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THE FUTURE OF SYSTEMS INTEGRATION:

How to Design and Build R&D Test Facilities

Written by
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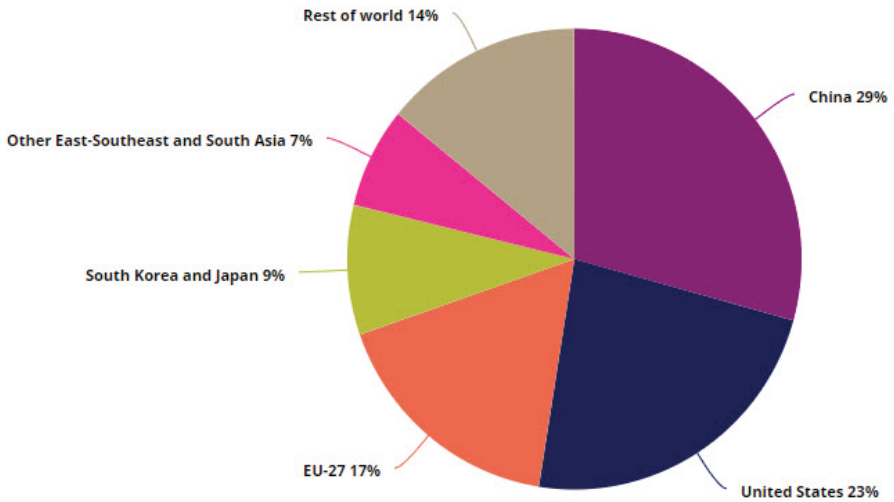
INTRODUCTION

A commitment to research and development (R&D) is vital for organizations in today's fast-paced and highly connected world. Global R&D expenditures tripled from $726 billion in 2000 to an estimated $2.47 trillion in 2022. R&D spending is projected to continue with massive leaps in growth. R&D arms organizations with data to make better decisions that result in efficient, effective, and innovative product development. Essential to R&D is a physical testing facility that makes R&D possible. An R&D testing facility is not simply a building, but rather a complex network of precise, interconnected systems to support successful products, end-user satisfaction, and ongoing innovation. It relies on robust tools to improve test processes that make it simpler to implement, operate, and maintain testing programs and environments.

The complexity of R&D testing facilities calls for a systems integration approach to meet facility goals and client expectations. It is a common misconception that technology ranging across devices, systems, controls, equipment, and automated systems will work together seamlessly. Instead, it takes a dedicated commitment to systems integration that leverages the experience and expertise of test equipment, supply chain, and industry experts to help plan, design, build, commission, and validate acceptance on an organization's vision for a new test environment.

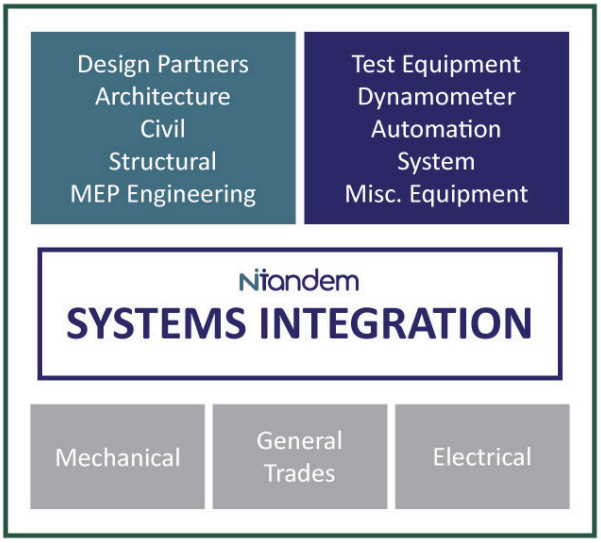


Gross domestic expenditures on R&D, by selected country: 2000–19

Source(s): NCSES, National Patterns of R&D Resources; OECD, MSTI March 2021 release; UNESCO, UIS, R&D dataset

EXECUTIVE SUMMARY

Systems integration takes a focused approach to the minute details of the organization's big-picture goals during the design and build of R&D test facilities. It is the deliberate task of bringing the operational requirements of equipment and processes into light during the pre-planning, design, build, commissioning, and acceptance stages. The teams involved with designing and building R&D test facilities benefit from a systems integration approach throughout all phases of project planning, execution, commissioning, closeout, and turnover to the customer. Today's technology, automation, and R&D trends are driving forces that make the case for why systems integration is increasingly important and why it will be an essential component of any complex building process in the future.



