MISSE Thermal Control Materials

With Comparison to Previous Flight Experiments

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Materials on International Space Station Experiment (MISSE)

Over 4,000 material samples exposed to the space environment with 5 MISSE "suitcases" from August 2001 to August 2007

Effects of Atomic Oxygen, Ultraviolet Radiation, Thermal Cycling, Vacuum on:

- Zinc oxide / potassium silicate thermal control coating
  - Z-93/Z-93P from Alion Science (formerly IITRI)
  - AZ93 from AZ Technology
- Deft polyurethane coatings
- Lord Chemical A-276 with leafing aluminum

NASA gives no recommendation, endorsement, or preference, either expressed or implied, concerning vendors of the materials discussed in this paper.

MISSE Thermal Control Materials
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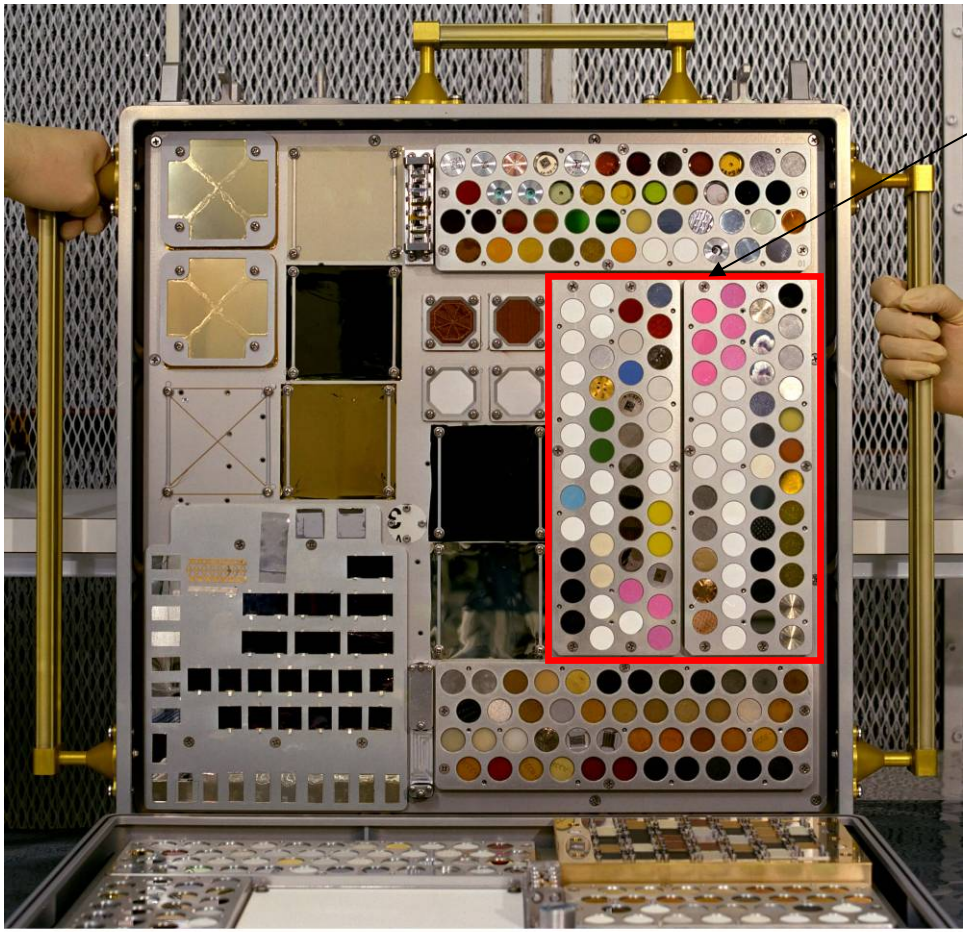

MISSE 1
Materials International Space Station Experiment
AO/UV tray
PEC 1, Tray 1

Photo courtesy of Langley Research Center

Trays E2, E3
Located on ram-facing side of MISSE-1

9.45×10^{21} atoms/cm^2
calculated AO fluence

5,545 – 6,152 ESH
calculated solar exposure

"Estimated Environmental Exposures for MISSE-1 & MISSE-2"
Dr. Gary Pippin and Dr. Eugene Normand
Boeing Phantom Works

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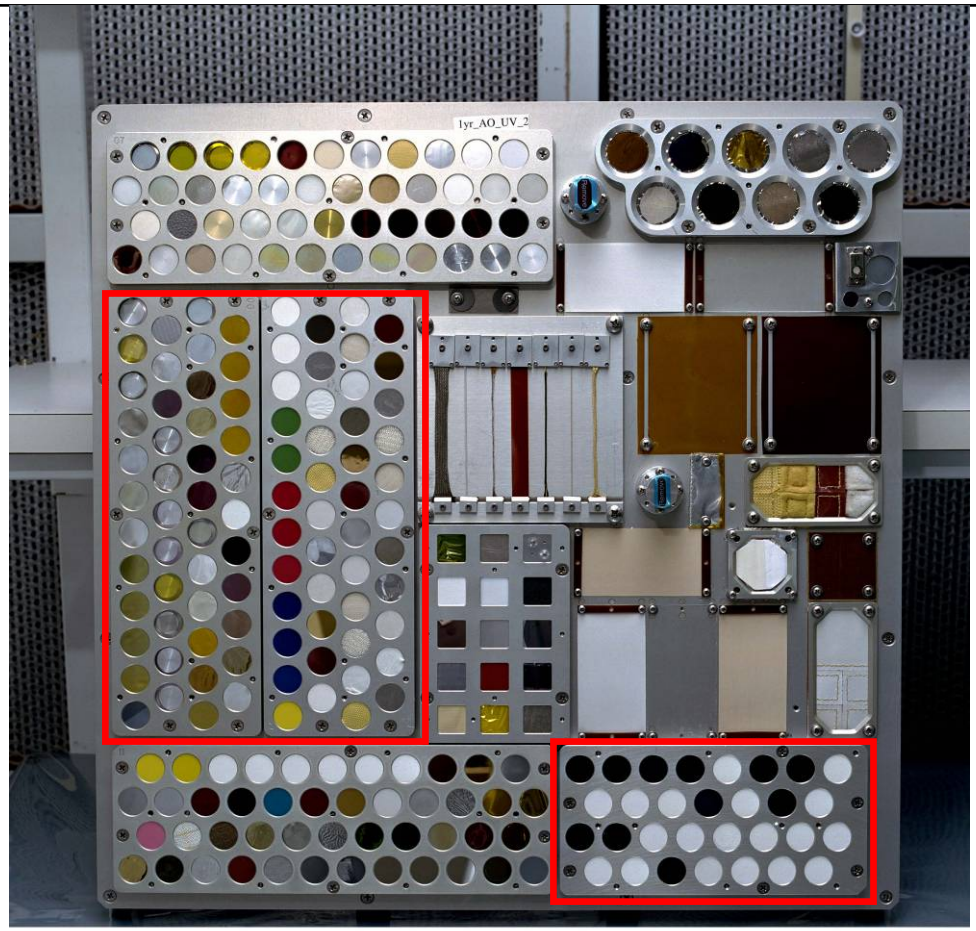

MISSE 2
Materials International Space Station Experiment
AO_UV_1 tray (PEC 2, tray 1)

Photo courtesy of Langley Research Center

Trays D1, E7, E8
Located on ram-facing side of MISSE-2

7.2 to 7.6 x 10^{21} atoms/cm^2 measured AO fluence (mass loss of surviving polymers)

5,100 – 6,000 ESH calculated solar exposure

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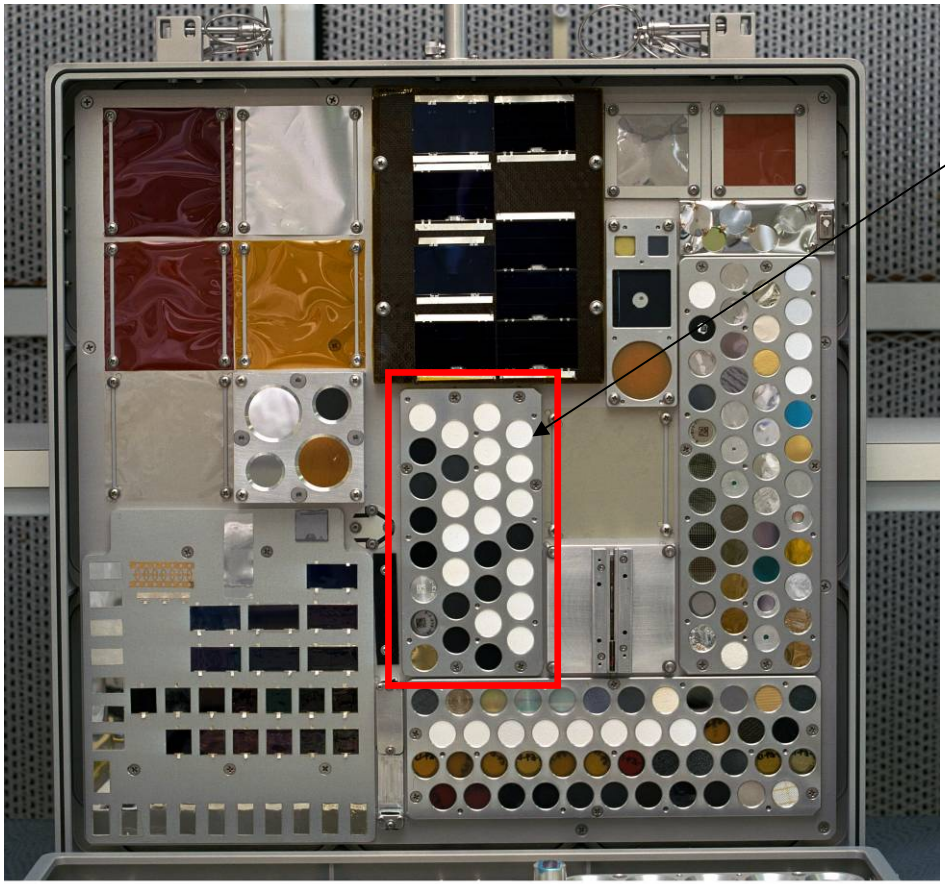

MISSE 2
Materials International Space Station Experiment
UV_2 tray (PEC 2, tray 2)
Full Tray

