Section 002-001 — Foundations of High-Containment Laboratory Design

Instructor: Luis Linares

Course: High-Containment Laboratory Design

Purpose of the document:

This lecture map is designed to help participants navigate the content of Section 002-001. It identifies the main conceptual sections, key ideas, and logical transitions of the session. It functions as an orientation and study tool and does not replace the lecture.

Section 1 — Introduction: the laboratory as a living system

Main focus: Establish the foundational idea that a high-containment laboratory is not merely a building, but a living system shaped by design, systems, procedures, and human behavior.

Key points:

- A containment laboratory depends as much on human behavior as on technical systems.
- Physical barriers, equipment, procedures, and safety culture work together as a single system.
- Failure in any one element weakens the entire system.
- The session sets the conceptual foundations for understanding containment as integrated protection.

Rhetorical questions / Attention signals:

- What truly makes a laboratory safe?
- Is safety defined by infrastructure, equipment, or culture?

Orientation signal: Introduces the central question that will accompany the entire course.

Section 2 — Scope and objectives of the course

Main focus: Clarify the purpose, structure, and pedagogical approach of the course.

Key points:

- The course offers an integrated view of high-containment laboratory design, particularly BSL-3.
- Biological safety principles are translated into design decisions.
- The content is framed within Latin American institutional and operational contexts.
- The course emphasizes not only what to do, but why decisions are made.

Rhetorical questions / Attention signals:

- How do biosafety principles become design choices?
- Why must design adapt to local contexts?

Orientation signal: Aligns participant expectations with the technical and conceptual goals of the course.

Section 3 — Structure of the course and thematic blocks

Main focus: Present the internal organization of the course and the progression of topics.

Key points:

- The course is divided into two main parts.
- Part 1 addresses historical context, technical foundations, materials, and engineering controls.
- Part 2 addresses human-centered design, regulatory balance, operational continuity, and sustainability.
- Each block builds toward an integrated understanding of containment.

Rhetorical questions / Attention signals:

- Why is containment discussed from history to sustainability?
- How do these topics connect?

Orientation signal: Provides a roadmap for how concepts will accumulate across sessions.

Section 4 — Historical context and origin of biological containment

Main focus: Explain why biological containment emerged and how it evolved historically.

Key points:

- Early containment laboratories originated in the United States during the 1940s and 1950s.
- Facilities such as Fort Detrick and Plum Island shaped early containment strategies.
- Containment initially served defense programs before shifting to public health and research.

- Epidemic outbreaks reinforced the need for safer laboratories.

Rhetorical questions / Attention signals:

- Why were the first containment laboratories created?
- How did historical events shape today's laboratories?

Orientation signal: Connects present-day containment design to its historical roots.

Section 5 — From technical systems to integrated protection

Main focus: Reinforce containment as an integrated system rather than a collection of technical components.

Key points:

- Containment is not achieved through a single system or device.
- Design decisions span materials, spatial organization, and personnel training.
- All decisions align with a guiding principle of comprehensive protection.
- Protection extends to people, animals, the environment, and research integrity.

Rhetorical questions / Attention signals:

- Can equipment alone ensure containment?
- How do design and training interact?

Orientation signal: Transitions from historical context to systemic thinking.

Section 6 — Planning as the foundation of containment

Main focus: Introduce planning as the most critical factor in laboratory safety and performance.

Key points:

- Laboratory planning defines access control and spatial hierarchy.
- The "box-in-a-box" concept isolates the laboratory from external environments.
- Planning supports both energy efficiency and biosafety.
- Design must anticipate operational needs and risks.

Rhetorical questions / Attention signals:

- Why must containment be planned before technical design?
- What happens when planning is insufficient?

Orientation signal: Positions planning as the basis for all subsequent decisions.

Section 7 — Influence of SOPs on design and containment

Main focus: Explain how Standard Operating Procedures directly shape laboratory design.

Key points:

- SOPs determine primary containment measures such as biosafety cabinets.
- Workflows influence spatial layout and equipment placement.
- Aerosol-generating activities require specific containment strategies.
- SOPs guide personal protective equipment requirements.

Rhetorical questions / Attention signals:

- How does work practice influence spatial design?
- Can SOPs be separated from architecture?

Orientation signal: Links operational behavior to physical design requirements.

Section 8 — Secondary barriers, airflow, and pressure zoning

Main focus: Describe how SOPs influence secondary containment systems.

Key points:

- Pressure differentials organize clean, less clean, and potentially contaminated zones.
- Personnel and material flows must align with negative pressure zoning.
- HVAC systems respond to procedural needs.
- Airflow direction reflects biological risk.

Rhetorical questions / Attention signals:

- What happens when airflow contradicts workflow?
- How does zoning protect containment?

Orientation signal: Bridges procedures with mechanical systems.

Section 9 — Decontamination and waste management as design drivers

Main focus: Present decontamination requirements as determinants of laboratory design.

Key points:

- SOPs may require autoclaving or chemical disinfection before material exit.
- Design may include pass-through autoclaves and effluent treatment systems.
- Whole-room decontamination requires hermetic sealing and injection ports.
- Finishes must resist chemical exposure.

Rhetorical questions / Attention signals:

- What design changes are required by VHP decontamination?
- Why must hermeticity be planned early?

