



UNIVERSITY OF  
**LOUISVILLE**®

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MICRO/NANO TECHNOLOGY CENTER

**FY20  
Annual Report**

*Your makerspace for nanotechnology.*

<http://louisville.edu/micronano>

**MNTC Personnel**



**Prof. Kevin Walsh  
Director**



**Julia Aebersold, Ph.D.  
Manager**



**Curt McKenna, M.Eng  
Senior Process Engineer**



**Evgeniya Moiseeva, Ph.D.  
Senior Process Engineer**



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**Mary Watson  
Administrative Specialist**



**Mallory Lucas, Part-time  
Program Assistant**

## **Executive Summary**

This document serves as the MNTC's official annual report for FY20 ending June 30, 2020. The University of Louisville's Micro/Nano Technology Center (MNTC) is a service center established in 2004 and consists of three facilities:

- The class 100/1000 \$30M 10,000 ft<sup>2</sup> cleanroom with an extensive array of processing equipment for the fabrication of novel thin film materials and devices.
- The Huson Imaging and Characterization Lab (HICL) is comprised of a scanning electron microscope (SEM), atomic force microscopes (AFM), mid-wave thermal imaging, Parylene C coater and wire bonding capabilities.
- The 300 ft<sup>2</sup> design/layout/simulation lab for MEMS and IC devices.

Together, these laboratories provide capabilities for researchers to perform a wide variety of micro and nanotechnology research. The University of Louisville faculty, academic institutions and external businesses utilize the facility for research, training and device prototyping.

## **Highlights:**

- \$14.2M of federally funded research utilized the MNTC by internal clients, not including start-up funds, RIF or DRIF funds.
- Overall revenue was \$233,593 for FY20 and was down primarily attributed to Covid-19 interruptions from March to the end of the FY. External income was \$133,840 and \$99,753 for internal revenue.
- The MNTC supported the 2019 KY Nano+AM Symposium held in July & August of 2019.
- Both Zeiss SEM's in the Huson Imaging & Characterization Laboratory were replaced with the Thermo Scientific FEI Apreo C Low Vac Scanning electron Microscope (SEM).
- Covid-19 shut down the facility for most of the final quarter of FY20.
- The MNTC submitted an NSF MRI proposal to acquire a new DRIE that was recommended, but not funded.
- The MNTC participated in the 2019 Southeast Regional IDeA conference held in Louisville, KY.

## **Issues:**

- Impact of Covid-19
- DRIE replacement
- Infrastructure maintenance.

- Increase the MNTC user base.

## Financials

The MNTC is utilized for research, process development and characterization by clients internal and external of the University. The MNTC’s engineering personnel also perform processing and characterization services as needed by clients. Figure 1 shows historical revenue data of the center since its inception in 2004. These data show a modest decline in overall revenue for the center, for FY20, but the is primarily attributed the interruptions by the covid-19 virus.