THE EVOLUTION OF SYSTEMS INTEGRATION

A traditional approach to the design and build of R&D test facilities operates as siloed project execution and involves a single project manager acting as the primary interface between test equipment or process system vendors and the design firms. There is a common assumption that systems integration will happen effortlessly through the long-established design and build process. In this circumstance, the client (who is often embodied by a leader within the organization and has daily operational responsibilities), the equipment vendors, the design firm, engineers, and other stakeholders act autonomously to make decisions that will result in the delivery of an R&D facility, not realizing there are potential risks in meeting testing requirements, interoperability, and overall success. Systems integration is best accomplished by a dedicated integration team that is focused on the requirements of the equipment and facility during the design, build, and hand-off stages.

Systems integration is an established need in the information technology (IT) sector where constant innovation is rapidly changing how different software and hardware interact with each other. In IT spaces, development isn't necessarily constrained by space and material, at least not in the same way a facility might be. That said, the complexity and innovation of R&D testing facilities is analogous to (and overlapping with) the fast-paced IT sector, making systems integration a powerful approach and mindset when building R&D testing facilities. Essentially, when systems are abundant and complex in and of themselves, it takes a strategic, big-picture mindset to ensure those systems can speak with each other. If an IT systems integrator must understand an organization's entire ecosystem of interconnected software and the technical know-how to enable these programs to interact with each other seamlessly, a facility systems integrator must have proven experience to accomplish the same across the abundance of a facility's equipment, systems, and people. To maximize capital project and R&D facility success in regard to budget and efficiency, an effective systems-integration approach calls for a dedicated systems integrator role with all-inclusive experience regarding equipment and facility systems to firmly understand, translate, and communicate needs to all stakeholders and involved parties of the facility ecosystem at every stage of the process.

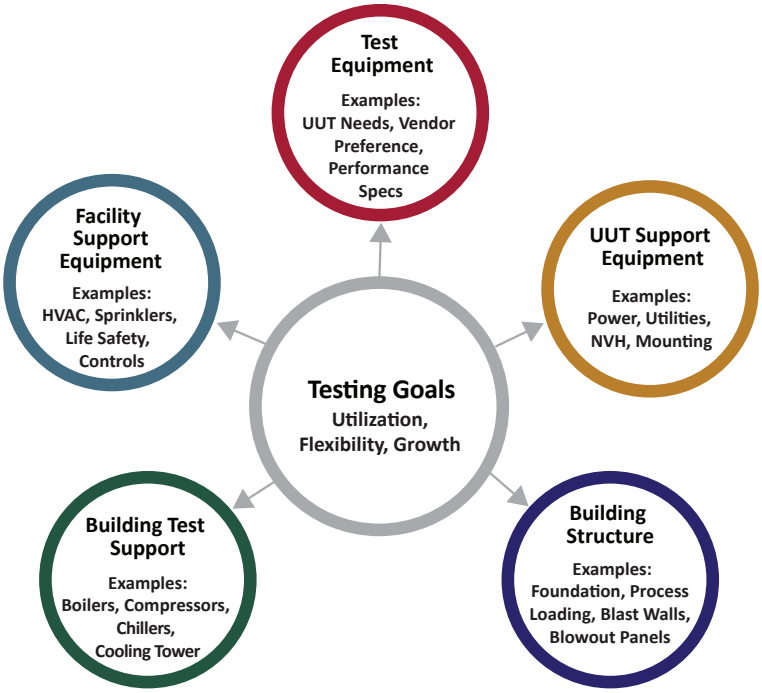
This integrator works in partnership with architects, all facility engineering disciplines, equipment suppliers, and contractors. Each of these individual roles has vital expertise to contribute to the design and build of the R&D testing facility, but their focus and experience come from vastly different worlds. In other words, they don't always speak the same language. This is where a dedicated systems integrator comes in. A systems integrator possesses the overall knowledge and experience to understand every party's perspective in conjunction with the ultimate technical goal of the facility. This is accomplished by holding the right conversations and identifying the most vital requirements of the facility from a holistic point of view. From there, the systems integrator filters input from all parties based on R&D testing goals and intermediates tasks to ensure an efficient design and build process that results in a seamless, streamlined final product. This isn't just a step-by-step process hinged on

technical knowledge. It is a dedicated approach that requires proven experience, frequent and consistent communication, and a mindset that keeps a constant eye on the big picture.

TRENDS SHAPING THE NEED FOR A DEDICATED APPROACH TO SYSTEMS INTEGRATION

Labor trends: According to the U.S. Department of Labor, during the months of April, May, and June of 2021, 11.5 million workers quit their jobs, in an exodus widely termed the "Great Resignation." As the mass fluctuation of employment continues, its impact is seen in businesses of every size and industry. This uncertainty continues into 2023, where an alarming 96 percent of workers are looking for a new position this year, indicating that the effects of the Great Resignation are not over. These new levels of employee turnover, reduced staff, and shifting workplace roles result in internal challenges, but what do they mean for the execution and success of capital projects? When an R&D testing facility is needed, there's a network of individuals who bring their expertise to the table. When labor is in fluctuation, tapping into that expertise can be a challenge, especially with new employees, frequent turnover, and a workforce spread thin to cover all the jobs that keep a product or program running. This results in the increased need for organizations to call on an expert systems integrator to harness proven knowledge, skill, and past experience to establish and communicate a clear vision, work through the technical project complexities, and avoid common pitfalls.