Orientation signal: Shows how operational requirements fix physical design decisions.

Section 10 — Hermeticity and verification of containment

Main focus: Explain the importance of laboratory airtightness and its verification.

Key points:

- Hermetic laboratories are safer and more energy efficient.
- Airtightness stabilizes pressure differentials and airflow.
- Laboratories must be isolated from atmospheric pressure fluctuations.
- Pressure decay testing verifies containment performance.

Rhetorical questions / Attention signals:

- How do we know a laboratory is truly airtight?
- Why is verification as important as design?

Orientation signal: Introduces validation as a measurable requirement.

Section 11 — Sustainability and energy considerations

Main focus: Address sustainability within the constraints of high-containment laboratories.

Key points:

- BSL-3 laboratories renew 100% of air and cannot rely on recirculation.
- Energy efficiency is possible when addressed through planning and design.
- Containment integrity must always take precedence.
- Sustainability begins with airtightness and system optimization.

Rhetorical questions / Attention signals:

- Can a high-containment laboratory be sustainable?
- Where do efficiency gains come from?

Orientation signal: Prepares the transition from fundamentals to advanced system design.

Section 12 — Closing reflection: containment as shared responsibility

Main focus: Conclude the session by reinforcing containment as a shared technical and human responsibility.

Key points:

- Safety emerges from the interaction of systems, people, and culture.
- Design decisions carry long-term consequences.
- Containment is maintained through continuous attention and discipline.
- The guiding question remains central throughout the course.

Rhetorical questions / Attention signals:

- Who is responsible for containment over time?
- How do decisions made today affect future safety?

Orientation signal: Closes the session by reinforcing the foundational principles that support all subsequent lectures.

Lecture 002-002 — In-Depth Design: Critical Systems and Infrastructure

Instructor: Luis Linares
Course: High-Containment Laboratory Design

Purpose of the document:

This lecture map is designed to help participants navigate the content of Lecture 002-002. It identifies the main conceptual sections, critical design decisions, and logical transitions of the lecture. It functions as an orientation and study tool and does not replace the lecture.

SECTION 1 — The laboratory as a living system

Main focus: Introduce the laboratory as a dynamic, living system rather than a static collection of walls, equipment, or specifications.

Key points:

- The course is grounded in accumulated experience from high-containment projects across Latin America.
- The laboratory is not defined only by walls, filters, or ventilation.
- Containment, comfort, and efficiency depend on how systems interact over time.
- The laboratory must be understood as a system that evolves during operation.

Rhetorical questions / Attention signals:

- Is a laboratory just a collection of components?
- What happens when one part of the system changes?

Orientation signal: Establishes systems thinking as the foundational lens for the entire lecture.

SECTION 2 — Design in depth as a performance-based approach

Main focus: Define what “design in depth” means in the context of high-containment laboratories.

Key points:

- Design in depth goes beyond drawings and equipment catalogs.
- It requires anticipating laboratory behavior over 10, 15, or 20 years.
- Decisions affect hermeticity, system response to failure, energy use, and personnel safety.
- Each component exists for a reason within a broader balance.

Rhetorical questions / Attention signals:

- How will this laboratory behave years after commissioning?
- What happens when one component is altered?

Orientation signal: Frames design as a long-term performance question, not a short-term construction task.

SECTION 3 — Layers of containment design

Main focus: Present containment as a layered system composed of multiple interacting elements.

Key points:

- The lecture introduces physical barriers as one layer of containment.
- Critical engineering systems support containment.
- Energy management is integrated into containment performance.
- The lecture will culminate in a real integrated case study.

Rhetorical questions / Attention signals:

- Where does containment actually reside?
- Can a single system ensure containment on its own?

Orientation signal: Prepares participants to see containment as a system, not an isolated feature.

SECTION 4 — Critical systems as containment elements

Main focus: Position critical systems as integral components of containment, not auxiliary infrastructure.

Key points:

- HVAC systems are not just comfort systems.

- Airflow behavior directly affects containment stability.
- Directional airflow and pressure gradients are containment mechanisms.
- System balance is essential; altering one element affects all others.

Rhetorical questions / Attention signals:

- What happens if airflow balance is modified without coordination?
- Can containment exist without stable airflow control?

Orientation signal: Transitions from conceptual containment to mechanical and operational realities.

SECTION 5 — Directional airflow and pressure control

Main focus: Explain the logic of directional airflow and differential pressure in BSL-3 laboratories.

Key points:

- A BSL-3 laboratory is not fully sealed.
- The secondary barrier is directional airflow.
- Controlled leakage is intentional and managed.
- Pressure differentials between rooms maintain containment.

Rhetorical questions / Attention signals:

- Where do we want leaks to occur?
- What happens when doors open?

Orientation signal: Clarifies common misconceptions about sealing and containment.

SECTION 6 — Airflow control devices as critical containment components

Main focus: Describe airflow control devices as critical containment elements.

Key points:

- Airflow control devices are not generic HVAC components.
- Venturi valves and dampers control directionality and stability.
- These devices determine recovery after dynamic events.
- They must meet both aerodynamic and containment integrity criteria.

