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GE Power Systems

Installation and Outage Management Processes and Technologies

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Installation and Outage Management Processes and Technologies

Introduction

Availability is critical to an equipment owner. When equipment is not operable, revenue generation capability is reduced. Whether an owner is installing new units or performing maintenance on its existing fleet, rigorous project management is key. Most owners will quantify the quality of an installation or outage by a few critical factors:

- On-time completion
- Equipment performance
- Quality of workmanship
- Completion within budget

With over 11,000 units installed worldwide, GE has developed standard processes for the planning and execution of installations and outages, continually building on experience. This paper discusses these procedures.

Installation Planning and Management

An efficient and high quality installation requires Management, Supervision, and Technical Direction to supplement the materials purchased. General Electric International, Inc. (GEII) provides a full range of services beginning with the simplest form, *Technical Direction of Installation;* continuing with complete turnkey solutions, *Centerline Installation Services;* and culminating in plant *Performance Testing Services.* While technical direction is the most common activity, both performance testing and turnkey centerline installations are increasing.

Technical Direction of Installation for the turbine equipment is an active, on-site service provided by GEII. It provides engineering and technical guidance, advice, and counsel to the customers and their agents, with the objective to provide a technically-correct, high-quality, safe installation. Work that is supervised, managed, and performed by others is audited, observed, evaluated, and reported with comparisons being made to applicable and up-to-date GE specifications, instructions, drawings, recommendations, practices, procedures, and techniques.

The balance of this section will be arranged in a sequential timeline of key events and processes (refer to *Figure 1*). Included is a review of the processes and information transmittal recommendations to help in planning any upcoming installations.

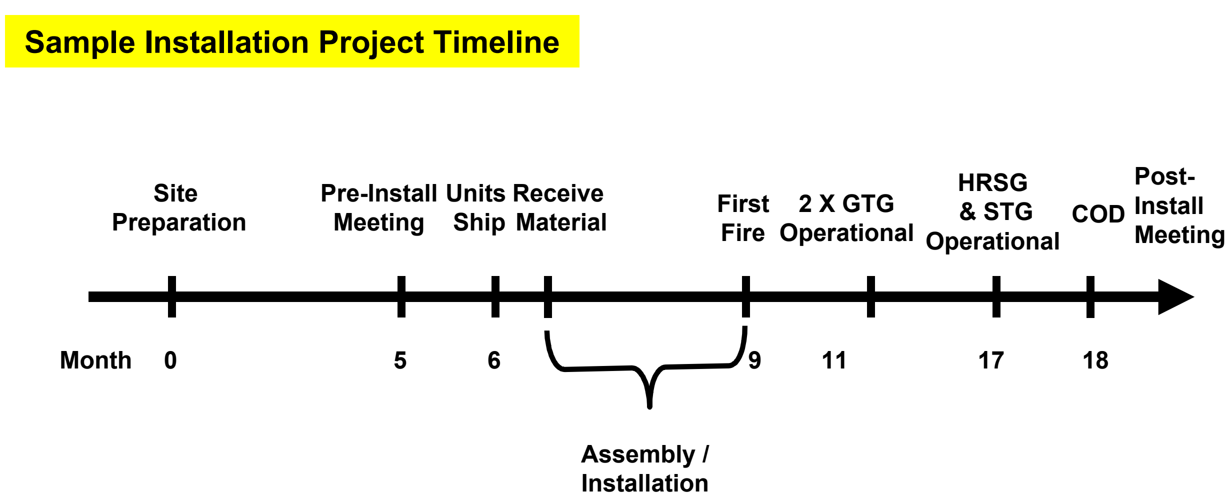

Figure 1. Installation project timeline

Pre-Installation Meeting

A pre-installation meeting is normally held before shipment of the major alignment components.

Pre-installation meetings are held for the purpose of bringing together those people who will be responsible for the successful installation of the GE turbine equipment.

The objectives are fourfold:

1. To discuss the information described in the installation plan.
2. To establish a mutual understanding of commitments.
3. To describe the General Electric International, Inc. installation support activities
4. To establish a channel of communication during the installation period.

