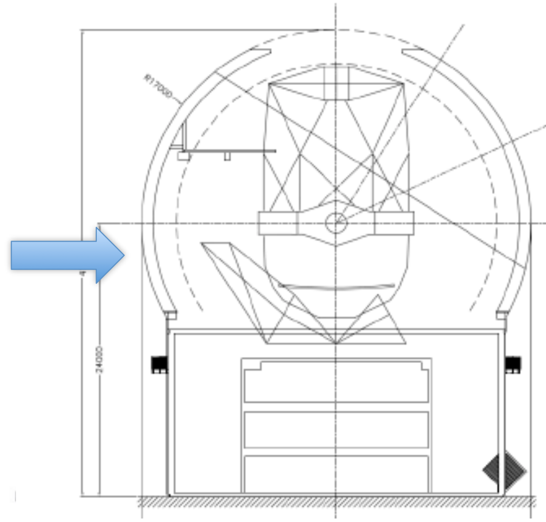
The Next Generation of the Canada-France-Hawaii Telescope: A 10m, Wide-Field Multi-Object Spectroscopic Facility

David Crampton (NRC Herzberg)

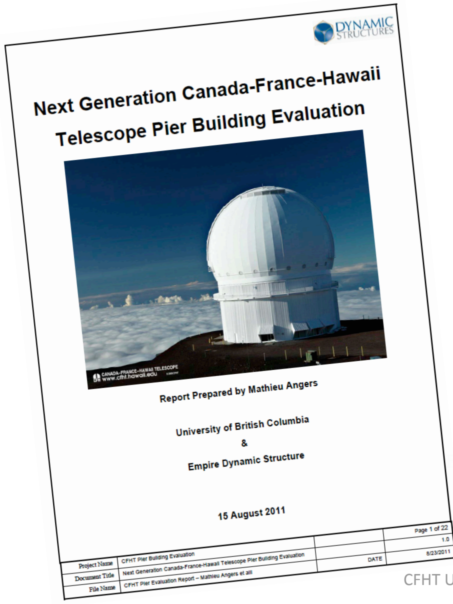
Constraints from Science

- Faint sources => need 10m collecting area (many exposures will still be > 4h)
- Wide field, many targets, with moderate to high spectral resolution => fibres
- Fibre input efficiency => f/ratio > f/2.3
- 10m f/2.3 => 1" = 110mu
- Wide field constrained by diameter of refractive optics (< 1.5m) => 1.5 deg^2
- Hence there are strong constraints on basic design – fortunately the result is consistent with densities of targets on sky

Task: Convert 3.6m to 10m



Detailed studies provide excellent cost and schedule estimates



DYNAMIC STRUCTURES

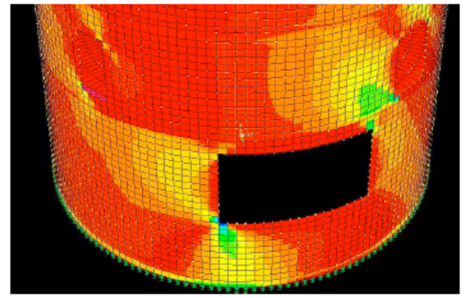
Next Generation Canada-France-Hawaii Telescope Pier Building Evaluation

Report Prepared by Mathieu Angers

University of British Columbia
&
Empire Dynamic Structure

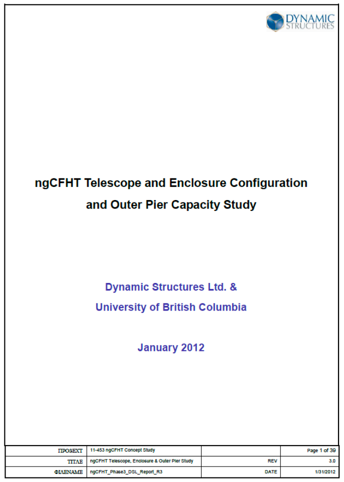
15 August 2011

Project Name	CFHT Pier Building Evaluation		Page 1 of 22
Document Title	Next Generation Canada-France-Hawaii Telescope Pier Building Evaluation		1.0
File Name	CFHT Pier Evaluation Report – Mathieu Angers et all	DATE	8/23/2011



'igure 11: Shear forces envelope in the pier structure under earthquake loading.