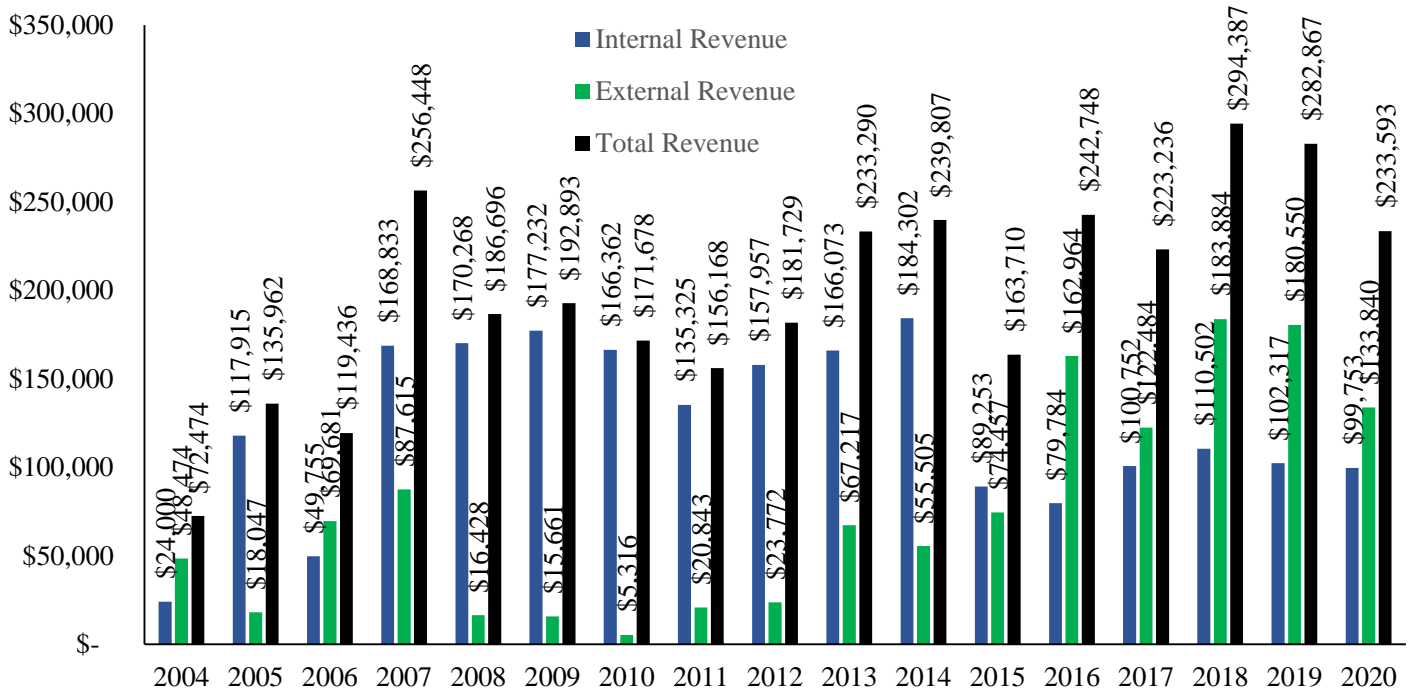


Figure 1. Internal and external revenue since the opening of the MNTC.

Figure 2 illustrates the percentage of internal versus external client revenue, which is similar to prior years. Partial reasoning for this difference are higher rates utilized by external clients and their tendency to utilize engineering personnel for service projects. The MNTC desires to achieve a closer percentage balance of 50% for each group and has made it an area of focus. Rates for the center are listed in the Appendix.

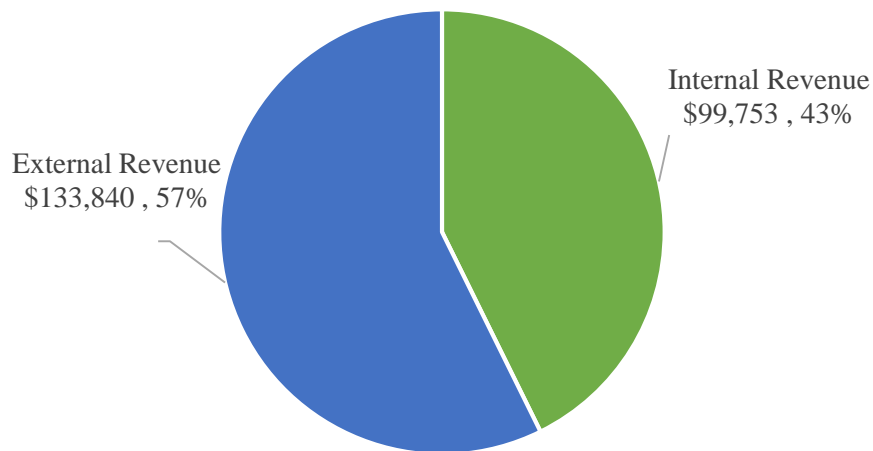


Figure 2. Income from internal and external clients for FY 20.

Tables 1 and 2 show an itemized breakdown of revenue for internal clients from the cleanroom and the Huson Imaging and characterization Laboratory, whereas a majority of revenue comes from processing activity within the cleanroom and its extensive capabilities.

Table 1. Internal client Cleanroom usage.

Internal Revenue - CR		Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	TOTALS
<b>TOTAL</b>		<b>5,859.10</b>	<b>8,159.60</b>	<b>7,047.25</b>	<b>11,115.05</b>	<b>12,870.35</b>	<b>3,125.00</b>	<b>12,330.50</b>	<b>10,466.35</b>	<b>7,621.50</b>	<b>5,359.55</b>	<b>57.60</b>	<b>736.50</b>	<b>84,748.35</b>
Abell	GAS													0.00
Alphenaar	ECE	572.70	41.40	258.20		10.00		477.60	1,579.50	441.20	206.00	12.60	114.00	3,713.20
Baldwin	CHEM													0.00
Bara	BIO													0.00
Berfield	ME									989.70	366.25			1,355.95
Capstone	CAP													0.00
ECE Class	ECE					6,896.05								6,896.05
Farg	ECE									410.10	324.10			734.20
Fu	CHE	1,652.45	10.00	1,427.10	45.00	45.00		1,024.25	420.80	2,416.40	1,170.00		45.00	8,256.00
Grapperhaus	CHEM	45.00	135.00	135.00	45.00				45.00					405.00
Harnett	ECE		10.00		156.00	498.40		847.90	339.10	44.80				1,896.20
Jones - Howard	MED													0.00
Kopechek	BE				810.00	155.00		153.50					532.50	1,651.00
McNamara	ECE	125.00	1,765.00											1,890.00
O'Toole	BE													0.00
Popa	ECE	579.15	2,491.85	2,484.40	1,797.65	1,884.90	-125.00	2,408.55	2,969.60	1,780.90	1,722.55			17,994.55
Roussel	BE				2,366.45	421.30	3,250.00	60.00	1,902.00					7,999.75
Smadici	PHY													0.00
Soucy	BE													0.00
Spurgeon	CONN				125.00			105.00	920.70		332.00			1,482.70
Stolowich	CHEM		90.00								45.00	45.00	45.00	225.00
Sumanasekera	PHY													0.00
Walsh	ECE	2,704.80	3,792.85	3,142.55	4,063.90	2,779.70		7,208.70	2,019.65	1,493.40	1,058.65			28,264.20
Williams	ME				811.75									811.75
Willing	CHE													0.00
Worley	BIO				45.00	45.00			45.00					135.00
Yang	IE													0.00
Yoder-Himes	CHEM	45.00				45.00					45.00			135.00
Zamborini	CHEM													0.00
Zhang	CHEM	135.00	135.00		849.30	90.00		45.00	225.00	45.00	90.00			1,614.30
Grote Check	MISC		-311.50	-400.00										-711.50