Photo courtesy of Langley Research Center

Tray D2
On nominally wake-facing side of MISSE-2

1.4×10^{20} atoms/cm^2 by thickness loss of polymer samples

4,760 – 5,130 ESH calculated solar exposure

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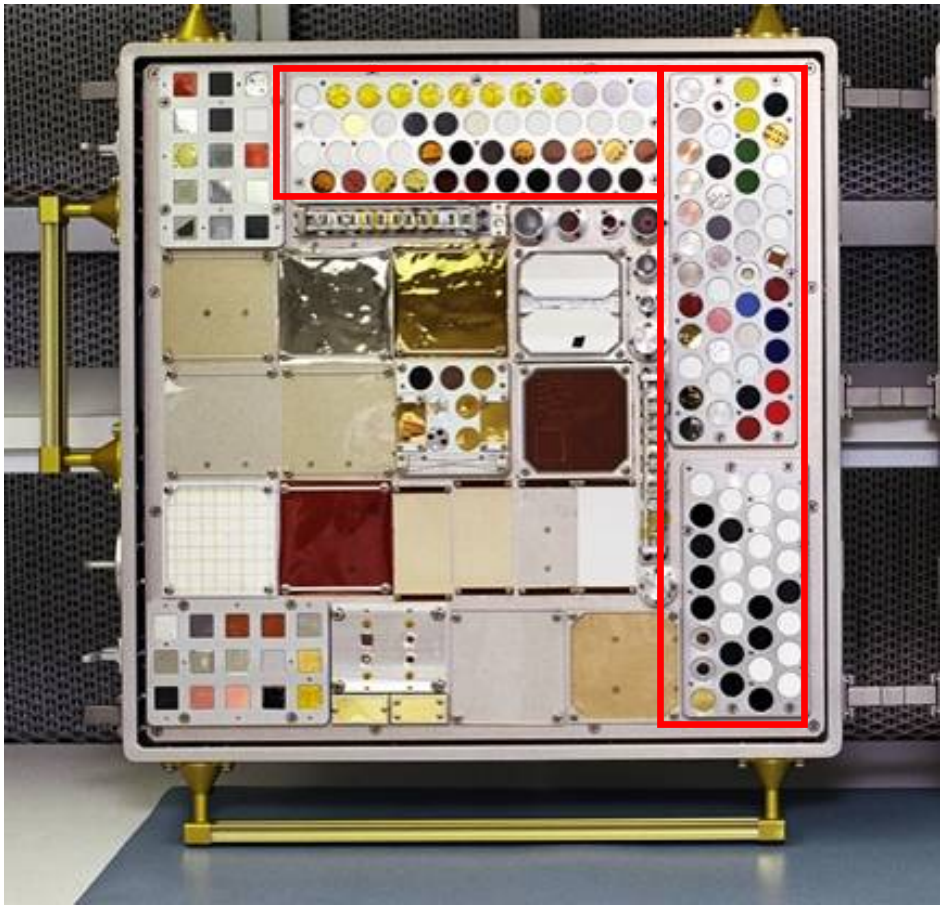
Boeing Phantom Works

MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



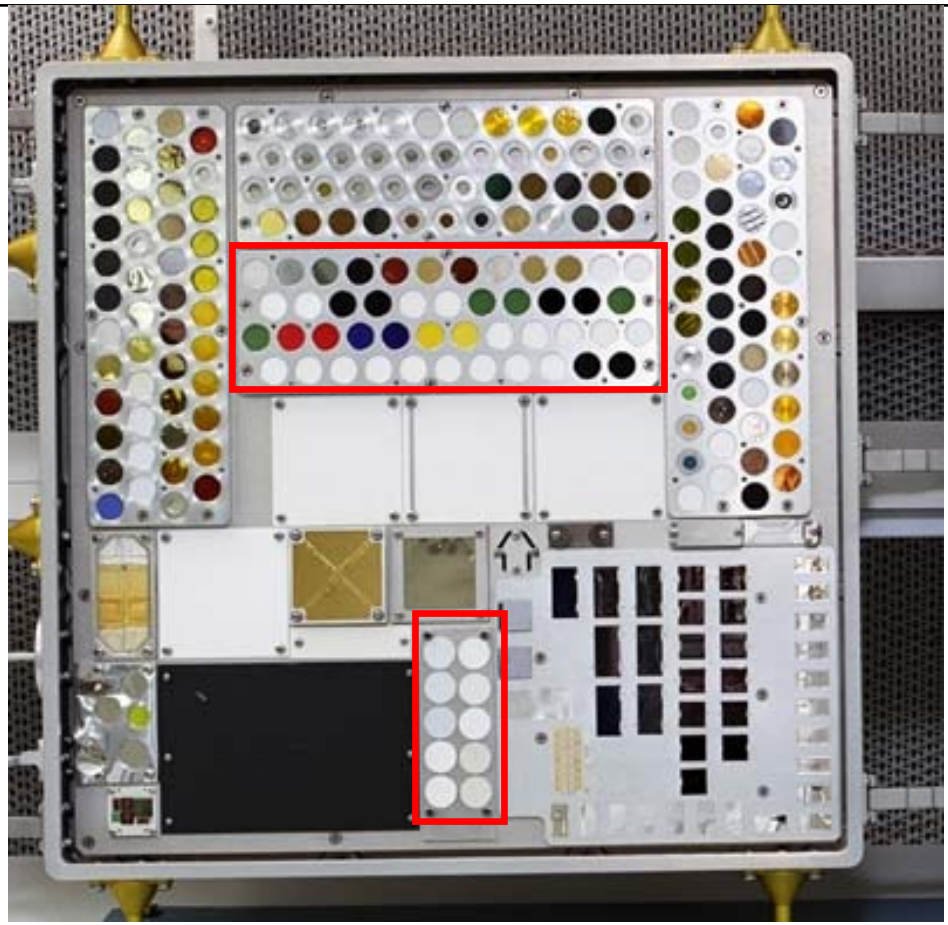
Trays D4, E13, E14
On nominally ram-facing side of MISSE-3

