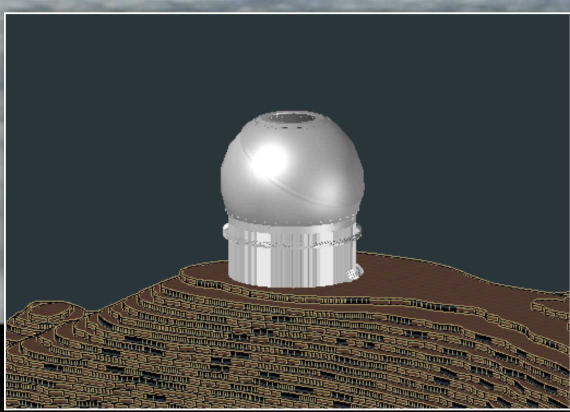
Report on the Next Generation CFHT Project

Patrick Côté (NRC-Herzberg)



10^{th} CFHT Users' Meeting, May 6-8, 2013

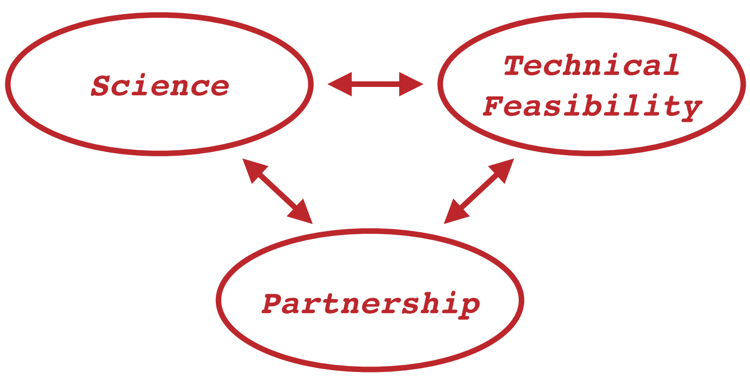
The Next Generation CFHT Proposal

- concept introduced to the CFHT community at the 2010 users' meeting in Taipei.

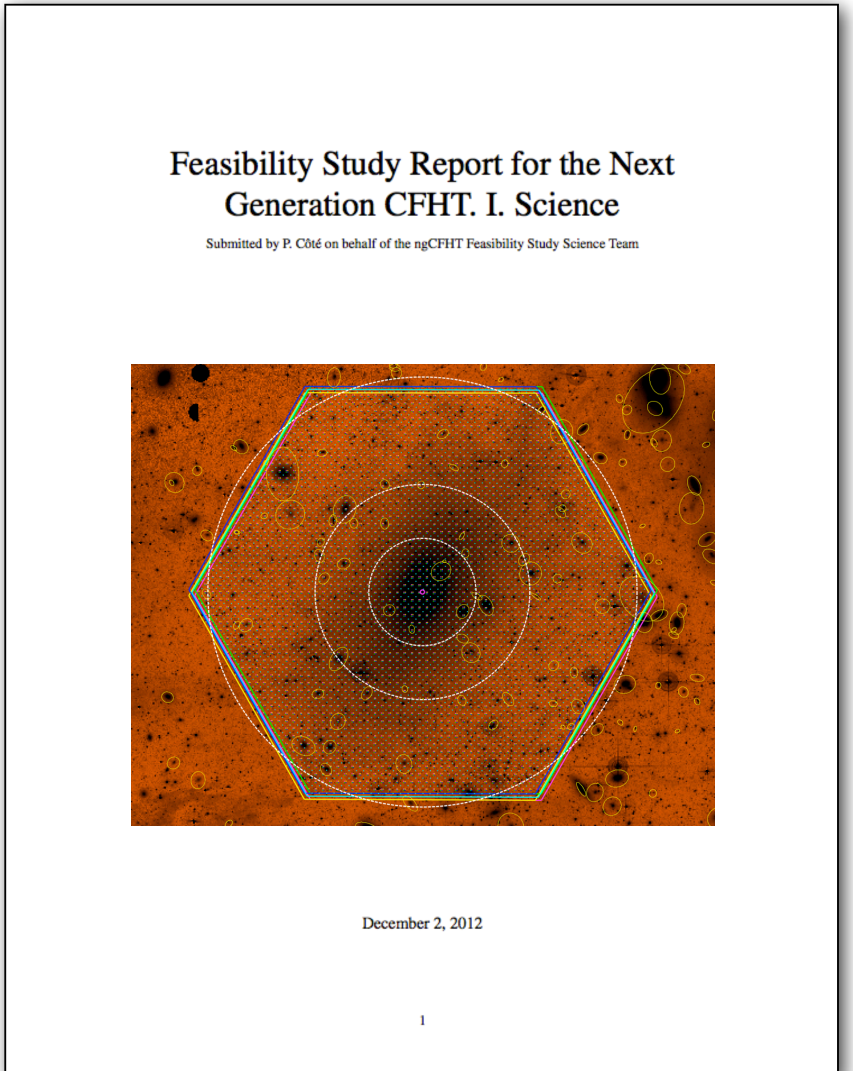
Create a new and expanded partnership to

1. replace the 3.6m telescope with a ~10m telescope, mounted on the existing pier and within the volume of the current dome.
2. install a dedicated wide-field (1.5 deg^2) multi-object spectrograph that can simultaneously collect spectra for more than ~3000 sources.
3. do this by the early 2020s and immediately begin spectroscopic surveys.

- significant enthusiasm, but recognition that additional study was required.
- the project is beyond the scope of the current partners alone.
- a **two-year feasibility study** begun in January 2011.
- three components:



Primary Outcomes and "Final" Specifications



Feasibility Study Report for the Next Generation CFHT. I. Science

Submitted by P. Côté on behalf of the ngCFHT Feasibility Study Science Team

December 2, 2012

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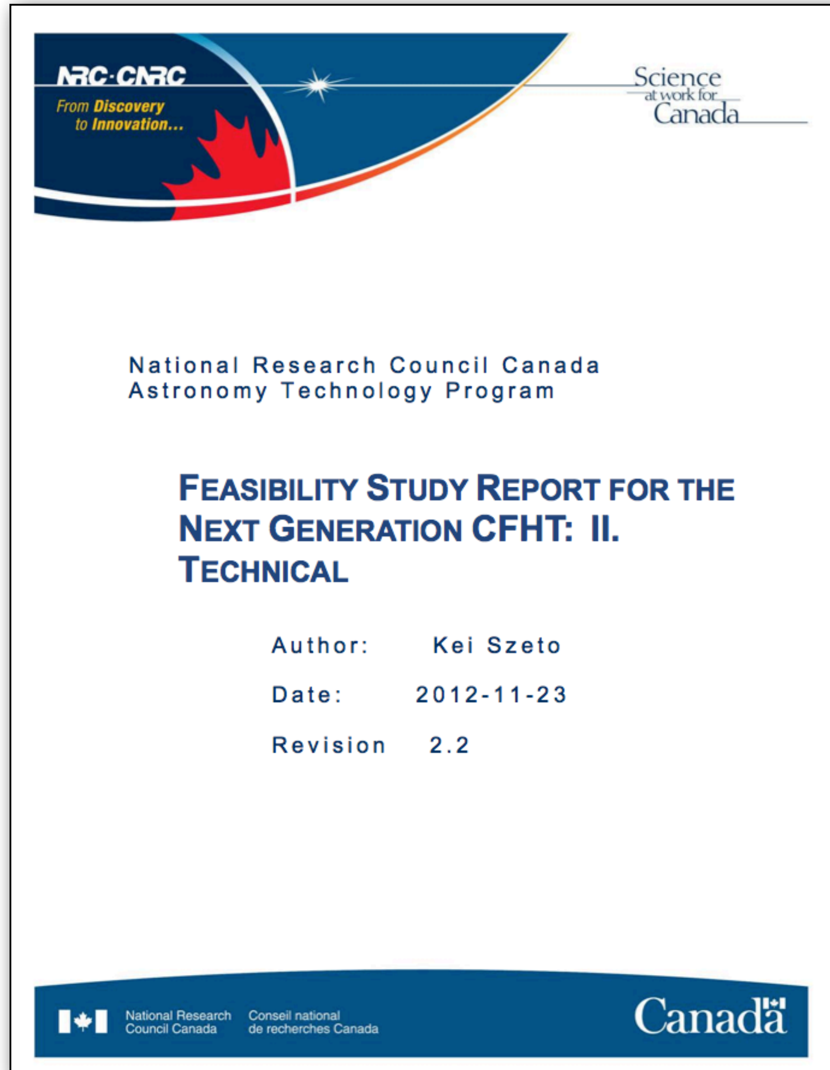


National Research Council Canada
Astronomy Technology Program

FEASIBILITY STUDY REPORT FOR THE NEXT GENERATION CFHT: II. TECHNICAL

Author: Kei Szeto

Date: 2012-11-23

Revision 2.2

National Research Council Canada Conseil national de recherches Canada

- final reports available at www.ngcfht.org

Primary Outcomes and “Final” Specifications

- **No existing, planned or proposed facility would rival ngCFHT in its capacity for wide-field spectroscopic mapping of the faint universe.**
- **ngCFHT would fill what is perhaps the most important “missing capability” in the portfolio of international astronomy projects.**
- Redevelopment could utilize the existing pier and building with only minor modifications.
- The conversion would not increase the visual footprint of CFHT on Mauna Kea.
- **No technical “show stoppers”** with the telescope, enclosure, spectrograph, fibre-feed system, or operations model.
- Reliable estimates for cost and schedule are now in hand.

Parameter	Specification
Telescope Diameter (M1)	10m (segmented, equivalent)
M1 Segments	1.45m (hexagonal, corner-to-corner)
Overall f-ratio	f/2.1
Inst. Field of View	1.5 deg^2 (hexagonal)
Tele. Image Quality	EE80 diameter < 0.45” (FWHM ~ 0.3”)
Total Throughput	> 25% over 90% of the λ range
Plate Scale	102 arcsec/mm
Observing Modes	low resolution (LR) medium resolution, high multiplexing (MR-HM) medium resolution, full coverage (MR-FC) high resolution (HR)
Wavelength Range	370 – 1300 nm (LR) 370 – 1000 nm (MR-HM) 370 – 1000 nm (MR-FC) 370 – 1000 nm (HR)
Multiplexing	N = 3200, full coverage from 370-1300 nm (LR) N = 800, full coverage from 370-1000 nm (MR-FC) N = 3200, two (λ/7) windows in visible (MR-HM) N = 800, two (λ/7) windows in visible (HR)
Resolving Power	2000 (low resolution) 6500 (medium resolution) 20000 (high resolution)
Available Zenith Angles	0° - 60°

Strategic Motivation

- We are on the cusp of a transformation in astronomy, with a large number of revolutionary imaging and astrometric facilities about to begin operations.
- Spectroscopic follow up has emerged as perhaps the single most important "missing capability" in the portfolio of international astronomical facilities.

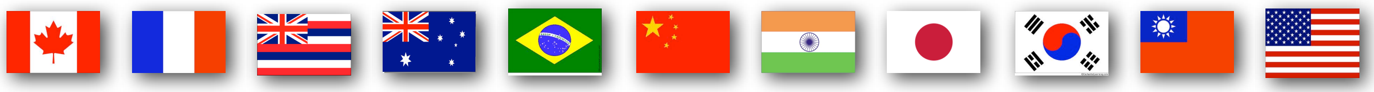
Instrument	Telescope	D_{M1} (m)	Status	λ	Available	FOV (deg^2)	AΩ (m^2 deg^2)	Ω_{tot} (10^3 deg^2)
Pan-STARRS-1		1.8	Operational	Optical	2009	7.3	18.6	30.9
VIRCAM	VISTA	4.1	Operational	IR	2010	0.6	7.5	20.0
OmegaCam	VST	2.6	Operational	Optical	2011	1.0	5.3	4.5
DEC	Blanco	4.0	Operational	Optical	2012	3	38	5
Hyper-SC	Subaru	8.2	Operational	Optical	2012	1.7	90	2.0
Skymapper		1.35	Pending	Optical	2014	5.7	8.2	20.6
ODI	WIYN	3.5	Pending	Optical	2014	1	9.6	...
Pan-STARRS-2		2x1.8	Pending	Optical	2014	7.3	37	30.9
GAIA		2x(1.4x0.5)	Pending	Optical	2013-2022	All Sky		41.2
LSST		8.4	Pending	Optical	2021	6.7	370	24.2
Euclid		1.2	Pending	IR/Optical	2021	0.5	0.6	15-20
WFIRST		1.5	Proposed	IR/Optical	2025?	0.5	0.9	23.2

≈ $4.5 B investment

- ngCFHT would be the only dedicated, 10m-class, wide-field MOS telescope capable of capitalizing fully on these facilities and surveys.

