Imagineering Future R&D Facilities: A Practical Guide

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Draper Laboratory

- Started in 1930’s by Charles S. Draper as the MIT Instrumentation Laboratory
  - Early work on Mark 14 gun sight during WW2
  - First auto pilot 1947
- Divested from MIT in 1973
- Now independent, not-for-profit
- Dedicated to
  - Applied research and development
  - Technology transfer
  - Advanced technical education
- Headquarters in Cambridge, Mass.
  - Site offices in Houston; Huntsville; Tampa Bay; and Washington, D.C.
- $420 million in revenues
- 1,311 employees
  - 65% technical staff
  - 63% advanced degrees
Drapers Business Focus

Advanced Packaging
- Multi-chip Module Packaging
- Silicon-based integrated ultra-high density platform (iUHD)

Microsystems
- Electronics
- MEMS/NEMS
- Optics
- Microfluidics
- Bio-Mems

Signal Processing & Communications
- Communications
- Audio & Video Processing
- GPS Processing
- Embedded SW

Power
- Micro Battery
- Power Management

Vanishingly Small Systems
Draper Focus on Bio-Mems

Artificial Kidney

Micromachined Blood Vessel Network

Esophagus Endoscope
Where is Draper Laboratory?

- Harvard
- MIT
- Boston
Where is Draper?
Why Build a New Laboratory?

• Draper’s Miniature Systems business continues to grow
  ▪ Based on Draper’s *proven* ability to *continually* innovate in miniature systems
  ▪ Existing facilities have served us well for nearly two decades, but cleanroom technology has advanced
  ▪ Better temperature-humidity control required to support new materials
  ▪ Support continuously decreasing feature sizes
  ▪ Provide well-laid-out, contiguous space for efficient execution
    ▪ Existing laboratories spread out over 2 floors, 10 labs and 10K sqft under filter
Project Team Makeup

- Construction Manager (CM)
- Architect / Engineer (AE)
- Commissioning Agent (Cx)
- Draper Facilities Structure / Envelope Physical Plant EH&S Security
- Draper Engineering / Operations
Team Selection

Create List of Companies
- Types of cleanroom experience considered: Semi, MEMS, Bio
- Size of projects: $5M < x < $50M
- Remodel experience
- Who are their partners

Selection Process
- RFP
- Walkthrough, who came, what questions they asked
- Presentations
- References
- Selection matrix and quantitative scoring

Selection
- Architect / Engineer (AE) - SMRT
- Construction Manager (CM) - Hodess Construction Corporation
- Commissioning Agent (Cx) - Hallam ICS
Delivery Method vs. Schedule

- Traditional Design/Bid/Build
- Design/Build
- Construction Manager
- Cost Structure
  - Fixed Fee
  - Guaranteed Maximum Price
  - Cost Plus
- We Chose
  - Construction Manager
  - Guaranteed Maximum Price
- Other criteria
  - Union vs. Non-Union
Physical Constraints

- Steam plant location and operation
- Normal power tie-point
- Standby power capacity
- Chilled water tie point
- Existing exhaust infrastructure
- Vibration & EMI Concerns (Studied by Acentech)
Logistical Constraints

- Occupied Building in an Urban Setting
- Operational Cleanrooms Above and Below
- Asbestos Abatement
- Security / Access Control

How do we move people and material?
- External access via staircase attached to outside.
- Staging material on site then lift to 3rd floor
- People access to the site via staircase
- Waste material removal
Design Considerations

- Environmental Conditions / Cleanroom Classifications
- Cleanroom Envelope Construction
- Air Circulation Approach
- Facility Services
• Environmental Conditions
  • ISO 4 (Class 10): 68°F ± 2°F  45% RH ± 3%
  • ISO 5 (Class 100) & ISO 6 (Class 1000): 68°F ± 2°F 45% RH ± 5%
  • ESD safe floors

- Expose Class 10 | Room 3327
- Sem Class 10,000 | Room 3328
- Coat Class 10 | Room 3329
- Develop Class 100 | Room 3333
- Metal Etch Class 1000 | Room 3335
- Silicon Etch Class 1000 | Room 3337
- Furnace Class 100 | Room 3341
- Evaporation Class 1000 | Room 3343
- Sputter Class 1000 | Room 3346
- Metrology Class 1000 | Room 3347
- Dry Etch Class 100 | Room 3348
- Coat Room | Room 3352

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Walls and Ceilings

- Modular aluminum honeycomb wall panels by PortaFab.
- 2-inch gasketed ceiling grid system by PortaFab.
- Interstitial strut grid for utility support.
Recirc vs. FFU Considerations

- Considerations:
  - Tight floor-to-floor height
  - How Much of the Fourth Floor to Take?
  - Speed Control, Adjustment, Maintenance
  - Redundancy
  - Vibration

- Selection:
  - 4’x4’ Fan Filter units by Envirco
  - Low wall returns
Fan Filter Approach

DIAGRAM:

PENTHOUSE

MAKE-UP AIR UNIT

26,500 CFM

ROOF

13,500 CFM
CORROSIVE EXHAUST

10,500 CFM
SOLVENT EXHAUST

AIRFLOW—RESISTANT CONSTRUCTION
(PRESSURIZATION CONTROL ENVELOPE)

SENSIBLE-ONLY COOLING COIL
(TYP.)

