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MSE Observatory: A revised and optimized astronomical facility

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ABSTRACT

The Canada-France-Hawaii-Telescope Corporation (CFHT) plans to repurpose its observatory on the summit of Maunakea and operate a (60 segment) 11.25m aperture wide field spectroscopic survey telescope, the Maunakea Spectroscopic Explorer (MSE). The prime focus telescope will be equipped with dedicated instrumentation to take advantage of one of the best sites in the northern hemisphere and offer its users the ability to perform large surveys.

Central themes of the development plan are reusing and upgrading wherever possible. MSE will reuse the CFHT site and build upon the existing observatory infrastructure, using the same building and telescope pier as CFHT, while minimizing environmental impact on the summit. MSE will require structural support upgrades to the building to meet the latest building seismic code requirements and accommodate a new larger telescope and upgraded enclosure. It will be necessary to replace the current dome since a larger slit opening is needed for a larger telescope. MSE will use a thermal management system to remove heat generated by loads from the building, flush excess heat from lower levels, and maintain the observing environment temperature.

This paper describes the design approach for redeveloping the CFHT facility for MSE. Once the project is completed the new facility will be almost indistinguishable on the outside from the current CFHT observatory. Past experience and lessons learned from CFHT staff and the astronomical community will be used to create a modern, optimized, and transformative scientific data collecting machine.

Keywords: Maunakea Spectroscopic Explorer (MSE), observatory building, seismic, structural, observatory, infrastructure, facility, thermal management system, plant equipment, site redevelopment, Maunakea

1. INTRODUCTION

The Maunakea Spectroscopic Explorer (MSE) is a project to upgrade the Canada-France-Hawaii Telescope (CFHT) to a dedicated spectroscopic facility by replacing the existing 3.6m with an 11.25m segmented-mirror telescope. It will be equipped with a fiber-fed multi-object spectrograph with reconfigurable fiber inputs at prime focus. The scientific need for a dedicated wide-field, multi-object spectrograph on a 10m class telescope has been expressed by the international astronomical community for more than a decade. The potential scientific value of such a facility was discussed in 2010 in a paper by Côté [1]. In 2011, Crampton [4] wrote a white paper supporting the MSE project and described the facility on Maunakea as “priceless”, stating the current CFHT includes extensive equipment and infrastructure that would be of

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direct value to a revitalized next generation facility. Feasibility studies were led by Cote [2] and Szeto [3] in 2012 which demonstrated the scientific importance and technical viability of the project.

The existing observatory, including the inner pier, outer building and foundation will be retrofitted to become the MSE Observatory building and facilities (OBF) while retaining the current structural configuration. The new enclosure will be supported by the outer observatory building steel structural framework and outer ring foundation and the new telescope structure will be supported by the concrete inner pier, both similar to CFHT.

1.1 Value of CFHT

The observatory and headquarters (HQ) provides key facilities and extensive infrastructure that would be of direct value to a revitalized upgrade project, the sections below discuss the value of the contributions to a future upgrade.

1.2 Headquarters facility

The CFHT headquarters facility in Kamuela, HI houses all the facilities necessary for the operation and support of the summit facility, including the vehicle fleet, automotive and machine shops, a computer sever room, and optics and electronics laboratories. CFHT currently has around 45 people on staff who work at the nearly 29,000 sqft building comprised of around 27,000 sq ft of office space and 2,000 sq ft of automotive and machine shop space. Replacement estimates for the HQ facility will surely amount to tens of millions of dollars based on a comparison quoted for a TMT headquarters facility in Hilo. In addition to the facility, the value of the land CFHT headquarters currently occupies (3.2 acres) has significant value when determined using the current Hawaii state tax assessment. The TMT estimate should also be on the low end as building and land costs in Kamuela are greater than in Hilo.

1.3 Observatory facility

The CFHT summit facilities that will be reused for MSE include the building which is comprised of the 5 levels below the telescope observing level and the three levels inside the central concrete pier. They include the physical plant, aluminizing facility, mechanical, electronic, and optics shops, two spectrograph rooms, a kitchenette/lounge, a control room, and a computer server room. The interior of the circular building is 94.4ft in diameter therefore the total area per floor is about 7000 sqft, for a grand total of 30,000 sqft on the 5 levels (not including the crawl space area above the 4th floor). There is also useful space on the mezzanine and observing floor, but that space is not included since these work areas will not exist for MSE.

Ballpark figures scaled from different square footage estimates again amounted to tens of millions of dollars for the value of the summit facility. In addition, there is the cost of preparing the site, regardless if the soil at CFHT is cheaper to work than the rock at other sites, the amount will be in the couple of millions. Access to the CFHT site requires 400ft of paved road along the summit ridge with underground electrical power and communications conduits, estimates to build the road were millions of dollars per couple feet of road.

Although these estimates touch on the cost of replacing the existing CFHT infrastructure, the actual value of MSE will depend on whether the majority of these facilities are still applicable for effective operation of MSE, and what renovations or modifications would be required to provide new support capabilities. Initial discussion of the operations model suggests that the total staff and infrastructure required to support a modern single-purpose 10m wide field spectroscopic facility will not be very different from the existing CFHT observatory and instrument suite. Thus, most of the infrastructure is likely to be applicable. This value does not consider the depreciated value of the HQ and summit facility, taking depreciated values into account could result in a significant reduction in the final value of both assets.

2. PIER STATUS, MODIFICATIONS, & UPGRADES

The structure of the CFHT observatory consists of an inner pier and an outer building ring foundation, both concrete. The two structures are built independently of each other on two separate foundations, see figure 1 below. This isolates the central pier on which the telescope sits from vibrations generated in the other areas of the outer building.

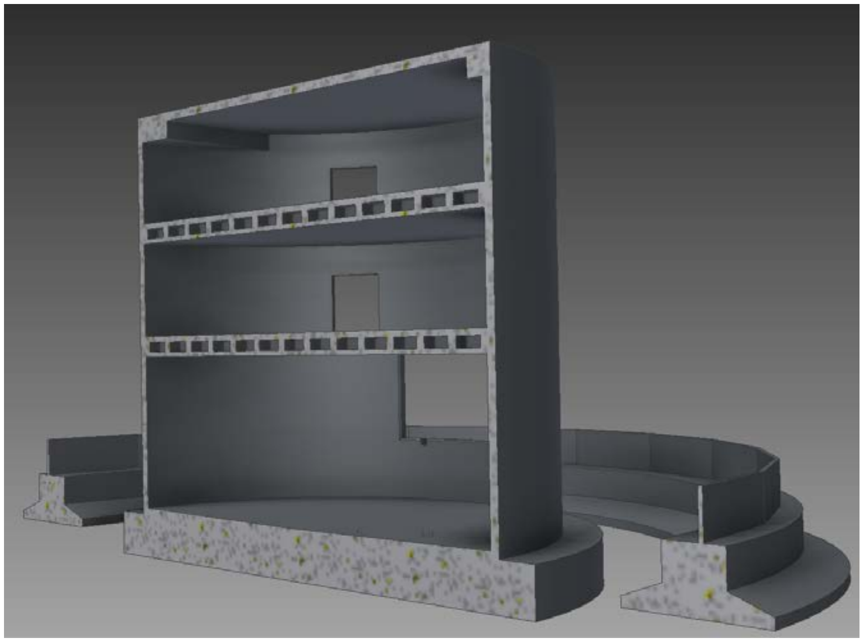

Figure 1: Image showing a half section view of the inner concrete telescope pier and outer building ring foundation

2.1 Inner pier modifications

The modifications planned for the inner pier will mostly be cosmetic such as: room and wall modifications, plumbing, electrical piping, conduit locations, and removal of obsolete equipment, floor and wall anchors. No structural modifications are planned to take place that will modify the inner concrete pier.

Since CFHT was built in the late 1970's the original drawings were all on paper. To facilitate MSE development CFHT created a 3D architectural solid model in house.

2.2 Inner pier capability studies

The inner Pier was analyzed to verify the current pier can support the mass of a new 10-12m class telescope; for more information regarding the feasibility study see Szeto [11]. Since the pier was designed in 1974 it was also necessary to verify that the structure meets the new building codes requirements, especially the seismic design requirements. The shear capacity, bending capacity, steel reinforcement, foundation capability, and soil capacity were all evaluated. All walls, slabs, footings were found to have sufficient structural capacity and the allowable soil bearing capacity under dead load and live load was found to be sufficient. A future geotechnical investigation involving core sample drilling is planned which will affirm the soil parameters and foundation capacity.

