



NanoLab 2023 Principal Investigators Meeting

*"The great thing about the
Microlab is the way it evolves."*

UC Berkeley EECS Professor,
William G. Oldham



Professor Kris Pister

Faculty Director

Dr. Bill Flounders

Executive Director



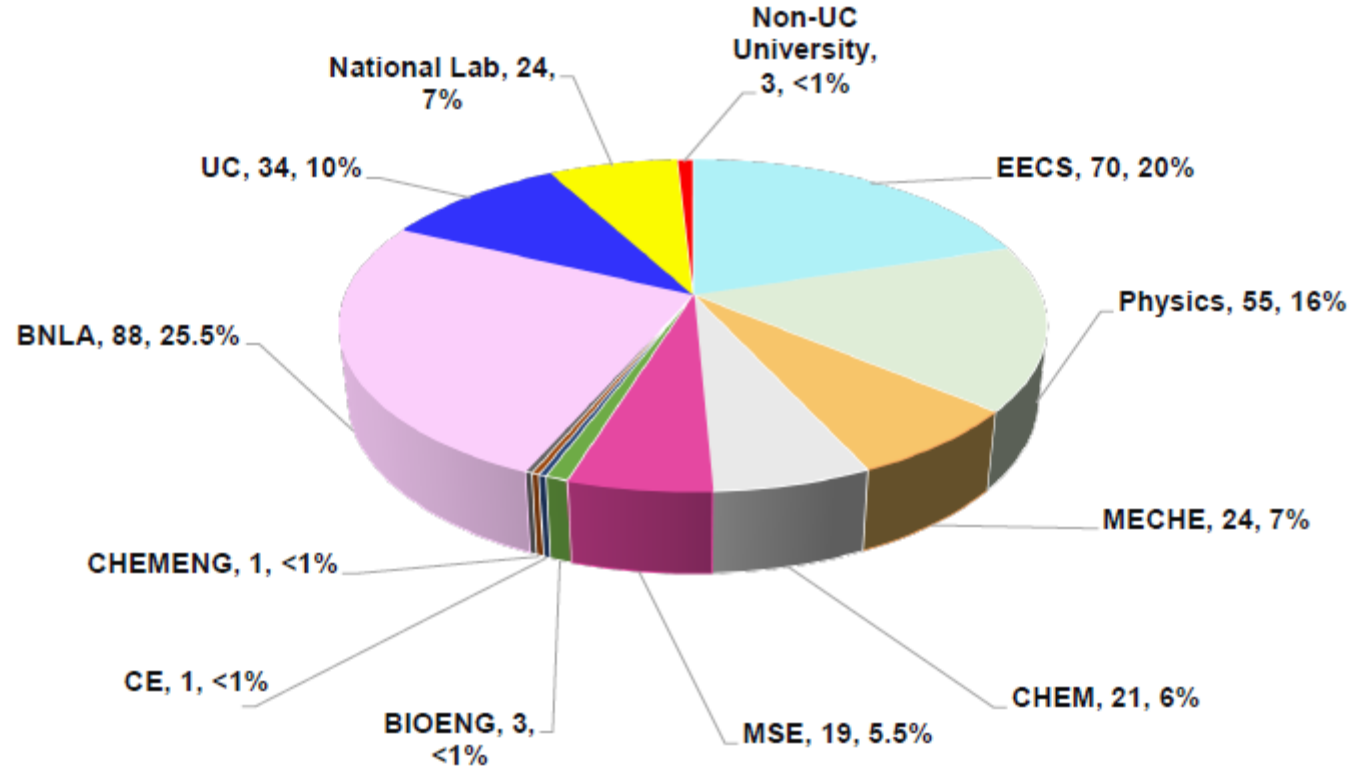
Agenda

- Membership Analysis / Financial Status
 - FY 24 Recharge Rates July – Dec
 - FY24 Recharge Rates Jan – Jun

- New Equipment / Capabilities
 - Reality – here and released.
 - Dreams - Donation Requests

