Reflectivity measurements of WHT Primary mirror before and after CO2 cleaning, 15 Feb 2016
Using "food grade" CO2 for the first time on this mirror, following successful test on INT.
Cleaning, measurements and report by Neil O'Mahony.
Note M3 at Nasmyth was not cleaned as it had been scheduled for Aluminizing (later cancelled).

					% Reflectivty per waveband of measurement (nm)						
data #	date-time	C#	Location	T/°C	365	404	464	522	624	760	970
652	15/02/2016 09:54	1	WHTM1 L	15.3	89.2	87.8	87.4	88.1	87.3	84.9	90.8
653	15/02/2016 09:56	1	WHTM1 L	15.1	89.2	88.1	88.1	88.3	87.8	85.2	91.1
654	15/02/2016 09:57	1	WHTM1 L	15.1	88.1	86.7	86.8	87.2	86.7	84.0	90.1
655	15/02/2016 09:59	1	WHTM1 T	15.1	88.4	87.4	87.6	87.7	87.1	84.6	90.3
656	15/02/2016 10:01	1	WHTM1 T	15.2	88.8	87.5	87.5	87.6	87.1	84.4	90.1
657	15/02/2016 10:02	1	WHTM1 T	15.3	89.2	87.8	87.6	87.7	87.2	84.4	90.6
658	15/02/2016 10:04	1	WHTM1 R	15.4	89.7	88.3	87.8	88.4	87.3	84.7	90.7
659	15/02/2016 10:05	1	WHTM1 R	15.5	89.6	88.4	88.2	88.6	87.7	85.2	90.7
660	15/02/2016 10:06	1	WHTM1 b	15.7	88.0	86.9	87.2	87.9	87.2	84.8	90.4
661	15/02/2016 10:07	1	WHTM1 b	15.9	87.6	87.4	87.4	87.8	87.1	84.4	89.6
662	15/02/2016 10:08	1	WHTM1 b	16.1	88.9	87.3	87.4	87.6	87.2	84.3	90
	global average				88.8	87.6	87.5	87.9	87.2	84.6	90.4
	minimum values				87.6	86.7	86.8	87.2	86.7	84.0	89.6
	maximum values				89.7	88.4	88.2	88.6	87.8	85.2	91.1
	range				2.1	1.7	1.4	1.4	1.1	1.2	1.5
	std deviation				0.7	0.5	0.4	0.4	0.3	0.4	0.4
	Fresh Aluminium coating June 2015				93.4	91.7	91.2	91.2	90.2	87.5	93.5
	Average shortfall from fresh Aluminium				**4.6**	**4.1**	**3.7**	**3.3**	**3.0**	**2.9**	**3.1**

dust index measurements

652	WHTM1 L	7.8	7.4	7.6	5.4	6.2	4.8	4.6
653	WHTM1 L	7.7	7.3	6.9	5.1	5.3	4.2	4.2
654	WHTM1 L	9.1	9.1	8.7	6.9	7	6	5.5
655	WHTM1 T	9.1	8.1	7.9	5.9	6.9	5.4	5.5
656	WHTM1 T	8.3	7.7	7.7	6.2	6.6	5.6	5.7
657	WHTM1 T	7.8	7.5	7.8	6	6.4	5.6	4.9
658	WHTM1 R	6.6	6.1	7.1	4.6	6.1	4.8	4.4
659	WHTM1 R	7	6.4	6.4	4.7	5.5	4.2	4.4
660	WHTM1 b	7.8	7.2	7	5	5.8	4.6	4.7
661	WHTM1 b	8.1	7.3	7.1	5.3	6	4.8	5.3
662	WHTM1 b	8	8	7.7	6.2	6.3	5.3	5.4
		7.9	7.5	7.4	5.6	6.2	5.0	5.0

