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# Optimization of 100-meter Green Bank Telescope

Douglas Strain

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Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California

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## **Acknowledgment**

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## **Abstract**

Candidate designs for NRAO's 100-m clear-aperture radio telescope were evaluated and optimized by JPL using JPL-developed structural optimization and analysis software. The weight of a non-optimum design was reduced from 9.4 million pounds to 9.2 million pounds. The half-pathlength error due to gravity deformations was reduced from 0.041-inch rms to 0.034-inch rms.

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## Section 1 Introduction

The National Radio Astronomy Observatory (NRAO) is designing and building the 100-m clear aperture Green Bank Telescope (GBT) in Green Bank, West Virginia. This structure will be the largest fully-steerable radio telescope in the world, and will stand almost 500 feet high. This report describes efforts to reduce the weight of the elevation tipping structure model while improving its performance using JPL-developed microwave antenna structure optimization software.

The telescope structure will comprise a "ring and rib" main reflector backup structure and a subreflector boom supported on an "elevation box" structure. The elevation box also supports the elevation drive gear and counterweight. The tipping structure rotates on a heavy shaft between the elevation bearings at the top of the alidade. The alidade rotates on a 64-meter-diameter track (see Figure 1).

The topology of the rings and ribs of the backup structure is a circular section of a 208-meter-diameter symmetric paraboloidal geometry (see Figure 2). This arrangement was chosen to take advantage of the repetitive panel shapes in order to achieve economies of scale in the manufacture of the reflector surface panels.

NRAO has developed NASTRAN finite element models of the alidade and elevation components of the proposed structure. These models were used for verification purposes during the structural design. The objective of the JPL effort reported here was to reduce the weight of the telescope elevation tipping structure while improving its performance. The NRAO NASTRAN models were used as the starting points for this task.

The optimization effort proceeded in two phases: Phase 1 was completed in August 1993, and Phase 2 was completed in March 1994. Each phase was similar in that a "final design" was proposed by the design contractor and then JPL attempted to improve it. The improved model from the first phase was accepted by the contractor, who made modifications and updates to the optimized model to facilitate fabrication and construction. These modifications caused an increase in weight and a loss in performance. The second phase used this modified model as a starting point and (although not as dramatically as the first effort) also reduced the weight of the model and improved its microwave performance.

