FY21
Annual Report

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Executive Summary

This document serves as the MNTC's official annual report for FY21 ending June 30, 2021. The University of Louisville's Micro/Nano Technology Center (MNTC) is a core facility established in 2004 and consists of five facilities:

- The class 100/1000 $30M 10,000 ft^2 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 and wire bonding capabilities.

- The Hitachi HT7700 Transmission Electron Microscope housed in the Medical-Dental Research Building

- A 400 ft^2 laboratory shared with bioengineering that houses the Parylene C Coater and chemical mechanical polishing (CMP) instruments.

- The 300 ft^2 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:

- $16.4M of federally funded research utilized the MNTC by internal faculty.

- Overall revenue was $196,208.26 for FY21 and was down primarily attributed to Covid-19 interruptions for the entire FY. External income was $111,298.38 and $84,909.88 for internal revenue.

- SEM imaging in the Huson Imaging & Characterization Laboratory increased significantly due to the new ThermoScientific Apreo C Low Vac SEM.

- The MNTC added the Hitachi HT700 TEM to its arsenal of electron microscopy capabilities with the hope of making additional in roads with the School of Medicine.

- With support from the Speed School of Engineering and the EVPRI office the MNTC pursued a loan to acquire a new Oxford Estrelas Deep Silicon Etcher to replace the 20-year old current tool.

- The MNTC secured funds from the Speed School of Engineering and School of Arts & Sciences to replace the reverse osmosis (RO) membranes and tubes needed by the Shumaker research Building and cleanroom to produce reverse osmosis water.

- The REU program occurred again in summer of 2021 after a 1-year hiatus from Covid-19 during 2020.

- The MNTC is pursuing a replacement director of the center.

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 FY21, but the is primarily attributed the interruptions by the covid-19 virus.