Mary:  
Transferred to  
Conn Ctr.

Mary:  
Usage of  
Berfield's  
Tool

Table 2. Internal client Huson Laboratory usage.

Internal Revenue-HL		Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	TOTALS
<b>TOTAL</b>		<b>1,986.80</b>	<b>2,426.00</b>	<b>1,519.60</b>	<b>1,737.40</b>	<b>1,100.20</b>	<b>0.00</b>	<b>2,792.70</b>	<b>545.90</b>	<b>937.30</b>	<b>352.60</b>	<b>1,039.60</b>	<b>566.30</b>	<b>15,004.40</b>
Alphenaar	ECE	39.50						190.00		130.00				359.50
Baldwin	CHEM													0.00
Bara	BIO													0.00
Berfield	ME													0.00
Chou	IE		400.00					90.00						490.00
Fu	CHE													0.00
Harnett	ECE				40.60	8.40		224.00						273.00
Jones	MED				170.00	220.50		105.00						495.50
Kopechek	BE													0.00
Lian	ME													0.00
Maurer	CHEM													0.00
McNamara	ECE													0.00
Menze	BIO		80.90	178.00							114.70			373.60
Naber	ECE													0.00
O'Toole	BE	400.00		387.50	341.00	400.00		330.00						1,858.50
Popa	ECE		750.50	315.00	250.00					203.00		1,039.60	500.00	3,058.10
Rasipuram	OLP			180.00	67.50									247.50
Running	BIO													0.00
Soucy	BE													0.00
Starr	CHE							205.00						205.00
Steinbach	BE	223.50	170.00	104.10	298.50	71.30		550.00	59.90	128.00	60.50		66.30	1,732.10
Stolowich	CHEM													0.00
Sumanasekera	PHY							73.00	187.50					260.50
Walsh	ECE	923.80	667.60	355.00	391.70	400.00		597.70	298.50	308.80	177.40			4,120.50
Williams	ME													0.00
Yanorviak	BIO				178.10			428.00						606.10
Zamborini	CHEM	400.00	357.00											757.00
Zhang	CHEM									167.50				167.50

Tables 3 and 4 are itemized listings of internal revenue categorized by department showing a large diverse group utilizing the center. The Electrical and Computer Engineering (ECE) Department was the largest contributing department at 30% of total percentage of internal revenue for both the cleanroom and the Huson Laboratory.

Table 3. Internal income for the Cleanroom FY 2019.

TOTAL	\$ 84,748.35	100%
BE	9,650.75	11%
BIO	135.00	0%
CHE	8,256.00	10%
CHEM	2,379.30	3%
CONN	1,482.70	2%
ECE	61,388.40	72%
IE	-	0%
ME	2,167.70	3%
MED	-	0%
MISC	(711.50)	-1%
PHY	-	0%

Table 4. Internal income for the Huson Laboratory FY 2019.

TOTAL	\$15,004.40	100%
BE	3,590.60	24%
BIO	979.70	7%
CHEM	924.50	6%
CHE	205.00	1%
ECE	7,811.10	52%
IE	490.00	3%
ME	0.00	0%
MED	495.50	3%
MISC	0.00	0%
OLP	247.50	2%
PHY	260.50	2%

Table 5 displays revenue collected from external clients for both the cleanroom and the Huson Laboratory for a total of \$133,839.51. Company names have been removed to protect privacy.

Table 5. External clients for the Cleanroom and Huson Laboratory.

Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	TOTAL
19,085.39	7,270.85	12,260.51	6,367.20	10,532.80	14,666.15	7,273.90	13,018.17	8,932.75	8,778.11	12,034.97	13,618.71	133,839.51
					1,037.80	1,238.95	1,314.05				1,607.20	5,198.00
3,915.00		3,195.00					5,833.32		2,916.66	5,833.32	2,916.66	24,609.96
1,341.91		2,589.75		1,750.00								5,681.66
											115.00	115.00
138.00							50.50			115.00		303.50
		695.76										695.76
											4,876.50	4,876.50
			2,500.00	1,000.00								3,500.00
												-
	1,175.00	2,625.00										3,800.00
			1,660.20		92.00	2,836.20	1,027.35	2,969.50	1,022.00	130.00	2,178.60	11,915.85
			419.00				625.00					1,044.00
												-
351.00	311.50			410.00		720.00						1,792.50
					605.00							605.00
2,298.15	875.00			5,069.45	1,537.65	1,299.00	2,337.95		1,972.45		1,856.75	17,246.40
					2,300.00		1,084.00	1,235.00				4,619.00
				953.00								953.00
	136.00	68.00		34.00			136.00				68.00	442.00
									100.00			100.00
												-
										196.00		196.00
1,414.35	1,603.00	732.00	168.00		1,599.50	236.00						5,752.85
65.00		70.00								200.00		335.00
												-
						103.00						103.00
									2,000.00			2,000.00
			25.00									25.00
	363.00				24.15							387.15
395.00												395.00
							390.00					390.00
		2,285.00					220.00					2,505.00
	167.05											167.05
9,166.98	2,640.30		1,595.00	1,316.35	7,470.05	840.75		4,008.25	767.00	5,560.65		33,365.33
												-
								720.00				720.00
												-

**Facility Usage**

Figure 3 shows the historical number of internal clients, faculty and external clients since opening of the facility. The primary indicator of this data is that while the number of clients increased overall in all categories, revenue did not increase proportionately as per the cleanroom entries listed in Table 7.

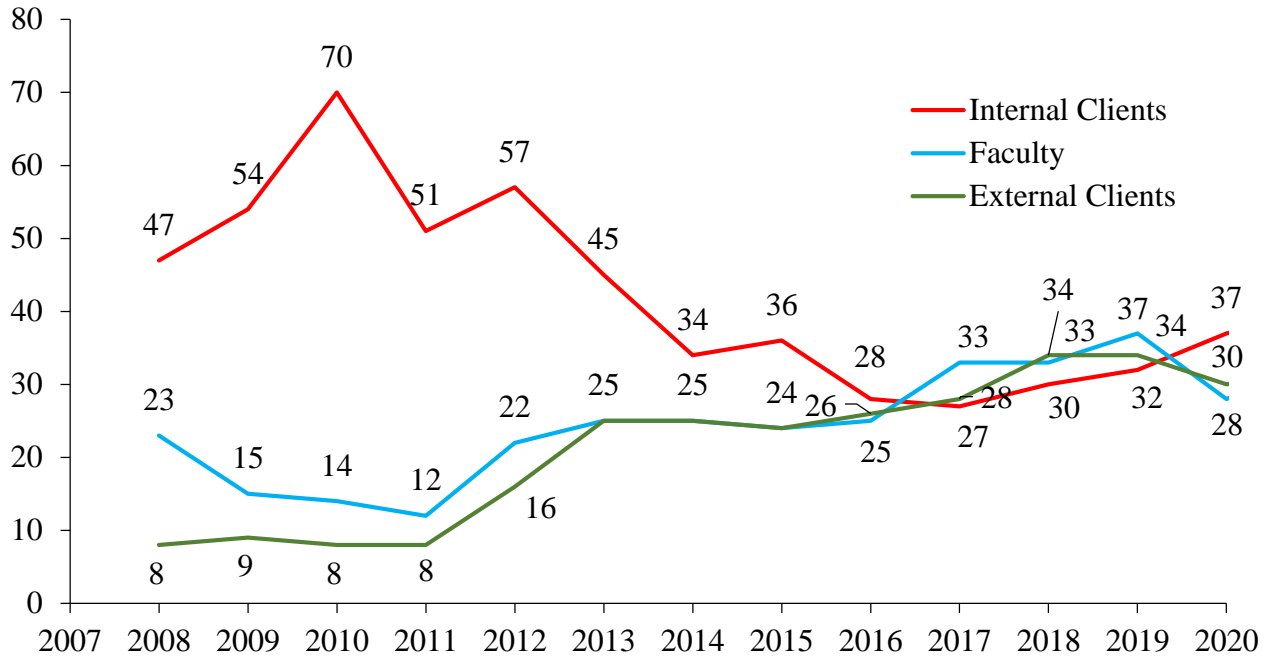


Figure 3. A historical representation of external, internal and faculty clients utilizing the Cleanroom and Huson Laboratory.

