Lean Aircraft Initiative
Plenary Workshop

SUPPLIER INTEGRATION INTO DESIGN AND DEVELOPMENT

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Presented by:
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MIT
**Outline**

- **Focus on integrative research:**
  *Supplier Integration into Design and Development*
  - Joint with Product Development and Supplier Relations Focus Teams
  - Part of longer-term research on technology supply chain management

- **Report on interim findings**
  - Research overview: Kirk Bozdogan
  - JDAM Case Study: John Deyst
  - F119 Engine Nozzle Case Study: Dave Hoult
  - Summary and next steps: Kirk Bozdogan
Lessons from Auto Industry

Early supplier integration key to efficient product development (shorter cycle time, lower cost, higher quality, enhanced competitive advantage)

- Early supplier involvement in design
- Supplier participation IPPTs
- High design content by suppliers
- Joint engineering problem-solving
- Reduction in design change traffic
- More efficient coordination; fosters innovation
- Up-front design/process integration; improved producibility
- Reduction in rework cycle

Key Enablers

- Pre-sourcing; long-term commitments
- Target costing
- Supplier-capability-enhancing investments
- Strong communications links
Early Supplier Involvement in Military Product Development Programs and in Integrated Product & Process Development Teams (IPPTs)
(By responding business units, before Milestone 1*, by type of component)

(N1,N2 = 29,28: Total number of business units responding to questions on programs & IPPTs, respectively)

* During requirements definition and concept exploration & definition; before demonstration & validation

Source: MIT Product Development Survey (1993-94)
Early Supplier Involvement in IPPTs in Military Product Development Programs vs. Cost-Related Requirements Changes Primarily Driven by Producibility Problems during Dem/Val and EMD Phase

Note: Early supplier involvement before Milestone 1: during requirements definition and concept exploration & definition; before demonstration & validation

Source: MIT Product Development Survey (1993-94)
Major Hypothesis

- Early supplier integration into IPPTs is a critical enabler of “architectural innovation” in product development

- “Architectural innovation”: Major modification of how components in a system are linked together, resulting in significant new benefits for entire value stream including changes in:
  - Physical system form and structure
  - Functional interfaces
  - System configuration; relationships among components
  - Materials
  - Manufacturing processes
  - Tooling
  - Assembly methods

* Concept draws on Henderson and Clark (1990)
**Innovation Framework**

<table>
<thead>
<tr>
<th>Impact of Innovation on:</th>
<th>Existing Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linkages Among Components</td>
<td>Further Exploited</td>
</tr>
<tr>
<td>Unchanged</td>
<td>Incremental (e.g., 286,386,486 processors)</td>
</tr>
<tr>
<td>Changed</td>
<td>Architectural (e.g., Front wheel drive cars; small copiers)</td>
</tr>
</tbody>
</table>

*Framework draws on Henderson and Clark (1990)*
<table>
<thead>
<tr>
<th>Intra-Organizational Perspective</th>
<th>Inter-Organizational Perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept originally developed in context of single product development organization</td>
<td>First-time application of concept here in inter-organizational context (over supplier web)</td>
</tr>
<tr>
<td>Emphasis on impact of architectural innovation upon firm’s technological capability</td>
<td>Emphasis on value chain (prime-key suppliers-subtiers)</td>
</tr>
<tr>
<td>Narrow focus on new system configuration (how components are linked together)</td>
<td>Broader focus on enablers &amp; incentive systems for integration of specialized knowledge bases over supplier web</td>
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</table>
Evolution of Supplier Role in Product Development*

Increasing Supplier Role

- Build-to-Print
  - Supplier proprietary parts
- Black Box
- Integration into IPPTs

Increasing Benefits

- Arm's Length
- Cooperative Relationships
- Long-term Strategic Partnerships

Supplier Highway

- Knowledge Integration
  - Architectural Control (Systems Integration)
  - Design (Major Sub-Assemblies)
  - Manufacturing Consultation (Components)
  - Supply simple or standard parts (parts)

Increasing Supplier Integration

*Extends general idea expressed in Virag and Stoller (SAE, 1996)
Focus on Two Case Studies