1.3×10^{21} atoms/cm^2 by mass and thickness loss of polymer samples

~1,500 ESH
calculated solar exposure

Photo courtesy of Langley Research Center

MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments

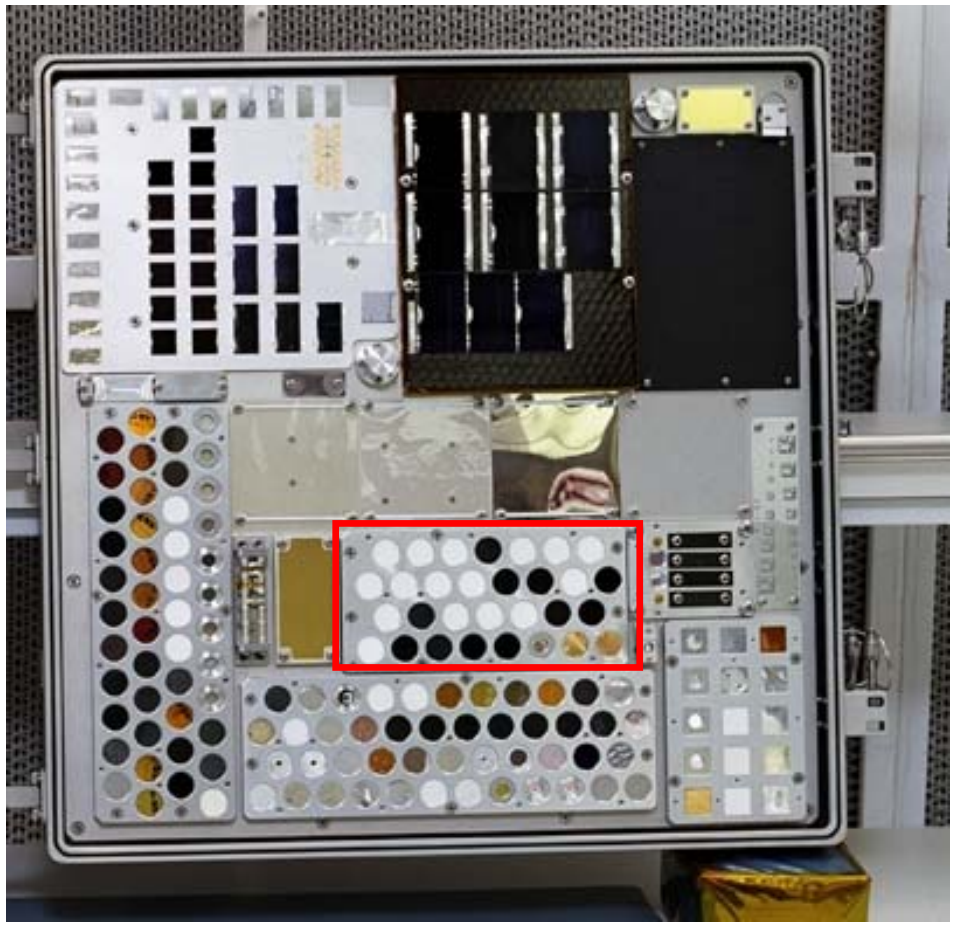


Trays B23, E17
On nominally ram-facing side of MISSE-4

1.8×10^{21} atoms/cm^2 by mass and thickness loss of polymer samples

~1,200 ESH approximate solar exposure

Photo courtesy of Langley Research Center

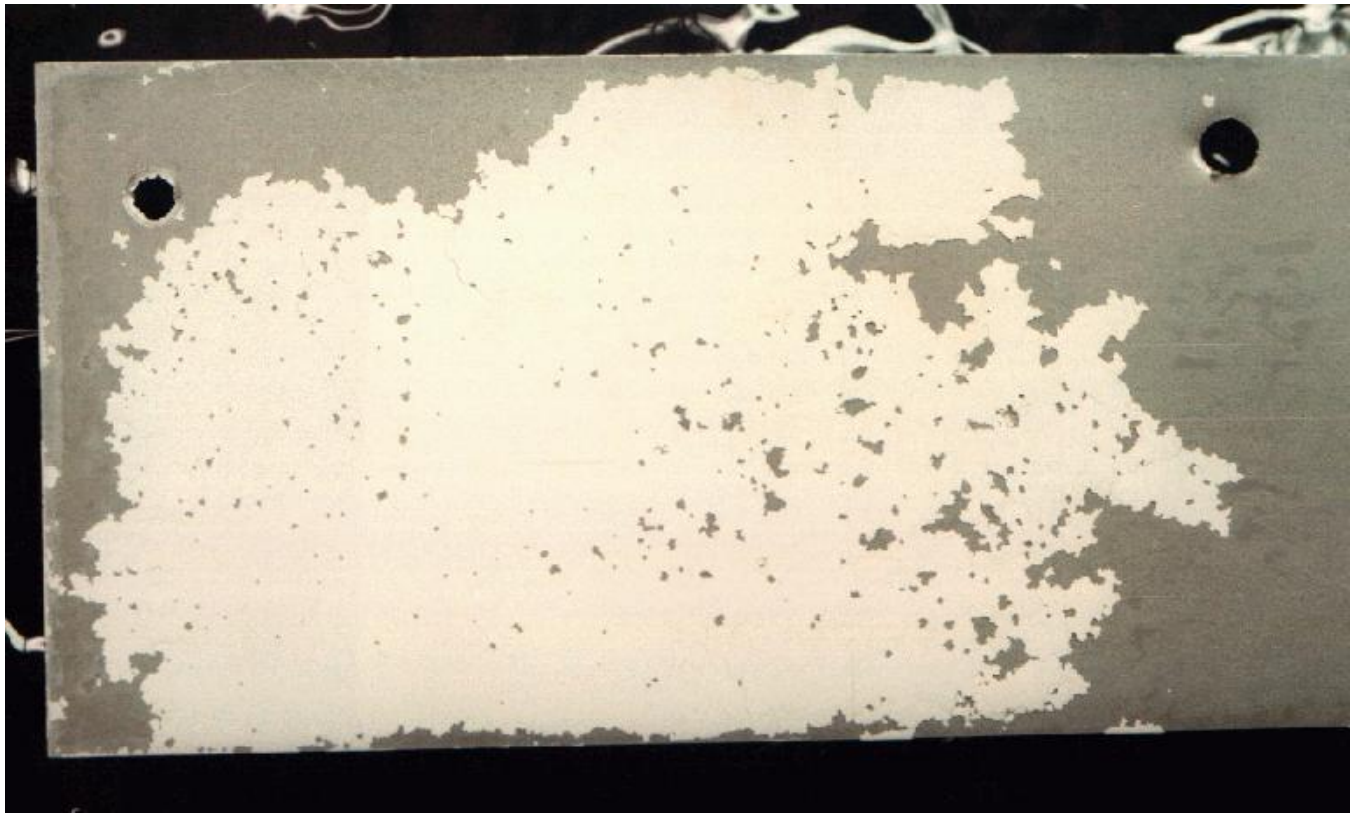


Tray D6
On nominally wake-facing side of MISSE-4

2.0×10^{20} atoms/cm^2 by modeling

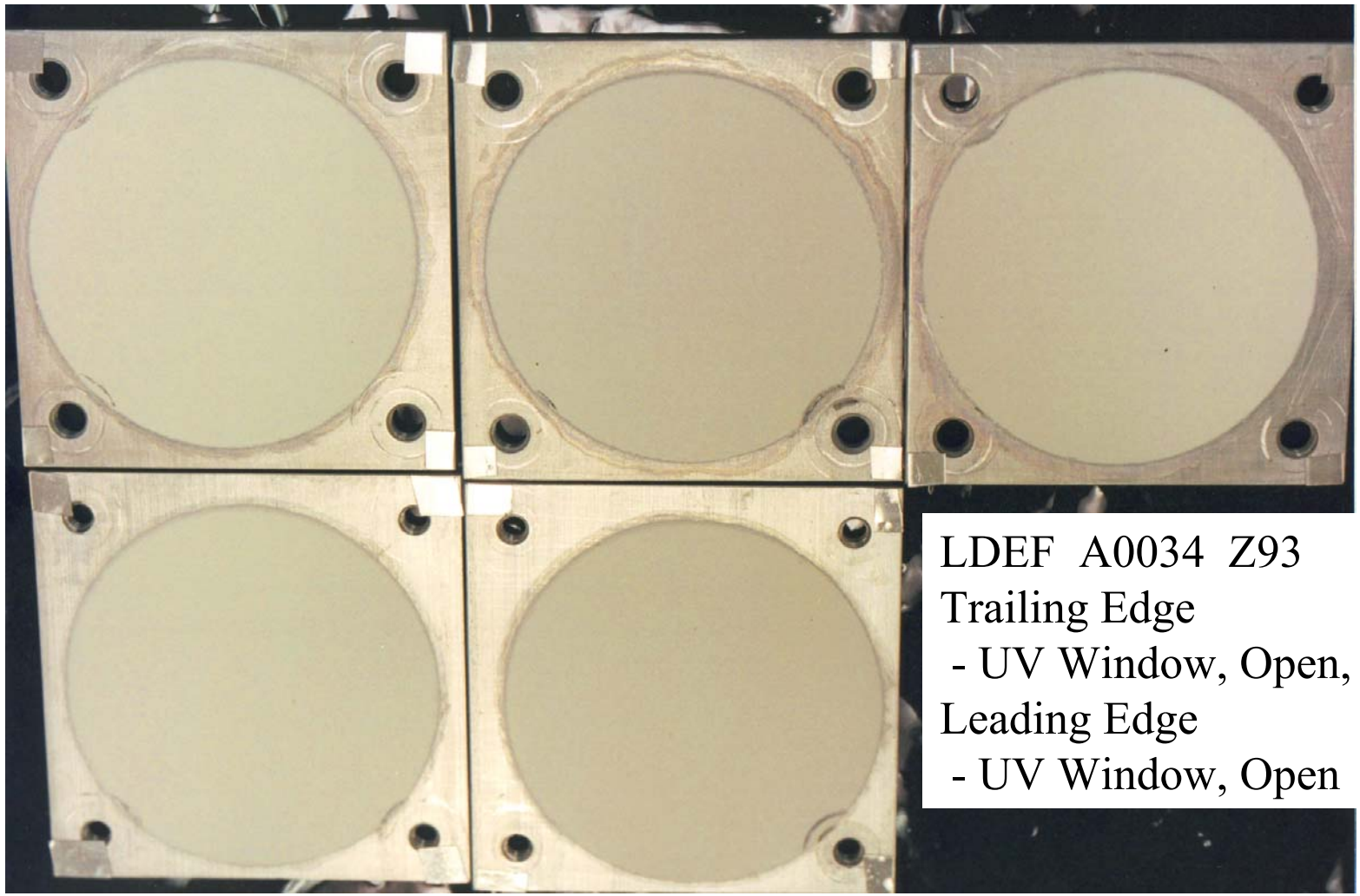
~1,200 ESH approximate solar exposure

Photo courtesy of Langley Research Center



Z-93P / AZ93 has good durability in the space environment ***IF*** applied properly and molecular contamination is minimized.

MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



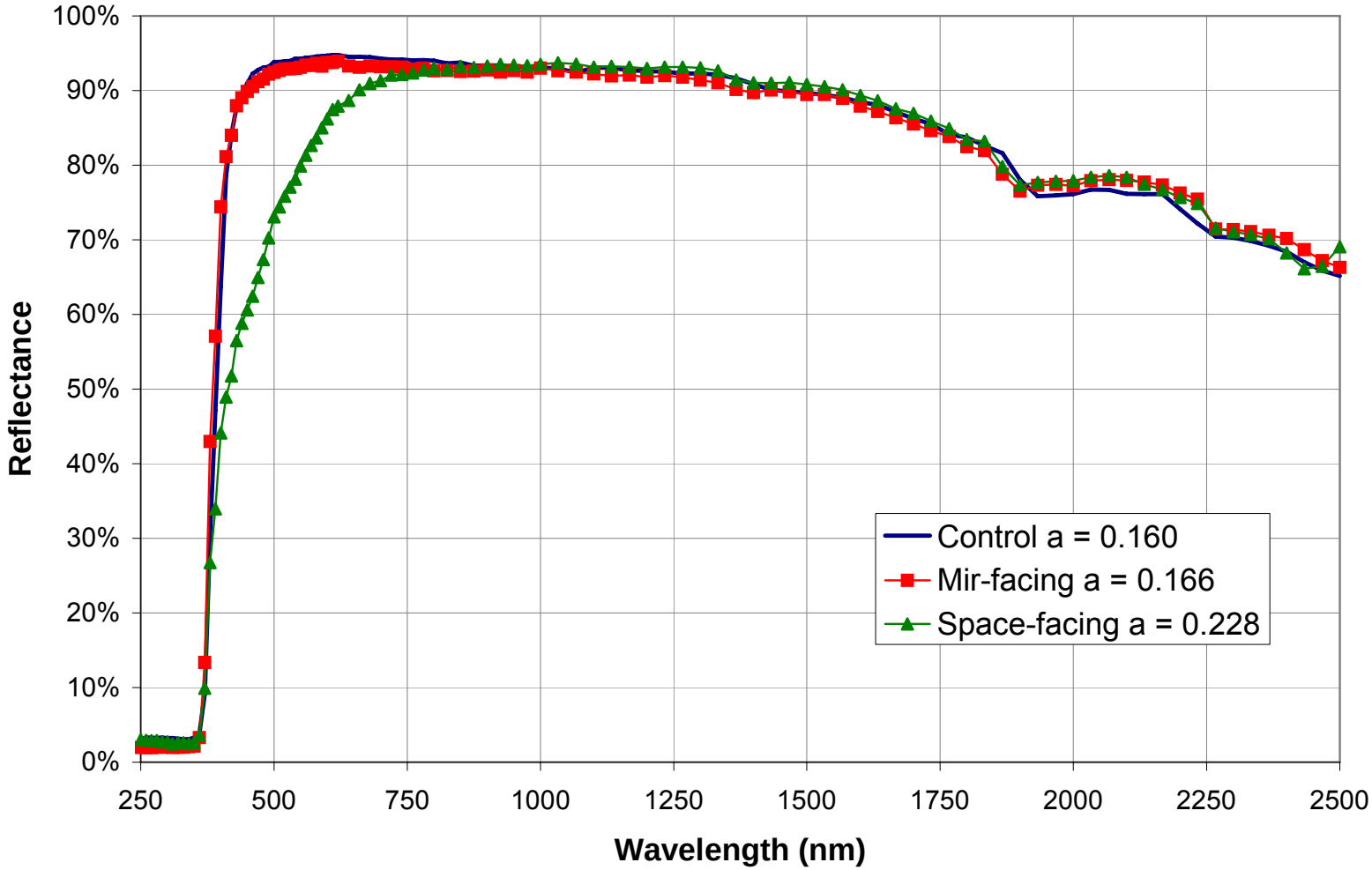
LDEF A0034 Z93
Trailing Edge
- UV Window, Open, Covered
Leading Edge
- UV Window, Open

