Industrial Plant Equipment Maintenance Strategy

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Abstract — *At Robins Air Force Base, specifically in the engineering equipment maintenance department, a problem has been identified in the management of labor. Equipment / machineries used in the production area suffer from high amounts of downtime and poor reliability when manufacturing parts for the aircraft fleet. Most of the equipment / processes show to be automated and have complex systems, which require specific skills on the part of the employees to be able to provide support to these equipment / processes. The results show a deficiency on the part of the skills technicians targeting automated systems. Similarly, it is shown that the current structure in which the workshops are organized (electricians' workshop, electronics technicians' workshop, mechanics workshop, etc.) is not the most efficient. This project seeks to improve the structure in which the workshops are currently organized in order to improve the availability and reliability of the equipment / processes in the production area. The analysis shows that multi-skill team building would be the most efficient maintenance strategy.*

Key Terms — *Availability and Reliability Maintenance, Maintenance Strategies Management, Process Improvement*

INTRODUCTION

Reliability Centered Maintenance (RCM) is a maintenance strategy applied in most industries today. This strategy wants to optimize the maintenance program of any production or manufacturing. By implementing a specific maintenance strategy on the assets in the production lines, the RCM improves their performance. [1].

At Robins Air Force Base in Warner Robins Georgia, the Department of Maintenance Support has as its primary task ensure the efficiency, availability and reliability of the equipment or machines used in production by performing Reliability-Based Maintenance strategies. One of the problems identified is the man-power allocation system for the work orders submitted by the production department, causing low reliability and availability in production processes/equipment.

The objective for this project is to determine the most applicable and cost-effective Industrial Plant Equipment (IPE) maintenance strategy for labor shops in order to improve production support. This will be achieved by performing an in-depth analysis of equipment type/classification and current maintenance performance history. Based on this analysis, a comprehensive maintenance approach will be determined with the following strategies (explorative) in mind:

- Multi-skilled maintenance teams by asset/system type (CNC, Robotics, etc.)
- Shops division labors (not multi-skilled) that can be assigned to any maintenance request (currently structured).
- A hybrid approach with combination of the above.
- Operator/maintenance position blended (more ownership & familiarity)

Based on the analysis and procedure performed on the following section, it will be demonstrated that the use of multi-skilled employee groups, the creation of autonomous work teams and the use of probabilities to demonstrate their efficiency have proven to be the most effective strategies.

LECTURE REVIEW

Over the years, the manufacturing and process industries have changed their perspective on the role that maintenance departments play. And, along with this change, the strategies and structures of the existing maintenance departments have also been updated according to the needs and goals of management.

In the same way, maintenance personnel play an important role in changes in technology used in the industry, which has led to studies on the management of skills in personnel and job assignments. These studies have concluded by emphasizing the need to evaluate current structures and improve them to obtain better results [2].

Another reason for carrying out analyzes and improvements in the management structures of maintenance strategies is the result of technological equipment and complex machinery. This has led to studies which demonstrate the lack of skills in the workforce and the need to prioritize processes and machinery to achieve a more efficient work. [3]. The traditional organizational structure in the workforce must be restructured, so that personnel are able to perform an efficient job in a short period of time. Studies in this area have shown very relevant data in work environments similar to where the project will be developed.

The use of multi-skill employees, the creation of autonomous work teams and the use of probabilities to demonstrate their efficiency have been subjects of study for professionals in the field, which have demonstrated evidence of their results and their effectiveness. [4] - [6].

ANALYSIS APPROACH

This section was performed on the following sequence. First, equipment type / classification analysis where the computerized platform of the maintenance department is used to extract the data and information of the equipment according to the type and its classification. Secondly, the IPE (Industrial Plant Equipment) priority calcification This maintenance department provides support to more than 2,400 assets, for which the number was reduced based on the priority of the production processes. The highest priority processes turned out to be the following:

- Propeller Shop (Aircraft C-130)
- Heat Treatment Process
- CNC (Computer Numerical Control) & Sheet Metal Process
- Robotic Process (Blasting and Painting)

Tables 1 to 5 show the teams classified by process and priority.

