2011

TECHNICAL ASSIGNMENT 3

Submitted 11/16/2011

Construction Management
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11/16/2011

Executive Summary

The Biological Research Lab is an Animal Biological Safe Laboratory (ABSL-3) located on the Pennsylvania State University Campus. The laboratory's design of a modern barn captures the nature of the surrounding facilities. Making up the façade, the rusticated concrete masonry units, metal roof and unique windows fit with the agricultural part of campus while providing a high efficiency building envelope. The facility as seen in figure 1 is approximately 20, 330 square feet and has a scheduled cost of $23 million which is funded by the National Institutes of Health (NIH) along with Penn State.

Figure 1 - Courtesy of Payette Associates

In the third technical assignment concepts such as actual and anticipated constructability issues along with schedule acceleration scenarios can be viewed in the report. Value Engineering topics are also discussed where changes benefited the users. A meeting with industry professionals sparked innovative ideas that have been incorporated in the assignment. Concluding the report is a series of analysis methods focusing primarily on problem areas and places of improvement throughout the construction project. The research laboratories are one of these places where improvements can be made. Other areas of analysis include energy consumption as well as providing viable alternative solutions. Virtual mockups and the Integrated Project Delivery method express nontraditional ways of successfully completing the project.

Every one of the following sections in the assignment has been created to gain knowledge and help improve the everyday function of the project. The following report expresses the findings into analyses, where research laboratories involving quality control is one area where improvements can be made. Other areas of analysis include energy consumption as well as providing viable alternative energy solutions. Virtual mockups express nontraditional ways of successfully modeling spaces without generating waste. Concluding the assignment, the Integrated Project Delivery method compares against the current contracting method on the project, evaluating which organization structure would be superior.

Contents

Constructability Issues

Bio containment Laboratories around the world are being constructed with a new approach, Integrated Project Delivery (IPD). The Biological Research Laboratory located at The Pennsylvania State University utilizes a hybrid of typical Design-Bid-Build as well as IPD. On the project the Architect, Payette Associates, the Construction Manager, Torcon Inc., and the Commissioning Agent, Cornerstone Commissioning worked together throughout the two years of design for the project. The benefit of incorporating the necessary parties early in design is to collaboratively review the drawings as well as suggest different approaches in the construction process which might be more efficient. The collaborative design is implemented on these projects because of intricate and atypical building systems as well as the high level of quality finishes prevents the project from finishing on schedule.

Lack of Structural Information

One of the first constructability issues on the Biological Research Laboratory involves the superstructure. At the Pennsylvania State University any building proposed is governed by architectural features and criteria by the surrounding building and structures. The BRL facility is located on the agricultural part of campus, bordered on the west by cow barns holding facilities, while on the east are acres of pastures and the Animal diagnostic laboratory to the south seen in Figure 2. This led Payette Associates to architecturally design the "Bio-Barn" resembling a traditional version of an animal holding facility with modern day features and state of the art equipment. While the design seems relatively simple, structurally the roof is very complicated with different angles and connections while incorporating a large window for conferences at the west end of the building. Sections of the roof can be noted in Appendix A.

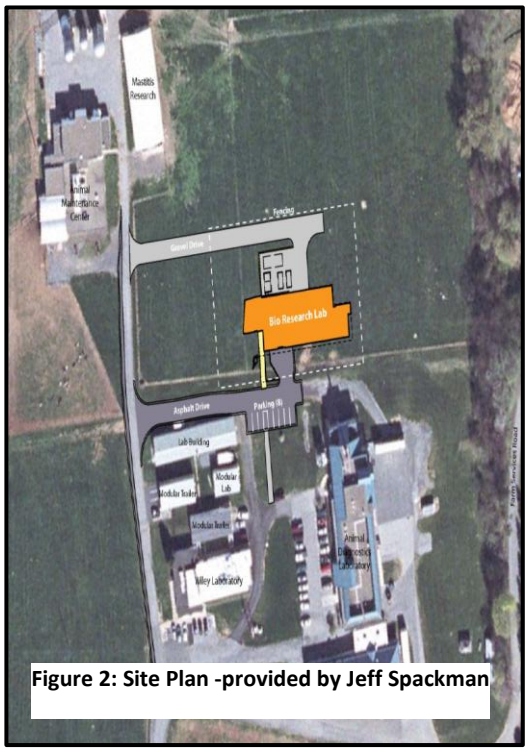

Figure 2: Site Plan -provided by Jeff Spackman

On the BRL, subcontractors were not involved with the design and were traditionally brought on through the bid and award process as the project progressed. The steel subcontractor when awarded the bid began to notice discrepancies in both the architectural as well as the structural drawings provided and the design of the "Bio-Barn's" roof proved to be a challenge. The steel sub-contractor was not given enough information in order to properly order the correct material. The roof encompasses two floors, the mechanical penthouse and the mechanical mezzanine, as seen on the East/West elevations in Appendix A. This metal paneled roof system and the two floors contained a large majority of the building's structural steel, posing a scheduling impact to the project if the correct sizes of beams and columns were not ordered on time.

On every framing plan in the structural drawings a General Note provides the top of concrete slab and top of steel elevation. The steel subcontractor began to run into problems where both of the floors met the roof on the penthouse and mezzanine levels. The solution to the problem would be referencing the roof details for the structure except when the roof detail states "please SEE PLAN" for elevation. This can be noted in the roof detail, Figure 3 below.

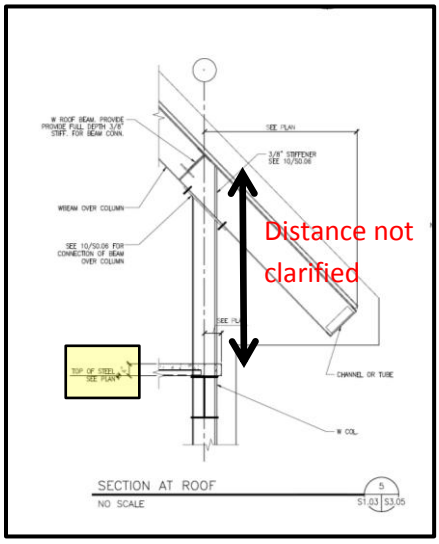

Figure 3- Roof Detail provided by Payette Associates

There are many details for the structure of the Biological Research Laboratory where heights of columns or roof joists lengths are unknown because of the lack of provided information. Missing information can delay procurement of the material, which can slow or delay the schedule of the project.

