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A Process for the Agile Product Realization of Electro-Mechanical Devices

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This paper describes a product realization process developed and demonstrated at Sandia National Laboratories by the A-PRIMED (Agile Product Realization for Innovative Electro MEchanical Devices) project that integrates many of the key components of "agile manufacturing" (Nagel & Dove, 1992) into a complete, design-to-production process. For two separate product realization efforts, each geared to a different set of requirements, A-PRIMED demonstrated product realization of a custom device in less than a month. A-PRIMED used a discriminator (a precision electro-mechanical device) as the demonstration device, but the process is readily adaptable to other electro-mechanical products. The process begins with a qualified design parameter space (Diegert et al, 1995), and encompasses all facets of requirements development, analysis and testing, design, manufacturing, automated assembly quality assurance and concurrent engineering communications (Forsythe et al, 1995).

Phase 1: Requirements Specification. Compared to traditional product realization, development of requirements and translation of requirements into design concepts was greatly shortened, as a result of the parent/child™ design approach (Parrat et al., in submission). In qualifying the design parameter space, a relatively exhaustive set of potential customer requirements covering a broad range of anticipated applications was created, and a set of design parameters was identified that could be varied to meet each potential requirement.

Having a well-defined parameter space allows customer requirements to be readily translated into a conceptual (child) design. Inclusion of the customer in Requirements Specification allows early confirmation that the proposed product meets initial customer expectations.

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Phase 2: Child Design Definition. Early Child Design Definition activities focus on answering outstanding design and manufacturing questions through analysis, testing and process studies. From the earliest opportunity, the design is reviewed to determine which if any well defined piece parts may be identified for formal release. The intent is to release all well-defined parts so that fabrication may begin at the earliest practical point. Ordinarily, releasing parts for fabrication prior to formal review and acceptance of the final design would be quite risky. However, this risk is largely mitigated due to the knowledge gained in qualifying the parameter space and the ready accessibility of past product data.

Two forums exist for making collaborative design decisions. First, meetings of the Quality Assurance team provide a forum where design decisions may be discussed among representatives of Design, Analysis, Testing, Manufacturing, and Automated Assembly. Second, Interactive Collaborative Environments, allows CAD and other X applications to be shared across the communications network, fostering collaborative work between project team members (Ashby & Lin, 1994). Through these collaborative design approaches, only the most routine design decisions are made in isolation and input/feedback to design decisions is obtained early in the decision making process when minimal time and resource commitments have been made.

Once new part designs become available, the Manufacturing team develops tool paths for their fabrication, and animated illustrations to assess potential problems in machining. Assemblability is assessed using the Archimedes automated assembly planner and illustrator to produce an optimized assembly sequence and animated illustrations of a robot assembling the device in a simulated workcell (Jones et. al., 1995).

Throughout Child Design Definition, the objective is to assure every foreseeable problem in functionality, manufacturing and assembly is identified and addressed prior to beginning Child Design Build. While this may extend Child Design Definition, it is acceptable given the potential delays and costs that could be incurred if a redesign was necessary due to either fabrication problems or deficiencies in product performance. However, qualification of the design parameter space eliminated most problems that could have arisen during traditional design efforts.

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Phase 3: Child Design Build. Due to extensive consideration of manufacturability and assemblability in qualifying the design parameter space and the depth of interactions between the Design, and Manufacturing and Assembly teams during the Child Design Definition process, the potential for such problems is substantially diminished. Thus, when the NC programmer develops tool paths and graphic illustrations to test manufacturability during Child Design Definition, it is highly unlikely that there will be subsequent modifications to design that would require modification of NC programs. Consequently, during Child Design Build, minimal NC programming will be needed prior to commencing with machining operations.

Similarly, robot assembly programs generated from the assembly planner during Child Design Definition are unlikely to need modification, and due to the flexible design of the robotic workcell, all necessary modifications should be completed and the robotic workcell should be ready for automated assembly once parts arrive from fabrication.

Conclusion

All evidence indicates that the A-PRIMED product realization process has been successful in reducing the product realization cycle and in assuring product quality. For the first A-PRIMED build, a discriminator for a robotic quick change adapter was designed and produced in 24 days. The second build focused on developing a discriminator that met the requirements of an electronic defense system and required 30 days, despite significant changes to tolerances made to improve manufacturability and assemblability, and testing to assure product performance was not degraded by these changes.

The A-PRIMED product realization process was also successful in assuring product quality. Whereas previous discriminators have been built to meet strenuous random vibration requirements and tested to those requirements under non-operational conditions, discriminators built using the A-PRIMED product realization process have been shown to meet random vibration requirements within both non-operational and operational modes. Similarly, life cycle testing has shown discriminators built using the A-PRIMED product realization process exhibited life cycles that far surpass the performance obtained from earlier product realization efforts.