Detailed studies provide excellent cost and schedule estimates



ngCFHT Telescope and Enclosure Configuration and Outer Pier Capacity Study

Dynamic Structures Ltd. &
University of British Columbia

January 2012

ΠΡΟϑΕΧΤ	11-453 ngCFHT Concept Study		Page 1 of 39
ΤΙΤΛΕ	ngCFHT Telescope, Enclosure & Outer Pier Study	REV	3.0
ΦΙΛΕΝΑΜΕ	ngCFHT_Phase3_DSL_Report_R3	DATE	1/31/2012

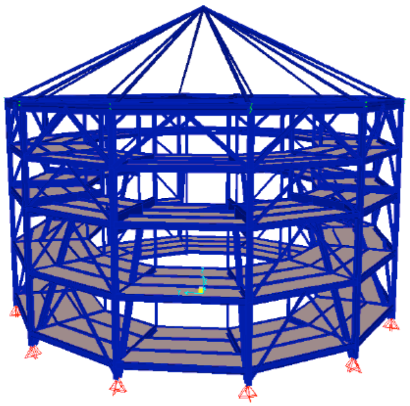


Figure 19: SAP2000 isometric 3-D view of outer pier steel frame and slabs

Detailed studies provide excellent cost and schedule estimates

Programmatic Study for Upgrade of Telescope Structure and Enclosure

amic Structures Ltd

rsity of British Colu

October 2012

At factory

Table 3: ngCFHT enclosure manufacturing estimate

Enclosure Manufacturing	
PM, Engineering, DO, Travel	$1,317,967
Superstructure	$1,457,046
Cladding	$317,379
Insulation	$334,070
Azimuth mechanical	$947,536
Cap/base interface mechanical	$495,766
Shutter structural/mechanical	$415,941
Ventilation doors	$507,564
Walkways, cranes	$765,674
Electrical & control	$1,375,039
Shipping	$747,089
Subtotal	**$8,681,073**
Mark-Up (15%)	$1,302,161
Contingency (20%)	$1,996,647
TOTAL	**$11,979,880**

On summit

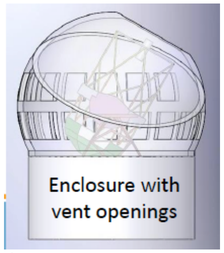
Table 5: ngCFHT enclosure & telescope construction estimate

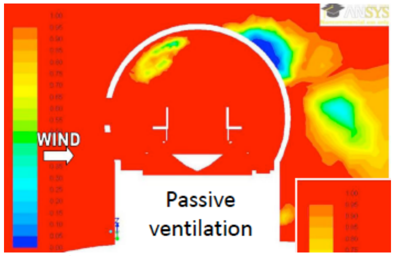
Enclosure Labour	
Supervision & crane operators	$1,416,987
Live-out & travel	$685,994
Enclosure labour	$4,855,082
Shipping	$979,697
Insurance	$1,449,846
Total Enclosure	**$9,387,605**
Telescope Labour	
Supervision & crane operators	$1,307,988
Live-out & travel	$534,064
Enclosure labour	$2,392,314
Shipping	$2,174,545
Insurance	$1,097,082
Total Telescope	**$7,505,993**
Construction Equipment	
Large equipment	$4,093,665
Misc. equipment, tools & falsework	$2,193,673
Ground transport & trucking	$152,800
Total equipment	**$6,440,138**
Subtotal	**$23,333,736**
Mark-Up (15%)	$3,500,060
Contingency (20%)	$5,366,759
TOTAL	**$32,200,556**

Dome venting

(CFD analysis by WindEEE Research Institute of UWO)

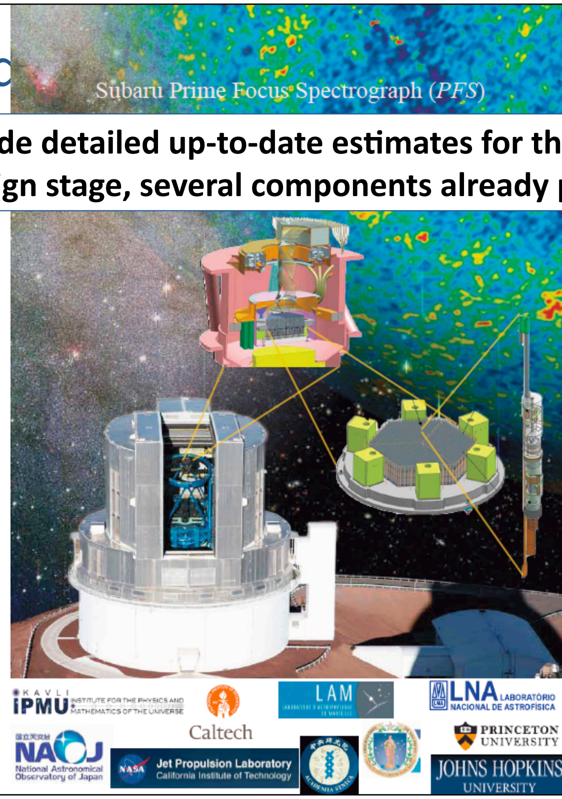
- Compared performance of vented calotte enclosure with unvented but active ventilation





