Large Submillimeter Atacama Telescope

A Strawman Concept

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The Real Process

An Approach Which Ensures That the Science Drives the Design

- **Define Science Goals**
- **Derive Telescope Reqts**
- **Flow-Down Subsystem Reqts**
- **Develop Concepts**
- **Analysis & Modeling**
- **Formal Trades**
- **Integrated System Concept**

But…It's Also Useful to Develop Some Initial "Straw-Man" Concepts as a Vision of Where We Might Go

Straw-Man Assumptions

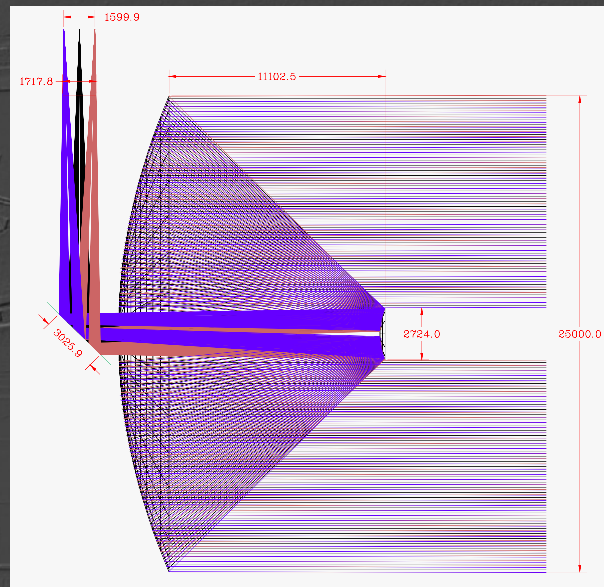
- 25 Meter Aperture: Not Confusion Limited for Exposures Up To ~24 hours @ 350μ
- On-Axis Design to Achieve Lowest Cost & Best Structural Dynamics
- Basic Ritchey Chretien Design
- Multiple Hot Instruments at Nasmyth
- Operational Wavelengths: Routinely to λ=350μ Operations to λ=200μ When Conditions Permit
- Site: Atacama Peak tbd
- Anticipate Dome Will be Required
  - Windloads Will Reduce Operational Envelope
  - Precision of Reflectors Will be Optimal if Protected

Basic Design

Primary Diameter	25 meters
Primary f/#	f/0.6
Total f/#	f/12 (CSO match)
Field of View	~18 arc minutes
Plate Scale	0.68755 arc sec/mm
Size of 18 arcmin FOV	1.57 meters
Maximum Array Size (Nyquist @ 18 arcmin)	~300 x 300
Window Size (256^2 Array)	1.56 meters
Secondary Diameter	2.62 meters
M1/M2 Distance	13.42 meters
M2 Obscuration	1.57%
Diffraction Limit	2 arcsec @ λ=200μ

Optical Design

- Classical RC
- Balance Between
  - Structural Problems if Longer & Slower
  - Field Curvature & Challenging Alignment Tolerances if Faster
- Permits Multiple Hot Instruments
- Principal Aberration is Field Curvature



This is a "Snapshot" of the Design Space…Work Needed!

Subsystem Concepts

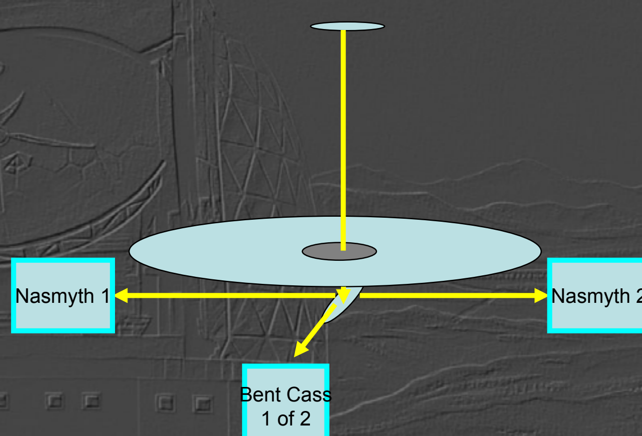
- Strategy: Take Advantage of Extremely Large Optical Telescope Design Studies
  - CELT, GSMT, VLOT, Euro-50 are Radio-Like Designs
  - Most in the 30 meter Size Class
  - We Can Scale Down!
  - Alternative to Scale Radio Telescopes to Larger Sizes and/or More Precise Tolerances
- Objectives:
  - Use Existing Technologies and Off-the-Shelf Components When Available
  - Minimum Part Count & Machining Operations
  - Allow Pre-Assembly and Test Prior to Disassembly and Shipping to Atacama
  - Engineer for Ease of Integration On-Site

