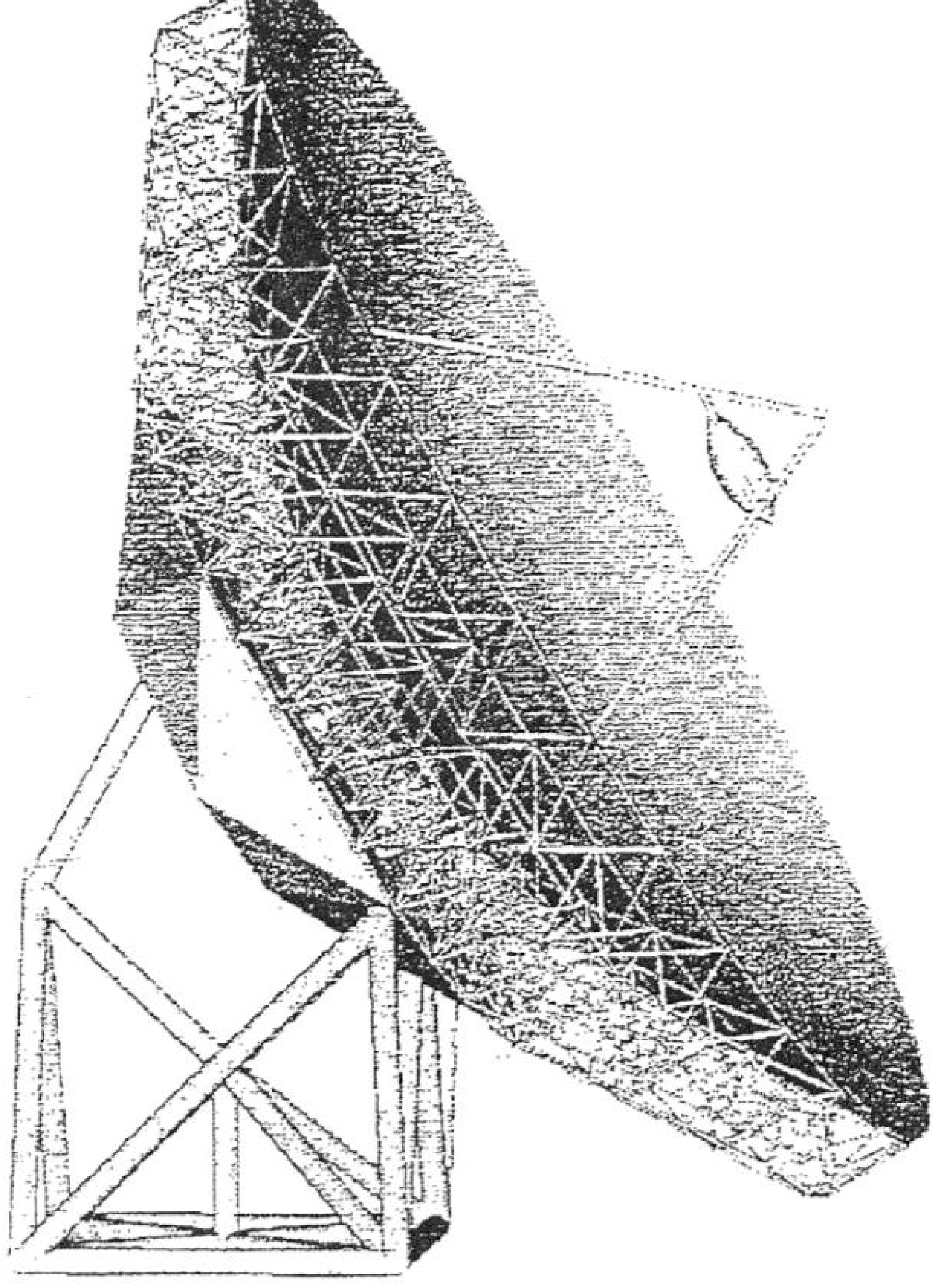

The 15m (12.8m) Telescopes for the MMA/LSA Project

Report prepared at IRAM in September 1997

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Report prepared at IRAM
in September 1997
by D.Plathner
assisted by
M.Bremer
J.Delannoy

CONTENTS

1. *Introduction*

The combined array for radioastronomy of the American and European astronomical communities shall cover a wide range of observing frequencies. With this report, we want to prove that the proposed 15m telescope can meet the high pointing requirements for submillimeter work and provides at the same time a large surface area for mm-observations. This is achieved by applying advanced technologies most of which have already been in use on the IRAM Plateau de Bure Interferometer and a strict mechanical design providing maximum stiffness at minimum weight to bring the reflector loads down into the ground.

In the annex, some information is given for a 12.8m telescope which is derived from the 15m by taking the outermost ring of panels and back-up structure off.

2. *Description of the Design*

The proposed 15m telescope is shown in figure 1 as a simplified computer vision. It is an alt-az mount telescope with the elevation axis off-set to increase stiffness in the support system of the reflector and to render the frame work structure of the mount more compact. In addition, it facilitates the installation of an optically controlled encoder system which senses the position of the reflector independently of the telescope structure. Wind and temperature induced deformations in the mount are therefore corrected by the servo system, and the general pointing performance of the telescope is considerably increased. Furthermore, a large receiver area can be provided with easy access.

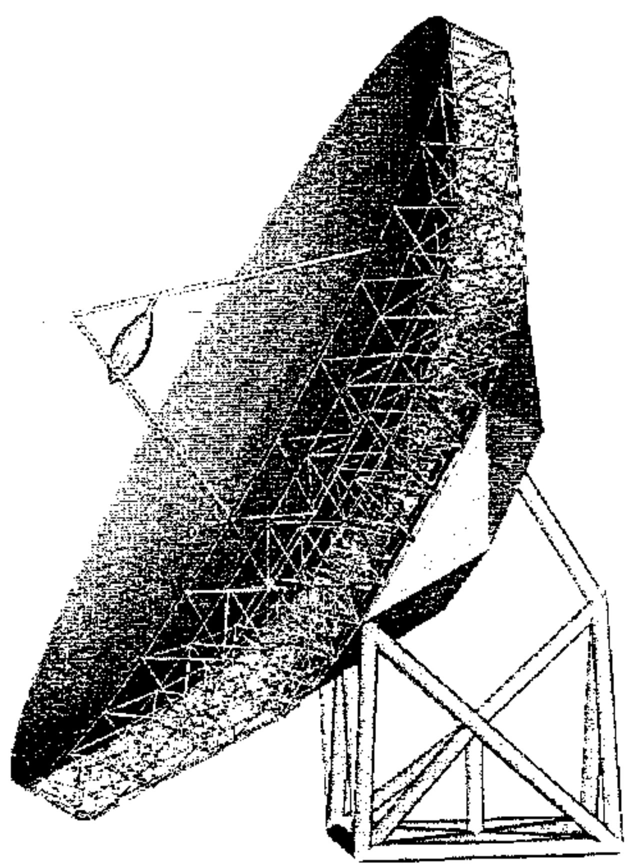


Fig. 1 : Computer vision of the 15m telescope

2.1 Carbon Fibre Back-up Structure

Quality and design of the carbon fibre composite struts and the connecting nodes were taken from the IRAM Plateau de Bure Interferometer where these elements are used since 1985 and have proven to be of the specified performance and long-term stability. Due to the selected matrix of the composite and the choice of fibre quality and the layer set-up humidity influences have never been detected.

The configuration of the back-up structure was modified following the results of a first order investigation on the amelioration of the support points. As presented in figure 2, it can be shown that a straight bar with the extension corresponding to a 15m diameter and supported as the IRAM P.d.B. dishes deflects less when the support points are taken further out, i.e. the weight distribution is better balanced.

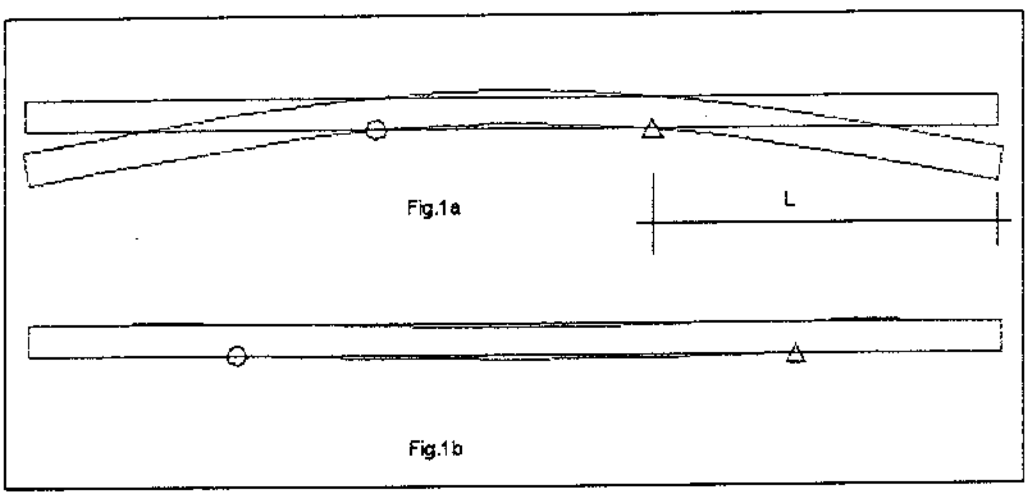


Fig. 2 : Test bar under gravity deformation

The corresponding reflector geometry is shown in fig. 3. In the proposed design, ring 4 of the back-up structure is connected in 6 points to a box type element commonly known as cabin. The whole structure is supported by the pedestal in three of the six connecting points which results in an elevation motion as schematically indicated in fig. 4.

The application of the carbon fibre struts in the b.u.s. highly increases the thermal stability due to the low C.T.E. of the composite material ($< 0.3 \times 10^{-6}$). The low mass density considerably reduces the weight without loosing in stiffness with a Young's modulus close to the one of steel (160 GPa compared to 210 GPa for steel). This brings the Eigenfrequencies up and improves pointing.

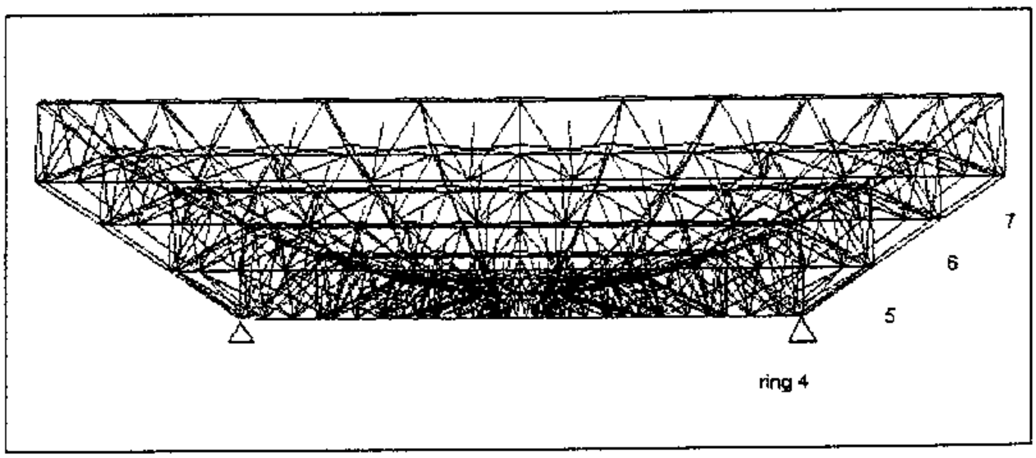


Fig. 3 : Proposed reflector geometry

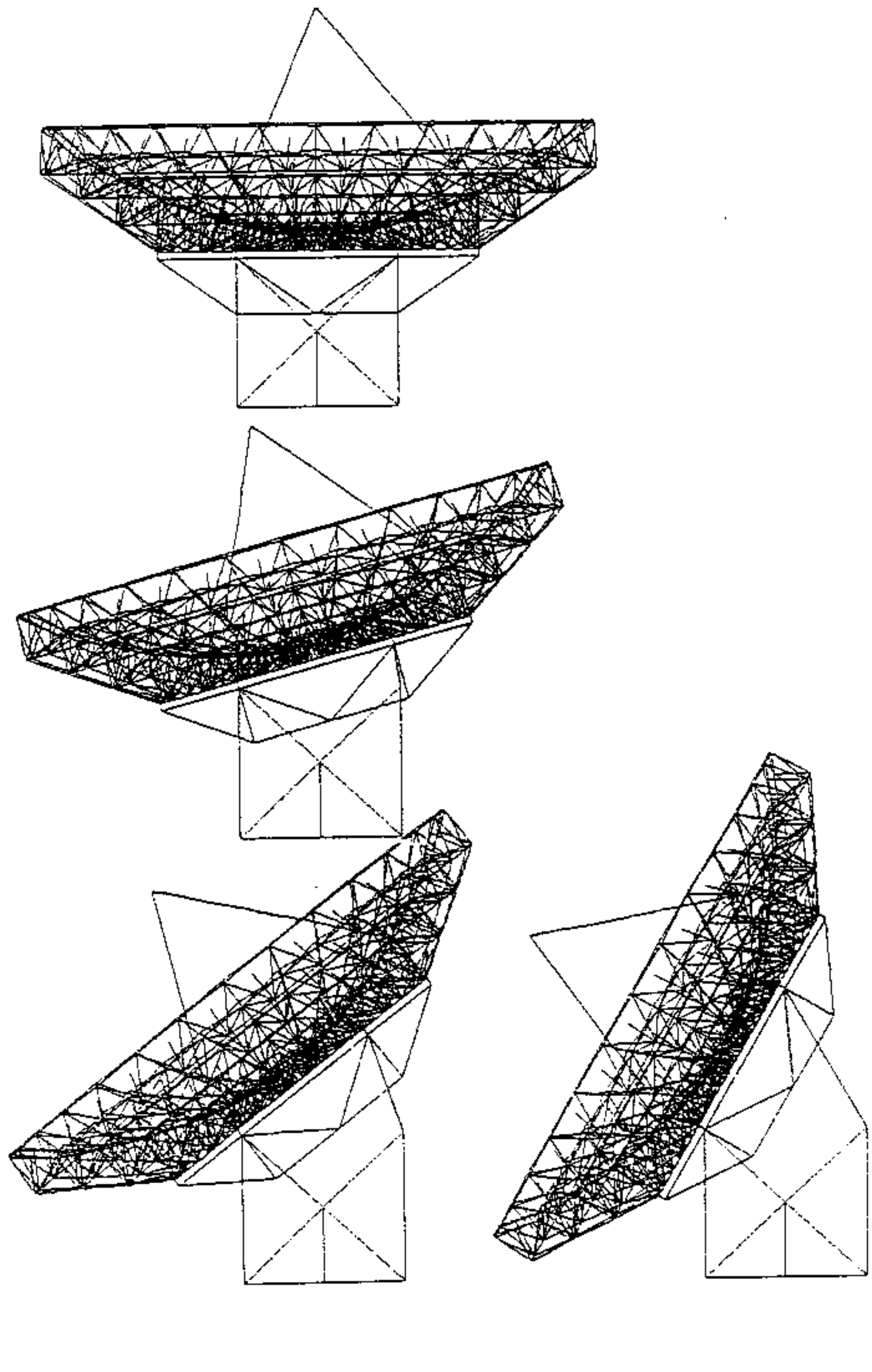


Fig. 4 : Motion of the 15m telescope in elevation

2.2 Pedestal Framework

As it can be seen from fig. 1 and 4, the reflector back-up structure is mounted on a frame work pedestal which is configured in a way that it directs the reflector loads on the straightest possible way to the ground. Applying only push-pull truss elements, the whole cross-section of the structural items is used for load transfer thus creating high rigidity for the lowest possible weight with the known advantages for Eigenfrequencies and pointing. The frame work is for the time being designed in steel but could, if found necessary, also be executed in carbon-fibre material due to its simple configuration.

The center of the pedestal is defining the azimuth axis by a radial bearing which can also take axial loads. The bearing is preloaded in the axial direction to keep the four corners of the pedestal to the ground. These corners are equipped with directly driven rollers which run on a circular rail fixed to the foundations. The relatively extended square base of the pedestal (typically 4.5 x 4.5 m) creates high resistance against tilts, and the related foundations will positively support this due to low specific pressure onto a soil which is probably not configured of solid rock.

Again from fig. 1 and 4 it can be seen that the elevation rotation is achieved by a linear drive which is connected to the cabin of the reflector structure on one end and to the frame work of the pedestal on the other. Details have not been worked out, but there is reason to hope that a linear direct drive system can be used to optimize the servo system.

2.3 Light Weight Aluminium Panels and Secondary Structure

Based on the IRAM P.d.B. experience, light weight aluminium panels (< 15 kg/m^2) are proposed to reduce gravity deformations and to increase Eigenfrequencies. The panels are supported by the b.u.s. in 5 points (4 corners and center). The thin surface plate is reinforced by a rib system on the back. A similar configuration is used for the secondary mirror.

All aluminium surfaces are anodized, the oxyde layer being 3µm thick. Special machining can be given to the reflecting surfaces to prepare for sun observations. The support for the secondary mirror and its adjustment devices is configured as a tripod which joins at the lower end to three of the six support points of the back-up structure. It is made from low thermal expansion carbon fibre composites with its advantages in stiffness and weight.

2.4 Pedestal Independent Measuring and Encoding System

The configuration of the pedestal permits the installation of a measuring and encoding system which is not influenced by the supporting structure. It automatically corrects the angular position of the reflector for errors due to deformations in the pedestal. Random pointing errors are thus limited to the reflector contributions and those of the measuring and drive system.

Fig. 5 shows the set-up of this system schematically. The az. and el. rotational supports are encoder-controlled turn-tables. The az. table is fixed to the ground in the center of the azimuth bearing, and the second table can rotate about the elevation axis. Both turn-tables are connected by an optical link (either a laser interferometer measuring two perpendicular angles or an electronic autocollimator again for two perpendicular angles). The lower turn-table creates a reference beam which is positioned in azimuth and does not change angle in elevation. The reflected beam errors are taken as input for the servoes which control the motion of the telescope axes in elevation and azimuth.

In azimuth, the telescope simply follows the motion of the encoder while, in elevation, the reflector has to perform a counter-rotation to the rotation of the encoder to keep the reflecting target(s) in zero-deviation position with respect to the alignment beam. The encoders will possibly be high resolution absolute encoders to simplify orientation and calibration.

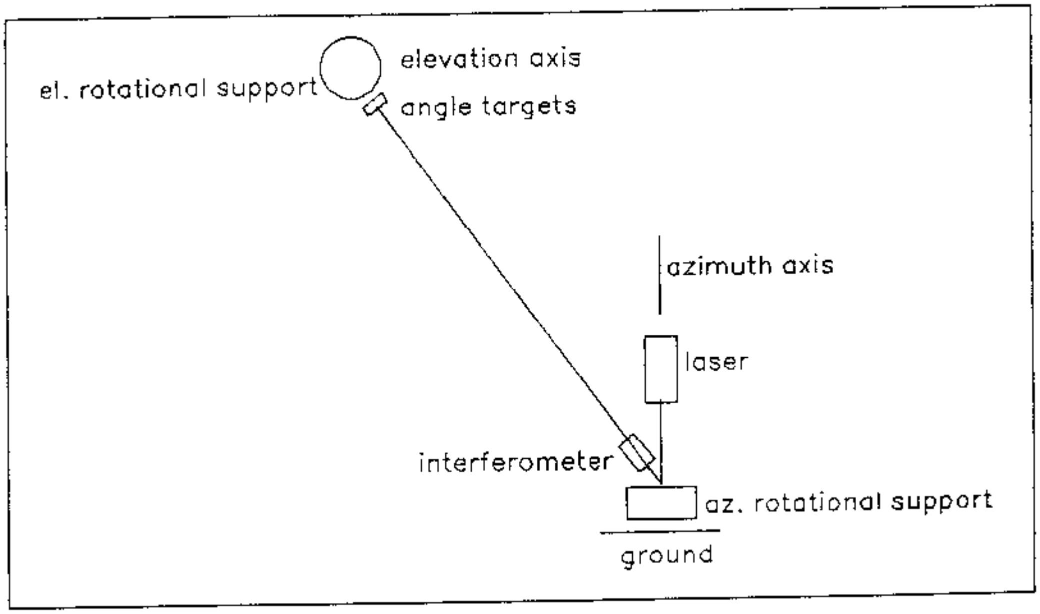


Fig. 5 : Encoder measuring system

3. *Remarks on the Proposed Solutions*

The previous chapter describes in some detail the different elements which compose the proposed 15m telescope. Here some additional information shall be given stressing particularly the new design of the pedestal which is completely different to the technology applied for the IRAM 15m P.d.B. antennae or other telescopes.

