JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Dust and Particulate Mitigation for Flight Hardware in APL Cleanrooms

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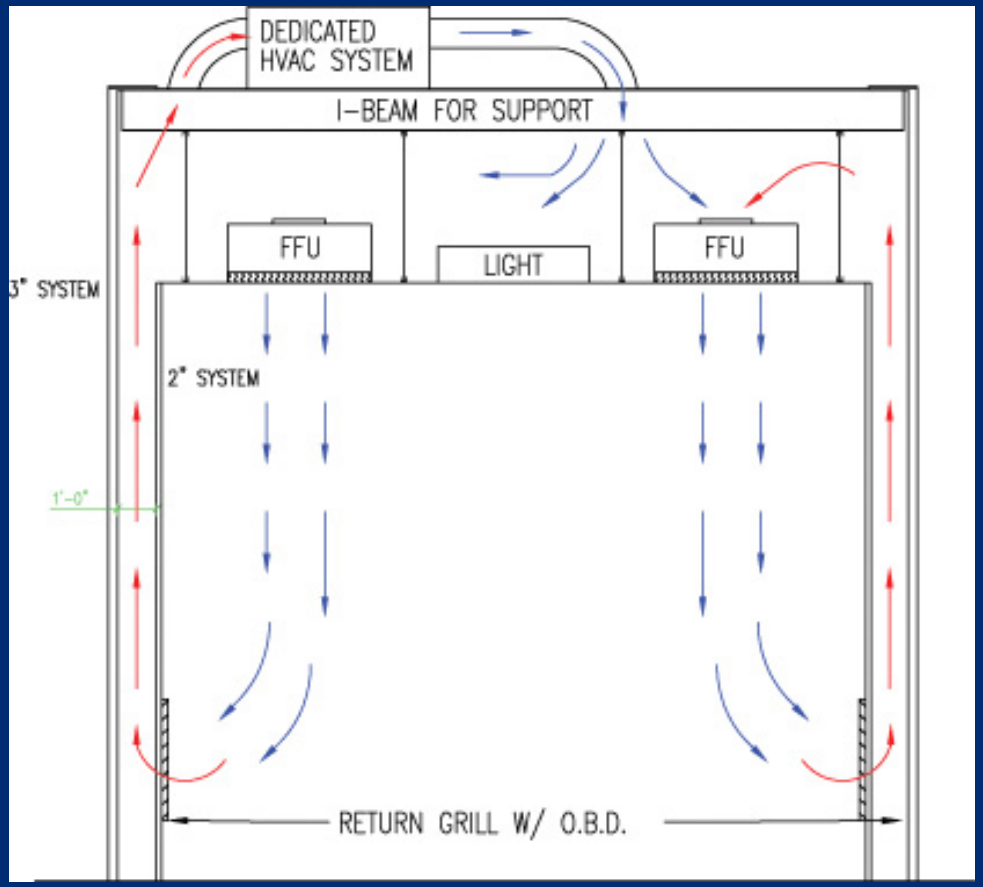
Overview

- Contamination control is part of every single build that we do at APL; mission requirements for level of cleanliness vary, but we always have some kind of requirement to meet from a contamination perspective.

