Developing and Managing a Laboratory Ventilation Management Plan (LVMP)

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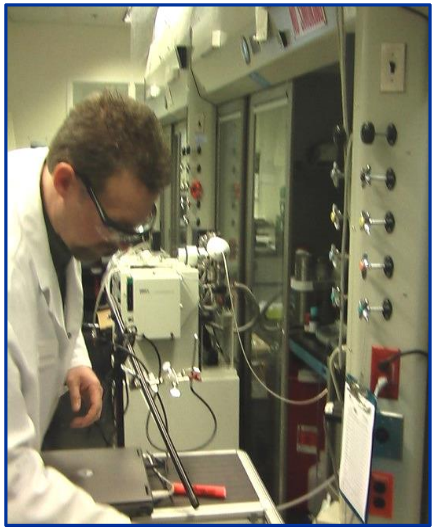
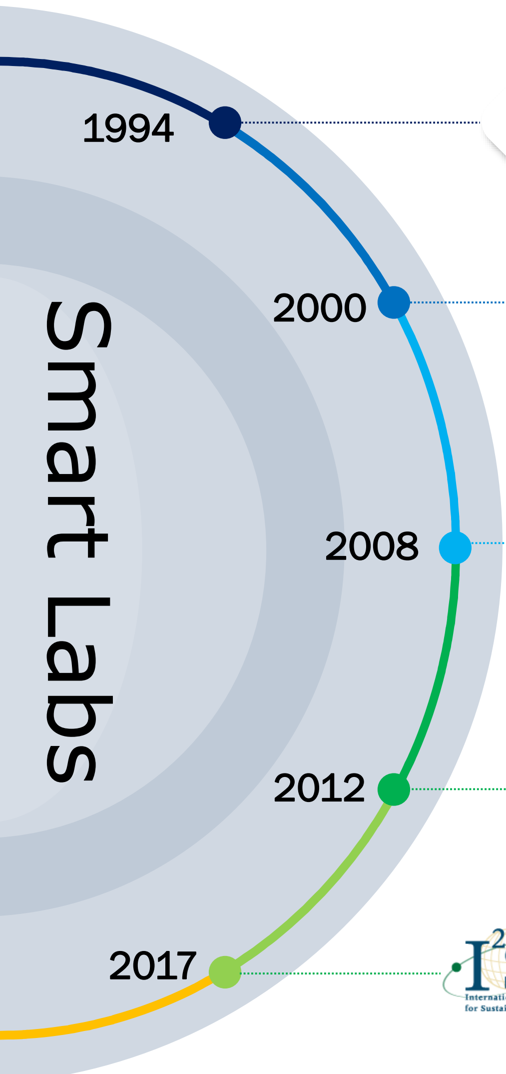
Agenda:

- What is Smart Lab?
- Ventilation Risk Assessments and Establishing ACR'S
- Demand for Ventilation
- Fume Hood Upgrades
- Labs are Dynamic - Managing Change and Staying Sustainable

Improve Safety, Minimize Waste and Facilitate Success in Critical Workplace Environments



Smart Labs™ evolved over 25 years



Exposure Control Technologies, Inc.

Founded to test laboratory fume hoods. Transformed to provide services and products to improve safety, reduce waste and help facilitate success.

U.S. EPA – Lab Controls Optimization Project

LCOP - Scalable and replicable program for optimizing lab safety and energy efficiency

UCI - Smart Labs™

Upgraded performance of lab buildings. Improved safety performance, occupant satisfaction and reduced energy use >50%

ANSI Lab Standards

Hazard Evaluation and Risk Assessment
Lab Ventilation Management Program

DOE Smart Labs Accelerator

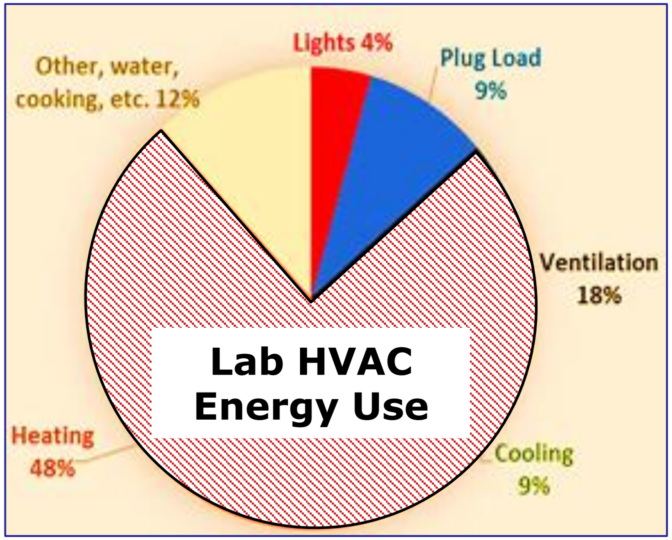
National partnership program based on success at EPA, UCI and elsewhere

Organizations can improve safety, reduce risk and operate more effectively.

- **Attract & retain top talent**
- **Ensure safety**
- **Minimize waste**
- **Improve sustainability**
- **Maximize resilience**
- **Accommodate change**
- **Mitigate risk**
- **Enhance return on investment**

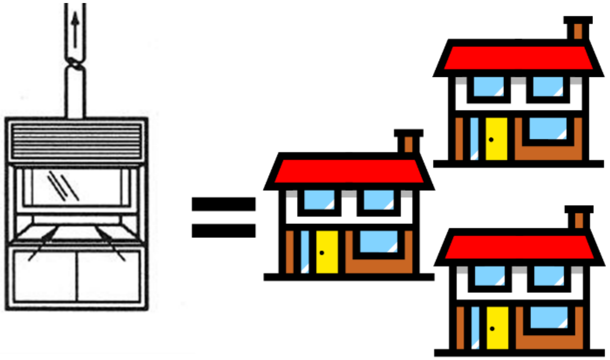
Laboratories are expensive and complicated

- Average Lab Size ≈ 100,000 ft^2
- Construction$_{(USA)}$ ≈ \$45 Million to \$100 Million
- Energy Cost ≈ \$700,000/year (Avg. \$7 per ft^2)



45% to 85% of the energy is consumed by Fume Hoods and the Lab HVAC Systems

- Lab HVAC and Fume Hoods ≈ 30% of Construction Cost
- Fume Hood Installation ≈ \$25,000 - \$50,000 each
- Fume Hood Annual Cost ≈ \$2,400 – \$5,000 per year



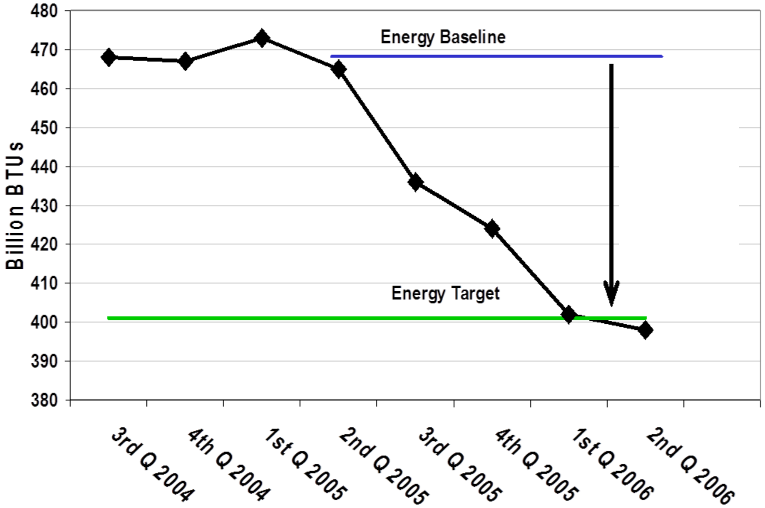
As much as <u>50% of HVAC energy is wasted</u> by excess airflow, inefficient fume hoods and improper modulation of flow

The goal is high performance Smart Labs

- **Effective**
  - Support research and development
  - Flexible to change
- **Safe**
  - Protect people from exposure
  - Compliance with standards
- **Efficient**
  - Minimum energy consumption
  - Minimum operating costs
- **Sustainable**
  - Minimum carbon footprint
  - Maintainable
  - Demonstrable Return on Investment

UCI Smart Lab

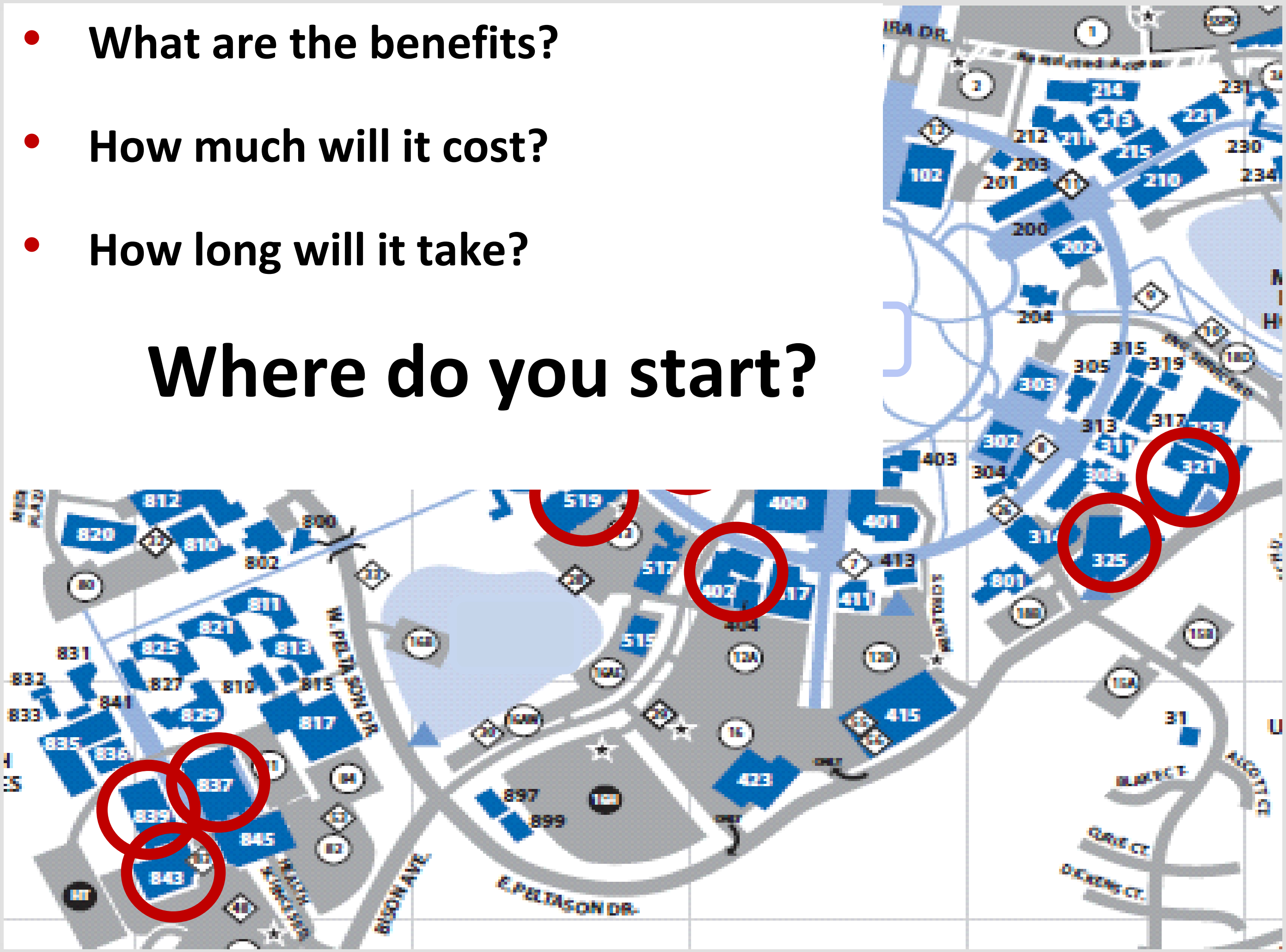
Campus Wide Aggregate Energy Reduction



You may have many buildings, limited budgets and competing interests

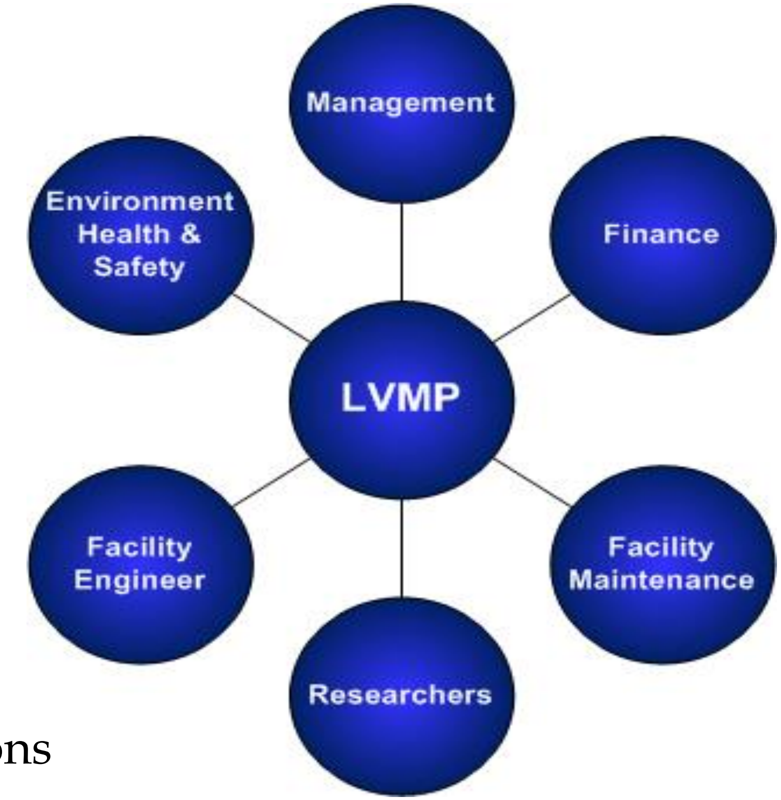
- What are the benefits?
- How much will it cost?
- How long will it take?

Where do you start?