Table 1
C-130 Propeller Shop Assets

Asset ID	Description	Status	Priority
WR002562	TEST STAND, PROPELLER	OPERATING	5
WR002563	TEST STAND, PROPELLER	OPERATING	5
WR002564	TEST STAND, PROPELLER	OPERATING	5
WR003204	ROBOT, PROPELLER SHOT PEEN	OPERATING	5
WR005769	ROBOTIC FPS, PROPELLER	OPERATING	5
WR005082	TEST STAND, PROPELLER	OPERATING	4
WR000037	TEST STAND, PROPELLER	OPERATING	4
WR000038	TEST STAND, PROPELLER	OPERATING	4
WR000039	TEST STAND, PROPELLER	OPERATING	4

Table 2
Heat Treatment Process Assets

Asset ID	Description	Status	Priority
WR004215	OVEN #17, 2D, HEAT TREATING, 351 CUFT	OPERATING	5
WR003748	OVEN #5, 1D, HEAT TREATING, 50 CF	OPERATING	4
WR003856	GENERATOR, GAS	OPERATING	4
WR003857	GENERATOR, GAS	OPERATING	4
WR004938	OVEN #16, 2D, HEAT TREATING, 160 CUFT	OPERATING	4
WR003854	OVEN #11, 1D, HEAT TREATING, 54 CF	OPERATING	4
WR003855	OVEN #3, 1D, HEAT TREATING, 54 CF	OPERATING	4
WR004895	OVEN #7, 2D, HEAT TREATING, 394 CUFT	OPERATING	4

Table 3
CNC Process Assets

Asset ID	Description	Status	Priority
WR003325	CNC, MAKINO, HORIZONTAL, 5 AXIS, MAG3	OPERATING	5
WR005767	CNC, MAKINO, HORIZONTAL, 5 AXIS, MAG3.EX	OPERATING	5
WR005461	CNC, MAKINO, HORIZONTAL, 5 AXIS T1 #1	OPERATING	5
WR005462	CNC, MAKINO, HORIZONTAL, 5 AXIS, T1 #2	OPERATING	5
WR005463	CNC, MAKINO, HORIZONTAL, 5 AXIS, T4 #1	OPERATING	5
WR005464	CNC, MAKINO, HORIZONTAL, 5 AXIS, T4 #2	OPERATING	5
WR005448	MAKINO, ELECTRICAL DISCHARGE (EDM), U6	OPERATING	5
WR002669	CNC, GRINDER, CYLINDRICAL	OPERATING	5

Table 4
Sheet Metal Process Assets

Asset ID	Description	Status	Priority
WR000700	PRESS, QUINTUS, FLUID CELL, PRATT	OPERATING	5
WR002532	CNC, PRESS, STRETCH WRAP	OPERATING	5
WR003179	WATER JET, 3 AXIS	OPERATING	5
WR003257	WATER JET, 3 AXIS	OPERATING	5
WR005734	PRESS, FLUID CELL, QUINTUS	OPERATING	5
WR003008	CNC, PRESS, SHEET STRETCH, 250 TON	OPERATING	5
WR003296	SHEAR, HYDRAULIC SQUARE	OPERATING	5
WR004330	BRAKE, SHEET METAL	OPERATING	5

Table 5
Robotic (Blasting and Painting) Process Assets

Asset ID	Description	Status	Priority
WR002804	BLAST SYSTEM, PLASTIC MEDIA	OPERATING	5
WR005739	ROBOT, PAINT BOOTH	OPERATING	5
WR003252	ROBOT, WATER BLAST CABINET	OPERATING	5
WR003205	BEAD BLASTER, GRIT, ROBOT, PROPELLER	OPERATING	4
WR005790	ROBOT, PAINT REMOVAL SYSTEM	OPERATING	4
WR005394	ROBOT, RADOME PAINT	OPERATING	4
WR005666	ROBOT, PAINT BOOTH	OPERATING	4

In order to analyze the performance of the different workshops, the maintenance department has established certain metrics which must be executed. These metrics are availability and reliability.