Cleanroom Design

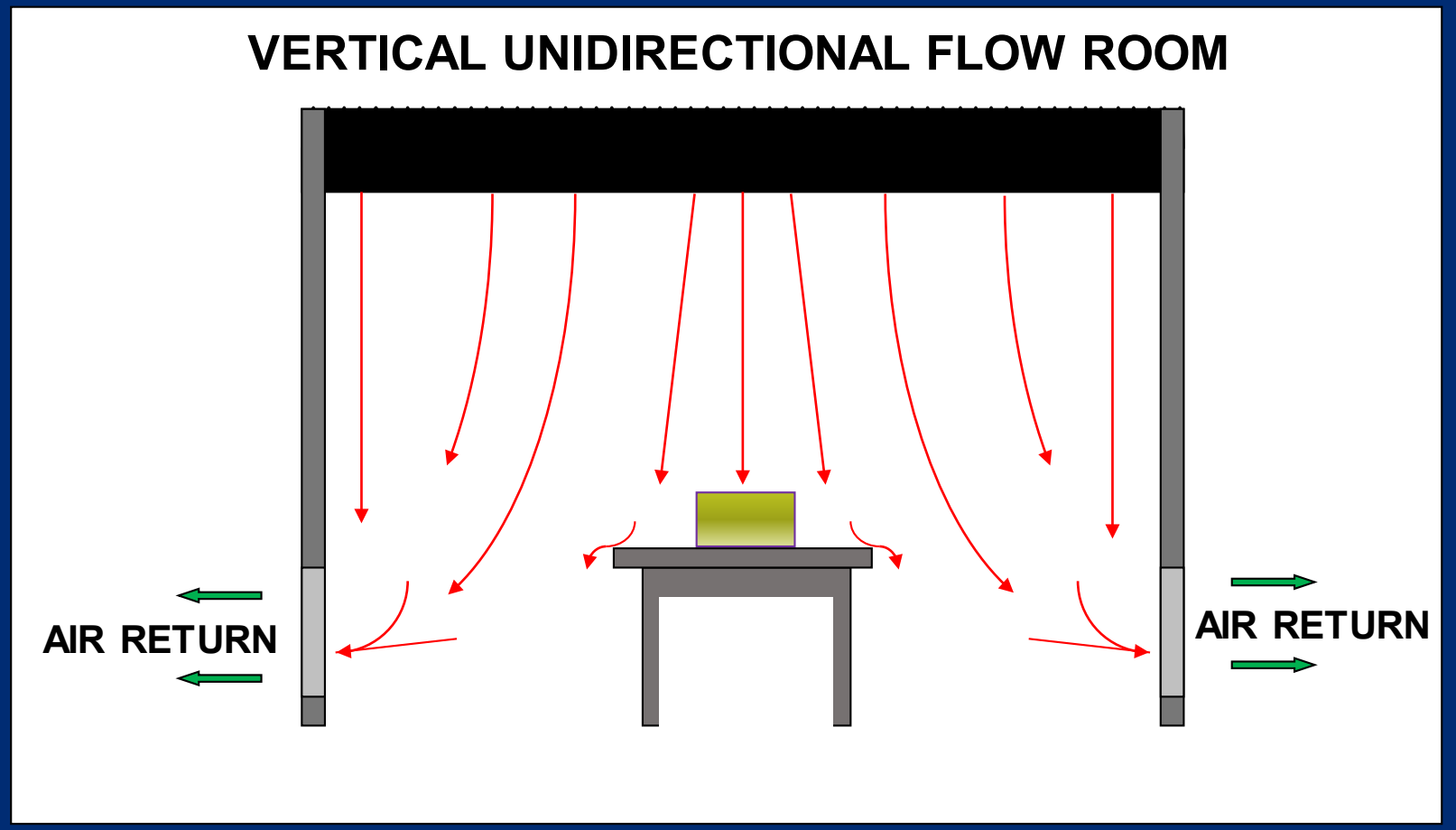
- HEPA filtered air supplied at ceiling typically (or one wall)
- Floor or floor-level air returns
- Positive pressurization
- Frequently separate gowning/staging areas
- Temperature and humidity control
- Constructed from non-shedding, low outgassing materials
- Room cleanliness is largely determined by the number of Air Changes per Hour (ACPH)



Contamination Airborne Particulate Classification

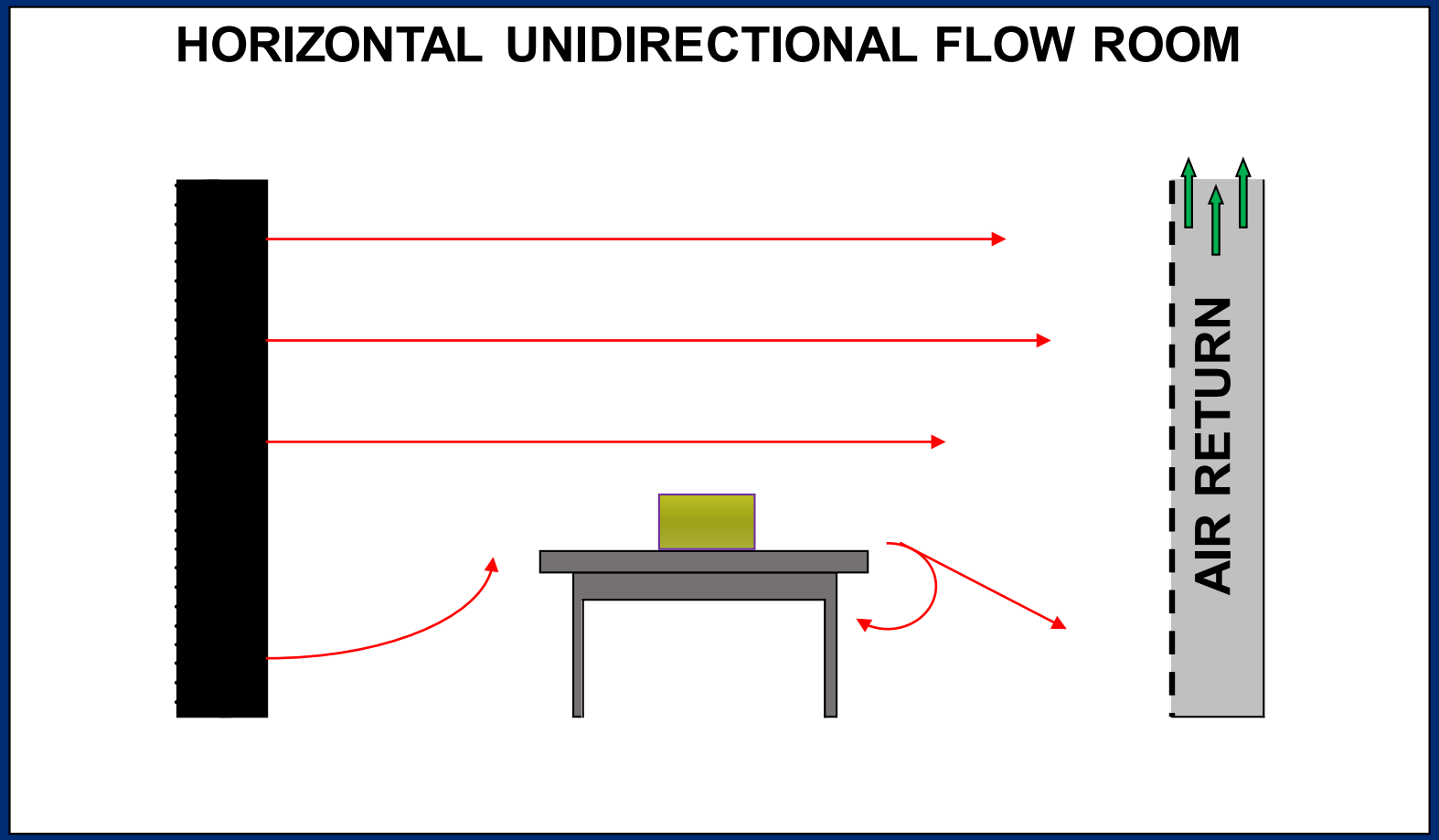
Area	Class Number	ISO Class
Office	Class 1,000,000+	Not Classified
Cleanrooms	Class 100,000	ISO Class 8
	Class 10,000	ISO Class 7
	Class 1,000	ISO Class 6
	Class 100	ISO Class 5
Semiconductor Industry	Class 0.1	ISO Class 2