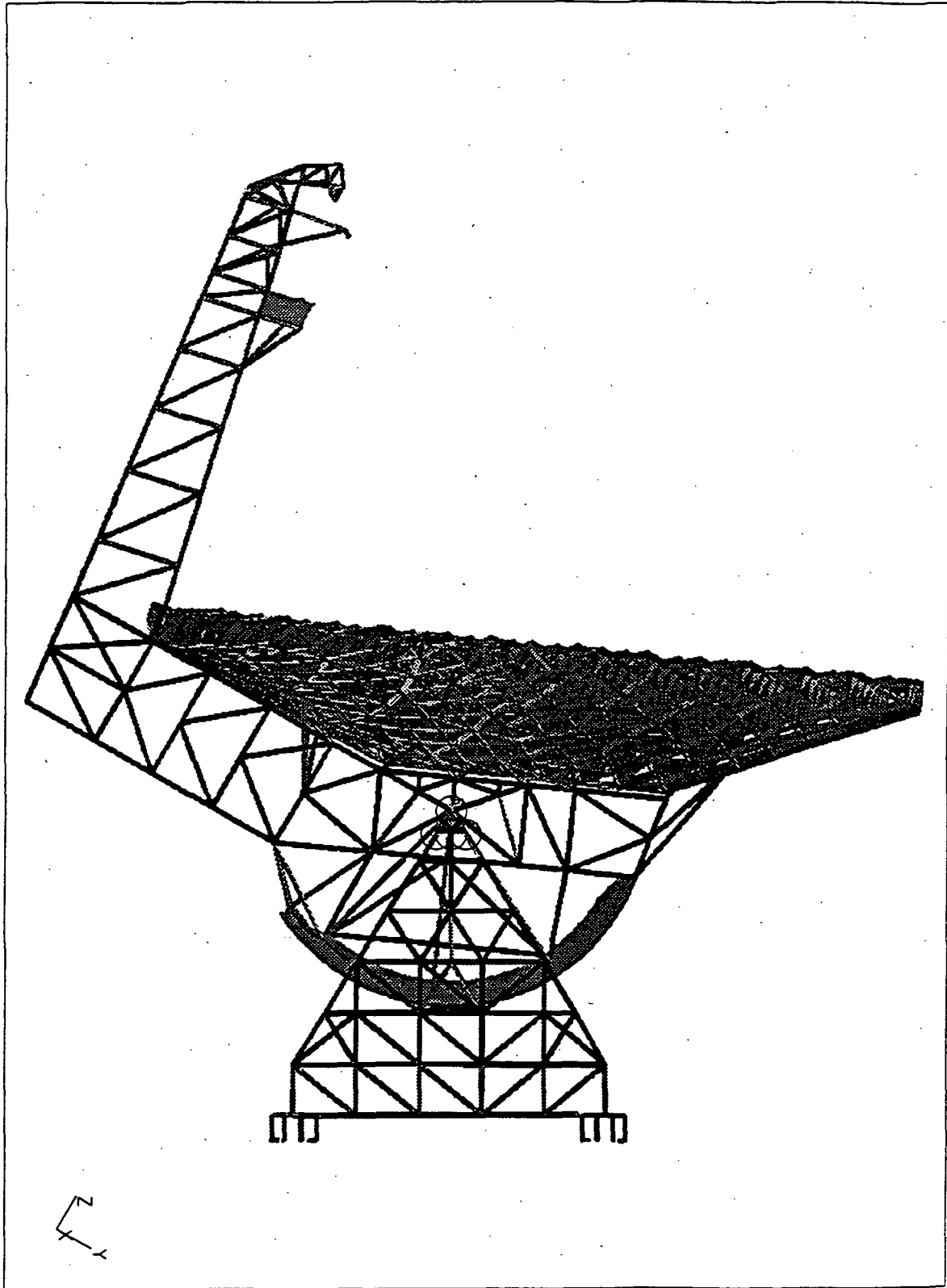


Figure 1a. Green Bank Telescope at 60° Elevation

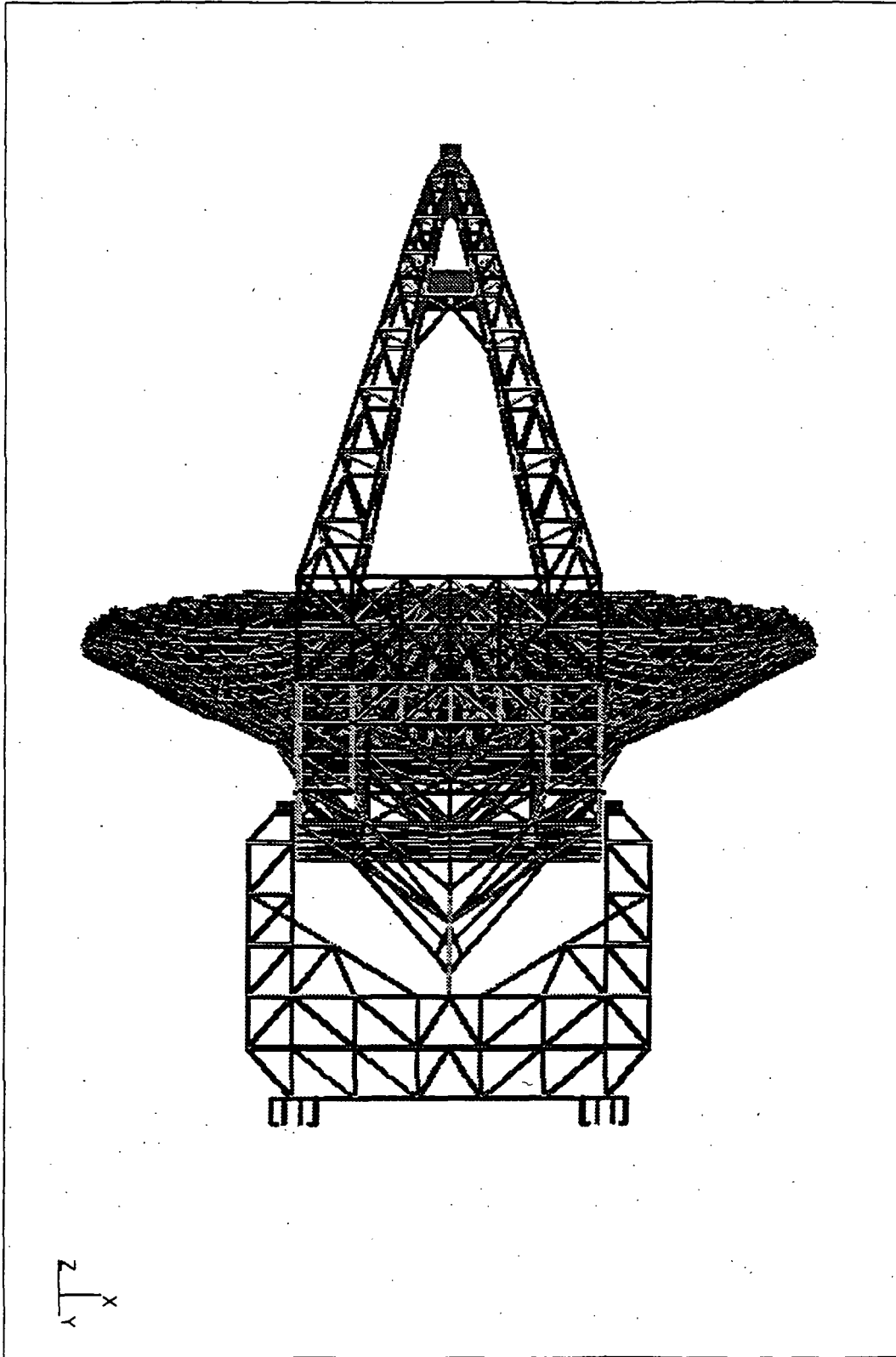


Figure 1b. Green Bank Telescope at 60° Elevation

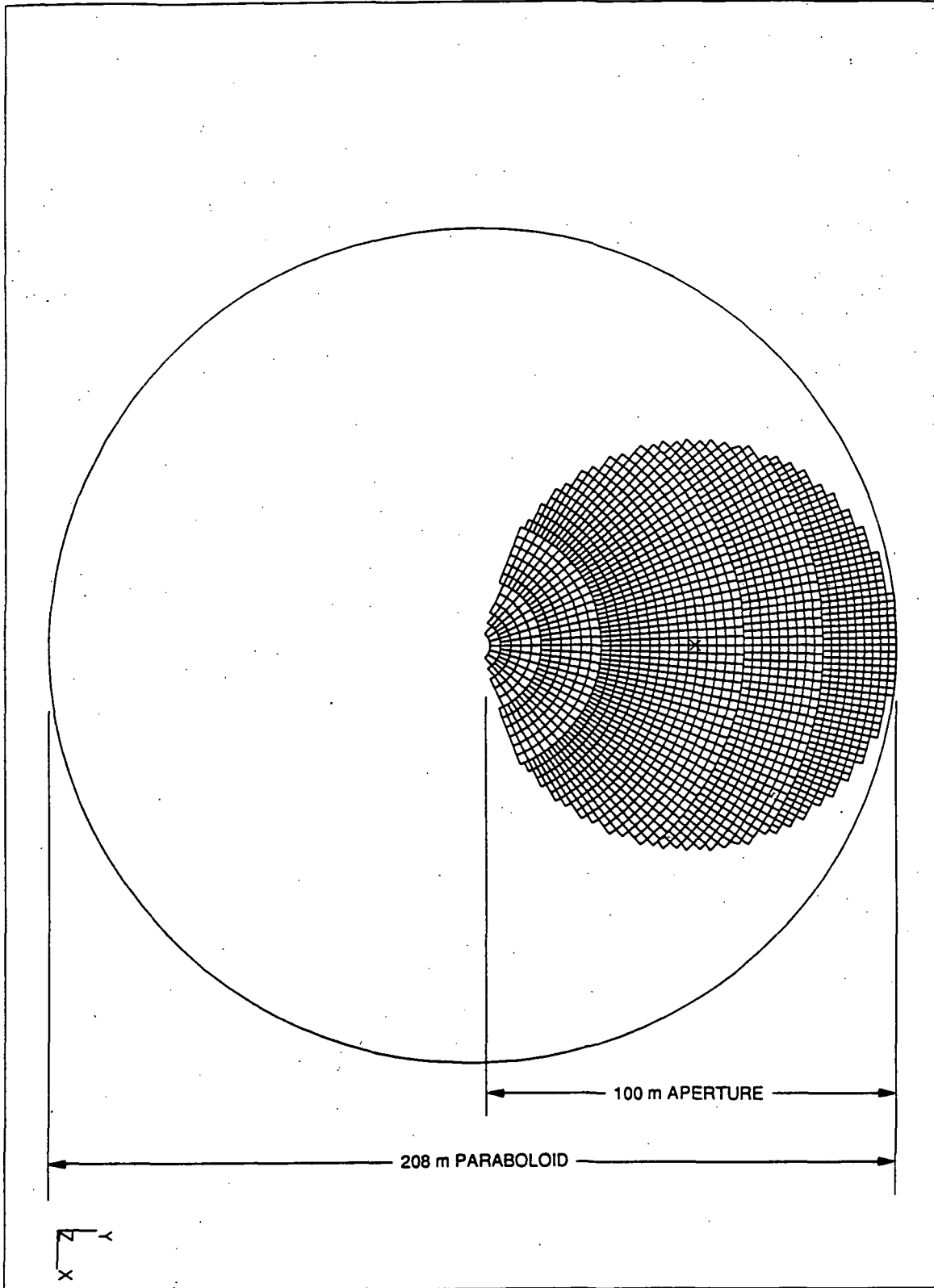


Figure 2. Panel Configuration

## Section 2

# Optimization Process

The JPL-IDEAS [1] antenna structure optimization program was used to obtain the lightest weight feasible structure that would meet the performance goals. IDEAS attempts to find a minimum weight structure that meets specified displacement constraints. The constraints used for this task include antenna pathlength errors and pointing errors. The displacements used in the constraint equations in IDEAS are derived from the virtual work of an adjoint load. IDEAS automatically generates these dummy loads for pathlength and pointing error constraints. A Lagrange multiplier algorithm is used to minimize the objective (structure weight) subject to specified displacement constraints. Additional strategies are employed to ensure an efficient, feasible solution for the multiple constraint problem.

Minimum sizes are enforced for buckling and other stress criteria. Tables of allowable loads for the 33 cross-sections were used internally by IDEAS to select minimum bar sizes. The IDEAS program assumed the possibility of stress reversals for all loading cases when calculating minimum bar sizes for stress requirements.

The program has a limited library of finite elements, and supports only three translational degrees-of-freedom per joint. The design variables used in IDEAS are the cross-sectional area of pin-jointed rod elements and the thicknesses of plate elements.

Since the stability of the NASTRAN GBT model depends extensively on bending stiffness, a subset of the full NASTRAN model was used as the IDEAS model. Most of the differences between the NASTRAN and IDEAS models are in the front surface of the main reflector, where many elements were eliminated or consolidated to make the IDEAS model. Most of the top chord members of the rib trusses have mid-span joints; these were replaced by single elements. Many of the hoop elements, in addition to having mid-span joints, were connected to the joints eliminated when the rib members were consolidated; these elements could not be modeled as simple elements, and since they did not contribute significantly to the stiffness or stability of the overall structure, they were deleted. In compensation, the weight of the deleted members was lumped onto adjacent parallel members.

The main reflector surface was modeled in NASTRAN as shell elements attached to the top chord surface of the backup structure by cantilevered bars representing the panel actuators. The surface panels contribute little stiffness to the structure. The weight of the surface panels and actuators was lumped onto the front surface joints of the IDEAS model.

Where elements crossed the plane of symmetry, midspan nodes were stabilized with weightless rods connected to adjacent joints.

IDEAS supports design-variable linking. The case of a symmetric ring and rib antenna structure allows the linking of elements with similar topology (e.g., all the rib truss

