Venting the CFHT Dome

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CFHT Users' Meeting – May, 2015

Acknowledgements

IQ studies, guidance and wisdom
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Water / wind tunnel models and tests
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CFD calculations
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Software and controls
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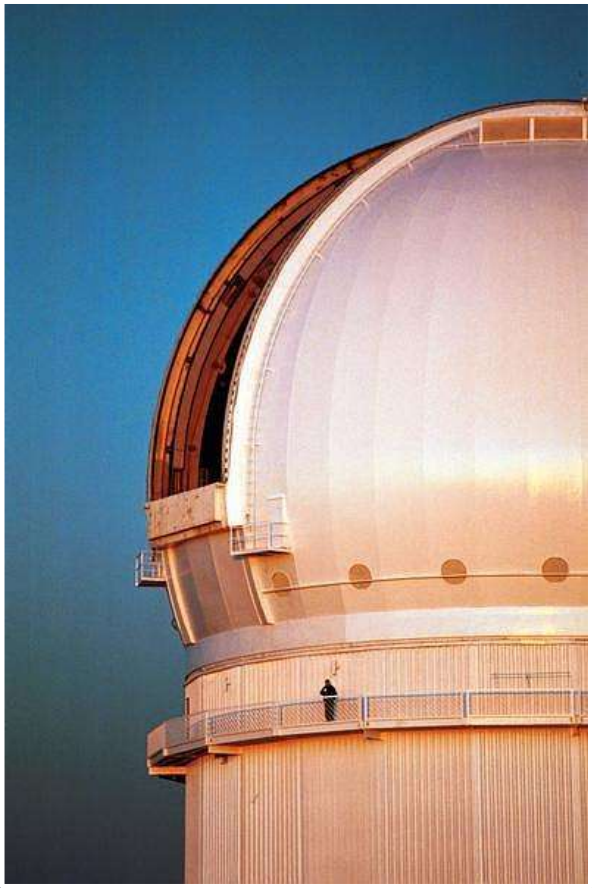


Contractors
- Caid Industries
- M3
- Nexus Steel
- SteelTech

Facility seeing – what causes it?

Optical turbulence (facility seeing) requires:
- physical turbulence
- incomplete mixing of air parcels of differing temperature
- transport of poorly mixed air into the optical path

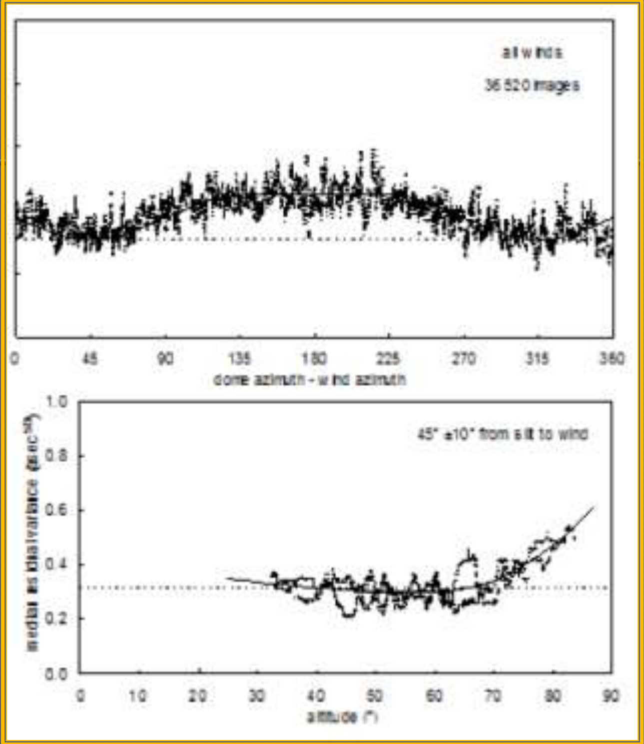
Temperature of advected air changes much more rapidly than structural temperatures
- air temperature is changed when in contact with heavy structures
- stagnant air leads to large d Temp

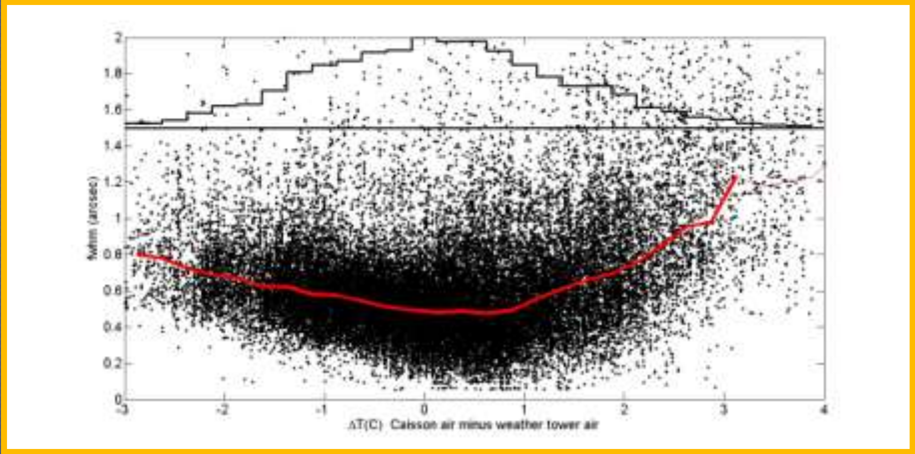
Two passive solutions:
- minimize d Temp between air and telescope structures (insulate) and/or
- limit the time air is in contact with structures (venting)

IQ pathologies

• image quality degrades when :

  • dome air temp differs from outside air
  • the dome slit points downwind
  • observing near the zenith

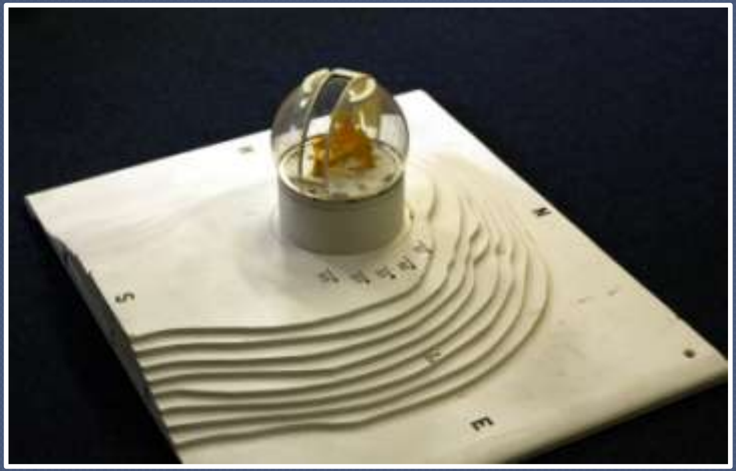




Approach to vent development

- Understand air flow in and around the dome – limits on improvements
  - Fluid dynamics consultants and literature
  - Water tunnel tests of 160:1 scale model
  - Computational fluid dynamics models
- Understand the dome structure and limitations to vent design / installation
  - Excellent set of construction drawings from Brittain Steel (DSL)
  - Computer solid model of dome and telescope
- Contract structural design firms to develop vents within budget, schedule and existing structure
  - Structural analysis of the vented dome
  - Detail and fabrication drawings
  - Fabrication
  - Installation

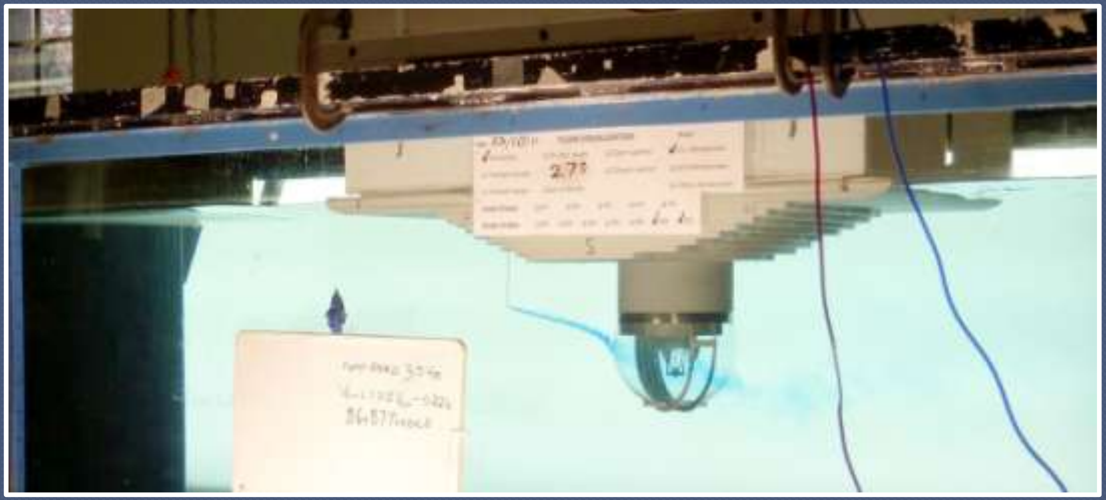
Flow in the dome
– U of Washington water tunnel



