CLEAN ENERGY INSTITUTE

Clean Energy Testbeds: Capabilities and Time Table

Daniel T. Schwartz
Director of the Clean Energy Institute
Boeing-Sutter Professor of Chemical Engineering

To accelerate the creation of a scalable clean energy future, we must be impatient scholars.

CEI’s Mission:
Nurture your impatience for impact

- **Innovation:** Facilitate research discoveries and accelerate translation to breakthrough technologies
- **Education:** Create the next generation of clean energy engineers, scientists, and leaders
- **Transformation:** Break siloed approaches to clean energy research, education, and partnerships

Transformation

Building & supporting teams on our roadmap


Chu


Schlenker


Subramanian


EE


Zhang


MSE/ChemE


Holmberg


MacKenzie


CSE


MechE

The Washington State Clean Energy Testbeds

$8M was allocated to University of Washington in FY 15-17

A testbed is a platform for conducting rigorous, transparent, and replicable testing of scientific theories, computational tools, and new technologies.

- Wikipedia

Overview of the Testbed Facilities

- Research training – NanoES Building

  Student access to research quality tools and concepts that cut across all CEI disciplines, in one laboratory.

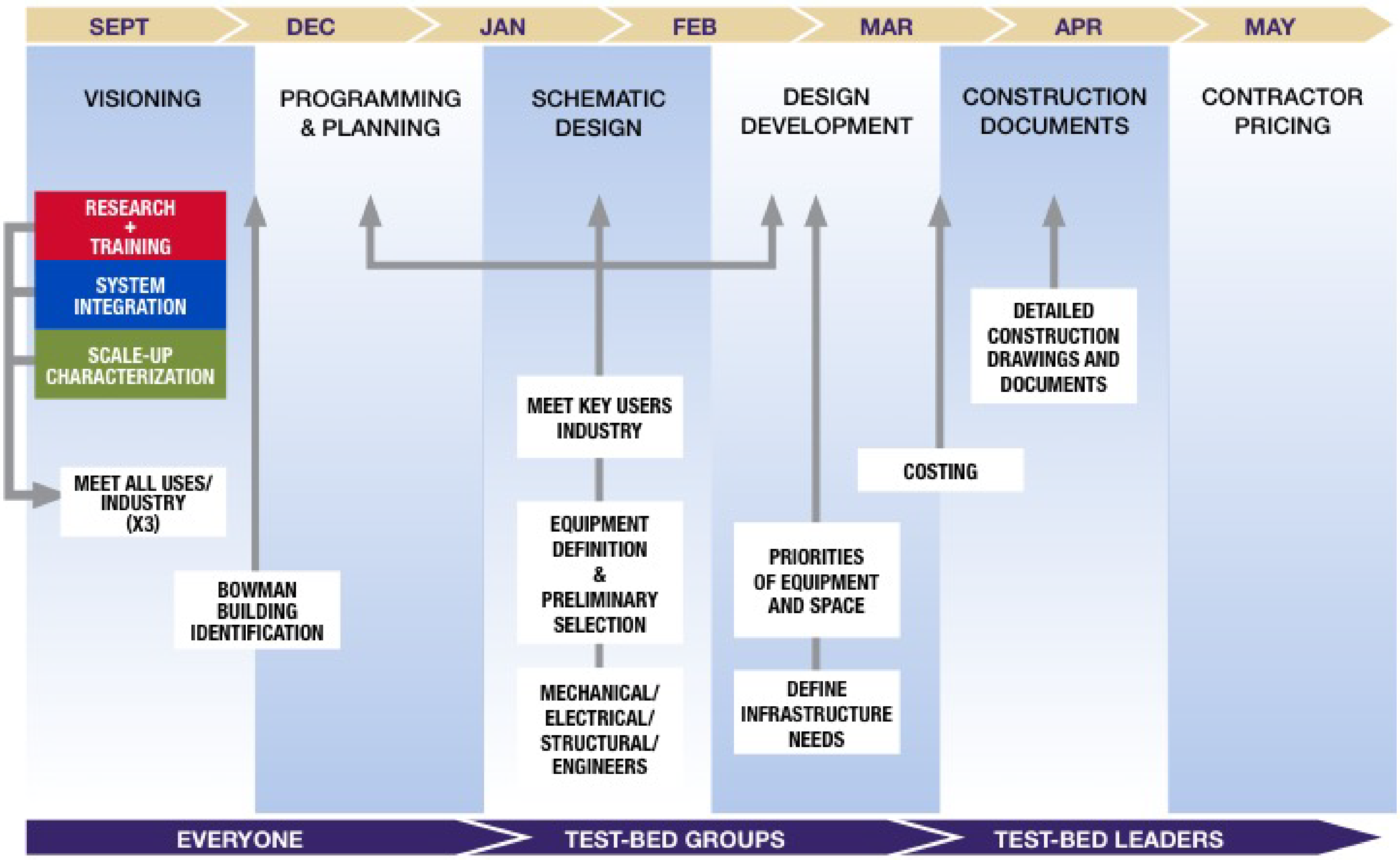
- Scale-up and characterization – Bowman Building

  Affordably prototype and test scaled-up devices. UW & Industry.

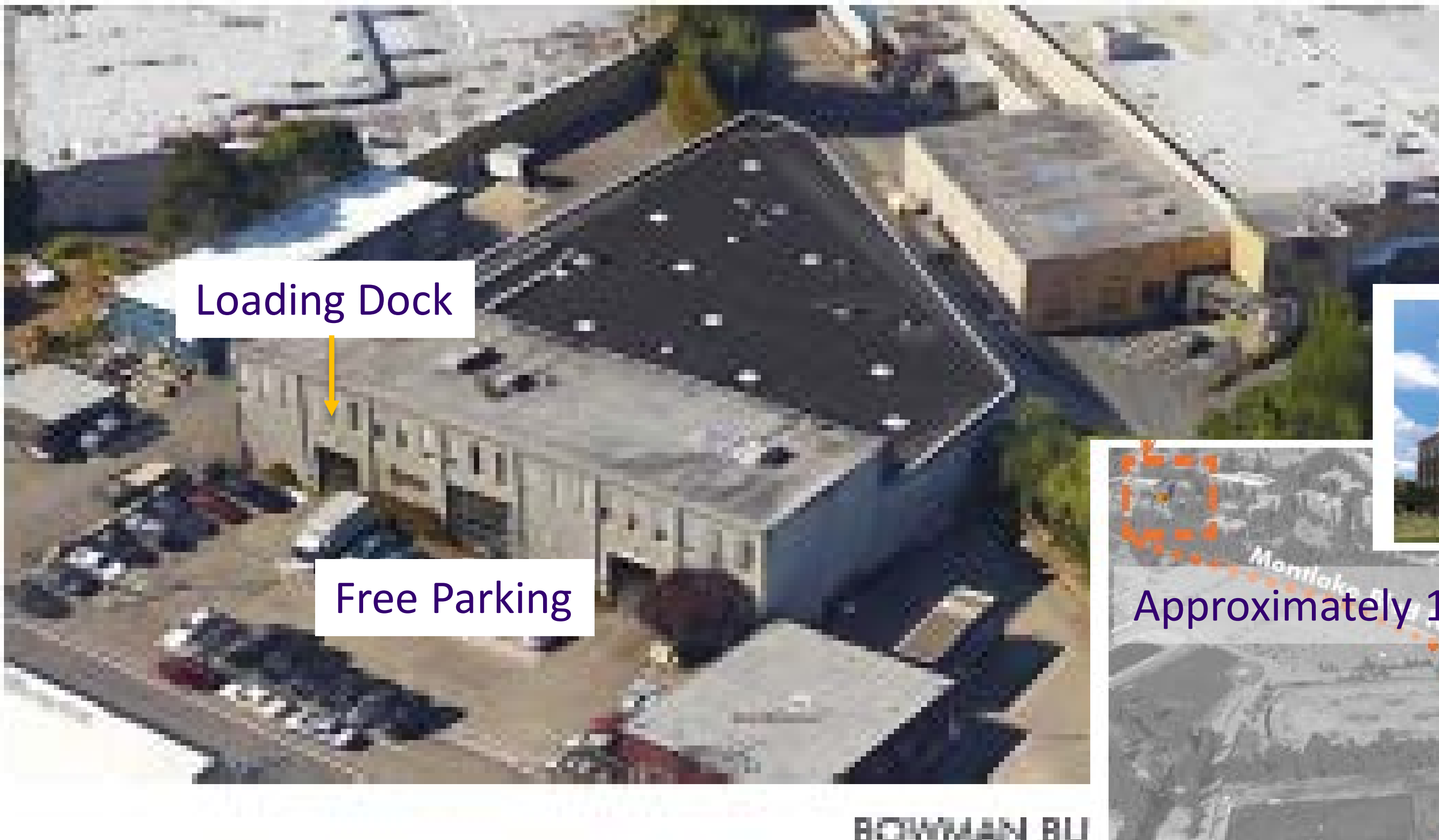
- Systems Integration – Bowman Building

  Affordably analyze how your hardware or software technology meshes with a system.

Facility Design Process



Bowman Building Site
10,000 ft^2 TB adjacent to University Village



Equipment move-in starts Fall 2016

How can you use the facility?

Fee-for-use facility like MAF and WNF

We are working on the boiler plate to help you write it into your proposals for research and broader impact.

House your researchers in Bowman

The space includes computational workstations, desks, offices, meeting rooms, larger conference/teaching rooms

Collaborate with Industry, PNNL, and others

Beyond equipment, a computational lab, meeting spaces, seminar room, and future home to PNW Materials Institute

Place new equipment in the Facility

Work with Director of Operations (ad is out now)

Serious Bowman Testbed users get a 26% Indirect Cost Rate

Your proposal must include some combo of:

- Significant Testbed user fees in your grant.
- Key grant-funded personnel sitting at a Bowman desk or office.
- Funding for an instrument to be placed in Bowman *(talk with the Director of Operations first!)*

Overview of the Session

Systems Integration Testbed

Daniel Kirschen (EE), co-Lead

Characterization and Scale-up Testbed

Devin MacKenzie (MSE/ME) & Jihui Yang (MSE), Leads

Research Training Testbed

David Ginger (Chemistry), co-Lead

Architecture, Construction, and Schedule

Naomi Gross, Architect, Chernoff/Thompson Assoc.

Dawn Lehman, Infrastructure Advisor for CEI

System Integration Testbed

System Integration Testbed

- Research questions:
  - New energy technologies: PV, batteries, building controls
  - How do they affect the grid?
  - How can we optimize their interactions?
- Campus as a testbed concept
- Real Time Digital Simulation

Systems Integration Testbed

Goal: Design an evaluation platform for testing the performance of energy devices & algorithms when integrated into real & simulated system environments.

- **Chairs:** Daniel Kirschen (EE) and Venkat Subramanian (ChemE)
- Dan Sowder/Daniel Malarkey (1 Energy Sytems)
- Miguel Ortega-Vazquez (EE)
- Baosen Zhang (EE)
- Jan Whittington (Built Environment)
- Norm Menter (UW Facilities)
- Rick Winter (UniEnergy)
- Ron Melton (PNNL)
- Chris Heimgartner (SnoPUD)
- David Ridley (UE Technologies)
- Vish Viswanthan (PNNL)

Campus as a testbed

> UW solar has installed PV on several campus dorms
> We are installing a large battery in the basement of the electrical engineering building
> We have access to smart meter data from all campus buildings
> We hope to get access to some building management systems
> Campus “energy control center” in the Bowman building
  – Access the information from all these devices
  – Develop and test optimal control techniques

Campus energy control center

Real Time Digital Simulation

> Model the grid under more extreme conditions

Specialized grid simulation

Power amplifiers

Hardware-in-the-loop simulation

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CEI Scale-up & Characterization Testbed

Goal: Design a platform for prototyping & testing authentic scale solar & storage devices & manufacturing processes. Complement other user facilities in region.

- **Chairs:** Jihui Yang (MSE) and Devin MacKenzie (MSE/ME)
- Jason Zhang (PNNL)
- Karl Bohringer (EE)
- Dirk Weiss (First Solar)
- Aaron Fever (Energ2)
- Pedro Arduino (CoE)
- Steven Leith (MicroFlow CVO)
- Steve Majeski (A&S)
- Hugh Hillhouse (ChemE)
- Hanson Fong (MSE)
- Arka Majumdar (EE)

First Solar.
enerG2 NEXT GENERATION ENERGY STORAGE
microflowcvo
Pacific Northwest NATIONAL LABORATORY

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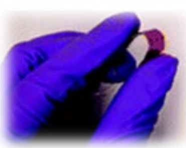
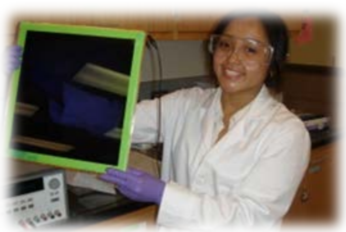
CEI Scale-up & Characterization Testbed

Vision: A testbed to develop, prototype, test and translate energy devices and low carbon footprint manufacturing processes at the scale required for commercial production and national impact.

Lab Scale



Device Demo Scale



Scaled Manufacturing

The S&C Testbed will focus on supporting the processing and characterization of scalable devices and modules

Create and grow a facility for academic/industry collaboration that supports UW and industrial goals in energy devices and beyond

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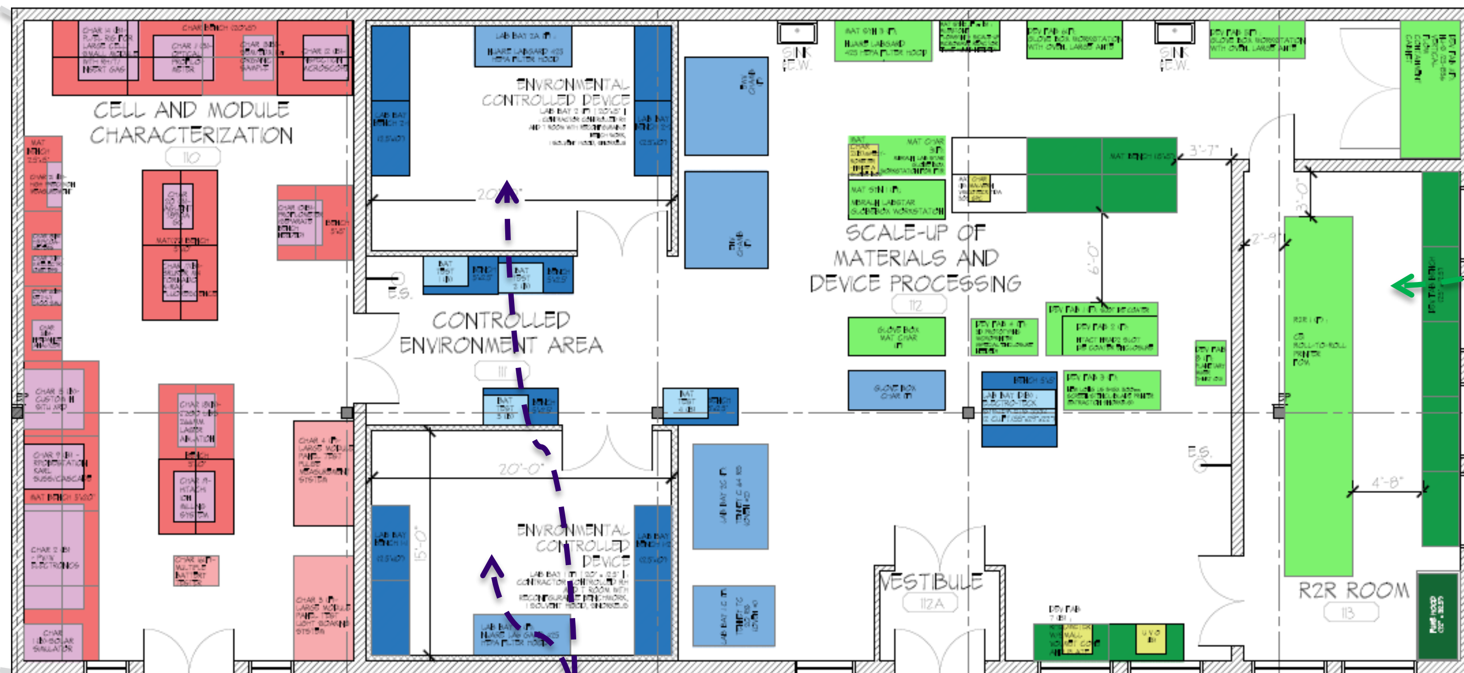
CEI Scale-up & Characterization Testbed

