Feasibility Studies to upgrade the Canada-France-Hawaii Telescope Site for the Next Generation Canada-France-Hawaii Telescope

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ABSTRACT

The Next Generation Canada-France-Hawaii Telescope is a dedicated, 10m aperture, wide-field, fiber-fed multi-object spectroscopic facility proposed as an upgrade to the existing Canada-France-Hawaii Telescope on the summit of Mauna Kea. The Next Generation Canada-France-Hawaii Telescope baseline concept assumes the new facility is built on the existing Canada-France-Hawaii Telescope telescope pier and enclosure pier and occupies the same three dimensional exterior "footprint". Three technical studies have been planned to examine the validity of these assumptions. The technical studies are executed in series as they represent technical decision points in a logical sequence. The three technical studies in succession are: 1. Telescope Pier Study – Load Capacity and Structural Interface, 2. Enclosure Fixed Base Study – Telescope and Enclosure Configuration and Load Capacity and 3. Aero-Thermal Study – Dome Thermal Seeing and Air Flow Attenuation over the Enclosure Aperture Opening. The paper outlines the baseline facility (telescope, spectrograph and enclosure) concept and the status of these studies, and discusses the proposed telescope and enclosure configuration in terms of the redevelopment assumptions. A consolidated feasibility study report will be submitted to the CFHT Board and Science Advisory Committee in the Fall of 2012, with first light for the facility aiming to be in the early 2020s.

Keywords: Next Generation Canadian France Hawaii Telescope, pier, ASCE, ACI, AISC, dome seeing, CFD

1. INTRODUCTION

The scientific importance of a dedicated wide-field, multi-object spectrograph on a 6.5-10m telescope are well documented and the potential scientific value of such a facility is universally recognized by the international astronomical community for more than a decade. The scientific need for such a facility will only sharpen with time in light of the many wide-field imaging and astrometric surveys scheduled for the coming decade (e.g., Pan-STARRS, VISTA, VST, Hyper-SuprimeCam, GAIA, the Dark Energy Survey, Skymapper, LSST, Euclid and WFIRST).

The Next Generation Canada-France-Hawaii Telescope (NGCFHT) is a proposal to redevelop the Canada-France-Hawaii Telescope (CFHT) site by replacing the existing 3.6m telescope with a 10m segmented-mirror telescope equipped with a dedicated wide-field, prime focus, multi-object fiber-fed spectrograph capable of carrying out spectroscopic surveys of the faint universe. Achieving first light in the early 2020s, the proposed NGCFHT will fill that much anticipated capability in astrophysics by the end of this decade.

This began as a grassroots movement within the CFHT user communities in 2010. By the beginning in early 2011, a Feasibility Study of the NGCFHT was launched to develop both the facility's scientific capabilities and

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requirements, and examine its technical feasibility and readiness. In this paper, we discuss the technical progress to date. A companion paper by McConnachie et al.[1] discusses the science case development of this facility and the resulting requirements flow-down. Table 1 lists the current top level baseline requirements[2] for the intended science goals.

Table 1: Top level design requirements.

Aperture	10 m (segmented)
Field of View	1.5 deg^2 (hexagonal)
Wavelength Range	370-1300 nm
Number of Fibers	3,200 (low resolution); 800 (high resolution)
Spectral Resolution	R2,000 (370-1300 nm); R20,000 (480-680 nm)

The principles to redevelop CFHT into NGCFHT follows the Office to Mauna Kea Management Comprehensive Management Plan[2] (CMP) which allows the replacement of CFHT provided the new facility stays within the current three dimensional "footprint". Based on considerations for the CMP, we have adopted the three basic guidelines for redevelopment that:

- NGCFHT will not disturb the ground beyond what has already been done
- NGCFHT will stay within the current CFHT space envelope
- NGCFHT will minimize the work at the summit by reusing the telescope and enclosure piers.

Furthermore, we will leverage on the current design knowledge available on segmented-mirror telescope[3,4], prime focus fiber-fed spectrograph[5] and compact enclosure[3] in the engineering and technical development of the NGCFHT in order to facilitate the design schedule and minimize cost and schedule risks.

2. FACILITY CONFIGURATION

The facility configuration (Figure 1) assumed for the technical studies are:

- A f/2 10 m diameter segmented primary mirror (M1)
- The distance to the image plane after the wide field corrector (WFC) is 17.9m from the M1 vertex
- The height of the spectrograph fiber positioning system and guide camera at prime focus is an additional 1.5m for a total elevation distance of 19.4m from the M1 vertex to the top of the telescope
- The enclosure provides a clear aperture for a zenith angle observing range from 0 degrees to 65 degrees and enables the telescope to point to 90 degrees to facilitate maintenance of the top end components
- The enclosure provides a dome-mounted crane(s) to facilitate handling and servicing of the M1 segments and the prime focus unit components with a piece size of 1 m dia. by 0.5 m tall and a mass of 500 kg[3]

[2] The baseline requirements are evolving as the development of science cases of NGCFHT is in progress.
[3] The top end components are modular such that they stack together.

