Mid-Atlantic Data Center 5

Ashburn, Virginia

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Senior Thesis Presentation 2009

The Pennsylvania State University

B.A.E./M.A.E. Program

Construction Management

Presentation Outline

Function:	Data Center
Size:	360,000 SF Total
	180,000 SF Raised Floor
	23,000 SF Office Space
Height:	2 Stories
Redundancy:	N+2
Construction:	2 Phases
Schedule:	February 2008 – March 2009
Delivery Method:	CM @ Risk w/ Cost + Fee

Project Overview

Project Team

Owner

DuPont Fabros Technology

Construction Manager

HOLDER

Architect

DVA Architects

MEP Engineer

CCG FACILITIES INTEGRATION INCORPORATED

Structural Engineer

RATHGEBER/GOSS ASSOCIATES Consulting Structural Engineers

Electrical System

***Total System**

- 34.5 kV Total Utility Power
- 59.6 MW Total Electrical Load

***Equipment per phase**

- (8) 600 V Pad-Mounted Transformers w/ Integral VFI
- (16) 2500 kW Engine-Generators
- (16) UPS Systems

Project Overview

Mechanical System

***Equipment per phase**

- (3) 14,400-23,000 cfm AHU's in Chiller Plant
- (8) 1080 ton Chillers
- (8) 3240 gpm Cooling Towers
- (240) 18,000 cfm CRAH's Units
- (2) 50,000 gal Underground Diesel Storage Tanks



Background

- Owner views as one project, Project Seven, including 3 data centers
  - Northwest Data Center (NWDC) in Santa Clara, CA
  - Northeast Data Center (NEDC) in Piscataway, NJ
  - Mid-Atlantic Data Center 5 (MADC5) in Ashburn, VA

Problem

1. Project Seven has been completely suspended.
   - NWDC August 2008
   - NEDC October 2008
   - MADC5 November 2008
2. DuPont Fabros maintains several completely leased data centers producing steady revenue.

Goals

1. Evaluate:
   - Current economy and Project Seven status
   - Project schedule & cost projections
2. Develop a project execution plan to successfully complete Project Seven in a down economy.

Industry & the Economy

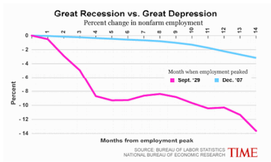


Economy

September 2007:	Economy slowly declines to a temporary halt.
January 2008:	Begins another continual decrease.
November 2008:	Government finally declares a recession.

Causes:

1. "Credit Crunch"
2. Federal Reserve response to a tightening of available capital



Construction Industry

- Trouble securing loans and allocating funds
  - Operate on rolling-over short-term loans
- Projects are suspended, shut down, postponed

Market Segment	2008	2009
Commercial/Industrial		
Hotels	5.1%	-3.1%
Office Buildings	1.7%	-3.7%
Industrial Facilities	-3.8%	0.4%
Retail	-5.7%	-3.6%
Institutional		
Healthcare Facilities	5.6%	3.6%
Education	5.5%	-0.1%
Public Safety	3.5%	0.4%
Amusement/Recreation	1.4%	-2.6%
Religious	-1.0%	4.0%

Source: (DiLouie, 2008)

Existing Schedule/Cash Flow

Existing Schedule/Cash Flow

Original Plan

Project Seven Duration: **20 months**
Start: February 2008
Finish: September 2009

Project	Start	Finish	Orig. Duration (months)	Overlap (months)
MADC5	Feb 2008	Apr 2009	15	-
NEDC	May 2008	May 2009	13	11
NWDC	July 2008	Sept 2009	15	10
Total	**Feb 2008**	**Sept 2009**	**20**	**-**