2.3 Inner pier stability tests

Inner pier stability tests were performed to determine how much the inner pier moved when the CFHT dome was rotated with the enclosure shutter open and closed. These tests were to verify that coupling from the building foundation to the inner telescope pier would not negatively affect the pier stability. The tests showed that the wobble or translation induced from the building to the inner pier with respect to dome rotation was on the order of 30 microns or 1/1000 of an inch when measured at the bottom of the pier.

The graphs below show the vertical displacement of the inner pier base during dome enclosure rotations. The two bumps in the plots below correspond to the back and front of the arch girders passing over the measurement point; each plot shows one full rotation of the dome. The centerline of the dome is the midpoint between the two arch girders. In figure 3 the first hump is greater as the weight of the dome shutter is passing over the measurement point and on the second hump it’s less as the weight of the dome shutter has been shifted to the back.

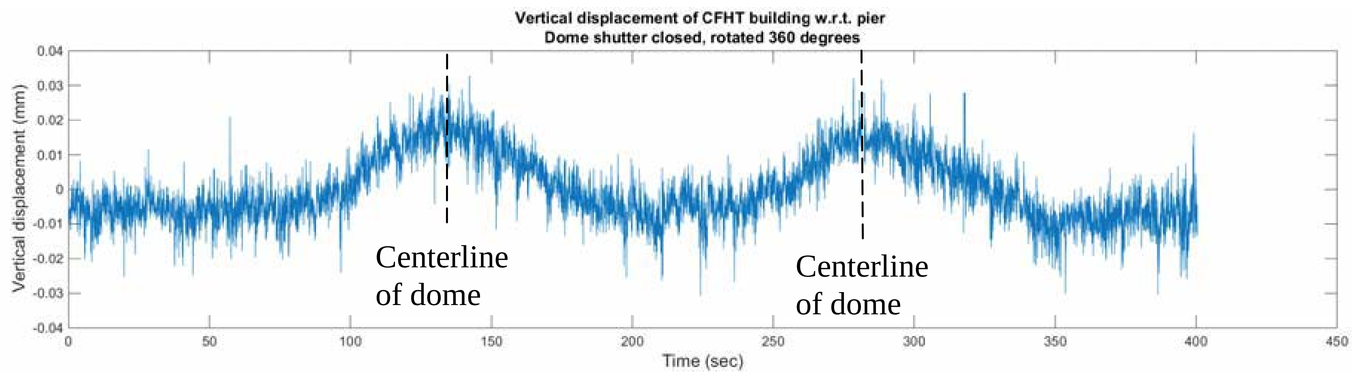

Figure 2: Vertical displacement plots of the inner pier in conjunction with dome rotations with the shutter closed, courtesy of Salmon 2015

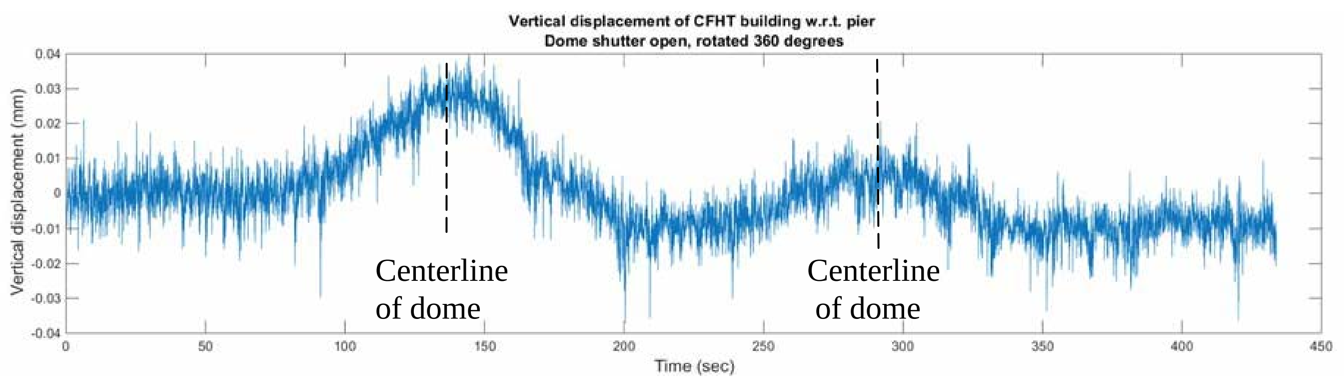

Figure 3: Vertical displacement plots of the inner pier in conjunction with dome rotations with the shutter open, courtesy of Salmon 2015

2.4 Inner pier

The current telescope pier supports the telescope and houses the coating facility and two spectrograph rooms. It will remain mostly unchanged and be used to support the MSE telescope structure. Recent feasibility studies, including structural analysis reports, past structural design briefs, and soil studies, verify the structure meets current seismic and new building codes. Therefore no structural alterations are anticipated for the inner pier foundation. The inner pier internal diameter is 51 ft and is supported by footings below ground, see figure 4.

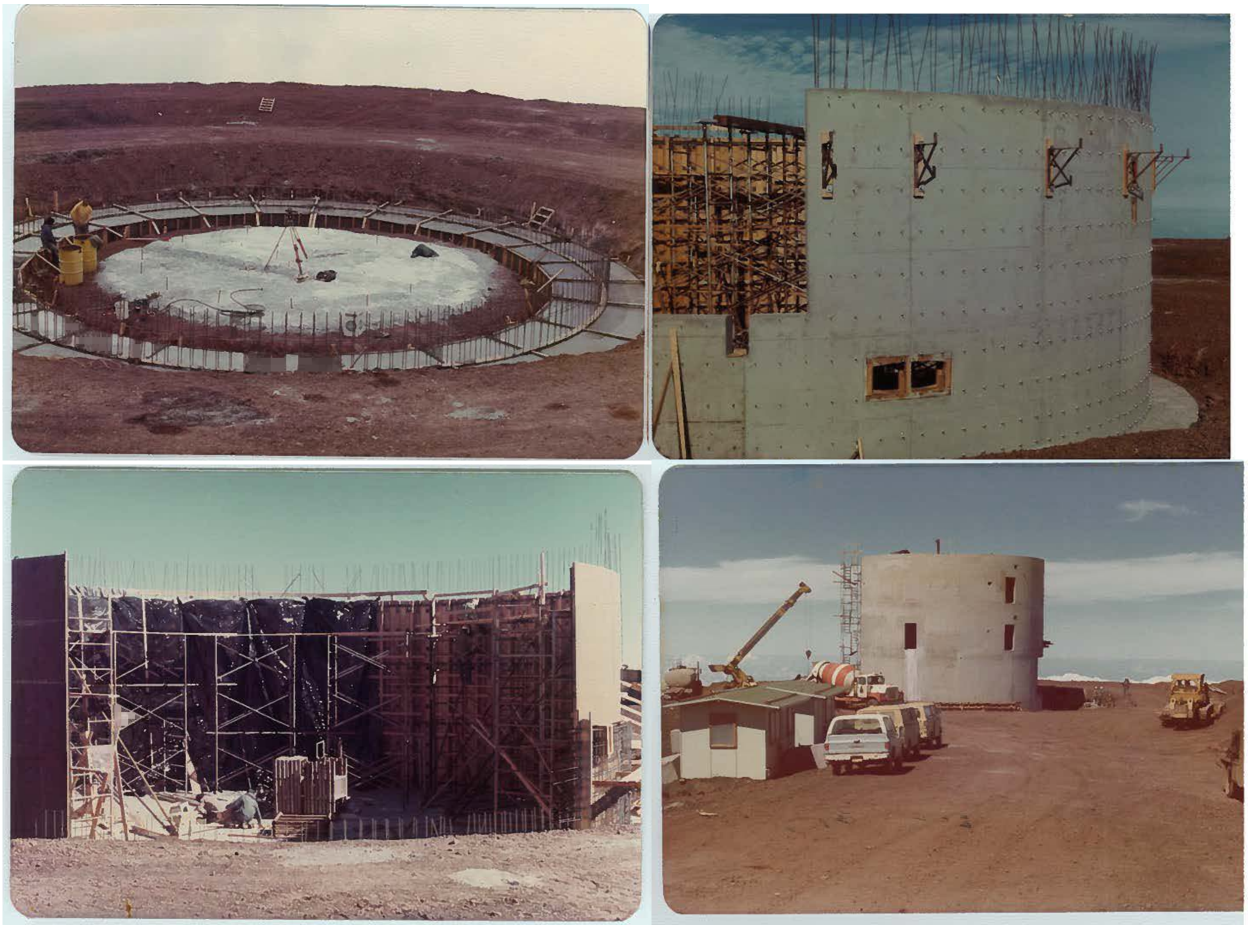

Figure 4: Construction photos of the inner telescope concrete pier

The inside of the pier has three rooms which MSE will reuse. The bottom room (2 stories high) currently houses the mirror coating facility, and will be used the same way by MSE. The upper coude spectrograph level will house the MSE high resolution spectrographs and azimuth cable wrap and in the second level either additional spectrographs/instrumentation or parts/equipment storage.