Installation Processes

The following activities must be considered and planned as part of a successful installation and start-up:

- Unloading of material
- Material movement, such as skidding and cribbing of heavy components
- Examination of material for loss or damage
- Inspection of site storage and warehousing facilities
- Maintenance of adequate storage records
- Installation coordination
- Coordination and administration of the procurement of tools and equipment
- Inspection of foundation and setting of foundation plates
- Installation, inspection, and assembly of the turbines and associated equipment
- Inspection of assembly, clearances, alignment and cleanliness
- Fluid and auxiliary systems flushing and cleaning operations
- Commissioning coordination
- Equipment start-up and initial operation responsibilities
- Equipment placed into service
- Post-installation meeting

Material Control

Recent data collected on global installation sites indicates that 10.8% of all installer delays may be linked to material receiving, storage and control processes. The importance of creating proper facilities and procedures for receiving, cataloguing, and storing material at the job site cannot be overemphasized. We recommend the following procedures for handling the material after it is received. It has been demonstrated that installation efficiency can be maximized when material is readily available at the required time. While identification and accessibility are major factors, the need for quickly replacing damaged or missing material is probably more significant in maintaining a sensible work plan. We strongly recommend that the methods outlined in this section be given careful consideration to ensure prompt replacements or repairs when required.

Arrival and Inspection

All material and equipment should be inspected upon arrival at the carrier's final delivery point. This inspection should include but not be limited to the following:

1. Inspect the protective covering and packing for obvious damage in transit.
2. Inspect the "HUMP METERS" and blocking of components on the transport vehicle for shifting during shipment.
3. Check the orientation of any components related to gas turbine foundation where special orientation had been requested.
4. Check the condition of all equipment and material when received, and inventory it.
5. Review the carrier's documentation before accepting the delivery for the following:
   - Material Safety Data Sheets (MSDS) for HAZARDOUS material.
   - A packing list of the equipment being delivered.

Carload shipments should be promptly unloaded to avoid demurrage charges and arranged in an accessible and convenient manner for further inspection and handling.

Inventory Control

The importance of a system for proper inventory control cannot be overemphasized if an effective and efficient installation is to be accomplished.

The process of receiving material shipped directly from GE suppliers includes the following steps:

Once the proper information is received, GE issues a Notification of Shipping Release (NSR) to the supplier. A copy of this notification is faxed to your material representative. The NSR contains the following information:

- Weights and dimensions
- Package type (case, skid, crate, box)
- Vendor
- Case number

Case Number

The case number is very important. It identifies the material with the following information. The first digit is the unit number designated for this material. The next four alphanumeric characters identify the MLI or model list item number. The last two digits are assigned sequentially for the particular MLI, starting with 01. For example, the first case (or crate or skid) for the Inlet Duct Arrangement, A041, will be assigned case number 1A04101. If there were 16 "cases" for this shipment, the last case would be 1A04116.

When the material is received, the bill of lading should include the case number(s). However, it should be checked against the actual case numbers to make sure the material was delivered as intended. Each case should have a packing list, both outside and inside the box.

A running tally of the cases received against the Notification of Shipping Release (NSR) should be kept. We suggest using a site map using the case numbers to identify the locations of the various boxes. Generally, all the crates for single items should be received within three weeks after the NSR is issued.

Material Shortages

As materials are received, shortages may appear. In a broad sense "shortages" are defined as any part needed but not available at the job site. Shortages fall into one of four categories:

1. Material known to be shipped but not received at the job site.
2. Material not known to be shipped but known to be needed.

3. Material received in insufficient quantity.
4. Material received but damaged in shipment or on site, or lost on site.

Material Shortage Report

The Technical Director will issue a Material Shortage Report in all cases where:

1. An insufficient quantity of materials is received at the site.
2. Needed materials are not received and are not known to be shipped.
3. Materials are known to be shipped but are not received.

A Material Shortage Report, indicating the required information and reason for the shortage, will serve as an order for the required materials and initiate shipment of the part(s) to the job site.

Installation Coordination

Technical Direction Role

The size and complexity of many turbines prohibits full assembly and testing in the factory. To ensure that the equipment is properly installed, aligned, and checked out before operation, GEII provides Technical Direction during installation. This service is essential for a proper interpretation of the design criteria, as expressed in the drawings and instruction books during installation and start-up.

Installation Change Control

Equipment changes are sometimes required in the field for a number of reasons. Additionally, GEII continuously evaluates installation methods. As new and better methods are developed, they will be provided. The formal transmittal of these changes is made through the use of Engineering Change Notices (ECNs) or Technical Information Letters (TILs).

