Introduction

Presentation Outline
- Summary of Pentagon Renovation & Commissioning
- Financial Costs & Benefits Approach
- Pentagon Metrics
- Commissioning Process Lessons Learned

Summary of Pentagon Renovation & Commissioning
- 1998 Commissioning Start
- Design-Bid-Build → Design-Build
- 5 Million Square Feet Renovation
- 1 Million Square Feet New Construction
- Systems Commissioned
  - HVAC
  - Electrical Power
  - Lighting Controls
  - Life Safety

Washington Headquarters Services
Engineering & Technical Support Directorate
Quantifying Costs & Benefits: A 6 Year Check-up on Commissioning at the Pentagon
National Conference on Building Commissioning
April 19, 2006
Rebecca Ellis, Sebesta Blomberg
Wade Shankle, WHS/ETSD
Peter Stockard, Sebesta Blomberg
Charles Wendt, Sebesta Blomberg

SEBESTA BLOMBERG
Providing Technical & Business Solutions

Introduction
Project Costs

• 2006 Summary of Pentagon Renovation & Commissioning Costs

<table>
<thead>
<tr>
<th>Project</th>
<th>Area (Sq. Ft.)</th>
<th>Cx $ vs Const $ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wedge 1</td>
<td>1,077,000</td>
<td>0.8%</td>
</tr>
<tr>
<td>Remote Delivery Facility</td>
<td>215,000</td>
<td>2.7%</td>
</tr>
<tr>
<td>Metro Entrance Facility</td>
<td>21,000</td>
<td>1.1%</td>
</tr>
<tr>
<td>Phoenix (9-11 Reconstruction)</td>
<td>400,000</td>
<td>0.6%</td>
</tr>
<tr>
<td>Wedge 2+ including Basement</td>
<td>1,415,000</td>
<td>1.0%</td>
</tr>
<tr>
<td>Pentagon Athletic Center</td>
<td>150,000</td>
<td>1.2%</td>
</tr>
<tr>
<td>Pentagon Library and Conference Center&lt;sup&gt;2&lt;/sup&gt;</td>
<td>250,000</td>
<td>1.8%</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td>1.0%</td>
</tr>
</tbody>
</table>

<sup>1</sup> Wedge 1 was construction phase commissioning only. It was also the only commissioned Design-Bid-Build project. All subsequent projects were Design-Build.

<sup>2</sup> This project is in early construction at the time of this report. Final numbers are likely to be different.

Benefits of Commissioning

• Energy Benefits
  – Easy to quantify
  – Secondary importance to facility owners

• Non-Energy Benefits
  – Not-so-easy to quantify
  – Primary importance to facility owners

Non-Energy Benefits

• Assurance that owners get the building they want and are paying for
  • Smoother turn over
  • Improved comfort control
• Opportunity to monitor building performance over 1st year of operation
  • Improved building performance
• Better communication between project team members
• Reduced construction and warranty issues
Benefits Quantification Approach
- Establish the Metrics
- Mine the Data
- Derive Conservative Benefit Numbers

Potential Non-Energy Metrics
- Productivity
  - Maintenance worker hourly rate
  - Maintenance supervisor hourly rate
  - Average tenant hourly rate
  - Value of daily production
- Working Hours
  - Normal work week
  - Production hours
- Analysis Timeframe
  - One time effect
  - Life cycle effect

Mine the Data
- Potential Project Data Sources
  - Design review comments
  - Prefunctional checklist results
  - Functional test results
  - Commissioning action lists
  - Commissioning meeting minutes
  - "As built" drawings
  - Test and balance reports
  - O&M manuals

- Potential Operations Data Sources
  - Trouble call log
  - Work order log
  - Preventive maintenance records
  - Service contractor reports and invoices
Financial Costs & Benefits Approach

Derive Conservative Benefit Numbers

- **Project Benefits**
  - Reduced change orders
  - Reduced requests for information
  - Expedited problem resolution
  - On-time project completion
  - Reduced warranty calls
  - Improved perception of project success

- **Facility Benefits**
  - Reduced energy consumption
  - Decreased O&M staff time finding and correcting problems
  - Decreased O&M staff budget demand for correcting problems
  - Improved preventive maintenance
  - Improved predictive maintenance
  - Improved trouble call responsiveness

- **Tenant Benefits**
  - Staff productivity
  - Process productivity

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**Example Project Benefit Calculation**

**REDUCED REQUESTS FOR INFORMATION**

**Variables:**
- $X_o$: Labor time to administer one request for information, including reproduction and distribution of the response (hours)
- $X_c$: Labor time to administer one commissioning comment (hours)
- $Y$: Labor cost, fully loaded ($/hour)
- $Z$: Number of total commissioning comments likely to have eliminated future RFIs

**Calculation:**

\[
\text{Savings (S)} = (X_o - X_c) \times Y \times Z
\]

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**Example Facility Benefit Calculation**

**IMPROVING ACCESSIBILITY & MAINTAINABILITY OF A SPECIFIC SYSTEM**

**Variables:**
- $X_o$: Labor time to perform preventive maintenance procedures without commissioning benefit (hours)
- $X_c$: Labor time to perform preventive maintenance procedures with commissioning benefit (hours)
- $Y$: Labor cost, fully loaded ($/hour)
- $Z$: Number of affected systems
- $W$: Frequency of procedure (procedures/year)
- $V$: Period of time over which procedure will be performed (years)