The coating facility floor is rated for 5-tons therefore no changes are necessary to house the MSE coating equipment. The coude spectrograph rooms are designed for a maximum deflection of five (5) microns under a point load of 200 pounds so that a person walking on the surface will not affect the spectrographs stability. The top of the inner pier is rated for a dead load of 280 tons, a live load of 51 psf, and seismic horizontal forces of 96 tons.

3. BUILDING STATUS, MODIFICATIONS, & UPGRADES

The outer building was constructed around the central telescope pier to facilitate access and support while still providing separation between the two structures, see figure 5. However observatories are not constructed in this manor anymore because they have negative thermal influence on the observing environment, and also generate unwanted vibrations. Today support buildings are built away from the observatory to isolate the thermal and vibration sources from the telescope observing area. The MSE project is developing some thermal management strategies for removing and mitigating thermal affects while keeping this old configuration of the observatory structure; section 5 discusses the plan in more detail.

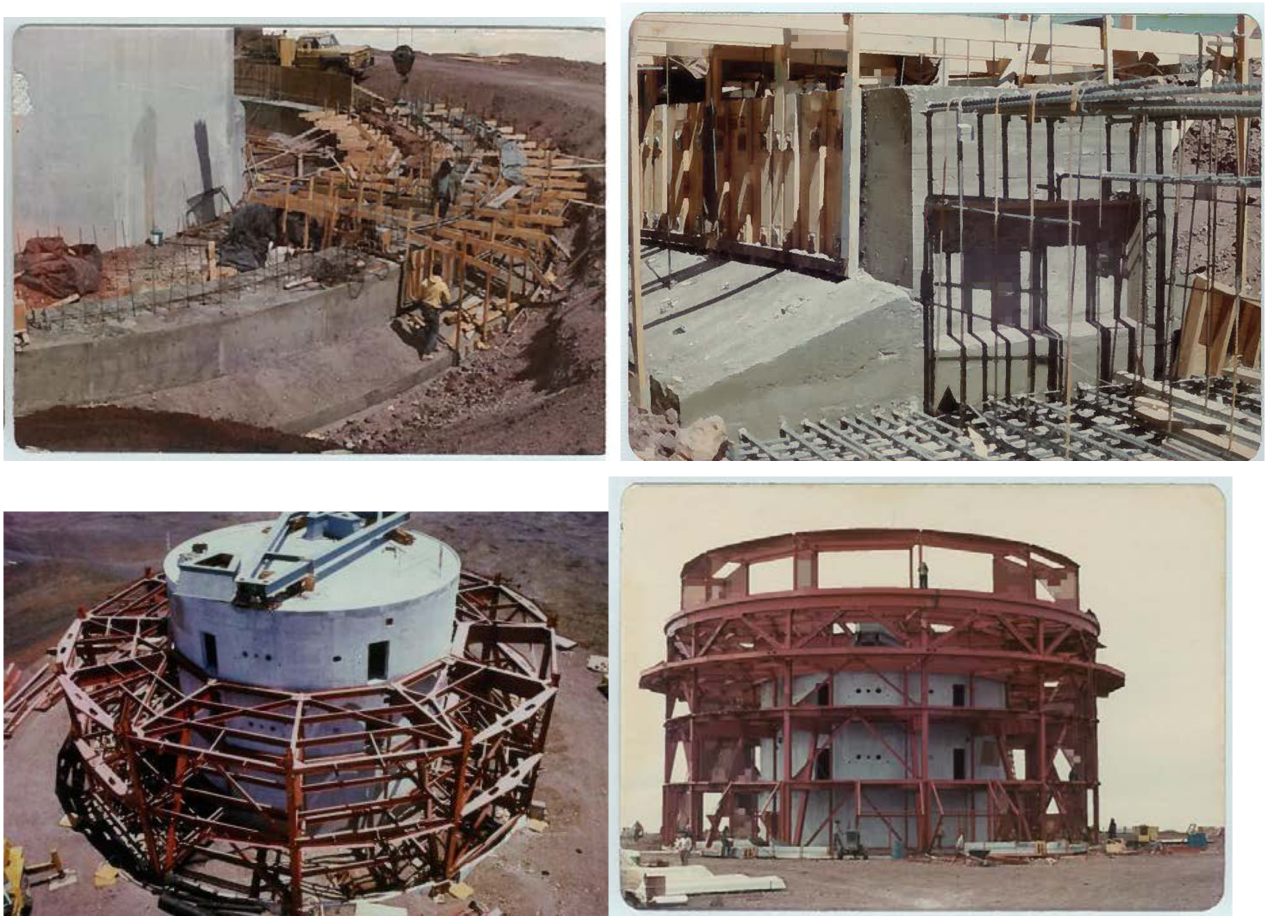

Figure 5: Construction photos of outer building ring foundation (top) and main steel building structure (bottom)

3.1 Outer Building

The Outer building structure is supported on a ring foundation separate and isolated from the telescope pier. The isolation, at the time of construction, was a method to decouple vibrations between the two structures. The main structure of the building consists of 12 vertical steel columns with cross bracing in alternative bays for torsional rigidity which anchor to the ring foundation. All structural levels are supported back to the outside columns by inclined thrust beams.

The existing outer building of the observatory will remain mostly unchanged on the outside, however some additional structural modifications will be needed to accommodate newer building codes for seismic requirements and support a different dome. It will also be one floor lower.

3.2 Outer building structural studies

The outer building foundation and steel structure were analyzed to determine if the current structure has the capacity to support the mass of a new enclosure with a larger slit opening to accommodate a larger aperture telescope. Again, since the concrete ring foundation and steel structure were designed in the mid 70's, it was necessary to reevaluate the capacity of the outer building to verify it meets newer building codes and seismic design requirements. The capacity of the beams, columns, bracings, footing and foundation evaluated were found to have sufficient capacity to meet new building codes with a new enclosure however the study showed that the building shear strength was very much below code, and fortunately it seems we can correct this by replacing the cross bracing with new designs, see Szeto [11] for more details.

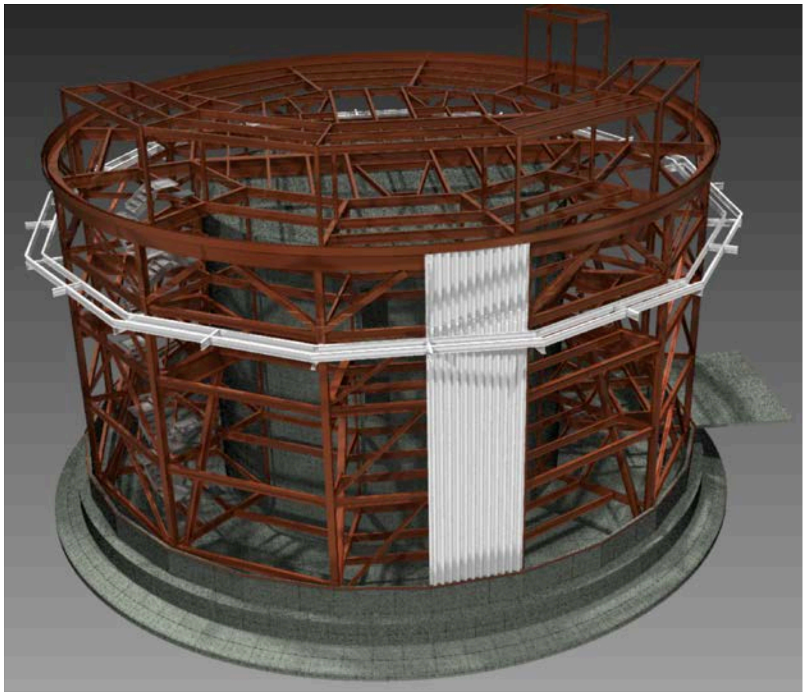

Figure 6: Model of the observatory, showing the outer building ring foundation and steel building structure

3.3 Outer building modifications

To support redevelopment planning and evaluation studies, a 3D solid model of the outer building was created. The model created only depicts structural drawing details and not as built drawings of the CFHT outer building.

To accommodate a bigger enclosure for a taller telescope the 5th floor of the observatory will be eliminated. This will create more vertical clearance for telescope motion, reduce wind shake from the slit being too close to the telescope prime focus upper end (PFUE) and free up horizontal clearance for the low-mid resolution (LMR) spectrograph platforms. It also increases the overall clearance inside the enclosure and provides better maintenance access. More clearance around the telescope structure improves overall handling of mirror segments, instrument components, and other equipment.