On vs Off Axis

Lower Cost	Higher Cost (~2x)
Better Structurally (1.7Hz)	Poorer Dynamics (1 Hz)
Fewer Segment Types	More Segment Types (~2x)
Compatible w Nasmyth	Multiple Hot Instruments Problematic
Accessible Alignment References	More Difficult to Align
Less Aspheric Panels	More Aspheric Panels
More Blockage & Diffraction	No Blockage & Less Diffraction

Telescope Layout

- 2 Nasmyth Platforms Outside of M1
- 2 Bent Cassegrain
  - 1 Large Enough for Science Instrument
  - 1 Smaller for Wavefront Sensor for Mirror Optimization
- Rotating M3 Selects Instrument…Could be Fast Tip/Tilt for Jitter Reduction



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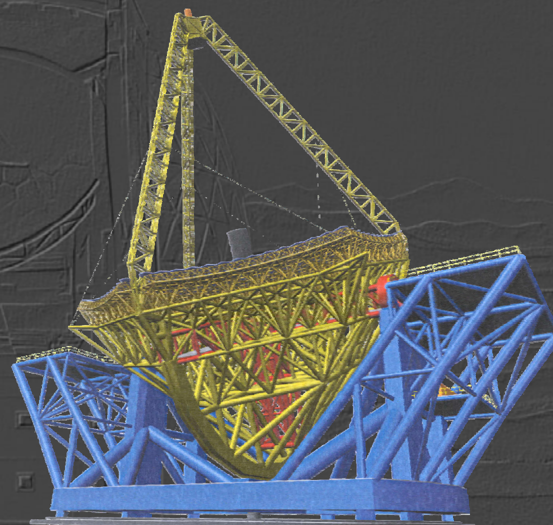
Telescope Mount

- Euro 50 Developed by T. Andersen et al, Lund
- Provides:
  - Well Resolved Loads into Hydrostatic Azimuth Bearings
  - Opportunity for Low-Cost Rolling Element Elevation Bearings w Large Holes
  - Stiff Sector Elevation Drive
- Balance Seems Good for Light Facesheets



