<div style="margin: 0 auto; padding: 20px 15px;"><section style="margin-bottom: 40px;">
<h2 style="color: #000; border-bottom: 2px solid #000; padding-bottom: 8px;">Introduction</h2>
Effective modular cleanroom layout design plays a crucial role in manufacturing efficiency, product quality, and regulatory compliance across industries like pharmaceuticals, microelectronics, and biotechnology. A well-planned modular cleanroom layout design can reduce contamination risks by up to 85% compared to traditional facilities, while offering significant advantages in flexibility, rapid deployment, and scalability.

This comprehensive guide provides a complete framework for modular cleanroom layout design, from initial concept through final implementation. We'll explore the fundamental principles, systematic design steps, and optimization strategies that ensure your modular cleanroom layout design meets both current operational needs and future expansion requirements.

</section><!-- Part 2: Understanding Modular Cleanroom Basics -->

<section style="margin-bottom: 40px;">
<h2 style="color: #000; border-bottom: 2px solid #000; padding-bottom: 8px;">Understanding Modular Cleanroom Basics</h2>
Modular cleanrooms consist of prefabricated components that offer significant advantages over traditional construction. The key elements include insulated wall panels (typically 50mm-100mm thickness), fan filter units (FFUs) with HEPA/ULPA filtration, suspended ceiling grids, anti-static vinyl flooring, and specialized doors/windows with airtight seals.

These standardized components enable rapid assembly and reconfiguration. For example, a typical Deiiang ™ modular cleanroom can be installed 40-60% faster than conventional

construction. The modular approach allows for precise control over environmental parameters, with temperature maintained at 21 ± 2 ° C, humidity at 45 ± 5% RH, and pressure differentials between zones typically at 10-15 Pascals.
<div style="text-align: center; margin: 10px 0;">

<p style="font-size: 14px; color: #666; margin-top: 8px;">Figure: Key components of a modular cleanroom system</p>

</div>
</section><!-- Part 3: Fundamental Principles of

Cleanroom Layout Design -->

<section style="margin-bottom: 40px;">
<h2 style="color: #000; border-bottom: 2px solid #000; padding-bottom: 8px;">Fundamental Principles of Cleanroom Layout Design</h2>
Successful modular cleanroom layout design requires adherence to several core principles that ensure contamination control and operational efficiency. These principles form the foundation of any effective cleanroom environment regardless of industry application.
<div style="background-color: #f8f9fa; padding: 10px; border-left: 4px solid #000; margin: 10px 0;">
<h3 style="color: #000; margin-top: 0;">3.1 Unidirectional Flow Principle</h3>
Personnel and materials should follow a predetermined path from lower to higher cleanliness areas, preventing cross-contamination. For example, in pharmaceutical applications, personnel typically follow this sequence: entrance

→ gowning area (ISO 8) → airlock → main clean area (ISO 7) → core process area (ISO 5).

</div>
<div style="background-color: #f8f9fa; padding: 10px; border-left: 4px solid #000; margin: 10px 0;">
<h3 style="color: #000; margin-top: 0;">3.2 Cleanliness Zoning/Grading</h3>
Areas should be classified according to required cleanliness levels (ISO 5 to ISO 8), with proper isolation between zones. A typical electronics cleanroom might have ISO 7 for assembly areas and ISO 5 for critical processes, separated by airlocks maintaining 15 Pa pressure differential.

</div>
<div style="background-color: #f8f9fa; padding: 10px; border-left: 4px solid #000; margin: 10px 0;">
<h3 style="color: #000; margin-top: 0;">3.3

Pressure Differential</h3>
Higher cleanliness areas must maintain positive pressure relative to adjacent less-clean areas. The standard pressure cascade is typically: ISO 5 > ISO 6 > ISO 7 > ISO 8 > non-clean area, with minimum pressure differentials of 10-15 Pa between adjacent zones.