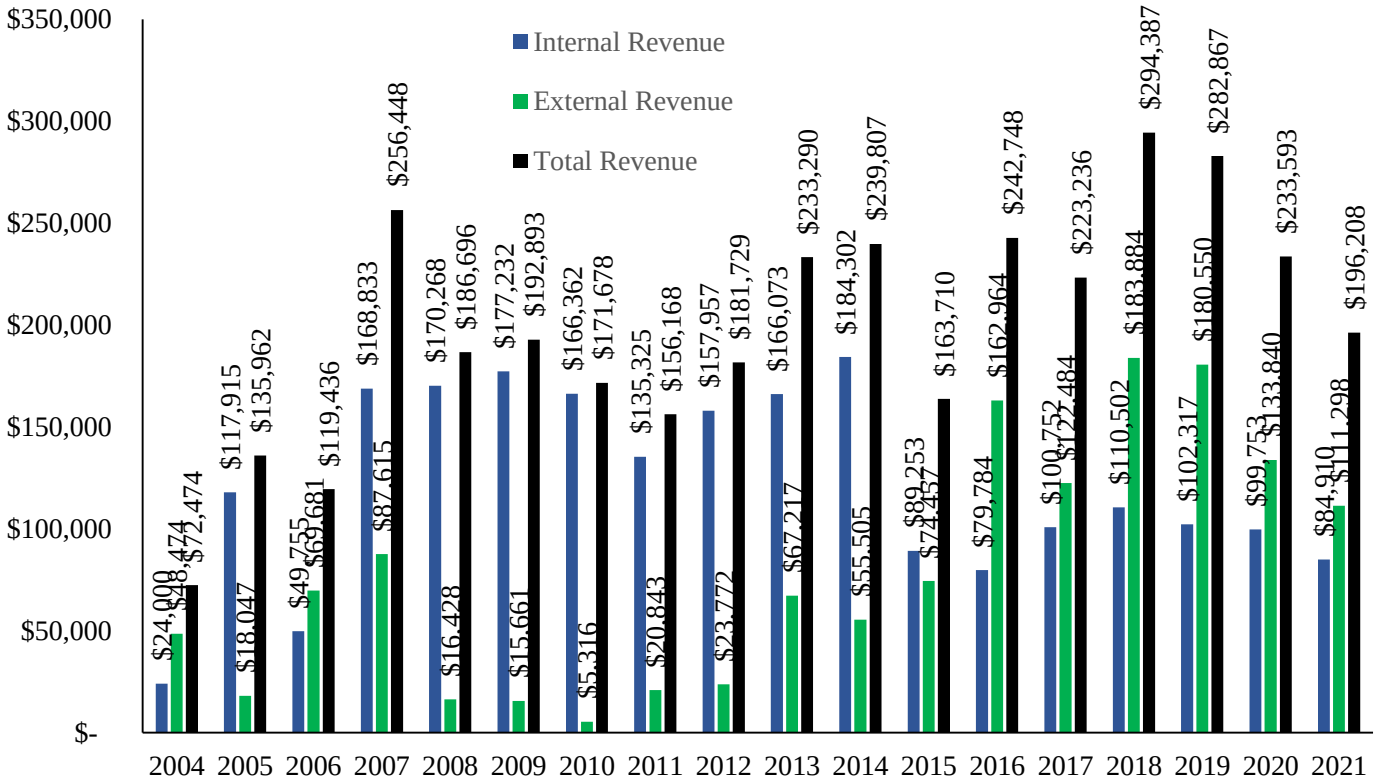

Figure 1. Internal and external revenue since the opening of the MNTC.

Figure 2 illustrates the percentage of internal versus external client revenue, which is the same as 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.

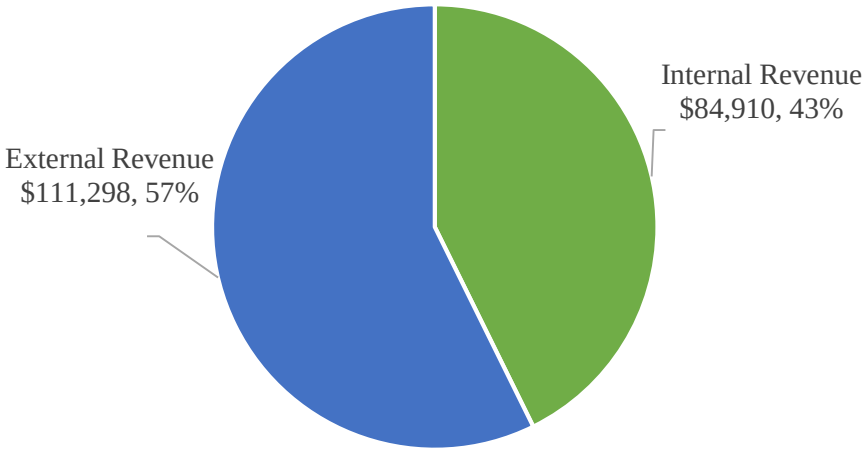

Figure 2. Income from internal and external clients for FY 21.

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-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-21	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	TOTALS
	TOTAL	3,660.40	5,440.90	1,626.05	7,159.50	0.00	15,720.80	2,496.25	14,266.13	2,166.30	5,430.70	324.75	6,186.40	64,478.18
Abell	GAS													0.00
Alphenaar	ECE	282.20												282.20
Berfield	ME													0.00
Bikram, Bhatia	ME												45.00	45.00
Chen	BE										387.25			387.25
Druffel	CONN				75.00		112.50	-56.25	75.25	94.75	176.00	144.75		622.00
ECE Class	ECE							2,900.00	3,224.73					6,124.73
Fu	CHE	45.00					1,653.30	54.00	231.25	2,373.10	3,028.15		1,308.80	8,693.60
Grapperhaus	CHEM	90.00		90.00	135.00			45.00			135.00			495.00
Guerra	BIO										45.00	45.00		90.00
Harnett	ECE				1,221.25		3,268.50	-379.25	580.00	276.25			689.45	5,656.20
Hsu	ME	625.00												625.00
Kopechek	BE	146.00	320.00	395.25	40.00									901.25
Miller, Donald	MED												580.00	580.00
Popa	ECE	1,377.95	2,713.70	-862.35	3,083.75		4,247.00	-801.55	5,406.00	-1,845.00	1,052.70		1,810.80	16,183.00
Roussel	BE						4,508.20	-125.00	3,114.50					7,497.70
Smadici	PHY										45.00			45.00
Spurgeon	CONN			158.00	136.00									294.00
Stolowich	CHEM							45.00		45.00				90.00
Sumanasekera	PHY				120.00				180.00					300.00
Walsh	ECE	914.25	2,137.20	1,665.15	2,258.50		1,706.30	454.30	1,274.40	772.20	426.60		1,482.35	13,091.25
Williams	ME													0.00
Worley	BIO		45.00		45.00		45.00	0.00			45.00		45.00	225.00
Yang	IE													0.00
Yoder-Himes	CHEM						90.00	360.00	45.00					495.00
Zahin Cancer CT	MED									360.00				360.00
Zhang	CHEM	180.00	225.00	180.00	45.00		90.00		135.00	90.00	90.00	135.00	225.00	1,395.00