- Summary of ME Commons Support
 - Work Force Development
 - Equipment / Staff

Lab Members by Department FY 23 Total

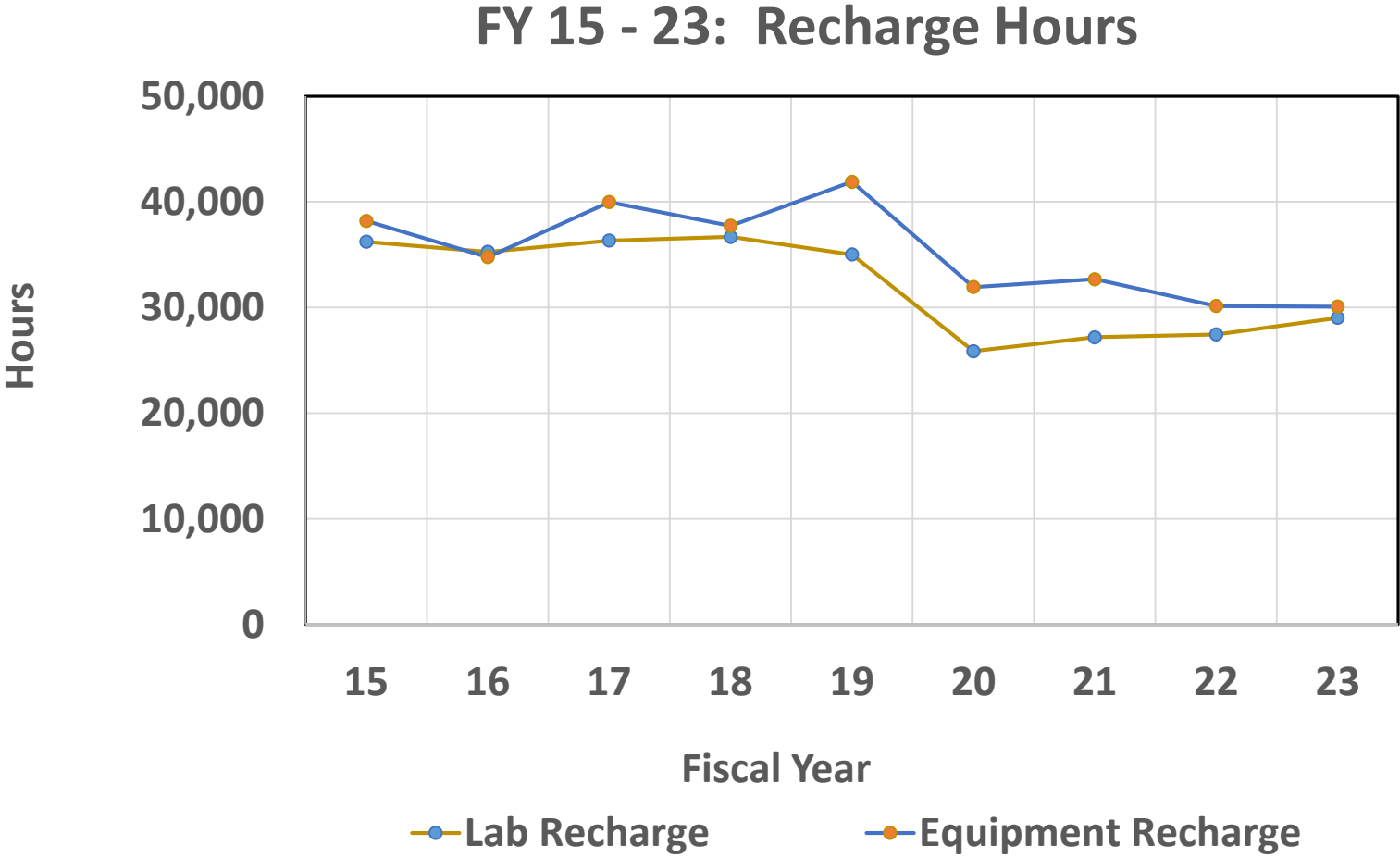


Fiscal Year	2018	2019	2020	2021	2022	2023
Total	382	376	342	304	329	343
UCB	257	241	217	191	189	194
Commercial	73 (19%)	84 (22%)	73 (21%)	72 (24%)	82 (25%)	88 (26%)
All Academic	309	292	269	232	247	255
External	125 (33%)	134 (36%)	125 (37%)	113 (37%)	140 (43%)	149 (43%)

Lab Members Historical Analysis

FY	2017	2018	2019	2020	2021	2022	2023
Total	370	382	376	342	304	329	343
UCB	252	257	241	217	191	189	194
Ext Acad	49	52	51	52	41	58	61
BNLA	69	73	84	73	72	82	88
EECS	125	114	111	94	79	71	69
Mech Eng	46	58	52	41	31	28	24
Physics	36	41	35	36	41	49	55
MSE	16	20	23	22	18	18	19
BioEng	1	1	0	3	2	5	3
Chem/ChE	27	23	20	21	18	17	18

Membership is Stable – But Activity is Down



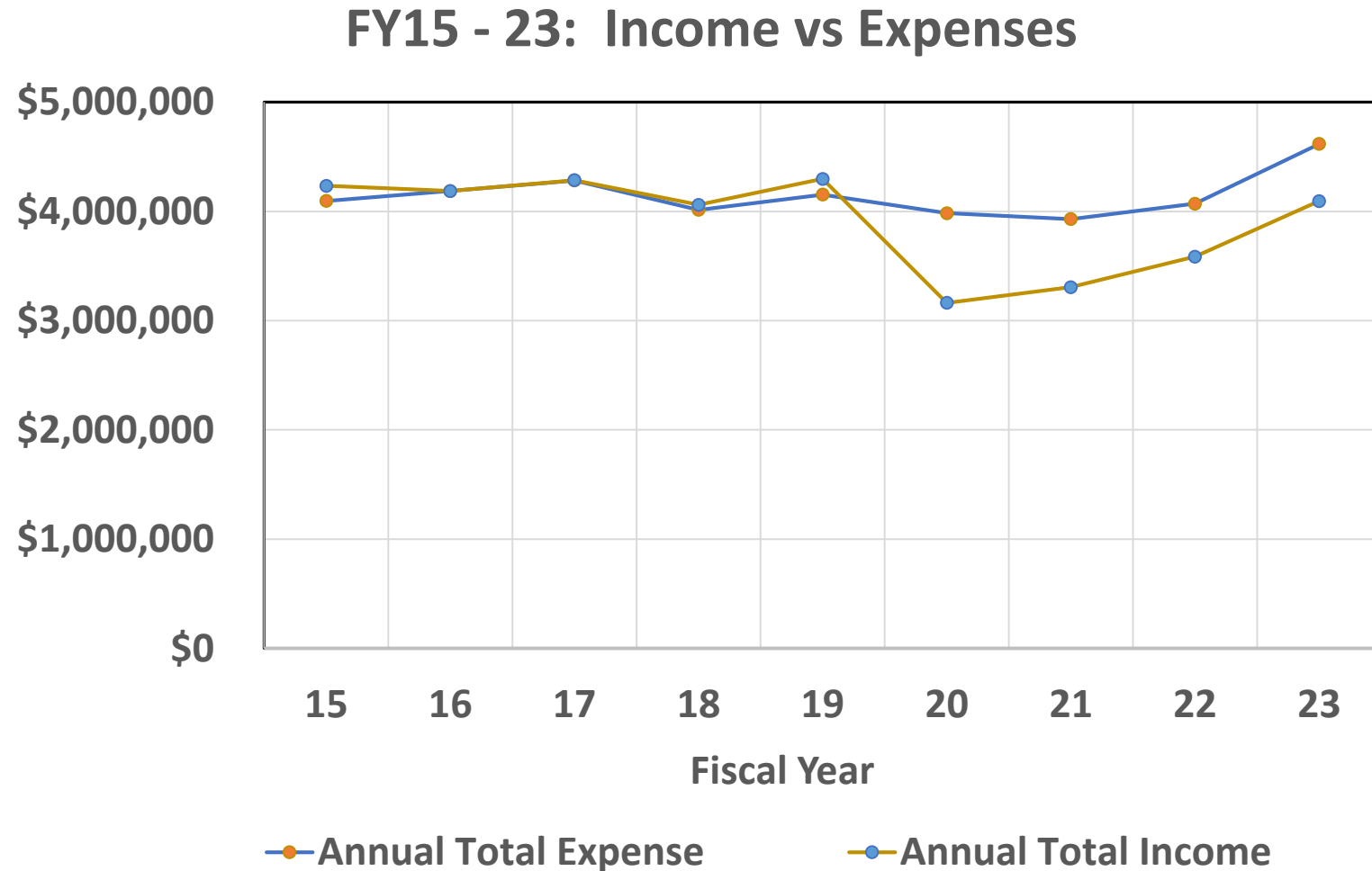
The NanoLab 2023

The Top 20 and Academic vs BNLA

Top 20 PI by Dept Δ '22			Financial Overview		Δ '22
EECS	7	0	All Academic	\$1.68 M	- \$179 K
Mech Eng	2	↓1	Top 20 Academic	\$1.35 M	- \$ 70 K
Physics	4	↑1	All BNLA	\$2.11 M	+ \$479K
MSE	3	↑1			
Chem/ChE	2	↑1	Top 10 Academic	> \$40K	- \$15 K
UCD EE	1	↓2			
UCSF BioE	1	0	Top 10-20	> \$20K	- \$12 K