3.4 Outer building upgrades

Structural support upgrades to the building will be needed to accommodate the larger telescope and different enclosure and also meet new building seismic code requirements. Additional radial bracing will be added to support the outer azimuth ring girder supporting the enclosure. The new diagonal bracing will transfer loads from above the third floor level to the existing radial member from the bottom of third floor down to the foundation. The tangential cross bracing between the main 12 vertical beam columns which transfer load to the footings will also need to be replaced. Lateral buckling restraint bracing (BRBS) will replace the current 1st, 2nd, and 3rd floor perimeter bracing. All structural modifications will be implemented from inside the building to minimize disturbances to the summit environment. Once the building upgrade project is completed there will be no noticeable difference on the outside of the building.

3.4.1 Radial bracing upgrades

Additional radial bracing will be added from the new azimuth ring girder to the third floor existing bracing. This additional bracing will provide continuity with the existing first and second floor bracing and upgrade the members to meet structural requirements. Figure 7 below depicts the new structural radial bracing upgrades needed in yellow.

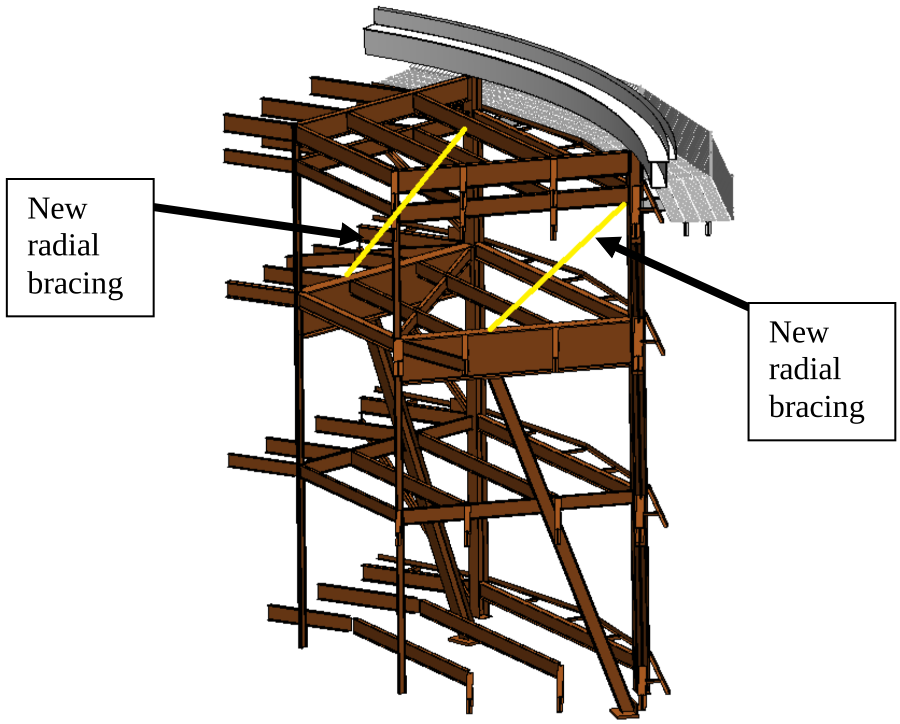

Figure 7: Section view of the existing building steel structure (brown) and new radial bracing members (yellow)

3.4.2 Lateral support upgrades

Existing tangential bracing on the first, second and third floor bays of the outer perimeter of the building steel structure will be removed and replaced by buckling restrained bracing (BRBs). Bracing can be removed from the inside of the building by accessing bolted connections. They will then be replaced with BRBs, thicker gusset plates, and larger fasteners, see figure 8.

Using the BRBs in their elastic load range meets structural requirements and has the added advantage that for major earthquakes they do not need replacement and provide a seismic load reduction factor, R, of 2. The lateral support upgrades can be made prior to the 5th floor removal and will benefit the project timeline as work that can be performed before deconstruction. Next, after the new enclosure azimuth ring girder is installed, the radial support upgrades can take place, interfacing with the new structure.

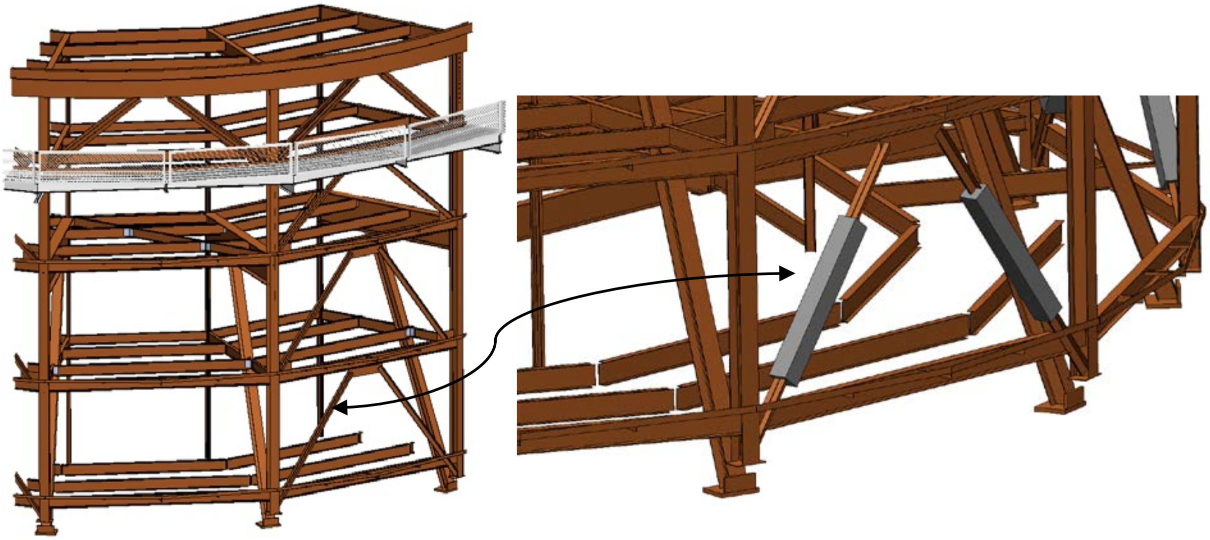

Figure 8: Model of the steel building structure and the modification of replacing a lateral beam with a BRB member

4. INFRASTRUCTURE AND FACILITIES

4.1 Overview

The observatory building and facilities (OBF) is primarily the structural support for the MSE enclosure and telescope but also provides the infrastructure and equipment required to support, operate, and facilitate daytime and nighttime operations. The OBF consists of the existing five story steel frame outer building and concrete ring foundation that supports the enclosure and the inner concrete pier that supports the telescope. Existing equipment and infrastructure will be reused wherever possible while meeting new requirements.

The basement and first level of the building contain the mechanical and electrical plant rooms that supply and distribute the utilities to operate the observatory. These include the domestic water system, electrical power distribution system, uninterrupted power supply (UPS), backup power generator, compressed dry air systems, building and instrument chiller systems, cryogenic and vacuum systems, humidifier system, fire protection system, telescope hydrostatic power unit, motion controllers, and drive electronics. For environmental protection, berms and catchments for spill prevention are currently used at CFHT and will remain an integral part of the new design.

The second and third levels contain the infrastructure to support observatory and telescope functions. These include the control room, computer server room, engineering labs, and a chemical storage room which is fire proof for the safe storage of general lubricants, paints, and solvents. The outer building also provides staff with equipment elevators, stairways, meeting rooms, offices, and restrooms.

For optimal thermal management, the largest heat generators are placed furthest from the observing level, in the basement and just a few on the first floor, where waste heat can be isolated and managed. It is primarily extracted as hot air and exhausted away from the building through the two existing underground tunnels, see figure 9.