In order to fix the problem the Subcontractor is working with the Construction Manager Torcon to submit a Request for Information (RFI) to the Architect. Once the Payette Associates received the (RFI) they resubmit to the Structural Engineer so the drawing can be adjusted to provide the necessary information for the Steel Subcontractor. Usually incorporating design professionals well before construction eliminates problems such as lack of information in the structural drawings. This issue was not recognized on this project until construction.

Laboratory Finishes

Delays in the construction of Biological Containment Facilities are 90 percent because of poor detail execution and the coordination of the laboratory areas[1]. Housed in the building are two ABSL-3 animal holding rooms and two double animal holding suites which are separated by a procedure room and air lock. Also in the bio containment space are two BSL-3 laboratories which look at microbiology. The last workspace in the laboratory is an insectary which examines pathogens. Equipment in the laboratory which is also extremely important is a gas/decontamination chamber, an autoclave and a shower for scrubbing out procedures. This type of facility requires attention to detail as well proper testing of equipment for turnover.

Material finishes next to the coordination and installation of mechanical equipment are the most complicated to finish correctly. The contractors hired to complete and perform the drywall installation as well as the floor finishes have specific requirement which must be met in order for their work to be considered finished. The material requirements as laid out in the specs for wall construction call for caulked joints, resistant to disinfectants, impact protection, water and moisture resistant, and pest resistant. All of the walls will also contain a plastic chair rail at 18" and 42" along the height of the wall. Exposed corners are also protected with moldings to prevent chips and deformation of the drywall.

One test that is used to test the finishes of the walls is called the glove test. This is during final inspection where a user would place a set of latex gloves on, rubbing their hands along the wall. If the glove does not rip, tear or puncture in any way then the wall finishes pass. Figures 4 and 5 below shows how small a wall defect can be to fail the "glove test."[2]

Figure 4 - Wall Imperfection, Courtesy of NIAID

Such a small imperfection (left) can tear a glove (right) compromising the experiment and safety of the researcher.

Figure 5 Torn Glove, Courtesy of NIAID

Floor finishes are also a key component in an Animal Biological Safe Laboratory. The epoxy resin floor system needs to be seamless along the walls to prevent bacterial and other pathogens from dwelling in the surface imperfections[2]. A water tight finish is required due to the wash downs after procedures in the bio containment space with enough texture to be slip resistant. The picture below shows an ABSL-3 laboratory finished floor, Figure 6.

Figure 7 - Finished Floor, Courtesy of NIAID

Hollow wall construction or cold formed metal studs with impact resistant drywall (Figure7) is the hardest to fabricate to acceptable levels. The Bio-Containment labs where cage racks are present, a reinforced epoxy with fiber glass is to be used to increase the structural integrity of the wall[2]. Normally a standard coating of epoxy is applied to resistant impact on drywall surfaces. The finishing subcontractor's biggest issue is ensuring the space is airtight.

Figure 6 - Impact Resistant Drywall, Courtesy of NIAID

Experienced subcontractors for drywall construction take initiative to chalk seam, corners and joints before the final pressure test at closeout.

Another constructability issue within wall fabrication is the application of different epoxy coatings. The concern is the peeling of the epoxy coating after it has been applied due to poor preparation. Many times in the final coats of containment walls, latex filler is used to smooth out imperfections, a component in the filler is a thixotrope specifically PVA.

A thixotrope is a material which viscosity decreases when a stress is applied[5]. When there is moisture on wall the latex filler will emulsify causing the epoxy finish to flake or peel after the completion of construction.

Equipment Testing and Turnover

Researchers and users of the facility have a lot of input in the selection of equipment from Autoclaves, Bio seals, Capture Hoods, Casework, and Bio safety cabinets. Due to expenses, equipment purchasing is based on lowest cost and preferences of the users. A problem that arises during installation of equipment is all the pieces do not originate from the same manufacturer, and are not exactly the same size creating a possible layout and space problem. During the turnover of the project, the commissioning agent takes a hands on approach to deliver a laboratory the owner expects with regards to performance and efficiency.

Cornerstone Commissioning's role on the project for turnover is to operate systems and perform zone tests ensuring that the BRL facility is functioning at a normal day to day operation. This process can be very tedious and push back the project schedule if the quality of finishes or equipment was not installed correctly. Recently a new standard on Vivariums require audits to many forms of safety and compliance bodies that have to be notified of the completion of the ABSL-3. These regulatory codes must be addressed in order to obtain licensing and operational authorization for the users to begin performing tests. On most Vivarium projects training researchers and users are allotted into the project schedule but cannot start until the Cornerstone Commissioning approved the punch list.

Schedule Acceleration Scenarios

Project Critical Path

The Biological Research Laboratory's critical path contains several activities including a procurement which consists of awarding contracts as well as submittal and reviews. The project started with excavation of the site in preparation of the footings and foundations. The superstructure or steel was then placed by floor along with the metal decking. As the steel approaches completion, concrete slabs are poured starting from the basement level. After the floors have been poured construction on enclosing the BRL lab with the exterior building begins. Installation of building systems such as the mechanical, electrical, plumbing and fireproofing systems follow. Construction on the interior partitions has also begun during installation of building systems which includes drywall, taping and finishing. Interior finishes and trim out follow the construction of the wall partitions, then closingout with the placing of equipment in laboratory spaces. Afte substancial completion, commissioning, punchlist items and training the faculty are encompassed in the final completion of the project.

The critical path of the project lies with the construction process and if one or more of these activities were not completed on time the project completion date would not be achieved. Important project activities consist of MEP systems installation as well as laboratory finishes and equipment. These processes are the most susceptible to falling behind on the project schedule because of the coordination and sequencing with other trades along with maintaining quality of work.