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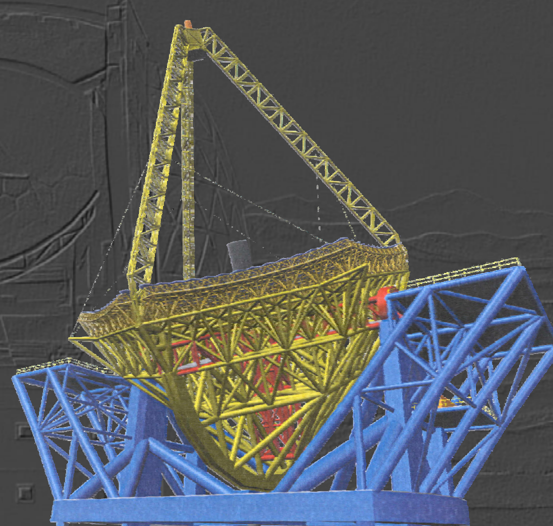
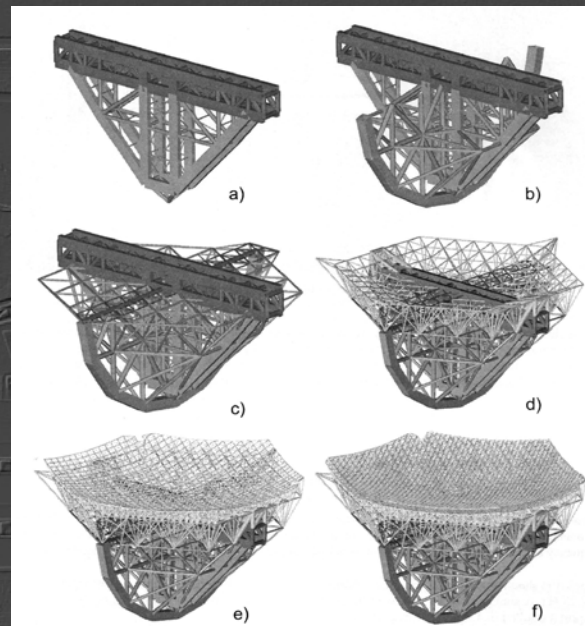
Advantages of "Optical" Nasmyth Approach

- Permits Elevation Axis to be Closer to PM
- Provides Large Level Platforms for Instruments
- Instruments Easily Changed
- Additional Bent Cass Focii Helpful
- Fewest Reflections Hence Maximum Throughput



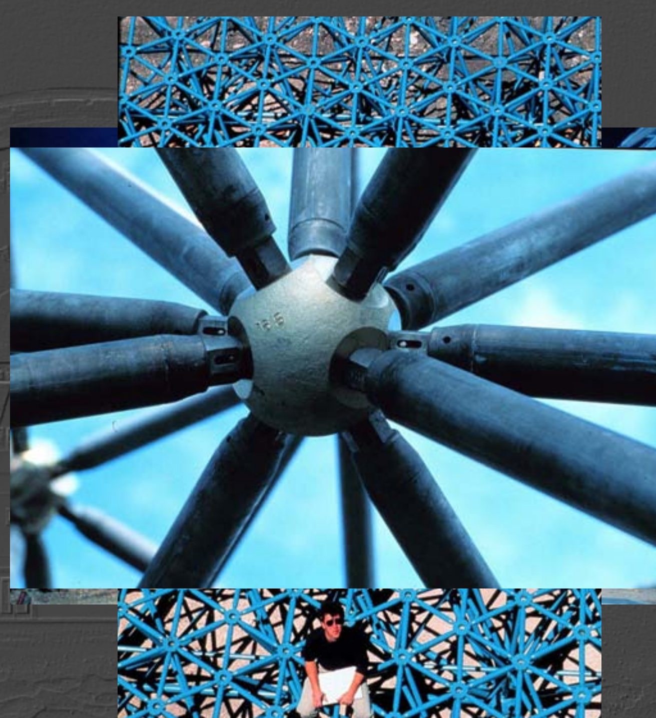
Mount Structural Build Up

- "Axle" Joins El Bearings
- Triangulated for Stiffness
- M3 in Housing at Center of "Axle"
- Additional Space Frame Structure to Sector Gear
- Provides Points for Mounting of M1 Truss & M2 Supports



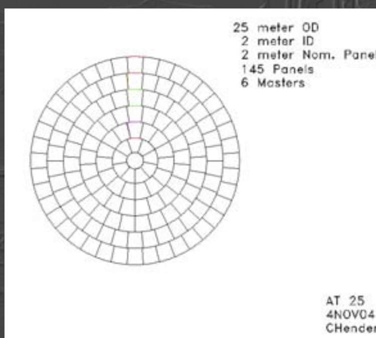
M1 Truss

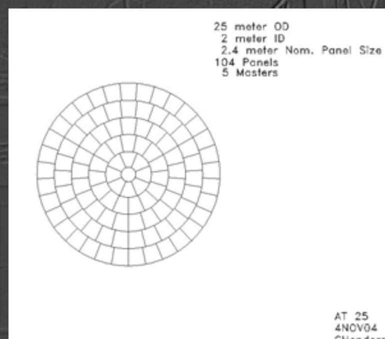
- Mero Structures
  - Wurzburg, Germany
- Hobby Eberly Telescope Truss
- 10m Diameter
- $400k Total
- Arrives in 1 Truck
- Assembles On Site
- Precision Manufacture via Robotic Machines