Success requires a combination of efforts

- Design and Mechanical Attributes
  - High performance fume hoods
  - Variable Air Volume Systems
  - High efficiency mechanical systems
  - Building information and control systems
- Management and Leadership
  - Occupant Information and Floor Plans
  - Ventilation Safety Demand Assessment
  - System Diagrams and Airflow Specifications
  - Airflow Management Program (AMP)
  - LVMP Manager / Coordinator



Lab Ventilation Management Plan

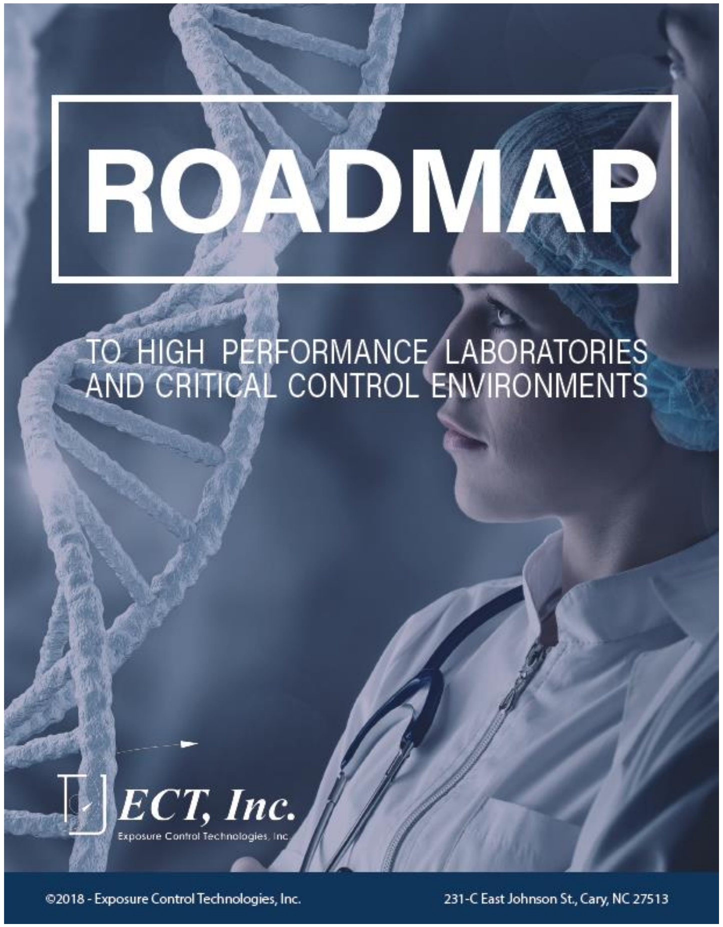
Success of Smart Labs™ at UCI

Laboratory Building		Before "Smart Lab" Retrofit			After "Smart Lab" Retrofit		
Name	Type*	Estimated Avg. ACH	VAV or CV	Was more efficient than code?	kWh Savings	Therm Savings	Total Savings
Croul Hall	P	6.6	VAV	~ 20%	41%	60%	55%
McGaugh Hall	B	9.4	CV	no	40%	66%	47%
Reines Hall	P	11.3	CV	no	70%	76%	72%
Natural Sciences II	P, B	9.1	VAV	~ 20%	48%	62%	50%
Biological Sciences 3	B	9	VAV	~ 30%	45%	81%	60%
CALIT2	E	6	VAV	~ 20%	46%	78%	62%
Gillespie Neurosciences	M	6.8	CV	~ 20%	58%	81%	61%
Sprague Hall	M	7.2	VAV	~ 20%	58%	82%	71%
Hewitt Hall	M	8.7	VAV	~ 20%	58%	77%	69%
Engineering 3	E	8	VAV	~ 30%	59%	78%	61%
Averages	–	8.2	VAV	~ 20%	**55%**	**76%**	**58%**

Even the most well designed and well maintained buildings will degrade over time!


The Roadmap to High Performance Labs
and Critical Control Environments

Achieving high performance labs and critical control environments requires a process



I. Strategic Planning

II. Team Responsibilities and Training

III. Systems Theory

IV. Implementation

   A. Phase 1A - Plan

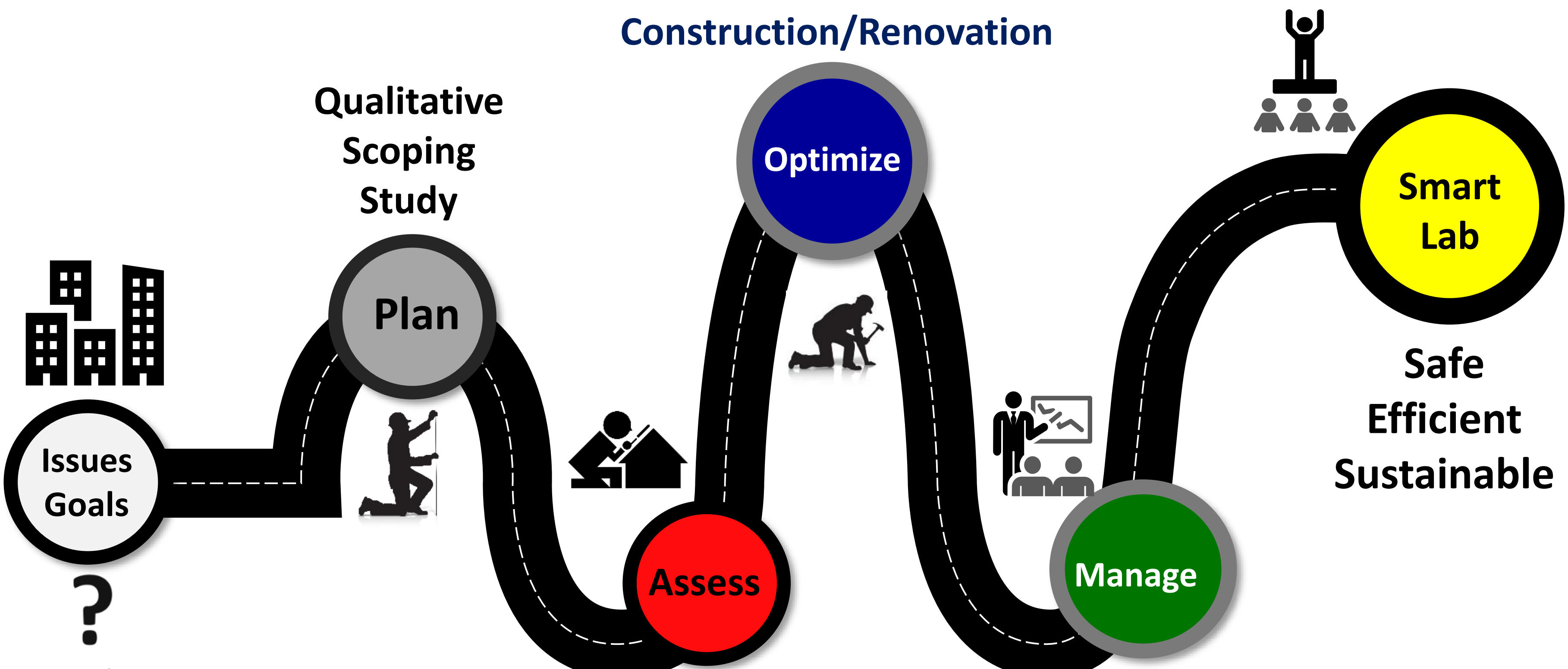
   B. Phase 1B - Assess

   C. Phase 2 – Optimize

   D. Phase 3 - Manage

V. Management Plan

Smart Labs™ provides a roadmap to success



- Safety
- Energy Efficiency
- Lab Conditions
- Operating Costs
- Deferred Maintenance
- Reliability

Coordination of stakeholders is the key to achieving sustainable, high performance, Smart Labs

Leadership, Coordination and Collaboration

Management

Research

Environmental Health & Safety

Engineering

Maintenance

Space Planning

Purchasing

- Common Objectives
- Realistic Goals
- Teamwork

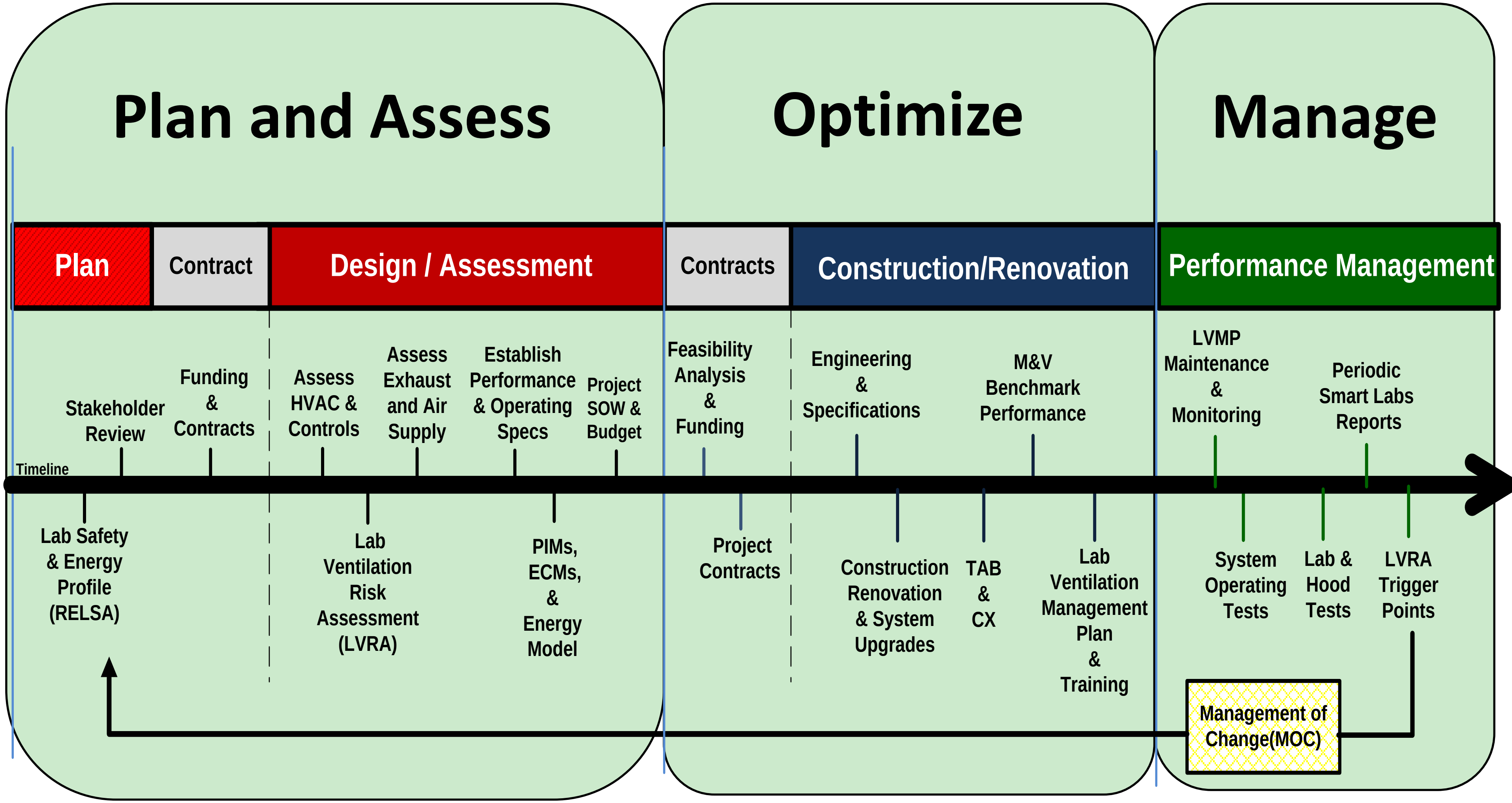
Smart Labs™ Optimization Process

A replicable and scalable process that combines services and products to achieve safe, energy efficient and sustainable laboratories.