top chords in one ring) into one design-variable group. The topology of the main reflector backup structure for the GBT has only right-left symmetry. In profile, the structure appears similar to a traditional circularly symmetric antenna with tapered trusses deepening to supports near the center. When viewed in plan, though, it is not clear where the boundaries of groups of adjacent members should be set. Throughout the optimization, the cross-sectional area of every bar element was treated as a separate design variable. (The bar elements representing the counterweight and elevation gear flange and the plate elements representing the elevation gear web and microwave feed room were excluded from the optimization process.)

The performance specifications are:

- Gravity pathlength error <= 0.034 in rms (at any elevation)
- Wind-induced pathlength error <= 0.017 in rms @ 7m/s
- Wind-induced pointing error <= 14 arc-sec @ 7m/s

The initial performance goals were about 80% of the respective values of the design specification. This allows for differences between the performance of the IDEAS "design" models and their NASTRAN "verification" counterparts, and the probability that the performance of the actual structure will be worse than that of these preliminary, conceptual, "optimum" models. The design and detailing tasks which necessarily follow will entail many deviations from these ideal models. Any deviations from the "optimum" can have only deleterious effects on performance, so it is best to allow some margin for the final design and detailing.

Unfortunately, the several conflicting requirements of the design problem led to a progressive relaxation of the performance goals.

The design loading conditions were:

Gravity loads:

- 1.25g Z direction gravity load
- 1.25g Y direction gravity load
- 1.00g Z direction gravity plus a 20-psf "snow" load

Wind loads:

<u>Azimuth</u>	<u>Elevation</u>	<u>Wind Speed, mi/h</u>
0	36	50 (wind into the face)
0	66	50
0	95	100
180	95	100
180	66	50
180	36	50 (wind into the back)

NRAO developed the wind loads from JPL-conducted windtunnel studies [2] and adjusted them based on windtunnel studies of a scale model. Loads on the main reflector surface were supplemented to include drag forces on microwave components and support structures.

Achieving the structure optimization objective involved:

- (1) Making reduced-set (IDEAS) models of the elevation structure.
- (2) Optimizing the IDEAS models for gravity pathlength and wind pathlength and pointing constraints (symmetric loads only) with minimum sizes based on survival (wind and snow) load cases.
- (3) Incorporating the IDEAS properties into the full-set NASTRAN models. (Hoop elements which appear only in the full-set NASTRAN models take the properties of the adjacent hoop element of the sub-set IDEAS models.)
- (4) Making new IDEAS property minima to compensate for overstresses found by the NASTRAN analyses.

An iteration of steps 2, 3, and 4 eventually yielded the candidate designs presented here.