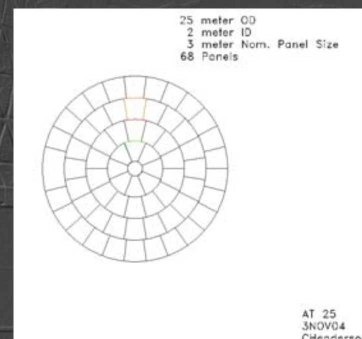


Panel Configurations

- Hexagonal Panels
  - Many More Segment Types, Only 6 of Each Type
  - Non-Circular Aperture
  - More Symmetrical Support Geometry an Advantage
- Radial Panels & More or Less Rings







Limit at 2.4 meters Fits Machinery Available to Make Masters to Optical Tolerances & Holds Potential for Simple 3 Point Support

Trade on Panel Sizes

Panel Size	Number Masters	Number Segments	Mandrel Cost	Panel Cost	Mirror Cost
2	6	145	$3,000,000	$7,975,000	$10,975,000
2.4	5	104	$3,733,694	$8,145,775	$11,879,469
3	4	68	$4,880,123	$8,306,555	$13,186,678
4	3	44	$6,892,190	$9,651,606	$16,543,797
	Mandrel Cost (r1/r2^2.2)			Panel Cost (r1/r2^2.1)	
	Diam			Diam	
	2	$500,000		2	$50,000
	2.4	$746,739		2.4	$73,325
	3	$1,220,031		3	$117,155
	4	$2,297,397		4	$214,355

- There is a Range Over Which Total Cost is About the Same… Must Consider
  - Machine and Process Limitations
  - Substrate Formation for Mandrels a Problem
  - Supports Become More Complex
  - Optical Telescopes Have Mostly Decided on ~1 meter
  - 2.4 Seems Good for a Straw-Man…5 rings…Existing Machines

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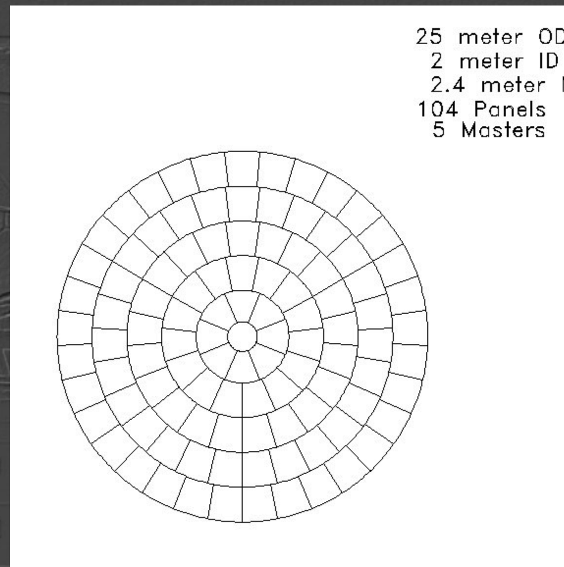
M1 Panel Segmentation

- Circumferential Preferred as Many More Panel Types for Hexes
- Size of 2.4 meters Allows 5 Panel Types and 104 Panels
  - 2 meter Panels=145 Panels and 6 Types
  - 3 meter Panels=68 Panels and 4 Types
- 2 Optical Mfgs Have Equipment to Make and Measure Mandrels to 2.4 meters