1. ECNs are limited to the description of equipment changes. The principal purpose of ECNs is to leverage corrective actions that were discovered in the field on similar units, and implement the corrective action before the same issue is realized. The ECN will list the drawings affected, parts required, and the disposition of the affected equipment.
2. TILs are used when a generic-type of change is involved, especially when a large distribution is required. TILs are also used as a means to transmit installation recommendations in various areas where drawing changes are not involved.

For gas turbine installations, the site Technical Direction team will conduct three periodic conference calls with the Product Service and Engineering teams. These calls occur three months prior to first fire, one month prior to first fire, and one week prior to first fire. The intent of this call series is to ensure that the site team has received and implemented all TILs and ECNs applicable to your particular unit and that the team has access to the latest and most current system documentation.

Procedural Documentation

GEII uses several other methods of providing installation directions to the job site. Many publications with identifying series numbers such as GEI-86151 (Low Voltage Power Circuit Breaker) and GEK-39672 (Switchgear) are issued by cognizant engineering functions. Most of these publications are included in the instruction books that are distributed at the time the unit ships. There are a few that are not directly related to specific equipment and are not included in the instruction book. These are distributed by the local GEII office when they are applicable to the installation.

Installation Schedule

A basic requirement for a successful installation plan is the installation schedule. This schedule can take various forms from a bar chart to a complex logic network programmed with provisions for resource allocations. The bar chart allows you to list your work activities in sequential order, plan your job duration, determine your labor and material requirements, and track the job. The logic network, when properly programmed, allows all of the above plus critical-path planning, periodic job tracking with compensation for manpower and material deficiencies, and job-cost tracking. The installation schedule that you use on the turbine installation should be designed to meet your needs and provide the optimum installation cycle.

While responsibility for schedule creation, maintenance, and adherence remain with the installer, it is critical that the installer and GEII Technical Direction team review the schedule tasks in concert, to ensure that all work tasks are provided for and to fully leverage the past experiences of both parties.

Certain interfaces between the turbines and other equipment on-site will take place during the installation. Prior to interface activities, depending on the operation involved, a meeting should be held to discuss dates, problems, specifications, and any special requirements that may be involved.

Progress Meetings

Periodic reviews of the installation and commissioning activities are of major importance if the commercial operating date is to be achieved.

As Built Construction Prints

The Construction Print List contains all the primary and secondary drawings, process instructions, applicable parts lists, and a few detailed machine drawings. These prints, which represent the "as built" condition of the gas turbines, are provided to the technical director to assist him in his consulting capacity. Any drawings in the sets that are changed during the installation period are replaced with the updated drawing. When the installation is complete, the Technical Director will provide the customer with a set of the construction prints less the parts lists (PLs) and machine drawings. This set will describe the "as built" condition of the gas turbine.

Special Tools

GE will supply a variety of special tools for the gas turbines and generators that are not normally furnished by the installation contractor. A list of special tools provided by GE is included with the construction print list under "Tool List" or "Installation Device." The special tools shown on these lists are part of the turbine and generator packages and are turned over and documented at the completion of the turbine installation. It is important that these devices be carefully stored and protected for future maintenance on the machine.

Post-Installation Meeting

In addition to the pre-installation meeting, additional job-site meetings will be scheduled on an as needed basis. The last meeting that GEII will schedule as part of turbine installation is the post-installation meeting. The post-installation meeting is the formal conclusion of all installation activities and includes the presentation and review of installation data, tools, and construction prints. The post-installation meeting is normally held one month after the commercial operating date.

Maintenance Management

Turbine maintenance has been viewed traditionally as an activity that takes place at standard intervals during a scheduled outage. That view is changing. While turbine maintenance often takes place according to established plant schedules (for example, during a nuclear refueling) the approach has evolved to one of managing *Asset Performance.* Equipment owners are evaluating their overall fleet and analyzing the most effective way to maximize the revenue generated. This could include extending intervals between maintenance cycles, or it could mean taking an outage earlier than usual in order to install a performance enhancement package. The increasingly macro view of turbine equipment compels a need for even more rigorous planning and analysis. In the past, Owners and Service Providers considered the planning for maintenance as an activity that began about 6 months to a year in advance of an outage. It would begin with an Advanced Review Meeting and end with a Post-Outage Review Meeting, where the final inspection report and future recommendations would be reviewed. Some actions were taken, but often the report would not be filed until the next planning cycle.