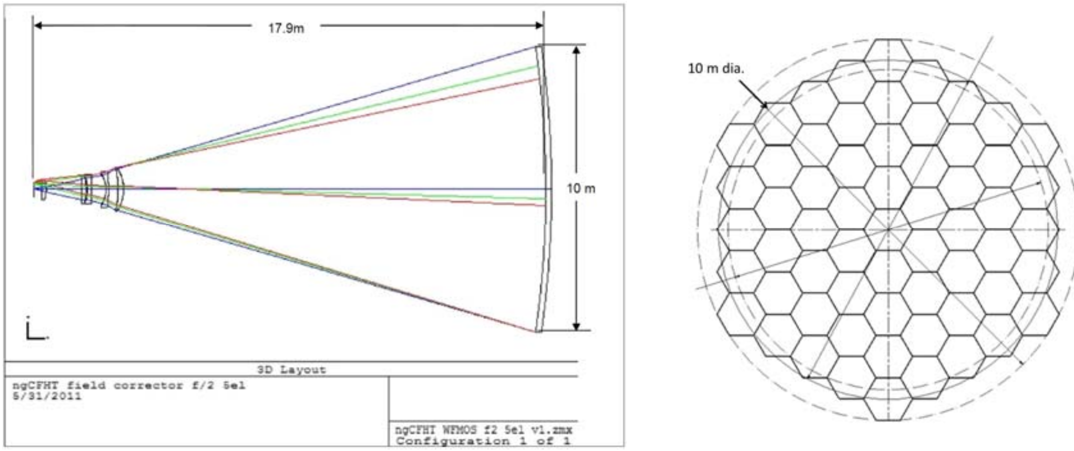

Figure 1: Optical Configuration of NGCFHT – overall focal plane height with wide field corrector (left) and primary mirror with 60 1.44 m segments (right)

We will follow the WFMOS)[5] prime focus components and fiber link design concepts developed for the Subaru telescope. The prime focus fiber positioner unit will use the same Cobra positioner fiber pickoffs to fill the focal plane and the same fiber link handling arrangement. The fiber link routing on the telescope will be the same is PFS expect the NGCFHT spectrograph will be located in the lower floor coudé room (Figure 2).

The NGCFHT spectrograph design development is currently in progress. Currently, we are studying spectrograph options between an innovative single spectrograph with dual-resolution and the more conventional approach with separate high and low resolution spectrographs. We will finalize the spectrograph design by a thorough trade design including risk and life-cycle cost analyse.

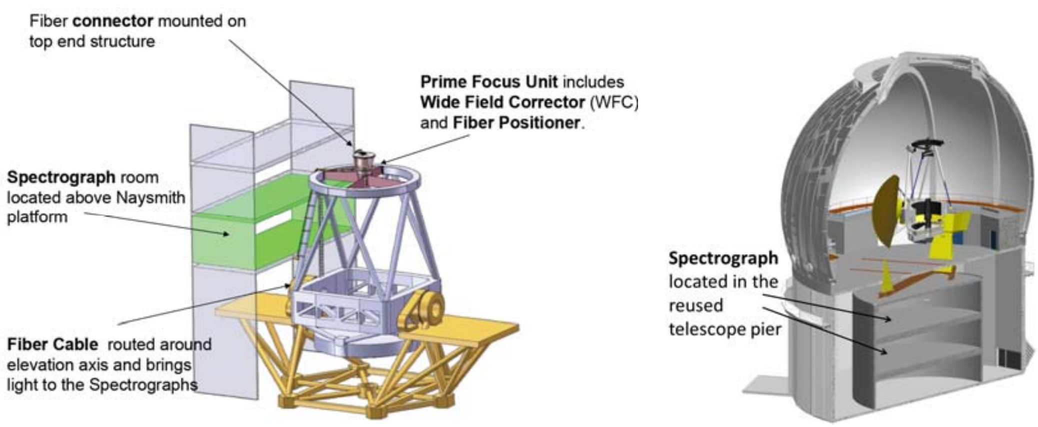

Figure 2: Spectrograph locations – Subaru[4] (left) and NGCFHT (right) with section view of the current CFHT facility.

3. TELESCOPE PIER LOAD CAPACITY STUDY

3.1 Objectives of the Study

The objective of the study is to evaluate the feasibility of having the current telescope pier support the mass and configuration of a next generation telescope. The assessment was based on the comparison of the forces induced by

[4] Source: Michael Seiffert, presentation on Jet Propulsion Laboratory Caltech for the SuMIRe PFS collaboration[6].

the loads in the different members to their capacity. This section presents the existing structure, the proposed changes, the analyses performed, and the conclusions.

3.2 Existing Structure Configuration

The CFHT telescope pier building is a three storey reinforced concrete cylindrical pier (Figure 2). Its external diameter is 16.6 m and its height is14.4 m. The walls are 305 mm wide and the slabs of the first and second storey are 711 mm thick hollow slabs. The top slab is 305 mm thick. The first storey is 6.3 m high and a large opening of 3.2 m high and 5.8 m wide is present. The second and third storeys are 4.0 m high. The telescope pier building during its construction is shown on Figure 3 with the steel enclosure pier around it. The footing is a continuous ring beam of 610 mm of thickness and of 2240 mm of width. The mass of the structure excluding the telescope is of approximately 1343 tons.