Class 100 (ISO 5) Cleanroom Vertical Airflow



Typically >100 Air Changes per Hour

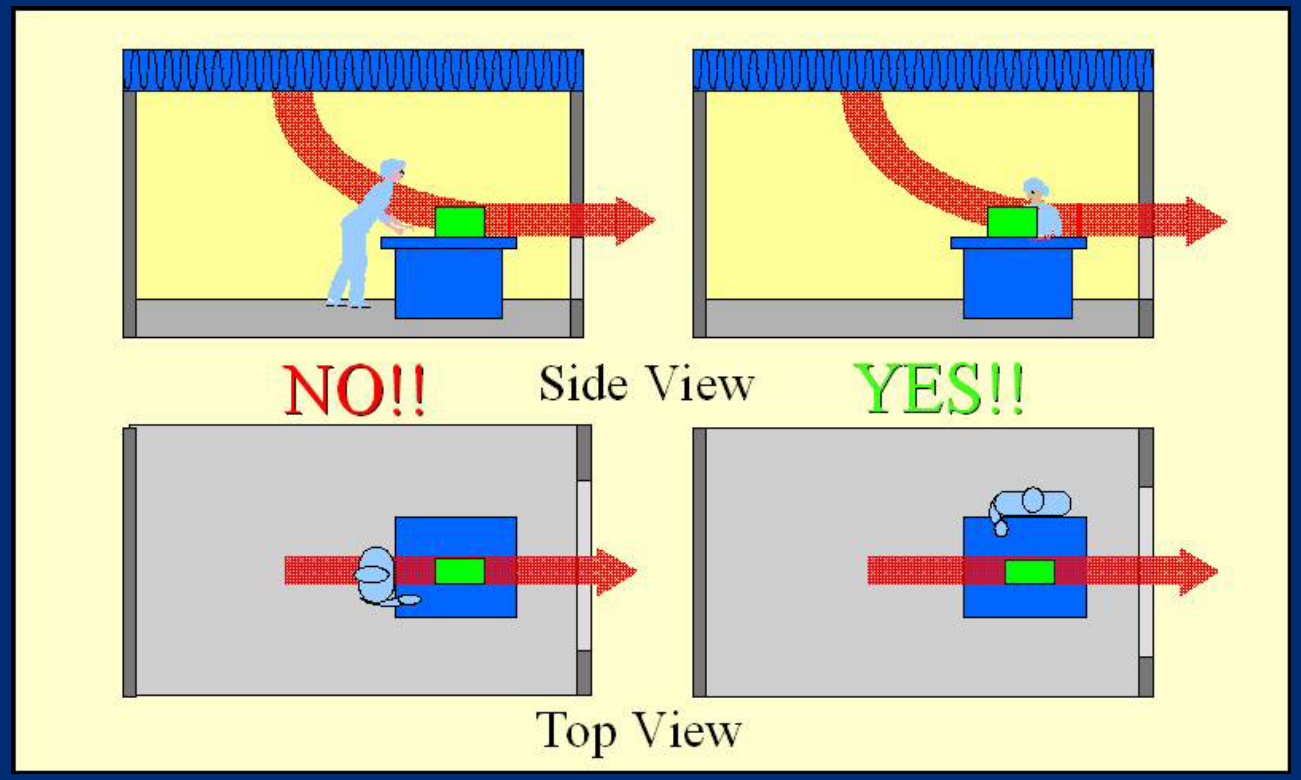
Class 100 (ISO 5) Cleanroom Horizontal Airflow