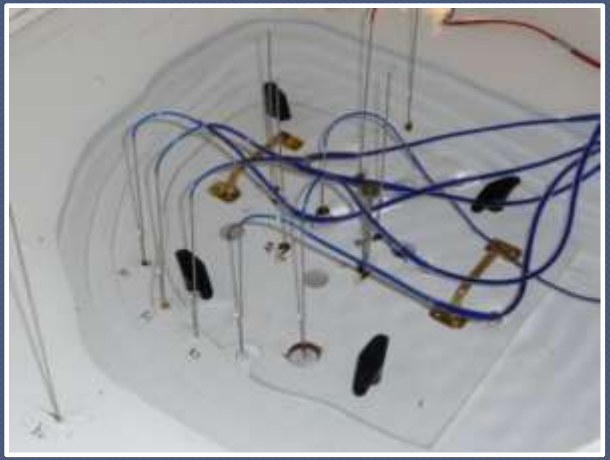
The CFHT Water Men

- Tom Benedict
- Marc Baril
- Karun Thanjavur

Water tunnel model



- terraced terrain model
- flow from the East
- full dome rotation
- dye probes
  - 6 in dome
  - 5 up stream
  - 2 down stream



Water tunnel test suite

- Flow from east only

- All dome slit orientations: east through south to west – 15 degree increments

- Vents

  Unvented dome
  8 small vents
  8 larger vents

- Flushing / clearing times

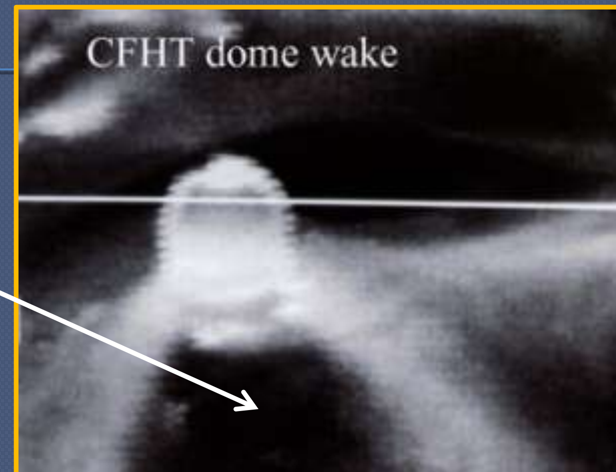
- Flow patterns

  - onto dome
  - in lee of dome
  - inside dome starting at floor level
  - inside dome in telescope tube