Increase Labor Hours (Steel Erection and Fabrication)

Problems permitting with the Labor and Industry and the inability to receive and start work caused the project to be delayed from the start. Members of the Penn State Office of Physical Plant traveled up to Harrisburg Pennsylvania to review the variances and submit additional information provided by Payette Associates to expedite the building permit in order to start construction. Another problem that posed a scheduling issue was the weather in late August to the end of October; rain forced the excavation of the site to stop as well as the utility banks to be delayed.

As the project fell behind schedule increasing labor hours of crews became a promising solution to recover two weeks of lost work from permitting and unforeseen conditions. An activity where time was to be reduced was in Steel erection and the placement of metal decking. The time to finish the super structure of the building has a duration of approximately five weeks. Utilizing overtime for crews by implementing ten hour days as well as working on Saturdays for ten hours cuts one week off the project schedule. Allowing the steel crew to work overtime for the entire duration enables the crew to finish steel erection and metal decking in three weeks and two days compared to the original five week duration. Eight days were reduced off the schedule which allows the schedule to be behind by two days.

Detailed Review Sessions and Inspection

The biggest possible schedule impacts on the Biological Research Laboratory are finishes and details within the laboratory space. Detail review sessions explain issues such as new construction techniques, unfamiliar product application along with multiple trade sequencing and coordination. Important aspects of these toolbox talks were to inform subcontractors in unique sequencing plans during construction of the Animal Biological Safe Laboratory. Educating contractors on the complexities of a ABSL-3 vivarium helps with fabrication details and mistakes that would require contractors to return and fix the problem. The meeting also gives time for contractors to talk about sequencing of work and how they could possibly perform work more efficiently. Understanding the dissimilarity between different laboratories and their details can also reduce down time on the project and possibly shorten the time the contractor is on site[1].

Attention to detail as well as educating the proper parties can save time on a project. Planning and meeting collaboration is a tool used to help coordination, by expressing a contractor's problem or implementing one of their ideas[1]. The Biological Research Laboratory is not typical construction, these high tech air tight spaces need to be perfect to pass the National Institutes of Health guidelines. Reviewing special construction details such as wall penetrations, sprinkler heads penetrating drywall and fixtures with contractors helps prevent incorrect fabrication. Inspections are also utilized every week to enforce quality control as well as enforce construction details reviewed in the meetings. The worst possible outcome on a vivarium project is the commissioning agent finding finishes and details installed not as designed, setting the project back past the initial completion date.

BIM Implementation

Torcon, the Construction Manager, has a lot of experience with vivarium facilities in the past and has used Building Information Modeling to not only aid in the coordination process but the schedule as well. Subcontractors as soon as they were awarded the contract were told to start creating a model which would be used for coordination and clash detection. Cadnetics developed the structural and architectural model to prepare for MEP coordination. Once a week all the trades presented their models and combined them to the Cadnetics base model to create a clash report. The clash report created, generates multiple clashes; the first is false clashes which is usually an incorrectly modeled component. Field important clashes are called "hard clashes" and "soft clashes." A hard clash or a relevant clash is two system components interfering which needs to be resolved. A "soft clash" or a clearance clash can also be important when dealing with an example of insulated ductwork moving through a tight space.

Using NavisWorks along with clash detection eliminated many clashes which would have been found in the field. This coordination helped maintain the schedule for the most complicated phases of construction. BIM also helped contractors visualize the model quicker than viewing traditional two dimensional drawings. The addition of extra planning as well as modeling tools drove the project to completion without implications to the schedule.

Value Engineering

The original design of the Biological Research Lab in 2006 was intended to be constructed modularly with a proposed budget of approximately $8 million. After further design and cost analysis the design and project team realized that the conceptual design for the laboratory exceeded the original budget. Cost reduction meetings were implemented looking at reducing redundancies in the facility to the minimum acceptable levels and reducing the size of the containment space. After the proposed cuts to the design, the project was still over budget and attempts to receive additional funding had failed due to design requirements.

In order to receive grant money for the project, special design requirements needed to be met as well as incorporating high levels of redundancy in the Mechanical, Electrical and Plumbing systems. The design team and CM proposed to traditional built the vivarium instead of using modular units; because benefits of modular construction had no value to the users besides a short schedule of 120 days from the start of fabrication to delivery on site. While this was very appealing to the users of the new proposed facility, overall quality and flexibility was sacrificed compared to a traditional new construction project. The value engineering on the project is untraditional where the focus is on increasing value instead of reducing cost. Mechanical system layout and design, window glazing, and flexibility and the master plan of the facility are value engineering topics that were utilized on the project.

Mechanical System Layout and Planning

Modular construction of a Vivarium is restrained 100 percent on transportation to the site. The height restriction for a modular unit is 8' which provides enough space for work and experimentation but not enough room for mechanical equipment above the ceiling. Mechanical Rooms are usually placed in small designated rooms or separate buildings where access is from outside the laboratory in modular construction[4]. In modular vivariums access panels are utilized to perform maintenance on systems throughout the containment space. This can potentially pose one of the biggest issues by letting unauthorized personal into a containment zone with risking a breach. These panels as seen in Figure8 also have gaskets which over time and due to age have the potential to leak creating a path for air borne pathogens to escape[2].

Figure 8 - Access Hatch courtesy of NIAID

In traditional construction, the design of the facility allowed for all of the Bio-containment labs to be located on the first floor while the mechanical systems were located above and below. In the Biological Research Lab, a mechanical basement which has access from the outside, houses all of the wet mechanical systems below while the mechanical penthouse and mezzanine contain all of the air handling units and dry systems above. This eliminates the need for maintenance personal entering the white space and possibly contaminating experiments. Another important issue solved by changing the design to traditional construction is the sound levels from equipment. Modular units had

higher decibel levels due to the mechanical systems adjacent location to the bio-containment space[4]. In the new design, the mechanical spaces above and below were insulated and far enough from the laboratories providing a quieter environment.

Window Glazing

The design of a modular Vivarium does not include many windows because according to National Institutes of Health, all windows must be blast proof. A modular facility is typically all "hard space" which is 75 percent laboratory space and limited areas for offices[3]. Animal care staff usually works under artificial lights during the day only to have access to daylight during their break; because of this many of these research facilities have a high turnover rate which is extremely costly to the owner. Wherever possible architects are installing skylights and transom windows which help keep employees happy in their work environment. Increased day lighting also affects research animals resulting in larger group sizes and produces more responsive results. The alternative to not providing natural daylight is expensive lighting equipment that has the ability to consume high amounts of energy[3].