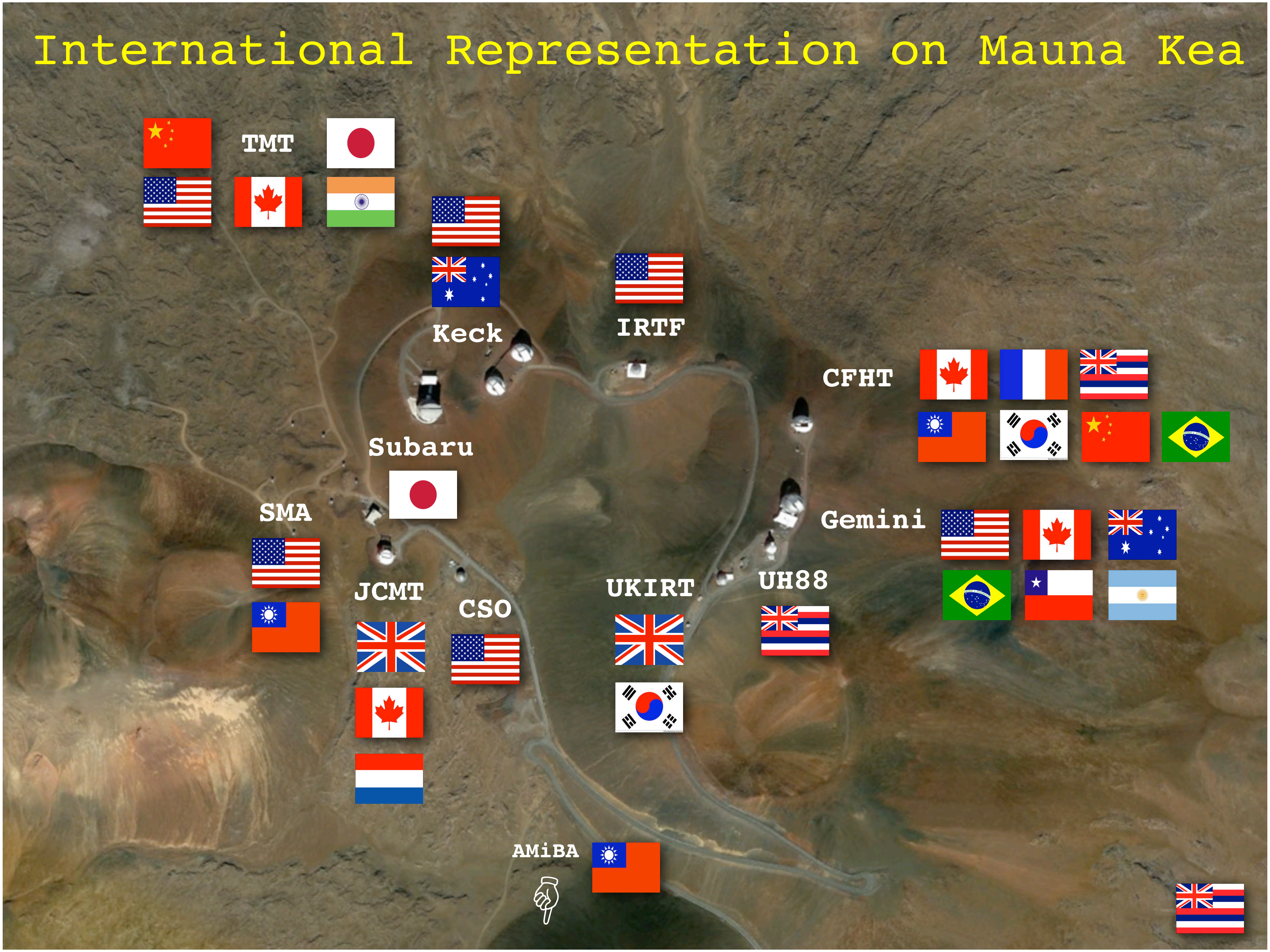
Feasibility Study. I. Partnership

- Science working groups (SWGs) formed to examine the concept in ten scientific subfields.
- The science studies involved ~60 scientists from Canada, France and Hawaii, as well as Australia, Brazil, China, India, Japan, South Korea, Taiwan, and the USA.



1. **Exoplanets**
   - Magali Deleuil (Lab. d'Astrophysique de Marseille, France)
   - Francois Bouchy (IAP, France)
   - Ernst de Mooij (Toronto, Canada)
   - Norio Narita (NAOJ, Japan)
2. **The Interstellar Medium**
   - Rosine Lallement (GEPI/Observatoire de Paris, France)
   - Patrick Boissé (Institut d'Astrophysique de Paris, France)
   - Ryan Ransom (Okanagan College, DRA, Canada)
3. **Stars and Stellar Astrophysics**
   - Kim Venn (University of Victoria, Canada)
   - Katia Cuhna (NOAO, USA)
   - Patrick Dufour (Montreal, Canada)
   - Zhanwen Han (Yunnan Observatory, China)
   - Chiaki Kobayashi (ANU, Australia)
   - Rolf-Peter Kudritzki (IfA, Hawaii, USA)
   - Else Starkenburg (Victoria, Canada)
4. **Milky Way Structure and Stellar Populations**
   - Piercarlo Bonifacio (GEPI, France)
   - Nobou Arimoto(NOAJ, Japan)
   - Ken Freeman (ANU, Australia)
   - Bacham Eswar Reddy (IIA, India)
   - Sivarani Thirupathi (IIA, India)
5. **The Local Group**
   - Alan McConnachie (HIA, Canada)
   - Andrew Cole (Tasmania, Australia)
   - Rodrigo Ibata (Strasbourg, France)
   - Pascale Jablonka (Observatoire de Paris, France)
   - Yang-Shyang Li (KIAA, China)
   - Nicolas Martin (Strasbourg, France)
6. **Nearby Galaxies and Clusters**
   - Michael Hudson (University of Waterloo, Canada)
   - Richard de Grijs (KIAA, China)
   - Simon Driver (ICRAR, Australia)

6. **Nearby Galaxies and Clusters (cont'd)**
   - Eric Peng (Peking University, China)
   - Yen-Ting Lin (IPMU, Japan)
7. **Galaxy Evolution**
   - Michael Balogh (University of Waterloo, Canada)
   - Sebastien Foucaud (NTNU, Taiwan)
   - Damien Le Borgne (IAP, France)
   - Karl Glazebrook (Swinburne, Australia)
   - Lihwai Lin (ASIAA, Taiwan)
   - Changbom Park (KIAS , South Korea)
   - Swara Ravindranath (IUCAA, India)
   - Marcin Sawicki (St. Mary's, Canada)
   - Luc Simard (HIA, Canada)
8. **The Intergalactic Medium**
   - Céline Péroux (Lab. d'Astrophysique de Marseille, France)
   - James Bolton (Melbourne, Australia)
   - Sara Ellison (Victoria, Canada)
   - Raghunanathan Srianand (IUCAA, India)
9. **QSOs and AGNs**
   - Pat Hall (York University, Canada)
   - Len Cowie (IfA, Hawaii)
   - Scott Croom (Sydney, Australia)
   - John Hutchings (HIA, Canada)
   - Patrick Petitjean (AIP, France)
   - Thaisa Storchi-Bergmann (UFRGS, Brazil)
   - Ting-Gui Wang (USTC, China)
   - Chris Willott (HIA, Canada)
   - Jong-Hak Woo (Seoul, South Korea)
   - Xue-Bing Wu (Peking University, China)
10. **Cosmology and Dark Energy**
    - Jean-Paul Kneib (Lab. d'Astrophysique de Marseilles, France)
    - Carlo Schimd (LAM, France)
    - Charling Tao (CPPM, France and Tsinghua, China)
    - Martin Makler (Rio de Janeiro, Brasil)
    - Keiichi Umetsu (ASIAA, Taiwan)


International Representation on Mauna Kea
TMT
Keck
IRTF
CFHT
Subaru
SMA
Gemini
JCMT
CSO
UKIRT
UH88
AMiBA

Feasibility Study. II. Science

- A multi-stage process used to develop the science cases and settle on the facility's technical specifications:
  - Nov. 2010. Initial concept is presented at CFHT Users' Meeting, in Taipei.
  - Jan. 2011. Begin with a "baseline" design for the facility and its surveys (Ellis et al. 2009, Côté et al. 2010).
  - Nov. 2011. Interim SWG reports are submitted, which are used to refine technical parameters and survey designs.
  - Mar. 2012. Revised technical specifications are provided to SWGs.
  - Aug. 2012. Final SWG reports are submitted, based on updated facility specs.
  - Nov. 2012. Final science and technical reports are submitted to SAC and Board.
  - Mar. 2013. Next Generation CFHT Workshop, in Hilo, Hawaii.

- Two major science 'themes' emerged:
  1. **Galactic Archaeology** (see posters, appendices)
  2. **Cosmology and Galaxy Evolution** (see posters, appendices)

- But transformational science would be enabled across a wide range of fields. This breadth was reaffirmed during the ngCFHT Workshop in Hilo (March 27-29, 2013).
  - exoplanet host characterization, pulsating/variable stars, time-domain spectroscopy, SN follow-up, ISM 3D structure, high-velocity clouds, solar "twins", fundamental stellar parameters, stellar multiplicity, Lyman-α systems, AGN reverberation mapping, photo-z calibration and dark energy, structure growth, non-standard gravity, redshift-space distortions, cluster growth, etc.

Next Generation CFHT Workshop

- **"The Next Generation CFHT: A 10m, Wide-Field, Spectroscopic Telescope for the Coming Decade"**

  "This workshop is intended as a forum for discussion of the science cases and technical plans that have emerged from the feasibility study. It will last for 2.5 days, with summary talks discussing the science drivers and current technical status. Contributed talks are encouraged to highlight synergies with current and future facilities, and to propose opportunities for subsequent development. A large amount of time will be reserved for discussion. This will be a key opportunity to define a strategic road map for the scientific and technical development of the project, and to establish a foundation for the growth of the new partnership that will deliver this unique scientific facility to the international community."

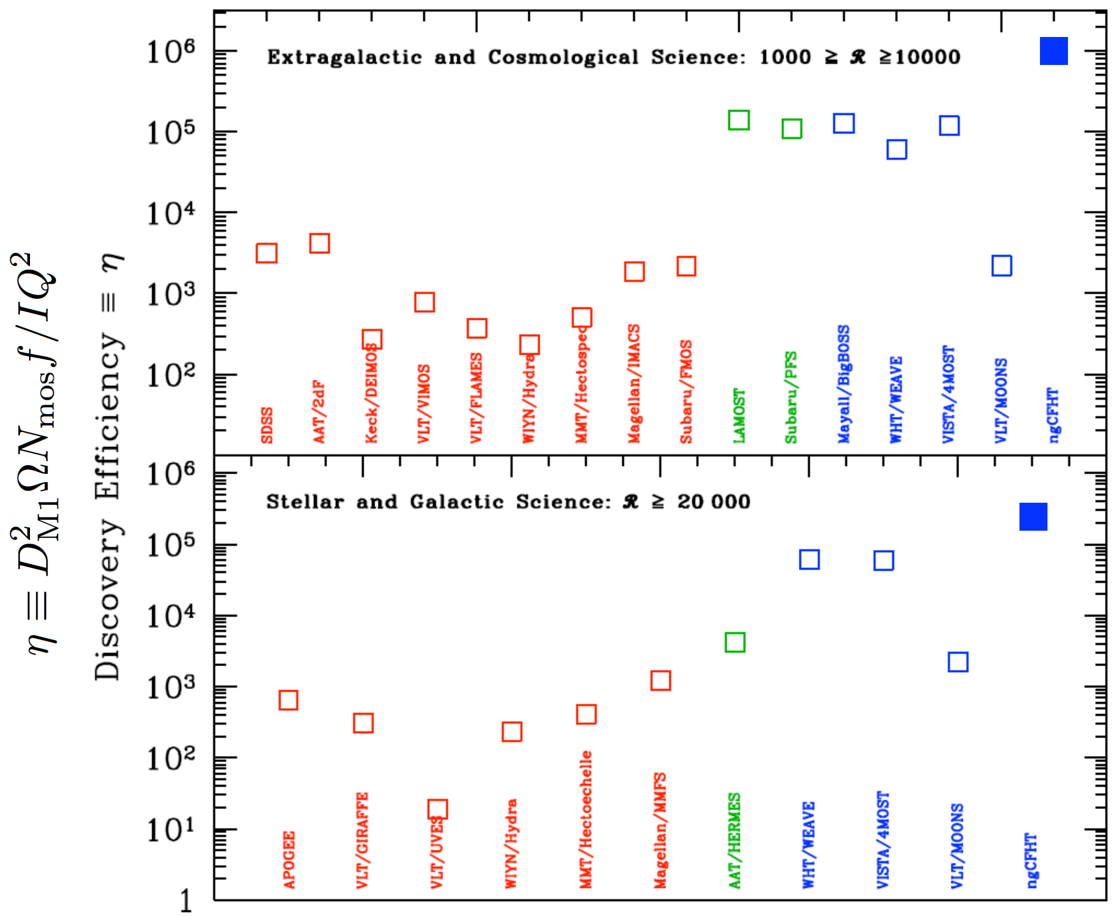
- Location = 'Imiloa Astronomy Center of Hawaii, Hilo
- Dates = 27-29 March, 2013
- Co-Chairs = P.Côté, A. McConnachie

- Scientific Organizing Committee
  - N. Arimoto (Japan)
  - M. Balogh (Canada)
  - P. Bonifacio (France)
  - B. Castilho (Brazil)
  - L. Cowie (Hawaii)
  - K. Freeman (Australia)
  - E. Peng (China)
  - S. Ravindranath (India)
  - S.-Y. Wang (Taiwan)
  - J.-H. Woo (South Korea).


Next Generation CFHT Workshop
March 27-29, 2013
'Imiloa Centre, Hilo, Hawaii

Feasibility Study. II. Science

- ngCFHT's performance advantage is due to several factors:
  1. a 10m aperture and a high-throughput design (D_{M1}).
  2. a wide-field with massive spectral multiplexing (Ω, N_{MOS}).
  3. an excellent site - as important for spectroscopy as it is for imaging (IQ).
  4. an operations model that is dedicated to surveys (f).
  5. a wide range of available spectral resolutions (R ~ 2000, 6500, 20000).



operational
in development
proposed

Feasibility Study. III. Technical

Technical Components of the Feasibility Study

1. Load capacity studies of telescope and enclosure piers.
2. Telescope and enclosure configuration studies.
3. Aero-thermal study.
4. Telescope optical designs.
5. Spectrograph conceptual designs.
   - PFS + a second spectrograph for the medium and high resolution modes.
   - a triple-resolution spectrograph using pupil slicing technologies (with 4 channels and 3 arms per channel).
6. Telescope downtime study (deconstruction and construction).
7. Valuation study of existing infrastructure.
8. Cost, schedule and development plan.