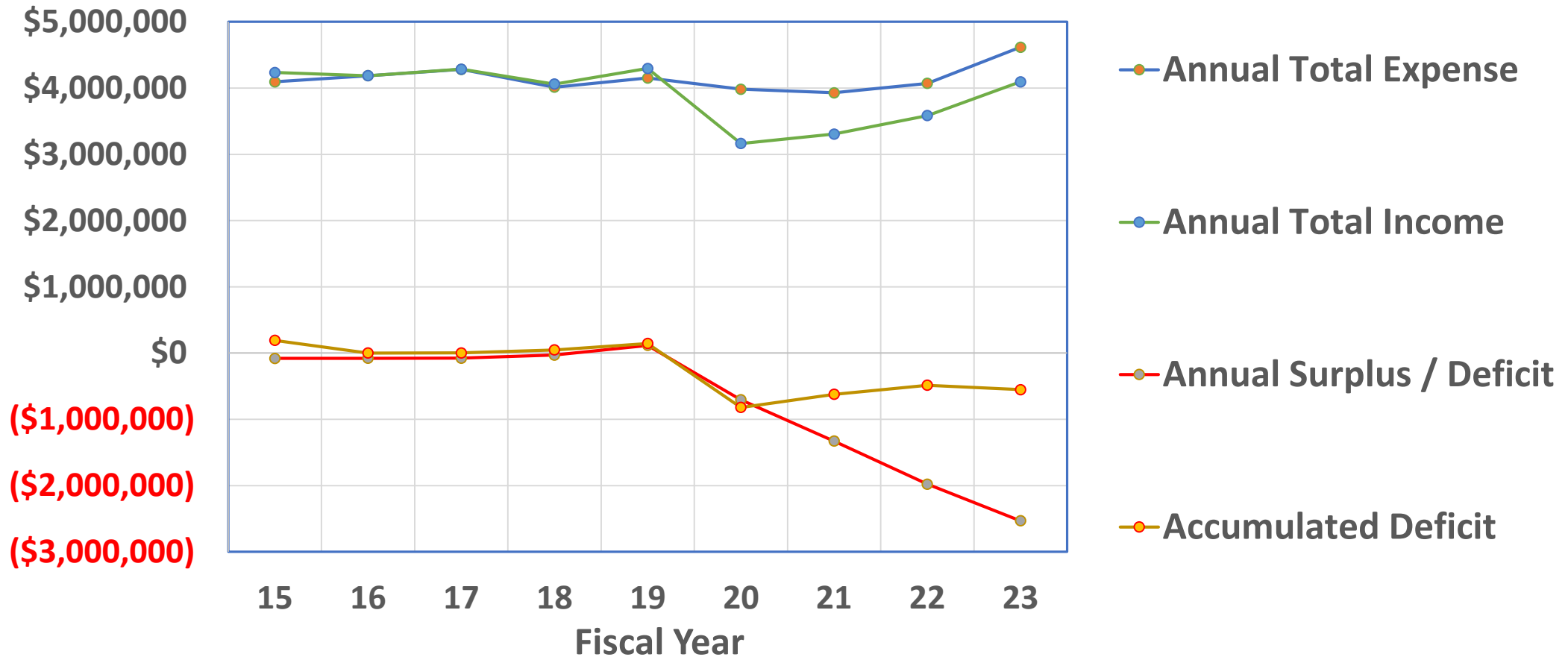
Best Regards to: Connie Chang-Hasnain, Vivek Subramanian, Eli Yablonovitch,
Xiang Zhang, Ramesh Ramamoorthy, Lane Martin

Year to Year Income Vs Expenses – The Positive Spin



Income Vs Expenses – The Whole Picture

FY15 - 23: Annual Expense, Income, Deficit And Total Deficit



Rates were increased at the beginning of FY24 (July 1, 2023)
Rates increasing again for 2nd half of FY 24 (Jan 1, 2024)

NanoLab Recharge Rates FY '24 vs FY '23		Academic				Affiliate			
		Jul - Dec 2023		Jan - Jun 2024		Jul - Dec 2023		Jan - Jun 2024	
		Rate	Δ	Rate	Δ	Rate	Δ	Rate	Δ
Access Fee / Month		\$94.00	0.0%	\$98.00	4.3%	\$180.00	4.7%	\$196.00	8.9%
General Lab Rate Use/Hour <i>(Includes sinks, microscopes, probe stations)</i>		\$50.40	2.4%	\$52.80	4.8%	\$64.20	3.9%	\$67.20	4.7%
General Lab Max/Month		\$1,400.00		\$1,500.00		\$2,700.00		\$2,800.00	
Tier 1 Equipment Rate Use/Hour <i>(Simple metrology, cpd, wirebond)</i>		\$25.80	2.4%	\$27.00	4.7%	\$30.60	8.5%	\$32.40	5.9%
Tier 1 Max/Month		\$200.00		\$300.00		NA			
Use Rate/Hour Over Max/Month		\$0.00		\$0.00	0.0%	NA			
Tier 2 Equipment Rate Use/Hour <i>(Advanced metrology, CVD, DRIE, contact litho)</i>		\$55.20	2.2%	\$57.60	4.3%	\$67.20	3.7%	\$70.80	5.4%
Tier 2 Max/Month		\$1,400.00		\$1,500.00		NA			
Use Rate/Hour Over Max/Month		\$6.00	1.7%	\$6.00	0.0%	NA			
Tier 3 Equipment Use/Hour <i>(SEM, epi SiGe, DUV, ebeam litho)</i>		\$66.00	0.9%	\$69.00	4.5%	\$119.20	15.5%	\$158.40	32.9%
Tier 3 Cap		\$1,500.00		\$1,600.00		NA			
Use Rate/Hour Over Max/Month		\$19.80	1.5%	\$19.80	0.0%	NA			
Staff Services		\$111.00	4.5%	\$116.90	4.9%	\$111.00	4.5%	\$116.40	4.9%