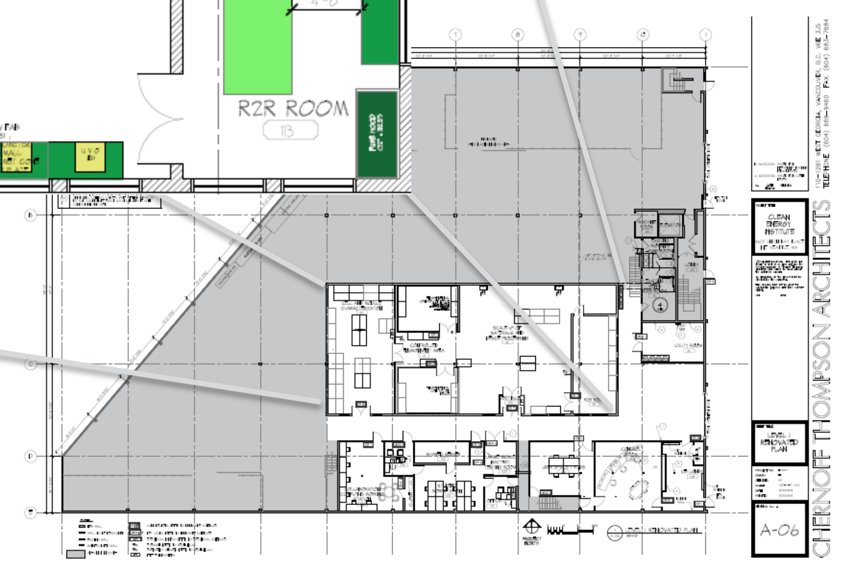
Device & Module Characterization

Controlled Environment Labs

Sheet and R2R Device Scale-up Processing

Dedicated Pilot Scale R2R Print Processing Lab

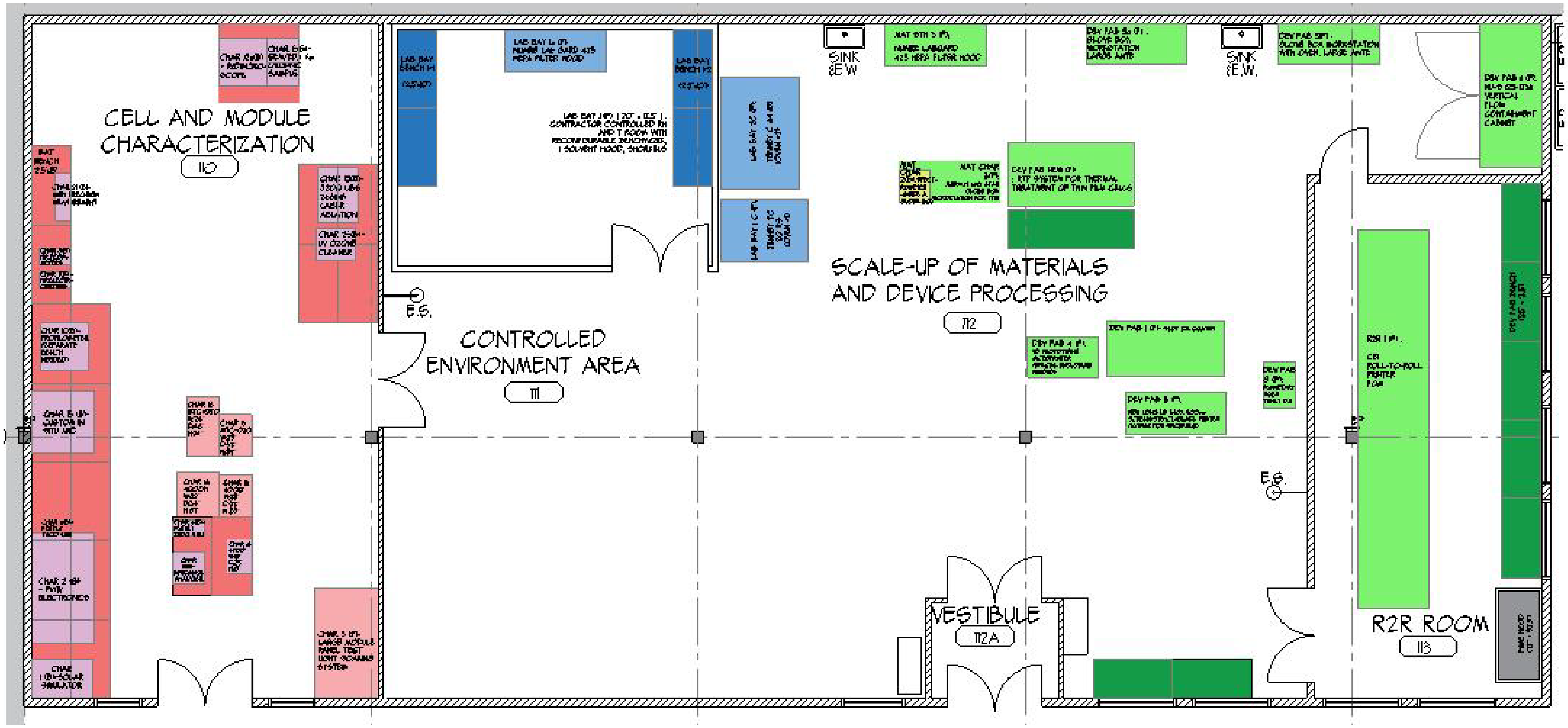




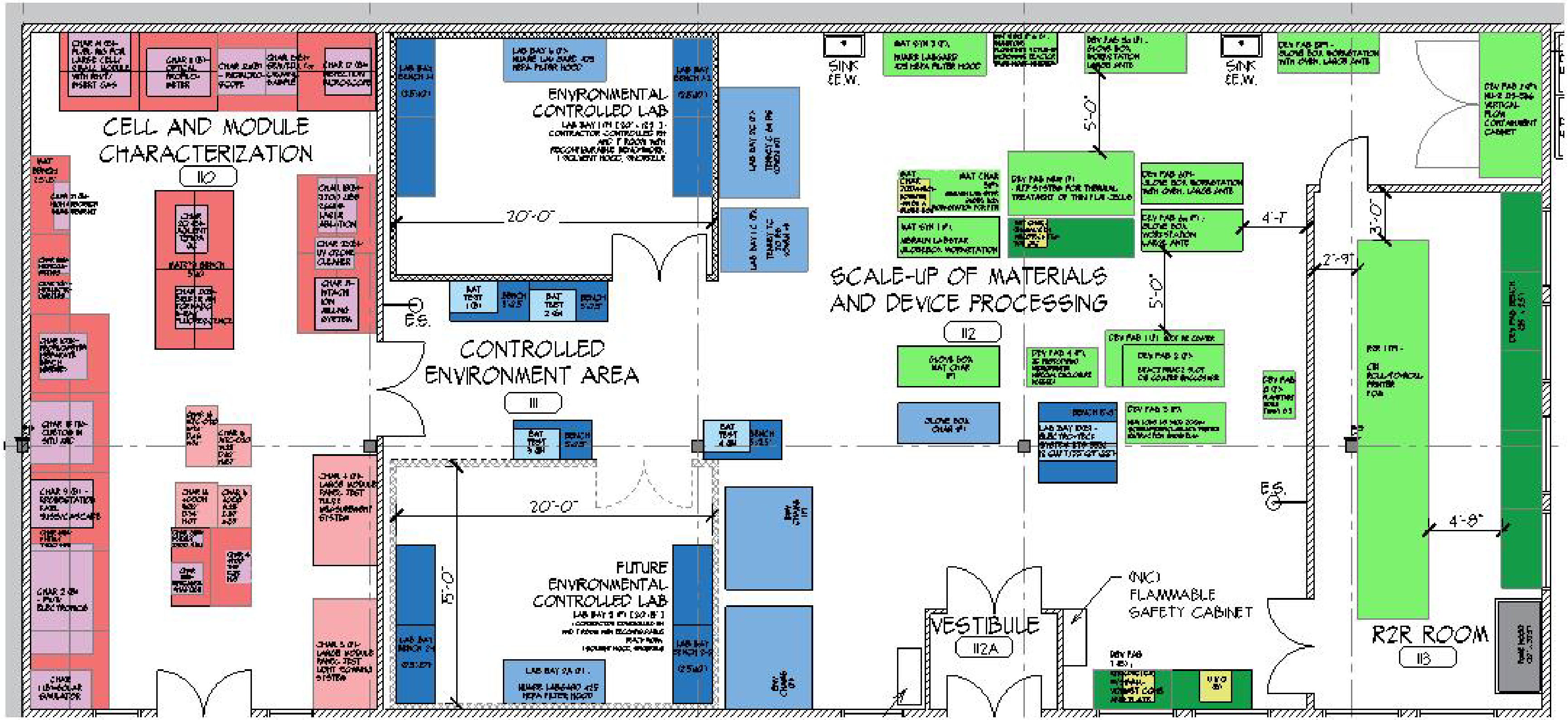
- User controlled humidity & temperature
- HEPA filtered hood
- Accommodates equipment exchange

Facility opens to users: January, 2017

Phase I Equipment



Complete Equipment



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CHERNOFF THOMPSON ARCHITECTS

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CEI Scale-up & Characterization Testbed

Sheet & R2R Device Scale-up Processing

FOM Tech Solar X3:

3rd generation R2R system design with unique capabilities for perovskite and high resolution print patterning of active materials, electrodes, and encapsulation for PV, sensors, TFTs and thin film batteries. 300mm wide web w/ single pass multilayer deposition & drying.

FOM Tech R&D Sheet Coater:

R&D sheet coater for coating functional materials (OPV, OLED, LEC) on rigid or flexible substrates

NewLong LS-34GX High Precision Screen Printer

- High precision/flatness
- Flex or rigid substrates
- Blade coating/Stencil mode

nScript 3Dn 3-D Printer

- 10nm resolution, 500nm repeatability, 1 um accuracy
- 300mm+ x, y, z travel with z tracking for conformal printing
- Multiple heads:
  - Electronic materials
  - Structural
  - Biomaterials
- 3-D mapping pre and post prints

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CEI Scale-up & Characterization Testbed

Device and Module Characterization Lab Module

PV Testing

Oriel Sol3A Class AAA Solar Simulator
8 in x 8 in illuminated area

Spire Spi-Sun Simulator 4600SLP
large module/panel test/light soaking system

Battery & Electronic Testing

Maccor Series 400 Automated Battery Tester with Temperature Chamber
96 & 15 channel systems

PV/IV Electronics (high & low current); Impedance Analyzer; Keithley 2400 SourceMeter Electrometers/Picoameters

Analytical

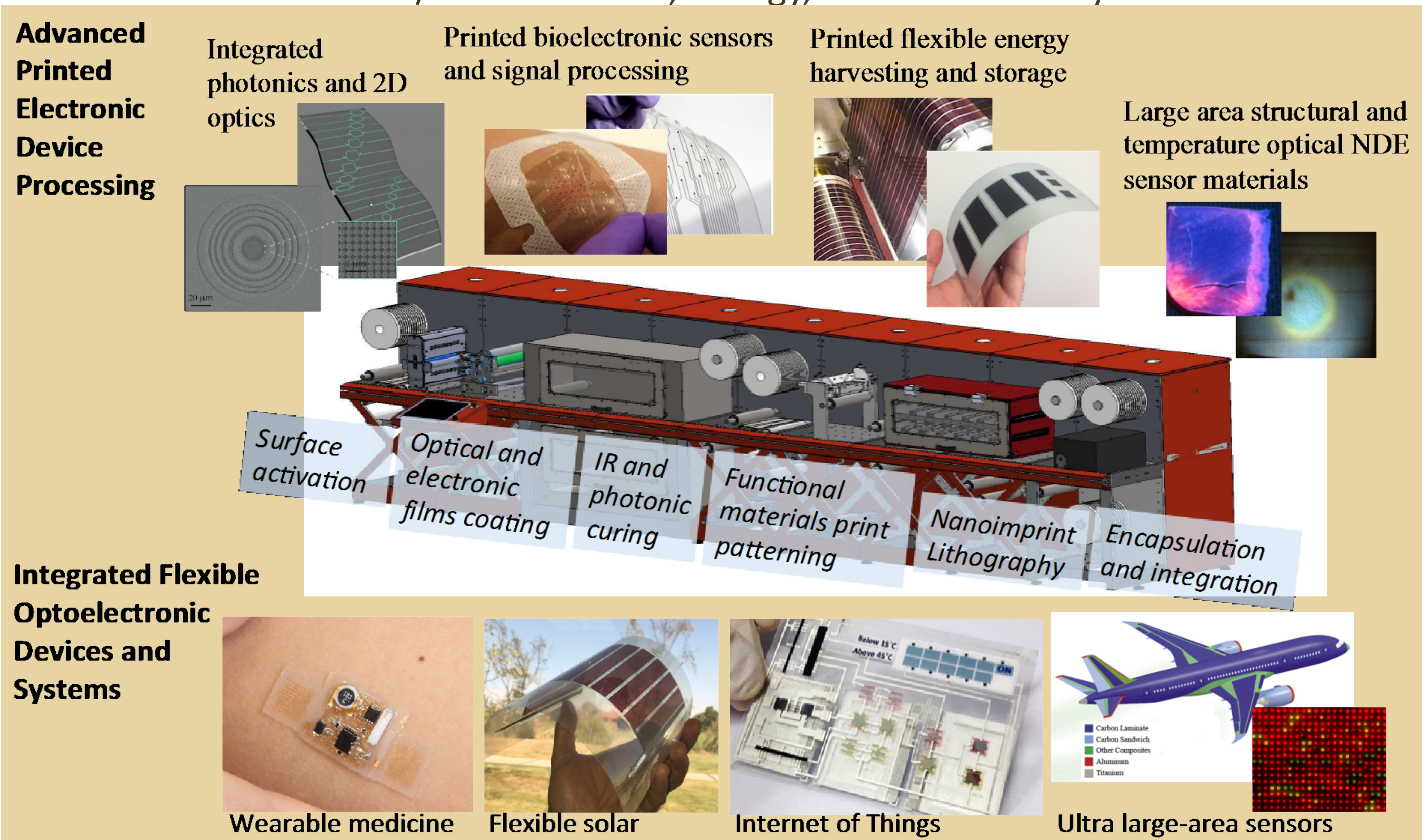
Bruker Twin/Twin D8 Advance X-Ray Diffractometer (XRD) w/ Lynxeye XE-T detector
High speed/intensity for in situ measurements; < 380 eV & 0.05 deg 2-theta resolution

Desktop SEM

w/ EDS & BSD, fast pump down

FUTURE VISION:

Center for Integrated Printed Optoelectronic Systems (CIPrOS):An Integrated Advanced Printing Platform for Innovative Integrated Electronics/Bioelectronics, Energy, and Photonics Systems



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Your Research & Training Testbed

What does $1.5M buy you with help from classroom services?

David Ginger

Associate Director, CEI
Professor of Chemistry
dginger@uw.edu

Vision

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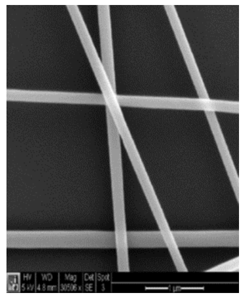
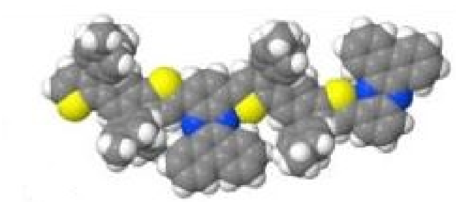
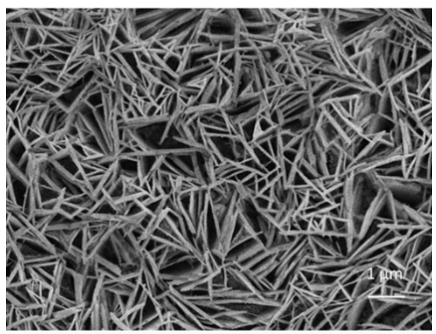
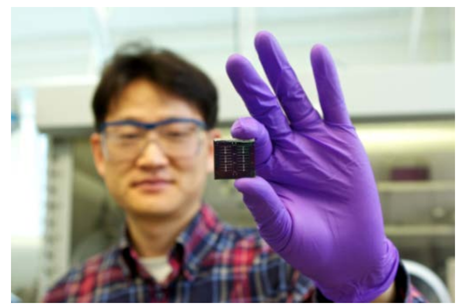
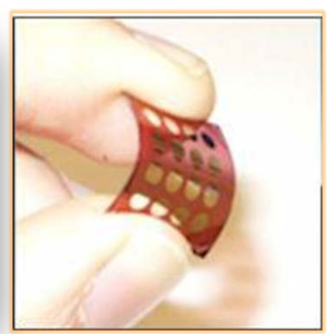
Provide an integrative training environment for upper-division undergrads and grad students that helps them understand energy materials, devices, and systems, from molecules to miles

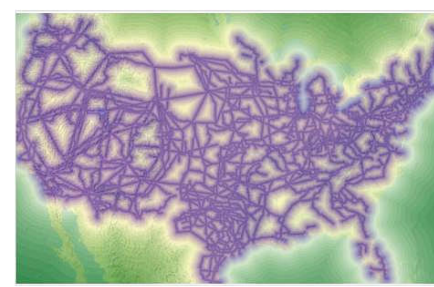












10^{-10} *meters* → 10^{7} *meters*

Research Training Testbed

Goal: Design a flexible facility for growing T shaped scholars; a project-based “Maker Space” for students that want to test ideas that span molecules to miles & markets.

