Salt Waste Processing Facility Project Lessons Learned: Acquisition through Construction – 15518

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ABSTRACT

The Salt Waste Processing Facility (SWPF), located at the Savannah River Site (SRS) in Aiken, South Carolina, is a multi-billion dollar Liquid Radioactive Waste (LRW) processing facility that represents the keystone for the U.S. Department of Energy (DOE)-EM clean-up mission at SRS. The SWPF facilitates DOE-EM clean-up at SRS by decontaminating the salt waste, which is the dominant volumetric component in the LRW tanks, thereby allowing the cleaned salt waste to be removed from the tanks and stabilized into an approved grout-based final waste form. The small volume of removed radionuclides is sent to the Defense Waste Processing Facility (DWPF) for vitrification. Emptied LRW storage tanks are then grouted into an approved configuration for final closure.

The SWPF project is currently 100% complete with design, 80% complete with construction, and 10% complete with commissioning. To date there have been numerous lessons learned with regard to project acquisition, design, procurement, construction, and quality assurance (QA) approaches (both good practices and mistakes) that are considered to be of significant value in improving the state of major project execution within the DOE-EM clean-up program as well as to the wider DOE enterprise.

An overview of the current SWPF project status is provided and key lessons learned in the aforementioned areas are presented relative to improving future DOE major project execution performance. Specific areas to be addressed include strategies to optimize integration of design and nuclear safety, constructability tools for design and construction synchronization, commercial grade dedication (CGD) approaches to mitigate atrophy in the nuclear supply chain, and QA perspectives to facilitate effective and efficient project execution.

INTRODUCTION

SWPF Background

Nuclear material production operations at the SRS resulted in the generation of radioactive waste that was sent to the F- and H-Area Tank Farms for storage. Approximately 140 million liters of radioactive waste is currently being stored on an interim basis in 49 existing underground waste storage tanks in the F- and H-Area Tank Farms. The radioactive waste in these tanks includes approximately 11 million liters of sludge, containing precipitated solids and insoluble waste, and 129 million liters of salt solution and crystallized salts. The waste in the tanks is comprised of three forms:

1. Precipitated Sludges (approximately 11 million liters of primarily metal oxides containing over one-half the total inventory of radioactive material within the tanks);
2. Saltcake (approximately 61 million liters of salt precipitate); and

3. Supernate (approximately 68 million liters of salt solution).

Considerable liquid is mixed interstitially with the precipitated sludge and saltcake. The interstitial liquid is estimated to be 30 percent (%) of the saltcake volume and 70% of the sludge volume. Additionally, water will need to be added to dissolve the saltcake and to wash sludge that has been removed. The water added for waste removal, sludge washing, and the continued generation of radioactive waste by other SRS facilities will increase the total salt solution volume to be processed to approximately 379 million liters.

The waste removal process involves mobilizing and pumping liquids and sludge from the tanks and dissolution and pumping of the saltcake waste. The sludge waste is pretreated by a sludge washing process and sent to the DWPF for vitrification. Salt solutions removed from the tanks after SWPF startup (including supernate, interstitial liquids, and dissolved saltcake) will be processed by the SWPF.

The supernate and any dissolved saltcake solutions removed from various tanks that are to be treated by the SWPF will be sent to blending and staging tanks to prepare batches for processing at the SWPF. Each SWPF feed batch collected in a blending and staging tank will be analyzed for chemical and radionuclide concentrations prior to delivery to the SWPF Feed Tank located in the H-Area Tank Farm. Waste from the SWPF Feed Tank will be transferred directly to the SWPF for processing.

Processing of salt waste at the SWPF is intended to remove and concentrate the radioactive Cs-137, Sr-90, and actinides from the bulk salt solution feed. The concentrated waste containing the Cs-137, Sr-90, and actinide constituents will be sent to the DWPF, where the waste will be immobilized in glass through a vitrification process. The bulk decontaminated salt solution will be sent to the Saltstone Production Facility for immobilization in a grout mixture and disposed in grout vaults.

SWPF Status

The SWPF project is currently approximately 80% complete with Construction and approximately 10% complete with Commissioning activities with a revised Total Project Cost estimated at approximately $2.3 Billion and a target project completion date of late-2018/early-2019. This Total Project Cost remains below the original Critical Decision-0 estimate for the SWPF project which was performed in 2001. Parsons and DOE have agreed to an aggressive and unique bilateral contract modification that addresses the construction completion scope of the project under an incentivized “cost cap” model with a contract construction completion date of December 31, 2016.