## **A. First Design Phase**

The model of the proposed elevation structure used as a starting point for Phase 1 was dubbed "Model 84, Rev.2" (Model 842). The structure has right-left symmetry and Model 842 is of the "right" half of the full structure. A summary of the NRAO-developed model can be found in Tables 1a and 1b. All beam properties for all structural beam elements used in the main reflector backup structure, the subreflector support structure, the elevation box structure, and the elevation gear wheel are selected from a set of only 33 round and square tube sections of ASTM A36 steel. These range from a 7-inch-diameter round tube with a 0.075-inch wall to a 36-inch square tube with a 2-inch wall. The elevation axis is parallel to the model's X-axis, the Z-axis is parallel to the paraboloid's generating axis and points up when the telescope points to the zenith, and the Y-axis points down when the telescope points to the horizon.

Table 1a. Model 842 Summary

Component	No. of Elements
GRIDs (half-model)	3037
CBAR elements	5581
CQUAD4 elements	1063
CONM2 elements	1302
Backup structure	3904
Surface panel actuators	1127
Reflector surface panels	1002
Reflector S/T	6033
Feed & S/R boom and elevation gear wheel	614
Half-model of elevation structure	6647

Weight:	<u>Half-model</u>	<u>Doubled</u>
Elevation Structure	4726 kip	9452 kip

Table 1b. Model 842 Performance Predictions  
(Elevation Structure Only)

Gravity pathlength error                      0.037-in. rms at zenith or horizon  
(0.0 at 41-deg elevation)

Wind performance (7 m/s steady)

<u>Azimuth</u>	<u>Elevation</u>	<u>Pathlength</u>	<u>Pointing</u>
0	36	0.009	15
0	66	0.003	4
0	95	0.002	4
180	95	0.003	7
180	66	0.003	5
180	36	0.006	3

Model 842 had 667 bars that were overstressed as defined by the ASCE Manual of Steel Construction Specification of allowable stresses (combined stresses), or are marginal (stress factor greater than 0.95).

Numerous optimization and verification models were developed from Model 842 over the course of Phase 1. Several connectivity additions were tried in an attempt to improve structural efficiency; only one modification was retained, as it had a significant beneficial effect on gravity pathlength performance. Otherwise, only cross-sectional properties were subject to change during the optimization process. The geometry of the models was not changed. Cross-sectional properties for the new models were selected from the same set of 33 tubing sections used in the NASTRAN models.

Table 2 summarizes two models which were submitted to NRAO at the end of Phase 1. The performance of the models does not meet the specification but is about the same as that of the initial model. The weight is about 1.4 million pounds less. The number of overstressed members is reduced from 667 to 28. The worst error of any wind loading case (7 m/s steady) is tabulated.

Table 2. Summary of Proposed Models (Phase 1)

	<u>Model Designation</u>		<u>Spec</u>
	<u>N15a3u3</u>	<u>N15a3u4</u>	
Weight (kips)	7964	7984	
Gravity pathlength (in. rms)	0.037	0.039	0.034
Rigging elevation (deg)	45	44	
Wind pathlength (in. rms)	0.008	0.008	0.017
Wind pointing (arc-sec)	17	17	14
Overstresses	28	20	

Both of these models contain members that are overstressed. The difference between the two models is the result of an attempt to reduce overstresses by increasing the cross-section of the overstressed members.

As can be seen here, due to the highly redundant nature of this structure, increasing the cross-section proportionate to an overstress often fails to eliminate the overstress. An alternative approach to reduce the overstressed elements of Model N15a3u3 (using higher strength steel for some subset of members, for instance, or selectively hinging a joint to reduce bending stress) would retain the lighter weight and better performance.

## B. Second Design Phase

The model presented above was accepted by the design contractor and was modified during the detailing process. Table 3 summarizes a subsequent "final design" that was submitted. The geometry of "Model 95" is the same as of Model 842 with a few connectivity changes. The cross-sectional areas of most of the members were changed, however.

Table 3a. Model 95 Summary

Component	No. of Elements	
GRIDs (half-model)	3053	
CBAR elements	5594	
CQUAD4 elements	1063	
CONM2 elements	2433	
Weight	<u>Half-model</u>	<u>Doubled</u>
Elevation Structure	4706 kip	9412 kip

Table 3b. Model 95 Performance Predictions  
(Elevation Structure Only)

Gravity pathlength error	0.041-in. rms at zenith or horizon (0.0 at 44-deg elevation)		
Wind performance (7 m/s steady)			
<u>Azimuth</u>	<u>Elevation</u>	<u>Pathlength</u>	<u>Pointing</u>
0	36	0.008	14
0	66	0.003	3
0	95	0.009	1
180	95	0.002	5
180	66	0.002	4
180	36	0.005	3

Forty bar elements are overstressed in Model 95.

Many more constraints were placed on this phase of optimization: the entire front surface of the main reflector backup structure was fixed in size, as were 131 bars that had already been fabricated from 14-inch and 18-inch square tube.

Numerous connectivity changes to the original Model 95 were tried with optimization iterations; all but two resulted in inferior designs. Two bracing members were deleted (18003 and 18007) and two were relocated (18004 and 18008). These members were bracing the strong axis of very stiff, built-up beams attached to the elevation shaft. The NASTRAN analyses showed that the bracing members were distorting the box structure in a way that did not show up in the IDEAS analyses. All the 18000-series elements were pin-jointed as well, to reduce stresses. The other beneficial change was to pin-joint the 19000-series bars, which attach the backup structure to the elevation box structure. The telescope's performance is very sensitive to the properties of these members. IDEAS can account for axial loads only; upgrading of these members to reduce overstress due to bending upsets the fine balance and degrades performance.

Two more candidate designs are summarized in Table 4.

Table 4. Summary of Proposed Models (Phase 2)

	<u>Model Designation</u>		<u>Spec</u>
	<u>N01B3</u>	<u>N01A3</u>	
Weight (kips)	9204	9204	
Gravity pathlength (in. rms)	0.034	0.030	0.034
Rigging elevation (deg)	48	47	
Wind pathlength (in. rms)	0.009	0.009	0.017
Wind pointing (arc-sec)	14	14	14
Overstresses	67	59	

The properties and connectivity of these two models is the same except that Model N01A3 has the 19000-series bars pin-jointed and Model N01B3 does not.

Though the number of overstressed bars is greater than for Model- 95, the number of major load carrying members which are overstressed and the magnitude of the overstresses is less. See Appendix A, Stress Factors for Selected Bar Elements.

## Section 3

# Observations and Recommendations

Several points should be remembered when evaluating the feasibility and predicted performance of these models.

First, the elevation shaft was not redesigned and is overstressed, as is the outer side of the elevation box structure. Increasing the stiffness of the shaft should reduce some of the overstresses due to bending of the elements connected to the elevation shaft. However, increasing the shaft stiffness will probably affect performance as well.