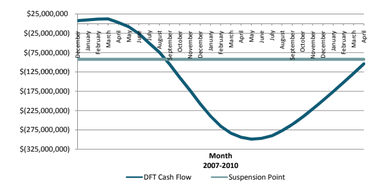
Actual Plan

Project	Start	Suspended	Finish	Orig. Duration (months)	Suspension (months)	Total Duration (months)
MADC5	Feb 2008	Aug 2008	July 09	15	3	18
NEDC	May 2008	Oct 2008	Mar 10	13	10	23
NWDC	July 2008	Nov 2008	Apr 10	15	20	35
TOTAL	**Feb 2008**	**-**	**Apr 10**	**-**	**-**	**40**

After temporary suspensions and restarts, the project duration is **40 months**.
Start: February 2008
Finish: April 2010

Existing Schedule/Cash Flow

Original Plan

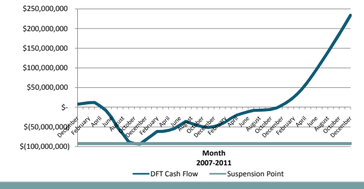


- Total Construction Cost = $520 million.
- May 2009 = ultimate low net income of -$298.9 million.

Actual Plan

First Suspension (NWDC): -$50.4 million
Second Suspension (NWDC): -$87.9 million
Third Suspension (MADC5): -$92.5 million

-$92.5 million deemed the "suspension value" – stay above to complete Project Seven



P7 PLAN

Evaluate

- Owner's construction expenditures
- Construction schedule
- Existing revenue

Successful completion of Project Seven could occur:

1. Prolong each project schedule.
2. Maintain durations and sequence projects with a finish-to-start relationship.
3. Maintain durations with less of an overlap than the original plan.

Project Execution Plan

Option 1 | Prolong Projects

1. Schedule:
   - Decrease in the amount of work performed each month
   - Lengthen the OPS significantly
2. Cash Flow:
   - Cost increase in equipment rental, labor, GC's, and O&P
   - Delay in receiving revenue from each project due to leased spaces.
     - Limits the amount of overlap between each project
     - OPS further delayed to remain above the suspension point

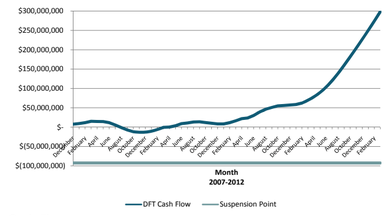
Project Execution Plan

Option 2 | Maintain Durations w/ Sequential Projects

1. Schedule:
   - Projects constructed with finish-start relationship
   - Lengthen the OPS significantly

Project	Start	Finish	Orig. Duration (months)
MADC5	Feb 2008	Apr 2009	15
NEDC	May 2009	May 2010	13
NWDC	June 2009	Aug 2011	15
Total	**Feb 2008**	**Aug 2011**	**43**

Project Execution Plan



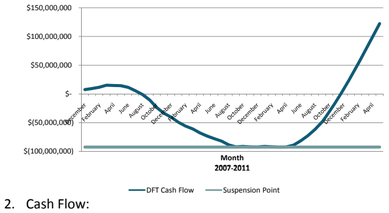
2. Cash Flow:
   - Same cash flow as actual plan
   - Remains above suspension point
   - Delays potential revenue

OPTION 3 | MAINTAIN DURATIONS W/ LESS OVERLAP

1. Schedule:
   - Less extreme project overlaps – finish-start
     - Original = NEDC 11 month NWDC 10 month
     - New = NEDC 5 month NWDC 2 month
   - Shorter OPS by 6 months

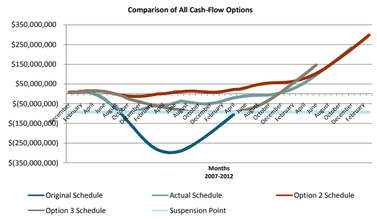
Project	Start	Finish	Orig. Duration (months)	Overlap (months)
MADC5	Feb 2008	Apr 2009	15	-
NEDC	Nov 2008	Nov 2009	13	5
NWDC	Sept 2009	Nov 2010	15	2
Total	**Feb 2008**	**Nov 2010**	**34**	**-**

PROJECT EXECUTION PLAN



2. Cash Flow:
   - No added costs or suspension
   - Nears suspension at completion of NEDC and start-up NWDC
   - Receive revenue earlier causing drastic increase in cash flow at the end
     - Able to start another project

Given the economic times, the possibility of successfully constructing all three projects is nonexistent.



