Part III

Flying Fortresses and Liberators: A Letter from Grandpa

Few Flying Fortresses and Liberators can still take to the air. When they were built we had a single-minded purpose: Get 'em flying — without CAD/CAM or ERP. Few people seriously cared about stock prices, ROI, or even government purchasing regulations, so we cut our tiger teams loose to build airplanes as fast as we could.

It worked. Close in the early going, by 1943 the World War II production race was dominated by the Allies. Although the growth in Axis production didn't stall until their final collapse, by 1944 the lead in material was so overwhelming that the outcome of the war was inevitable. We knew it, and they knew it.

In 33 months, Willow Run built more airplanes than were in the entire active commercial aircraft inventory of the United States in 1995. During its B-17 production run, Plant II built almost as many.[1]

Figures 1 and 2 show Plant II and Willow Run at their 1944 peak. Soon afterward, Plant II's production runs slowed to a trickle, and at Willow Run they stopped for good. Most people just wanted to get the hell out of there and forget about it.

At Plant II, life went back to normal. The building was gutted to make room for civil aircraft production by more conventional, less efficient methods. The teams disbanded. Most of the members were retired or laid off. Out the door walked most of the knowledge of how B-17 production had been accomplished. Their reports, photos, and articles were collected and filed away.

The cranked timers disappeared. The tooling disappeared. The moving assembly lines disappeared. Maybe we thought we couldn't afford such systems after the need for such high-volume production disappeared. Finally, both the Flying Fortress and its follow-on, the B-29, rumbled off into history.

At Ford, Charlie Sorenson resigned — or was fired by old Henry after 40 years — in March 1944, just as Willow Run production peaked. He had made good on his bomber-an-hour boast, but before Willow Run could ramp to full throttle, peace broke out. Based on the plant's wing fixtures,

Charlie figured that Willow Run could have built 9000 bombers a year (about 30 a day) had the government needed them. Fortunately, it never did.

When Liberator production ceased at Willow Run, the men that made it run walked into the sunset: William Pioch who fathered the wing fixtures; Logan Miller, perhaps the best sheet metal guy in manufacturing at the time; and many others. In 1944, Miller's Farnham rollers made sheets for the B-29; the only equipment in the country that could roll anything that big. Unfortunately a lot of daring and imagination went with them. Willow Run's B-24 production was better publicized, but likewise its methods and its implications were never seriously studied by the aviation industry.

One can only wonder today what might have been had aviation companies seriously used both Plant II and Willow Run as baselines of large airplane production efficiency. Had we used them as models, perhaps we would not be fighting to relearn the principles of lean manufacturing today. However, then, as now, it is very difficult to see the future potential of new ideas.

Mass Production at Willow Run vs. Lean Manufacturing at Plant II

Willow Run was a turbocharged version of Model T production: Contrary to its only-color-is-black legacy, the Model T system was not totally rigid. However, when the Model T system was adapted to make airplanes, Willow Run's size and tooling made it very capital intensive. Rough estimates suggest that its $103 million cost for plant and equipment was 3-4 times higher than Plant II's.[2] Since it never finished ramp up, Willow Run's maximum daily actual output (18 airplanes per day, with half the wing fixtures idle) barely beat the maximum daily output of Plant II (17 airplanes per day).

One can speculate that for Willow Run to actually hit 30 or more bombers a day, more of the lean principles pioneered at Plant II would have been necessary. Ford engineers would have had to become more attentive to efficient use of space and people — and perhaps outsource more of the work.

At Willow Run, productivity meant maximizing individual work rates and displacing workers with machines. While workers vied for plant honors in rivets per hour, engineers vied to design automatic riveters that would displace them. Each machine had to pay for itself by the labor saved in building 5000 planes.[3] Had the production volume not justified big capital expenditures, Willow Run might have been just as efficient with less sprawl and less automation — but we might never have seen those wing fixtures either.

By contrast, the B-17 design had a larger number of smaller parts, and Plant II's production space was cramped. Boeing had little choice but to maximize manual productivity more by teamwork and incentives, and less by automation.

Plant II and Willow Run were bigger contrasts when they started their production runs than when they finished them. "Lean production practices" were necessary for Plant II to get going. Willow Run, the automated colossus, had to self-discover "lean practices" to continue ramping up. Except for some of the floor stocks, neither plant's inventories were lean by today's standards. In due course, stocks might have been trimmed. Perhaps these production runs didn't last long enough to "put it all together," but Plant II and

Willow Run were on the way. The leadership of both organizations instinctively understood concepts of production flow.