The concrete compressive strength is of 20.7 MPa and the yielding strength of the reinforcing bars of 413 MPa. The soil bearing capacity was evaluated by Dames & Moore in 1973 to be of 191 kPa assuming a differential settlement of less than 10 mm. The original design was performed assuming the telescope to have a mass of 250 tons, a center of gravity 9.5 m over the top slab, and to be supported at three points on the perimeter of the top slab (Figure 3).

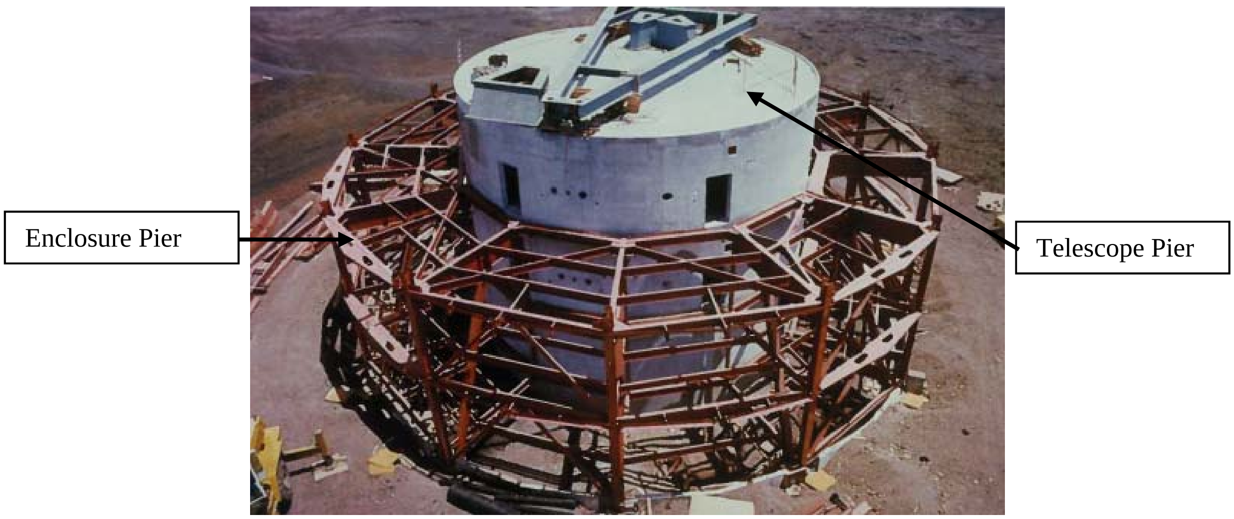

Figure 3: Telescope pier building and enclosure during construction

3.3 Next Generation Telescope

In order to assess the capacity of the telescope pier, it was necessary to approximate the mass and the center of gravity of the next generation telescope. The telescope is supported and rotates on four hydrostatic bearing pads sitting on a steel ring girder placed over the cylindrical wall to distribute as uniformly as possible the loads to the pier. The mass is assumed to be of 270 tons[5], an increase of 6.0% over the previous design and the center of gravity to be 7.0 m over the top slab. The total mass of the telescope pier with the next generation telescope is 1613 tons. The design goal for the first natural frequency of the telescope is to be 4.0 Hz or greater.

3.4 Requirements

The load requirements were determined using American Society of Civil Engineering 7 – Minimum Design Loads of Buildings and Other Structures[7], (ASCE-7 2010). Dead, live and seismic loads were considered; the telescope pier was assumed to be isolated from wind loads. The load combinations were defined following ASCE-7 2010 recommendations. Capacities were evaluated using the aics(ACI 2008)[8] requirements.

[5] Based on the mass of the Keck telescope

The seismic analysis was performed using an equivalent lateral force procedure following the ASCE-7 2010 recommendations. The first natural period was estimated to be of 0.2 sec which was confirmed later by the Finite element analysis (FEA). Assuming an Importance Factor of 1.0 and a Response Modification Factor of 4.0, the seismic response coefficient was determined to be of 0.25g.

3.5 Analysis

The evaluation of the telescope pier was done by comparing the forces induced by the loads to the capacity of each member. The global evaluation was based on the assessment of the individual member failures. FEA and first principles approaches were used to perform the analysis. The main findings are summarized in this section.

The FEA was performed using the structural analysis software SAP2000. The model is shown in Figure 4. Shell elements with membrane and plate stiffness were used to represent the walls and slabs. The telescope was modeled as a beam element frame supporting a lumped mass at its top and connected to the structure via springs. The spring stiffnesses were tuned to represent the appropriate dynamic characteristics and to ensure that the telescope model does not contribute to the stiffness of the pier. The springs are connected to the pier via the ring girder. The overall model was verified by comparing its deflections and modal properties to a simplified four degree-of-freedom system. The ground support was modeled as spring elements representing the stiffness of the foundation.