Rhetorical questions / Attention signals:

- What defines a containment-grade air valve?
- How does recovery time affect safety?

Orientation signal: Links mechanical design decisions directly to biosafety outcomes.

SECTION 7 — Measurement, monitoring, and system stability

Main focus: Emphasize measurement and monitoring as the foundation of containment control.

Key points:

- Containment depends on reliable measurement.
- Without data, the system is blind.
- Differential pressure sensors must be strategically located.
- Calibration is essential to avoid instability and excess energy use.

Rhetorical questions / Attention signals:

- What happens when sensors are inaccurate?
- Can containment be trusted without verification?

Orientation signal: Introduces verification as a continuous operational requirement.

SECTION 8 — HVAC systems and energy demand in BSL-3 laboratories

Main focus: Explain why HVAC systems dominate energy consumption in high-containment laboratories.

Key points:

- Air is the main energy consumer in BSL-3 laboratories.
- Single-pass air and continuous operation drive demand.
- Air must be fully conditioned before entering the laboratory.
- HVAC design choices directly affect energy and containment.

Rhetorical questions / Attention signals:

- Why do BSL-3 laboratories consume 10–20 times more energy?
- Where can efficiency be introduced without risk?

Orientation signal: Sets the stage for integrating sustainability with containment.

SECTION 9 — Sustainability as a containment strategy

Main focus: Present sustainability as an integral part of biosafety, not a separate objective.

Key points:

- Sustainability does not mean reducing energy at any cost.
- Efficiency must not compromise containment.

- Technical improvements can also be environmental improvements.
- Sustainability is a way of thinking, not a decorative option.

Rhetorical questions / Attention signals:

- Can a safer laboratory also be more efficient?
- What happens when sustainability is considered late?

Orientation signal: Reframes sustainability as a safety and resilience issue.

SECTION 10 — The hierarchy of energy strategies

Main focus: Introduce the priority sequence for energy decision-making.

Key points:

- First: reduce demand.
- Second: optimize systems.
- Third: recover energy.
- Fourth: generate renewable energy.
- Renewable generation only makes sense after demand is defined.

Rhetorical questions / Attention signals:

- Why does photovoltaic sizing come last?
- What happens when generation compensates inefficiency?

Orientation signal: Establishes order and discipline in energy decision-making.

SECTION 11 — Integrated case study: SAG Lo Aguirre

Main focus: Apply the lecture concepts to a real high-containment laboratory project.

Key points:

- The SAG Lo Aguirre BSL-3+ laboratory in Chile is presented.
- Design decisions led to a carbon-neutral building.
- Certified under CES and ISO 50001.
- Demonstrates that containment and sustainability are compatible.

Rhetorical questions / Attention signals:

- How do these decisions translate into real buildings?
- What trade-offs were required?

Orientation signal: Demonstrates integration of theory and practice.

SECTION 12 — Life-cycle cost and ethical responsibility

Main focus: Close the lecture by linking design decisions to life-cycle cost and responsibility.

Key points:

- Construction is only a fraction of total life-cycle cost.
- Operation and maintenance dominate long-term costs.
- Continuous training and recommissioning are essential.
- Planning is an ethical responsibility, not just a technical exercise.

Rhetorical questions / Attention signals:

- What defines success if a laboratory cannot be sustained?
- Who bears the consequences of poor planning?

Orientation signal: Closes the lecture by reinforcing long-term responsibility and accountability.

Session 002-003 — Planning

Instructor: Luis Linares

Course: High-Containment Laboratory Design

Purpose of the document:

This lecture map is designed to help participants navigate the content of Lecture 002-003. It identifies the main conceptual sections, decisional points, and logical transitions of the course. It functions as an orientation and study tool and does not replace the lecture.

SECTION 1 — The laboratory as a life-cycle system

Main focus: Introduce the high-containment laboratory as a living installation governed by a full life cycle, and establish planning as the fundamental framework of the course.

Key points:

- The high-containment laboratory is not a conventional construction project.
- It is conceived as a repetitive cycle of evaluation, validation, training, and operation.
- The typical analysis horizon is 20 to 25 years.
- Operation and maintenance constitute the longest and most costly phase of the cycle.

Rhetorical questions / Attention signals:

- Why can a laboratory not be understood as a straight line of design and construction?
- What does it mean to plan for decades rather than only for inauguration?

Orientation signal: Establishes the temporal and conceptual framework from which all subsequent decisions will be evaluated.

SECTION 2 — Planning failures as the origin of problems in high containment

Main focus: Dismantle the idea that problems in BSL-3 laboratories are primarily technical failures.

Key points:

- Most problems are not errors in calculation or equipment selection.
- Failures arise when critical decisions are made too early, too late, or without sufficient information.
- Planning errors propagate into design, construction, operation, and maintenance.

Rhetorical questions / Attention signals:

- When a BSL-3 does not work, what actually failed?
- Why are early errors difficult to correct later?

Orientation signal: Introduces the central thesis of the course: planning is deciding, and poor decisions have irreversible consequences.

SECTION 3 — Viability as the central objective of the lecture

Main focus: Clearly define what kind of lecture this is and what kind of lecture it is not.

