NAC Executive Insights

Innovation
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Innovation Spaces and Stories

Key Points

- Innovation is a requirement for sustainable, profitable growth.
- Innovation ranges from incremental through breakthrough and from serendipitous to intentional.
- Three innovation spaces—optimize, innovate, and disrupt—are characterized while considering client value and value chain improvement.
- The innovation spaces are described through a series of innovation stories.

Introduction

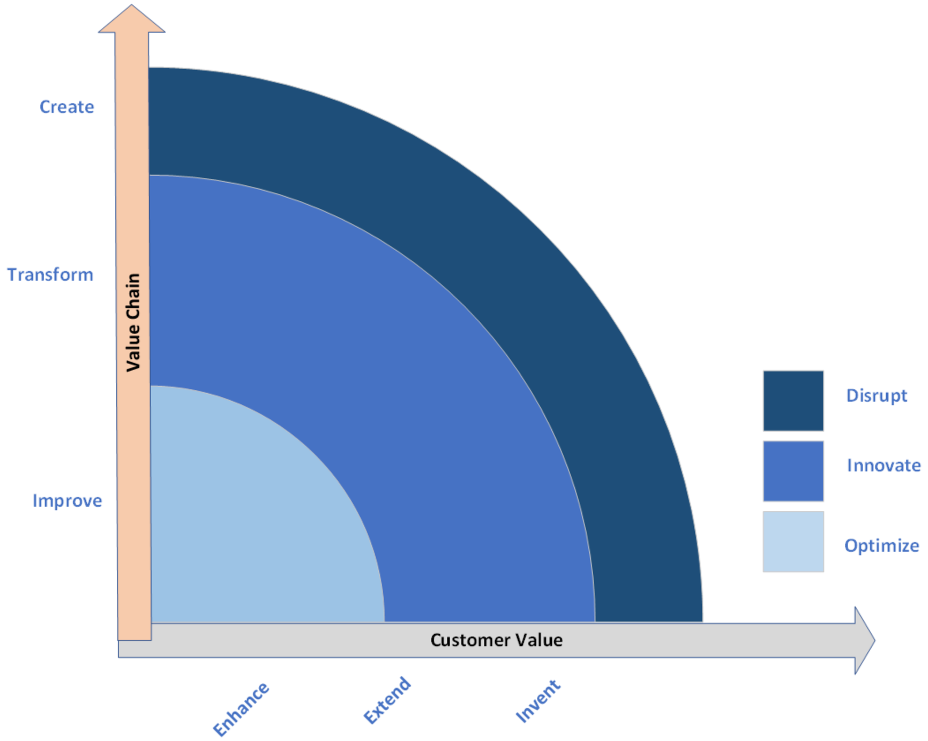
This Executive Insight illustrates the range of innovations that are possible. They range from incremental innovations, focused on optimizing current systems and processes, and extend to breakthrough innovations, which have the effect of disrupting business models and markets.

Incremental innovations include both unplanned improvements as well as incremental innovation based on intentional efforts. Unplanned improvements reflect incremental change with low to medium revenue and efficiencies potentials, and are often characterized as being either accidental or uncontrolled. By contrast, intentional innovation differs in that it is initiated within the organization or directly by the organization. Said another way, innovation is intentional and focused.

At the other end of the spectrum, breakthrough innovations range from serendipitous to strategic. While both result in disruptive changes and have high to medium revenue potentials, serendipitous is accidental and uncontrolled, similar to unplanned improvements, while strategic is initiated by the organization and is similar to the intentional innovation associated with incremental innovations.

The following figure illustrates the universe of potential innovations compared against customer value created as well as value chain improvements that a company experiences. Customer value propositions range from enhancing to extending to inventing, while the value chain extends from improvement through transformation to creation. This results in three innovation spaces: optimize, innovate, and disrupt.

What follows is a series of innovation stories. They are grouped into the three spaces: optimize, innovate, and disrupt. The stories are intended to illuminate and illustrate the innovations that one might expect in each of these three areas. All occurred in engineering and construction and reflect the author’s experience.



Optimize

Optimize Story #1

A petrochemical facility located in the far north was faced with the recurring challenges of reconfiguring process valves through all seasons. While this was challenging even in the summer months, the efforts were compounded during winter, when prevailing north winds created both frigid temperatures and increasingly unsafe working conditions. As the facility owner contemplated the construction of a second similar facility in a nearby location, it sought to address this operating and maintenance challenge in the new project. Numerous options were considered, ranging from complete reconfiguration of process and tank units to the introduction of heated, motorized valves. Each of these candidate solutions represented a “heavy” engineering solution to the problem.

As part of the project design value improvement process, thinking was opened to other available solutions. In the end, the selected solution was about as low tech as could be. The decision was made to locate and orient the various valves such that valve stem extensions would permit the valve open and close functions to be performed from the south side of the project with the plant itself acting as a wind break. The added cost associated with valve stem extensions was significantly less than all other options considered. It demonstrated that a key part of the innovation process is clearly understanding the problem that truly needs to be solved.