For equipment usage, work horse equipment from both facilities are the Supra SEM, Dektak Profilometer, DRIE, Lesker PVD 75 Sputterer, March RIE, Photoresist Spinners and Suss Mask Aligner. Service contracts exist on the SEM while a 3<sup>rd</sup> party vendor services the Suss Mask Aligner each year.

Table 6 is a compilation of grants and contracts utilized by faculty to conduct research that pays for access, service and equipment fees. Equipment fees are listed in the Appendix. These fees are used to maintain operations of the facility and its infrastructure. Not listed within the table are other funding sources that are not grants and contracts. Most of these awards were based upon availability of the MNTC that helped to award their proposals.



Table 6. Grants and contracts utilized by faculty in FY20.

GRANT #	PI Name	Dept	CR	HL	LN	SR	Grant Amt.	MNTC Exp
GB140779	Alphenaar	ECE	✓	✓		✓	1,749,999.00	4,108.70
GB170286	Chou	IE		✓			188,674.00	90.00
CCDB151153	Fu - Xie CR	CHE	✓		✓		200,000.00	287.10
GB161177J3	Fu	CHE	✓				178,872.00	1,026.10
GB170954	Fu-Zhenzhen	CHE	✓			✓	762,259.00	725.00
GB180260	Fu	CHE	✓	✓	✓	✓	408,775.00	4,838.40
GB170358	Grapperhaus	CHEM			✓		450,000.00	405.00
GB180796	Harnett	ECE	✓	✓		✓	402,803.00	2,159.20
OIEN190151	O'Toole	BE		✓			348,000.00	2,080.50
GB170954	Popa	ECE	✓	✓			762,259.00	7,913.60
GB180796	Popa	ECE	✓	✓		✓	1,530,219.00	4,169.65
GB200157	Popa	EDE	✓	✓		✓	3,672,164.00	9,638.70
GB190952	Rasipuram	ME		✓			5,000.00	247.50
GB141515V	Roussell	BE	✓	✓		✓	75,000.00	8,179.75
OIEB171329	Starr	CHEM		✓			299,628.00	205.00
GN180655C	Steinbach	BE		✓			33,410.00	877.50
GB180729H2	Steinbach	BE		✓			202,447.00	233.50
GB190506	Steinbach	BE		✓			498,301.00	633.10
GB180533	Sumanasekera	PHY		✓			322,061.00	260.50
GB151257	Walsh	ECE	✓	✓		✓	1,272,164.00	34,656.50
GB151393	Williams	ME	✓			✓	372,500.00	811.75
GB171268A	Yoder-Himes	BIO			✓		67,263.30	135.00
GB160551	Zamborini	CHEM		✓			438,605.00	757.00
							<b>14,240,403.30</b>	<b>84,439.05</b>

Figure 4 and 5 are historical account of operating expenses of the facility since opening in 2004. During FY20 expenses outpaced income due to effects from the pandemic. Figure 5 is an itemized listing of expenses accumulated by category for FY20, where the center's salary and fringe expenses increased by a factor of two from FY19 to FY20.