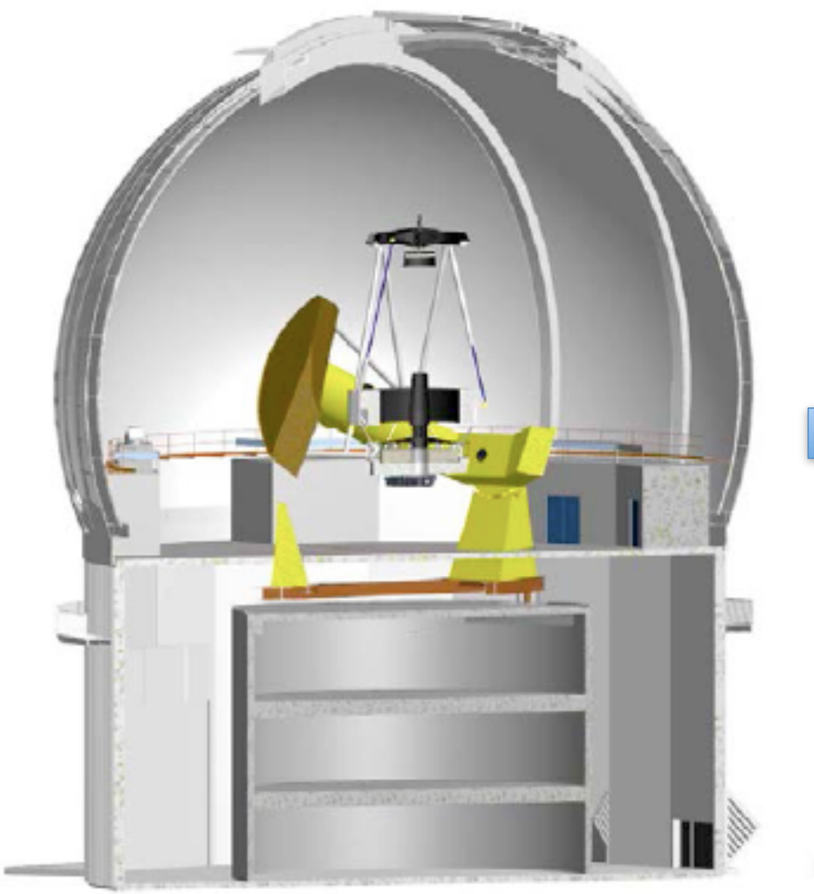
The Next Generation of the Canada-France-Hawaii Telescope: A 10m, Wide-Field Multi-Object Spectroscopic Facility

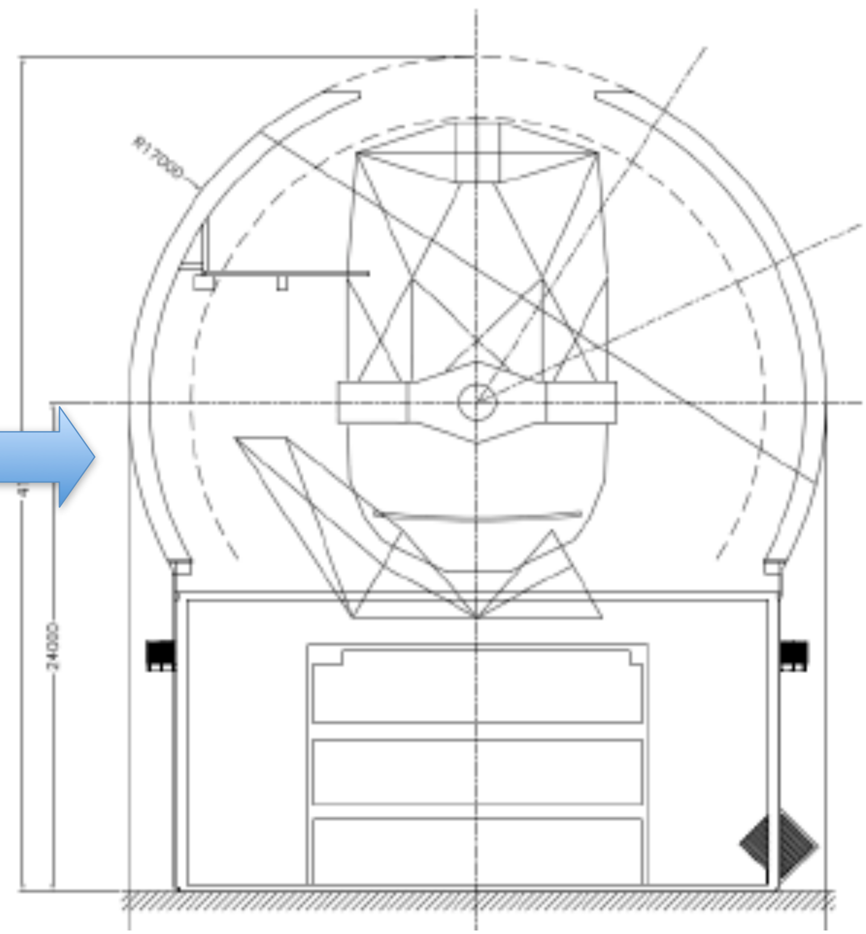
David Crampton (NRC Herzberg)

Constraints from Science

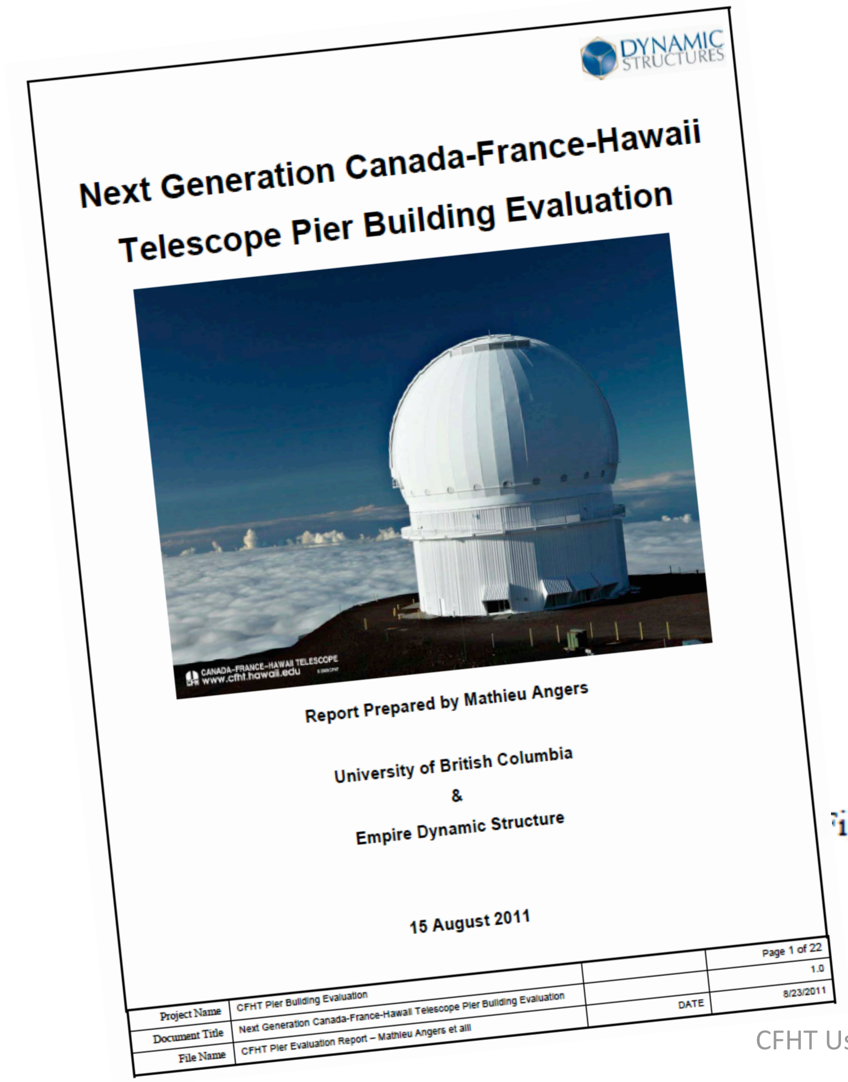
- Faint sources => need 10m collecting area (many exposures will still be > 4h)
- Wide field, many targets, with moderate to high spectral resolution => fibres
- Fibre input efficiency => f/ratio > f/2.3
- 10m f/2.3 => 1” = 110mu
- Wide field constrained by diameter of refractive optics (< 1.5m) => 1.5 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

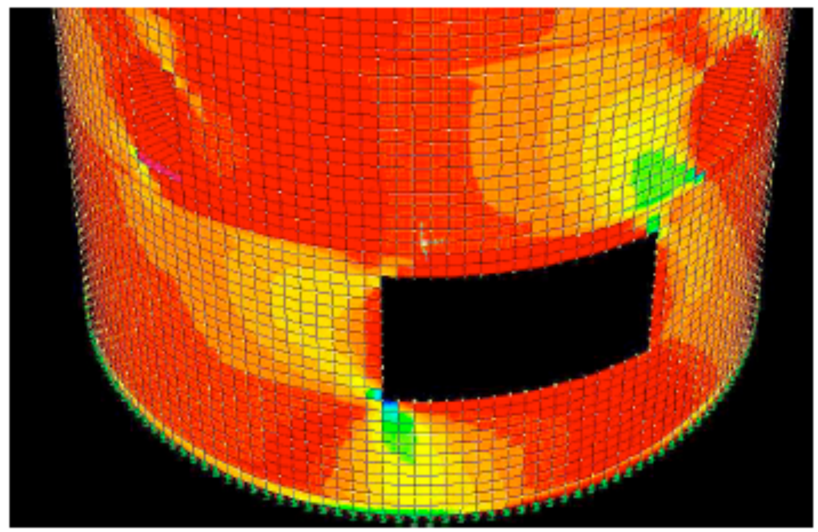
Next Generation Canada-France-Hawaii Telescope Pier Building Evaluation

Report Prepared by Mathieu Angers

University of British Columbia
&
Empire Dynamic Structure

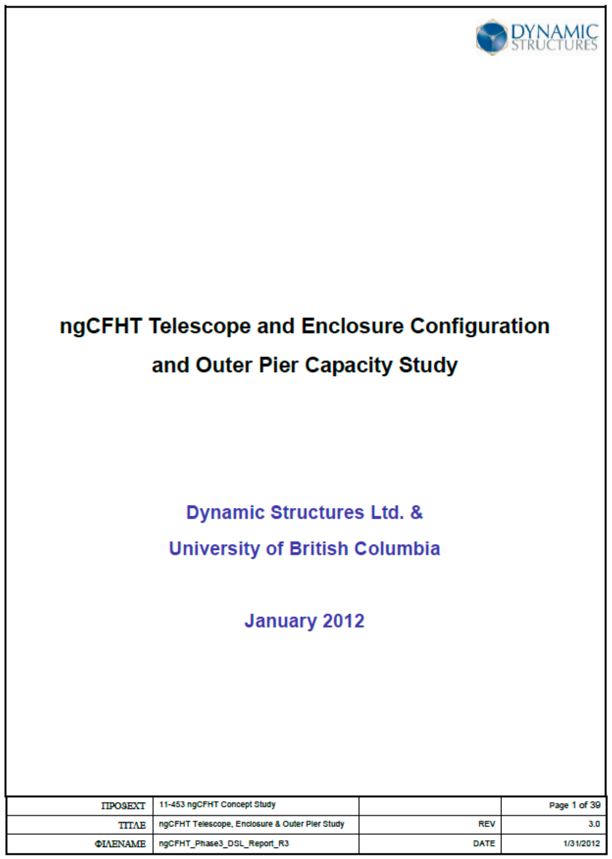
15 August 2011

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



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

Detailed studies provide excellent cost and schedule estimates



DYNAMIC STRUCTURES

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

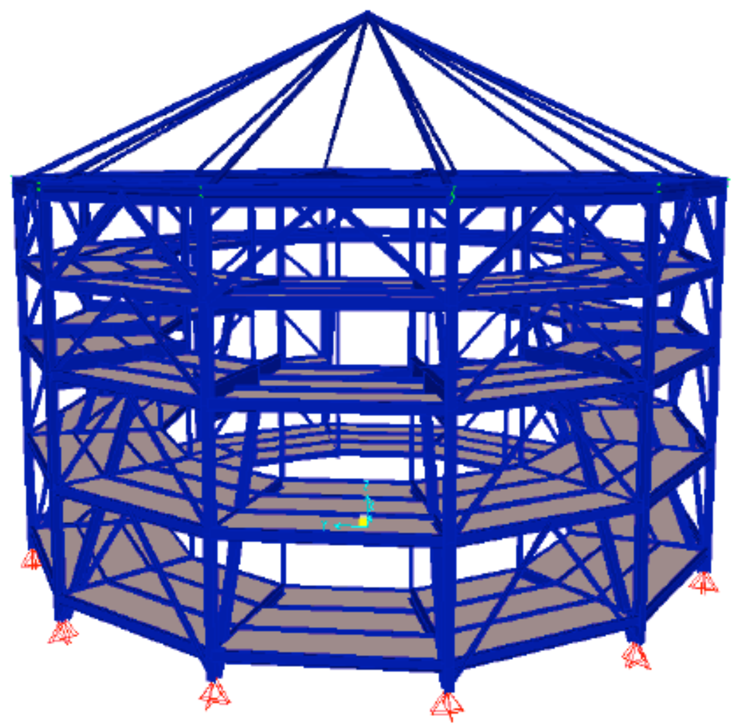


Figure 19: SAP2000 isometric 3-D view of outer pier steel frame and slabs

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

Study
of Telescope Structure and Enclosure
2.doc

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

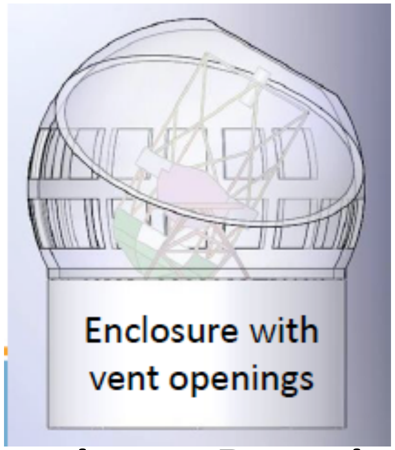
Table 5: ngCFHT enclosure & telescope construction estimate