- **Chair:** David Ginger (Chem)
- Christine Luscombe (MSE)
- Eric Stuve (ChemE)
- Jerry Seidler (Phys)
- Shaun Taylor (CEI)
- Xiaodong Xu (EE)
- Steve Majeski (A&S)
- Jiangyu Li (ME)
- Jihui Yang (MSE)
- Jim DeYoreo (PNNL)
- Paul Hopkins (Chem)
- Pedro Arduino (CoE)

Pacific Northwest
NATIONAL LABORATORY

R&T Testbed Objectives

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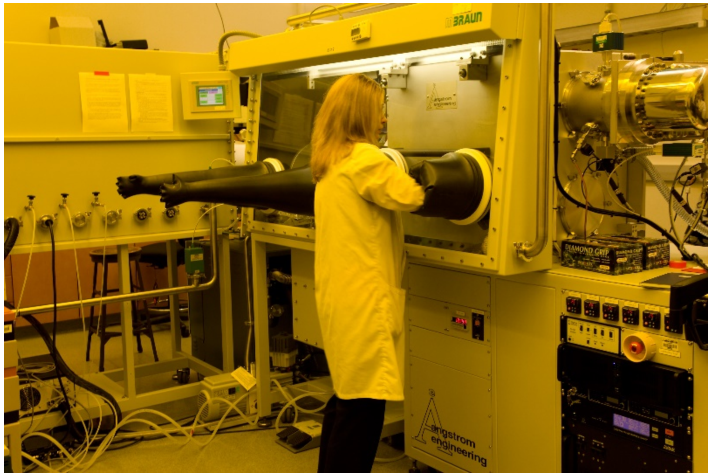
Core Objectives:

1) Get students into research faster by anchoring a CEI “Energy materials, devices, and systems” course offered for upper division undergrads and first year grad students

2) Provide controlled access to trained users outside of booked class hours to support graduate, undergraduate, and postdoctoral trainee research

3) Provide collaborative space for senior capstone projects, or student teams competing in events such as Environmental Innovation Challenge



R&T Testbed Space *Wish* List

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General Space Needs/Wants:

1) Floorplan to allow access to lab experiments in both group project and individual student project modes (e.g. require more space than in a typical research lab)

2) Flexible, mixed use space for student use of small scale electronics, optics, and wet chemistry (balances, sinks, water, N2, house vacuum?)

3) Dedicated hoods and exhaust capability for EH&S compliance

4) Storage for materials, group project supplies, and wet and dry chemicals

5) PC sand network access

6) Access control for safety compliance (e.g. keycard access, CORAL)

7) External view of lab

Future Home of R&T Testbed

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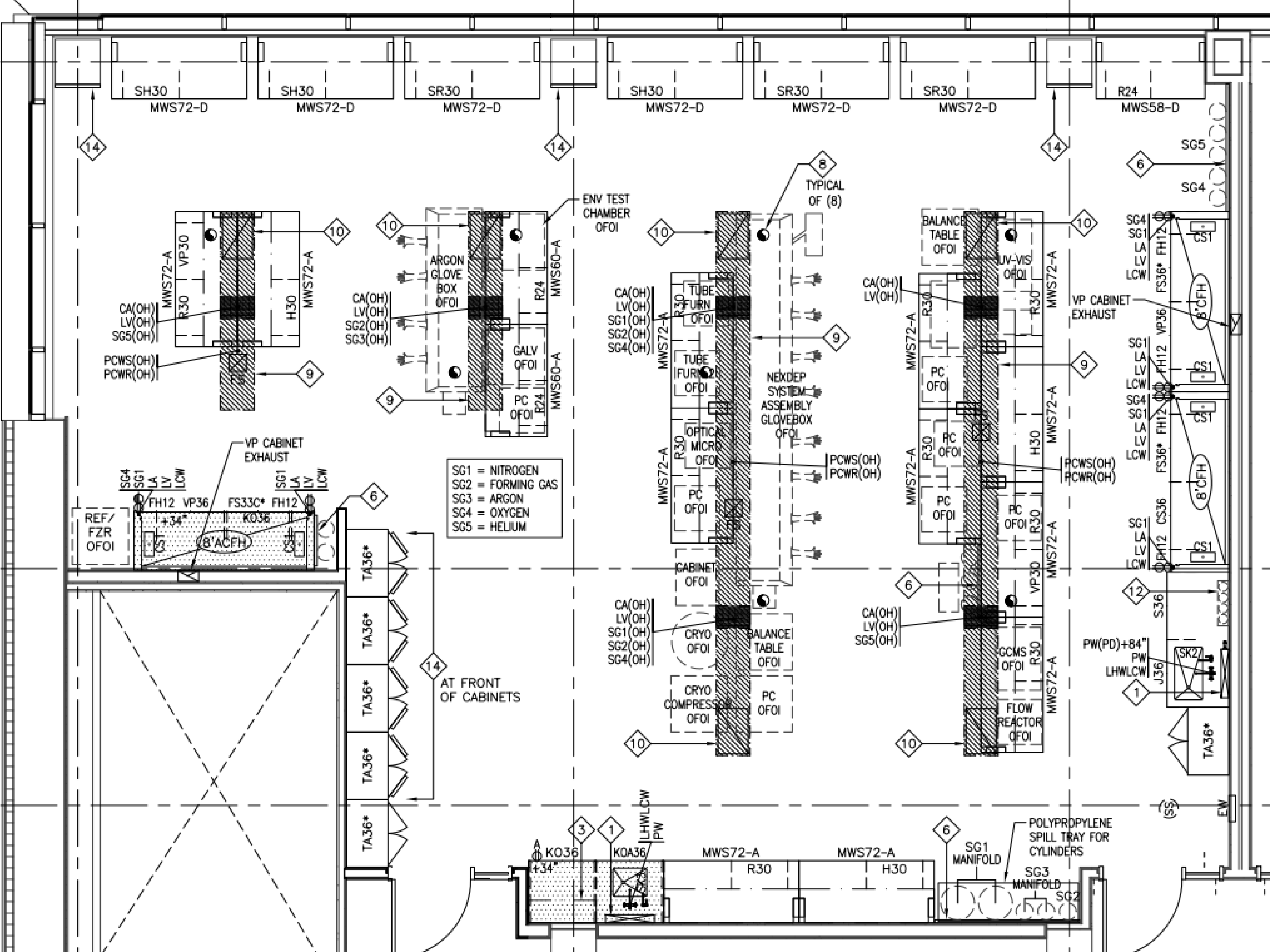
~1750 Square feet in NanoES building will be designated for “Clean Energy Maker Space”

Partnership with UW Academic Services Classroom Technology and Events (thank Associate Vice Provost Phil Reid)



SH30
MWS72-D
SH30
MWS72-D
SR30
MWS72-D
SH30
MWS72-D
SR30
MWS72-D
SR30
MWS72-D
R24
MWS58-D
14
SG5
6
SG4
8
TYPICAL OF (8)
ENV TEST CHAMBER OFOI
10
VP30
MWS72-A
R30
H30
CA(OH)
LV(OH)
SG5(OH)
PCWS(OH)
PCWR(OH)
9
ARGON GLOVE BOX OFOI
CA(OH)
LV(OH)
SG2(OH)
SG3(OH)
R24
MWS60-A
GALV OFOI
PC OFOI
TUBE FURN 1 OFOI
TUBE FURN 2 OFOI
OPTICAL MICRO OFOI
PC OFOI
CA(OH)
LV(OH)
SG1(OH)
SG2(OH)
SG4(OH)
NEXDEP SYSTEM ASSEMBLY GLOVEBOX OFOI
PCWS(OH)
PCWR(OH)
BALANCE TABLE OFOI
UV-VIS OFOI
CA(OH)
LV(OH)
PC OFOI
H30
VP CABINET EXHAUST
SG4
SG1
LA
LV
LCW
FH12
FS36*
CS1
8'CFH
VP36
CS36
VP CABINET EXHAUST
SG4 SG1 LA LV LCW
FH12 VP36 FS33C* FH12
+34"
K036
8'ACFH
SG1 LA LV LCW
REF/ FZR OFOI
SG1 = NITROGEN
SG2 = FORMING GAS
SG3 = ARGON
SG4 = OXYGEN
SG5 = HELIUM
TA36*
AT FRONT OF CABINETS
CABINET OFOI
CRYO OFOI
BALANCE TABLE OFOI
CRYO COMPRESSOR OFOI
PC OFOI
CA(OH)
LV(OH)
SG1(OH)
SG2(OH)
SG4(OH)
CA(OH)
LV(OH)
SG5(OH)
GCMS OFOI
FLOW REACTOR OFOI
12
S36
PW(PD)+84"
PW
LHWLCW
SK2
J36
1
TA36*
SS
EW
3
KO36
+34"
KOA36
LHWLCW
PW
MWS72-A
R30
MWS72-A
H30
POLYPROPYLENE SPILL TRAY FOR CYLINDERS
SG1 MANIFOLD
SG3 MANIFOLD
SG2

R&T Testbed Space *Planned* List

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Planned Laboratory Capabilities (Draft)

1) Solar cell training and testing lab (dual gloveboxes, vacuum evaporator, solar simulator + electronics)

2) Battery training and testing lab (glovebox, coin cell press, potentiostat)

3) Nanoparticle synthesis and characterization lab (hood, Schlenk line, ICP, UV-Vis-NIR, DLS, fluorescence)

4) Solar Photochemistry lab (photochemical reactor, GC/MS with RGA)

5) Semiconductor properties lab (“2D materials foundry”, PPMS, optical microscope)

6) Grid system simulation lab (workstations/laptops)

7) Possibly if partnering with other organizations: profilometer, desktop SEM

1. Solar Cell Lab (1/2)

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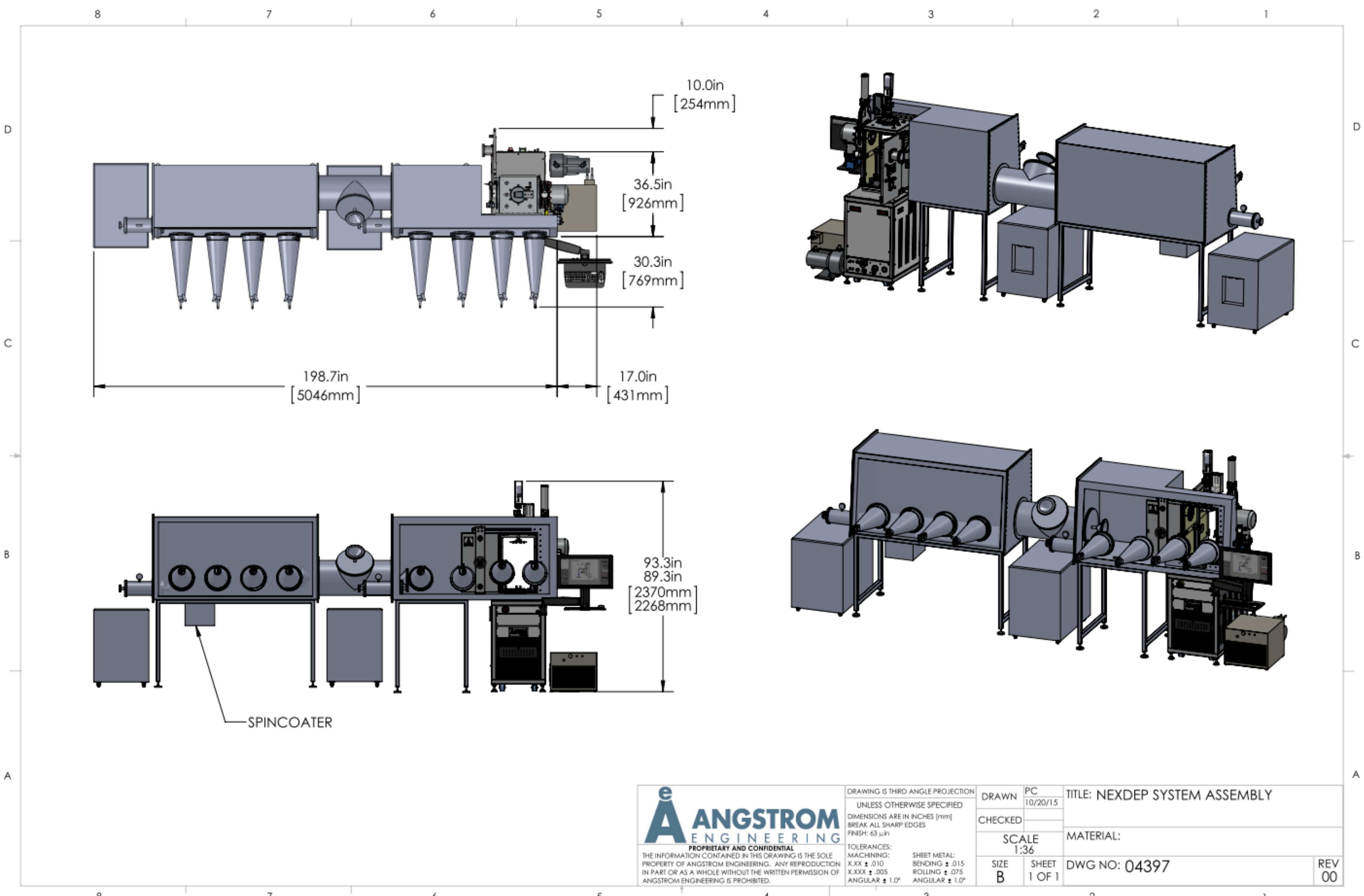
Provide New Facilities for Research-Scale Thin Film PV Fab and Testing

Spin coater, glove box, evaporator, solar simulator and test electronics



Solar Cell Lab (2/2)

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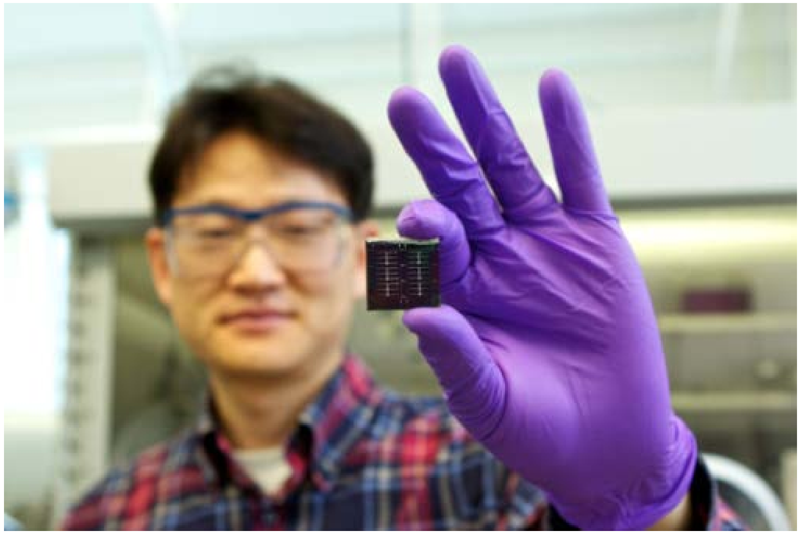
1) Solar simulator (110V ac) (attached to box)
2) Source measure unit (110V ac)
3) PC/small desk (near box)
4) Shared access to
    a) a hood with sonicator (share with e-chem) for sample cleaning and etching
    b) laboratory balance
    c) hotplate/stirrer
    d) Plasma cleaner
    e) bench space