Table 2. Internal client Huson Laboratory usage.

Internal Revenue-HL		Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	TOTALS
	TOTAL	969.30	1,873.00	837.60	789.25	0.00	2,719.70	1,695.45	1,485.20	2,558.90	2,612.80	1,038.00	3,852.50	20,431.70
Baldwin	CHEM													0.00
Bara	BIO													0.00
Berfield	ME													0.00
Bikram	ME									186.00	489.00			675.00
Chen	BE						500.00	160.00			162.00	750.00	994.50	2,566.50
Druffel-Ren	CONN								264.00	444.00	634.50		378.50	1,721.00
Fu	CHE									312.00				312.00
Gupta, Ramesh	PHA												387.00	387.00
Hadizadeh	GEO			431.30	385.00									816.30
Harnett	ECE						52.40	-26.20			13.30		18.90	58.40
Jones, Steven	MED							381.50	118.10	-72.50	136.50		72.00	635.60
Kopechek	BE													0.00
Lian	ME													0.00
Maurer	CHEM													0.00
McNamara	ECE													0.00
Menze	BIO							304.90	100.90		129.80			535.60
Naber	ECE													0.00
O'Toole	BE													0.00
Popa	ECE	255.00	708.00	-254.00					16.20	173.00	186.00		156.00	1,240.20
Rasipuram	OLP													0.00
Running	BIO													0.00
Spurgeon	CONN			327.50			228.00	27.00	141.00	417.00	-141.00		84.00	1,083.50
Soucy	BE				209.95		552.50	358.75	345.00	87.00			147.00	1,700.20
Steinbach	BE	240.30	203.20	66.70			746.00	-373.00		340.40	194.70		299.40	1,717.70
Starr	CHE									246.00				246.00
Stolowich	CHEM													0.00
Sumanasekera	PHY													0.00
Walsh	ECE	474.00	961.80	266.10	194.30		640.80	-144.50		270.00	308.00		252.00	3,222.50
Willing	CHE							249.00					166.20	415.20
Wilson, Andrew	CHEM											288.00	252.00	540.00
Yanorviak	BIO													0.00
Zamborini	CHEM							758.00	500.00	156.00	500.00		150.00	2,064.00
Zhang	CHEM													0.00
Naber (Software)	MISC												495.00	495.00

Overall revenue from the Huson Laboratory has been increasing due to increased utilization of the new Thermo-Fisher Apreo SEM and its ability to see organic and specimens that tend to charge. With the addition of the TEM it is hoped this trend will continue.

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 64% of total percentage of internal revenue for the cleanroom and 22% of the Huson Laboratory.

Table 3. Internal income for the Cleanroom FY 2020.

TOTAL	64,478.18	100%
BE	8,786.20	14%
BIO	315.00	0%
CHE	8,693.60	13%
CHEM	2,475.00	4%
CONN	916.00	1%
ECE	41,337.38	64%
IE	-	0%
ME	670.00	1%
MED	940.00	1%
MISC	-	0%
PHY	345.00	1%

Table 4. Internal income for the Huson Laboratory FY 2020.

