

## Effective Technology Transition Processes

A study to determine how to transition technology from R&D to existing products successfully and efficiently has been conducted under a cooperative agreement between the AFRL (Air Force Research Laboratory) and the Boeing Company. Other team members were Central State University, Raytheon, Ford, Pratt & Whitney, MIT and Integral, Inc. The program, referred to as LeanTEC (Lean Transition of Emerging Industrial Capability), was started January 1998 and extends through January 2002. Principles from the study may apply to insertion of any technology, including environmental technology, into new products and/or technology transfer from the initial application to other similar applications.

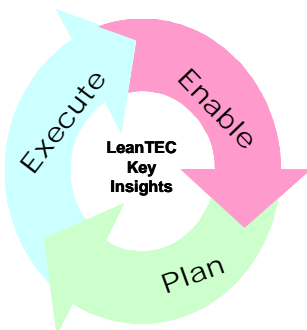
A draft version of Volumes I and II along with the Quick Start Implementation Guide of the LeanTEC Manual is currently being reviewed by selected team members and potential users. Once the user perspective has been incorporated, the full five volume dynamically linked Manual will be produced on CD for review by Boeing and the Air Force to allow unlimited release. The CD will be

(Lean Aerospace Institute). The Manual is scheduled for January 2002 availability.

The pay-off from R&D is effective insertion of technology to products that increases short and long term enterprise value. In CY 2000, \$264B was invested in R&D, \$109B by industry and \$72B by government. Based on public domain data and a LeanTEC survey of 450 R&D projects from 10 companies or divisions it is estimated that less than 40% of technology projects that are intended to transition actually do so. Of those that transition to product 60% were either late, or had many significant late changes, did not meet cost goals, or did not meet technical goals. Five percent had all of the above deficiencies. The data indicates an annual \$100B in waste and \$320B in lost savings or almost 8% of sales for firms doing R&D. Attempts to improve the situation have been going on for several decades with varying degrees of success.

The typical firm engaged in the design, manufacture and selling products invests between 3.5% of net sales revenue in R&D. The payoff depends on effective technology transition. Technology projects must successfully provide the benefit they were intended to provide or be terminated for proper cause at the

### Three Steps to Lean Technology Transition



- **The three steps - Enable, Plan and Execute - form a continuous cycle driven by the “Learn, Improve” actions of Continuous Process Improvement. The 10 Major Areas in the Summary of Key Building Blocks apply in all three steps of the cycle.**
- **Each step has unique tasks - Major local improvement and limited overall improvement in efficiency can be achieved by application of selected building blocks to single steps or parts of steps**
- **Major overall gains are only made when the solution elements are applied considering all three steps as a system.**

Figure 1

available at Boeing, from the Air Force, through AIA (Aerospace Industries Association) or LAI

right time. Those technologies that transition must transition on schedule, have zero or minimum late design changes and meet technical and cost goals. In terms of Lean principles it is – “the right thing, at the right place, at the right time and in the right quantity.” The enhanced performance/lower cost that the customer wants and is willing to pay for needs to be provided to him in a cost effective and timely manner.

The LeanTEC approach was unique in several ways. The team included major players in industry and academia. It placed heavy reliance on actual industry experience by conducting in-depth investigation of selected TT (technology transition) projects. This consisted of a 145 variable survey of 450 TT projects from 10 companies or divisions and full day workshops with R&D executives from 10 world-class companies. The effort was linked to current theory and industry best practices and used feedback from industry and government organizations. Pilot projects were used to test implementation and insure that practicality and people issues were addressed as well as methodology.

LeanTEC summarizes some 72 Building Blocks for Success in ten areas; suggests the three “action” steps (Fig 1) involved and then defines the steps with eight Solution Elements (Fig 2). A self-inventory allows the user to define which of some 215 best practices that are highly related to success should be addressed for the specific problem and links the user directly to specific detailed examples of best practices. A searchable database of over 600 barriers and enablers is also contained on the CD.

The “Manual for Effective Technology Transition Processes” summarizes the findings of the LeanTEC program in a document designed to guide either the creation of a new set of processes or improvement of current technology transition processes by the application of the Solution Elements and

overarching principles through the implementation of Key Building Blocks. The Manual consists of the following five volumes: Volume 1 – Summary: gives an overview of the Manual and answers the question ‘Why read this?’ Volume 2 – Stakeholders Guide to Technology Transition Processes – Appendix “Quick Start Implementation Guide”: describes the process and introduces the key building blocks. Volume 3 – Guide to Technology Transition Process Implementation: details the process and elements of success with detailed examples, best practices and lessons learned. Volume 4 – Background: gives details of methods, findings and results presented in Volumes 1-3. Volume 5 – Data (CD only – no paper copy): provides raw data, data bases and reports – barrier/enabler database.