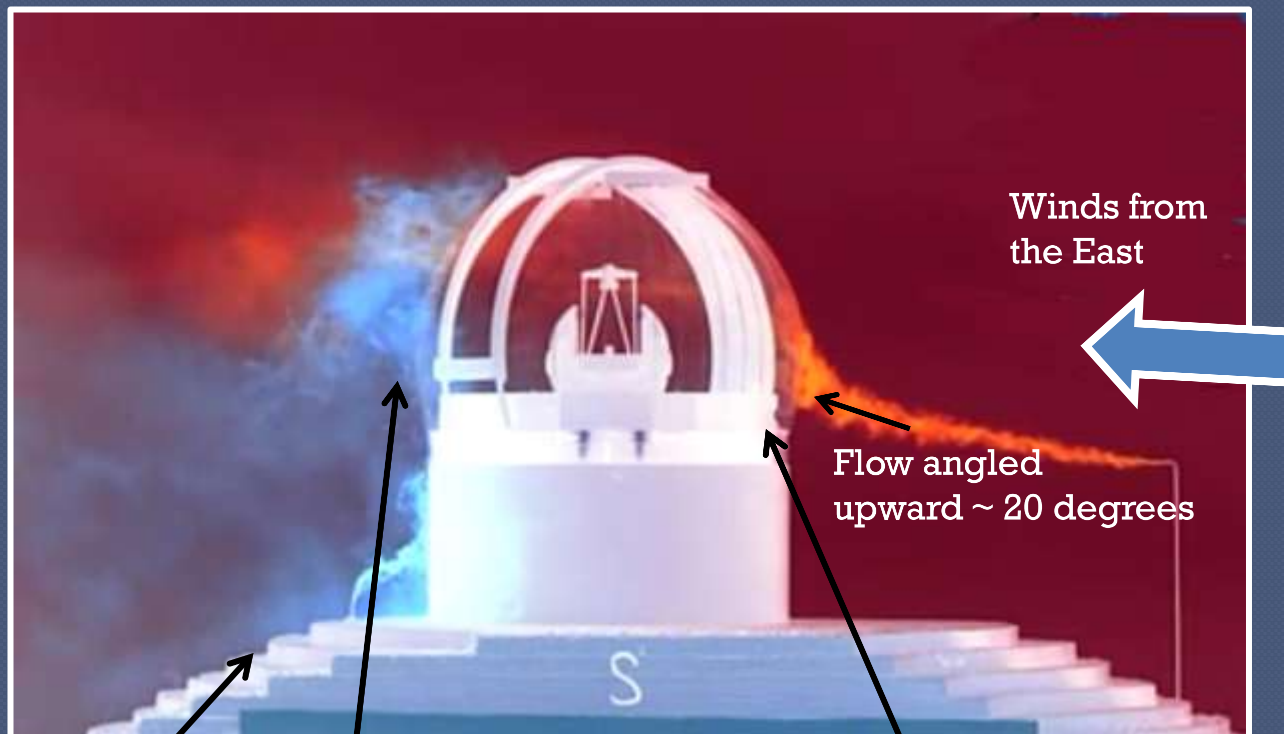
Horseshoe vortex

Vortex scours cold air and lifts it to height of building radius

Air in contact with ground 5 to 8 C below ambient



Flow around the dome
- water tunnel

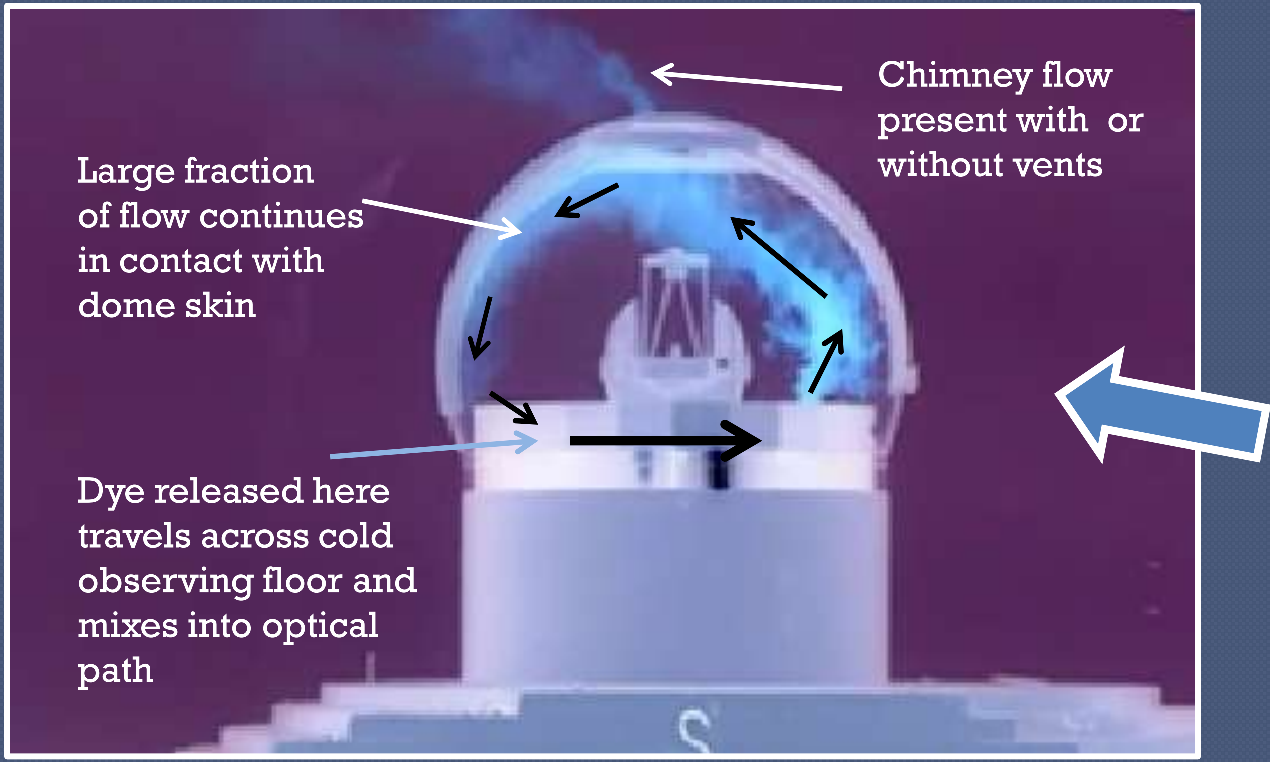


Radiatively cooled
terrain

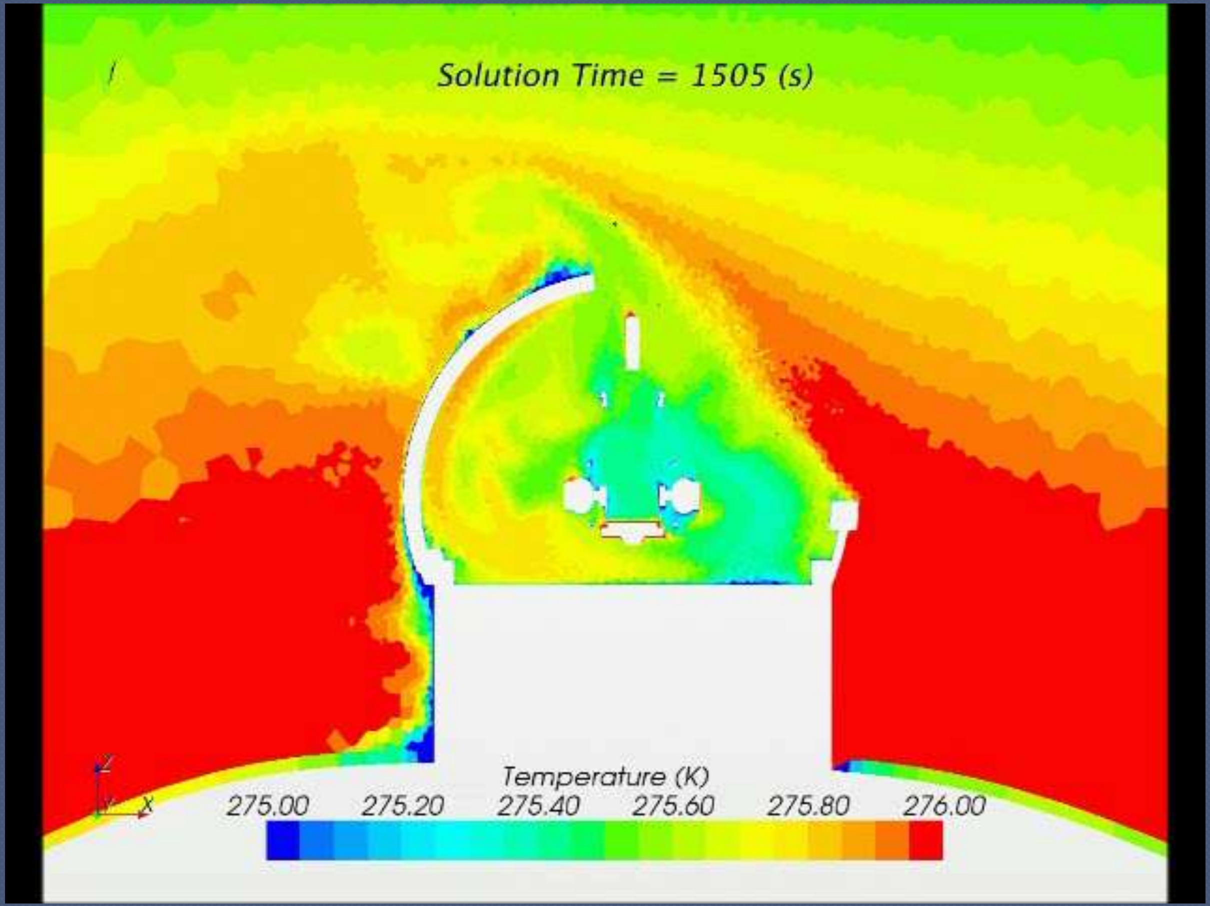
Lee side upwelling

Upwind stagnation point
(best vent location) is low

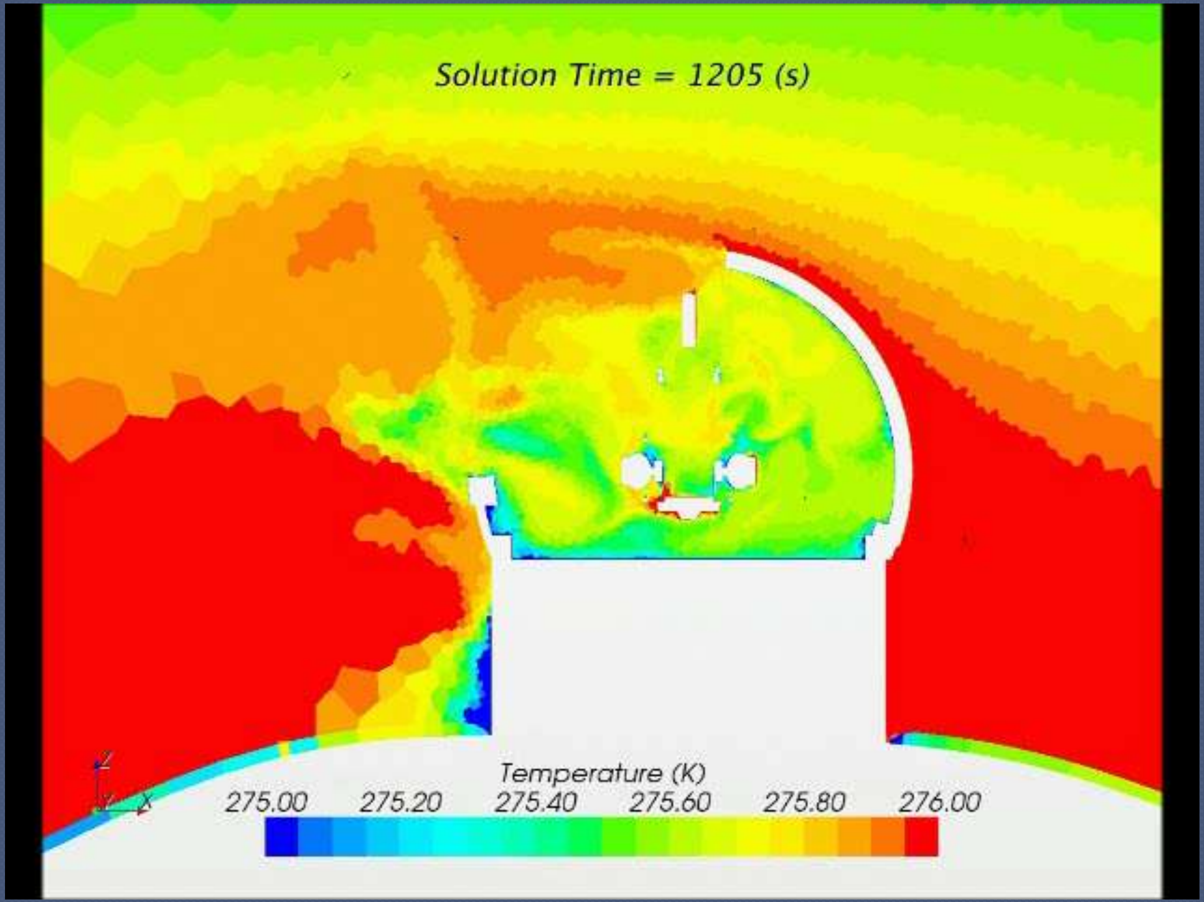
Simple flow case – slit into the wind



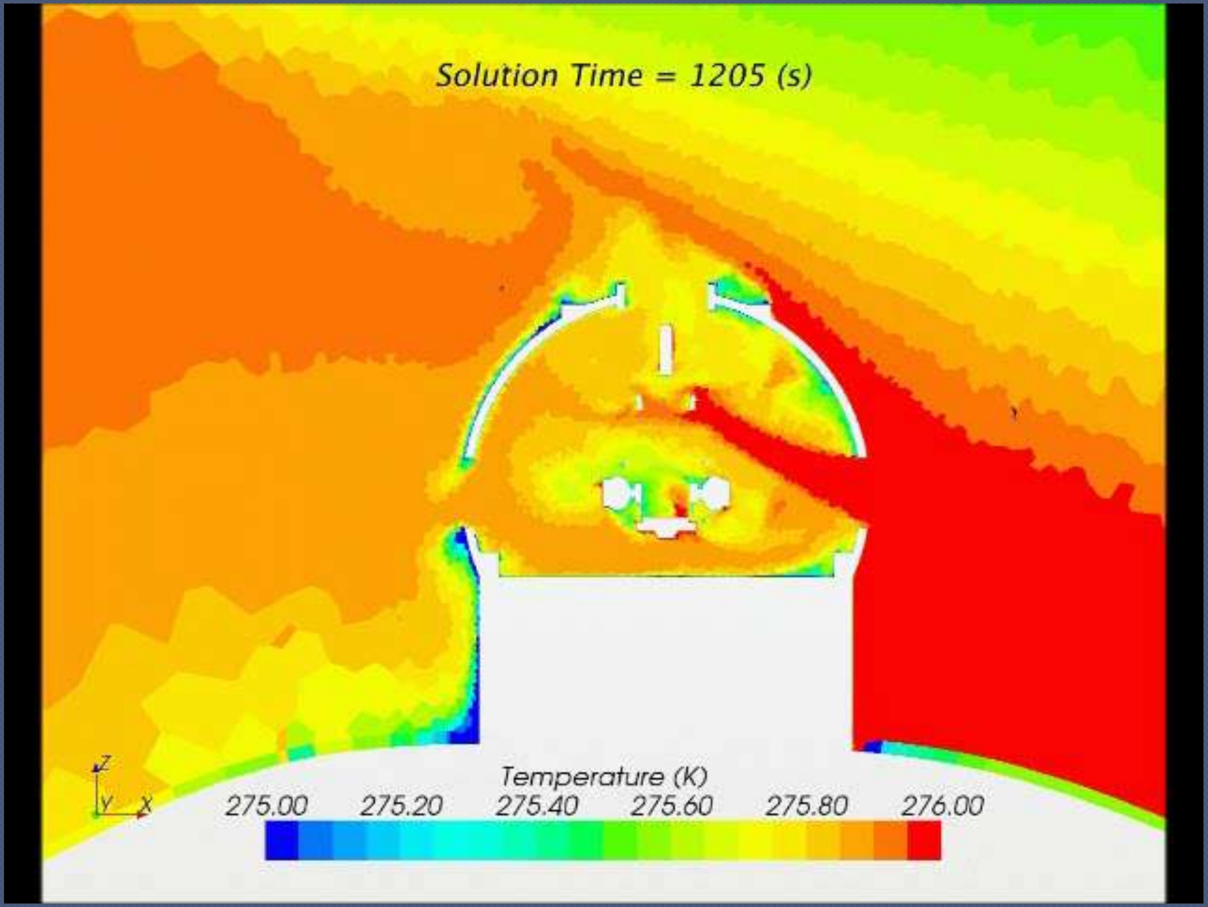
CFD : Dome Unvented – Slit Upwind



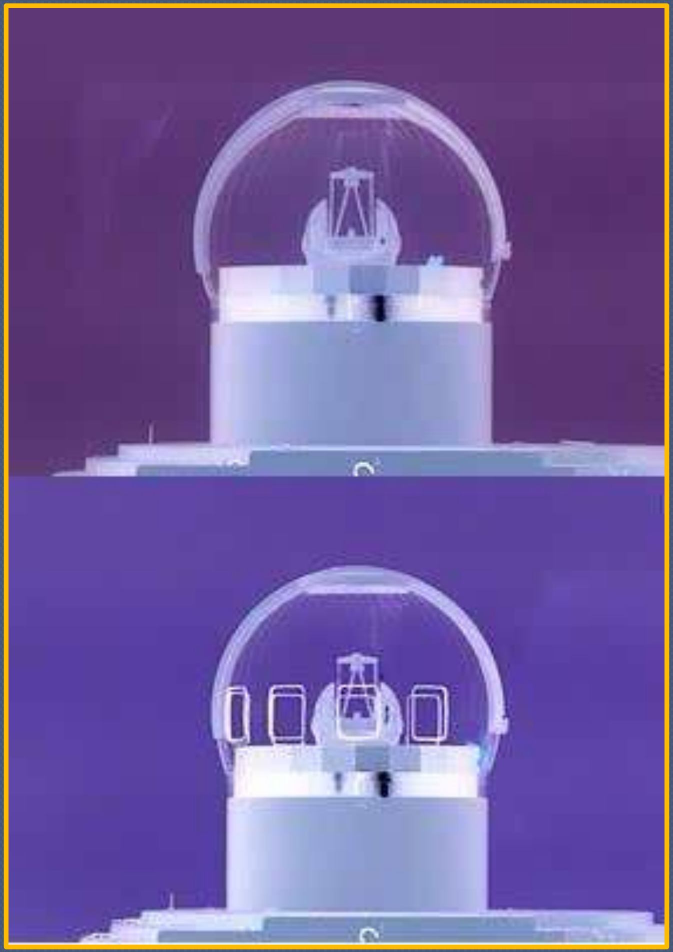
CFD – Dome unvented – Slit Downwind

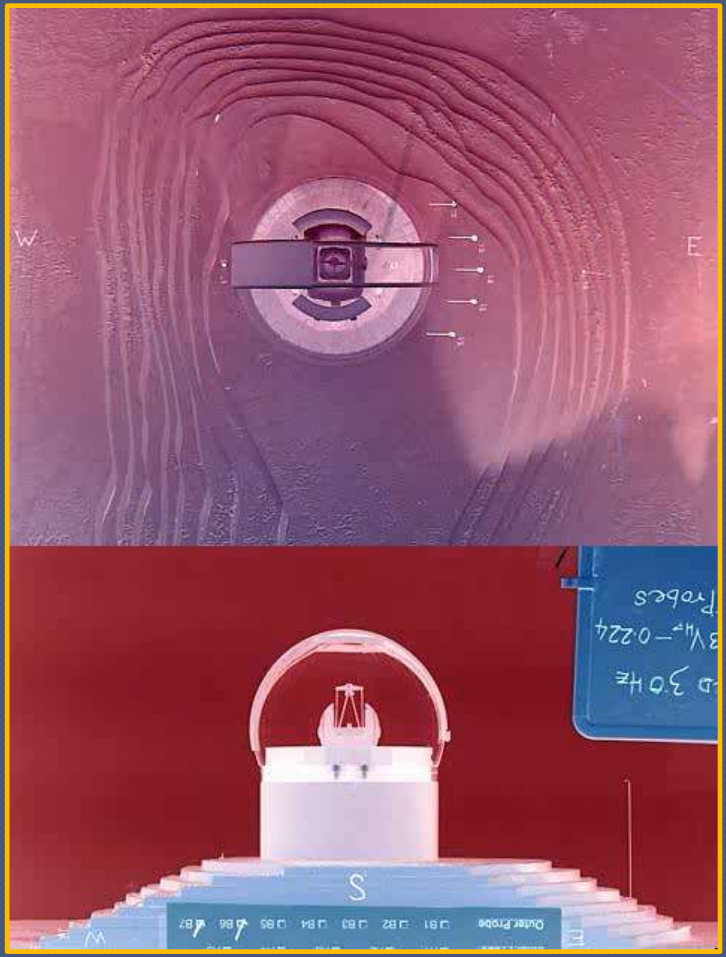


CFD - Dome Vented - Slit South

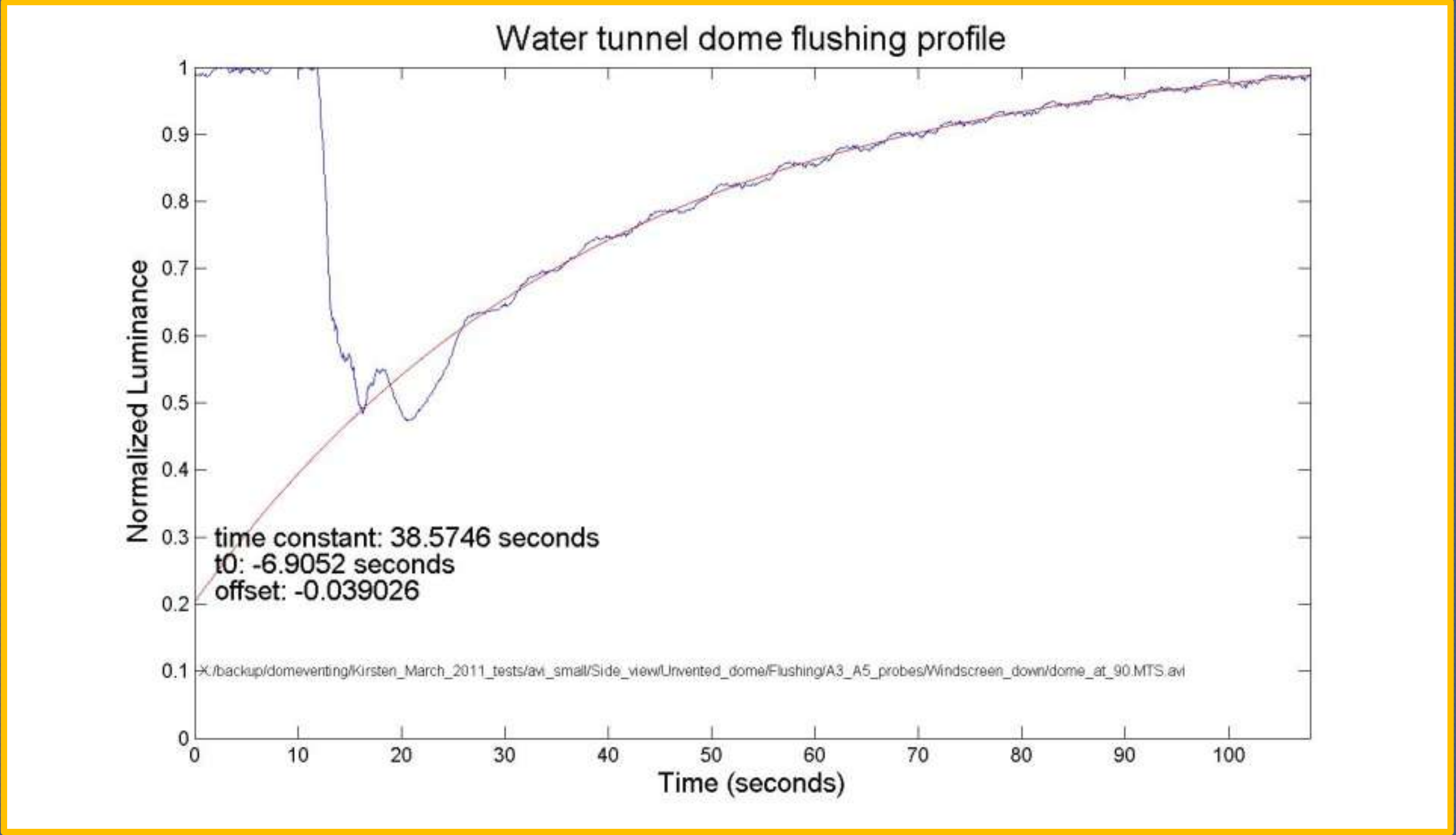


Flow visualization – a few water tunnel examples

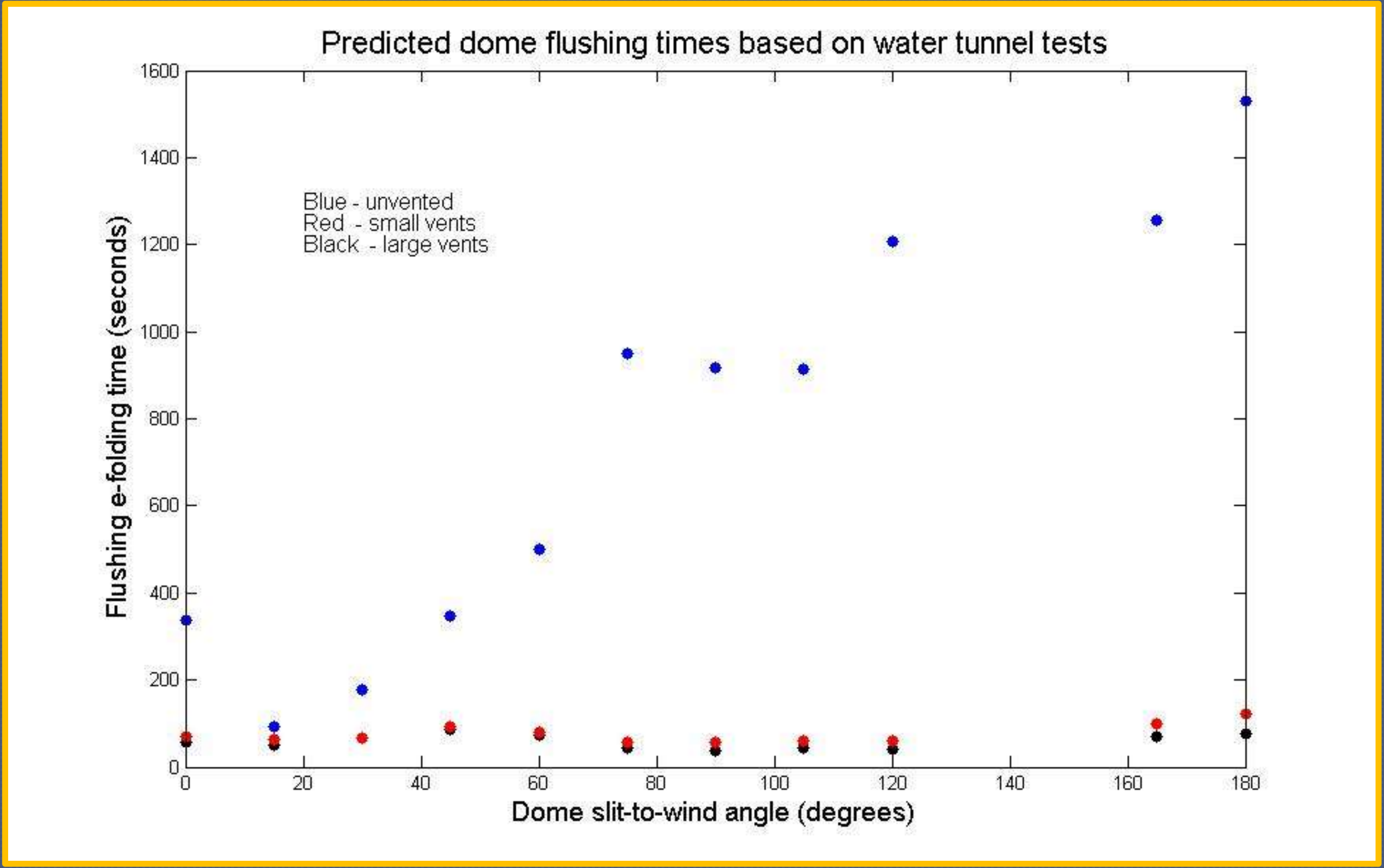




Flush time estimates



Flush times – vented vs unvented



Study conclusions

- Closed enclosure is a bad idea
