Brocade & Cal Poly Project Challenge

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General Information

Introduction

Multidisciplinary projects occur in the building industry almost everyday. The most successful engineering companies work with a variety of discipline backgrounds to increase their support on all components of the project. Within the architectural engineering (ARCE) undergraduate program at the California Polytechnic State University in San Luis Obispo, students are challenged to take courses outside their major curriculum. Students are required to take business economics, computer, electrical and mechanical engineering courses. More importantly, as students learn about the different disciplines, they build on basic concepts and background knowledge that enable successful collaboration with other professionals.

The purpose of the Brocade Cal Poly Project Challenge is to design a new data center that is efficient, scalable, and cost effective for Brocade's Colorado campus. Architectural engineering students work with electrical, mechanical and finance students to collaborate in designing: the power and cooling system of the IT racks and servers, the structure of the building holding all of the equipment, and the financial model needed to build the center. With guidance from current Brocade employees, students are encouraged to design the most cost and energy efficient data center possible.

Background

Brocade is based out of San Jose, California and has over 100 different locations all over the world. Brocade is a technology company that specializes in data and storage networking products. Brocade is committed to energy efficiency and sustainability. Their new San Jose campus recently received a LEED Gold Award based on its environmentally friendly design.

Brocade's second largest site is located in Broomfield, Colorado. The site needs additional space due to increased business, particularly in their data center, where Brocade develops and tests its products. The current set up does not provide the appropriate infrastructure to efficiently address current business or future growth. The overall goal of the project is to help Brocade develop the infrastructure for a new data center. The project should include state-of-the-art technology to provide the company's needs for continual growth, while maintaining it's commitments to energy efficiency and sustainability.

Objectives and Requirements

The objective is to design a new a data center to support Brocade's research and development, including product testing rack laboratories. The center should include innovative ideas to lower both initial construction costs and operation costs, while achieving highly efficient and best in class Power Utilization Effectiveness (PUE). The building needs to be designed with scalability and flexibility, allowing for racks to be added, as well as allowing for redundancy to be incorporated through its life. The building must also be financially feasible, taking into consideration all associated costs.

The project includes requirements pertaining to power, cooling, and an efficient redundancy system. All of these issues need proper consideration to design an appropriate space for the data center. The main focus of this project is to optimize the electrical and mechanical system.

The data center should also be designed under space requirements including an initial space for 150 racks. Once fully operational, the data center will have increments of 150 racks to reach 600 total. The layout should maximize useable space within the labs. Lastly, the space should be designed to support 50 engineers working within the labs.

The Architectural and Civil Engineering Requirements of the project are listed below and can be found in the appendix:

- Gravity design loads (based on rack load bearing capacity and power and cooling equipment) providing supporting calculations
- Architectural layout or floor plan of placement of racks and columns in the lab
- Structural material selected and supporting reasoning for selection (e.g. steel, concrete, pre-stressed concrete, timber, masonry, etc.)
- 3D model of building
- Single story or multistory – Reasoning for determination
- Location of building within the provided lot
- Structural system designed –Provide supported calculations
- Use the appreciate design guidelines (e.g. Load and Resistance Factor Design (LRFD), International Building code, Manual of Steel Constructions, etc.)

Team Members

The team consists of sophomore to senior year Cal Poly engineering students and one business student. The team was reorganized several times in order to give all teams a fair opportunity in the competition. The Brocade and Cal Poly Project Challenge received over 100 participants interested in competing, however only 30 participants followed through to the end.

Our team had at least one member from each discipline, allowing the team to spread workload and research according to discipline. All of the members listed below volunteered for the competition with the exception of both seniors on the team, who had the opportunity to fulfill their senior project requirements.

Name	Discipline	Year
Nikhila Perugupalli	Industrial Engineer	Sophomore
Jennifer Huckleberry	Business Finance	Senior*
Sourabh Katti	Electrical Engineer	Junior
Azra Skeljo	Electrical Engineer	Sophomore
Theodore Newman	Mechanical Engineer	Sophomore
Cinthya Mendez	Mechanical Engineer	Sophomore
Andy Vallejo	Architectural Engineer	Senior*

*** Fulfilled senior project requirements**

Team Solution

The team's plan was to focus extensive time and effort early in the design phase of the project, in order to allow sufficient time to examine the different ideas and systems. Given the limited amount of information provided, the team needed to complete early research and ask the client questions to gain further understanding of the project.

Each member of the group separated responsibilities according to their discipline. Once a week, the entire group would agree on a time and place to get together and share each individual's weekly research and ideas. To help with the communication process between the weekly meetings, the team created a Facebook group in addition to exchanging phone numbers and emails.

Timeframe

The project began the third week of January and the presentation date was scheduled the first week of March. Providing a time frame of approximately seven weeks for project completion. Below is a timeframe of how the weeks were divided in order to complete the design of the data center.

- Request for Proposal (RFP) (problem statement) – January 17, 2013
- Request for Information (RFI) period – (2 weeks)
- Design Development – (4 weeks)
- Reports Completion – March 5, 2013
- Preliminary Presentation at Cal Poly – March 5, 2013
    - 30 minute presentation
- Final Presentations/Interviews at Brocade San Jose Site – March 8, 2013
    - 30 minute presentation

Design Development

The following design development outlines the structure of the data center and the electrical and mechanical system designs can be found on the team's report in the appendix.

Material Selection and Comparison

Gravity Framing System

The gravity framing system is intended to support the roof and floor loads of a building. To select the structural material for the data center, it was important to find a framing system that could resist heavy snow and mechanical roof loads, while minimizing the number of framed members. As recommended by the mechanical engineering students in the group, in order to cool the racks and servers and operate under appropriate temperatures, multiple fans and pumps will be installed on the roof, increasing the roof loads dramatically.

Typical Steel Joist and Girder

Using typical steel joist and girders provides for a more efficient framing with system with fewer members than timber. Simple connections will save design and building time when compared to reinforced concrete, providing a quicker construction time.

Structural Material: Recycled Steel (Sustainable Features)

Not only is steel a non-combustible material, but recycled steel is actually cheaper in cost with no change in the quality and strength of the material. At a glance, recycled steel may seem like a skeptical choice of material due to the unappealing aesthetics of used steel, but a simple spray-on paint could be a quick and cost effective solution.

Open-Web Steel Joist

Open-Web steel joists maximize the number of racks inside the data center with room for expansion and density growth. This class of material can be designed to have longer spans, minimizing the number of columns within the labs. Spans can be a long as 56ft wide, which is an ideal solution to fit a total of 600 racks inside the center. Open-web steel joists are typically pre-manufactured which helps decrease construction time.

Roof Steel Deck with Rigid Insulation

One of the major criteria of the data center's electrical and mechanical operations is to keep the system from overheating. A roof steel deck with a rigid insulation is intended to keep out any external heat during Colorado's hot summers, which can reach up to 100 degrees Fahrenheit.

Lateral Framing System

The lateral framing system resists governing lateral forces such as wind or seismic. Building the data center in Broomfield, CO resulted in governing wind loads. Using steel as the main structural material, the framing system will designed to be ordinary concentric braced frame system.

Ordinary Concentric Braced Frame (OCBF)

Some of the advantages of OCBF are that it provides for an open layout, eliminating the use of shear walls scattered throughout the structure. The goal is to maximize the useable space of the data center while resisting the governing wind forces; therefore the fewer interior walls designed, the more space designated for the racks. OCBF is also cheaper in cost than a Moment Frame.

Site Location

The location of the proposed data center within the provided lot is seen in Figure 1 (below). Brocade's second largest branch is located in Broomfield, Colorado and the current data center infrastructure is in need of an expansion. The existing site includes acres of available space surrounding current infrastructure. The site is home to the branch's main office building, which includes: offices, labs, conference rooms, and a data center. The site also has a large parking lot at half-capacity and a small pond off of Brocade Parkway and Simms Street.

Fig. 1: Proposed Site Location for Data Center

As I investigated the civil plans provided by Brocade, I realized the location of the Data Center has a direct effect on the operational and cost efficiencies. The farther the center is placed from the nearest electrical utility, the higher the cost of equipment to power the building; therefore it is important to locate the center somewhat near the electrical utility, while still proportional to headquarters. The site includes a small central plant at the south end of the main office that is currently functional. Brocade verified that the current site includes ample and reliable power to extract from its current utility location.

An important consideration of the proposed site of the new center is the operational and cost efficiencies. The proposed site considers: small commuting distances for employees and outside support vendors between the main office and data center, close proximity to the electrical utility, and the use of the general parking lot currently on-site. The site also minimizes traffic congestion and is already located in a remote area away from surrounding neighborhoods.

Architecture

Floor Plan

A building type can affect occupancy costs, flexibility for expansion and facility maintenance. The proposed structure avoids multiple stories and areas with small bays to maximize the space and versatility of placing the racks. The floor plan of the data center in Figure 2 (below) depicts the spacing and size of the building bays and layout.

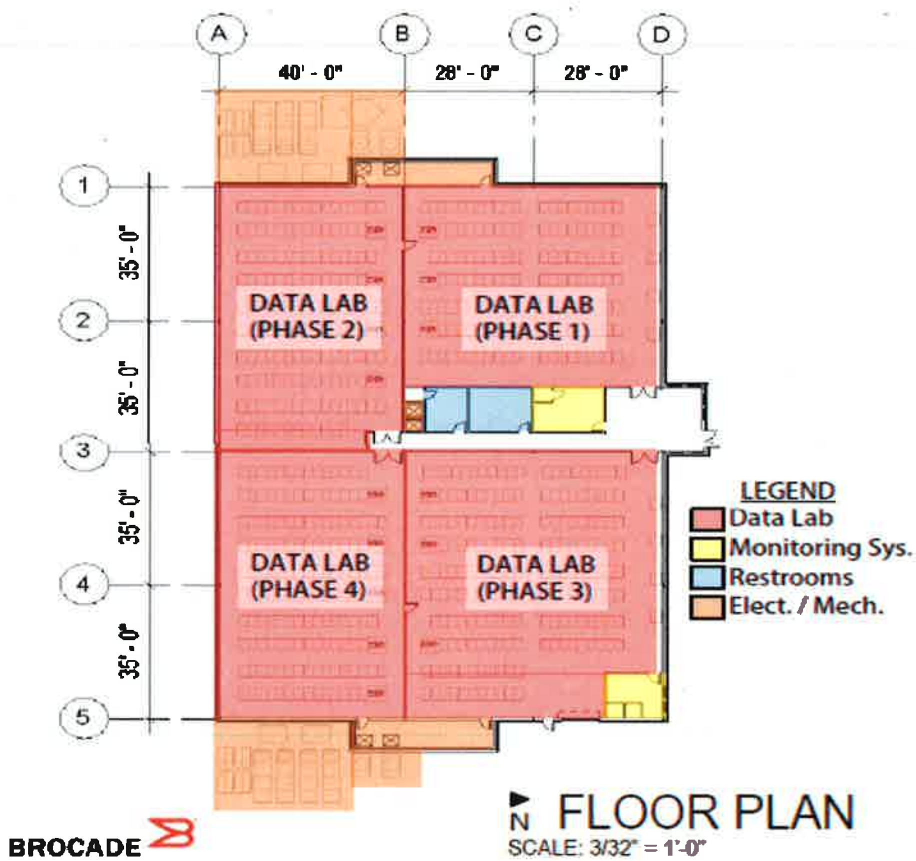

Fig. 2: Floor Plan with Build Phases

The building bays were designed for large column spacing between 40 to 56 feet. Inside the center the ceilings were given 14-foot clearance, to provide plenty of room for rack height requirements, electrical raceways and other mechanical equipment to keep the labs cool. The total square footage of the building is approximately 14,000 sq. ft.

Exterior / Interior Building

The exterior of the building is a brick veneer with steel stud framing (see fig. 3). The exterior is designed for aesthetic purposes to match the existing main office on site, along with the majority of the buildings in the state of Colorado (fig. 4). The single-story structure includes limited amount of windows, which helps lower cooling operation costs by minimizing the amount of natural sunlight entering the building. The interior walls of the data center are finished and fire rated between all rooms. The rooms are exposed to the insulated roof deck at the ceiling, keeping hot weather out.