Optimize Story #2

In executing a large minerals project in Western Australia, a decision was made to utilize inland modules. This represented the first use of mining modules away from a port. A key component in the module decision process was the availability and capacity of access routes from a port on the Indian Ocean to various mine sites located throughout the Outback. Module size was not constrained in any significant way for marine shipping loads, but concerns quickly emerged over a potential choke point in the overland logistics route. As one exited the port area it was necessary to cross a light duty bridge over a dry riverbed. While the bridge was more than adequate for the various other loads that would be shipped to the respective construction sites, its overall carrying capacity was less than the desired module weights for efficient use of modules at the various sites. The bridge was evaluated for carrying capacity and would clearly be underrated for the kinds of loads anticipated. Various options for strengthening or replacing the bridge were carried out by the logistics team. Costs and schedules were determined to be unattractive. The dry riverbed only flooded during any local monsoon event that might hit the port area and it was not unusual for there to be no signs of water in the riverbed for years at a time.

At this point the module logistics team considered a range of options, including the use of smaller modules or multipart larger modules which could be rapidly reassembled once at the site. The innovation team included a number of individuals familiar with construction in remote locations around the world. The developed solution consisted of ramping down one side of the river bank crossing the dry riverbed, which would be engineered to carry module loads, and then ramping up on the other side of the riverbed, alleviating any need to modify the existing bridge. As part of the innovation effort, the team assessed the risk of a typhoon and associated flooding of the riverbed. Experience showed that the riverbed would likely retain water for only a few weeks, after which the earthen ramps and engineered bed could be quickly repaired or replaced. This technique for crossing dry riverbeds had been used elsewhere in the world and opened up the opportunity to use larger modules.

This innovation effort demonstrated the value gained by bringing together a range of different perspectives.

Innovate

Innovate Story #1

On one large project where essentially all construction materials and equipment would be arriving by marine transport, it was necessary to address the capacity of existing port facilities. These facilities were constrained by the significant export of the very minerals for which expanded mining and processing capabilities were to be constructed. Various options for increasing port capacity to handle construction materials and equipment were considered, including the construction of a global scale ocean wharf. It was judged that the construction time and cost associated with such construction was prohibitive, with schedule considerations being even more important than cost considerations. Various other options to improve throughput of the existing port were considered, such as the addition of cranes, increased use of containerized cargo, and more efficient landside unloading techniques, including rail on dock.

Each option faced a similar constraint, namely that any facility modifications at the existing port would act to diminish throughput, at least in the short run. It was clear that a solution outside of the existing port area was required.

The team sought to identify another potential port facility that was capable of handling ocean going marine barges. As sites were identified, a significant marine challenge was common to all of the sites: significant daily tidal swings, up to 20 feet. It was therefore necessary to come up with a solution that would allow any marine barges bringing materials and equipment for the project to be able to operate through the full cycle of the tidal swing. An innovation workshop was conducted. The result was an approach drawing on prior naval experience with the use of floating dry docks. That experience was complemented by individuals participating in the workshop who had been involved in the evaluation of lock designs for a significant canal facility.

The developed solution was termed a "lock dock," which was essentially a floating lock that would be connected to a relatively short wharf. As the marine barges approached the lock dock, the water inside the lock doc would be equalized with the then current tidal height. Once the barge was inside the lock dock, the water level inside would be raised or lowered to coincide to a level associated with efficient unloading onto the wharf. As the tidal swing went through its full daily range, the water level inside the lock would be sustained at an appropriate level to allow efficient drive-on, drive-off of barge laden cargo.

This solution demonstrates the value of bringing together a diverse set of skills and opinions focused—not on the building of a wharf—but rather on providing a means for quickly expanding the capacity to offload construction materials and equipment.

Innovate Story #2

The rebuilding of a main span for a major, nationally significant bridge required the rethinking the approach to fabrication and erection of the new facility. Landside access was challenged, with one of the approaches itself under construction. It would be necessary to erect the main span from the bay. Evaluation of a range of erection sequences was considered and it quickly became evident that erecting directly from the heavy marine vessels bringing major bridge sections to the project was the best alternative. The size and weights of the sections would be constrained by the lifting capacity of whatever marine or other cranes were deployed on the project.

The innovation team identified the benefits that would accrue through the use of larger sections from what might have been originally contemplated. The constraint, of course, was that there was no pre-existing marine crane capable of operating in U.S. waters to provide the necessary lifting capacity. To address this challenge the team designed a new heavy lift marine vessel that permitted maximization of the section lengths and weights that could be accomplished.

This is a demonstration of an innovation team focusing on existing constraints and identifying solutions to remove them. It is also a clear demonstration of the important relationship between the building and use of tools. As the industry has evolved from the days of the master builder, serial specialization has led to disconnects between tool building and tool use in all too many instances. Innovation efforts require not only creativity, but insight in how to implement the developed solutions.