1. Planning and Assessment
2. Systems Optimization
3. Performance Management

Plan → Assess → Optimize → Sustain

Roadmap to Smart Labs™
High Performance Ventilation Systems



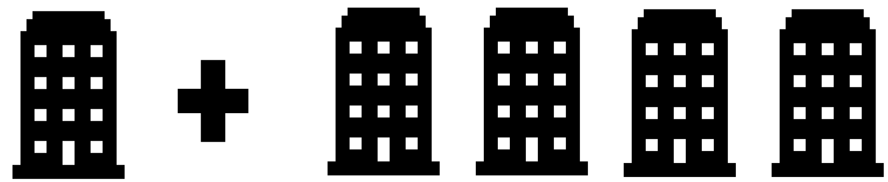
Smart Labs™ - Phased Implementation

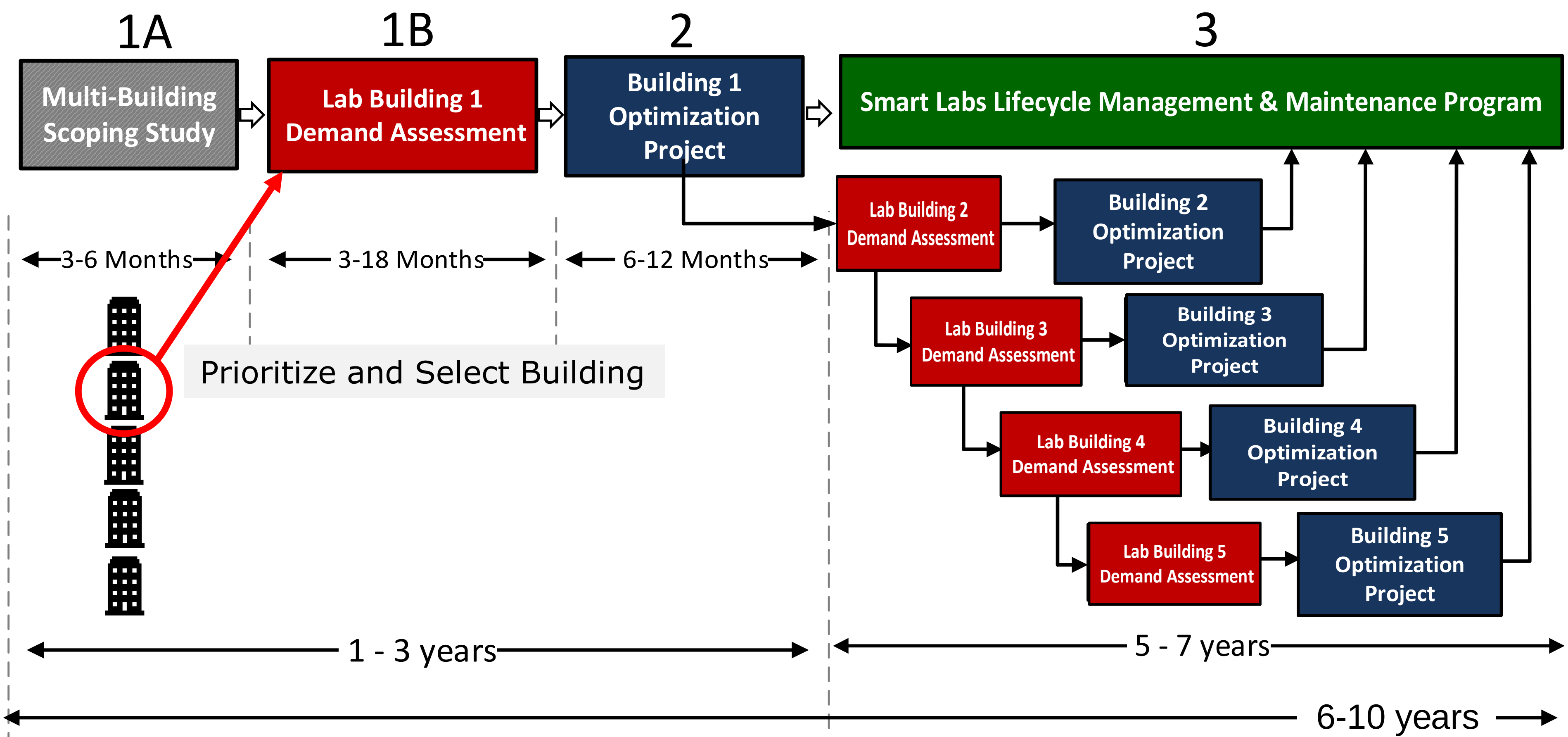
1A - Plan

1B - Assess

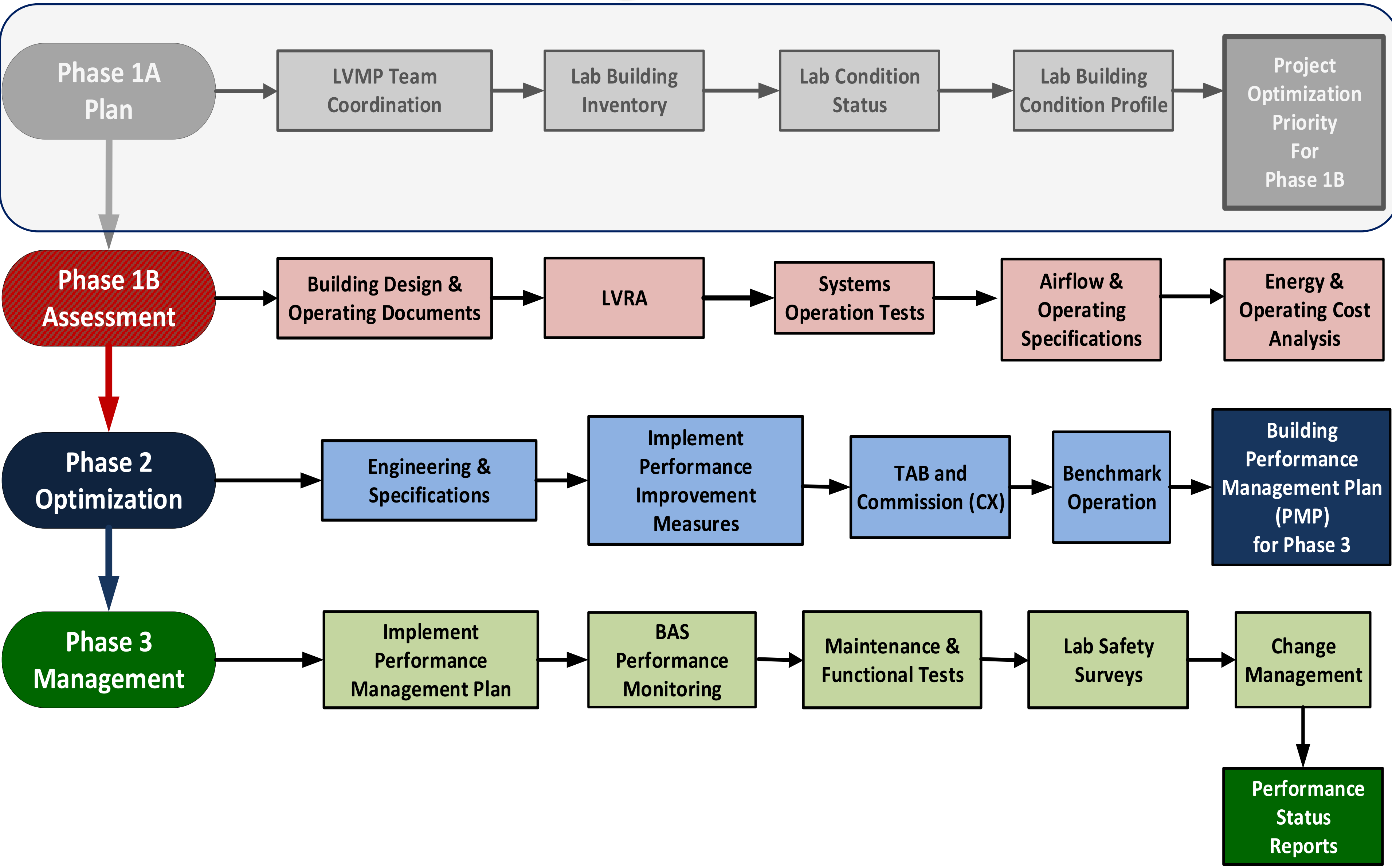
2 - Optimize

3 - Manage

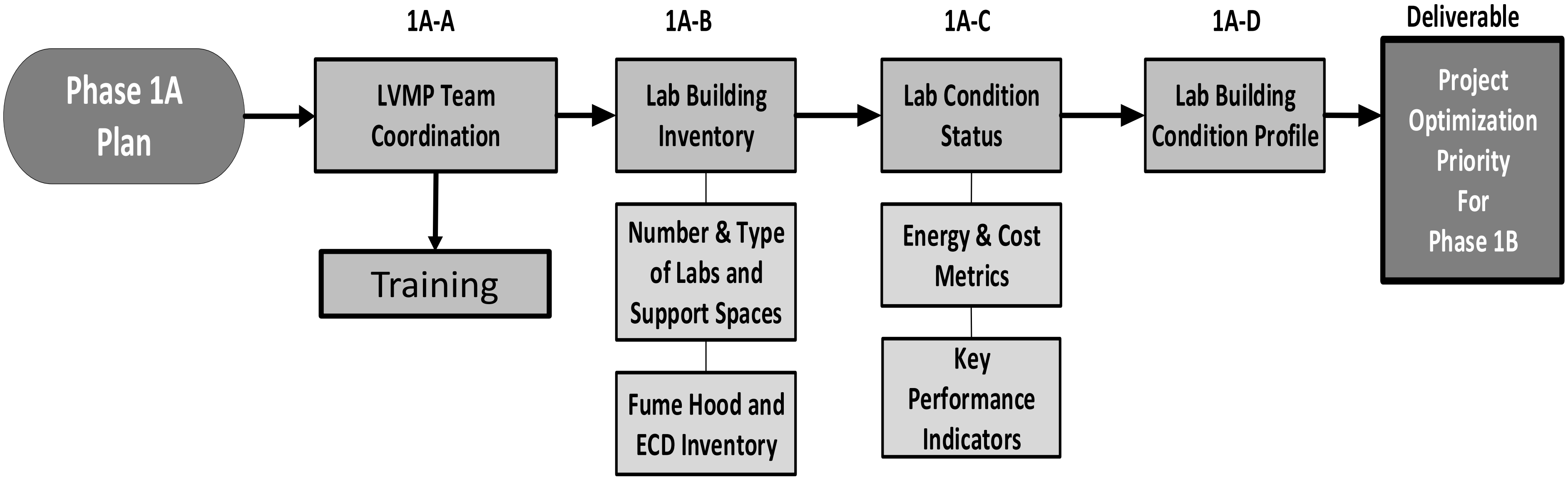




Roadmap to High Performance Labs



Roadmap to High Performance Labs

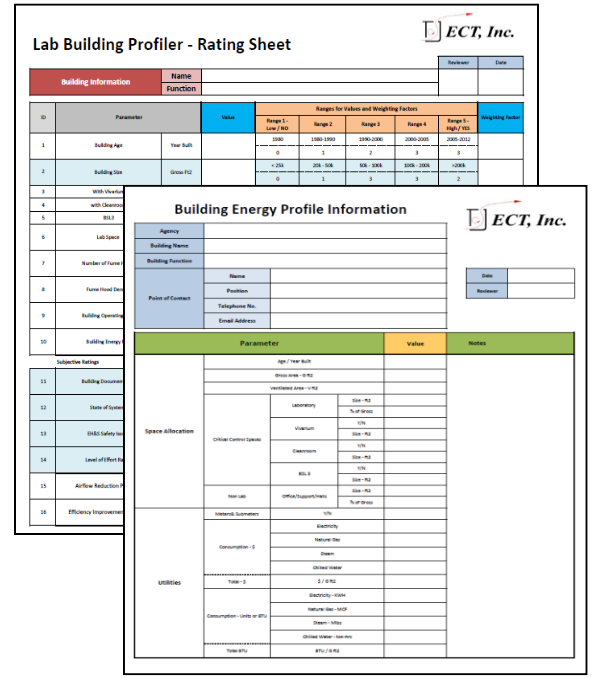


Qualitative Scoping Study

- 1A-A Assemble Team of Stakeholders and Provide Training
- 1A-B Inventory and Survey Lab Buildings
- 1A-C Assess Condition of Labs and Determine Key Performance Indicators
- 1A-D Appraise and Profile Lab Buildings
- Deliverable: Select lab buildings and prioritize projects

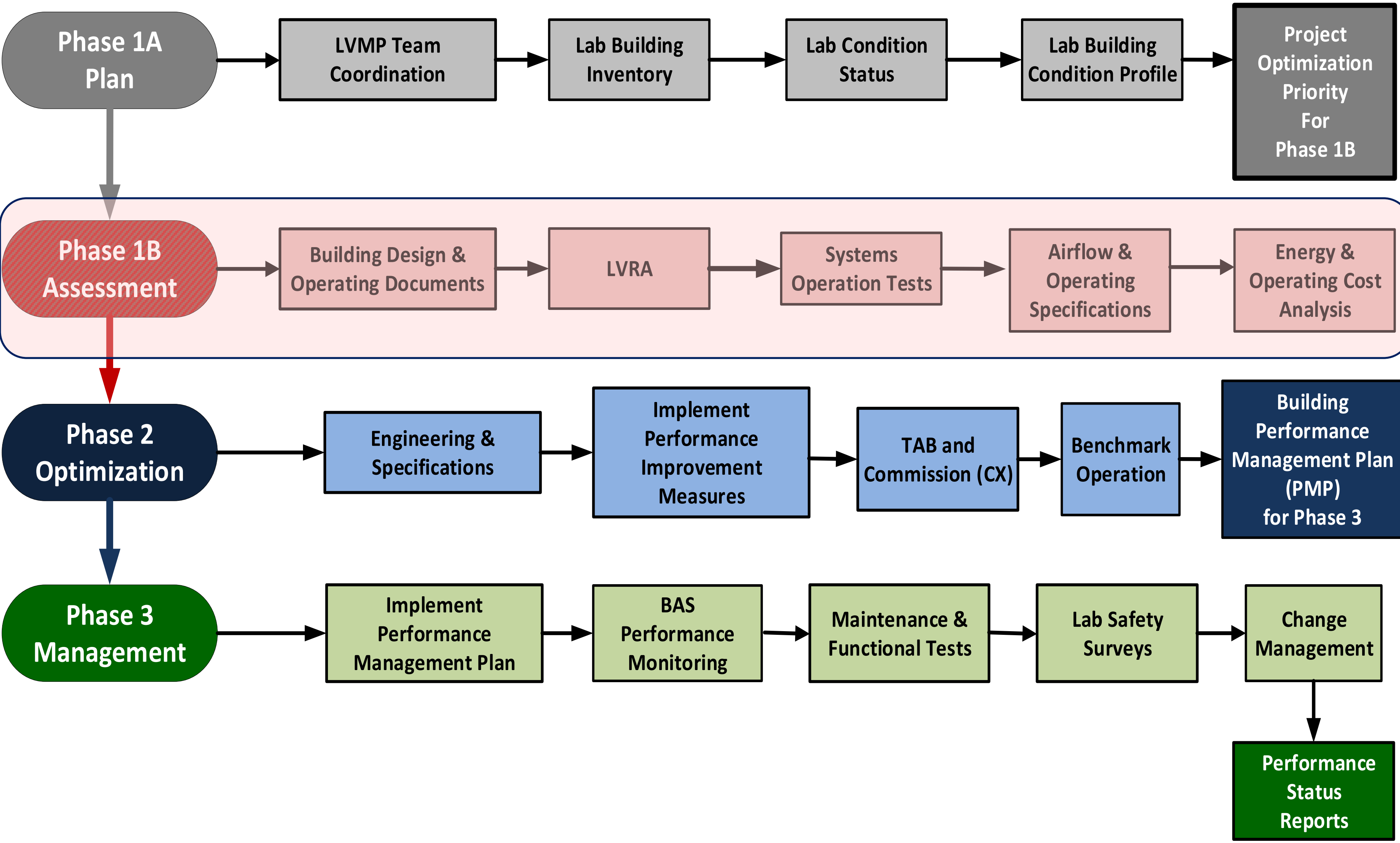
Qualitative Scoping Study

- **Facility and Building Qualifying Tool**
  - Select & Prioritize Best Projects First
- **Key Performance Indicators**
  - Size & Space Allocation
  - Energy Use & Operating Costs
  - State of the Systems
  - Energy Reduction Potential
- **Building Profile Report**
  - Classification and Categorization
  - Potential for Energy Reduction
  - Estimated Level of Effort, Project Costs & Potential Payback