New Capabilities 1: Semicore 2 chamber, loadlock, multi-target, co-sputter



Last year ...moved,



...modified for install



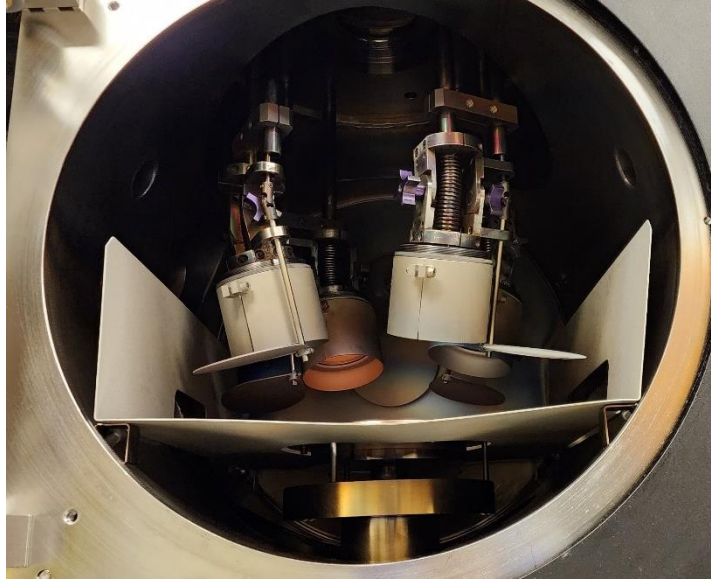
...sited and reassembled in the NanoLab

New Capabilities 1 – Semicore - Load lock, 2 chamber, 7 target sputter



This year – released Nov 2023

New Capabilities 1: Semicore 2 chamber, loadlock, multi-target, co-sputter



Process Chamber 1 (200mm):

- 1x RF gun
- 3x DC guns
- Ar/N2 process gases
- Cooled chuck

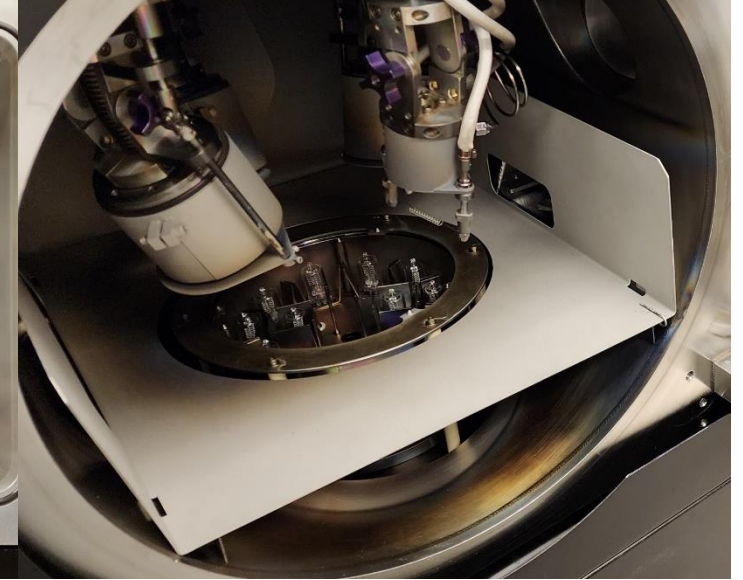
Dedicated for metals and nitrides.
Standard targets (subject to change
based on demand analysis):

T1: Al
T2: Cu
T3: TiW
T4: Ta



Load Lock (200mm) :

- IR Bakeout lamps
- Single wafer load
- 5-10 minute load time/wafer
- Process time estimates:
 - Setup ~2 hrs
 - Per wafer load time: 5-10 min
 - Per wafer run time: 5-30 min



Process Chamber 2 (200mm) :

- 2x RF gun
- 1x DC guns
- 1x ion mill (Ar)
- Ar/O2 process gases
- 12kW IR heater

Dedicated for metals and oxides.
Standard targets (subject to change
based on demand analysis):

T1: ITO
T2: Ti
T3: SiO2

NanoLab Target Inventory – Semicore Compatible

Semicore specific targets:

Al
Al₂O₃
AlO_x
Cu
Cu₂O
Fe
Gd
Gd₂O₃
Ge
Ge₂Sb₂Te₅

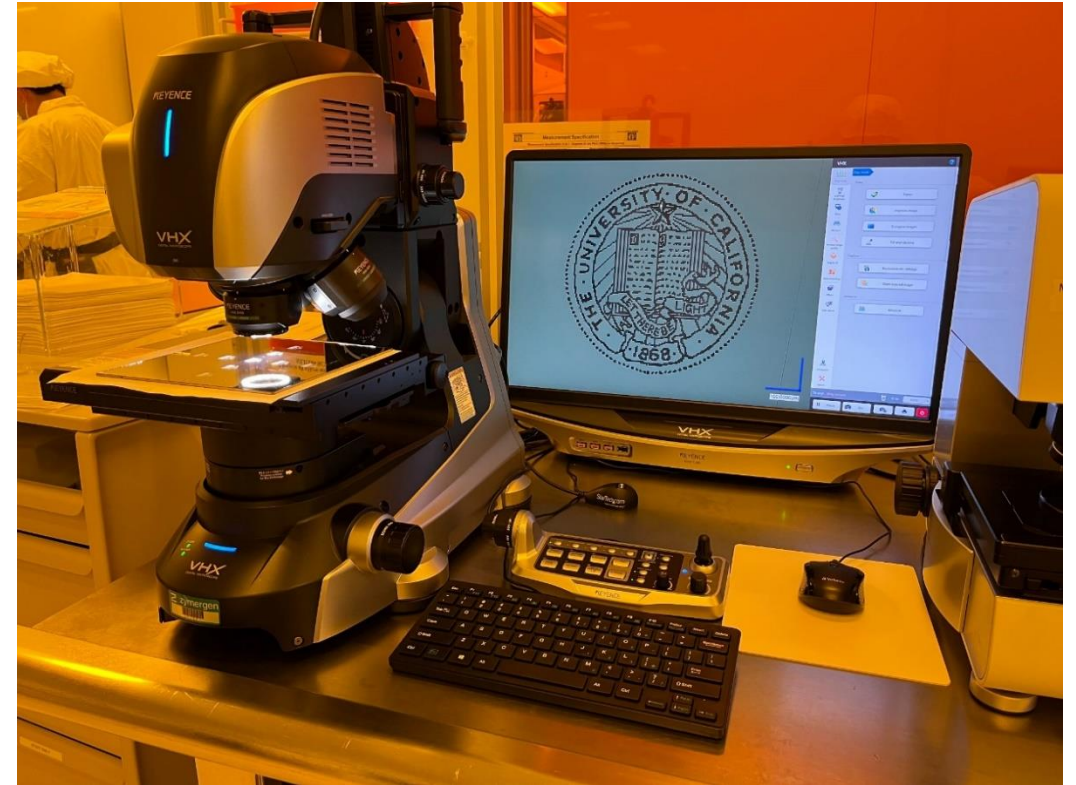
GeO
Hf
HfO₂
HfTe (33/67)
ITO
Sb
SiO₂
SiN
Sn
Ta