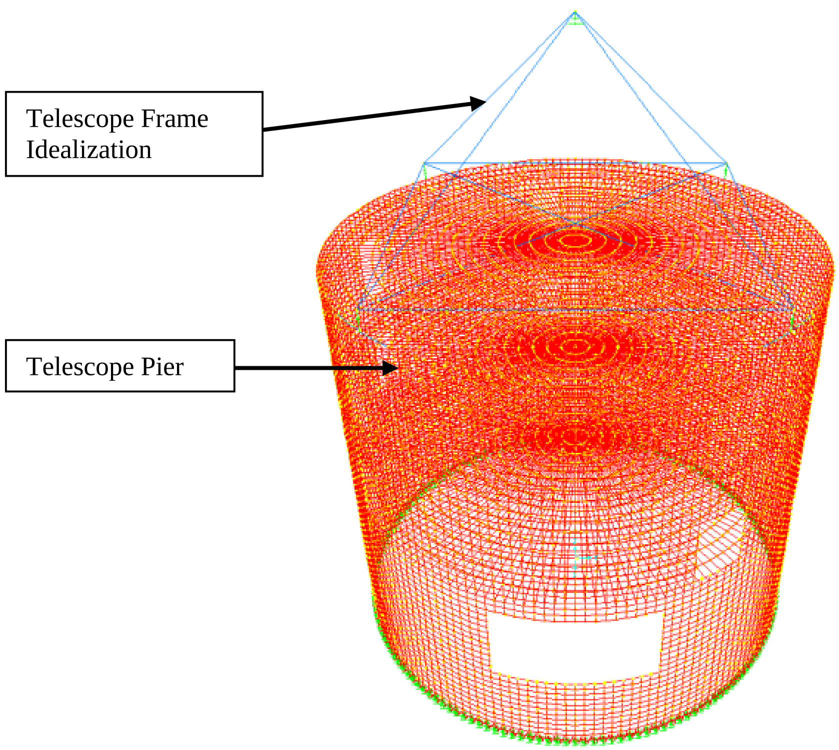

Figure 4: SAP2000 telescope pier and telescope representation finite element model

First, the bending capacity of the pier walls was analyzed. The bending capacity at cracking, yielding, and ultimate strengths was determined for the cylindrical wall section with consideration for the effect of axial loads. The capacities were then compared to the maximum bending moment induced by the seismic loads. The ratios of utilizations are respectively of 0.38, 0.28 and 0.23 for cracking, yielding, and ultimate capacity. Based on this result the bending capacity of the telescope pier was assumed to be sufficient.

The shear forces induced by the seismic loads were also analyzed. It was assumed the loads were resisted by two straight walls. The shear distribution difference between both walls due to the main floor opening was accounted for. It was assumed the shear capacity was provided by the horizontal steel reinforcement and the concrete shear resistance. The utilizations at foundation and at the main opening height were evaluated. The ratios of utilizations were of 0.48 and 1.06 respectively. The capacity at the main opening was slightly exceeded, but it was not judged to be significantly surpassed.

The ring footing structural capacity was then evaluated. Its maximum utilization was found to be of 0.74. The foundation bearing capacity was also reviewed. Its utilization under gravity loads was of 1.02 and under earthquake loads of 1.33. It was concluded that the soil under dead and live load can bear the pressure distributed by the footings. In the case of earthquake load combinations, Coduto[9] states that the bearing capacity can usually be increased by 33%. However, because of the variability of soil properties, not every soil type provides this improved capacity. In recent codes, increasing the bearing capacity by one-third is not recommended anymore. It was decided that additional geotechnical consultation is required to confirm bearing capacity under dynamic loads.

3.6 Findings and Solutions

The structural and foundation evaluation of the telescope pier to accommodate a next generation telescope concluded with the following key points:

- Walls, slabs, and footings were considered to have enough structural capacity.
- Under gravity loads, the soil allowable bearing capacity was considered sufficient as the utilization was estimated to be 100%.
- The bearing capacity of the soil under seismic loads was estimated to be exceeded by 33%. Because of the dynamic nature of earthquake loads, it is common practice to increase the bearing capacity by one-third. Before studying how to reinforce the foundations, a geotechnical investigation will be performed to re-evaluate the soil parameters and foundation capacity to confirm sufficient soil capacity under major seismic events.

4. ENCLOSURE PIER LOAD CAPACITY STUDY

4.1 Objectives of the Study

The enclosure load capacity evaluation provides an assessment of the possible reusing of the current enclosure pier and foundation for future upgrade of the dome and potential dynamic interactions with the telescope pier. The procedure used was similar to the telescope pier building evaluation since it was based on force vs. capacity utilization ratios. The existing enclosure pier is described as well as the new enclosure concept. The analyses and the conclusions are then presented.

4.2 Existing Enclosure Pier

The enclosure is a steel frame structure covering the telescope pier building and supporting the telescope dome (Figure 5). It is a cylindrical 4 storey building with an overall height of 14.9 m and of an outer diameter of 28.8 m. Its inner diameter is 16.7 m and there is a gap of 80 mm between the inner concrete pier and the outer steel pier to provide isolation. A mezzanine is also present on top of the observation floor.

Figure 5: CFHT enclosure pier steel frame during construction

The structure is divided in 12 bays along its perimeter. Chevron type bracings are present on the exterior every two bays for the first 3 storeys and are present every bay for the top storey. The observation floor runs over the telescope pier top and provides lateral support to the enclosure pier. The loads are transferred to the foundation via external and diagonal columns to a single ring footing placed on the exterior perimeter of the enclosure pier. The concrete floor slabs are 64 mm thick except for the observation floor which is 250 mm thick. The footing is 4.3 m wide and 1.8 m thick. Steel member properties are defined according to CSA G40.12 – 1971. The yield strength is 304 MPa, and the ultimate strength is 448 MPa. The existing telescope dome has a mass of 385 tons and a diameter of 32.2 m. The enclosure pier has an estimated mass of 893 tons.