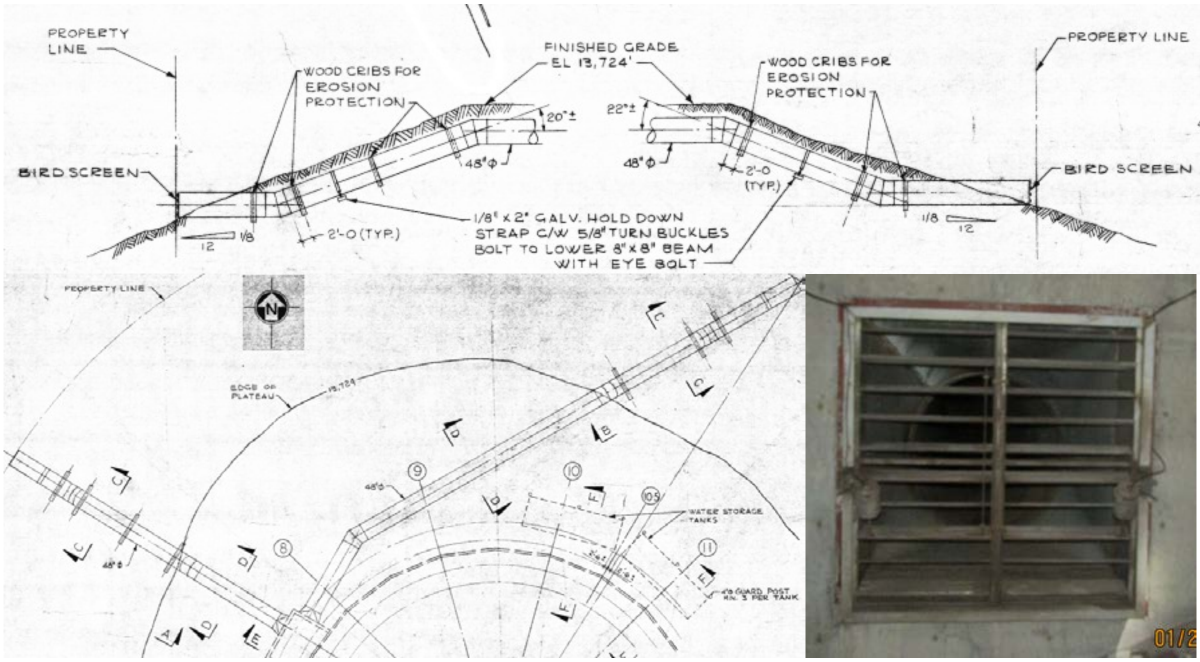

Figure 9: Heat rejection system: Top, exhaust tunnel details. Left, Tunnel length and locations Right, exhaust opening

4.2 Requirements

Requirements are being developed for the OBF for MSE as part of the conceptual design work which are currently in draft form.

4.3 Inside the pier

The inner pier foundation supports the telescope and azimuth track, as well as the coating facility and spectrograph rooms. The inner concrete telescope pier structure will remain unchanged; however the top of the pier will be modified to include an opening for a cable wrap system. The old CFHT telescope support pillars, mounted to the top of the pier, will be removed to accommodate the new MSE telescope azimuth track.

4.3.1 Coating facility - Lower level

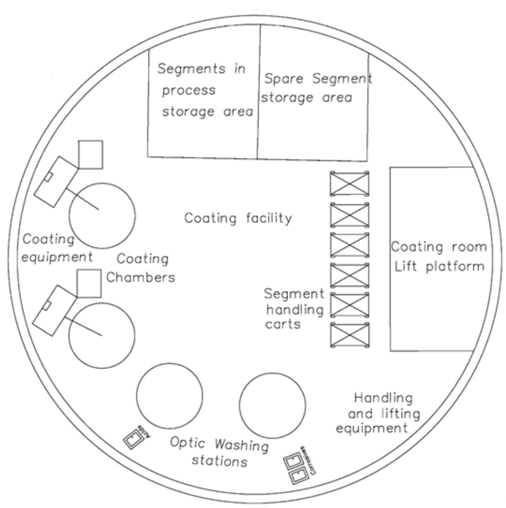

Figure 11: Magnified layout of the coating facility in the bottom level of the inner pier

The coating facility provides a laboratory to clean, coat, store, maintain, and manage mirror segments that make up the primary mirror, see figure 11.

The bottom level of the pier, comprised of the basement level and first level, will remain a mirror coating facility; however most of the CFHT infrastructure and equipment will be removed to allow upgrades. The new MSE coating facility will be a space dedicated to mirror segment coating, servicing, and safe storage. The coating facility will contain "dirty" and "clean" areas for removal of old coatings using a traditional wash stand, cleaning and final prep for new coating, and multiple vacuum coating chambers along with the appropriate sized roughing pumps, turbo molecular pumps, and power equipment. It will also contain designated storage areas for segments in process and off-telescope spare mirror segments. The coating facility will provide handling and lifting equipment and segment handling carts for safe transportation of segments to and from the observing level. A lift platform will be added to the coating facility to safely lift/lower segments on handling carts from the first level of the building to the bottom floor of the coating facility. The current CFHT 1 ton and 22 ton polar crane will be reused and upgraded with new motors, reduction units, and motor controllers as required. Any equipment that can be repurposed will be used accordingly.

4.3.2 Parts and supply storage - Second level

At this time the second level of the pier will be either used for additional spectrographs or for parts and equipment storage. If it is decided to use the space for storage it will house the mechanical and electrical parts, general supplies, spares, and preventative maintenance consumables.

4.3.3 High resolution spectrograph lab space -Third level

The third floor, as well as the second floor, were originally designed as coude spectrograph rooms and intended to create a thermally stable environment isolated from vibrations and ambient temperature changes. The upper room of the inner pier for MSE will house the high resolution spectrographs and associated instrumentation. The center of the room will have a support structure for the cable wrap system and provide access for maintenance; however the detailed layout will be developed during the conceptual design phase.

4.4 Outer building and ring foundation

The outer building and its ring foundation provide the fixed structure of the observatory which supports the rotating enclosure and protects the inner pier. The outer building houses the electrical and mechanical equipment necessary to operate the telescope, enclosure, and instruments. Work spaces, laboratories, and other facilities support regular operations and maintenance activities by observatory personnel. The facilities and support equipment will be positioned in optimal locations based on telescope configuration and technical needs.

4.4.1 Basement

The basement of the MSE observatory building will house the major mechanical and electrical plant equipment, see figure 12. The preexisting building exhaust system will continue to be used to remove heat and minimize thermal loads on the building but will be upgraded with new motors, controllers, and ducting to maximize air flow.

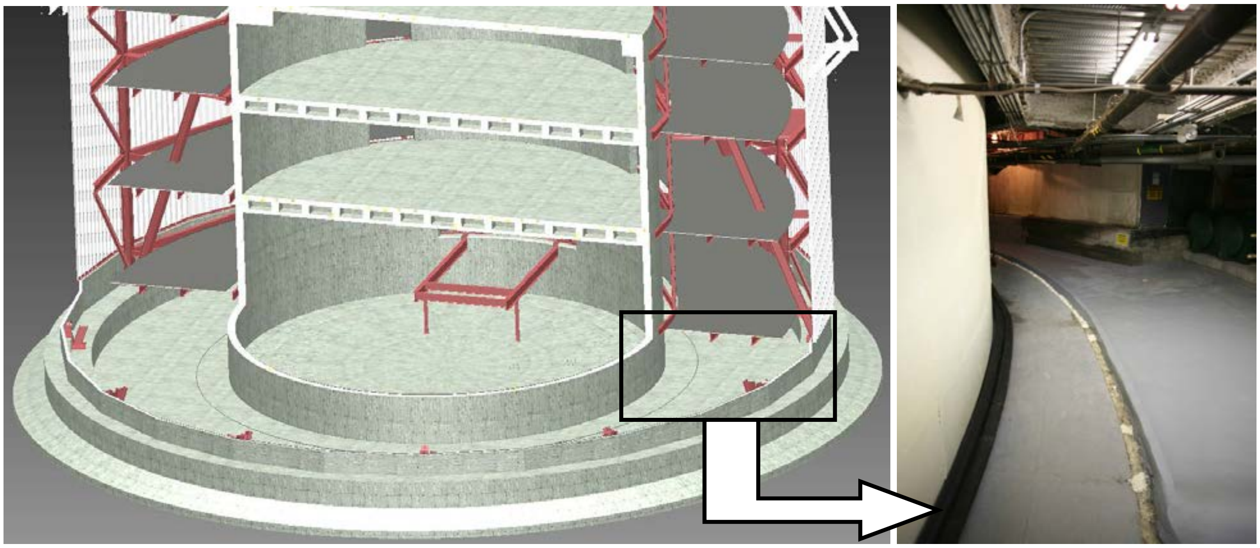

Figure 12: Half section model image and actual image of the basement level of the CFHT observatory

The main electrical room, currently on the second floor of the CFHT observatory, will be moved to the basement. This will simplify heat removal and will locate the main distribution panel closer to the incoming power from the electrical company, HELCO. All major heat generating equipment such as the building and instrument chillers, cryocooling systems, UPS, dry air compressor system, and enclosure drive rotation motor controller system will be located in the basement. The three existing elevators will be reused for MSE; but the elevator machinery rooms already located in the basement will be upgraded with new hydraulic power units, see figure 13.

