An Engineering Report on the 25 m Radio Telescope

General discription

Figure 1 through 3 shown the 3 general views of the radio telescope. This telescope is altitude-azimuth mounted. The elevation range is from horizon to 35° beyond the zenith; and the azimuth range is 270° in both directions. The elevation motion is driven by the elevation drive assembly on the mounting tower against ~~on~~ the elevation wheel about the elevation axis. There are four azimuth trucks. Each truck carries drive motor, gear box and brake, and has a ~~$~~ capacity to 35 ton in case the telescope is protected by a dome, or ___ tons for a exposed telescope. The ~~top~~ entire structure ~~f~~ rotates about a pintle bearing at the center. ~~The~~ Pintle brg takes the lateral force induce by wind. A cable wind-up passes through its center, provides a ±270° rotation. The ~~radius~~ diameter of the azimuth track is 35 feet.

During the normal operation, the telescope is able to track a radio source at the azimuth and elevation rate which corresponds to the sidereal rate of the source. The max. acceleration rate on both axis is

0.25°/~~sec~~ sec². The telescope has a full sky coverage except a cone of avoidance with a 2.5 degree radius near the zenith. The telescope can slew to stow position at an adverse situation at a rate of 20° per minute.

The telescope's life expectancy is 20 years. It is design to sustain a 120 mph wind at stow position, or a 20 lb/ft² snow load on the surface.

~~Parallel efforts~~ There are parallel efforts in studies of the telescope should be protected by a dome structure or to be exposed to environment. The telescope structure, on the other hand, has been optimized with respect to its weight that the structural design is governed not only by survival condition but also by geometry as well. A protective dome will eliminate large wind and thermal deformation and point, but will not reduce the total cost of material of the telescope in a great extend.

The analysis of the telescope are divided into four major components. ~~However~~, the result of the analysis on ~~each~~ one component became an input parameter of other component, that ~~repeati~~ it is necessary to cycle the analysis several time in order to ~~so~~ ~~net~~ resolve a final result. The four components are (1) Back-up structure, (2) Intermediate panel structure (3) Feed support structure and (4) Mounting structure.

The design goals are mentioned in detail in various reports ( ), ( ). The telescope is designed to observe the radio universe at a shortest wave-length of 1 mm (300 GHz) under a suitable environment. The overall ~~deviation~~ ~~from~~ tolerance of the surface is 2 μ rms, at 30% ~~opti~~ aperture efficiency. The overall pointing error is 1.6 arc-sec, ~~based~~ at one fifth of half power beam width. The surface deformed mainly due to gravity ~~tolerances~~ ~~thos~~ ~~and~~ and manufacturing ~~error~~ error and rigging accuracy. The pointing error are mainly induced by wind and temperature difference.

The tools for these analysis consist of ~~(1)~~ Homology optimization program, version no. 9; ~~the program is developed in NRAO based on~~ STRUDL for static and dynamic structural analysis; Half span length least square best fit program for surface tolerance analysis; REPLACE program for selections of ~~comp~~ commercially available tubings ~~and members~~; and various computer programs for data generations and graphic presentations.* The recent replacement of IBM 360, model 50 by model 65 had greatly enhance the speed of computations. A factor of 4 ~~improvement~~ improvement reduce the computational time of homology optimization from ~~260~~ 160 min to 40 minutes.

In order to view this particular 25 meter radio telescope design in relation to other similiar antenna ~~with the same~~ in size, various parameters are list below for comparison:

* Wind loadings information is based on (JPL-CP4), on the results ~~in~~ published in the report; load distribution on the surface of paraboloidal reflector antennas

	Homology	VLA	NRAO Interferometer	Chilbolton/Eng
Wt (kip)	253	511	660	800
λ_{min} (mm)	1.1	12.0	39.5	30.0
Wind ptg (sec)	5.4	9.0		1.4

Adding material to the structure usually means a stiffer structure, as illustrated by the British Chilbolton aerial. Surface accuracy, on the other hand, depends more on the analytical method. In this case, the homology telescope clearly ~~the~~ is a light weight and precision instrument.