Common is the extensive use of carbon fibre composite material for the reflector back-up structure and the secondary mirror support, which, in the present case, is proposed as a tripod for mechanical reasons, but also to reduce blockage compared to a quadrupod solution. Also the aluminium panel technology is copied because the P.d.B. solution is extremely light weight, mechanically stiff and thermally stable without being a pronounced cost driver.

The mount which is composed of the pedestal frame work, the drives and bearings, and also the encoder measuring system have been developped in a long process of iterations. Some major highlights shall be listed for the different elements or related items :

a) framework

- max. possible use of the effective material cross-sections for load transfer
- light weight
- easily to be adapted to stiffness requirements
- low cost
- large ground area
- mechanically advantageous location of connections to the reflector
- low wind attack
- eased temperature monitoring, if needed.

b) off-set between az. and el. axis

- low, compact pedestal framework
- eases the installation of the proposed encoder measuring system independent of the mount structure
- direct links to the reflector
- large space for receivers
- reduced height above ground of the receiver area
- simple cable bender
- contributes to low cost

c) encoder measuring system

- independent of the telescope structure
- no mech. couplings to mount structure
- high precision
- standard industrial componants
- allows to suppress thermal insulation on pedestal frame work, as it corrects for related distortions
- corrects for wind- and temperature-induced deformations of the pedestal

d) bearings

- clear separation between axial and radial about both axes
- therefore small units with high stiffness and low friction
- no thermal constraints
- all bearings preloaded
- low cost
- low maintenance requirements
- a solution with air bearings can be considered.

e) drives

- direct drives possibly in both axes
- backlash-free
- low cost
- low maintenance requirements

f) foundations

- the large base of the pedestal frame work requires also an extended foundation exerting a low pressure on the ground
- this is required for the existing soil
- gives nevertheless high stiffness
- insensitive to temperature changes

g) transportability

- easy handling of the whole telescope due to the low center of gravity, as the pedestal is compact
- easy access to the central bearing and the encoder system which have to be disconnected for transport
- requires large transporter (5 x 5 m) which increases safety against tip over in case of high winds and/or earthquakes

Two critical remarks :

- because of the off-set between el. and az. axis, pointing errors can contribute to the phase stability error budget. They are, however, eliminated by the applied encoder system, and only the mispointing caused by the encoder and servo system has to be considered (see phase stability table 6.3 further down).
- the rail track on which the pedestal rotates may collect some dust particles while the telescope is in operation. The bogies will be equipped with appropriate cleaning devices (e.g. brushes) so that the telescope motion can be kept undisturbed.

4. *Technical and Scientific Specifications*

The 15m telescope is designed to cope with a large number of technical and scientific requirements. They are summarized in the following tables of specifications :

4.01 Site

♦ altitude	≈ 5000 m
♦ location	desert
♦ ground	stony
♦ soil rigidity	t.b.d.
♦ configuration	flat plane
♦ mean wind speed	6 m/s
♦ min. temperature	- 20°C
♦ max. temperature	+ 20°C
♦ max. thermal gradient	5°C/h
♦ rel. humidity (min./mean/max.)	t.b.d.
♦ survival conditions	
◊ wind speed	56 m/s
◊ temperature	- 35°C
◊ rain	yes but rare
◊ snow	yes but rare
◊ ice formation	yes
◊ projection of dust, stone and/or ice particles on telescope	yes

4.02 Telescope

♦ Diameter	15 m
♦ f-ratio	0.325
♦ Mount	alt-az
♦ Pointing-absolute	≤ 0.5 arc sec
♦ Pointing-differential	≤ 0.2 arc sec
♦ Slewing (both axes)	2 deg./sec
♦ Natural frequency (for el. angles > 20 deg.)	≥ 10 Hz
♦ Max. az. angle	± 270 deg.
♦ Max. el. angle	from 10 to 90 deg.
♦ Typical el. angle for observations	from 20 to 75 deg.
♦ El. angle for alignment	t.b.d.
♦ Sun observations	yes
♦ Radome or windshield	no
♦ Backside cladding of reflector	no
♦ Thermal insulation	no
♦ Thermal conditioning or stabilization	no

4.03 Panels

♦ number of panels	165
♦ adjustable supports/panel	5 (4 corners, 1 middle)
♦ motorized adjusters	no
♦ number of panel rings	6
♦ number of panels/ring	15 inner ring ; 30 all others
♦ material	alu (US quality 5083)
♦ configuration	monobloc with thin surface plate and ribs
♦ surface protection	sulfuric anodization (3μm thick)
♦ mass	≤ 15 kg/m²
♦ surface precision (after machining)	14 μm r.m.s.
♦ special maching of surface for sun observation	t.b.d.
♦ deicing	no

♦ backside thermal insulation	yes
♦ sealing between adjacent panels	no

4.04 Subreflector

♦ material	alu (US quality 5083)
♦ configuration	monobloc with thin surface plate and ribs
♦ surface protection	sulfuric anodization
♦ surface precision	$\leq 8\ \mu$m r.m.s.
♦ deicing	no
♦ backside thermal insulation	yes
♦ motorized adjusters	yes
♦ position measurement	yes
♦ mass including adjusters	≤ 60 kg

4.05 Tripod

♦ material	carbon fibre composite
♦ spec. mass	≤ 1.6 kg/dm^3
♦ Young's modulus	≥ 160 GPa
♦ thermal expansion coefficient	$\leq 0.3 \times 10^{-6}$
♦ humidity protection	yes
♦ UV protection	yes
♦ surface	paint TiO_2
♦ fittings	steel
◊ corrosion protection	yes
◊ surface	paint TiO2
♦ bond material	Redux 640
♦ safety riveting	no
♦ primering of bonded surfaces	yes

4.06 Reflector Back-up Structure

♦ general configuration	bolted framework
♦ beams	
◊ material	carbon fibre composite
◊ spec. mass	≤ 1.6 kg/dm^3
◊ Young's modulus	≥ 160 GPa
◊ thermal expansion coefficient	$\leq 0.3 \times 10^{-6}$
◊ humidity protection	yes
◊ UV protection	yes
◊ surface	paint TiO_2
♦ fittings	steel
◊ corrosion protection	yes
◊ surface	paint TiO_2
◊ surfaces to be bonded	sand blasted + primer
♦ bond material	Redux 640
◊ safety riveting	no
♦ nodes	
◊ material	steel
◊ corrosion protection	yes
◊ surface	paint TiO_2

4.07 Pedestal

♦ configuration	welded framework
♦ material	steel
♦ corrosion protection	yes
♦ surface	paint TiO_2
♦ thermal insulation	no

4.08 Bearings }	
4.09 Measuring and Encoding System }	t.b.d.
4.10 Drives }	
4.11 Foundations }	

4.12 General

♦ telescopes displaceable	yes
♦ means for displacement	independent transporter(s) on pneumatic wheels
♦ frequency of displacement	2 x/year
♦ weight/telescope	< 40 tons
♦ maintenance	in oxigenized hall
♦ maintenance frequency	once/year
♦ bolts	steel
♦ bolt surface	corrosion resistant
♦ liquid fastener for bolts	yes
♦ torque control during bolting	yes
♦ shimming or safety washers	no
♦ lifetime warranty for all parts	5 years
♦ expected lifetime	> 15 years

5. *Calculations*

Many FEM calculations have been carried out with the telescope structures, as defined in the chapters above. The results of the calculations with loads from

- gravity,
- temperature changes and gradients,
- wind,

and also mode shapes for the lowest eigenfrequencies are shown in the following figures. All deformations are given in millimeters and in z-direction (parallel to the optical axis). Δ z-values are absolute deformations, as calculated by the FEM program.

Fig. 5 indicates how the rigging angle was defined.

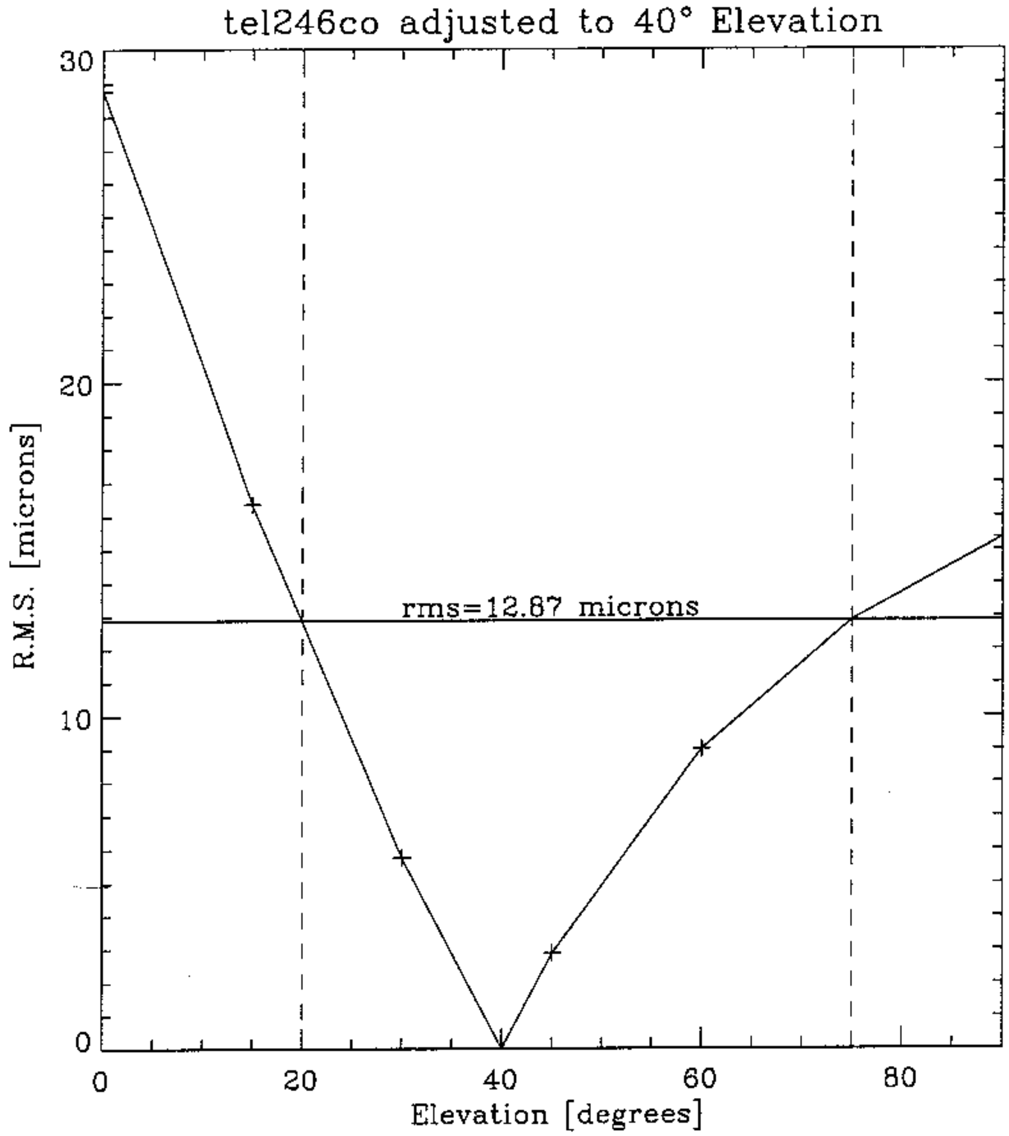


Figure 5: Optimization of the reference elevation

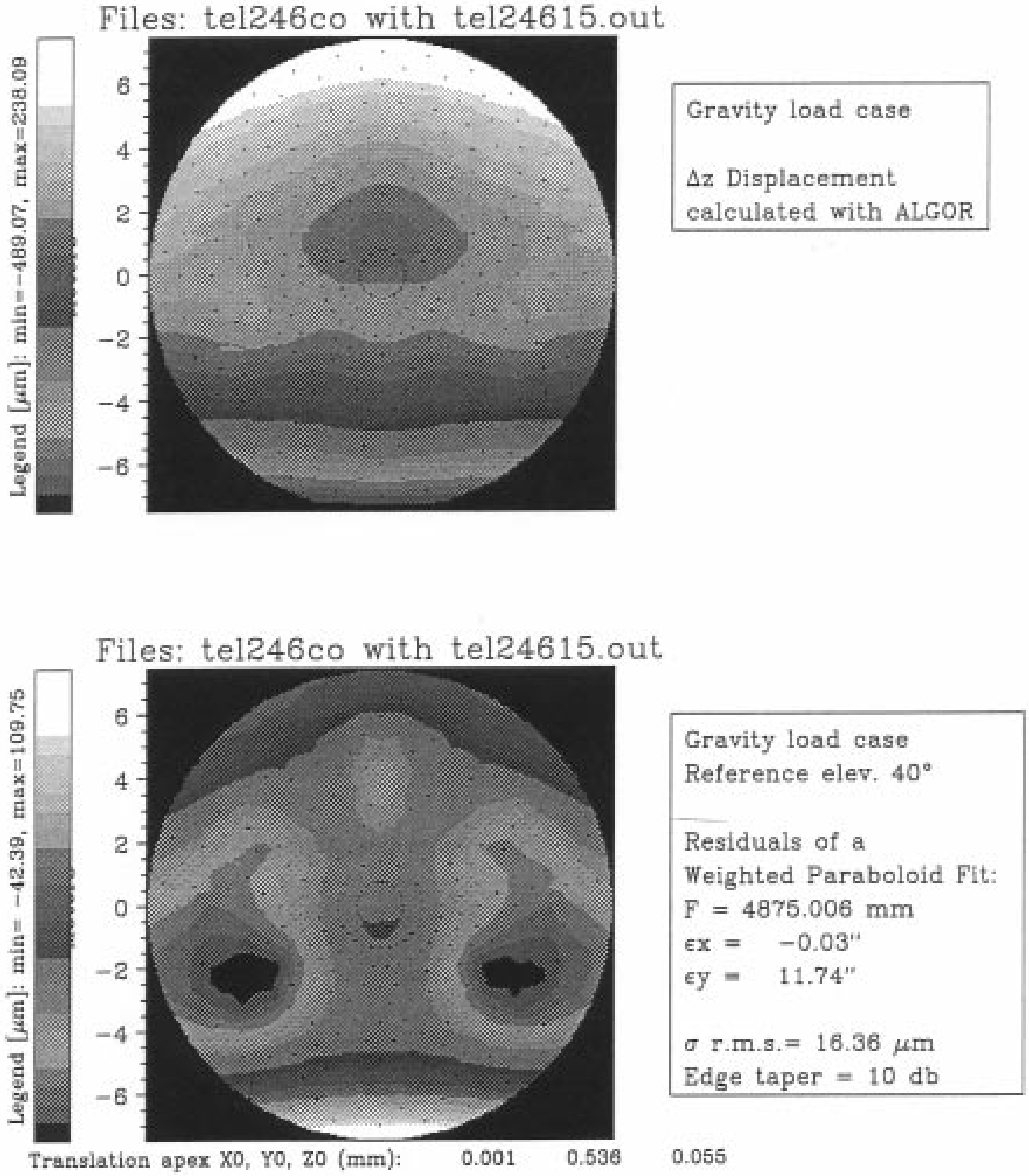


Figure 6: Gravity deformation and r.m.s. surface errors (15° elev.)

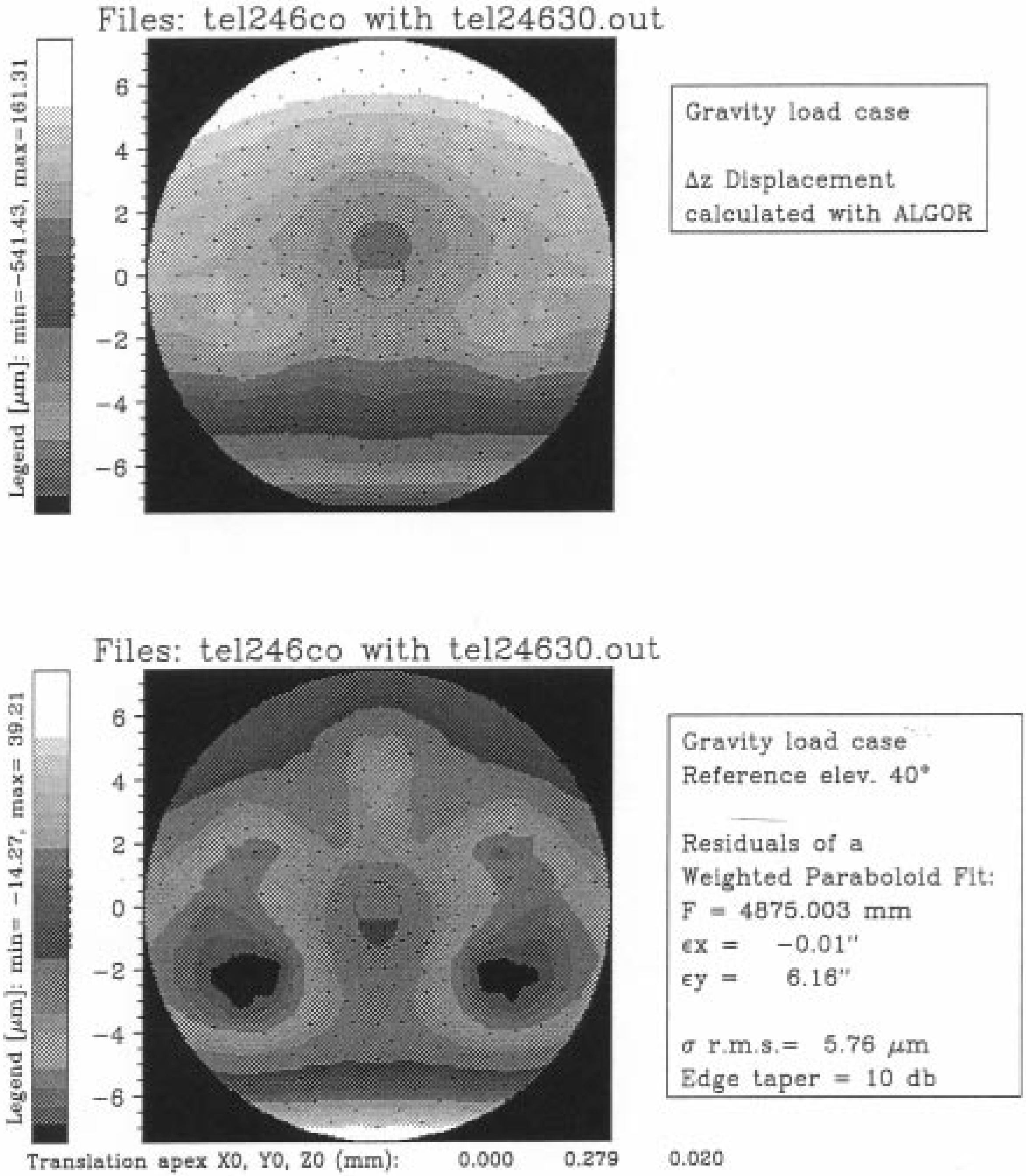
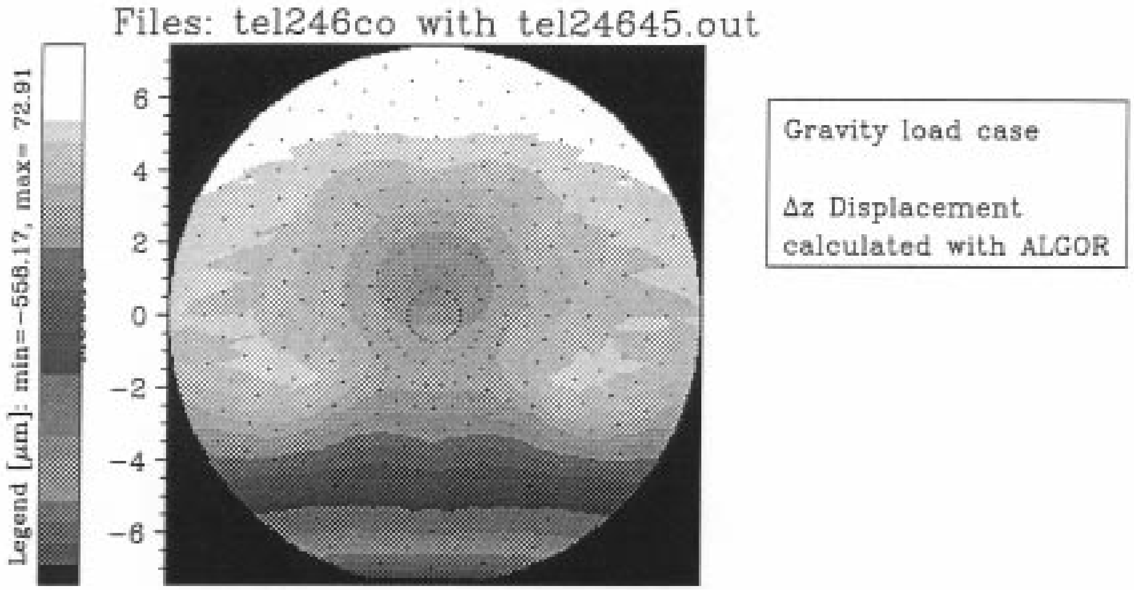


Figure 7: Gravity deformation and r.m.s. surface errors (30° elev.)