Figure 9 - Picture Illustrating the large amounts of windows, Courtesy of Jeff Spacman

The new design for the ABSL-3 facility is more of a typical building that incorporates a Bio-containment lab inside. Offices, corridors, and conference rooms are present in the 20,000 square foot laboratory which has ample day lighting for employees. This creates a better work environment as well as produces improved results when carrying out experiments on animals. Window were highly utilized and strategically placed in common areas such as the stair well, conference room, facility manager's office and the service area compared to installing blast proof glass in the containment area which can be seen in Figure9.

Flexibility and the Master Plan of the Facility

Modular vivarium construction limits the design flexibility of the structure. The Penn State University has a strict plan on architectural features and finishes regarding the location on campus. Typical new construction can provide different architectural finishes such as aluminum panels instead of a standard box like design with a crude shipping container finish. Simplicity is the key for modular design offering the basics to the users, where non-modular promotes more to the user needs rather than their minimum requirements. Changing the type of construction from modular to typical construction allowed research and the facility users to incorporate more labs and animal holding rooms, ultimately a better layout for their needs. Due to the low ceiling heights in prefabricated vivariums shorter cabinets are placed on the walls whereas in the new design higher floor to floor height incorporates more room for storage[3].

The Master Plan of both Penn State as well as the researchers was also important in determining the actual value of design. One goal of Penn State is to incorporate LEED on every new construction project, by changing the design and fabrication techniques Penn State was able to achieve LEED silver on the project utilizing onsite construction. Future planning and development also posed an issue for head officials in the Life Sciences department. One of the concerns of the owner was future expansion of laboratory spaces. The architect Payette Associates designed the "Bio-barn" with the intent for expansion on the North end of the building. The architectural design of the building utilizes a central corridor with labs on either side. This design allows for the corridor to run to the absolute end of the building with a window instead of a wall separating the corridor from the environment. In the future if needed the ABSL-3 facility could be expanded by removing the end as seen in Figure 10-11 and continuing the exterior's design into the new addition. This same concept could have been accomplished with modular units but provides a messy finish especially if the site location is not flat, which is true for the BRL facilities. Value for the owner is not only in the building processes but also the appearance to other researching Universities and organizations when they are touring the facilities.

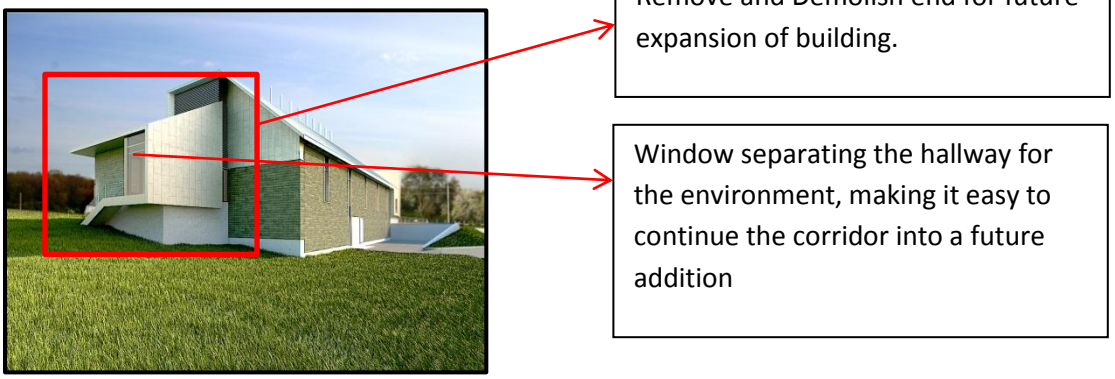

Figure 10 - Demolition proposal, Courtesy of Payette Associates

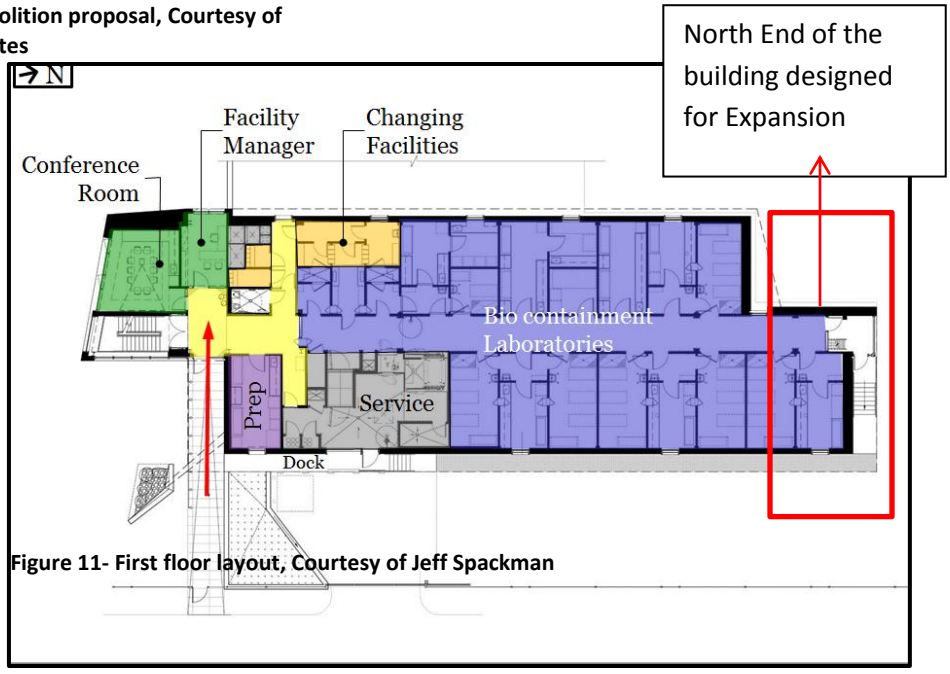

Figure 11- First floor layout, Courtesy of Jeff Spackman

Critical Industry Issues

The PACE roundtable session, held at the Penn Stater, gathered many industry professionals to discuss innovative construction ideas and technologies of today with the goal of implementing these ideas into future construction projects. Round table topics discussed throughout the day consisted of Sustainability/Green Building, Process Innovation, Technology and finally Differentiation in a Down Economy. The first breakout meeting at the PACE Roundtable incorporated Integrated Project Delivery.