MEASUREMENTS ON M1 AFTER CO2				% Reflectivty per waveband of measurement (nm)						
				365	404	464	522	624	760	970
666	17/02/2016 15:12	1 WHTM1 L	24.4	89.4	88.1	87.9	88.6	87.7	85.5	91.9
667	17/02/2016 15:13	1 WHTM1 L	24.1	88.9	87.7	87.8	88.4	87.9	85.5	91.6
668	17/02/2016 15:14	1 WHTM1 L	23.9	89.6	88.3	88.3	88.9	88.2	85.6	92.0
669	17/02/2016 15:16	1 WHTM1 T	23.4	89.5	88.3	88.2	88.8	87.8	85.4	91.6
670	17/02/2016 15:17	1 WHTM1 T	23.1	89.6	88.2	88.1	88.7	88.0	85.4	91.7
671	17/02/2016 15:18	1 WHTM1 T	22.9	88.8	87.7	87.8	88.4	87.8	85.3	91.5
672	17/02/2016 15:20	1 WHTM1 R	22.5	90.1	88.8	88.8	89.1	88.4	85.8	91.7
673	17/02/2016 15:21	1 WHTM1 R	22.4	88.2	88.5	89.0	89.0	87.9	85.9	91.2
674	17/02/2016 15:23	1 WHTM1 b	22	89.0	87.9	88.0	88.6	87.8	85.6	91.6
675	17/02/2016 15:25	1 WHTM1 b	21.7	90.2	88.9	88.8	89.0	88.4	85.7	91.7
676	17/02/2016 15:26	1 WHTM1 b	21.5	89.8	88.7	88.8	89.0	88.4	85.8	91.8
	averages			89.5	88.3	88.3	88.8	88.0	85.6	91.7
	minimum values*			88.2	87.7	87.8	88.4	87.7	85.3	91.2
	maximum values			90.2	88.9	89.0	89.1	88.4	85.9	92.0
	range			2.0	1.2	1.2	0.7	0.7	0.6	0.8
	std deviation			0.5	0.4	0.4	0.3	0.3	0.2	0.2
	Fresh Aluminium coating June 2015			93.4	91.7	91.2	91.2	90.2	87.5	93.5
	Average shortfall from fresh Aluminium			**3.9**	**3.4**	**3.0**	**2.5**	**2.2**	**1.9**	**1.8**

*Data set #673 contains both minimum and maximum values. Occurrence at start and end of sequence may indicate movement during measurement. Inconsistent and best omitted from statistics.

Improvement in %R from CO2 cleaning	0.7	0.7	0.7	0.9	0.8	0.9	1.3
Minimum after minus average before	0.0	0.1	0.3	0.5	0.5	0.7	1.1
waveband (nm)	365	404	464	522	624	760	970

DUST INDEX measurements

666	7.7	7.8	7.6	5	5.4	3.9	3.2
667	9.7	9	8.2	5.8	5.5	4.1	3.6
668	7.7	7.1	6.7	4.6	4.5	3.5	2.8
669	7.6	6.8	6.8	4.7	5.3	4.1	3.8
670	8.2	7.7	7.6	5.2	5.4	4.3	3.4
671	10.4	9.2	8.8	6	6.1	4.4	3.7
672	6.4	6.1	5.8	4.1	4.3	3.3	3.1
673	6.7	5.7	5.5	3.6	4.3	3	2.9
674	9.4	8.1	7.7	5	5.8	3.7	3.3
675	6.3	5.7	5.5	4	4.1	3.2	2.9
676	7.1	6.1	5.6	4.1	4.2	3	2.8
	7.9	7.2	6.9	4.7	5.0	3.7	3.2

Sum of Dust Index and Reflectivity before	96.7	95.1	95.0	93.5	93.4	89.7	95.4
after	97.4	95.5	95.1	93.5	93.0	89.2	94.9

SMS Reflectivity measurements of WHT Primary mirror before and after CO2 cleaning, 15 Feb 2016

SMS Measurements usually in pairs at same location, to check 0.05% repeatibility.
Those marked "Not rep" are omitted from statistics. Instrument clock is approx. 15 minutes ahead

SMS Summary characteristics			
	Lambda	0.67 micron	
	Incident Angle	25 deg	
	BW Limits	1	0.01