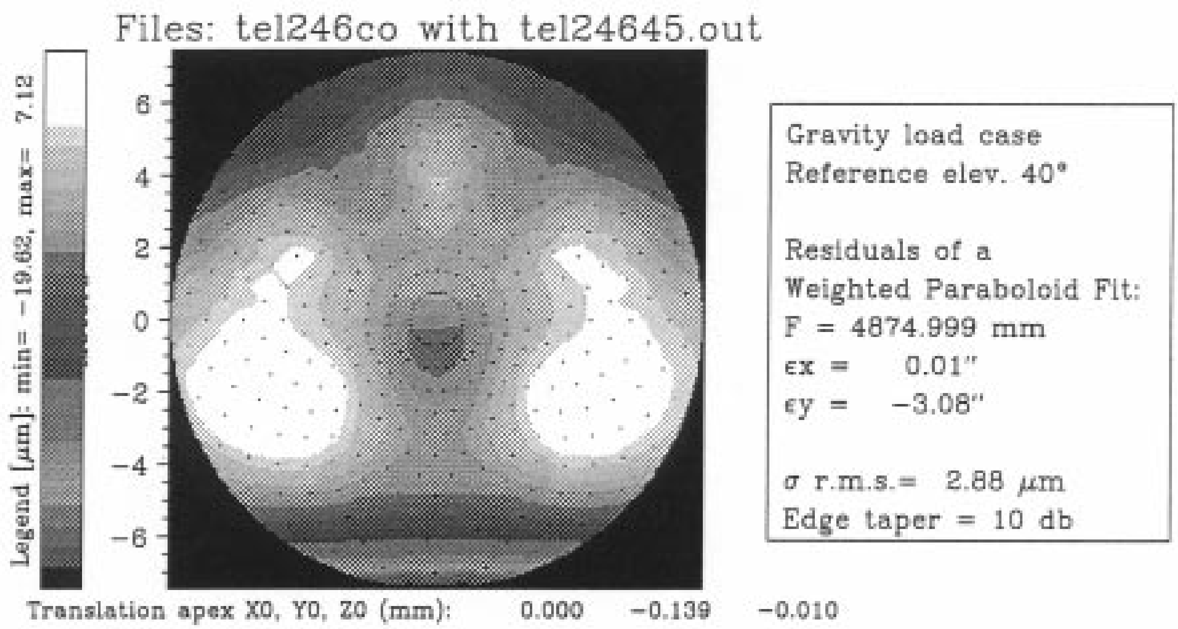


Figure 8: Gravity deformation and r.m.s. surface errors (45° elev.)

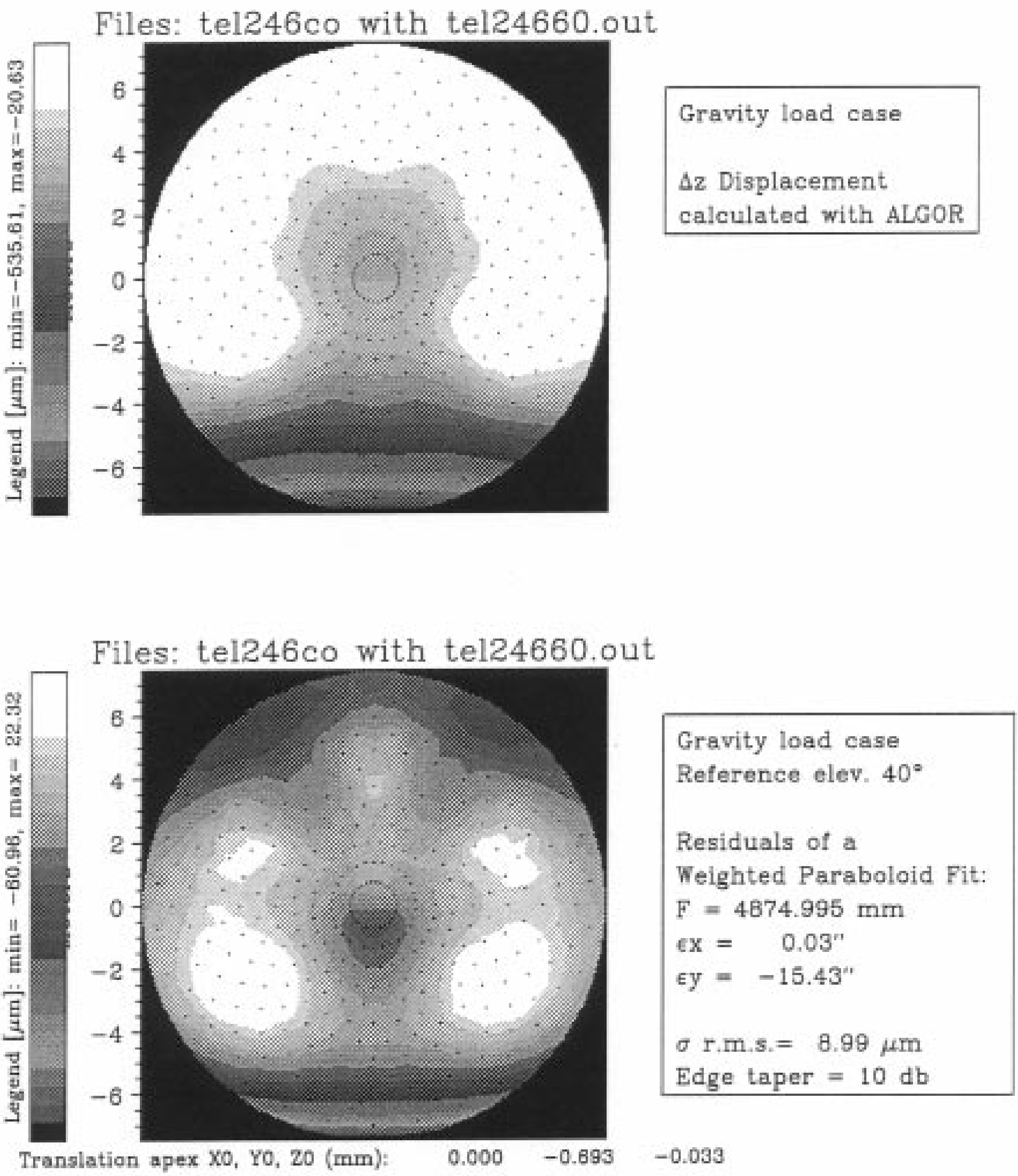
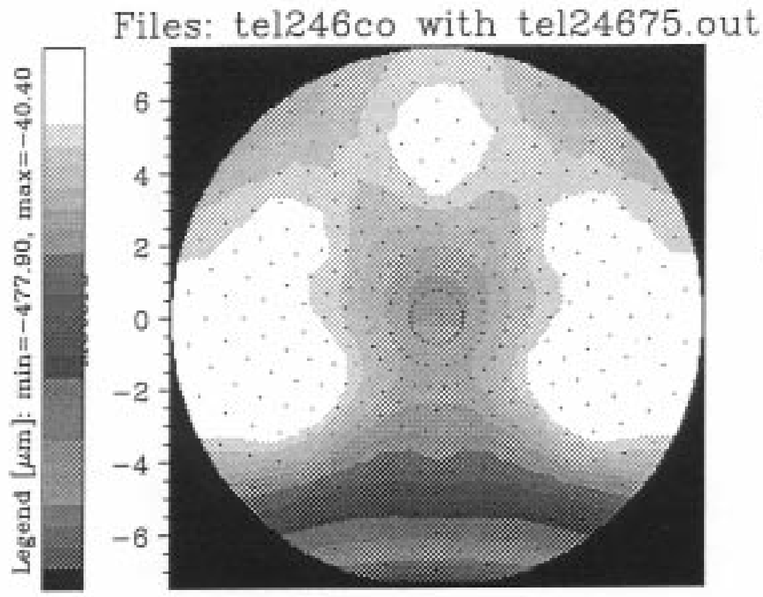
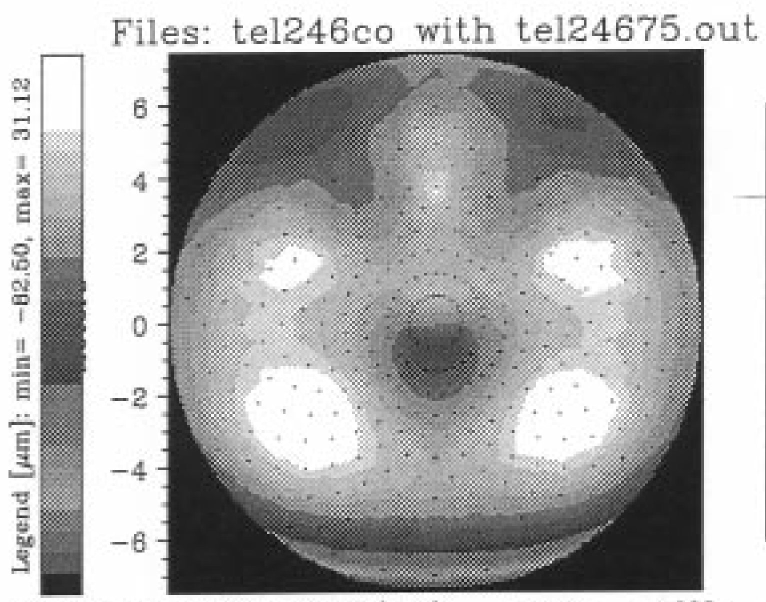


Figure 9: Gravity deformation and r.m.s. surface errors (60° elev.)



Gravity load case

Δz Displacement
calculated with ALGOR



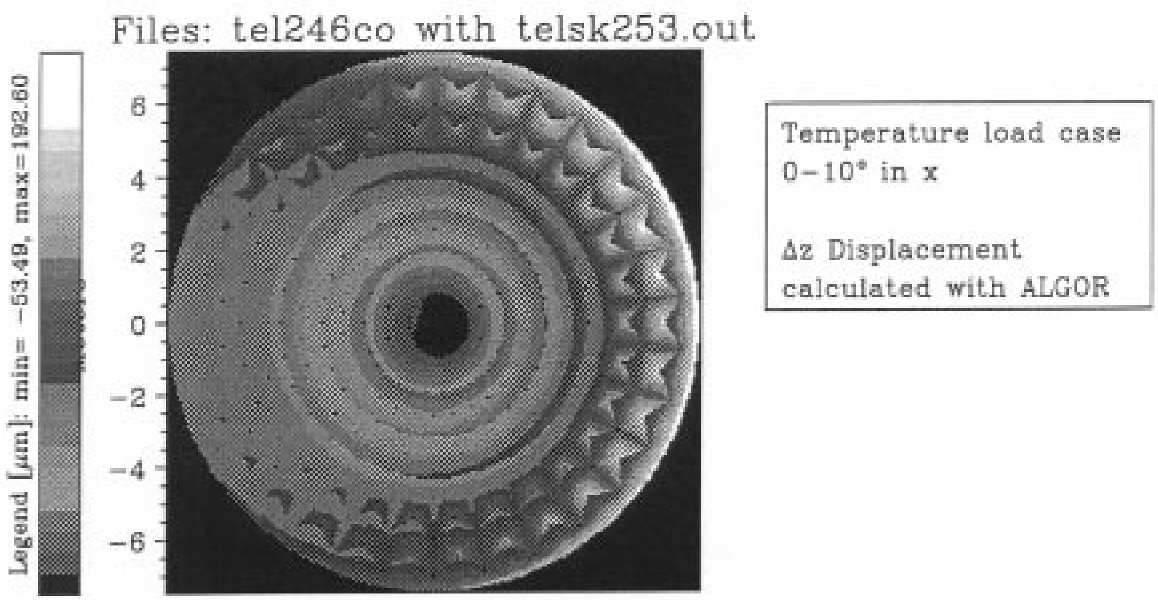
Gravity load case
Reference elev. 40°

Residuals of a
Weighted Paraboloid Fit:
F = 4874.991 mm
ϵx = 0.05''
ϵy = -29.69''

σ r.m.s.= 12.87 μm
Edge taper = 10 db

Translation apex X0, Y0, Z0 (mm): -0.001 -1.328 -0.047

Figure 10: Gravity deformation and r.m.s. surface errors (75° elev.)



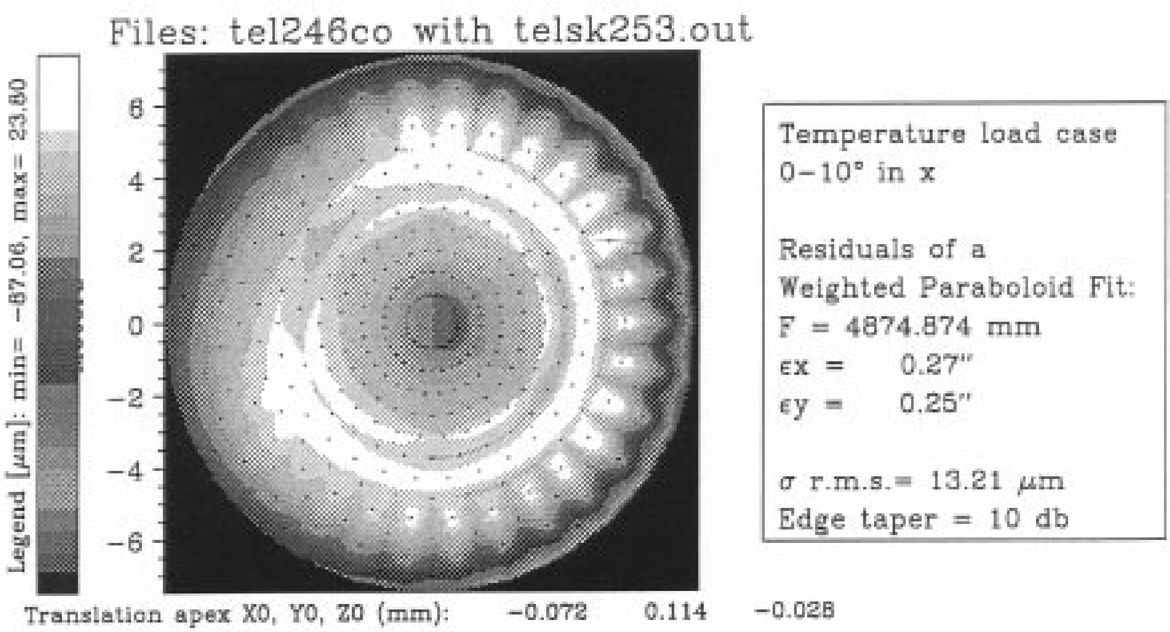


Figure 11: Thermal deformation and r.m.s. surface errors (dT=10K left-right)

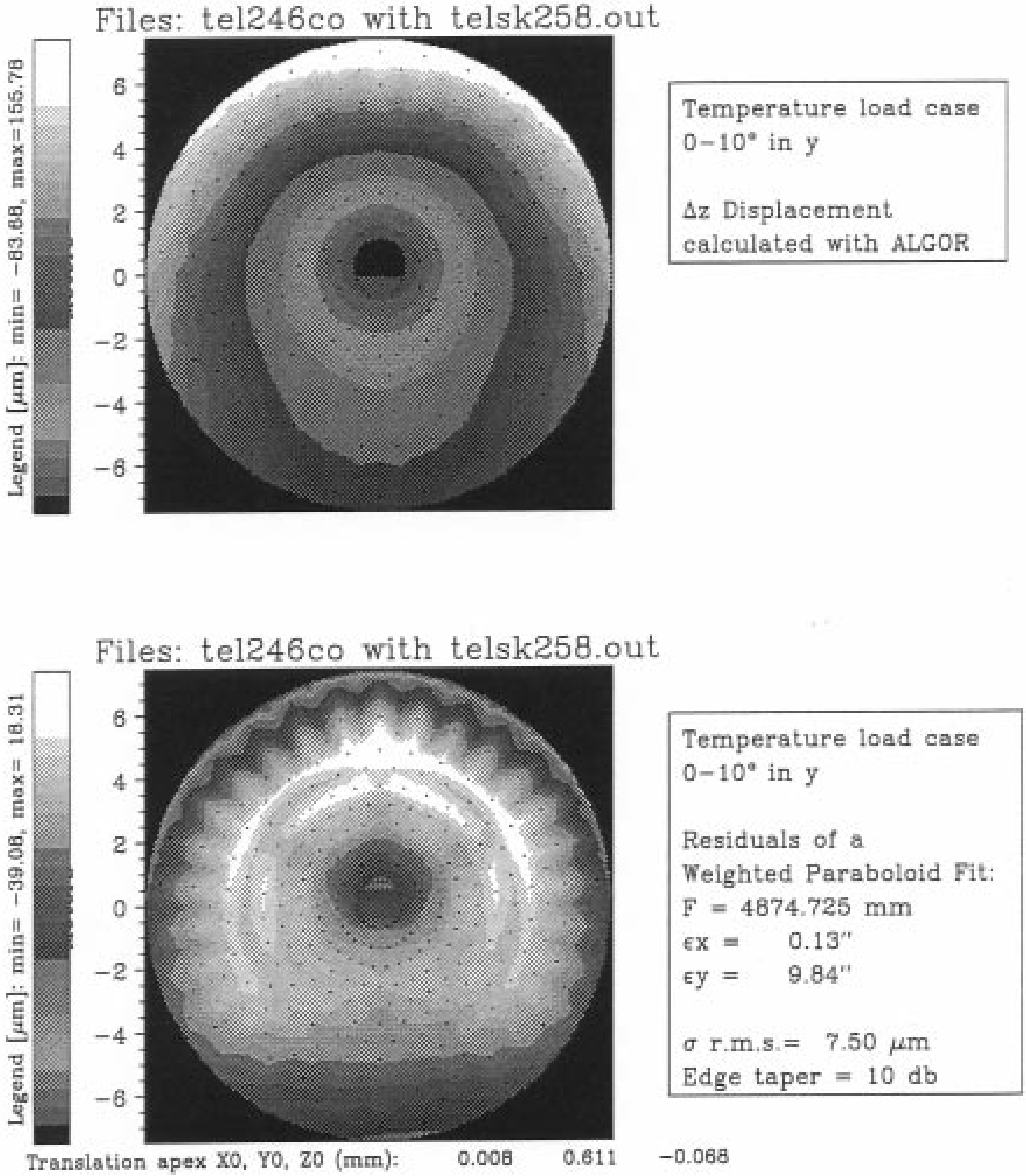


Figure 12: Thermal deformation and r.m.s. surface errors (dT=10K bottom-top)