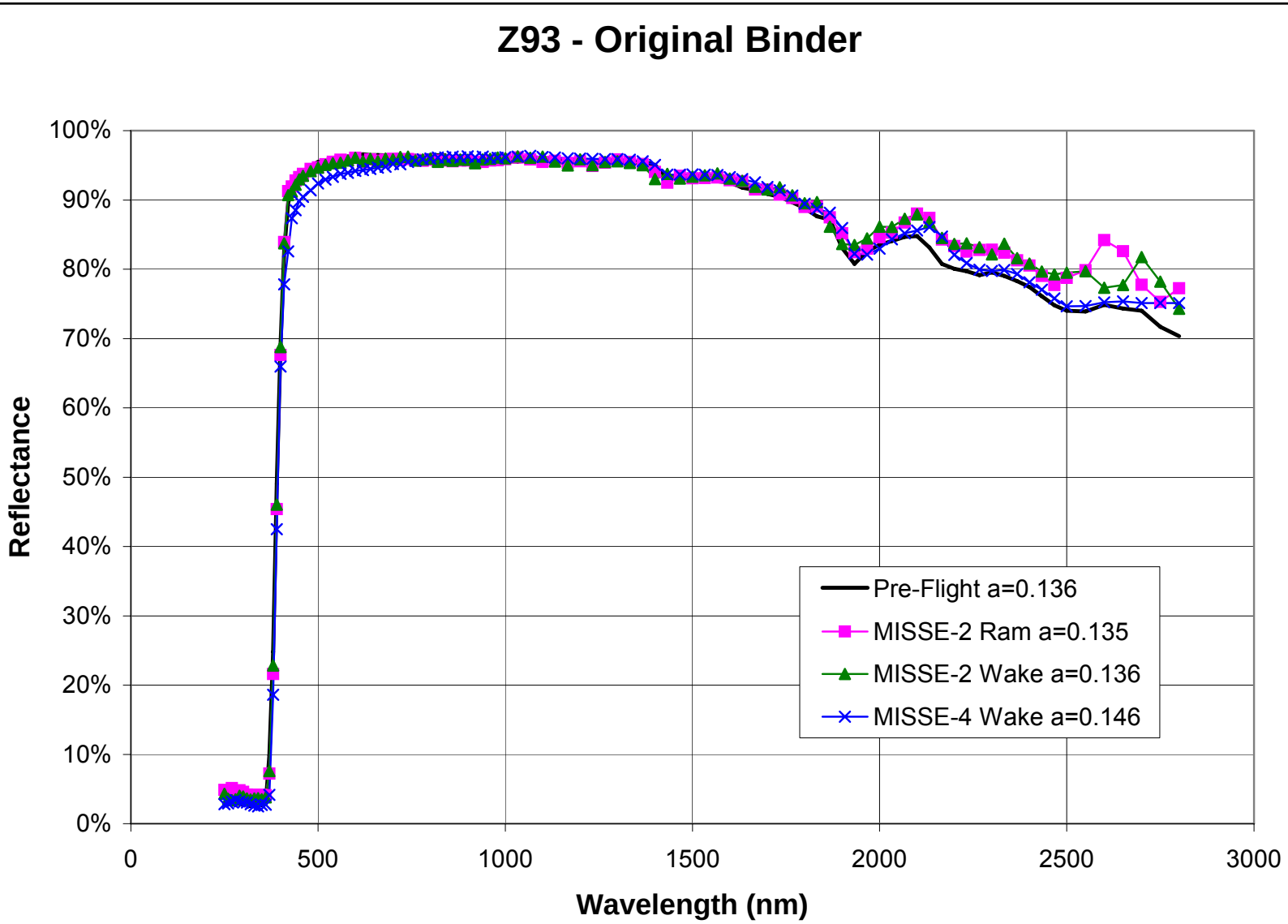
POSA-I Control

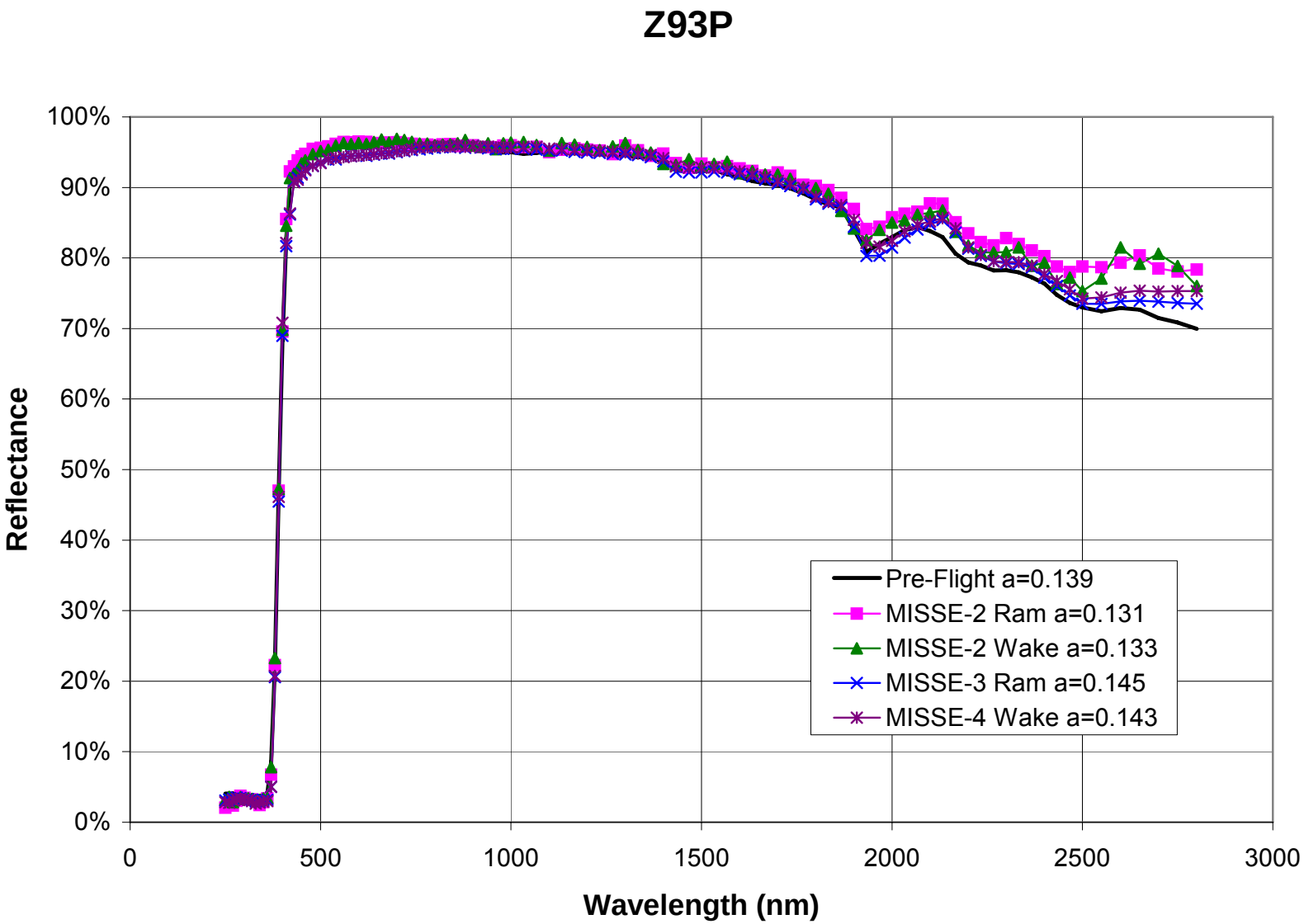
Space-facing ~5,000Å SiO_x Mir-facing ~250Å SiO_x