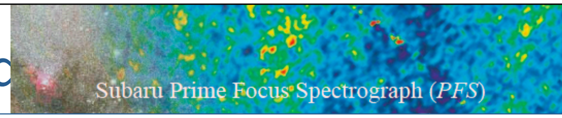
- Conclusion: Passive ventilation provides superior dome-flushing while maintaining uniform temperature and low turbulence
- Vents included in cost estimate

Detailec nt cost

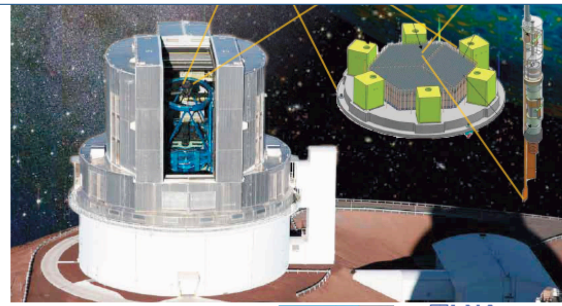


PFS studies provide detailed up-to-date estimates for the instrument (now at final design stage, several components already purchased)

Detailec … nt cost



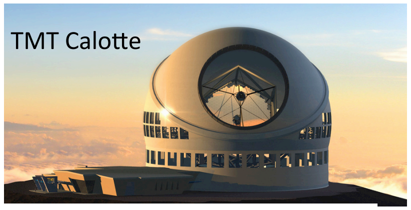
- **Close collaboration with Subaru and PFS is very advantageous**
- **Could bring scientific opportunities earlier (especially for DE and galaxy evolution) and would bring technical benefits to ngCFHT**
- **Re-use or transfer of PFS elements to ngCFHT is also a possibility**
- **Opportunity to join PFS is now being actively explored in Canada**
- **LAM, LNA, Taiwan are already partners**



KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE
Caltech
LAM
LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA
NAOJ National Astronomical Observatory of Japan
NASA Jet Propulsion Laboratory California Institute of Technology
PRINCETON UNIVERSITY
JOHNS HOPKINS UNIVERSITY

Step 1a: Design and fabricate “dome”

- Copy design of TMT enclosure
  - Extensive design and development for TMT, intensively reviewed!
  - “Calotte” is most structurally efficient and cost effective.
  - Much smaller (D=34m) than TMT dome (66m)



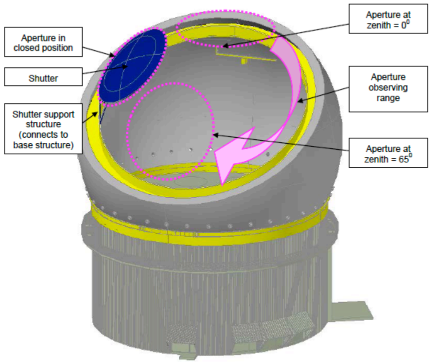
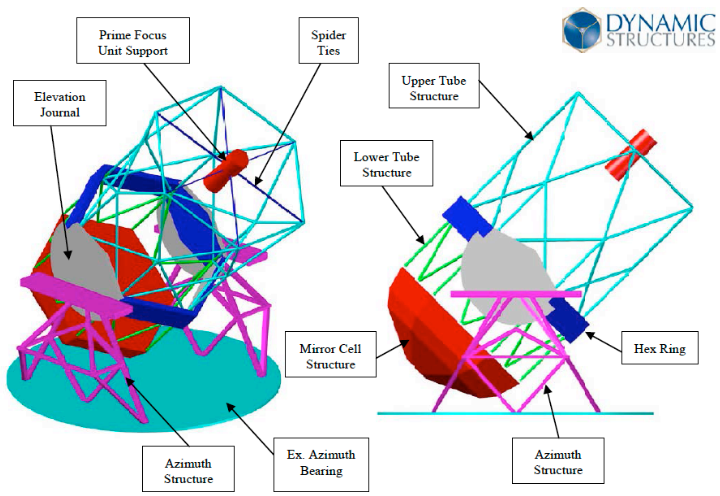


Figure 6: Shutter concept (cap is removed to show shutter, aperture indicated by dotted lines)