~~Mockup Structure~~ -

Specification and Criteria

The structure is analysis in accordance with the specification ~~suggested~~ by A.I.S.C. Manual of Steel Construction ~~Section 1.5 and 1.6.~~ ~~(In addition Addition guide lines~~

Cor-Ten (U.S. Steel trademark) steel is choosed for its high yeild strength. Its corrosion resistance is six times higher than normal steel. It is specially advantageous for tubings with thin wall thickness.

Maximum slenderness ratio is decided upon 200. Effective length factor is 0.8 for all members with cross-sectional area less than 0.4 sq. in.

Stress ~~ratio~~ of each member under survival load is ~~derived from~~ a combination of the corresponding axial stress and the max. bending stress under the dead wt. of the member. The stress level should be less than the allowable stress suggested by the A.I.S.C. Manual.

The lateral dynamical frequency of each member is not low than 2.5 Hz. It is demanded that the the diameter of each member either large enough that the air flow around the member is turbulent; or the alternating stress due to vibration is less than 25 ksi.

The wall thickness of each member should not be less than ~~[illegible]~~ 0.1 inch. ~~[illegible] It is considered that impossible to weld~~ for weldability. However, it is also demand that the wall thickness should not ~~more~~ be larger than 0.4 inch to maintain the ground time constant of the structure ~~is less than~~ about half an hour. ~~[illegible]~~ Furthermore, ~~local buckling~~ selected member ~~will not fail locally~~ should have a wall thickness large enough to avoid local buckling.

B U

Reflector structure

(Insert A)

The structure has two planes of symetry. It consists of 580 major structural members and 172 structural joints. The connections between the surface points (homologous points) represents the stiffness of the corresponding intermediate structures. It is necessary to iterate the analysis cycles several time. The forces on the intermediate structure obtained from the back-up ~~reflector~~ structure analy. ~~are used on the~~ These forces are in turn used on the intermediate structural analysis in order to ~~obtain~~ insure an ~~the~~ acceptable ~~intermediate~~ design structure. In case the intermediate structure requires changes, the adjusted stiffness are reflected on the ~~reflec~~ back up structure again for a new analysis. These ~~steps~~ solution converges after several cycles.