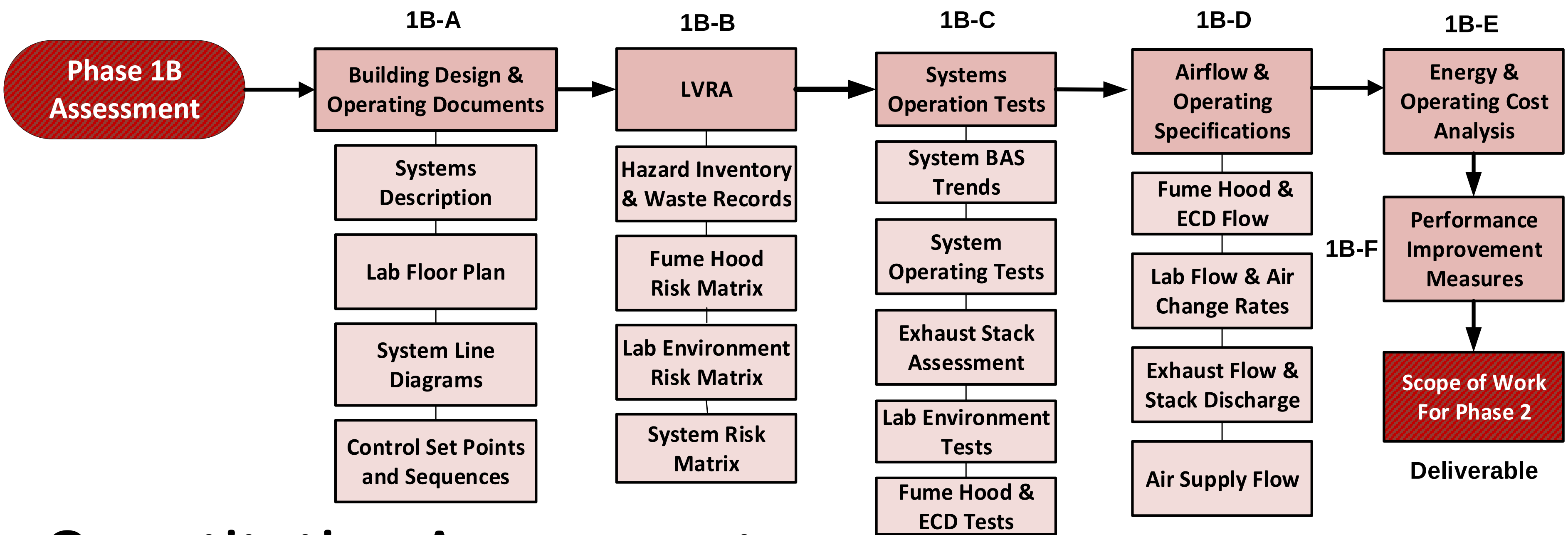


Attribute	Lab Building Profile Category			
• **Health and State of the Systems** • **Energy Reduction Potential** • **Project LOE & Complexity** • **Return on Investment (Payback)**	Class A	Class B	Class C	Class D

Roadmap to High Performance Labs



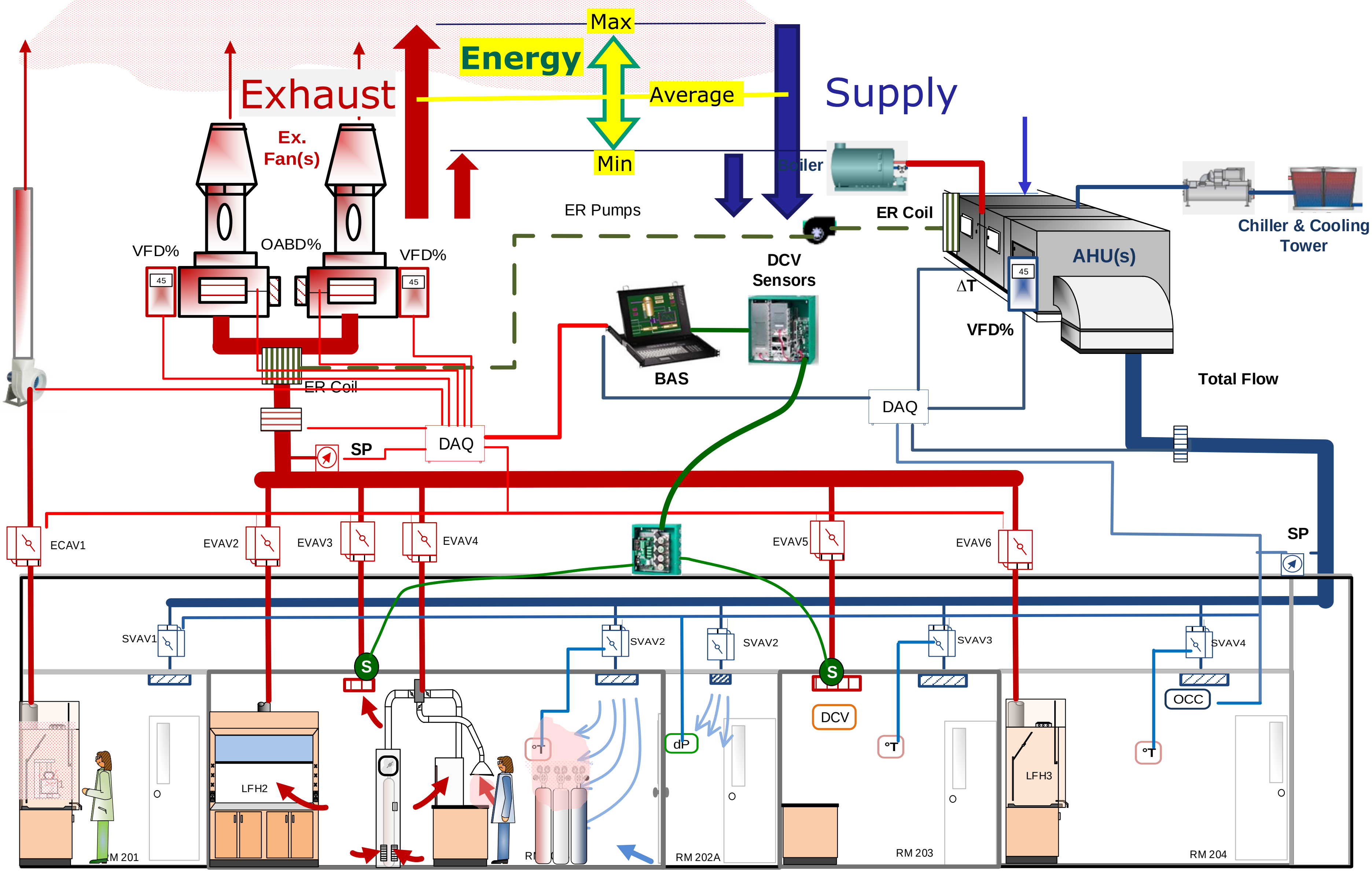
Roadmap to High Performance Labs



Quantitative Assessment

- 1B-A Assemble building design and operating documents
- 1B-B Conduct Lab Ventilation Risk Assessment
- 1B-C Conduct System Operating Tests to evaluate current operation
- 1B-D Develop airflow specifications for each system
- 1B-E Energy Model and Analysis
- 1B-F Determine Performance Improvement Measures
- Deliverable: Scope of Work for Phase 2 Optimization

Ventilation drives both safety and energy use

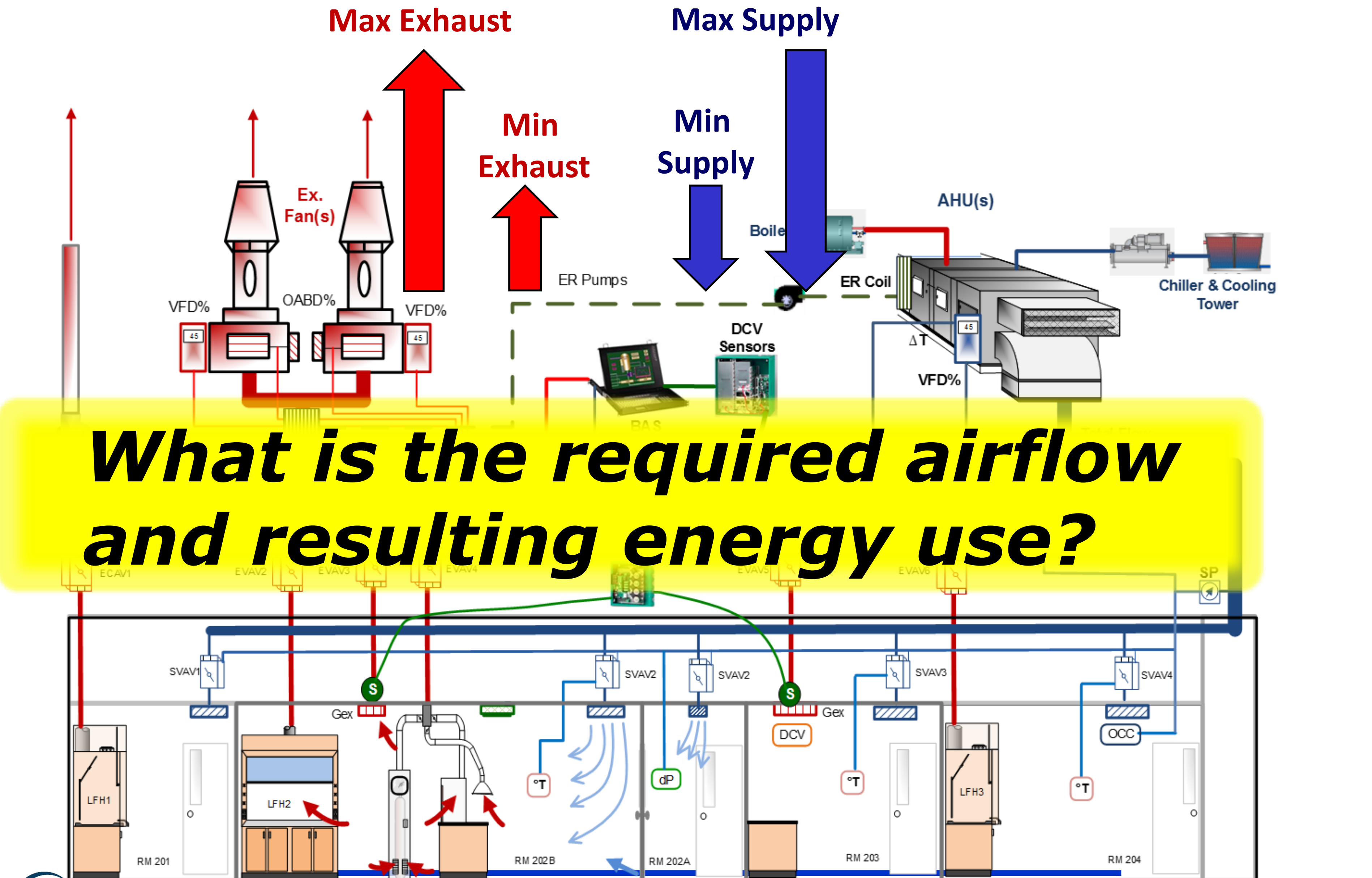


Different types of labs have different design and operating requirements

- Chemical Labs
- Biology Labs (BSL $_{2\text{-}4}$)
- Radiological Labs
- Nanotechnology Labs
- Clean Rooms
- Equipment Labs

Risk + Functional Requirements = Demand for Ventilation

Optimize Airflow Control and Energy Consumption



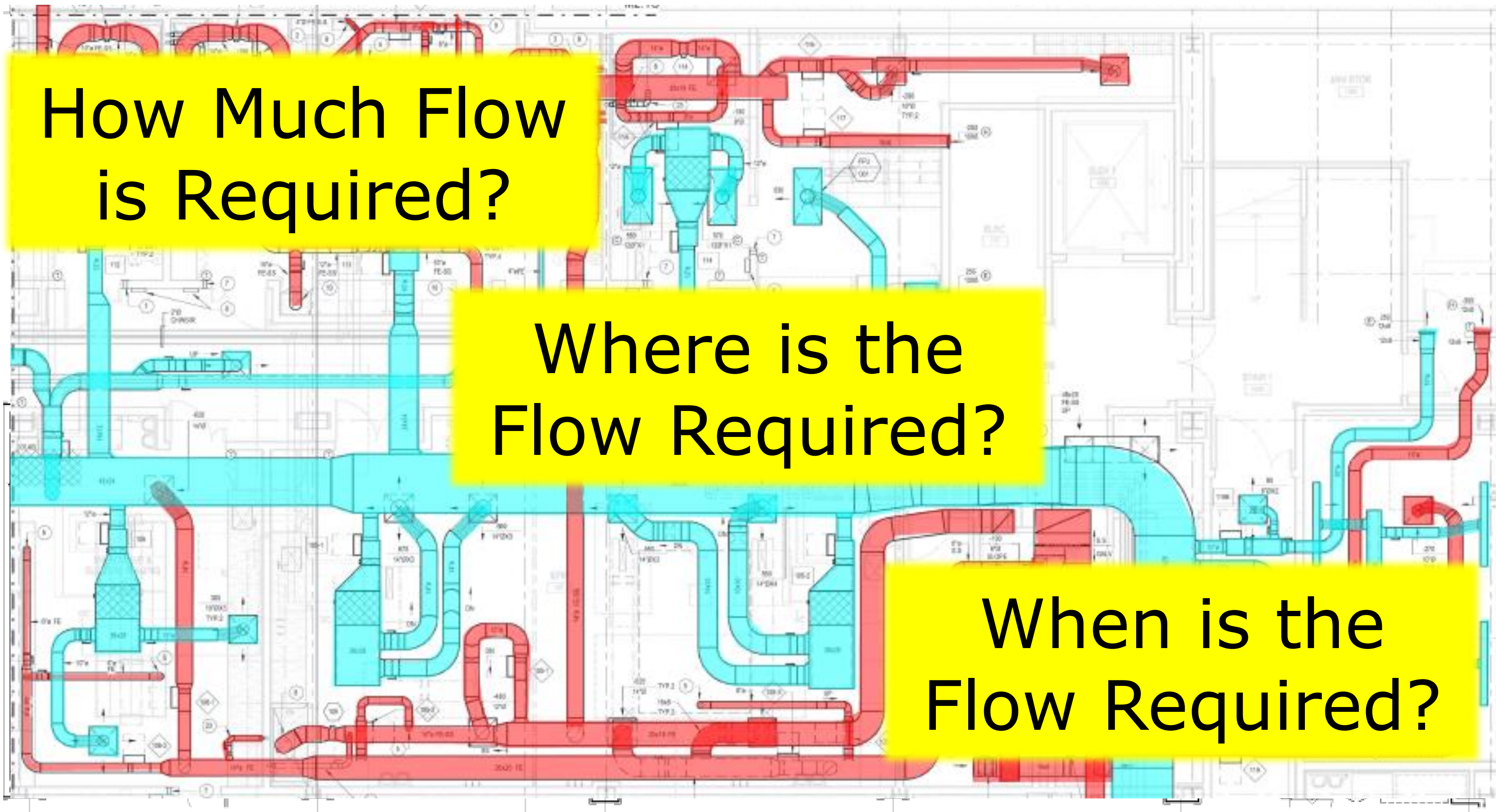
What is the required airflow and resulting energy use?

