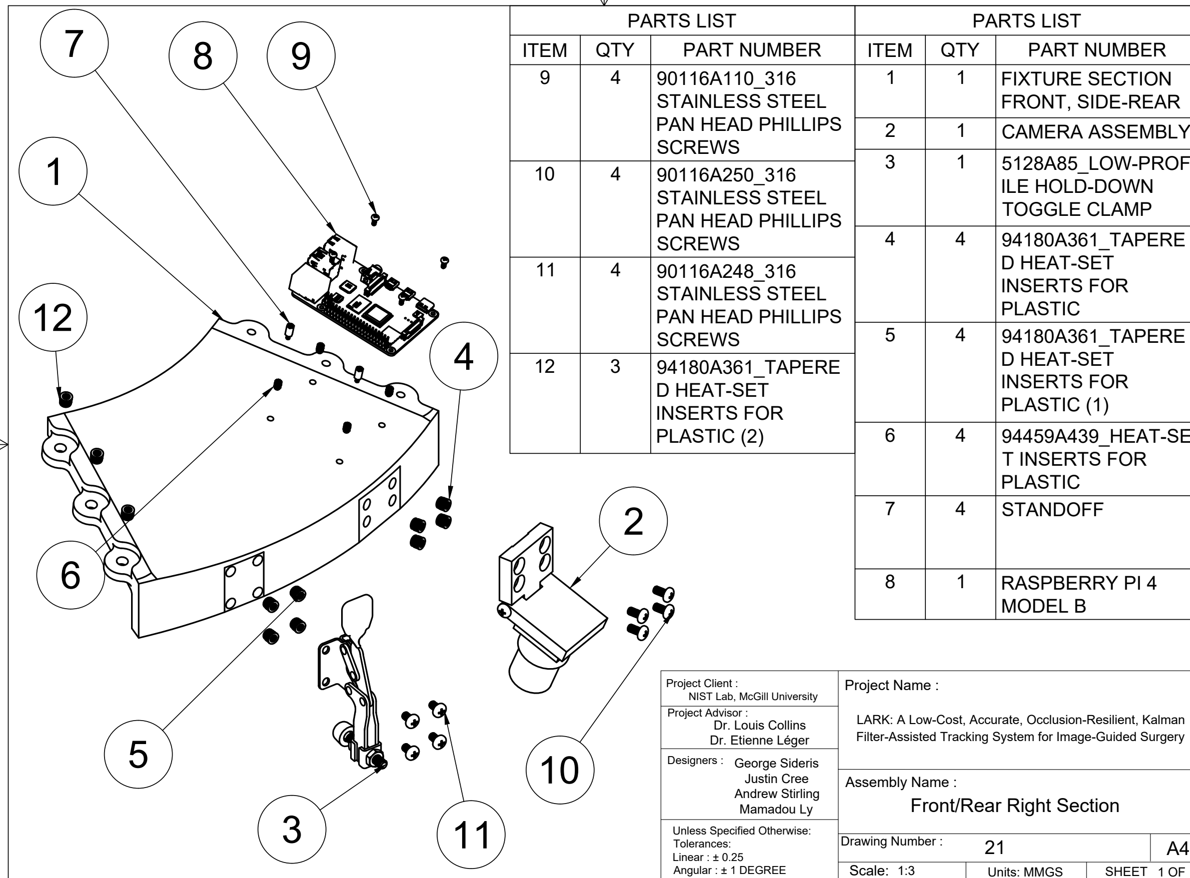
Project Name : LARK: A Low-Cost, Accurate, Occlusion-Resilient, Kalman Filter-Assisted Tracking System for Image-Guided Surgery

Assembly Name : Rear Section

Drawing Number : 20 | A4

Scale: 1:3 | Units: MMGS | SHEET 1 OF 1

Supplementary Figure 22: Rear Section Assembly Drawing.



