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Assembly Flow Simulation of A Radar

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Abstract

A discrete event simulation model has been developed to predict the assembly flow time of a new radar product. The simulation was the key tool employed to identify flow constraints. The radar, production facility, and equipment complement were designed, arranged, and selected to provide the most manufacturable assembly possible. A goal was to reduce the assembly and testing cycle time from twenty-six weeks to six weeks. A computer software simulation package (SLAM II) was utilized as the foundation for simulating the assembly flow time. FORTRAN subroutines were incorporated into the software to deal with unique flow circumstances that were not accommodated by the software. Detailed information relating to the assembly operations was provided by a team selected from the engineering, manufacturing management, inspection, and production assembly staff. The simulation verified that it would be possible to achieve the cycle time goal of six weeks. Equipment and manpower constraints were identified during the simulation process and adjusted as required to achieve the flow with a given monthly production requirement. The simulation is being maintained as a planning tool to be used to identify constraints in the event that monthly output is increased. "What-if" studies have been conducted to identify the cost of reducing constraints caused by increases in output requirement.

Introduction

In 1989, designers at Sandia National Laboratory/New Mexico began the process of designing a new radar. The radar sub-assembly includes nine hybrid modules and a printed wiring board interconnected with .047-inch coaxial cables and two flat flexible cables. Seven of the hybrid circuits modules were designed to be mounted on an aluminum plate that is connected to a printed wiring board with a flat flexible cable. Two hybrid circuits are attached to the printed wiring board. The mounting plate and printed wiring board are folded together, fastened in place, then mounted into an outer housing. The design is the product of a joint effort between the Sandia designers and AlliedSignal manufacturing engineers. The goal was to create a design that was consistent with the manufacturing capabilities at the Kansas City Division. The modular design was selected so that hybrid modules could be built individually then assembled onto a mounting plate. Previous radar products had housed hybrid assemblies in multi-cavity housings with difficult interconnections and an extreme assembly environment. A hybrid failure and subsequent rework would necessitate that good product be subjected to the rework environment. The modular design allows for "drop-in" replacement of hybrid modules.

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Past radars had cycle times as high as twenty-six weeks from the receipt of electrical and mechanical components to the completion of an assembly. Typically, a design change would effect numerous assemblies because of the work-in-progress (WIP). In order to become more responsive to design changes, the goal was to produce a radar in twelve weeks at the onset of production and reduce that cycle time to six weeks early in production. A dedicated manufacturing department was built. It contained all the manufacturing and test equipment except equipment for laser marking, radiography, potting, and welding. The equipment and workstations were arranged to economize on the distance traveled between processes. Some compromises were needed since the tester sizes and environment physically limited their location. When compromises were made, emphasis was placed on keeping the lines of communication between assemblers and inspectors open.

Simulation Model Preparation

Having designed the radar for manufacturability, the next steps in the journey to produce a new radar with a 75% reduction in cycle time were 1) verify that the goal was achievable, and 2) implement those controls within the manufacturing area that would insure efficient flow through the assembly process.

SLAM II and TESS, software packages licensed from Pritsker Corporation, were available to be used to conduct a computer simulation of the product flow from the receipt of component parts to completion of the radar. The SLAM II software along with additional FORTRAN code added to handle special cases was necessary for the final model to be designed for specific product flow of the radar.

The initial attempt for the simulation model was based on process information gathered through conversation with the engineers and electronic assemblers. The assumptions used for the early simulation were:

- The radar flow would be a "pull" controlled system.
- Lot size = 1.
- Sub-assemblies between functional test were minimized.
- Limiting equipment resources were accounted for.
- Times were estimates from conversations with assemblers and engineers.
- Testers were available for two shifts.
- Personnel was assumed to be available on demand.

Based on the above assumptions, the cycle time realized was twenty-nine days (six weeks) with a monthly output of seven radars.

Formation of Cross-functional team

The desired cycle time was verified with the early model but the output of seven radars per month was short of the eleven radars per month required. It was obvious that the simulation was a useful tool but the data used to operate the model would need to be more precise. It became apparent that a cross-functional team was needed to insure that the model would precisely represent the assembly processes. AlliedSignal had recently committed to using a Total Quality (TQ) nine step problem solving model. The approach appeared to be a perfect match for building the discrete event simulation model.