Innovate Story #3

Steam assisted gravity drained (SAGD) reservoirs require the continuous injection of steam into the developing underground reservoirs. After steam has been injected, an oil and water mixture is pumped to the surface for oil recovery. This steam contains not only oil and water, but other entrained and dissolved minerals, most notably silica.

The standard approach involves oil and water separation followed by treatment of the water stream by a series of settling tanks and filters to remove large quantities of entrained minerals. Silica, however, is persistent through much of this water treatment process. If removed by conventional means, it would be required to be treated as a hazardous material and appropriately disposed of. In typical operations it would be essential to remove this silica before the water stream is reheated in a steam generator for re-injection into the underground reservoir. This removed silica results in a high volume of a hazardous waste product.

The innovation team sought to identify strategies for eliminating this waste stream by returning the silica to the underground reservoir from which it was derived. Various approaches were considered, including removal of the silica before the steam generator and then subsequent reinjection into the underground reservoir. This involved a significant cost and materials handling effort and was deemed not optimal.

The constraints on passing the silica through the steam generator were associated with a combination of operating materials and warranty considerations regarding the steam generator. An innovation team consisting of mining, chemical, nuclear, construction, and materials staff sought to remove the constraints. The developed innovation focused on changing the water chemistry inside the steam generator by significantly increasing the pH of the water prior to injection into the steam generator. These higher pH levels were well within the tolerances of the steam generator materials and assured that the silica would remain in solution in the associated condensate flows. Condensate exiting from the steam generator would have its pH lowered back to more traditional levels.

Innovation efforts were focused on removing constraints to more efficient process operations and concomitantly eliminating significant amounts of treatment and filtration equipment, as well as reducing large volumes of offsite hazardous waste.

Innovate Story #4

Slurry pipelines have been used for many years. One of the recurring challenges of such pipelines is abrasive wear inside the pipeline. This abrasion challenge was brought to the forefront during the exploitation of Canadian oil sands. In oil sands mining, naturally water-wet oil sand is mixed at the mine site with hot water and NaOH (sodium hydroxide or caustic soda) to produce a slurry containing entrained air. The slurry is pumped through the pipeline and fed directly to a conventional gravity separation vessel. Importantly, the pipeline is of sufficient length so that in the course of being pumped through the pipeline sufficient coalescence and aeration of bitumen occurs. This is done so that when subsequently retained in the gravity separation vessel, viable amounts of the bitumen floats, forms a froth, and is recovered.

Reliability of slurry transport pipelines is a major ongoing problem across many industries. It was particularly acute for the operation of oil sands companies due to unexpected piping failures. These failures were the result of excessive wear of portions of the pipeline. Various approaches to minimize this risk had been tried, including the use of thicker walled and higher grade piping and even periodic rotation of the miles-long pipelines in order to distribute abrasive effects more uniformly throughout the inside of the pipe.

An innovation team focused on developing a range of solutions came up with a number of innovations. One of significance was understanding the drivers of the problem and the key boundary point between the area of challenge and the risks associated with pipeline failure. In addressing the challenge, the innovation team recognized that as oil sand clumps are introduced into the pipeline, they bounce along over its entire length with their size distribution being reduced as the bitumen flows through the length of the pipe. This breakdown of bitumen during the hydro transport process was essential for the subsequent process operations, but also created the abrasive effect that was driving pipeline failures. Many of these failures resulted from abrasion on the bottom portion of the pipe although abrasive effects could be seen throughout the internal circumference.

The team recognized that the boundary layer in contact with the abrasive oil sand clumps during transport was the point of attack for innovation. The solution was to clad the interior of the pipe using a nanomaterial in order to provide a high degree of abrasion resistance. The innovation effort subsequently recognized that a strengthened boundary layer would allow the use of lower grade steel piping that still met overall mechanical system performance factors for the hydro transport pipeline but at lower cost.

By focusing on understanding the true failure mechanism, the innovation team was able to combine then emergent materials technologies to provide the requisite abrasion protection while simultaneously reducing pipeline costs associated with the main piping material.

Innovate Story #5

The use of pipe with nanomaterial cladding across many industries and applications has facilitated the handling of highly corrosive and abrasive materials. One of the challenges created in the use of nano-clad piping relates to the welding of pipe sections. During the normal welding process, heat is transmitted through the pipe and acts to heat the internal nano-cladding material. This addition of significant heat may cause the breakdown of the essential properties of the nano-cladding in the vicinity of the weld locations. This potentially creates a failure path through the nano-cladding at the weakest points along the pipeline.

An alternative welding approach was required. The innovation team built upon a prior innovation that one of the team members had developed with respect to the use of high-speed friction stir welding, a method of fusing a variety of materials that does not require the use of any filler metal or flux.

In adopting the previously developed friction stir welding approach to nano-clad piping the innovation team incorporated features that permitted the selection of transverse and angular velocities that limited grain growth in the internally applied nano-cladding through a combination of weld penetration depth control, such that the spindle stir zone did not breach the cladding layer, and a spot surface cooling of the clad surface during the friction stir welding process, such that the heat affected zone, has limited penetration and duration within the nano-cladding.