PARTS LIST		
ITEM	QTY	PART NUMBER
9	4	90116A110_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS
10	4	90116A250_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS
11	4	90116A248_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS
12	3	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC (2)

PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	FIXTURE SECTION FRONT, SIDE-REAR
2	1	CAMERA ASSEMBLY
3	1	5128A85_LOW-PROFILE HOLD-DOWN TOGGLE CLAMP
4	4	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC
5	4	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC (1)
6	4	94459A439_HEAT-SET INSERTS FOR PLASTIC
7	4	STANDOFF
8	1	RASPBERRY PI 4 MODEL B

Project Client : NIST Lab, McGill University

Project Advisor : Dr. Louis Collins, Dr. Etienne Léger

Designers : George Sideris, Justin Cree, Andrew Stirling, Mamadou Ly

Unless Specified Otherwise: Tolerances: Linear : ± 0.25 Angular : ± 1 DEGREE

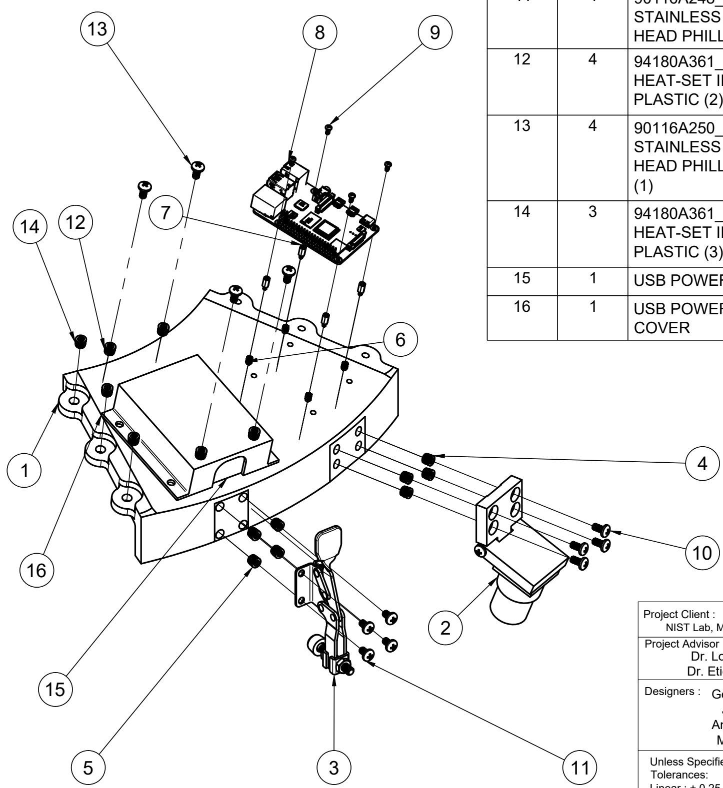
Project Name : LARK: A Low-Cost, Accurate, Occlusion-Resilient, Kalman Filter-Assisted Tracking System for Image-Guided Surgery

Assembly Name : Front/Rear Right Section

Drawing Number : 21 | A4

Scale: 1:3 | Units: MMGS | SHEET 1 OF 1

Supplementary Figure 23: Front/Rear Right Section Assembly Drawing.



PARTS LIST		
ITEM	QTY	PART NUMBER
11	4	90116A248_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS
12	4	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC (2)
13	4	90116A250_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS (1)
14	3	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC (3)
15	1	USB POWER SUPPLY
16	1	USB POWER SUPPLY COVER

PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	FIXTURE SECTION REAR LEFT
2	1	CAMERA ASSEMBLY V23
3	1	5128A85_LOW-PROFILE HOLD-DOWN TOGGLE CLAMP
4	4	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC
5	4	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC (1)
6	4	94459A439_HEAT-SET INSERTS FOR PLASTIC (1)
7	4	STANDOFF
8	1	RASPBERRY PI 4 MODEL B V1
9	4	90116A110_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS (1)
10	4	90116A250_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS

Project Client : NIST Lab, McGill University

Project Advisor : Dr. Louis Collins, Dr. Etienne Léger

Designers : George Sideris, Justin Cree, Andrew Stirling, Mamadou Ly

Unless Specified Otherwise:
Tolerances:
Linear : ± 0.25
Angular : ± 1 DEGREE

Project Name : LARK: A Low-Cost, Accurate, Occlusion-Resilient, Kalman Filter-Assisted Tracking System for Image-Guided Surgery