RECOMMENDATIONS

Option	Start	Finish	Orig. Duration (months)	Income at Nov 2010	Add'l Revenue
Actual Project Duration	Feb 2008	May 2011	40	$452,599,560	$0
1. Prolong Projects	Feb 2008	?	?	-	-
2. Maintain Duration with Sequential Projects	Feb 2008	Aug 2011	43	$457,185,960	$4,586,400
3. Maintain Durations with Less Overlap	Feb 2008	Nov 2010	34	$485,850,960	$33,251,400

Maintain the schedule durations with less of an overlap

- **6 months** shorter than actual schedule
- Produces **$33,251,400** of additional revenue
- Future development

I. Project Overview
II. Industry & the Economy
  I. Existing Schedule & Cash Flow
  II. Project Execution Plan
  III. Conclusions & Recommendations
III. Alternative Concrete Construction Process
  I. Constructability Analysis
  II. Schedule Analysis
  III. Cost Analysis
  IV. Conclusions & Recommendations
IV. Energy Efficient Technologies
  I. Thin Film PV's
  II. Water-side Economizers
V. Conclusions & Recommendations
VI. Q & A

Alt. Concrete Constr. Process

Background

- Concrete Utilization:

Foundation	Trenches – Mech. Rms. & Computer Rms.
Equipment Pits	Raised Slab in Engine-Generator Rms.
Slab-on-Grade (SOG)	Topping Slabs

- Computer Room Concrete Design
  - 6" SOG
  - Trenches along walls adjacent to CRAH's
  - Dimensions: 3'-0" deep x (3'-0" - 7'-0") wide
- Mechanical Trenches:
  - Chilled Water Pipes sized 8"-30" dia.
  - Connect CRAH's and chillers
  - Leak containment
  - Create more space below raised floor
  - Metal channels to support pipes

Alt. Concrete Constr. Process

Existing Concrete Process

- Contractor On-Site
  - May 28, 2008-Oct. 28, 2008 — 110 Days
  - Contract Value — $7.2 Million

Goals

1. Reduce concrete contractor time on-site & contract value by removing trenches & replacing with a continuous slab
2. Reduce OPS & produce significant savings for the owner

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Constructability Analysis

Underground Conduit

Requirements	Trenches		No Trenches
Coordination	•UG Electrical •UG Plumbing	•Storm Lines •Sanitary Lines	•None – SOG on top of underground systems
Excavation	•Underground systems + Trench depth **Lines crossing trenches must be lower*		•Underground systems

Chilled Water Piping

- No bridging required for new design
  - Rest on slab mounted tube steel
- Leak containment only 6" as opposed to 3'-4' with trenches
  - Require flat/level slabs to prevent ponding

Constructability Analysis

Access Floor

Maximum Tile: 24"x24"
Piping Diameter: 8"-30"
(+ insulation)

- Metal channels to bridge the piping
  - Less bridging required
- Quicker/easier to install on a continuous surface
  - Less worries about falling and maneuvering

Precast UPS Pits

- Quicker & easier to install
- Install Options:
  - **Pre-coordination – Rough-ins**
  - Post-coordination – Core-drill

Schedule Analysis

➢Alter sequences for a majority of the rooms

➢Precast dictates the OPS
- •Original Schedule: Sporadic concrete pours
- •New Schedule: Continuous concrete pours