The result was a method relying on proper depth selection to provide the required degree of control to assure that the structural properties of the piping system were not degraded with respect to corrosion and wear resistance.

Innovate Story #6

Even the best designed nano-clad pipelines are susceptible to spot loss and defects within the protective nano-cladding layer. To address this challenge an innovation team built on prior work associated with nano-clad pipelines. The team drew upon the experience of materials, mechanical, and maintenance engineers. The innovation team recognized that an in-situ apparatus and methodology for cladding or repairing cladding in installed piping systems was desirable.

The innovation team envisioned an apparatus that included a coating collar, a material reservoir, a cladding head, an adjustable cladding chamber, and a chamber controller. The cladding head and cladding material reservoir were coupled to allow efficient deployment of the cladding material on the pipe surface. Attention was paid to the mechanisms required to limit grain growth in the applied nano-clad materials.

In developing the innovation, the team built on the experience of several team members with existing nano-clad piping systems as well as equipment and mechanical engineering expertise to design the required transport and application mechanisms. The developed innovation is intended to work in conjunction with an internal piping inspection system that would identify longitudinal and radial locations of potential defects. This would provide proximate location information to the nano-clad pipe weld repair system, with final determination made by the repair system once it arrived at that suspected location.

Innovate Story #7

In post-disaster environments, understanding the nature and extent of damage represents a significant challenge, particularly in buildings of historical or societal importance. These buildings are often well monitored and many have 3D models that had been generated as the result of either laser scanning or initial development in a 3D BIM model.

An innovation team focused on the development of a disaster assessment system that could generate a range of impact reports that would provide initial information on how the building site has been impacted by the disaster. This impact assessment in part would be based on sensor data associated with the building site that is collected after the disaster.

The disaster assessment system the innovation team developed included a sensor platform, an important pre-disaster database, historical data associated with prior disasters and their impacts in the location, and a uniquely developed impact assessment engine. For structures in areas of recurring disasters such as earthquakes, pre-installation of the sensor array may be desirable. In all instances the post-event 3D model based on the sensor data collected is compared to a pre-event 3D model.

The developed system was granted a patent.

Innovate Story #8

The introduction of robots into the construction workplace is at its earliest stages. An emerging challenge is the use of construction robots across multiple construction workfaces, especially the efficient handoff of robotic control from one workface to another. A related challenge is in construction robots transiting through multiple workfaces in the course of performing their activities.

The innovation team addressing this emerging challenge recognized that the particular robots operating within a future construction environment would not be constant throughout the project nor even constant throughout the day or within a given workface. In addition to this challenge, the team also recognized that construction robots would come from a range of manufacturers with different functionality.

The innovation team focused on developing a method and system for integrating new robots into a work environment and conceiving of a control mechanism that would signal the presence of a new robot in a particular work environment as well as providing for a basis to hand off control of a work robot from one workface to another.

The developed solution was analogous in some ways to a universal remote control, where the deployed controllers within the construction environment would not be bespoke. This universal construction robotics controller, upon receiving a signal indicating the presence of a new robot in the work area, would open up an established negotiation channel between the controller and the new robot and begin a negotiation process with the new robot on a set of robotic functions controlled by the "remote." Again, this is analogous to what one sees in a multi-component system where a universal remote control is employed. Proprietary controllers would still be retained for specific robot functions that have not been identified as delegated for field control. Based on the comparison between a set of function attributes of the new robot and the interface attributes of the controller, the controller would generate a new robot user interface for controlling the set of robotic functions of the new robot.

A patent for this innovation was granted in 2016.

Innovate Story #9

Construction site safety remains, and likely will always remain, a major challenge for the industry. The growing complexity of construction sites, particularly on large projects, represents an opportunity for the integration of new technology into the construction safety function.

Construction hazards, especially at large multi-project construction sites, represent a varied and ever-changing safety challenge. Low hazard areas today may be high hazard areas tomorrow. Even during the course of a day, transient hazards may be present such as those associated with blasting, heavy equipment operation, and lifting activities. Other hazards may exist on a transient basis, such as refueling operations or use of harsh and potentially toxic chemicals for cleaning operations.

Safety briefings at the beginning of each shift may not capture the range of evolving hazards. Workers may potentially enter construction work areas without full cognizance of the risks they may encounter and the required cautions or preventive measures that may be required.

Additionally, the ability to identify workers in the vicinity of ongoing construction operations without requisite safety or other training provides an ability to alert supervisory and safety personnel and the specific workers.

Precise messaging is now possible because of the location-specific accuracy that is achievable through the use of a Bluetooth® beacon array. The array allows precise tracking of worker-associated Bluetooth® enabled devices such as smartphones or other similar devices with Bluetooth® technology and linking of such worker- and location-specific data to a project safety database. Worker location would be checked against a construction activity register updated by both manual (supervisor or safety engineer) or automatic (crane or vehicle location tracking) methods. Associated safety hazards would be transmitted via Bluetooth® to the workers' and others' (supervisor; safety engineer) smartphones or similar devices. A secondary check would be conducted when specialized training or certification is required at the location by confirming the necessary perquisites have been met by the worker in the training file.