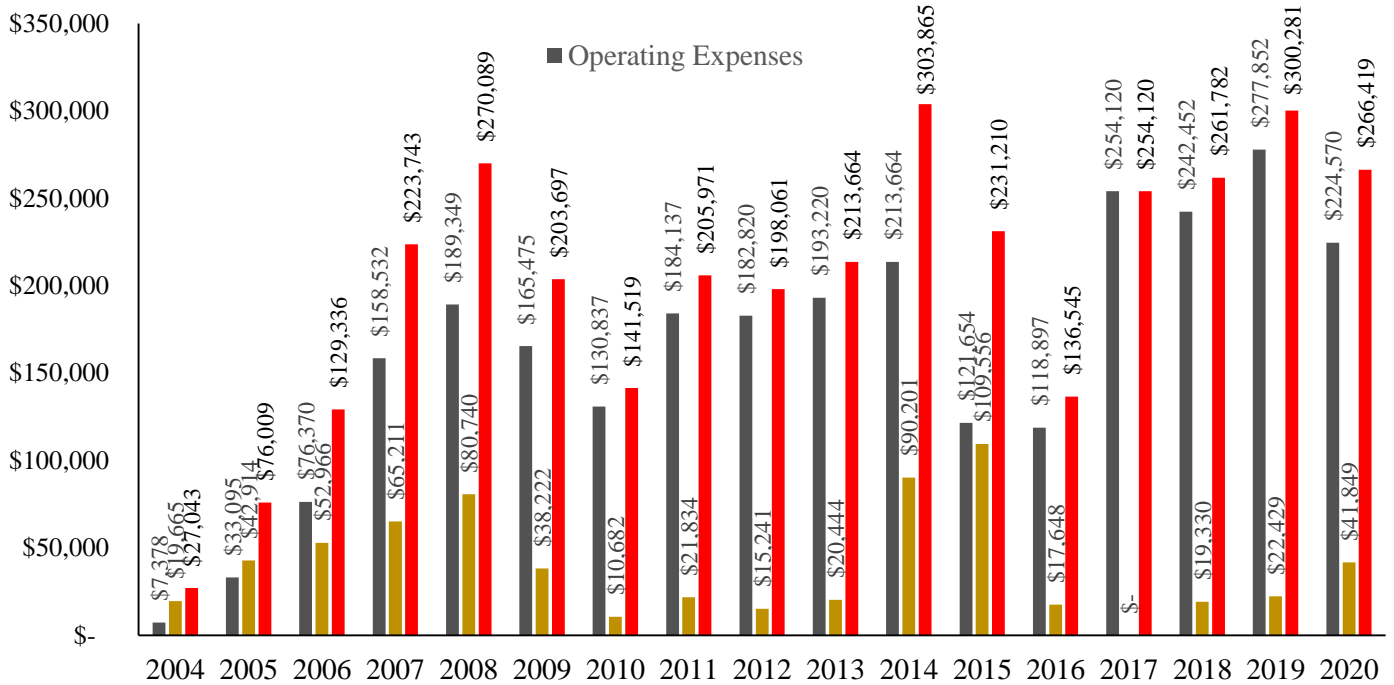


Figure 4. Operating and salary expenses since the since the opening of the MNTC.

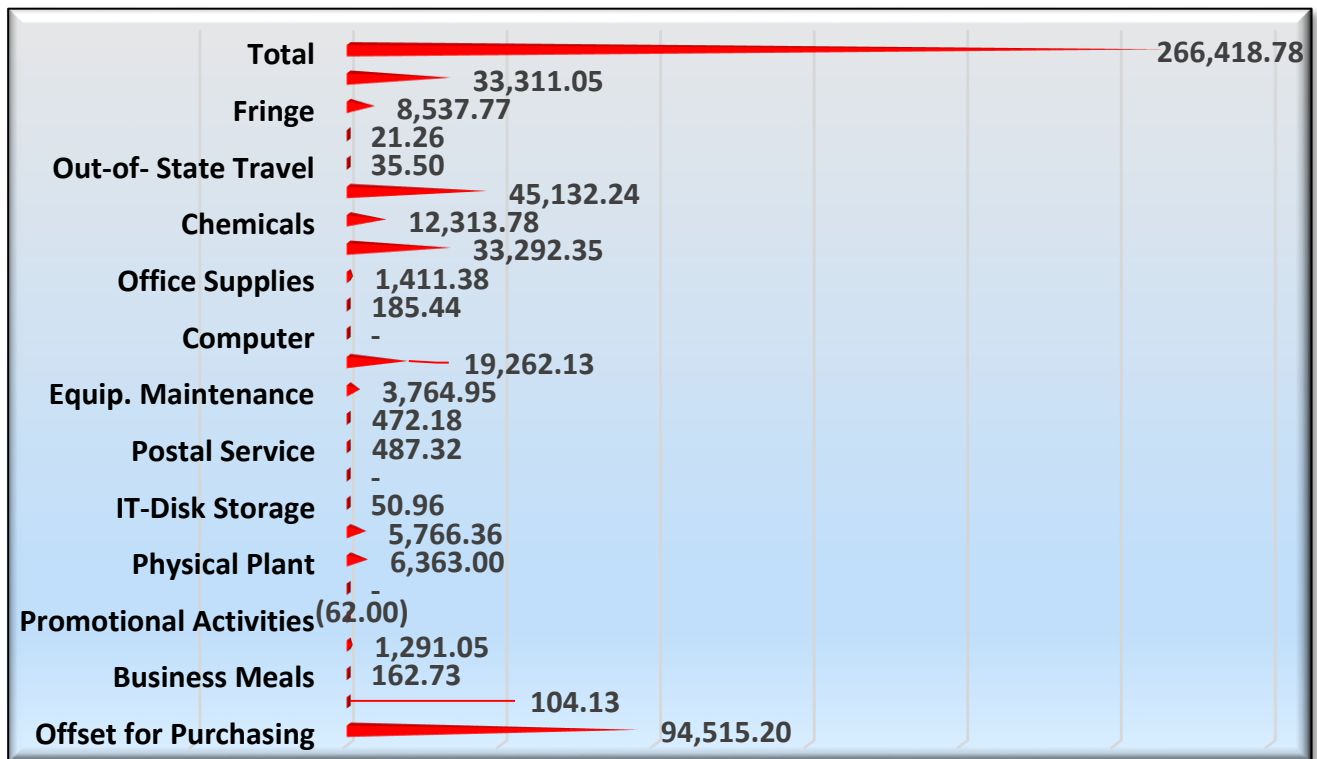


Figure 5. Operating and salary expenses of the MNTC for FY 20.

