Parkes windloading following the JPL upgrade.

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The upgrade would extend the perforated aluminium panels from 22m radius out to 27m. There are two consequences for the mechanical stability of the structure:

1. The windloading will increase as the porosity decreases from 75% to 50%.

2. The weight decreases by about 0.5 lb/sq. ft. (leading to a total weight reduction of 2 tonnes).

Several lines of investigation suggest that the wind loading increases will be in the range 10-25%.

Fortunately, the most serious condition - when the dish is at low elevation, and with a with the wind into the rear of the dish - is least affected : there is a counter torque which partly compensates for the increased wind loading because new panels are lighter than the steel mesh panels.

There are three immediate questions:

1. Will the ultimate safety of the antenna be compromised?

To a small degree - a 25% increase in the overturning moments would slightly reduce the safety margin : the “over-turning” wind spped drops from 160 km/hr to ~145 km/hr.

2. Will the increase in windloading under operational conditions require us to lower the "wind stow" conditions - thereby reducing the availability of the antenna?

Probably not.

3. Will the surface deformation increase, under windloading, thereby reducing the value of the upgrade at higher frequencies?

Little work has been done on this; it is worth noting, however, that the regions of highest wind loading are at the "10 o'clock" and "2 o'clock" regions, ie, in the spherical shadows of the tripod legs. We can therefore hope that the net effect will be modest.

The Arguments:

A. There is a Connell-Wagner report commissioned by Bruce in 1994. It concludes that the changes will be in the range 15-30%. This report can be found in Bruce's note :

"Use of Parkes by NASA in support of Mars Missions - A Preliminary Estimate of Costs for Antenna Preparation and Facility Use" (July 2001). (ref : BMT/gam:11_2001).

An earlier CW report ("Report on telescope behaviour & operation under wind loading conditions", 1993) is also of relevance.

The CW report : INCREASE OF AREA OF ALUMINIUM PANELS

6.1 General

Part B of this report refers to possible increase in the area of perforated aluminium panels from 44m diameter to 54m diameter .

An approximate analysis has been carried out to give an indication of the effect of replacing an annulus of steel mesh panels (72% porous) with aluminium panels of 50% porosity. (See Table El). The effects on the telescope include:

- pointing behaviour
- overturning moment on turret and tower (operation and at stow)
- wheel loading under wind load
- increased deadload bias
- torque at drives (EL & AZ) under wind load
- Loading in the backup structure

6.2 Pointing Behaviour

The pointing errors for the existing telescope due to side-on wind have been stated .in part B for wind speeds of 16km/h and 35km/h. The pointing error due to reflector and tripod distortion is a.summation of components which for Prime Focus operation are:

- Vertex shift of the best fit paraboloid
- Axis rotation of the best fit paraboloid
- Prime Focus shift due to tripod/ quadrupod deflection

The RF beam deviations (a) and (c) caused by backup structure deflections under wind. loading are cumulative and tend to compensate for the usually greater effect due to axis rotation (b).

An increase in area of more solid panels will result in additional distortion of the reflector backup structure for side on wind and it is assumed that pointing error is proportional to the increased wind moment.

(This calculation does not include. any component of pointing error due to the servo system).

6.3 Overturning Moment

The "Parkes Wind Report" of April 1993 (Ref. 4) recommended that the antenna be stowed at a wind speed of 30 km/h and this was related to a margin of safety on the antenna tipping over at high wind speeds.

If the area of more solid panels is increased , wheel lift-off (" overturning”) will occur at a lower wind speed than at present and the operational wind speed limit should be reduced.

The fact that aluminium panels are lighter than steel mesh also reduces the stability but this is a very small effect.

The effect of nett lift on the reflector has a minor effect on overall stability of the antenna (this also applies to Section 6.4).

6.4 Wheel Loading

The wheel loads during operation (below the stow speed) will increase due to the larger wind overturning moment caused by more solid panels. At stow (zenith) the wheel loads during "normal" wind storms will also increase.

The maximum wheel load at stow in an extreme wind situation when one wheel lifts is unlikely to be significantly different to the present situation but would occur at a lower wind speed than with the present configuration.

6.5 Dead Load Bias

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A change to aluminium panels would reduce the effect on the dead. load
bias caused by the heavier tripod. (See C;1.4)

6.6 Torque at Drives

If more solid panels are installed, the torque at the azimuth and elevation drives and hence the drive power will increase for a given wind speed. This may have the effect of reducing the limit on operational wind speed below 30km/h. (This effect is combined with dead load bias but for elevation only.) Detailed analysis of the drives has not been carried out in this study.

6.7 Loading to Back Up Structure

The increased solidity of the dish would result in an increase in stress in members of the back up structure due to wind loading.

6.8 Calculated Effects

Preliminary estimates of the above effects are given in Table C4.

These values are based on an extrapolation of data given in: Cohen et al "Calculation of Wind Forces and Pressures on Antennas" , New York Academy of Sciences Vo1116, Art. I, June 1964. (Ref. 5).

The approach has been to calculate the wind effect on the aluminium portion alone and add to this value the effect of the annular region of wire mesh. The inaccuracies in this approach are the assumptions that the wind regime around the aluminium paraboloid is unaffected by the surrounding mesh area and also that the annulus effect is equa1 to the difference between mesh reflectors of the inner and outer diameters. As the mesh is 72% porous this is not unreasonable.

