Advanced Manufacturing and the F-35 Lightning II

Dr. Don Kinard, LM Senior Fellow
A&D Forum
November 2016
Aeronautics Portfolio

Strike and ISR
- U-2
- P-3
- UAS

Fighter/Trainer
- F-35 CV
- F-35 CTOL
- F-16
- F-35 STOVL
- F-22
- T-50 Trainer

Air Mobility
- C-130J
- C-5

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Fort Worth Plant History

- Aircraft production started in the mile-long facility in 1942
  - B-24 Liberator
  - B-32 Dominator
  - B-36 Peacemaker
  - B-58 Hustler
  - F-111 Aardvark
  - F-16 Fighting Falcon
  - F-22 Mid-fuselage

- F-35 Production Commenced in 2004
Aeronautics Production Lines

**F-35 (FW)**
- 180+ Delivered
- 130 in Flow
- 4/Mo Production Rate

**C-130J (Marietta)**
- In Production Since 1956
- ~2500 Delivered
- Current Rate ~ 2/Mo

**F-16 (Fort Worth)**
- In Production since 1976
- 4500+ Delivered
- <1/Mo Production Rate
F-35 Acquisition Strategy

An Effective Coalition

Economies of Scale

Counters Current and Future Threats
Fighter Generations

1st Gen
- 1945
- 1st Jets
- Stealth Technology

2nd Gen
- 1955
- Supersonic
- 1st Radar

3rd Gen
- 1960
- Multi-Role
- Missiles
- LO Treatments
- Advanced Avionics
- Guided Weapons

4th Gen
- 1970
- Advanced Stealth
- Sensor Fusion
- Net Enabled Ops
- Fighter Performance
- Adv. Sustainment

5th Generation
- 2005
- Multi-Spectral Sensors
- Interoperability
- Weapon Types
- Modernized Avionics

Common Attributes
- Advanced Stealth
- Sensor Fusion
- Net Enabled Ops
- Fighter Performance
- Adv. Sustainment

5th Gen Capabilities & Effectiveness Are Superior To 4th Gen

High & Fast
Night, Non Maneuverable
Air-Surface Only
Maneuverable
All Weather Operations

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Advanced Stealth
Must Be Designed In

Internal Fuel Tanks
Fixed Array Radar
Engine Inlets
Full Line-of-Sight Blockage
Aligned Edges
Reduced Signature Nozzles
Internal Stores Carriage

Curved Diverterless Inlets, “Buried” Engine
Composite Structure
Radar Absorbing Material (RAM)
Large Capacity Internal Fuel Tanks
Weapons Carried Internally
Aircraft Shaping and Edge Alignment
Low-Obsevance Seams, RAM Seals
Low-Emission Radar and Avionics

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<td>18,250 lb</td>
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Fundamental 5TH Design Features Cannot Be Retrofitted
F-35 Mission Systems Coverage
AESA/DAS/RWR/EOTS – All Integral to the Aircraft (No Pods)

Electro-Optical Targeting System

Active Electronically Scanned Array (AESA)

Electronic Support Measures

Network Connectivity
- Data Links
- SINCGARS
- Have Quick
- MADL

Full Spherical Coverage Distributed Aperture System (DAS) and 360° RWR

RWR Antennae

DAS Apertures

Emitter Locating

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The F-35 – The Next Generation Difference
F-35 Master Schedule

As of 20 Mar 2015

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Low-Rate Initial Production and Multiyear Procurement

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Planned Production
- Air Force: 1,763 F-35A
- Dept of Navy: 680 F-35B/F-35C
- International: 800-1,500

Development
- First Flights: F-35B, F-35A, F-35C
- Air System SW Fleet Releases
- USMC IOC
- USAF IOC
- USN IOC
- DT Flight Test: F-35B, F-35A, F-35C

Base Stand-Up
- Eglin Edwards
- Cherry Point
- Nellis
- Yuma
- Ogden
- Luke
- Beaufort
- Hill
- NAS Lemoore

AF Ops 2

Time Now
F-35 Design/Supply Chain Roles

**NGC**
- Center Fuselage

**Systems Responsibilities**
- Weapons Bay Door and Drives
- Arresting Gear
- Radar
- IFO Doors (Fokker)

**BAES**
- Aft Fuselage
- Vertical Tails
- Horizontal Tails
- CV Wing Fold

**Systems Responsibilities**
- Fuel System
- Crew Escape
- Life Support
- EW System
- Throttle/Side Stick
- Flight Control Computer

**LM FW and LM Palmdale**
- Overall Air Vehicle Edges
- Wing
- Fwd Fuselage
- Mate thru Delivery and Finishes

**Systems Responsibilities**
- Autonomic Logistics
- Mission Systems
- Vehicle Systems
- Training Systems
- Team Harnesses (Fokker)