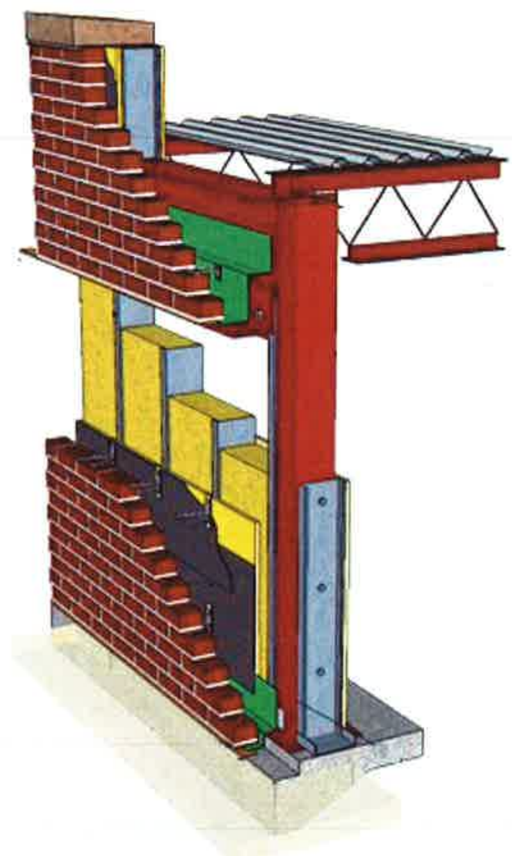

Fig. 3: Brick Veneer with Steel Stud Framing

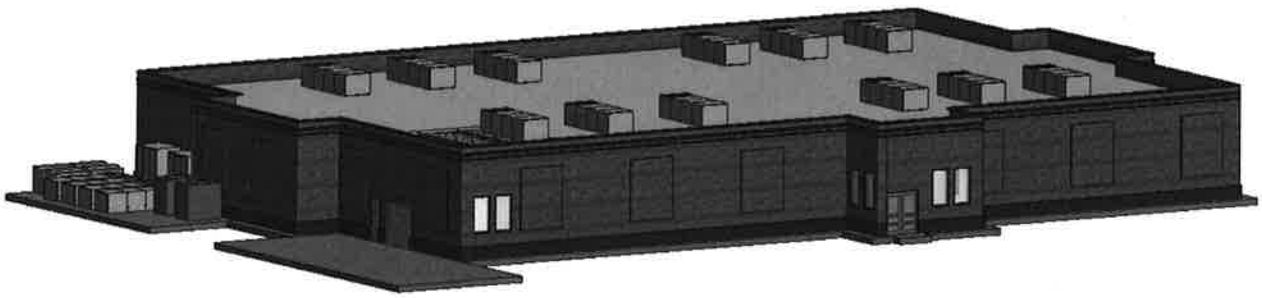

Fig. 3: Northeast Birdseye View of New Data Center

Building Safety Features

Once construction is complete, the data center will operate with 150 racks. The center will then expand its number of racks every 2 years in increments of 150 per phase (seen in Fig. 2). Ten years after construction, the center should contain more than 600 racks with around 50 workstations for Brocade engineers to access. The building will not be heavily populated and its major purpose will be storing equipment. Categorizing the occupancy of the building (IBC 2009 CH3 – Occupancy) is an important feature in design to avoid issues regarding serviceability interferences for all electrical and mechanical utilities.

Other safety features include multiple levels of security access inside the data center, including key code controlled access into the labs and surveillance. An appropriate fire suppression system is also an important feature to ensure high safety levels for the people and equipment in the center at all hours of the day.

Interdisciplinary Interaction

What Constitutes a Good Team

Good teams are capable of taking multiple ideas and combining them into one single great idea. In an interdisciplinary team, this task becomes much more difficult to achieve because each member needs to trust other's expertise in their discipline moving forward. Our goal was to combine the best solution from each of the 4 major design components: Power, Cooling, Structure, and Finance, and create one overall solution. However we did face some issues.

One of the major struggles our team encountered was the amount of time needed for researching and planning. As the only civil/structural engineer on the team, I averaged between 5-10 hours a week on preliminary design. Toward the final weeks of the competition, those hours increased to 15-20 hours a week. As a senior, I am used to maintaining a high workload. For some of the younger members in the group, spending more than 1-2 hours a week on the project was a difficult task. Since the seniors in the group utilized this competition a senior project, they contributed the most leadership and effort.

As a group, we created a solution to present to Brocade officials, however we all agreed that some aspects of the design lacked efficiency. More time needed to be spent on preparation and initial research and as we moved forward some questions were left unanswered. Even the strong components of our design, such as structure and finance, left room for improvement in our electrical and mechanical design. I realized in this competition, a team is only as strong as its weakest member.

Where Did Our Team Fail

Each of the design components needed to be compatible with each other, and communication is a big part of successfully combining those ideas. During a few weeks of the competition, our team failed to have consistent communication between all members. Some of the members did not complete their weekly assignments by the deadline or did not show up to the team's weekly meetings. These habits made it difficult to work on each assignment. As a group member, I counted on my teammates for ideas, information or requirements. When a member did not finish his portion of the project, it affected the entire team. As the competition continued, I made a greater effort to not only meet my own deadlines, but also the deadlines of others.

I needed to research cooling systems for our structure, including sizes, weight and requirements. I had to work within other disciplines on the project, making it difficult to stay on task with my own designs. All of the struggles I encountered during the competition helped me realize the importance of creating specific deadlines for yourself and proper communication with all the members of the team.

The last few weeks before the team presentations, our team was able to spend the time and effort to tie up all the loose ends of the design. Individual motivation had been a problem for a lot of the younger members, but when the group was together, the team seemed to flow better. Some of the members typed up the report, while others worked on the presentation. I was surprised by how efficiently the team worked together leading up the presentation, considering how much the team initially struggled. We managed to bring the entire presentation together in the weeks leading up to the competition, which leads me to wonder how much more progress we could have made if we worked with that same efficiency throughout the entire competition.

What Did You Learn

I took away a few lessons from this challenge that helped me understand how to effectively work on design projects with other team members. The first major lesson from this project, to utilize when working in industry, is to create an agenda. An agenda is important to stay on track and hold your team accountable to those deadlines. Ensure that deadlines are reasonable for your team to meet.

The second lesson I learned is to be responsible for your portion of the project. A major difficulty within our group was that other members would not complete their tasks. What some of the members failed to realize was that they were letting the entire team down. This incident occurred numerous times within the group and showed the risks of depending on others.

Finally, the overall project helped me understand the commitment to working with other team members. The project allowed for proper execution of the "Learn by Doing" motto, with plenty of trial and error throughout the project and practice working with actual professionals and engineers. Lastly, the team learned the overall process of designing a data center, along with all of its components.

Overall Project Results

Conclusion

The team was selected as one of the top three teams in the competition. Our team was given the opportunity to give our presentation to Brocade officials at the San Jose headquarters. We enjoyed Brocade's hospitality with a reception, closing speech and a tour of their local data center. Overall, the Brocade and Cal Poly project challenge became a valuable opportunity to work with actual clients along with receiving actual feedback for our design. The project allowed each member from all the groups to practice working on an innovative project, as it would be executed in the industry. We were able to work with other members of different disciplines, collaborate our different ideas and practices, and successfully communicate to bring fourth one general solution to Brocade's needs. For all of these reasons, this competition provided me with an advantage as I prepare to take my knowledge out into the real world.

APPENDIX

Preliminary

BROCADE

Brocade Cal Poly Project Challenge

Design an Efficient Data Center Building

Scope

Design a new data center building for our Broomfield, CO site that is efficient, scalable, and cost effective.

Background

Brocade is based out of San Jose, California and has over 100 different locations all over the world. Brocade is committed to energy efficient and sustainability, as evident by its new San Jose campus having received a LEED Gold Award around its environmental design.

Brocade's second largest site is located in Broomfield, CO. This site is rapidly running out of infrastructure as the business grows, particularly in the data center type labs where Brocades develops and tests its products. The goal of this project is to help Brocade decide the best way and what technologies to use in the infrastructure for a new building.

Definition

Plan and design a new building to support Brocade R&D and product testing rack labs. The space should use innovative ideas to lower both initial construction costs and operations costs, while being highly efficient, best in class Power Utilization Effectiveness (PUE). The building needs to be designed with scalability and flexibility, allowing for racks to be added, growth of density in the racks, as well as designed so that allow for redundancy to be incorporated/added through its life. The building must also be financially feasible, taking into consideration all associated costs.

Location of Building Site

4 Brocade Parkway
Broomfield, CO 80021

Brocade owns the land immediately surrounding the existing building and parking lot.

Duration of Project

- Request for Proposal (RFP) (problem statement) – January 17, 2013 (Tuesday of 2nd week of class)
- Request for Information (RFI) period – January 17 - February 1
- Design Development – January 17 - March 5
- Reports Due - March 5, 2013
- Preliminary Presentations at Cal Poly - March 5, 2013 (Tuesday of week before dead week)
    - 30 minutes presentations and all participants have to present

- Presentations/Interviews at Brocade - March 8, 2013
    - 30 minutes presentations and all participants have to present

Requirements

The space should be designed to the following characteristics

- Space
    - Initial space for 150 racks
    - To be scalable to in 150 rack increments to 600 racks total
    - Layout should maximize usable space
    - Space should be designed to have 50 Engineers working within lab
- Power
    - Initial power to supply 4kW/rack
    - To be scalable to 12 kW/rack
    - Additional power needed for lighting, HVAC load, and other auxiliary loads and equipment
    - Distribution infrastructure to focus on efficiency and scalability
    - Critical components of system should have some level of redundancy
- Cooling
    - Cooling to support 4kW/rack
    - Scalable to 12 kW/rack
    - Cooling needs to support labs, people, and space loads
    - Mechanical design needs to be efficient
    - Critical components of system should have some level of redundancy
- Redundancy
    - Initial design to be Tier 1
        - N+1 redundancy for electrical and mechanical infrastructure
    - To be scalable to Tier 2
        - 2N redundancy for electrical and mechanical infrastructure
    - Considerations for co-generation should be taken
    - Consider designs that allow maintenance to be performed without shutdown of racks or critical systems.

Deliverables

Deliverables from the technical design should include

- Construction costs of final design and other designs considered as required for the financial analysis
- Visual layouts of the final design
    - Architectural drawings
    - 3D model
    - Single line drawings (electrical, mechanical, plumbing)
- Analysis and reasoning for final design
    - Architectural write up: description of foundation, walls, roof, materials used.
    - Mechanical write up: description of cooling system, pumping/piping.

   - Electrical write up: description of electrical system, substation, medium distribution, low voltage.

The financial analysis should include the following:

- Pro Forma for first 10 years for the following scenarios and exit strategies:
- Build and own the building
- Build and conduct a sale lease back
- Build to suit - Lease
- Other Scenario – Creativity is key
- Each model should include full detailed analysis on:
  - Initial Capital Costs (Building materials, Lab Equipment, Labor, etc...)
  - Operating costs (Electricity costs, Maintenance costs, Taxes, etc...)
  - Cash and GAAP Analysis (Depreciation, Tax Benefits)
- All models should focus on two key components: Minimizing Capital Spend and Minimizing the average annual GAAP

Wrap Up:

- Summary that compares the final design compared to other, less efficient designs
- Provide and evaluation matrix to determine results and balance financial, environmental, and technical benefits

A 5-10 page report will be required with the following sections:

- Restate the problem
- Overview to recommended Solution
- Division of responsibilities
- Overview of design
- Financial analysis
- Recommendation
- Lessons learned

The team will also be required to give a presentation

- All team members must speak equally
- Maximum of 20 slides

20-30 minutes including Q&A

Incentive for Students

- Monetary Reward $12,000 total distributed among top teams
- Possible Internship at Brocade
- Visit to Brocade Campus in San Jose for top teams to meet with executives

Appendix to be provided

- RS Means (Construction Costs)
- Financial model template

- Work Packages (Mechanical, Electrical, Architectural)
- Map of Brocade Property
- Copy of survey property that we have
- Xcel Electrical Single lines

Mechanical Work Package

Location: Broomfield, Colorado

- Design for 0.1% Wet Bulb
- Initial space for 150 racks
- To be scalable to 600 racks
- Cooling to support 4kW/rack
- Scalable to 12 kW/rack
- Cooling needs to support labs, people and space loads
- Mechanical design needs to be efficient
- Critical components of system should have some level of redundancy
- Cold aisle air temperature should be designed for 85 deg F

Cooling system can be one type or a combination of type of systems (CHW, DX, Dry Cooler., etc.)
Free cooling systems should be incorporated into system to maximize efficiency.
Best practices and new ideas for energy efficiency should be implemented into design.

Provide:

- Mechanical write up: description of cooling system, pumping/piping.
- Single line and drawing of mechanical and piping system.
- Calculation of total cooling load required to initial 150 racks and 600 racks.
- Calculate respective power consumption for mechanical and pumping system for yearly energy consumption in kWh, and provide percentage of total energy consumption for systems.