The Demand for Ventilation establishes the design and operating requirements

- **Safety (Risk)**
  - Fume Hood Flow
  - Contaminant Removal (ACH)
  - Isolation (Lab Pressurization)
- **Comfort & Productivity**
  - Temperature
  - Humidity
- **Occupancy & Utilization**

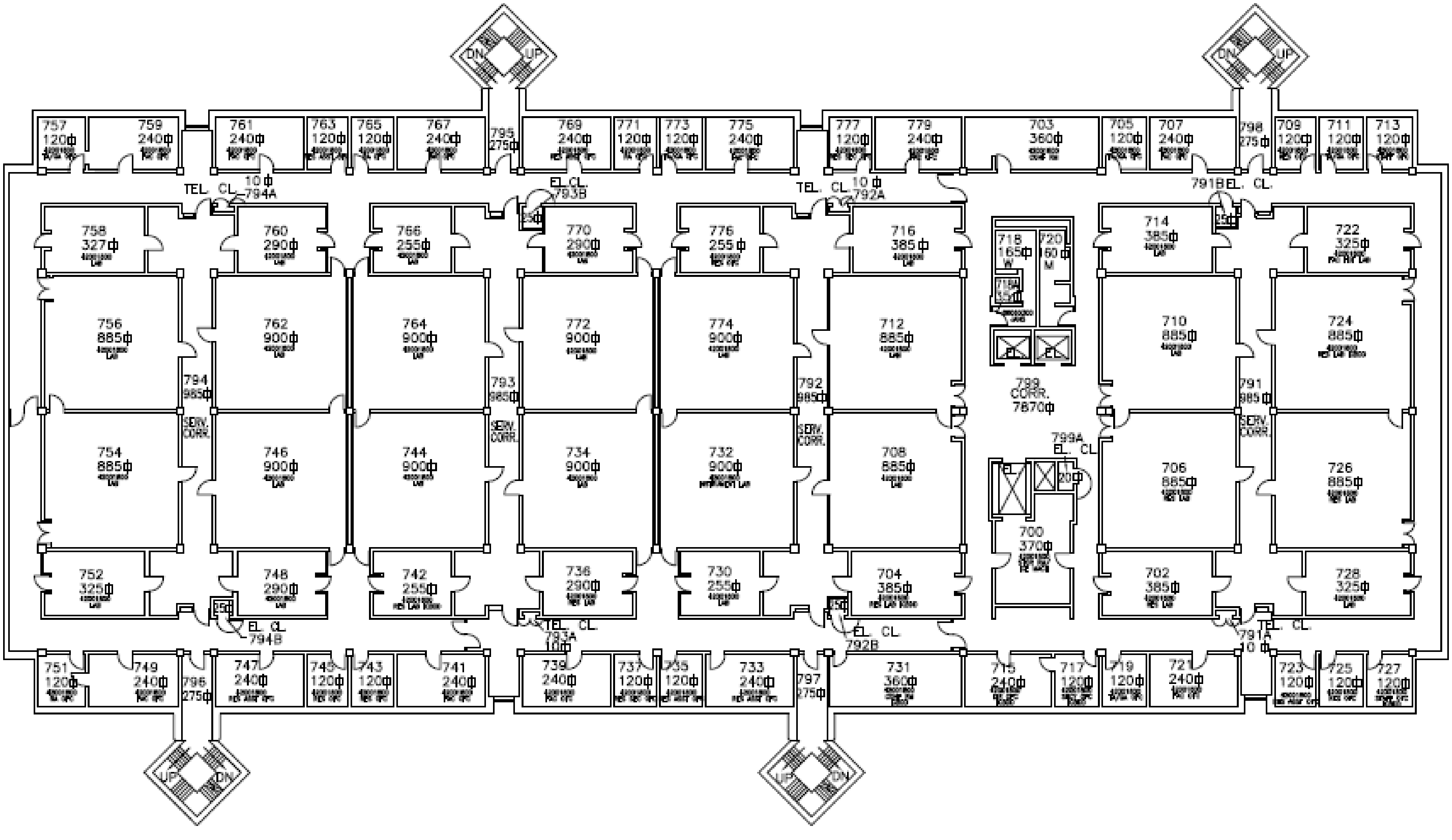
Minimum flow and range of modulation required to meet the functional requirements of the occupants

Achieving proper distribution or airflow requires establishing proper airflow specifications.



Laboratory Ventilation Risk Assessment (LVRA)

Where's the risk? What flow is required?



The LVRA categorizes risk using control bands based on Hazard Emission Scenarios

Risk Control Band	Description
0	**Negligible**
1	**Low**
2	**Moderate**
3	**High**
4	**Very High**
5	**Extreme**

<u>Hazard Emission Scenario</u>

- Exposure Limit (concentration)
- Quantity
- Generation Rate
- Concentration Profile

Rating of risk factors enables RCB assignment

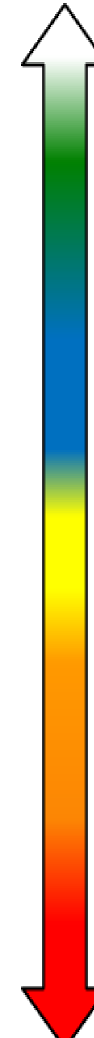
Total Score	Control Band	Description
< 16	0	Negligible
16-40	**1**	Low
41-64	**2**	Moderate
65-88	**3**	High
89-120	**4**	Very High
121-160	**5**	Extreme








Negligible



Extreme

Risk Factors and RCBs differentiate labs and identify areas of concern

Airflow specifications are recommended according to the RCB and validated prior to use

Laboratory Environment Specifications	Risk Control Band					
	0	**1**	**2**	**3**	**4**	**5**
Minimum Effective Occupied ACH (1)	N/A	**2**	**4**	**6**	**8**	**10**
Minimum Effective Unoccupied ACH (2)	N/A	1	2	3	4	N/A
Recirculation of Lab Air	**Yes**	**Yes**	**Filtered**	**Internal**	**Internal**	**No**
Lab Pressure "w.g.	Neutral	Neutral	**< -0.005**	**< -0.01**	**< -0.05**	**= > -0.05**
Room Monitor	N/A	N/A	N/A	Review	**Yes**	**Yes**
Airlock/Vestibule	N/A	N/A	N/A	N/A	N/A	**Yes**
Enthalpy Wheels	Yes	Yes	Review	No	No	No
Emergency Purge	No	No	No	No	Review	Yes
Ventilation Effectiveness (VEFF) (3)	<= 2	< =1.5	<= 1	< 1	< 1	< <1

Risk Control Bands

Alleviating Risk Through Optimization

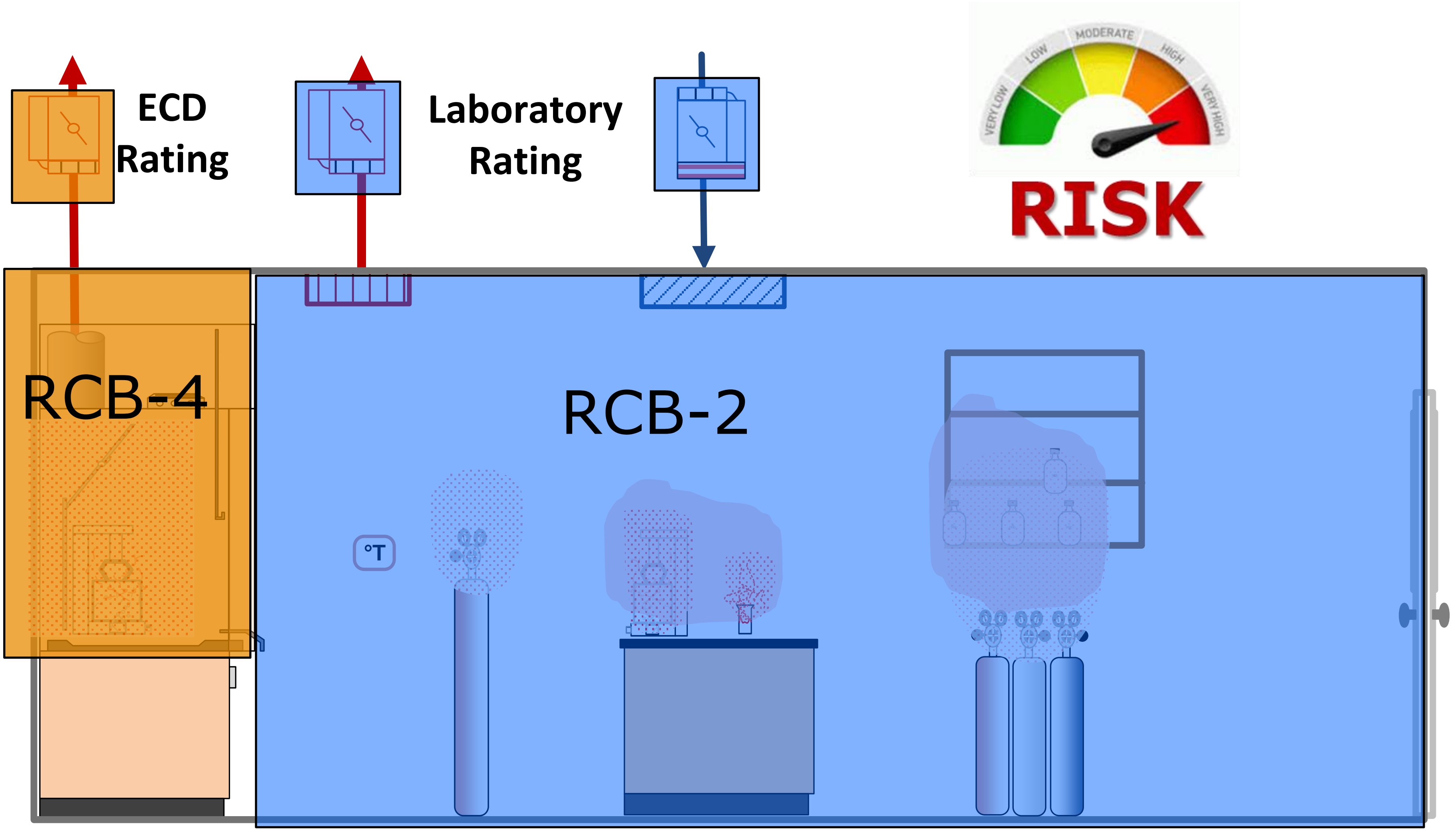
Lab Environment - Control Band Parameters

Lab	Hazard Rating	Material Quantity	Generation Potential	Generation (M, E, I, C)	Generation Locations	ECD Availability	Appropriate ECDs	Dynamic	Housekeeping	Air Change Effectiveness	Control Band	Min. ACH
	7	2	12	1	2	1	1	2	1	3		
503	3	3	3	4	4	1	1	1	2	2	**3**	8
504	5	5	2	5	5	1	1	2	4	4	**4**	10
505	4	3	2	4	5	1	1	1	3	4	**4**	10

Lab Environment - Control Band Parameters

Lab	Hazard Rating	Material Quantity	Generation Potential	Generation (M, E, I, C)	Generation Locations	ECD Availability	Appropriate ECDs	Dynamic	Housekeeping	Air Change Effectiveness	Control Band	Min. ACH
	7	2	12	1	2	1	1	2	1	3		
503	3	3	3	4	4	1	1	1	2	2	**3**	8
504	5	5	2	5	5	1	1	2	4	[illegible]	**4**	10
505	4	3	2	4	5	1	1	1	3	1	**3**	8
506	2	2	3	4	4	1	1	2	2	4	**3**	8
507	2	3	2	5	4	1	1	1	2	4	**3**	8
508	3	3	1	5	2	1	1	2	2	2	**2**	6
508A	1	1	1	5	1	1	1	1	2	4	**2**	6
509	4	4	2	5	4	1	1	2	2	4	**4**	10

The LVRA applied to ECDs and Labs can be used to optimize performance of the airflow systems