A team was formed that included personnel with the following job descriptions:

Process engineer	Inspector
Electrical product engineer	Sandia design engineer
Simulation engineer	Quality engineering
Industrial engineer	Electronic assemblers
Planner	Senior project engineer
Mechanical product engineer	

The team members were selected based on their knowledge of the radar function and processes required for assembly and testing. The TQ approach was presented to the team in four eight-hour-day training sessions. The team focused on "How can the the radar cycle time be reduced to six weeks or less?" The discrete event simulation program would be the tool to verify the cycle time improvements.

Refining the Process Flow

The team began the process of analyzing the current process for producing the radar. The process of collecting assembly steps, times, equipment capabilities, assembler classifications, and inspection points began. The assembly steps were identified in detail and written in the form of a flow diagram. The manufacturing and test equipment was evaluated to establish the most efficient utilization. In some cases, like parts were processed together in batch equipment, temperature cycles were commenced at specific times each shift and some testers were identified for multi-shift utilization. Technical factors such as process schedules for solder reflow of thick film and thin film hybrid network technology impacted the flow sequence decisions. Times were attached to each of the steps. The times were estimates based on experience gained manufacturing prototype parts.

The final radar assembly includes ten sub-assemblies that require electrical testing or circuit tuning. In the case of the hybrid modules two test are required, one before lids are installed and one after lid installation. A system of buffers were established in the model that would signal the start of a sub-assembly once a sub-assembly in work passed its electrical function test. Ideally it is desirable that one sub-assembly is built, completely tested, and qualified before another sub-assembly is started. A goal is to minimize the number of sub-assemblies requiring rework if a process or component causes electrical failures. To improve the output it was necessary to identify interim buffers for hybrid assemblies. The team agreed that the electrical test performed before a lid is attached to a hybrid typically identifies defective product, therefore, a buffer could be added at that point. This is an example of the compromises needed to reduce the cycle time and achieve the output required. The team established the following revisions to the assumptions list:

- Lot size = 1.
- All resources needed as required.
- One shift for assembly.
- Two shifts for testing and tuning.
- Infrared vacuum soldering restricted by part type.
- Two final testers.
- One tester for HMC-I,O ,R, and V.
- One tester for HMC-F, M, T.
- One tester for HMC-L.
- One tester for HMC-C/PWA assembly.
- One burn-in tester for the channel assembly.

One tuning system.

Temperature cycles begin on second shift (eighteen hour cycle).

Vacuum bake starts at beginning of first shift.

This addition of detail and adjustment of equipment utilization resulted in a simulation cycle time of four weeks with 16.7 radars/month output.

The simulation is being refined further to include restrictions to personnel. Classifications and skills of personnel are being included in the model. It is expected that limited personnel will have some impact on the cycle time and monthly output. It is also expected that the simulation can assist in determining the correct mix of skills and classifications of personnel necessary to meet the schedule and cycle time goals.

"What-if"

Soon after the team had developed and ran the simulation model, the impact of doubling the monthly output was considered. The engineers involved evaluated the equipment and tester utilization and presented a list of estimated additional requirements. The simulation engineer was asked if he could factor this into the model and create an equipment utilization prediction. This task was undertaken and eighteen hours later a list of additional equipment and tester requirements was presented along with analysis of the those items that did not need duplication but were highly utilized. The utilization analysis proved especially useful since the potential for flow constraints was more visible.

Next Step

A new team, that includes some members of the simulation team, has been formed to implement the controls on the factory floor that were established for the simulation model. A discipline will be required to insure that part flow is a first-in-first-out pattern and parts are not allowed to be placed in work when the WIP is at its maximum limit. It is expected that modifications to the process and the simulation model will be made to insure that the cycle requirements and output is achieved. It is also expected that the simulation model will be maintained as a tool to evaluate "what-ifs" driven by schedule changes.

Conclusion

The combination of the cross-functional team and computer simulation model created an early need for detailed understanding of the radar assembly processes required to build a radar, created an ownership attitude among the radar team members, provided a tool for future analysis of cycle times and radar output, and established a foundation for an implementation team that will actually produce the radar.