MEASUREMENTS BEFORE CLEANING

	Scattering at angles Θ,Φ			Reflect-ivity	user comm-ent	Rough-ness RMS(Å)		
	Θs->	0	50					
datum #	Φs->	0	180				TIME	DATE
1	location1	8.51E-03	2.41E-03	0.834		71.9	11:10:21	02-15-1916
2		8.52E-03	2.40E-03	0.834		72	11:10:26	02-15-1916
3	loc 2	9.51E-03	2.56E-03	0.836		76.6	11:10:34	02-15-1916
4	loc 3	8.29E-03	3.02E-03	0.832		68.7	11:10:45	02-15-1916
5	loc 4	9.85E-03	4.80E-03	0.831		73.1	11:10:56	02-15-1916
6		6.69E-03	2.05E-03	0.851	skip	62.3	11:11:04	02-15-1916
7	loc 5	6.69E-03	2.05E-03	0.841		62.7	11:11:10	02-15-1916
8		6.69E-03	2.05E-03	0.84		62.7	11:11:16	02-15-1916
9		6.09E-03	1.87E-03	0.798	skip	61.4	11:12:47	02-15-1916
10		6.13E-03	1.88E-03	0.81	skip	61.1	11:12:53	02-15-1916
11	loc 6	6.12E-03	1.88E-03	0.823		60.6	11:12:58	02-15-1916
12		6.13E-03	1.88E-03	0.828		60.4	11:13:03	02-15-1916
13	loc 7	7.91E-03	2.37E-03	0.834		68.7	11:13:11	02-15-1916
14		7.82E-03	2.34E-03	0.833		68.3	11:13:16	02-15-1916
15	loc 8	6.59E-03	1.86E-03	0.835		63.2	11:13:25	02-15-1916
16		6.59E-03	1.85E-03	0.839		63.2	11:13:32	02-15-1916
17	loc 9	9.50E-03	4.40E-03	0.823		72.4	11:13:40	02-15-1916
18		9.50E-03	4.37E-03	0.823		72.4	11:13:46	02-15-1916
19	loc 10	7.47E-03	3.41E-03	0.833		63.9	11:15:31	02-15-1916
20		7.48E-03	3.41E-03	0.835		63.8	11:15:36	02-15-1916
21	loc 11	7.92E-03	2.95E-03	0.834		66.8	11:15:46	02-15-1916
22		7.91E-03	2.94E-03	0.837		66.7	11:15:51	02-15-1916
23	loc 12	6.95E-03	1.96E-03	0.827		65.3	11:16:00	02-15-1916
24		6.95E-03	1.96E-03	0.832		65.1	11:16:06	02-15-1916
25	loc 13	6.82E-03	2.94E-03	0.841		61	11:16:16	02-15-1916
26		6.83E-03	2.96E-03	0.843		60.9	11:16:22	02-15-1916
27	loc 14	7.48E-03	2.58E-03	0.838		65.4	11:17:47	02-15-1916
28		7.49E-03	2.58E-03	0.837		65.5	11:17:52	02-15-1916
29	loc 15	9.26E-03	5.87E-03	0.813		71	11:18:01	02-15-1916
30		9.15E-03	5.89E-03	0.818		70.3	11:18:06	02-15-1916
31	loc 16	8.18E-03	4.16E-03	0.825		66.7	11:18:14	02-15-1916
32		8.18E-03	4.17E-03	0.829		66.6	11:18:23	02-15-1916
global average		7.80E-03	3.04E-03	0.832		66.8		
difference from CT7 at 624 nm				4.0				
std deviation		1.1E-03	1.1E-03	0.007		4.3		
std error		2.68E-04	2.86E-04	0.002		1.1		

Reference mirror check

	33	7.65E-03	2.68E-03	0.944		62.1	11:43:25	02-15-1916
	34	7.66E-03	2.70E-03	0.946		62.1	11:43:31	02-15-1916
	35	7.67E-03	2.70E-03	0.946		62.1	11:43:37	02-15-1916

Above threshold but an additional location should have been measured.