MNTC also supports work study students as it has for multiple years. Work study is a federal

financial aid program that offers hourly employment to eligible students. This program helps students make connections gain valuable work experience, while pursuing a college degree. Each semester the MNTC requests several work study students to cover positions within the cleanroom and administrative support. Students are trained in chemical safety, equipment maintenance and perform simple procedures on systems in the cleanroom. Work studies usually commit five to ten hours per week each semester and alternate semesters based upon co-op schedules. Experience gained by work studies in the MNTC is valuable in that it can assist their future endeavors. Work studies are not a financial responsibility on the MNTC and are thankfully provided by the University.

### **Ongoing Issues and Future Directions**

As the center ages its infrastructure costs continue to increase. Examples are the deionized water and filtration systems, air handling and exhaust systems, toxic gas monitoring and acid waste neutralization system. Each of these critical components keep the center operational and safe. As a result, additional funds were requested from the Deans' Office to help defer maintenance costs for these systems along with other expenses. Discussions with the Dean's office brought fruitful fiscal assistance to keep these systems operational, of which the MNTC is grateful. However, it has been communicated that these expenses will continue to rise as the systems age and maintenance costs increase.

An additional item of ongoing concern is salary funding for engineering personnel. Each year the burden of providing salary assistance for existing staff continues to grow. It is preferred to return to the model where salary and fringe benefits were covered by the Dean's Office. Therefore, continuing discussions are ongoing as fiscal opportunities become open.

In order to help with increased utilization of the facility the MTNC would like to increase its user base. The center has very limited control to expand its internal clients, but intends to make further inroads via the new Thermo-Fisher Electron Microscope.

## Appendix

### Rate Structure

Below is the rate structure of the MNTC, which is also available online. Clients of the MNTC are charged a daily cleanroom access fee and associated equipment fees.

Daily Access Fee to the Cleanroom	Internal User:	\$10/day
	External User:	\$34/day

#### *Equipment Usage Fees*

Equipment fees are defined below for all clients and services. A cap of \$1,500 per month per internal users only researcher was implemented for equipment usage, access fees and training. This cap does not include consumables (wafers, wafer containers, tweezers, etc.) or services performed by the MNTC staff (i.e. dicing and photomasks). A cap is not instituted for external users.

### CLEANROOM EQUIPMENT FEES

Equipment	Internal Rate	External Rate	Service Center Rate Internal	Service Center Rate External
Dektak Profilometer	\$0.25/min	\$0.50/ min	\$60/hour for training and labor (does not include tool rate)	\$100/hour for training and labor (does not include tool rate)
Filmetrics Film Measurement System	\$0.25/min	\$0.50/ min		
Toho Thin Film Stress Measurement	\$0.25/min	\$0.50/ min		
Zeiss Axioscope Optical Microscope	\$0.25/min	\$0.50/ min		
Flip Chip Bonder	\$0.50/min	\$0.85/min		
QFI Thermal Imaging System	\$0.50/min	\$0.85/min		
Zygo Optical Laser Profilometer	\$0.50/min	\$0.85/min		
Chemical Mechanical Polishing (CMP)	\$0.50/min	\$0.85/min		
Vase Ellipsometer	\$0.50/min	\$0.85/min		
Critical Point Dryer	\$0.50/min	\$0.85/min		
Ball /Wedge Bonder	\$0.60/min	\$1.00/min		
Hi-Speed Camera	\$0.60/min	\$1.00/min		
March RIE	\$0.60/min	\$1.00/min		
Rapid Temperature Processing (RTP/RTA)	\$0.60/min	\$1.00/min		
ABM Aligner	\$0.70/min	\$1.15/min		
DRIE	\$0.70/min	\$1.15/min		
Lesker E-beam Evaporator (**extra for Au)	\$0.70/min	\$1.15/min		
Lesker PVD 75 (**extra for Au and Pt)	\$0.70/min	\$1.15/min		
Molecular Vapor Deposition (MVD)	\$0.70/min	\$1.15/min		
Oxford PECVD	\$0.70/min	\$1.15/min		
Suss Aligner	\$0.70/min	\$1.15/min		
Suss Bonder	\$0.70/min	\$1.15/min		
Technics Sputterer	\$0.70/min	\$1.15/min		
Trion Metal Etcher	\$0.70/min	\$1.15/min		

Hitachi SEM	\$1.00/min	\$1.50/min		
Xactix XeF <sub>2</sub> Isotropic Etching	\$1.00/min	\$1.60/min		
HF Vapor Etcher	\$1.00/min	\$1.60/min		
Beneq ALD	\$1.00/min	\$1.60/min		