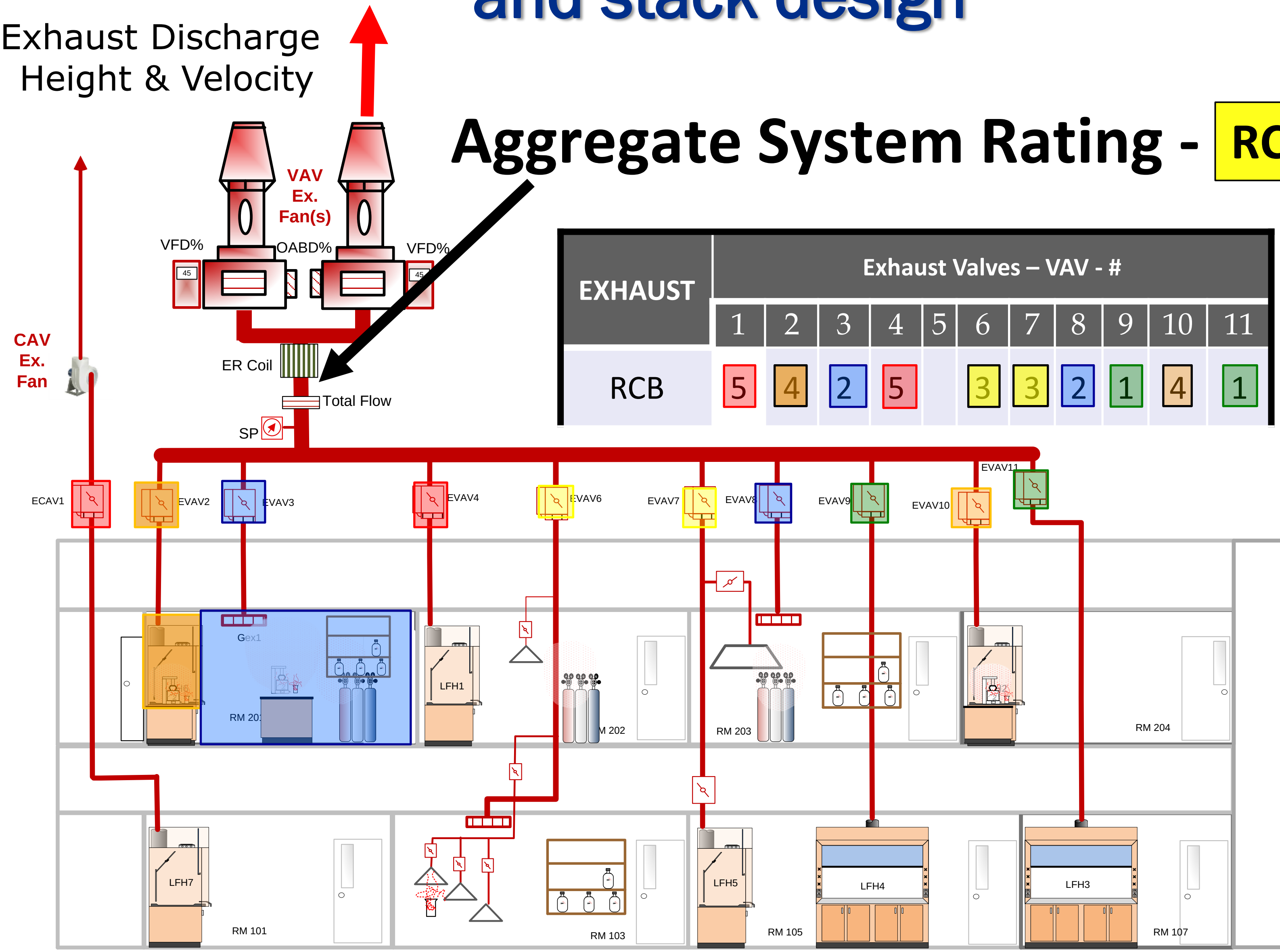


Risk ratings can be used to optimize exhaust fan and stack design

Exhaust Discharge Height & Velocity

Aggregate System Rating - RCB-3

EXHAUST	Exhaust Valves – VAV - #										
	1	2	3	4	5	6	7	8	9	10	11
RCB	5	4	2	5		3	3	2	1	4	1



Demand determines the airflow specifications

Room Information								Supply		Transfer Flow	Exhaust						Resultant ACH	
											Hood ID	Open Area - ft2	Qex for Exhaust Devices		Room Exhaust Flows – Max/Min based on Exh Devices, dP, Cond., or ACH			
Room #	Room Name	Area (ft²)	Height (ft)	Volume (ft³)	Room Type	Heat Load Label	Control Band #	Room Flow @ Max (cfm)	Room Flow @ Min (cfm)	Greater of Door and 10% Max Exh (cfm)			Qex at FV	Sash Closed - Unoccupied	Room Max Flow (cfm)	Room Min Flow (cfm)	Max ACH	Min ACH
728	Research Lab	325	9.0	2925	Stg	N	2	193	193	100	FH - CAV	7.9	792	146	293	293	6	6
											FH - CAV	7.9	792	146				
730	Research Lab	385	8.8	3369	Lab	N	4	1433	1433	150	FH - CAV	7.9	792	792	1583	1583	28	28
											FH - CAV	7.9	792	792				
732	NMR	900	14.5	13050							FH - CAV	7.9	792	792	4222	4222	19	19
											FH - CAV	7.9	792	792				
											FH - CAV	7.9	792	792				
											FH - CAV	18.5	1847	1847				
734	Research Lab																	27
736	Research Lab																	11
742	Research Lab																	26
744	Research Lab																	27
											FH - CAV	18.5	1847	1847				
746	Research Lab	900	14.5	13050	Lab	N	4	5231	5231	575	FH - CAV	7.9	792	792	5806	5806	27	27
											FH - CAV	18.5	1847	1847				

Risk Control Band

Airflow Specs

Design Flow

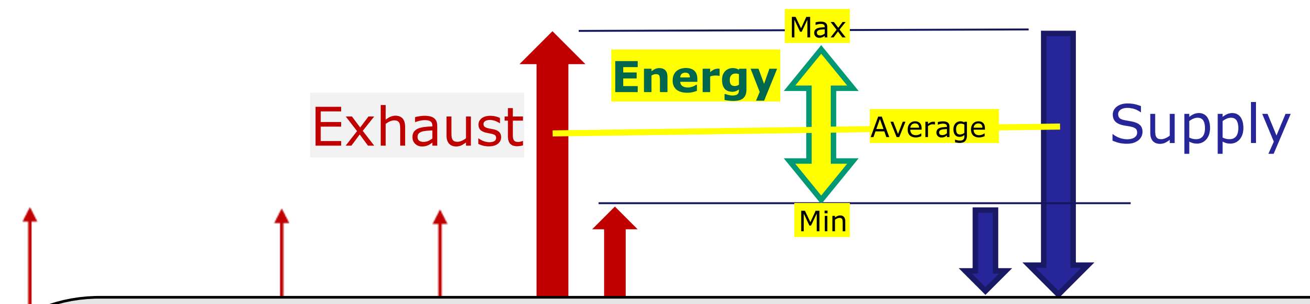
or

Theoretical Flow Requirements

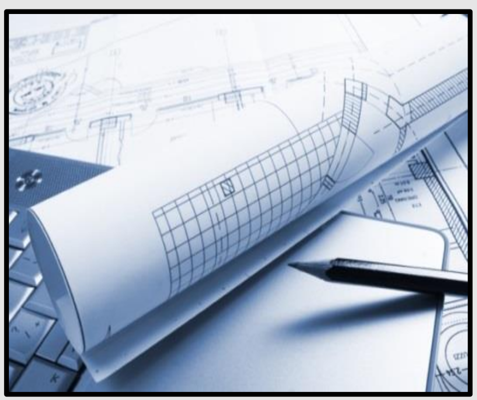
Min and Max Supply Flow

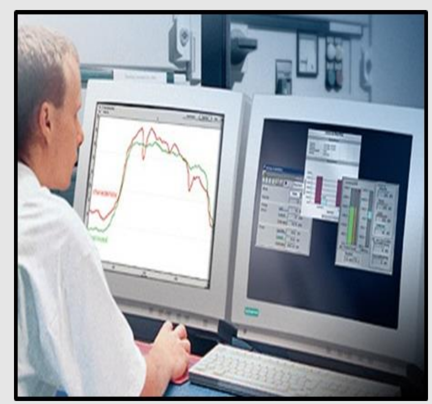
Min and Max Exhaust Flow

Optimize Airflow Control and Energy Consumption

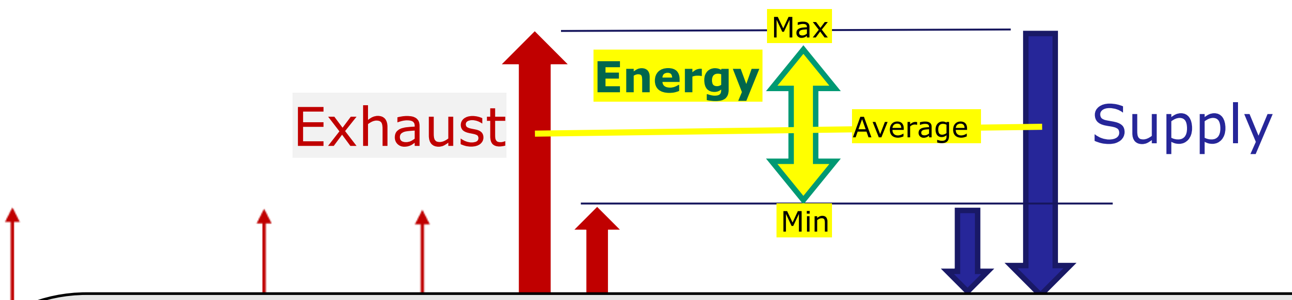


Theoretical Required Flow = Actual Measured Flow = BAS Reported Flow





Optimize Airflow Control and Energy Consumption

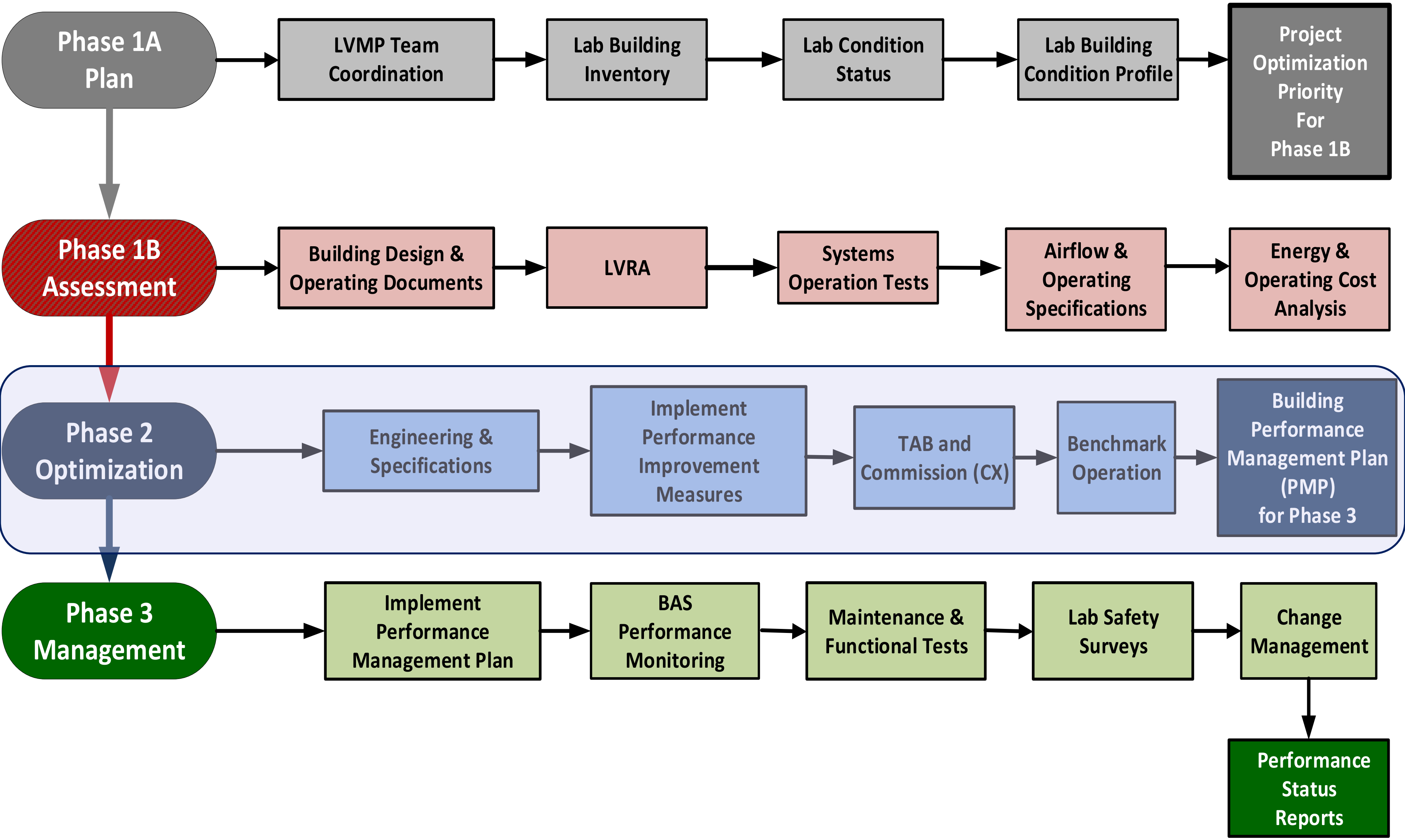


Energy — **Airflow** — **Efficiency**

$/ft² → **cfm/ft²** → **$/cfm**

Maximum savings are achieved by reducing total airflow and improving system efficiency

Roadmap to High Performance Labs

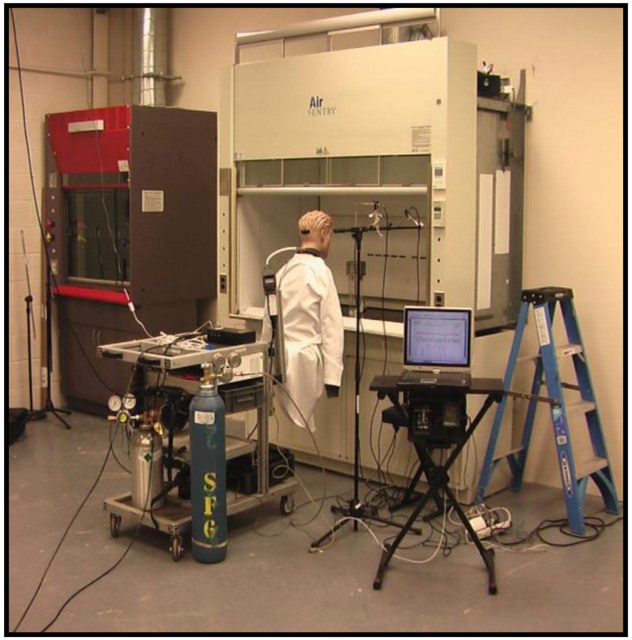


Identify measures to improve performance (PIMs) and conserve energy (ECMs)

- Remove or Hibernate Unnecessary Hoods
- Modify Inefficient Hoods
- Replace & Retrofit Traditional Fume Hoods
- Upgrade CAV & VAV Controls
- Optimize Temperature & Humidity Controls
- Install Demand Control Ventilation
- Reduce / Reset System Static Pressure
- Optimize Exhaust Fan and AHU Operation
- Implement Energy Recovery