Leadership trends: The first question organizational leaders often ask when determining the need for an R&D testing facility is: "If we're the experts in our own industry and product, why can't we plan, build, and implement the testing facility ourselves?" It seems straightforward enough, however, facility managers and organizational leaders are dedicated to their day jobs first and foremost. Their daily tasks are centered around product planning, development, and manufacturing, which hinders their ability to take a singularly focused and devoted approach to develop all of the tools and aspects required for an R&D facility. When the competing priorities of leadership's commitment to a future asset are daily operations, the daily needs will always win. This contributes to delays, unfocused decision-making, and reliance on



siloed teams to communicate with each other, often lacking accountability to the overall facility vision. This can result in facilities and systems that don't work together flawlessly or simply don't address all agreed-upon testing requirements, costing time and money to operate or to restructure. A systems integration approach doesn't assume leadership, but rather alleviates the pressure of having a single manager by incorporating broader and deeper technical input into a dedicated plan that can adapt to new challenges and shape fluctuating needs. It is essential to leverage the knowledge of experts, including end-users, stakeholders, data analysts, automation experts, and integrators who can offer efficiency-focused solutions and methodologies based on their own specialized skill sets and experience.

Technology trends: With the rapid pace of today's technology evolution, clients dedicated to R&D and product innovation understand the importance of investing in new technologies incorporated into custom simulating equipment or automated processes. It is easy to think that with its constant acceleration, the technology across equipment, data collection, analysis, and safety will work together with little effort. Instead, the more complex the technology, the more complex the integration. Clients have high expectations for the interoperability of sophisticated technology and processes, but seamless integration takes an ongoing, committed process, and not a part-time effort.

SYSTEMS INTEGRATION IN THE TYPICAL CAPITAL PROJECT DEVELOPMENT PROCESS

An effective R&D facility development process can leverage a systems integration approach across the following five steps:

1. Plan It

The first facility development step utilizes systems integration for front end planning including analyzing requirements and constraints, needs versus wants, people, processes, and tools. The planning phase is where the client and system integrator determine the client's goal for the facility, effectively defining acceptance criteria and answering what project success will look like. The systems integrator helps to drive efficient iterations and modifications ultimately resulting in an approved project charter.

2. Design It

With the plan in hand, the design team is assembled, and the systems integrator bridges the information between the process systems. In the case of an R&D facility, this most centrally includes testing equipment in conjunction with the facility to ensure that everything is designed according to the plan and criteria. The other key task in this phase is to fully specify and procure the process equipment. Due to typically long lead time, this must happen at early stages. The systems integration focus ensures this is done efficiently and in alignment with the program's technical details.

3. Build It

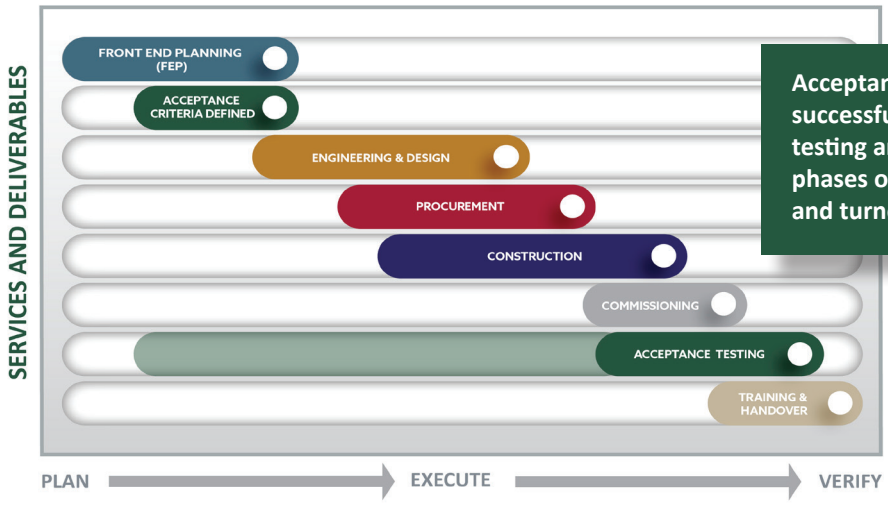
After thorough and precise planning and design, the project moves to the building stage. This stage encapsulates how to execute and implement the construction of the R&D testing facility and all related equipment and processes. During this stage, the project team works with skilled trades to ensure a seamless transition from a conceptual design into a tangible reality. For fast-tracked projects, this phase can begin before the design is 100 percent completed, with the early site and foundation packages. Note that scrutiny through the lens of systems integration is required to take advantage of this overlap and ensure that the best technical data is available to develop the early package designs. The key to this phase is managing the technical process implementation across scope, schedule, and budget to maintain alignment with project planning goals.

