Lean Engineering Post-Certification Decision Making in the Aerospace Industry

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Decision Making in Post Certification

Lean Engineering

P&WC Intro
UNITED TECHNOLOGIES CORPORATION

Commercial Engines
P&W Aftermarket Services
Military Engines
Space Propulsion
P&W Power Systems
P&WC PRODUCT MANDATE
68,000 engines produced

Turboprops
600 – 6,500 shp
- PT6A
- PW100
- PW150

Turboshafts
600 – 2,200 shp
- PW200
- PT6T/B
- PT6C

Turbofans
900 – 20,000 lbf
- PW600
- JT15D
- PW500
- PW300
- PW800

Auxiliary Power Units
- PW900
Decision Making in Post Certification

Lean Engineering

P&WC Intro
WHY LEAN IN AEROSPACE?

1. Aerospace is an extremely competitive industry.

2. Organizations need help understanding, measuring, managing and optimizing the work of people involved in product development systems.

3. Opportunities do exist for improvement.
Data
Calendar days (includes w/ends, holidays) 106
Lead Time (working days) 76
Touch days (> 2 hrs) 42
Charged hours 811
# Nodes (people who touched job) 81

Touch time calculations
Touch time ratio 0.55

Information Flow “Spirogram”
(Intellectual Spaghetti chart)

Description
PWXX FUEL
COOLER OIL
COOLER ADDITION

Risk Mitigation Job
Cancelled Nov. 18, 2004

DENSE INFORMATION FLOW
Lean Engineering is a philosophy oriented toward achieving the shortest time from customer need to validated & incorporated design.

A business strategy that results in a focus on value improvement.

Connects everything to the customer.

Right Product
Efficient Processes
Effective Integration
CREATE RIGHT PRODUCT

Under Study
Preliminary Design
Detailed Design
Aftermarket

Authorization to study
Authorization to offer
Authorization to launch
Authorization to order Production Hardware
Authorization to manufacture
Production Lessons Learned

CREATE RIGHT PRODUCT
INVENT
DEVELOP
DELIVER
MAINTAIN
EFFICIENT ENGINEERING PROCESSES

Eight Deadly Wastes

- **Excessive Motion**
  - “Chasing” approvals
  - “Searching” for information

- **Waiting Time**
  - Waiting for approvals
  - Meetings and conference calls

- **Over-Engineering of Product**
  - Poorly defined or communicated customer requirements
  - Excess resources lacking clear work activities

- **Unnecessary Processing Time**
  - Processing information from “non-standard” sources

- **Defects**
  - Rework
  - Failing to meet customer requirements

- **Excessive Resources**
  - Poor resource leveling to meet demand
  - Minimal understanding of bottlenecks

- **Unnecessary Handoff**
  - Unnecessary approvals
  - Verification loops

- **Over Production**
  - Allowing inventory to build up in front of bottleneck operations (i.e. Static Systems)

Source: Deloitte Consulting client experiences
EFFECTIVE INTEGRATION

TOC: Improve throughput by bottleneck resolution
Bottleneck operation $i$: \[
\text{max} \{\frac{\text{Demand}_i}{\text{Capacity}_i}\},
\]
Decision Making in Post Certification

Lean Engineering

P&WC Intro
NEED FOR POST-CERTIFICATION DECISION TREE

Before engine cert (P4)?

No

Yes

Pre-Cert

New requirement?

No

Yes

Repositioning

Modified requirement?

No

Yes

Improve-ment

Initial requirements met?

No

Yes

Post-Cert

Std Work, Best Practices Met?

No

Yes

New Learning

- Metrics
- KPI
- DIVE

Escape

- Pareto
- Metrics
- DIVE Resolution

Enables consistent classification
Provides basis for lean performance benchmark

Benchmark historical data
### JOB MULTI-CRITERIA VALUE INDEX

**Job value:**

\[ V_j = \sum_{i=1}^{n} w_i(c_i)v_i(c_i) \]

Where:
- \( V_j \): Multi-Attribute job value
- \( w_i \): Weight associated with criteria \( c_i \)
- \( v_i \): Value level associated with criteria \( c_i \)