</div>
<div style="background-color: #f8f9fa; padding: 10px; border-left: 4px solid #000; margin: 10px 0;">
<h3 style="color: #000; margin-top: 0;">3.4 Maintainability & Cleanability</h3>
Design must facilitate easy maintenance and cleaning. This includes providing adequate space for filter replacement (minimum 600mm clearance above ceiling), smooth and non-porous surfaces, and rounded corners (minimum 25mm radius) to prevent particle accumulation.

</div>

<div style="background-color: #f8f9fa; padding: 10px; border-left: 4px solid #000; margin: 10px 0;">
<h3 style="color: #000; margin-top: 0;">3.5 Scalability & Flexibility</h3>
Modular cleanrooms should accommodate future expansion or reconfiguration. Deiiang™ systems typically allow for 20-30% expansion without structural modifications, with panel connections designed for easy disassembly and reassembly.

</div>
<div style="background-color: #f8f9fa; padding: 10px; border-left: 4px solid #000; margin: 10px 0;">
<h3 style="color: #000; margin-top: 0;">3.6 Safety & Emergency</h3>
Layout must incorporate safety features including emergency exits, eyewash stations, fire detection systems, and clear evacuation routes. Emergency exits should be located within 30m of any workstation and open outward without special

knowledge or effort.

</div>
</section><section style="margin-bottom: 40px;">
<div style="text-align: center; margin: 10px 0;">

</div>
<div style="text-align: center; margin: 10px 0;">
<p style="font-size: 14px; color: #666; margin-top: 8px;">Figure: Unidirectional personnel flow from "dirty" to "clean" areas</p>

</div>
</section><!-- Part 4: Key Steps in Modular Cleanroom Layout Design -->

<section style="margin-bottom: 40px;">
<h2 style="color: #000; border-bottom: 2px solid #000; padding-bottom: 8px;">Key Steps in Modular Cleanroom Layout Design</h2>
The systematic approach to modular cleanroom layout design ensures all critical factors are considered from the beginning. Following these steps methodically reduces the risk of costly redesigns and ensures regulatory compliance while optimizing operational efficiency.
<div style="background-color: #f8f9fa; padding: 10px; margin: 10px 0; border-radius: 8px;">
<h3 style="color: #000; margin-top: 0;">4.1 Phase 1: Requirement Analysis & Goal Setting</h3>
Thorough analysis of operational requirements forms the foundation of successful modular cleanroom layout design. Key considerations include:
<ul style="padding-left: 20px;">
Application Purpose: Pharmaceutical (GMP compliance),

microelectronics (particle control), biotechnology (microbial control)
Cleanliness Requirements: ISO Class 5-8 based on process sensitivity
Process Flow: Sequential operations, batch vs continuous processes
Equipment Specifications: Dimensions, heat load, utility requirements
Personnel Requirements: Number of operators, gowning protocols
Material Flow: Raw material entry, in-process handling, finished goods exit
Space Constraints: Building dimensions, ceiling height, column locations
Budget & Timeline: Capital investment, installation schedule
Future Expansion: 2-5 year growth projections

For example, a pharmaceutical filling line might require ISO 5 for critical zones, ISO 7 for background, and specific temperature control at $21 \pm 1\ ^{\circ}C$ with $45 \pm 5\%$ RH.

</div>
<div style="background-color: #f8f9fa; padding: 10px; margin: 10px 0; border-radius: 8px;">
<h3 style="color: #000; margin-top: 0;">4.2 Phase 2: Preliminary Conceptual Layout</h3>
Based on requirement analysis, create initial sketches dividing the space into functional zones. A typical $100m^2$ cleanroom might allocate:
<ul style="padding-left: 20px;">
15% for entrance/gowning area ($15m^2$)
10% for material airlock ($10m^2$)
60% for main process area ($60m^2$)
10% for equipment/service area ($10m^2$)
5% for exit/waste handling ($5m^2$)

Initial FFU placement follows the rule of thumb: ISO 5 requires 25-40% ceiling coverage, ISO 7 requires 15-25%, and ISO 8 requires 5-15%.
<div style="text-align: center; margin: 10px 0;">