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**Integrated Airframe and Systems Designs**
JSF International Participation

**NGC**
- Center Fuselage
  - Turkey

**LM FW and LM Palmdale**
- Conventional Edges
  - Denmark
  - Norway
  - Netherlands

**BAES**
- Vertical Tails
  - Australia
- Horizontal Tails
  - Denmark
  - Canada
- CV Wing Fold
  - Canada

**Wings**
- Italy
- Israel (outer wing boxes)

**Final Assembly and Check-out**
- Italy
- Japan

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**Strategic Second Sourcing for Major Subassemblies Capacity and Business Case Driven**

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Actions To Achieve Rate Readiness

Material

Manpower

Machine

Methods

Maturing Now for Rate
Flow Manufacturing – Lean Implementation

F-35 Manufacturing Line Is Configured to Enable Flow to Takt Manufacturing. This Means That Components Move Positions at the Same Frequency as Aircraft are Delivered

Wing Box Rail Line Incorporates Overhead Rail System To Create Flow, Drive Standard Work, and Reduce Cost and Span
What is the Digital Thread?

**Form**
- Solid Model Part
- Solid Model Tool

**Digital Verification**
- Digital Process Verification
- Maintenance Simulation
- Electronic Mock-up

**Integration**
- Creation
- Integration
- Digital Fab (NC Driven)
- Lean Assy Planning

**Producibility**
- Digital Assy (NC Auto Drill)
- Factory Simulation
- Digital Inspection (Laser Tracker)

**Hardware/Software Applications**
- Digital Assy (NC Auto Drill)
- Training / Maintenance Media

**Common Digital Data Flow**

**Data Re-use**
- Lean Assy Planning
- Digital Inspection (Laser Tracker)
- Training / Maintenance Media

**Rapid Product Development**
- Concurrent Engineering
- Improved Quality
- Reduced in Changes

**Validated Producibility**
- Tooling Reduction
- Process Flexibility

**Improved Quality**
- Automated, Repeatable Processes

**Consistent, Accurate Source Data**
- Consistent, Accurate Source Data
Advanced Manufacturing Technologies

Fiber Placement

Automated Drilling

Laser Ultrasonic Inspection

Graphical Work Instructions

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Methods - Robotic Coating Process

Direct Use of the Digital Thread Allows Higher Quality, Tighter Tolerances, Reduced Span, and Lower Cost
Work Instruction Optical Projection Using the Digital Thread
Methods - Non-Contact Metrology

Non-Contact Metrology Could Replace CMM and Allow Rapid Measurement of Fastener Flushness, Gaps, and Mismatches
Methods - Use of Portable 3D Data in Production

- Ease Of Use
- Wireless Connectivity
- Current Software Functions
- Ergonomics
- Device Management

Delivery of 3D Data to the Mechanics is Enabled by AeroSource
F-35A Price (TY$)

Continuous Focus on Affordability

As of 15 Oct 2014

Lot Average Aircraft Price TY$M

Aircraft Quantity

Buy Year


$0 $50 $100 $150 $200 $250

$0 50 100 150 200

AUSA USDoN International SAR 2013 F-35A With Engine TY$
Blueprint for Affordability

- Saves Approximately $1.8 Billion by 2019
- Reduces the Cost of an F-35 Jet, by Approximately $10 Million by 2019
- F-35 Will Cost Less Than $80 Million per Jet in Then-Year Dollars by 2019
- Cost Savings Begin Now and Continue Throughout 25-Year Production Profile

Leveraging Ideas From Across the Global Supply Chain
Future Affordability
So What Are We Doing About it?

• Additive Manufacturing (EBDM, Electron Beam Direct Manufacturing)
• Cryo-Machining Projects
• Increased Automation (hole drilling, material application, inspections, etc.)
• Structured Light Scanning Inspections and First Article Validation
• Additional projection applications
• Tablets, Movies, and 3D visualization deployment
• Lower Cost Precision Machining
• Material Flow Implementation (Lean Manufacturing)
• SCM Initiatives
  – Multi-Year Packaging
  – Best Value Sourcing
  – Technology Insertion
  – Strategic Inventory
2015 – STOVL IOC Declared!
2016 - Air Force Declares IOC for F-35A!!!
2016 Major F-35 Events

First F-35A Transatlantic Flight – Italy’s AL-1

- Negotiating both LRIP 9 &10 for Approximately 160 Aircraft

F-35 Appearing at RIAT and Farnborough in July

DT-III for F-35B and F-35C Sea Trails

AF IOC Declaration (August)

- First Japan Delivery in November
- First Israel Delivery in December
- Deliver 45 Jets Worldwide – 40 from FW; 5 From Cameri