Upgrading Fume Hood Performance

Evaluation of Fume Hood Performance at 3Flow



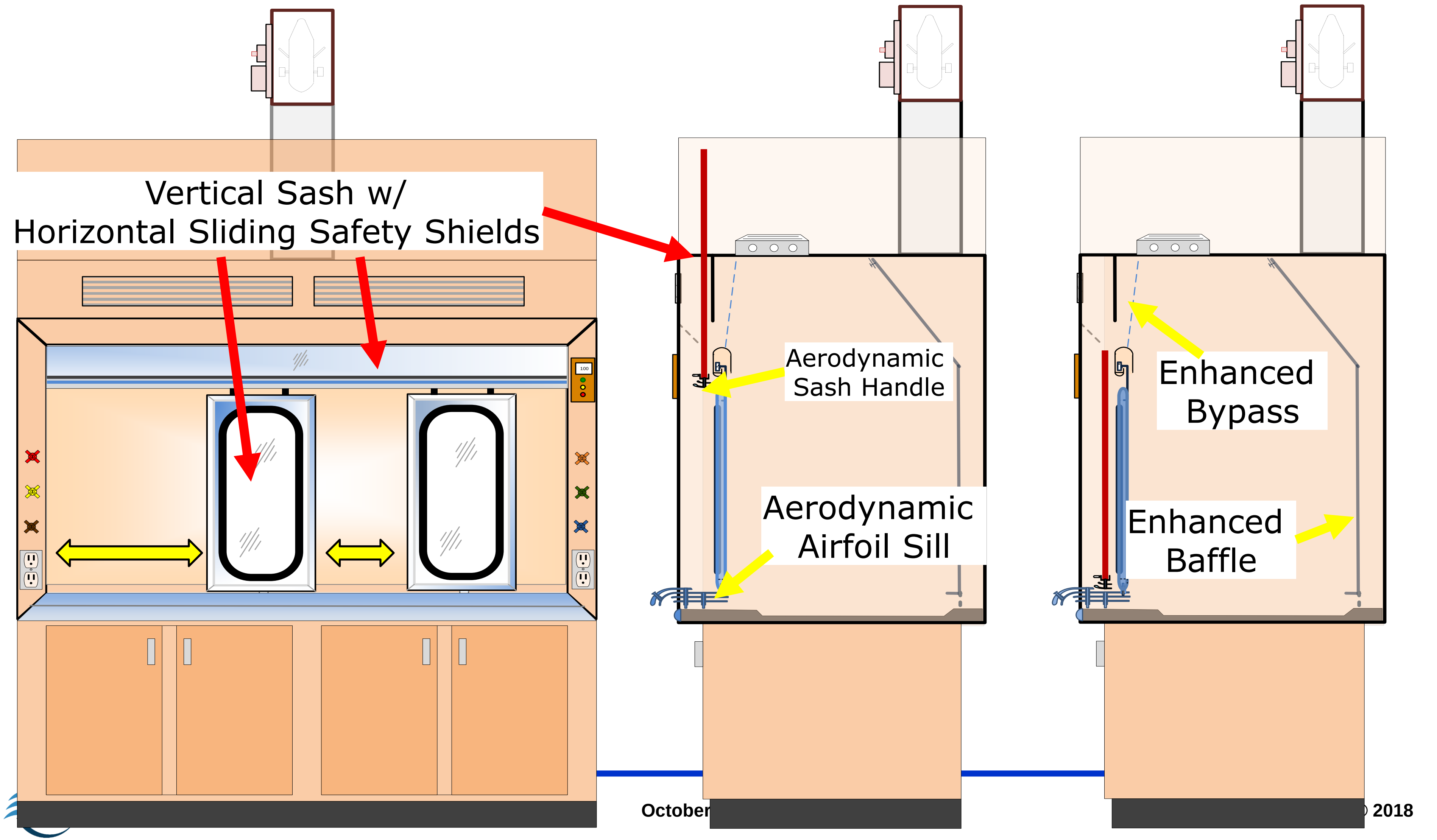
- **Manufacturer Prototype Tests**
- **Factory Acceptance Tests (As Manufactured)**
  - EPA, NIH, GSK, Merck, Pfizer, UNC, Duke, etc.
- **Extensive Field Tests**
  - EPA Research Triangle Park Fume Hood Optimization
  - UCI Low Flow Hood Study
  - State of Wisconsin High Performance Hood Study

Traditional vs. High Performance Fume Hoods

Critical Components

- **Airfoil Sill**
- **Sash Handle**
- **Baffle and Slots**
- **Bypass**

Fume hoods can be upgraded to improve performance, reduce flow and conserve energy



Upgrading Performance of Fume Hoods
How It Works?

Advanced Aerodynamic Design

1. **Vortex Displacement Sash Handle**

   Displaces & dilutes vortex behind sash

2. **Aerodynamic Airfoil Sill**

   Improves flow over work surface

3. **Ergonomic Safety Shields**

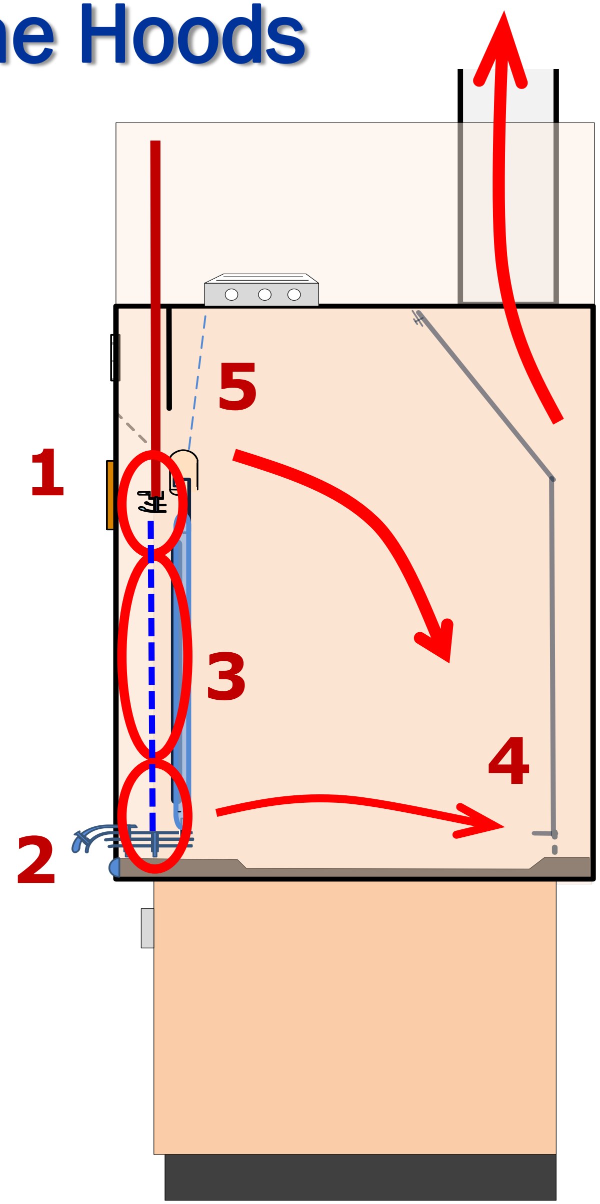
   Provides moveable barrier for Users

4. **Contaminant Capture Baffle**

   Directs airflow through the hood

5. **Bypass Distribution Panel**

   Helps sweep contaminants from hood interior



Containment, Dilution, Capture & Removal

Examples of Upgraded Fume Hoods

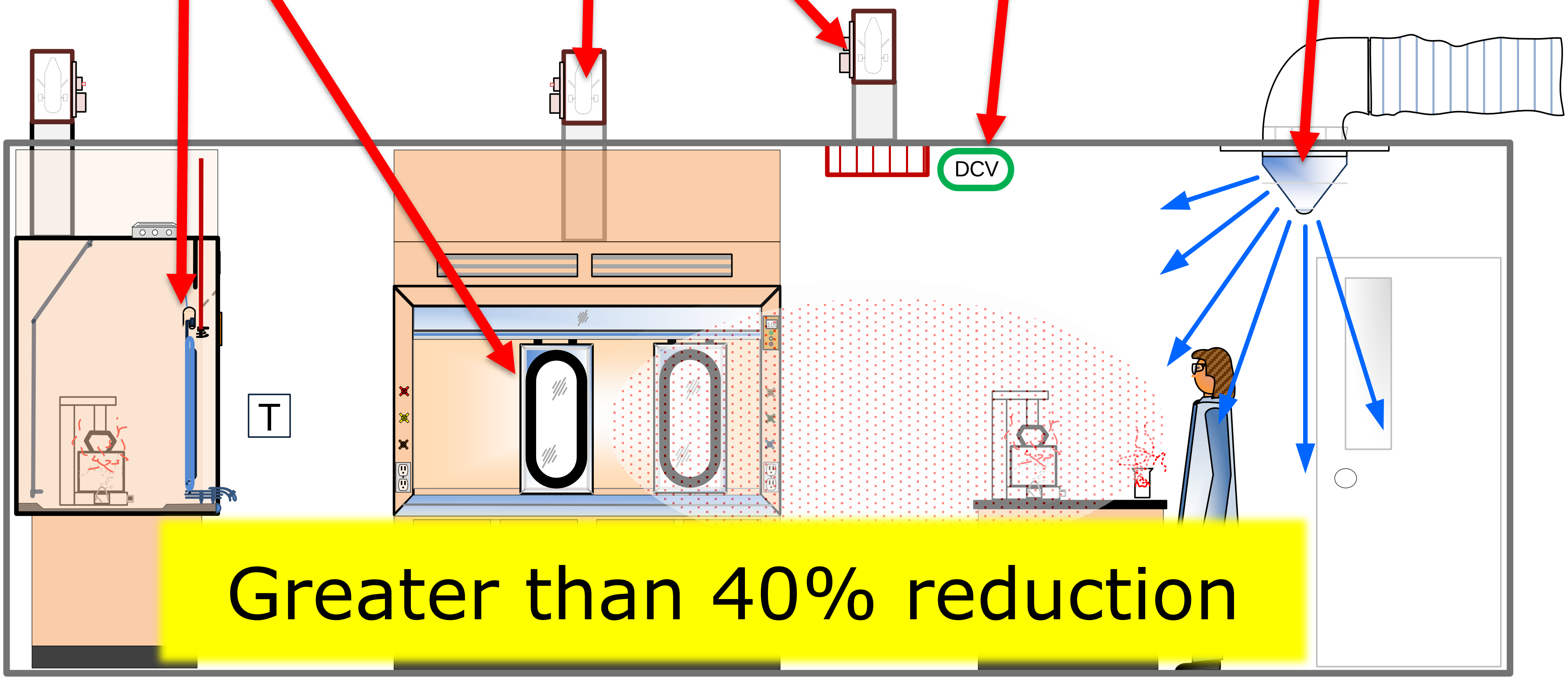
Understanding risk has enabled development of new technologies for safer and more efficient labs