Electrical Work Package

- Power comes in at 480 VAC 3ø
- IT (racked) equipment runs mostly on 208 VAC
- Initial space for 150 racks
- To be scalable to 600 racks
- Power infrastructure to support 4kW/rack
- Scalable to 12 kW/rack
- Electrical needs to support racks, HVAC load, lighting load, and other miscellaneous plug loads
- Electrical design and equipment needs to be efficient

- Critical components of system should have some level of redundancy
-
- Best practices and new ideas for energy efficiency should be implemented into design.
- Rack level distribution should be flexible to accommodate any standard plug types utilized in data center environments (L6-30, L15-30, L21-30, 4WC-90, etc...). Our standard is two L6-30 plugs per rack.
- Brocade's standard is to use Starline power bus for row level distribution, but other options could be considered.
- Consider primary/secondary energy sources other than grid provided power.
- Isolation between load types should be considered in electrical design.
- Electrical monitoring should be considered at all levels of distribution.

Provide:

- Electrical write up: description of transformers and electrical distribution, and any assumptions made.
- Single line and drawing of electrical system.
- Calculation of total power required to initial 150 racks and 600 racks.
- Calculate respective power consumption for electrical system for yearly energy consumption in kWh, and provide percentage of total energy consumption for systems.

Architectural and Civil Engineering Work Package

Note to students: The focus of this project is to optimize the electrical and mechanical system while maximizing the ROI. Although the architectural, structural, and civil design considerations are extremely important in a real life project, we understand that this expertise might not be in every group. Therefore, the following design guidelines are broken down into two categories "required" and "optional." You must satisfy the "required" category, and based on your team's experience you can try to satisfy the "optional" category.

Required:

- ✓ Gravity design load (based on rack load bearing capacity and power & cooling equipment)
- ✓ Architectural layout or floor plan of placement of racks and columns in the lab
- Structural material selected and supporting reasoning for selection (e.g. steel, concrete, prestressed concrete, timber, masonry, etc.)
- Model of exterior architectural materials & "look & feel" – reasoning for selection ✓
- IN REPORT → ✓ Single story or multistory – Reasoning for determination ✓
- ✓ 3D model of building ✓
- ✓ Location of building within the provided lot ✓ SITE PLAN

Optional:

- Gravity design load (based on rack load bearing capacity and power & cooling equipment) - provide supporting calculations
- Structural material selected and supporting reasoning for selection (e.g. steel, concrete, prestressed concrete, timber, masonry, etc.)
- Structural system designed – Please provide supported calculations
- Based on your selected material please use the appreciate design guidelines (e.g. Load and Resistance Factor Design LRFD, International Building code, Manual of Steel Construction, Building Code Requirements for Reinforced Concrete, etc.)
- Exterior architectural materials & "look & feel" – reasoning for selection and supporting design process and calculations
- Design considerations for civil engineering requirements (i.e. grading, sewer piping, gas piping, water piping, etc.).
- Provide a list of the local agencies with which you would need to interact during this project. Explain which permits you would get from each agency and the process to acquire the same.

1. What are the average dimensions and weight of the racks?
-They vary from 24"-28"wide x 36"-42" deep x 7'-8' tall
- Empty racks weigh about 100 pounds, and can support up to 1500 pounds of IT equipment.

2. What type of working space do the 50 engineers require? (Ex: cubicles, meeting rooms, etc.)
The space that the engineers require will not be a permanent space for them, but rather a drop in space if they need to do some quick work. They will have a permanent cubicle in the existing buildings. Work that they do would likely be on a laptop or doing some "tinkering" or physical setup of the equipment before they rack it in. I will let you decide what kind of work space is needed from this information.

3. What program is used for the electrical drawings, and how detailed should the drawings be?
AutoCAD is what is commonly used. Any 2D CAD software is fine. Drawings should include major electrical components and sizing of those components. Use your judgment to determine if time is better spent on more detailed drawings or other aspects of the design.

4. What are some of the problems with the current building that we can avoid repeating?
Most buildings are designed to house people and the dimensions and layouts take this into consideration. Adjustments need to be made to fit racks and increased infrastructure and the type of infrastructure. This building should think of the labs first and what are the best ways to package racks, cooling, and power, and what is needed by those. Temperatures, finishes, dimensions are not necessarily the same.

5. Are there floor plans available of the existing building on the site?
I will upload some old floor plans to the Google Docs site. They are from 2007, so are not 100% accurate, but mostly so.

6. Are the state taxes for this building under CO, CA or both?
Colorado taxes

7. Is the power distribution system 240V?
Power into the building is 277V/480V 3phase power in a wye configuration. i.e. phase to neutral is 277V and phase to phase is 480V. Rack level distribution is 120V/208V 3 phase. 240V is can either be 3 phase in the delta configuration or two legs of single phase 120V. No 240V services are used at Brocade, just the 277/480V and 120/208V.

8. What are the dimensions of each rack?
See #1 above

9. How are the racks situated? (Like do they align in rows)
They are aligned in rows, with equipment blowing from front to back (cold aisle to hot aisle)

10. We were guessing that the racks form rows, so if so how much space is needed in between each rack?
Racks can` be right next to each other.

11. How much does each rack weigh?
Empty racks weigh about 100 pounds, and can support up to 1500 pounds of IT equipment.

12. What kind of work space is required for the 50 engineers? Do they each need their own cubicle or space? Extra space like a conference room?
Please see answer #2

13. We noticed that the image of the site that was provided doesn't have a scale, is there one that we could work off of?
I will provide a pdf on the Google Docs site that has the size of the existing building to use as a reference scale.

14 The space should be designed to have 50 engineers working within lab however, depending on the engineer, the space could be utilize differently. Are we working with individual work-spaces, or collaboration tables/ drafting tables?
Please see answer #2

15 The program of the building has a few specific requirements, but since we are making the data lab a working office as well, our team is assuming we will need bathrooms, break-room/kitchen, conference room?
Bathrooms and water fountains are required by law so will need to be there. I will let you decide what else "nice to have" rooms you would like to provide base on some of the previous questions. There are many right answers, depending on what you think is valuable to provide the most efficient space. It should be efficient for the employees to do work as well as energy efficient.

16. The Broomfield site has a lot of space and land, should we include parking for the new site, or continue using current parking lot.
Include more parking if you think the new space will need it. Right now the parking lot is generally only half full on normal business days.

Milestones for Each Week

Week 1 (Jan 17-24)
1. Group First Meeting/ Introduction
2. Scope of Project/ Requirements
3. Brainstorming
4. Research for Information

Week 2 (Jan 25-31)
1. Create Milestones for each week
2. List of RFI questions
3. Site Location/Options
    a. Location of building within the provided lot

Week 3 (Feb 1-7)
1. Material Selection
2. Material Configuration
    a. Single or multi story
3. Load-Take Off (based on rack load bearing capacity and power & cooling equipment)
4. RS Means

Week 4 (Feb 8-14)
1. Gravity Design (to Code)
2. Structural System Design
3. Architectural layout (Floor Plan)
4. Revit Modeling

Week 5 (Feb 15-21)
1. Revit Modeling
2. Exterior architectural material "Look & Feel"
3. Civil Engineering Requirements (grading, sewer piping, gas piping, water piping)
4. Permits from agencies

Week 6 (Feb 22-28)
1. Revit Modeling
2. Polish existing work

Week 7 (Feb 29- Mar 5)
1. Reports Due March 5th

Zimbra **vallejo@calpoly.edu**

Brocade Project Challenge Team 3

From : Nathan Lattyak <nlattyak@Brocade.com> Wed, Jan 30, 2013 04:47 PM

Subject : Brocade Project Challenge Team 3 1 attachment

To : dlarse02@calpoly.edu, vallejo@calpoly.edu, askeljo@calpoly.edu, innewmant@gmail.com, corneliofurlan@hotmail.com, cinthyamendez93@yahoo.com, nperugup@calpoly.edu

Team 3,

Due to a few people dropping from the Brocade Project Challenge, I need to reorganize the teams a little bit. This is necessary to give all the teams a fair shot. Below is the information that includes the new members of the team. Please let me know any questions or concerns, and I hope to see you all tomorrow.

~~David Larsen~~	~~805-478-1654~~	~~dlarse02@calpoly.edu~~	~~BUS I/S~~
Andy Vallejo	805-756-9323	vallejo@calpoly.edu	ARCE
Azra Skeljo	949-357-4474	askeljo@calpoly.edu	EE
Theodore Newman	206-306-5463	innewmant@gmail.com	ME
~~Cornelio Furlan~~	~~310-383-7311~~	~~corneliofurlan@hotmail.com~~	~~EE~~
Cinthya Mendez	559-312-5010	cinthyamendez93@yahoo.com	ME
Nikhila Perugupalli	510-552-7687	nperugup@calpoly.edu	IE

Thanks,
Nathan Lattyak
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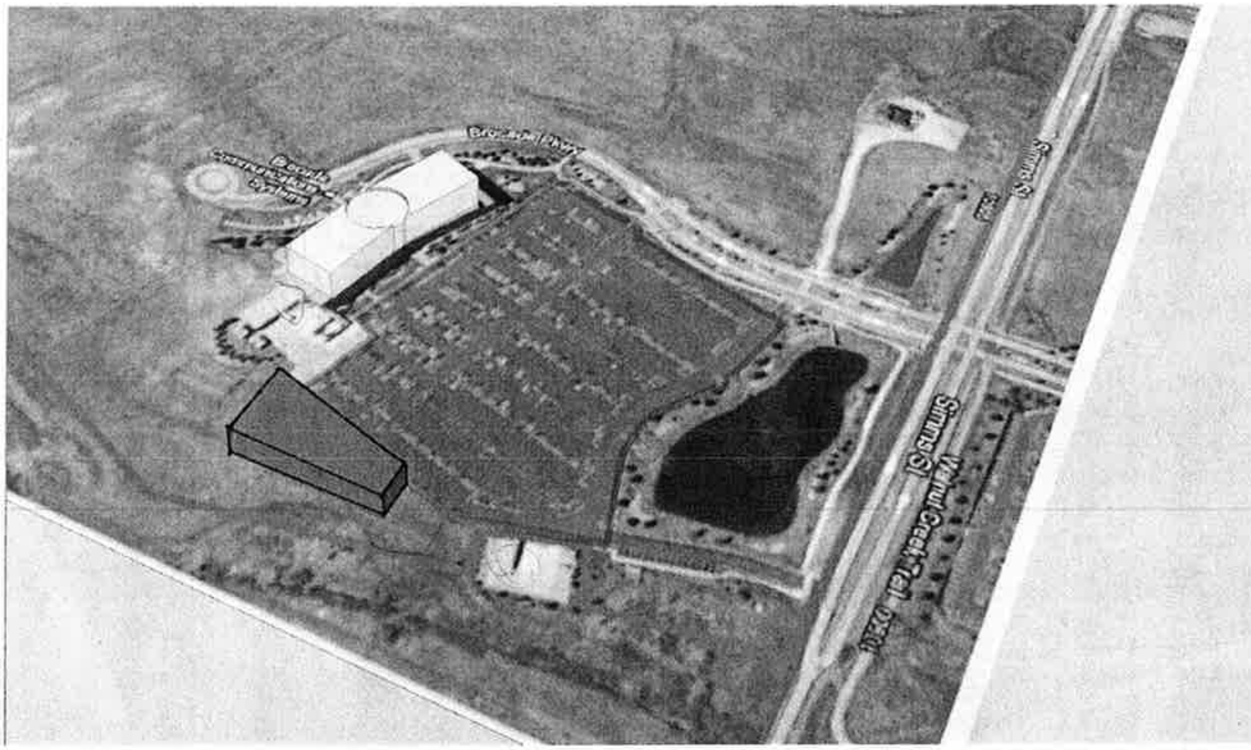
BROCADE