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Panel Materials Trades

Glass	CFRP	Nickel/Al	Machined Al
Heavy & Low Specific Stiffness	Light & Excellent Specific Stiffness	Light & Excellent Specific Stiffness	Light & Good Specific Stiffness
No Replication Technique	2 m Replication Process Extant	Replication to 1 meter Sizes	Machined 1x Time
Moderate CTE for Affordable Glass	“Zero” CTE	Bimetallic CTE	High CTE
Expensive in Larger Sizes	Moderate Scaling Not a Problem	Scaling Process Expensive	Machining in Larger Sizes Difficult & $$$
Cored Techniques Expensive	Cored Techniques Inexpensive	Cored Techniques Less Expensive	Expensive Machined Coring
Uniform & Temporally Stable	Uniformity & Stability Depend on Layup & Matl.	Bimetallic, Temporally Stable	Uniformity an Issue Temporally Stable
Requires Coating	Requires Coating	No Coating Required	No Coating Required

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Panel Construction

- CFRP Panels Preferred
  - Replication Process
  - Dimensionally Stable
  - Monolithic Material
  - Low Aerial Density
- FIRST Mirror (COI)
  - 2 meter Diameter
  - Meets Dimensional Requirements
  - Successful Environmental Testing
  - Compatible with Sputtered Metal Coatings

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Mandrels for Panel Mfg

- Optical Profilometer at Goodrich
- Precision to 1μ
- Mandrels of Borosilicate Glass
- Machine to ~ 10 μ RMS, Then Polish to Final Required Shape
- No Optical Testing, Only Profilometry
- Shine Back Surface

Similar Capability at "Eastman Kodak"

Mirror Support/Actuation Trade

Direct Support	Whiffle Tree Support
3 points on Back Surface	9 Point Support Likely
Loads Distributed by Substrate	Loads Distributed by Whiffle Tree
Central Support for Lateral Loads	Central Support for Lateral Loads
3 Flexures Accommodate Dimensional Changes	9 Flexures Accommodate Dimensional Changes
Invar Intermediate Interface Structure	No Intermediate Structure
Low Part Count	High Part Count

An Objective Will be to Design Substrates to Enable Use of Simplest Support Strategy

Panel Support and Actuation

- Panels Supported on 3 Points Kinematically
  - Or 4 with Simple Whiffle Tree for Two
- Actuators for Tip/Tilt and Piston
- Panel Cores Designed to Accommodate 3 or 4 Point Mounting
- One Actuator per Truss Top Surface Node
- Need to Decide How to Accommodate CTE Difference Between CFRP and Steel
- Center Hub Accommodates Lateral Loads (Gravity at Horizon)

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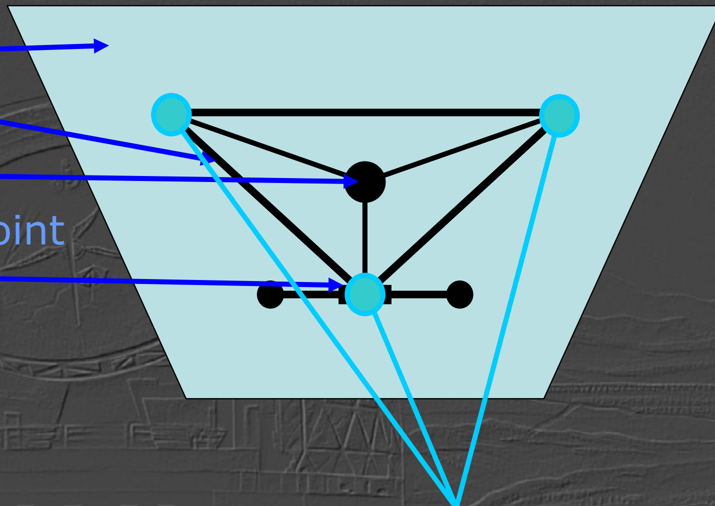
1st Panel Mount Concept

- Facesheet
- Invar Frame
- Center Hub
- 1 to 2 Support Point Whiffletree



Devil in the Details for These Systems!