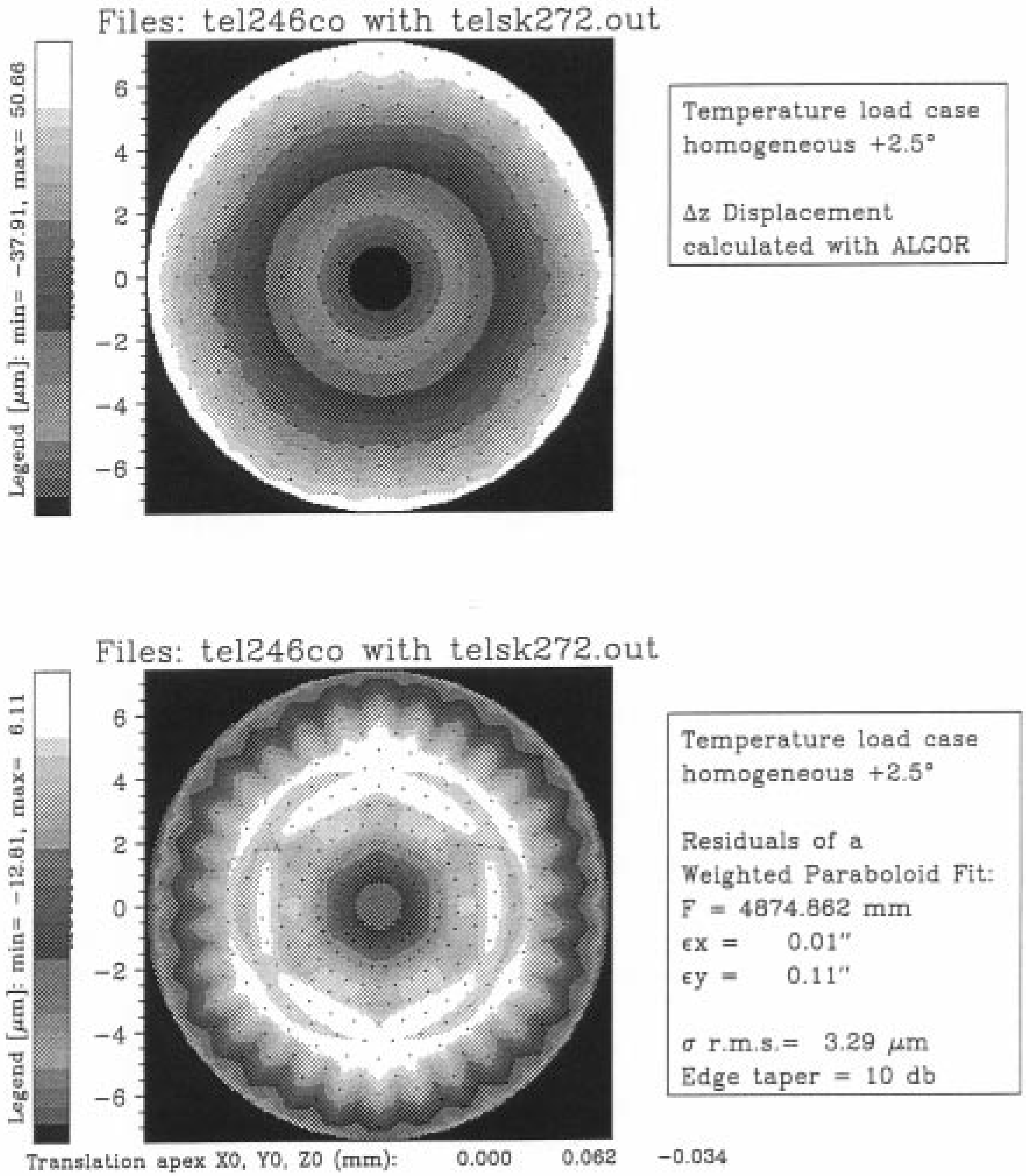


Figure 13: Thermal deformation and r.m.s. surface errors (dT=2.5K entire structure)

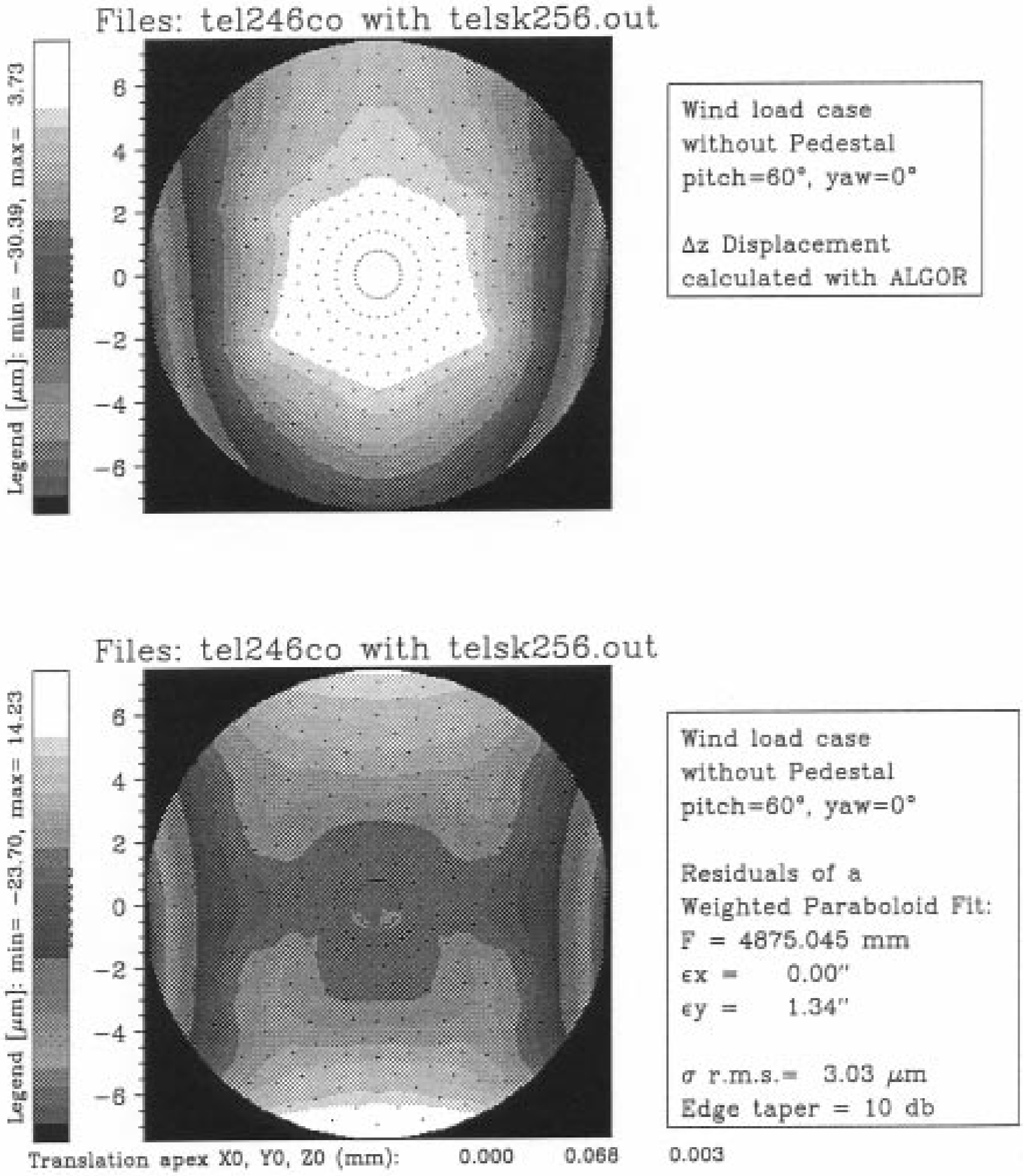


Figure 14: Deformations and r.m.s. surface errors under wind load 6 m/s, attack angle 0° az, 60° el

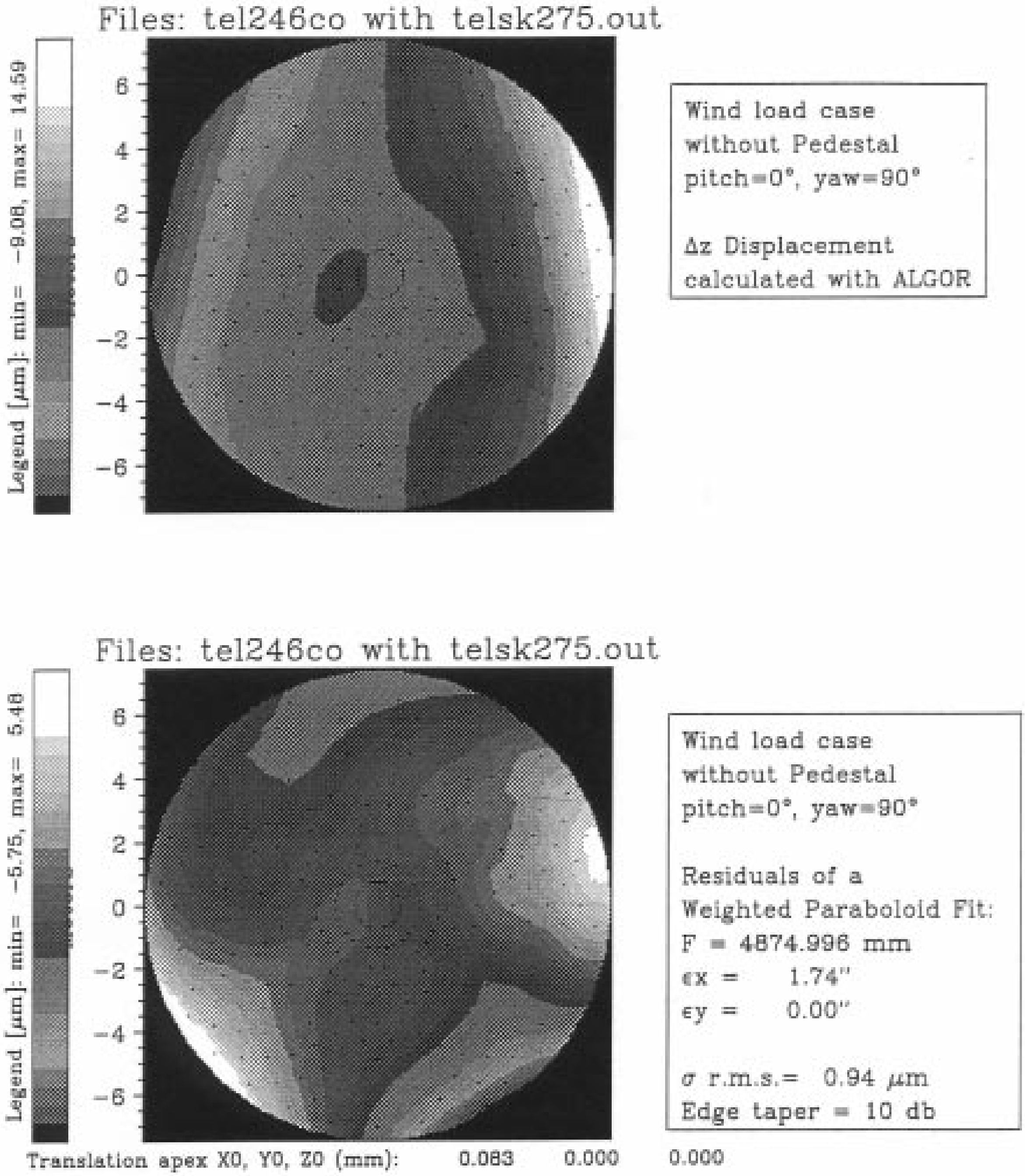
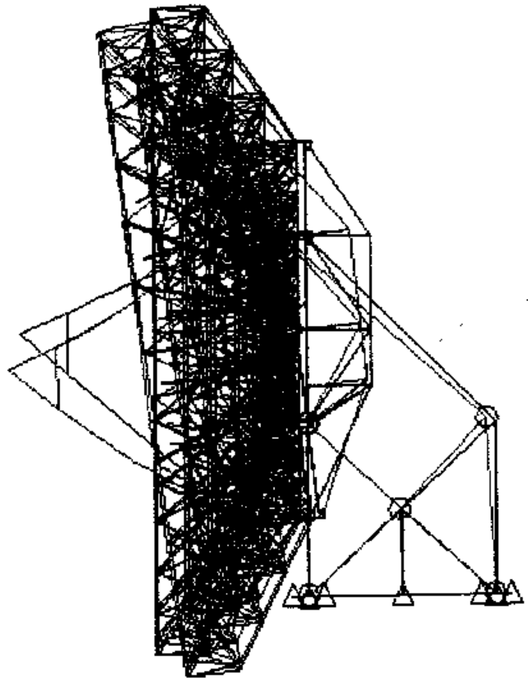


Figure 15: Deformations and r.m.s. surface errors under wind load 6 m/s, attack angle 90° az, 0° el



4.5 m long
13,000 mm² cross section

Fig. 16: Lowest eigenfrequency mode at f = 9Hz (telescope in hor. position)

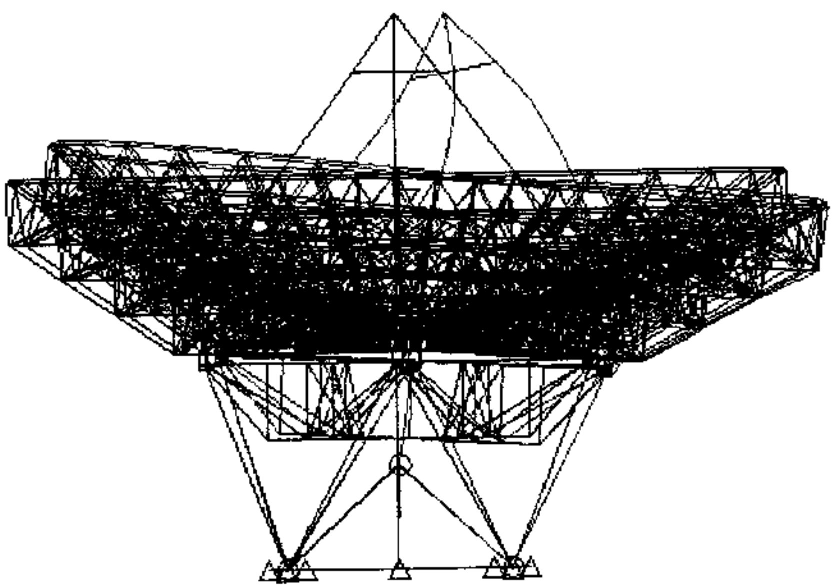


Fig. 17: Lowest eigenfrequency mode at f = 15.5Hz (telescope in zenith position)

6. *Resulting Error Budgets*

Error budgets are established for the

- surface,
- pointing, and
- phase stability.

Most are based on the above presented computational results ; others (e.g. for encoders, bearings, etc.) are derived from documented information. The load cases to be considered have been defined by the antenna working group. The following tables 6.1 to 6.3 summarize the obtained data for the proposed 15m telescope, and figures 18 to 26 show the computational results.

Table 6.1 : Surface Error

1. Reflector Back-up Structure

♦ gravity (worst case for el. angles between 20 and 75 deg., correction of secondary position included)		12.9 µm r.m.s.
♦ windload (6 m/s at 5000 altitude static load averaged over attack angles)		2.0 µm r.m.s.
- 0 az., 60 el.	3.0 µm r.m.s.	
- 90 az., 0 el.	0.9 r.m.s.	
♦ thermal (averaged over temp. gradients)		10.4 r.m.s.
- temperature gradient of 10C front to back	7.5 µm r.m.s.	
- temperature gradient of 10C left to right	13.2 µm r.m.s.	
♦ $\Delta T = 2.5C$ in entire structure		3.3 µm r.m.s.
♦ **total back-up structure**		**17.0 µm r.s.s.**

2. Panels

♦ machining (best fit for tilt and warp)	14.0 µm r.m.s.
♦ wind and gravity (static load for 6 m/s, form factor $c_f = 2$, gravity, no best fit)	2.5 µm r.m.s.
♦ thermal (deformation due to full face-on solar load)	0.5 µm r.m.s.
♦ **total panels**	**14.2 µmr.s.s.**

3. Secondary

♦ machining (best fit for tilt and focal length)	8.0 μm r.m.s.
♦ thermal	
ΔT = 10C entire element	0.0 μm r.m.s.
10C/m gradient	1.4 μm r.m.s.
♦ **total secondary**	**8.1 μm r.s.s.**

4. Alignment	10 μm r.m.s.
5. **GRAND TOTAL**	**25.6 μm r.s.s.**

Table 6.2 : Pointing Error Budget

General Remarks

- for thermal loading, only the reflector structure has to be considered ;
- for wind load, two values are indicated ; the first for information without any encoder system, the second with the proposed encoder system for the 15m telescope, which operates independently of structural deformations and therefore also corrects for the contributions coming from the pedestal ;
- pointing errors quoted shall be the total pointing error on the sky.

1. Wind loading (6 m/s at 5000 m altitude)	(without encoder / with encoder)
♦ attack angle 0 az., 60 el.	0.02 arc sec / 0.15 arc sec
♦ attack angle 90 az., 0 el.	0.50 arc sec / 0.19 arc sec
2. Thermal	
♦ Δt = 3C left-right across the dish	0.19 arc sec
♦ Δt = 3C front-back across the dish	0.19 arc sec
3. Servo system	0.20 arc sec
4. Non-repeatable bearing errors and friction	0.20 arc sec
5. **TOTAL**	**0.46 arc sec r.s.s.**

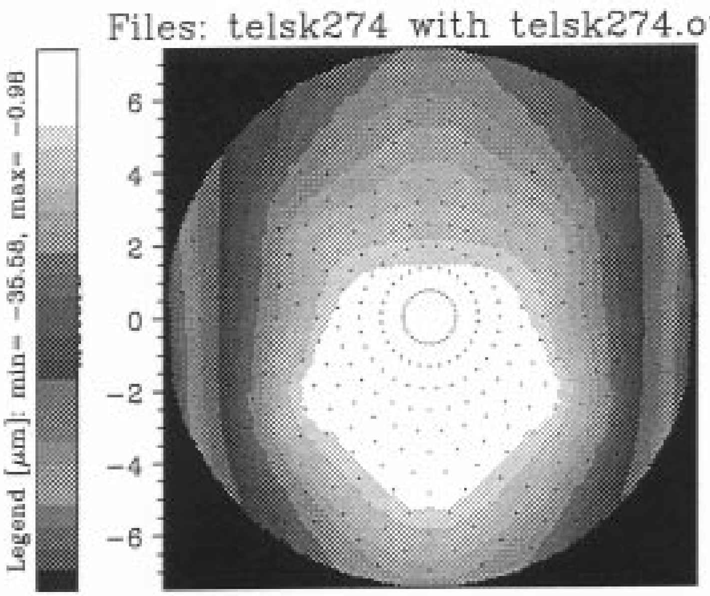
Table 6.3 : Phase Stability

Remarks : 1. the entire telescope has to be considered ;

2. due to the off-set between the el. and az. axes, certain pointing errors contribute to the aperture phase shift ;

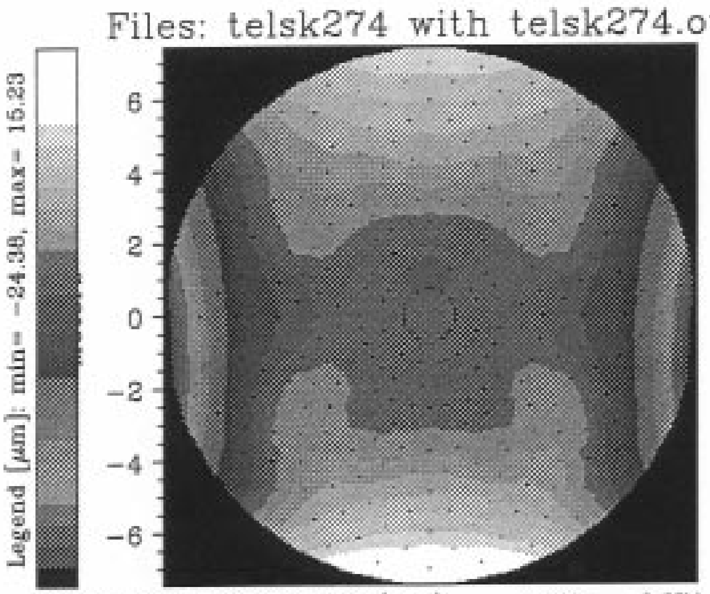
3. the special encoder system of the proposed 15m telescope does not correct for phase shifts.