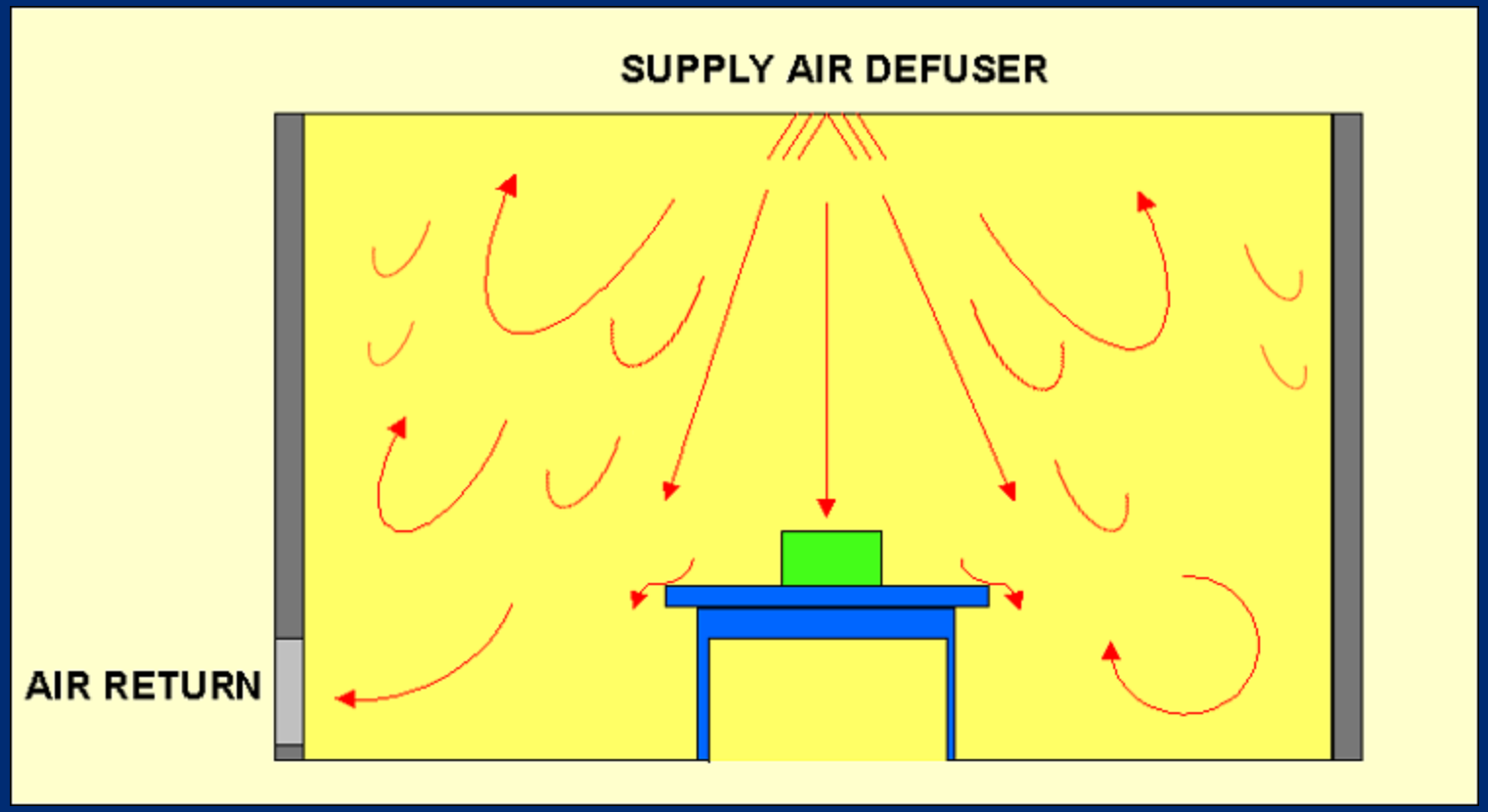
Typically >100 Air Changes per Hour

Airflow Management

- Working in displaced air environment: important to be cognizant of airflow in order to avoid interfering with the cleanliness
  - Work parallel or downstream of hardware