Design

Site Option – 1



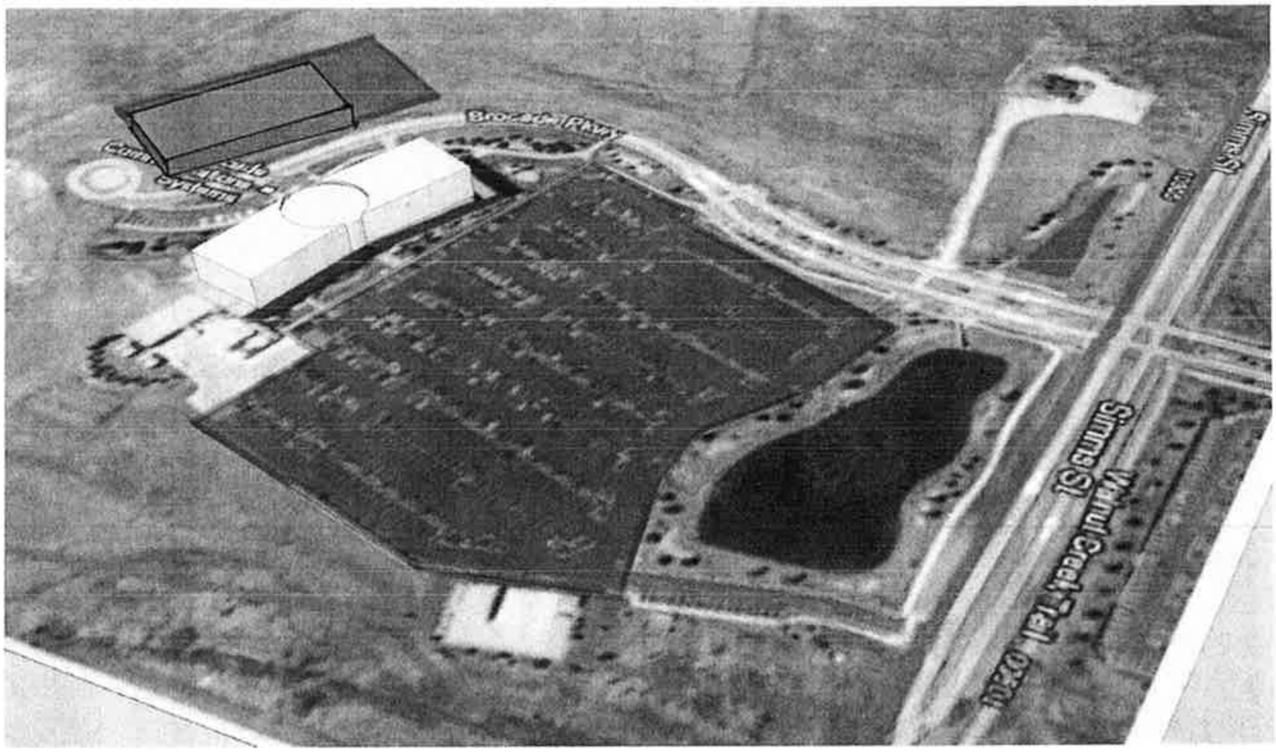
Pros:

- Efficient Utilization of Parking Lot
    - No need to repave more spaces
    - Plenty of Parking in current lot
    - More Green
- Data Lab is visible (Preference)
    - Easy access from Simms St. and Brocade Pkwy.
    - Visible when driving on Simms St.
- Close Proximities to Main Office
- Allows a small footprint in entire Brocade Lot
    - Property is expensive
    - Keep as much as possible (open)

Cons:

- Property Line directly behind proposed site
    - Expansion might be limited (tucked away)
- Drive through entire Parking Lot for access
    - Located at end of Lot
- More restrictions
    - Building shape and size

Site Option – 2



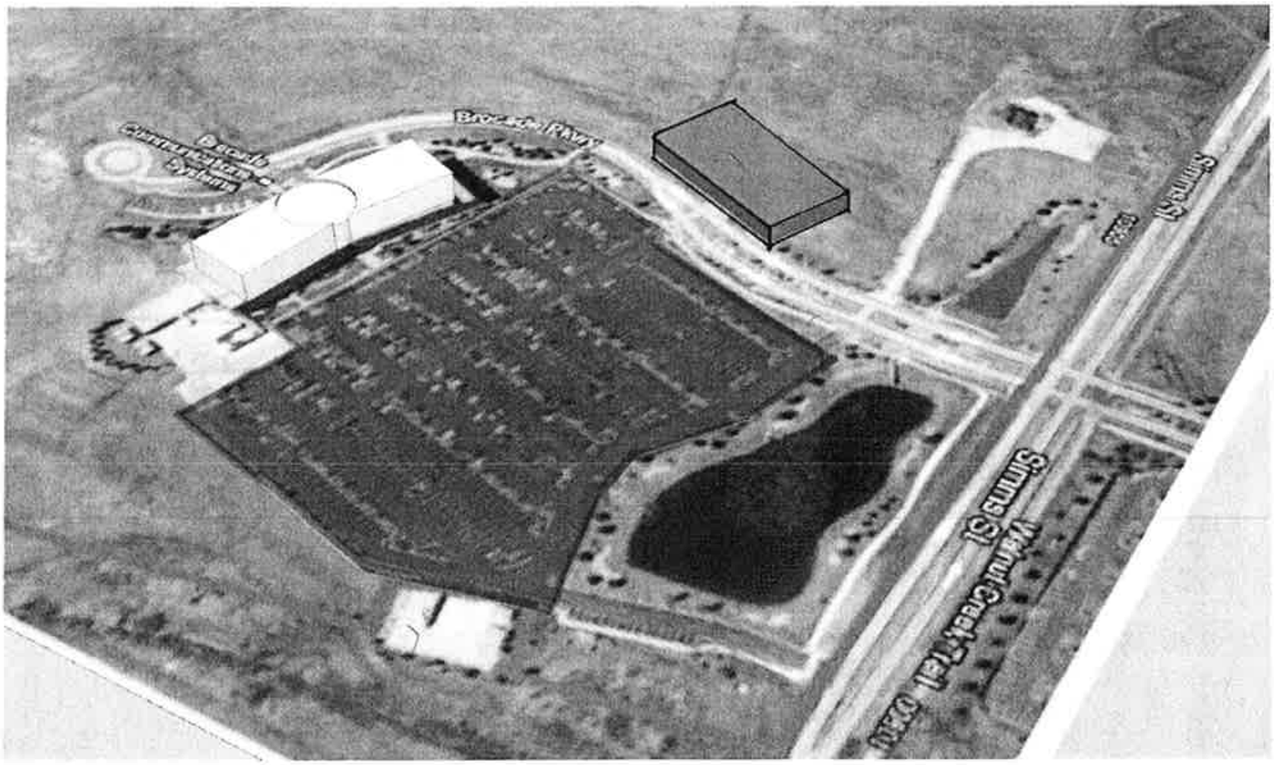
Pros:

- Direct Access from Brocade Pkwy.
  - Drive directly to front of Data Lab
  - New "Focal Point" to site
- Data Lab is not visible (Preference)
  - Hidden Behind Main Office
- Close Proximities to Main Office
  - Across the Brocade Pkwy.
- No Restriction due to location of site

Cons:

- Pave more parking
  - $$$
  - Not Green
- Takes up a bigger size in site
  - Amount of property used

Site Option – 3

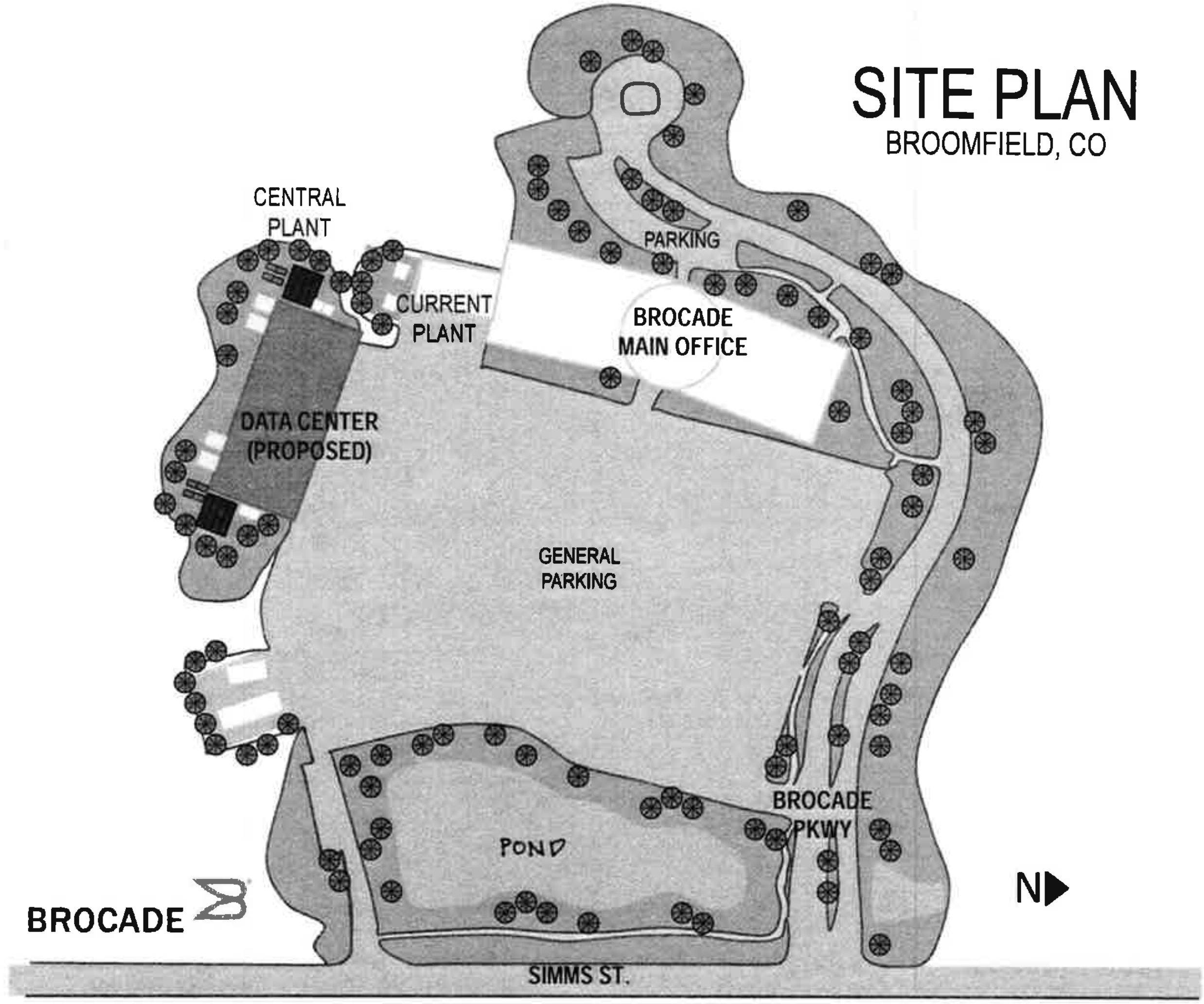


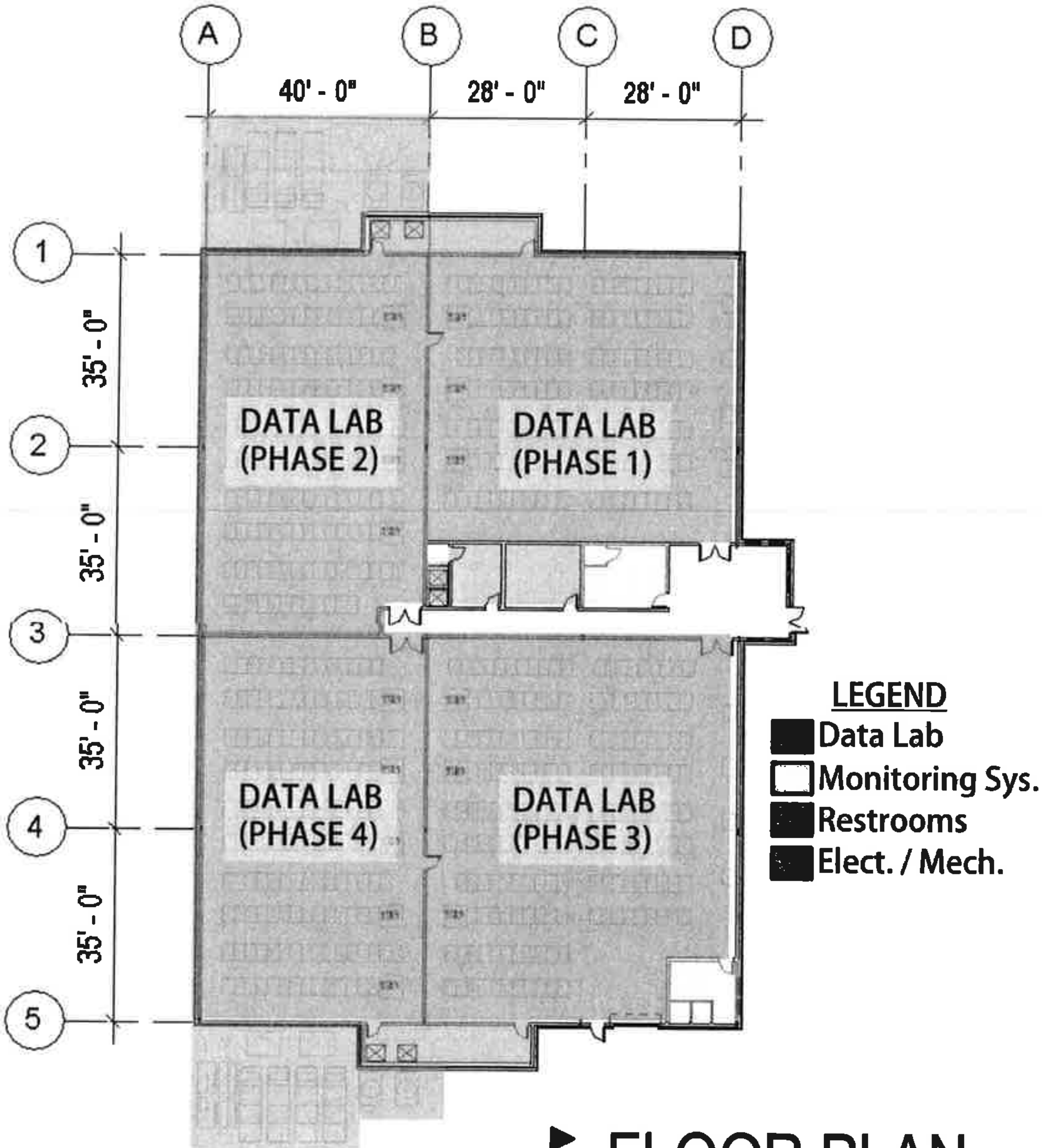
Pros:

- Direct Access from Brocade Pkwy.
  - Drive directly to front of Data Lab
  - New "Focal Point" to site
- Data Lab is visible (Preference)
  - Located right off of Simms St.
- Close Proximities to Main Office
  - Across the Brocade Pkwy.
- No Restriction due to location of site

Cons:

- Pave more parking (Possibility)
  - $$$
  - Not Green
- Takes up a bigger size in site
  - Amount of property used
- Increase Vehicle Conjestion
  - Traffic

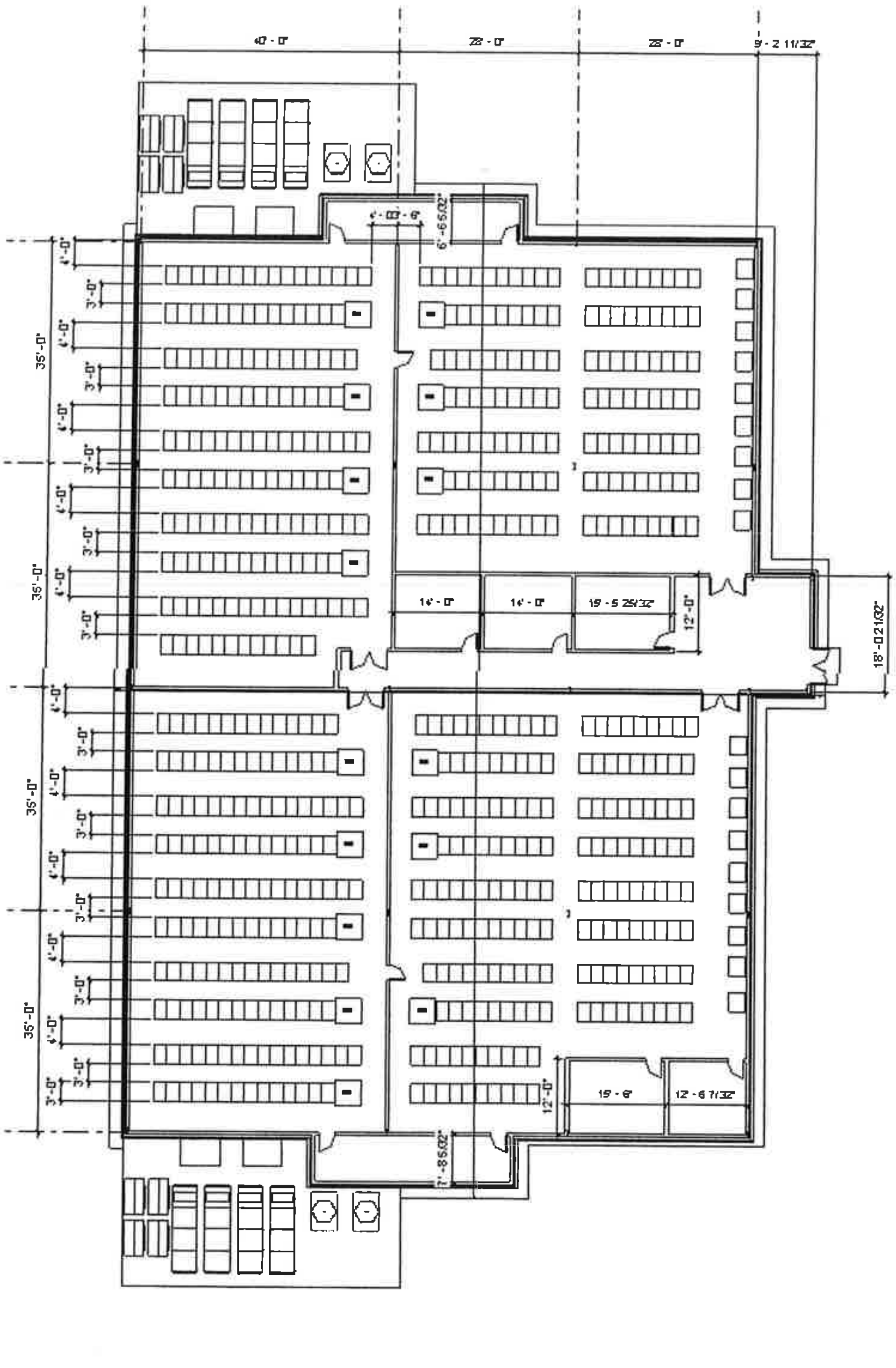

SITE PLAN
BROOMFIELD, CO
CENTRAL PLANT
CURRENT PLANT
PARKING
BROCADE MAIN OFFICE
DATA CENTER (PROPOSED)
GENERAL PARKING
BROCADE PKWY
POND
SIMMS ST.
N
BROCADE

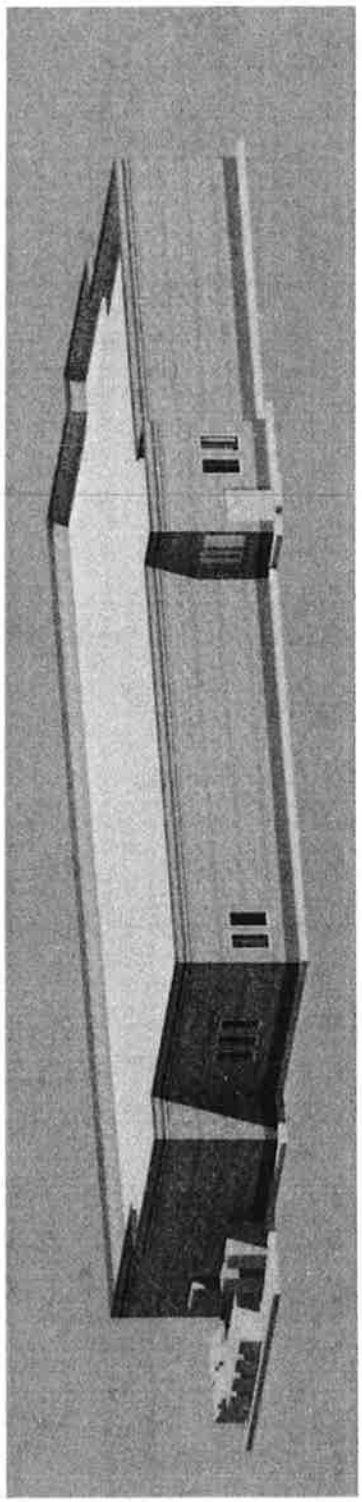


BROCADE

FLOOR PLAN

SCALE: 3/32" = 1'-0"

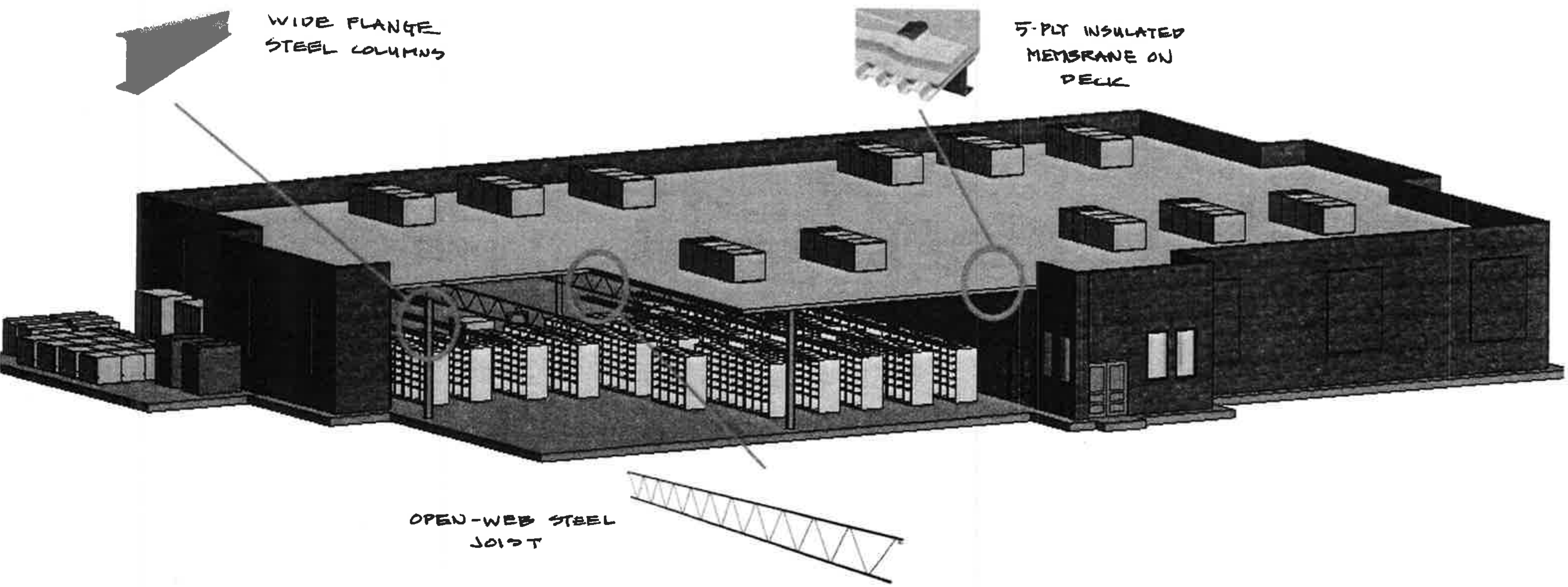

40' - 0"
28' - 0"
28' - 0"
9' - 2 11/32"
35'-0"
35'-0"
35'-0"
35'-0"
4'-0"
3'-0"
14' - 0"
14' - 0"
15' - 5 25/32"
12'-0"
18'-0 21/32"
15' - 6"
12' - 6 7/32"