Ta₂O₅
Ta₅Si₃
Ti
W
Y
ZrO₂
ZrTe (52/48 & 35/65)

Additionally – All ast-sputter targets are compatible with semicore!

New Capabilities 2: Keyence 7000 Digital microscope

- NanoLab demo'd unit in March 2021.
Received quote for \$87,600
- Identical unit discovered available for auction from Emeryville biotech June 2023.
- NanoLab pre-auction bid \$18K accepted.
Staff inspect and review prior to purchase.
Total with tax and auction fees \$23K

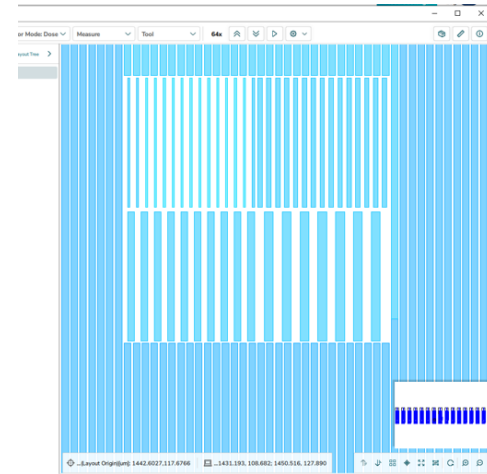


Fully automated digital microscope 3 objectives 20-100x / 100-500x / 500 – 2500x on motorized turret.
Motorized X/Y stage able to accommodate up to 8" wafers with stage registration to return to saved locations.
Capable of 2D and 3D stitching, depth composition, and grain size analysis.

New Capabilities 3: Ebeam Litho SW and HW Upgrades

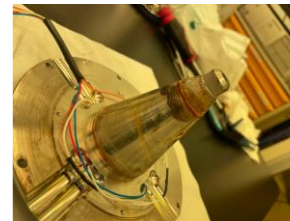
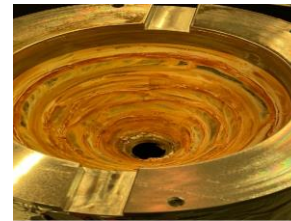
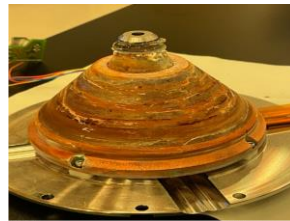
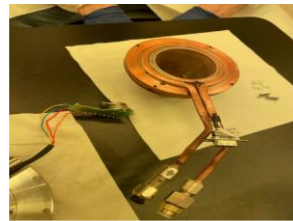
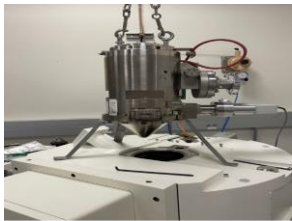
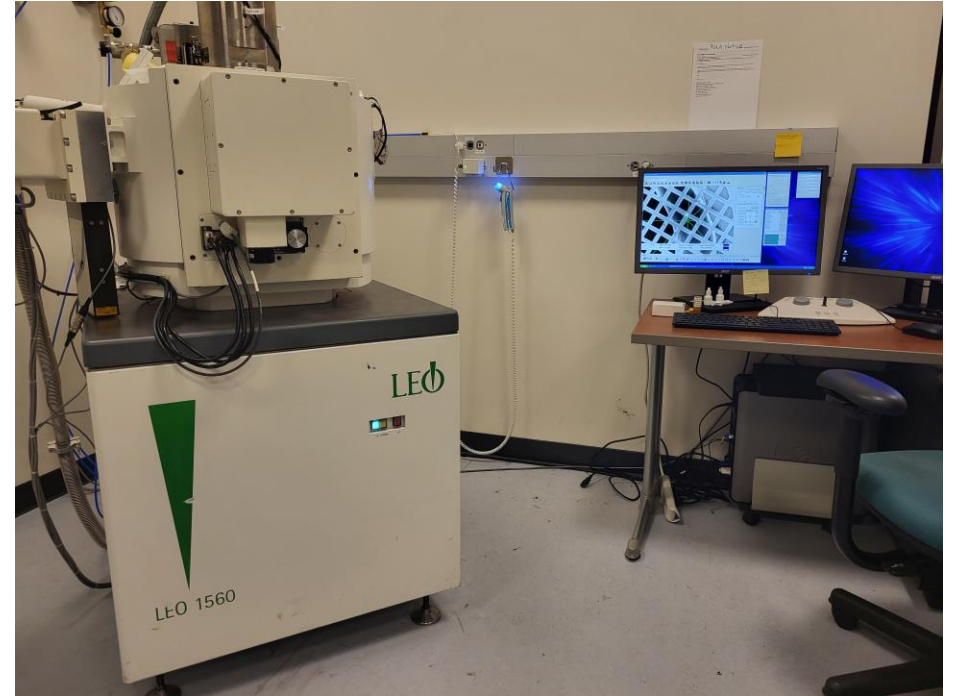
New dose variation / image density calibration layout See Allison for details

- Genisys SW upgrades and on call support package (\$58K past year)
 - Beamer ver 5.4 → 7.0 (\$115K - \$75K discount = \$40K)
 - Beamer key for PEC; dose variation with image density and shape
 - Latest version (7.1) to support r/theta addressing for circular structures
 - On call support and Tracer SW: \$21K - \$3K discount = \$18K
 - Tracer is separate package for exposure simulation
- Crestec HW repairs / upgrades (\$73K past year)
 - PG upgrade for 100 KV tool: board (\$3K) plus Service (\$6.5K)
 - Improved dwell time resolution control from 10ns to 1 ns
 - High voltage insulator repair for 50 kV tool (\$15K) serviced at same time
 - Tip replacement both tools (\$10K each) 2 week service visit (\$28K)