Key points:

- It is not a lecture on architectural design.
- It is not a normative or regulatory compliance lecture.
- It is not a technology selection lecture.
- It is a lecture about viability.

Emphasis:

- Assessing whether a laboratory can be built, operated, and maintained safely and sustainably.
- Viability precedes design.

Rhetorical questions / Attention signals:

- Can this project be sustained technically, operationally, and financially for 20–25 years?
- Orientation signal: Defines the scope of the lecture and aligns participant expectations.

SECTION 4 — Budget as a result, not as a starting point

Main focus: Reorder the traditional logic used to initiate laboratory projects.

Key points:

- The budget cannot be the starting point.
- It is the explicit result of the planning process.

- Early numbers are hypotheses, not commitments.
- Many costly decisions are fixed early without being recognized as financial decisions.

Rhetorical questions / Attention signals:

- Why does asking for numbers before decisions generate structural errors?
- Which decisions fix costs without us realizing it?

Orientation signal: Connects planning with long-term financial consequences.

SECTION 5 — Sequential chain of decisions in planning

Main focus: Present the lecture's logic as a structured sequence of decisions.

Key points:

- Each step reduces uncertainty.
- Each step fixes technical and financial decisions.
- Real options close progressively.
- The order of steps matters.

Rhetorical questions / Attention signals:

- What happens when this order is reversed?
- Which decisions cannot be undone later?

Orientation signal: Introduces the logical diagram of the lecture and prepares the transition to client inputs.

SECTION 6 — Initial client inputs: value and limits

Main focus: Distinguish between preliminary inputs and validated technical requirements.

Key points:

- Proposed scientific program.
- Preliminary pathogen list.
- Available site.
- Target budget.
- Institutional timeline.

Central concept:

- These inputs are not wrong, but they are not sufficient.
- At this stage, they are hypotheses, not requirements.

Rhetorical questions / Attention signals:

- What happens when we treat hypotheses as requirements?

- What information is still missing?

Orientation signal: Prepares the transition toward validation and biological risk analysis.

SECTION 7 — Validating is not questioning: translating intentions into consequences

Main focus: Explain what validation means during planning.

Key points:

- Validating is not stopping the project or questioning client authority.
- It is translating intentions into technical consequences.
- Biology → space → systems → costs.
- Failing to validate pushes consequences forward, where they are more expensive.

Rhetorical questions / Attention signals:

- What does “we want to work with influenza” really mean?
- What does operating 24/7 imply in practical terms?

Orientation signal: Closes the input phase and opens the path to biological risk.

SECTION 8 — Biological risk assessment as a decisional event

Main focus: Present biological risk analysis as the project’s inflection point.

Key points:

- It is not an administrative requirement.
- It is the most important decisional event of the project.
- It transforms institutional intention into technical obligation.
- Biology ceases to be abstract and begins to impose physical conditions.

Rhetorical questions / Attention signals:

- What changes after risk analysis?
- What happens if this step is superficial?

Orientation signal: Marks the moment when the project becomes biological.

SECTION 9 — Activity-based risk, not pathogen-based risk alone

Main focus: Dismantle automatic classification by pathogen or BSL level.

Key points:

- The same pathogen can imply different risks.
- Risk depends on activities, frequency, personnel, and context.

- Evaluating only the pathogen is a common cause of failure.

Rhetorical questions / Attention signals:

- What happens when we evaluate the pathogen but not the activity?
- How does risk change between culture, animal work, or diagnostics?

Orientation signal: Introduces the direct relationship between risk and spatial design.

SECTION 10 — From risk to space, flows, and containment

Main focus: Show how risk fixes irreversible spatial decisions.

Key points:

- Laboratory size is not defined by the budget.
- It is defined by flows, separations, and SOPs.
- Risk changes the budget, not the other way around.
- Space imposes a containment strategy.

Rhetorical questions / Attention signals:

- What happens when risk requires showers, airlocks, and decontamination?
- Why must the building still remain abstract at this stage?

Orientation signal: Leads into the definition of containment as an integrated system.

SECTION 11 — Containment as an integrated system

Main focus: Define containment beyond a single isolated element.

Key points:

- Physical barriers.
- Mechanical systems.
- Operational procedures.
- Human behavior.
- If one fails, the entire system fails.

Rhetorical questions / Attention signals:

- Where does the containment barrier really exist?
- Can a procedure correct poor geometry?

Orientation signal: Prepares the transition toward envelope, HVAC, and performance.

SECTION 12 — Integrated design and early decision-making

Main focus: Introduce the Integrated Design Process (IDP).

Key points:

- Multidisciplinary teams from the outset.
- The greatest cost impact occurs during planning and schematic design.
- Oversizing is paid for over decades.
- Planning decides which risks are accepted.

Rhetorical questions / Attention signals:

- What happens when disciplines work sequentially?
- Why must the building absorb human errors?

Orientation signal: Closes the lecture by establishing planning as a strategic decision, not a design exercise.

BIOLAB SOLUTIONS

Session 002-004 — Design

Instructor: Luis Linares

Course: High-Containment Laboratory Design

Purpose of the document:

This lecture map is designed to help participants navigate the content of Lecture 002-004. It identifies the main conceptual sections, structural inflection points, and logical transitions of the session. It functions as an orientation and study tool and does not replace the lecture.

