Relex Case Study: Redesign of a Robot for Improved Reliability

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Introduction

Many product manufacturers realize the need to establish reliability process goals and commit to continual product improvement in order to meet customer, as well as internal, quality goals. Oftentimes, companies committed to reliability improvement turn to Relex Professional Services to aid in their reliability programs. Recently, Relex Professional Services was contracted to help in the reliability improvement objectives of a robot manufacturer. The company designed, developed, and deployed an electromechanical multi-axis robot for use in a retail environment. Once deployed, the company wanted to improve the rates of field failures and repairs. Overall, the company recognized the importance of high reliability in the marketplace and took the steps necessary to ensure their product met their high quality objectives. One of the first decisions made was to work with Relex Professional Services, a team of engineers with a proven track record of achieving reliability improvement objectives.

Although the field data obtained was very limited, the company identified what they believed to be the key subsystems requiring redesign to improve the reliability of the robot. Because reliability issues negatively impact customer confidence in the product, the company's management was looking for quantifiable indicators that the release of a redesigned robot would be able to demonstrate improved reliability. To support their efforts, Relex Professional Services was contracted to:

- Identify and validate the key subsystems affecting product reliability.
- Develop a test plan to prove that the redesigned robot is capable of achieving its targeted reliability.
- Provide guidance for developing a comprehensive reliability framework for future product development.

Through analysis of the available field failure and repair data, Relex Professional Services was able to:

- Validate that the correct subsystems for redesign had been identified.
- Identify additional potential reliability issues.
- Provide a test plan to demonstrate that the redesigned robot would be capable of achieving the required MTBF.
- Establish a framework for a comprehensive reliability program that would allow the company to incorporate reliability tools throughout the entire product life cycle.

Data Collection

The first step in the process was to gather as much pertinent data as possible. Because the team recognized that the hard data collected over the product life could be augmented with experiential data from those involved with the product, it was necessary to collect soft data to supplement the investigation. This soft data was collected through one-on-one interviews with key personnel who could identify crucial reliability issues. The inclusion of the soft data helped

to identify potential root causes that could not be identified from the hard data alone. For example, the tools used to calibrate and teach the robot were identified as potential sources of variance that could cause reliability problems. Based on this finding, Relex Professional Services was able to recommend that a Gage R&R study be performed on the calibration and teaching tools to determine whether they were able to perform the required functions and whether technicians could use them effectively. The results of this study would determine whether the tools needed to be redesigned or if technicians needed to be better trained in how to use them.

Data Analysis and Calculations

In analyzing all the data collected, Relex Professional Services confirmed that the key subsystems requiring redesign had been identified. Relex Professional Services then performed Weibull analyses on the data for these subsystems at the system level. The results of these calculations are shown in Tables 1, 2, and 3. The analyses allowed for the calculation of the achieved MTBF of the subassemblies and the system. Additionally, Relex Professional Services recommended that the company revisit the design of one of the key robot components to conform to industry best practices.

Parameter	Value
Best Fit Distribution	Gumbel- [t0 = None … 2 parameter]
ξ	174.235
δ	42.728
Estimation Method	Bernard (rr)

Table 1. Subsystem A

$MTBF_{SA1} = \xi - 0.577\ \delta = 149.581$ days

Parameter	Value
Best Fit Distribution	Weibull [t0 = None ... 2 parameter]
β	1.023
η	108.72
Estimation Method	Bernard (rr)

Table 2. Subsystem B

$MTBF_{SA2} \approx \acute{\eta} = 108.72$ days

Parameter	Value
Best Fit Distribution	Weibull [t0 = None ... 2 parameter]
β	1.361
η	48.62
Estimation Method	Bernard (rr)

Table 3. System

$MTBF_{SYSTEM} \approx \acute{\eta} = 48.62$ days

Allocations

Once the key subsystems requiring redesign had been identified, it was necessary to determine the required level of improvement needed for each subsystem to achieve the target MTBF for the system. To identify subsystem reliability goals, Relex used the ARINC Allocations method. This method reduces subsystem failure rates by equal percentages such that the failure rate goal for the system is achieved. For the robot to achieve the required MTBF at the system level, each subassembly must achieve its target MTBF value shown in Table 4.