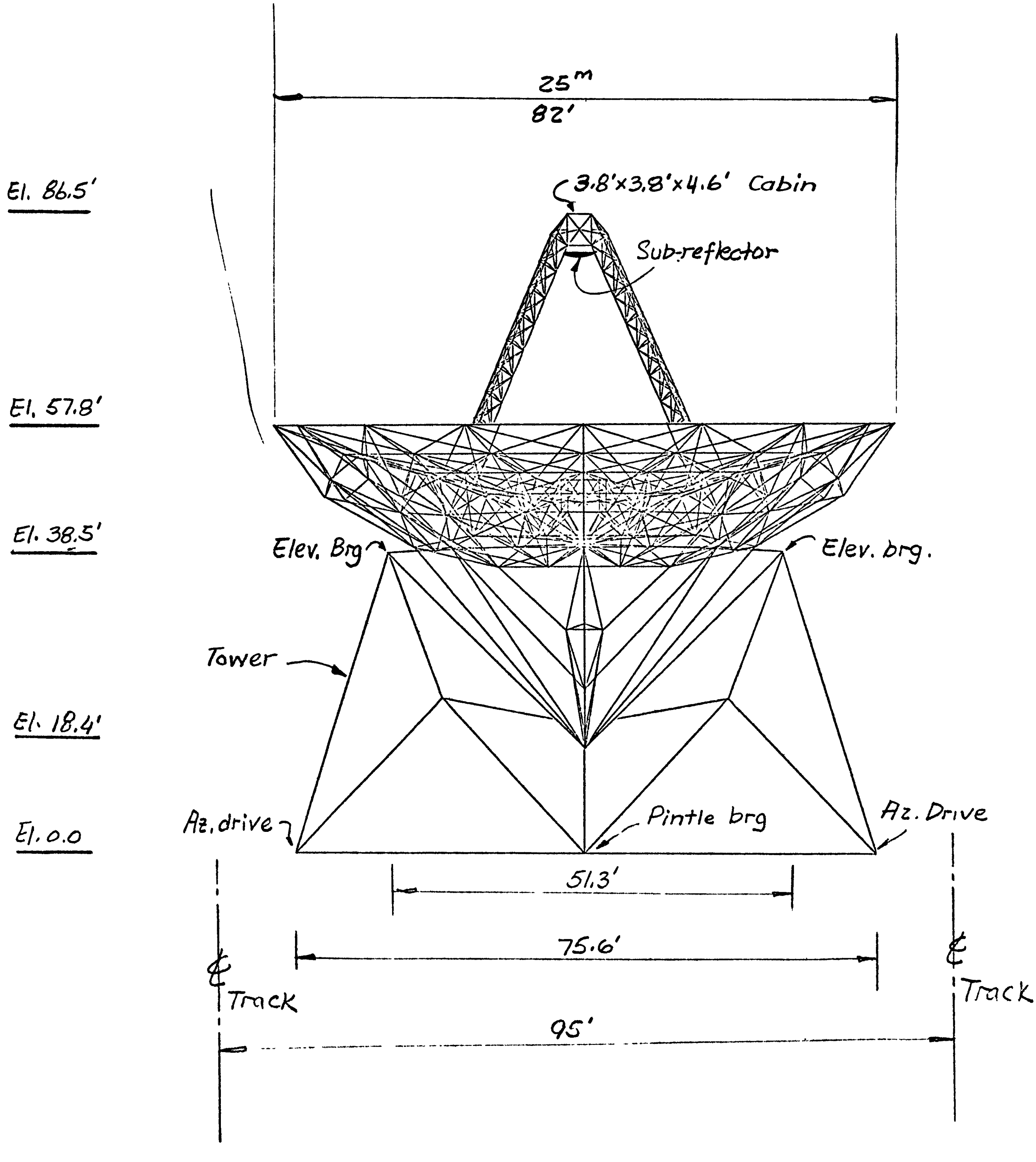
Insert (B)