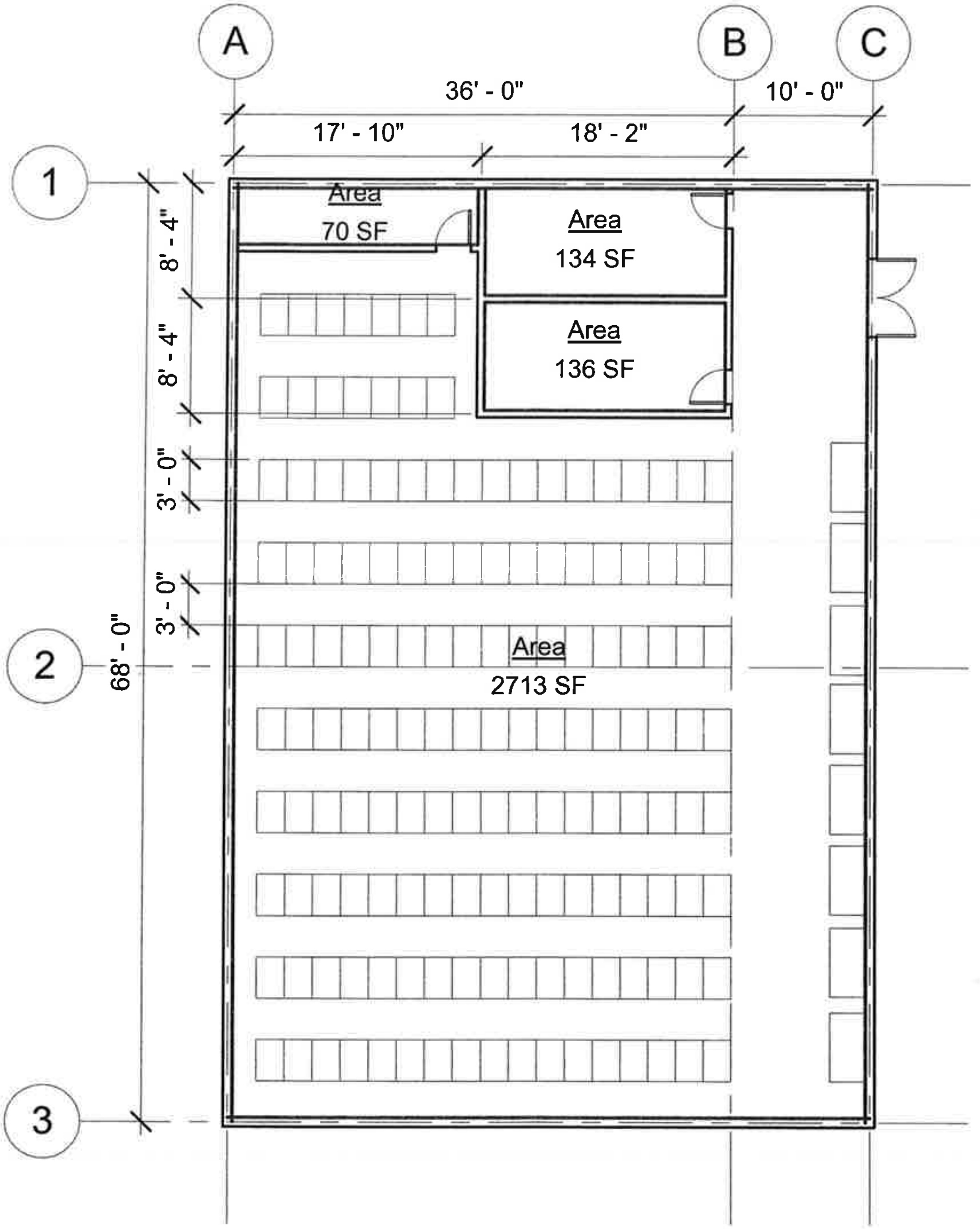


3D VIEW

DATA CENTER

BROCADE


WIDE FLANGE STEEL COLUMNS
5-PLY INSULATED MEMBRANE ON DECK
OPEN-WEB STEEL JOIST



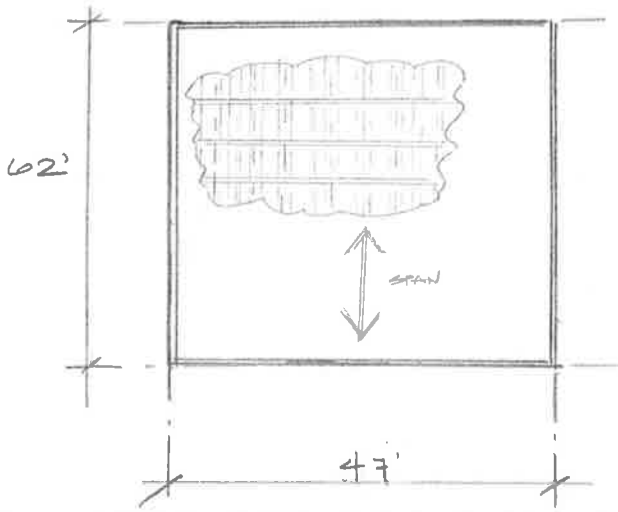
2 Level 1 Dimensions
3/32" = 1'-0"

BROCADE	BROCADE	FIRST FLOOR PLAN (OPTION - A)		
		Project number	1	FLOOR PLAN
	DATA CENTER	Date	2/3/2013	
Cal Poly & Brocade Challenge		Drawn by	A. VALLEJO	
		Checked by	AV	Scale 3/32" = 1'-0"

2/4/2013 8:54:23 PM

ROOF STEEL DECK

- BAY SIZE @ 62' x 47' (DECK ORIENTED PARALLEL TO 62')



LOADS (ASD)
DL: 90 PSF
LL: 20 PSF

EQN: D+L = 110 PSF

REFS

VERCO STL DECK

- SPAN (PARAMETERS)

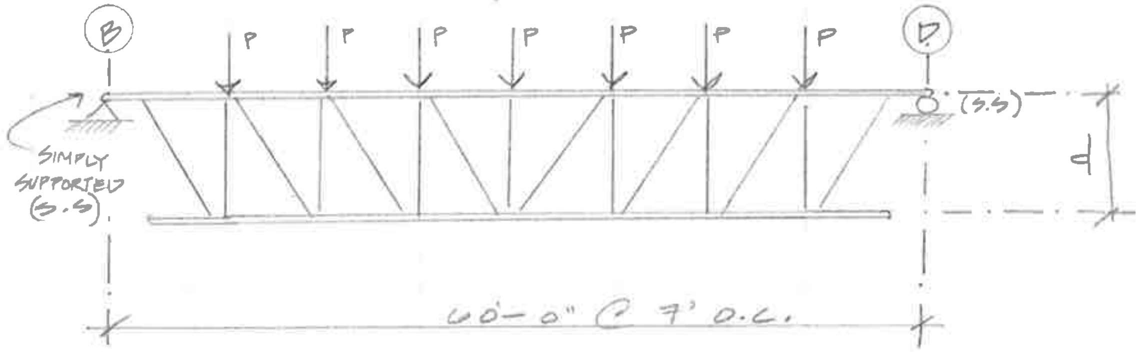
CHOOSE BETWEEN DECK OPTIONS

DECK ORIENTED PARALLEL TO 62'
PERIMETER WALLS PROVIDE LATERAL RESTRAINT
UNDERSIDE OF DECK EXPOSED TO VIEW FROM INTERIOR
TOTAL VERTICAL LOAD 110 PSF

1. SINGLE 16 GAUGE PLB-36 ROOF DECK (127 PSF)
2. TRIPLE 18 GAUGE PLB-36 ROOF DECK (130 PSF)
3. SINGLE 22 GAUGE PLN-24 ROOF DECK (112 PSF) ← MUCH SMALLER GAUGE

∴ USE 22 GA PLB-24 3' DEEP DECK ON ROOF
(USE FOR ALL BAYS ON ROOF FOR ~~EASE~~ OF CONSTRUCTION)
– FINISHED W/ PRIMER PAINT FOR FIRE PROOFING –

OPEN-WEB STEEL JOIST (TYP)



REFS

LOADS:

TOTAL LOADS — UNFACTORED

IBC '09 CH. 16

$DL = 90 \text{ PSF} \cdot 7' \text{ O.C.} = 630 \text{ PLF}$

$LL = 20 \text{ PSF} \cdot 7' \text{ O.C.} = 140 \text{ PLF}$

GOV. EQN.

$1.4D \Rightarrow 1.4(630 \text{ PLF})$ .... = 882 PLF

$1.2D + 1.6L_r \Rightarrow 1.2(630 \text{ PLF}) + 1.6(140 \text{ PLF})$ .... = 980 PLF

∴ 980* PLF GOVERNS

* HEAVY MECHANICAL LOADS ON ROOF (DL)

PARAMETERS:

VULCRAFT STD LOAD TBL

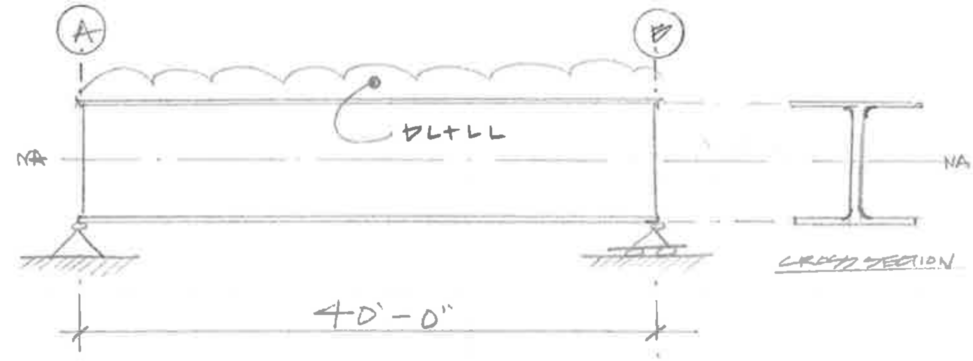
SPAN → 60 FT @ 7' O.C.

$\phi F_n = 981 \text{ PLF} \geq 980 \text{ PLF}$ ∴ ok

∴ d = 36' → MAX LOAD 1407 PLF

Vulcraft Steel Joist ∴ USE 36LH13 LONGSPAN STEEL JOISTS LH SERIES

GIRDER - 1



LOAD TAKE-OFF

DL : 70 PSF

LL : 20 PSF

SL : 35 PSF (ASCE 7-10 CH 4)

REFS

FACTORED LOADS FOR REDUCTION

$A_W = 7'/2 = 3.5$ FT

ASCE 7-10 CH 4

$R_1 = 0.6$ WHEN $A_t > 600$ FT²

$0.6(20 \text{ PSF}) = 12$ PSF

IBC 09 CH. 16

GOV EQN :

$1.2D + 1.6S \Rightarrow 1.2(90) + 1.6(35) = 164$ PSF

$\hookrightarrow 164 \times 3.5 \text{ FT} = 574$ PLF

- MAX BENDING :

EQ. FOR DISTRIBUTIVE LOAD

$\therefore WL^2/8 = (574)(40)^2/8$

$\therefore M_{MAX} = 114.8^{K \cdot FT} = M_u$

- MAX SHEAR :

$\therefore WL/2 = (574)(40)/2$

$\therefore V_{MAX} = 114.8 K = V_u$

- DEFLECTION :

AISC TBL 1-1

$\Delta_{ALLOW} = l/240 = 2''$

$W = 20\text{PSF} \times 62\text{FT} = 1240$ PLF

$$\therefore I_{REQ} = \frac{5(1240 \text{ PLF})(1/12 \text{ FT/IN})(40^{FT} \times 12^{IN/FT})^4}{384(29{,}000{,}000 \text{ PSI})(2'')} = \frac{5wl^4}{384 E \Delta_{ALLOW}} = 1232 \text{ IN}^4$$

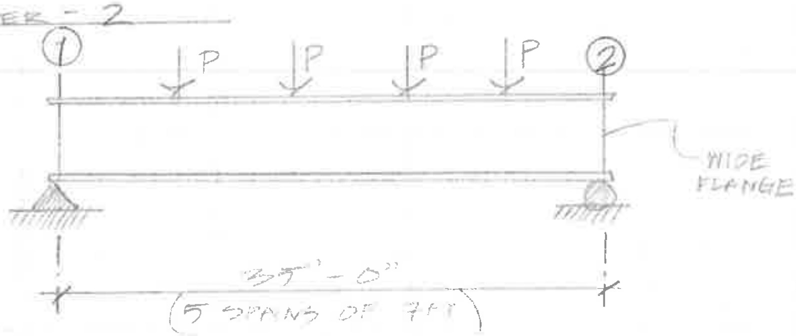
GIRDER - 1

OPTIONS

	I_x (in⁴)	ϕM_n (k-ft)	ϕV_n (k)	
• W21x62	1330	540	252	∴ ok ✓
• W24x55	1350	503	252	∴ ok ✓

∴ USE W21x62 FOR GIRDER-1 (SPAN OF 40-0") W_{SELF} = 55 plf
SATISFIES ALL 3 CATEGORIES.

GIRDER - 2



P = 27 KIPS

$M_u = 0.6\,(27^{kips})(35^{ft}) = 567$ K-FT

$\Delta_{ALLOW} = l/240 = 1.75^{in}$

$I_{REQ} = 0.063\,(27^{k})(35\times12)^3 / (29\,000^{ksi})(1.75^{in})$

∴ = 2484 in⁴

	I_x (in⁴)	$(\phi)M_u$	ϕV_n
• W21x111	2670	1050	355
• W24x94	2700	953	250

∴ USE W24x94 (SPAN 35') FOR GIRDER 2
[illegible]

COLUMN

REFS

- Tributary Area = A_T

$A_T = 35' \times 40' = 1400$ SF

- Loads (D+L)

D = 90 PSF
L = 20 PSF
S = 35 PSF

- GOVRN EQN: (LRFD)

$1.2D + 1.6(L \text{ or } S)$

$\Rightarrow 1.2(90) + 1.6(35) = 164$ PSF

- AXIAL LOAD (P)

P = 164 PSF × 1400 SF
∴ P = 229.6 ~ 230 KIPS

- EFFECTIVE LENTH (KL)

AISC STL MANL. (T-C-A 7.1)

h = 14'-0"
K = 1.0 (ASSUMED)

- CHOOSE BETWEEN

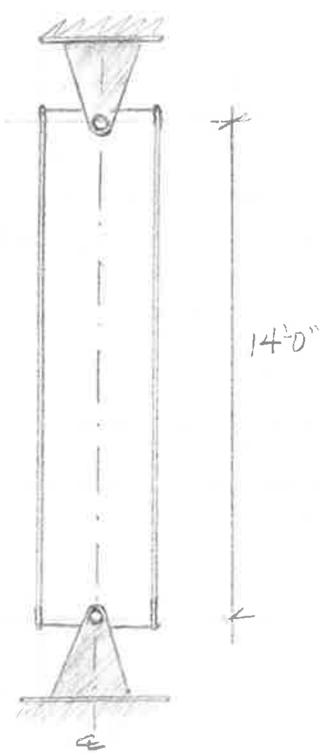
AISC (TBL 4.1)

W8x31 $\phi P_n = 248$ K

W10x33 $\phi P_n = 253$ K

FOR SIZING PURPOSES USE W10

∴ USE W10x33 FOR ALL COLUMNS



K = 1.0 (PIN-PIN)

Result

BROCADE

April 19, 2013

Dear Andy,

Congratulations! Your team has been selected as the Third Place winner in the 2013 Brocade Challenge. Thank you for your participation in helping make this year's project a success. Enclosed is your prize amount of $200 for your hard work and dedication.