2. Battery Lab

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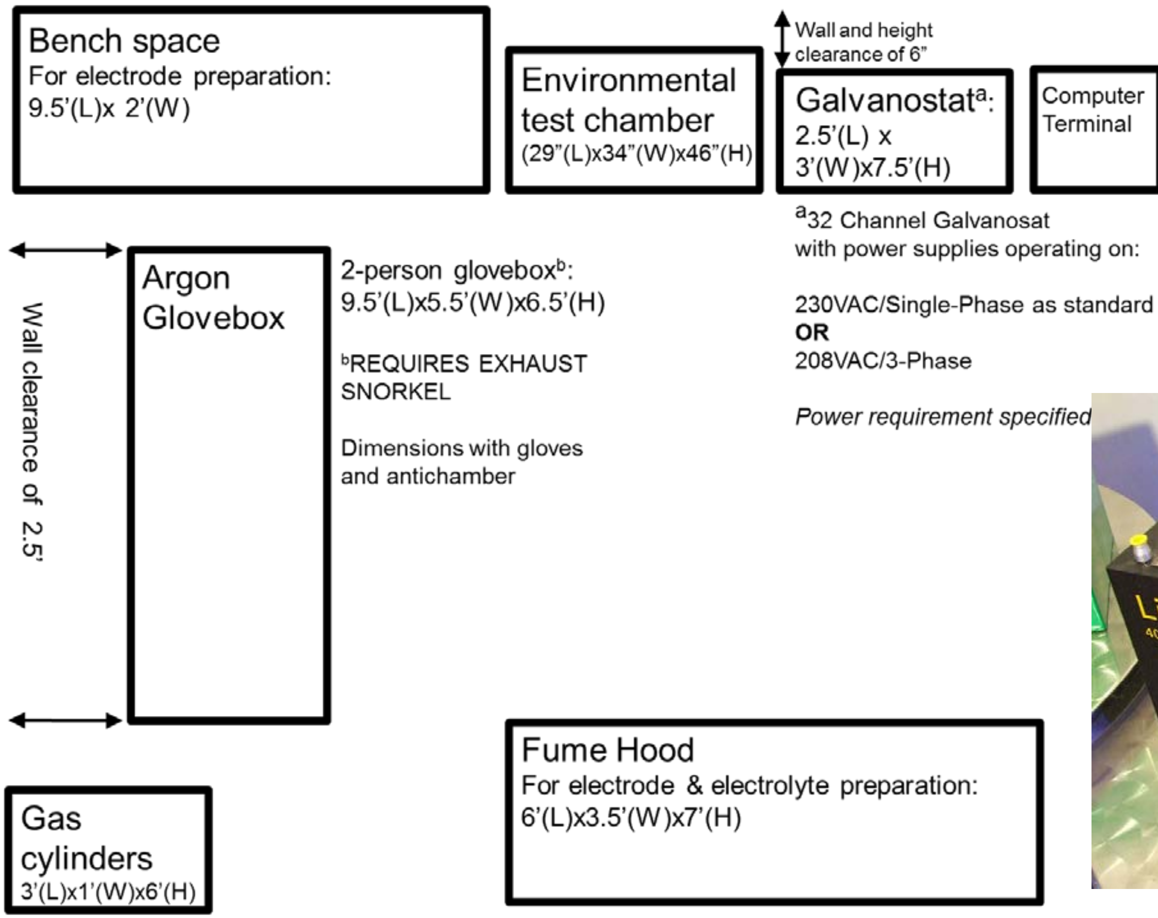
Provide Facility for Lab Scale Battery Training and Research

Coin cell fabrication, controlled temperature and atmosphere testing, test electronics



3. Nanoparticle Synthesis Lab

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Provide Facility for Synthesis and Characterization of Nanomaterials

Growth and optoelectronic characterization of colloidal semiconductors and nanoparticles for solar light harvesting, efficient catalysis, battery applications, and beyond

1) Fumehood

2) Schlenk line + vacuum pump cabinet

3) Lab benches for DLS, ICP, UV-Vis-NIR, fluorescence

3) Bench space for centrifuge, balance

4) Sink (shared with other experiments)

5) House N_2 line

6) Wet and dry chemical storage, including standard size explosion-proof fridge/freezer unit

4. Solar Photochemistry Lab

Measure products from photochemical reactions for solar fuels projects:

Solar simulator + photochemical reactor + GC/MS

5. Semiconductors Lab (1/2)

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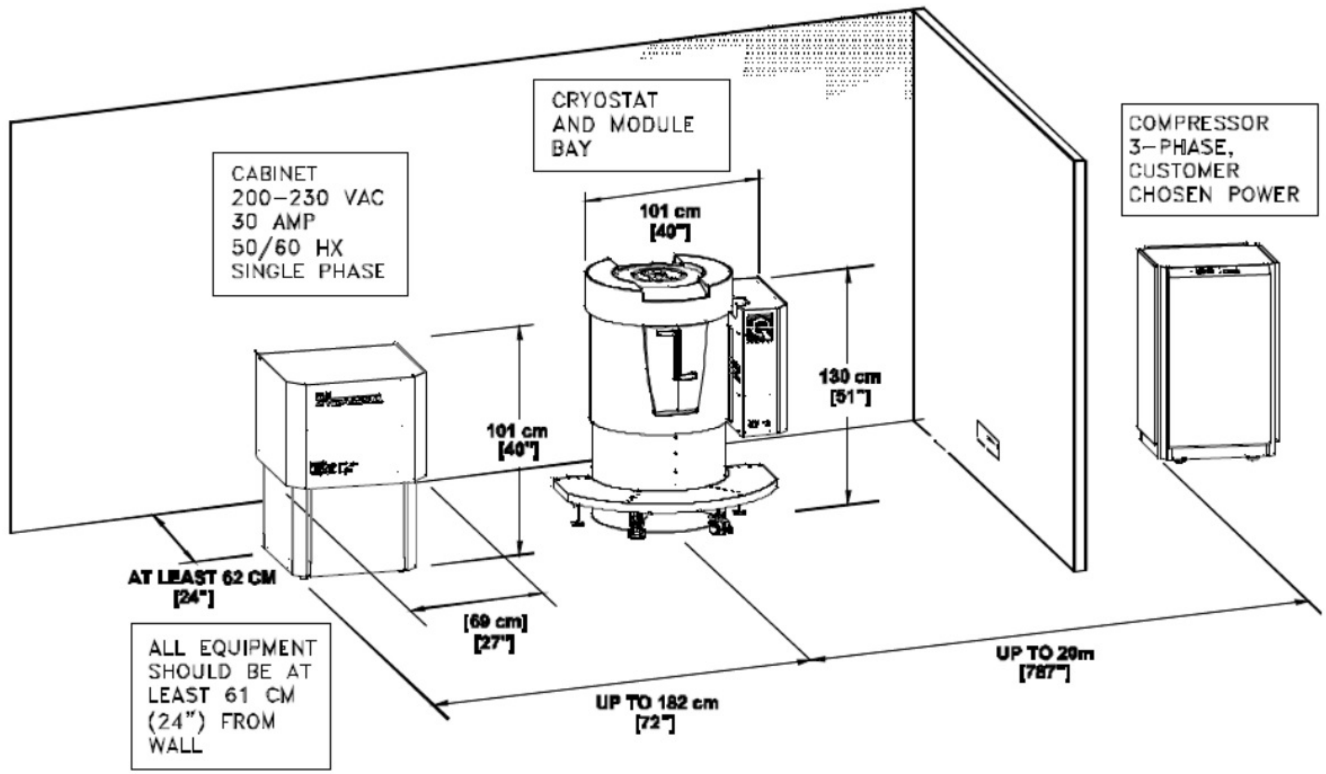
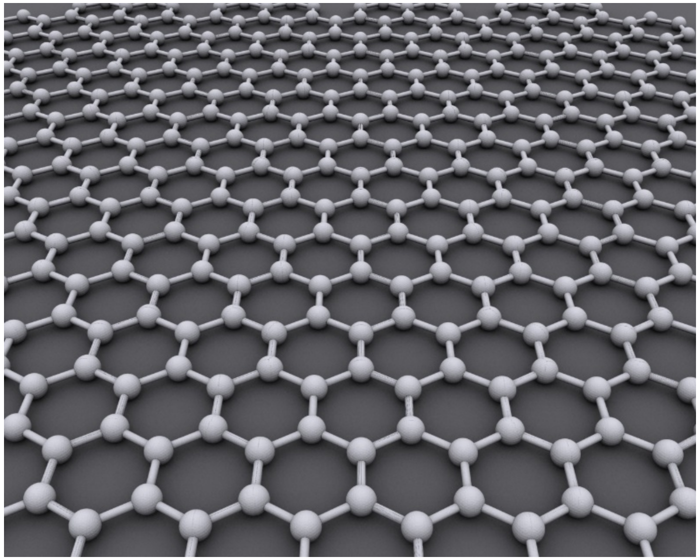
Provide Core Characterization of Semiconductor Materials

Variable temperature semiconductor characterization
Resistivity, dI/dV, T-depedent transport, Hall effect mobility, etc.



Semiconductors Lab (2/2)

1) workbench space
2) Lab balance
3) 2 tube furnaces + exhaust snorkels
4) Small optical microscope / microprobe station (30”x30” footprint) + PC



6. Grid Simulation Lab

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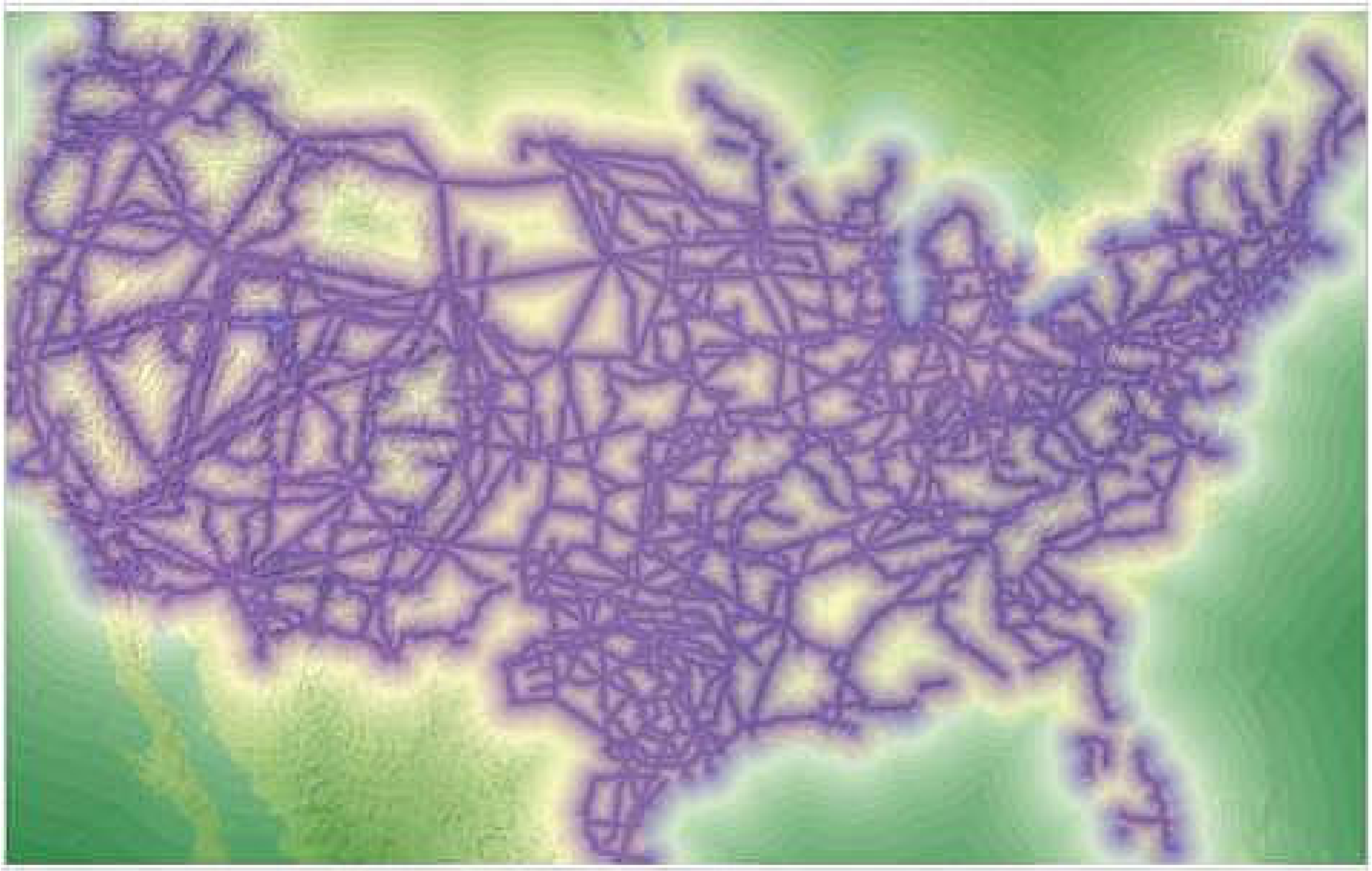
Introduce students to concepts of electrical grid

Provide computational resources for small-scale grid simulations



Next Steps

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Next steps:

1) May 6, 2016: final pricing from NanoES builders fixes budget

2) May/June 2016 ordering commences

3) delivery summer/fall 2016 into temporary spaces (TBD)

4) commissioning, lab development – research use

5) NanoES finishes / Move to NanoES in mid/late 2017

Get Involved with *Your* Testbed

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1) Become a student lead for a piece of equipment during procurement/installation

2) Apply for STF funding for new ideas to help outfit lab

3) Help create official lab experiments

4) Volunteer to create training videos for products of lasting value

5) TA for the lab

6) Use your imagination – and the facility!

Facility Layout

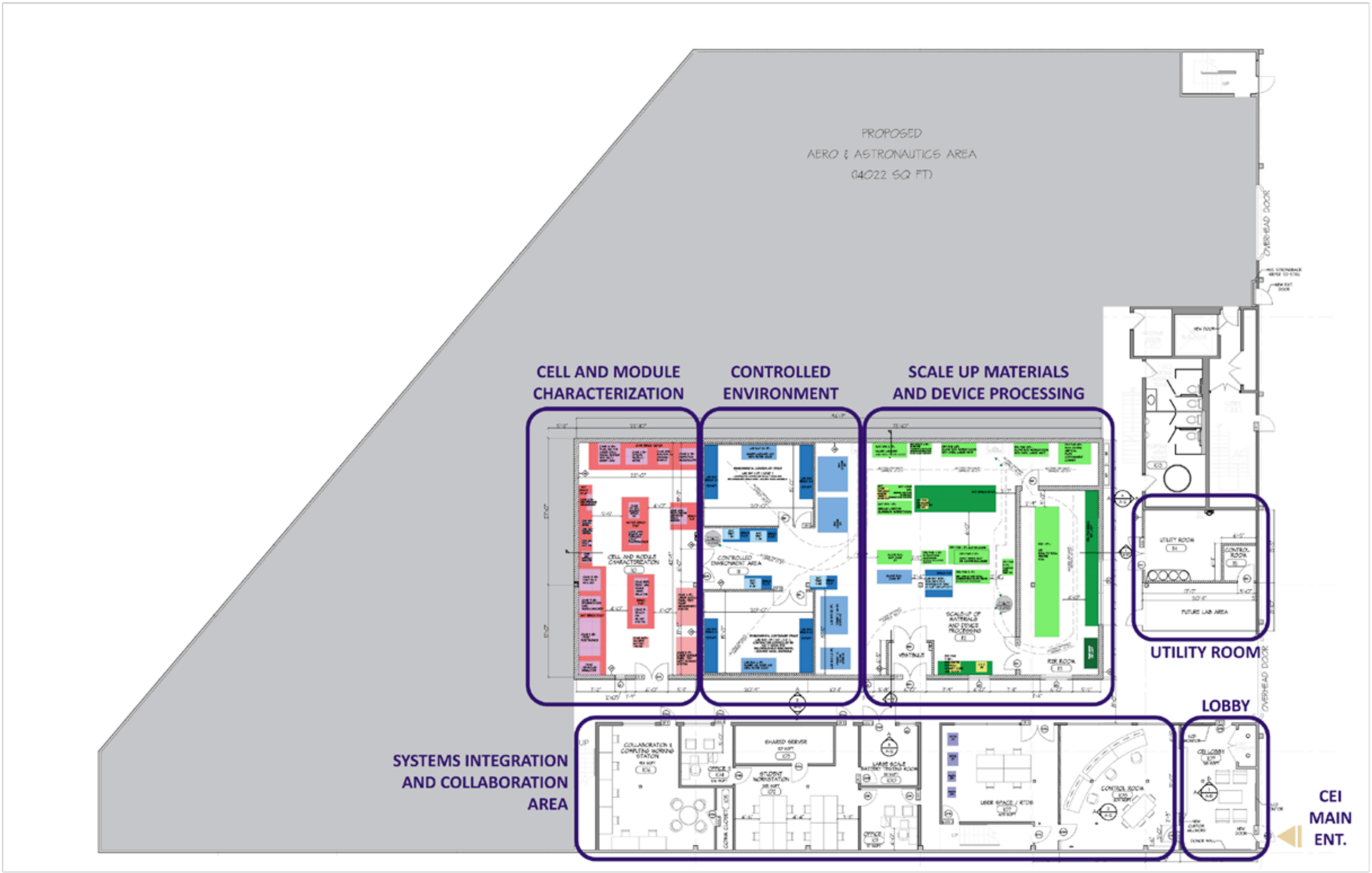
Naomi Gross
Chernoff/Thompson Architects

Bowman Building Site

10,000 ft^2 TB adjacent to University Village

Equipment move-in starts Fall 2016

Level 1


PROPOSED
AERO & ASTRONAUTICS AREA
(14022 SQ FT)
CELL AND MODULE CHARACTERIZATION
CONTROLLED ENVIRONMENT
SCALE UP MATERIALS AND DEVICE PROCESSING
UTILITY ROOM
LOBBY
SYSTEMS INTEGRATION AND COLLABORATION AREA
CEI MAIN ENT.