N°	Loading	Aperture phase shift	Optical path length	Total
1	dT = 1 K, el. = 0 deg.	- 14 μm	20 μm	6 μm
2	dT = 1 K, el. = 90 deg.	- 35 μm	20 μm	- 15 μm
3	6 m/s wind at 5000 m altitude, face on	16 μm	- 10 μm	6 μm
4	servo system mispointing	1 μm	--	1 μm
5	mispointing due to bearings and fixation	1 μm	--	1 μm



Wind load case
with Pedestal
pitch=60°, yaw=0°

Δz Displacement
calculated with ALGOR



Wind load case
with Pedestal
pitch=60°, yaw=0°

Residuals of a
Weighted Paraboloid Fit:
F = 4875.044 mm
ϵx = 0.00"
ϵy = 1.17"

σ r.m.s.= 3.18 μm
Edge taper = 10 db

Translation apex X0, Y0, Z0 (mm): 0.000 0.074 -0.002

Pointing characteristics with Subreflector:

X direction:

ϵx = 0.00 "
ΔFx = -0.06 μm
γx = 0.00 "
ΔSx = -0.09 μm

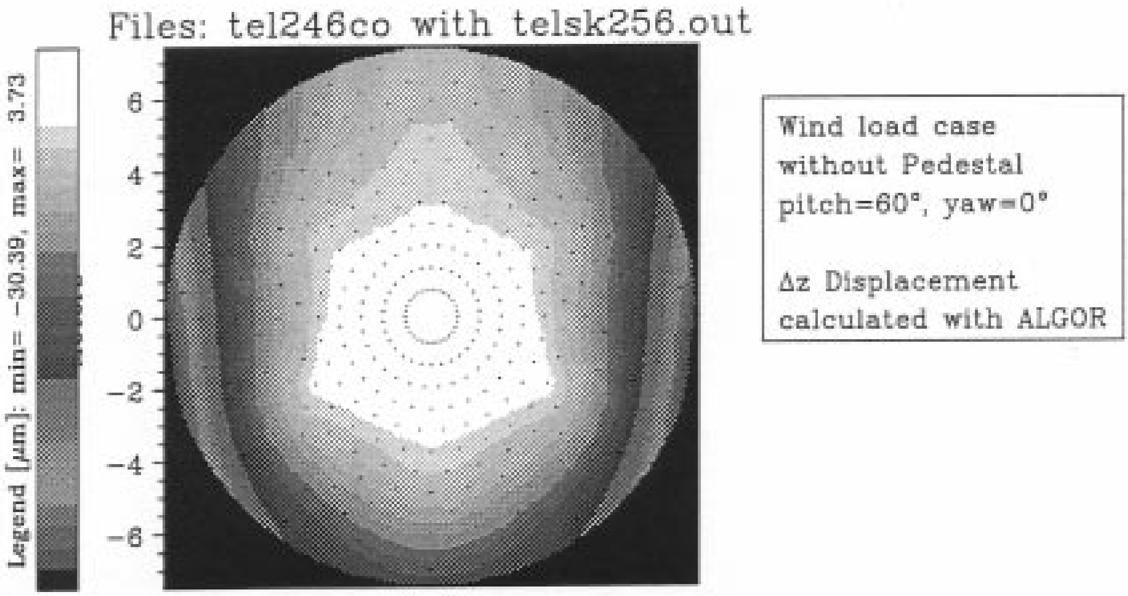
δx = 0.00 "

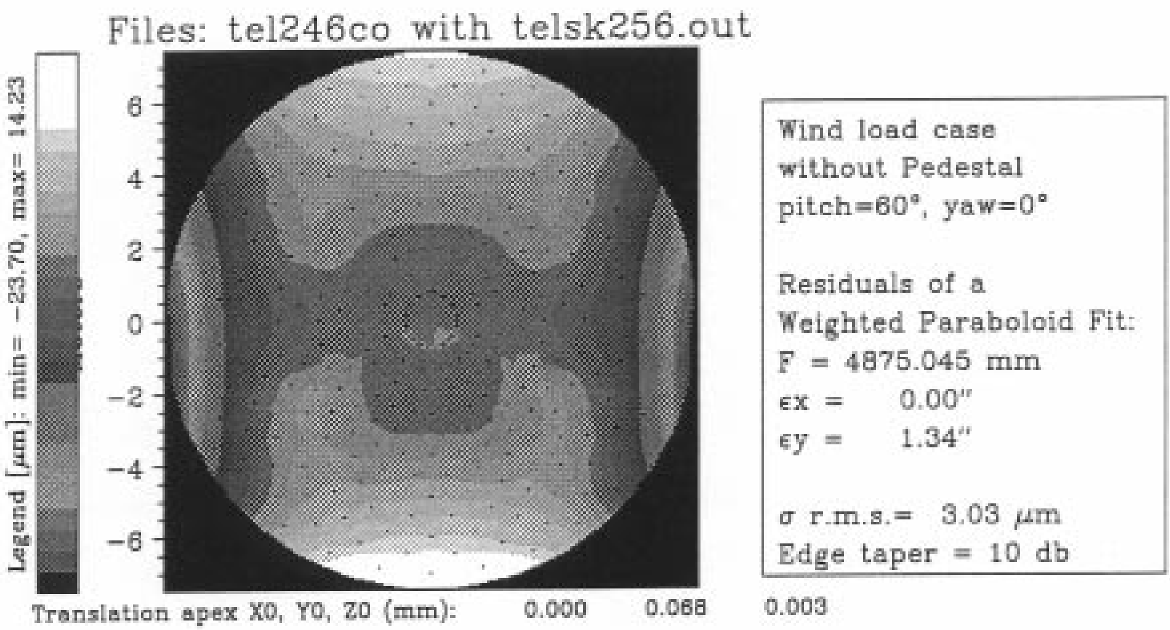
Y direction:

ϵy = 1.17 "
ΔFy = 46.53 μm
γy = -0.17 "
ΔSy = 11.55 μm

δy = 0.02 "

Figure 18: Pointing error without encoder, wind load 6 m/s, attack angle 0° az, 60° el





Pointing characteristics with Subreflector:

X direction:

$\epsilon x = 0.00$ ″
$\Delta Fx = -0.03$ μm
$\gamma x = 0.00$ ″
$\Delta Sx = -0.04$ μm

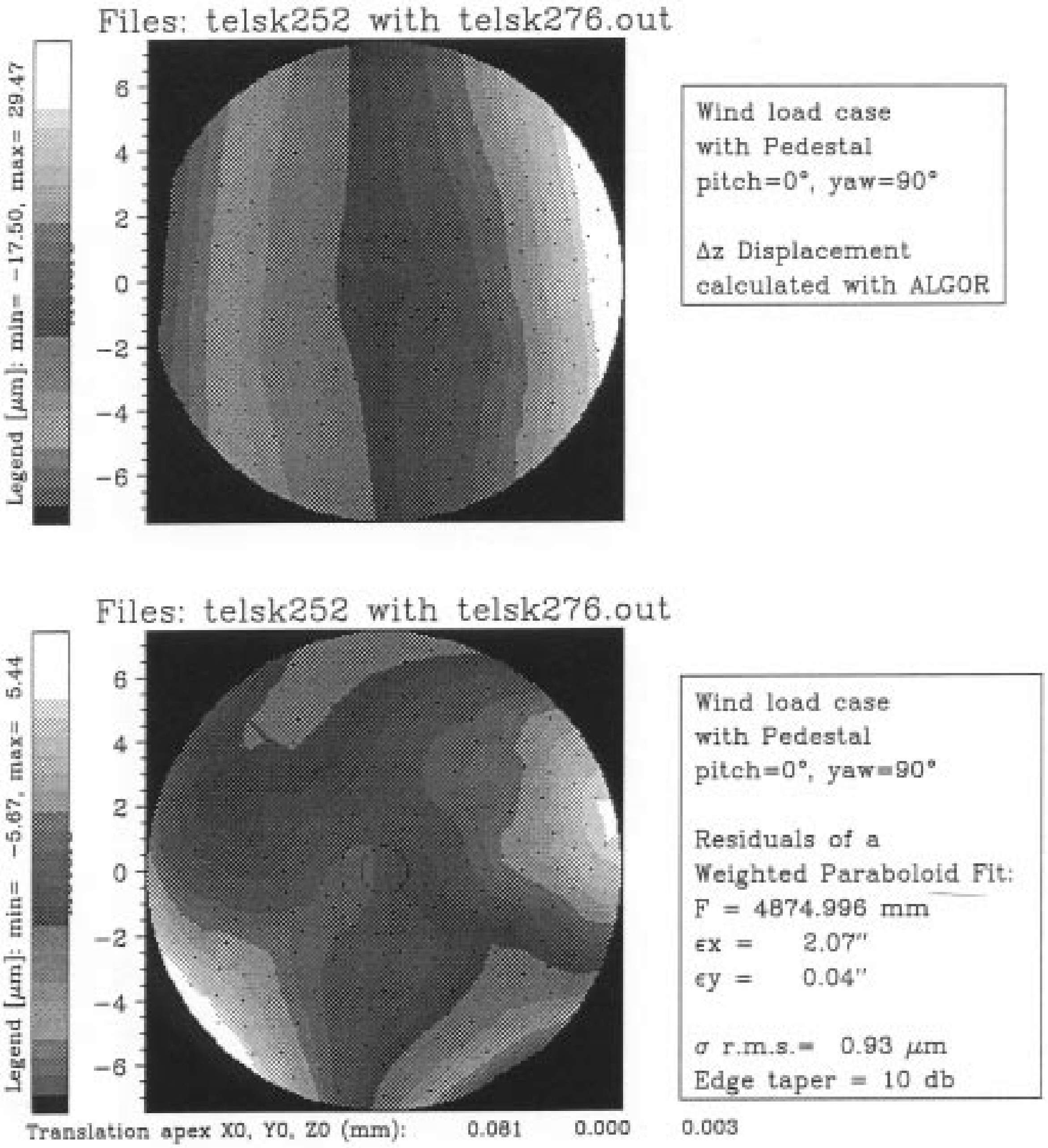
$\delta x = 0.00$ ″

Y direction:

$\epsilon y = 1.34$ ″
$\Delta Fy = 36.81$ μm
$\gamma y = -0.32$ ″
$\Delta Sy = -0.81$ μm

$\delta y = 0.15$ ″

Figure 19: Pointing error with encoder, wind load 6 m/s, attack angle 0° az, 60° el



Pointing characteristics with Subreflector:

X direction:

ϵx = 2.07 "
ΔFx = 31.60 μm
γx = 0.25 "
ΔSx = −17.51 μm

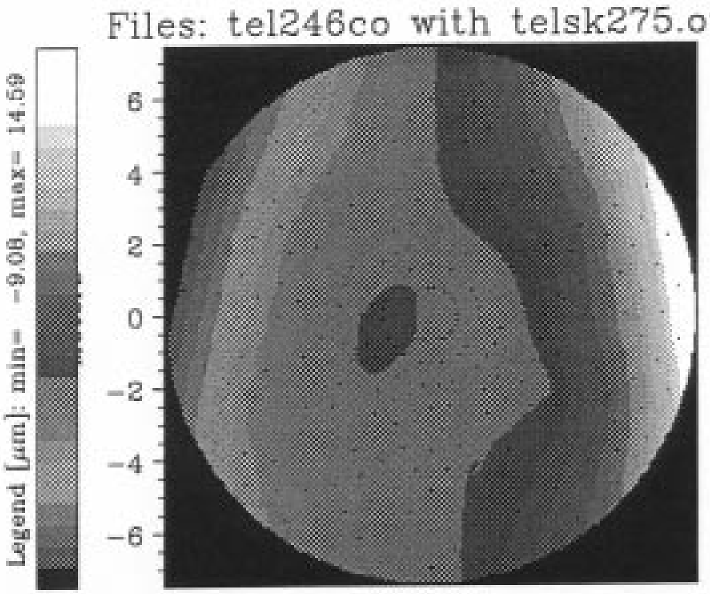
δx = 0.50 "

Y direction:

ϵy = 0.04 "
ΔFy = −1.24 μm
γy = 0.08 "
ΔSy = −1.38 μm

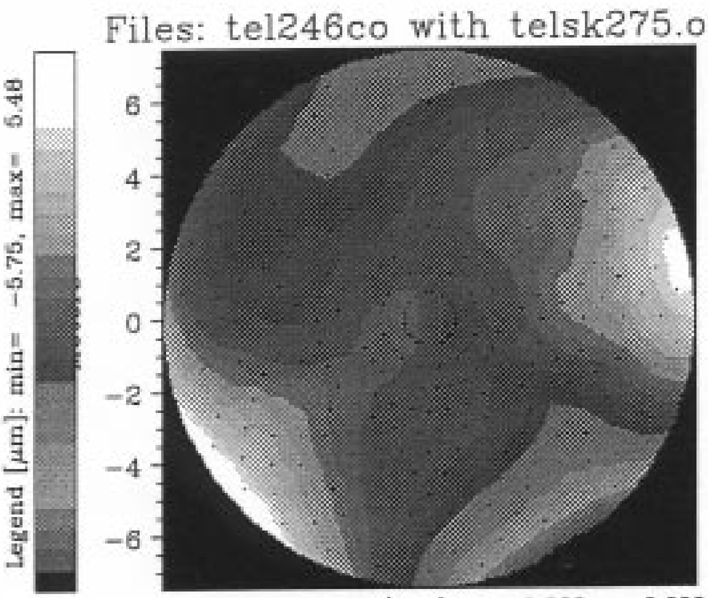
δy = 0.03 "

Figure 20: Pointing error without encoder, wind load 6 m/s, attack angle 90° az, 0° el



Wind load case
without Pedestal
pitch=0°, yaw=90°

Δz Displacement
calculated with ALGOR



Wind load case
without Pedestal
pitch=0°, yaw=90°

Residuals of a
Weighted Paraboloid Fit:
F = 4874.996 mm
ϵx = 1.74"
ϵy = 0.00"

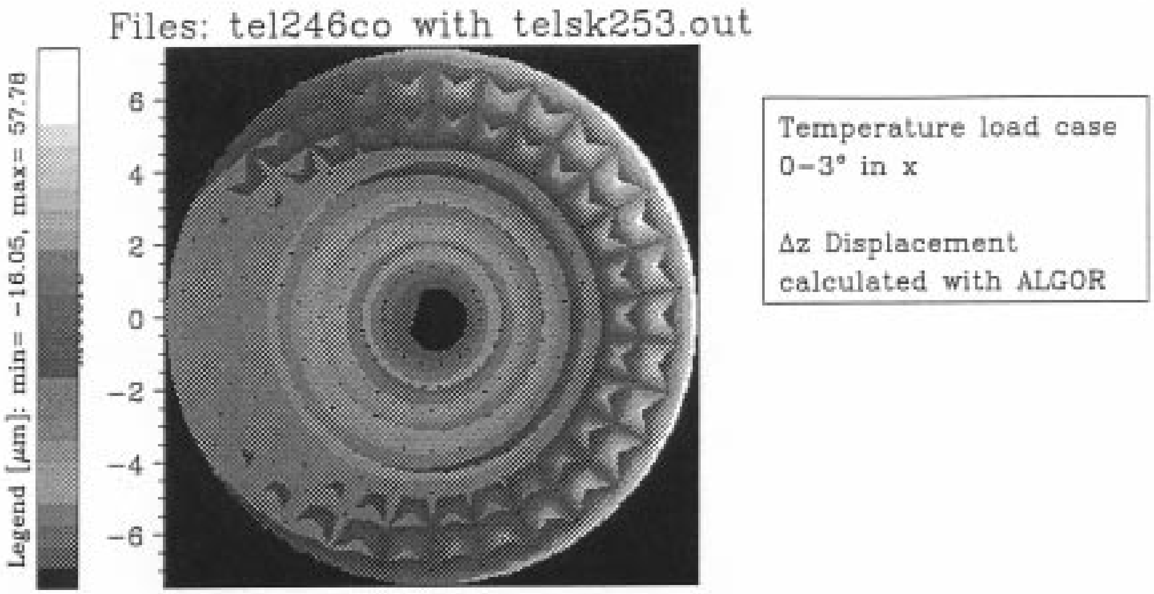
σ r.m.s.= 0.94 µm
Edge taper = 10 db

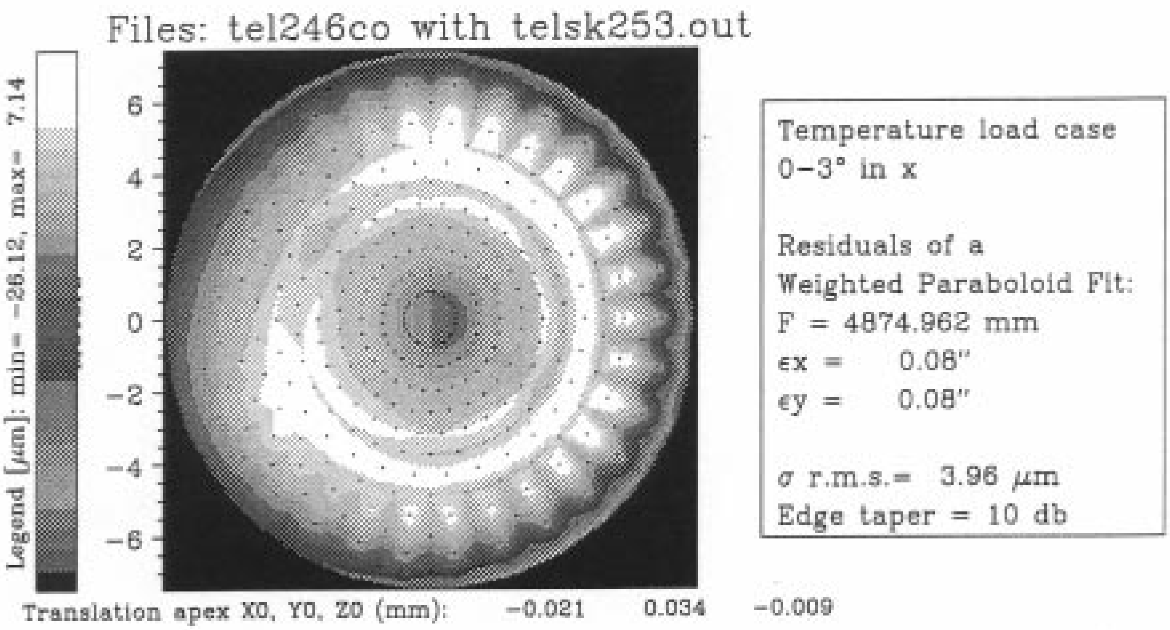
Translation apex X0, Y0, Z0 (mm): 0.083 0.000 0.000

Pointing characteristics with Subreflector:

X direction:			Y direction:		
ϵx	=	1.74 "	ϵy	=	0.00 "
ΔFx	=	42.03 µm	ΔFy	=	-0.13 µm
γx	=	0.15 "	γy	=	0.05 "
ΔSx	=	-5.38 µm	ΔSy	=	-0.27 µm
δx	=	0.19 "	δy	=	-0.01 "

Figure 21: Pointing error with encoder, wind load 6 m/s, attack angle 90° az, 0° el





Pointing characteristics with Subreflector:

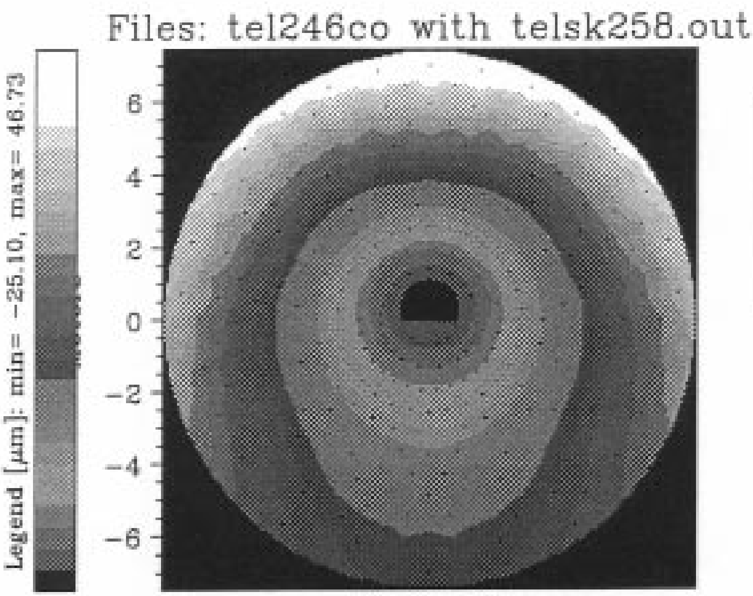
X direction:

ϵx	=	0.08 "
ΔFx	=	−23.35 μm
γx	=	0.10 "
ΔSx	=	−21.55 μm
δx	=	0.19 "

Y direction:

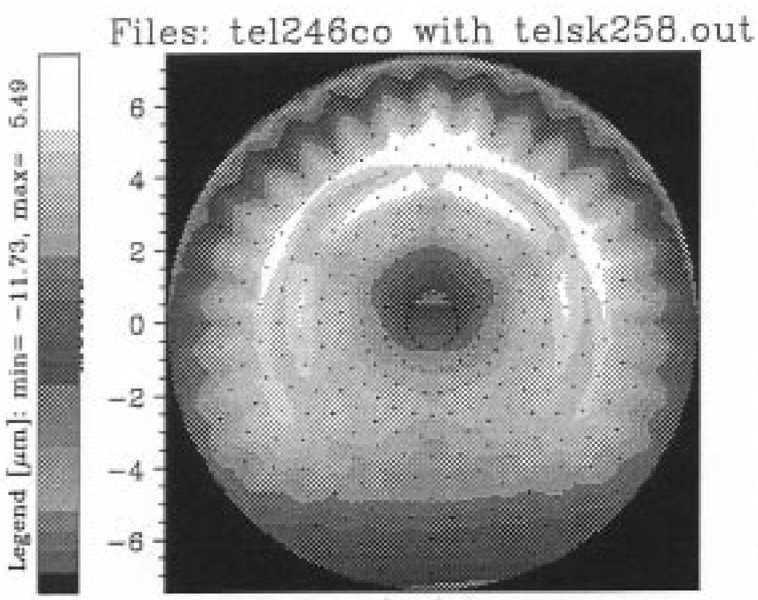
ϵy	=	0.08 "
ΔFy	=	32.55 μm
γy	=	0.08 "
ΔSy	=	34.03 μm
δy	=	0.02 "

Figure 22: Pointing error under thermal load (dT=3K left-right)



Temperature load case
0–3° in y

Δz Displacement
calculated with ALGOR



Temperature load case
0–3° in y

Residuals of a
Weighted Paraboloid Fit:
F = 4874.917 mm
ϵx = 0.04"
ϵy = 2.95"

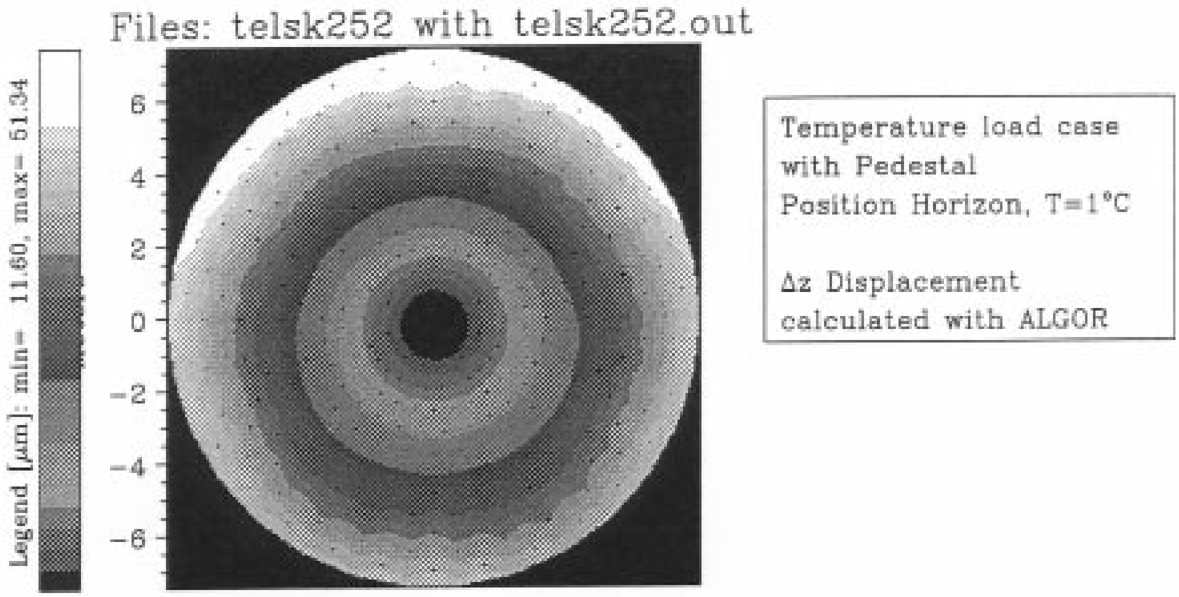
σ r.m.s.= 2.25 μm
Edge taper = 10 db

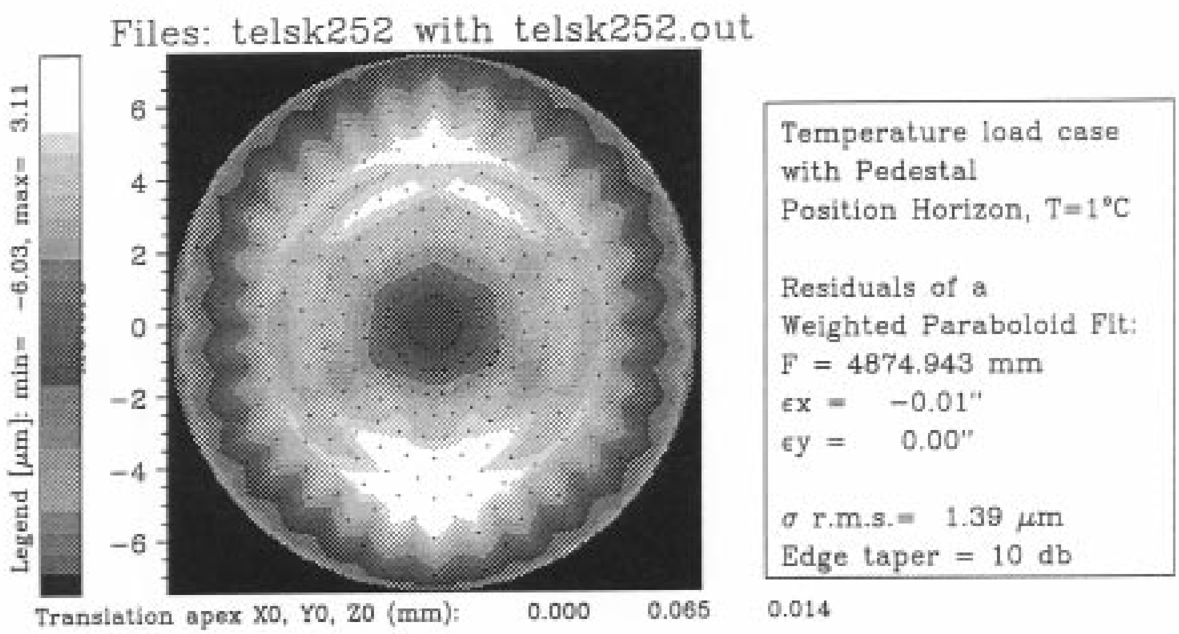
Translation apex X0, Y0, Z0 (mm): 0.002 0.183 -0.020

Pointing characteristics with Subreflector:

X direction:			Y direction:		
ϵx	=	0.04 "	ϵy	=	2.95 "
ΔFx	=	1.41 μm	ΔFy	=	113.53 μm
γx	=	0.02 "	γy	=	0.12 "
ΔSx	=	0.30 μm	ΔSy	=	31.68 μm
δx	=	0.00 "	δy	=	0.19 "

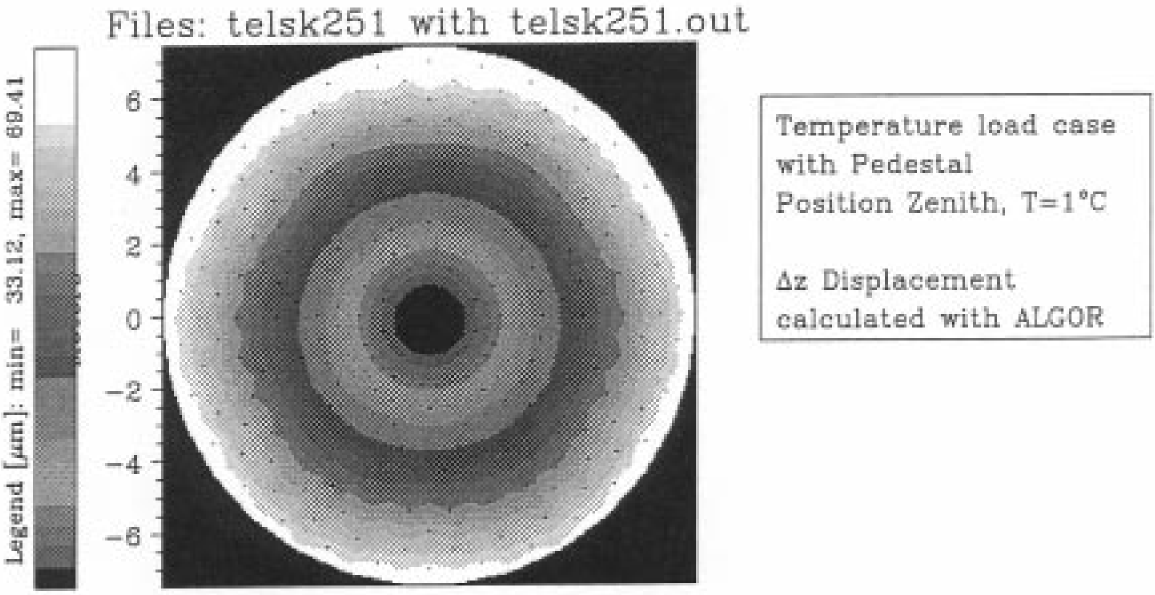
Figure 23: Pointing error under thermal load (dT=3K bottom–top)

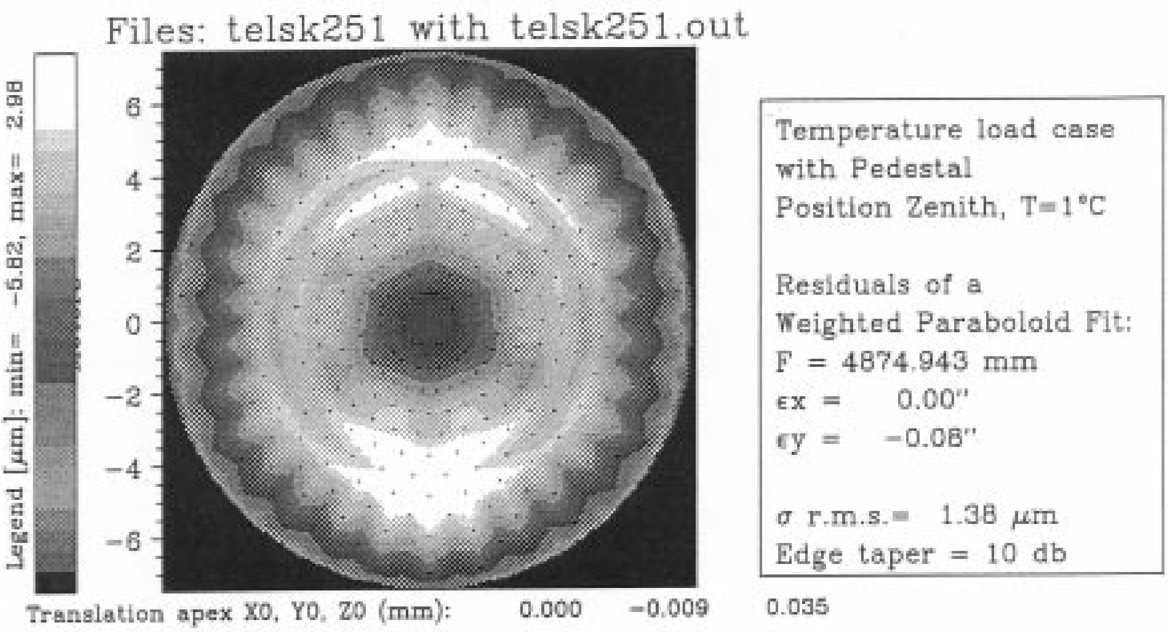




Phase shift (apex and subreflector movement): 6.00 μm

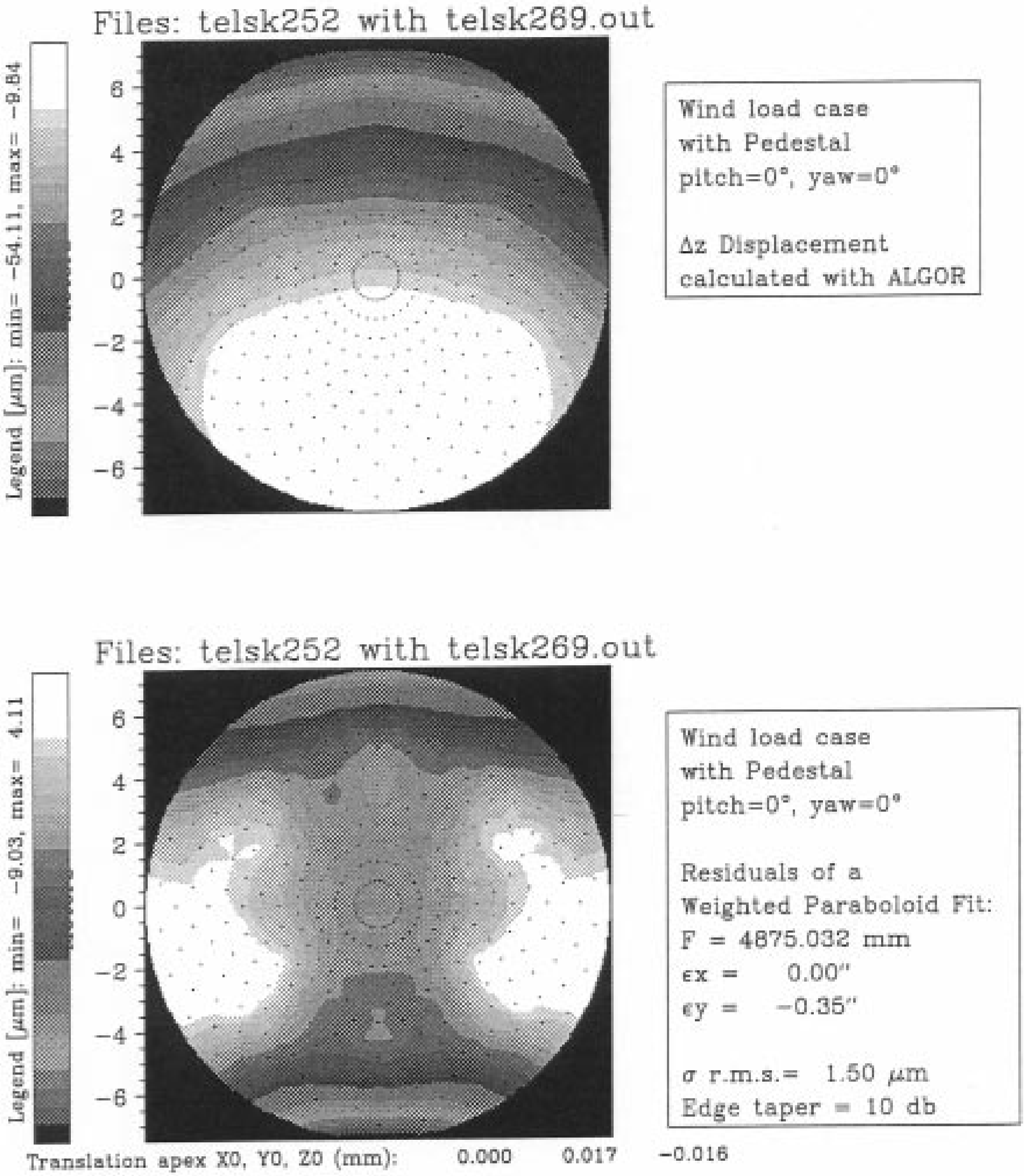
Figure 24: Phase error under thermal load (dT=1K, el=0°)





Phase shift (apex and subreflector movement): -15.22 μm

Figure 25: Phase error under thermal load (dT=1K, el=90°)



Phase shift (apex and subreflector movement): 5.51 μm

Figure 26: Phase error under wind load (6 m/s, face-on)

7. *Industrialization, Manufacture*

It is assumed that one or more prototype telescopes will have been built, and the blue prints will have been finalized befor the full industrialization of the project

Based on the approved blue prints and the corresponding set of manufacturing and acceptance specifications, contracts will be concluded with industry. The industrialization includes typically :

- preparation of tooling,
- preparation of machining programs,
- preparation of a planning on manpower and machines ,
- preparation of a planning on manufacturing,
- preparation of quality control and acceptance procedures,
- purchasing of materials,
- planning on delivery dates, packing and transport,
- planning on temporary storage and other logistics,
- planning on assembly.

The following manufacture of the telescope parts will be organized such that the contractor(s) runs a series production with a specified monthly output that is matched to the assembly needs and the commissioning of the individual telescopes. The project management surveys the quality control, the completeness of deliveries and the time schedule.

8. *Transport, Assembly, Alignment, Maintenance*

The proposed telescope is composed of mainly 5 elements :

- pedestal,
- drives and bearings,
- encoder system,
- cabin,
- reflector.

Pedestal and cabin are each single pieces in steel of low complexity and fragility. Drives, bearings, and encoder system in contrary have a high degree of complexity and/or precision. The last but most complex, part, the reflector, is composed of multiple elements.

8.1 Transport

General experience in transportation of many items requires a minimization of the number of boxes between the departure point and the destination. This means that a telescope will be composed of :

♦ the pedestal	1 box
♦ cabin	1 box
♦ drives	several small boxes
♦ bearings	several small boxes
♦ encoder system	1 box
♦ reflector	many boxes of small to medium size

For the transport to Chile, the pedestal and the cabin could be shipped in their boxes while the rest of the component boxes will be grouped in two containers, i.e. the telescope will arrive at the site of assembly in a limited number of units.

8.2 Assembly

Although various possibilities can be envisaged for the assembly of the telescope units, it is proposed here to do it on the site itself in an oxigenized hall which will be necessary anyway for maintenance. The hall should be large enough for the additional storage of spare parts and tooling. The parts for an assembly should, however, mainly be stored outside. The hall has to be equipped with lifting facilities according to size and weight of the parts and special assembly platforms for the reflectors. A lift should connect the ground floor with the different levels of the assembly platforms. It should have a capacity of at least 500 kg and be relatively spacy.

The hall has to have at least one gate through which the assembled telescope can be taken to the observing site by the transporter.