➢Allow larger duration between precast erection and concrete pour sequences
- •Eliminates the chance of pours catching up to precast
- •Allows for smoother, continuous pour sequences
- •Crews constantly working and no wasted time between pours

➢Delay subcontractor start date to June 18, 2008 vs. May 28, 2008

Sequence	Original Duration	New Duration
Computer Room	5/28/08 – 8/15/08 (50 days)	7/2/08 – 8/6/08 **(26 days)**
UPS Room	6/12/08 – 8/15/08 (47 days)	6/23/08 – 8/1/08 **(30 days)**
Mechanical Room 2	8/1/08 – 8/22/08 (16 days)	8/1/08 – 8/14/08 **(10 days)**
Admin. Office Area	8/4/08 – 9/16/08 (32 days)	8/13/08 – 9/19/08 **(28 days)**
Phase II SOG	9/11/08 – 2/10/09 (109 days)	9/18/08 – 12/2/08 **(54 days)**
Topping Slab	6/4/08 – 10/14/08 (95 days)	8/14/08 – 10/14/08 **(44 days)**
Transformer Yard	10/17/08 – 10/28/08 (8 days)	8/28/08 – 9/8/08 **(8 days)**

Schedule Analysis

Schedule Analysis

Other Affected Activities

Sealing Concrete
SOGs sealed earlier

Access Floor Install Time
5 days to 4 days

CWP & Insulation Install Time
Piping : 15 days to 10 days
Insulation: 5 days to 3 days

Medium Voltage 1 (MV)
MV equipment installed earlier
Level 3 commissioning

Set CRAH Stands/Units – earlier delivery

Schedule Analysis

Results

Concrete Contractor Savings 65 days
OPS Savings 15 days

➢Discrepancy due to activates not on critical path & other trade sequences
- •Precast Concrete
- •Electrical Equipment
- •Power

➢Precast and concrete dictate the ability to install the equipment

➢All equipment must be in place before starting commissioning
- •Only go as fast as the last UPS room

Cost Analysis

Construction Cost Comparison

	Material	Labor	Equipment	Total
Original Process	$ 5,488,661	$ 1,142,884	$ 325,848	$ 7,227,393
Alternative Process	$ 5,140,523	$ 1,096,322	$ 316,720	$ 6,599,565
% Savings	**6%**	**4%**	**3%**	**9%**

Savings = **$627,828**

- Precast UPS equipment
- Removing trenches

Other cost savings:

- Overhead and profit,
- Personnel
- Reduction in contractual fees.

9% REDUCTION

General Conditions Savings

Company	Total Cost	Duration (wk)	Unit Cost ($/wk)	Savings (wk)	Savings ($)
Holder Construction *Construction Manager*	$ 7,025,338	58	$ 121,000	3.0	$ 363,000
Dynalectric (Dyna) *Electrical Contractor*	$ 1,756,335	58	$ 30,000	3.0	$ 90,000
John J. Kirlin (JJK) *Mechanical Contractor*	$ 1,756,335	58	$ 30,000	3.0	$ 90,000
				TOTAL	**$ 543,000**
				HCC % Savings	**3%**
				Dyna % Savings	**5%**
				JJK % Savings	**5%**

**Dyna and JJK total GC value is approximately 25% of HCC's value (per HCC estimate)*

Cost Analysis

Conclusions/Recommendations

Utilize a continuous slab design in lieu of trenches.

Constructability

- Less coordination efforts due to a simpler design and less material.

Schedule

- Concrete subcontractor onsite duration reduced **65 days**
- Reduced OPS by 15 days

Cost

This system saves the owner **$1,170,828** in construction costs.