<p style="font-size: 14px; color: #666; margin-top: 8px;">Figure: Preliminary conceptual layout with functional zones</p>

</div>
</div>
<div style="background-color: #f8f9fa; padding: 10px; margin: 10px 0; border-radius: 8px;">
<h3 style="color: #000; margin-top: 0;">4.3 Phase

3: Detailed Layout Design</h3>
This phase transforms the conceptual layout into a detailed, operational design addressing all critical aspects:
<div style="margin: 15px 0;">
<h4 style="color: #000;">Personnel Flow Design</h4>
Detailed planning of personnel movement: entrance → locker area → pre-gowning → gowning room → airlock → clean corridor → workstations → exit. Each transition includes appropriate contamination control measures like sticky mats, air showers, or hand sanitation stations.

</div>
<div style="margin: 15px 0;">
<h4 style="color: #000;">Material Flow Design</h4>
Planning of material movement: receiving →

quarantine → decartoning area → pass-through → process area → packaging → finished goods. Critical calculation: pass-through dimensions = largest component + 150mm clearance (minimum 600 × 600mm).

</div>
<div style="margin: 15px 0;">
<h4 style="color: #000;">Equipment Placement</h4>
Precise positioning of all equipment with adequate clearances: operational space (minimum 900mm), maintenance access (minimum 600mm), and safety zones. Utility connections planned with 10-15% spare capacity for future modifications.

</div>
<div style="margin: 15px 0;">
<h4 style="color: #000;">Cleanliness Zoning & Pressure Control</h4>

Defining cleanroom classifications and pressure cascades: ISO 8 (15Pa) → ISO 7 (25Pa) → ISO 5 (40Pa). Airlocks sized for 2-3 personnel (minimum $2m^2$) with interlocking doors and pressure monitoring.

</div>
<div style="margin: 15px 0;">
<h4 style="color: #000;">Airflow Pattern Design</h4>
Determining airflow direction, velocity, and distribution. Unidirectional flow for ISO 5 (0.45m/s ± 20%), non-unidirectional for ISO 6-8 (20-40 air changes/hour). Return air grilles strategically placed low on walls for optimal particle removal.

</div>
<div style="text-align: center; margin: 10px 0;">

<img class="wp-image-4311 size-large" src="https://www.deiiang.com/wp-content/uploa

ds/2025/11/ 未 标 题 -1-1024x566.jpg" alt="cleanroom Airflow Pattern Design" width="960" height="531" />
<p style="font-size: 14px; color: #666; margin-top: 8px;">Figure: Detailed layout with personnel flow (blue) and material flow (green)</p>

</div>
</div>
<div style="background-color: #f8f9fa; padding: 10px; margin: 10px 0; border-radius: 8px;">
<h3 style="color: #000; margin-top: 0;">4.4 Phase 4: 3D Modeling & Visualization</h3>
Using CAD/BIM software (AutoCAD, Revit, SolidWorks) to create precise 3D models that identify spatial conflicts, optimize ergonomics, and validate the design. Deiiang™ typically uses BIM for clash detection, reducing construction issues by 70-80%.

</div>

<div style="background-color: #f8f9fa; padding: 10px; margin: 10px 0; border-radius: 8px;">
<h3 style="color: #000; margin-top: 0;">4.5 Phase 5: Review, Revision & Final Approval</h3>
Comprehensive review with all stakeholders including production, quality control, maintenance, and safety personnel. Typical review checklist includes:
<ul style="padding-left: 20px;">
Regulatory compliance verification
Operational workflow efficiency
Maintenance accessibility
Safety and emergency protocols
Utility distribution adequacy
Future expansion capability

Following review, incorporate feedback and obtain formal approval before proceeding to fabrication and installation.