    - stagnation leads to large d Temp in air
    - circulation into optical path
    - mirror seeing is likely NOT the dominant contributor to facility seeing

-Venting works
    -- better flushing leads to lower air d Temp
    -- strategies needed to deal with jetting

-Chimney maintained at many slit orientations – but not all
    -Slit front and back might reduce chimney effect (a la NTT)

- Upwelling downwind should be controlled

- Upwind flow tilted upward about 20 degree (Ando and Seigmund)
    -- stagnation point low on the vertical cross section
    -- keep vents low for most efficient flushing

- Effective vent area < < projection onto upstream flow
    -- flow runs tangent to skin away from stagnation point

-- Low level vortex – keep openings above height = building radius
    -- possibility of cold ground air mixed into the dome.

Procurement milestones

Bids solicited from 8 pre-selected vendors – November, 2011
- design, build, install

4 participated in on-site pre-bid review – December, 2011

3 responses – February, 2012

- San Jaun Construction	$3.4 M US
- B&C Southwest	$1.9 M US
- SteelTech (M3 – CAID – Nexus)	$1.6 M US – selected

6 month delay due to dome shutter

CRC / Board approval – October, 2012

OMKM / DLNR approval – December, 2012

Contract signed – December, 2012

Prototype installed – April, 2013

Final install – September, 2013

Design approach

Functional goals – vent should:

- wide
- low on the dome skin
- maximum possible area !

Real world constraints

- budget
- dome vertical structural webs
- dome power bus bars and inner catwalk
- mezzanine blockage
- sever summit weather

Final design:

Vendor

- 12 vents – opening 1.8 m x 5 m
- concentrated toward back side
- vertical roll-up weather door
- vane (louver) on interior face
- drive motors, position sensors, electrical interface box

CFHT

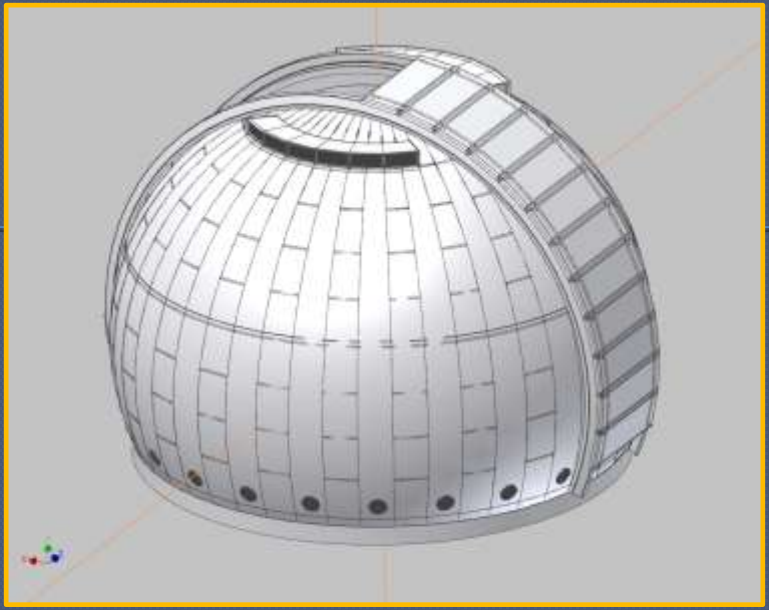
- computer (PLC) control with status log
- user interface for RO's and engineering