8.3 Alignment

The reflector surface should be prealigned by means of a high-precision tool. Two methods could be envisaged :

- assembling the reflector upside down starting with the panels laid out on the tool, followed by the back-up structure and placing this unit on the assembled pedestal ;
- the alignment tool is brought onto the reflecting surface of an assembled telescope in a certain elevation position.

The prealigned telescopes are fully aligned by holography outside the hall on a specialized station and using a transmitter on a nearby mountain peak.

8.4 Maintenance

The design of the proposed telescope and the choice of the materials is such that only a minimum of maintenance is necessary. Most of the smaller interventions can take place on the outside station, if one does not decide to take the telescope into the oxigenized hall for comfort and health reasons.

9. *Cost Estimate*

Remarks :

1. Reference is made to the technology applied for the IRAM 15m Plateau de Bure Telescopes.
2. The indicated prices are based on information from industry for fabrication according to blue prints.
3. Prices are based on a series of 50 identical telescopes.
4. Where prices were not available, they have been deducted or scaled from similar recent realisations.
5. Cost basis is 1997, taxes not included.
6. Prices are made in US K$/unit telescope, as described in the present report.
7. All indications are budget prices and can change by up to ± 20%.
8. The exchange rate was set to 1 US $ = 6 FFR.

9.1 Reflector

♦ alu panels including thermal insulation	630
♦ panel adjusters	20
♦ deicing system	-
♦ CFRP tubes	115
♦ inserts (parts and bonding)	250
♦ nodes	90
♦ tripod	175
♦ apex mechanism	12.5
♦ subreflector	52.5
♦ BUS insulation	-
♦ cabin	140
♦ assembly (includes mount assembly, food and logis for 5 people not included)	80

9.2 Mount

♦ pedestal structure	110
♦ bearings	260
♦ encoders	260
♦ servo drives	180
♦ cabling	30
♦ foundation x 4	t.b.d.
♦ az. ring x 4	t.b.d.
♦ assembly (included in reflector)	-

9.3 Management and Quality Assurance

♦ quality assurance (included in manufacturing	-
♦ logistics (included in assembly)	-
♦ shipping to site	210
♦ warranty, insurance, overhead, profit (included in manufacturing)	-
♦ contingency ≈ 15%	360
♦ coordination at institute's level 2%	50
9.4 **TOTAL**	**3.025**

10. *Modifications and Improvements*

Due to the short time available for detailing the telescope structures, it should be mentioned here that there is still room for improvements in the performance of the proposed telescope. No optimization of the structures could be done.

One example is the number of panels and the complexity of the back-up structure in the area of the innermost or even the two innermost rings of the reflector where a considerable simplification could be achieved by reducing the number of panels and the corresponding beams in the back-up structure from now 30 to 15. This will positively influence the costs, and the FEM calculations indicate that also a gain in performance is possible.

A second example is the pedestal frame work where, by an optimization of the beam members, including the linear drive, an even higher eigenfrequency value of the whole telescope could be achieved.

11. *Summary*

Although no optimization of the structures could be carried out, the proposed 15m telescope provides performances, already in this state, which qualify it with its large collecting area not only for mm-work but, due to its good performance in pointing, also for submillimeter observations.

The earlier prediction for the costs of typically 3 M US $ per telescope can be maintained after contacts to industry for the major cost drivers.

The annex gives some additional information on a reduced version of the 15m telescope by taking off the outer ring. The costs diminish only moderately (by the quantities for the corresponding panels and back-up structure) to about 94%, but the loss in collecting area is nearly 30%.

ANNEX

The 12.8m Telescope

The 12.8m Telescope

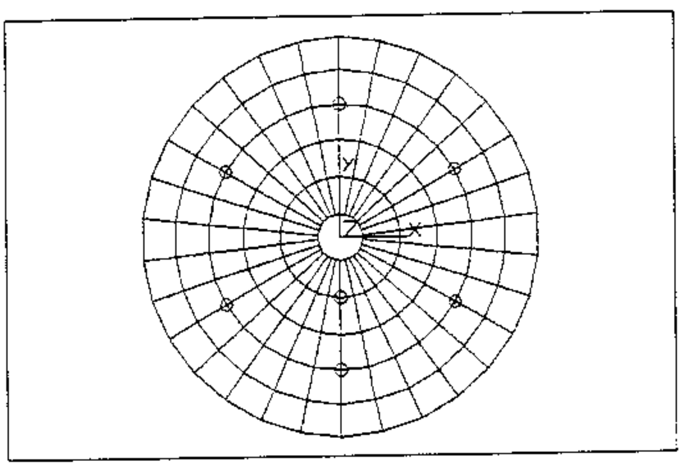
Following the positive results in performance of the proposed 15m telescope, some investigations have been carried out on a reduced 12.8m diameter version. Several possibilities for downgrading the dish size have been looked into. For this purpose the 15m dish was modeled in a first order approximation by a round plate configured of elements corresponding to the panel size. This plate is supported in the same six points as the proposed 15m reflector. The following modifications have been considered. :

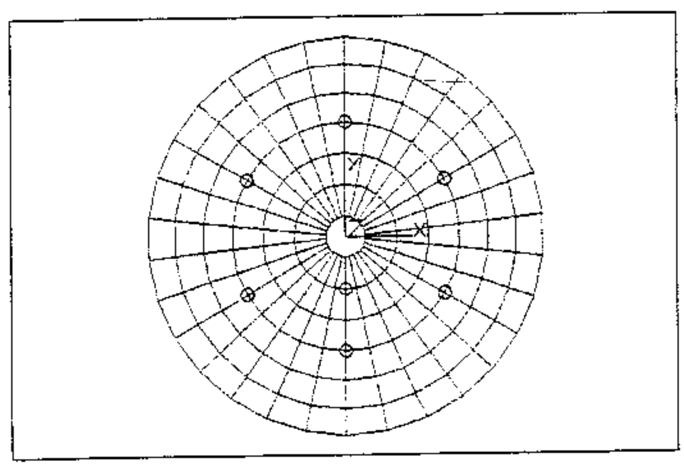
case1 - plate diameter reduced to 12.8m by taking the outer ring elements off and keeping the support points

case 2 - plate diameter reduced to 12.8m as above and the support points one ring further in

case 3 - shrinking the 15m plate to 12.8m

Fig. A1 shows the different configurations, and fig. A2 illustrates the deformations under gravity load. The lowest seems to be obtainable by a structure according to case 1.





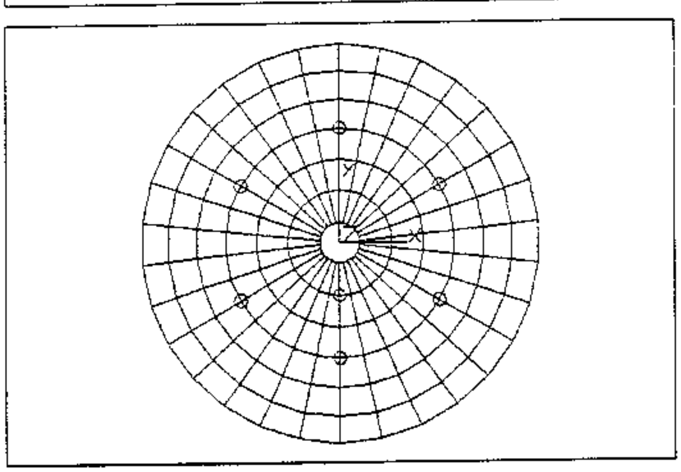


Fig A1: 3 versions of a 12.8m reflector

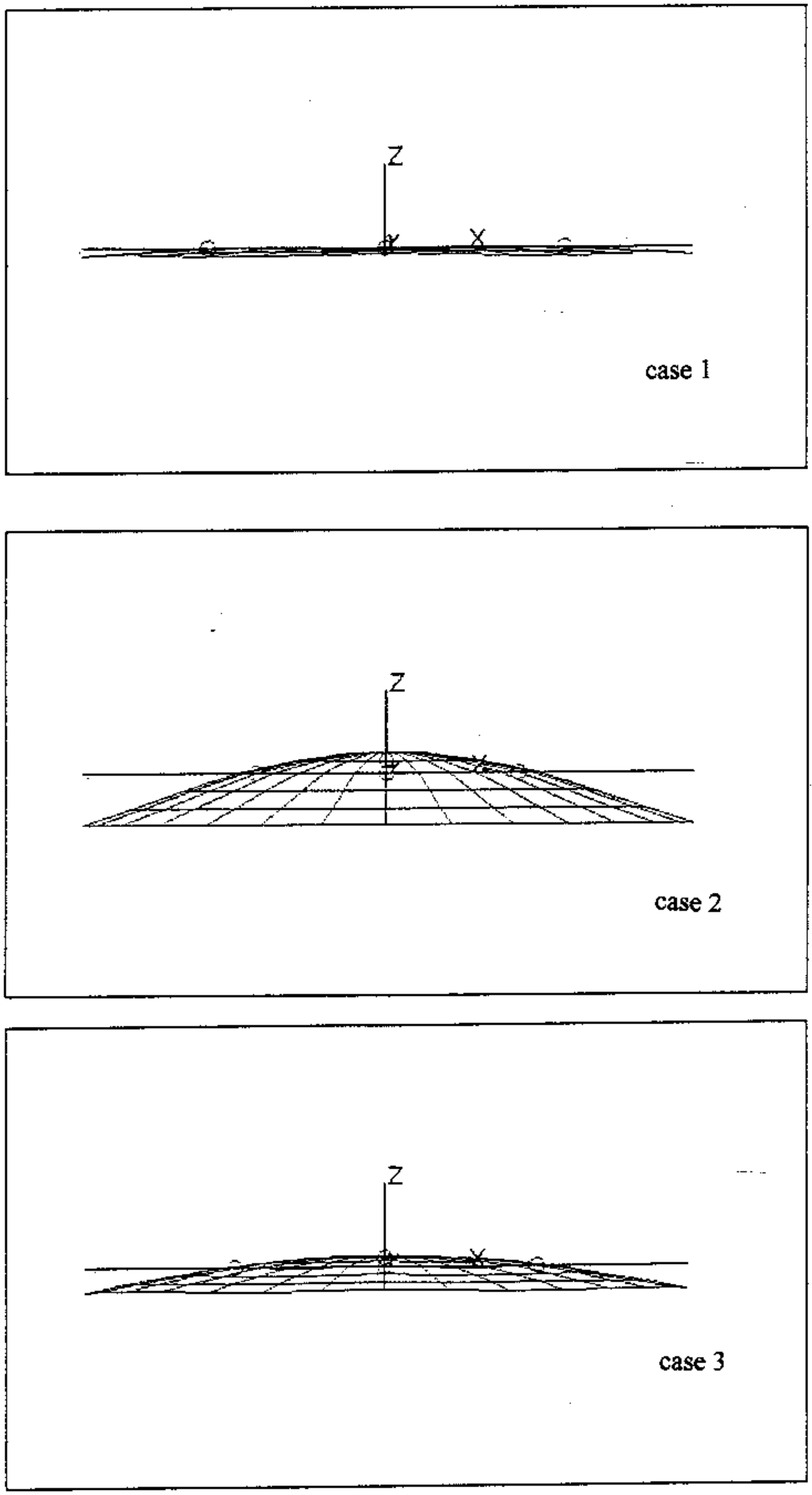


Fig A2: deformations of the different support cases

1. *Calculations*

Gravity calculations have been performed with a 12.8m reflector structure supported according to case 1 above. The results are shown in figures A3 to A7 for elevation angles between 15 and 75 deg. In fig. A8, a comparison is given with the 15m reflector performances and confirms the supposed superiority of the smaller dish diameter. The computer model of the 12.8m telescope is reprinted in fig. A9.

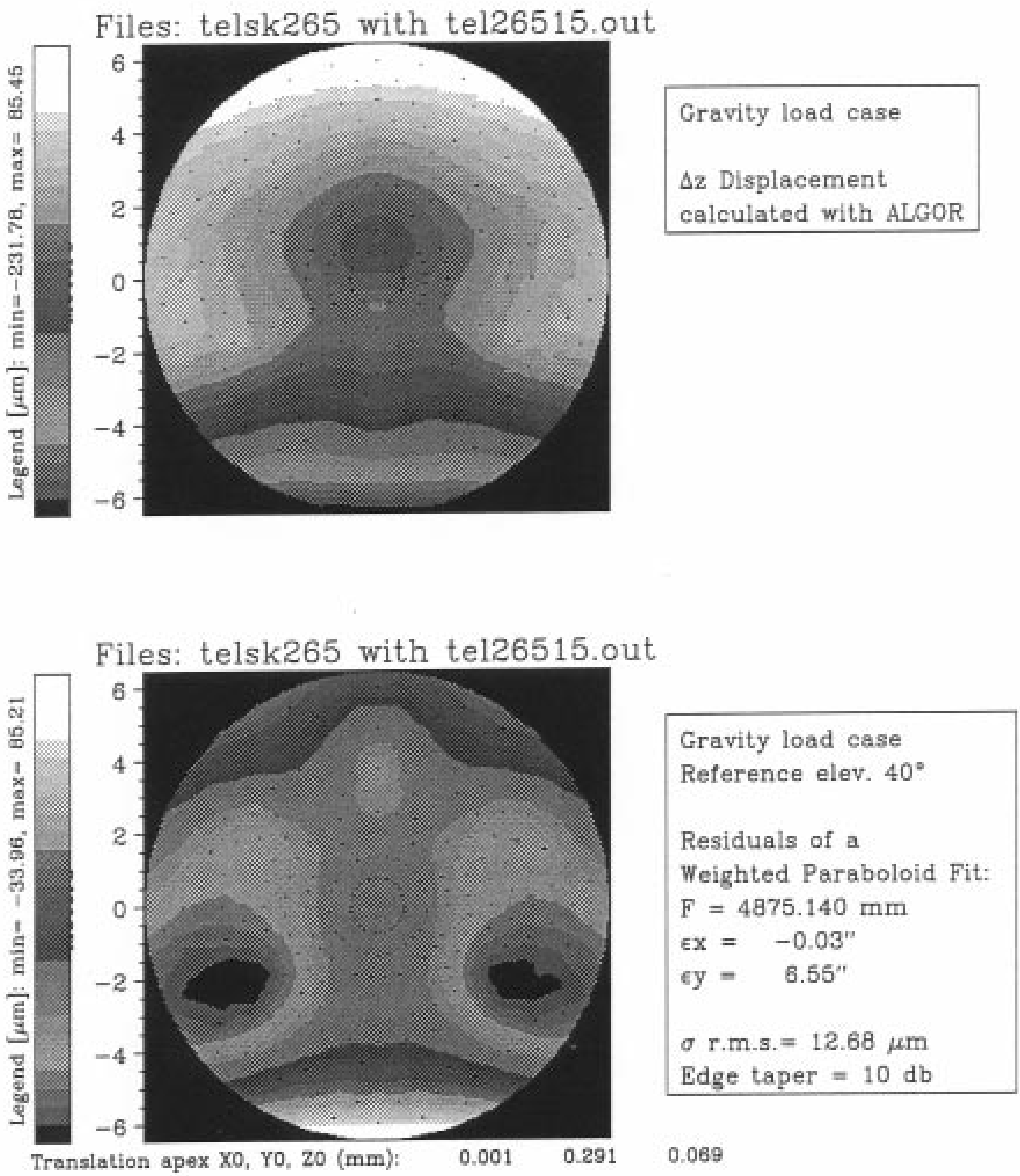
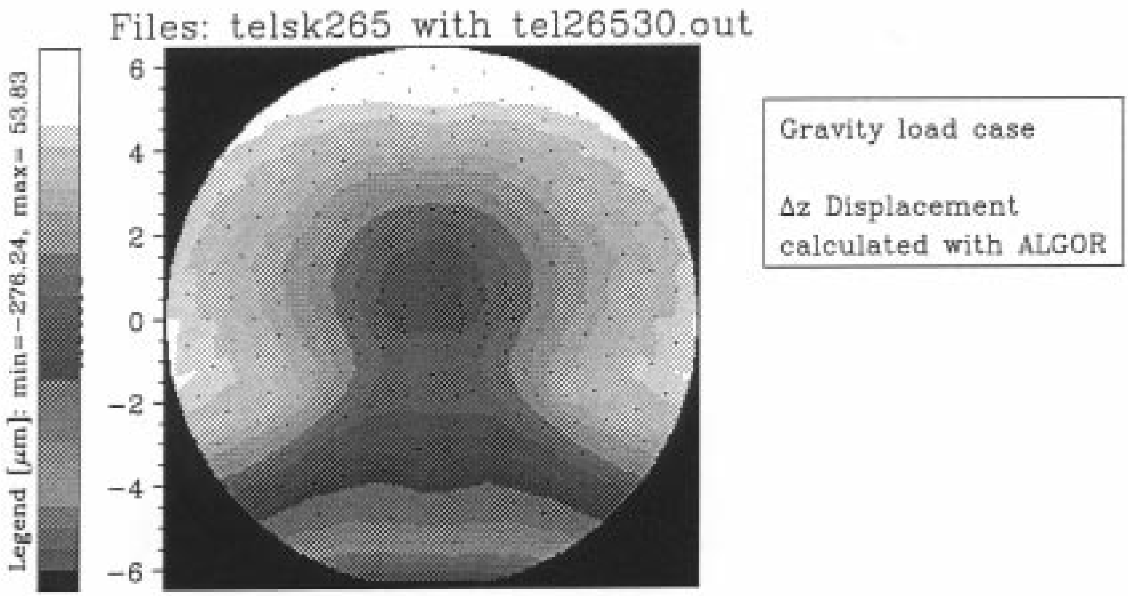


Figure A3: Gravity deformation and r.m.s. surface errors (15° elev.)



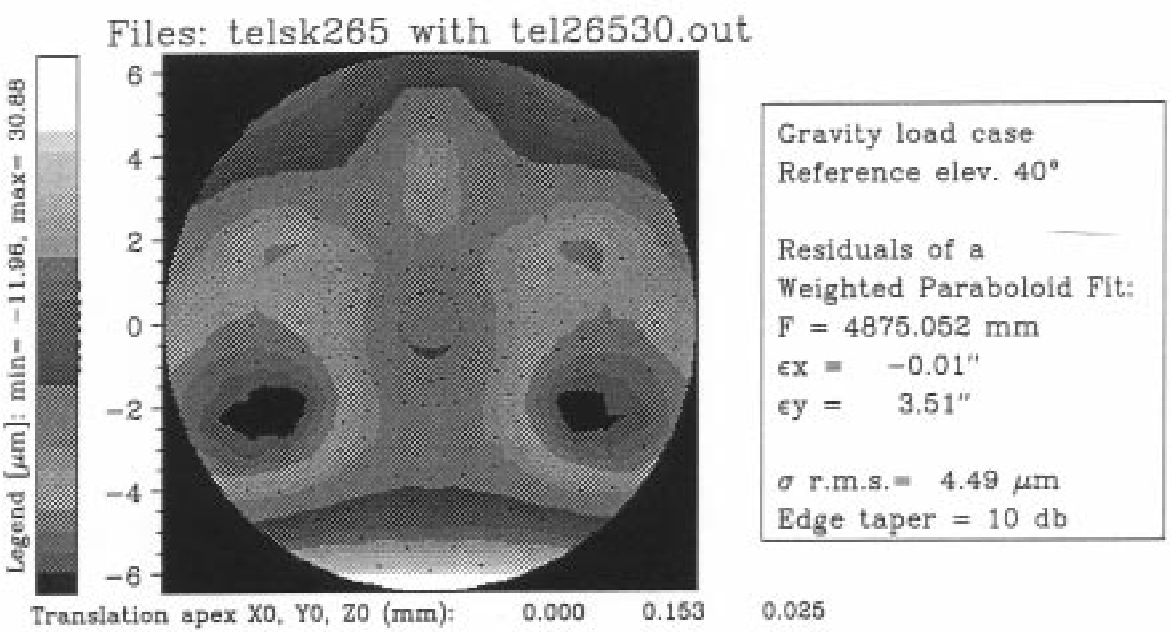


Figure A4: Gravity deformation and r.m.s. surface errors (30° elev.)