</div>
</section><!-- Part 5: Specific Factors Influencing

Layout Design -->

<section style="margin-bottom: 40px;">
<h2 style="color: #000; border-bottom: 2px solid #000; padding-bottom: 8px;">Specific Factors Influencing Layout Design</h2>
Several industry-specific and operational factors significantly impact modular cleanroom layout design decisions. Understanding these variables ensures the final design meets both technical and regulatory requirements.
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<div style="flex: 1; min-width: 300px; background-color: #f8f9fa; padding: 15px; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">5.1 Process Type & Particle Generation</h4>
Wet processes (pharmaceutical compounding) require chemical-resistant surfaces and drainage, while dry processes (electronics assembly) need enhanced ESD protection. High

particle-generating operations need increased air changes (up to 60 ACH for ISO 5).

</div>
<div style="flex: 1; min-width: 300px; background-color: #f8f9fa; padding: 15px; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">5.2 Product Sensitivity</h4>
Products sensitive to temperature (± 0.5 ° C), humidity (± 3% RH), or electrostatic discharge require specialized environmental controls and material selection. Pharmaceutical products may need 21 ± 1 ° C, while electronics might need <40% RH for ESD control.

</div>
<div style="flex: 1; min-width: 300px; background-color: #f8f9fa; padding: 15px; border-radius: 8px;">

<h4 style="color: #000; margin-top: 0;">5.3 Equipment Maintenance Space</h4>
Adequate clearance around equipment: front access (minimum 900mm), rear access (minimum 600mm), overhead clearance for filter replacement (minimum 600mm). Large equipment may require removable wall panels for installation.

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<div style="display: block; flex-wrap: wrap; gap: 20px; margin: 10px 0;">
<div style="flex: 1; min-width: 300px; background-color: #f8f9fa; padding: 15px; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">5.4 Regulatory & Standard Compliance</h4>
Industry-specific requirements: cGMP for pharmaceuticals, ISO 14644 for classification, FDA 21 CFR Part 11 for electronic records, and SEMI standards for microelectronics.

</div>
<div style="flex: 1; min-width: 300px; background-color: #f8f9fa; padding: 15px; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">5.5 Energy Efficiency & Environmental Control</h4>
Optimizing layout to reduce energy consumption: variable air volume systems, heat recovery, efficient equipment placement. Proper design can reduce HVAC energy use by 20-30% compared to conventional approaches.

</div>
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<div style="text-align: center; margin: 10px 0;">

[caption id="attachment_4318" align="alignnone"

width="960"] Process type analysis for determining required cleanliness levels[/caption]
<p style="font-size: 14px; color: #666; margin-top: 8px;">Figure: Process type analysis for determining required cleanliness levels</p>

</div>
</section><!-- Part 6: Common Modular Cleanroom Layout Configurations -->

<section style="margin-bottom: 40px;">
<h2 style="color: #000; border-bottom: 2px solid #000; padding-bottom: 8px;">Common Modular Cleanroom Layout Configurations</h2>
Several standard layout configurations have

proven effective for different applications and space constraints. Each offers distinct advantages for specific operational requirements.
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<div style="flex: 1; min-width: 300px; background-color: #f8f9fa; padding: 15px; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">6.1 Linear/Straight-line Layout</h4>
Process flow follows a straight path from raw material to finished product. Ideal for sequential operations with minimal backtracking.

Advantages: Simple workflow, easy supervision, minimal cross-traffic

Disadvantages: Requires longer space, limited flexibility

Applications: Assembly lines, packaging operations

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<div style="flex: 1; min-width: 300px; background-color: #f8f9fa; padding: 15px; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">6.2 U-shaped/L-shaped Layout</h4>
Process flow follows a U or L pattern, suitable for space-constrained areas or processes requiring material return.

Advantages: Efficient use of space, compact footprint

Disadvantages: Potential congestion at corners, complex material handling

Applications: Laboratories, research facilities, small-scale production

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<div style="flex: 1; min-width: 300px;

background-color: #f8f9fa; padding: 15px; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">6.3 Central Island Layout</h4>
Core process area in center with support areas surrounding it. Ideal for processes requiring multiple support functions.