Alerts can be provided when certain "electronic fences" have been crossed or when smartphone derived accelerometer info indicates approach of a changed safety regime.

The developed system aids in enhancing awareness of the ever-changing nature of one's surroundings at a construction site and will contribute to overall site safety.

A patent was granted for this innovation.

Innovate Story #10

Modularization of significant elements of a capital project were introduced several decades ago. First generation modules were primarily focused on the prefabrication of pipe racks required in large process facilities, especially those serving the oil and gas industry. The primary metric to measure the degree of modularization was related to shipping weights in tons. The industry quickly recognized the value associated with opening up a new work front and relocating measurable work-hours of construction off what were often remote and challenging sites.

The industry progressed into a second generation of modularization where 60-70 percent of the steel and piping associated with the plant were fully modularized. The second generation introduced the pre-installation of process equipment into these modules and achieved installation levels of approximately 20 percent on electrical and instrumentation. Pipe routing was automated and optimized. The net effect of this second generation was to relocate approximately 40 percent of above ground field hours away from the site and into the module yard. Owners and contractors realized that in addition to the cost and schedule benefits that accrued, a reduction in the overall site footprint could be achieved. This was largely due to the more highly integrated layouts possible through fabrication and assembly in the manufacturing-like environment of the module yard. The effect of these reduced footprints was to reduce associated off-sites and utilities, thus creating additional value for the project.

As these benefits were being realized, the opportunities for increased modularization were challenged by innovation teams. These innovation teams sought to combine additional value in the module together with the already present cost and schedule savings. This shift was accomplished through the integration of other (then state-of-the-art) tools in module design, construction, and start-up. Process blocks, the backbone of these large-scale industrial facilities, then were modularized and standardized at the block level, reducing engineering costs and providing greater certainty to cost estimates. The percentage of steel and piping on the modules was extended from the earlier 60-70 percent levels to 95 percent in third generation modules even as pipe racks were being eliminated through integration into these new process blocks.

The modularization of the process blocks was undertaken in such a way as to eliminate the need for concrete foundations, reducing costs and shortening overall project erection schedules. Electrical and instrumentation modularization percentages also increased to the 85-95 percent level with essentially all cable wiring and testing done in the module yard. Routing and route optimizations were significantly accomplished using an approach similar to that employed for piping in the earlier generation.

Mechanical, electrical, and instrumentation systems, to the extent possible, were checked at the module yard in order to create a plug and play approach upon arrival at the final construction site and shorten start-up and commissioning schedules. Together these innovations resulted in the relocation of over 90 percent of field hours to the module yard.

At each step in the innovation process, every constraint was challenged, every available tool was utilized, and new tools to help optimize the routing of piping (including small bore piping), electrical cabling, and wiring were developed. By the time the full impact of third generation modules was apparent, it was clear that there was a need for new metrics, something more representative of the value created than tons. One metric that provided a good measure of the degree of modularization was the number of work-hours that were moved away from the final site. Other metrics included value share and schedule reduction.

At each step in this modularization journey, innovation and improvement teams were put in place to create significant step changes in improvement and value in the next generation of modules. That journey continues even today with improvements that have integrated the added bracing required for shipping into the structural design itself. A new focus on the materials of construction, opportunities to reduce greenhouse gas emissions, and improve life cycle performance are creating new challenges for subsequent generations of modularization. The door has been thrown wide open for use outside the oil and gas sector with examples now found in the mining, power, infrastructure, nuclear, and food and beverage industries.

Innovate Story #11

The increased exploitation of deep offshore oil and gas created a need for cost-effective subsea liquefied natural gas (LNG) pipelines. Initial industry solutions for such cryogenic pipelines were expensive, relying on a combination of 36 percent nickel (Ni) steel pipe and vacuum insulation. The vacuum insulation was necessary to eliminate contraction and provide for a high degree of thermal efficiency.

An innovation team focused on achieving comparable functionality but at lower cost. The developed concept can simply be described as a pipe within a pipe. This approach allowed the use of lower nickel content steel pipe (nine percent) with a surrounding aerogel insulation. The annular space also facilitated the incorporation of sensors for monitoring and leak detection. In most instances the outermost pipe could be a simple carbon steel casing, or if required in some applications, nine percent Ni steel.

The innovation team recognized that containment of LNG differed from protection of an LNG pipeline. In addition, alternative insulation strategies and materials became available with the pipe in a pipe concept.

This is an example of a focused innovation effort to significantly improve an existing solution.