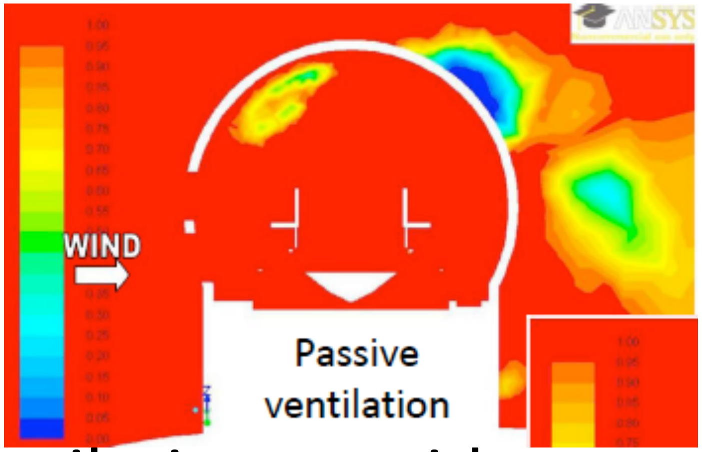
Enclosure Labour		
	Supervision & crane operators	$1,416,987
	Live-out & travel	$685,994
	Enclosure labour	$4,855,082
	Shipping	$979,697
	Insurance	$1,449,846
	Total Enclosure	**$9,387,605**
Telescope Labour		
	Supervision & crane operators	$1,307,988
	Live-out & travel	$534,064
	Enclosure labour	$2,392,314
	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

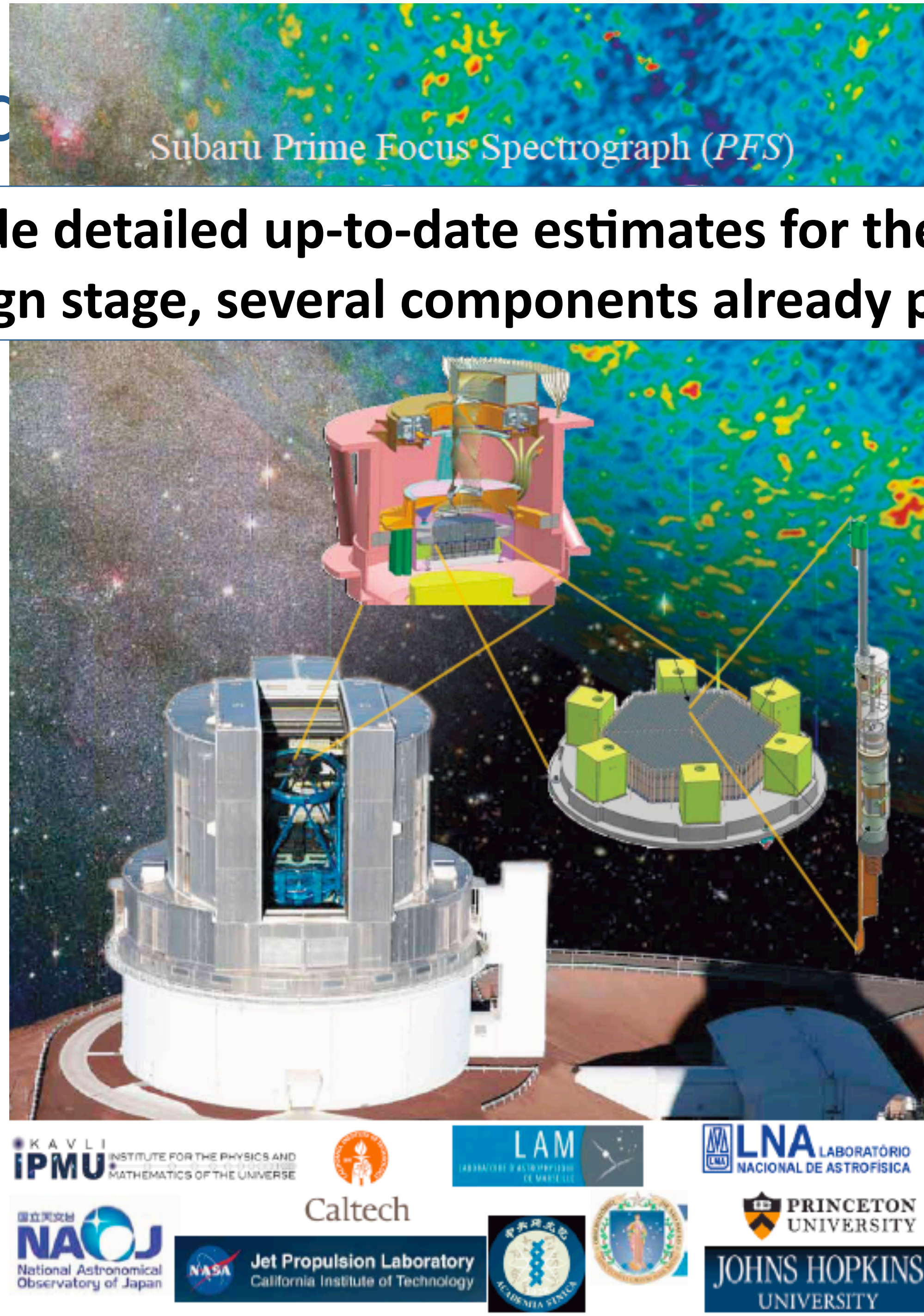




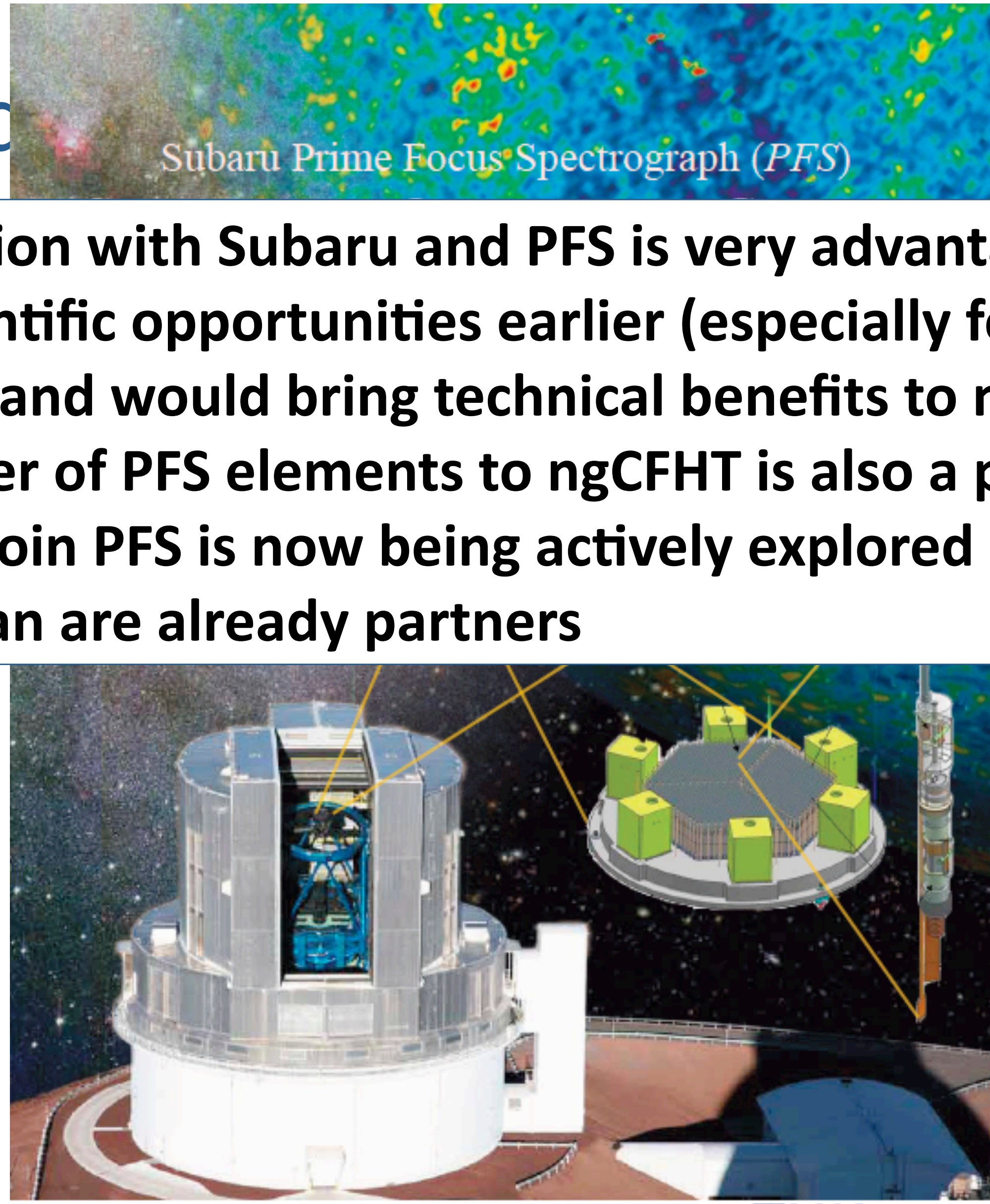
- Conclusion: Passive ventilation provides superior dome-flushing while maintaining uniform temperature and low turbulence
- Vents included in cost estimate

Detailed … nt cost

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



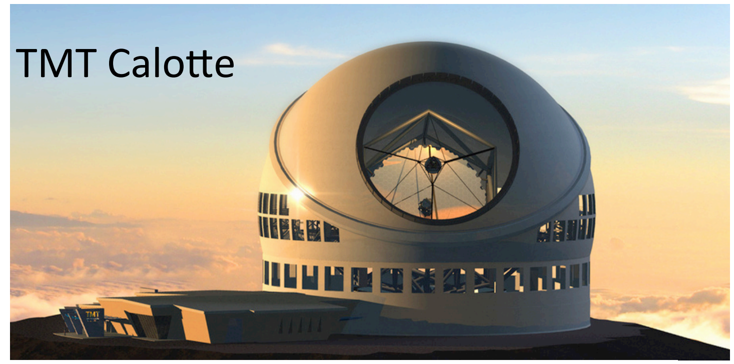
Detailed … nt cost



- **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**

Step 1a: Design and fabricate "dome" Estimate: $12M, 2.5 yr

- 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)



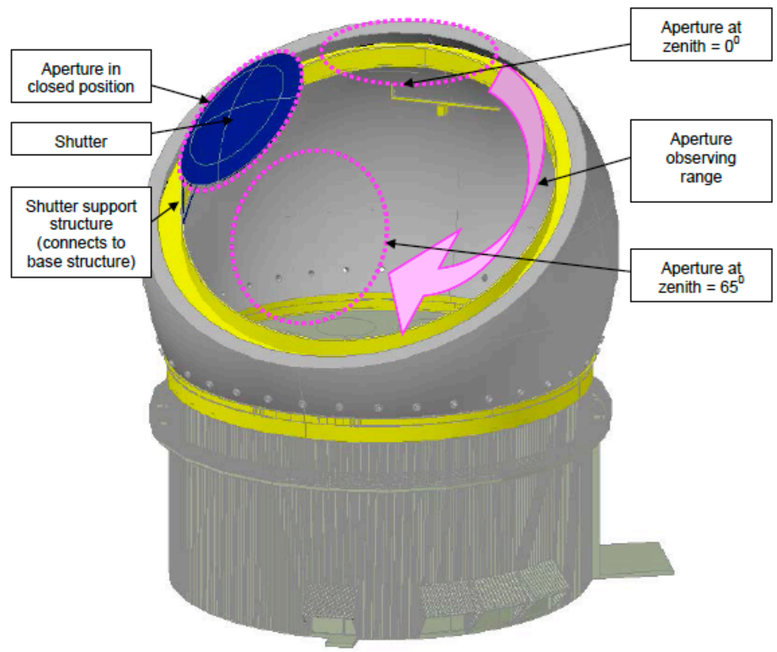
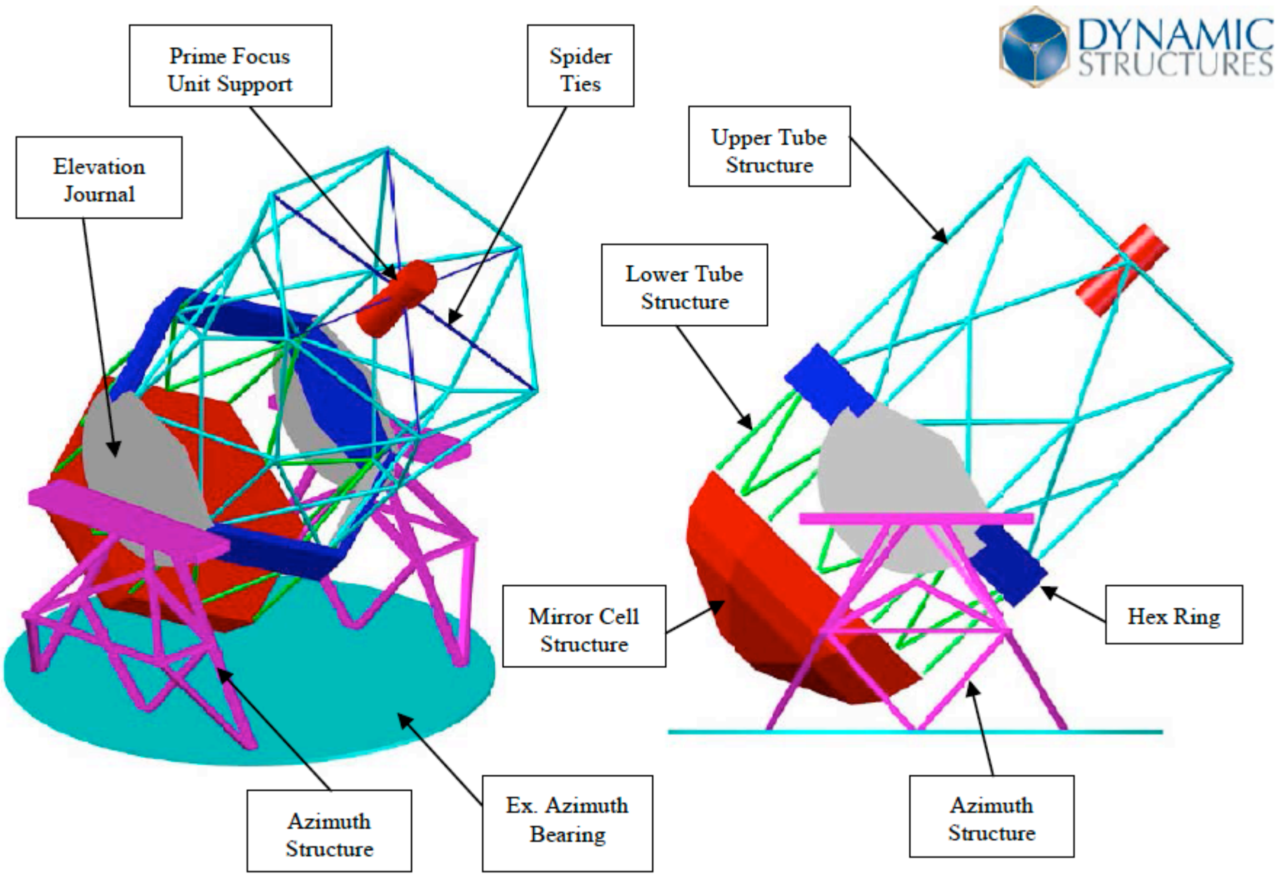