**Calculation:**

\[
\text{Savings (S)} = (X_o - X_c) \times Y \times Z \times W \times V
\]
Financial Costs & Benefits Approach

Derive Conservative Benefit Numbers
- Example Tenant Benefit Calculation

**IMPROVING BUILDING OCCUPANT STAFF PRODUCTIVITY**

**VARIABLES:**
- \( x_0 \): Productive labor time per person without commissioning benefit (hours/week)
- \( x_c \): Productive labor time per person with commissioning benefit (hours)
- \( a \): Number of affected tenants (# of people)
- \( b \): Tenant labor cost, fully loaded ($/hour)
- \( c \): Work hours per year (hours/year)
- \( d \): Period of time over which benefit will be realized (years)

**CALCULATION:**

\[
\text{SAVINGS (S)} = (x_c - x_0) \times a \times b \times c \times d
\]

**Benefits at the Pentagon Renovation**

**First 18 Months (2000):**
- 68 Benefits Evaluated
- 23 Benefits Quantified
- All Non-Energy Benefits

**Benefits at the Pentagon Renovation**

**2006 Benefits Analysis Status:**
- 1,672 Benefits in Database
- 23 Benefits Quantified

**Breakdown of Benefits by Project Phase:**
- Design Phase: 54%
- Construction Phase: 46%

**Relative Value of Quantified Design & Construction Benefits:**
- $\text{Total Design Phase Benefits per Total Benefits}$: 55%
- $\text{Total Const Phase Benefits per Total Benefits}$: 45%
Benefits at the Pentagon Renovation

2006 Benefits Analysis Status

• 1,672 Benefits in Database
• 23 Benefits Quantified

Breakdown of Benefits by Type

<table>
<thead>
<tr>
<th>Category</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Benefit</td>
<td>18%</td>
</tr>
<tr>
<td>Facility Operations</td>
<td>70%</td>
</tr>
<tr>
<td>Tenants/Productivity</td>
<td>12%</td>
</tr>
</tbody>
</table>

Overall Cx Cost per Identified Benefit

$2,500/Benefit

Benefit Values

- $ Value per Quantified Benefit (All) $125,000/Benefit
- $ Value per Benefit/Square Foot (All) $0.57/Benefit/Sq Ft
- $ Value per Quantified Design Phase Benefit $200,000/Benefit
- $ Value per Design Phase Benefit/Square Foot $0.85/Benefit/Sq Ft
- $ Value per Quantified Construction Phase Benefit $83,000/Benefit
- $ Value per Construction Phase Benefit/Square Foot $0.35/Benefit/Sq Ft

Identified Benefits per Square Foot

- Square Foot per All identified Benefits 1,900 Sq Ft/Benefit
- Square Foot per Identified Design Phase Benefit 3,500 Sq Ft/Benefit
- Square Foot per Identified Const Phase Benefit 4,100 Sq Ft/Benefit

What Does this Mean to You?

• 1,672 Benefits in Database
• 23 Benefits Quantified

METRICS

- $ Value per Benefit per sq ft
- $ Value per Benefit per sq ft
- $ Value per Benefit per sq ft
- $ Value per Benefit per sq ft

<table>
<thead>
<tr>
<th>Project Size (Sq Ft)</th>
<th>Cost per Benefit per sq ft</th>
<th>Value per Benefit</th>
<th>Total Benefits</th>
<th>100%</th>
<th>Total Cost</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>50,000</td>
<td>$150</td>
<td>$7,500</td>
<td>$750,000</td>
<td>15%</td>
<td>$75,000</td>
<td>15%</td>
</tr>
<tr>
<td>100,000</td>
<td>$300</td>
<td>$30,000</td>
<td>$3,000,000</td>
<td>60%</td>
<td>$300,000</td>
<td>60%</td>
</tr>
<tr>
<td>400,000</td>
<td>$600</td>
<td>$240,000</td>
<td>$24,000,000</td>
<td>48%</td>
<td>$480,000</td>
<td>48%</td>
</tr>
</tbody>
</table>
Lessons Learned Summary
- Planning & Scheduling Commissioning
- Project Phasing
- System Un-Readiness for Testing
- Failure Definition
- Failure Management
- Best Value Commissioning Documentation
- Test Sampling Strategies
- Best Value Testing Strategies
- Flexibility in Commissioning Approach
- Testing & Verification Techniques in Mission Critical Facilities
- Coordination with other Owner-Contracted Suppliers, Contractors & Vendors
- Training Building Users & Operators

Lessons Learned
• Planning and Scheduling Commissioning
  ▪ Single master construction schedule
  ▪ Commissioning milestones defined in specification
• Project Phasing
  ▪ Number of phases
  ▪ Size of phases

Lessons Learned
• System Un-Readiness for Testing
  ▪ System to be tested is not complete or ready
  ▪ Other systems’ status impacts ability to conduct scheduled performance test
• Failure Management
  ▪ Tie contractor payment to test metrics
  ▪ Is commissioning complete when testing is complete? Or when testing is successful?
Lessons Learned

- Best Value Commissioning Documentation
  - Performance requirements and criteria
  - Design intent documents
  - Systems operations and maintenance manuals
  - Master test procedures for Re-commissioning
  - Commissioning and De-commissioning Plans
  - Training plans, materials, and videos
  - Lock-out, Tag-out procedures
  - As built drawings

QUESTIONS?