SECTION 1 — Design does not begin with a blank page

Main focus: Reframe the design phase as a process of verification and consolidation rather than creative initiation.

Key points:

- Design inherits decisions from planning.
- Assumptions must be explicit before drawing begins.
- Silent re-decisions create downstream risk
- Design validates whether prior decisions are technically coherent.

Rhetorical questions / Attention signals:

- What exactly are we designing?
- What happens if we begin drawing without verifying inherited decisions?

Orientation signal: Establishes the conceptual boundary between planning (002-003) and design (002-004).

SECTION 2 — The critical transition from planning to design

Main focus: Define the formal handoff required before entering schematic design.

Key points:

- Inherited decisions must be documented.
- Unresolved constraints must be identified.
- The project must be demonstrably designable.
- Verification is a structural checkpoint, not administrative formality.

Rhetorical questions / Attention signals:

- Are we sure what has already been decided?
- What is still ambiguous but assumed to be fixed?

Orientation signal: Marks the inflection point where the project becomes structurally constrained.

SECTION 3 — Integrated Design Process (IDP) as decision architecture

Main focus: Introduce IDP as a coordinated and sequenced decision framework.

Key points:

- Architecture, engineering, and biosecurity must align early.
- Effort shifts forward in time.
- The order of decisions reduces later conflict.
- Sequential fragmentation increases redesign risk.

Rhetorical questions / Attention signals:

- What happens when each discipline works independently?
- When do costs actually become fixed?

Orientation signal: Positions integration as a structural necessity, not a management preference.

SECTION 4 — Decision timing and cost impact

Main focus: Establish the relationship between decision timing and lifecycle consequences.

Key points:

- Early decisions are inexpensive to adjust
- Late changes multiply cost and operational disruption.
- Between schematic and anteproyecto, most structural logic must be resolved.
- Executive documentation does not redesign the project.

Rhetorical questions / Attention signals:

- When is a change still affordable?
- What happens if layout shifts during executive phase?

Orientation signal: Connects decision sequencing with lifecycle cost and risk control.

SECTION 5 — Schematic design as freeze point

Main focus: Define schematic design as the structural locking of layout and flow logic.

Key points:

- Layout freeze defines spatial hierarchy.
- Flow paths become architectural constraints.
- HVAC and pressure cascades depend on geometry.
- Flexibility decreases after freeze.

Rhetorical questions / Attention signals:

- What becomes irreversible after schematic design?
- What does it mean to "change a wall" in BSL-3?

Orientation signal: Prepares the transition from layout logic to system coupling.

SECTION 6 — Operational flows as the first security system

Main focus: Establish flows as the foundational safety mechanism.

Key points:

- Personnel flow.
- Material flow
- Waste flow.
- Layered zoning (campus → building → lab → BSL-3).

Minimization of cross-traffic.

Rhetorical questions / Attention signals:

- Can mechanical systems compensate for poor flow logic?
- Where does safety actually begin?

Orientation signal: Reorients containment from mechanical systems to spatial behavior.

SECTION 7 — Containment as airflow behavior

Main focus: Define BSL-3 containment in behavioral rather than numeric terms.

Key points:

- Directional airflow stability.
- Controlled leakage
- Influence of door geometry and openings.
- Pressure differential as robustness, not origin.

Rhetorical questions / Attention signals:

- Does a pressure number create containment?
- What determines airflow direction in practice?

Orientation signal: Links spatial geometry with mechanical logic.

SECTION 8 — Redundancy (N+1) and resilience

Main focus: Introduce redundancy as architectural resilience.

Key points:

- Avoidance of single points of failure.
- Application to exhaust, supply, electrical, and control systems.
- Resilience under malfunction.
- Continuity of containment.

Rhetorical questions / Attention signals:

What happens when one fan fails?

- Is redundancy optional or structural?
- Orientation signal: Connects system architecture with operational continuity.

SECTION 9 — Barrier equipment as system decisions

Main focus: Treat autoclaves, EDS, and HEPA components as integrated design decisions.

Key points:

- Equipment location affects flow and envelope.
- Maintenance access affects exposure risk.
- Equipment placement influences lifecycle cost.

Rhetorical questions / Attention signals:

- Is equipment selection just a procurement task?
- Where should maintenance occur relative to containment?

Orientation signal: Reinforces system thinking beyond product choice.

SECTION 10 — Anteproyecto as full technical resolution

Main focus: Define anteproyecto as the stage of complete technical consolidation.

Key points:

- System dimensioning finalized.
- Pressure cascades validated.
- Interdisciplinary conflicts resolved.
- Redundancy confirmed.

Rhetorical questions / Attention signals:

- What must be fully resolved before executive documentation begins?
- What risks arise if systems remain undefined?

Orientation signal: Transitions from schematic logic to full system definition.

SECTION 11 — Basis of Design (BOD) as technical memory

Main focus: Present BOD as the document that anchors decision continuity.

Key points:

- Records validated requirements.
- Defines system architecture and redundancy logic.
- Captures airflow and containment strategy.
- Guides executive documentation and commissioning.

Rhetorical questions / Attention signals:

- What prevents reinterpretation during construction?
- Where are core decisions preserved?