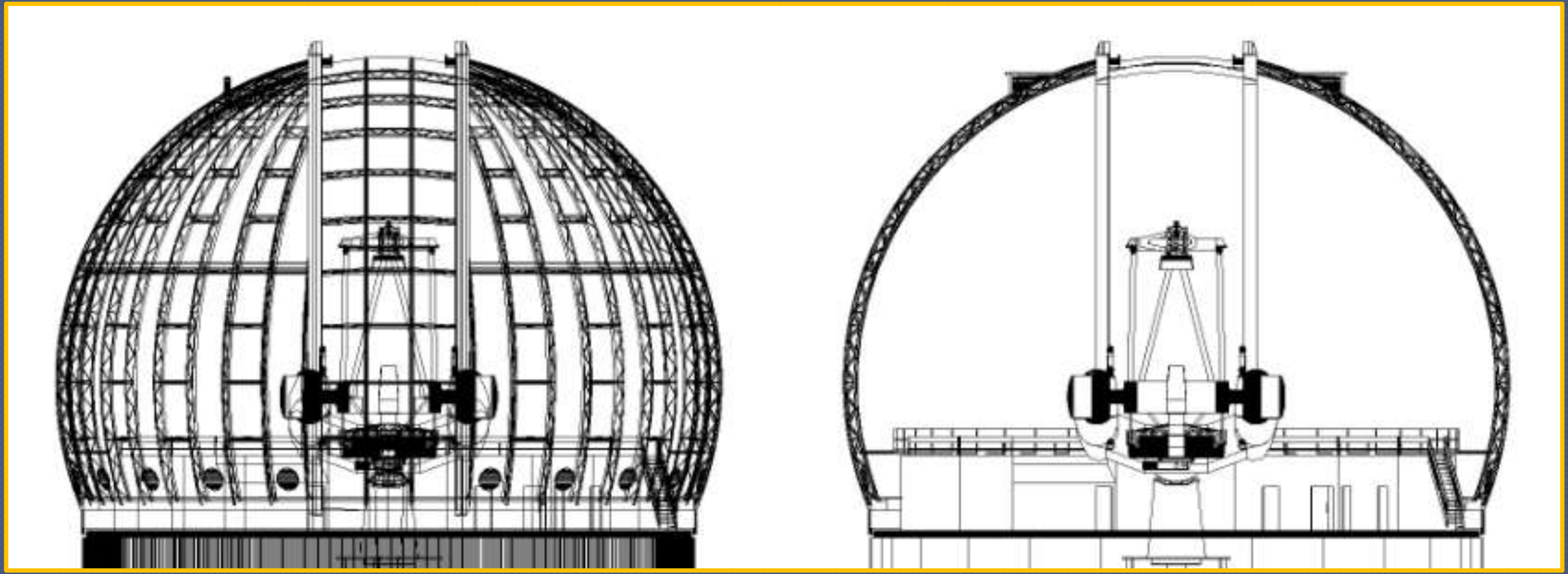
Dome structure

Vertical gores – ¼ inch steel plate

Vertical stiffening rib trusses

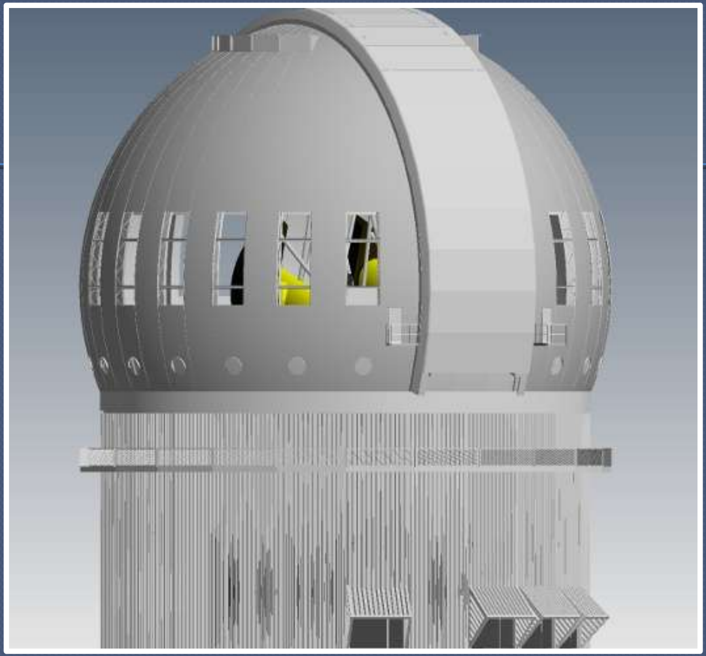
Horizontal trusses on alternating gores

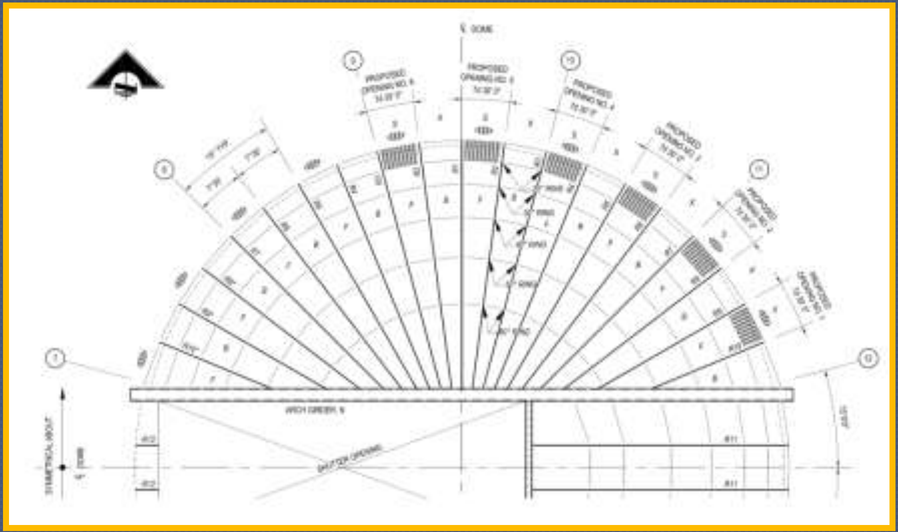




Design outline

- 12 vent units – 6 per side – cost constrained
  - 15 degree intervals
- mounted from the outside
- no observing down time
  - work from 7:00 to 16:30