- Improve availability of critical assets to >95%
- Reliability: Mean Time Between Failure (MTBF) > 30 days

The amount of time that an asset, machine, equipment or system is able to be fully and properly working when it's needed is known as Availability [7]. See Equation (1).

$$Availability = \frac{MTBF}{MTBF - MTTR} \qquad (1)$$

where:

MTBF = Mean Time Between Failure

MTTR = Mean Time To Recovery

Reliability is a measure of the probability that an item will perform its intended function for a specified interval under stated conditions [7]. See Equation (2).

$$Reliability = \frac{Total\ operational\ Time}{Total\ number\ of\ Failures} \qquad (2)$$

RESULTS

Based on Tables 1 to 5, it is clear that most of these assets are automated equipment. This means that, in order to provide support to these assets efficiently, the workforce must be trained or must possess multiple skills to achieve effective and reliable work. It has been proven that when maintenance work is carried out developing multi-skill equipment, the probabilities of transferring errors are much lower than when performing serial work, that is, skills after skill sequentially [4]. Later, more details about this matter will be presented.

Availability and Reliability metrics performance.

Metrics reviled important aspect of maintenance personnel performance and lack of skills and man-power allocation for specific equipment/process. The results of the analysis of these metrics are observed in Figure 1 and Table 6, where it shows those assets that have failed to meet the goals of the maintenance department in the availability results. Assets with availability of less than 95% (Maintenance Department goal is > 95%) are, for the most part, automated equipment that requires knowledge and skills in multiple areas. The assets present in Table 6 are of priority 5, which indicates that they are high-use machinery and that they are required to be in optimal conditions to avoid loss of time in production.

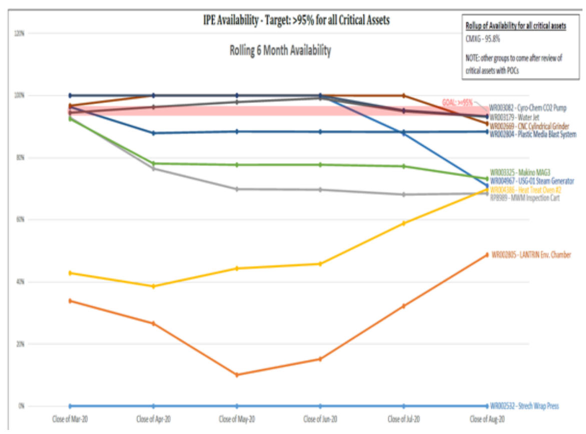

Figure 1
6-month IPE Availability (Target: Availability > 95%)

Table 6
6-month IPE Availability Assets (Less than 95%)

Asset ID	Description	Pri.
WR002532	CNC, PRESS, STRETCH WRAP	5
WR002805	CHAMBER, ENVIRON, LANTIRN	5
RP8989	INSP CART, MWM	5
WR004386	OVEN #2, 5D, HEAT TREAT, QUENCH, 25 CF	5
WR004967	GENERATOR, STEAM, USG-01 #1	5
WR003325	CNC, 5 AXIS, HORIZ, MAKINO, MAG3	5
WR002804	BLAST SYS, PLASTIC MEDIA	5
WR002669	CNC, GRINDER, CYLINDRICAL	5
WR003179	WATER JET, 3 AXIS	5
WR003082	PUMP, CYRO-CHEM, CO2	5

Figure 2 and Table 7 show those assets with reliability results less than 30 days. In other words, these priority 5 assets have not been able to be in production for more than 30 days without failure. Like the assets in Figure 1 and Table 6, these are mostly automated equipment.

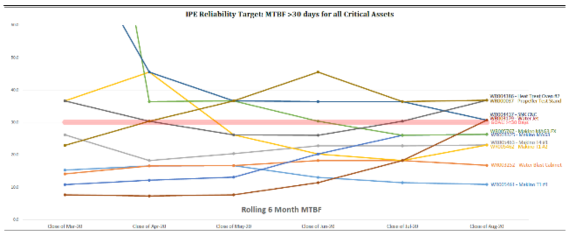

Figure 2
6-month IPE Reliability (Target: MTBF > 30 days)

Table 7
6-month IPE Reliability Assets (Less than 30 days)

