MSFC-186.

Post-Flight Analysis of Selected Fluorocarbon and Other Thin Film Polymer Specimens flown on MISSE-5

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Twenty thin film specimens were flown on MISSE-5 as a cooperative effort between several organizations. This presentation will report results of initial inspections and post-flight measurements of the optical properties and recession of these materials due to the ~13 month exposure period on the exterior of the International Space Station. These specimens were located on the "anti-solar" side of the MISSE-5 container and received a low number of Equivalent Sun Hours of solar UV exposure. Profilometry and/or ATF measurements will be conducted to determine thickness changes and atomic oxygen-induced recession rates

Six of the specimens were covered with thin Kapton films, 0.1 and 0.3 mil in thickness. The 0.1 mil Kapton was almost completely eroded, suggesting that the atomic oxygen fluence is $<8 \times 10^{19}$ atoms/cm2, similar to levels experienced during Space Shuttle materials experiments in the 1980's and 1990's. A comparison of results from MISSE-5 and Space Shuttle experiments will be included for those materials common to both the short and long-term exposures.

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Dr. Gary Pippin, Boeing Phantom Works

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Presentation Overview

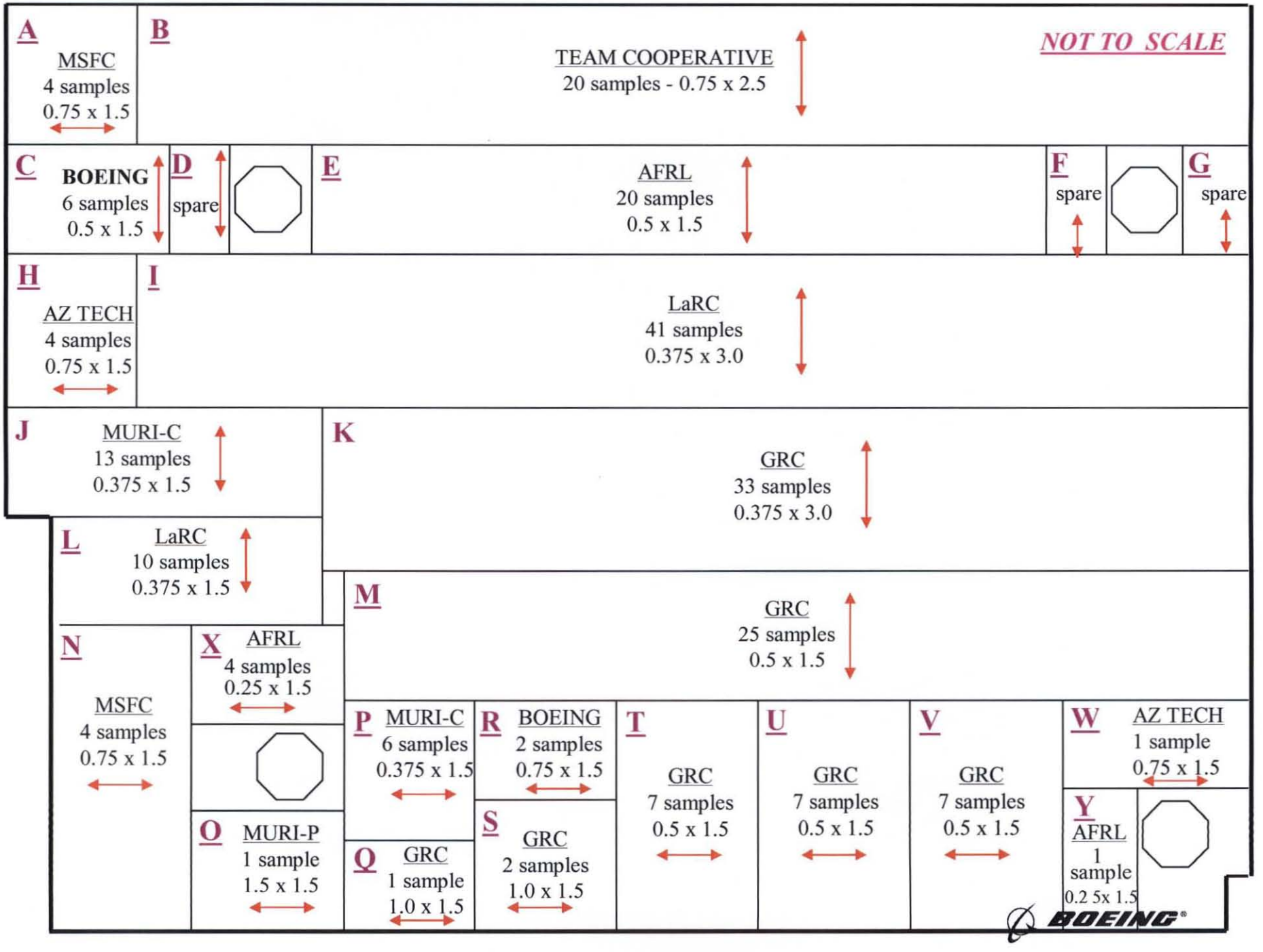
Purpose: To provide evidence of specific degradation mechanisms – relate degradation rates to structural features