<table>
<thead>
<tr>
<th>Level</th>
<th>Customer impact</th>
<th>Criticality of issue</th>
<th>Work Progression</th>
<th>Impact on business</th>
<th>Value (v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>No visible customer impact</td>
<td>Non-critical</td>
<td>(ACTUALS / ETC+ACTUAL) &lt; 10%</td>
<td>No significant NPV benefit</td>
<td>v1</td>
</tr>
<tr>
<td>Low</td>
<td>Dispatch reliability above spec, No quality or performance issues, IFSD &lt; 7, BUR &lt; 70</td>
<td>Non-critical</td>
<td>(ACTUALS / ETC+ACTUAL) &gt; 10-40%</td>
<td>Incremental NPV benefit (NRE + Warranty + FSC) &gt;5-50K$</td>
<td>v2</td>
</tr>
<tr>
<td>Med</td>
<td>MTBUR below spec Dispatch Reliability below spec, 7 &lt; IFSD &lt; 10, 70 &lt; BUR &lt; 200</td>
<td>Production, delivery issues</td>
<td>(ACTUALS / ETC+ACTUAL) &gt; 40-80%</td>
<td>Incremental NPV benefit (NRE + Warranty + FSC) 50-250 K$</td>
<td>v3</td>
</tr>
<tr>
<td>High</td>
<td>In flight shut down IFSD &gt; 10, BUR &gt; 200</td>
<td>Airworthiness safety reliability &gt; 1</td>
<td>(ACTUALS / ETC+ACTUAL) &gt; 80%</td>
<td>Incremental NPV benefit (NRE + Warranty + FSC) &gt;250K$</td>
<td>v4</td>
</tr>
</tbody>
</table>

Weight (w)

<table>
<thead>
<tr>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Given that:
5.0K$ FSC increase has a −6.7M$ consequence on project NPV value.
5.0M$ NRE increase has a −2.2M$ impact on project NPV value.
1.0Kg over target has a −0.9M$ impact on project NPV value.

Knowing that D8603-2 provides for:

- 0.163 Lb WEIGHT REDUCTION,
- $35 RECURRING and
- $178,100 NON-RECURRING

Value NOT Performing D8603-2

WEIGHT PENALTY VALUE
0.163 Lb x − 0.9 M$/1Kg = −0.07 M$ NPV

PREFERRED APPROACH
PRESERVES MORE ECONOMIC VALUE

Value Performing D8603-2

TRADE-OFF VALUE
0.035K$ x −6.7M$ NPV/5K$ FSC
+178.1K$ x −2.2M$ NPV/5MS/NRE
− 0.163 Lb x − 0.9 M$/1Kg = −0.19 M$ NPV

ANY OTHER STRATEGIC CONSIDERATIONS?
USE YOUR JUDGEMENT!!!

Note: Hypothetical Data
JOB BASED DECISION MAKING MODEL

Objective: Maximize Job Realized Value

\[ \text{Max} \sum_j O_j V_j \]

Subject to:

\[ \sum_e X_{je} = \sum_e \text{ETC}_{je} O_j \]

\[ \sum_j X_{je} \leq C_e \]

\[ \sum_j \sum_e X_{je} P_{jk} \leq B_k \]

Where:

- \( O_j \): Binary variable, 1 if job demand satisfied
- \( V_j \): Job value
- \( X_{je} \): Hours allocated by module e on job j
- \( \text{ETC}_{je} \): Demand in hours
- \( P_{jk} \): 1 if job j is related to project k, 0 otherwise
- \( C_e \): Engineering capacity
- \( B_k \): Project budgets
### DECISION MAKING IMPACT ON REALIZED VALUE

#### MONO-PERIOD MODEL

<table>
<thead>
<tr>
<th>Factor</th>
<th>Response</th>
<th>Number of Jobs Completed</th>
<th>Value Realized (or implicit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>10</td>
<td>531</td>
</tr>
<tr>
<td>Low</td>
<td>High</td>
<td>9</td>
<td>578</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>13</td>
<td>795</td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td>13</td>
<td>817</td>
</tr>
</tbody>
</table>

- Implicit value ↑ 9%
- Realized value ↑ 54%

Factor A: Post Certification budgets (low - distinct, high - combined)
Factor B: Job value (low - unitary, high - greater than 1)
FUTURE WORK

- Multi-attribute Value Index
  - Select Pilot  Done
  - Validate dimensions, criteria, weights and value levels  In Progress

- Decision Making Model
  - Generate industrial case study data  Done
  - Implement multi-period task based model  In Progress