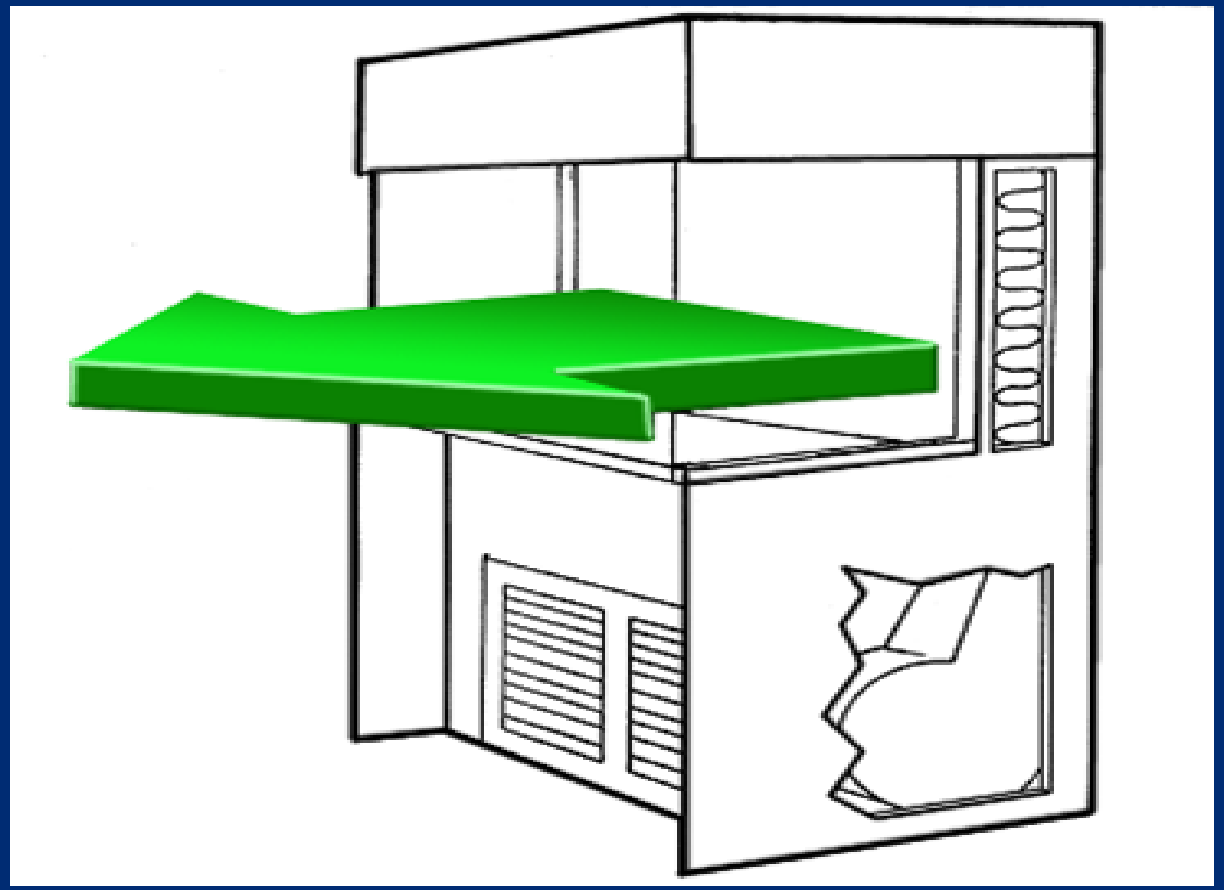


Class 100K (ISO 8) Turbulent Airflow



Typically >20 Air Changes per Hour

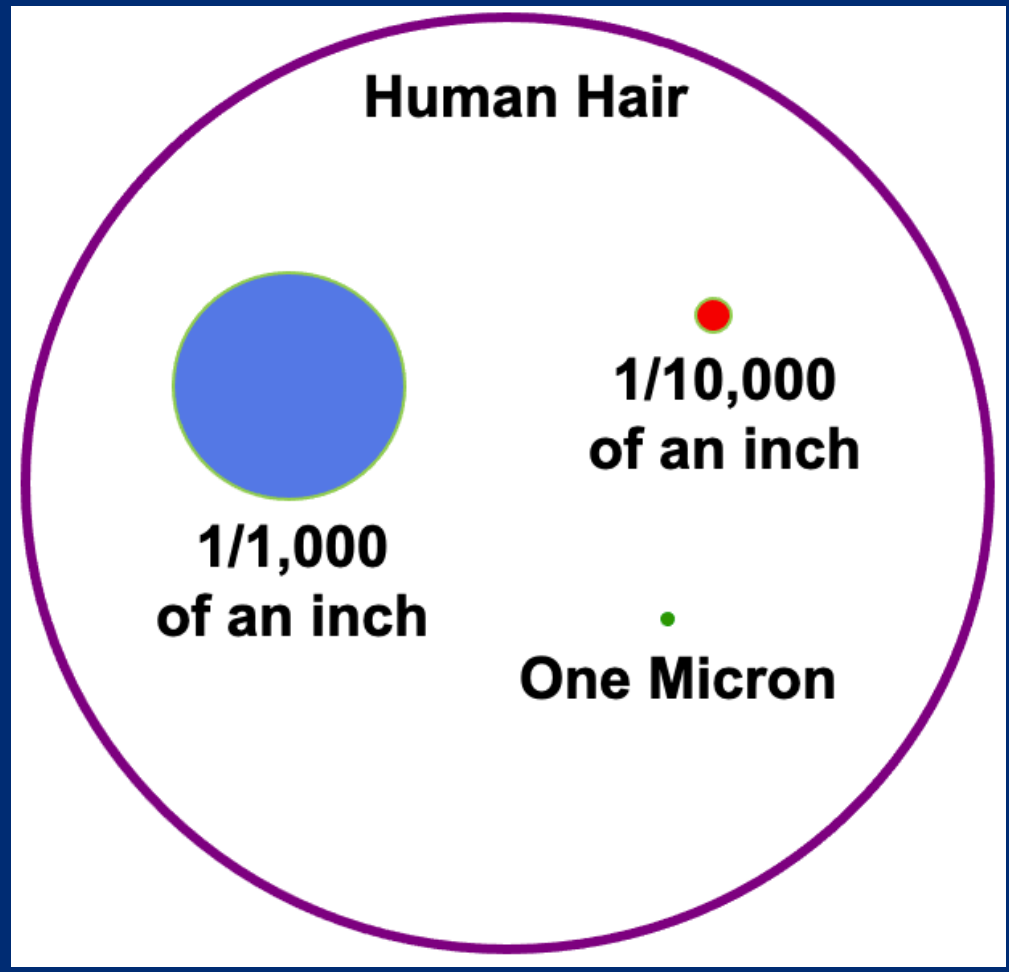