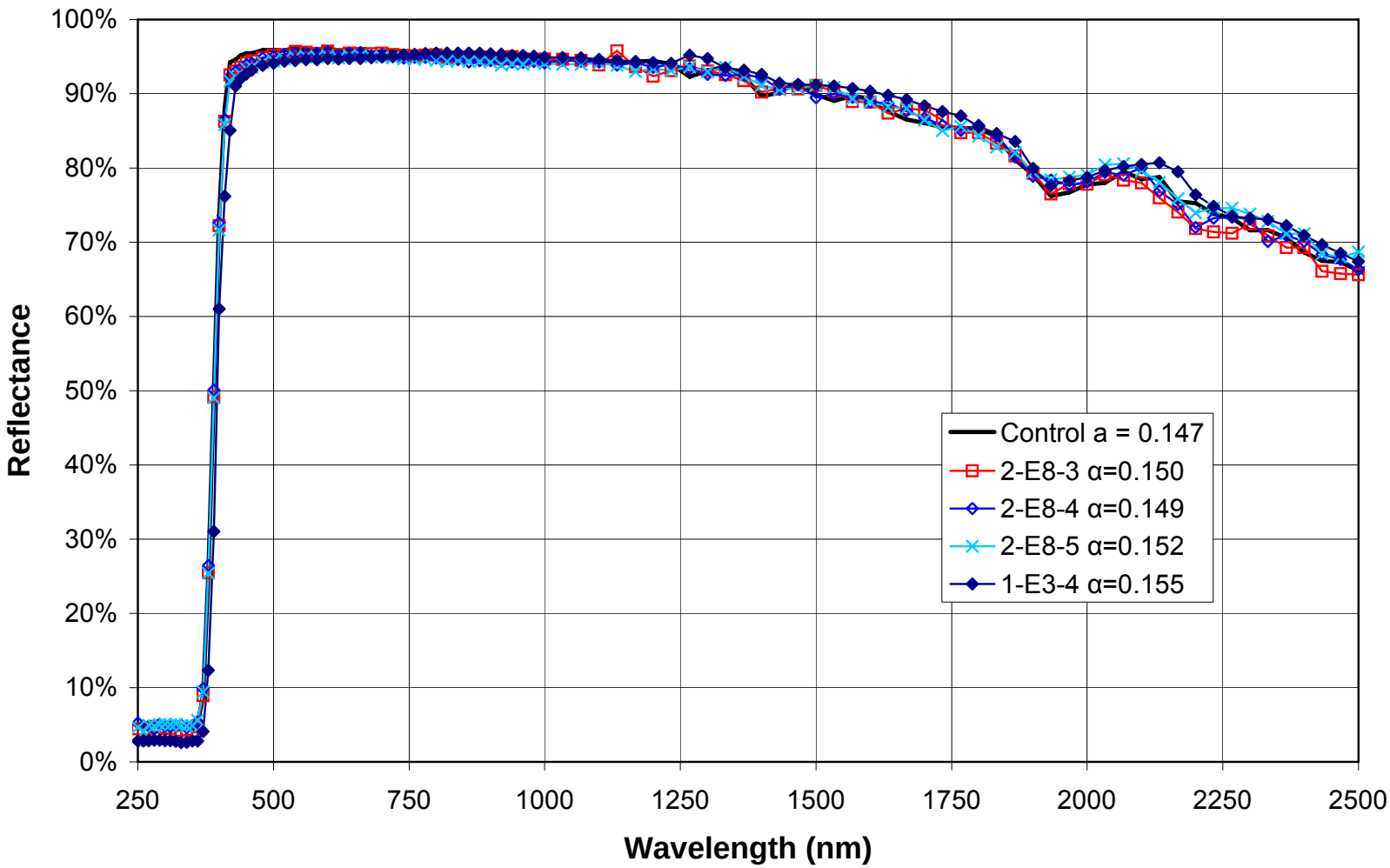
POSA-I Z-93P

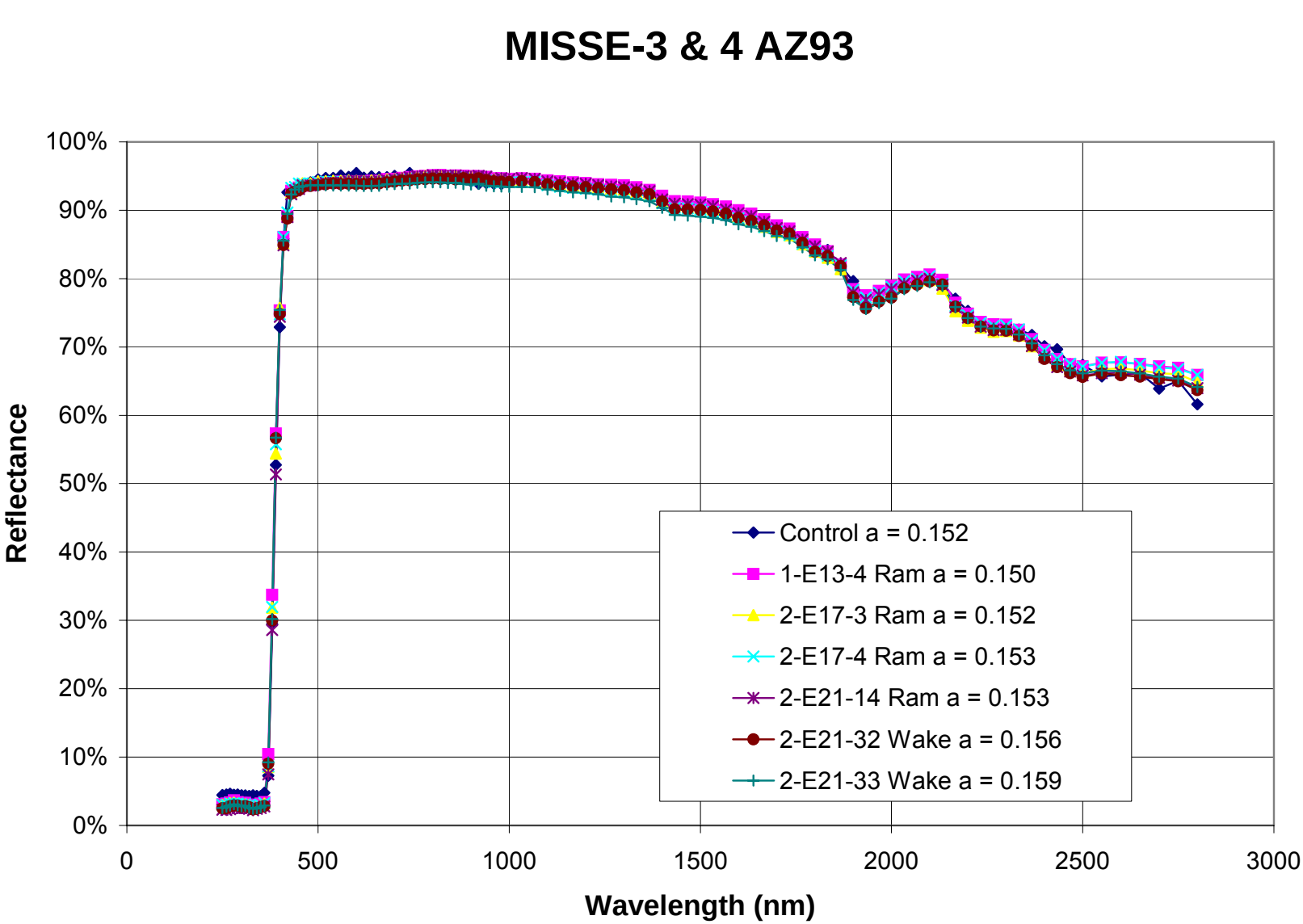
After 18 months on *Mir*



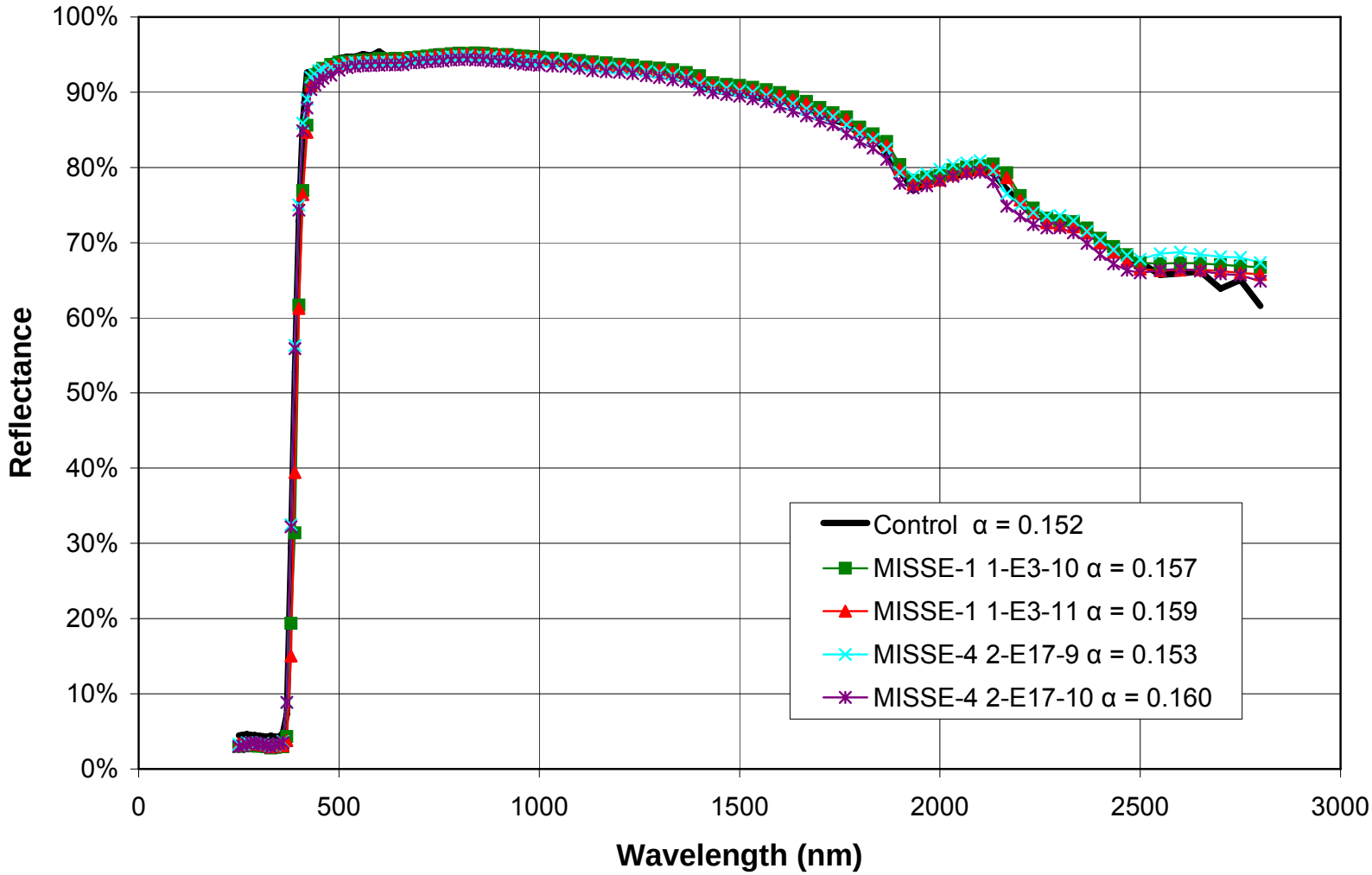

Z93 - Original Binder
Reflectance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000
Wavelength (nm)
Pre-Flight a=0.136
MISSE-2 Ram a=0.135
MISSE-2 Wake a=0.136
MISSE-4 Wake a=0.146


Z93P
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Reflectance
0
500
1000
1500
2000
2500
3000
Wavelength (nm)
Pre-Flight a=0.139
MISSE-2 Ram a=0.131
MISSE-2 Wake a=0.133
MISSE-3 Ram a=0.145
MISSE-4 Wake a=0.143


MISSE-2 AZ93 Inorganic White Coating
Reflectance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
250
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength (nm)
Control a = 0.147
2-E8-3 α=0.150
2-E8-4 α=0.149
2-E8-5 α=0.152
1-E3-4 α=0.155


MISSE-3 & 4 AZ93
Reflectance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000
Wavelength (nm)
Control a = 0.152
1-E13-4 Ram a = 0.150
2-E17-3 Ram a = 0.152
2-E17-4 Ram a = 0.153
2-E21-14 Ram a = 0.153
2-E21-32 Wake a = 0.156
2-E21-33 Wake a = 0.159

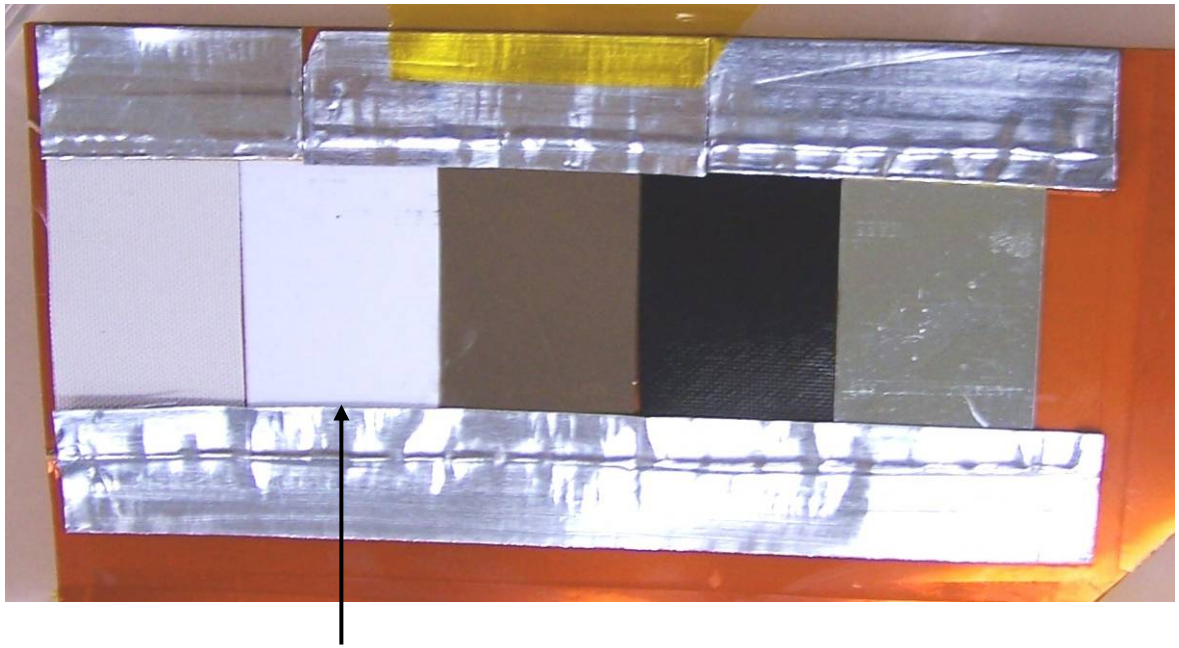
Post-Flight MISSE AZ93 / MLP-300-AZ on Composite



MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments

Environmental Exposure

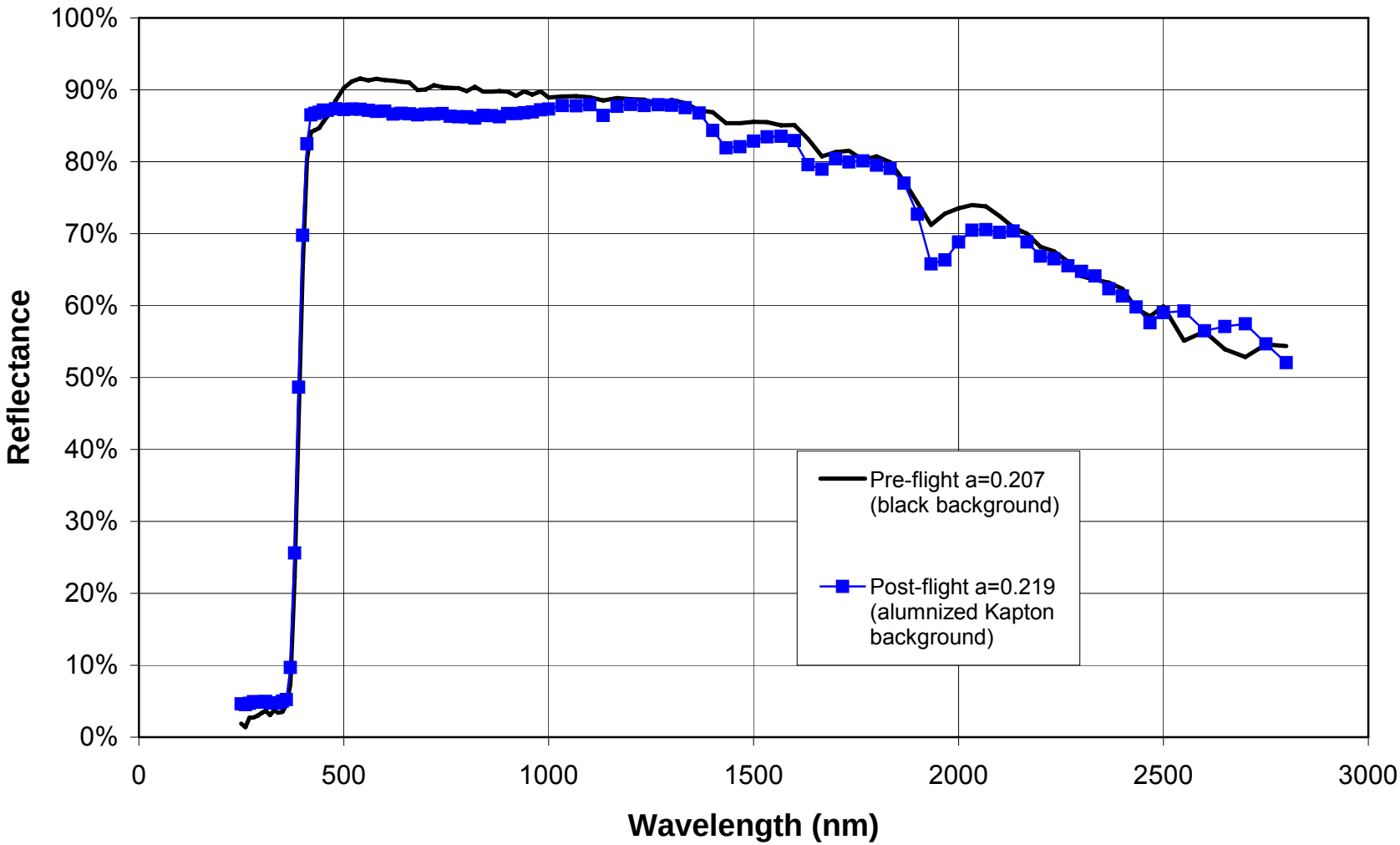
- ~1.8 x 10^{20} atoms/cm^2 atomic oxygen (Kapton erosion)
- ~ 525 equivalent sun-hours UV
- >6,500 thermal cycles of + 40/- 40 °C