New Capabilities 4: Additional SEM (now 3 total)

- Used Zeiss offered by 3rd party reseller.
Match to our existing zeiss sem
\$25K as is, “operable”.
- Sited last year. DOA. 18month rebuild.
All chamber and column seals.
All tubing and full rebuild of column
cooling circuit



- Tool is finally Up. New metrology room on
first floor of Sutardja Dai Hall now has 2 SEMS

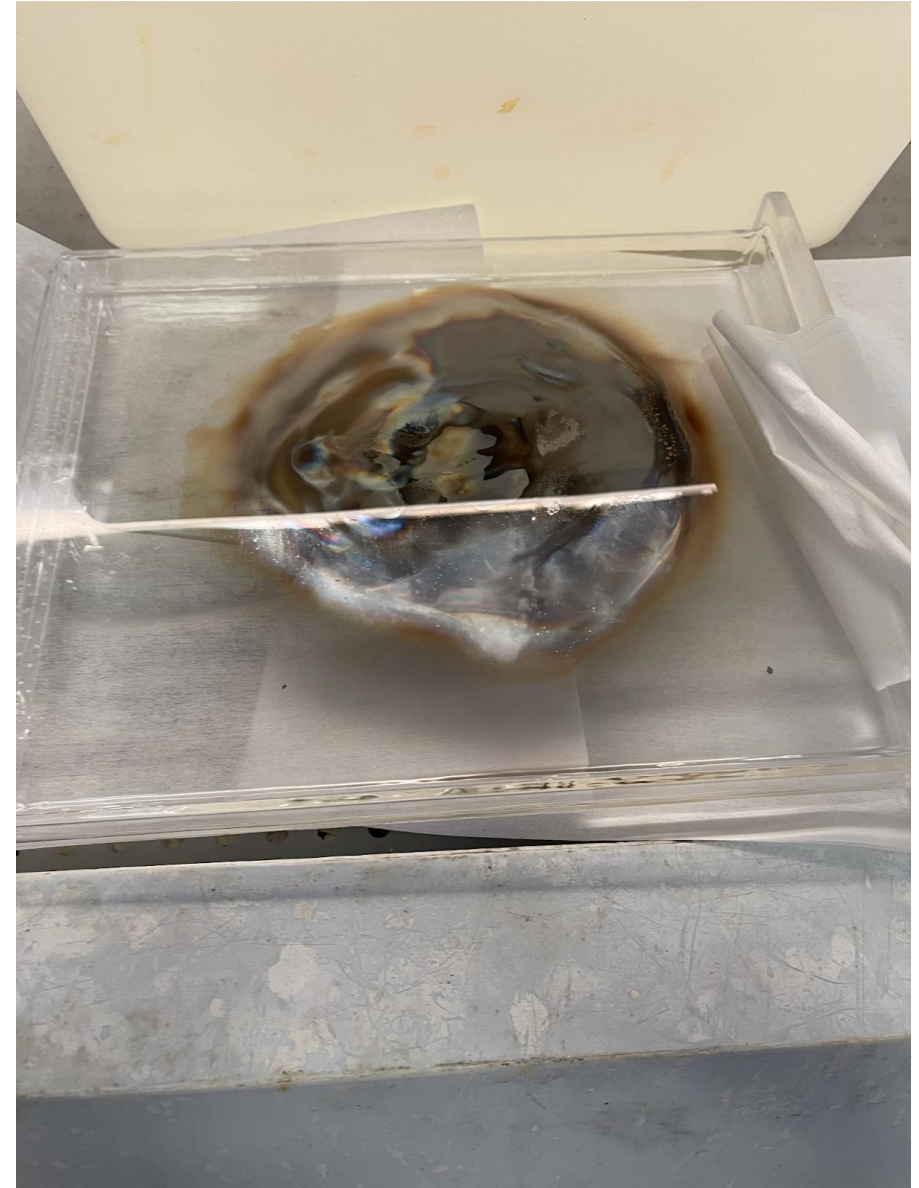
Restored Capabilities: AMAT Etch Platform

- Since Dec 2022 – the NanoLab has hosted 4 AMAT Field Service engineer training classes using our tools as training platform.
Two weeks of dedicated tool time each class
- Since May2023 – AMAT has provided more than 120 hours of field service support and ~\$80K parts for our 4 chamber etch platform and epi deposition platform.
All four etch chambers operational
ASP strip chamber first time up since donation
Better performance than this tool has provided in years



Request from Alp: RTP3 suspected contamination discussion

- Horrible black film on top of chamber
 - initially interpreted as organic contamination
 - All researchers / materials reviewed
 - stain not cleaned by acid. Chamber replaced
- Same researcher that reported first event reports a second suspect contamination because their film has turned black in some areas. Chamber not discolored.
- Researcher reports they thought they had Ni and W but they just had Ni. Process review to define acceptable time/temp for film stack