Horizontal Flow Bench



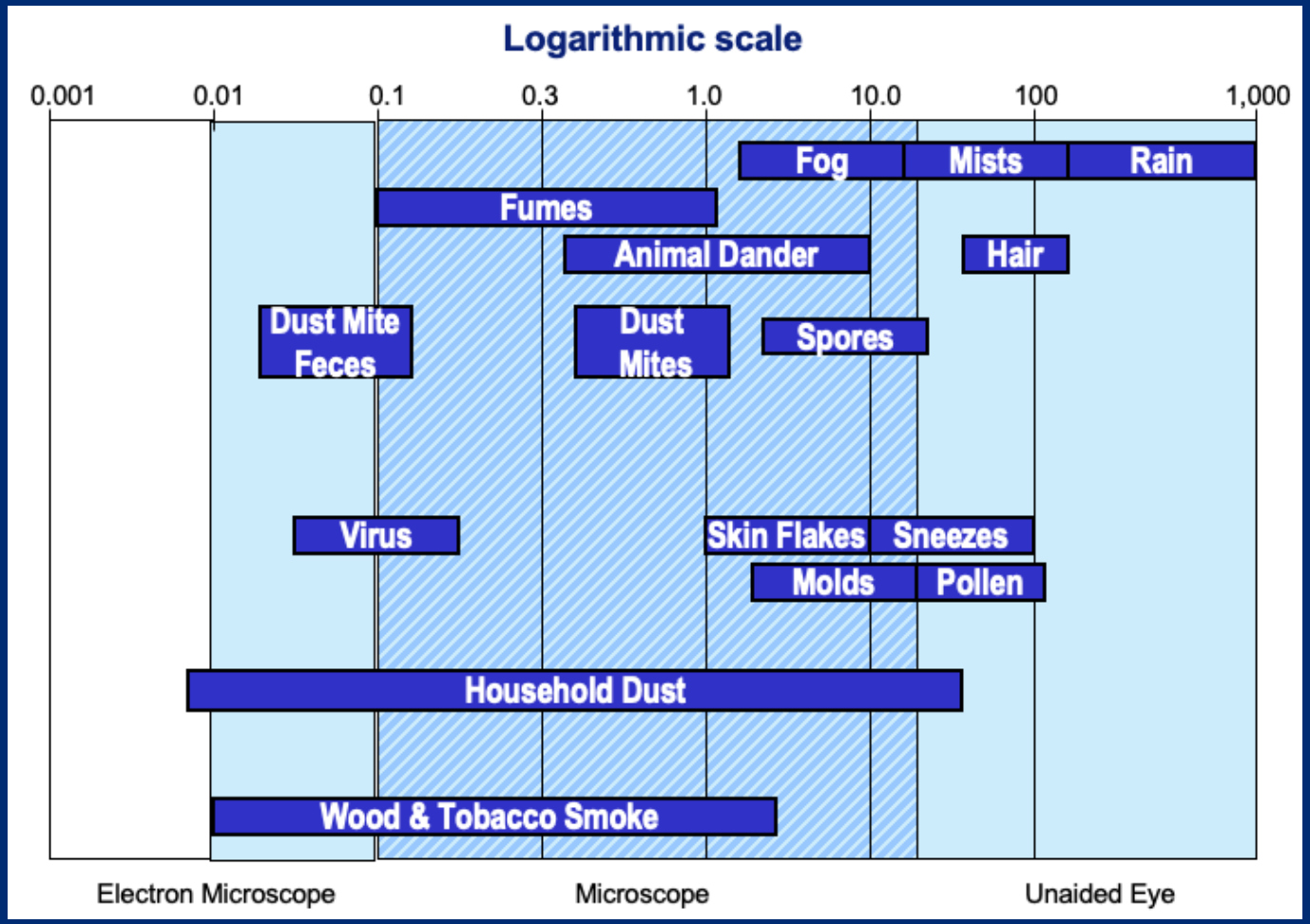
Class 1000 (ISO 6) or better capability within Class 10K (ISO 7) or better facility