An incentivized contract modification for the Testing and Commissioning (T&C) phase of the project has not yet been established and this phase of the contract remains under the previous cost-plus contract structure that does not accurately reflect the current cost estimates. At DOE direction, Parsons has developed an Over-Target Baseline (OTB) that reflects updated cost estimates for T&C. Parsons OTB has been submitted to DOE and is currently under review.

The design is 100% complete and there are no open technical or regulatory issues. The construction civil-structural work is effectively 100% complete and the current construction scope is focused on the mechanical, electrical, and instrumentation and control installations. The mechanical work is approximately 80% complete with skilled craft (e.g. welder) retention a significant challenge. Piping installation is nearing completion and the construction staff is beginning to ramp up their flush and leak testing activities. Electrical and instrumentation and control installation work is approximately 60% complete and progressing ahead of schedule. Construction is continuing to find ways to accelerate this scope to preclude inefficiencies associated with "stacking of trades" as the construction effort moves to completion.

T&C personnel are focused on the development of requisite test plans and procedures for start-up activities which are approximately 10% complete. Specifically, approximately 25% of the planned System Operation Test procedures are completed and issued and development of Standard Operating Procedures has commenced. T&C personnel are also implementing the asset preservation program for installed equipment during construction as a precursor to the preventive maintenance program that will be implemented during operations. T&C personnel have also successfully executed the technology development testing work for the key SWPF processing technologies, including cross-flow filtration, air pulse agitator mixing, and Caustic-side Solvent Extraction Cs-137 removal systems. The most recently completed Caustic-side Solvent Extraction testing with Next Generation Solvent has demonstrated the potential for significant throughput enhancements for the SWPF with minimal physical modifications.

Parsons continues to work constructively with DOE to successfully bring this key risk reduction facility online to facilitate the clean-up mission of the SRS. The near-term focus of both parties is the achievement of the Construction Complete contract milestone ahead of schedule and under budget. Contemporaneously, Parsons and DOE are striving to accelerate preparations for post-construction T&C activities to maximize the probability that start-up of the facility can be achieved on or ahead of schedule. Parsons and DOE are also heavily engaged with the site LRW Operating contractor to ensure that requisite interface integration and support capabilities will be in place to ensure that the SWPF will receive necessary feed and have adequate effluent receipt facilities.

LESSONS LEARNED

General

During the course of the last ten years, the SWPF project has identified several key lessons learned with regard to successful execution of large first-of-a-kind nuclear capital projects. These lessons learned cover all phases of the project experienced to date including project acquisition, design, procurement, construction, and QA. Some of these lessons learned reflect things that the project has done well and some of these lessons learned derive from things the project has done not so well (at least initially). For those areas where the project encountered challenges, Parsons has demonstrated strength in being able to rapidly learn from mistakes and implement effective course corrections. Lesson learned specific to each of these project phases will be addressed individually in subsequent sections of this paper. However, there is an overarching and axiomatic lesson learned on leadership and personnel that transcends all of these phases and will be discussed here.

Specifically, the foundation of any successful endeavor is the establishment of a strong and experienced leadership team. This leadership team must clearly understand the scope of work to be performed and have demonstrated experience in successfully executing this scope of work. This will allow the leadership team to set a clear vision of where the project is going and how it will get there. Setting this vision is one of the three key roles of the leadership team. The second key role of the leadership team is to assemble the personnel needed to effectively execute the vision and provide these personnel with the requisite organization, tools, and guidance to succeed. The third, and possibly most important, key role of the leadership team is to hold personnel accountable for performance. This needs to be done in a tactful and professional manner, but it needs to be done. This can be a difficult and at times awkward proposition, but without true accountability in an organization, the odds of success are exceedingly small.