Asset Performance requires looking at post-outage reports and evaluating the plan for the equipment at the time of the post-outage meeting. Evaluation of equipment performance and long-term maintenance planning is therefore a continual process beginning at the end of one outage (refer to *Figure 2*). Alternatives for improving performance, whether in output, efficiency, emissions, reliability, or availability often require more time to evaluate, procure, and implement than the 6-month to 1-year window allows. Many companies have budgeting cycles that make it difficult to support a major maintenance or capital expenditure not identified well in advance. Thus it becomes critical to view this planning as a continuous process, rather than a discrete event.

Maintenance Planning

A maintenance plan is a continuous process of review, recommendation, and implementation. Service providers can develop a pro-active plan with the customer to support the inspection and repair of the equipment involved. It is critical that a plan tailored to the specific outage

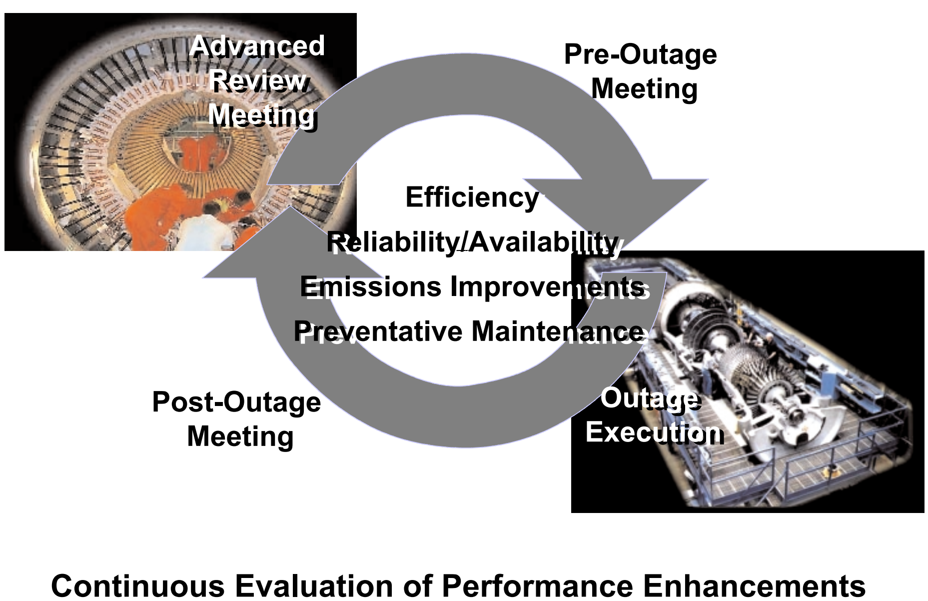

Figure 2. Outage management cycle

scope is developed so that participants understand their responsibilities and the impact that outage planning has on its successful completion. This plan must include all work activities, as well as the schedule, parts lists, tooling and equipment requirements, and repair services expected. Service providers can assist in developing recommendations for parts, and can track and expedite as needed. Additionally, they can review repair requirements and can assist in planning the workscope with the selected repair facility. It is key to the outage schedule that all repairs are coordinated. Utilizing a *Three Meeting Concept* is an effective process to use for developing maintenance plans. The purpose of each meeting is described below.

Post-Outage Review Meeting

This meeting is the end point of one outage and the start point for the next. It is held following the completion of an outage. Its purpose is to review the outage report, performance, and findings, as well as to identify problems, determine best practices, and discuss recommendations. A performance review, for which criteria should be established at the pre-outage meeting, should take place. In addition, parts recommendations can be made and a preliminary plan for the next scheduled outage can be outlined. The final outage report should include:

- Job summary
- Inspection summary
- Recommendations
- Parts used and recommended
- TIL/ECN activity
- Combustion section data
- Compressor section data (if applicable)
- Turbine section data (if applicable)
- Lube oil system inspection (if applicable)
- Coupling inspection (if applicable)
- Enclosures (if applicable)
- Alignment and clearance overview (if applicable)
- Start Up comments

Advanced Review Meeting

The current condition of the equipment is reviewed to determine recommendations for operational and outage planning. Parts, material, technical and procedural issues are addressed to ensure that actions are implemented as required to support the scheduled maintenance program. These meetings are held 6-to-8 months in advance of all scheduled outages. The following activities take place at this session.