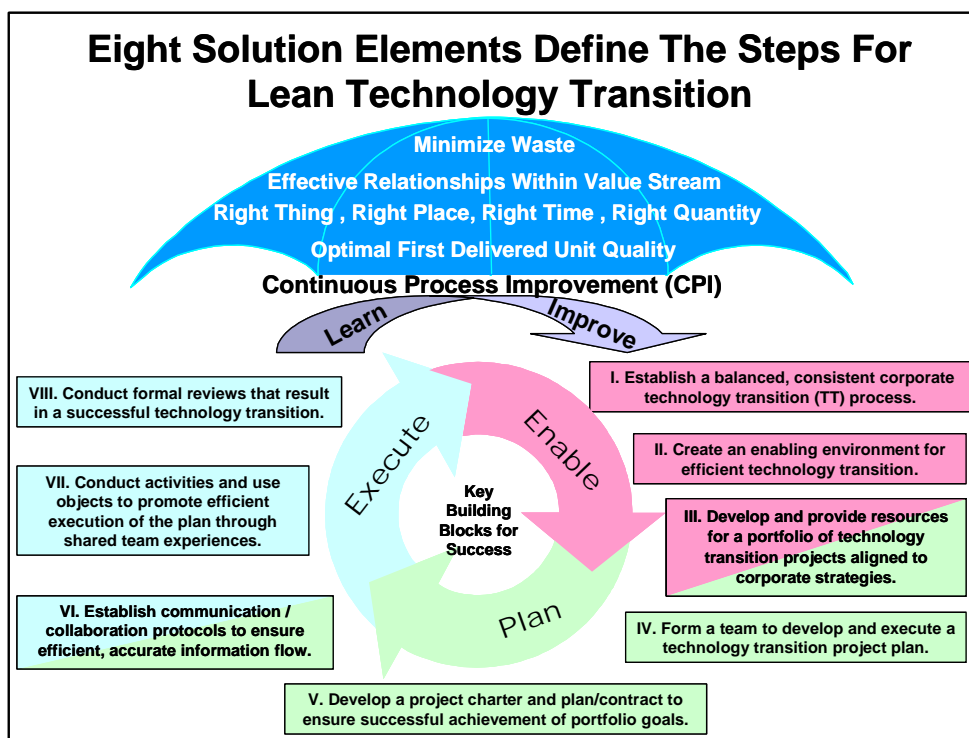


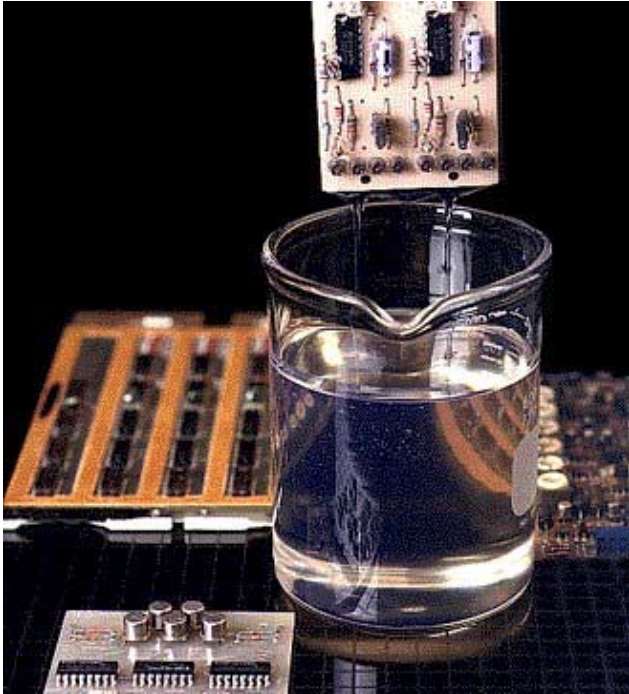
Figure 2

LeanTEC provides a structured approach for effective technology transition to existing products. It focuses on processes, tools, procedures, activities, and behaviors that are highly related to successful and efficient transition outcomes that maximize value to the enterprise. Systemic application of LeanTEC Solution Elements including Lean principles is the key to breakthrough improvement.

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# Low VOC Conformal Coatings

Conformal coatings are thin organic layers designed to protect electronic equipment from chemical, electrical, mechanical, and environmental problems. This improves and extends their working life and ensures reliability. Conformal coatings have widespread use in military, aerospace, marine applications, telecommunications, industrial controls and instrumentation, consumer electronics, and the automotive industries. They are normally applied by dipping, spraying, or flow coating processes and are chosen based on their dielectric properties, abrasion, solvent and thermal resistance, and ease of application.



A conformal coating being applied by the dipping process. Photo supplied by Cytec Industries Inc.

Environmental regulations under the Clean Air Act have had a significant impact on coating materials as well as their application and curing methods. A particular focus is the control of volatile organic compounds (VOCs), which have been used extensively as solvent carriers and react in the atmosphere to form ground level ozone. Suppliers of conformal coating materials have responded by developing environmentally acceptable alternatives and methods of application and curing.