A strong and experienced leadership team is a necessary, but not sufficient, condition for success. The supporting personnel executing the work on a day to day basis need to be top performers and they need to be able sustain performance at a high level throughout the project. Just like it is impossible for a great coaching staff to consistently win with sub-par talent, a great leadership team cannot succeed without sound talent throughout their organization. Leadership should not make the mistake of assuming that good processes and procedures can make bad personnel succeed. To establish a winning project staff, the leadership team needs to be willing to thoroughly screen the personnel they bring onto the project and to hold them to high standards once on board. Mediocre performance should not be tolerated in an organization that strives for excellence and leadership needs to be willing and able to remove sub-par performers. However, it is important to remember that accountability cuts both ways and make sure to have means in place to reward personnel for great performance; this is just as important as having means in place to penalize mediocre and sub-par performance.

Acquisition Strategy

A well considered and planned acquisition strategy is essential to the success of any major capital project and especially so for a complex first-of-a-kind nuclear capital project. The primary objective of a sound acquisition strategy is to clearly and completely outline the scope and requirements for the project and to establish a delivery framework and incentive structure that properly allocates risks and aligns the contractor’s fee achievement with the customer’s priorities and objectives. Failure to properly define the project scope and/or clearly establish the complete set of requisite requirements up front virtually ensures significant project cost growth and schedule over-runs.

A proper understanding and appreciation of the unique supply chain challenges, the rigorous level of quality control inspections and the complex and evolutionary safety-basis approval paradigm for large nuclear capital projects reveals that there are significant risks associated with a traditional “Design-Bid-Build” acquisition approach. The net effect of the above considerations is that nuclear capital projects will not reach a true “design completion” state until relatively late in the Procurement and Construction phases and these projects will require a much more significant reconciliation effort between the design and the procured and installed equipment than is experienced for a large routine commercial project. This situation creates an environment that is highly vulnerable to change order risks that can foster a corrosive adversarial relationship between the designer and the builder, with significant attendant cost and schedule impacts. When an adversarial "blame and claim" culture takes root on a project, significant management time becomes tied up in contractual change order activities that would otherwise be focused on project execution. A project in this situation is extremely unlikely to be completed successfully within schedule and budget targets.

An integrated Engineering, Procurement, Construction, and Commissioning (EPCC) acquisition approach can provide an important advantage with respect to delivery of a complex nuclear capital project. The EPCC approach directly aligns the interests of the key project elements (design, procurement, construction, commissioning) so that they are all focused on optimizing the overall project delivery. Since the EPCC contractor is responsible for all phases of the project, there tends to be better involvement of the procurement, construction, and commissioning personnel throughout the design effort to optimize the equipment availability, constructability, operability of the facility. Additionally, the EPCC approach eliminates any "blame and claim" culture and focuses all of the project management team on win-win as opposed to win-lose solutions. This is particularly important since the large nuclear capital projects require a significant design effort throughout the construction phase to reconcile the design against the available market equipment at the time of procurement. There is also a continuous risk of design changes to address engagement from regulatory and oversight entities that can affect Construction execution plans. Similarly, the exacting quality requirements and rigorous quality control inspections can result in numerous non-conforming condition reports during the procurement and construction phases that can require appreciable Engineering resources to resolve. Under an EPCC acquisition model, both design changes and non-conformance dispositions result in far less impacts to the project because the Engineering and Construction teams are focused on joint solutions that minimize overall impact as opposed to jockeying for advantage via the contractual change order processes.

For any acquisition strategy pursued, it is imperative that the project cost and schedule estimates be realistic and properly reflect the actual risks and uncertainties present at the time of the estimate. Over aggressive and unrealistic baselines set or endorse false customer expectations and ultimately result in disappointment for the customer and a tarnished reputation for the contractor. Often the cost impacts associated with hotel load extensions due to funding limitations for poorly baselined projects exceed the costs associated with a more realistic initial baseline. Strive to find cost and schedule savings via defensible changes to non-value added work scope and/or requirements as opposed to overly optimistic forecasts that are rarely, if ever, achievable.

Design

Arriving at a complete design that satisfies the myriad requirements of a first-of-a-kind nuclear facility in a cost effective manner is of central importance to a successful project. Establishing an effective Engineering organization is an essential first step toward achieving a successful design. The SWPF project has had great success using an Engineering model with a single integrated design organization under an accountable leader with broad knowledge across all relevant design disciplines. The integrated design organization includes process, balance of plant, and nuclear safety groups and uses a common set of design practices and procedures. The SWPF design procedures implement robust inter-discipline reviews that also include construction, commissioning, and operations personnel in the review of all design products which has significantly improved the overall design and greatly minimized latent design errors or problems. Maintaining a self-sufficient and complete design organization under a common set of processes and procedures facilitates effective coordination and management of a complex and highly inter-dependent design effort. It also avoids the numerous integration and contractual pitfalls associated with other Engineering models where various scopes of design work are farmed out to multiple different subcontractors.