Innovate Story #12

An innovation team was challenged with considering the application of solar energy to improve capital efficiency of a copper flash smelter located in the solar rich Southwest U.S. As part of this focused innovation effort, the team examined each step of not only the contemplated energy generation process but the plant process operations as well. This reflected the projects goals of capital efficiency improvement as contrasted with developing a solar energy plant only. The developed concept utilized a solar central receiver and 5M square feet of heliostat to collect available solar insolation. The developed solar field produced several hundred megawatts of thermal energy for use in the smelter and in generation of electricity to support plant loads in this remote location.

In developing the solar configuration, the innovation team recognized that the integrated system (energy and process plants) was characterized by three time constants. The first was the potentially rapid change in solar insulation provided to the central receiver as the result of something as simple as a passing cloud. The second dealt with heated air transferring collected energy from the solar central receiver into the more conventional thermal and power energy systems. The final time constant dealt with changes in the flash smelter performance that occurred over longer periods of time.

The recognition of these three significantly different time constants let the team develop an innovative, multi-power port gas turbine configuration that represented a fundamental improvement in the application of gas turbines to cogeneration systems. While this configuration was initially developed for the particular solar cogeneration opportunity, its applicability proved to be much broader and provides greater value capture in many other areas.

A second innovation recognized the reality that the sun does not shine 24 hours a day, but that the smelter needed to be able to operate on essentially a 24-hour basis for 365 days a year or until those points in time when it was shut down for maintenance and refurbishment. This created a need to store large quantities of thermal energy for injection during night time as well as during any periods of extended inclement weather. The required thermal energy to be stored meant identifying a high heat capacity material that would support both transfer of a portion of the energy stream into thermal storage during daytime collection and efficient withdrawal of that thermal energy for use in the smelter process at other times.

After considering various thermal storage options, the team identified a readily available, no cost material that could be efficiently used for storage of the thermal energy volumes that the facility would require. This material was copper slag, which was available in essentially unlimited quantities at the smelter site. The slag was equipped with input and output piping, a geotextile cover, and a large earthen mound to provide insulation for heat storage. Further development of the concept led to all heated air flow from the central solar receiver to pass through this large thermal mass to provide constant inlet temperatures to the flash smelter. The use of copper slag as a thermal storage material remains a viable option for solar thermal projects today.

Process outputs were modeled for both the current configuration as well as the developed, modified configuration. In the modeling of plant performance, the innovation team identified increased process throughput associated with the enhanced oxygen content in the inlet air as a result of the displacement of oil firing to preheat the air. It is here that the innovation team came to a principle insight with respect to the displacement of oil firing directly into the inlet air, but rather accomplishing it in an introduced closed loop heater with transfer in an air-to-air heat exchanger. This provided attractive benefits.

A fresh look at the drivers of process performance allowed the innovation team to discover a previously unconsidered approach to improving process plant throughput. Taken together with the innovations associated with gas turbine modification and other modifications driven by the requirements of the solar cogeneration facility, large value capture resulted.

Innovate Story #13

During the U.S. conflict in Afghanistan (2001-2021), the various and numerous forward operating bases around the country housed a variety of military units, with the composition of the force at each base continuously changing to meet mission requirements. A common characteristic of each unit arriving at a forward operating base was that it would bring its own diesel generators to meet its own power needs. The fuel for these diesel generators was brought to the forward operating bases through fuel convoys that were subject to continuous attacks. This necessitated significant amounts of military resources for these fuel convoys to provide protection.

Each of the diesel generators arriving at a forward operating base and associated with a particular unit had been sized for a peak performance level, often a combat or response mission that was significantly larger than that required during residency at the forward operating base. The result was that each of the diesel generators operated at less than efficient levels.

The innovation team was challenged to consider ways to essentially reduce the number of targets that were represented by the fuel convoys. The focus was on how to reduce demand for the diesel fuel being transported.

While a review of each operating unit's needs for power on both a peak and forward operating base basis had been considered, it was judged to not provide the opportunity for quicker target reduction, which was essential. The team analyzed forward operating base energy demands, by unit, on a daily basis, both during peak and off-peak operations. It determined that improving the aggregate energy efficiency of available diesel generators offered the greatest scope for improvement.

Essentially the innovation team focused on how to achieve a more efficient economic dispatch of power in the forward operating base context. The solution was to interlink available on-site diesel generators utilizing a micro-grid. This allowed for the economic dispatch of power base-wide by operating diesel generators at more efficient load factors. The innovation team established parameters to guide the dispatch of power utilizing the micro-grid. These included considerations of individual generator load factors, total runtime on each diesel generator, the likely required dispatch of discrete military units together with their associated diesel generators, and an overall level of spinning reserves.

The overall energy savings were significant and reduced the fuel demand at each forward operating base where a micro-grid was to be deployed, and concomitantly, reduced the number of fuel convoys and their frequency. This target reduction achieved the focus that the innovation team had been charged with and further reduced theater fuel demands since less convoys and less escort vehicles consumed less fuel. From a mission standpoint, the protection and escort resources, which were significant, were now available instead for military missions. The pointy end of the spear had just been sharpened.