Integrated Project Delivery

The construction and building industry over the past decades has made no significant advancement in efficiency and crew productivity and production, partly due to Construction Managers and General Contractors. These firms are still implementing traditional Design-Bid-Build design process where the design of the facility would be completed by the time sub-contractors are incorporated into the project. On the breakout session 1B (Assembling/procuring an integrated team) under Process Innovation, IPD teams was the focus. Most Contractors and Industry professionals in the roundtable session expressed previous experimentation with integrating subcontractors earlier in design, but have not gone any further. One of the limiting factors suppressing integrated project development is the risk/ reward sharing. In this new contracting method which involves the Owner, Architect, Construction Manager, General Contractor, and Sub Contractors, defining the incentives can be very challenging.

A common agreement between the Industry professionals at the round table was the acknowledgement of Trust in the Design Teams. Procuring and assembling an integrated team needs reliable parties with the ability to work and coincide alongside the rest of the project team for the project to be successful. The owner is crucial to the project team and getting them to see the benefits of IPD. As a contractor or a Construction Manager convincing the owner or developer that the lowest bid subcontractor is not the best option is very difficult. Industry professionals at the breakout session explained by using IPD there are increased costs initially for the design and collaboration which results in less change orders over the course of the project. This cohesive collaboration between all the parties involved results in a better quality project, which is turned over to the owner after final completion. Insurance issues also developed amongst the professionals who stated that there is no form of insurance policies to cover a Integrated project team, therefore IPD has never been carried out on paper. Many companies however are taking small steps by incorporating a couple of subcontractors early on in the project.
Open book costs or construction also was discussed as a necessary component for IPD but hard to convince all parties to accept. This type of arrangement allows the owner to benefit on the cost and control of the work and trades. Advantages of using this type of contract consist of the owner only paying for work required, all savings revert back to owner (unless a saving clause is imposed), and construction usually can begin earlier with a shorter project schedule. The large disadvantage to open book costs involves the high risk of the overall project costs bared by the owner.

BIM in the Field

Building Information Modeling (BIM) is a relatively new tool used in the construction process which helps the coordination of trades installing building systems, in the special planning of trades, four dimensional scheduling, as well as life cycle management for the owner. Construction firms at the round table involved with the Strategies and opportunities for taking BIM into the field (2C) first discussed present day uses of BIM. While not all construction projects implement BIM, projects that do utilize three-dimensional coordination along with clash detection, four-dimensional scheduling, and the coordination of the sequences of work.

"Where is BIM going to be in the future? ", was the main question posed to industry professionals at the breakout session. Office trailer in the past has been used to house the model and documents needed for the sub-contractors, today and looking toward the future, contractors are implementing mobile kiosks or stations in the field. These stations allow subcontractors to look at the model retrieving crucial information needed to install a component of the building. Consisting of a large monitor to view drawing these kiosks increase the productivity of crews and make it visually easier to find information needed. DPR Construction as well as other companies also are looking at implementing I pads in the field for punch lists and reviewing drawings, linking back to the job trailers. I pads are beneficial in multiple ways; the first is the reduction of paper, second is the ability to view drawings in the field as well as the related RFI's that are associated with the page, and the ability to mark up drawings for further review.

Also discussed at the meeting with industry professionals were the future uses of BIM still in design. Many professionals at the meeting brought up the potential idea to design a construction model which can be used in the replacing of two dimensional drawings, creating a new standard. Using a three dimensional model for four dimensional modeling as well as safety was also talked about. The safety aspects would consist of labeling areas of danger on the model that was present in the building. These locations in the building could be linked to the model letting contractors know if the area was safe or use precaution. Local code officials expressed the need for code checking in the model which is in the preliminary stages of design. Virtual and augmented reality is also used in the industry for virtual mockups, saving money on field mockups with the ability to change without demolition.

Differentiation in a Down Economy

As graduating students begin looking for jobs in today's industry, the economic downturn of the last couple of years has been a real point of interest. At the PACE assembly, industry professionals as well as students gathered onto a panel revealing their thoughts on the matter. One important fact about growth in construction is that it lags behind the economy by approximately 18 months. Since 2008 the economy as well as the construction industry has been struggling to survive. Companies in all sectors have been placing low bids, cutting unnecessary waste, and restructuring their company to hopefully endure the economic recession. As a result these construction firms have been hiring fewer graduates and raising the standards on the students they do hire. Implementing Building Information Modeling, Integrated Project Delivery, as well as lean construction has been a large focus for companies throughout the country when looking at future employees. A question an industry professional would ask is "How can you help or add value to my company?"
Industry experience, internships and co-ops are one of the most sought after commodities on a resume. Depending on the company, experience with coordinating sub-contractors and every day jobsite problems can be just as valuable as an education. A rotational program, used by many companies, where employees spend time in preconstruction, as field engineer, as well as a project engineer provides a well rounded experience for future Architectural Engineering students in the industry. The panel at the PACE Roundtable answered many questions, but continuing education seemed to be very important. Every year, a multitude of students graduate from top schools with new innovative ideas, staying up to date with technology as well as other construction practices keeps a new professionals value high with their company.

Reflection

In an Industry which is struggling, new and innovative ideas such as Integrated Project Delivery and BIM must be utilized. The Biological Research Laboratory after further research and an interview with the Project Manager, Jeff Spackman from Office of Physical Plant, implemented IPD by incorporating the CM in design two years before construction. The laboratory facility also incorporated BIM for trade coordination and sequencing, with the intent to complete an As-Built to turn over to the project owner, The Pennsylvania State University. A more effective design will require less change orders in the field as well as deliver a higher quality product. These techniques have higher upfront costs but provide a saving at the end of the project benefiting all parties on the project.