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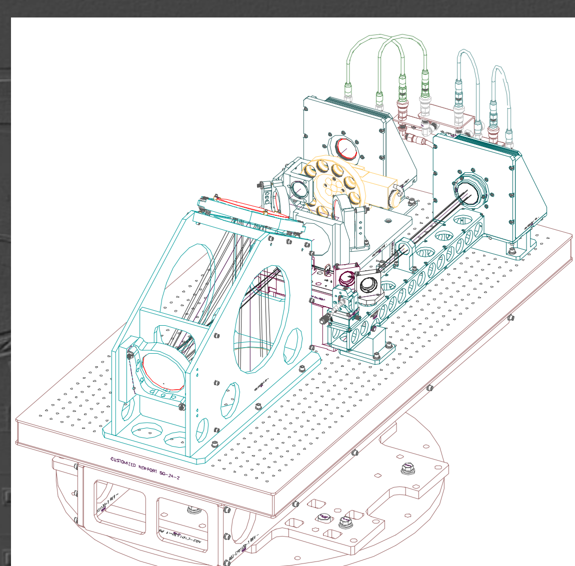
Panel & Telescope Alignment

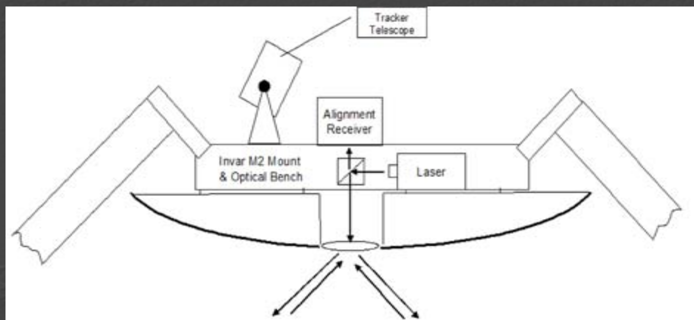
Will Need Calibration Sensor…Holography & Rangefinding Systems Run Out of Gas at 200μ

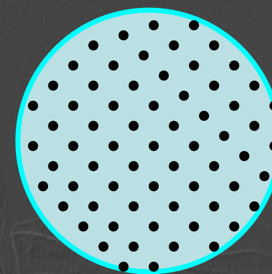
- Panels Coated to Provide Good IR Reflectivity
- Bent Cassegrain Position Used for Wavefront Sensor (Shack Hartmann Likely) in IR
- Panel Tip/Tilt and Piston and M1/M2 Alignment Optimized on Stellar Source
- Used to Calibrate Operational Alignment Maintenance Sensor



SOAR Telescope Calibration WFS

Alignment Maintenance Sensor





- Shack Hartmann Like Sensor Sends Beams to Segments
- Return Mirrors Form Spot Pattern in Receiver
- Panels Actuated to Maintain Spot Alignment
- Mechanical Reference to M2 Maintains M1/M2 Alignment
- Addition of Tracker Links Telescope Optical Axis to Pointing/Tracking Control

Dome Concepts

- Calotte Type Dome
  - Proposed by Canadian VLOT Concept
- Two Rotating Segments
- Steel Interior Frame
- Aluminum or Fiberglass Panels
- Top Drive via Cable Wrap
- Rotate Opening to Lowest Position and Use Panel on Hydraulic Rams to Close

Conclusions

- Prior Concepts Exist for Many Required Subsystems
- Application of Optical Telescope Technologies Probably Useful for "Transoptic" IR/Submm Telescopes
- Manufacturers of Subsystems Must be Included in Concept Development Process to Get Best Price and Technologies
- LSAT Will Almost Certainly Include:
  - Panel Position Sensing and Active Alignment
  - Panel/Telescope Maintenance Alignment System
  - Dome for Protection from Wind and Weather