- Concrete Contract Savings = $627,828
- Project General Conditions Savings = $543,000

Background

- MADC5 will be certified LEED Gold
- Data centers still consume a great deal of energy and struggle with efficiency issues.
- Escalating energy costs – harsher carbon emission policies

- Developers seeking to reduce energy costs and build "Green"

Goals

1. Evaluate state-of-the-art electrical & mechanical technologies:
   - Thin-Film Photovoltaic Systems for building lighting load
   - Water-Side Economizers
2. Implement systems that produce the following results:
   - Create a more energy efficient building
   - Reduce energy costs
   - Relatively quick payback period (less than 10 years)

Research

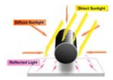
- CIGS (Copper-Indium-Gallium-Selenium)
  - Semi-conductor light absorbing material
  - Microstructure allows for cells to be a few micrometers thin
- Most efficient solar technology available in the market
  - 19.5 % efficiency

Solyndra

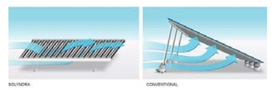
- CIGS technology inside cylindrical PV panels
- Panel Dimensions: 6' x 3.5'
- (40) 1-in. diameter cylinders per panel

Product Selection

- Greater rooftop coverage

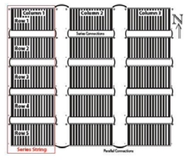


- More electricity per rooftop
- Wind performance
  - Negligible wind loads
  - Sustain 130 mph



DESIGN ANALYSIS

1. Determine the maximum amount of panels that could fit onto the roof, which includes a main roof and a second level mezzanine roof.
   - Main Roof = 236,000 SF
   - Panel Size = 6 ft x 3.5 ft = 21 SF
   - **11,000 panels**
2. Determine the amount of panels in each array.
   - Connected in Series = **5 panels**
   - Connected in Parallel = **3 strings**
3. Determine the amount of panels required to power 508 kW building lighting load.
   - Requires 19 Arrays @ 27.3 kW/array
   - Array = 150 panels
   - **2850 Panels** = 518.7 kW



DESIGN ANALYSIS

4. Determine the amount of inverters required for the system.
   - Typical:260kW inverter
   - For a factor of safety: **3 inverters**
5. Determine the wire and conduit sizes of the conductors connecting the combiner boxes to the inverters.

DC Wires – Combiner Boxes to Inverters

From Combiner	To Inverter	# of Arrays	Cable Size	Conduit Size
AF01	1	10	**300**	**2"**
AF02	1	10	**4/0**	**1-1/2"**
AF03	1	10	**3/0**	**1-1/2"**
AF04	1	10	**2/0**	**1-1/4"**
AF05	1	10	**1**	**1"**
AF06	1	10	**2/0**	**1-1/4"**
AF07	1	10	**4/0**	**1-1/2"**
BF01	2	10	**300**	**2"**
BF02	2	10	**250**	**2"**
BF03	2	10	**4/0**	**1-1/2"**
BF04	2	10	**2/0**	**1-1/4"**
BF05	2	10	**1/0**	**1-1/4"**
BF06	2	10	**3/0**	**1-1/2"**
BF07	2	10	**4/0**	**1-1/2"**
CF01	3	10	**350**	**2"**
CF02	3	10	**300**	**2"**
CF03	3	10	**4/0**	**1-1/2"**
CF04	3	10	**3/0**	**1-1/2"**
CF05	3	10	**2/0**	**1-1/4"**

THIN-FILM PV'S

CONSTRUCTABILITY ANALYSIS

➢Panel Weight:	70 lbs (3.3 lbs/ ft^2 distributed load)
➢Mounting:	Self-ballasted No roof penetrations or anchoring 9" above roof membrane
➢Wiring:	Prewired for connection to each other #12 AWG between panels and combiner boxes
➢Safety:	Voltage is present when sunlight is present

SCHEDULE ANALYSIS

Labor Rate for 5-man Crew:	15 panels/hour
Number of Panels:	2,850
Installation Duration:	190 hrs = **24 Days**
Affected Activities:	
Roof Completion	Sept. 12, 2008
Level 3 Commissioning start-up	Dec. 1, 2008
Available Time Period:	2.5 months