Advantages: Excellent supervision, efficient material distribution

Disadvantages: Higher construction cost, potential airflow challenges

Applications: Biotechnology, pharmaceutical compounding, critical processes

</div>
</div>
<div style="overflow-x: auto; margin: 10px 0;">
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<thead>
<tr style="background-color: #000; color: white;">
<th style="padding: 12px; text-align: left; border: 1px solid #ddd;">Layout Type</th>
<th style="padding: 12px; text-align: left; border: 1px solid #ddd;">Space Efficiency</th>
<th style="padding: 12px; text-align: left; border: 1px solid #ddd;">Workflow Efficiency</th>
<th style="padding: 12px; text-align: left; border: 1px solid #ddd;">Expansion Potential</th>
<th style="padding: 12px; text-align: left; border: 1px solid #ddd;">Cost Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td style="padding: 12px; border: 1px solid #ddd;">Linear/Straight-line</td>
<td style="padding: 12px; border: 1px solid #ddd;">Medium</td>
<td style="padding: 12px; border: 1px solid #ddd;">High</td>
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<td style="padding: 12px; border: 1px solid #ddd;">Low</td>
<td style="padding: 12px; border: 1px solid #ddd;">Low</td>
</tr>
<tr style="background-color: #f8f9fa;">
<td style="padding: 12px; border: 1px solid #ddd;">U-shaped/L-shaped</td>
<td style="padding: 12px; border: 1px solid #ddd;">High</td>
<td style="padding: 12px; border: 1px solid #ddd;">Medium</td>
<td style="padding: 12px; border: 1px solid #ddd;">Medium</td>
<td style="padding: 12px; border: 1px solid #ddd;">Medium</td>
</tr>
<tr>
<td style="padding: 12px; border: 1px solid #ddd;">Central Island</td>
<td style="padding: 12px; border: 1px solid #ddd;">Low</td>
```

<td style="padding: 12px; border: 1px solid #ddd;">High</td>
<td style="padding: 12px; border: 1px solid #ddd;">High</td>
<td style="padding: 12px; border: 1px solid #ddd;">High</td>
</tr>
</tbody>
</table>
<p style="font-size: 14px; color: #666; text-align: center; margin-top: 8px;">Comparison of different modular cleanroom layout configurations</p>

</div>
</section><!-- Part 7: Design Tools & Best Practices -->

<section style="margin-bottom: 40px;">
<h2 style="color: #000; border-bottom: 2px solid #000; padding-bottom: 8px;">Design Tools & Best Practices</h2>
Utilizing appropriate design tools and following

industry best practices significantly improves the quality and efficiency of modular cleanroom layout design projects.
<div style="background-color: #f8f9fa; padding: 10px; margin: 10px 0; border-radius: 8px;">
<h3 style="color: #000; margin-top: 0;">7.1 Common Design Software</h3>
<ul style="padding-left: 20px;">
AutoCAD: 2D drafting and detailed drawings
Revit (BIM): 3D modeling with building information
SolidWorks: Equipment modeling and integration
Specialized Cleanroom Software: Computational fluid dynamics for airflow simulation

Deiiang™ typically uses BIM for complex projects, reducing design conflicts by up to 80% compared to traditional 2D approaches.

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<div style="background-color: #f8f9fa; padding: 10px; margin: 10px 0; border-radius: 8px;">
<h3 style="color: #000; margin-top: 0;">7.2 Best Practices</h3>
<ul style="padding-left: 20px;">
Early Multidisciplinary Integration: Involve production, quality, maintenance, and safety teams from concept stage
Lifecycle Cost Consideration: Evaluate operational costs (energy, maintenance) alongside capital investment
Airflow Simulation: Model particle distribution and airflow patterns before construction
Detailed SOP Development: Create comprehensive standard operating procedures for all operations
Continuous Validation:

Implement ongoing monitoring and periodic requalification

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<div style="background-color: #f8f9fa; padding: 10px; margin: 10px 0; border-radius: 8px;">
<h3 style="color: #000; margin-top: 0;">7.3 Common Mistakes to Avoid</h3>
<ul style="padding-left: 20px;">
Ignoring personnel and material flow intersections
Inadequate clearances for maintenance and filter replacement
Insufficient consideration of future expansion needs
Over-specifying or under-specifying cleanliness requirements
Poor placement of utilities and service connections
Inadequate emergency and safety provisions

According to industry data collected by Jason.peng, approximately 65% of cleanroom design issues stem from inadequate upfront planning and failure to involve all stakeholders early in the process.