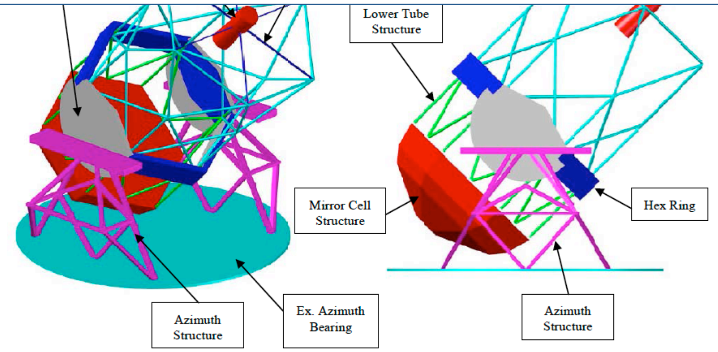
Step 1b: Design and fabricate 10m telescope Estimates: $14.7M, 3 .0yr

- Design builds on Keck 10m telescope



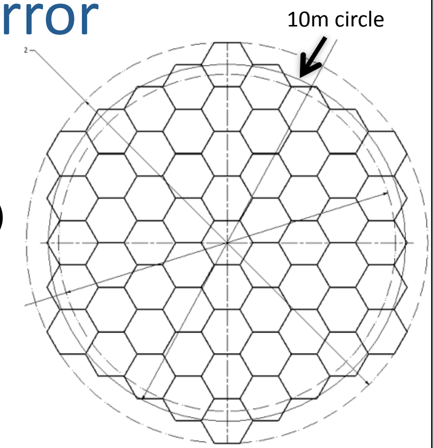
Step 1b: Design and fabricate 10m telescope
Estimates: $14.7M, 3 .0yr

Investigated alternate 2 and 3 mirror designs during feasibility study
Straightforward "Keck design" + wide field corrector is most efficient and cost-effective

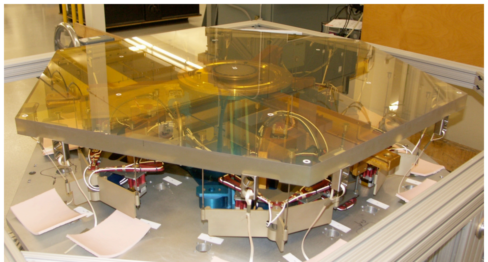


Primary Mirror

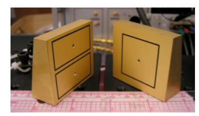
- Segment size currently preferred (by manufacturers): 1.44m
  - ~500 for TMT, ~1000 for E-ELT
- Compared to Keck: (36, 1.8m segments)
  - Segments are cheaper ("industrialized")
  - New edge sensor technology
  - New actuators
  - Improved wavefront control



10m with 60 segments, 1.44m



TMT segment prototype (E-ELT similar)



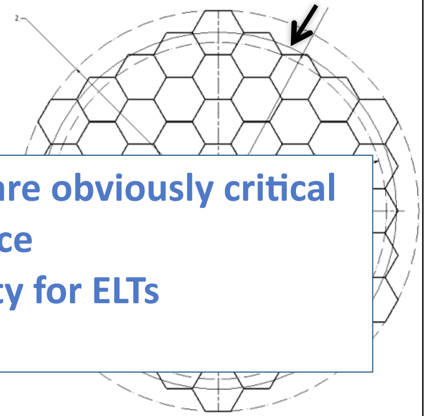
Actuators and edge sensors

Primary Mirror

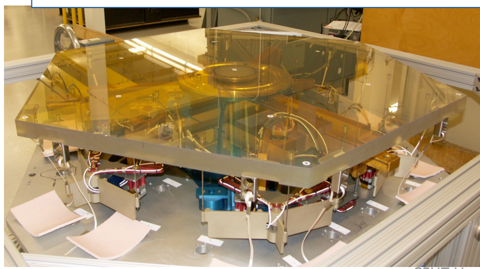
- Segment size currently preferred (by manufacturers): 1.44m
  – ~500 for TMT, ~1000 for E-ELT

M1 mirror optics, cell and control are obviously critical components for overall performance
Many vendors developing capability for ELTs
Cost: $19.5M

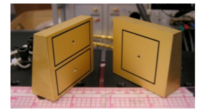
10m circle



10m with 60 segments, 1.44m



TMT segment prototype (E-ELT similar)



Actuators and edge sensors

“Instrument” is a major component
Total $82.6M, 6 yrs, composed of several packages

- Wide Field Corrector
- Fibre Positioner
- Fibre transport system
- Spectrograph
- Acquisition, guiding, metrology
- Calibration
- Software
- Mature technology - build upon existing designs. Heritage from Subaru HSC & PFS, LAMOST, HERMES, BOSS, etc.