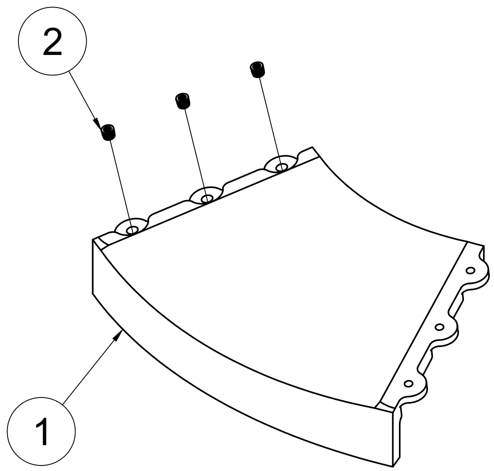
Assembly Name : Rear Left Section

Drawing Number : 22 | A4

Scale: 1:3.5 | Units: MMGS | SHEET 1 OF 1

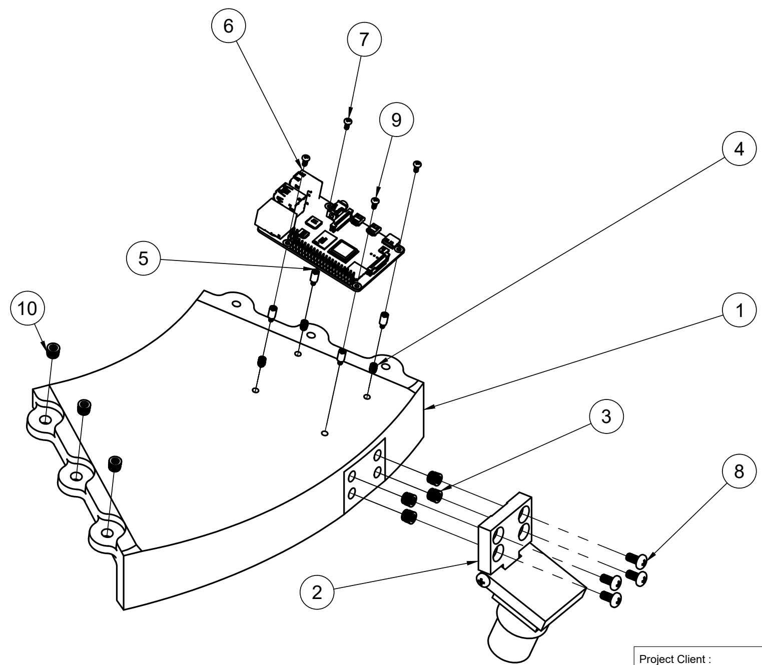
Supplementary Figure 24: Rear Left Section Assembly Drawing.

PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	RING SECTION SIDE FRONT
2	3	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC



Project Client : NIST Lab, McGill University	Project Name : LARK: A Low-Cost, Accurate, Occlusion-Resilient, Kalman Filter-Assisted Tracking System for Image-Guided Surgery
Project Advisor : Dr. Louis Collins, Dr. Etienne Léger	
Designers : George Sideris, Justin Cree, Andrew Stirling, Mamadou Ly	Assembly Name : Side Front Section
Unless Specified Otherwise: Tolerances: Linear : ± 0.25 Angular : ± 1 DEGREE	Drawing Number : 23 A4
	Scale: 1:3 Units: MMGS SHEET 1 OF 1

Supplementary Figure 25: Side Front Section Assembly Drawing.



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	FIXTURE SECTION SIDE
2	1	CAMERA ASSEMBLY V23
3	4	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC
4	4	94459A439_HEAT-SET INSERTS FOR PLASTIC (1)
5	4	STANDOFF (1)
6	1	RASPBERRY PI 4 MODEL B V1
7	3	90116A110_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS (1)
8	4	90116A250_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS
9	1	90116A110_316 STAINLESS STEEL PAN HEAD PHILLIPS SCREWS (2)
10	3	94180A361_TAPERED HEAT-SET INSERTS FOR PLASTIC (1)

Project Client : NIST Lab, McGill University

Project Advisor : Dr. Louis Collins, Dr. Etienne Léger

Designers : George Sideris, Justin Cree, Andrew Stirling, Mamadou Ly

Unless Specified Otherwise:
Tolerances:
Linear : ± 0.25
Angular : ± 1 DEGREE

Project Name :
LARK: A Low-Cost, Accurate, Occlusion-Resilient, Kalman Filter-Assisted Tracking System for Image-Guided Surgery

Assembly Name :
Side Section

Drawing Number : 24 | A4

Scale: 1:3 | Units: MMGS | SHEET 1 OF 1

Supplementary Figure 26: Side Section Assembly Drawing.

References

[39] Fitzpatrick, J.; West, J.; Maurer, C. Predicting error in rigid-body point-based registration. *IEEE Transactions on Medical Imaging* **1998**, *17*, 694–702. `https://doi.org/10.1109/42.736021`.