Particulate Size – How Small is Small?

- One Micron Equals…
  - 0.00003937 Inches
  - 1/1,000,000 Meter
  - 1/25,400 Inch
  - 25 microns = 1 Mil



Sizing Up Particles in Microns



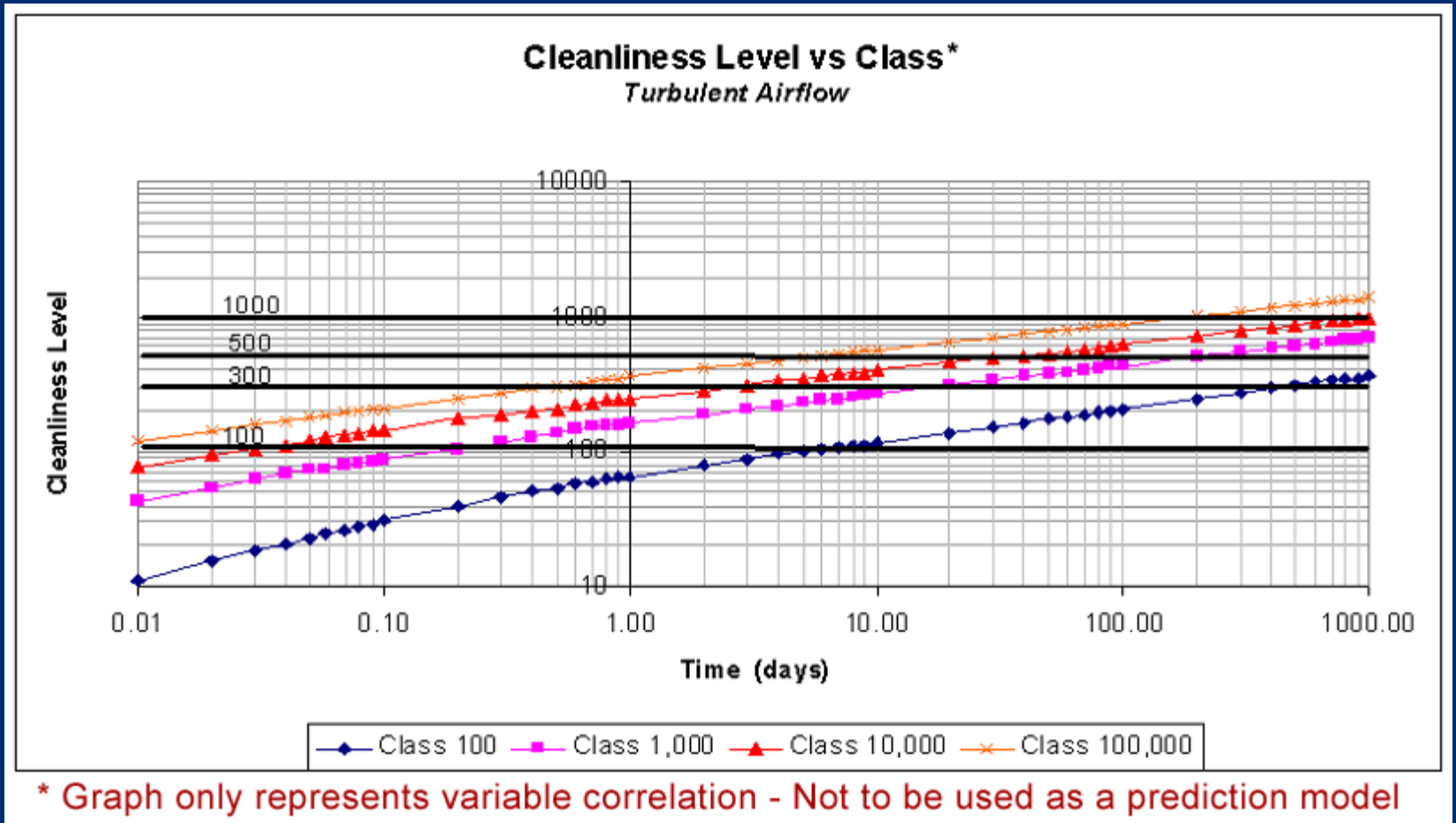
Typical threshold of unaided vision is around 50 microns