The “instrument” is a significant project on its own, to be carried out in parallel with telescope conversion – presumably by a consortium

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The “instrument” is a significant project on its own, to be carried out in parallel with telescope conversion – presumably by a

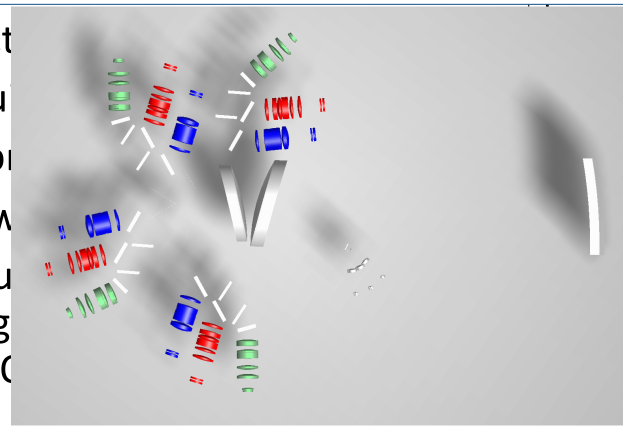
Baseline concept is to duplicate (or re-use) PFS designs and components
Need new design for high resolution spectrograph
New cost estimates derived during feasibility study

LAMOST, HERMES, BOSS, etc.

“Instrument” is a major component

Total $82.6M, 6 yrs, composed of several packages

Spano 2012
Clever design based on pupil slicing would allow same spectrograph to be used for all three dispersions



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On-site deconstruction and renovation
Estimate: $9.3M, ½ yr (2017)

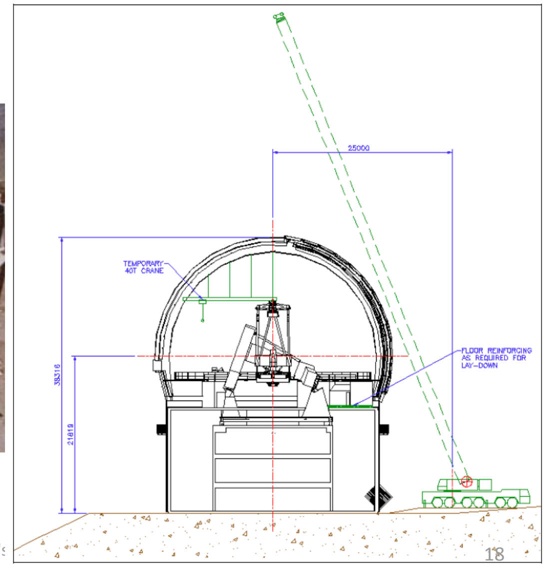
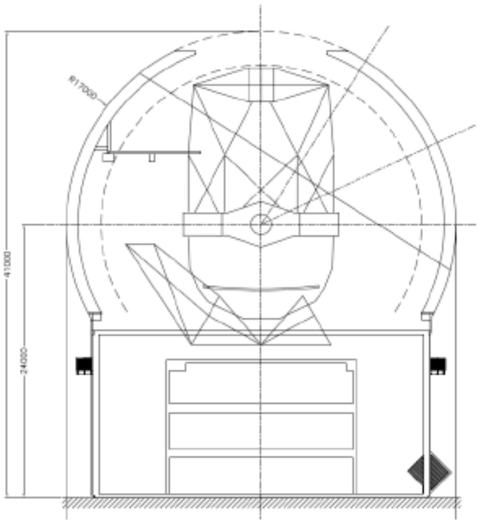