Second, all elements of these models are not equal. Small changes in the properties of some elements can have disproportionate effects on telescope performance. For example, a weight difference of 0.25% between the two models presented in Phase 1 resulted in a gravity pathlength error increase from 0.034-in. to 0.037-in. rms.

Third, while the worst surface distortion error for wind loads appears to be about half of the specified maximum of 0.017-in. rms, the lateral and axial subreflector offsets produce an "equivalent rms" of over twice the specification for some wind loads.

Fourth, all members were automatically sized during the optimization procedures based on telescope performance and element stress requirements. In several cases, all of the members coming into a particular joint do not carry similar loads (or carry no load at all) and/or contribute little to the performance of the telescope. This leads to a disparity in the dimensions of the members at particular joints. Some of these member properties will need to be changed during the detailing process. This will lead to a weight increase and, probably, a performance degradation.

Finally, the gravity pathlength error and the pointing error for the  $Az=0$ ,  $EI=36$  wind loading cases were the two critical ones for performance. The rest were easily satisfied. In many cases (especially in the area of the elevation box-to-backup structure interface) the IDEAS optimization algorithm would encounter conflicting bar-size requirements. That is, for one load case the algorithm would require a bar's area to be reduced, but it would have increased the area for the other case; or it would have reduced a bar's area to improve performance for both loads, but was constrained by stress requirements. This is an indication that the backup-structure support scheme would benefit from a re-examination.

## References

- [1] *JPL-IDEAS User's Manual, Finite Element Analysis and Design Optimization*, NPO-17783, October 1988, NASA Patent Office, Washington, DC.
- [2] "Load Distributions on the Surface of Paraboloidal Reflector Antennas," Internal Memo CP-4, Reorder No. 62-710, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, July 1962.

## Appendix A

### Stress Factors for Selected Bar Elements

This table shows all elements which are overstressed for any of the models M95A1, N01A3 or N01B3, for any load case. Only the worst case load is shown for each model.

Load cases are:

33 Z-gravity  
 22 Y-gravity  
 320 Survival Snow Load  
 200036 Az= 0, El= 36 50mph Wind Load (wind into face)  
 200066 Az= 0, El= 66 50mph Wind Load  
 200095 Az= 0, El= 95 100mph Wind Load  
 218036 Az= 0, El= 36 50mph Wind Load (wind into back)  
 218066 Az= 0, El= 66 50mph Wind Load  
 218095 Az= 0, El= 95 100mph Wind Load

	Label	Area	Length	Stress factor	axial	Components "Z" "Y"		ldcase
m95a1s.28	10002	263.100	100.5	1.234	0.515	0.306	0.413	320
n01b3.28	10002	213.600	100.5	1.459	0.588	0.399	0.472	320
n01a3.28	10002	213.600	100.5	1.453	0.591	0.401	0.461	320
m95a1s.28	100091590.000		34.0	1.492	0.000	0.464	1.028	320
n01b3.28	100091590.000		34.0	1.464	0.000	0.449	1.014	320
n01a3.28	100091590.000		34.0	1.464	0.000	0.449	1.014	320
m95a1s.28	10127	84.000	157.6	0.951	0.422	0.115	0.413	320
n01b3.28	10127	51.800	157.6	0.760	0.572	0.025	0.163	320
n01a3.28	10127	51.800	157.6	0.776	0.609	0.069	0.098	320
m95a1s.28	10142	57.800	463.9	1.037	0.850	0.019	0.168	320
n01b3.28	10142	84.000	463.9	0.890	0.709	0.028	0.153	320
n01a3.28	10142	84.000	463.9	0.909	0.764	0.015	0.130	320
m95a1s.28	10144	144.000	393.1	1.109	0.529	0.030	0.550	320
n01b3.28	10144	144.000	393.1	1.180	0.563	0.009	0.607	320
n01a3.28	10144	144.000	393.1	1.167	0.587	0.055	0.524	320
m95a1s.28	10148	35.000	393.1	1.163	0.499	0.217	0.447	320
n01b3.28	10148	35.000	393.1	1.132	0.439	0.257	0.436	320
n01a3.28	10148	35.000	393.1	0.998	0.469	0.339	0.191	320
m95a1s.28	10218	39.000	570.6	0.797	0.454	0.114	0.229	320
n01b3.28	10218	23.440	570.6	0.962	0.611	0.143	0.208	33
n01a3.28	10218	23.440	570.6	0.937	0.594	0.215	0.128	33

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m95als.28	11038	5.020	393.1	1.176	0.791	0.181	0.204	320
n01b3.28	11038	9.750	393.1	0.583	0.345	0.109	0.129	320
n01a3.28	11038	9.750	393.1	0.580	0.335	0.106	0.140	320
m95als.28	11046	14.610	393.1	0.933	0.628	0.189	0.116	22
n01b3.28	11046	14.610	393.1	0.952	0.631	0.195	0.126	22
n01a3.28	11046	14.610	393.1	0.959	0.626	0.188	0.145	22
m95als.28	11050	9.590	393.1	1.003	0.773	0.167	0.063	22
n01b3.28	11050	14.610	393.1	0.691	0.542	0.111	0.038	22
n01a3.28	11050	14.610	393.1	0.667	0.534	0.112	0.020	22
m95als.28	17033	256.000	71.2	1.284	0.237	1.027	0.020	320
n01b3.28	17033	256.000	71.2	1.355	0.246	1.101	0.008	320
n01a3.28	17033	256.000	71.2	1.324	0.236	1.045	0.043	320
m95als.28	17042	14.610	244.6	0.739	0.483	0.127	0.129	320
n01b3.28	17042	9.750	244.6	0.961	0.655	0.164	0.142	320
n01a3.28	17042	9.750	244.6	1.004	0.666	0.146	0.193	320
m95als.28	18008	9.590	579.9	2.118	0.917	0.339	0.862	22
n01b3.28	18008	20.440	426.3	0.371	0.371	0.000	0.000	320
n01a3.28	18008	20.440	426.3	0.422	0.422	0.000	0.000	320
m95als.28	19005	23.440	319.9	0.953	0.671	0.179	0.103	320
n01b3.28	19005	35.000	319.9	0.749	0.519	0.160	0.070	320
n01a3.28	19005	35.000	319.9	0.522	0.522	0.000	0.000	320
m95als.28	19013	100.000	294.5	0.912	0.321	0.150	0.441	320
n01b3.28	19013	45.800	294.5	1.392	0.683	0.144	0.566	320
n01a3.28	19013	45.800	294.5	0.702	0.702	0.000	0.000	320
m95als.28	19014	57.800	298.6	0.999	0.450	0.134	0.415	320
n01b3.28	19014	45.800	298.6	1.253	0.597	0.193	0.463	320
n01a3.28	19014	45.800	298.6	0.669	0.669	0.000	0.000	320
m95als.28	19016	23.440	195.8	1.117	0.945	0.111	0.061	320
n01b3.28	19016	39.000	195.8	0.770	0.614	0.096	0.059	320
n01a3.28	19016	39.000	195.8	0.623	0.623	0.000	0.000	320
m95als.28	19101	123.000	290.1	1.219	0.482	0.563	0.174	320
n01b3.28	19101	92.000	290.1	1.478	0.650	0.601	0.226	320
n01a3.28	19101	92.000	290.1	0.675	0.675	0.000	0.000	320
m95als.28	42020	3.730	180.4	1.252	0.824	0.195	0.234	218095
n01b3.28	42020	4.270	180.4	0.406	0.292	0.046	0.068	218095
n01a3.28	42020	4.270	180.4	0.406	0.292	0.046	0.068	218095
m95als.28	300061	4.800	201.0	1.029	0.506	0.000	0.523	320
n01b3.28	300061	1.632	201.0	1.745	0.877	0.000	0.867	320
n01a3.28	300061	1.632	201.0	0.393	0.345	0.000	0.049	320