Innovate Story #14

The sheer scale and complexity of Boston’s Big Dig (1991-2007) created opportunities for technical innovation and differentiation. The megaproject, formally known as the Central Artery/Tunnel Project, would reroute the Central Artery of I-93 into the 1.5 mile Thomas P. O’Neill, Jr. Tunnel. Creating that overwhelming sense of an already engaged team led to assembling 40 experts into five teams from across all firms on the bidding team in Boston for a full week.

The experts came up with dozens of potential innovations and outside-the-box solutions. Essentially all of these found their way into aspects of the proposal to demonstrate serious engagement and interest. Of these dozens of innovations, five were selected, covering all key aspects of the project. These were highlighted in depth in the executive summary and, more importantly, became the backbone for the presentation storyboard and key elements in the constructed project.

One of these innovations related to the relocation of utilities from underneath and alongside the existing elevated Central Artery Into a series of utility corridors. These utility corridors would become a key concept of the project and critical to project success. Under the proposed innovation, utilities were relocated into temporary corridors so that construction workers would know precisely where the wires and pipes were during the slurry wall and tunnel work. In creating the corridors, the locations had to fit within the alignment of the highway. There were limited locations where enough clear space above the tunnel allowed utilities to cross. In some instances, profiles of the highway tunnels were adjusted to allow for eventual passage of utility conduits between the roof of the tunnel and the surface.

In one instance, a utility tunnel crossing the future buried Central Artery was placed on a supporting bridge built underground in such a way as to allow excavation of the highway tunnel to occur underneath while the utilities remained safely supported above.

The concept would have these temporary utilities moved into permanent utility corridors aligned with permanent street patterns. In this configuration the utility lines would not only be modernized, but would be accurately mapped to support future work and arrayed more conveniently to permit more effective and efficient maintenance.

Today, this concept would seem an obvious one. In the planning era of the Big Dig, however, it represented both a solution for the construction phase and enhancements for the operations phase. The use of multi-utility tunnels thus became more common.

Disrupt

Disrupt Story #1

In the early days of private development of roads in the U.S., numerous constraints existed in the ownership and financing models available to the industry. Concerns for new models, such as the public-private partnerships (PPPs) in use today, ranged from the perceived higher cost of debt to questions on ultimate ownership of the facility. To address these concerns, an alternative project delivery and financing model was conceived that represents a different form of today’s public-private partnership. This model utilized existing tax-exempt debt structures while providing for the added leverage that equity would traditionally bring through the creative use of subordinated debt.

The use of traditional tax-exempt debt structures provided the public sector clients testing the market for alternative delivery solutions with the comfort they needed. The subordinated debt acted as a form of quasi equity.

This innovative new project execution delivery and financing model represented an early effort to open up the funding of infrastructure projects to greater participation by private capital. At the time of its creation no existing business or financing model for privately developed public infrastructure existed. Several projects were successfully delivered under this model until the current equity-based, public-private partnership model took hold. It is worth noting that while this model has been overshadowed by the for-profit PPP model, it still remains a potentially viable tool in select instances.

The development of this new model involved a cross-section of sales, construction, engineering, government affairs, and stakeholder engagement specialists.

Disrupt Story #2

The nuclear industry has been plagued by cost, schedule, and quality problems. Massive overruns in these already large capital investments have created a significant challenge to the viability of the industry. Over a 20-year period, the industry has made efforts to improve the quality of the constructed works as well as reducing their overall cost and schedule.

One of the efforts that subsequently gained traction was the development of small modular reactors. This would allow for smaller projects with higher degrees of manufacturing content to be delivered in shorter timeframes than what was being experienced. One such effort focused not just on the construction aspects, but also on rethinking the basic process schemes associated with nuclear power generation and its ultimate safe operation and disposal at its end life. This process focus was combined with the recognition of the need to reduce or eliminate equipment and reduce the size of the facility and the individual modules and its parts. As part of the new process schemes being envisioned, advantages were sought in energy efficiency to improve overall lifecycle capital efficiency.

The innovation team set out to take maximum advantage of modern technologies and techniques as well as advanced materials and codes. Construction methodologies, including the underlying concepts of third generation modules, were combined with manufacturing thinking to improve overall project sequencing and optimization.

In one innovation effort, a special purpose company was created to develop and commercialize safe, cost-effective, scalable small modular reactor technology. NuScale Power, the created company, built on earlier advanced physics research to further innovate a self-contained assembly composed of a reactor core, a pressurizer, and two steam generators integrated within the reactor pressure vessel. These components were all housed in a compact steel containment vessel. These innovation efforts were initiated in 2007 and accelerated in light of the core degradation sustained from the catastrophic Tōhoku earthquake and tsunami in Japan in March 2011. This event served to highlight the advantages of an inherent safety profile.

The innovation team developed a commercial concept that would produce both electricity and heat for industrial applications. Larger scale applications would be addressed by incorporating up to 12 modules in one application.