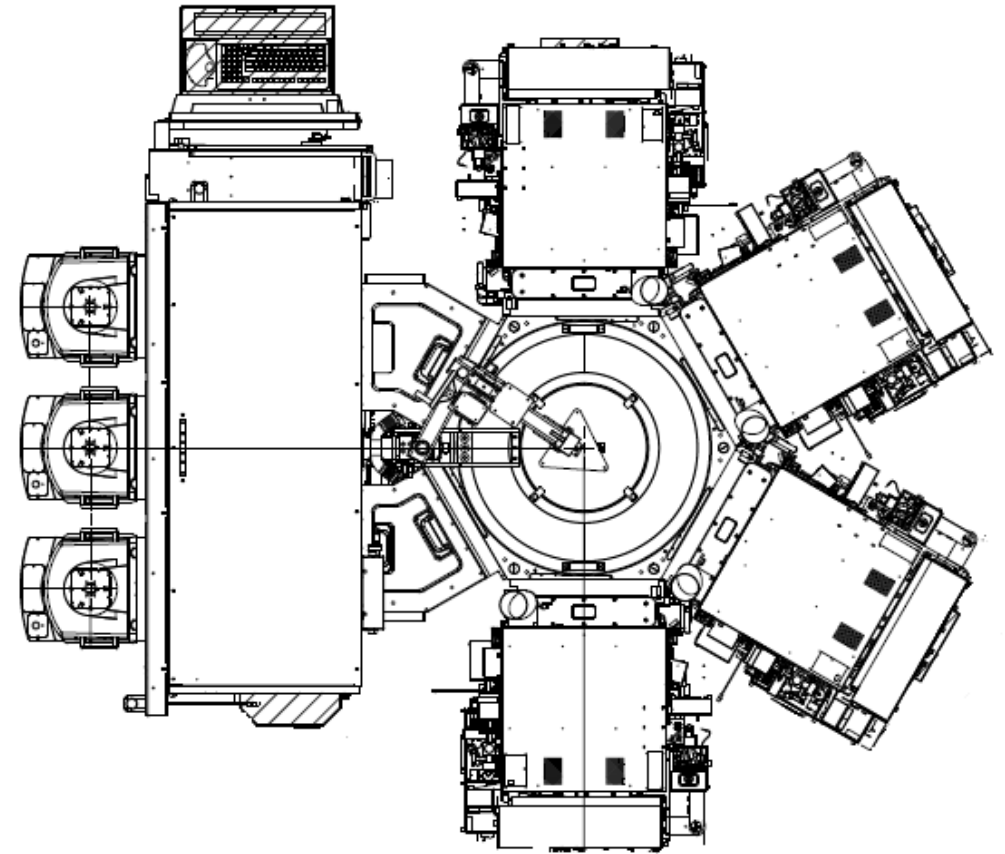
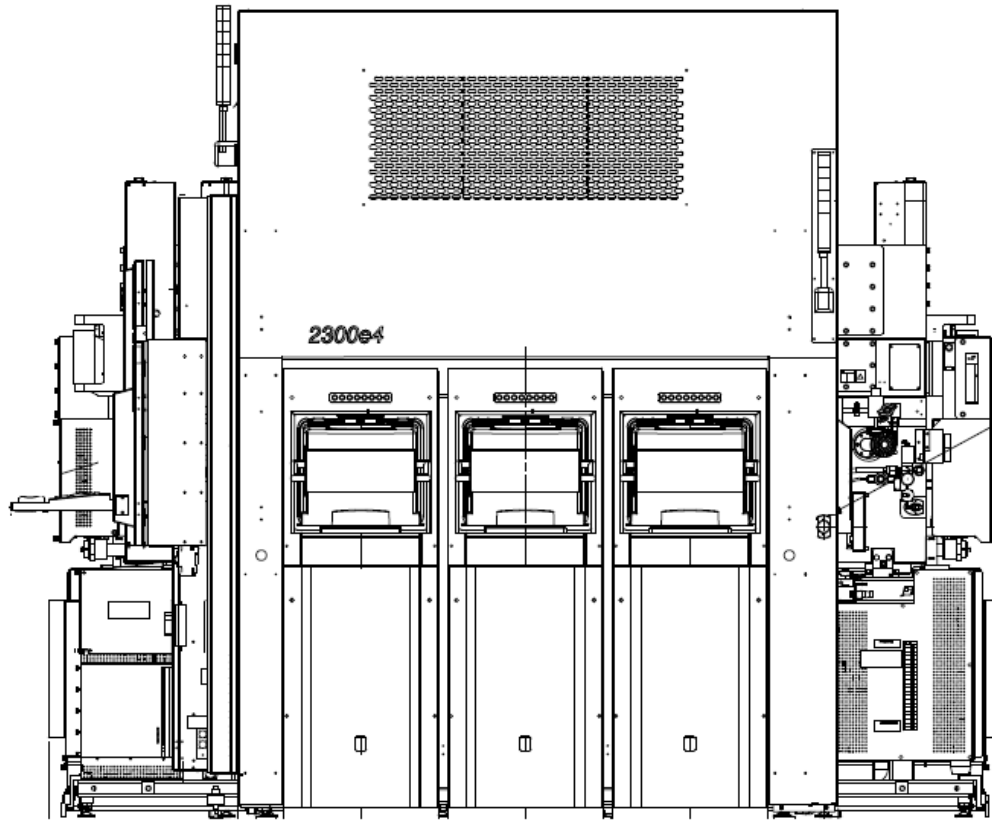
Lam 2300 e4

The Recommended 200mm Etch Platform for the UC Berkeley Marvell



Etch is the Major Missing Piece

The Lam 2300 e4 will bring the ME-Commons AI Hardware Hub to 200mm
NanoLab is already 200mm capable for oxidation, LPCVD, lithography, metrology



Established hexapod design, 4 chambers, dual loadlock, powered load lock chlorine passivation in development

This compact cluster with 4 unique process chambers verified compatible with NanoLab Bay and Chase layout.

Lam 2300 e4 Provides NanoLab with TSV / ALE Next Gen Etch and ME-Commons CMOS equivalent nodes																	
	Chamber Type	Purpose	Special Notes	Materials of Interest	Cl2	BCl3	HBr	SF6	CF4	CHF3	C4F8	O2	H2O	N2	H2	Ar	He
Chamber 1	Kiyo	Conductor Etch	ALE compatibility	Si/SiC/SiGe/Diamond	Y		Y	Y	Y			Y		Y	Y	Y	Y
Chamber 2	Versys	Metal Etch	ALE compatibility	Al, Ti, W, Ru, Co, Nb	Y	Y	Y	Y	Y	Y		Y		Y	Y	Y	Y
Chamber 3	Flex	Dielectric Etch	ALE compatibility	SiO2, SiN, high-k dielectric				Y	Y	Y	Y	Y		Y	Y	Y	Y
Chamber 4	Syndion	TSV Deep Etch						Y			Y	Y		Y		Y	Y
Loadlock add-on	Passivation	Post-Chlorine Passivation											Y	Y			

Gases are based on existing NanoLab processing. LAM recommendations for updated gas selections are welcome, and additional gases will be chosen if recommended. E.g., NF3 vs SF6 for TSV applications

NanoLab assessment of desired chambers is based on updating existing processing and meeting ME-Commons foundation technology deliverables. There are many additional processes of interest, e.g., Pulsus PLD. Some are not available at 200mm, e.g., Selis processing suite..

Goal is to support research into cutting edge GAAT and other advanced electrical device fabrication. LAM recommendations on preferred pathways the NanoLab may be unfamiliar with are always welcome.