LEVEL 1

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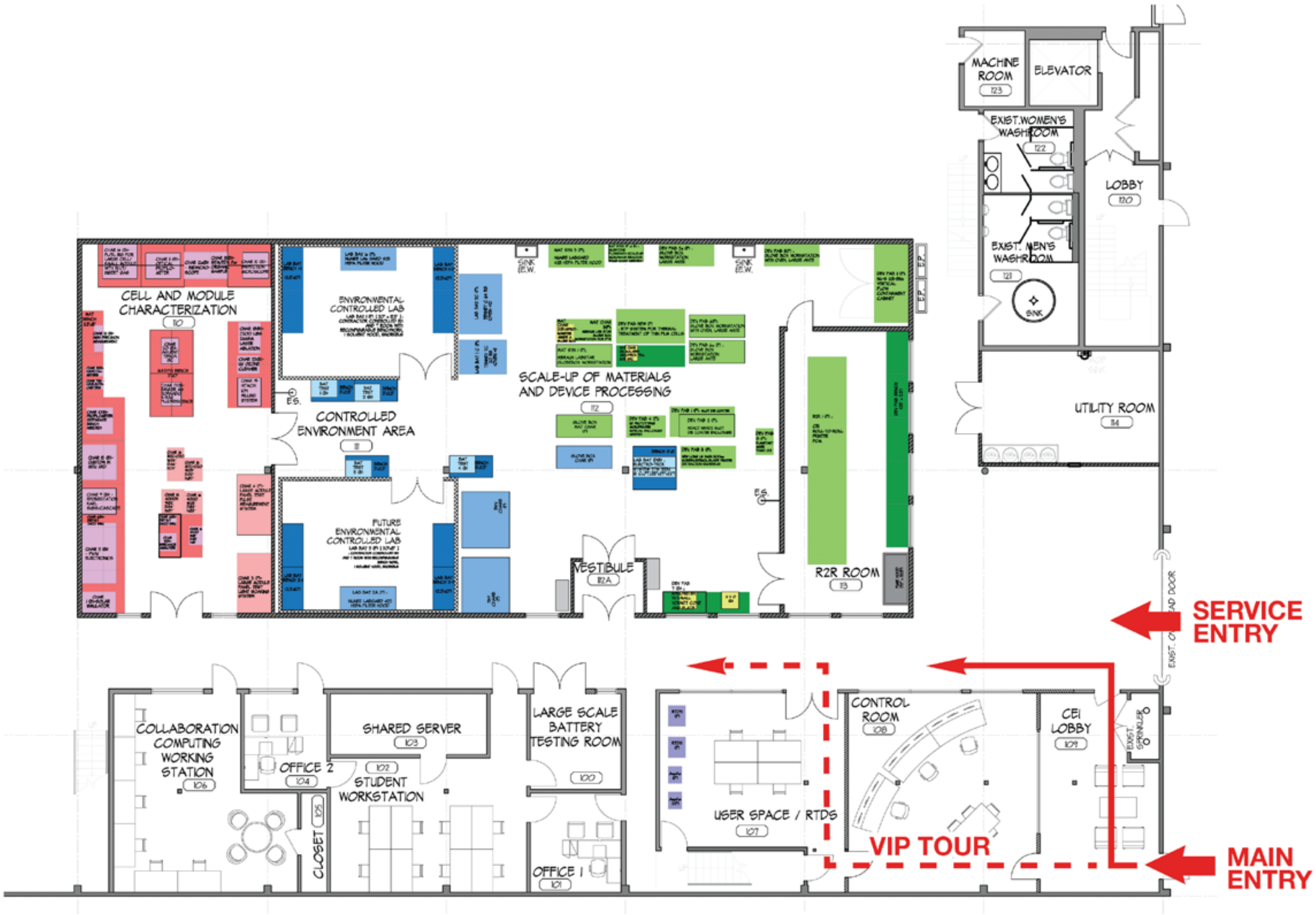
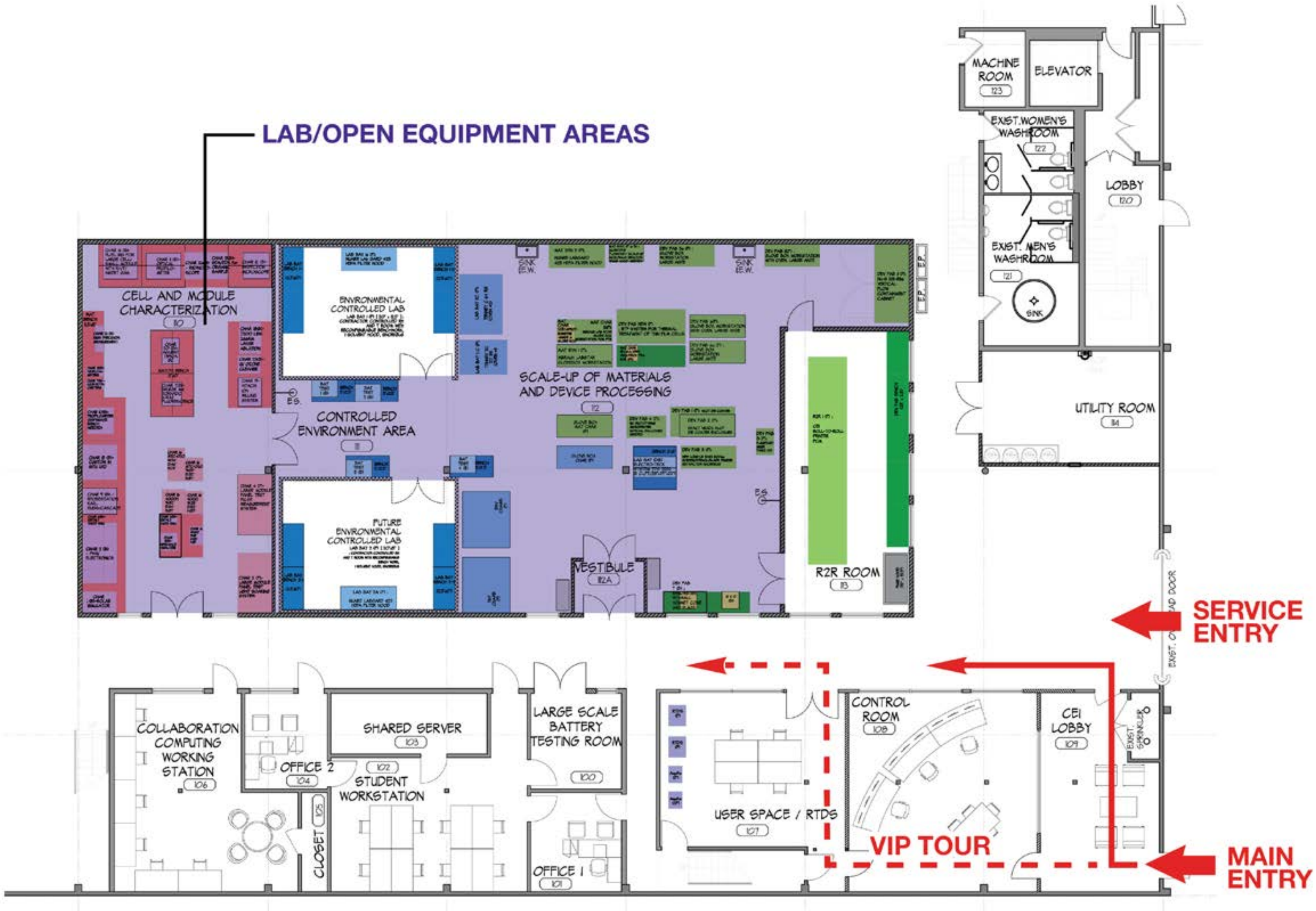
CHERNOFF THOMPSON ARCHITECTS

LEVEL 1



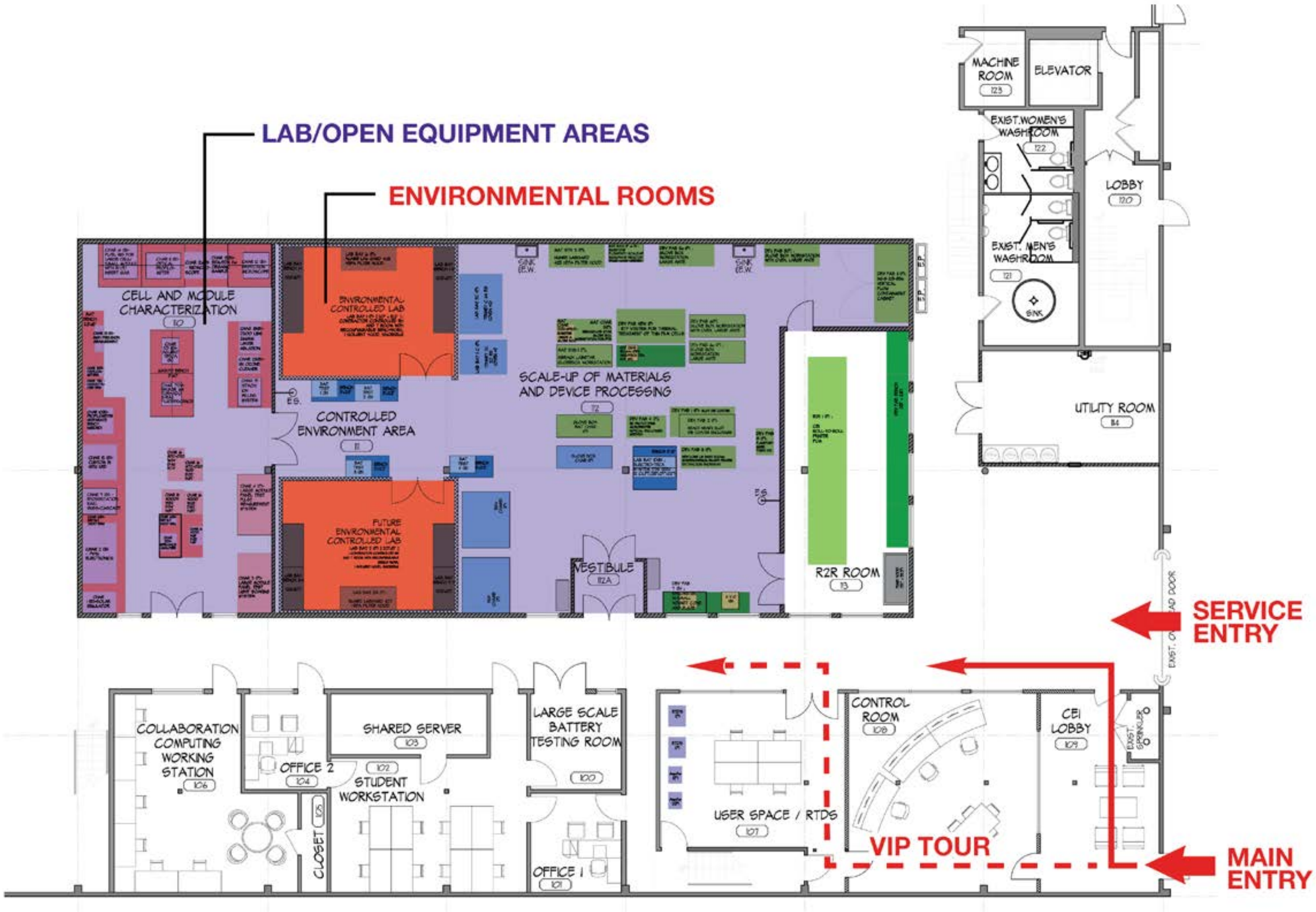
MACHINE ROOM
123
ELEVATOR
EXIST. WOMEN'S WASHROOM
122
LOBBY
120
EXIST. MEN'S WASHROOM
121
SINK
UTILITY ROOM
114
CELL AND MODULE CHARACTERIZATION
110
ENVIRONMENTAL CONTROLLED LAB
CONTROLLED ENVIRONMENT AREA
111
SCALE-UP OF MATERIALS AND DEVICE PROCESSING
112
FUTURE ENVIRONMENTAL CONTROLLED LAB
VESTIBULE
112A
R2R ROOM
113
SERVICE ENTRY
VIP TOUR
MAIN ENTRY
COLLABORATION COMPUTING WORKING STATION
106
OFFICE 2
104
SHARED SERVER
103
STUDENT WORKSTATION
102
CLOSET
105
LARGE SCALE BATTERY TESTING ROOM
100
OFFICE 1
101
USER SPACE / RTDS
107
CONTROL ROOM
108
CEI LOBBY
109

LEVEL 1

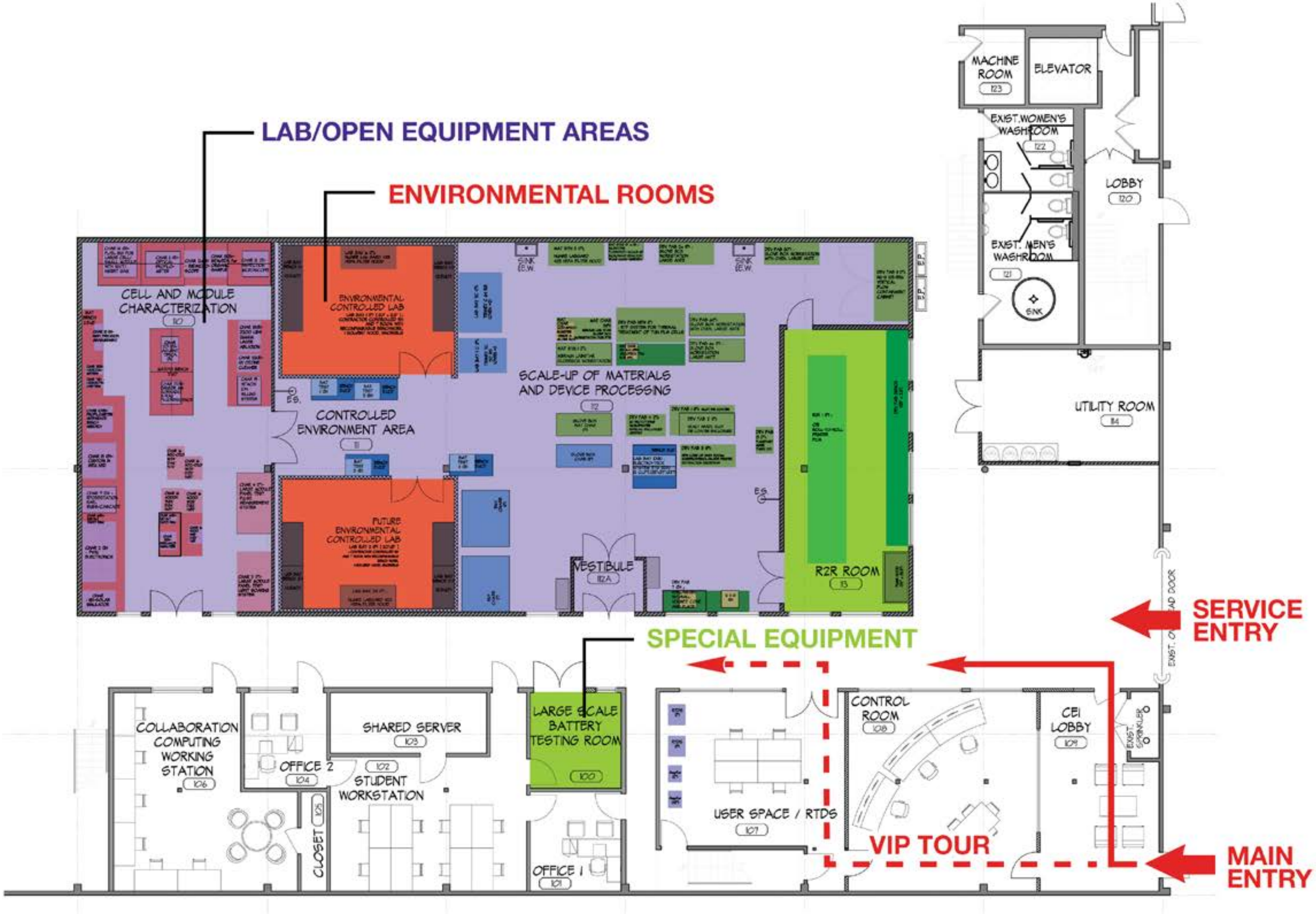


LAB/OPEN EQUIPMENT AREAS
CELL AND MODULE CHARACTERIZATION
110
ENVIRONMENTAL CONTROLLED LAB
CONTROLLED ENVIRONMENT AREA
111
FUTURE ENVIRONMENTAL CONTROLLED LAB
SCALE-UP OF MATERIALS AND DEVICE PROCESSING
112
VESTIBULE
112A
R2R ROOM
113
MACHINE ROOM
123
ELEVATOR
EXIST. WOMEN'S WASHROOM
122
EXIST. MEN'S WASHROOM
121
LOBBY
120
UTILITY ROOM
114
SERVICE ENTRY
COLLABORATION COMPUTING WORKING STATION
106
OFFICE 2
104
SHARED SERVER
103
102
STUDENT WORKSTATION
CLOSET
105
LARGE SCALE BATTERY TESTING ROOM
100
OFFICE 1
101
USER SPACE / RTDS
107
CONTROL ROOM
108
CEI LOBBY
109
VIP TOUR
MAIN ENTRY