Figure 6: Shutter concept (cap is removed to show shutter, aperture indicated by dotted lines)

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

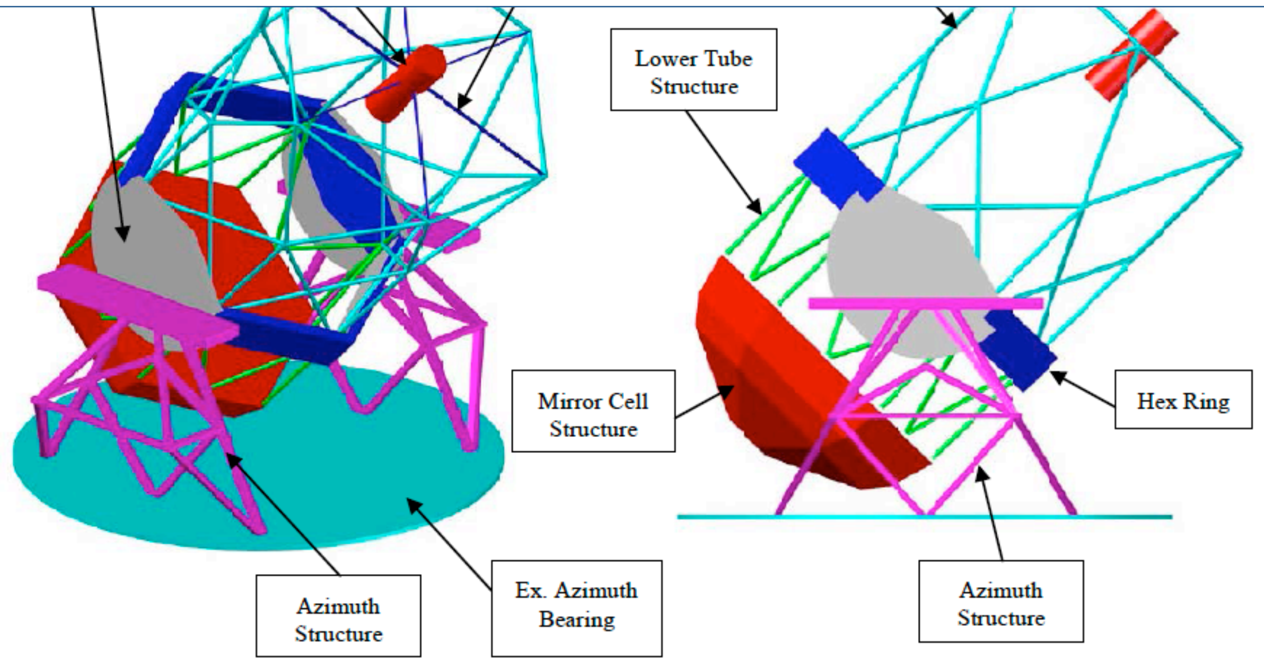
- Design builds on Keck 10m telescope



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

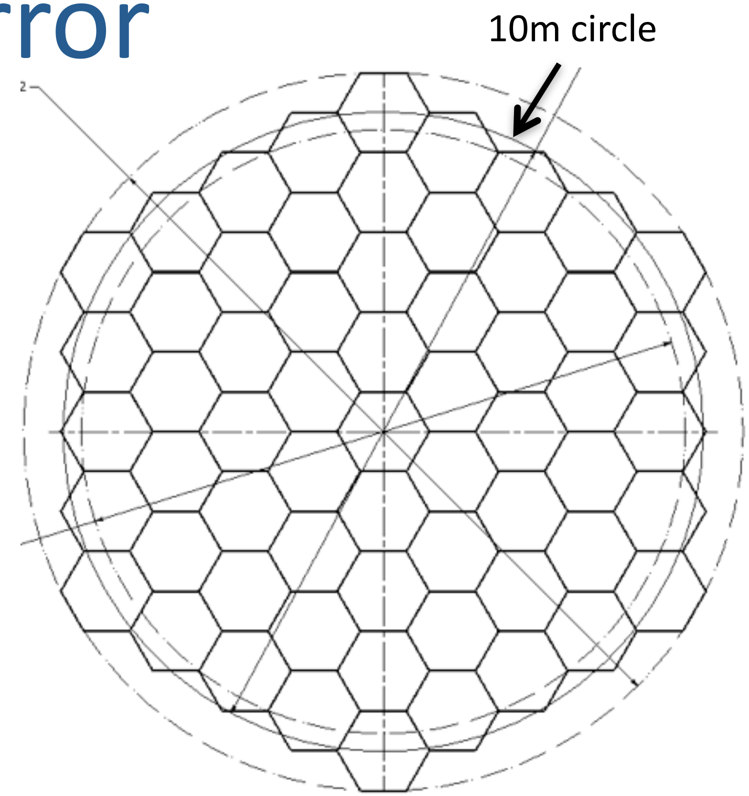
Investigated alternate 2 and 3 mirror designs during feasibility study

Straightforward "Keck design" + wide field corrector is most efficient and cost-effective

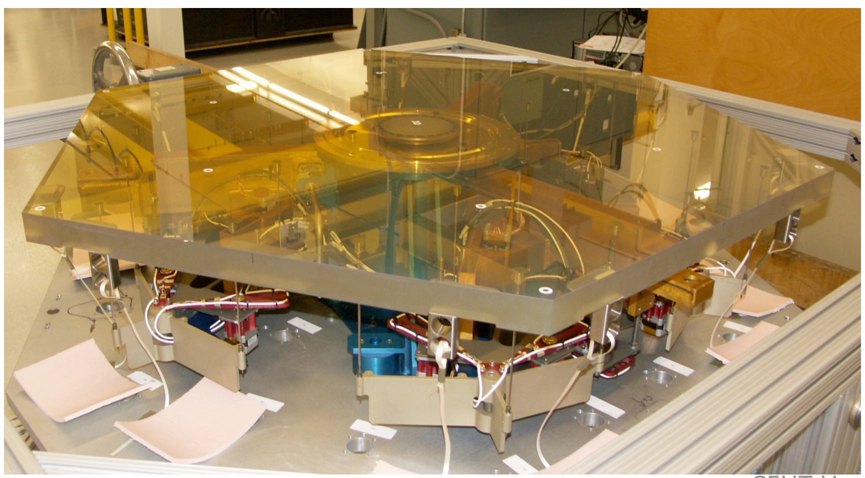


Primary Mirror

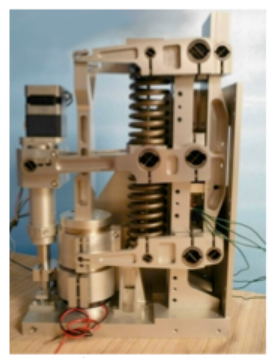
- Segment size currently preferred (by manufacturers): 1.44m
  - ~500 for TMT, ~1000 for E-ELT
- Compared to Keck: (36, 1.8m segments)
  - Segments are cheaper ("industrialized")
  - New edge sensor technology
  - New actuators
  - Improved wavefront control

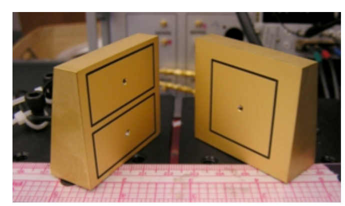


10m with 60 segments, 1.44m



TMT segment prototype (E-ELT similar)





Actuators and edge sensors

Primary Mirror

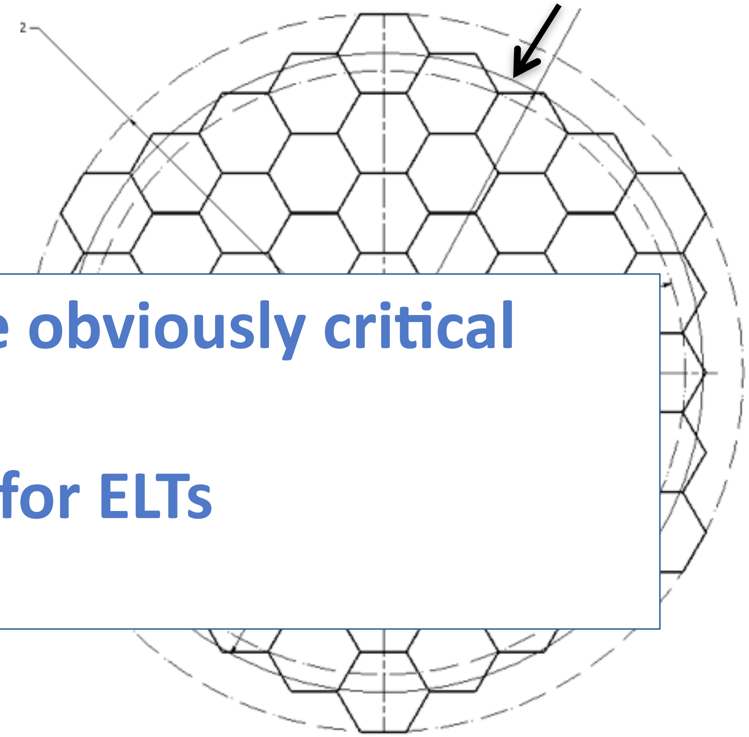
- Segment size currently preferred (by manufacturers): 1.44m
  - ~500 for TMT, ~1000 for E-ELT

M1 mirror optics, cell and control are obviously critical components for overall performance

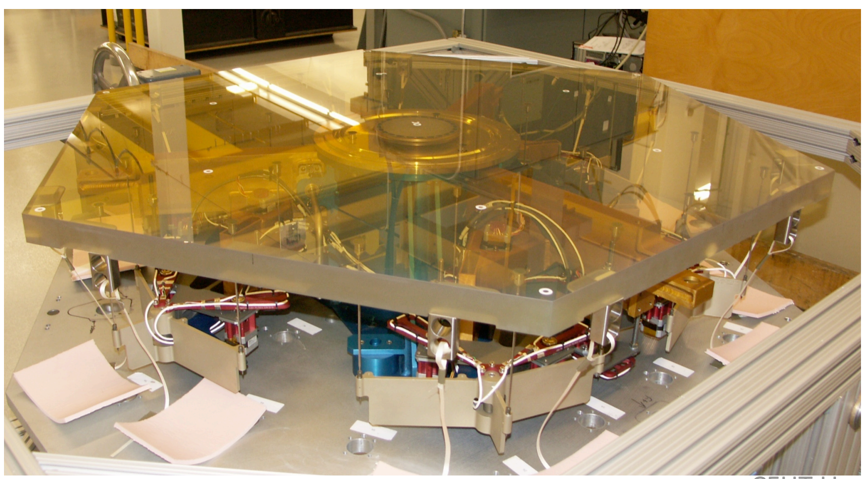
Many vendors developing capability for ELTs

Cost: $19.5M

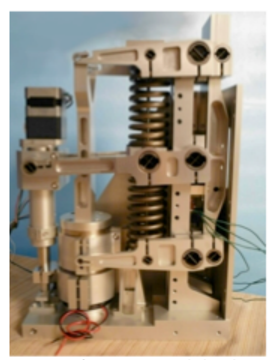
10m circle

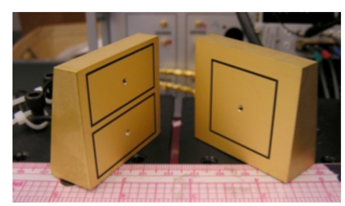


10m with 60 segments, 1.44m



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

- Wide Field Corrector
- Fibre Positioner
- Fibre transport system
- Spectrograph
- Acquisition, guiding, metrology

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

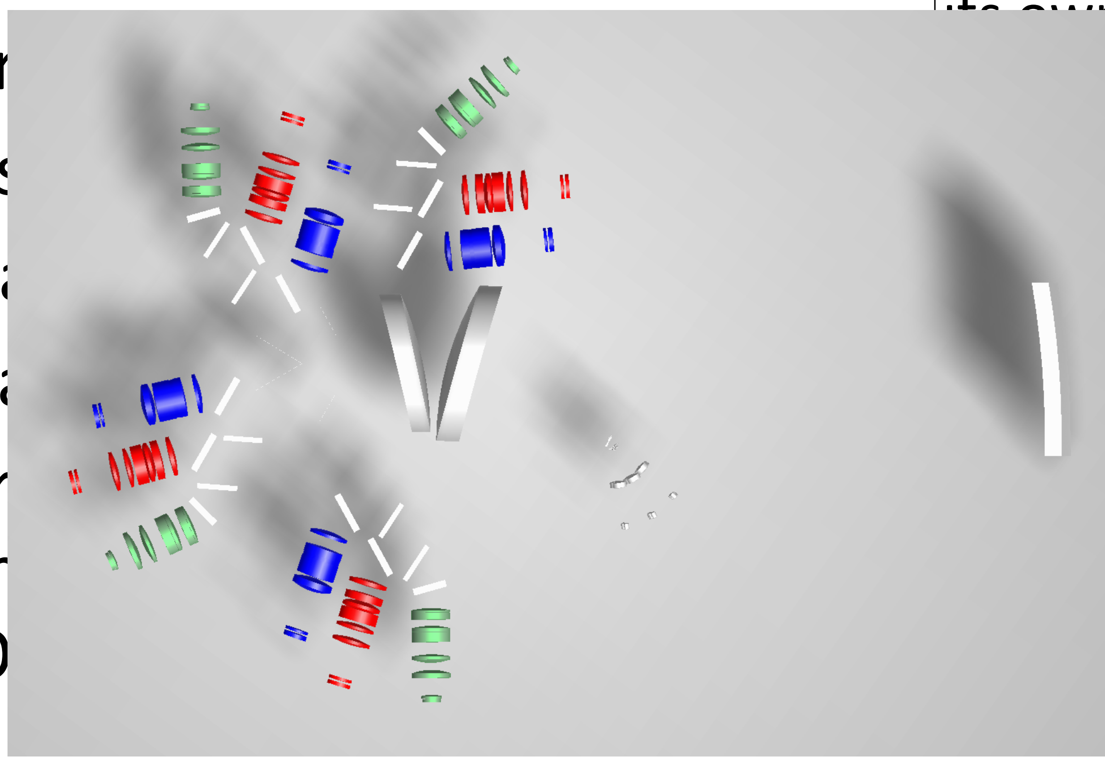
LAMOST, HERMES, BOSS, etc.