TOTAL	$20,431.70	113%
BE	5,984.40	29%
BIO	535.60	3%
CHEM	2,604.00	13%
CHE	973.20	5%
CONN	2,804.50	14%
ECE	4,521.10	22%
IE	0.00	0%
GEO	816.30	4%
ME	675.00	3%
MED	635.60	3%
MISC	495.00	2%
OLP	0.00	0%
PHA	387.00	15%

Table 5 displays revenue collected from external clients for both the cleanroom and the Huson Laboratory for a total of $111,298.38. Company names have been removed to protect privacy.

Table 5. External client revenue for the Cleanroom and Huson Laboratory.

Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	TOTAL
4,949.09	13,972.10	5,759.40	17,321.37	11,699.50	3,427.06	8,913.00	963.25	27,054.65	5,317.91	4,994.25	6,926.80	111,298.38
170.80												170.80
					259.35	1,266.30						1,525.65
										995.00		995.00
	5,833.32		5,833.32		2,950.66				2,916.66			17,533.96
												-
			615.10									615.10
		805.75										805.75
			300.00									300.00
3,280.15	1,918.18	630.00	5,003.50	2,943.30	3,465.55			2,241.50		2,594.75	1,268.50	23,345.43
325.00				850.00								1,175.00
	1,132.00										562.75	1,694.75
		413.00										413.00
								1,385.40	938.00			2,323.40
988.30	1,864.95	1,864.15		1,345.50	1,434.00		424.75	507.35	600.00		3,155.80	12,184.80
										304.00		304.00
											414.75	414.75
221.00									532.25			753.25
	34.00							684.00	254.00	34.00		1,006.00
	170.00	1,047.50		997.45	675.75							2,890.70
											1,105.00	1,105.00
	507.50					960.00		144.00	77.00			1,688.50
										420.00	420.00	840.00
				205.00			105.00					310.00
			934.85			1,670.55						2,605.40
		999.00					213.50	65.00				1,277.50
												-
										646.50		646.50
							220.00					220.00
						576.00						576.00
			857.00									857.00
								1,739.00				1,739.00
						273.00						273.00
	2,512.15		3,777.60			4,167.15		2,443.40				12,900.30
								17,845.00				17,845.00
(36.16)				5,358.25	(5,358.25)							(36.16)

Process Materials Transferred to laboratory

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 primarily due to continuing effects of covid-19.

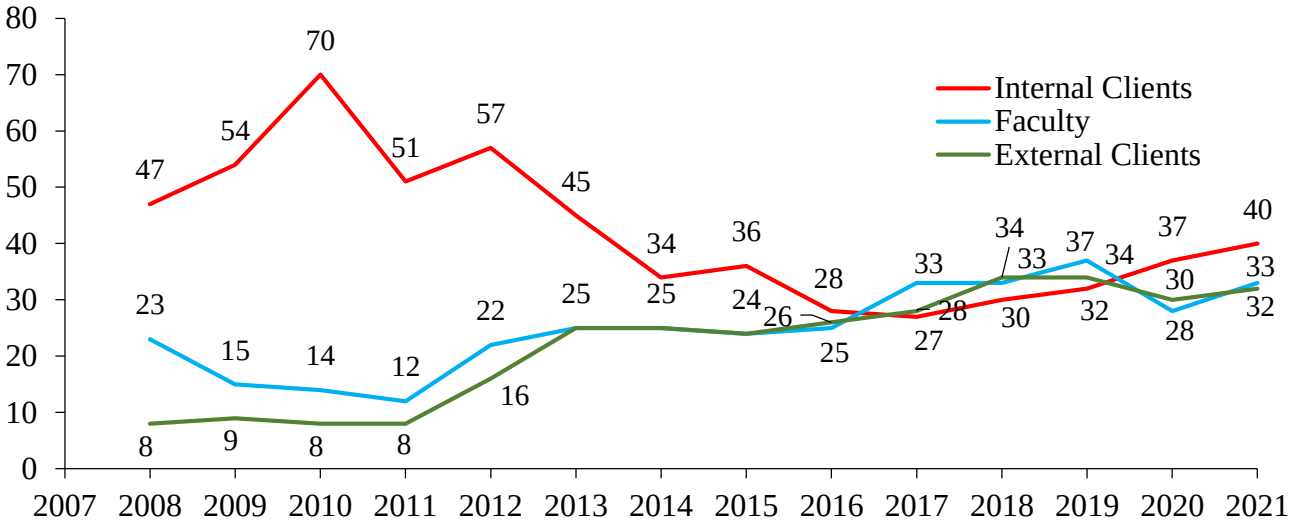

Figure 3. A historical view of the number of internal and external clients from FY04 to FY21.