LEVEL 1


LAB/OPEN EQUIPMENT AREAS
ENVIRONMENTAL ROOMS
MACHINE ROOM
ELEVATOR
EXIST. WOMEN'S WASHROOM
EXIST. MEN'S WASHROOM
LOBBY
CELL AND MODULE CHARACTERIZATION
ENVIRONMENTAL CONTROLLED LAB
SCALE-UP OF MATERIALS AND DEVICE PROCESSING
CONTROLLED ENVIRONMENT AREA
UTILITY ROOM
FUTURE ENVIRONMENTAL CONTROLLED LAB
VESTIBULE
R2R ROOM
SERVICE ENTRY
COLLABORATION COMPUTING WORKING STATION
OFFICE 2
SHARED SERVER
STUDENT WORKSTATION
CLOSET
LARGE SCALE BATTERY TESTING ROOM
OFFICE 1
USER SPACE / RTDS
CONTROL ROOM
CEI LOBBY
VIP TOUR
MAIN ENTRY

LEVEL 1


LAB/OPEN EQUIPMENT AREAS
ENVIRONMENTAL ROOMS
SPECIAL EQUIPMENT
SERVICE ENTRY
MAIN ENTRY
VIP TOUR
MACHINE ROOM
ELEVATOR
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UTILITY ROOM
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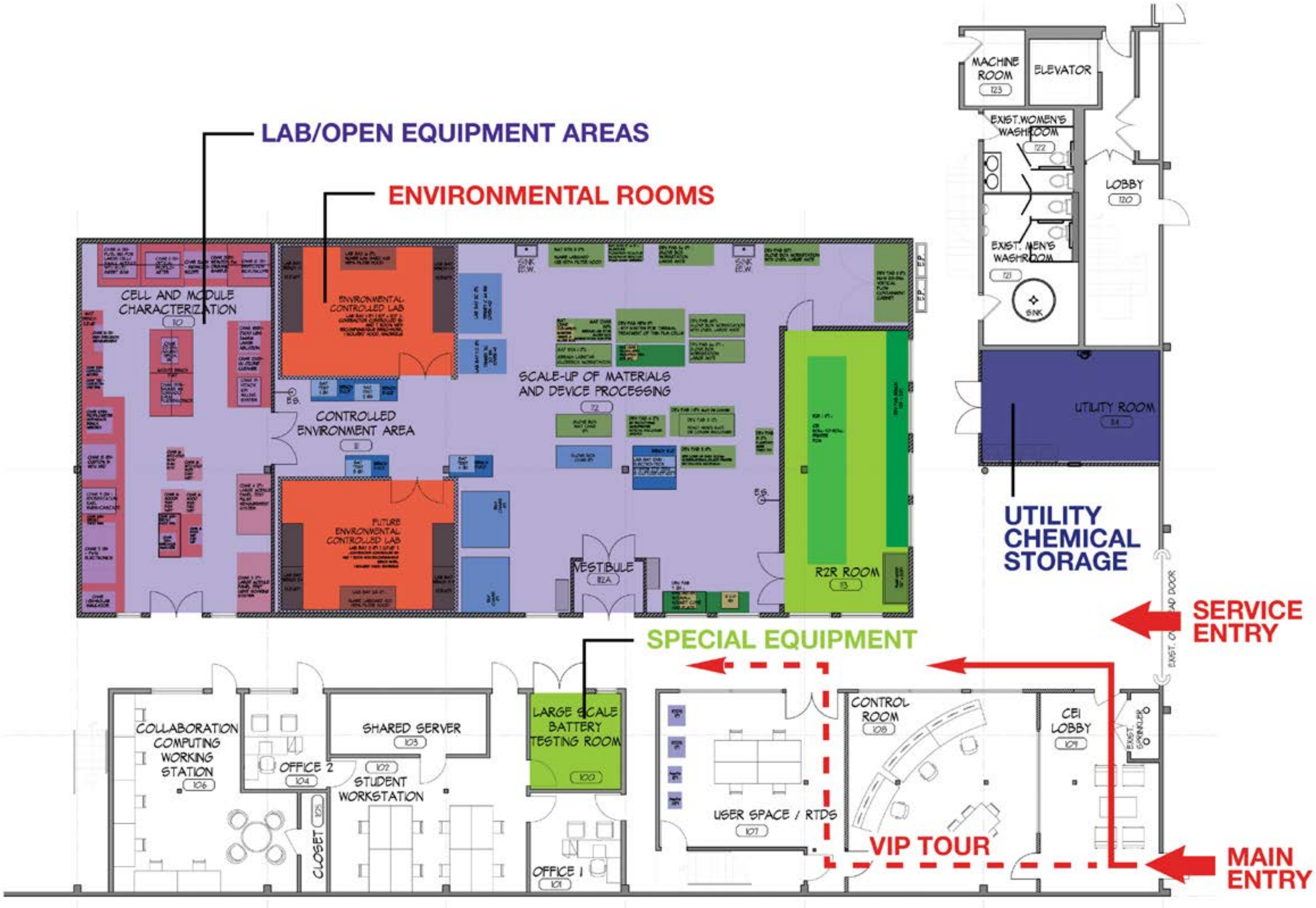
R2R ROOM
COLLABORATION COMPUTING WORKING STATION
OFFICE 2
SHARED SERVER
STUDENT WORKSTATION
CLOSET
LARGE SCALE BATTERY TESTING ROOM
OFFICE 1
USER SPACE / RTDS
CONTROL ROOM
CEI LOBBY

LEVEL 1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ENVIRONMENTAL CONTROLLED LAB
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SCALE-UP OF MATERIALS AND DEVICE PROCESSING
FUTURE ENVIRONMENTAL CONTROLLED LAB
VESTIBULE
R2R ROOM
UTILITY ROOM
UTILITY CHEMICAL STORAGE
SERVICE ENTRY
SPECIAL EQUIPMENT
COLLABORATION COMPUTING WORKING STATION
OFFICE 2
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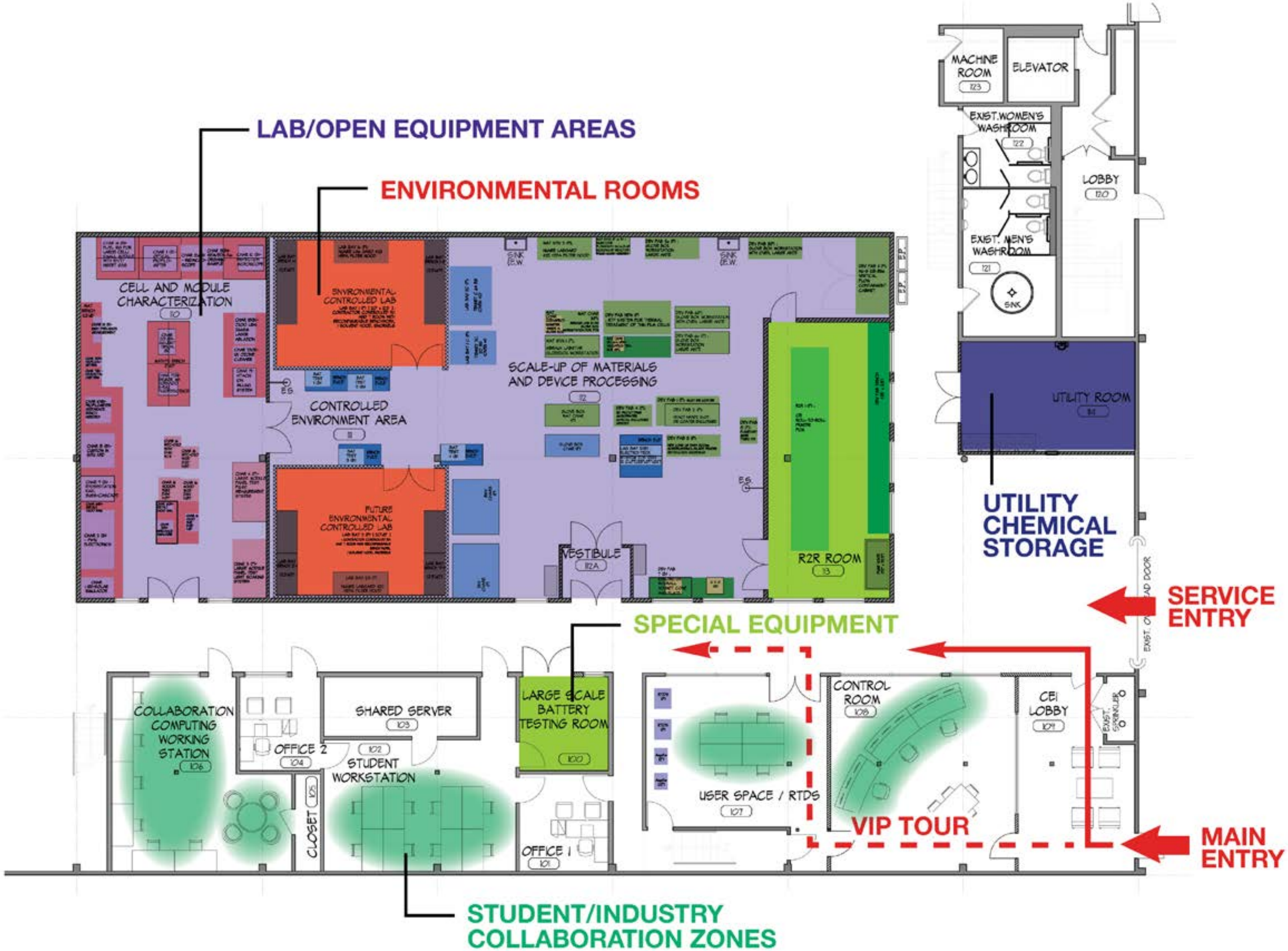
STUDENT WORKSTATION
CLOSET
LARGE SCALE BATTERY TESTING ROOM
OFFICE 1
USER SPACE / RTDS
CONTROL ROOM
CEI LOBBY
VIP TOUR
MAIN ENTRY

LEVEL 1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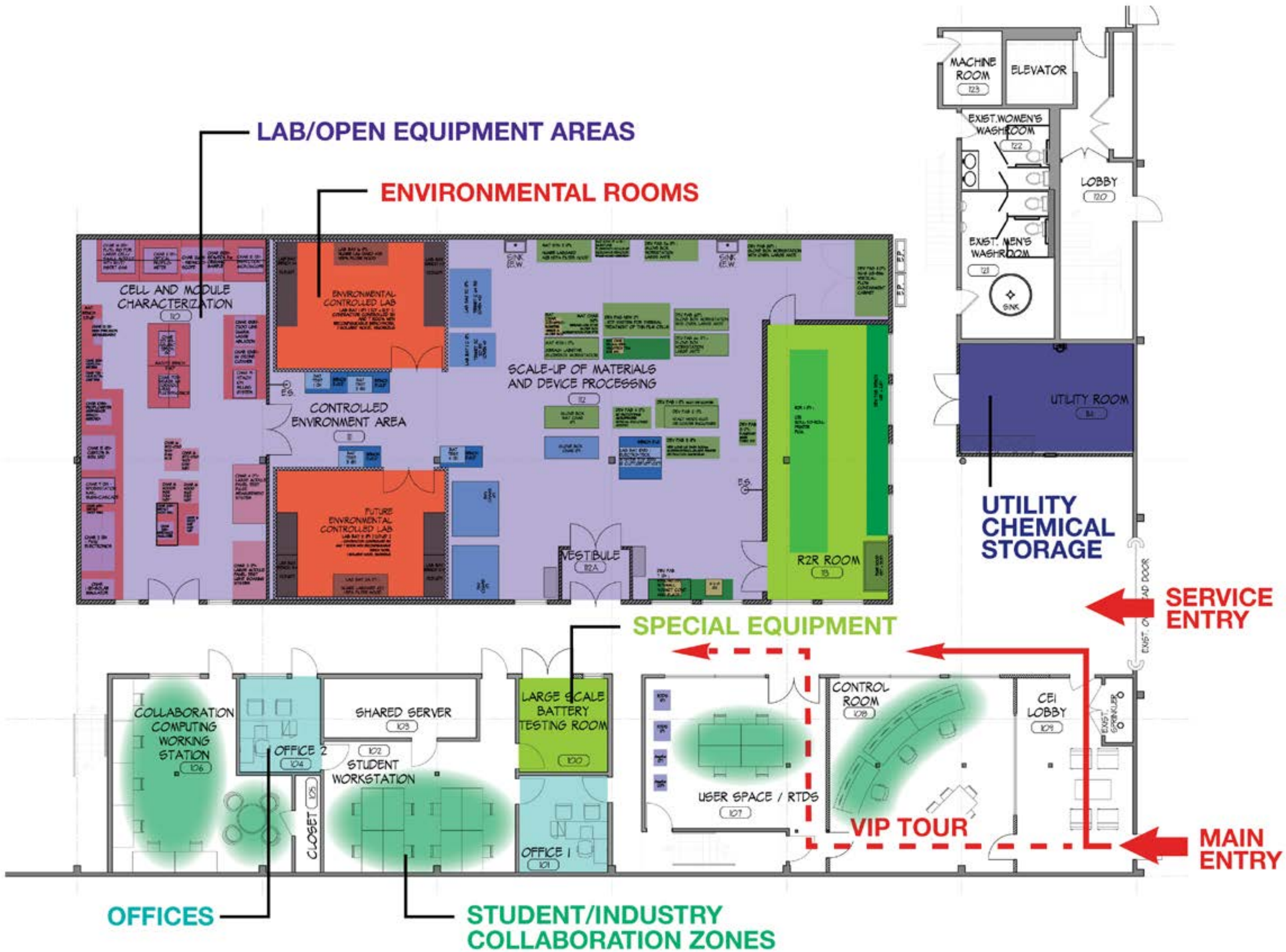
ENVIRONMENTAL ROOMS
CELL AND MODULE CHARACTERIZATION
ENVIRONMENTAL CONTROLLED LAB
CONTROLLED ENVIRONMENT AREA
SCALE-UP OF MATERIALS AND DEVICE PROCESSING
FUTURE ENVIRONMENTAL CONTROLLED LAB
VESTIBULE
R2R ROOM
MACHINE ROOM
ELEVATOR
EXIST. WOMEN'S WASHROOM
LOBBY
EXIST. MEN'S WASHROOM
UTILITY ROOM
UTILITY CHEMICAL STORAGE
SERVICE ENTRY
SPECIAL EQUIPMENT
COLLABORATION COMPUTING WORKING STATION
OFFICE 2
SHARED SERVER
STUDENT WORKSTATION
CLOSET
LARGE SCALE BATTERY TESTING ROOM
OFFICE 1
USER SPACE / RTDS
CONTROL ROOM
CEI LOBBY
VIP TOUR
MAIN ENTRY
STUDENT/INDUSTRY COLLABORATION ZONES

