Barriers to Automation of Aircraft Production
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Three cost elements contribute almost 100% of the cost of airline operations: fuel, capital, and personnel[1]. The capital cost is almost entirely attributable to aircraft (most of which are, of course, leased, but the high lease cost is reflective of the high intrinsic cost of the asset), and a visit to any typical aircraft manufacturing facility instantly reveals why: an aircraft plant doesn't even remind you of an auto plant ca. 1950: it reminds you of a medieval craft workshop. Aircraft assembly is artisanal work. Much progress has been made in recent years, with the advent of the moving assembly line, introduced by Boeing initially on its B737 final assembly plant[2], and with highly automated processes being applied by companies such as Spirit Aerosystems (a Boeing spinoff) on major subassemblies for the B737 and B787 and various Airbus products[3]. By and large, however, final assembly, sub assembly and piece part manufacturing in the aircraft industry remains a high-touch operation. The contrast is equally striking between the manufacture of consumer electronics and avionics components. In Olathe, KS, within about 2 miles of each other, a Garmin consumer GPS plant operates with about 6 employees on the shop floor, turning out a higher number of units per day than the Honeywell Bendix King plant just down the road with a staff of hundreds of line workers producing General Aviation avionics[4]. Why?

There are a number of reasons for the picture painted above, but from a manufacturing technology point of view, there appear to be a small number of salient factors:

1) Conservatism. The aircraft industry is possibly the most conservative industrial community extant (maybe with the exception of nuclear power…) It is rare, but not unheard of, to hear of a school bus in rural Pick-your-state going off the road and tragically killing a couple of dozen middle schoolers on a field trip. An accident involving two dozen passengers on a commercial aircraft makes banner headlines nationwide and sparks an NTSB investigation. Consequently, there hasn't been one of those in years. As a result of this conservative viewpoint, designers tend to stick to well known designs for the aircraft, their components, and the systems and processes used to produce them;

2) Government regulation. Aircraft and their systems are tightly regulated and certified by the FAA. To change even one component aboard a new aircraft is an expensive and time consuming process. The Government employees charged with this process put their names and reputations personally on the line every time they certify a new product, variant, use, or modification. Naturally, they are not big fans of change.

3) Design for manufacturing. Because of the above two factors, designs for new airplanes tend to be extensions or modifications of old designs, adapted for a new appplication. Consequently, they are not designed with a view to automation of the production process[5]. If given a choice between making the essential change to improve the performance of the ultimate product, or incorporating process oriented elements, the choice will always be made in favor of the former. "Both" is not an option here because of the negative impact on the certification result.

4) Issues of scale. Unlike consumer electronics, appliances, or automobiles, aircraft, particularly large commercial and business aircraft, span a far larger set of scales. Assembly of a commercial airliner requires fine scale accuracy on an assembly hundreds of feet in length[6]. This reality puts extreme stress on the performance of automated tools (fit of components has therefore traditionally been the work of highly skilled artisans) In recent years progress has been made on this front, by relaxing overall positioning demands while maintaining precision locally.

5) Low production rate of final product. A highly ambitious production schedule for a aicraft plant or major sub-assembly plant, is one item per day. This is compared to hundreds at a typical auto plant, or thousands at a typical consumer products plant[7]. The capital cost of production machinery is therefore amortized over a much smaller production run, which increases the cost sensitivity. Hand work remains cheaper.

6) Low production rate of supply chain[8]. A corollary exists for the supply chain. Since the demand is low for parts industry wide, suppliers are blocked from implementing automation for piece parts, and are caught in the same bind as the final assemblers.

The questions for the technology community are these:

1) What would it take to develop a flexible aircraft production environment at the major sub-assembly and final assembly stages with the same level of automation now seen in auto manufacturing?

2) Which extremely efficient manufacturing approaches are most likely to help with this goal?

3) Is this fundamentally a problem of technology (we don't know how) or is it fundamentally a problem of money (we know how but can't afford to)?

4) What should the role of the U.S. Government be in this process?

Aviation is the quintessential supporting transportation mechanism for the information revolution. The aviation community's inability to grapple with the issues of affordability it faces has arguably resulted in a brake (perhaps even a significant brake) on U.S. economic growth. Others (the Canadian National Research Council and the EU, for example) are actively tackling this problem[9]. Continued viability of aviation as a contributor to national well being demands that we respond.

A useful approach to addressing this problem would perhaps be the establishment of a National Institute for Aircraft Production Technology formed as a public-private partnership among major aircraft buyers, parts manufacturers, academia, and Federal Labs. The first goal of such an entity might be to demonstrate the fully automated assembly of a fully FAA Certified small General Aviation aircraft capable of operation as an unmanned aerial system (UAS). Such a project would address both the automated aircraft production challenge, and the parallel problem of UAS certification.

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[1] References provided with final version of this paper.

References:

1. 2009 data can be found at http://www.airlinefinancials.com

2. Cort, Adam, (2008), *One Lean, Mean Airplane*, Assembly Magazine (online), 21 August 2008, p.1.

3. Weber, Austin, (2009), *High-flying Robots*, Assembly Magazine (online), 29 April 2009, p.2.

4. My personal observation as a result of visits made during the 2003-2006 period.

5. Sholl, Phil, (2006), *Automating the assembly of aircraft*, Editorial feature, Aircraft Engineering and Aerospace Technology, Vol. 78 Iss: 2, p.142.

6. Weber, op cit., p.2.

7. Weber, op cit. p.6.

8. Ibid.

9. E.g.: Bres, Antoine, Bruno Monsarrat, Laurent Dubourg, Lionel Birglen, Claude Perron, Mohamad Jahazi, and Luc Baron, (2010), *Simulation of Robotic Friction Stir Welding of Aerospace Components*, International Journal of Industrial Robots, pp. 36-50, Vol. 37, No. 1, January 2010