MANUFACTURING COST PROJECTIONS FOR THE JOINT STRIKE FIGHTER CONCEPT

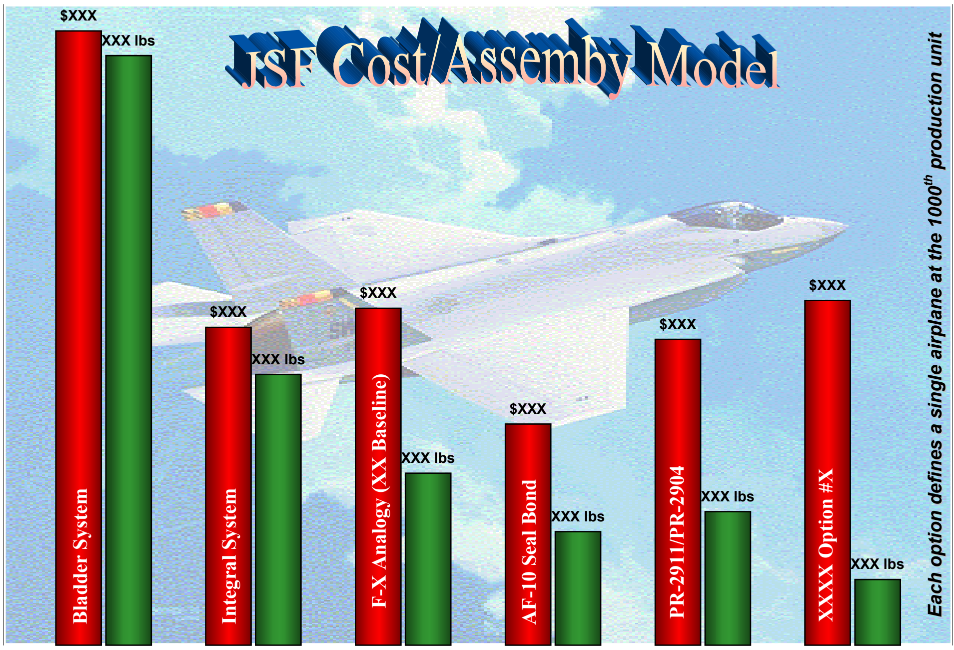
Analysis by Randy Lee for Lockheed Martin, Fort Worth, TX, January, 2000

Special portions of the design phase of Lockheed Martin's Joint Strike Fighter (JSF) concept were assigned to the Advanced Affordability Initiative group with the mandate to identify, characterize and validate new and emerging technologies, alternative cost reduction approaches and next generation manufacturing concepts. Integrating all the various technologies that go into the assembly scheme for a sophisticated tactical fighter aircraft such as the JSF is a great challenge requiring a large team of highly specialized professionals from varying backgrounds (electrical, structural, mechanical, industrial, materials, etc...). In addition, advanced skills and efforts are required to develop realistic concepts that were newer, better, stronger, smaller, more efficient and most importantly, more cost effective since the winner of the contract was expected to produce and test a superior design concept for the various military branches that, not only had the highest performance capability, but was also the most affordable.

A number of concentration areas were envisioned and covered by the various project managers within the AAI group including the use of more cost effective automation techniques for structural assembly such as laser precision component alignment, advanced concepts in the areas of radar signature and low observables, lower cost composite fabrication methods, new methods and equipment for machining and aluminum structural fabrication, the use of six sigma and lean manufacturing techniques, feasibility of fiber optics and advanced avionics systems, alternative fuel containment configurations, structural shimming approaches and enhanced fastening concepts. My assignment covered the areas of fuel containment, shimming and fastening concepts, and required the development of particular skills from several engineering disciplines including industrial, design, project, materials and manufacturing with heavy emphasis in cost estimation, information research, hypothesis formulation and substantiation. This project report provides an update to the ongoing, long-term assignment investigating concepts for fuel containment and associated assembly operations. An overview of the methods developed and employed is given along with a graphical illustration and sample of the estimation model which was constructed to provide the cost/assembly requirements for each scenario investigated.

Initial efforts focused on investigations into the properties, application requirements, feasibility, producibility and environmental impact of innovative polyurethane spray-on coatings, nitrile-phenolic adhesive films and polysulfide paste sealants which might be utilized during JSF component manufacture and substructure-to-skin attach assembly scenarios. Additionally, integration of various fastening strategies and fastener reduction concepts were examined relative to their role in the various approaches for fuel containment, signature tolerance, gap filling and shimming methodologies. While the polysulfides are the most common (and conservative) approach and have a long history of proven success for integral fuel tank sealing throughout the industry, certain cost factors and less-than-desirable weight consequences were a major concern. The phenolic adhesive film (so called 'Seal-Bond') method for fuel sealing is well established for the aluminum-based F-16 AFT and CTR fuel tank configurations and provided the lowest cost and weight scenario hands down, but the risk factor was of great concern among many designers because of possible incompatibility issues when used with composite skins or structures. The less common spray-on polyurethane technique has seemingly demonstrated good success on the F-117 program but ran into considerable difficulties during the first and second F-22 prototypes. This approach offered good weight reductions and reasonable costs but was considered to have a very high risk factor. The traditional bladder system, while employed on a variety of programs throughout the industry, was the highest in cost and weight contribution to the aircraft.