Figure 3: West elevation of site set-up for deconstruction

Install Dome & Telescope

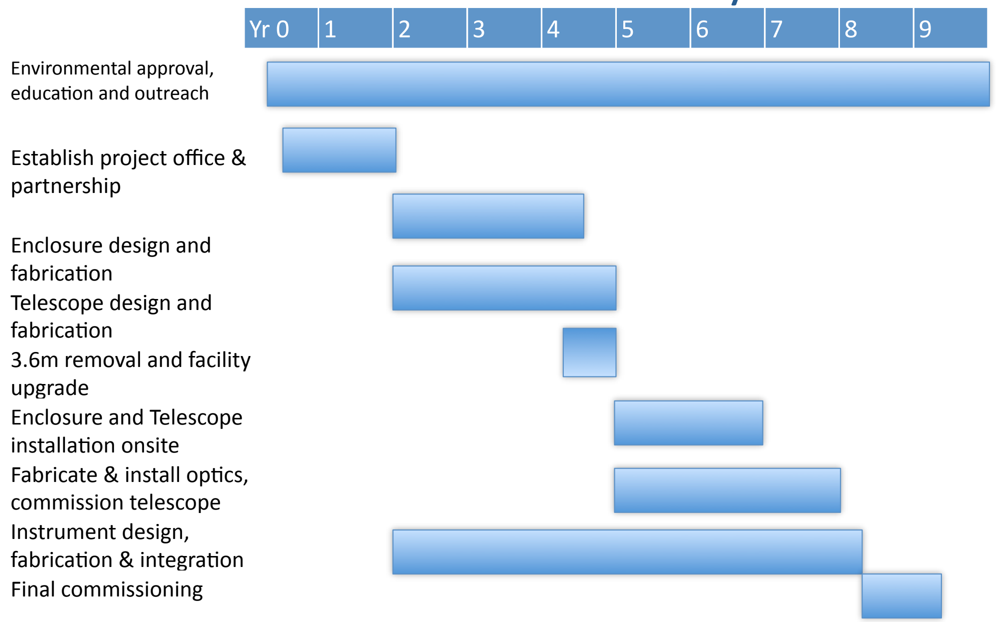
- (Telescope $7.5M, Enclosure $9.4M, Equipment $6.4M + contingency and markup)
- Ideally managed by one firm
  - Major sub-contracts to telescope and dome fabricators
- Fully functioning telescope structure by completion but without optics or instrument



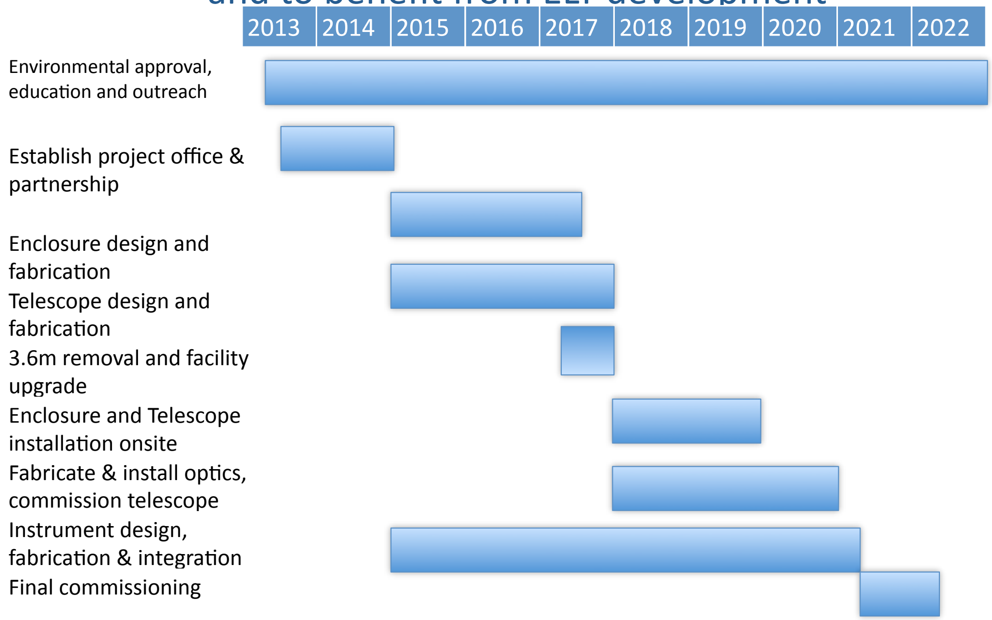
Install optics & commission

- Install, align and phase segments
- Commission telescope
- Install and align widefield corrector
- Install, integrate and test prime focus instrument plus fibre system
- Install, integrate and test spectrograph
- Commission entire MOS facility
- Ready for initiation of surveys by completion

Schedule based on Feasibility Studies



Schedule to realize optimal scientific synergy and to benefit from ELT development