Subassembly	Achieved MTBF (cycles)	Target MTBF (cycles)
Subsystem A	66478	120,000
Subsystem B	48318	90,000

Table 4. Achieved and Target MTBFs

Test Coverage Analysis

Once the decision to target the product for reliability improvement was made, the company immediately began testing a robot that had just come off the production line. This robot operated for more than 30,000 cycles without experiencing any of the failures previously seen in the field. Because the robots in the field had experienced failures before reaching 30,000 cycles, it was concluded that the testing conditions must not be representative of the field conditions, indicating that the test coverage was inadequate.

To analyze the client's test coverage, flow charts were created for the processes followed by both the test robot and a robot in the field. These two flow charts were compared, and all differences were identified. The key differences were in the processes of crating the robot, transporting the robot to the installation site, de-crating the robot, and installing the robot. Based on these findings, Relex Professional Services recommended that the following actions be included in the test coverage:

- Crate the robot at the test facility per the process used by manufacturing personnel.
- Perform transportation/packaging testing per MIL-STD 810 or some other certified methodology.
- De-crate and install the robot at the test facility by installation personnel with knowledge no greater than that likely to be found in the field.

Test Planning

After determining the MTBF targets for the subsystem level, it was necessary to determine what testing was required at the subsystem and system level to demonstrate that the robot was capable of achieving the target reliability. The criteria used for test planning calculations were Target MTBF, Weibull analysis parameters from data analysis, the number of test units, confidence level, and the number of allowed failures.

The system level target MTBF was supplied by the client, and the subassembly target MTBF values were calculated using allocations. Weibull analysis parameters were calculated during the analysis of the field data. The client indicated that the maximum number of available test units for both the subassembly testing and system testing was four. The company also requested that the test planning be performed with confidence levels of 95% and 90%.

Because of the tight development and testing timeline, zero failures were allowed. This resulted in the shortest testing time. Based on these criteria, the reliability demonstration test planning established the required number of test cycles to run to achieve the target MTBF for the system and subassemblies. Tables 5, 6, and 7 summarize the calculation results.

Confidence	95%	90%
Test Units	4	4
Required Cycles– each unit	44,154	36,931
Failures Allowed	0	0

Table 5. System Level Test Requirements

Confidence	95%	90%
Test Units	4	4
Required Cycles – each unit	120,012	120,001
Failures Allowed	0	0

Table 6. Subsystem A Test Requirements

Confidence	95%	90%
Test Units	4	4
Required Cycles– each unit	79,477	65,504
Failures Allowed	0	0

Table 7. Subsystem B Test Requirements

Reliability Program

Data analysis and test planning are only a small part of a reliability program. Considering the stage of development for this client's product, these were the most appropriate steps to implement. In addition to these immediate steps, Relex Professional Services recommended a comprehensive reliability program for future product life cycles. These recommendations included:

- Performing Failure Mode and Effects Analysis
- Creating process flowcharts
- Performing structured Root Cause Analysis (such as fault tree analysis)
- Using statistical process control techniques (such as Gage R&R)
- Analyzing test coverage
- Establishing test plans
- Performing Accelerated Life Testing (both quantitative and qualitative)
- Implementing a FRACAS (Failure Reporting, Analysis, and Corrective Action System) process

Conclusion

Although the initial launch of the robot did not achieve company reliability goals, it provided a foundation on which to build a more successful re-launch. By having field data from which to learn and identify weaknesses in the product, the design group has a clear understanding of what areas need to be addressed. By incorporating this knowledge with a reliability program that is structured to develop the most reliable product possible, the company has the framework in place to introduce a robot that does not merely meet but actually exceeds their customers' expectations.

Relex Consulting Services offers service and support in four main areas: reliability consulting, implementation, training, and customer service. In each area, the group is staffed by reliability experts. Each project is supervised by

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