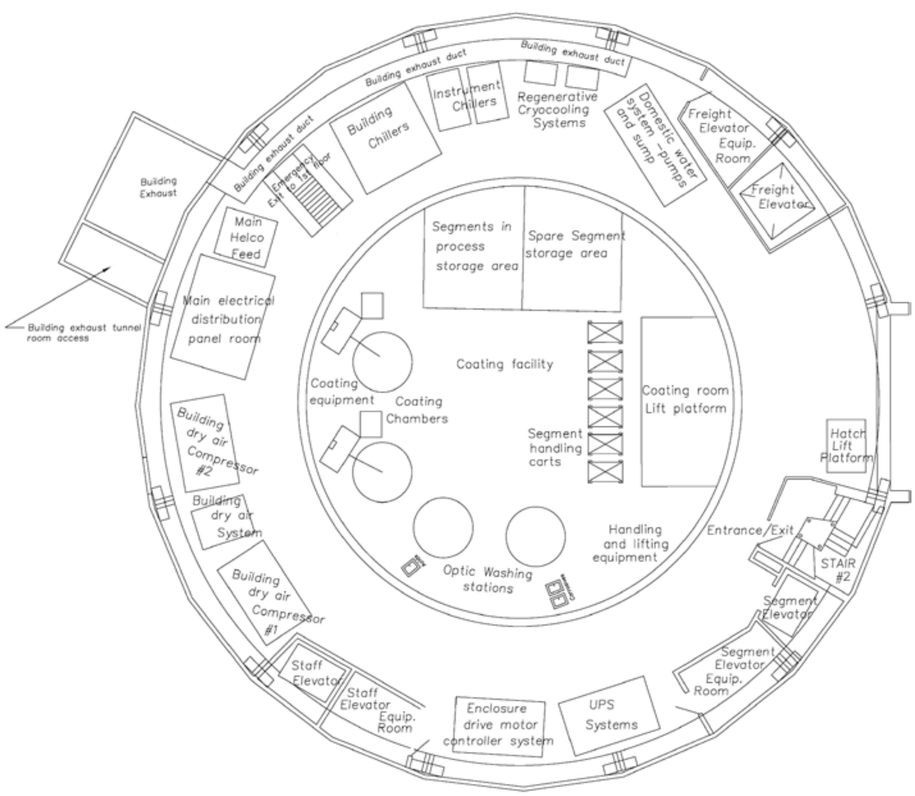

Figure 13: MSE observatory basement layout

4.4.2 First level

The main entrance and first level of the observatory are redesigned and arranged to support staff and visitors' needs. Just after the front entrance is a mail room, area for hand held radios, a time clock, an observatory status screen providing feedback on all observatory systems and equipment, and restrooms and a common area.

The common area has a first aid treatment room with cot, a lounge with chairs, and a kitchenette for food and drink preparation, and tables for eating meals. There is also a small work area with guest computers and desks, and a covered patio area adjacent to the kitchen for sitting outside. The relocation of the common area from the 4th floor to the first level provides access to the covered patio area, accommodates visitors' needs upon entry, and mitigates heat by keeping body heat sources away from the observing level.

The fabrication shop is located on the first level and includes a machine shop, welding shop, material storage area for metal stock, hand tool storage, and hardware and plumbing stock storage area. The main shipping and receiving storage area, with shelving and space to contain large deliveries, is just next to the fabrication shop to accommodate ease of restocking inventory of parts and supplies and to support repair and maintenance of large components and equipment. The main shipping and receiving area has a multi-leaf access door to the outside of the building measuring 21ft wide by 24 ft high, a lift platform to reach the basement below, a 3 ton loading and unloading jib crane, and handling and lifting equipment stored in the delivery area. Much of this equipment already exists and is being reconfigured to improve workflow and logistics, see figure 14.

The telescope hydrostatic bearing power unit (HBPU), hydraulic fluid reservoir, motors; pumps, filtration, plumbing, lines, and fittings for the hydrostatic fluid bearing support system will remain on the first floor. The area around the HBPU has catchment berms installed in case of fluid leaks. The first floor remains the location for the HBPU since it provides an additional layer of protection before reaching the basement level and prevents any fluid from encountering the concrete basement floor and soil beneath. The backup diesel power generator also stays on the first floor to accommodate a new above ground storage tank for diesel fuel which eliminates the old underground storage tank and reduces environmental and health department regulations. Berms will continue to be used around the diesel generator and tank, and a storage tank with secondary lining will be used to eliminate leaks.

Figure 14: MSE observatory first level layout

4.4.3 Second level

The second level of the building will provide staff with laboratories, offices, and general working and meeting areas. The offices for the site engineer will have a designated area for a technical documentation library (shelves with paper design documents and drawings), large format printer, scanner, and general office supply materials. A locker room area will provide staff with individual lockers for personal items, cold weather gear, personal protective equipment (PPE), boots, etc. A large conference room will accommodate 20 people for meetings and include modular tables, chairs, a digital projector, computer interface, and video communications equipment.

A chemical storage vault will safely store chemicals and provide secure protection from fire sources. The laboratories will consist of: electronics laboratory, a clean room, a fiber optic lab, and a vacuum/cryogenic laboratory, see figure 15.

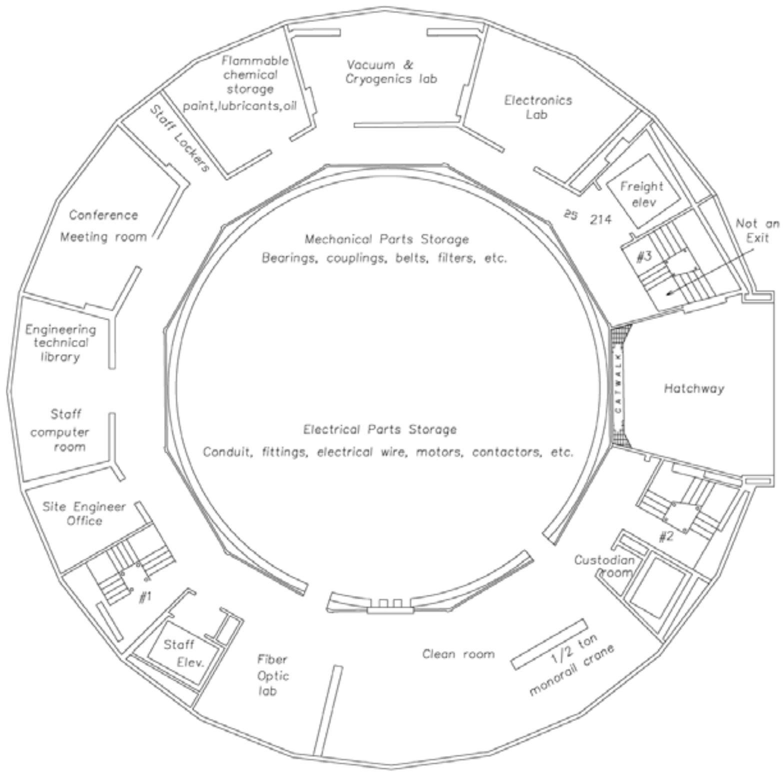

Figure 15: MSE observatory second level layout

4.4.4 Third level

Just below the observing level, the third floor contains the main computer room, observatory control room, and HR spectrograph laboratories. The telescope and building control and observing room is located adjacent to the main computer server room which utilizes passive and active cooling to be discussed in more detail later. The fire protection system monitors the clean agent fire suppression system in the server room, heat and smoke detectors distributed throughout the building on every level, and the manual pull stations. There is a space for safety equipment storage and a secondary first aid room with emergency supplies. Another set of bathrooms and another staff common computer area are conveniently located. Just outside the inner pier which houses the HR spectrograph instrumentation is a laboratory with a spectrograph lab, optics lab, and small semi-clean room/CCD lab. A few rooms have been designated as empty in the current design for future unforeseen additions and expansion, see figure 16.