4.3 New Enclosure Concept

To evaluate the outer pier capacity, it was necessary to consider the forces produced by the new enclosure. The enclosure center of gravity was estimated to be 12.0 m above the top of the enclosure pier and was estimated to have a horizontal eccentricity of 1.0 m due to the asymmetry of the calotte concept. Its mass was estimated to be of 510 tons, an increase of 32% compared to the existing design.

4.4 Requirements

The ASCE-7 2010 requirements were used to determine the loads and load combinations. Dead, live, ice, snow, wind, and seismic loads were considered. Capacity was evaluated using the ACI 2008 and the American Institute of Steel Construction[10] (AISC 2005) requirements.

The dead and live loads were applied as area loads on the floors. The snow load applied was 150 kg/m^2 and the ice load was 68 kg/m^2. The wind loads were evaluated following the recommendations for dome roofs of the ASCE-7 2010. The pressures were evaluated using a maximum wind speed of 78 m/s. An equivalent lateral force procedure according to ASCE-7 2010 was adopted to determine the response under seismic loads. The first natural period was estimated to be of 0.5 sec which was confirmed later by FEA. Assuming an Importance Factor of 1.0 and a Response Modification Factor of 2.0, the seismic response coefficient was determined to be of 0.5g. For reference, the original design was done using a lateral acceleration of 0.12g in 1974, so the new loading represents a 416% increase in lateral loads.

4.5 Analysis

The evaluation of the enclosure pier was based on the same procedure as for the telescope pier; the forces in the members were compared to the capacities. If failures of members were observed, their impact on the global behavior was analyzed and solutions were proposed.

The FEA determining the member forces in the enclosure pier building was done using the structural analysis software SAP2000. The enclosure pier 3D frame and dome idealization are shown in Figure 6. The supports were modeled as pinned connections. The slabs were modeled as shell elements with membrane stiffness only. Most of the connections for the steel members were modeled with pinned connections. To avoid modeling a complex structure, the dome was idealized as a pyramidal space frame with its mass concentrated at its top and was connected to the ring girder of the enclosure pier via spring elements, with the same considerations in the telescope pier analysis. The mezzanine on the observatory level was ignored in the analysis since it has no significant impact on the results.

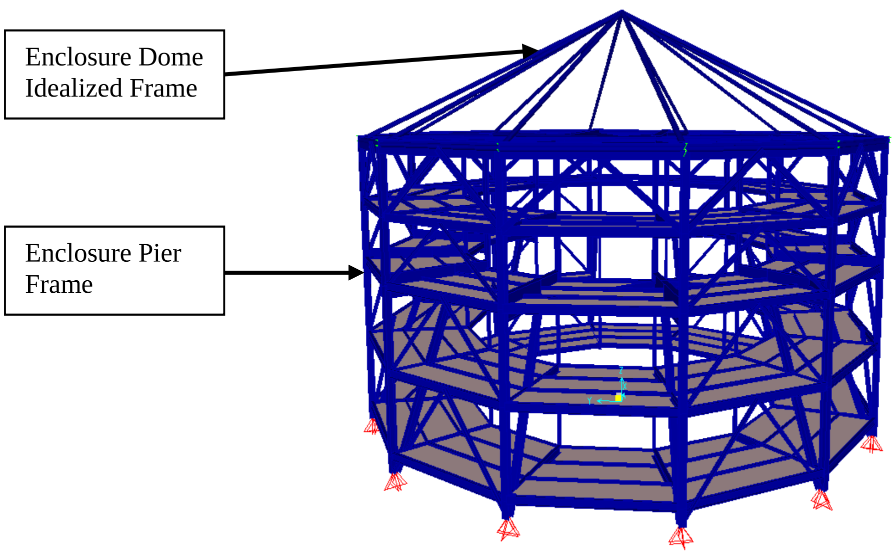

Figure 6: SAP2000 finite element model with the telescope frame idealization

The forces induced in the beams, columns, and bracings by the loads are compared to their capacity. It was found that the utilizations were not exceeded in the beams and columns. However the utilizations are near 100% for the external columns.

The chevron bracings have their capacities exceeded by a factor of 4.2 under earthquake load combination. This result was verified by hand calculations assuming all earthquake loads are resisted by these bracings, and the calculated forces were within 5.0% of the FEA results. It was concluded that the bracings were under designed in 1974 due to less severe seismic requirements. The bracings are critical components and it should be assured that they have sufficient capacity. Our solutions are proposed in the next section.

The footing structural capacity was also verified, and the utilizations were found to be under 0.50. The foundation bearing capacity was utilized by 0.66 under gravity loads and by 0.97 under seismic loads. The footing and the foundation were considered to have sufficient capacity.

The deflections of the enclosure pier under seismic loads were studied to verify if there are interactions with the telescope pier. The displacement at the top of the telescope pier is of 94 mm. The space between the enclosure and telescope pier being of 80 mm, interaction between both structures can be expected during major seismic events.