Although the absolute values are approximate, the estimated change in values should be more accurate as the same method has been used for both configurations.

TABLE C4 Indicative Preliminary Values
Increase of Area of Aluminium Panels of 50% Porosity

ITEM	CONTRIBUTING FACTOR	% CHANGE (44m TO 54m)
Pointing	Moment about El axis	+20 to +30
Overturning Moment (Operation)	Front drag.	+ 15 to +25
Overturning Moment (Stowed)	Moment about vertex + (side drag x height.)	+ 15 to +25
Wheel Load (Operation)	Moment about vertex + (side drag x height.)	+ 15 to +25
Dead Load Bias	(No conclusion reached)	
Torque at Drives	Moment about El axis.	.+20 to +30
Load to B.U.S.	Moment about El axis	+25 to +50

B. Fresh calculations

I have redone the calculations - this is probably not very independent from the CW approach, as we are both likely to be referencing to the original JPL wind-tunnel data. It does provide some additional information not easily found in the CW reports.

1. Estimates from JPL data

I have found the JPL wind tunnel data for a 210 ft antenna, 50% porosity. JPL have invested quite some effort validating this data - including direct comparison of the measured and predicted torques (in azimuth) on real antennas. They suggest that the tables are good to about 10%.

I have computed the wind loading for a variety of speeds and wind directions (wind directly into the dish - "az = 0", or from behind "az = 180").

The numbers compare realistically with the CW report. (I attach a typical run)

Since we will have 50% porosity just out to 27.5m, with much less drag thereafter, my estimates should be conservative.

I don't see any serious impact on the quoted safety limits -

a speed of 170 km/hr will overturn the stowed dish if incident along the el-axis;

the overturning wind speed for a dish at 30 degrees el is also about 170 km/hr (the longer wheel base helps).

My impression is that survival would not be greatly compromised in these terms.

The other failure modes - eg, el gearbox or az gearbox are another matter, for which I have no information.

Case study - windloading at V = 100 km/hr

Wind speed : 100. km/hr

azimuth	elevation	Horizontal load	Vertical load	Torque about el axis	F1 : Wheel 1 load	F2 :Wheel 2 load
(deg)	(deg)	(Tonnes)	(Tonnes)	(Tonnes-m)	(Tonnes)	(Tonnes)
0.	30.	108	-46	401	625	329
0.	60.	67	-46	674	614	340
0.	90.	30	8	810	619	388
180.	30.	-106	31	-368	372	659
180.	60.	-53	27	-902	366	660
180.	90.	-31	8	-794	390	618

F1 and F2 are the forces at the azimuth track - each is twice the actual wheel loading, since I've assumed symmetry.

2. I have also estimated the fractional changes - examination of wind tunnel reports (eg, Cohen, Vellozzi and Suh) suggest that at our levels of porosity (50 - 75%) the windloading effects simply scale with porosity; I can therefore determine the contribution from the various annuli of panels, mesh or perforated aluminium.

The calculations show that the changes fall in the range 15% to 20% :

Repeating the previous case study: the antenna is modelled with a central 45m (dia) section with 50% porosity; an outer annulus (54m to 64m) with 75% porosity; and an intermediate annulus with either 50% or 75% porosity, as indicated in the last column.

Wind speed : 100. (km/hr)

azimuth	elevation	Horizontal load	Vertical load	Torque about el axis	Wheel1 load	Wheel2 load	Porosity
0.	30.	79	-34	272	590	377	75%
0.	30.	92	-39	326	606	355	50%
Change		16%	16%	20%	3%	-5%	

These calculations do not take into account the additional torques relating to the weight differential - Torque (el) will be increased by 11 T-m.

The wind tunnel experiments which lead to these tables used simple paraboloids; these calculations probably overestimate the magnitude of the change for the wind blowing onto the back of the antenna.

3. Extrapolating from Don Yabsley's data:

"Progress report on the effect of re-surfacing on the wind loading observed on the 64m Parkes Reflector" (unpublished, 1972).

Don's report is mostly related to stage 1 --- 580 m^2 of panels. with addenda for 804 m^2. We are now at 1520 m^2, and are proposing to go to 2290 m^2.

Don's table 2 is a the closest I can find to a definitive statement:

Wind into face of dish, 30 mph wind.

nett change in torque (relative to the mesh panels):

stage 1 (580 m^2) -56 tons-ft
stage 2 (1520 m^2) -168 tons-ft.

ie, seems roughly to scale with area. Stage JPL would thus be expected to lead to -253 tons-ft

If I repeat my calculations for DEY's stage 2 (rings 1-16), and compare with DEY's table 2 data, using just the aerodynamic forces I find:

30 mph wind into the dish.

	azimuth	elevation	Horizontal load	Vertical load	Torque about el axis	Wheel1 load	Wheel2 load
Original	0.	30.	13	-6	47	515	479
Stage 2	0.	30.	18	-8	63	521	472

The change in torque about the el axis : 16 T-m
This compares well with DEY's 58 T-ft -- 17.6 T-m