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m95a1s.28	308025	4.270	99.2	0.884	0.121	0.068	0.695	218095
n01b3.28	308025	4.270	99.2	1.010	0.131	0.077	0.802	218095
n01a3.28	308025	4.270	99.2	1.011	0.129	0.084	0.798	218095
m95a1s.28	308026	4.270	100.9	0.878	0.134	0.068	0.676	218095
n01b3.28	308026	4.270	100.9	1.005	0.145	0.077	0.783	218095
n01a3.28	308026	4.270	100.9	1.006	0.143	0.084	0.780	218095
m95a1s.28	308119	4.270	214.4	0.956	0.698	0.075	0.182	320
n01b3.28	308119	5.020	214.4	0.757	0.575	0.065	0.117	320
n01a3.28	308119	5.020	214.4	0.768	0.582	0.066	0.120	320
m95a1s.28	316035	4.270	100.4	0.830	0.054	0.158	0.618	320
n01b3.28	316035	4.270	100.4	0.950	0.056	0.168	0.725	320
n01a3.28	316035	4.270	100.4	0.956	0.062	0.170	0.725	320
m95a1s.28	316036	4.270	100.5	0.830	0.090	0.157	0.582	320
n01b3.28	316036	4.270	100.5	0.944	0.092	0.167	0.685	320
n01a3.28	316036	4.270	100.5	0.952	0.098	0.169	0.685	320
m95a1s.28	316039	2.600	100.4	0.960	0.101	0.190	0.669	320
n01b3.28	316039	2.600	100.4	0.945	0.098	0.181	0.666	320
n01a3.28	316039	2.600	100.4	0.932	0.094	0.171	0.667	320
m95a1s.28	316041	2.600	100.4	1.027	0.083	0.197	0.747	320
n01b3.28	316041	2.600	100.4	1.040	0.080	0.189	0.771	320
n01a3.28	316041	2.600	100.4	1.027	0.080	0.176	0.772	320
m95a1s.28	318035	4.270	100.4	0.854	0.023	0.191	0.641	320
n01b3.28	318035	4.270	100.4	0.991	0.019	0.205	0.767	320
n01a3.28	318035	4.270	100.4	0.984	0.009	0.206	0.768	320
m95a1s.28	322037	4.270	100.4	0.885	0.195	0.236	0.454	320
n01b3.28	322037	4.270	100.4	0.964	0.182	0.258	0.524	320
n01a3.28	322037	4.270	100.4	0.945	0.171	0.250	0.524	320
m95a1s.28	324035	4.270	100.4	0.917	0.087	0.261	0.569	320
n01b3.28	324035	4.270	100.4	1.034	0.077	0.290	0.666	320
n01a3.28	324035	4.270	100.4	1.032	0.078	0.288	0.667	320
m95a1s.28	324036	4.270	100.5	0.841	0.052	0.256	0.533	320
n01b3.28	324036	4.270	100.5	0.952	0.042	0.285	0.625	320
n01a3.28	324036	4.270	100.5	0.951	0.042	0.282	0.626	320
m95a1s.28	324037	4.270	100.4	0.879	0.161	0.260	0.457	320
n01b3.28	324037	4.270	100.4	0.975	0.157	0.287	0.531	320
n01a3.28	324037	4.270	100.4	0.966	0.156	0.279	0.531	320
m95a1s.28	324060	30.770	201.8	0.988	0.512	0.161	0.315	320
n01b3.28	324060	30.730	201.8	0.994	0.519	0.153	0.322	320
n01a3.28	324060	30.730	201.8	0.709	0.579	0.094	0.036	320