4.6 Findings and Solutions

In order to have the enclosure pier supporting the new enclosure and conforming to modern requirements the following points were concluded:

- The beams forming the different floor levels have sufficient capacity to resist the loads applied on them.
- The different columns transferring the loads to the footings have utilizations close to 100% which means that they have little capacity to sustain higher loads than the new enclosure.
- The bracings resisting the lateral loads have their demand exceeding their capacity by a ratio of 4.2. This outcome results from the fact that the earthquake forces are 420 % higher than for the original design requirements. Different solutions exist to resolve this issue. Increasing the number of bays with bracings while strengthening and adding ductility to the bracings is a common option. Replacing the chevron type bracings for cross braced type can also be considered. Adding dampers or steel shear walls is also solution for improving the seismic performance of the building.
- The footings have sufficient bending, shear and tension structural capacity to resist the load demands. The ratios of demand to capacity are under 0.50.
- The maximum bearing pressure induced by the footing to the foundation was 97 % of the 161 kPa bearing capacity.
- The maximum deflection at the third floor was of 94 mm and exceeds the 80 mm space between the outer and inner pier. Therefore the lateral stiffness of the enclosure pier structure will have to be increased. Increasing the lateral stiffness of the enclosure pier structure can be achieved by adding braced bays or replacing the chevron braced system with a stiffer system.

5. PROPOSED TELESCOPE AND ENCLOSURE CONFIGURATION

The goal of the concept design is to develop a new enclosure and telescope system for the NGCFHT installations that should match the space envelope of the current observatory as closely as possible, including realistic space allocations for structural and mechanical subsystems. Preserving the overall observatory space envelope will facilitate the approval process and reusing the enclosure and telescope piers is beneficial for cost and schedule considerations.

5.1 Requirements

As stated previously the requirements are: the primary mirror is an f/2 segmented 10 m diameter mirror; the distance from the primary mirror vertex to the top of the telescope is of 19.4 m; the enclosure will provide a clear zenith angle observing range from 0 degrees to 65 degrees; the telescope will be able to point to 90 degrees to facilitate maintenance; a dome-mounted crane will handle the primary mirror segments and the prime focus components.

5.2 Enclosure Concept

A calotte configuration for the enclosure was selected due to its compact design and structural efficiency (Figure 7). These features give it the best possibility of matching the existing enclosure size and mass, which would allow the existing enclosure pier to be utilized. A telescope sweep radius of 14.0 m is assumed. The inside radius of the enclosure is set at 16.0 m (inside of the dome insulation) and the outside radius is set at 17.0 m. To reuse the existing dome rotating ring girder and azimuth bogie system, the height of the elevation axis needs to be approximately 24 m above grade.

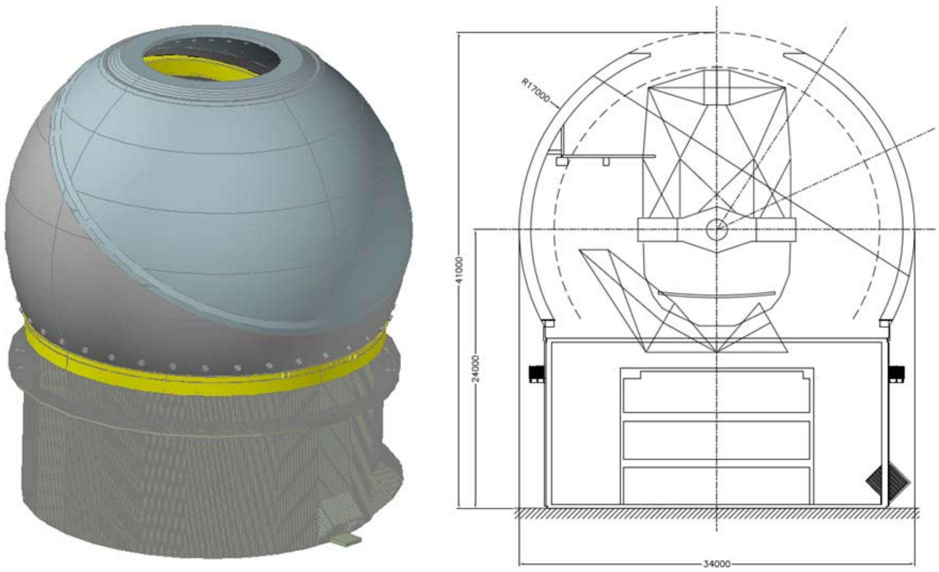

Figure 7: Proposed NGCFHT calotte enclosure

The lower portion of the calotte is referred to as the “base”, and the upper portion as the “cap”. The cap has a circular aperture opening. The geometry of the enclosure permits a fixed shutter concept to be used, where the shutter is a cantilevered extension of the base structure. The aperture is closed by rotating the aperture over top of the shutter. This approach eliminates the need for additional major mechanisms to open and close the shutter. In the closed position, a locking mechanism secures the aperture to the shutter at reinforced points around its perimeter. A sealing mechanism seals the interface.

The basic structural elements include ring girders at the circular mechanical interfaces, and a rib structure for the spherical portions of the structure. Cladding is provided by a welded steel plate skin. The major mechanisms are the azimuth bogie and drive systems, and the cap bogie and drive systems. It is intended that the existing azimuth bogie and drive system can be reused, but this will need to be verified in further design studies. The cap bogies are distributed around the perimeter of the inclined cap plane. The cap drives consist of a rack and roller pinion drive system located with drive motors located on the base structure at the lowest point of the inclined cap plane. The drive system is similar to that used on the existing CFHT shutter.