Table 6 is a compilation of grants and contracts utilized by faculty to conduct research that pay 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 the capabilities of the MNTC. This tally is a decrease as compared to previous years again due to the impacts of Covid-19.

Table 8. Grants and contracts utilized by internal faculty in FY21.

GRANT #	PI Name	Dept	CR	HL	LN	SR	Grant Amt.	Revenue
GB140779	Alphenaar	ECE	X				1,749,999.00	282.00
GB181279	Druffel	CONN				X	849,216.00	301.25
EB200078	Druffel	CONN					400,422.00	909.00
CS181279	Druffel	CONN						176.00
GB180260	Fu	CHE			X		408,775.00	45.00
GB161177J4	Fu	CHE	X				293,550.00	1,748.55
GB210206	Fu	CHE					1,026,672.00	5,903.25
GB170358	Grapperhaus	CHEM			X		450,000.00	90.00
GB200299	Grapperhaus	CHEM			X		323,542.00	405.00
GB180291	Hadizadeh	GEO		X			290,478.00	816.30
GB180796	Harnett	ECE	X				402,803.00	2,546.55
GB191043	Harnett	ECE	X				293,232.00	987.45
EN191017	HSU	ME	X			X	50,440.00	625.00
GB170344G1	Jones	MED		X			331,397.00	563.60
GB180776	Kopechek	BE	X				249,954.00	842.15
GB191102	Menze	BE		X			335,364.00	333.80
GB200157	Popa	ECE	X	X		X	1,530,219.00	11,573.85
GB200157A	Popa	ECE	X	X		X	927,936.00	1,960.85
GB170954	Popa	ECE				X	762,259.00	1,191.50
GB180796	Popa	ECE	X			X	1,530,219.00	226.50
GB201141	Rousssel	BE				X	50,000.00	4,383.20
GB190837	Soucy	BE					390,000.00	1,283.20
GB200056	Spurgeon	CONN		X			401,359.00	1,134.50
OIEB171329	Starr	CHE		X			578,321.00	246.00
GB190506	Steinbach	BE		X			498,301.00	1,418.30
GB180533	Sumanasekera	PHY					322,061.00	300.00
GB151257	Walsh	ECE	X	X			1,272,164.00	4,714.55
GB200743	Walsh	ECE	X	X		X	700,000.00	5,752.25
GB171268A	Yoder-Himes	CHEM			X		67,263.30	90.00
GB200475	Zamborini	CHEM		X			163,197.00	1,258.00
GB160551	Zamborini	CHEM		X			438,605.00	156.00
							16,418,683.00	50,759.60

Figure 4 is a historical account of operating expenses of the facility since opening in 2004. Expenses were higher than previous years due to the large down payment provided for the new Oxford Estrelas DRIE system.