Regards,

Victor Garcia
Director, Facilities Engineering
Brocade
408.333.6128

Senior Project Record of Meeting

Date/Time/Location: 1/24/13

Participants: Andy / Kevin / Chandler

What was worked on – activities:

Attended Brocade meeting

What was discussed

Reports due 5 March

Senior project will be full package (required/optional) for ARCH/Civil

What should be completed prior to next meeting

- Milestones ✓
- RFI ✓
- Tues 4:00pm ??

Time spent on project since last meeting:

Andy: 3 hrs
Chandler: 5 hrs
Kevin: 4 hrs

Senior Project Record of Meeting

Date/Time/Location: 1/31/13

Participants: Andy/Kevin/Chandler

What was worked on – activities:

Attended group meetings

What was discussed

new people added to teams -- made things less productive

covered individual milestone documents

discussed RFI results

What should be completed prior to next meeting

See milestone sheet

next meeting 14 Feb ♡ Valentines Day

Time spent on project since last meeting:

Andy: 9 hrs

Chandler: 6 hrs

Kevin: 6 hrs

Senior Project Record of Meeting

Date/Time/Location: 1/31/13

Participants: Andy | Kevin | Chandler

What was worked on – activities:

Attended group meetings

What was discussed

New people added to teams -- made things less productive

covered individual milestone documents

discussed RFI results

What should be completed prior to next meeting

See milestone sheet

next meeting 14 Feb ♡ Valentines Day

Time spent on project since last meeting:

Andy: 9 hrs

Chandler: 6 hrs

Kevin: 6 hrs

Senior Project Record of Meeting

Date/Time/Location: [illegible]

Participants: [illegible]

What was worked on – activities:

[illegible]

What was discussed

[illegible]

What should be completed prior to next meeting

[illegible]

Time spent on project since last meeting:

Kevin 16 hrs
Chandler 12 hrs
Andy 15 hrs

Senior Project Record of Meeting

Date/Time/Location: 21 Feb 4:00 pm

Participants: [illegible] / [illegible] / Chandler / [illegible]

What was worked on – activities:

[illegible]

[illegible]

What was discussed

[illegible]

[illegible]

3-D model [illegible]

[illegible]

[illegible]

[illegible] Chandler

[illegible]

What should be completed prior to next meeting

Show: cost estimate
· site civil
· 3D model

Time spent on project since last meeting:

[illegible] 12 hours

[illegible] 10 hours

Chandler [illegible]

Senior Project Record of Meeting

Date/Time/Location: 3/14/13

Participants: Andy | Kevin Chandler

What was worked on – activities:

Actual competition
Cal Poly
Fan [illegible]

What was discussed

- Summary of trip
- Organization of report
  - Overall project results ✓
  - Interdisciplinary interaction ✓
    - what constitutes a good team ✓
    - where did your team fall ✓
    - what did you learn ✓
  - Structural report ✓

What should be completed prior to next meeting

Before spring break
- turn in draft report

- Digital commons submission
- Projects day presentation   Photos

Time spent on project since last meeting:

Chandler: 40 hrs
Andy: 37.5 hrs
Kevin: 35 hrs

- LOGGED HOURS SINCE LAST MEETING

DATE	HOURS
JAN - 24	3
JAN - 31	9
FEB - 14	15
FEB - 21	12
FEB - 29	12
MAR - 14	37.5 *
TOTAL	88.5 HOURS

* TIME MOSTLY SPENT IN PREPERATION OF BOTH GROUP REPORT AND PRESENTATION

BROCADE

THE BROCADE PROJECT CHALLENGE

Winter 2013

Team 3: Interdisciplinary Innovated Solutions

Jennifer Huckleberry

Sourabh Katti

Cinthya Mendez

Theodore Newman

Nikhila Perugupalli

Azra Skeljo

Andy Vallejo

Table of Contents

Problem

The Brocade Cal Poly Project Challenge is a task delegated to Cal Poly students. This year the task is to challenge the students to develop a new data center for Brocade in Broomfield, Colorado while working in a team with their business and engineering peers. The guiding principles behind this new facility are efficiency, scalability, and cost effectiveness. This new facility aims to support Brocade R&D and product testing rack labs through a design that encompasses flexibility and scalability, while maintaining financial feasibility. This problem was solved by innovative solutions through teamwork, proper division of work, and sharing of knowledge to the best of their capabilities.

Overview to Recommended Solution

This report looks through the solutions come up by Brocade Group 3 for the data center in terms of the cooling system, electrical and power system, the architectural foundations and planning as well as the cost analysis of these different aspects and the most cost efficient way of building the data center.

For the cooling system, the benefits of several different systems were first picked, then intensively researched and finally analyzed through the utilization of decision matrix and ranking based on compatibility with climate, type of durability, cost, type of maintenance (listed in order of highest to least priority) and finally ranking based on the most beneficial to the least. The final system that was settled upon was an engine driven chiller system which is run by a natural gas engine and is extremely versatile in terms of its capabilities relative to other types of systems.

For the electrical system, major issues such as redundancies, renewable energy, power output and efficiency were examined. A final decision was made through the utilization of a design matrix to distinguish scalability, efficiency, and reliability factors.

For the architectural design, the team developed plans through research of existing data centers, type of roofing, placement of work tables and other equipment, etc. The expertise of the Architectural Engineer allowed the team to come to a final conclusion, render a 3D design, and properly execute the ideas of location and building type.

Division of Responsibilities

The division of responsibilities was done in an organized manner to ensure that each task was assigned to the proper individual by thoroughly examining each section of the project proposal:

- Mechanical Work Package – the Mechanical Engineers of the team (Cynthia Mendez and Theodore Newman)
- Electrical Work Package – the Electrical Engineers of the team (Sourabh Katti and Azra Skeljo)
- Architectural and Civil Engineering Work Package – the Architectural Engineer of the team (Andy Vallejo)
- Financial Analysis – the Finance and Business students of the team (Jennifer Huckleberry)
- Providing organization/management of group/creating final report – the Industrial Engineer of the team (Nikhila Perugupalli)

Financial Analysis

First, in order to evaluate the most cost efficient method of financing the datacenter, it was pertinent to examine the multiple methods of purchasing and leasing. These methods include simple mortgage payments, balloon payment loans with the option of either equity financing or refinancing, issuing debt, build to suit lease, exit strategy purchase, rent for an additional ten years, and sale lease back. Among the assumptions that were made (in order to determine the superior method of financing) was the inaccurate assumption that Brocade would be able to issue debt at a rate comparable to that of its 2023 year maturity bonds.

As mentioned in the annual 10-k report, Brocade has already issued a considerable amount of debt, and would most likely not be able to issue debt at the low rate of their existing debt, so the cost of issuing debt should be higher. Another instrumental but questionable assumption that was made was that, in the event that Brocade would lease out the building, the leaser would shift the operating costs of the electrical and cooling systems onto Brocade. This assumption was made on the basis that the higher rent would reflect these costs.

Furthermore, this assumption made it possible to (somewhat accurately) compare and stack the financing options and decisions against one another to determine the most cost effective way to finance the data center. This was a viable option since we were able to look primarily at installation costs and other capital costs (since the operating costs are constant among all financing decisions). Due to the dichotomous nature of the operating costs and capital costs, and the respective

separate analysis of the two, we were able to more closely examine the impacts that various decisions such as influential tax benefits had on the operating costs.

Type of Scenarios	Total Cost	Total Depreciation
Purchase	$ (17,786,631.51)	$ 27,253,431.98
Balloon Payment w/Equity Financing	$ (9,687,561.78)	$ 27,253,431.98
Balloon Payment w/Refinancing	$ (8,332,647.69)	$ 27,253,431.98
Issuing Debt	$ (17,753,143.43)	$ 27,253,431.98
Build to Suit Lease	$ (13,085,186.17)	$ 5,400,000.00
Exit Strategy Purchase	$ (41,409,787.79)	$ 5,400,000.00
Exit Strategy Cont. to Rent for 10 yrs	$ (27,855,486.39)	$ 5,400,000.00
Sale Lease Back	$ (2,547,216.06)	$ 27,253,431.98

Upon analysis, it was discovered that the Sale Lease Back method was far superior to the other methods in regards to this particular data center; it output a negative 2.5 million dollars in comparison with the other consistently lower negative NPV values associated with the other methods. Therefore, it can be deduced that Brocade should purchase the building, sell it (after it has appreciated in value for ten years) and then lease it back from the company it sold the data center to. Furthermore, exploitation of this method would also enable Brocade to depreciate the data center, which would position Brocade more favorably with regards to taxes.

Overview of Design

Mechanical Engineering Work Package: Computer Room Air Handler (CRAC)

	Coefficient of Performance	Compatible with Climate	Durable	Low Energy Cost	Low Maint.	Total	Ranking	Points
Coefficient of Performance	0	-1	0	1	1	1	2	4
Compatible with Climate	1	0	1	1	1	4	1	5
Durable	0	0	0	0	1	1	2	4
Low Energy Cost	-1	-1	0	0	1	-1	4	2
Low Maintenance	-1	-1	-1	-1	0	-4	5	1

First, after much deliberation and research, the team decided that a computer room air handler would be the most efficient cooling system for the data center. This water based system, would allow for efficient cooling during all seasons, but would also enable free cooling in the colder months due to the drop in temperature of the air available for usage. Furthermore, its rapid restart time and fairly low maintenance allows it to be ranked higher than its competitor systems in the design matrix as well as the best choice for a cooling system.

Next, as seen in Figure 1, after comparing several different types of chillers, the top choice is a tie between an engine driven chiller and a hybrid between an absorption and electric chiller. Both chillers scored equally throughout the table compared to the average, an absorption chiller, but the top ranking is given to an engine driven chiller

due to its simplistic nature. An engine driven chiller is one that is run by a natural gas engine. It is similar to an electric motor for an engine to drive a compressor. A main advantage of this specific chiller is that it can operate at different speeds depending on the need; so in times in the winter where free cooling can be implemented, the chiller does not need to be run at full speed it could be slowed down to save energy. Thus engine chillers tend to have high coefficient of performances since they can adjust to the needs of the data center versus running at full power at all times.

A hybrid system takes the best parts of an electric chiller and an absorption chiller, but only utilizes each component when they would be most beneficial. For example, an absorption system would be utilized in the summer where the use of free cooling would be most efficient, and it would utilize an electric chiller in the winter where absorption would not be as efficient and save energy. Such as an engine chiller, a hybrid system has a high coefficient of performance and would be compatible with the changing climate of Colorado. Both hybrid and engine chillers require roughly equal maintenance and durability. In conclusion, both are excellent choices for a chiller, but the team's final decision laid on the simplicity of the system.

Third ranked is a centrifugal chiller, a type of electrical chiller. A centrifugal chiller scores roughly the same as the average, an absorption chiller, with only scoring a higher value in the coefficient of performance; thus resulting in a slightly more efficient chiller. Fourth ranked would be the average, an absorption chiller. An absorption chiller is a heat driven chiller versus a mechanically driven chiller, thus it is more efficient in the summer versus in the winter. It is a good method, though not the most efficient and thus the reason why it is not the top choice.

A helical rotary water chiller ranks below the average on the basis of durability, low maintenance and coefficient of performance. The complex components require heavy maintenance and therefore have an average lower coefficient of performance than an absorbance chiller. Lastly, reciprocating chiller was ranked the lowest among the choices. Due to its tendency to have malfunctions, these chillers require lots of maintenance. Thus results in a low coefficient of performance and high energy cost. Lastly, due to their malfunctions, these chillers are not durable, and need constant replacing. So in conclusion, a reciprocating chiller would be a bad choice of chiller for the cooling system.