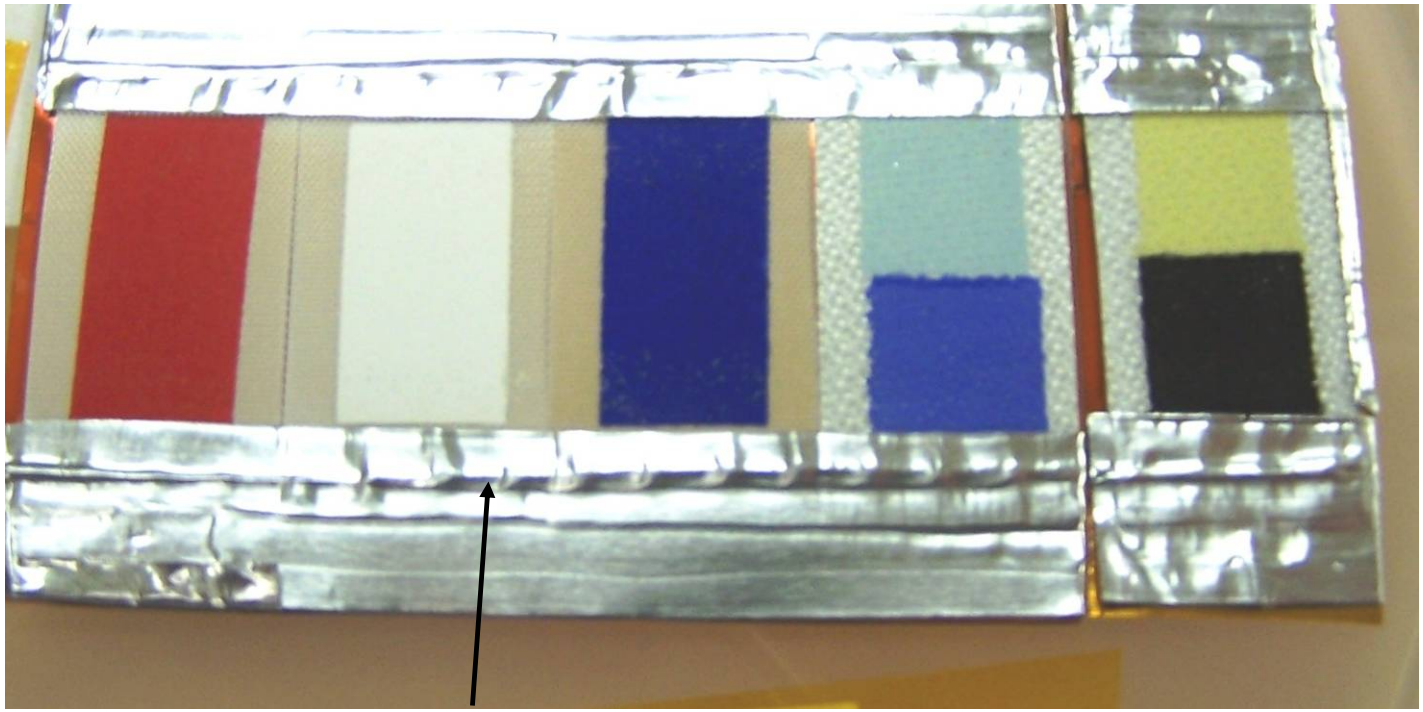


AZ93 on Kapton

- Thinner layer than aluminum substrate
- No indication of contamination at 400 nm knee

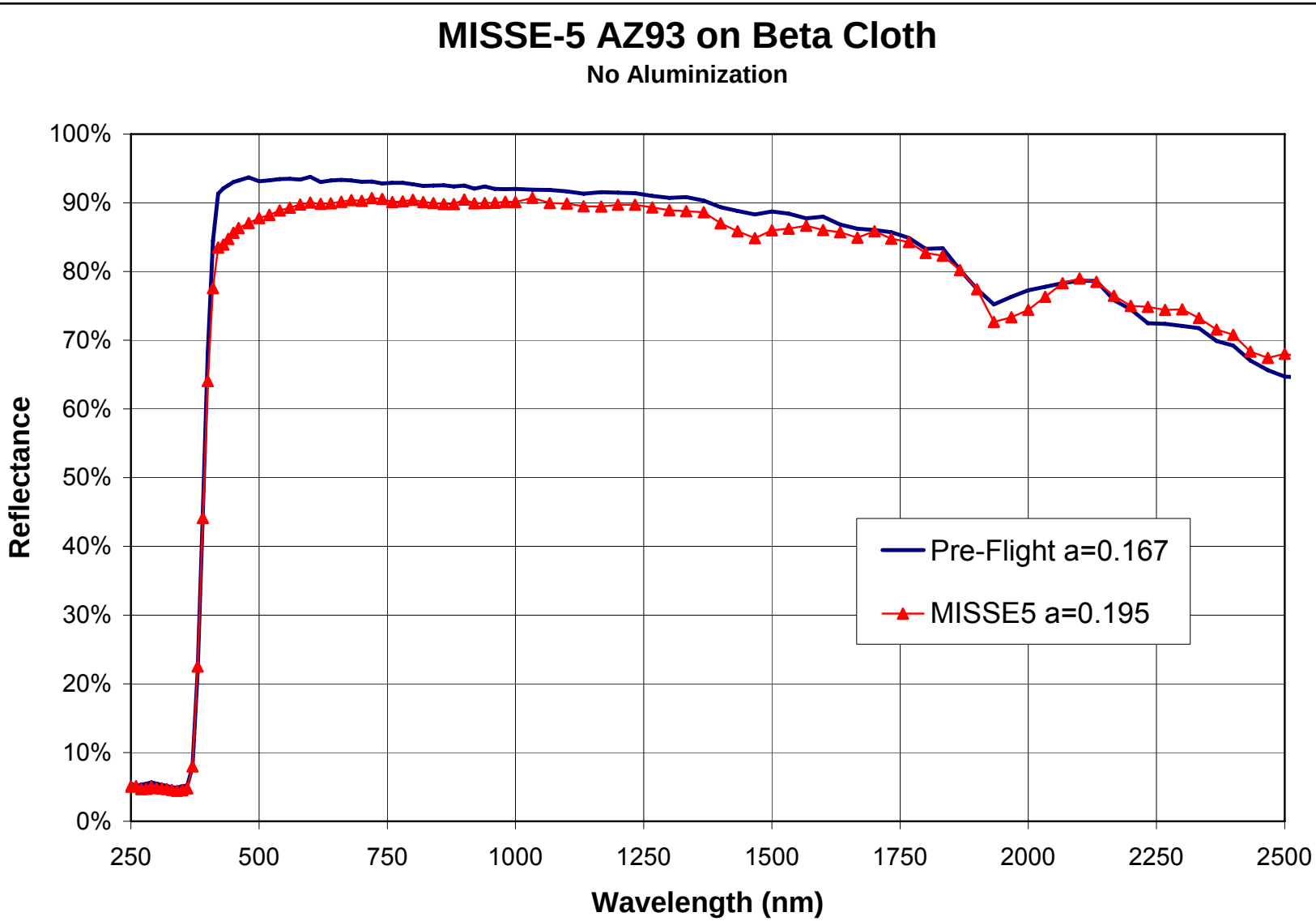
MISSE-5 AZ93 on Kapton





AZ93 on Beta Cloth looks white.

Change in reflectance spectra may indicate darkening of beta cloth underneath coating.

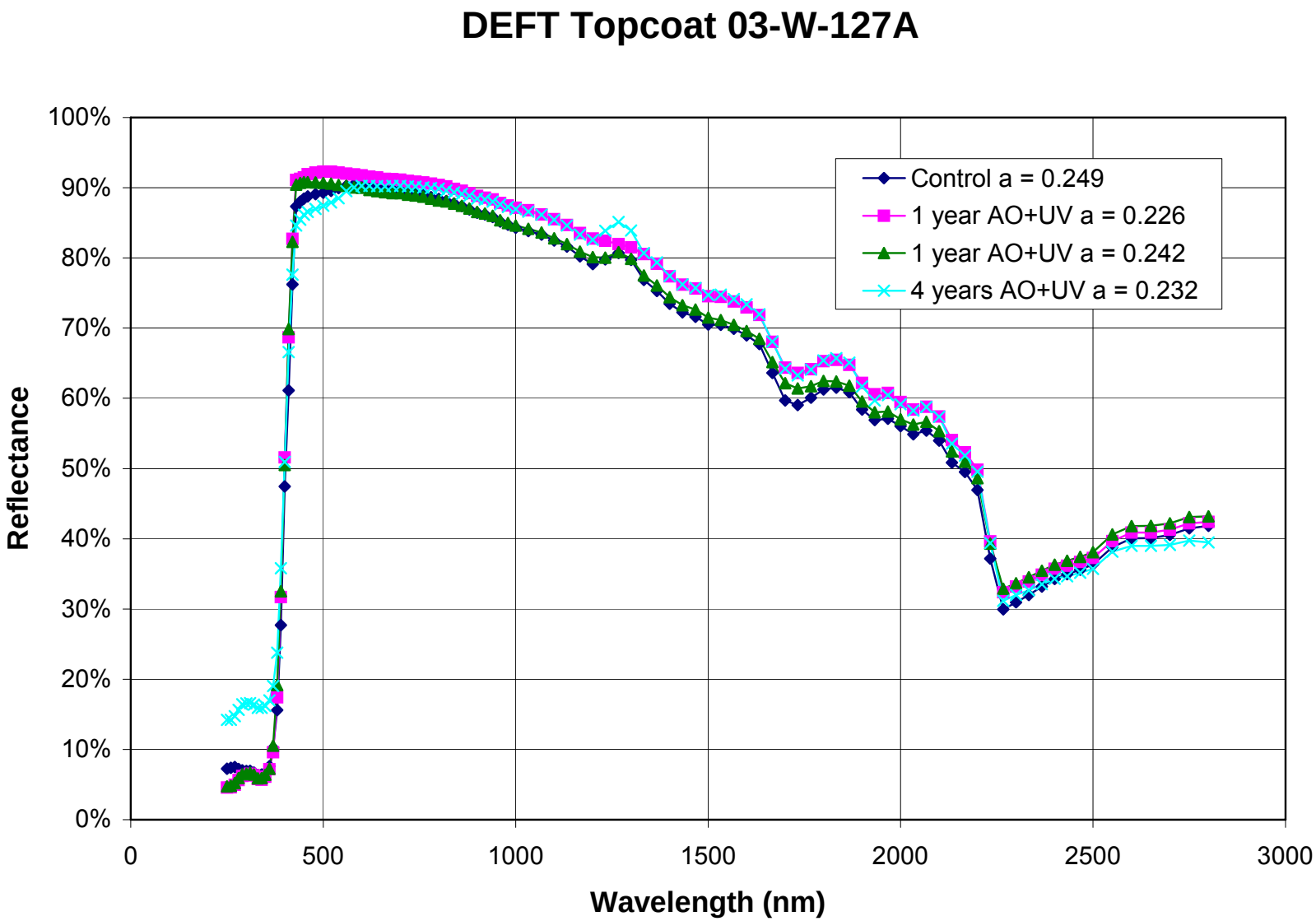

MISSE-5 AZ93 on Beta Cloth
No Aluminization
Reflectance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
250
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength (nm)
Pre-Flight a=0.167
MISSE5 a=0.195