During the last breakout session with industry professionals, Thomas Shumaker from Holder Construction gave insight on how to make senior thesis Capstone Projects better. Tom proposed ideas such as prefabrication of projects components and examples where he implemented them into the field. He also described the scheduling and cost differences to prefabrication where quality is higher and usually takes less time because of the repetitive construction inside a ware house to normal "stick built /on site" construction. Prefabricating lab could be applied to the BRL affecting and shortening the schedule while increasing the quality of the laboratory module. Matt Hedrick who works for DPR Construction also expressed his knowledge in the area of BIM uses and upcoming technologies the

industry is currently implementing. His expertise was in augmented and virtual reality along with BIM uses. The BRL has a lot of labs and the use of virtual mockups would show more options to the user and owner of equipment layout.

Problem Identification

Sustainability

The Biological Research Laboratory assumes no effort in conserving energy besides the common practices of new buildings that are constructed today with regards to building envelope. The National Institutes of Health requires many standards of redundancy in an Animal Biological Safety Laboratory. These areas of redundancy fall under back up boilers and duel air handling units for the laboratory spaces. At the Pennsylvania State University most all project without changing the design, score between LEED Certified to LEED Silver. Even though a higher LEED rating was not sought after; looking at other renewable sources of energy, to offset the high energy consumption, seems more realistic.

Quality Control (Laboratory Finishes)

Finishes and Details in the laboratory spaces are crucial to the building operation and function. All laboratory spaces must be airtight and withstand a pressure of 20 pounds per square foot. Floor finishes are an epoxy layer which needs to be seamless to prevent pathogens from escaping. These details can prove to be challenging to inexperienced contractors in the research laboratory sector. Cornerstone Commissioning has the role of checking the all aspects of quality within the lab before the turnover to the owner. If standards are not met, contractors have to revisit the site ultimately delaying the project schedule.

Project Delivery Method

On the vivarium project the architect, construction manager, commissioning agent and engineering firms were brought on to the project for design. Subcontractors should have been brought onto early in the project; many of the problems with constructability could have been resolved in design. A lot of new vivarium construction projects utilize Integrated Project Delivery to successfully complete the project. Establishing a project team also falls under this category of delivery method. IPD's main focus is trusting your project team and working with qualified contractors not the lowest bidder.

Sequencing of Work

The project design contains a half of a basement for mechanical equipment and two floors of mechanical equipment above the first floor. The original sequencing on the project utilizes a floor by floor construction. In the area of bio containment laboratories for finishing trades, sequencing should be per room instead of the whole floor. Crews would be more effective with a goal accelerated schedule by room, implementing a lockout procedure after a certain date.

Analysis Method 1: Prefabricated Laboratory Spaces

Modular units in recent years have been a viable solution for quality construction. Prefabrication takes a lot of planning but contains a lot of value with little time spent in the field with installation. The fabrication of modular units are assembled in a warehouse and transported to the site just before installation. Fabricating in an offsite location is less expensive compared to field assembly, the schedule also benefits by reducing the overall duration of the activity. Quality is also assumed to be higher than if constructed in the field and is a large constructability issue with inexperienced subcontractors in research laboratories.

Along with fabricating modular units for the structure other areas of the building need to be examined. Structurally, half of the first floor that lies on metal decking. This structure possibly might need to be redesign because of additional load. The columns need to be examined for shear and moment loading; footings depending on the bearing capacity of the soil could potentially be increased as well to account for the extra weight in prefabrication. The MEP systems will also need to be redesigned to be prefabricated in racks in the interstitial space above the laboratory and animal holding rooms. Looking at the difference in cost as well as comparing the difference in schedules to see the value by implementing prefabricated units.

Analysis Method 2: Virtual Reality Mockups Compared to Field Mockups

Incorporated into the project are field mockups of the lab spaces for the users as well as the commissioning agent. These mockups are to see the quality of finishes within the space along with examining the details of the construction such as wall penetration and the epoxy floor finishes. The users also get to express their opinion on these sample lab areas for space requirements and layouts. Many field mockups can be very costly where virtual mockups of the same space are inexpensive and offer more flexibility with instant changes.

Comparing virtual mockups to field mockups along with the users' opinion on which space can be more effective is a large piece of this analysis. Techniques learned in 597A will be applied regarding modeling and the presentation of the virtual mockup. A benefit of not using as many field mockups is the reduction of waste associate with the project which can affect the LEED rating. Virtual mockups can also be made well before the purchasing of any lab equipment and used as a selection process for specialty equipment.

Analysis Method 3: Sustainability

Sustainable and energy efficient design is becoming mandatory by many owners and facility managers. The BRL labs are high in consuming energy because of the redundant systems, only achieving LEED silver. Using techniques learned in AE 897G as well as other architectural engineering classes the idea of solar panels will be implemented as well as utilizing geothermal loops. Adding these two energy systems accomplish multiple venues; first it significantly lowers the electric bill as well as amount of water needed to heat. Second by incorporating solar panels in multiple locations it should be able to

achieve LEED gold according to the 2.2 checklist which is currently being used for the building. A cost analysis of the total system will be looked at as well as the possible redesign of the K joists located in the roof.

Analysis 4: (Detailed Analysis of Organization Structure) IPD

Looking at the original project and how they incorporated parties early into design, changing the delivery method to IPD would have been a better option for a complicated project. Choosing your own project team is crucial and dividing the risk/reward is always beneficial in the end. Many of the problems or anticipated problems would have been solved because it falls on all parties not just the subcontractor performing the work. What makes IPD difficult is that most times government projects won't allow IPD because it doesn't respect equality and public bids. Careful examination of the two delivery methods will be the focus for this analysis. One way the methods will be compared are the problems over the duration of the project and what stemmed their faults.