LEVEL 1



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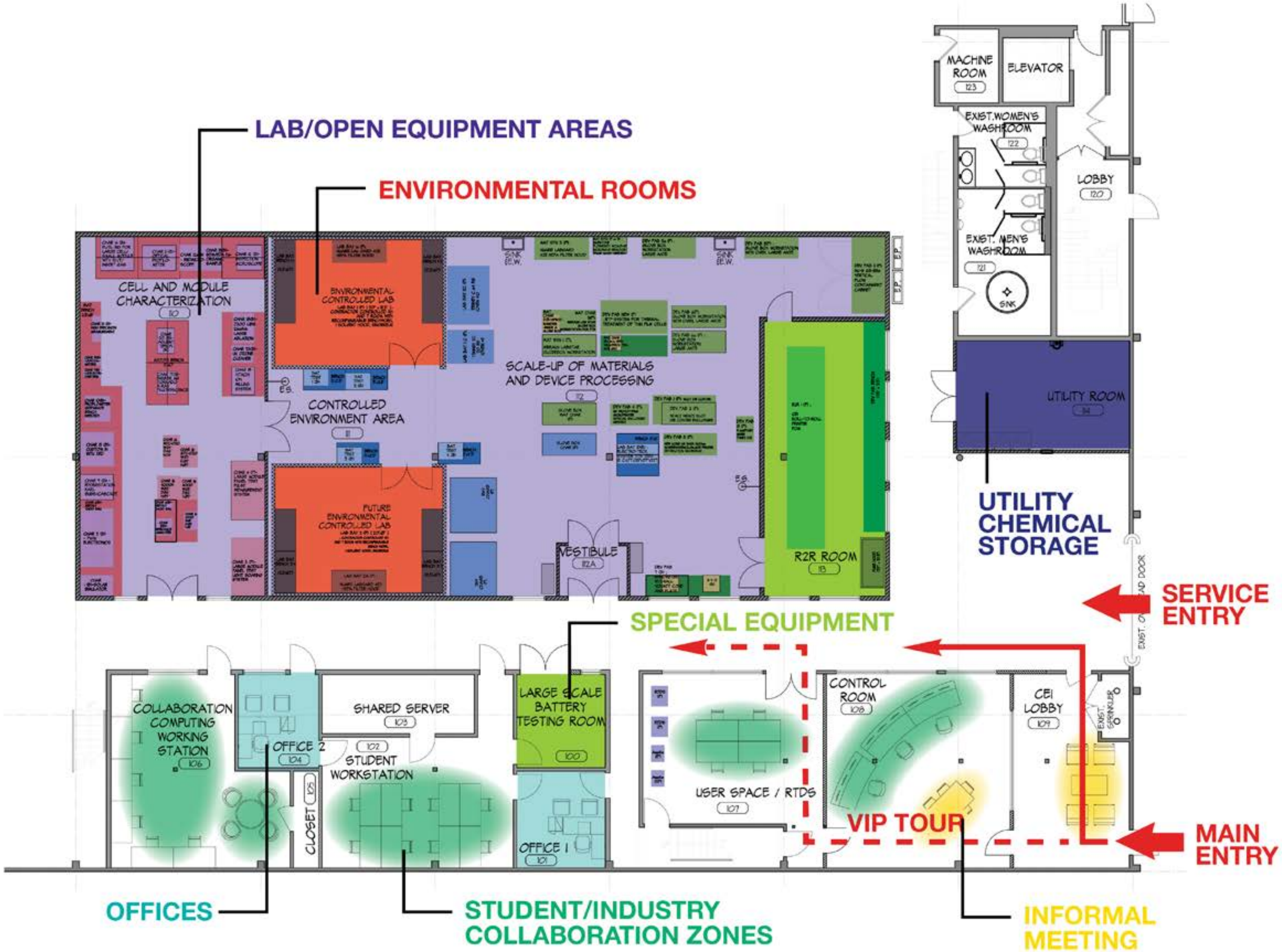
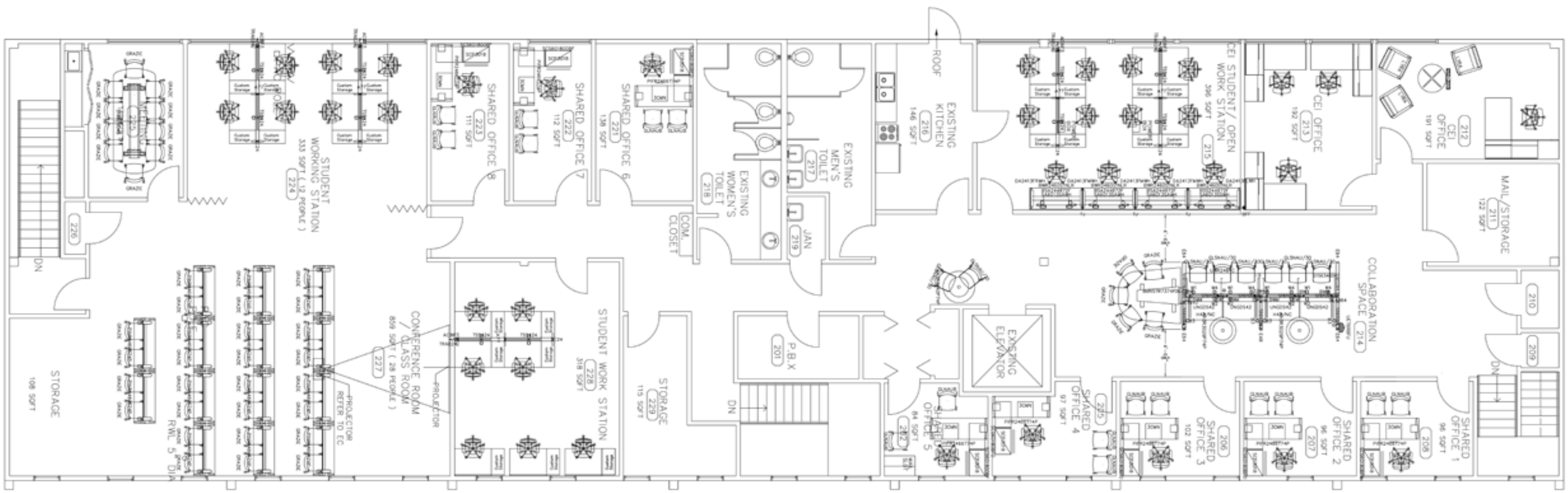
CHERNOFF THOMPSON ARCHITECTS

LEVEL 1

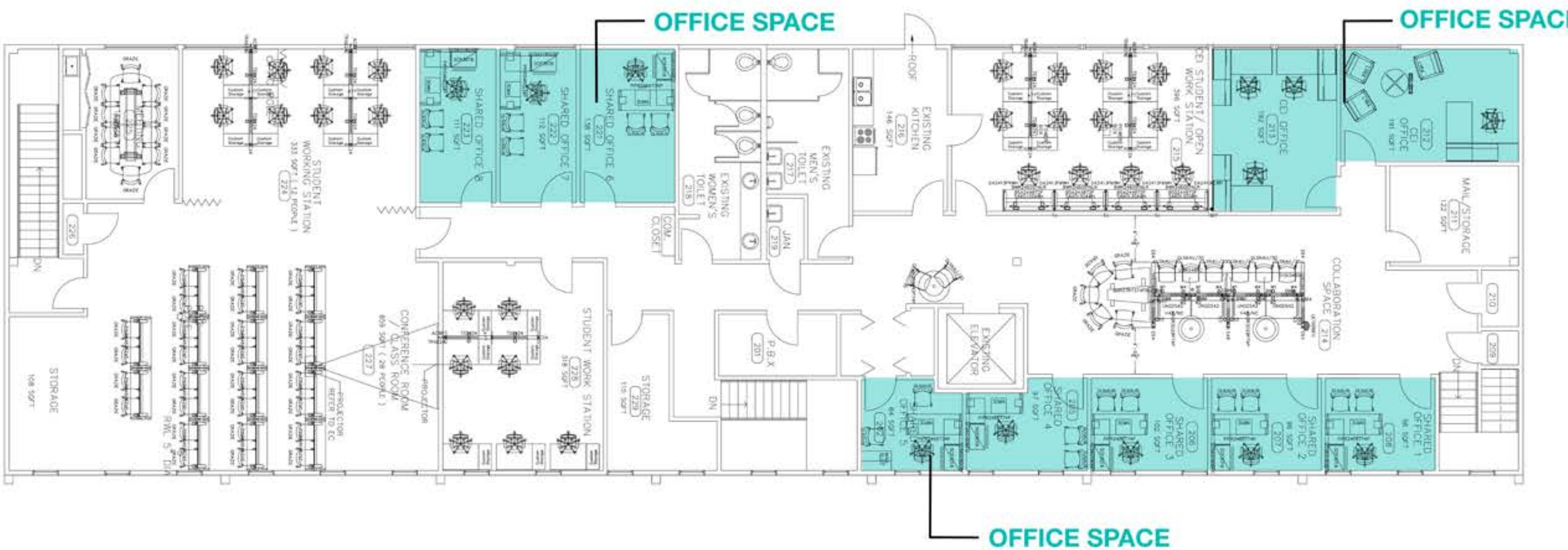

LAB/OPEN EQUIPMENT AREAS
ENVIRONMENTAL ROOMS
CELL AND MODULE CHARACTERIZATION
110
ENVIRONMENTAL CONTROLLED LAB
CONTROLLED ENVIRONMENT AREA
111
FUTURE ENVIRONMENTAL CONTROLLED LAB
SCALE-UP OF MATERIALS AND DEVICE PROCESSING
112
VESTIBULE
112A
R2R ROOM
113
MACHINE ROOM
123
ELEVATOR
EXIST. WOMEN'S WASHROOM
122
EXIST. MEN'S WASHROOM
121
SINK
LOBBY
120
UTILITY ROOM
114
UTILITY CHEMICAL STORAGE
SERVICE ENTRY
SPECIAL EQUIPMENT
COLLABORATION COMPUTING WORKING STATION
106
OFFICE 2
104
SHARED SERVER
103
102
STUDENT WORKSTATION
CLOSET
105
LARGE SCALE BATTERY TESTING ROOM
100
OFFICE 1
101
USER SPACE / RTDS
107
CONTROL ROOM
108
CEI LOBBY
109
VIP TOUR
MAIN ENTRY
OFFICES
STUDENT/INDUSTRY COLLABORATION ZONES
INFORMAL MEETING