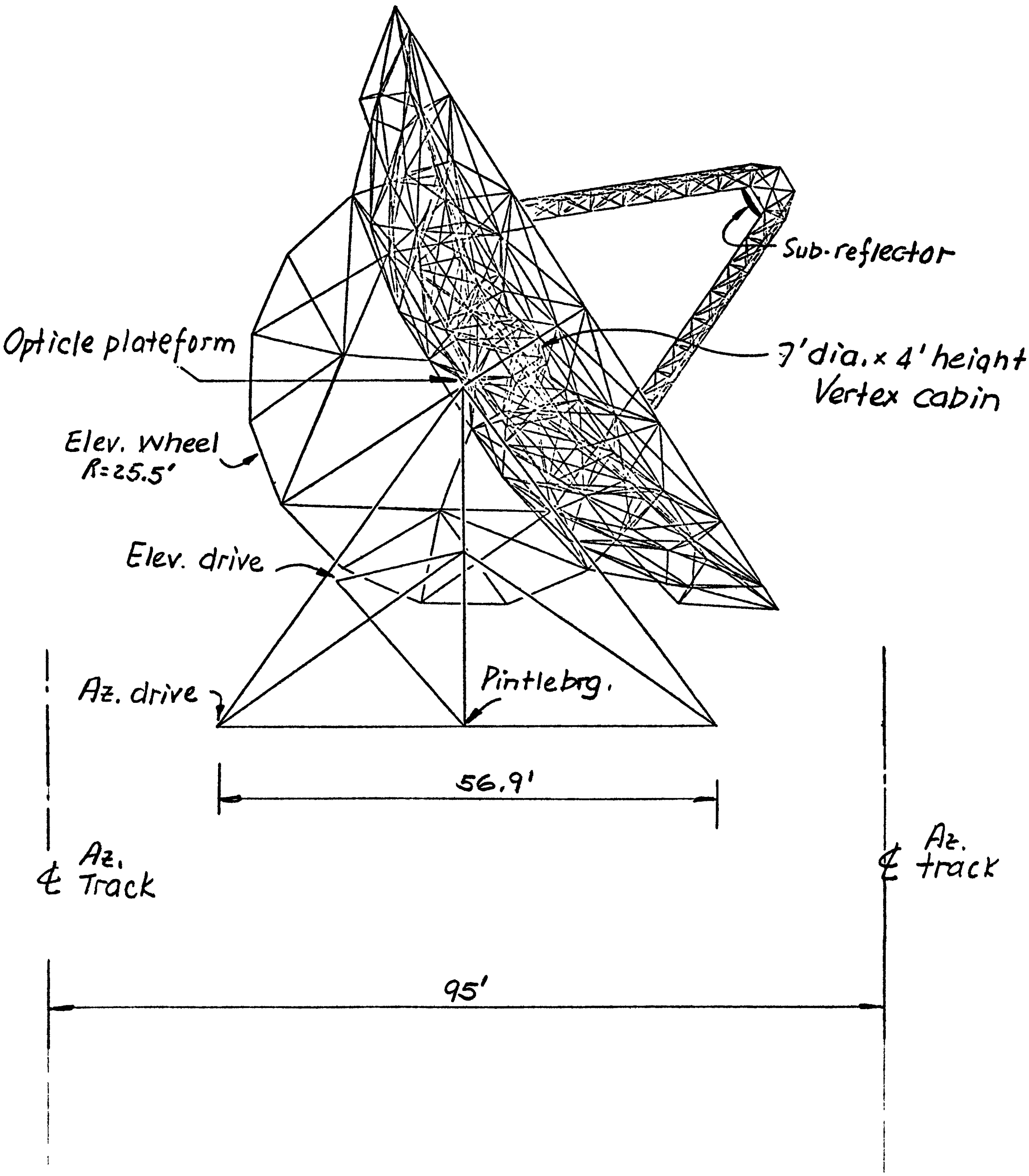
There is a ~~provision~~ space close to the vertex provided for the installation of the optical platform. Clearance between members are check by a computer program to insure a space between each member and the angle between to joining members is no less than 13°.