2500 CFM
EXFILTRATION
(10,000 SF
@0.25 CFM/SF)

FFU

CLEANROOM

CHASE

4TH FLOOR

FFU

CLEANROOM

CHASE

3RD FLOOR

FFU

CLEANROOM

CHASE

FFU

CLEANROOM

CHASE

FFU

CLEANROOM

CHASE

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Facility Orientation
Project Impact – Roof Level

- **Roof / Mech Penthouse**
  Make Up Air, Exhaust
- **4th Floor**
  Electrical & Utility
- **3rd Floor**
  Microfab Cleanroom
- **2nd Floor**
  Spec Gases and UPW
- **1st Floor**
  WWT, Power, Gas

- Relocated Chiller
- Relocated Chiller
Project Impact – 4\textsuperscript{th} Floor

- Roof / Mech Penthouse
  Make Up Air, Exhaust
- 4\textsuperscript{th} Floor
  Electrical & Utility
- 3\textsuperscript{rd} Floor
  Microfab Cleanroom
- 2\textsuperscript{nd} Floor
  Spec Gases and UPW
- 1\textsuperscript{st} Floor
  WWT, Power, Gas
Project Impact – 3rd Floor

- Roof / Mech Penthouse
  Make Up Air, Exhaust

- 4th Floor
  Electrical & Utility

- 3rd Floor
  Microfab Cleanroom

- 2nd Floor
  Spec Gases and UPW

- 1st Floor
  WWT, Power, Gas
Project Impact – 2nd Floor

- Roof / Mech Penthouse
  Make Up Air, Exhaust

- 4th Floor
  Electrical & Utility

- 3rd Floor
  Microfab Cleanroom

- 2nd Floor
  Spec Gases and UPW

- 1st Floor
  WWT, Power, Gas
Project Impact – 1st Floor

- Roof / Mech Penthouse Make Up Air, Exhaust
- 4th Floor Electrical & Utility
- 3rd Floor Microfab Cleanroom
- 2nd Floor Spec Gases and UPW
- 1st Floor WWT, Power, Gas
Mechanical Penthouse

- 26,500 cfm York MAU with parallel supply fans
  - Steam pre-heat, CHW cooling, HW reheat
  - steam-to-steam humidification
- Gas-fired Cleaver Brooks steam boiler plant
Exhaust and Air Entrainment

- Make Up Air Entrainment:
  - Process Exhaust (MK Plastics fans)
  - Vehicle Exhaust
  - Boiler Breeching
  - Snow Intake

- Entrainment / Wind Study by RWDI

- Generator capacity limitations dictated fan sizing
UPW and WWT

• Second Floor: 18 megohm UPW plant, 7 gpm product RO, 750 gpm storage – Atlas Water Systems

• First Floor: 50 gpm peak continuous flow active pH adjustment and waste water treatment system – Mar Cor
Other Remote System Ties

• Natural gas – from A Core level 1 / underground
• Chilled Water – from B Core penthouse
• Normal Power – from B Core level 1
• Emergency Power – from B Core penthouse
• Nitrogen – from B Core third floor
• Hazardous / Spec gasses – from C Core level 2 (remaining)
Regulatory and Code Limitations

- Hazardous Production Material (HPM) storage quantity vs. building level
- Air Emissions
- Wastewater Discharge
- Local (building, fire, other) officials
  - Maintaining good relations
Challenges

• Consistent delivery of RO water to humidifiers

• Window condensation

• Particle counts around high flow fume hoods
Metal Etch Room

- New high flow hoods – Plastic Design, Inc. (PDI)
- Chemical waste stored under hoods – no return air path
- High particle counts in the room
Project Time Line
Design to Completion in 17 months

- July 2011: Design Kickoff
- October 2011: Construction Starts
- January 2012: Demo / Abatement Starts
- April 2012: Construction Starts
- July 2012: Construction Completed
- October 2012: Operational
Owner Support During Design / Construction

- Do you have accurate record drawings?
- Availability of Facilities Staff to assist with evaluations of existing systems
- 150 people had to be moved. 7-8 labs had to be moved
- Defining work restrictions & Managing unforeseen conditions
- What systems and functions do you need to maintain during construction?
- Involve your Insurance Carrier / Underwriter
Owner Support After Project Completion

• Is your organization ready to operate and maintain your new space?

• What is done to make sure it works?
  – Commissioning
  – Cleanroom Certification

• What Internal Group is Responsible for What?
  – Operations
  – Facilities
  – EH&S
  – Security
  – IT
Draper’s O & M Work Split

• Microfabrication Operations
  – Ultra Pure Water
  – Specialty Gasses
  – House Nitrogen
  – Cleanroom / Process Equipment

• Facilities
  – Process Exhaust
  – HVAC, including cleanroom Make Up Air
  – Cleanroom Humidity

• Environmental Health and Safety
  – Toxic Gas Monitoring System (TGMS)
  – Process Exhaust Monitoring
  – Waste Water Treatment
How to Measure Project Success

• Was the project completed on **TIME**?

• Was the project delivered within **BUDGET**?

• Was **START UP** / commissioning successful?

• **PERFORMANCE**: Were the environmental conditions met?
  – (Particles, temperature, humidity, vibration, EMI)

• Was impact to on going **OPERATIONS** minimized throughout the process?
Lessons Learned

• The cycle is long from idea to completion
  – Many stakeholders in the design and selection process
  – Must manage closely to be able to move fast.
  – Document all assumptions carefully along the way, as players may change

• Many constraints
  – Available budget is key design driver
  – In a remodel, constraints of the available space (e.g. ceiling height) drive the design
  – How large can the lab be and where will it go.

• How to control the outcome
  – Manage stakeholders so that you have a lab that works instead of a palace
  – Manage budget and timeline...control scope creep!
  – Weekly meetings
  – Final decisions on scope and cost made by one person, not the committee
  – You need to have a commissioning agent, he/she is your Quality control

• Understand customer / user expectations

• NO ISSUE STANDS ALONE. ..EVERYTHING IS INTERRELATED!
Thank you!

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• Questions??