4. Start It Up

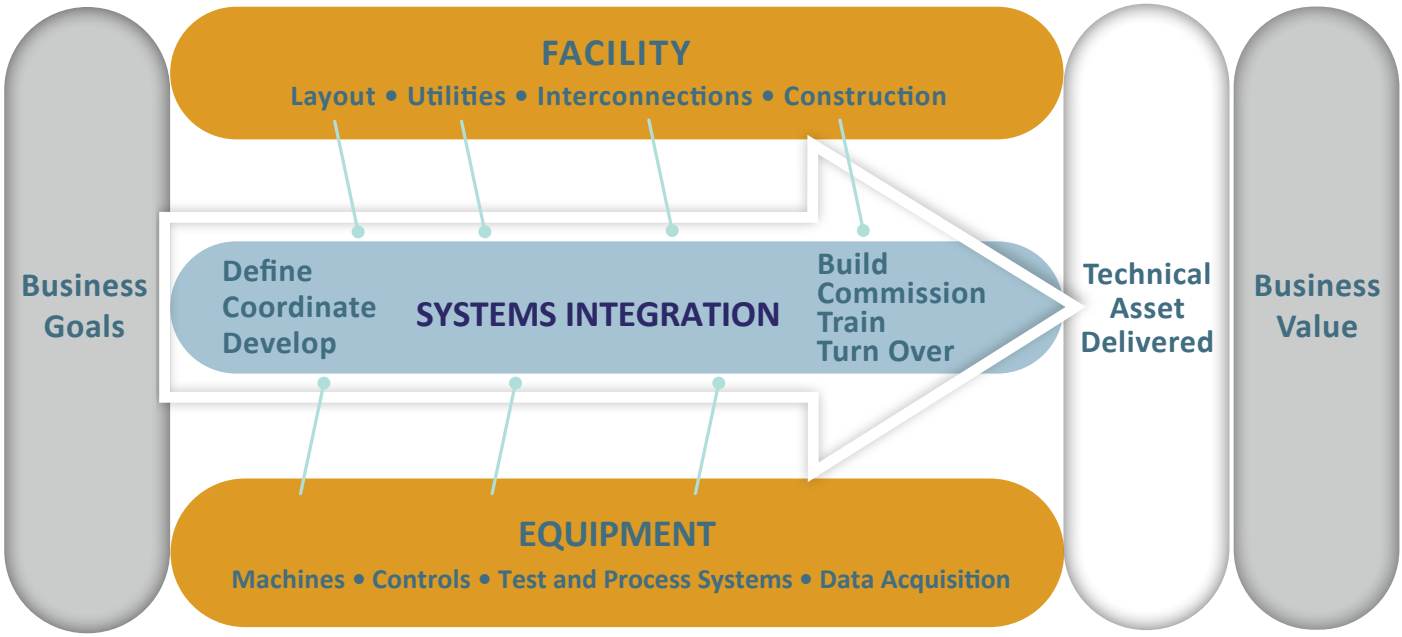
Bringing a facility to "operational readiness" includes an efficient and comprehensive start-up plan and functional verification of all process equipment, infrastructure, and facilities – a team effort between the owner, system integrator, suppliers, and contractors. To achieve this, the systems integrator comprehensively performs commissioning and acceptance testing according to the project's acceptance criteria developed during the planning and early design stages of the project.

5. Use It

Finally, the client is ready to begin utilizing their R&D testing facility. Successful systems integration takes into account that the handover isn't done in a snap, but rather demands thorough documentation, dedicated training and education, and continued communication about the facility's operability. This final stage ensures the owner can fully utilize the functionality of the facility and fundamentally answer the question "does it do the job it was intended to do?" with an affirmative.



Acceptance criteria is a key component of successful systems integration. Clearly defined testing and process requirements drive all phases of the project through commissioning and turnover to client.



FIVE PILLARS FOR SUCCESSFUL SYSTEMS INTEGRATION

Pillar #1: Technology

Every facility has different goals based on the products it supports and the requirements of the units under test (UUTs). Typically, technology is at the heart of these goals, making it one of the priorities for successful systems integration. Most fundamentally, the objective of R&D testing is to simulate the real world in a controlled environment so the client can put their product through its paces in highly specific, controlled, and repeatable ways. R&D technology needs to incorporate everything required to create that simulated environment and to collect vital data for creating and improving products and processes. These needs can range widely within a single facility, and even within a single test cell, including custom test stands, power necessities, temperature control, acoustics and vibration, fluid management, electrical systems, mechanical equipment, conveying systems, controls, and data acquisition. This wide net of possibilities makes it more important than ever to ensure technologies can interact with each other seamlessly and be operated efficiently, effectively, and safely by product engineers, maintenance personnel, and operating technicians.