Orientation signal: Positions documentation as structural control, not paperwork.

SECTION 12 — BIM precision and early LOD requirements

Main focus: Explain why high-containment design requires early modeling precision.

Key points:

- Critical systems require LOD 350–400.
- Clash-free coordination is safety-critical.
- Progressive ambiguity is unacceptable.
- Model precision supports regulatory validation.

Rhetorical questions / Attention signals:

- Can containment tolerate “approximate” duct routing
- When must coordination be final?

Orientation signal: Closes the lecture by reinforcing that design in high containment is a process of disciplined decision closure, not incremental refinement.

How to use this lecture map

When reviewing the session:

Distinguish verification logic from creative design logic.
– Identify freeze points and irreversible decisions.
– Relate layout directly to airflow behavior.
– Treat redundancy as architectural resilience.
– Understand anteproyecto as full technical resolution.
– Recognize BOD as structural continuity.
– Avoid reducing containment to numeric compliance.

BIOLAB SOLUTIONS

Session 002-005 — Construction, commissioning, and final acceptance

Instructor: Luis Linares
Course: High-Containment Laboratory Design

Purpose of the document:

This lecture map is designed to help participants navigate the content of Session 002-005, identifying not only the topics covered, but the logic that connects them. The session does not introduce isolated elements, but develops a continuous chain: from the materialization of risk in construction, through the loss or preservation of system coherence, to performance verification and final acceptance based on evidence. This document functions as an orientation and study tool and does not replace the lecture.

SECTION 1 — Risk becomes physical in construction

Main focus:
Establish that the construction phase marks the point at which risk defined in planning and design ceases to be a technical abstraction and becomes a real physical condition that must be executed, controlled, and verified.

Key points:

- The risk defined in previous phases does not disappear or resolve automatically.
- In construction, that risk is translated into concrete physical conditions.
- Containment ceases to exist as intent and becomes fully dependent on execution.
- Each construction decision introduces or preserves conditions that affect system performance.
- From this point on, the laboratory ceases to be a conceptual project and becomes a real system with physical behavior.

Rhetorical questions / Attention signals:
- At what point does risk stop being a definition and become a real condition?
- What happens if execution does not correspond exactly to the defined risk?

Orientation signal:
This section marks the beginning of the critical shift in the project: from design to physical system, where real containment performance begins to be defined.

SECTION 2 — Construction as the determinant of containment

Main focus:
Reposition the concept of containment from design to construction, establishing that containment does not exist in drawings or specifications, but only in what is actually built.

Key points:
- Design defines intent, but does not guarantee outcome.
- Construction determines whether containment exists in reality.
- The laboratory operates according to installed conditions, not according to design intent.
- Coherence between design and execution is the necessary condition for containment.
- A deviation during construction breaks that coherence, regardless of design quality.

Rhetorical questions / Attention signals:
- Where does containment truly exist: in drawings or in execution?
- Can a correct design produce a system that does not contain?

Orientation signal:
Establishes that responsibility for containment shifts from technical intent to physical result.

SECTION 3 — Loss of coherence as the origin of failure

Main focus:
Explain that failure in a BSL-3 laboratory is not a single event, but a progressive process in which coherence between defined risk and physical execution is lost.

Key points:
- Failure does not occur due to a single critical decision.
- It results from the accumulation of deviations throughout construction.
- Each deviation introduces a difference between what was defined and what was executed.
- That difference affects system performance cumulatively.
- The system may appear complete, but have lost the coherence required to contain.

Rhetorical questions / Attention signals:
- At what point does system failure actually begin?
- Is the loss of coherence visible during construction?

Orientation signal:
Introduces the cumulative logic of failure and eliminates the idea of a single error.

SECTION 4 — Variability in construction and its impact on performance

Main focus:
Analyze how small variations during construction generate deviations that affect overall system performance.

Key points:
- Variations in materials, tolerances, and sequence introduce deviations.
- These deviations are not isolated; they integrate into the system.
- System behavior depends on the interaction of its parts.
- A local variation can affect global containment.
- Performance is not the sum of elements, but the result of their interaction.

Rhetorical questions / Attention signals:
- What real impact does a small variation have in a containment system?
- Can a seemingly minor deviation affect total performance?

Orientation signal:
Connects detailed execution with full system behavior.

SECTION 5 — Construction as the last point of control

Main focus:
Establish that construction represents the last effective opportunity to correct deviations before they become permanently integrated into laboratory operation.

Key points:
- Deviations can be identified and corrected during construction.
- Once built, the system enters operation with those conditions.
- Later corrections involve greater technical complexity.
- They also involve higher cost and operational impact.
- Uncorrected decisions are transferred directly into the laboratory life cycle.

Rhetorical questions / Attention signals:
- When does it stop being viable to correct a deviation?
- What happens if a deviation is accepted during construction?

Orientation signal:
Defines construction as the last real point of technical control.

SECTION 6 — Cost and schedule pressure as drivers of deviation

Main focus:
Analyze how real execution conditions influence technical decisions that may introduce deviations.

Key points:
- Construction occurs under cost and time pressure.
- These pressures affect decisions on site.

- Decisions may diverge from the defined risk.
- Deviations are introduced and justified by operational conditions.
- Technical coherence can be lost under these conditions.