Vent units

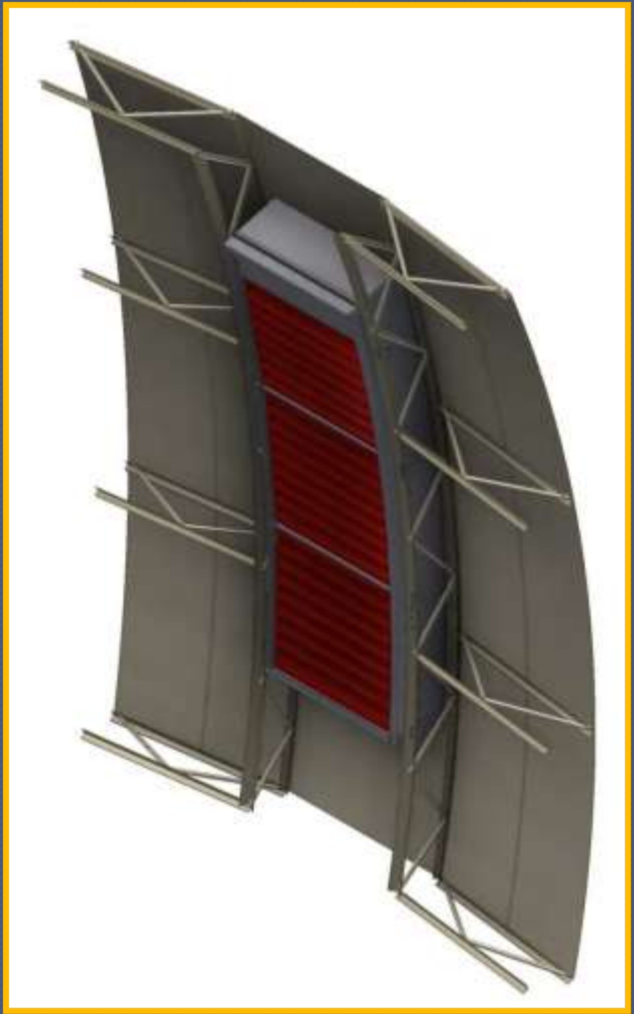
vents delivered as assembled units

units extend from outer dome shell
to inner insulation shell

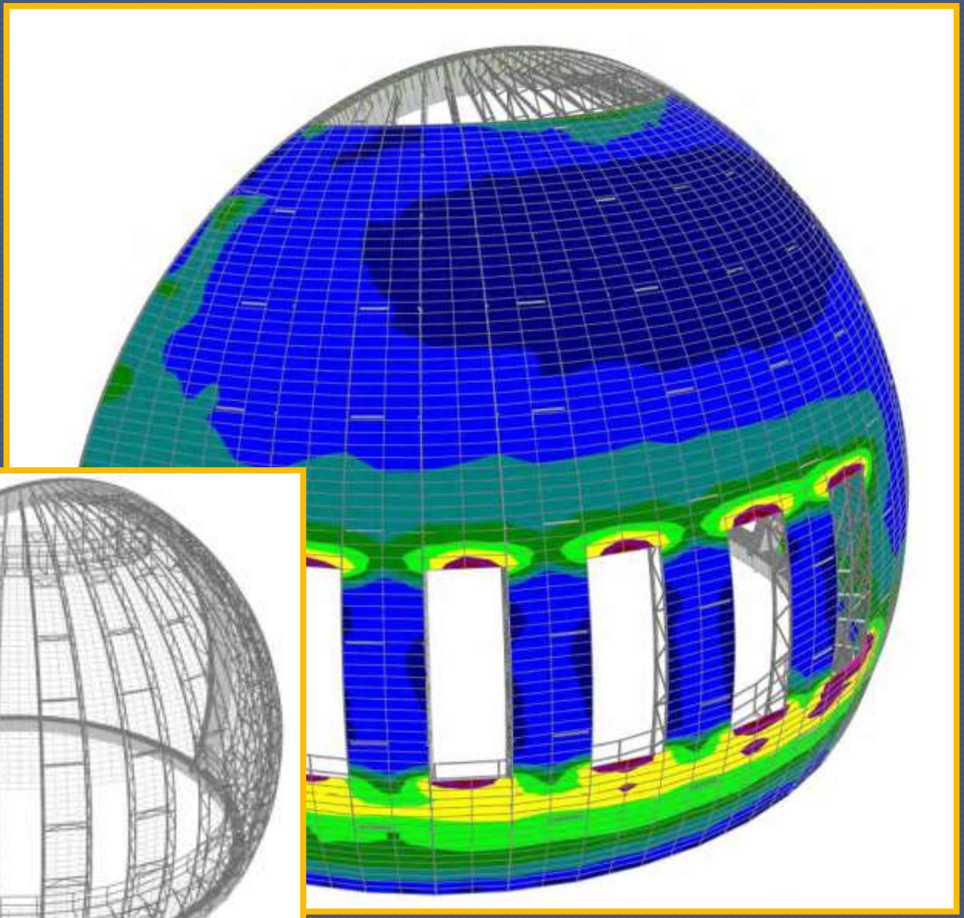
sealed from inter-skin cavity

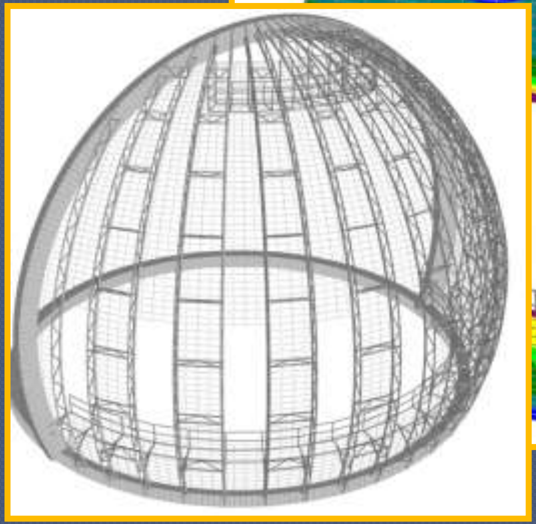
Outer rollup 'garage' door
- weather doors
- flow throttling – 4 positions
  - fully open
  - 2/3 open
  - 1/3 open
  - fully closed
- inner vanes
  - flow redirection
  - flow throttling
  - weather backup
  - easily removable