Provide selected property measurements of the material specimens flown on these experiments

Correlate results with other flight experiments

Team Cooperative Samples
(From Gary's MISSE 5 Table)

B-01	C421	Team Cooperative	PTFE
B-02	C422	Team Cooperative	0.1 mil Kapton over PTFE
B-03	C423	Team Cooperative	0.3 mil Kapton over PTFE
B-04	C424	Team Cooperative	FEP
B-05	C426	Team Cooperative	0.3 mil Kapton over FEP
B-06	C429	Team Cooperative	0.3 mil Kapton over THV
B-07	C430	Team Cooperative	Tedlar
B-08	C433	Team Cooperative	Tefzel
B-09	C435	Team Cooperative	PFA
B-10	C436	Team Cooperative	THV
B-11	C438	Team Cooperative	Halar
B-12	C439	Team Cooperative	PVDF
B-13	C440	Team Cooperative	TEFLON AF 1600
B-14	C444	Team Cooperative	Kapton environment witness sample - 5 mil
B-15	C446	Team Cooperative	0.3 mil Kapton over PVDF
B-16	C447	Team Cooperative	Polyethylene
B-17	C448	Team Cooperative	Polypropylene
B-18	C432	Team Cooperative	0.3 mil Kapton over Tedlar
B-19	C434	Team Cooperative	Aclar
B-20	C442	Team Cooperative	Ag Teflon