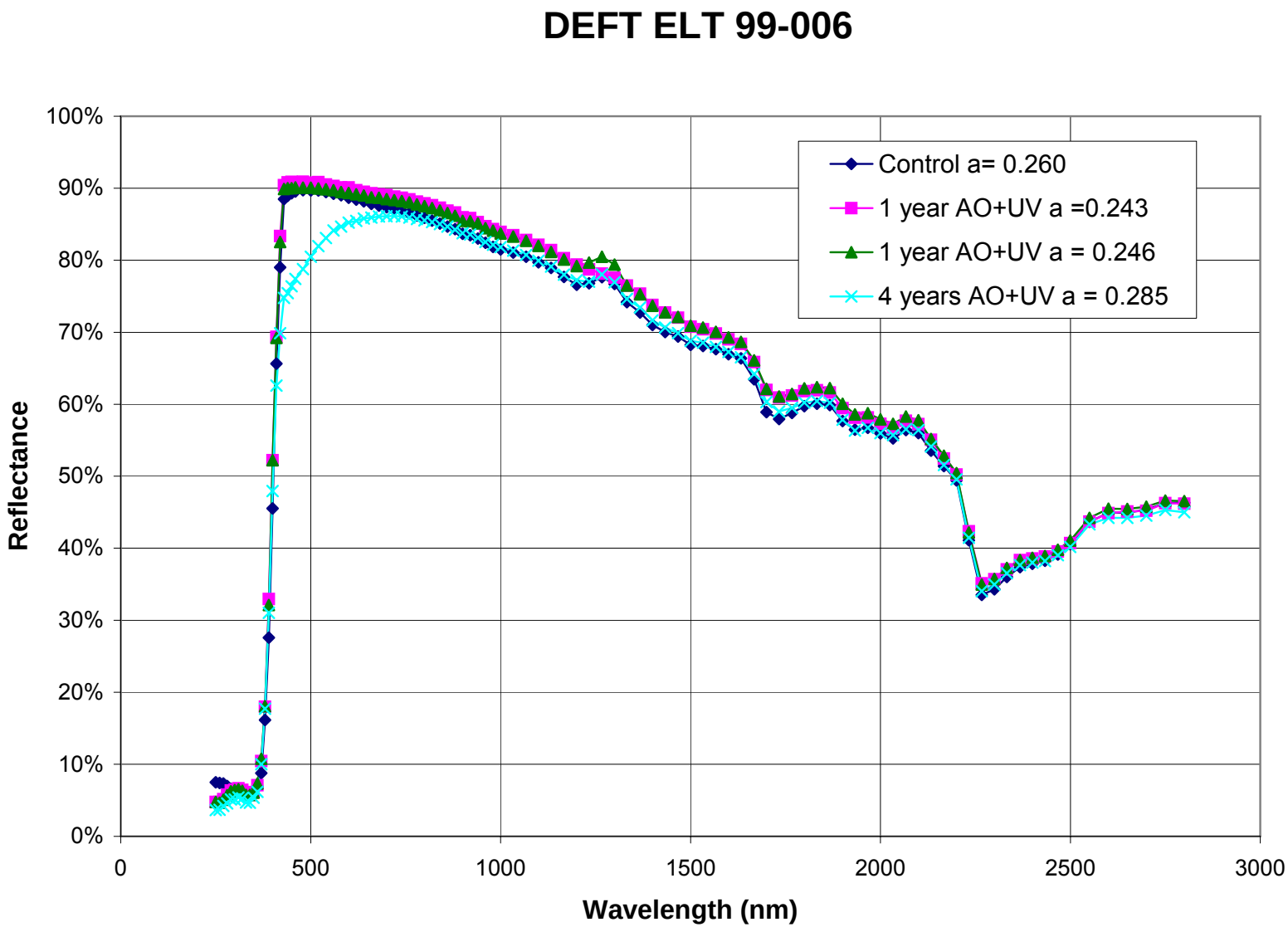
Deft Coatings
Used on the Solid Rocket Booster
Proposed for use on Ares-I First Stage
Also considered for LCROSS
Lunar CRater Observation and Sensing Satellite

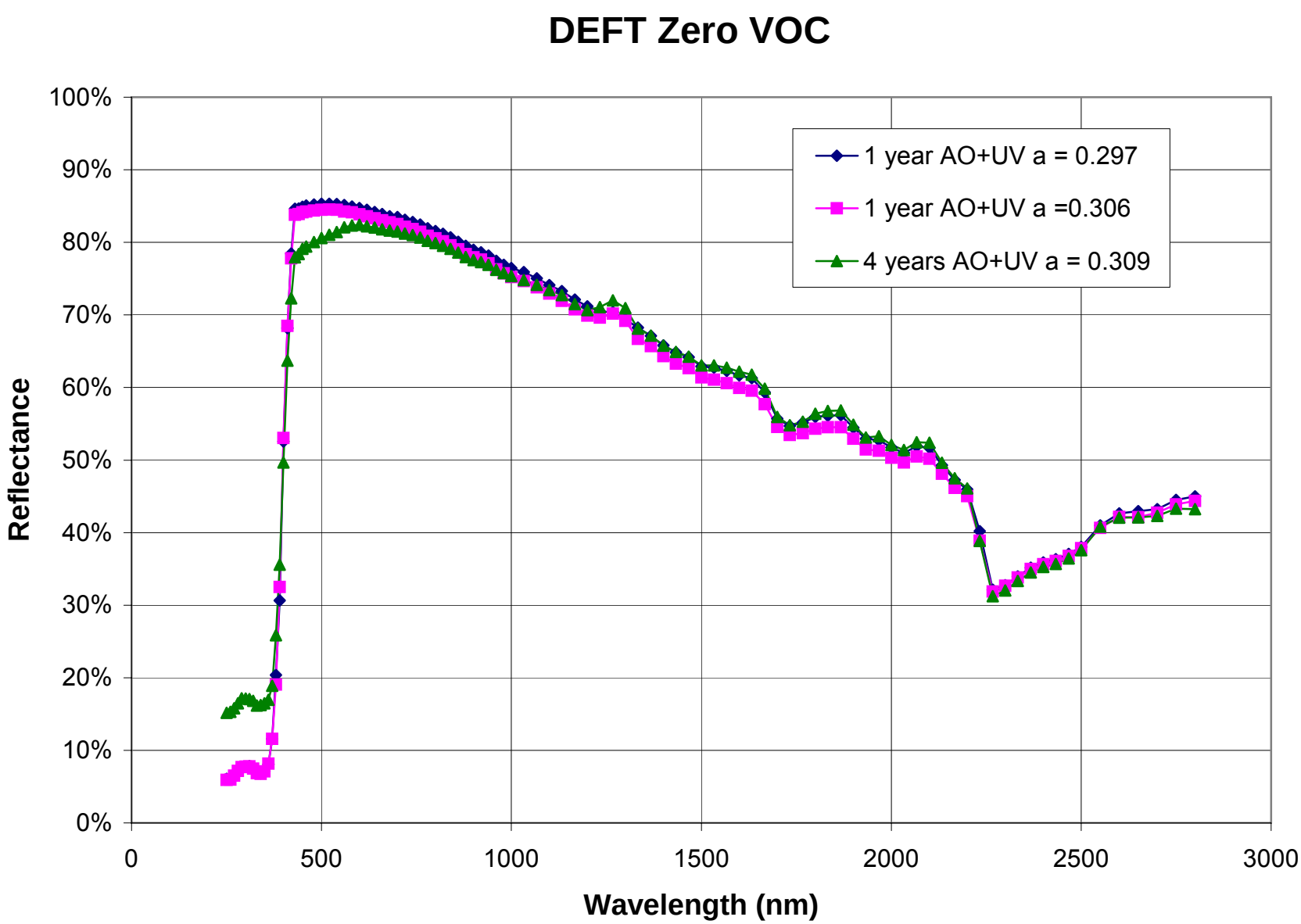
- 03-W-127A - current standard
- ELT - Extended Life Topcoat
- Zero VOC - Volatile Organic Compound

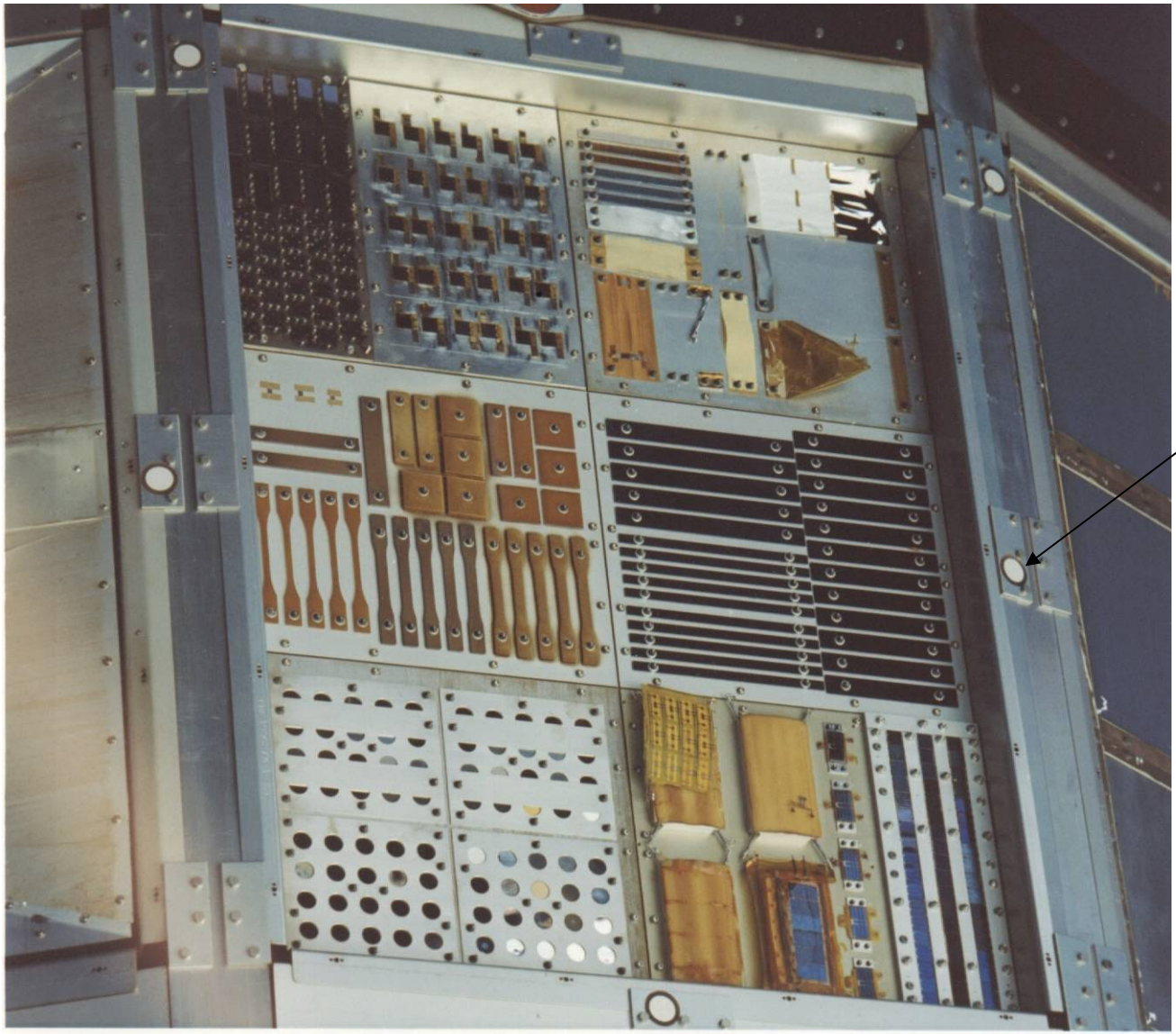
Solar absorptance (air mass zero) is converted to solar absorptance (air mass 1.5) for ground thermal analyses