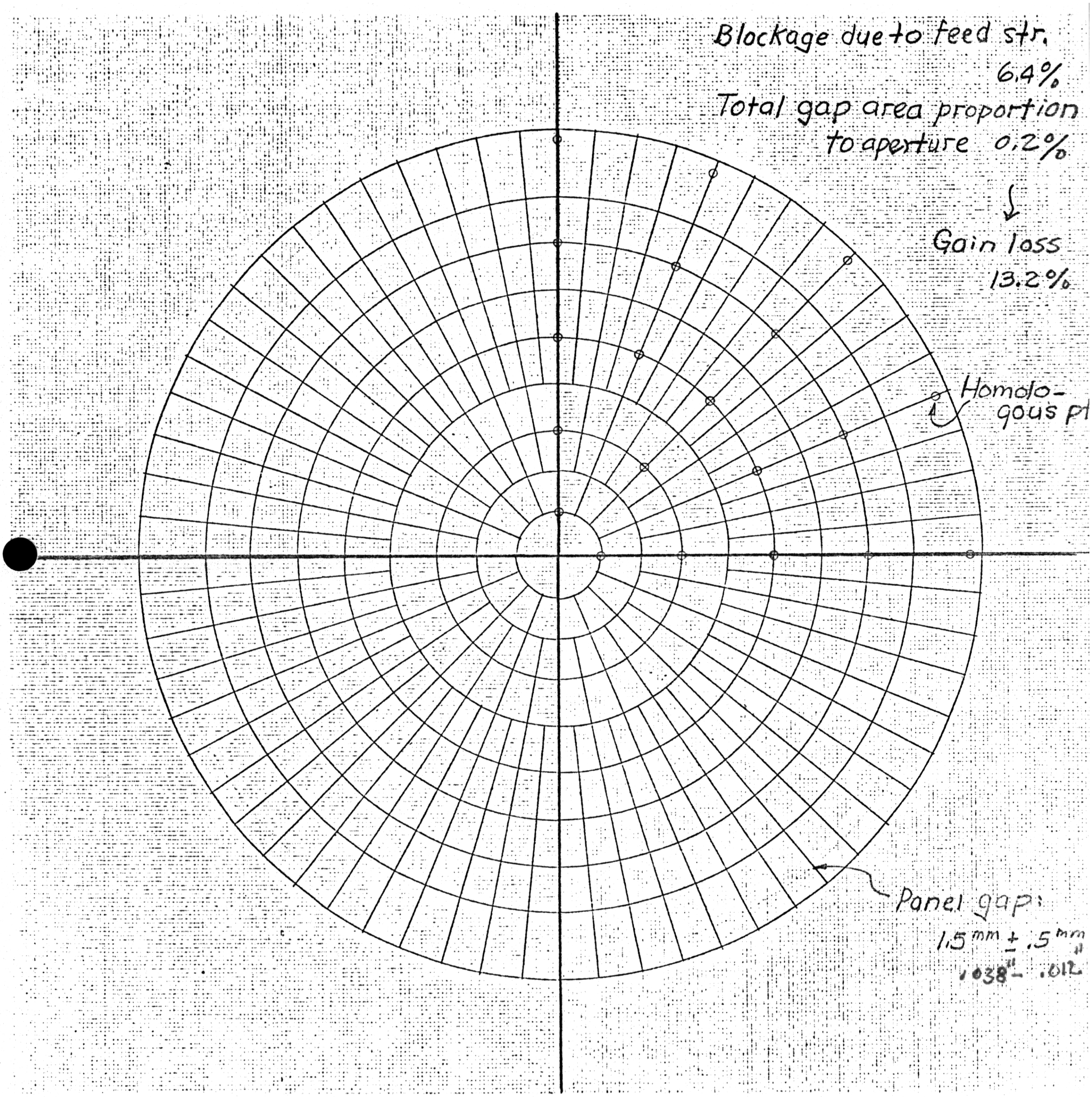
(B) The basic configuration is a tetrahedron suspended by heavy members, connecting to the elevation bearings. Four members of the tetrahedron formed the feed supports. Unlike most of the antennas, the feed support members are active in structural sense. However, the size of the feed structure is defined not by homology solution but by the pointing requirement of the feed. With radome or astrodome, it is possible to reduce the size of the feed structure, which in turn reduce the need counter weight. In this aspect, the over all weight of the reflector will be lighter inside the protective dome.

A Review of Design - 25^m telescope

- W.Y. Wong 4/17/74




Sub-reflector
Opticle plateform
7'dia. x 4' height
Vertex cabin
Elev. wheel
R=25.5'
Elev. drive
Az. drive
Pintle brg.
56.9'
Az.
Track
Az.
track
95'



Surface plates arrangement for the 25 m telescope.

Avg. size : 65" × 30"
Total no. : 400
Total surface area : 5820 S.F.

WEIGHT

		Structural Wt		
Feed Structure	2.3^K	87.1^K	Wt. on elev. brg.	
Reflector structure	84.8^K		156.6^K	
		Loads		
Surface plates	22.1^K			Wt. on az. track
Counter Wt.	28.4^K	69.5^K		241.6^K +Pintle brg
Drive & Brgs	15.0^K			
Instrument	4.0^K			121 Ton
Tower structure	85.0^K			

Comparison with the 25m VLA telescope

	Homology	VLA
Reflector, Includes Surface plates, feed,	116^K	140^K
Counter Wt.	28^K	180^K
Mounting structure	97^K	187^K
TOTAL	241^K	507^K

No. of structural members	581	428	1630 } ?
No. of structural joints	172	163	670
No. of Surface structural Pt.	60	290	