Thin-Film PV's

Thin-Film PV's

Cost Analysis

Funding Opportunities

➢Business Energy Investment Tax Credit
- 30% tax credit on solar energy systems

➢Local Option Property Tax Exemption for Solar
- VA - solar energy equipment can be exempt from property taxes

Description	Cost
System	$3,316,700
Panels (2,850)	
Wiring from Panels to Combiner Boxes	
Combiner Boxes	
Inverter	
Labor	
Monitoring System	$22,900
20-yr Warranty for Inverter/System	$62,000
Permitting	$5,000
Electrical Installation (Conduit & Labor for Combiner Box to Grid)	$320,400
TOTAL INSTALLATION COST	**$3,727,000**
Installation Cost $/W	**$7.39**
Incentives	
Business Energy Investment Tax (30%)	$1,118,100
Local Option Property Tax Exemption for Solar	$0.00
Post Incentive Installation Cost	**$2,608,900**
Installation Cost $/W	**$5.03**

PV Avg. Power Output (kWh/yr)	Electricity Cost ($/kWh)	Total Savings	Savings (lbs of CO_2/yr)
687,796	0.068	$46,770	962,914
With Future Proposed Carbon Tax			
687,796	0.1762	$121,190	962,914

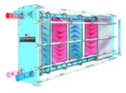
Total Cost
$2,608,900

Payback
Current 55.8 years
Carbon Tax 21.5 years

Recommendation
Building volatility & extreme payback
vs.
Sustainability and protecting the environment

Water-Side Economizers

Water-Side Economizers



Purpose
➢Allows cooling towers to produce chilled water when weather conditions permit.
➢Bypass chillers if wet-bulb temperature is below 24°F

How
➢Pre-cools the chilled water prior to flowing into the evaporator
➢Heat transfer from the CHWR to the CW loop from the cooling tower.
➢Lowers the temperature of the water entering the evaporator, reducing the chiller load and energy consumption.

➢Ideal in temperate climates, i.e. Washington, D.C.

➢No schedule impact

Wet Bulb Temp.	Cooling Load (tons)	Cooling Plant Efficiency (kWh/ton)	Electricity Cost ($/kWh)	Load Hours (h)	Savings per Chiller	Total Savings	Savings (lbs of CO_2/Plant)
24°F	840	0.5	0.068	803	$22,934	$183,472	4,704
With Future Proposed Carbon Tax (+$0.1082)							
24°F	840	0.5	0.1762	803	$59,425	$475,400	4,704

Total Cost
$376,000

Payback
Current 2.05 years
Carbon Tax 9.5 months

Recommendation
Implement (8) water-side economizers for Phase I construction.

Conclusions

Project Execution Plan
- Maintain schedule durations with less overlap = No Suspension
- Shorter construction schedule (6 months) & $ 33,251,400 additional revenue
- Future development

Alternative Concrete Construction Process
- Continuous slab system
- Concrete contractor off-site 65 days earlier & accelerates OPS 15 days
- $1,170,828 Owner savings

Thin-Film Photovoltaic System
- Reduce electrical system grid dependency & energy consumption
- 55.8 year payback

Water-Side Economizers
- Reduce mechanical system energy consumption
- 2 year payback

Recommendations

Analysis	Cost Savings	Schedule Savings	Additional Savings
New Execution Plan*	-	6 mo.	$33,251,400 Additional Revenue in 6 months
Continuous Slab Design*	$1,170,828	0.5 mo.	65 days for the concrete subcontractor
Thin-Film PV's	($2,608,900)	No effect	$183,472 in electricity cost & 962,914 lb of CO_2 saved annually
Water side Economizers*	($376,000)	No effect	$46,770 in electricity cost & 4,704 lb of CO_2 saved annually
* Savings - 3 systems	$794,828	6.5 mos.	
Total Savings	(-1,814,072)	6.5 mos.	

Questions?

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