In executing the design process it is imperative that a philosophy of including as much discretionary conservatism and design margin as practical is adopted. The use of cost-effective conservatism in the design is an investment in decreased risk and uncertainty. Increased (but reasonable) conservatism facilitates streamlined negotiations with regulators and oversight with regard to final agreements on safety strategies and control sets. Similarly, design margin is an investment in downstream delay (and associated hotel load cost) avoidance. There will inevitably be errors made in the fabrication of procured equipment and in the field construction of the facility. Generous design margins allow for defensible use-as-is dispositions to these non-conformances and can preclude painful schedule delays once the construction forces are mobilized.

The design process should also always keep the next phase of the project, construction, directly in mind. In doing so, they need to seek to maximize tolerances and “or equal” provisions to the extent possible and seek to use standardized equipment and complementary design solutions wherever they can. A good example of standardizing equipment would be the establishment of standard embedment plate sizes that can be combined or separated to achieve the desired lengths. Similarly, an example of complementary design solutions would be including adequate concrete clear cover above rebar where you expect to be using post-installed anchorage to avoid the need deal with potential rebar interferences.

One of the biggest risks to a nuclear capital project can be late-breaking issues that are raised by regulators or oversight with regard to the safety-basis or control set. To minimize this risk, it is imperative that the Engineering team engage with regulators/oversight early and proactively and document agreements that are made. Good meeting minutes are a very important component of a successful relationship with regulators/oversight. Complex nuclear capital projects can span a decade or more and personnel on both sides can come and go over those time frames. Investing in clear documentation of interactions and agreements can avoid painful rehashing of issues that were considered closed and ensure that both sides have a clear understanding of the project commitments and path forward. The Engineering team should strive to find win-win solutions with oversight and be willing to trade reasonable conservatisms for closure and certainty regarding regulatory/oversight matters. Standing on ceremony is not a pragmatic course of action and rarely leads to success with regulators/oversight entities. Pragmatism should be the preferred mode of operation in these areas. However, if regulators or oversight entities are pushing for impractical commitments or untenable paths forward, the project's Engineering organization needs to be willing and able to defend their work to a first principles level when they are correct.

Where first-of-a-kind processes are being implemented in a complex nuclear capital project, investment in full scale system testing is essential. The SWPF project has executed a best-in-class full scale technology development testing program for all of the key facility processing systems and this investment has significantly reduced project risks and improved overall cost and schedule performance. When possible, hot pilot testing facilities provide an excellent complement to full scale cold testing results and allow achievement of the highest level of technology readiness prior to actual operations. It is important to include nuclear safety personnel in the development of test plans and completion of test reports to ensure that any opportunities to improve safety or optimize controls through data collected from the tests are identified and exploited. It is often the case the a significant decrease in conservatism or cost for controls can be enabled by a relatively inexpensive addition to a planned test if the data need is identified by nuclear safety prior to the test being performed.

As was stated earlier, the design of a complex nuclear capital project is never fully complete until relatively late in the Procurement and Construction phase of the project. However, the design needs to be mature and the risks of any open design items need to be clearly understood and mitigation measures identified and in place prior to commencement of Procurement and Construction activities. Often design maturity is defined as the achievement of "Revision 0" status for an arbitrarily defined percentage of design output documents. Resist the urge to define design maturity in this manner as it usually simply incentivizes the premature issuance of design documents as "Revision 0" status with incomplete coordination performed and thus with a still large integration risk in place. Determination of design maturity requires a focused review by a competent independent technical team of practicing engineers to understand what work remains and how well the risks of that remaining work have been mitigated relative to potential Procurement and Construction rework. This independent review also must evaluate the viability of the project Engineering team's plans to complete any remaining work within their cost and schedule estimates and if this work has been logically tied to the subsequent Procurement and Construction activities that are proposed to move forward.