- Review previous inspection report
- Review unit history since last inspection and identify additional work scope
  - This includes operational trending data
  - Forced outage occurrences
  - Operational issues, which require maintenance activity at a scheduled inspection (such as lube oil leaks, faulty instrumentation, etc.)
  - Specific fleet issues, which may affect reliability of the unit
- Review parts inventory for unit
- Review all parts orders and associated delivery dates
- Review TIL list for unit for additional workscope and parts requirements
- Review status of parts being refurbished

- Review completion / ship dates
- Review inspection reports / findings
- Review changes in safety regulations, which require implementation during the next inspection

Managing Outage Duration

Many factors affect the length of an outage. Two of them are a well-defined workscope and the appropriate combination of skilled people. Workscope and responsibilities of all parties are discussed during the pre-outage meeting. Access to skilled engineers and technicians should be considered when scheduling the work. As the U.S. industry moves from performing maintenance in spring or fall to having outages primarily in the spring (refer to *Figure 3*), one must consider the impact on the availability of trained craft labor, technicians, and specialists. With more operations moving toward outsourcing versus in-house maintenance crews, this concern is magnified.

To effectively manage the outage and minimize the impact of the unexpected, it is important to consider several elements.

Critical Path Management - Any given outage is likely to have unexpected work that can impact the schedule. Data shows that 39% of outage delays are due to emergent or unplanned work. GEII approaches Critical Path Management with standard processes developed through years of project experience, coupled with the use of custom-designed software developed specifically for this application. The software enables the incorporation of emergent work into the schedule. Resource loading can be evaluated and shifted as required. Incoming parts, repairs, and other work, which can affect the timeliness of task completion, are tracked with alternatives developed in advance to the furthest extent possible. The project baseline schedule is developed utilizing task level data, best practices, and lessons learned from past and current outages.

Once the schedule is finalized, the work on critical path is identified. GEII personnel then use a Failure Modes and Effects Analysis (FMEA) to identify the areas of greatest risk and develop contingency plans to mitigate that risk (refer to *Figure 4*). The FMEA is a systematic approach

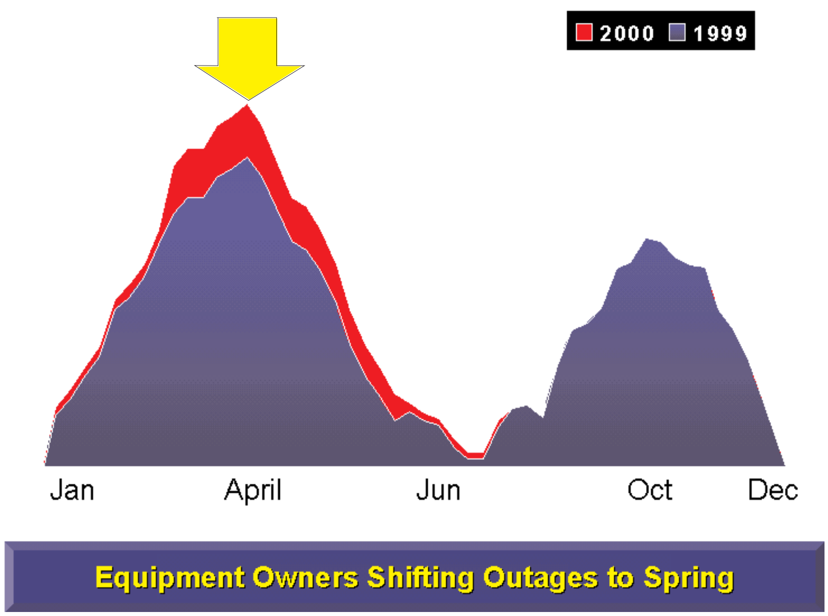

Figure 3. U.S. maintenance shift

that has proven powerful in this application. It involves identifying the manner in which a process could fail to meet requirements, the failure's effect, potential causes of the failure, current controls in place, and recommended actions. By rating the severity, the likelihood of occurrence, and the ability to detect the cause or failure mode, a risk priority number (RPN) can be calculated. This assists the Project Manager to determine which area needs risk mitigation efforts first. Another tool utilized is the Cause and Effect Diagram (also referred to as a Fishbone Diagram). Traditionally used by engineers in Root Cause Analysis, this tool has been leveraged for pro-active applications in contingency planning (refer to *Figure 5*). The Cause and Effect Diagram provides an organized visual method of displaying all possible causes of a problem and is helpful in considering all reasons for occurrence.