Particulate Settling Rates

Size in microns	Time to fall one meter
0.1	36 days
0.5	1.4 days
1	8.6 hours
5	21 minutes
10	5.2 minutes
15	2.3 minutes
20	1.3 minutes
25	50 seconds

Surface Cleanliness and Air Cleanliness

Hamburg curves show the complex relationship between airborne and surface particulate

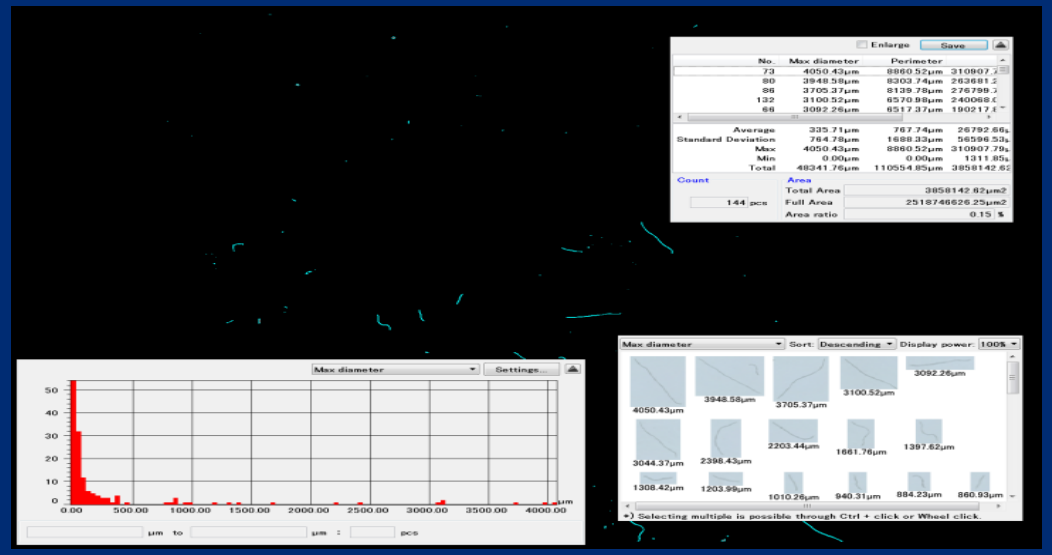


Cleanliness Verification

Verification	Levels	Measurement Technique
Surface Particulate	Level 500, Level 200, Level 100, Level 50	Count and size compared to standard distribution
Visual Inspection	VC1, VC2, VC2 + UV	Qualitative inspection with light
Molecular Residue	Level B, Level A, Level A/2, Level A/5	Solvent rinse and gravimetric analysis

cleanliness level

Particulate Verification



Count and Size Particles
- **Manual or automated**
- **Compare particle counts to 1246E distribution**

Maximum particles per sq. ft.

	≥5µ	≥15µ	≥25µ	≥50µ	≥100µ	≥200µ	≥300µ	≥500µ
Level 50	165	25	7	1				
Level 100	1785	4190	78	11	1			
Level 200			1240	170	16	1		
Level 300			7450	1020	95	2	1	
Level 500				11800	1100	26	10	1

Visual Inspection

White Light	Ultraviolet Light
Generic particles	Natural fibers
Oils	Hydrocarbon lubricants
Metals	Epoxies
Composites	Skin flakes
Man-made fibers	Highly reflective surfaces
Smooth surfaces	Complex geometries

White and UV light are complementary

Personal Hygiene

- The human body constantly generates huge quantities of particulate contamination
  - 2 million particles released each minute
  - Lose 50-100 hairs per day
  - 5 pounds of dead skin flakes per year
  - Column of warm air around body carries these particles upwards
- Good personal hygiene helps to reduce the contamination that the human body gives off
- A properly-worn, full cleanroom garment can decrease particle shedding by **300X**

Activity (w/o cleanroom garment)	# of 0.3 micron particles/minute
Motionless, sitting or standing	100,000
Head, arm, neck, leg motion	500,000
All above with foot motion	1,000,000
Standing to sitting, sitting to standing	2,500,000
Walking at 2 mph	5,000,000
Walking at 3.5 mph	7,500,000
Walking at 5 mph	10,000,000

Garment Types

Frocks
Class 10K/100K
(ISO 7/8)

Full Suits
Class 100/1000
(ISO 5/6)

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