Consider the technology common to the automotive test space. The testing process is typically centered around the load system responsible for absorbing and motoring the load of the vehicle, engine, electric motor, or powertrain. The load is often imparted by an electric dynamometer, such as a chassis dynamometer for full vehicles, or an engine or electric motor dynamometer, via the attachment of a rotating shaft to a hub. Typically, these systems are electrically-powered and force-cooled, requiring distinct power capabilities and feeds. Depending on the size of the load system, this can lead to major upgrades of an existing facility's electrical infrastructure or significant additional costs in new construction projects involving more space or heat rejection capacities, including air-handlers, cooling towers, and chillers. By focusing on the load process and system first, then building out from that core function, integration will happen from the inside out and the technology and facility structures will fit together like a hand in a glove.

This complex ecosystem of technologies must operate together seamlessly for the testing process to deliver meaningful results. Naturally, obstacles can stand in the way. For this technology to function properly, it also requires control over the surrounding environment, with dedicated equipment to support power, utilities, ventilation, controls, and safety, alongside operational workflow criteria. It is vital for the requirements of the UUT to be well-understood from the start so the right technology is selected in the first place, implemented with a clear plan, continually maintained, and monitored for potential improvement.

Keep in mind that scalability and flexibility are central to R&D technology. For research and development to garner actionable results, the design and build of the facility must account for the need for technology to scale up or change for the future. Incorporating future growth goals into technology decisions, whether considering hardware, such as ensuring a piece of equipment can be upsized or software, including data storage, will allow an organization to meet throughput needs that will inevitably change or increase.

Pillar #2: Automation

Test automation systems are critical systems in the operation of R&D test facilities. In fact, a recent survey by Gartner, Inc. found that 80 percent of executives think automation can be applied to any business decision, much less an industry as complex and cutting-edge as R&D testing. Historically, and still in many test facilities, a human is responsible for executing nearly all steps of a test sequence, whereas fully automated testing relies on software, actuators, and sensors to make decisions and close all the control loops, creating availability for the individual's time to be spent on higher value tasks, such as analysis or exploratory tests while automating more simple or repetitive tests. Automation solutions result in improved operator safety and reduced maintenance intervals and provide vital mechanisms for gathering repeatable, accurate, and precise data leading to improved product design and, eventually, more streamlined manufacturing processes. Intrinsically, effective integration is at the core of successful automation initiatives.

The systems integrator can help the client to specify a complete test automation and data acquisition system that integrates across the facility for seamless interoperability across departments. When it comes to process automation and control, there are countless varying hardware and software platforms, so it is important for the systems integrator to make specialized design recommendations to the client based on particular needs. Alternatively, many clients have pre-determined hardware and software choices based on current organizational legacy, which can be integrated into the overall design and build projects.

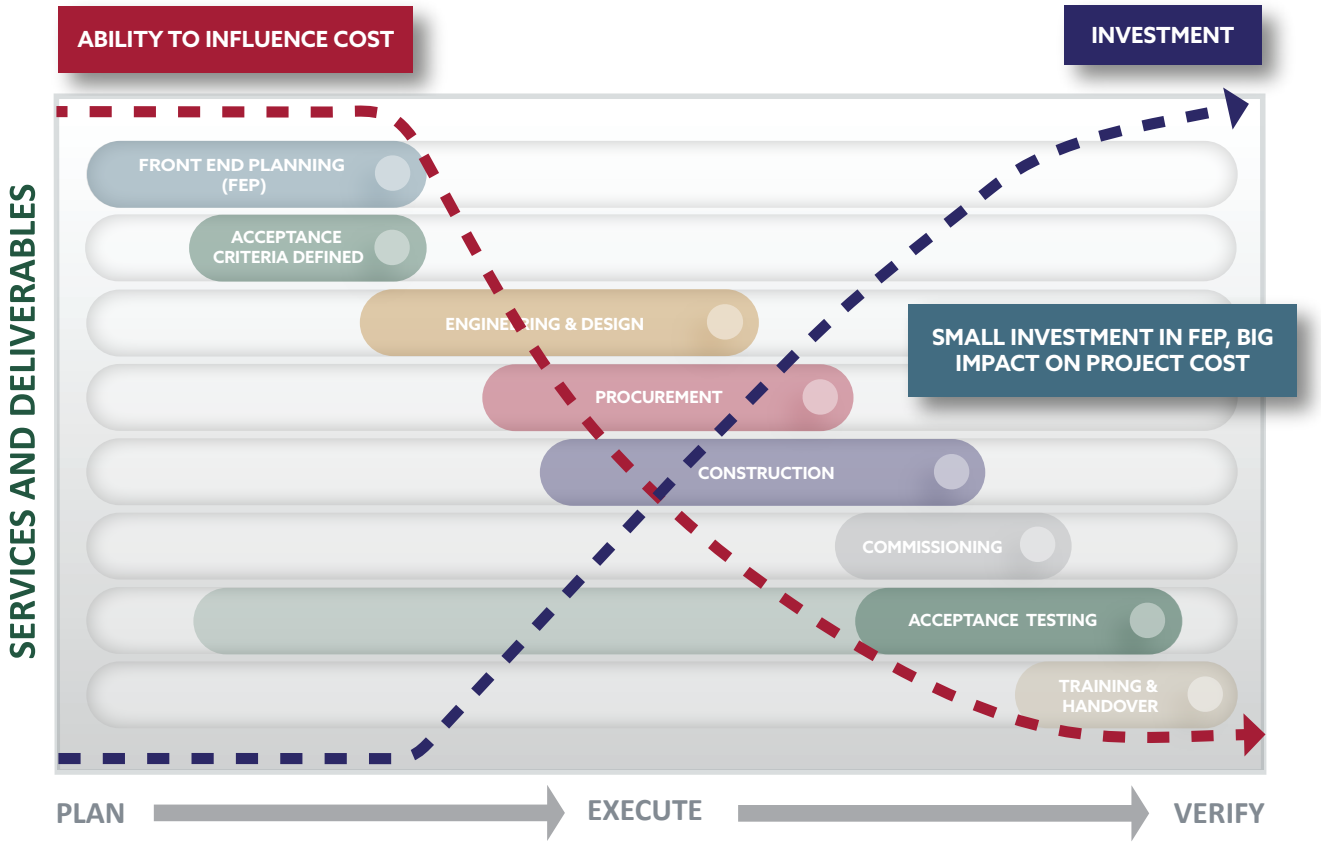
At the start of every process automation and controls project, the testing facility's unique process requirements and desired results must be made clear. This includes assessing production, ergonomic, health, and safety needs. If integrated well, this leads to the delivery of intuitive, flexible, and reliable mechanical, controls, and instrumentation system solutions that maximize investment.