	Equipment	Internal Rate	External Rate	Service Center Rate Internal	Service Center Rate External
	HF-8 Axic Barrel Asher	\$30/batch	\$45/batch	\$60/hour for training and labor (does not include tool rate)	\$100/hour for training and labor (does not include tool rate)
	Reynolds Electroplating Bench	\$30/batch	\$45/batch		
	Tube Furnace (Anneal, Oxidation, Diffusion)	\$40/batch	\$60/batch		
Wet benches	RCA Clean Hood (RCA Cleaning)	\$40/batch	\$60/batch		
	305 Acid Hood (Nanostrip, Aluminum Etch, Chrome Etch, BOE)	\$40/batch	\$60/batch		
	307 Base Hood (KOH, TMAH)	\$40/batch	\$60/batch		
	308 EDP Etch Hood (Gold Etch, Copper Etch)	\$40/batch	\$60/batch		
	YES Polyimide Oven	\$45/batch	\$70/batch		
	YES Image Reversal Oven	\$45/batch	\$70/batch		
	Parylene Deposition System	\$45/batch	\$70/batch		

#### ADDITIONAL FEES

Fees	Internal Users	External Users
Training	\$60/hour	\$100/hour
Gold/Platinum Deposition	\$20/0.10 gram	\$35/0.10 gram
Dicing ( <i>Process performed by MNTC staff ONLY, Service fee included</i> )	\$60/1 <sup>st</sup> -hr flat rate \$1/minute after 1 <sup>st</sup> hour	\$100/1 <sup>st</sup> -hour flat rate \$1/minute after 1 <sup>st</sup> hour
Dewar Fill (LN <sub>2</sub> )	\$45/fill	N/A

<i>Photomasks (Process performed by MNTC staff ONLY. Service fee is included.)</i>	Internal Users	External Users
4" substrates Resolution 6 um and larger	\$125	\$200
6" substrates Resolution 6 um and larger	\$225	\$300
CAD File Development	\$100/hour	

Usage fees are not assessed on the following items.

Spin Rinse Dryers, Vacuum Ovens, Four Point Probe, Probe Station, Solvent Wet Bench, Developer Wet Bench (LF8-1A Solvent Develop Hood), Developer Wet Bench (115X Base Develop Hood), PDMS Spinner and Blue M Vacuum Ovens.

HUSON IMAGING & CHARACTERIZATION LABORATORY (HICL)

Equipment	Internal Rates		External Rates
SEM's (Supra and EVO)	\$50/hour	OR Monthly cap of \$500/month for each user	\$100/hour
AFM's (Bio and Conductive)	\$25/hour		\$40/hour
SEM Sputter Coater** **Doesn't included in the monthly cap	\$0.70/min		\$1.05/min
Training & Labor	\$60/hour for training and labor (does not include tool rate)		\$100/hour for training and labor (does not include tool rate)

CONSUMABLES/SUPPLIES

Item	Internal Rate	External Rate
Photoresist S1805, bottle 50 g	\$38	\$60
Photoresist S1805, bottle 100 g	\$53	\$80
Photoresist S1813, bottle 50 g	\$40	\$60
Photoresist S1813, bottle 100 g	\$56	\$85
Photoresist S1827, bottle 50 g	\$56	\$85
Photoresist S1827, bottle 100 g	\$78	\$120
Photoresist SPR 220-3.0, bottle 50 g	\$58	\$90
Photoresist SPR 220-3.0, bottle 100 g	\$81	\$125
Photoresist SPR 220-7.0, bottle 50 g	\$60	\$90
Photoresist SPR 220-7.0, bottle 100 g	\$84	\$130
Photoresist AZ4620, bottle 50 g	\$60	\$90
Photoresist AZ4620, bottle 100 g	\$84	\$130
Polyimide 2611, bottle 50 g	\$56	\$85
Polyimide 2611, bottle 100 g	\$78	\$120
4"Non-Oxidized Prime SSP Wafers	\$25/wafer	\$35/wafer
4"Oxidized Prime SSP Wafers	\$35/wafer	\$50/wafer
4"Non-Oxidized Prime DSP Wafers	\$35/wafer	\$50/wafer
4"Oxidized Prime DSP Wafers	\$45/wafer	\$63/wafer
6"Non-Oxidized Wafers	\$35/wafer	\$45/wafer
4"Bonafloat 33 Wafers	\$25/wafer	\$35/wafer
4"Wafer Container	\$4/each	\$6/each
4"Wafer Container Lid	\$4/each	\$6/each
Cleanroom Notebook	\$12/each	\$17/each
Metal Tipped Wafer Tweezers	\$50/each	\$70/each
Plastic Tipped Wafer Tweezers	\$50/each	\$70/each

Petri Dishes	\$3/each	\$5/each
Gel pack	\$8/each	\$12/each
Microscope Slides	\$5/box	\$7/box