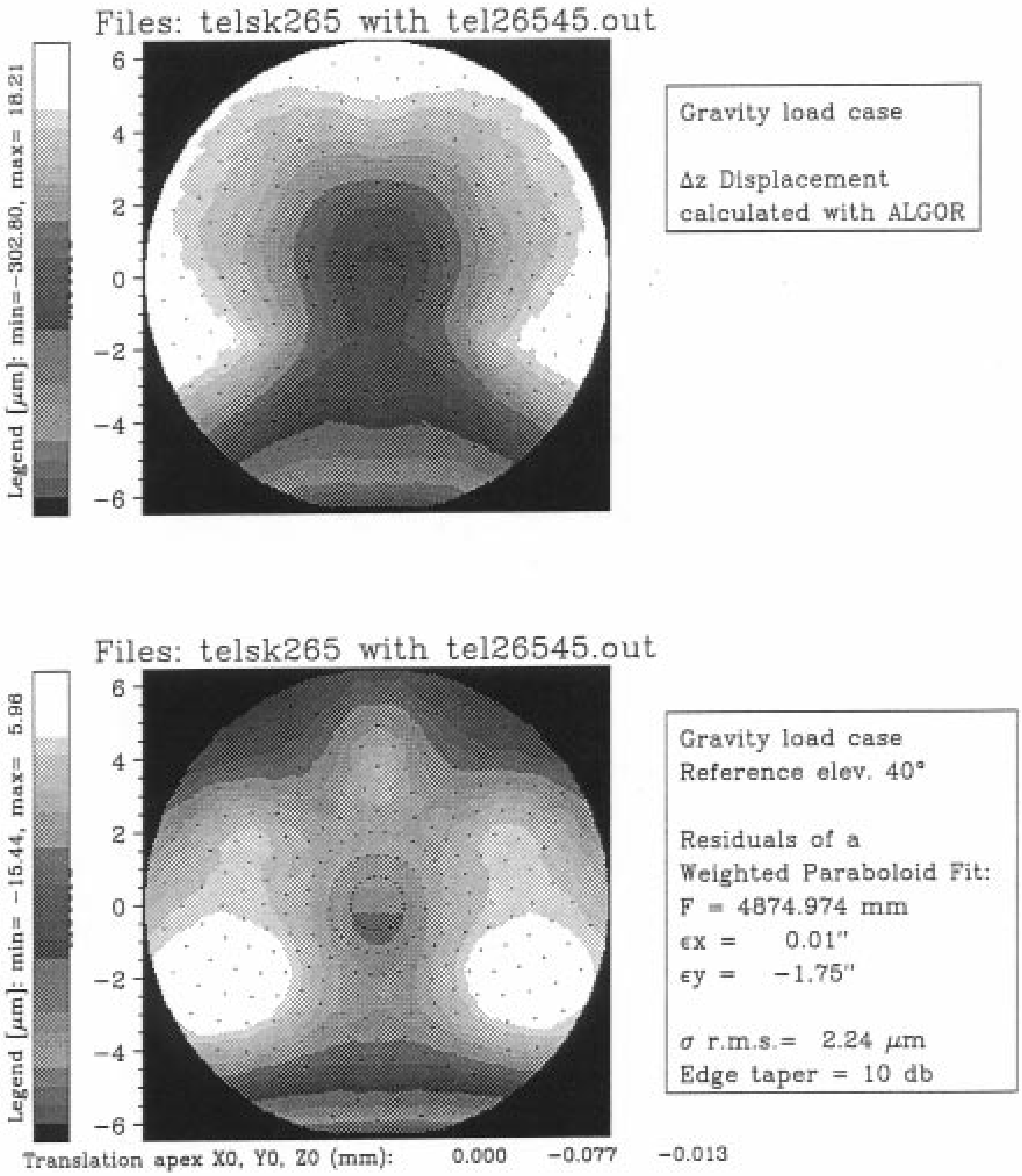


Figure A5: Gravity deformation and r.m.s. surface errors (45° elev.)

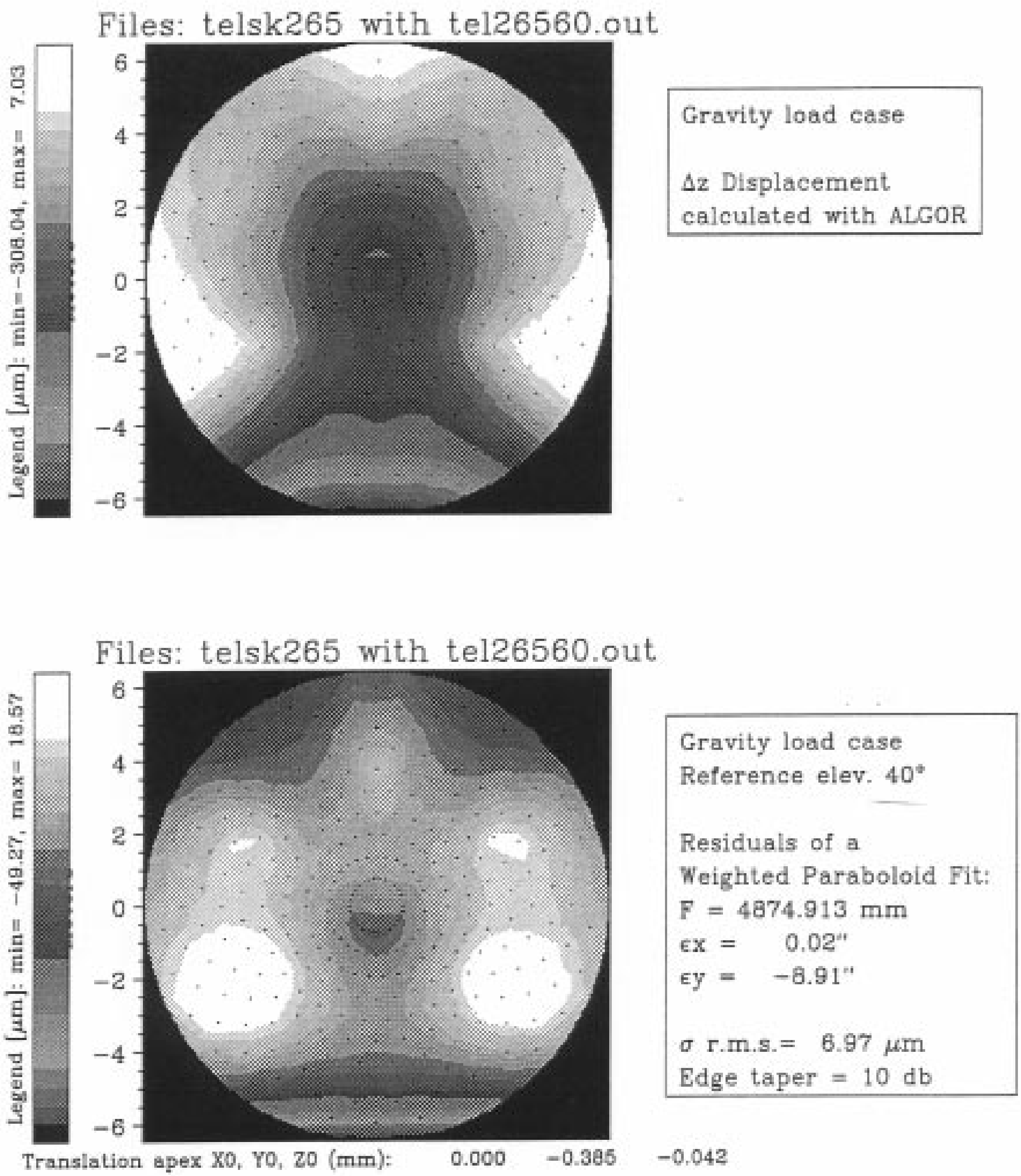
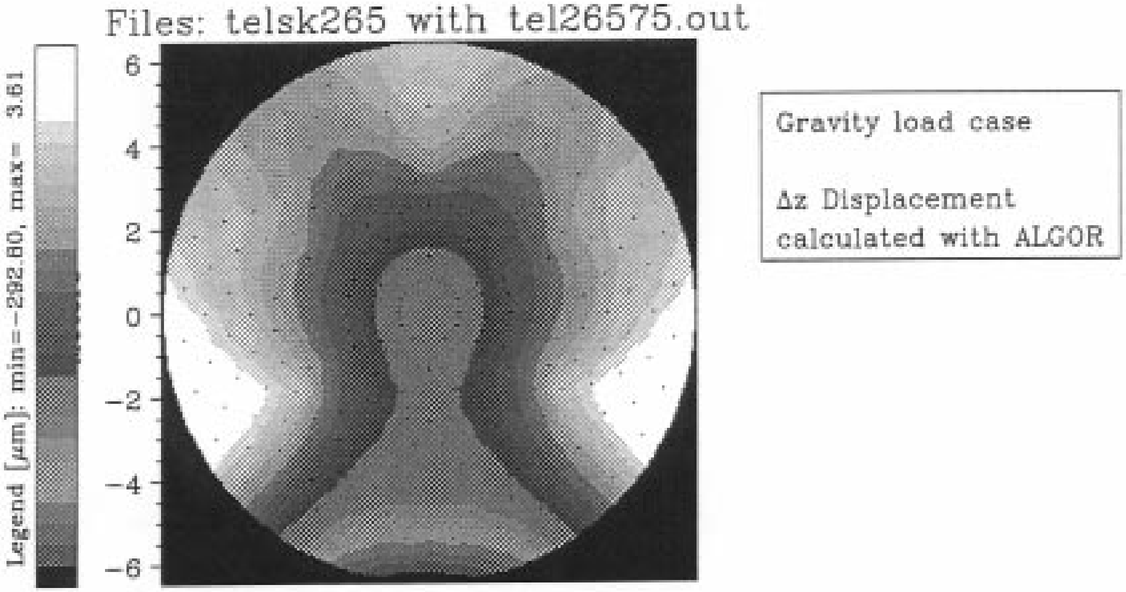


Figure A6: Gravity deformation and r.m.s. surface errors (60° elev.)



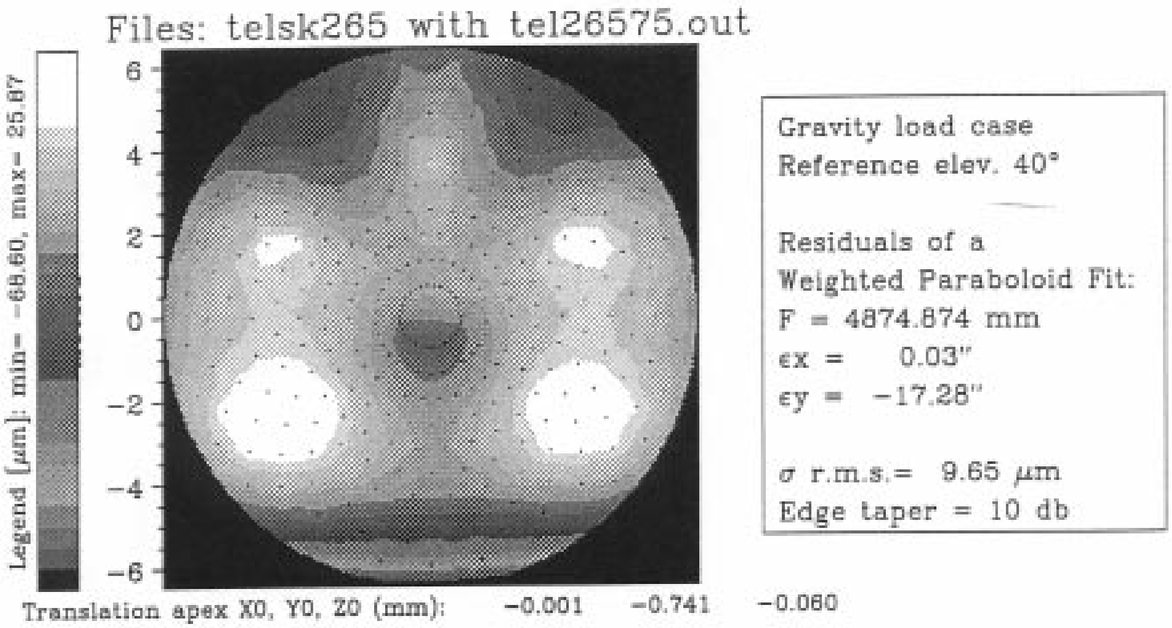


Figure A7: Gravity deformation and r.m.s. surface errors (75° elev.)

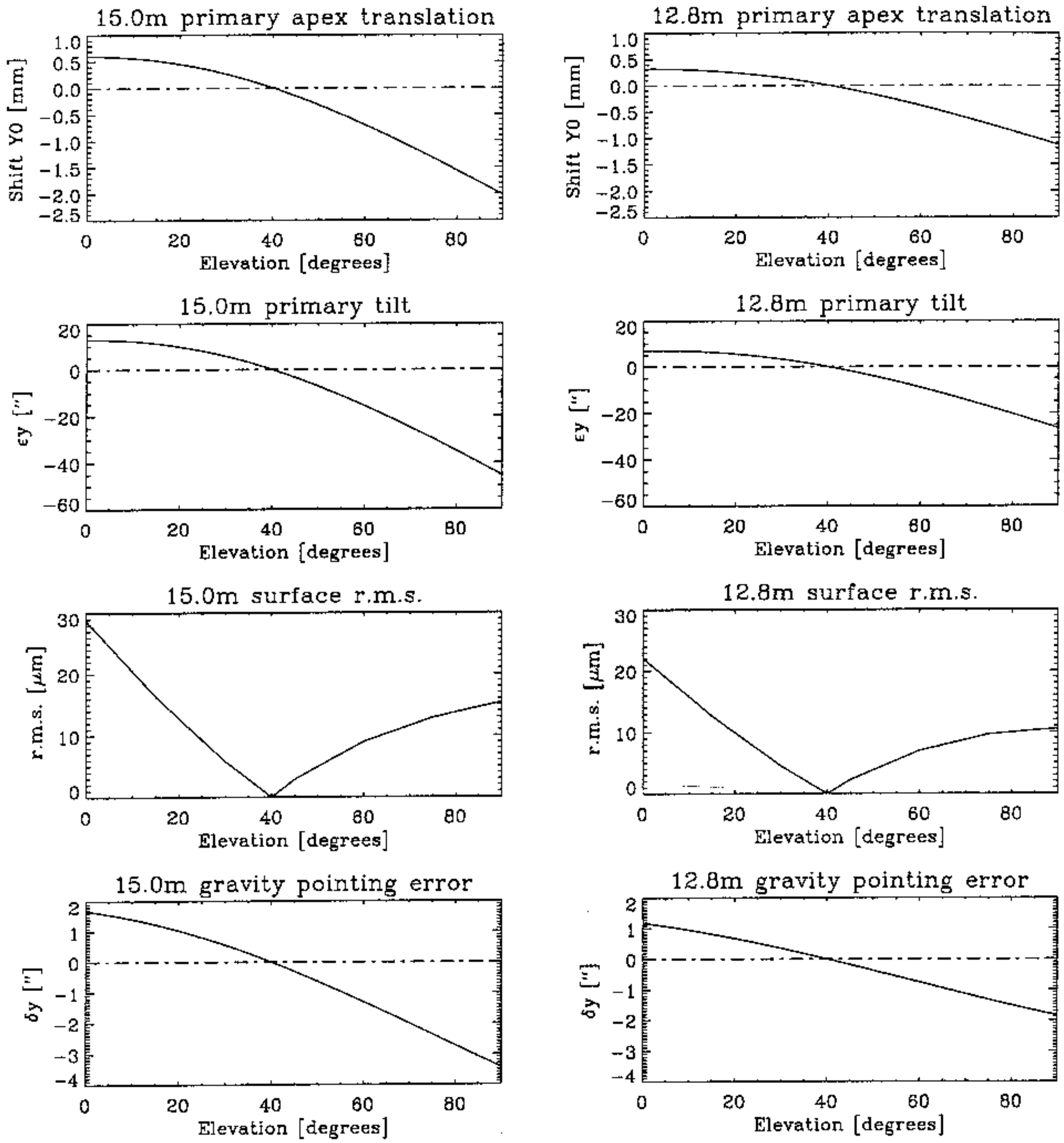


Figure A8: Comparison of the 15.0m and 12.8m antenna models for gravity load

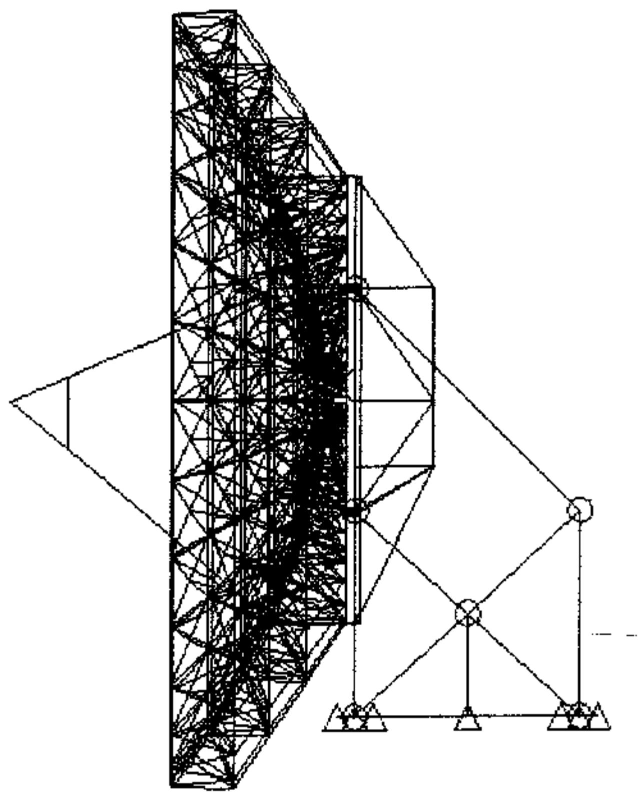


Fig. A9: 12.8m telescope model

2. *Costs*

Here again a comparison shall be given to the 15m dishes by using the same listing and indicating the two price categories. In this case, the 15m telescopes are in a favourite position, as their price/m² observing area with 15 K$ is considerably less than the one for the 12.8m which is at 19 K$.

Remarks :

1. Reference is made to the technology applied for the IRAM 15m Plateau de Bure Telescopes.
2. The indicated prices are based on information from industry for fabrication according to blue prints.
3. Prices are based on a series of 50 identical telescopes.
4. Where prices were not available, they have been deducted or scaled from similar recent realisations.
5. Cost basis is 1997, taxes not included.
6. Indications are made in US K$/unit telescope, as described in the present report.
7. All indications are budget prices and can change by up to 20%.
8. The exchange rate was set to 1 US $ = 6 FFR.

1. Reflector	**15m**	**12.8m**
♦ alu panels including thermal insulation	630	525
♦ panel adjusters	20	17
♦ deicing system	-	-
♦ CFRP tubes	115	95
♦ inserts (parts and bonding)	250	208
♦ nodes	90	75
♦ tripod	175	175
♦ apex mechanism	12.5	12.5
♦ subreflector	52.5	52.5
♦ BUS insulation	-	-
♦ cabin	140	140
♦ assembly (includes mount assembly, food and logis for 5 people not included)	80	80

2.	Mount		
	♦ pedestal structure	110	110
	♦ bearings	260	260
	♦ encoders	260	260
	♦ servo drives	180	180
	♦ cabling	30	30
	♦ foundation x 4	t.b.d.	t.b.d.
	♦ az. ring x 4	t.b.d.	t.b.d.
	♦ assembly (included in reflector)	-	-
3.	Management and Quality Assurance		
	♦ quality assurance (included in manufacturing	-	-
	♦ logistics (included in assembly)	-	-
	♦ shipping to site	210	205
	♦ warranty, insurance, overhead, profit (included in manufacturing)	-	-
	♦ contingency ≈ 15%	360	350
	♦ coordination at institute's level 2%	50	50
4.	**TOTAL**	**3.025**	**2.825**

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