Pillar #3: Customer Expectations

A core goal of a systems integrator is to determine the stakeholder expectations at the conception of a project. When expectations are known, a clear and defined finish line is created for the project, improving the process for all parties and the likelihood of success. An ideal relationship for a systems integrator working with a client is to act as an extension of the client's own staff. This requires the systems integrator to interlink with the client's team and to gather intimate knowledge of its facilities and products. This inside insight allows for expectations to be more easily identified.

The best approach to designing R&D testing facilities is from the "inside out." At the core lies the customer's expectations, goals, and overall operational needs. These expectations directly define the UUT and how it must be tested. Without understanding the physical and operational requirements of the product and its test stands, the path between the core and the most external manifestation of the R&D facility, the building, can easily misalign. This disorder can be driven by competing constraints in space, money, time, and/or resources. The result of poor integration from this perspective is a facility that either falls well short or fails to meet its data production goals or must be modified at an even further cost.

Customer expectations around the R&D testing criteria cannot be loosely defined. Early conversations and front end planning are necessary to identify, clarify, and then further hone the client's expectations. This starts by leveraging intimate knowledge of the UUT requirements and acceptance criteria in conjunction with project scope and constraints. It's common for clients to be optimistic and vague without in-depth evaluation, sometimes resulting in inconsistencies, unrealistic budgets relative to scope, and high risks. Further, the client's vision must be communicated across stakeholders for aligned resources and decision-making. It can result in challenges when projects have multiple decision-makers or have decision-makers who lack a technical background. It's the system integrator's job to initiate the discovery process with all stakeholders, help communicate both laterally and vertically through the organization, and interrogate project goals within the context of scope, constraints, schedule, and budget.



Pillar #4: Capital Investment

Tied closely with customer expectations, a clearly articulated budget is one of the early needs to identify the achievable parameters and possibilities of an R&D testing facility. The Project Management Institute states a lack of realism in initial cost estimates is the number one cause of budget overruns. This is where early conversations are vital. In front end planning, fully defined program requirements are considered as a whole, translated into clear concepts, then advanced into actionable steps for all scope elements. Working with the client's team, the systems integrator develops a project budget and an overall program schedule that supports moving the technical elements of the project forward into execution. An experience-based rough order of magnitude (ROM) helps establish a data-driven budget for smooth entry into the execution phase. Of course, early budgets are based on metric data subject to fluctuation and market disruption. The ROM must be established with awareness of this volatility, potentially setting a larger ROM, including contingency, to cover inevitable fluctuations and consistently represent the risks and changes. Further, investments can be made incrementally and on a smaller scale, minimizing risk and fostering continuous alignment of a project's scope, schedule, and budget with the project's overall demands. This results in the highest potential for the best possible outcome before any significant capital investment is made.