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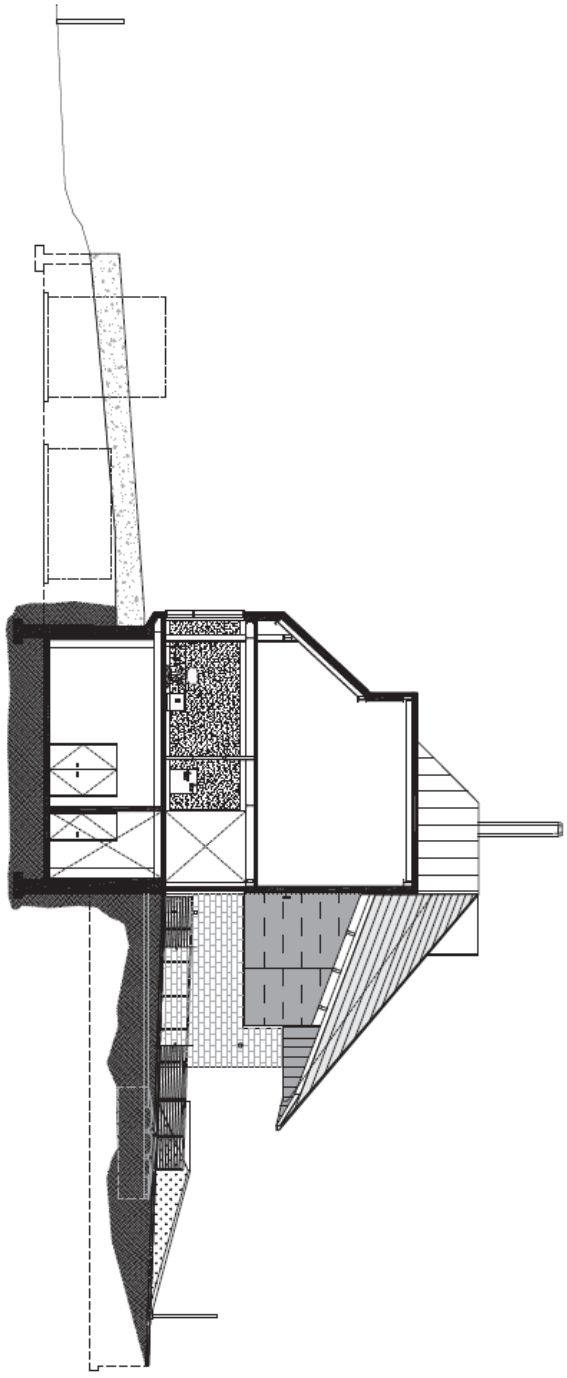
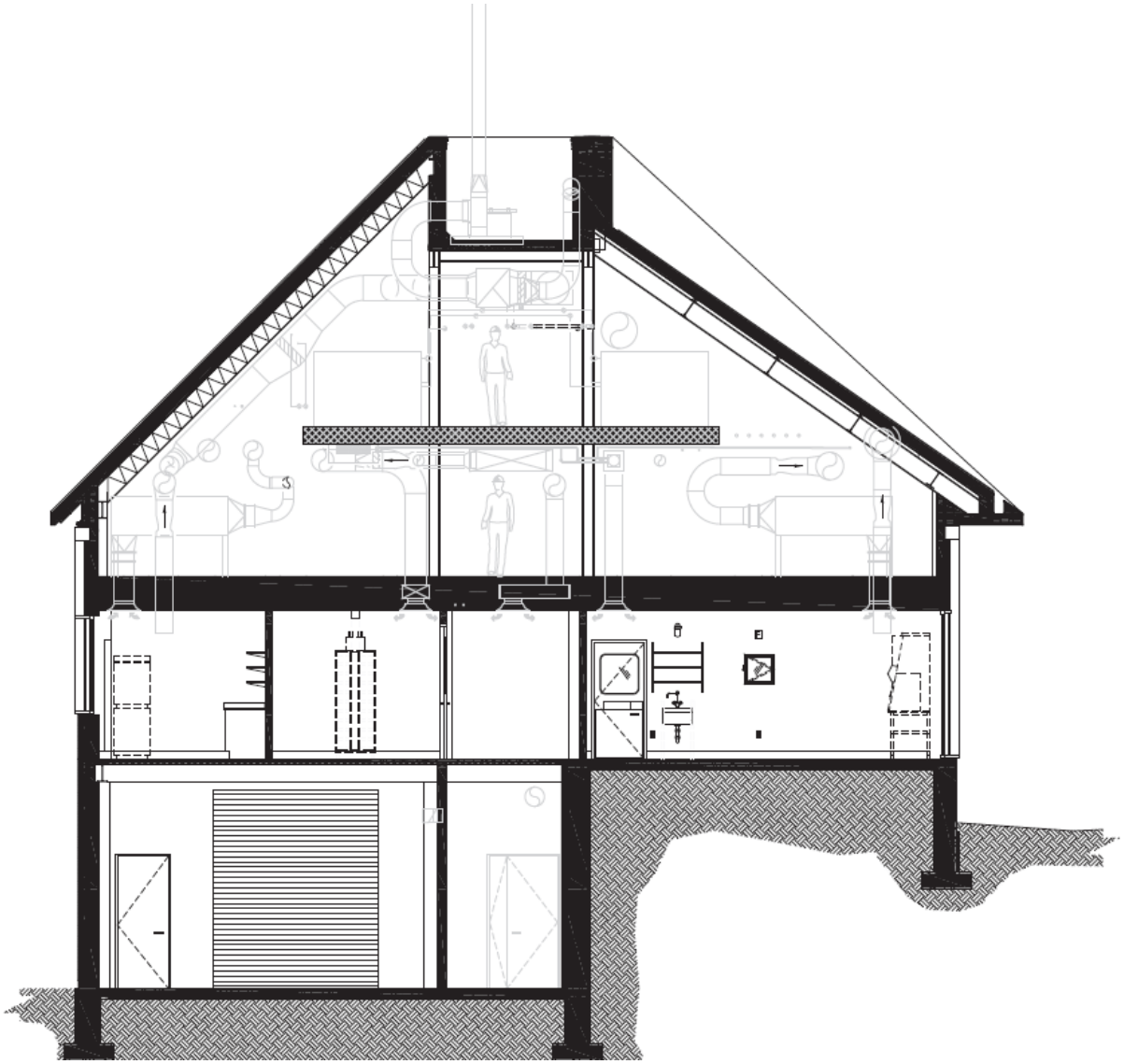
[APPENDIX A]