AFTER CO2 CLEANING

71	Left p1	6.79E-03	1.52E-03	0.839		67.3	16:31:36	02-17-1916
72		6.79E-03	1.52E-03	0.841		67.1	16:31:41	02-17-1916
73	p2	4.35E-03	9.68E-04	0.852		53.5	16:31:52	02-17-1916
74		4.35E-03	9.73E-04	0.856		53.3	16:31:57	02-17-1916
75	p3	6.78E-03	3.43E-03	0.838		60.3	16:32:32	02-17-1916
76		6.78E-03	3.44E-03	0.839		60.3	16:32:37	02-17-1916
77	p4	9.42E-03	1.57E-03	0.84		86.7	16:33:11	02-17-1916
78		9.42E-03	1.57E-03	0.841		86.6	16:33:16	02-17-1916
79	Top p5	4.16E-03	6.05E-04	0.85		60.5	16:33:23	02-17-1916
80		4.16E-03	6.05E-04	0.843	skip	60.8	16:33:28	02-17-1916
81		4.16E-03	6.06E-04	0.853		60.4	16:33:34	02-17-1916
82	p6	5.18E-03	9.71E-04	0.84		61.7	16:33:42	02-17-1916
83		5.18E-03	9.67E-04	0.843		61.6	16:33:47	02-17-1916
84	p7	3.32E-03	6.08E-04	0.856		49.2	16:34:58	02-17-1916
85		3.28E-03	6.07E-04	0.859		48.7	16:35:03	02-17-1916
86	p8	4.74E-03	8.67E-04	0.849		59.2	16:35:11	02-17-1916
87		4.74E-03	8.67E-04	0.848		59.2	16:35:15	02-17-1916
88	right p9	6.52E-03	1.78E-03	0.843		63	16:35:26	02-17-1916
89		6.52E-03	1.77E-03	0.844		63	16:35:31	02-17-1916
90	p10	4.29E-03	1.84E-03	0.846		48.2	16:37:15	02-17-1916
91		4.29E-03	1.84E-03	0.846		48.2	16:37:20	02-17-1916
92	p11	6.84E-03	3.42E-03	0.829		60.9	16:39:50	02-17-1916
93		6.84E-03	3.41E-03	0.83		60.9	16:39:56	02-17-1916
94	p12	4.42E-03	9.85E-04	0.843		54.2	16:40:04	02-17-1916
95		4.43E-03	9.85E-04	0.844		54.2	16:40:09	02-17-1916
96	Bottm p13	4.37E-03	7.63E-04	0.85		57.6	16:40:17	02-17-1916
97		4.34E-03	7.55E-04	0.858		57.3	16:40:21	02-17-1916
98	p14	4.32E-03	7.49E-04	0.86		57.1	16:40:27	02-17-1916
99		4.31E-03	7.48E-04	0.866		56.9	16:40:34	02-17-1916
100	p15	4.40E-03	1.07E-03	0.875	v.high	52	16:40:42	02-17-1916
101		6.09E-03	1.17E-03	0.871		65.2	16:40:48	02-17-1916
102	p16	5.56E-03	1.16E-03	0.852		61.4	16:40:57	02-17-1916
103		5.62E-03	1.20E-03	0.857		61.2	16:41:05	02-17-1916
104		1.37E-02	5.04E-04	0.001	null	>1177	16:43:43	02-17-1916
105	p18	7.92E-03	1.51E-03	0.832		76.3	16:44:02	02-17-1916
106		7.90E-03	1.51E-03	0.825		76.4	16:44:07	02-17-1916
107	p19	7.46E-03	1.40E-03	0.848		73.6	16:44:16	02-17-1916
108	p20	3.37E-03	5.43E-04	0.855		52	16:44:45	02-17-1916
109		3.37E-03	5.43E-04	0.857		52	16:44:49	02-17-1916
110	p21	3.80E-03	6.24E-04	0.863		54.6	16:44:58	02-17-1916
111		3.79E-03	6.23E-04	0.862		54.6	16:45:03	02-17-1916
112	p22	5.23E-03	1.09E-03	0.851		59.8	16:45:11	02-17-1916
Avgs excl. Bottom		5.56E-03	1.55E-03	0.845		60.342		

Avgs Bottom	5.12E-03	9.65E-04	0.855	60.500
Avgs All	5.39E-03	1.40E-03	0.849	59.903
Std deviation	2.00E-03	1.02E-03	0.007	12.6
Std error	4.27E-04	2.18E-04	0.001	2.7
Difference of CT7 at 624 nm from SMS			3.2%	

Some some 5 extra locations were measured in the bottom quadrant because some unusually high values were obtained (p14, p15, p21) but these appear to be repeatable and the following reference measurements are at the usual 94%. No evidence this is a device artifact.
Scattering is also lower at these locations, which is consistent with higher reflectivity.
FINAL REFERENCE MEASUREMENTS

113		2.06E-03	1.29E-03	0.94		31.2	16:57:28	02-17-1916
114		2.06E-03	1.29E-03	0.94		31.2	16:57:34	02-17-1916
115		1.89E-03	1.14E-03	0.935		29.9	16:57:44	02-17-1916
116		1.89E-03	1.13E-03	0.934		30	16:57:50	02-17-1916
117		5.18E-03	1.71E-03	0.932		51.9	16:57:57	02-17-1916
118		2.54E-03	1.79E-03	0.935		34.6	16:58:05	02-17-1916
119		3.56E-03	1.74E-03	0.929		41.6	16:58:12	02-17-1916

Result of cleaning WHT primary mirror with new CO2:

Increase in Reflectivity	**1.7%**		
Decrease in Scattering by factors of	1.4	and	2.0