Fume Hood upgrades:
- Better containment
- Lower flow

VAV Valves:
- More Accurate
- Better Control

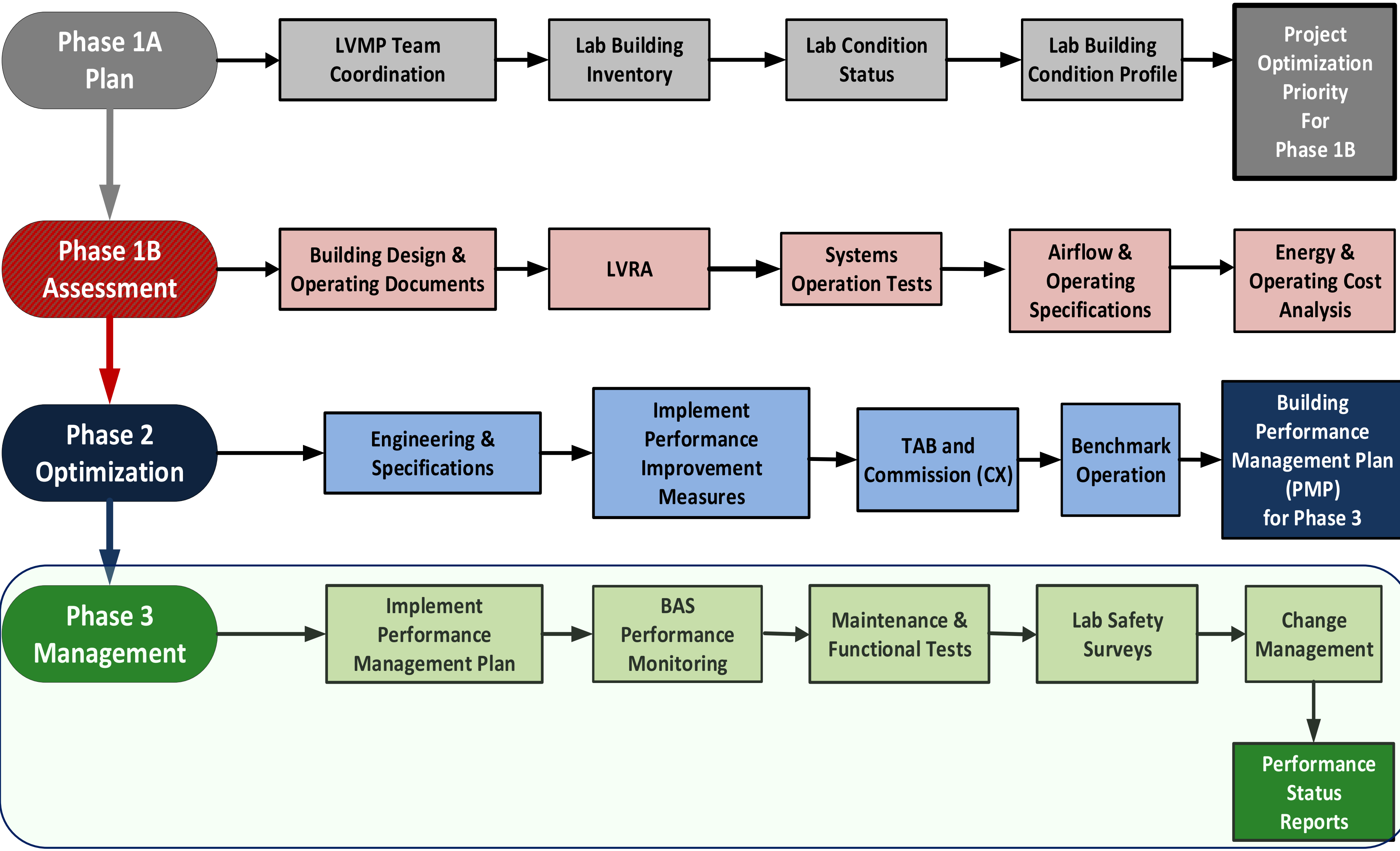
Demand Control Ventilation

High VEFF Diffusers
- Better Distribution
- Lower Flow

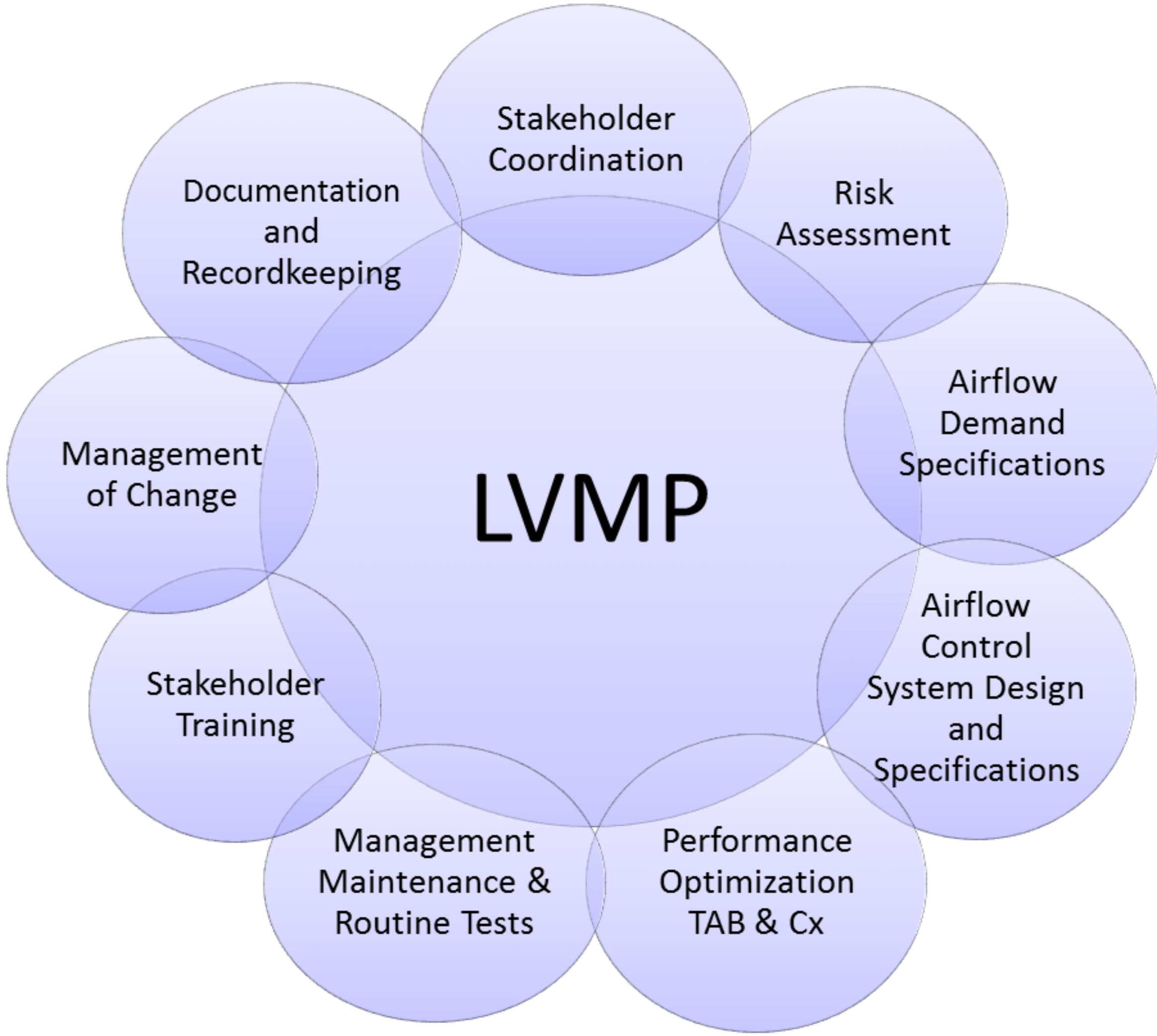


Greater than 40% reduction

Roadmap to High Performance Labs



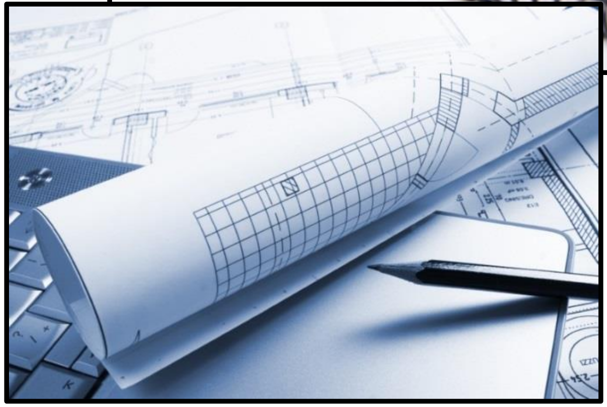
Airflow Management Program for Labs is comprised of multiple elements



Operating Manual for Building Systems

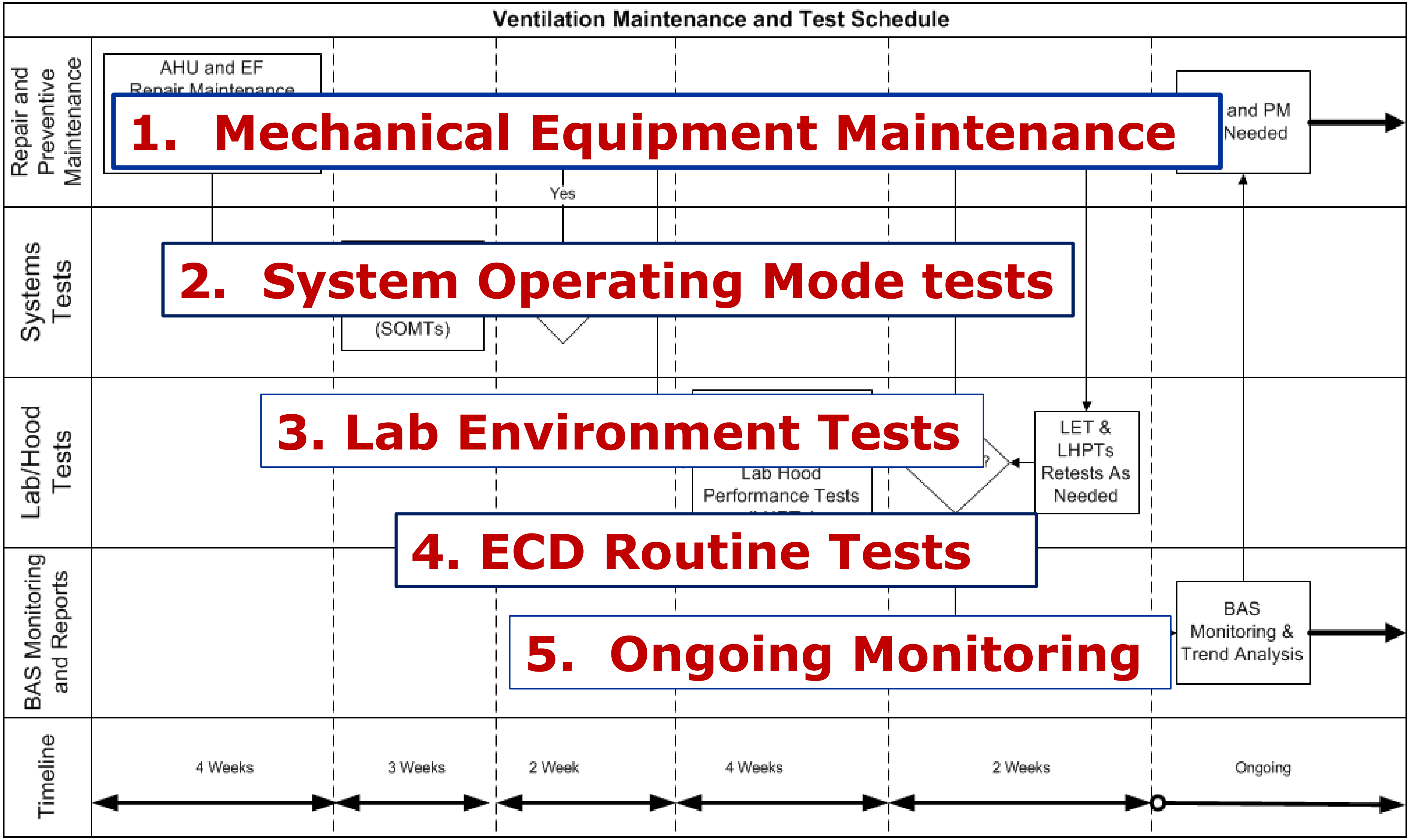
Performance Management Plan

- **Accurate Drawings / Diagrams**
- **Up to Date Equipment Inventories**
- **Lab Ventilation Risk Matrix**
- **Appropriate Flow Specifications**
- **Control Sequences and Parameters**
- **Key Performance Indicators and Metrics**
  - Operational Boundary Conditions
- **Standard Operating Procedures**
  - Routine Tests & Maintenance Tasks
  - Schedules and Management of Change
- **Adequate Training for Stakeholders and Staff**

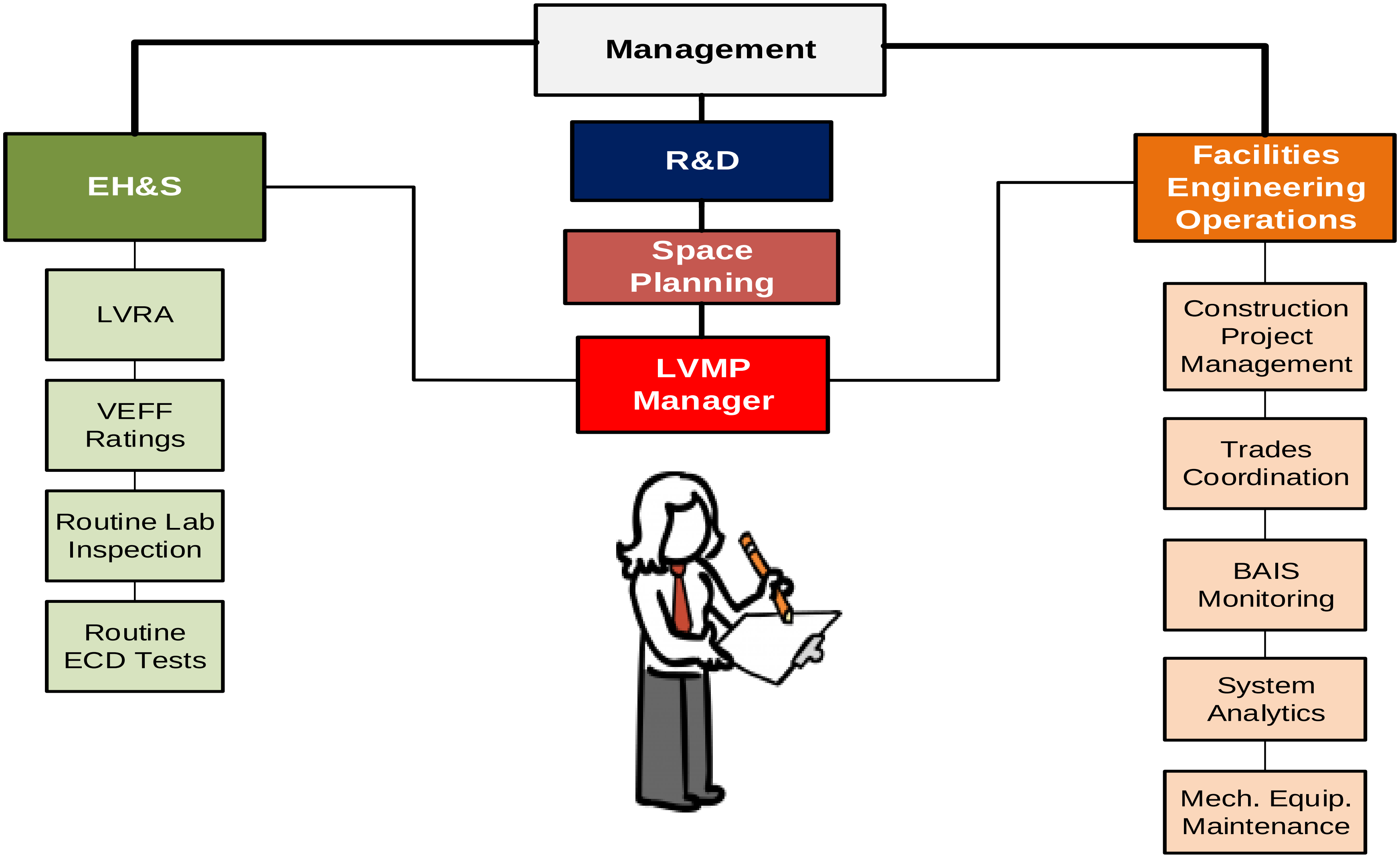


Protect Return On Investment

ECD & Ventilation Maintenance / Test Schedule



The LVMP Manager helps integrate and coordinates the efforts of key stakeholders



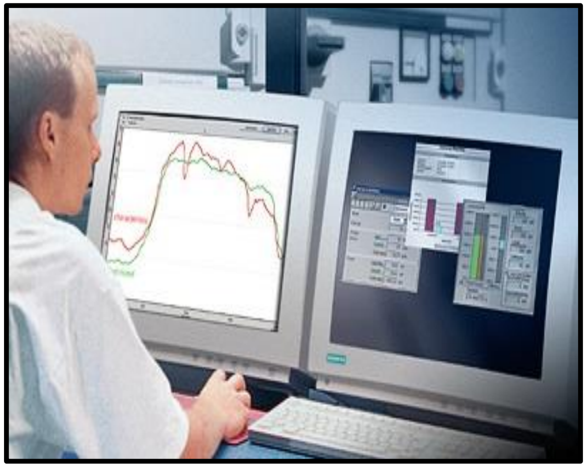
Smart Labs starts with training of stakeholders and the assignment of a LVMP Manager

- Program Managers & Supervisors
  - Facilities Engineering
  - Operations and Maintenance
  - EH&S & Lab Management

LVMP Manager

- Maintenance

- Building Operators



- Lab Personnel

New methods, technologies and training deliver benefits of safer and more energy efficient labs

- Government
- Universities
- Chemical
- Biotechnology
- Pharmaceutical
- Industry


The right flow in the right place at
the right time!
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Thank You!

Questions

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