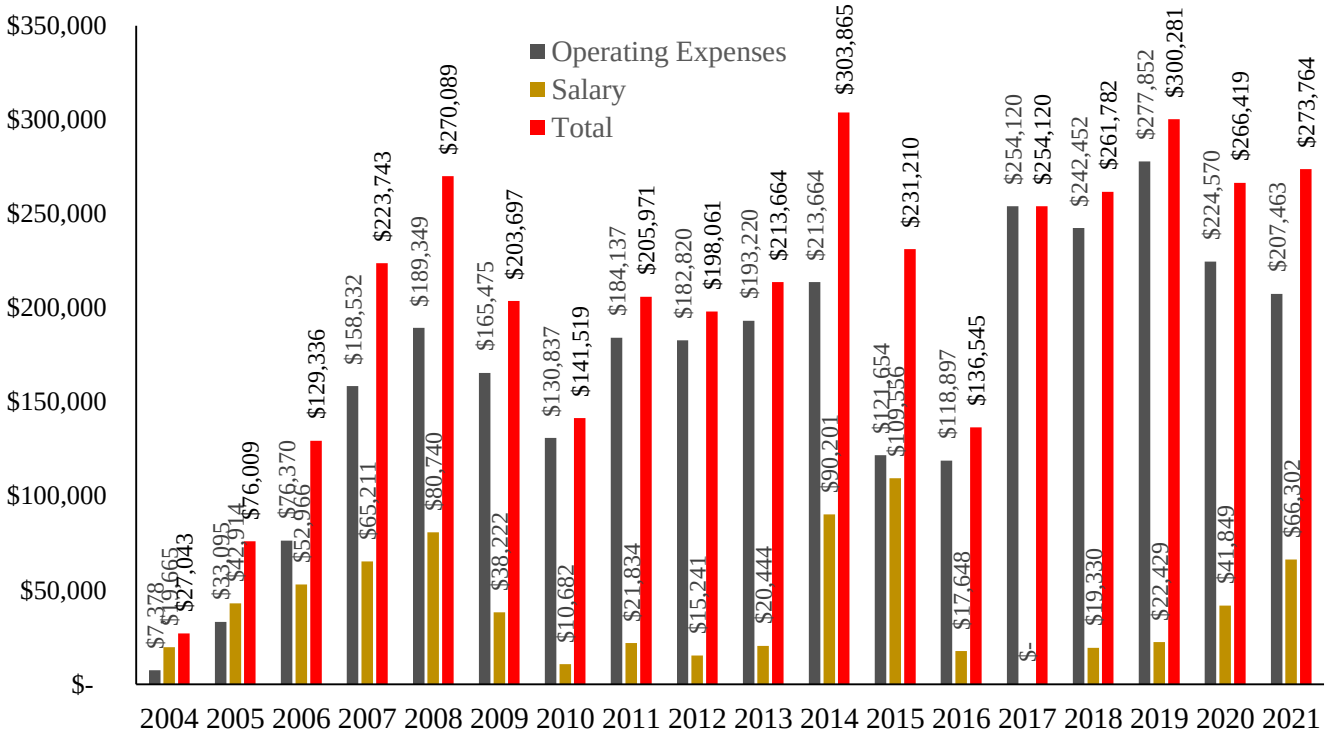

Figure 8. Operating and salary expenses since the since the opening of the MNTC.

Figure 5 is an itemized listing of expenses accumulated by category for FY20. As noted previously the acquisition of the Oxford Estrelas DRIE system increased expenditures beyond typical expenses for the year. Of similar note, the center's salary expenses continue to increase roughly $20,000 per year, which is unsustainable.