Perimeter Wall of Laboratory

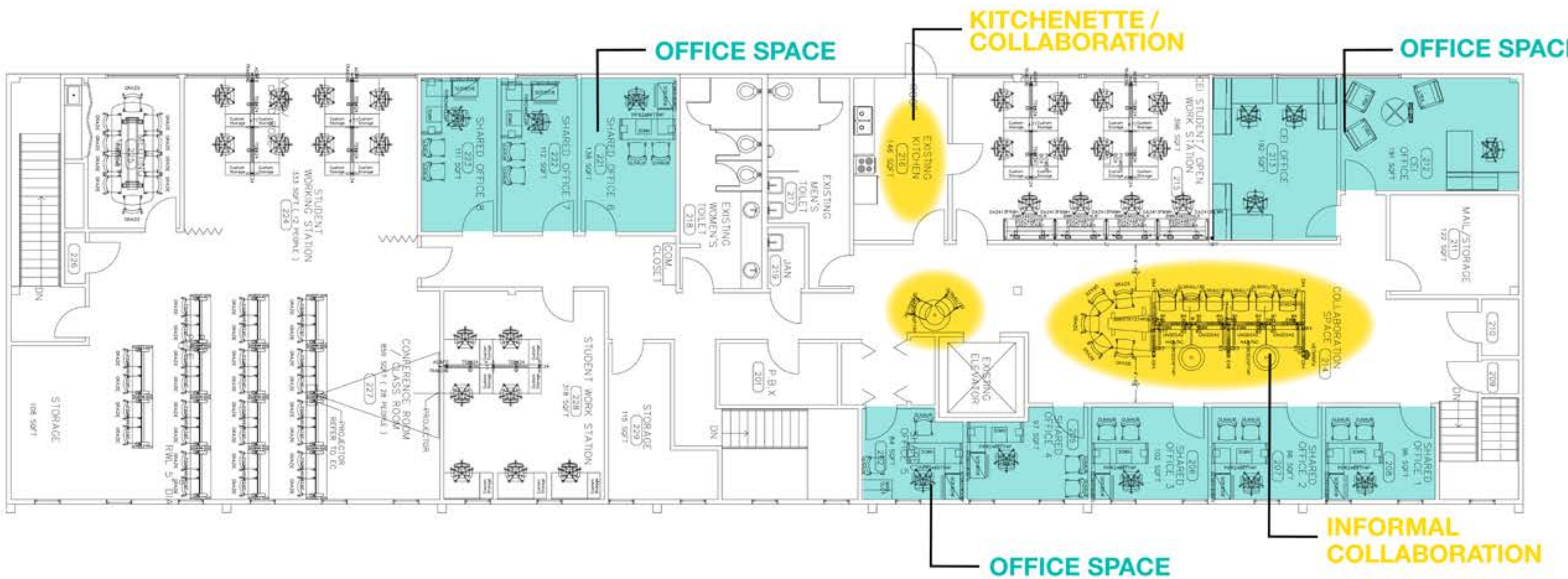
LEVEL 2



LEVEL 2

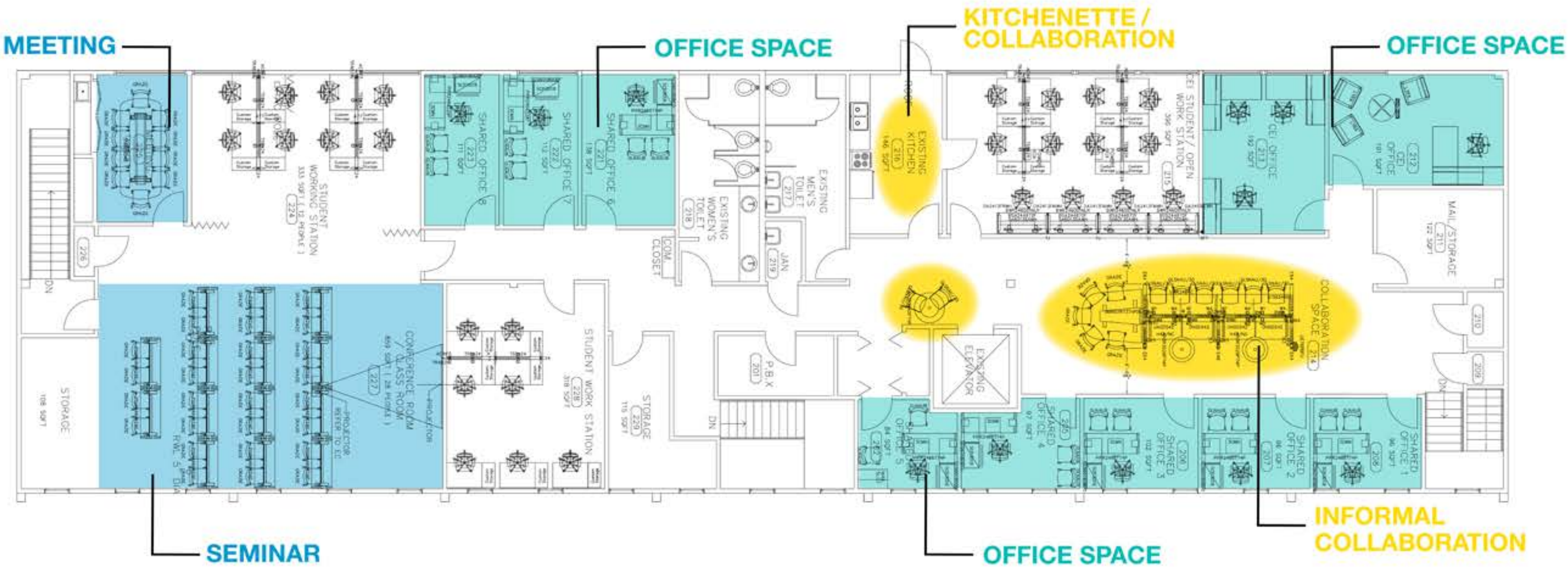


LEVEL 2

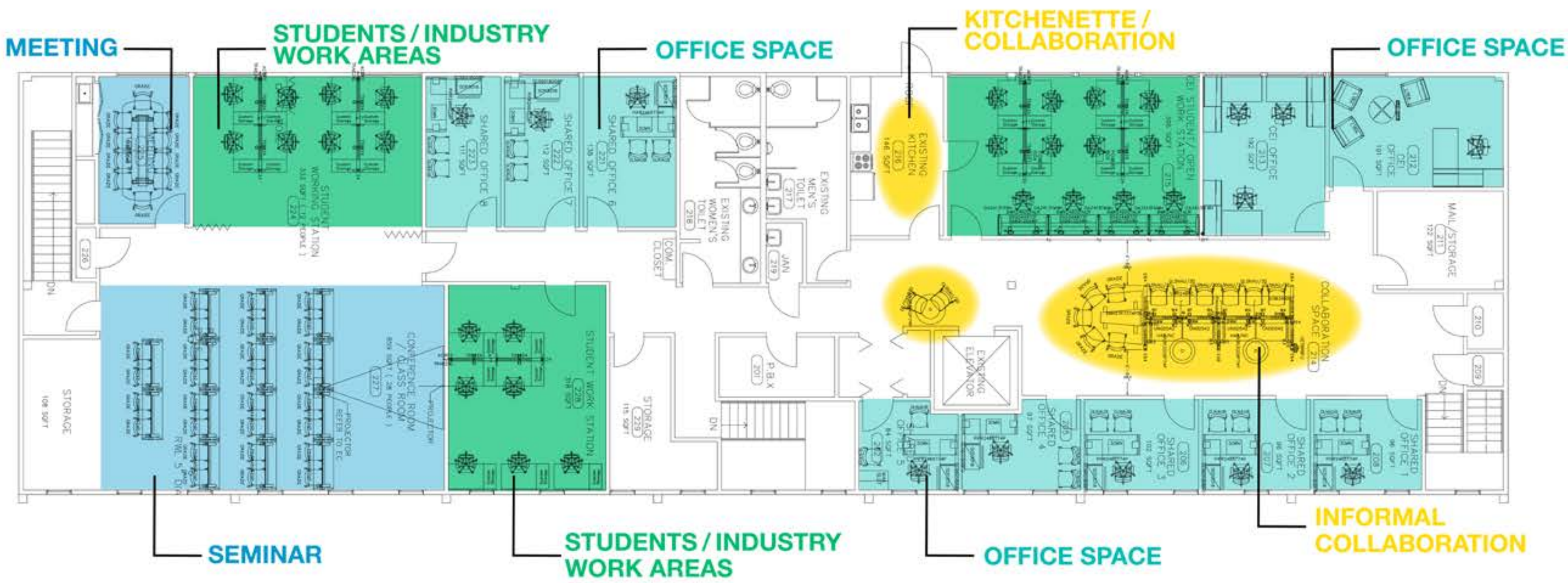


KITCHENETTE / COLLABORATION
OFFICE SPACE
OFFICE SPACE
OFFICE SPACE
INFORMAL COLLABORATION

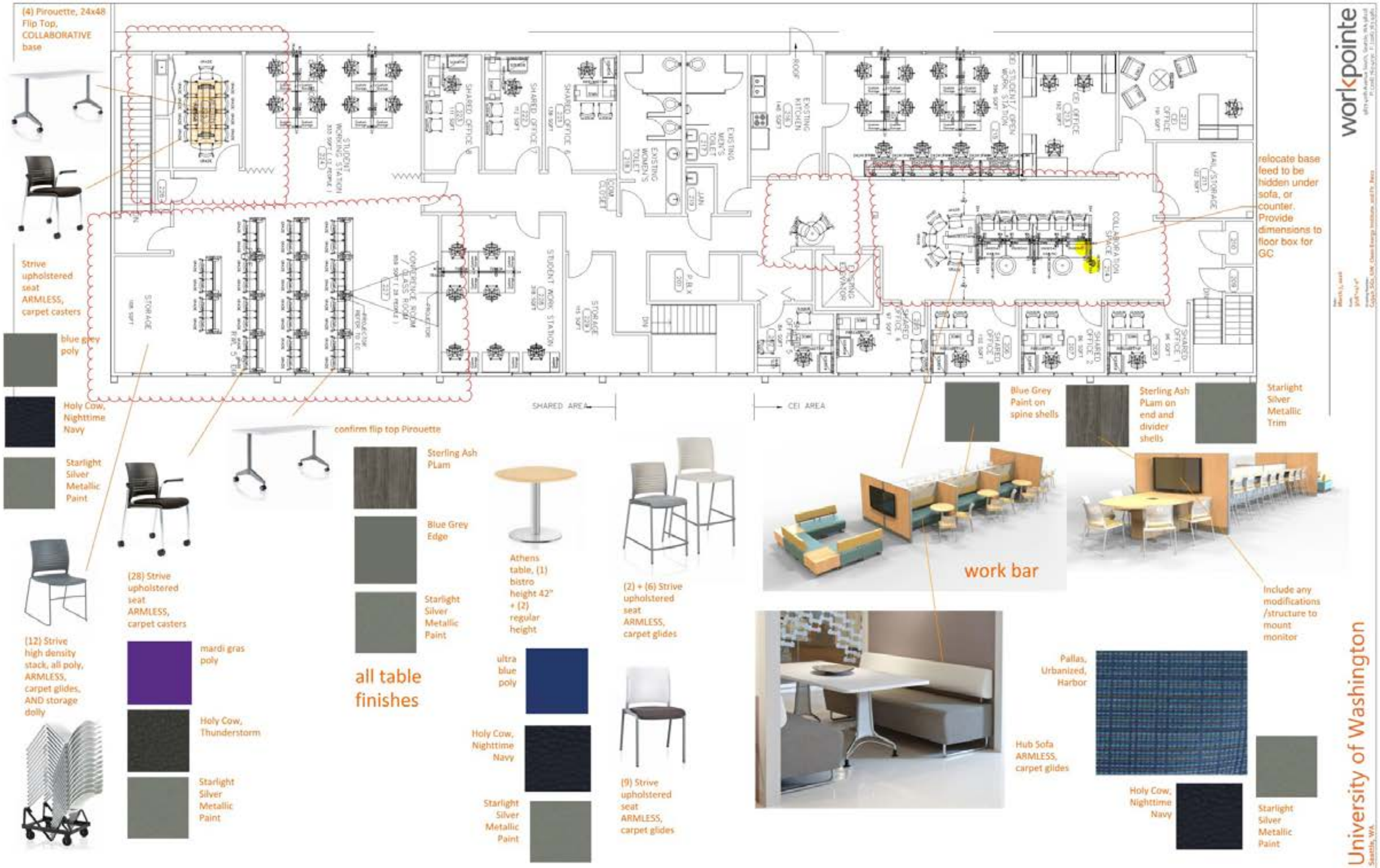
LEVEL 2


MEETING
OFFICE SPACE
KITCHENETTE / COLLABORATION
OFFICE SPACE
SEMINAR
OFFICE SPACE
INFORMAL COLLABORATION

LEVEL 2


MEETING
STUDENTS / INDUSTRY WORK AREAS
OFFICE SPACE
KITCHENETTE / COLLABORATION
OFFICE SPACE
SEMINAR
STUDENTS / INDUSTRY WORK AREAS
OFFICE SPACE
INFORMAL COLLABORATION

LEVEL 2 – Furniture



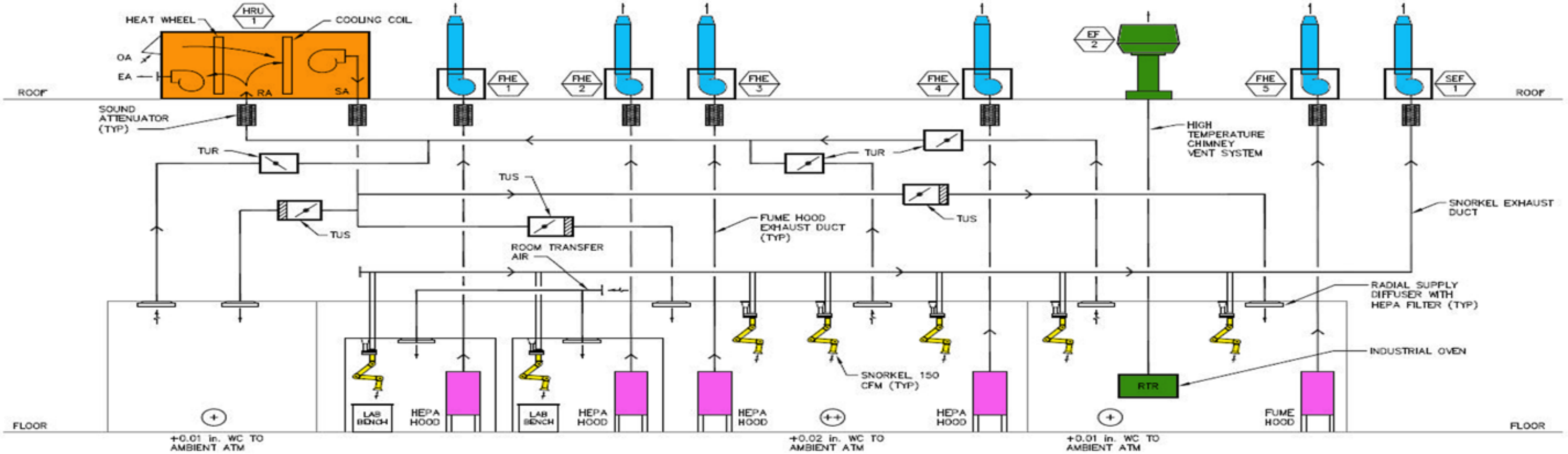
R2R Room &
Scale-up of Materials and Processing

Cell & Module Characterization

Flexible HVAC & Electrical Systems Design

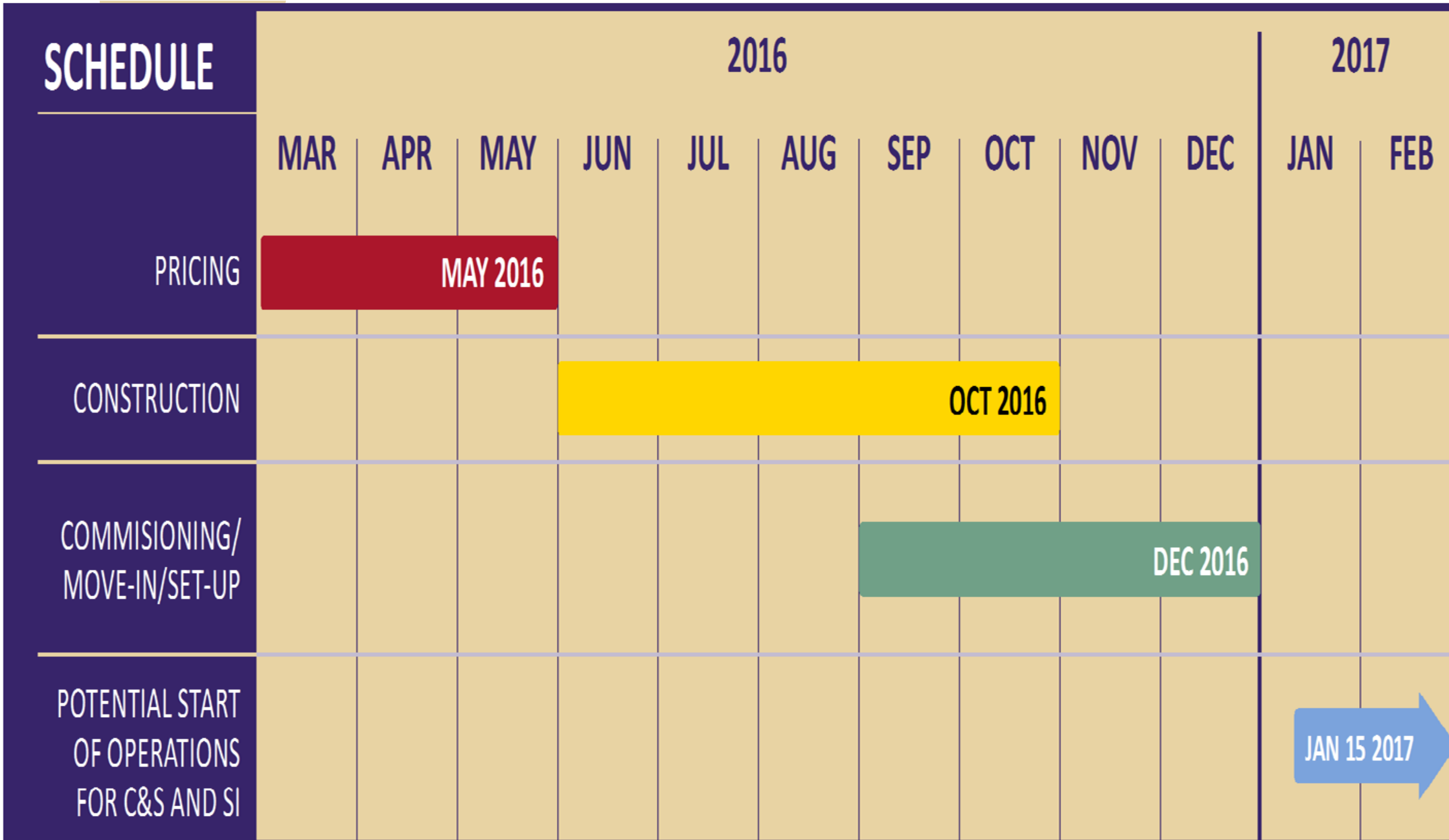
- Designed for fully utilized space
- Scaled back to meet start-up needs
- Minor adjustments to system as load changes

- Large cooling loads
- High ventilation rate requirements
- Heat Recovery



1 AIR FLOW DIAGRAM
NOT TO SCALE

Schedule


SCHEDULE
2016
2017
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
PRICING
MAY 2016
CONSTRUCTION
OCT 2016
COMMISIONING/
MOVE-IN/SET-UP
DEC 2016
POTENTIAL START
OF OPERATIONS
FOR C&S AND SI
JAN 15 2017

Team

Clean Energy Institute / University of Washington	Daniel T. Schwartz Dawn Lehman Ben Newton	Director Infrastructure Planning Real Estate Property Services
Kidder Mathews	Earl Wayman	Property Manager
Chernoff Thompson Architects	Russell Cherno Naomi Gross Sang Kim Eunha Kim	Principal Principal Intern Architect Designer
CG Engineering Ltd.	Joe Galusha	Structural Engineer
IES	Mike Dean Brian Hanson	Mechanical Engineer Mechanical Engineer
Stantec	Greg Glenwood	Electrical Engineer

CLEAN ENERGY INSTITUTE

Learn more and get involved!

Website: **www.cei.washington.edu**

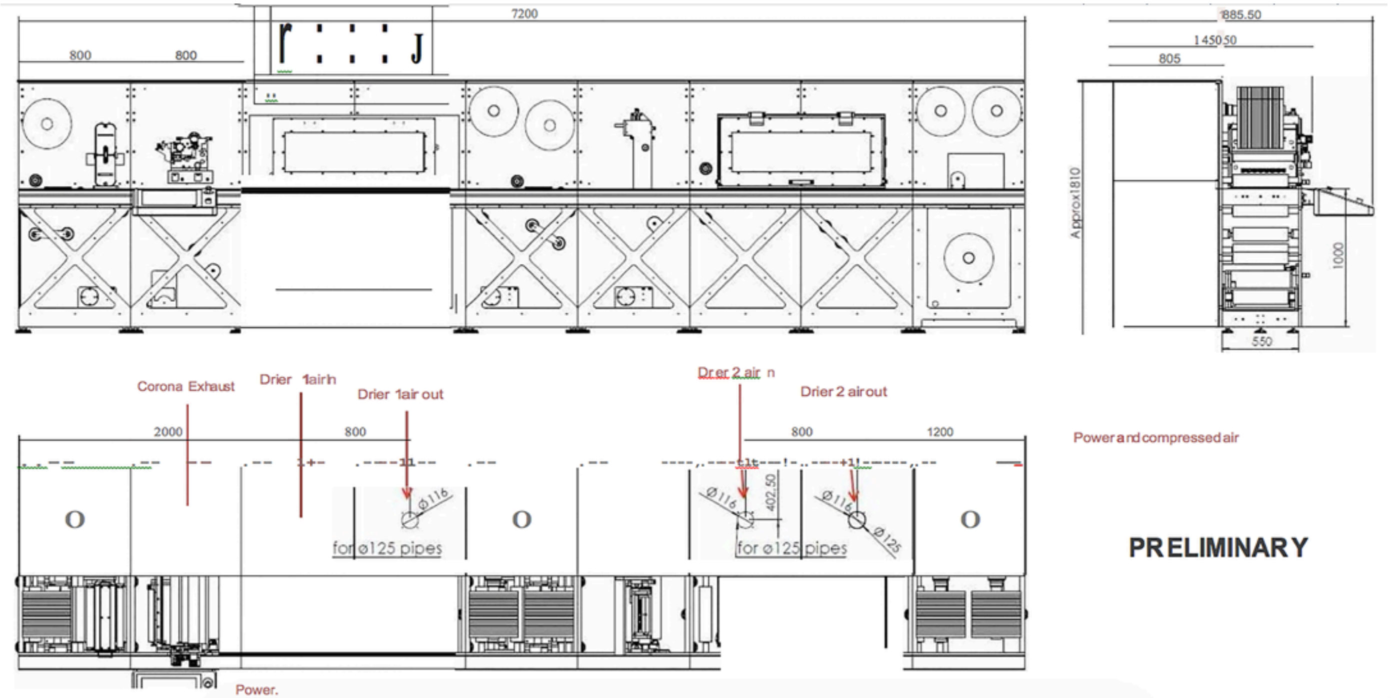
Email: **UWCEI@uw.edu**

Twitter: **@UW_CEI**

LinkedIn: **UW Clean Energy Institute**

Unique Equipment Requirements

- Unique equipment – 1st time application
- R2R voltage requirement 400 Volts
- Special high temperature exhaust connections
- Compressed air connections
- Nitrogen gas connection
- High ventilation rate requirement



Unique Equipment Requirements

POWER:

480V/100A,3 Phase+Neutral+PE (4 wire grounded Wye, drawing attached). 300mA RCCB recommended.

COMPRESSED AIR:

6 – 10 bar. Clean and dry. Non lubricated. ISO 8573-1:2010 Class 1.3.2 or better. Consumption: <25l/min.

08mm Festo connection.

AIRINPUT FOR DRIERS:

Dryer 1:012Smm connection.1000m³/hour. Dryer 2:012Smm connection.500m³/hour.

EXHAUST:

Dryer 1:0125mm connection. Min 1000m³/hour. Max 250 Pa backpressure. Dryer 2:0125mm connection. Min 500m³/hour. Max 250 Pa backpressure. Corona: 0125mm connection. Min100m³/hour. Max 250 Pa backpressure.

(assisting fan with pressure/vacuum feedback sensor is recommended if long ducting is connected to the machine.)