K: kip, =1000#

: Wind pointing error @ 18 mph for Cassegrain optic

Rotation of Best-Fit on main reflector	+ ~~7.0~~ 5.3	sec
Lateral translation of sub-reflector	− ~~1.6~~ 0.6	sec
Rotation of sub-reflector	+ ~~1.3~~ 0.1	sec
Rotation of tower	+ ~~2.8~~ 0.9	sec
Σ	+ ~~9.5~~ ~~2.6~~	sec
RSS	5.4	
RMS	2.2	sec

These are 3σ values, based on 18 mph wind, with angle of attack equals 120°

RMS Pointing Error due to 18 mph wind* $= \frac{3\sigma}{3} = 3.2$ sec

Surface rms due to direct wind @ 18 mph = ~~0.0007 in~~

= 0.0016 in

Effect of wind deformation on panel = ~~0.0008~~ 0.00002 in **

Effect of wind deformation on plate = 0.0006 in **

Effect of wind on sub-reflector = 0.~~0002~~ .00003 in **

RSS = 0.~~0012~~ ~~.0019~~ in

0.0017 in

RMS = 0.4 × RSS

= 0.00068 in

* A detail investigation for pointing error with various wind direction is in preparation. Information will base on JPL-CP4 wind data.

** J.W.F. + S.V.H. "A 65 m Telescope" P. 93

Deviation from Homology	$\Delta H_1 \times 10^{-3}$ in	$\Delta H_2 \times 10^{-3}$ in
Structural design throught homologous Optimization	0.21	0.10
Add spherical joints	0.60	0.20
Manufacturing error, coordinates off randomly by ±.25 in.	0.53	0.33
Replacement of commercially available tubing	0.24	0.11
RSS	0.86	0.41
RMS		0.67×10^{-3} in

Contribution to the surface errors (No wind)	$\times 10^{-3}$ in	
Deviation from homology	0.67	Deviation
Panel gravity deformation	~~1.00~~ 0.74	~~Estm.~~ 5/13/74 panel [illegible]
Fabrication tolerance of surface plates	0.50	N/C, milled skin
Gravitational deformation of surface pl.	~~1.40~~ 0.81	Same as 65m
Surface plates setting accurracy	2.00	- J.F + J.P.
Subreflector	1.00	Estm
RSS	~~2.94~~ 2.67 $\times 10^{-3}$ in	

Point Error and Surface Error due to 18 mph Wind

Back-up structure

Pitch angle	Rotation of B.F. (arc-sec)	Rotation of R.F. due to feed movement *	Surface Best fit error ($\times 10^{-3}$ in)	W
0°	-0.4		1.0	0
60°	-11.8		3.8	.87
90°	+4.4		0.3	1
120°	+0.8		1.0	.87
180°	-1.4		0.4	0
				$W = \sin\alpha$
Wted RMS	5.3 sec		1.64×10^{-3} in	

* Wind force is a function of α, or equals $F \sin\alpha$. Discount the defocusing effect, the lateral deformation equals $\Delta = R \cdot F \sin\alpha$. where R is the lateral deformation in X or Y direction where the telescope is a zenith position.

Thermal deformation of the 25 m telescope

Based on report by V. Herrero, dated Oct 6, 1970, the max. temperature different at 85' ft - 1 is 5.4 °F at 95% level. Temperature different of 5 °F is also used in the design of VLA telescope. $\Delta T = 5.4°F$ is to be used in this 25 m telescope study. $\Delta T = 2.0°F$ for night.

<u>Z-gradient</u> - A temperature different of 10°F between 2 extreme pts in Z direction (Zenith direction) of the back up structure shows the following result:

① Tilt of axis: 0 arc-sec

② Best fit of surface pts 3.16×10^{-3} in. Rms

③ ~~Defocusing due to thermal~~ Z deformation of the focal pt.
10.39×10^{-3} in

④ Parallel shift of the best fit paraboloid
1.99×10^{-3} in

Based on items no. ③ & ④, the defocusing due to 10°F temp different is: $(10.39 - 1.99) \times 10^{-3}$ in $= 8.4 \times 10^{-3}$ in.