Boeing sites in El Paso and Irving, Texas are being affected by the Texas Natural Resources Conservation Commission (TNRCC) consideration of VOC limits for conformal coatings. SHEA staff at both sites have informally discussed with TNRCC staff whether conformal coatings are within the Texas surface coating rule, Title 30, 115.421, and if so, what the VOC lb/gal emission limit is. There are a variety of possible interpretations that have been considered by Boeing and TNRCC regional staff:

- Circuit boards are a miscellaneous metal part, subject to a 3.5 lb/gal limit.
- Circuit boards are a plastic part, subject to a limit lower than 3.5 lb/gal.
- Conformal coatings used on aerospace circuit boards are an aerospace specialized function coating, with a 7.4 lb/gal limit.
- Conformal coatings are not within the Texas surface coating rule.

Under the first two interpretations, there is a near-term need to convert to conformal coatings that are significantly lower in VOC's than the acrylic and urethane materials used now. Under the latter two interpretations, there is no near-term requirement to convert; however, upcoming federal NESHAP/CTG development may drive conformal coatings toward lower VOC content.

At the federal level, EPA is considering placing conformal coatings in either the Miscellaneous Metal Products NESHAP, the Plastic Parts NESHAP, or the Electronics NESHAP. For metal and plastic parts, EPA also intends to issue revised Control Technology Guidelines (CTG) that would set a ceiling for limits in State Implementation Plans (SIP). The CTG is particularly significant for El Paso, which may be able to stay under major source HAP thresholds, and thus may not be subject to the NESHAPs. The coatings being developed should meet the immediate needs in Texas as well as future federal and state limits for maximum benefit. The specific limits depend upon the quantity of coating emissions and whether the site is located in a nonattainment area (see Table 1).

The Electronics Materials Technology Group is currently identifying low VOC conformal coatings for potential use in the Boeing facilities in El Paso and Irving, TX. The Conformal Coatings Team, whose members include technical and regulatory experts, was chartered to address the problem. Irving currently uses a high VOC acrylic; El Paso currently uses the same high VOC acrylic, as well as

high VOC polyurethanes. The team believes that two options available are to replace all the current high VOC conformal coatings with either a silicone conformal coating or a UV curable conformal coating. Each option has advantages and disadvantages. The silicone is already qualified for use at Boeing but it is difficult to rework. In addition, programs that currently use an acrylic or polyurethane coating would have to make expensive drawing changes in order to switch to a silicone. These programs would also have to requalify each electronic board design with the silicone conformal coating (i.e., redo moisture and insulation resistance testing, dielectric withstanding voltage testing, etc.).

Emissions	Attainment Area	Nonattainment Area
> 10 ton/yr individual HAP or 25 ton/yr aggregate HAPs	NESHAP	NESHAP + Local rules (via SIP)
< 10 ton/yr individual HAP or 25 ton/yr aggregate HAPs	None	Local rules (via SIP)

Table 1. NESHAPs usually only apply to major sources. Permit limits may apply to all emission levels and areas.

The team decided that the best approach was to evaluate the available UV curable conformal coatings. These coatings can be sprayed onto printed wiring assemblies and then rapidly cured by exposure to an intense UV light source. Most of these coatings have a secondary cure mechanism (heat or moisture) to ensure that any coating that is shielded from direct UV exposure (by components, etc.) will properly cure. The VOC content of these coatings is typically 5 grams/liter, compared to 590 grams/liter for the currently used acrylic.

Testing of seven UV curable coatings was recently completed. Testing included the following:

- Appearance
- Moisture and Insulation Resistance
- Temperature and Humidity Aging
- Adhesion
- Thermal shock
- Rework
- Cure

The coatings tested were those that would meet the requirements of both El Paso (which builds military printed wiring boards) and Irving (which builds

boards for commercial aircraft). Three of the coatings passed all testing requirements. The leading candidate is a UV curable acrylated urethane that did very well in the testing. What makes it especially attractive is that it is listed on the qualified products list for MIL-I-46058 as both an acrylic coating and a urethane coating. This means that it can act as a drop-in replacement for either type. Since it is a drop-in replacement, no drawings that call out either a MIL-STD acrylic coating or a MIL-STD urethane coating will have to be changed. Also, the fact that one coating can substitute for both an acrylic and a urethane means that an opportunity exists to reduce the number of coatings

lines at El Paso, which would result in a large cost savings. The same coating can also be used at Irving and it should meet their

unique FAA flammability requirements. Shop trial testing is still required to verify that the coatings can actually be used in a production environment. This testing would include some application tests (to verify that the coatings can be applied and cured in a reasonable amount of time) and rework tests (to prove that the coating can be easily reworked in a production environment). Irving is in the process of doing this testing now, in addition to the FAA flammability requirements. This project is essentially complete and the test report should be available by the end of 2001.

Irving has also begun their own study that will begin testing soon. The intent of this study is to look at other low VOC conformal coatings that were outside the scope of the initial project discussed above. Between the two projects, essentially all of the promising candidate low VOC conformal coatings that are commercially available will be covered.

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