The innovation team recognized that the economies of scale that drove the nuclear industry to ever larger plants had reached its limits and, equally important, that many markets do not need or cannot accommodate larger plants. Also, as plant sizes grew the global manufacturing capabilities soon reached a diseconomy of scale. Other diseconomies resulted from the significant financial commitments and risks that these larger plants carried. In addition, construction of a largely bespoke facility proved to be extremely complex. The innovation team developed and implemented a concept best described as “economies of small.” This concept was built on four principles that guided the innovation team: (1) design simplicity, (2) manufacturing assembly and ultimately mass production, (3) simplified parallel construction, and (4) innovative operations.

This small modular reactor innovation thus built on 50 years of nuclear technology evolution, with a strong focus on enhancing plant safety even under extreme events such as the earthquake and tsunami. The safety concept eliminated any requirement for operator action, any requirement for AC or DC power, and any need for additional water for cooling over an extended period of time.

That developed concept reduces plant costs and risks by increasing the overall level of modularization within a factory environment beyond that contemplated for even the most extensively modularized capital construction projects today. The modular nature of the project provides added operational flexibility, allowing for one module to be refueled or maintained while other modules continue to operate. Modules can be sequenced to further reduce the capital at risk and improve overall capital efficiency.

A range of other advantages occurred, including associated smaller exclusion zones and the ability to capture the learning curve advantages one typically sees in manufacturing.

This innovation demonstrates the importance of coupling ideation with implementation. At each step in the implementation process, innovative improvements were identified that built on the initial concepts and philosophy. Implementation requires commitment, especially when long, regulatory-driven processes are involved.

Disrupt Story #3

The emergence and broadening use of artificial intelligence (AI) across numerous industries, simultaneously, became attractive as an innovation target area within a firm. Throughout the innovation exercise, additional team members were added to foster the translation of the innovative concepts into implementation.

In the early stages of the innovation exercise, two streams of efforts were being undertaken simultaneously. The first stream, the subject of a provisional patent, conceived of the project data as a series of pixels in a project snapshot taken at a point in time. The innovation team recognized that this was analogous to pictures, especially in facial recognition. The innovation team felt that the underlying mathematics and AI principles could be applied to this project picture, allowing it to be compared to other similar project pictures to help determine the degree of commonality and to highlight those portions of the picture which differed from a composite reference picture. The innovation team also recognized that the series of pictures that existed on a project, typically weekly, biweekly, or monthly project status reports, could be combined to create a project movie. Trained project movies would provide a sense of the likely trajectory of similar projects.

This first stream also considered how the growing use of sentiment analysis as an AI tool might be applied within a project management setting. Also subject to provisional patent, it was recognized that narratives by project managers, typically incorporated in monthly project status reports, used certain words to convey negative concerns about either the project's current condition or how it was developing. The project managers' reports from over 100 similar multi-billion dollar projects were analyzed to determine the negative terminology most likely to occur in project managers' sentiments when the project condition was of concern. A set of about 100 words were identified that, when used in the project manager's monthly narratives, represented negative sentiment about the condition of the project. This first innovation team classified this collection of words as trade secret as they provided an initial insight into emerging degraded performance.

The second stream focused more explicitly on the application of machine learning to the large volumes of data available within the firm. This effort built on some of the insights of stream one and partnered with a major industry AI developer to develop and train an AI tool focused on predicting project failure at an earlier stage than when the project manager was raising his hand saying "I think I have a problem."

The two streams combined, refining the various innovative concepts that could be deployed using various forms of AI, to predict project performance. Emphasis was placed on developing an initial usable tool that would provide a high level of confidence in its predictions, avoiding large numbers of false negatives.

In order to achieve this, the innovation team was required to assess currently available data; identify those data that were actively used on a recurring basis within the firm; further identify the subset of data that was used at the project management and department levels for managing project execution; and supplementing that data with data elements utilized by executive management in their review of the project. This initial effort focused on the structured data that was available, considering the unstructured data available within the project management narratives at a later stage. This represented the final convergence between the two innovation streams.

In the process of conducting the nearly year-long innovation effort to arrive at a meaningful proof of concept, the team uncovered weaknesses and opportunities within its existing data collection and utilization processes. A subsequent continuous process improvement effort focused on refining these identified weaknesses and opportunities, providing immediate valuable returns to the organization.

This innovation effort resulted in the development of a game-changing proprietary tool to aid in the management of large complex projects. It created a range of valuable intellectual property while simultaneously flagging low hanging fruit that could be harvested by various continuous process improvement teams.

Conclusion

As shown in the stories above, innovations may be guided by a range of "principles" that guide the innovator and the innovation team. The stories above look for task- or location-specific value creation; recalibrated thinking and practices for a changed paradigm; a move towards a higher value life-cycle solution; seeking to own the standard; transforming previously fixed operations to mobile; and providing next-level assurances.

Innovation is a requirement for continued leadership and is an area in which the construction industry must greatly improve.

About the Author

Bob Prieto was elected to the National Academy of Construction in 2011. He is a senior executive who is effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering, and construction industries.