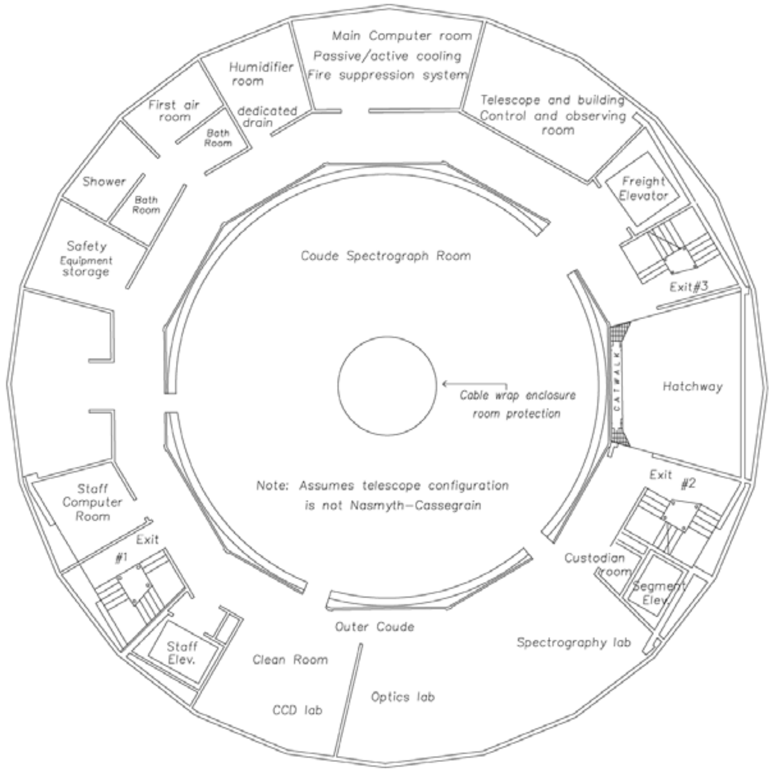

Figure 16: MSE observatory third level layout

4.4.5 Crawl space

Above the third floor ceiling and the observing level is a residual unused empty space that will be used as a thermal barrier and to house cables and lines. This void will be used to flush heat percolating from below before it can reach the observing level. By using outside air as a flushing agent, heat dissipation will be minimized into the observing space by providing an insulation layer and flushing excess heat out exterior vents. This concept will be discussed in further detail in the upcoming thermal management system.

4.4.6 Telescope level (Observing level)

The observatory level is still in development but will include the telescope mechanisms, enclosure azimuth drive system, azimuth track rotation structure, cable wrap system, enclosure, cranes, vent units, and mount control system. The observing level remains a working surface for staff and provides handling and lifting equipment to access and service the telescope and enclosure, see figure 17. The telescope and enclosure are discussed in more detail in a paper by Szeto[8].

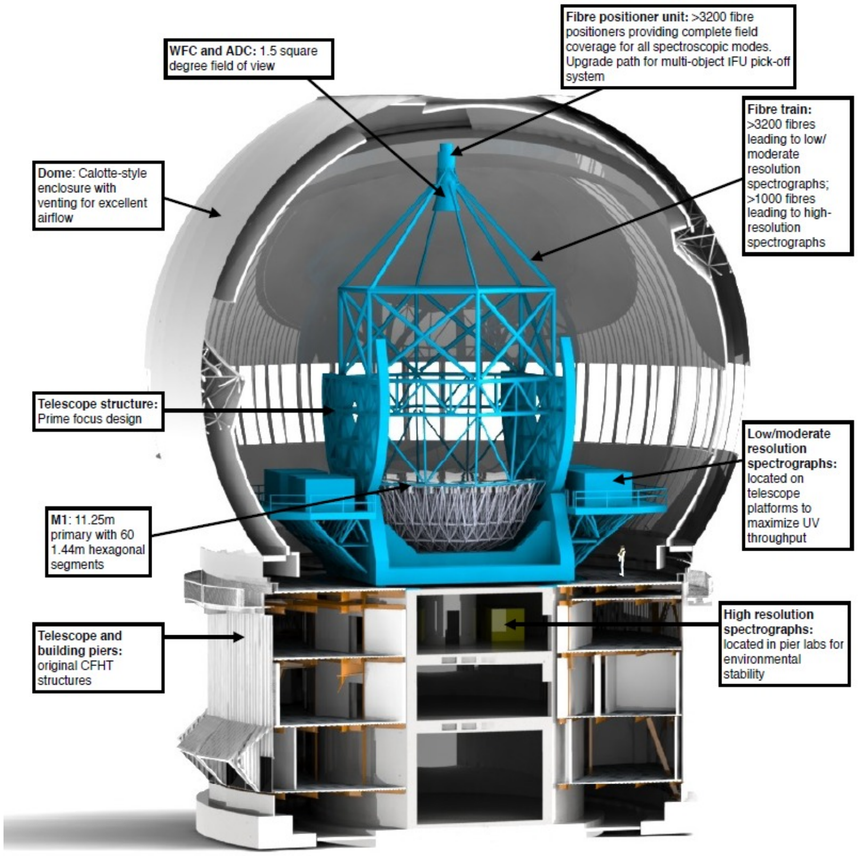

Figure 17: Section view of the MSE observatory showing various subsystems

5. THERMAL MANAGEMENT SYSTEM

5.1 Overview

CFHT is an older facility; designed with a cooled observing floor to absorb heat loads directly under the observing floor. Modern designs isolate heat sources from the telescope therefore MSE will use a thermal management system to remove heat loads from the building, flush excess heat from lower levels, and maintain the observing environment temperature. The observatory control room, located adjacent to the main computer server room, mitigates heat by utilizing a passive cooling system via outside air plenums and active cooling system with an inside humidification system.

The existing building exhaust tunnels will continue to be used to remove heat loads deliberately positioned in the basement and minimize thermal loads on the observing environment. Remaining heat will extracted from the lower levels prior to reaching the observing environment using a passive ventilation system. An active cooling system will be used in the observing level to keep large structures near the ideal nighttime observing temperatures. This strategy has been proven effective currently.

5.2 Strategy

The new MSE building floor plans will be reorganized to minimize heat dissipation into the observing space and optimize operational efficiency. The observing environment will be reconfigured to facilitate ventilation and dome flushing while keeping air flow free of obstructions and enable ventilation using outside air. The two strategies for removing heat loads are remove energy generated and minimize heat produced. The two methods to mitigate heat loads are decrease heat leakage and diminish heat transfer.

5.3 Heat removal plan

The plan for the MSE thermal management system involves heat removal of large thermal loads generated by equipment consuming large amounts of current and running nonstop. This equipment will be located as near to the inlet of the heat rejection system as possible; this will remove the majority of the largest heat loads and minimize the amount of residual heat remaining. Future work is planned to calculate the heat load removal capacity of the existing heat rejection exhaust tunnels.

Secondarily, smaller residual thermal loads such as electronics and controllers will be fitted with heat exchangers and an insulated enclosure to manage small heat loads. Any equipment running continuously, consuming more than 500 watts, and located above the first level and below the observing floor will be contained with a thermal enclosure. Active cooling and temp sensing inside the enclosure maintains the outer enclosure temperature to match the exterior ambient air level at the enclosure spring line.

5.4 Heat mitigation Plan

Diminishing heat leakage into the observing floor is the plan for the primary heat mitigation method. A void between the old 4th floor and new MSE observing floor will be used as a thermal barrier to prevent such a thing from occurring. Vents will be used in the outer diameter of the building as an air plenum to flush the interstitial space passively. If needed active fans and/or cooling could be implemented to increase the amount of flushing and heat mitigation, see figure 18.

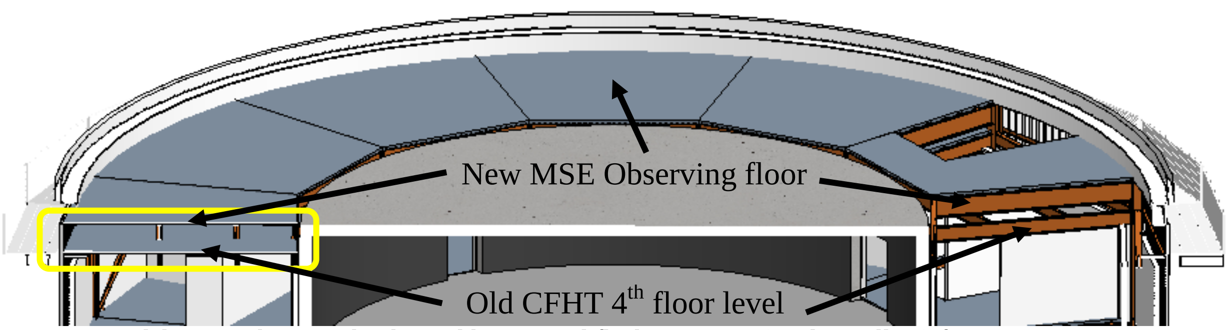

Figure18: Model image showing the thermal barrier and flushing cavity (void in yellow) for MSE

Heat transferred from surfaces with large thermal masses will be addressed by using secondary heat mitigation. The large thermal mass of the telescope, enclosure skin, building structure and concrete inner telescope pier will be insulated and/or low emissivity like surface treatments will be made to eliminate radiative cooling. Active cooling, by means of large air handling units, will provide air conditioning inside the enclosure volume during the day. Passive cooling will be accomplished using dome vents to provide an air exchange flushing of the enclosure volume during the night.