Early in the study, it was discovered that, regardless of which approach was chosen, manpower and labor requirements would comprise an overwhelming portion of the expected production expenditures (70-90%). Hence, extensive labor studies were conducted examining current production methods and floor level assembly procedures for the in-house F-16 and F-22 manufacturing sequences which eventually became baseline models for the JSF concept. In addition, specific fuel containment configurations for the F-117, F-18, F-15, F-14, B-2, B1B, A-10, F-106 and various European fighters were characterized and documented in order to make meaningful comparison between the various technologies. Heavy use was made of labor time standards derived from historical IE motion studies for the enormous number of processes employed within specific production areas and throughout the LM factory. Complete, independent process sequences (modules) were constructed from individual time standard elements for numerous process sequences and variations, and these were incorporated into the beginning of an expanding spreadsheet model. Not all required motions and time consumption elements were covered in current IE time standards and either had to be measured, calculated or estimated by other means. Twelve unique concepts and configurations were postulated in the final JSF study. Each concept required a different combination of sequence modules in varying degrees depending on frequency of use, particular material applied and location. Taking into account factors of personal fatigue and delay, set-up time and miscellaneous actions, the bottom line time values could then be linked with standardized labor cost rates, overhead and support labor expectation figures to produce an estimated labor cost for the entire configuration (of course, integrating all of the process components of the model was a bit more complex than indicated here).



Estimations for materials were also incorporated into the model and, in simple terms, consisted of raw material requirements, amount of material remaining after assembly (weight contribution to the aircraft) and material waste. All of these figures had to be estimated from within the model because reliable sources were not available from any department or historical study. The applied raw material factor (material issued to do the work) was derived from process observations, manual calculations, database research and best guess estimates. The remnant material factor was achieved from precise design estimates of total mating surfaces, process studies and manual calculations. This factor ultimately provided specific weight consequences for the each of the various scenarios. The material waste factor had to be improvised from special techniques. Standard realization factors were incorporated into the model covering material procurement, logistics and overhead, process performance efficiency, personal fatigue and delay and support labor which produced net recurring cost estimates per unit airplane. Development and refinement of the models spanned about one and a half years and eventually provided net production cost expectations for the twelve candidate configurations. The primary deliverable consisted of a comprehensive trade study package (94 page publication, charts, validations and presentations) which detailed total cost expectations for manpower, support labor, overhead, raw material requirements, material waste, environmental and safety consequences. Each cost element and weight contributor was broken down by detail and then the entire study presented a bottom line estimate for each scenario in terms of total recurring unit flyaway cost and net weight contribution.

Traditional & Alternative Configurations

Fuel Containment Description	Material Costs Unit Cost		total per F-16	Labor Costs Estimated Touch Labor Hours (1)	Estimated Touch Labor Costs (2)	Estimated Support Labor Costs (3)	Total Costs Estimated Overall Costs (4)	Total Weight Contribution to Vehicle (lbs.)
Bladder System Tear-resistant bladder cells in F-1, F-2, F-3 and F-4; cavities are also fay, and fastener/seam fillet sealed with MC-275 polysulfide; wings use MS-275 for fay, fillet *and* groove sealing; double fastener rows thruout	$133,358 $6	total cost for 7 cells per lb. (MC-275)	$XXX	XXX hrs	$XXX	$XXX	$XXX	XXX lbs
Integral System Polysulfide (MC-275) on faying surfaces, for fastener and seam filleting and pre-packed seal groove throughout all tanks in fuselage and wings	$6	per lb. (MC-275)	$XXX	XXX hrs	$XXX	$XXX	$XXX	XXX lbs
XX Baseline Approximate F-X scenerio; Lightweight polysulfide (PR-XXX) for faying, fastener/seam filleting and seal groove in all tanks throughout; Average fastener fillet thickness taken as ~ XXX" (not theoretical spec values)	$29	per lb. (PR-1776)	$XXX	XXX hrs	$XXX	$XXX	$XXX	XXX lbs
AF-10 Adhesive/Sealant AF-10 adhesive/sealant film used on all fuel tank faying surfaces through-out fuselage and wings; Minimal to no filleting on fasteners or seams; Overall level of PR-1776 polysulfide reduced to 1/4 normal levels	$38 XXX $29	per lb. (AF-10) seal washers per lb. (PR-1776)	$XXX	XXX hrs	$XXX	$XXX	$XXX	XXX lbs
Spray-On PR-2911/PR-2904 Similar to F-X scenerio; All tank structures fay and seam sealed with PR-1776; Post-assembly application of PR-2904 spray polysulfide then PR-2904 spray polyurethane/sulfide over all fasteners and seam areas	$49 $44 $29	per lb. (PR-2911) per lb. (PR-2904) per lb. (PR-1776)	$XXX	XXX hrs	$XXX	$XXX	$XXX	XXX lbs
Spray-On System XXX Option #X All tank structures fay and seam sealed with EFC-5993 paste form; Post-ssembly application of EFC-100 spray form over all fasteners and seam filleted regions (same as (E))	$57	per lb. (EFC-100)	$XXX	XXX hrs	$XXX	$XXX	$XXX	XXX lbs