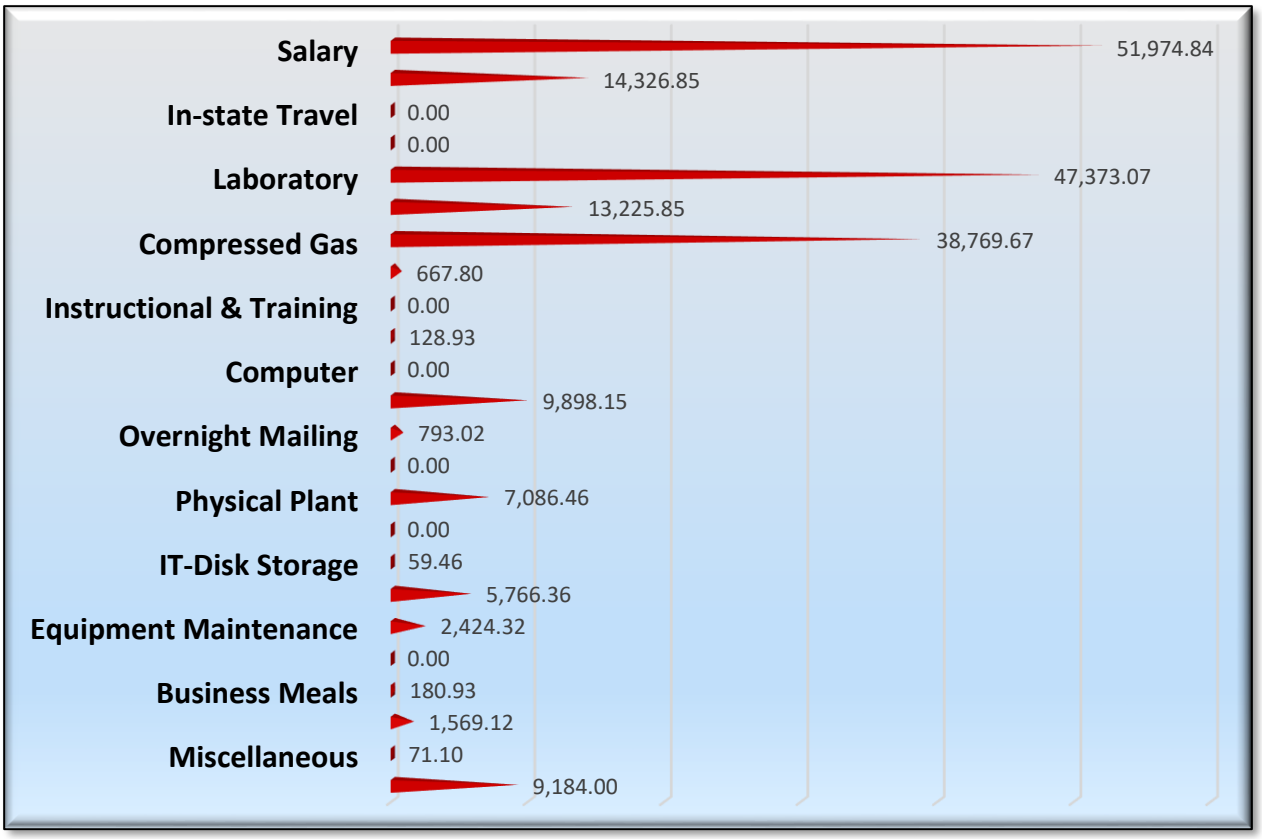

Figure 5. Operating and salary expenses of the MNTC for FY 21.

The 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 multiple work study students to cover positions within the cleanroom and for 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. These student workers are not a financial responsibility on the MNTC and are provided graciously 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 approximately $20,000 per year. It is preferred to return to the model where salary and fringe benefits were covered by the Dean's Office. However, Covid-19 has prevented movement in this preferred position.

The center will continue to focus the capabilities of the cleanroom and amplify availability of the its imaging and characterization capabilities.

Appendix

MNTC Rates Effective April 1, 2021

Clients of the MNTC will be charged a daily cleanroom access fee and associated equipment fees.

Daily Access Fee for the Cleanroom: **Internal User:** $10/day
External User: $34/day

Cleanroom Equipment Usage Fee: The usage rates are defined below for internal users, external users and services.
A cap of **$1,500** per month for the cleanroom per researcher will be implemented for equipment usage, access fees and training for internal users only. 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 clients using the Cleanroom or the Huson Imaging & Characterization Laboratory (HICL).**

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		
Spinners	$0.25/min	$0.50/ min		
Ultrasonic Bath	$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		
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	$1.60/min		
Xactix XeF_2 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 (Piranha, 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 C 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 (*Process performed by MNTC staff ONLY, Service fee included*)	**$60/per wafer** **$1/minute after 1st hour** if required	**$100/per wafer** **$1/minute after 1st hour** if required
Dewar Fill (LN_2)	**$45/fill**	N/A

PHOTOMASKS

Photomasks (*Process performed by MNTC staff ONLY, Service fee included*)	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	$60/hour	$100/hour

A usage fee is not assessed on the following items, but does not exclude MNTC labor fees.

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.

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”Borofloat 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

HUSON IMAGING & CHARACTERIZATION LABORATORY (HICL)

Equipment	Internal Rates		External Rates
Thermo-Fisher Apreo SEM	$60/hour	OR Monthly cap of $750/month for each user	$110/hour
Hitachi HT-7700 TEM	$60/hour		$110/hour

AFM’s (Bio and Conductive)	$30/hour		$50/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)