Finally, a great design team always remains focused on continuous improvement. However, this cannot be at the expense of completion of work on schedule and within cost. Rather, there needs to be a culture of pride in identifying ways to complete planned work in a more effective and efficient manner and means to reward such innovations should be in place. Additionally, a percentage of the design team's time should be allotted to looking for ways to implement "tweaks" that leverage the existing process and equipment to enable safety or production capacity gains that can appreciably improve life cycle costs. There is no one better positioned to recognize and exploit these potential opportunities than the facility design team.

A great example of continuous improvement is the Next Generation Solvent opportunity that Parsons is working with the DOE to implement at SWPF. This relatively minor change to the chemical extractant uses the same facility equipment and nearly the same flow sheet to enable significant plant throughput capacity gains that could save the DOE billions of dollars of life-cycle costs associated with clean-up at the SRS.

Procurement

Procurement activities on a complex nuclear capital project carry significant risks due to the fact that most suppliers do not truly understand the rigorous nuclear quality requirements necessary to successfully deliver nuclear products and the extreme costs associated with project hotel loads during the Construction phase that amplify the cost impacts of equipment delays.

One of the best ways to mitigate the risks associated with procurement activities on a nuclear construction project is to insist on the use of “Best Value” procurements and invest in thorough pre-award supplier evaluations. This allows the project adequate discretion to determine the suppliers most likely to be able to deliver quality products on schedule. Even when the best supplier is identified, it is prudent to plan on investing in a significant on-site Engineering and QA presence at the supplier’s facility to ensure that fabrication specifications and all applicable requirements are being followed the first time. The penalties in terms of cost and schedule delays associated with rework dwarf the investment in overseeing that the work is done correctly the first time.

Given the atrophy in the supply chain for nuclear-grade equipment in the United States, there will be many instances where requisite equipment will only be available from a commercial supplier or where the costs associated with a sole-source nuclear supplier are determined to be excessive or untenable. This means that it is imperative that a nuclear capital project develop a robust CGD capability to upgrade commercially purchased items for use in safety-related systems. The SWPF project has enjoyed great success with the CGD activities by having this program lead by the Nuclear Safety group. This has facilitated accurate and effective identification of Critical Characteristics for Acceptance that adequately support the equipment’s safety function. Two key aspects of a successful CGD program are the establishment of a viable and defensible statistical sampling program and good integration with the Procurement group to ensure that equipment purchase orders with commercial suppliers whose equipment will undergo CGD include the requisite submittal documents to support successful execution of the CGD process.

Firm Fixed Price (FFP) contracts with equipment suppliers are good and prudent contract vehicles. However, they have limitations and risks that must be understood to avoid major project impacts. First, it is important to note that almost no suppliers fully understand the nuclear quality requirements that are being flowed down to them. Second, most suppliers are extremely proficient at administering change orders to their advantage. Finally, most suppliers cannot absorb the true liability costs of a failed nuclear contract and there is always the risk that a supplier will either default or declare bankruptcy if an equipment order undergoes a significant cost overrun. Based on these factors, FFP contracts for nuclear equipment will require comparable oversight to a cost-plus contract and a lot of patience and forbearance on the part of the EPCC contractor to ensure that the FFP subcontracts do not fail. It is important to remember that the first priority is receiving quality equipment on schedule. Over reliance on the assumed cost protections of a FFP subcontract should be avoided as this can introduce extremely large project risks.

It is also important to pay close attention to proper subcontract administration details. Be sure to include relevant subcontract clauses and ensure that your subcontracts actually incentivize your priorities. In the administration of on-going subcontracts, make sure that proper schedule of values payments are established and don't get upside down relative to those payments.

Construction

Construction execution is critically important to the success of a complex nuclear capital project. The importance of setting the correct relationship with the craft workforce from the beginning cannot be over emphasized whether the project is being run with open-shop or union labor. The SWPF project employs union labor and the establishment of a sound and fair Project Labor Agreement is an important foundation for the Construction effort and needs to be developed by experienced Construction personnel.

One of the most important lessons learned that the SWPF project has to share is our Constructability Review Team program. At SWPF, this program was implemented by a standing group that operated continuously throughout the Design and Construction phases and not by a discrete set of external reviews. During the Design phase, a cadre of Construction personnel was brought on-board to review each of the design documents as they were produced from a Constructability perspective and provided comments that significantly improved the design in this area. As the Construction phase commenced, a standing Constructability team comprised of an equal number of Engineering and Construction personnel was established whose role was to continuously review the design documents relevant to the next several months of scheduled Construction work to plan the work execution and identify any potential design changes that could make the Construction work proceed more efficiently. This effort identified innovative approaches and paid great dividends by significantly improving both Construction efficiency and avoiding rework.