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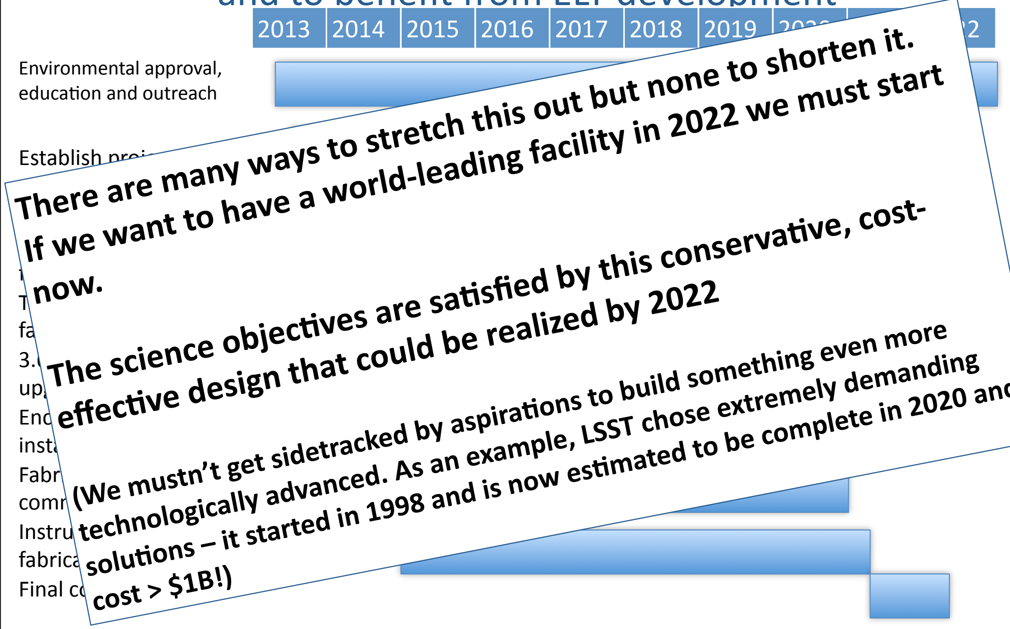
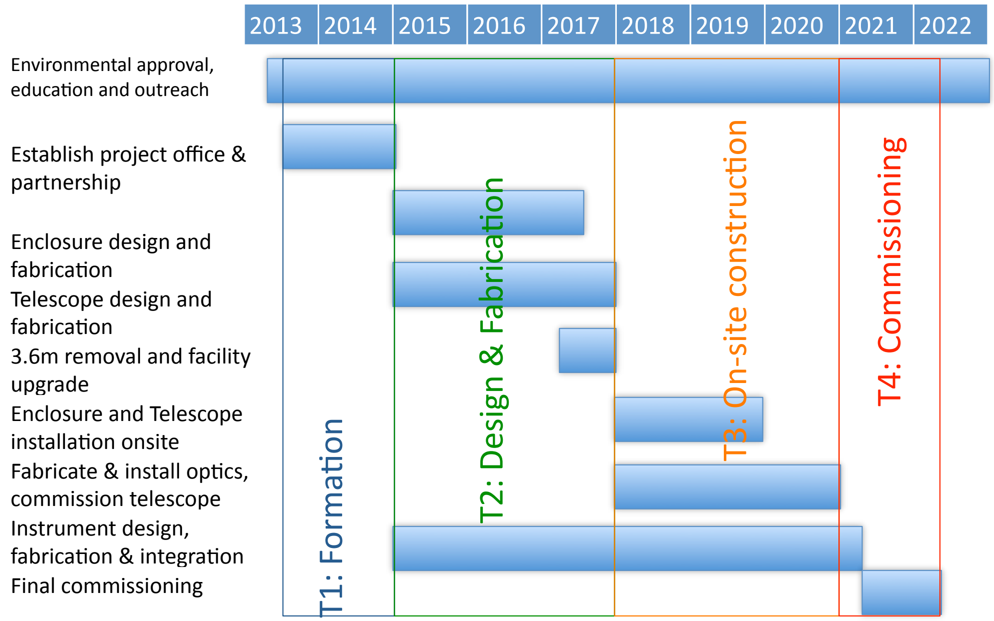


There are many ways to stretch this out but none to shorten it. If we want to have a world-leading facility in 2022 we must start now.

The science objectives are satisfied by this conservative, cost-effective design that could be realized by 2022

(We mustn't get sidetracked by aspirations to build something even more technologically advanced. As an example, LSST chose extremely demanding solutions – it started in 1998 and is now estimated to be complete in 2020 and cost > $1B!)