It is assumed the dome will be insulated. Sandwich panels with aluminum skins and expanded polystyrene core provide a cost effective solution, and can deliver good insulation to a spherical dome. No ventilation specifications have been developed at this point. Options exist to ventilate the interstitial space of the enclosure (as on the existing CFHT dome) during daytime and to actively ventilate of the entire dome interior via floor mounted exhaust vents at night (as in Keck dome). Unlike the Thirty Meter Telescope (TMT) calotte enclosure[3] (Figure 8), we have assumed that ventilation door modules[6] and aperture flaps that attenuates air flow around the aperture opening to minimize telescope windshake are not required for the NGCFHT enclosure. However, we plan to validate these assumptions by aero-thermal study which will be discussed in the following section.

The current enclosure accommodates a dome-mounted handling crane to handle the primary mirror segments and also components at the telescope top-end. A crane similar in design to the Keck segment handling crane is proposed.

[6] The TMT enclosure has 88 ventilation modules on the base structure, each consists of a commercially available exterior roll-up door, with high wind load ratings, and a secondary set of insulated interior double doors to provide thermal break when closed.

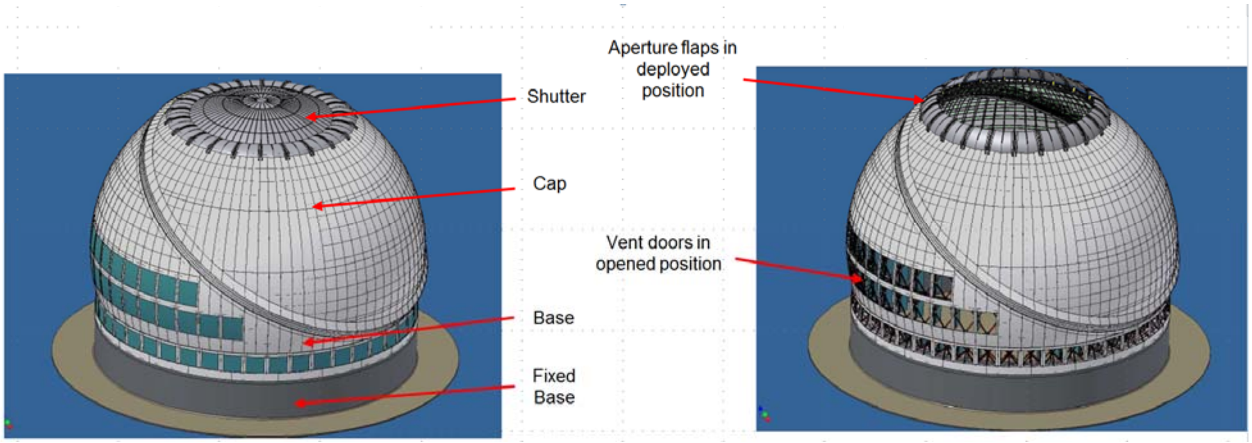

Figure 8: TMT calotte enclosure – vent modules and aperture flips closed (left) and deployed (right).

5.3 Telescope Concept

The telescope structure and mechanical concept can largely be derived from the two Keck telescopes, which are also 10 m diameter segmented alt-az telescopes. However, the major difference between the Keck telescopes and the NGCFHT telescope as it only utilizes the prime focus. This significantly reduces the size of the structural support required for the side and rear of the telescope azimuth structure. Space savings between the Keck design and the NGCFHT arise from the removal of the two Nasmyth platforms and the rear Cassegrain platform which are not required for the proposed facility. This results in significant reduction in the rotating mass and size of drives. However this does not affect in the telescope swept-envelope as no savings can be realized in the telescope rotational volume as it is governed by the "zenith range" sweep of the telescope elevation structure.

Mechanically, the telescope structure has two rotational axes; the elevation axis which is located above the primary mirror and the azimuth axis which is at the bottom center of the telescope azimuth structure. The rotational elements of the elevation axis are a pair of conventional bearings. The azimuth bearings are specialty hydrostatic bearing pads. The size of these bearings could be slightly smaller than the Keck design due to the reduction in rotating mass. The baseline drive systems are assumed to be friction drives that are proven technology on Keck and Gemini.

The last area of consideration is the prime focus area and its related mechanical systems. The considerations are largely flow-down of the operational requirements of the prime focus unit and the prime focus area will be designed in concert with those constraints. At the very minimum, the design will include accommodations for optical adjustments and the servicing and utility needs.

6. AERO-THERMAL STUDY

The motivation for simplifying the NGCFHT enclosure design is to minimize design, construction and operating costs of the proposed facility. Where possible, it is desirable to reduce the enclosure mechanical systems. By not having vent doors, aperture flips and shutter drive system, additional benefits are realized such as cost saving from the elimination access stairs and walkways, and gain in system reliability and safety due fewer moving mechanisms.

As mentioned, we plan to ventilate the NGCFHT enclosure through floor vents and we need to understand the effectiveness of this approach. In general, we need to establish the facility thermal seeing management strategies by accounting for the effects from potential heat sources within the enclosure and contributions from the mechanical plant room, and considering site conditions and physical constraints within the current facility to direct (ventilate and exhaust) air flow through the enclosure pier and underground tunnels.