Some of the key innovations that emerged from the Constructability Review Team included the establishment of “smart” weld lots that minimized exposure to progressive sampling rework, embedded “drop lines” above construction openings in concrete walls that allowed the closure pours to come from above with greater that ten feet of head as opposed to “birds mouth” arrangements that are more prone to residual voids, and wire mesh covering for rebar that improved both safety and productivity by making a more navigable surface for craft personnel during basemat and deck concrete preparatory activities.

QA

QA requirements for the nuclear industry are more rigorous than for any other industry. To meet these exacting requirements, quality needs to be an ingrained part of the project culture in all of the line management organizations. As has been quoted many times, quality cannot be inspected in, it needs to be built in. The project management culture needs to be continuously vigilant about reinforcing their expectations that quality is an absolute prerequisite to all work that is done on the project and that everyone is responsible for ensuring that their work is performed to the best of their ability at all times.

It is imperative that a constructive quality culture is established for the project and that everyone understands that the achievement of quality means that the facility will safely meet its functional needs. Compliance with design requirements is the path that must be taken to achieve quality and defined processes must be established for adjudicating instances of non-compliances; some of which are more important than others. As was stated previously, non-conformances are inevitable on a complex nuclear capital project and the successful projects understand how to effectively and efficiently resolve non-conformances in a defensible yet pragmatic manner.

The QA group serves an essential function in establishing an administering the QA program and defining and defending a graded approach. Engineering, Procurement, and Construction execute the project in accordance with the established QA program. It is important for the line management and QA groups to establish clear and common QA expectations up front that are firm but fair and to hold each other accountable for performing to those expectations. The QA oversight should remain pragmatic and not dogmatic and refrain from “majoring in the minor.” When the Engineering group appeals to design margins to resolve an issue, the QA groups needs to respect those appeals. Similarly, the line management groups need to respect the QA group’s independence and adopt a firm commitment to meeting or exceeding the established QA requirements established for the project. Developing and maintaining a positive and constructive relationship between the line management groups and the QA group is extremely important and requires constant vigilance and effort. However, this is an investment of management time that is extremely important. A sustained constructive relationship between line management groups and the QA groups rooted in mutual respect and fed by the common goal of project success is an invaluable, if intangible, asset.

A successful approach used on SWPF relative to QA was to involve the QA group with the Engineering group early in the development of the inspection program (e.g. Inspection and Test Plans, CGD Plans, and Receipt Inspection Criteria Plans). This drives a partnered approach to quality control and ensures that measurement and test equipment are viable for the inspections established and that they are aligned with relevant tolerances.

It should come as no surprise that the volume of QA records on a complex nuclear capital project is immense. It is important that these records be completed and closed as near to real-time with the completion of work as possible. Successful projects should invest in real-time QA document closure and avoid the development of a bow wave of documents to be closed at the end of the project when key personnel have moved on and the effort to resolve potential issues will have amplified exponentially.

CONCLUSION

The SWPF project provides the keystone for a DOE clean-up effort that is poised for success at SRS. The DOE-Savannah River Office has established a sound and integrated clean-up strategy. The LRW operations contractor has demonstrated the capability to clean and close tanks, prepare and make glass at high capacity, and safely prepare and transfer waste feeds. The South Carolina Department of Health and Environmental Control has established a reasonable and predictable regulatory framework for executing cleanup work and Parsons is ready to deliver the technically-mature and high-capacity SWPF project on schedule and within cost.

Success is possible on complex DOE nuclear capital projects. It takes great leadership and talented personnel as the foundation. Acquisition strategies need to be well considered and planned with realism. These acquisition plans need to be executed effectively and with discipline. The design efforts need to be organized in an integrated manner and executed with conservatism and margin. Procurements need to be carefully planned and administered with a clear purpose. Construction needs to be executed with vision and foresight. QA needs to conduct their inspections with principle and perspective. If these noble objectives are properly implemented with commitment, then a complex nuclear capital project will succeed together as a team.