DOD Names 8 Locations to Serve as New 'Microelectronics Commons' Hubs

Sept. 20, 2023

\$15.3M awarded to CA-Pacific-Northwest AI Hardware Hub

UC Berkeley to co-lead Microelectronics Commons regional innovation hub funded by the Department of Defense
October 13, 2023 by Berkeley Engineering

The Northwest AI Hub leadership includes H.-S. Philip Wong, professor of electrical engineering, and Subhasish Mitra, professor of electrical engineering and of computer science, both at Stanford University's School of Engineering; and from UC Berkeley, Tsu-Jae King Liu, dean of the College of Engineering and professor of electrical engineering and computer sciences, and Sayeef Salahuddin, professor of electrical engineering and computer sciences. The hub includes more than 40 other members from academia, government laboratories, and industry.
<https://engineering.berkeley.edu/news/2023/10/15-3m-awarded-to-northwest-ai-hardware-hub/>

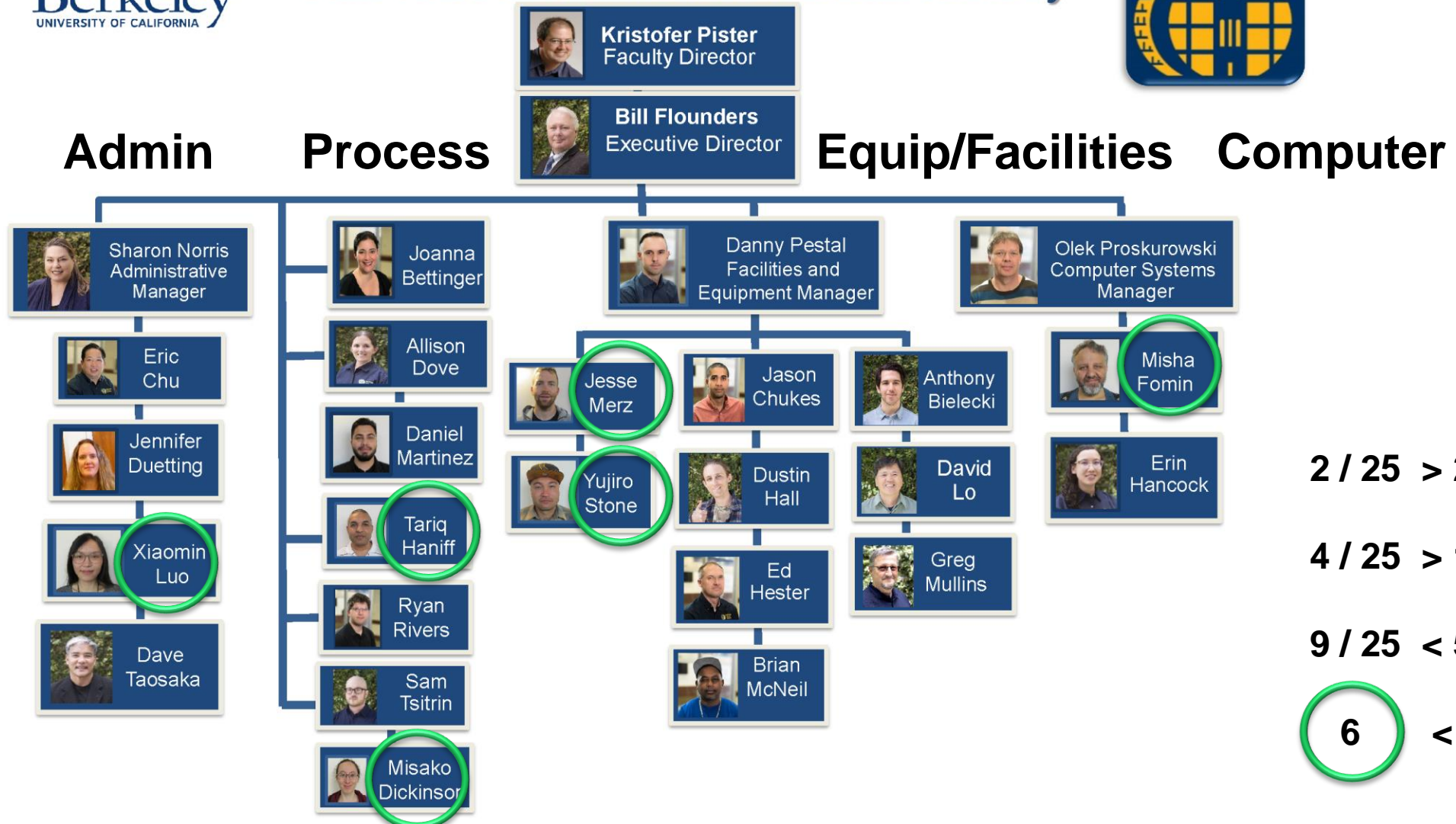
Specifics received to date:

WFD: 115K/yr for the Nanolab - supports 4 student interns and 40% of an Engineer to mentor.
Equipment: \$5M for equipment. \$2M Y1 / \$2M Y2 / \$1M Y3.
200mm cmp for dielectric / 200mm cmp for metal / 200mm epi dep / 200mm 3chamber etch

Current Staff Organizational Chart



Marvell Nanofabrication Laboratory



2 / 25 > 25 Years

4 / 25 > 15 Years

9 / 25 < 5 Years

6 < 2 year

In the past ten years, 17 staff have retired, 14 with >25 years of service.

NanoLab Staffing News

- NanoLab Executive Director position posted October 11, 2023
35 Applicants as of Dec 11, 2023
- Search and Hiring Committee:
Kris Pister, Bill Flounders, Sharon Norris, Danny Pestal
- Select and Interview candidates planned for Spring 2024
Lead candidate to return for follow up meetings and seminar
Seeking faculty for follow up meetings /provide feedback to Faculty Director
- Onboarding Summer 2024
6-10month overlap planned Fall 2024 / Spring 2025
Bill steps down by June 30, 2025

Summary

- Pandemic and inflation have created a significant deficit
 - Rate increases moderated and recovery allowed over several years
 - Activity decline in EECS and ME is a concern
- NanoLab continues to expand services and capabilities as able
 - Transition to 200mm continues
 - We have wet process, oxidation, LPCVD, lithography, some metrology
 - ME Commons targeting cmp, epi, and etch
 - We NEED improved ALD. We NEED 200mm ALD
 - Picosun thermal only - 2008
 - Cambridge with plasma – 2012 Both tools thanks to Clark Nguyen
- Staff turnover has been steadily addressed

**The NanoLab responds
to your issues and works
to control your costs.**



Berkeley Fire Department Annual Tour

**The shared lab model is
alive and well thanks to
your support.**

Thank you