Asset ID	Description	Pri.
WR005461	CNC, 5 AXIS, HORIZ, MAKINO, T1 #1	5
WR003252	ROBOT, WATER BLAST CABINET	5
WR005463	CNC, 5 AXIS, HORIZ, MAKINO, T4 #1	5
WR005462	CNC, 5 AXIS, HORIZ, MAKINO, T1 #2	5
WR003325	CNC, 5 AXIS, HORIZ, MAKINO, MAG3	5
WR005767	CNC, 5 AXIS, HORIZ, MAKINO, MAG3 EX	5
WR004434	CNC, SNK	5
WR003179	WATER JET, 3 AXIS	5
WR004386	OVEN #2, 5D, HEAT TREAT, QUENCH, 25 CF	5
WR000037	TEST STAND, PROPELLER	5

Evaluation for the strategies proposes.

Analysis results and performance proof that the most applicable and cost-effective Industrial Plant Equipment (IPE) maintenance strategy for labor shops in order to improve production support the development of multi-skills teams.

A typical example is the change out of a small motor. Traditionally, a change-out could require an electrician to disconnect the motor leads and a millwright or mechanic to disconnect the coupling, physically replace the motor, and perform the alignment. The electrician would then return to the job, reconnect the motor leads, check and possibly change rotation. The mechanic or millwright would, at this point, be able to connect the coupling halves to complete the job [3]. See Figure 3 and let's assume that the example mentioned above is being represented in this image.

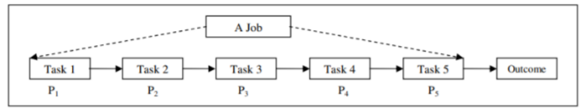

Figure 3
A Series of Tasks Performed in a Work Process

Maintenance and operation activities are common error rates. A range of 10%, or 1 error in 10 opportunities is very common when executing maintenance work. Based on this, the probability that effective work will be done is 90%. In this example, each of the tasks in Figure 3 has a 90% chance of success. Once we know that, we can calculate the probability that all the work is correct using the simple probability formula [4]. See Equation (3). This equation states that the result is the multiplication of the probabilities associated with each task. Therefore, observing the results of Equation (4), the final result is a 59% probability that the work is done correctly.

$$P_{Series} = P_1 \, x \, P_2 \, x \, P_3 \, x \dots P_n \qquad (3)$$

$$P_{Series} = 0.9 \, x \, 0.9 \, x \, 0.9 \, x \, 0.9 \, x \, 0.9 = 0.59 \qquad (4)$$

On the other hand, Figure 4 shows the same 5 task work but with team creation. In Figure 4, Technician 1 is doing the job, supported by two other technicians from the team. Each person adds their useful contribution according to their skill. Each task is one parallel activity. This structure also has a mathematical formula to calculate the possibility. [4]. See Equation (5).

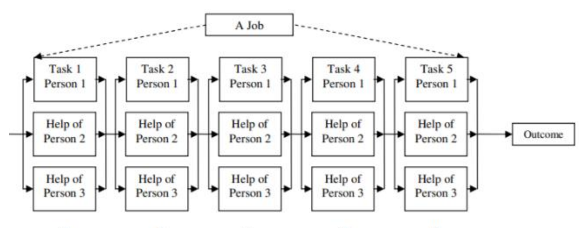

Figure 4
Working as a Team Creates Parallel Teamwork

$$P_{parallel} = 1 - [(1 - P_1) x \dots (1 - P_n)] \qquad (5)$$

Using this equation, we would find that with three people, each with 90% probability of accuracy, parallel probability gives us a correct task 99.9% of the time, and the job is correct 99.5% of the time [4]. By equating tasks with a team, the results change 59% chance that the job is correct when the person works alone, up to 99.9% with a team of subject matter experts working together [4].

CONCLUSION

The creation of multi-skill teams shows to be the best strategy to be applied in the management of job assignments and man-power allocation to improve the productivity, reliability and availability of the processes / equipment. The equipment/process with the lowest availability and reliability turns out to be automated equipment, which requires more varied and specific skills from the maintenance department for an efficient and effective support. As future jobs, it is suggested to investigate how to achieve, from top management, changes in the work culture, training resources, salary analysis and structures for conducting interviews to achieve employees with multiple skills and to facilitate the creation of multi-disciplinary teams.

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