</div>
</section><!-- Part 8: FAQ -->

<section style="margin-bottom: 40px;">
<h2 style="color: #000; border-bottom: 2px solid #000; padding-bottom: 8px;">Frequently Asked Questions</h2>
<div style="background-color: #f8f9fa; padding: 15px; margin: 15px 0; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">Can modular cleanroom layouts be easily modified?</h4>
Yes, one of the key advantages of modular cleanrooms is their reconfigurability. Deiiang ™ systems typically allow for layout changes with minimal disruption, often completed in 30-50% of

the time required for traditional construction modifications. Wall panels can be repositioned, and additional modules can be integrated as needed.

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<div style="background-color: #f8f9fa; padding: 15px; margin: 15px 0; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">How is isolation maintained between different cleanliness zones?</h4>
Isolation is achieved through a combination of physical barriers (walls, doors), pressure differentials (typically 10-15 Pa between adjacent zones), and procedural controls (gowning protocols, material transfer procedures). Airlocks with interlocking doors prevent simultaneous opening between zones of different classifications.

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<div style="background-color: #f8f9fa; padding:

15px; margin: 15px 0; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">How to design a cleanroom layout for small spaces?</h4>
For limited spaces, consider vertical utilization with mezzanines, compact equipment layouts, and multi-functional areas. U-shaped or L-shaped configurations often work well. Optimize every square meter by carefully analyzing workflow and eliminating non-value-added movements. Deiiang ™ has successfully implemented ISO 5 cleanrooms in spaces as small as 12m².

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<div style="background-color: #f8f9fa; padding: 15px; margin: 15px 0; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">How is fire safety addressed in cleanroom design?</h4>
Fire safety incorporates early detection systems, appropriate fire-rated materials (typically 1-hour rating for walls), emergency lighting, clearly

marked exits, and automatic fire suppression systems. Cleanroom-specific considerations include compatibility of fire suppression agents with sensitive equipment and processes.

</div>
<div style="background-color: #f8f9fa; padding: 15px; margin: 15px 0; border-radius: 8px;">
<h4 style="color: #000; margin-top: 0;">How to determine the number and placement of FFUs?</h4>
FFU quantity is calculated based on room volume, required air changes per hour, and filter efficiency. For ISO 5, typical coverage is 25-40% of ceiling area. Placement considers equipment layout, workflow, and return air locations. CFD analysis can optimize distribution for uniform airflow and particle control.

</div>

</section><!-- Part 9: Conclusion & Call to Action -->

<section style="margin-bottom: 40px; text-align: center; background-color: #f8f9fa; padding: 30px; border-radius: 8px;">
<h2 style="color: #000; margin-top: 0;">Conclusion</h2>
Effective modular cleanroom layout design requires careful consideration of multiple factors including workflow efficiency, contamination control, regulatory compliance, and future flexibility. By following the systematic approach outlined in this guide - from thorough requirement analysis through detailed design and validation - organizations can create cleanroom environments that support operational excellence while accommodating future growth and changes.

The modular approach offers significant advantages in speed of deployment, adaptability, and lifecycle cost, making it an increasingly

popular choice across industries requiring controlled environments. Proper planning and professional design consultation are essential investments that pay dividends throughout the cleanroom's operational life.
<div style="margin: 30px 0;">
<h3 style="color: #000;">Ready to Start Your Modular Cleanroom Project?</h3>
Contact our cleanroom specialists today for a free consultation and customized layout design.
<div style="display: flex; flex-wrap: wrap; justify-content: center; gap: 15px; margin: 10px 0;">Request Free Consultation
Download Design Guide</div>

<p style="font-size: 14px; color: #666;">Design Specialist: Jason.peng | Brand: Deiiang™</p>

</div>
</section></div>