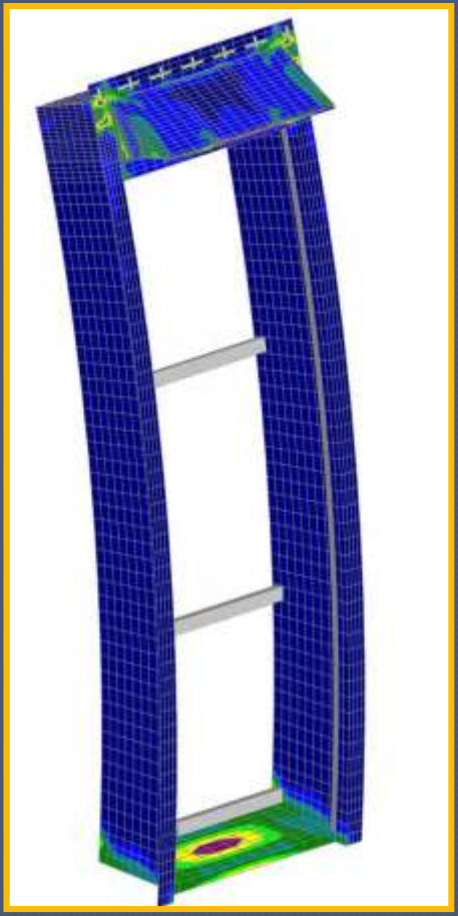
Vent unit placement



Structural analysis and design – M3 Engineering







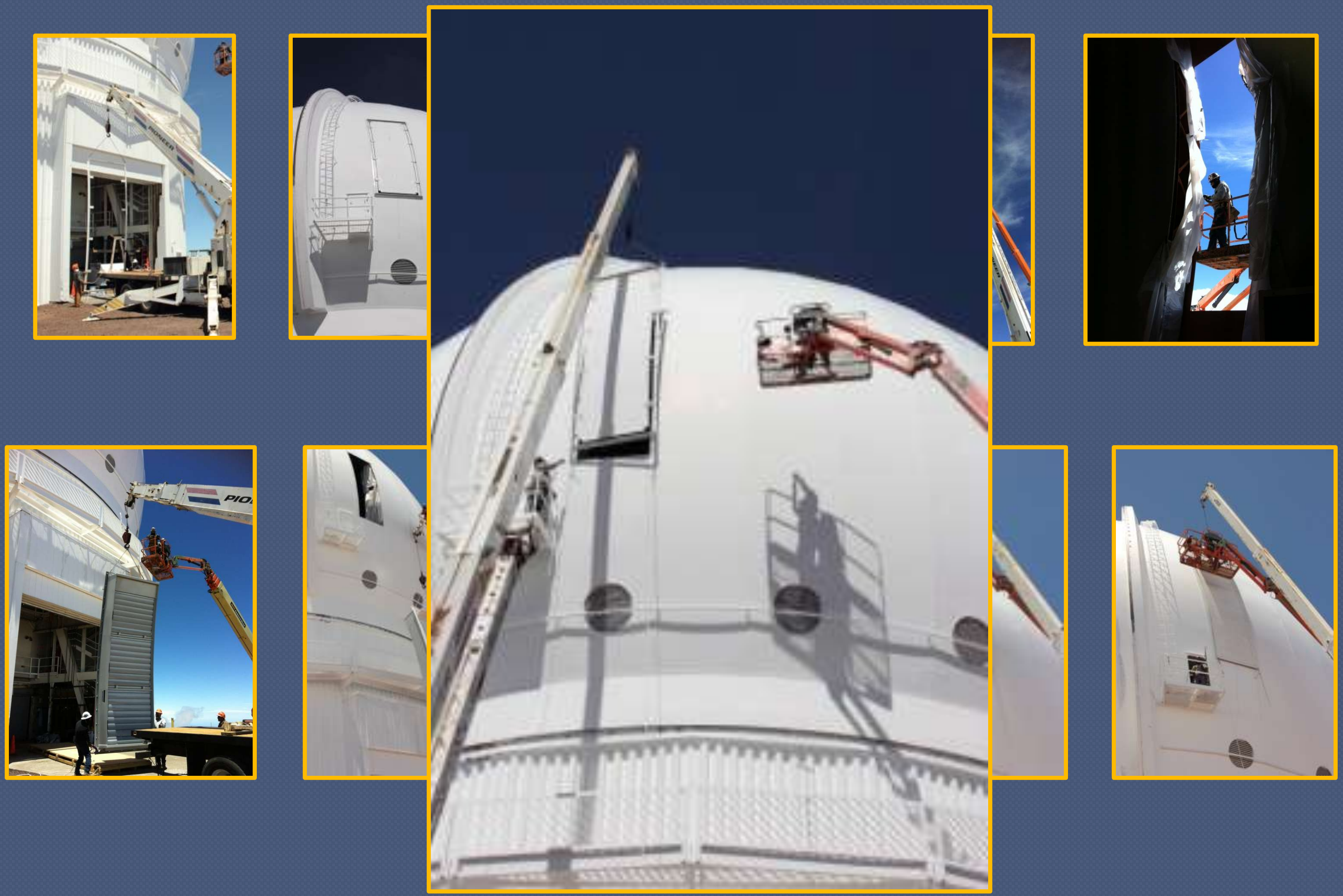
The real thing – CAID Industries

Prototype installation – April 24, 2013

Prototype installation – April 24, 2013

Prototype installation – April 24, 2013

Prototype installation – April 24, 2013



Prototype installation – April 24, 2013

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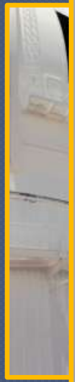
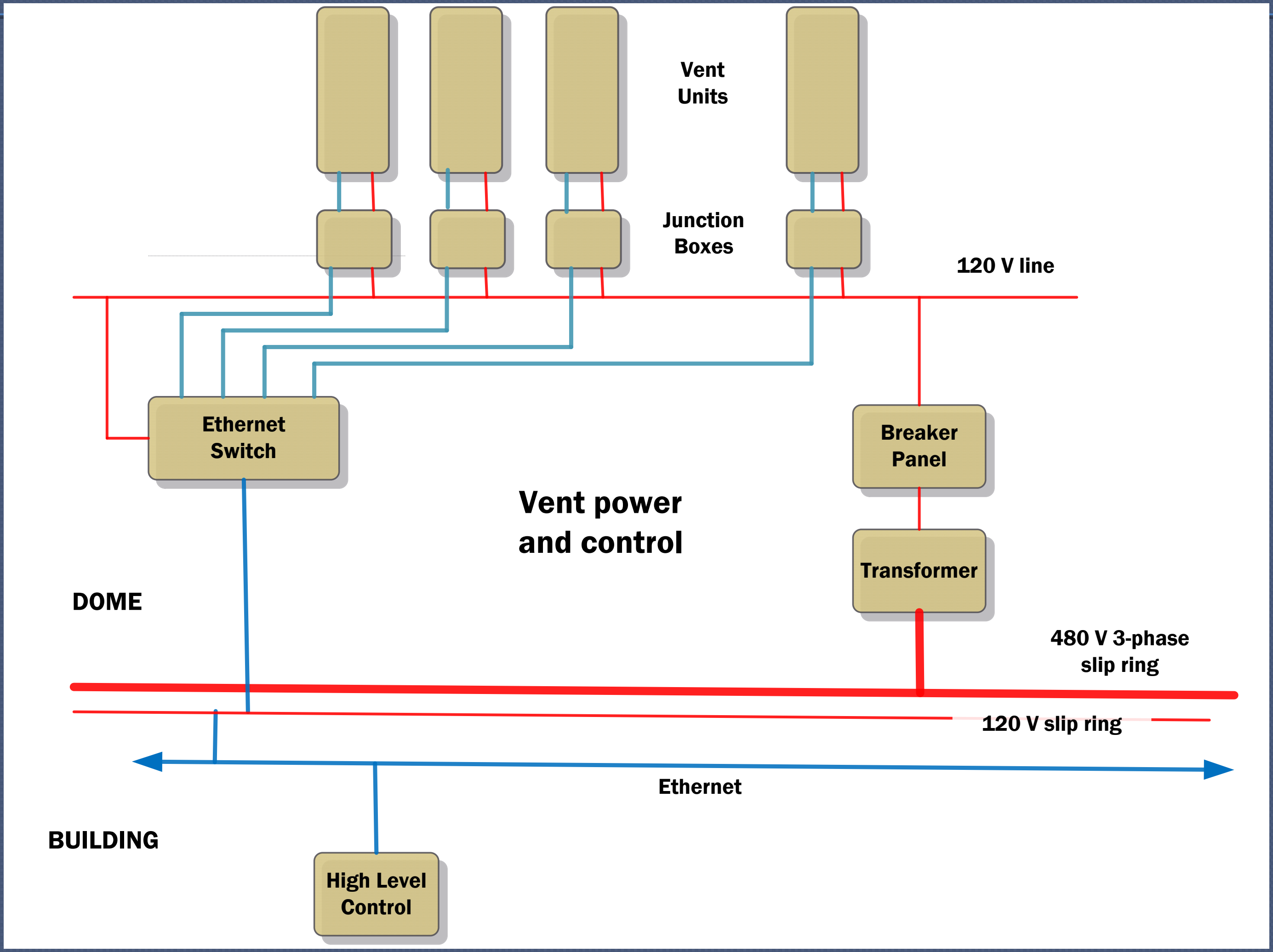


Prototype installation – April 24, 2013

Prototype – April 26, 2013

Control architecture



Controls and RO interactions

- Initially RO can select between 3 modes of operation – no "random" RO control permitted

- Mode 1 fully closed – wind, rain, snow, daytime – whatever mode

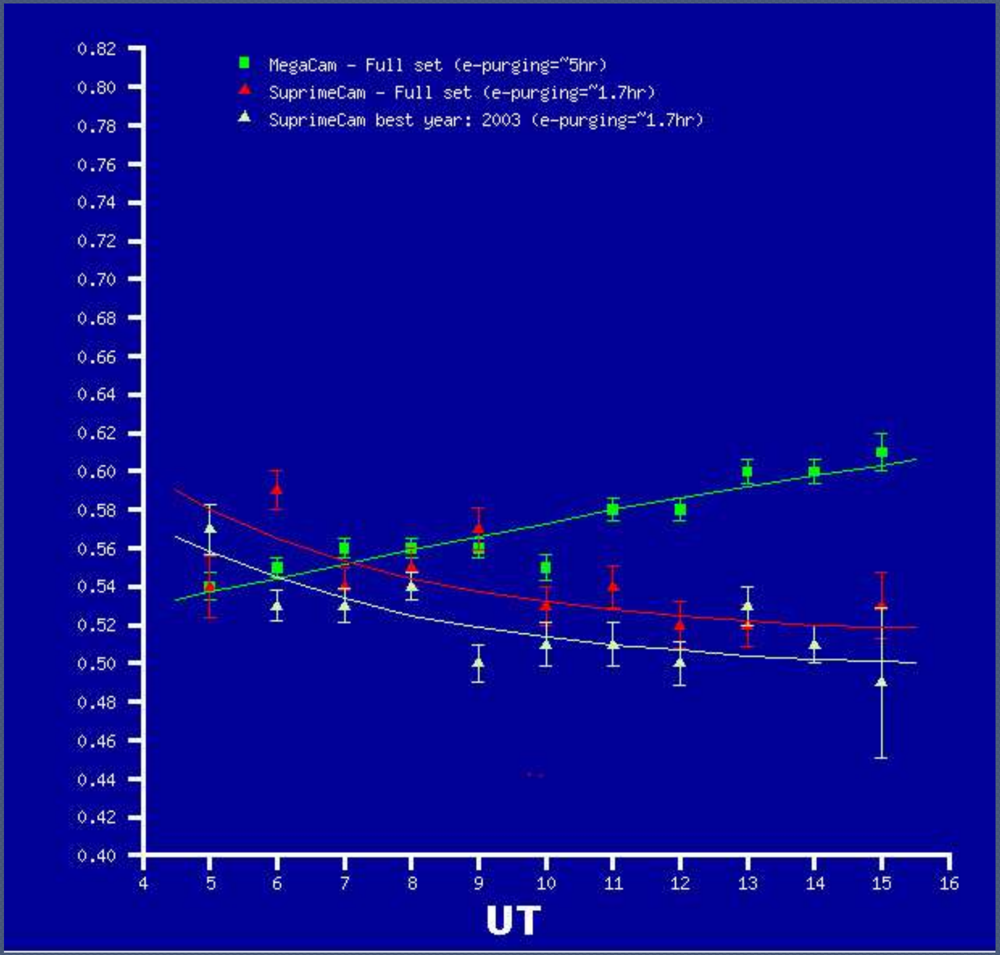
- Mode 2 all vents fully open, vanes pointed 20 degrees – directly into wind

- Mode 3 vents fully open vanes 20 degree down into wind, BUT to reduce wind shake:
  a) upwind vent(s) 1/3 closed or …
  b) upwind vent(s) 2/3 closed or …
  c) upwind vent(s) fully closed

- Reconfigure vents only if telescope is tracking (avoids crazies during slews)

- Reconfigure vents only if dome rotated more than 10 degrees

… and the gain is ?



Coming in September – 11 more !

Stay Tuned !

Primary mirror refiguring – ROM cost estimates

Requirements:

- cost / schedule for in-house work only (exclusive of shipping, etc)
- CFHT delivers the primary mirror and mirror support systems
- two options:
  1) refigure primary mirror maintaining conic constant and radius
     - maintain radius of curvature
     - maintain figure - parabola
     - 20 nm rms final figure error
     - test the delivered and in-process optical figure

  2) regrind/ refigure to a shorter focal length / new conic
     - radius change from 27 m to 15 m
     - 20 nm rms final figure error
     - test the delivered and in-process optical figure

Image quality improvement program (IQIP)

The Image Quality Improvement Program SAC / BoD – 2010
(a cost-effective means to improve CFHT's delivered image quality)

Four components:

1) Dome Venting – in process
2) Thermal Imbalance Mitigation - staffing
3) Dome Painting – LoMIT - after vent installation
4) Primary and Secondary Mirror Refiguring – ROM quotes

Primary mirror refiguring – ROM cost estimates

Company	Refigure	Regrind / refigure
Exelis (Kodak, ITT)	$2400k US / 77 wks	No interest
L3 – Brashear (Contraves)	No interest	> $3500k / 72 wks
LZOS (Moscow)	$ 325k US / 36 wks	No response
Sagem (Paris)	$1600k US / ?	> $ 2890 US / ?
Uof Arizona mirror lab	Interest - No specifics	Interest - No specifics

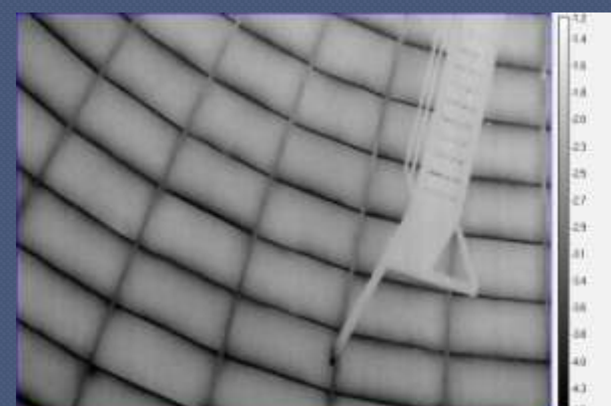
IQIP - Thermal imbalance status

Kevin Ho, Karun Thanjuvar, Sarah Gadjadhar

MegaCam storage electronisc - SOLVED

Dome hydraulic motors - ELIMINATED

WIRCam (non) cooling - PENDING



Dome skin print through - VENTING