Elevations and Roof Sections



N-S Elevation 1



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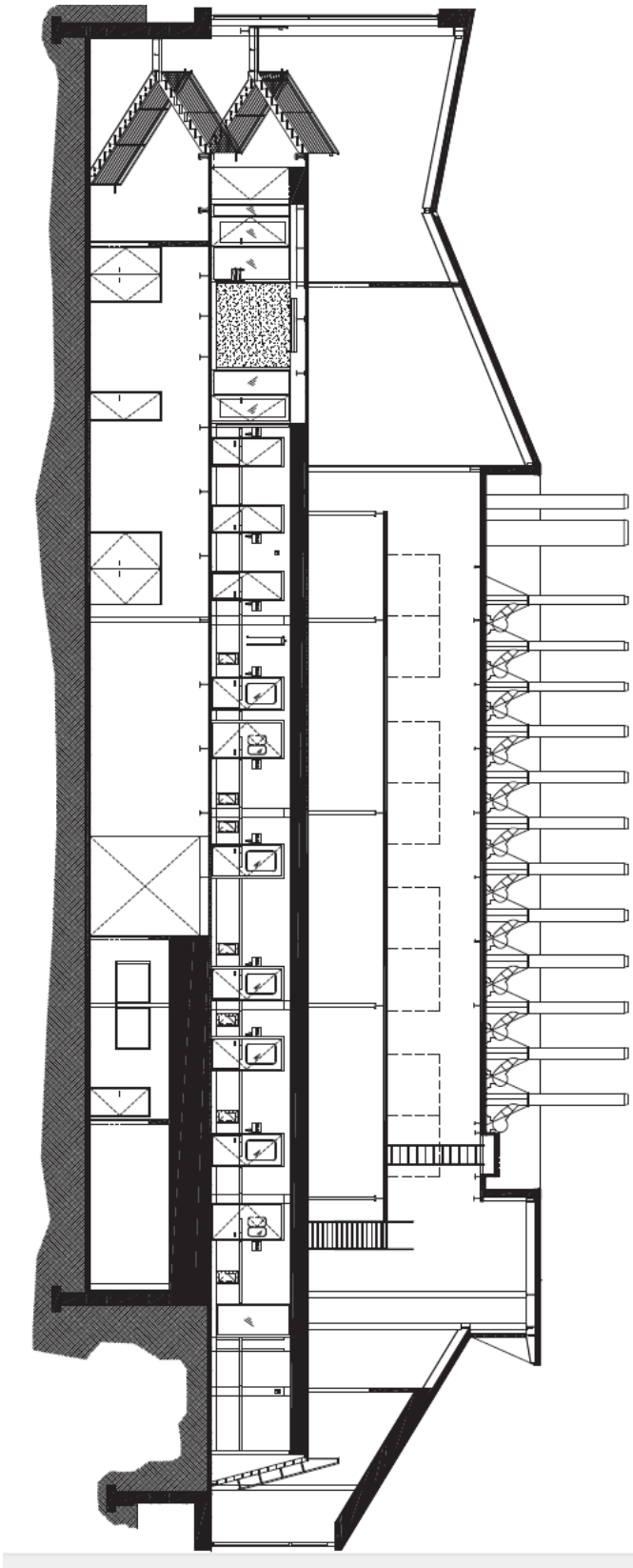

E-W Elevation 1

[APPENDIX B]

PACE Round table Discussion Sheet

Student Name MICHAEL CARRIGAN

Session #1

Topic: ASSEMBLIES / PROCESS IN INTEGRATED TEAM

Research Ideas:

(1) PROBLEMS WITH THE INTEGRATED PROJECT DELIVERY METHOD OF DESIGN-BUILD PARTNER LIKE WITH LIABILITY & LEGAL ISSUES. PUTTING THAT ASIDE GETTING OWNERS ON BOARD COULD POTENTIALLY BE ACCOMPLISHED THROUGH A SHARED RISK / REWARD BETWEEN

(2) ANOTHER POSSIBLE SOLUTION TO USING DESIGN / BUILD ON A PROJECT WOULD BE DEVELOPING A SUITABLE PROJECT TEAM THAT IS WILLING TO DO BUSINESS IN A INTEGRATED FASHION, OPEN BOOK BASIS

Session #2

Topic: STRATEGIES AND OPPORTUNITIES FOR TAKING BIM INTO THE FIELD

Research Ideas:

(1) ONE BIM USE WHICH COULD BE IMPLEMENTED IN THE FIELD WOULD BE VIRTUAL MOCK-UPS. THIS ALLOWS FOR DETAILS AND SPECIFIC ROOM TO BE MODELED INSTEAD OF FABRICATED IN THE FIELD. THIS TECHNIQUE COULD ALSO BE USED ON MY THESIS PROJECT WITH SPACE PLANNING

(2) TO CUT DOWN ON PRODUCTION TIMES AND TRAVELING BACK AND FORTH TO JOB TRAILERS OR "SMART BOXES", IPAD TECHNOLOGY COULD BE UTILIZED TO PULL UP DRAWINGS & MODELS DIRECTLY IN THE FIELD FOR SUBCONTRACTORS TO REFERENCE.

Industry Panel: Differentiation in a Down Economy

Research Ideas:

(1) MAKE YOUR SELF VALUABLE TO COMPANIES
- SELL YOUR SELF COMPLETING FOR MULTIPLE JOBS

(2) CONTINUED EDUCATION TO MAKE ONESELF MORE VALUABLE

Student Form

Pg. 1

Industry Member Discussion

Key Feedback:

Which research topic is most relevant to industry? What is the scope of the topic?

LEAN AND GREEN TOPIC SEEM TO BE MOST RELEVANT TO THE INDUSTRY. THE IDEA OF IMPLEMENTING BIM FOR MORE USES THAN JUST CLASH DETECTION CAN BE USEFUL FOR THE FUTURE

Suggested Resources:

What industry contacts are needed? Is the information available?

AN INDUSTRY CONTACT WILL HELP AND ALL THE INFORMATION IS AVAILABLE BUT JUST BURIED WITHIN THE HISTORY OF PROJECTS

TOM - HALDER CONSTRUCTION

Student Form

Pg. 2