5.5 Thermal analysis

Thermal analysis is planned to access the radiative, conductive, and convective heat transfer since all surfaces either transmit, emit, and/or absorb heat. The approach will involve keeping all surfaces at a uniform temperature or thermal equilibrium. The assessment will begin with a simple steady state static thermal temperature gradient (difference) analysis; however nothing is ready for reporting.

6. SUMMARY

The justifications for the MSE project are many: repurpose one of the best sites in the northern hemisphere to continue scientific exploration of the universe, utilize the facility value to minimize construction costs, exploit the knowledge and experience from CFHT staff to optimize the design and engineering of an updated facility, and minimize the cultural and environmental impacts on the summit of Maunakea. The updated MSE observatory will reuse the same building and telescope pier as CFHT, salvage the equipment and infrastructure, and replace the CFHT telescope and dome. Only minor structural building changes will be required to accommodate a larger enclosure and taller telescope and meet new building requirements; and these will be performed from inside the building. No structural changes are anticipated to the inner pier. Development of a thermal management system will minimize heat transfer inside the observing environment. Once the project is completed the updated facility will be almost indistinguishable on the outside from the current CFHT observatory, See figure 19 and 20 below.

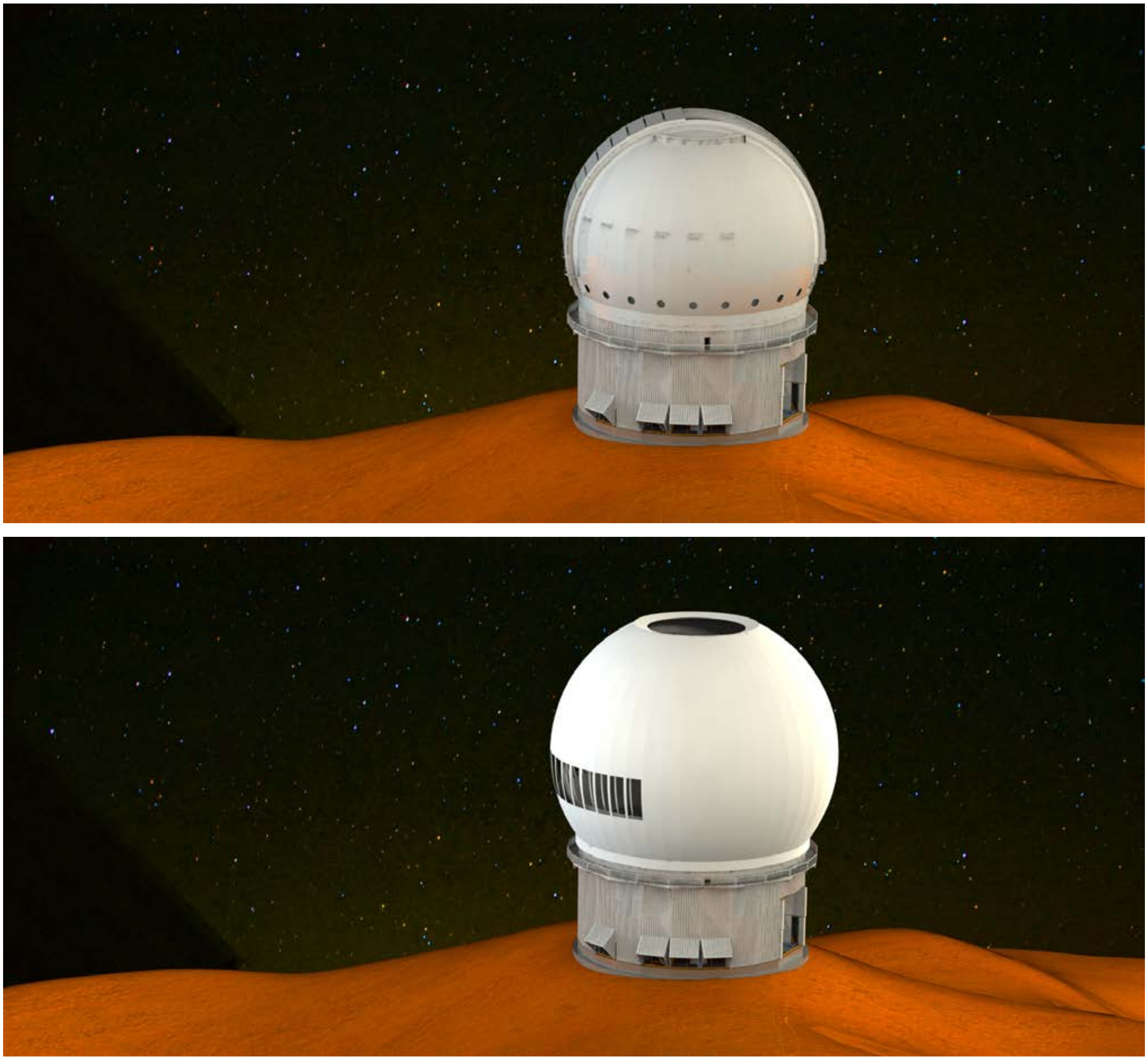

Figure 19 & 20: Digital renderings of the CFHT observatory and the upgrade to the Maunakea Spectroscopic Explorer

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REFERENCES

[1] Côté P., et al., "The Next Generation CFHT", white paper submitted to the Canadian Long Range Plan decadal review, (2010).

[2] http://mse.cfht.hawaii.edu/observatory/Feasibility_Science_Final.pdf (2012)

[3] http://mse.cfht.hawaii.edu/observatory/Feasibility_Technical_Final.pdf (2012)

[4] Crampton, et al., "Estimated Value of CFHHT Infrastructure assets to ngCFHT Project, October 2011

[5] Murowinski, R., McConnachie, A. W., Simons, D., and Szeto, K., "Maunakea Spectroscopic Explorer: the status and progress of a major site redevelopment project", *Ground-based and Airborne Telescopes*, Proc. SPIE 9906 (July 2016, this conference).

[6] McConnachie, A., "Science-based requirement and operations development for the Maunakea Spectroscopic Explorer", *Ground-based and Airborne Telescopes*, Proc. SPIE 9906 (July 2016, this conference).

[7] http://www.malamamaunakea.org/?p=323

[8] Szeto, K et al., "Maunakea Spectroscopic Explorer Design Development from Feasibility Concept to Baseline Design", Ground-based and Airborne Instrumentation for Astronomy, Proc. SPIE 9906 (July 2016).

[9] Mignot, S. B., Flagey, N., Szeto, K., Murowinski, R., and McConnachie, A. W., "Systems budgets architecture and development for the Maunakea Spectroscopic Explorer", *Modeling, Systems Engineering, and Project Management for Astronomy*, Proc. SPIE 9911 (July 2016).

[10] Flagey, N., Mignot, S. B., Szeto, K., McConnachie, A. W., and Murowinski, R., "The Maunakea Spectroscopic Explorer: throughput optimization", Ground-based and Airborne Instrumentation for Astronomy, Proc. SPIE 9908 (July 2016).

[11] Szeto K., Angers M., Breckenridge C., Bauman S., Loewen N., Loop D., McConnachie A., Pazder J., Salmon D., Spano P., Stiemer S., Veillet C., "Feasibility studies to upgrade the Canada-France-Hawaii Telescope site for the next generation Canada-France-Hawaii Telescope", *Ground-based and Airborne Telescopes*, Proc. SPIE. 8444, (September, 2012)

[12] Saunders, W. and Gillingham, P. R., "Optical designs for the Maunakea Spectroscopic Explorer telescope", *Ground-based and Airborne Telescopes*, Proc. SPIE 9906 (July 2016, this conference).

[13] Flagey, N., McConnachie, A. W., Murowinski, R., Szeto, K., and Mignot, S. B., "Spectral calibration for the Maunakea Spectroscopic Explorer: challenges and solutions", *Observatory Operations: Strategies, Processes, and Systems*, Proc. SPIE 9910 (July 2016).

[14] Mignot, S. B., Flagey, N., Szeto, K., Murowinski, R., and McConnachie, A. W., "Systems budgets architecture and development for the Maunakea Spectroscopic Explorer", *Modeling, Systems Engineering, and Project Management for Astronomy*, Proc. SPIE 9911 (July 2016).

[15] Vermeulen, T. A., Isani, S., Withington, K. K., Ho, K. K. Y., Szeto, K., and Murowinski, R., "Observatory software for the Maunakea Spectroscopic Explorer", *Software and Cyber infrastructure for Astronomy*, Proc. SPIE 9913 (July 2016).