- JDAM case study -- John Deyst
- F119 Engine Nozzle Case Study - Dave Hoult
Figure 3-1: The JDAM Tail Kit
Guidance kit that attaches to
1,000 or 2,000 lb. bombs
- Tail fairing/structure
- Actuator subsystem and fins
- IMU/GPS guidance control unit
- Battery
- Wire harness assembly
- Strakes
- Container
Six “Live or Die” Requirements

1. Low unit cost (target of $40K)
2. Adverse weather capability
3. Multiple aircraft compatibility
4. Aircraft carrier suitability
5. In-flight re-targeting
6. Warhead compatibility
Program Factors

- Long term program
- Strong price competition
- Contractor configuration control
- Long term warranty
- Joint government/prime-contractor/supplier teams
Team Formation Factors

- Protection of trade secrets
- Allowance for commercial pricing strategy
- Preferred supplier program
- Supplier training
- Open communications with many informal links
- Shared win strategy
Program created strong incentives for cost reduction

Architectural innovation was key to cost reductions

Supplier knowledge base necessary for
  - Architectural innovation
  - Design for manufacturing and assembly

Shared goals allowed give and take on workshare
Architectural Innovation in the GCU

- Single battery design to supply both 28v and 100v
- Change from SEM-E module configuration to a highly integrated mission computer design resulted in:
  - Elimination of a circuit module
  - Reduced heat management requirements
  - Inherent EMI shielding
  - Reductions in wire harness assemblies and connectors
  - Better DFM/DFA
  - More economical/efficient workshare structure
  - Greater vibration tolerance
  - Reduced parts count/increased reliability
Front end receiver functions moved to antenna module
  - Reduced cost for antenna/receiver combination

Overall cost reduction of 40%-60% in GCU

Cost reduction impact on other areas (e.g. heat, power, volume, etc.)
Mission Computer Architecture Innovation

Original Mission Computer Design Concept

Mission Computer Design for the Low Cost GCU
## Benefits

**Benefits To**

**Key Benefits**

| Government | • AUPP reduction ($68K → $15K)  
|            | • Development time reduction (46 mo. → 30 mo.)  
|            | • Procurement cycle length reduction (15 yrs → 10 yrs)  
|            | • Warranty length increase (5 yrs → 20 yrs)  
|            | • Program office staff decrease (70 people → 40 people)  
|            | • No degradation on accuracy |

| Prime Contractor | • Increased design flexibility and configuration control  
|                 | • Reduced MIL-SPECS (87 → 0)  
|                 | • Reduced SOW (137 pgs → 2 pgs)  
|                 | • Reduced proposal length (1000+ pgs → 15 pgs)  
|                 | • Reduced government-mandated contract terms (243 reports → 15)  
|                 | • Long term stable program |

| Suppliers | • Protection of trade secrets  
|          | • Relaxed requirements for pricing data  
|          | • Elimination of MIL-SPECS  
|          | • Training program  
|          | • Long term business relationship (Preferred Suppliers Program) |
F119 Engine Nozzle: Introduction
The key issue of the F119 Nozzle
- High exhaust temperature (4300°F)
- Thermal cycling of nozzle (Fatigue)
- High tolerance requirements (to prevent leaks)

Very tight coupling between:
- (A) Design
- (B) Manufacturing process
- (C) Materials

Each of the ABCs impact the others strongly
Case Study Profile: 1980s

- Prime responsible for all design and engineering
- Role of suppliers: build-to-print
- Went through four generations of design; each one a separate invention (different materials, design, technology, processes)
- Traditional design/development process did not deliver optimal product
Case Study Profile: 1990s

- New material technology driving design and manufacturing/assembly process
- Co-located design teams (prime, key potential suppliers); supplier downselect
- Prime adopted new design approach based on make/buy
- Joint design/development with selected suppliers; design control by prime
- IPT approach; concurrent engineering
- Electronic integration with suppliers
- Not-to-compete agreement with suppliers (until Lot X)
Case Study Profile: Organization

F119 Nozzle Team

Pratt + Whitney - West Palm Beach
(Prime for F119 Engine)

Prime:

Tier 1:
- Key Supplier
  Convergent Sector
- (now P+W)
  Divergent Flap
- Ducts
- Side Walls