Rhetorical questions / Attention signals:
- What decisions change when a project enters pressure?
- How are deviations justified on site?

Orientation signal:
Introduces external factors that directly affect system performance.

SECTION 7 — Fragmentation in construction and loss of coherence

Main focus:
Explain how fragmented execution among multiple actors contributes to loss of system coherence.

Key points:
- Construction involves multiple disciplines and actors.
- Each executes a part of the system.
- Without integration, inconsistencies emerge.
- These inconsistencies translate into cumulative deviations.
- Containment depends on coordination among all actors.

Rhetorical questions / Attention signals:
- What happens when each discipline executes without integration?
- Where is system coherence lost?

Orientation signal:
Reinforces that containment is the result of integration, not isolated execution.

SECTION 8 — Commissioning as performance verification

Main focus:
Define commissioning as the process that verifies the real performance of the containment system.

Key points:
- It is not a final project activity.
- It is a process of verifying the complete system.
- It evaluates performance under real operating conditions.
- It includes evaluation under failure scenarios.
- It allows demonstration of whether the system contains or not.

Rhetorical questions / Attention signals:
- What does it really mean to verify a laboratory?
- Is it enough to prove that the system works?

Orientation signal:
Introduces verification as a requirement to validate containment.

SECTION 9 — Real conditions and failure scenarios

Main focus:
Establish the criteria under which system performance must be evaluated.

Key points:
- Static conditions do not represent real behavior.
- The system must be evaluated under real conditions.
- It must also be evaluated under failure scenarios.
- Containment must be maintained in both conditions.
- Performance must be demonstrated through evidence.

Rhetorical questions / Attention signals:
- What happens when the system stops operating under ideal conditions?
- Is containment maintained under failure scenarios?

Orientation signal:
Defines the technical criteria for verification.

SECTION 10 — As-built as the basis for verification

Main focus:
Establish that system verification depends on the real representation of what has been built.

Key points:
- As-built drawings represent the constructed system.
- They allow verification of real performance.
- They are the basis for operation and maintenance.
- The accuracy of the as-built affects the validity of commissioning.
- Without reliable as-built documentation, verification loses validity.

Rhetorical questions / Attention signals:
- What is being verified if the as-built does not represent the real system?
- Can a system be validated without reliable documentation?

Orientation signal:
Connects documentation with technical verification.

SECTION 11 — Contract as a structure for technical decision-making

Main focus:
Explain that the contract defines how technical decisions are made during construction.

Key points:
- The contract establishes performance criteria.
- It defines who has technical authority.
- Without measurable criteria, decisions become interpretative.
- Technical decisions are transferred to the construction site.
- Containment may depend on interpretations during execution.

Rhetorical questions / Attention signals:
- Who decides on site when the contract is not clear?
- What happens when there are no measurable criteria?

Orientation signal:
Introduces the contract as a structural mechanism for technical control.

SECTION 12 — Final acceptance based on performance

Main focus:
Define laboratory acceptance as the result of technical evidence of system performance.

Key points:
- Acceptance does not depend on completion of construction.
- It does not depend on commissioning alone.
- It depends on evidence of system performance.
- This evidence must include real conditions and failure scenarios.
- Acceptance establishes that the laboratory meets containment criteria.

Rhetorical questions / Attention signals:
- When can a laboratory be considered compliant?
- What evidence is required to accept containment?

Orientation signal:
Closes the session by establishing acceptance as performance-based technical verification.

How to use this lecture map

When reviewing the session:
- Identify the point at which risk becomes physical.
- Recognize the relationship between design and execution.
- Identify deviations and their accumulation.
- Understand commissioning as performance verification.
- Evaluate acceptance as technical evidence, not as completion.

Session 002-006 — Training, Operation, and Maintenance

Instructor: Luis Linares
Course: High Containment Laboratory Design

Purpose of the document:

This lecture map is designed to help participants navigate the content of Session 002-006, identifying not only the topics covered, but the logic that connects them. The session does not introduce isolated elements, but develops a continuous chain: from operation as the critical point of containment, through system interpretation under real conditions, to decision-making, governance, and the sustained performance of the system over time. This document serves as a study and orientation tool and does not replace the lecture.

SECTION 1 — Containment is defined in operation

Primary focus:
Establish that containment is not lost in the absence of systems, but during operation under real conditions, where system behavior determines performance.

Key points:
- The laboratory does not fail when it is off.
- Containment is sustained under real operating conditions.
- Variability and human intervention are constant.
- The system degrades over time if not actively controlled.
- Operation determines whether containment exists in practice.

Rhetorical questions / Attention signals:
- When is containment actually lost?
- Can a technically correct system fail in operation?

Orientation signal:
Introduces operation as the critical point where containment is confirmed or lost.

SECTION 2 — The laboratory as an integrated system

Primary focus:
Reframe the laboratory as a system composed of people, rules, decisions, and maintenance, where infrastructure is only one component.

Key points:
- The laboratory is not the building.
- It is a system of interdependent elements.
- People, procedures, decisions, and maintenance interact continuously.
- Infrastructure does not guarantee behavior.
- Containment depends on system coherence.