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m95a1s.28	324061	45.800	203.2	0.998	0.698	0.167	0.133	320
n01b3.28	324061	51.800	203.2	0.932	0.656	0.161	0.115	320
n01a3.28	324061	51.800	203.2	0.909	0.686	0.066	0.157	320
m95a1s.28	324111	9.590	362.2	0.896	0.406	0.301	0.189	320
n01b3.28	324111	7.750	362.2	1.266	0.614	0.394	0.258	320
n01a3.28	324111	7.750	362.2	0.566	0.489	0.027	0.050	320
m95a1s.28	324202	14.610	421.5	0.943	0.520	0.231	0.192	320
n01b3.28	324202	14.610	421.5	1.003	0.571	0.228	0.204	320
n01a3.28	324202	14.610	421.5	0.585	0.532	0.000	0.053	320
m95a1s.28	326035	4.270	100.4	0.930	0.072	0.279	0.579	320
n01b3.28	326035	4.270	100.4	1.062	0.070	0.314	0.678	320
n01a3.28	326035	4.270	100.4	1.057	0.069	0.310	0.678	320
m95a1s.28	326036	4.270	100.5	0.862	0.035	0.277	0.550	320
n01b3.28	326036	4.270	100.5	0.993	0.033	0.313	0.647	320
n01a3.28	326036	4.270	100.5	0.988	0.032	0.309	0.647	320
m95a1s.28	328023	9.590	100.6	0.959	0.381	0.409	0.169	218095
n01b3.28	328023	9.750	100.6	0.942	0.368	0.405	0.169	218095
n01a3.28	328023	9.750	100.6	0.941	0.357	0.416	0.169	218095
m95a1s.28	328024	9.590	100.6	0.961	0.383	0.410	0.168	218095
n01b3.28	328024	9.750	100.6	0.955	0.371	0.407	0.177	218095
n01a3.28	328024	9.750	100.6	0.952	0.360	0.418	0.174	218095
m95a1s.28	328117	2.064	166.5	0.868	0.505	0.143	0.220	320
n01b3.28	328117	2.064	166.5	0.955	0.539	0.179	0.238	320
n01a3.28	328117	2.064	166.5	0.944	0.531	0.176	0.237	320
m95a1s.28	332033	4.270	100.5	0.911	0.077	0.325	0.509	218095
n01b3.28	332033	4.270	100.5	1.057	0.075	0.385	0.598	218095
n01a3.28	332033	4.270	100.5	1.057	0.074	0.386	0.598	218095
m95a1s.28	332034	4.270	100.5	0.897	0.072	0.324	0.501	218095
n01b3.28	332034	4.270	100.5	1.043	0.070	0.383	0.590	218095
n01a3.28	332034	4.270	100.5	1.043	0.069	0.384	0.590	218095
m95a1s.28	332035	4.270	100.4	0.972	0.111	0.324	0.537	320
n01b3.28	332035	4.270	100.4	1.122	0.101	0.372	0.650	320
n01a3.28	332035	4.270	100.4	1.114	0.100	0.364	0.649	320
m95a1s.28	332036	4.270	100.5	0.910	0.082	0.321	0.508	320
n01b3.28	332036	4.270	100.5	1.046	0.072	0.368	0.606	320
n01a3.28	332036	4.270	100.5	1.037	0.071	0.361	0.605	320
m95a1s.28	332115	2.064	192.4	0.892	0.609	0.185	0.099	218095
n01b3.28	332115	2.064	192.4	0.972	0.655	0.208	0.109	218095
n01a3.28	332115	2.064	192.4	0.975	0.656	0.209	0.110	218095

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m95a1s.28	334029	4.270	100.5	0.923	0.132	0.313	0.478	218095
n01b3.28	334029	4.270	100.5	1.061	0.139	0.362	0.560	218095
n01a3.28	334029	4.270	100.5	1.064	0.140	0.365	0.560	218095
m95a1s.28	334030	4.270	100.5	0.918	0.136	0.313	0.470	218095
n01b3.28	334030	4.270	100.5	1.057	0.143	0.361	0.554	218095
n01a3.28	334030	4.270	100.5	1.061	0.143	0.364	0.553	218095
m95a1s.28	334031	4.270	100.5	0.879	0.048	0.319	0.513	218095
n01b3.28	334031	4.270	100.5	1.021	0.046	0.376	0.599	218095
n01a3.28	334031	4.270	100.5	1.022	0.045	0.378	0.599	218095
m95a1s.28	334032	4.270	100.5	0.876	0.052	0.318	0.507	218095
n01b3.28	334032	4.270	100.5	1.020	0.050	0.375	0.595	218095
n01a3.28	334032	4.270	100.5	1.022	0.050	0.377	0.595	218095
m95a1s.28	334033	4.270	100.5	0.917	0.020	0.338	0.558	218095
n01b3.28	334033	4.270	100.5	1.087	0.021	0.401	0.666	218095
n01a3.28	334033	4.270	100.5	1.087	0.020	0.402	0.666	218095
m95a1s.28	334034	4.270	100.5	0.906	0.025	0.338	0.544	218095
n01b3.28	334034	4.270	100.5	1.062	0.026	0.400	0.636	218095
n01a3.28	334034	4.270	100.5	1.062	0.025	0.401	0.636	218095
m95a1s.28	336029	4.270	100.5	0.870	0.023	0.320	0.527	218095
n01b3.28	336029	4.270	100.5	1.013	0.035	0.367	0.611	218095
n01a3.28	336029	4.270	100.5	1.016	0.035	0.370	0.611	218095
m95a1s.28	336030	4.270	100.5	0.870	0.027	0.322	0.521	218095
n01b3.28	336030	4.270	100.5	1.017	0.038	0.371	0.608	218095
n01a3.28	336030	4.270	100.5	1.020	0.039	0.374	0.608	218095
m95a1s.28	336031	4.270	100.5	0.909	0.009	0.328	0.572	218095
n01b3.28	336031	4.270	100.5	1.058	0.001	0.388	0.668	218095
n01a3.28	336031	4.270	100.5	1.059	0.001	0.390	0.668	218095
m95a1s.28	336032	4.270	100.5	0.894	0.004	0.326	0.563	218095
n01b3.28	336032	4.270	100.5	1.050	0.003	0.386	0.660	218095
n01a3.28	336032	4.270	100.5	1.052	0.004	0.388	0.660	218095
m95a1s.28	338029	4.270	100.5	0.865	0.038	0.329	0.498	218095
n01b3.28	338029	4.270	100.5	0.991	0.027	0.377	0.586	218095
n01a3.28	338029	4.270	100.5	0.992	0.026	0.379	0.586	218095
m95a1s.28	338030	4.270	100.5	0.866	0.042	0.330	0.495	218095
n01b3.28	338030	4.270	100.5	0.990	0.031	0.378	0.581	218095
n01a3.28	338030	4.270	100.5	0.992	0.030	0.380	0.581	218095
m95a1s.28	340106	4.270	227.8	0.904	0.643	0.236	0.025	320
n01b3.28	340106	4.270	227.8	1.047	0.665	0.303	0.079	320
n01a3.28	340106	4.270	227.8	0.931	0.638	0.246	0.047	320