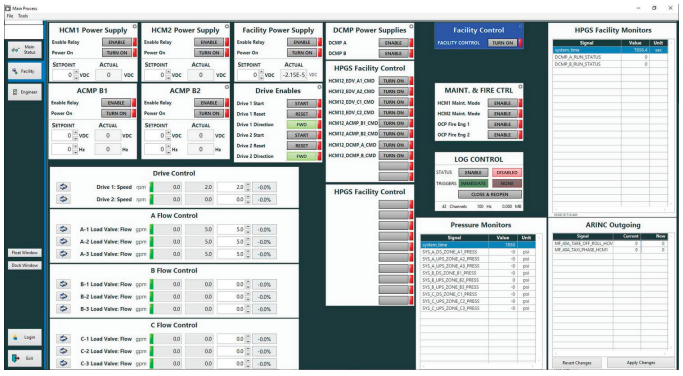
For R&D testing facilities to maximize an ROI, they must future-proof for needs beyond initial goals that incorporate the capacity for future objectives and growth. This, again, requires a big-picture, future-oriented mindset balanced with technical understanding. Take, for example, a customer in the automotive space that had a "five-year plan" for electrical testing upgrades at its existing facility. ACS, acting as the system integrator, worked with the customer to define what upgrades would be proceeding in the immediate future and how available electrical capacity in its facility would be allocated for immediate upgrades. From there, ACS and the client looked at how it would be reserved for future upgrades. By pushing the client's goals from the initial desires to possibilities in the next five to ten years, a project's budget can be better allocated to sustain continued product innovation and business growth well into the future, reducing overall spending in the long run.