Rhetorical questions / Attention signals:
- Where does the laboratory actually exist: in the building or in the system?
- What happens if one element is not aligned?

Orientation signal:
Defines the shift from component thinking to system thinking.

SECTION 3 — Operation and maintenance as system control

Primary focus:
Establish that operation and maintenance do not maintain equipment, but maintain containment conditions.

Key points:
- The objective is not that equipment functions.
- The objective is that the system maintains containment conditions.
- System behavior is the critical variable.
- Operation requires continuous control.
- Maintenance modifies system behavior.

Rhetorical questions / Attention signals:
- What is actually being maintained?
- What happens if equipment works but containment is lost?

Orientation signal:
Reframes the purpose of operation and maintenance.

SECTION 4 — Interpreting the system vs measured values

Primary focus:
Differentiate between indicators (such as pressure) and actual system behavior.

Key points:
- Pressure is an indirect indicator.
- Containment depends on airflow direction.
- A system can meet setpoints and still fail.
- The BMS represents the system but does not guarantee behavior.
- Verification requires real-world observation.

Rhetorical questions / Attention signals:
- What does a “correct” value actually mean?
- Can a system appear stable and still not contain?

Orientation signal:
Introduces interpretation as a requirement beyond measurement.

SECTION 5 — Transients and dynamic conditions

Primary focus:
Explain that most failures occur under dynamic conditions, not steady state.

Key points:
- The system does not operate under constant ideal conditions.
- Doors, loads, and usage create disturbances.
- Transients affect airflow direction.
- The system must recover quickly.
- Containment is compromised during these intervals.

Rhetorical questions / Attention signals:
- Where do failures actually occur?
- What happens during a disturbance?

Orientation signal:
Introduces real system dynamics.

SECTION 6 — System verification after intervention

Primary focus:
Establish that no intervention is complete until the full system behavior is verified.

Key points:
- A component may function correctly.
- The system may not have recovered equilibrium.
- Verification must be functional, not only technical.
- Flow, pressure, and direction must be validated.
- Lack of verification creates silent degradation.

Rhetorical questions / Attention signals:
- When is an intervention truly complete?
- What happens if the full system is not verified?

Orientation signal:
Introduces verification as an operational requirement.

SECTION 7 — Training as a condition of containment

Primary focus:
Define training as a structural component of the system, not a secondary activity.

Key points:
- Training is not optional or complementary.
- It is part of the containment system.
- Poor training equals operational failure.
- Knowledge must align with the real system.
- Training defines operational capability.

Rhetorical questions / Attention signals:
- Can containment exist without proper training?
- What happens when personnel do not understand the system?

Orientation signal:
Positions training as a critical system element.

SECTION 8 — Decision-making under real conditions

Primary focus:
Explain that procedures cannot cover all conditions and that operation requires decision-making.

Key points:
- Not all situations are defined by procedures.
- The system operates under uncertainty.
- Operators must interpret conditions.
- Behavior must be adapted.
- Decisions sustain containment.

Rhetorical questions / Attention signals:
- What happens when procedures do not apply?
- How are decisions made under uncertainty?

Orientation signal:
Introduces decision-making as a core capability.

SECTION 9 — Human factors as a system variable

Primary focus:
Analyze human behavior as an integral part of the containment system.

Key points:
- Behavior is not external to the system.
- Inexperience, complacency, and overconfidence create risk.
- Deviations become normalized.
- The system can degrade without being noticed.
- Containment depends on behavior.

Rhetorical questions / Attention signals:
- How does risk change with experience?
- Which type of operator represents the highest risk?

Orientation signal:
Integrates human factors into the technical system.

SECTION 10 — Governance and decision authority

Primary focus:
Define containment as the result of structured organizational decisions.

Key points:
- Containment is not purely technical.
- It depends on who decides.
- Roles must be clearly defined.
- Stopping criteria must exist.
- Ambiguity weakens the system.

Rhetorical questions / Attention signals:
- Who decides under critical conditions?
- What happens if authority is unclear?

Orientation signal:
Introduces governance as a control structure.

SECTION 11 — Continuous training as a system

Primary focus:
Establish that training must evolve with the system and not remain a one-time event.

Key points:
- The system changes continuously.
- Training must adapt to those changes.
- Real events must be integrated into training.
- Competence must be periodically validated.
- Operational coherence depends on it.

Rhetorical questions / Attention signals:
- What happens if the system changes but training does not?
- Is operational capability sustained over time?

Orientation signal:
Extends training across the operational lifecycle.

SECTION 12 — Operation within a broader system

Primary focus:
Introduce the laboratory as part of a network where local decisions affect global risk.

Key points:
- The laboratory is not an isolated unit.
- It is part of an institutional network.
- Local decisions impact the broader system.
- Interdependence exists between nodes.
- Capability depends on coordination.

Rhetorical questions / Attention signals:
- What happens when one laboratory fails within a network?
- How is risk distributed across nodes?

Orientation signal:
Closes the session by expanding the system to institutional scale.

How to use this lecture map

When reviewing the session:
- Identify how containment is sustained in operation.
- Recognize the laboratory as an integrated system.
- Understand the difference between measurement and interpretation.
- Evaluate the role of training and decision-making.
- Analyze governance as a control structure.