Process Step/Part Number	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN
Install Nuts	Galling of Threads	Stuck Nut	8	Dirty Stud	3	Visual Inspection	4	96
			8	Damaged Thread	4	Visual Inspection	7	224
Extensio-meter Measure-ment	Improper Stretch on Stud	Leaky Joint	9	Incorrect Measurement/ Under-Stretched Stud	5	Duplicate Measurement Process	6	270
		Broken Stud	10	Incorrect Measurement/ Over-Stretched Stud	3	Duplicate Measurement Process	6	180

Figure 4. Contingency planning – risk analysis

Information Management – With information technology playing an increasingly larger role in daily activity, it is necessary to consider the communications infrastructure. A dedicated phone line allows the Technical Adviser to interface with experts via computer to obtain faster response to questions, as well as access to drawings and technical documents. This also facilitates ordering and status of emergent work items and communication of the status of off-site work, such as repairs. GEII is also developing on-line collaboration tools that will allow faster exchange of information among outage participants. All of this can make communication more efficient, but it can happen only if the infrastructure to enable it exists.

Summary

Experience shows that the quantity and quality of advanced preparation heavily influence the successful execution of an installation or maintenance outage. GEII will continue to develop better and faster ways to plan and implement equipment service. Through development of new tools, communication and planning will become faster and more flexible.

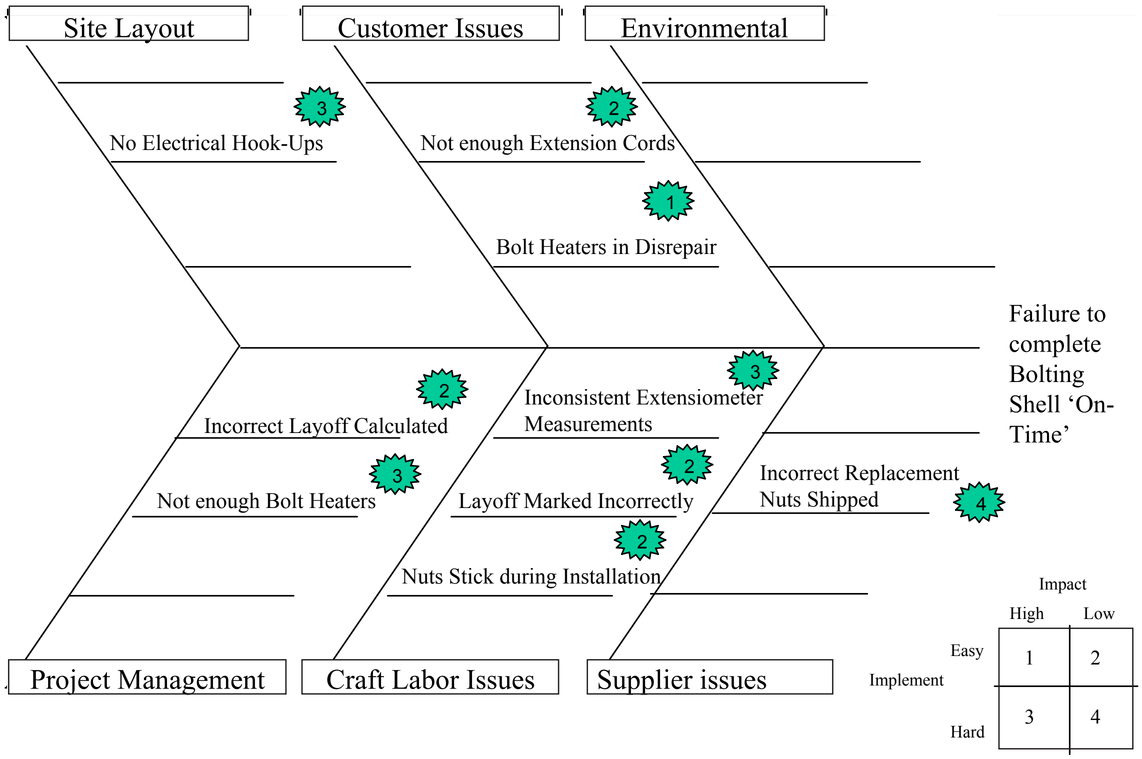

Figure 5. Contingency planning – cause and effect

Ongoing programs in technology will enhance the capability of GEII service personnel to communicate with experts globally, improving both responsiveness time and the quality of work on site. These advances, coupled with the unique skills of Customer/GEII teams, will help set new standards of service well into the future.

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