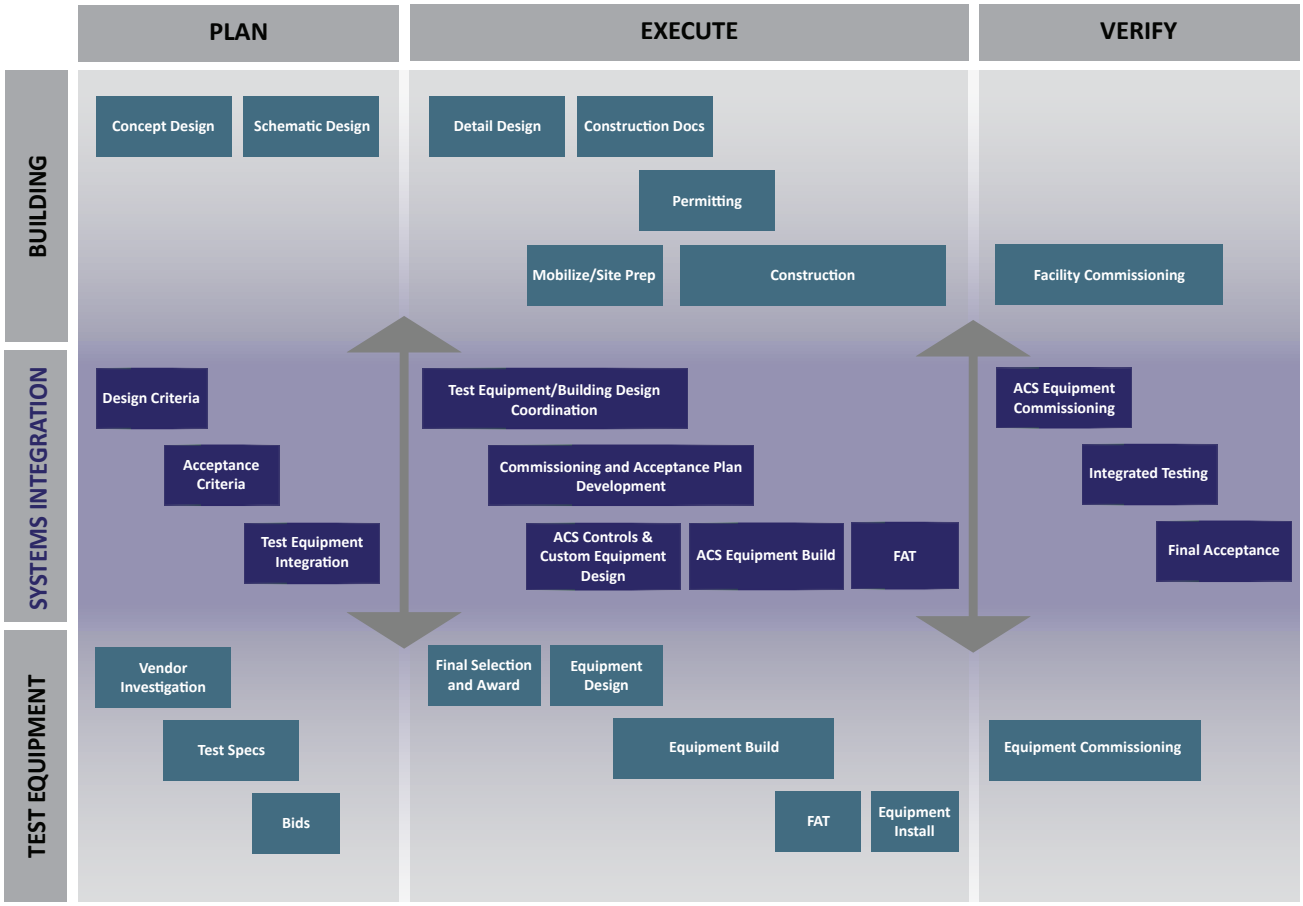
Pillar #5: Data

The overall goal of any R&D testing facility is to gather vital, accurate, and repeatable data about the unit under test (UUT) for decision-making, improved products, innovative solutions, and end-user satisfaction. This necessitates early specification of required data, a data acquisition system, and a storage solution, integrated with analytics to successfully harness data for research and development.

A test stand or test cell is the frontline of data acquisition and requires an integrated set of systems for reliable, robust, and safe use that maintains data quality. A client might assume with the importance of data to their R&D process that it is an effective choice to design the data acquisition hardware in a manner that is overly specific to the test space. However, this often results in systems that are custom and expensive. Keeping the focus on "inside-out," early development of a data acquisition channel list can be crucial, and can be used to create a "design freeze," a method used during the design development stage to mitigate the risks associated with potential change and keep the project focused and moving forward. A design freeze milestone is intended to control changes and ensure the completion of design stages on time. Studies showed that design changes account for 78 percent of the total cost deviation in construction projects.

For example, when designing a battery test facility, both the client and systems integrator must understand all the constraints associated with battery testing. This requires a dedicated discovery process to pinpoint all the right answers about testing circumstances and the data being gathered. Essential conversations are centered around critical questions that shed light on needs and potential risks, such as: What are the voltage and current limits of both the current and future UUTs? What environmental conditions or constraints need to be achieved during the test cycles? What space and safety requirements are needed to ensure operator safety? What regulatory requirements are applicable? Understanding and verifying these test requirements inform decision-making for data acquisition equipment as well as location and integration within the facility. Equipment locations can be designed to ensure the fastest response rates to align with testing profiles.





Systems integration spans all phases of a project. The system integrator brings subject matter expertise, skilled, disciplined project management, a proven process, and application knowledge to ensure that product development test goals are met. Every piece of the system will be designed, engineered, procured, installed, and commissioned to meet the needs of your test.

CONCLUSION

The design and construction of an R&D testing facility require a lengthy time commitment and an investment often reaching millions of dollars. With such intense resource requirements, it makes sense for organizations to match that level of commitment with a dedicated systems integrator who has the experience and approach necessary to deliver on facility goals, schedule, budget, and scope with no backtracking. Without an experienced focus on systems integration, it is more likely than not that companies will spend additional time and money to make major adjustments to facility design, re-work the space for use, or compromise overall testing objectives. With consumer trends, ongoing digital transformation, and supply chain pressures shaping the marketplace, systems integration is rapidly becoming a standard in the design and build process of R&D test facilities. Organizations that recognize and harness the value of system integration are a significant step ahead of the competition, paving the path for systems integration to be the industry-accepted norm, rather than the exception.

Climatic test chamber installed and integrated as part of applications lab renovation to expand engine manufacturer capabilities.

ABOUT ACS

ACS designs, engineers, and builds innovative equipment, machines, controls, and facilities for industry leaders in markets including automotive, aerospace, and manufacturing. We are a systems integrator, helping companies maximize their facilities' efficiency with systems designed and engineered to work together. We combine our knowledge of building design and construction with expertise and understanding of equipment, R&D and production test, process systems, automation, data acquisition, and controls for industry leaders who require high-performance systems. ACS is based in Verona, Wisconsin, with a regional office in Troy, Michigan, and serves customers across North America and around the world. For more information, visit www.acscm.com.

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Matt Thiel is a Principal at ACS and director of the Integration Engineering group. His group is responsible for systems integration including specifying and procuring test systems and equipment, developing facility workflow and layout, and managing and executing commissioning to meet acceptance criteria for capital projects. Matt brings his experience in academia, his research and technology expertise, and his knowledge of market and regulatory requirements for product development to the design and implementation of test solutions in a wide range of aerospace and automotive applications.

Everett Lenz

Mr. Lenz is a Project Integration Lead, primarily working with our clients in southeastern Michigan. In this role, Mr. Lenz acts as the main point of contact for technical solutions across projects with major automotive OEMs who are upgrading or building test facilities. He is involved in projects starting with the FEP (front end planning) stage and through the time the project is funded. Everett continues to oversee the project from a systems integration perspective during design, execution, and commissioning. He draws upon his application knowledge of technical scope, along with lessons learned from past project experience, to improve project execution and deliver successful projects to our clients.