"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

- Spectr
- Acquis
- Calibr
- Softw
- Matur design LAMO



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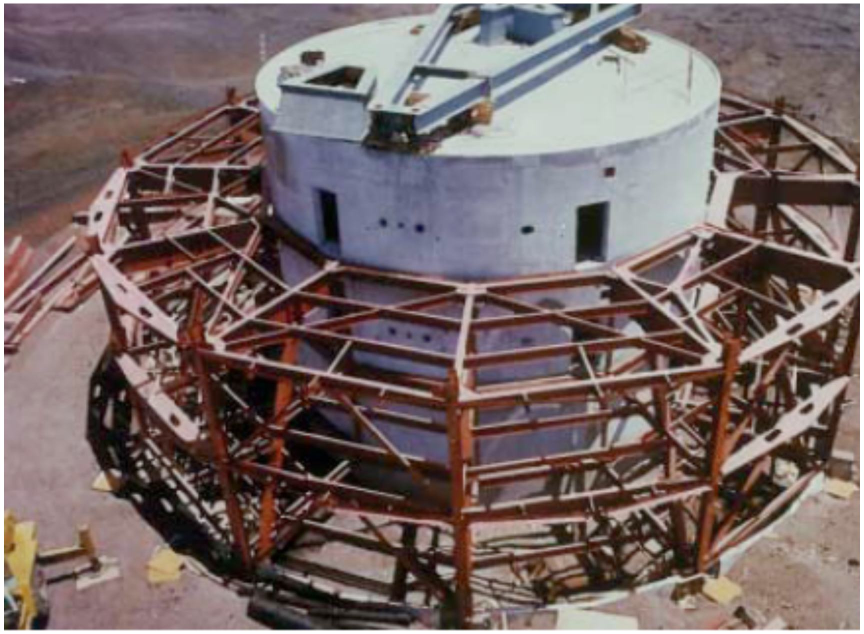
On-site deconstruction and renovation
Estimate: $9.3M, ½ yr (2017)



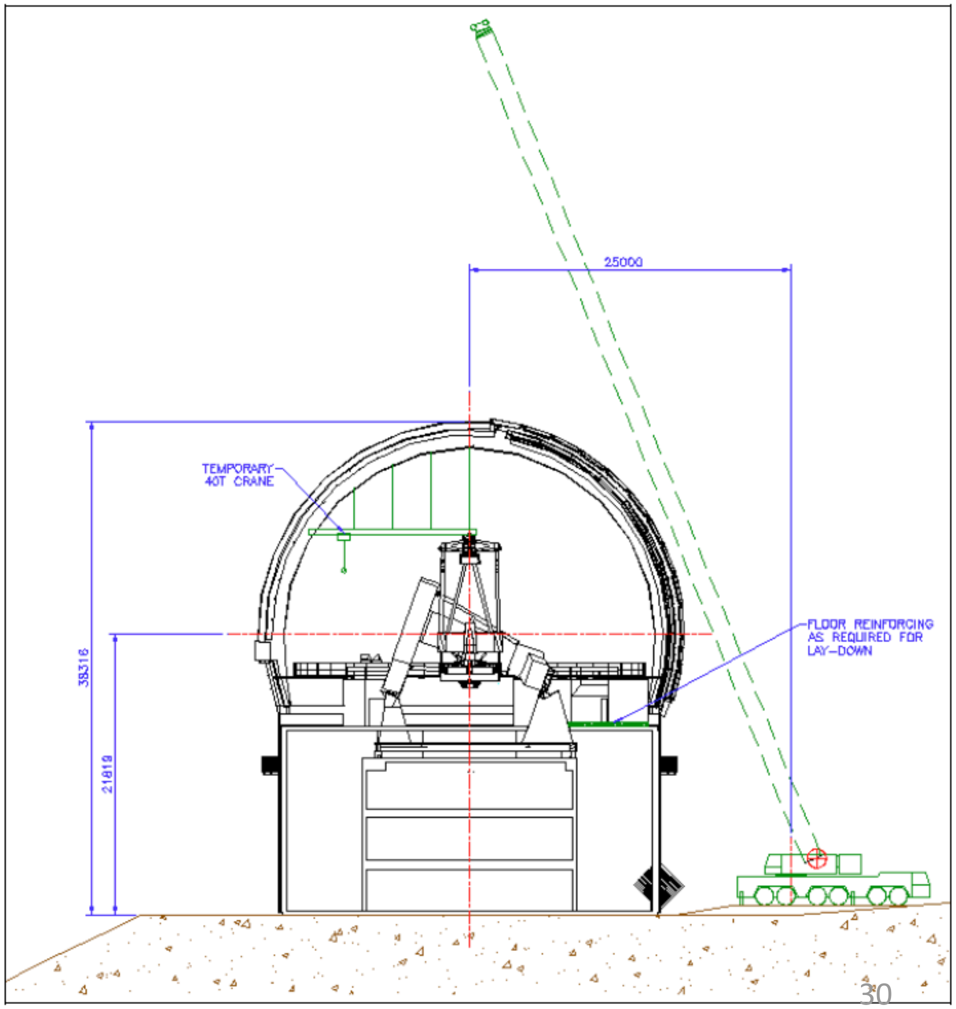
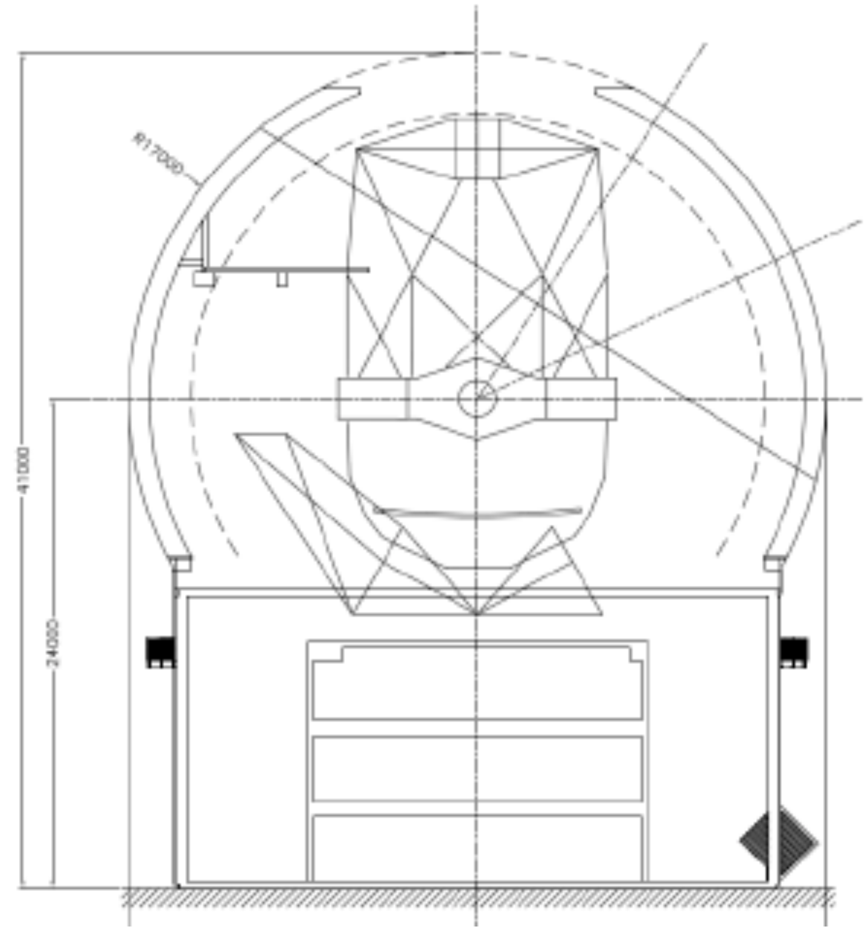


Figure 3: West elevation of site set-up for deconstruction

Install Dome & Telescope Estimate: $32.2M, 2 yrs

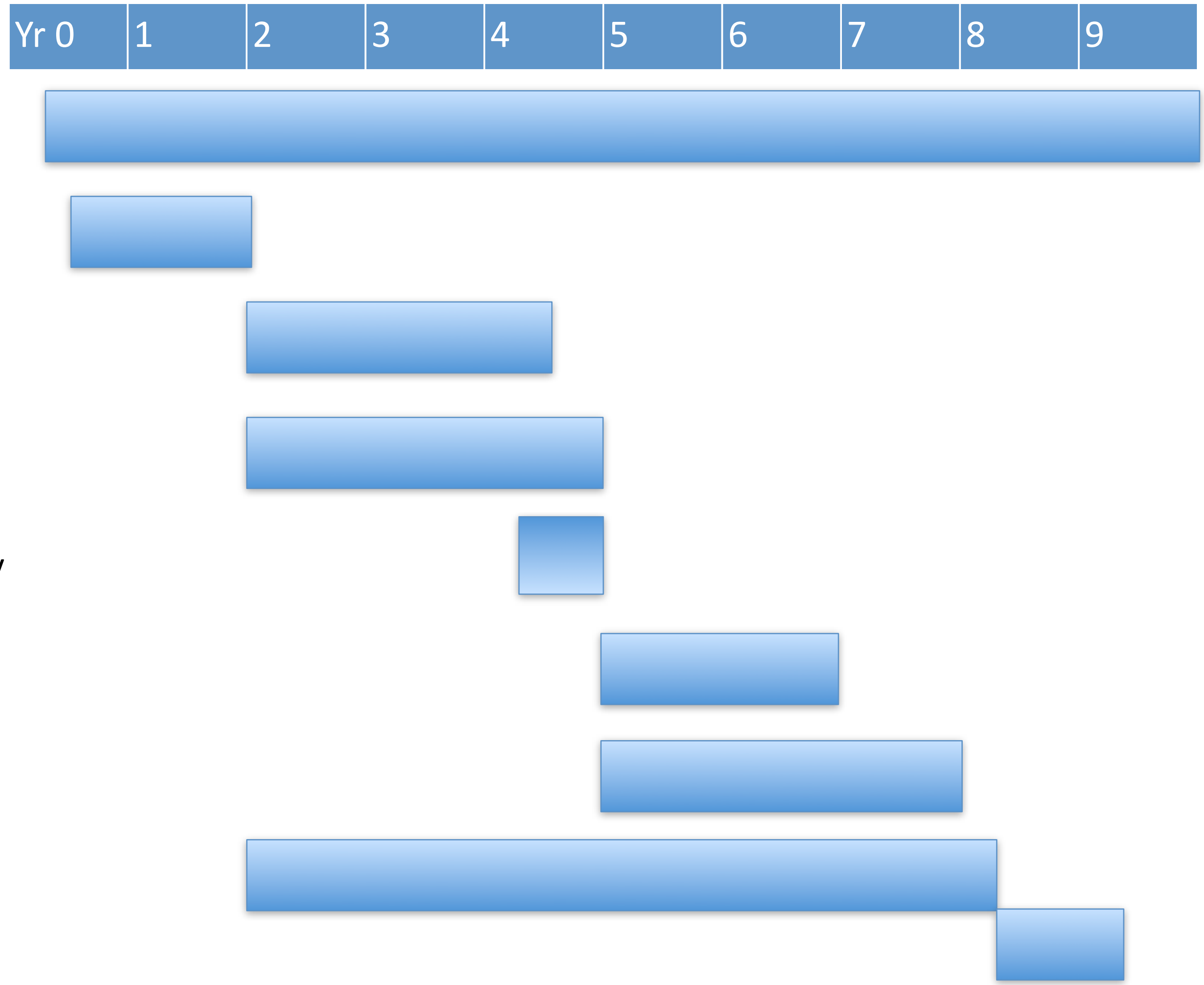
- (Telescope $7.5M, Enclosure $9.4M, Equipment $6.4M + contingency and markup)
- Ideally managed by one firm
  - Major sub-contracts to telescope and dome fabricators
- Fully functioning telescope structure by completion but without optics or instrument



