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Design Requirements Manual **News to Use**

August 2026
Vol. 03, No. 08

The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_j U_i)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ for building $\frac{\partial}{\partial x_j}(\rho \overline{U}_j \overline{U}_i)=-\frac{\partial \overline{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U}_i}{\partial x_j}-\rho\overline{u_i u_j}\right)+g_i(\rho-\rho_0)$ state of the art $\frac{\partial}{\partial x_j}(\rho \overline{U}_j \overline{H})=\frac{\partial}{\partial x_j}\left(\lambda\frac{\partial \overline{T}}{\partial x_j}-\rho\overline{u_j h}\right)$ biomedical research facilities.

Prioritizing Resilience: Integrated Design for Biomedical Facilities

Unplanned disruptions test resilience measures integrated into a biomedical facility's planning and design. Addressing resilience reactively or late in design increases costs, lowers failure thresholds, and lengthens return-to-service. Prioritizing resilience means deciding which functions must endure without interruption, which may operate in a defined degraded state, which may safely yield, and how quickly and in what order each must recover. Integrated design carries those priorities across the site, building, systems, operations, maintenance, and supply chain. The objective is not zero failure, but a facility that avoids preventable exposure, accommodates exceedance without sudden, cascading, or catastrophic loss, isolates disruptions, sustains essential functions, and preserves a credible path to safely restored operation.[1,2]

Six Integrated Design Questions

At major project milestones and when a change order, Architect's Supplemental Instruction (ASI), or value-engineering (VE) proposal could affect resilience acceptance criteria, the owner, architect/engineer (A/E), commissioning agent, and relevant subject matter experts (SMEs) should revisit these questions: (1) What must endure, what may degrade or yield, and in what order and how quickly must functions recover? (2) Has the project avoided preventable exposure and separated critical lifelines from common hazard paths? (3) If protections are exceeded, what yields first and what remains protected? (4) What is the failure domain of each critical room, route, utility, control path, and dependency? (5) How long can each function that must endure operate when all dependencies are considered? (6) Can the facility recover in the required sequence, including access, temporary services, inventory, testing, and release?

Priorities Before Solutions

Before approving the program, site concept, primary adjacencies, or utility topology, the A/E of Record should lead the owner and appropriate subject matter experts in developing Resilience Performance Requirements (RPR), an appendix to the Owner's Project Requirements (OPR). This article uses RPR because no consensus industry term has been identified for a document of this scope. After approval, the A/E incorporates the RPR into the program and design; inclusion in the OPR connects it to commissioning.[3] The RPR defines what must endure, operate at reduced capacity, or safely yield; the maximum acceptable interruption; and the required recovery sequence. Priorities attach to mission functions and dependencies, not room size or equipment cost. A utility vault, controls room, or loading route may be more consequential than a larger program space when multiple operations depend on it. The RPR also identifies the operational, staffing, supply-chain, inventory, replenishment, and, where applicable, off-site warehousing dependencies needed to achieve the required performance. At completion of coordinated design, Design Qualification (DQ), or an equivalent documented review, verifies conformance with applicable RPR requirements and identifies dependencies that remain the owner's responsibility. FDA Q7A defines DQ as documented verification that a proposed facility, equipment, or system design is suitable for its intended purpose. Evaluate value engineering, substitutions, and construction changes against RPR requirements and acceptance criteria to prevent degradation of approved resilience performance.[4]

Avoid: Resilience begins with selection of the most advantageous feasible site. Ground and terrain are site selection criteria, not merely foundation problems. Site selection must avoid expansive soils; soils subject to liquefaction; uncontrolled fill; sinkhole-prone terrain; subsidence; unstable slopes; landslide, debris-flow, or rockfall runout areas, and coastlines or bluffs subject to erosion or retreat.[5-8] Where avoidance is infeasible, the RPR should define the required mitigation and the residual risk accepted by the owner. A foundation may protect the building while ground movement disables utilities, access, drainage, or fire protection, defeating the purpose of the RPR. It is better to evaluate the building and its lifelines as one site system.[5,9] Separate utilities, loading, outdoor-air intakes, emergency access, fire protection, stored resources, and replenishment routes from common hazard paths. Site and hazard criteria should reflect mission consequences and recovery needs, not default to minimum code thresholds.[9]

Accommodate: Controlled exceedance addresses what happens after the first protective layer reaches capacity. It does not authorize under-design or unjustified, though technically allowable, reductions from code compliance. It establishes a hierarchy of concession: preserve life safety, containment, environmental protection, and emergency response; protect must-endure functions; activate degraded modes before systems become unstable; and direct initial effects toward bounded, lower-consequence, recoverable areas. For example, route stormwater through planned overland paths and detention areas, and shed lower-priority electrical loads or curtail cooling before critical systems overload or fail. A resilient facility yields deliberately rather than failing indiscriminately.[10,11]

Isolate: For this article, a failure domain is the group of spaces, systems, routes, resources, and functions that can be lost together because they share a component, location, pathway, control point, or dependency. The plan should isolate the smallest practical operational unit while keeping unaffected functions accessible. Evaluate redundancy as a complete service path, not an equipment count. Two chillers on one non-sectionalized header, or dual electrical feeds through one vulnerable vault, may not provide the functional

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independence required by the RPR.[2,9] Resilient systems need sufficient interconnection to reroute service and sufficient isolation to contain a defect.

Sustain: A must-endure function relies on utilities, environmental conditions, controls, communications, consumables, personnel, access, and outgoing services. Its credible endurance period is limited by its shortest-duration dependency. Seven days of generator fuel do not provide seven days of continuity if cooling water, wastewater capacity, staffing, or a critical consumable lasts only two.[9] Environmental boundaries should maintain required conditions while remaining durable, testable, inspectable, and repairable, and should minimize utility demand during degraded operation. Evaluate each utility and consumable as a complete path—from source or storage through transfer, distribution, use, outgoing service, and replenishment. A resource that cannot be transferred, used, or replenished is only temporarily resilient.

Recover: Recovery is a time-based objective that defines the sequence for stabilization, minimum operation, partial operation, and full restoration.[12-14] Its time budget includes assessment, isolation, access, parts, repair, boundary restoration, cleaning or decontamination, testing, qualification, and release. Maintainability is a resilience requirement. Service corridors, equipment rooms, shafts, interstitial spaces, lifting provisions, replacement paths, temporary utility connections, and staging areas are recovery infrastructure. Part availability is also part of recovery time. Critical-spares plans should account for lead time, obsolescence, interchangeability, shelf life, configuration data, and regional competition, using on-site, independent off-site, or reserved vendor inventory, as appropriate. A replacement path without an available replacement is incomplete. Recovery ends when the mission can continue, not simply when the equipment runs.

Conclusion

Resilience is not a late package of redundant equipment and emergency procedures. It is a hierarchy of owner-approved priorities carried across site, building, systems, operations, and recovery. Prioritization determines what must endure; integrated design gives the facility a credible way to endure, yield, and recover. Resilience is demonstrated not by preventing every event, but by yielding in a controlled order, preserving the critical mission, and returning to safe operation within the time the Owner has defined.

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