The corresponding surface error

⑤ $\sigma = 0.0589 \times 8.4 \times 10^{-3} = 0.49 \times 10^{-3}$ in

Item ② & ⑤ are correlate errors and they are additive.
The total error is $(3.16 + 0.49) \times 10^{-3} = 3.65 \times 10^{-3} / 10°F$ or $0.37 \times 10^{-3} / °F$ or, for 95% level, the thermal def. of the 25 m telescope back up structure is

$\Delta Z = 1.97 \times 10^{-3}$ in rms. day, full sun
$\Delta Z = 0.74 \times 10^{-3}$ in rms night

Thermal deformation on the surface plate, based on S.V.H. report no. 37, is 0.85×10^{-3} in /F°. Since we are using the same design on surface plate, this figure can be considered valid. Also, based on the measurement of surface plate, the thermal difference during the day time is 12° F max., for clear night, $\Delta T = 2°F$.

$\Delta Z = 10.2 \times 10^{-3}$ in rms day, full sun

$\Delta Z = 1.7 \times 10^{-3}$ in rms night

~~No works have been done on the panel structure yet.~~

~~Again, adopting the figures from 65" design~~ Panel B (5/13/74)

$\Delta Z =$ ~~5.24~~ 0.99 $\times 10^{-3}$ rms in day full sun

$\Delta Z =$ ~~0.87~~ 0.16 $\times 10^{-3}$ rm in night.

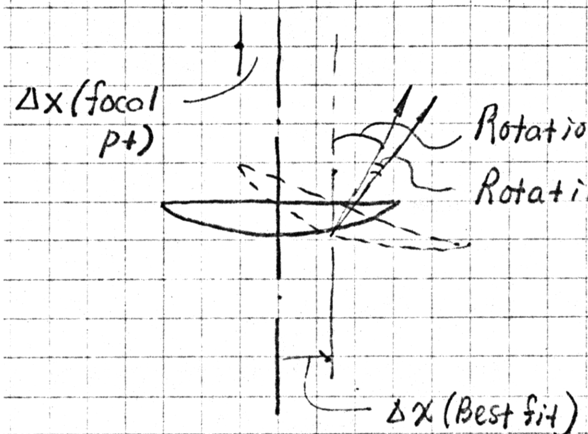
Thermal deformation for the complete telescope

	Day, full sun	Night	$\times 10^{-3}$ in
Backupstruct.	1.97	0.74	
Panels	~~5.24~~ 0.99	~~0.87~~ 0.16	
Plates	10.20	1.70	
RSS	~~11.64~~ 10.44 $\times 10^{-3}$ in	~~2.05~~ 1.86 $\times 10^{-3}$ in	~~(3σ)~~
	~~3.88 $\times 10^{-3}$ in~~	~~0.68 $\times 10^{-3}$ in~~	~~(1σ)~~
ΔT (overall)	5.4°F	2.0°F	~~(95% level)~~

X-Gradient

Based on 10°F temperature diff. in X-direction :

Surface rms	0.04×10^{-3} in.
Rotation of best fit	-1.6 sec
Δz deformation of feed	0. in
Δx deformation of feed	-5.71×10^{-3} in
Δx of best fit	5.39×10^{-3} in



Rotation of best fit = 1.6 sec

Rotation due to shift of focal pt $\cong \dfrac{\Delta x \text{ (focal pt)}}{\text{focal length}}$

$$= \frac{5.71 \times 10^{-3}}{34.8' \times 12} = 1.37 \times 10^{-5} \text{ rad}$$

$$= 2.82 \text{ sec}$$

Total pting per 10°F = 4.42 sec

Full sun shine , $\Delta T = 5.4°F$ $\qquad \varphi = 2.4$ sec

Clear night $\quad \Delta T = 1.5°F$ $\qquad \varphi = 0.7$ sec