Install optics & commission Estimate: 2 yr

- 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



Environmental approval, education and outreach

Establish project office & partnership

Enclosure design and fabrication

Telescope design and fabrication

3.6m removal and facility upgrade

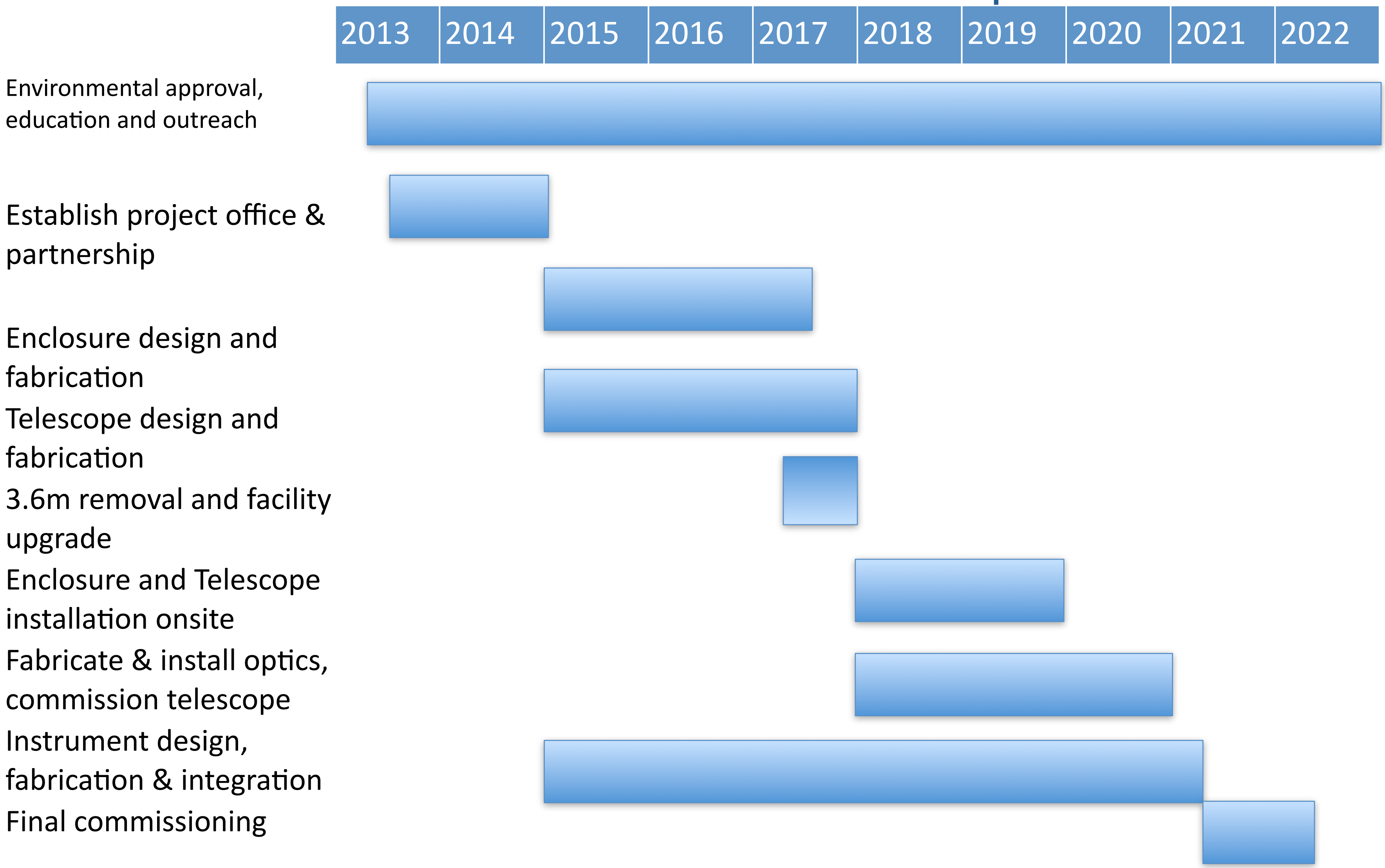
Enclosure and Telescope installation onsite

Fabricate & install optics, commission telescope

Instrument design, fabrication & integration

Final commissioning

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



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

2013	2014	2015	2016	2017	2018	2019	2020		2

Environmental approval, education and outreach

Establish proje

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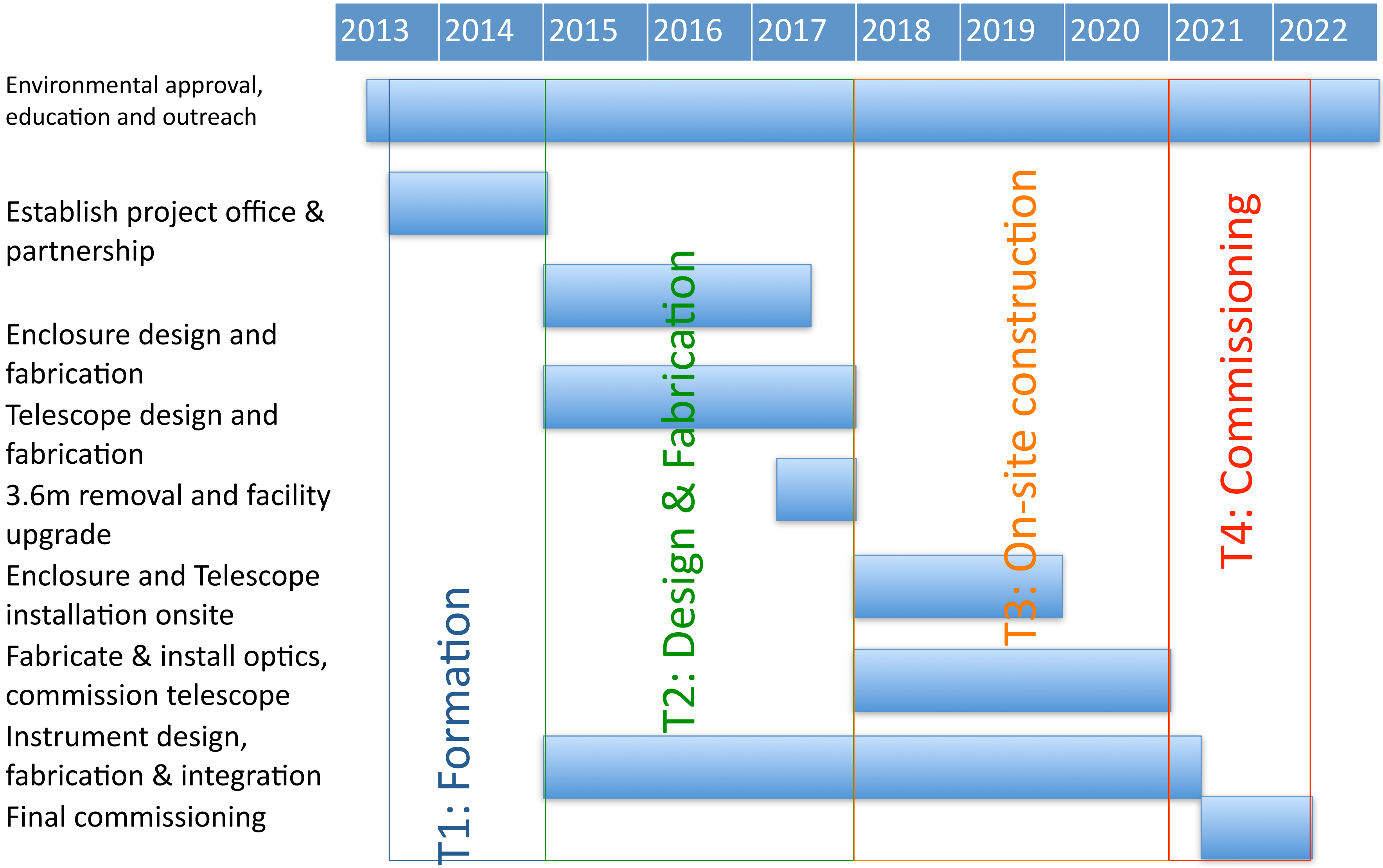
There are many ways to stretch this out but none to shorten it. If we want to have a world-leading facility in 2022 we must start now.

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)
- Welcome visits from scientists and engineers from partners

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!
CANADA-FRANCE-HAWAII TELESCOPE
CFH www.cfht.hawaii.edu
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Development and Construction Costs

Item	Cost ($M)
design and management	10
M1 optics	10
M1 support system	5
wide field corrector	10
software and control	12
25%-30% contingencies on above items	12
removal of telescope and dome	6.6
enclosure pier structural upgrade	2.7
telescope structure	30.8
enclosure	28.1
facility redevelopment & commissioning	10
spectrograph system	76.1
Total	**206.3**

Strawman Cost Profile (Total)

- Total development and construction cost: $206M, to be divided over ~7 yrs.

Year	Project Office	Enclosure Design	Telescope Design	Decon-struction	Onsite	M1	Software	Instru-ment	Redevel-ment	Total
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
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2021									3	3.0
Total	13	12	14.7	9.3	32.2	19.5	13	82.6	10	206.3

Strawman Cost Profile (Per Partner)

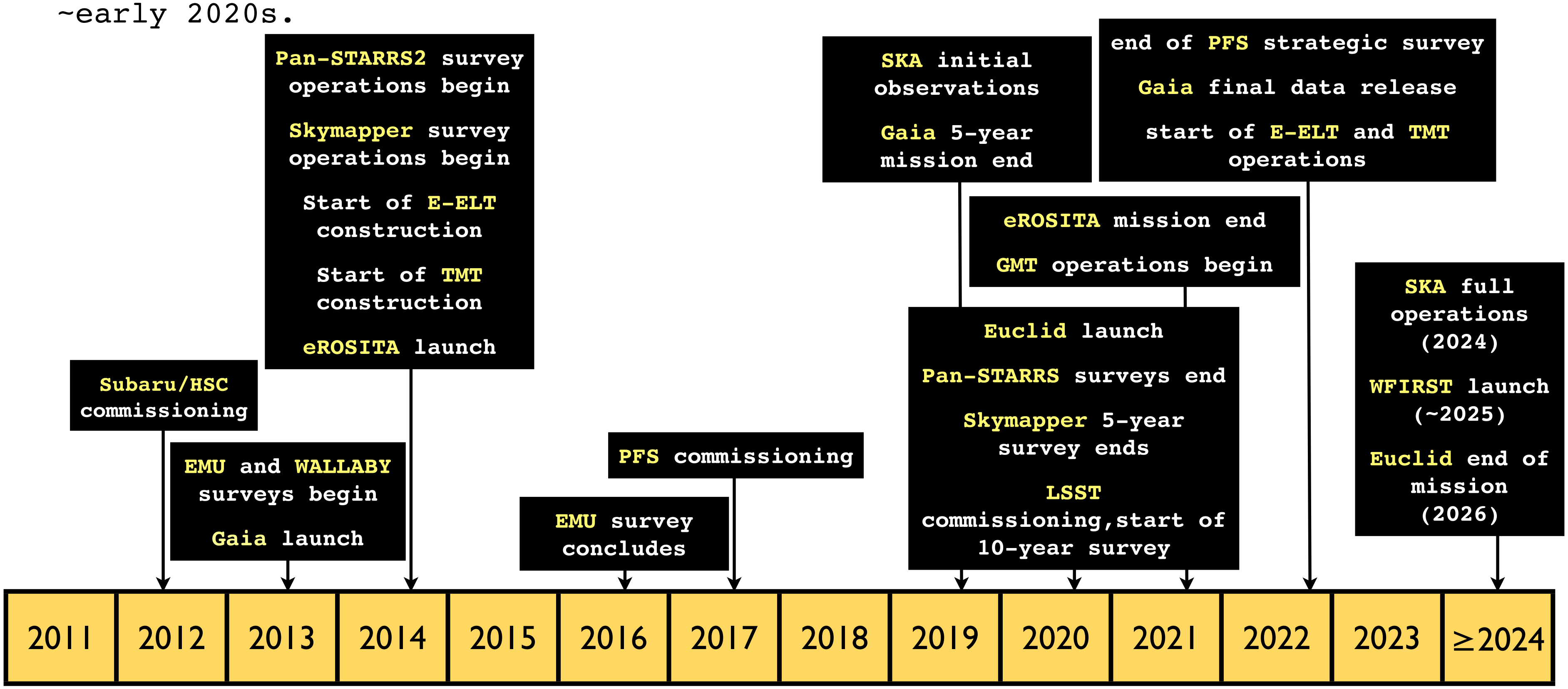
- **1/6th share** development and construction cost: $206M, to be divided over ~7 yrs.

Year	Project Office	Enclosure Design	Telescope Design	Decon-struction	Onsite	M1	Software	Instru-ment	Redevel-ment	Total
2013	0.08									0.08
2014	0.21									0.21
2015	0.29	0.80	0.83					2.30		4.23
2016	0.32	0.80	0.83					2.30		4.25
2017	0.32	0.40	0.78	1.55			0.53	2.30		5.88
2018	0.32				2.68	1.08	0.53	2.30	0.33	7.25
2019	0.32				2.68	1.08	0.53	2.30	0.33	7.25
2020	0.32					1.08	0.57	2.30	0.50	4.73
2021									0.50	0.50
Total	2.17	2.00	2.45	1.55	5.37	3.25	2.17	13.77	1.67	34.38

- Moreover, ngCFHT makes excellent financial sense for the current partners given their equity in the current telescope.

Development Urgency and Schedule Drivers

- There is both a scientific and a technical urgency to the schedule.
- Scientific urgency: need to begin survey operations in the early 2020s to match schedules of many other surveys, facilities and missions (i.e., Gaia, ASKAP, eROSITA, Pan-STARRS, LSST, Skymapper, SKA, Euclid, TMT and E-ELT).
- Technical urgency: to build on the major technology investments for the ELTs (e.g., mirror segments, supports, phasing, telescopes and enclosures).
- It is essential to move quickly if the facility is to begin operations by the ~early 2020s.