Transition to 10m MOS facility



Cost Summary

($206.3M(2012), including contingency)

Year	Project Office	ENC Design	TEL Design	De-const	On-site	M1	SW	INST	Re-dev	Totals
2013	0.5									0.5
2014	1.25									1.25
2015	1.75	4.8	5					13.8		25.35
2016	1.9	4.8	5					13.8		25.5
2017	1.9	2.4	4.7	9.3			3.2	13.8		35.3
2018	1.9				16.1	6.5	3.2	13.8	2	43.5
2019	1.9				16.1	6.5	3.2	13.8	2	43.5
2020	1.9					6.5	3.4	13.6	3	28.4
2021									3	3.0
Total	13	12	14.7	9.3	32.2	19.5	13	82.6	10	206.3

Deconst includes removal and renovation of pier and base
Onsite includes installation of telescope and dome
M1 includes segmented mirror and support system
INST includes wide field corrector, prime focus system, fibre transport and spectrograph
Redev includes facility redevelopment and commissioning support

Cost Summary

($206.3M(2012), including contingency)

Year	Project Office	ENC Design	TEL Design	De-const	On-site	M1	SW	I
2013	0.5							
2014	1.25							
2015	1.75	4.8	5					1
2016	1.9	4.8	5					1
2017	1.9	2.4	4.7	9.3			3.2	1
2018	1.9				16.1	6.5	3.2	1
2019	1.9				16.1	6.5	3.2	1
2020	1.9					6.5	3.4	1
2021								
Total	13	12	14.7	9.3	32.2	19.5	13	8

Year	Total/ partner
2013	$0.1M
2014	$0.2M
2015	$4.2M
2016	$4.2M
2017	$5.9M
2018	$7.2M
2019	$7.2M
2020	$4.7M
2012	$0.5M
Total	$34.4M

Deconst includes removal and renovation of pier and base
Onsite includes installation of telescope and dome
M1 includes segmented mirror and support system
INST includes wide field corrector, prime focus system, fibre transport and spectrograph
Redev includes facility redevelopment and commissioning support

Operations costs

- CFHT has long history and experience in operating on MK
- Exceptional staff
- Now operated from Waimea with no one at summit at night
- Current Ops budget is $6.4M
- With a single instrument, routine operations should not cost significantly more
- => annual ops budget in 2020 < $2M per partner
- Might be significantly less if combine operations with other telescopes (strongly recommended!!!!)

Phase T1 (ngCFHT formation phase)

- Important to separate ngCFHT project from on-going scientific operation of CFHT
- Project of this size must be run by a professional project manager responsible to achieve scientific capabilities on budget and schedule
- Small central project office located at CFHT headquarters in Waimea
  - Project manager
  - Project engineer (System Engineer)
  - Project scientist (half time may be sufficient)
  - Assisted by an optical, mechanical and control systems engineer (could be loaned from partner countries)
- Oversight by an interim ngCFHT (expanded CFHT) Board
- Form partnership
  - Encourage visits of scientists and engineers from partners to project office
  - Form satellite project offices in partner countries responsible for key components
- Form an interim ngCFHT Scientific Advisory Committee

Phase T1 Project Office Activities

- Overall Project Management
  - Organize project
  - Planning (WBS, Schedule, Milestones, Risk mgmt, Budgets)
  - Carry out trade studies and cost analyses
  - Responsible for project budget and schedule
  - Conduct project and planning meetings and reviews
  - Provide interface to CFHT and Mauna Kea knowledge and resources
- Develop overall system and interface requirements
- Initiate contracts for major subsystems
- Initiate discussions and meetings with instrument teams
- Provide project scientist functions (detailed scientific specifications, operation plan, scientific talks, PR)
- Work with partners to identify and define technical contributions (or work packages)

T1 Project Office Annual Budget

- Personnel:$0.8M
- Trade studies or design studies: $300K
- Travel (30 trips): $75K
- Local support for visiting workers: $75K

2013 Activities

- On-going: visits and discussions to develop details of new partnership
- Mar 27-29: ngCFHT Science meeting in Hilo
  - 96 participants from Canada, France, Hawaii, Australia, Brazil, China, India, Japan, Republic of Korea, South Africa, Taiwan and the USA
- Explore synergies with Subaru, PFS
- May 6-8: CFHT User's meeting
- Oct (17-18?): Technical meeting, probably in China
  - Exchange of concepts and ideas among partners
  - Develop understanding of partner strengths and aspirations
  - Stimulate collaborations
- Commence discussion of work shares
- Start building project team

Summary

- Substantial studies on key technical aspects have all been completed since last User's Meeting
- Studies confirm feasibility of converting 3.6m to a 10m MOS facility
- Studies provide reliable cost and schedule estimates
- Simple "copy-cat" design meets science requirements
- Schedule can exploit synergy with ELT development and be consistent with complementary science facilities (Gaia, Euclid, LSST, TMT, E-ELT, SKA…)
- Small project team now required to properly plan project, advance designs, consolidate partnership, and develop relationships with vendors

More info at ngCFHT.org

We are ready to go – we must get started now!