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m95als.28	340109	7.590	234.6	0.568	0.417	0.134	0.017	218095
n01b3.28	340109	5.020	234.6	0.926	0.609	0.222	0.094	320
n01a3.28	340109	5.020	234.6	0.958	0.625	0.234	0.100	320
m95als.28	342029	4.270	100.5	0.918	0.092	0.339	0.487	218095
n01b3.28	342029	4.270	100.5	1.065	0.105	0.389	0.570	218095
n01a3.28	342029	4.270	100.5	1.067	0.105	0.391	0.570	218095
m95als.28	342030	4.270	100.5	0.909	0.095	0.336	0.478	218095
n01b3.28	342030	4.270	100.5	1.050	0.108	0.384	0.557	218095
n01a3.28	342030	4.270	100.5	1.052	0.108	0.386	0.557	218095
m95als.28	344025	9.590	99.2	1.005	0.205	0.444	0.355	218095
n01b3.28	344025	9.750	99.2	0.994	0.219	0.439	0.336	218095
n01a3.28	344025	9.750	99.2	0.998	0.218	0.443	0.336	218095
m95als.28	344026	9.590	100.9	0.998	0.209	0.444	0.345	218095
n01b3.28	344026	9.750	100.9	0.990	0.222	0.438	0.330	218095
n01a3.28	344026	9.750	100.9	0.994	0.222	0.442	0.330	218095
m95als.28	348106	5.020	199.0	0.920	0.698	0.136	0.085	320
n01b3.28	348106	5.020	199.0	0.966	0.727	0.165	0.074	320
n01a3.28	348106	5.020	199.0	0.978	0.734	0.168	0.076	320
m95als.28	352019	5.020	100.6	1.033	0.201	0.229	0.603	218095
n01b3.28	352019	5.020	100.6	0.985	0.182	0.199	0.604	218095
n01a3.28	352019	5.020	100.6	0.991	0.183	0.204	0.604	218095
m95als.28	352020	5.020	100.7	1.021	0.201	0.229	0.591	218095
n01b3.28	352020	5.020	100.7	0.975	0.182	0.199	0.594	218095
n01a3.28	352020	5.020	100.7	0.981	0.183	0.204	0.594	218095
m95als.28	413040	5.020	103.1	0.846	0.417	0.190	0.240	320
n01b3.28	413040	3.338	103.1	1.158	0.555	0.273	0.330	320
n01a3.28	413040	3.338	103.1	1.143	0.606	0.268	0.269	320
m95als.28	419028	76.000	150.6	0.781	0.142	0.070	0.570	320
n01b3.28	419028	14.610	150.6	1.022	0.598	0.055	0.369	320
n01a3.28	419028	14.610	150.6	0.841	0.670	0.022	0.148	320
m95als.28	424025	2.064	83.0	0.964	0.026	0.007	0.930	218095
n01b3.28	424025	2.064	83.0	0.981	0.027	0.000	0.954	218095
n01a3.28	424025	2.064	83.0	0.980	0.027	0.000	0.953	218095
m95als.28	424026	2.064	83.0	0.968	0.010	0.011	0.947	218095
n01b3.28	424026	2.064	83.0	0.951	0.010	0.014	0.928	218095
n01a3.28	424026	2.064	83.0	0.952	0.010	0.014	0.928	218095
m95als.28	426023	2.600	89.2	1.112	0.015	0.029	1.068	218095
n01b3.28	426023	2.064	89.2	1.262	0.018	0.031	1.214	218095
n01a3.28	426023	2.064	89.2	1.261	0.017	0.031	1.214	218095

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m95a1s.28	426024	2.600	89.2	1.126	0.023	0.027	1.076	218095
n01b3.28	426024	2.064	89.2	1.287	0.029	0.026	1.232	218095
n01a3.28	426024	2.064	89.2	1.288	0.030	0.026	1.232	218095
m95a1s.28	427040	14.610	101.2	0.655	0.014	0.175	0.465	320
n01b3.28	427040	2.600	101.2	0.804	0.492	0.186	0.125	22
n01a3.28	427040	2.600	101.2	0.961	0.441	0.192	0.327	218095
m95a1s.28	427060	4.270	96.6	0.621	0.412	0.000	0.210	218095
n01b3.28	427060	2.600	96.6	1.020	0.663	0.000	0.358	218095
n01a3.28	427060	2.600	96.6	1.016	0.663	0.000	0.353	218095
m95a1s.28	502001	4.270	131.2	0.756	0.550	0.000	0.205	320
n01b3.28	502001	3.338	131.2	0.910	0.625	0.000	0.285	320
n01a3.28	502001	3.338	131.2	0.955	0.672	0.000	0.283	320
m95a1s.28	519032	2.064	122.7	1.068	0.226	0.226	0.615	320
n01b3.28	519032	2.600	122.7	0.832	0.164	0.171	0.497	320
n01a3.28	519032	2.600	122.7	0.833	0.165	0.172	0.497	320
m95a1s.28	523303	14.610	454.9	1.067	0.584	0.076	0.406	320
n01b3.28	523303	14.610	454.9	1.014	0.572	0.064	0.378	320
n01a3.28	523303	14.610	454.9	0.610	0.538	0.000	0.072	320
m95a1s.28	526001	2.600	134.0	0.847	0.127	0.217	0.503	320
n01b3.28	526001	2.064	134.0	1.056	0.169	0.233	0.654	320
n01a3.28	526001	2.064	134.0	1.058	0.171	0.233	0.654	320
m95a1s.28	526002	2.064	134.0	1.057	0.146	0.277	0.634	320
n01b3.28	526002	2.064	134.0	1.051	0.155	0.235	0.662	320
n01a3.28	526002	2.064	134.0	1.053	0.157	0.235	0.661	320
m95a1s.28	528001	2.064	55.6	1.137	0.451	0.184	0.502	320
n01b3.28	528001	2.064	55.6	0.811	0.306	0.130	0.374	320
n01a3.28	528001	2.064	55.6	0.814	0.308	0.130	0.375	320
m95a1s.28	532002	2.064	170.9	1.008	0.509	0.125	0.373	320
n01b3.28	532002	3.338	170.9	0.653	0.307	0.085	0.261	320
n01a3.28	532002	3.338	170.9	0.642	0.296	0.085	0.261	320
m95a1s.28	536001	2.064	116.7	0.901	0.136	0.207	0.558	320
n01b3.28	536001	1.632	116.7	1.156	0.151	0.232	0.772	320
n01a3.28	536001	1.632	116.7	1.153	0.150	0.231	0.772	320
m95a1s.28	536002	2.064	116.7	0.874	0.117	0.210	0.547	320
n01b3.28	536002	1.632	116.7	1.115	0.128	0.232	0.754	320
n01a3.28	536002	1.632	116.7	1.113	0.127	0.231	0.755	320
m95a1s.28	540001	2.064	119.6	1.064	0.224	0.379	0.461	320
n01b3.28	540001	1.632	119.6	1.184	0.249	0.355	0.579	320
n01a3.28	540001	1.632	119.6	1.150	0.234	0.337	0.578	320

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