Strategic Benefits for CFHT Partners

Canada

- strategic leveraging of resources based on equity in an existing facility.
- consolidation of most observing resources at a single location.
- a "second to none" share in one of the world's most powerful telescopes.
- leverage for participation in other facilities/surveys (e.g., LSST, Euclid, etc).
- future collaborative opportunities with the rapidly emerging science communities in Asia.

France

- strategic leveraging of resources based on equity in an existing facility.
- continued access to the northern skies (like the other major ESO member countries; i.e., GTC, LBT, TNG, Calar Alto, WHT, etc).
- ensured science return on its two flagship space astronomy missions (Gaia, Euclid).
- leverage for participation in other facilities/surveys (e.g., LSST, etc).
- future collaborative opportunities with the rapidly emerging science communities in Asia.

Hawaii

- strategic leveraging of resources based on equity in an existing facility.
- a continued partnership in one of the world's most powerful telescopes.
- ensured science return on its flagship facility: Pan-STARRs.
- a major increase in research capacity atop Mauna Kea, the centre of astronomical research in the northern hemisphere and the potential future "hub" of US observational astronomy.
- ngCFHT as leverage for other facilities/surveys.
- future collaborative opportunities with the rapidly emerging science communities in Asia.

Summary

- Feasibility studies have confirmed that the scientific potential of ngCFHT is immense. The facility would be unrivaled in its ability to perform panoramic spectroscopy of the faint universe.
- It would fill what is perhaps the most important “missing capability” in the portfolio of international astronomy projects.
- The project is technically feasible, and has relatively low risk.
- Redevelopment with an expanded partnership is outstanding ‘value for money’ for the existing partners. It also represents an exceptional strategic scientific opportunity for the current CFHT partners (and collaborators).
- To maximize both scientific and manufacturing synergies, we must aim for first light by 2021-2022.
- The project’s visibility is higher than ever before, and momentum continues to build.
- The timing is excellent for a number of upcoming community “strategic plans”.
- But the project is at a critical juncture.

The Next Steps

- ngCFHT cannot continue without formal structure.
- It is now essential to formalize the project with a small project office, based in Waimea, by early 2014.
- Essential tasks to be carried out by the project office:
  - lead efforts to expand the partnership and recruit personnel to carry out development studies.
  - carry out strategic planning for the full lifetime of the project (WBS, milestones, risk management, etc).
  - take leadership in securing environment approval and permits.
  - lead Hawaiian education and public outreach efforts.
  - oversee formation of satellite project offices in partner communities responsible for key components.
  - refine the scientific requirements in consultation with science teams in prospective partner communities.
  - continuously develop/refine project budget and schedule.
  - organize meetings, workshops and partners visits.
- A two-stage development plan for ngCFHT.

1. **2014-2015:** ngCFHT project office established (and funded at the modest level of ~$100-200k per year per partner, ~$1.5M total). Chinese have already expressed a willingness to send a senior scientist.
2. **2015 onwards:** partnership created and design/construction begins.

A1. ngCFHT Scientific Legacy. Major Science Thrust #1

1.Galactic Archaeology.

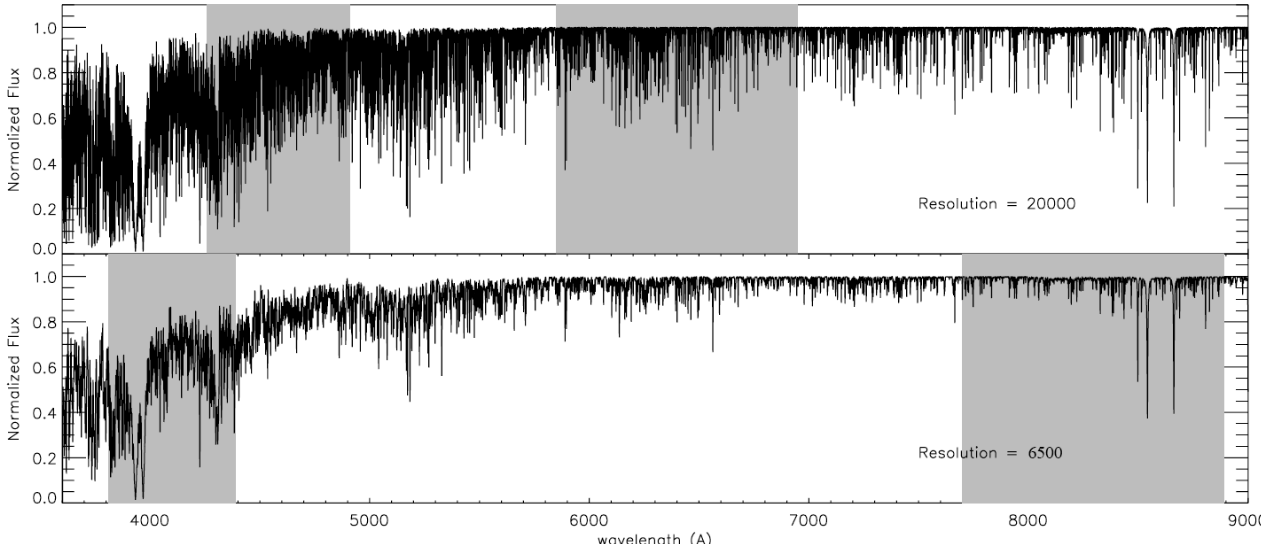
- Most ngCFHT bright/grey time devoted to a comprehensive, Galactic Archaeology programme (≈ 1400 nights over a decade).
- Aim: map 1/4 of the Galactic volume to a depth of g ≈ 21.4 (R=6,500) and 20.4 (20,000).
- 5 million stars at R=20,000 and 15 million stars at R=6,500. Fully half of these targets will belong to the halo. This would be the definitive follow up of the Gaia mission.

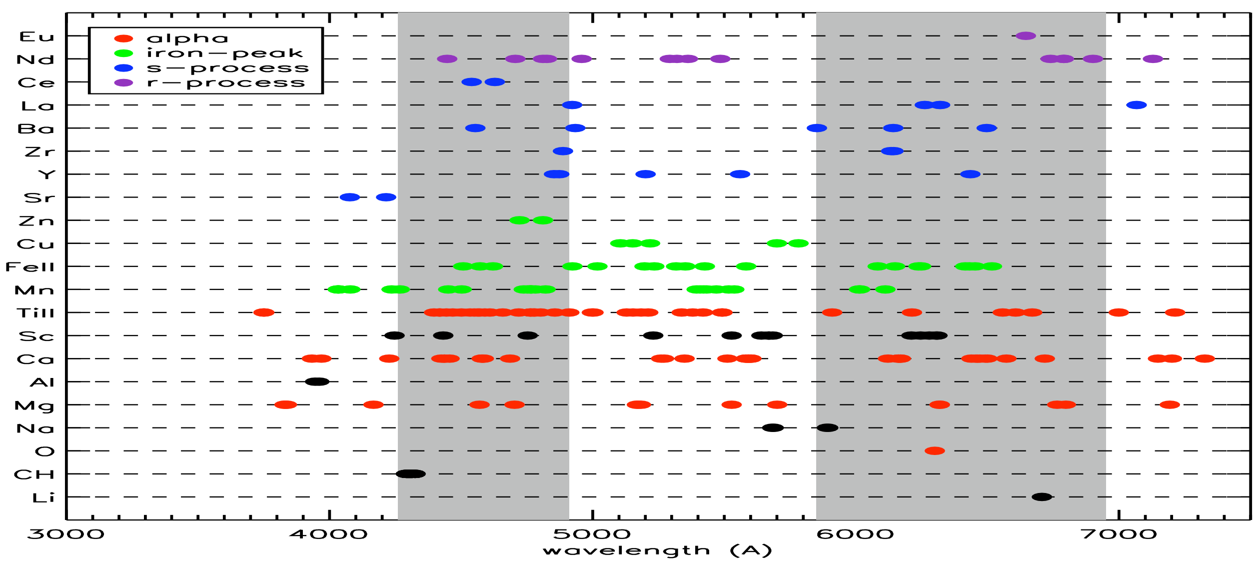
	R=6,500	R=20,000
WD	1.9 (kpc)	1.2 kpc
MSTO	30	20
HB	140	90
TRGB	470	300

- Included/related programmes focus on: (1) chemical labeling of halo stars, (2) the thin and thick disk populations, (3) the bulge and halo metallicity distributions, (4) density structure of the halo using BHB/BS/MSTO stars, (5) the most metal-poor halo stars, (6) the phase-space structure of the halo, (7) the shape of the Galactic potential, (8) tests of dark matter vs. non-equilibrium dynamics vs. non-Newtonian gravity, (9) ages of Galactic subcomponents from WDs, (10) structure of low-mass dark matter halos; (11) intermediate-mass black holes in star clusters; etc...

A1. ngCFHT Scientific Legacy. Major Science Thrust #1

1. Galactic Archaeology.





A1. ngCFHT Scientific Legacy. Major Science Thrust #2

2. Galaxies and Cosmology.

- "Wedding Cake" strategy for three important extragalactic dark-time surveys:
    1. Dark-Wide (4300 deg^2, $i \approx 23.5$), 10% completeness.
    2. Dark-Medium (100 deg^2, $i \approx 24.25$), >95% completeness.
    3. Dark-Deep (1.5 deg^2, $i \approx 26.0$), high completeness and repeated coverage.
- Dark-Wide would yield spectra ($R = 2,000$, $\lambda = 0.37$-$1.3\mu m$) for more than 10 million galaxies, allowing galaxy evolution studies in seven redshift bins from $z = 0.5$ to 1.5, each with the same statistical power as the SDSS.
    - How does stellar mass growth relate to halo mass growth?
    - How does satellite galaxy evolution differ from that of central galaxies?
    - What are the effects of environment on galaxy formation and evolution?
    - How does feedback work?
    - How do galaxies get their gas?
- Main Cosmology/DE programmes include
    1. BAO Cosmology Survey (10,000 deg^2, $r \approx 23.7$), LRGs, ELGs, QSOs, QSO Ly-α forest. 1% distance precision over the range $1 < z < 3$.
    2. Cluster Cosmology Survey (500 massive clusters in optical, SZ, X-rays), $0.3 < z < 1$.
- Redshift Space Distortions in BAO Survey ➜ law of gravity, neutrino mass, non-Gaussianity.
- Cluster Survey ➜ mass density of the universe, normalization of the power spectrum, dynamics of dark energy.

A1. Additional (Representative) Science

- A 3D map of the Galactic ISM, with the density structure and kinematics measured along hundreds of thousands of sight lines using high-resolution, absorption-line spectroscopy of molecular, atomic and ionized gas.
- Characterization of planetary host properties for exoplanet transit surveys (e.g., Kepler) including spectral types, ages, chemical properties; sample definition/selection for pointed planet surveys using direct imaging of 100-200 Myr stars (i.e., targets selected on the basis of Ca HK, Li, rotational velocity, UVW, etc).
- Baade-Wesselink parameters of pulsating variables throughout the Milky Way and Local Group, giving masses and radii for stars evolving through the instability strip.
- Fundamental parameters (e.g., spectroscopic masses, distances, metallicities, rotation rates) for high-mass stars belonging to the Milky Way and nearby galaxies.
- Time-domain spectroscopic surveys (e.g., stellar multiplicity, pulsating and eclipsing stars, novae and supernovae).
- The identification of rare stellar types, such as solar twins, white dwarfs associated with the Milky Way thick disk or halo, and extremely metal-poor stars.
- Chemo-dynamical surveys of Local Group galaxies, from low-mass, dark-matter-dominated dwarfs to M31.
- The measurement of gravitational masses and density profiles for dark matter halos in the nearby clusters.
- A complete census of compact stellar systems in the Local Volume, including masses, ages and abundances.
- The relationship between stellar and gravitational mass, baryon dynamics, and star formation efficiency in dark matter halos spanning a range of $\approx 10^6$ in stellar mass; survey would yield spectra for half a million galaxies within $z < 0.15$.
- A spectroscopic survey of 100 bright quasar fields allowing an order-of-magnitude improvement in our ability to probe the Galaxy-IGM connection based on 40,000 Ly-absorbers, and spectroscopy for 1000–2000 damped Ly-alpha systems to probe early nucleosynthesis and the evolution of metals out to $z \approx 4$.
- AGN feedback through high-S/N, high-resolution, time-domain spectroscopy, as well as an independent determination of the redshift evolution of dark energy through BAOs in the Ly forest, and an AGN Hubble diagram calibrated through reverberation mapping.

A1. Provisional Science Surveys

Survey	u_{sky}	Area (deg^2)	Resolution	λ (nm)	g_{lim} (mag)	T (ngts)
Multiplicity and Exoplanets	bright	115	20,000 2,000	425-491; 585-675 0.37-1.3	16.0	110
ISM Survey	bright	5,000	20,000	369-425; 761-879	16.0	140
Galactic Archaeology I	bright/grey	10,000	20,000	425-491; 585-675	20.4	1150
Galactic Archaeology II	grey	10,000	6,500	381-439; 770-889	21.4	290
Andromeda	grey/dark	350	6,500	436-504; 770-889	23.0	50
LOWZ	dark	1,000	2,000	0.37-1.3	i=22	190
Rich Clusters	dark	30	2,000	0.37-1.3	r=22	45
Virgo Cluster	dark	100	6,500 2,000	436-504; 770-889 0.37-1.3	23.6	30
Dark-Wide	dark	4,300	2,000	0.37-1.3	i=23.5	520
Dark-Medium	dark	100	2,000	0.37-1.3	i=24.25	480
Dark-Deep	dark	1.5	2,000	0.37-1.3	i=26	105
Quasar Reverb. Mapping	dark	1.5	2,000	0.37-1.3	i=22.7	105
Cosmological Cluster	dark	750	2,000	0.37-1.3	i=23.5	195
BAO/Cosmology	dark/grey	10,000	2,000	0.37-1.3	r=23.7	600