Tier 2:
- Tool Supplier
  Stamping Tools
Case Study Profile:
The Players

- Pratt + Whitney, West Palm Beach - Prime for F119 Engine
- Key supplier of convergent-divergent component of nozzle
- Tool supplier next door to key supplier, makes stamping tooling
Case Study Profile: Information Flows & Knowledge Integration

OLD

P+W

Key Supplier

Tool Supplier

Information flows:
• contractual requirements
• blueprints

NEW

P+W (West Palm Beach)
Materials
Design, Testing
Welding Fabrication

Tool Supplier
Stamping tool
Design
Sheet metal fabrication

Key Supplier
Fabrication
(Welding, Machining)

Knowledge integration (pooling of specialized core competencies)
Case Study Profile: The Story

- Pratt & Whitney make-buy decision
  - not to invest in new capital equipment
- Selection of Key Supplier because of its welding capability for convergent nozzle component
- Pratt & Whitney agrees not to compete with Key Supplier (until Lot X)
- Virtually no investment risk by suppliers
The IPT jointly agrees to rivet rather than weld the nozzle assembly, based on
- Tool supplier’s stamping experience
- Key supplier’s riveting experience
- Prior sharing of this information with P&W

Result: New way of linking components together; new manufacturing and assembly process; much improved product

Riveting idea originated from key supplier and its tool supplier
Architectural Innovation: Impact Stream

Riveting

New joining method for all components

Changes in how components assemble (interfaces, alignment)

Redesign at detail level

Unique riveting sequence

Nearly toolless assembly

Improved performance, cost and quality

Heat treatment sequence

Denotes iterative process
## Benefits

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<thead>
<tr>
<th>Benefits To:</th>
<th>Key Benefits</th>
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<tbody>
<tr>
<td>Program</td>
<td>- Substantial risk reduction</td>
</tr>
<tr>
<td></td>
<td>- Major cost reduction (more than 5-fold reduction in unit cost)</td>
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<tr>
<td>Prime</td>
<td>- Significant improvement in cost performance</td>
</tr>
<tr>
<td></td>
<td>- Significant savings of capital investment</td>
</tr>
<tr>
<td></td>
<td>- Control of new process by prime through proprietary technology</td>
</tr>
<tr>
<td>Key Supplier</td>
<td>- Repeat business in future; incentivized by not-to-compete agreement--nozzle is a wear part</td>
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<tr>
<td></td>
<td>- Enhanced capability for similar future programs</td>
</tr>
<tr>
<td>Tool Supplier</td>
<td>- Develops new technical capability</td>
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<tr>
<td></td>
<td>- Transfers technology to automotive practice, gaining new business (from .020” tolerance to .002” tolerance)</td>
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Early supplier integration into design and development key enabler of major enterprise-wide overarching practices

- Implement integrated product and process development
- Develop relationships based on mutual trust and commitment
- Assure seamless information flow
- Identify and optimize enterprise flow
- Optimize capability and utilization of people
- Make decisions at lowest possible level
- Nurture a learning environment
Key Lessons

- Follow proactive “make-buy” strategy based on understanding of core competency over entire value chain
- Integrate specialized knowledge bases over supplier web (key suppliers, subtiers)
- Facilitate early integration of key suppliers in design and development
- Retain flexibility in defining system architecture
- Develop incentive mechanisms for mutual gain, both internally and externally
Early supplier integration into design and development can yield potentially significant benefits

Major source of benefits: Enabling “architectural innovation” in product development

Requires proactive integration of core competency of suppliers into design process

Innovative government acquisition and oversight practices essential

Current and future research aimed at helping industry in this journey (e.g., define best practices, metrics, enablers, benefits, formal analytical methods)
Next Steps (Joint PD and SR)

- Identify strategies and systematic methods for cycle time reduction and risk management
  - Key characteristics
  - Design structure matrix
  - Software factories (continuing)
  - Dynamic modeling of design process
  - Reducing DOD product development time

- Technology supply chain design and management
  - Strategic make-buy decisions
  - Concurrent design of product development, technology supply chains and production supplier networks
  - Parts obsolescence and diminishing manufacturing resources

- Information infrastructure requirements and approaches
  - Vertical design/process integration information requirements
  - Structured methods (function/design/process decomposition; data flow management)