We will apply the knowledge and insight acquired from previous CFHT aerodynamic studies[11,12], computational fluid dynamics (CFD) analyses and scale-model testing, in the development of the facility thermal seeing management strategies. In the coming months, we plan to conduct CFD analysis to access the feasibility of dome venting through the enclosure floor to control local seeing and determine the flow velocity profile over the enclosure aperture in order to access the wind induced telescope jitter.

7. Summary

Given the redevelopment principle and the assumed facility configuration, we have developed a telescope and enclosure concept that reuses the current telescope and enclosure piers and matches the current CFHT space envelope. Figure 9 shows a comparison of the NGCFHT and current CFHT enclosure external dimensions. With additional fine-tuning of the telescope and enclosure geometries, we will reduce the enclosure dimensions to acceptable level within the CMP requirement.

We are encouraged by the findings from the load capacity studies that they did not identified major structural deficiencies other than the enclosure pier bracing and telescope pier soil capacity. We will conduct further geotechnical study to confirm the telescope pier soil capacity in supporting the new telescope (likely less massive than the assumed mass of the Keck telescope). Based on the recommendations of the load capacity studies, we are confident that cost efficient solutions can be found to augment the telescope pier capacity (if required) and reinforcing the enclosure pier. In the near future, we will conduct CFD analysis to verify the feasibility of the proposed "minimal" enclosure configuration.

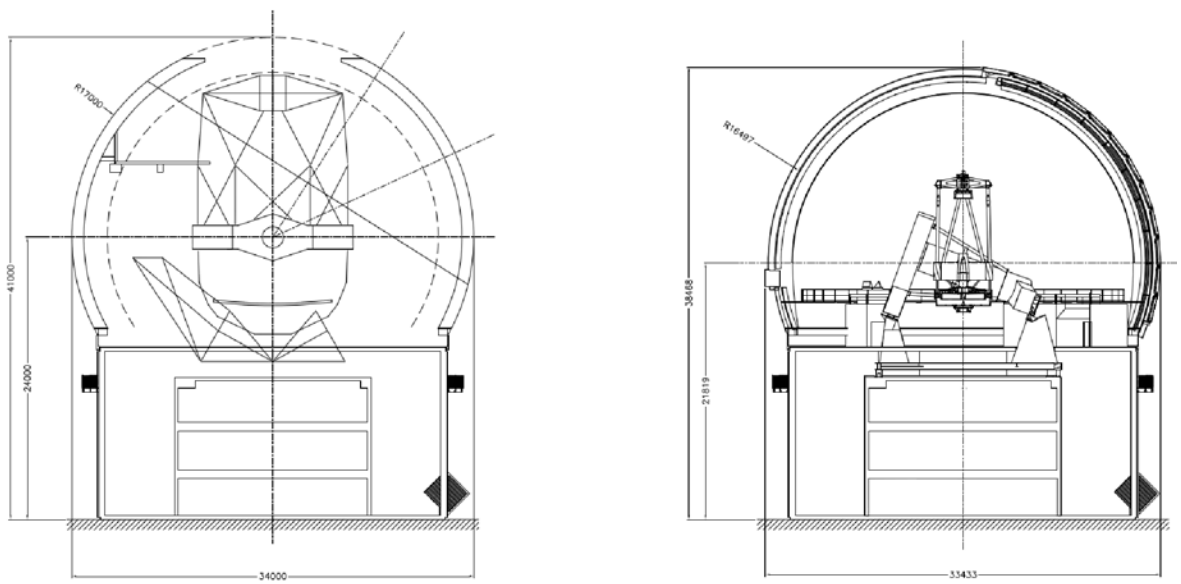

Figure 9: Comparison of the external dimensions of the NGCFHT enclosure (left) and current CFHT enclosure (right).

The findings of the three feasibility studies along with the telescope optical design and spectrograph concepts will be summarized in the final Feasibility Study Report for submission to the CFHT board and Science Advisory Committee in the Fall of 2012. The final Report will also incorporate cost estimates, project schedule, and a business plan. Currently, the order of magnitude (ROM) cost for NGCFHT, based on work completed to date, is USD170-200M. The project schedule will incorporate all the activities, with significant milestones and critical link points between scientific and technical development, that fully define the new facility to ensure a completion date of early 2020s for NGCFHT.

We fully expect the completed Feasibility Study will demonstrate that upgrading the existing CFHT telescope to a dedicated, 10-m class spectroscopic facility is a scientifically exciting, feasible, and affordable endeavor that will place the new facility in the top echelon of astronomical facilities throughout the next decade and beyond.

A key component to ensuring the realization of NGCFHT is the formation of a renewed partnership with additional partners from outside of Canada, France and Hawaii. The synergies enabled by NGCFHT are extensive; a wide field spectroscopic facility is an ideal complements the existing and proposed facilities co-located on Mauna Kea. The same applies even for facilities and surveys based at some southern sites due to the significant overlap in the observable sky.

Following the submission of the Feasibility Study Report, technical advancement will continue by building upon the excellent scientific and engineering accomplishments in the past 18 months. In parallel, business development effort dedicated to forming the new partnership will commence with a goal to turning this exceptional scientific promise into a reality by the early 2020s

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