Figure 3 shows a few major contrasts between the plants. Willow Run, with all its special machines and hard tooling, would have seemed to be the less flexible of the two. However, Ford rolled thousands of engineering changes into blocks and phased them in with about the same 15-day leadtime as Plant II. Special machines were designed, built, and put in place in about a year — not bad. If the same folks had had to convert from the B-24 to a completely different airplane, they could have done it faster when they were not building the plant at the same time.

The Dawn of Lean

Characteristic	Boeing Plant II	Ford Willow Run
Capital cost	Low	High
Space	Cramped and "squarish"	Big and long
Work flow	U-shaped multilines	Linear flow
Automation	Minimal and small-scale	Massive
Overhead cranes	3	68
Engineering	Design dominant, co-located	Production dominant, co-located
Design configuration control	Good, rigorous	Conflicts early on
Product design for production	Modular re-design	Modular re-design
Teams	Yes	No
Multi-functional workers	Common	Not so common
Morale	Good	Fair to good after start up
Suggestion program	Major in scope	Some participation
Takt times	Yes	Only by schedule intervals
Standard work	Simple and rigorous system	Check-off lists
Inspection system	Simple, fast, proactive feedback	Quality inspected in
Quality root cause analysis	Yes	Yes
Throughput time through plant	~ 50 days	~ 60 days

Figure 3.

But That Was Then and This Is Now

Of course, both large airplanes and their production processes are more complicated today. Almost everything is more complicated today. In their time, 1941, the B-17 and the B-24 were the most complex aircraft around, but when we had to build them in large numbers, we rapidly recognized a timeless basic: All that complexity has to be made simple. Work stops or slows unless everyone completely understands what they must do. But over the last 50 years, multitudes of other concerns seem to get in the way of us fully understanding why we should make processes simple.

Yes, we must turn out highly reliable aircraft today. During WWII, newly-designed aircraft from all companies sometimes entered service still laden with problems, to be flown by crews still lacking experience. We accepted that risk then; it was a war. However, both the B-17 and the B-24 were airworthy designs when these production runs began, and the Army Air Force did not accept shoddy production.

Unlike 1941, we don't need to build as many airplanes as we can. Now our goal is to take the waste out of production processes while building aircraft at the rate our customers want them. Running flat-out was an obvious and dramatic challenge in 1941-44. The challenge of removing the waste from today's large, complex aircraft production is no less urgent. And many lessons on how to understand and meet today's challenge can be found in the records of how our grandfathers made those B-17 and B-24 production runs. The basics haven't changed much.

The Timeless Lessons

- To avoid confusion keep all processes simple
- Use modular design of both products and production processes to enable flow
- Keep support staff close to real processes, not remote
- Smooth flow in limited space meets or beats large scale
- Limited resources force the invention of better methods
- Pay attention to human needs and morale
- Permanently solve problems at their source with root cause analysis
- For quick learning, employ immediate feedback
- Instill a gut-level sense of urgency so people don't hold up the process

- Overall process efficiency counts, not sub-optimization of support processes
- Standard work discipline: Make instructions clear, concise, and current
- Timing: Synchronize the work.

Willpower and Vision

For all their faults and oversights, the leadership at Plant II and Willow Run had something going for them. They rapidly grasped basic process concepts, and they innovated on their own. Sure, they had a few consultants, and they shamelessly stole ideas from each other, but they shared an important characteristic: They could visualize their entire process from concept to reality themselves, and they had the guts to act on their own vision. They did it when it really counted too.

1. Statistical Abstract of the United States 1997, Table No. 1056, p. 653. (Including helicopters, about 7400 aircraft were in active use in 1995, the last year for which numbers are available.)
2. Sources: 1) Warren B. Kidder, *Willow Run: Colossus of American Industry*, KFT, Lansing, MI, 1995, p. 273: 2) Burk, Clarence S., *Production Acceleration Case Study: Boeing B-17*, (TSZLA-7/FWF/ew); Los Angeles AAF Procurement Office, July 22, 1946, Exhibits 6 and 7.
3. From a summary by Franklin M. Reck in Aero Digest, July 1, 1945. From The Research Center, Henry Ford Museum and Greenfield Village, Accession 435, Box 22, Vol. 22.

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