Electrical Engineering Work Package

First, power output and efficiency needs to be discussed. The team designed a system to be redundant but be as efficient as possible, in the sense of using the least amount of transformers possible while increasing the amount of power output. Each initial transformer contains a switch and is compartmentalized in order to power as much or as little of the center and cooling as necessary at any point in time. The transformer we chose to use is Schneider Electric's Power II, Dry Type. It is a small power, medium voltage transformer that provides 112.5-13000 kVA three phase, 600-35 kVA primary voltage, and 120- 15kV secondary voltage. We chose a dry type in order to prevent leaks and fire danger due to weather conditions in Colorado. A parallel wire configuration on the small scale, allows for current to be split among a group of wires to

decrease the amount of current through each one and allow less power loss through heat to occur.

Our design includes an A and B-side. The A side ideally only powers the data center while the B side powers the rest of the data center along with any extra auxiliary loads including desks, laptops, and lighting. This unbalanced load system allows for only necessary items to run at a given time while current is split evenly using 3-pole breakers. We assumed that these 3-pole breakers would perfectly split current. Circuit breakers and switches are also included at every level to insure maximum power transfer and distribution. This way only the absolutely necessary amount of power is delivered to each load with minimal wasted power.

The fuel cells provide an alternative energy source that runs the racks and decreases total grid power energy. Though this is a high up front cost, after tax deductions and overtime, the fuel cells pay off greatly. A smart option is to run the grid mostly during the day with fuel cells as extra power and then at night switch to running mostly the fuel cells when cooling is used less, this way the cells can power a larger portion of the overall system. The initial fuel cell purchase would include 1 cell and which would jump to 2 and in phase 2 and 3 cells for phases three and four. The costs of implementing this data center are high to begin with; some of the methods described above can decrease cost while increasing power and efficiency.

Secondly, the team did an analysis on redundancies because outages can occur at every level, creating a high-risk environment for costumers and a capital loss for the company. The team's N+1 redundancy system backs up single pieces of equipment and is designed in a way to feed at one or more points therefore any PDU or UPS can

power any other piece of system at any time. Rechargeable batteries are charged by the UPS system and then switched off when full. These batteries can run the whole data center for the time span it takes for the generators to kick into full gear. Also, 2-3 fuel cells support the total power load by providing 200 kW each. In the design, every UPS, PDU, fuel cell, battery, and generator is connected with horizontal circuitry in a way to fuel every other piece of equipment in case of an outage. This allows for all around the board redundancy if a part of the system fails. However, the 2N redundancy provides a whole parallel system to ensure that generators properly synchronize with the UPS system so there is no interruption of service when moving to generator power and/or backup power. This includes double generators, PDUs, UPSs, batteries, and transformers and also allows for easy maintenance because the backup system can be implemented during this process.

In order to monitor all systems, the team implemented Schneider's SCADA system. This system provides monitoring at every level of distribution as long as the purchased equipment is compatible with a protocol called Modbus. A variety of sensors and drives are added to the date centers and interconnected using Ethernet, USB, etc. Using signals, the bases are hooked up to any outdoors equipment needed for communication, such a thing would be maybe fuel cell, UPS, utility. From there a control room comprises the data and displays it on a computer system. This control room is overlooked by specialists and then sent on to maintenance users and other servers for total system surveillance.

Next, the team researched 3 different methods of renewable energy to implement on the Broomfield campus along to support the utility grid: wind power, solar power, and

fuel cells. Wind power proved to be very efficient but Broomfield is not windy enough at an average of 5 mph winds when about 7.6 mph are needed to successfully run the system. Also, the noise from the wind turbine would be too bothersome for the campus. Solar power and fuel cells came to be very similar in cost; the only difference is that fuel is very expensive which put fuel cells above in cost. However, it is a trade off because fuel cells run on 100% efficiency almost constantly, whereas solar cells depend on sunlight and Broomfield only receives about 248 days of sun a year. Fuel cells are larger and more massive but to obtain the same amount of power output from the solar cells a total of about 1000 would need to be purchased. This also comes to a tradeoff, which pointed the team toward fuel cells. Fuel prices vary just like sunlight therefore fuel is a better option.

Finally, a decision matrix was used to help make good business decisions based on common factors such as power output cost, reliability, scalability, and efficiency. With such a sophisticated system, the equipment available was very limited due to the high current running in the system. Many parts cannot handle such a voltage and current so only a few options were left to weigh. A large decision was whether a natural gas generator or diesel generator would be better for a backup system. After looking at safety, efficiency, and reliability a diesel generator proved to be the better option.

Though fuel is better at starting in cold conditions and does not need gas storage, Diesel has lower risks of fire and engine life is longer. Transformers and PDUs were also in question during the design process. A PDU is just a series of transformers and circuit breakers so the option to buy the parts separately and install them was realistic. However, after some research it was decided that PDU are built as a system

and most can offer safety features and extra protective circuitry whereas the bare parts would need some sort of system on the side. The transformer parts make it easier to replace broken parts and conduct maintenance. A major worry is that the separate parts will not always be synchronized because they are put together, this would cause a large power loss and if the system were to break more equipment could be damaged as a byproduct. For these reasons, the extra price of the PDU is better to ensure a smooth operating, reliable system.

	Weighing	Natural Gas Generator	Diesel Generator	Solar Cell	Fuel Cell	Transformer	PDU
Efficiency	10	7	9	7	9	8	9
Maintenance	6	6	8	8	9	9	7
Compartmentalizing	6	5	6	7	8	9	8
Redundancy	10	8	7	7	7	8	9
Power Output Cost	9	7	9	7	9	8	9
Reliability	10	7	9	9	9	8	9
Size	8	9	7	9	8	9	7
Power Loss	9	8	8	7	9	8	9
Installation	7	7	7	7	8	9	8
Smell/Noise	5	7	9	10	9	7	7
Safety	8	7	8	10	9	8	9
Durability	9	7	9	9	9	7	8
Price	10	8	8	9	8	9	7
		730	832	868	912	879	883

Architectural Work Package

The location of the proposed data center within the provided lot can be seen in Figure 3. First, Brocade Communications System's second largest branch is located in Broomfield, Colorado. The existing site includes acres of available space for expansion. The site is also home to the branch's main office facilities with plenty of parking and a pond near the entrance of the Brocade Parkway. The Data center location will affect the operational and cost efficiencies significantly. In this case, the current site already includes a small data center located at the lower level, inside the main offices. Since there is already a data center on sight, it is assumed that the site includes ample and reliable power and communication infrastructures nearby. The location of the data center affects operational efficiency and operating costs.

Next, the site criterion includes easy commuting distance for employees and outside support vendors, including nearby source to water storage and power grid connections. The current site includes a large general parking lot that is only half full on its busiest days. The site also avoids potential hazardous areas away from wet labs, machine shops, cafeterias or other facilities that could present a hazard to the data center. The proposed building site is located in an area to minimize disruptions from direct neighboring traffic, yet still ensure all critical utilities. Zoning is not to be an issue to the City and County of Broomfield Planning Division.

FIGURE 3 – SITE PLAN OF NEW DATA CENTER

Finally, a building type can affect occupancy costs, flexibility for expansion and facility maintenance. The proposed structure avoids multiple levels and areas with small bays. Single-story structures with minimal windows offers lower rentals and operating costs, while minimizing the amount of natural sunlight to enter the building, bringing unwanted heat inside. The building bays were given a large column spacing between 30 and 40 feet. The ceiling height was taken at 13 to 14 feet from the structural slab, providing plenty of room for rack height requirements, Starline and other mechanical equipment to keep the racks/server rooms cool. In categorizing the occupancy of the

building per IBC 2009 CH3 – Occupancy), it is important to avoid issues regarding serviceability/vibrations and interferences from any other power utility lines. In terms of security, multiple levels of security access will be taken inside the data center, along with appropriate fire suppression system to keep safety levels high and people and equipment inside safe.

FIGURE 4 – 3D MODEL OF PROPOSED BUILDING

KEY DESIGN FACTORS

- Sufficient floor space
- Large column bays (high ceiling clearance)
- Leveled roof (no skylights)
- Loading Dock (equipment delivery

Recommendation

The team's recommendation for finances through cost analysis is to use a Sale Lease Back method for this data center because it resulted in a positive value of $6.5 million dollars while the other methods had a negative NPV value. Therefore, it is recommended by the team to purchase the building, sell it (after an appreciation of ten

years) and then lease it back from the company it sold its data center too. This overall would allow Brocade to depreciate the data center, and be more favorable in terms of taxes.

For the cooling system aspect, the team recommends a computer room air handler because it is water based and allows the data center to be cooled in all temperatures of the year. The chiller used with the cooling system is an engine driven chiller due to its simplistic nature which allowed it rank higher than the other chillers analyzed through the decision matrix.

For the electrical system, in order to efficiently power a data center at its max of 600 racks and 12 kW, the team's recommendation is to use a utility grid, 3 Bloom Energy ES-5700 fuel cells, 2 back up diesel generators, 6 Symmetra MW 1600kW Frame 480V UPSs, a series of Eaton Blade PDUs with Maintenance Bypass, and 5 Starline per PDU. With a horizontal circuitry method and grouping of parallel wires, efficiency is increased and power loss is minimized. The parallel wires allow for a lower current per wire and allows for less heating in the overall system. As the building is scaled, wires will need to be added from the main line in order to support the new racks but the current in each of the wire sets will be the same but the quantity of wire groupings will increase. The current is balanced using 3-pole breakers.

As for the horizontal circuitry, it allows for N+1 redundancy where if any piece of equipment fails, the other parts will assist in powering the racks. This is great for small problems but in order to support large outages, a 2N system is added which implements a complete parallel system that can be activated by switches if anything in the main system fails. The redundancy is a large up-front cost but it is well worth it because an

outage can cost anywhere from 100- 10 million dollars. After some research, the team's power recommendation would be to run the grid for a majority of the power but also include the fuel cells for a significant part. The cells cost is $0.06 per kilowatt-hour, which is not a huge difference compared to the $0.07 cost to run the grid. However, most of Colorado's power is not clean or renewable since it mostly comes from burning coal. This not only puts Brocade in the "sustainable company" category but also is more efficient during night hours for example when the data centers are cooler. Even a one-cent difference is a huge difference at such high power usage.

For the architectural aspect, it is important to meet the demands of the mechanical and electrical systems. In doing so, the building needs to have large bays to reduce the number of columns in the building. It is important to have the flexibility to power and cool the racks in order to have an efficient design. IIS also recommends minimizing the amount of windows in the building (no skylights) in order to keep temperatures low. Other sustainable and efficient designs will be included to the building, such as a white roof implementation to reduce heat absorption from the sun and into the data center. Overall, IIS designed the proposed data center according to engineering recommendations.

Lessons Learned

Throughout this quarter and working on this project, Team 3 learned many valuable lessons by committing mistakes, realizing situations, and recognizing their own strengths and weaknesses. First, each member of the team was a different discipline, either as an engineering student or a business student. With this attribute, each member was allowed to explore how it is to work with those who possess a different knowledge and different area of expertise as them. It allowed the team member to recognize their strengths in the areas where he or she could excel and help the team out overall and to also accept their weaknesses in areas where another team member was possibly more knowledgeable. By working in a team, it is the same as working in workplace with engineers and accepting others ideas as well as voicing one's own opinions.

Second, the team learned what a data center actually is. Each team member started off with minimal knowledge about the reasoning and basis behind a data center. Through extensive research, every member learned what goes behind building a data center and the different planning of efficiencies in their own disciplines. The mechanical engineers through the analysis of the different cooling systems discovered that using a water based system is more simple than any other system. The electrical engineers learned that backup circuitry is crucial from a business perspective. The architectural engineer learned how to work with other engineering systems to the extent of making their building compatible with a versatile amount of systems.

The team utilized learn by doing motto to a great extent. Each team member was allowed the opportunity to take their class room based learning and explore it outside of

the classroom. Each member used programs, research, ideas, and their own technical knowledge base and applied it to this project in a real life basis. It allowed each team member to harness their knowledge that they have learned thus far and teach other engineers and finance students as well as learn more about their own major themselves.

Overall, our final and main lesson learned was what engineering is actually defined is. Before, engineering to the team was a technical field in which each member utilized their own knowledge to perform their own work and tasks. Now, the team defines engineering as a discipline in which each field of knowledge is exchanged from discipline to discipline and it is a team effort. Engineering is the research, extensive planning, and final configuration of the product through the collaboration with all types of majors. Engineering is the main foundation for all products (such as the data center) and is the basis of all major aspects of the business world.