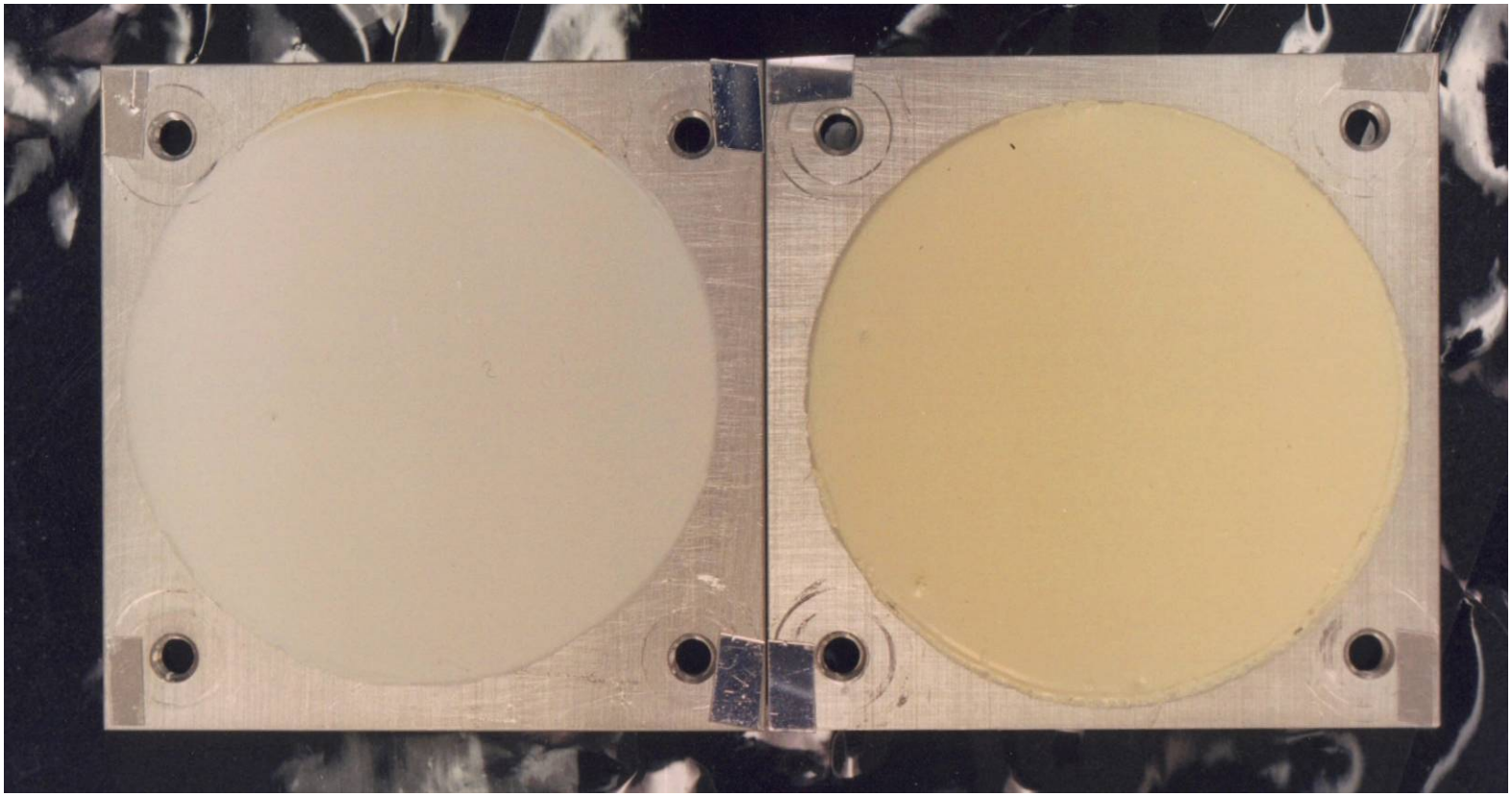
On-going effort to reduce environmental impact


DEFT Topcoat 03-W-127A
Reflectance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000
Wavelength (nm)
Control a = 0.249
1 year AO+UV a = 0.226
1 year AO+UV a = 0.242
4 years AO+UV a = 0.232


DEFT ELT 99-006
Reflectance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000
Wavelength (nm)
Control a= 0.260
1 year AO+UV a =0.243
1 year AO+UV a = 0.246
4 years AO+UV a = 0.285


DEFT Zero VOC
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Reflectance
0
500
1000
1500
2000
2500
3000
Wavelength (nm)
1 year AO+UV a = 0.297
1 year AO+UV a =0.306
4 years AO+UV a = 0.309


A-276 on
tray clamps



A-276 from A0034 Experiment

Leading Edge Trailing Edge

Lord Chemical Aeroglaze A-276

- Many samples flown on LDEF
- BOL $\alpha = 0.23 \pm 0.03$ per MSFC-PROC-547
- Leading edge $\alpha = 0.30 \pm 0.03$
- Trailing edge α as high as 0.57

MISSE samples

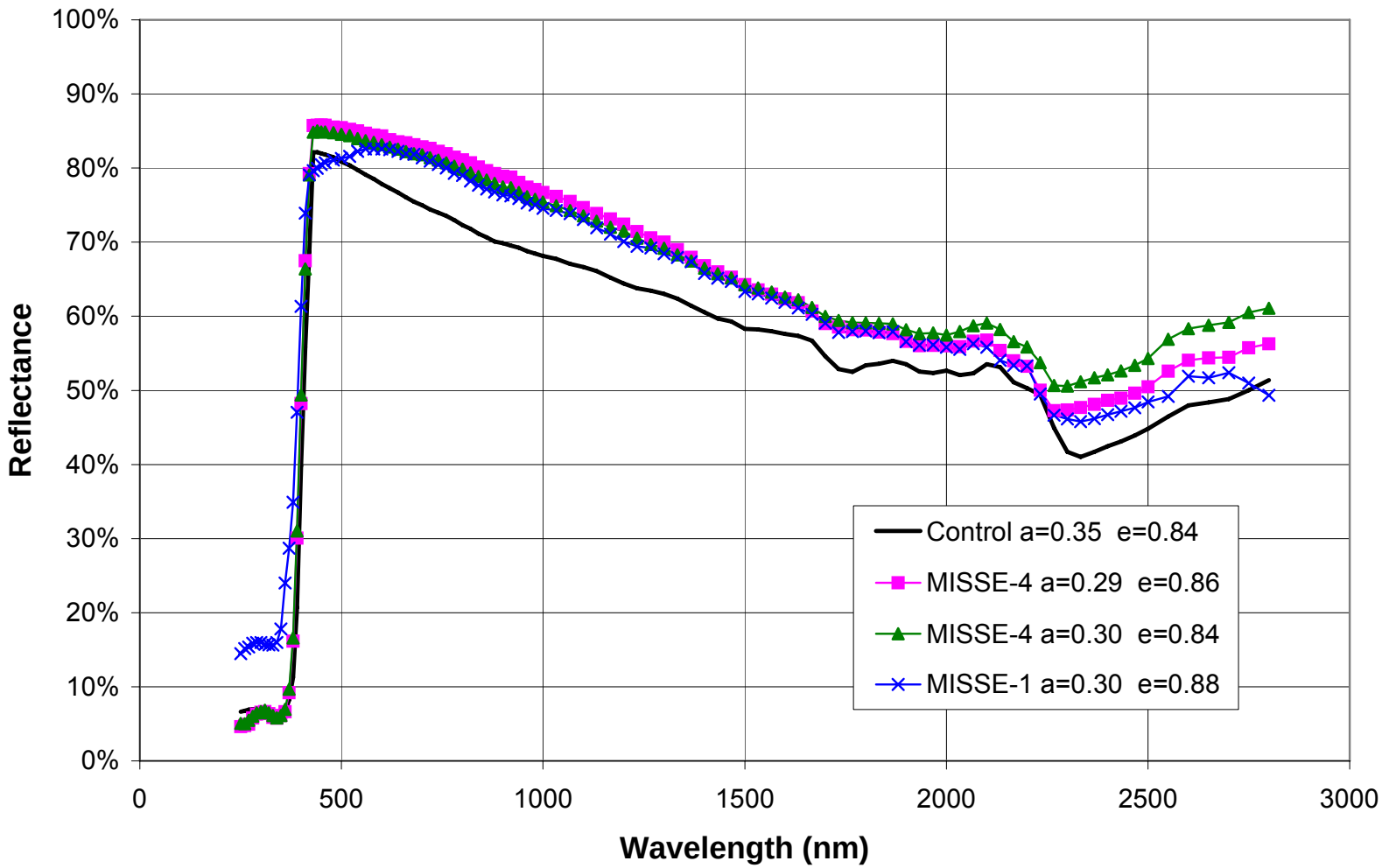
- Leafing aluminum added for charge dissipation
  - 1%, 3%, 5%, 10%, 15% by volume

Long-term use in LEO not recommended

- Polyurethane binder susceptible to AO erosion
- OK for short missions, like flight support equipment

A-276 with Leafing Aluminum

Material	Exposure	AO (atoms/cm^2)	UV (ESH)	Solar Absorptance	Infrared Emittance
1%	Control	-	-	0.35	0.84
1%	MISSE-4	1.8 x 10^{21}	~1,200	0.30	0.84
1%	MISSE-4	1.8 x 10^{21}	~1,200	0.29	0.86
1%	MISSE-1	9.5 x 10^{21}	5,700	0.30	0.87
5%	Control	-	-	0.40	0.79
5%	MISSE-4	1.8 x 10^{21}	~1,200	0.31	0.78
5%	MISSE-1	9.5 x 10^{21}	5,600	0.31	0.78
10%	Control	-	-	0.42	0.76
10%	MISSE-1	9.5 x 10^{21}	5,600	0.32	0.74
10%	MISSE-2	1.7 x 10^{20}	5,900	0.33	0.72
15%	Control	-	-	0.42	0.76
15%	MISSE-4	1.8 x 10^{21}	~1,200	0.30	0.69
15%	MISSE-2	1.7 x 10^{20}	5,900	0.38	0.71


A-276 with 1% Leafing Aluminum
Reflectance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
500
1000
1500
2000
2500
3000
Wavelength (nm)
Control a=0.35 e=0.84
MISSE-4 a=0.29 e=0.86
MISSE-4 a=0.30 e=0.84
MISSE-1 a=0.30 e=0.88

Conclusions

- Zinc oxide pigment with inorganic binder held up well with up to four years in LEO {AO+UV} environment.
- No evidence of significant contamination.
- Some yellowing of the Deft ELT coating.
- Some bleaching of the A-276 with leafing aluminum.