A
MSFC
4 samples
0.75 x 1.5
B
TEAM COOPERATIVE
20 samples - 0.75 x 2.5
NOT TO SCALE
C
BOEING
6 samples
0.5 x 1.5
D
spare
E
AFRL
20 samples
0.5 x 1.5
F
spare
G
spare
H
AZ TECH
4 samples
0.75 x 1.5
I
LaRC
41 samples
0.375 x 3.0
J
MURI-C
13 samples
0.375 x 1.5
K
GRC
33 samples
0.375 x 3.0
L
LaRC
10 samples
0.375 x 1.5
M
GRC
25 samples
0.5 x 1.5
N
MSFC
4 samples
0.75 x 1.5
X
AFRL
4 samples
0.25 x 1.5
O
MURI-P
1 sample
1.5 x 1.5
P
MURI-C
6 samples
0.375 x 1.5
Q
GRC
1 sample
1.0 x 1.5
R
BOEING
2 samples
0.75 x 1.5
S
GRC
2 samples
1.0 x 1.5
T
GRC
7 samples
0.5 x 1.5
U
GRC
7 samples
0.5 x 1.5
V
GRC
7 samples
0.5 x 1.5
W
AZ TECH
1 sample
0.75 x 1.5
Y
AFRL
1
sample
0.2 5x 1.5
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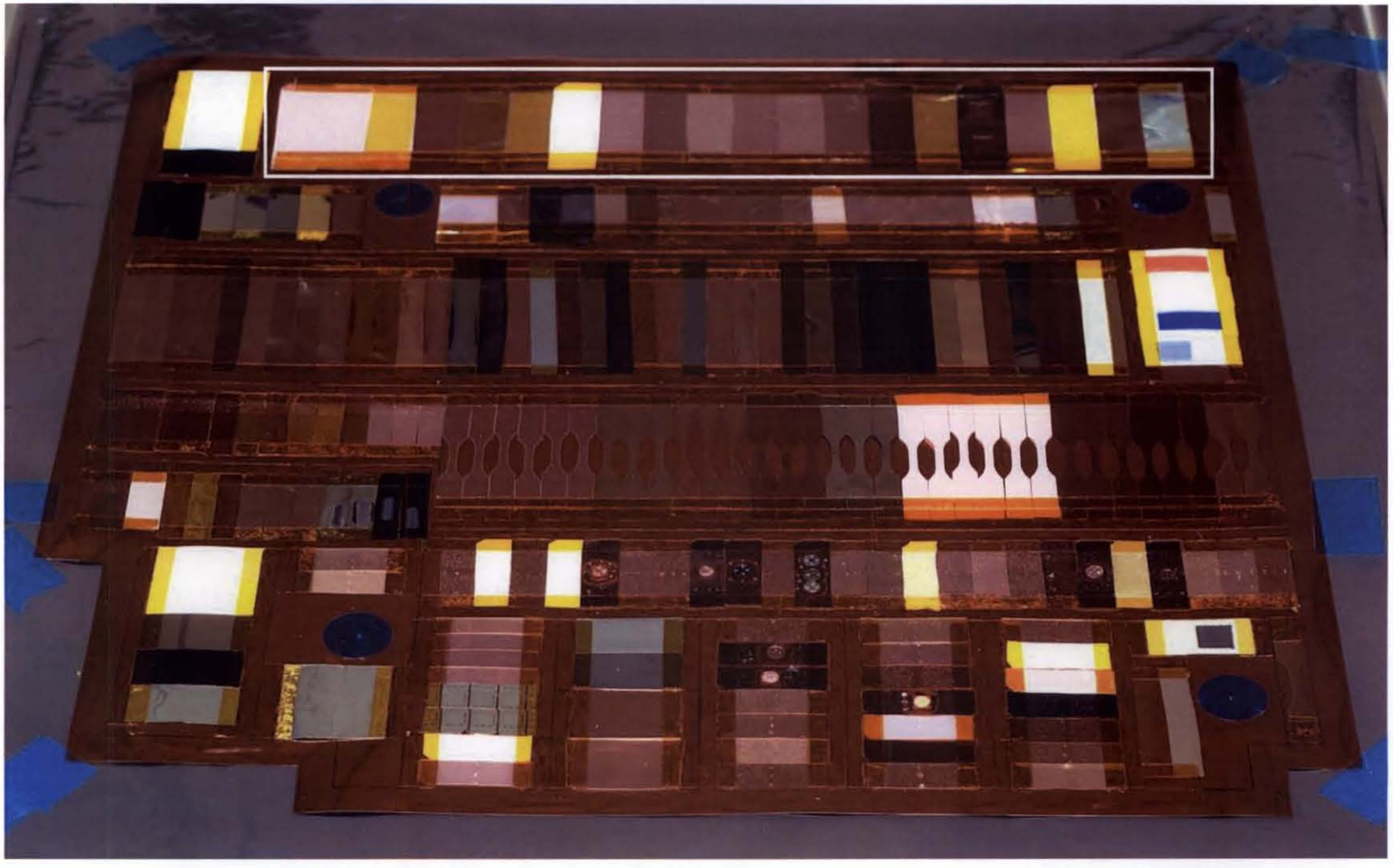
MISSE-5 Thermal Blanket Materials Experiment

(Pre-Flight)

Team Cooperative samples (20) outlined in white



NASA Image, specimens mounted on blanket, pre-flight

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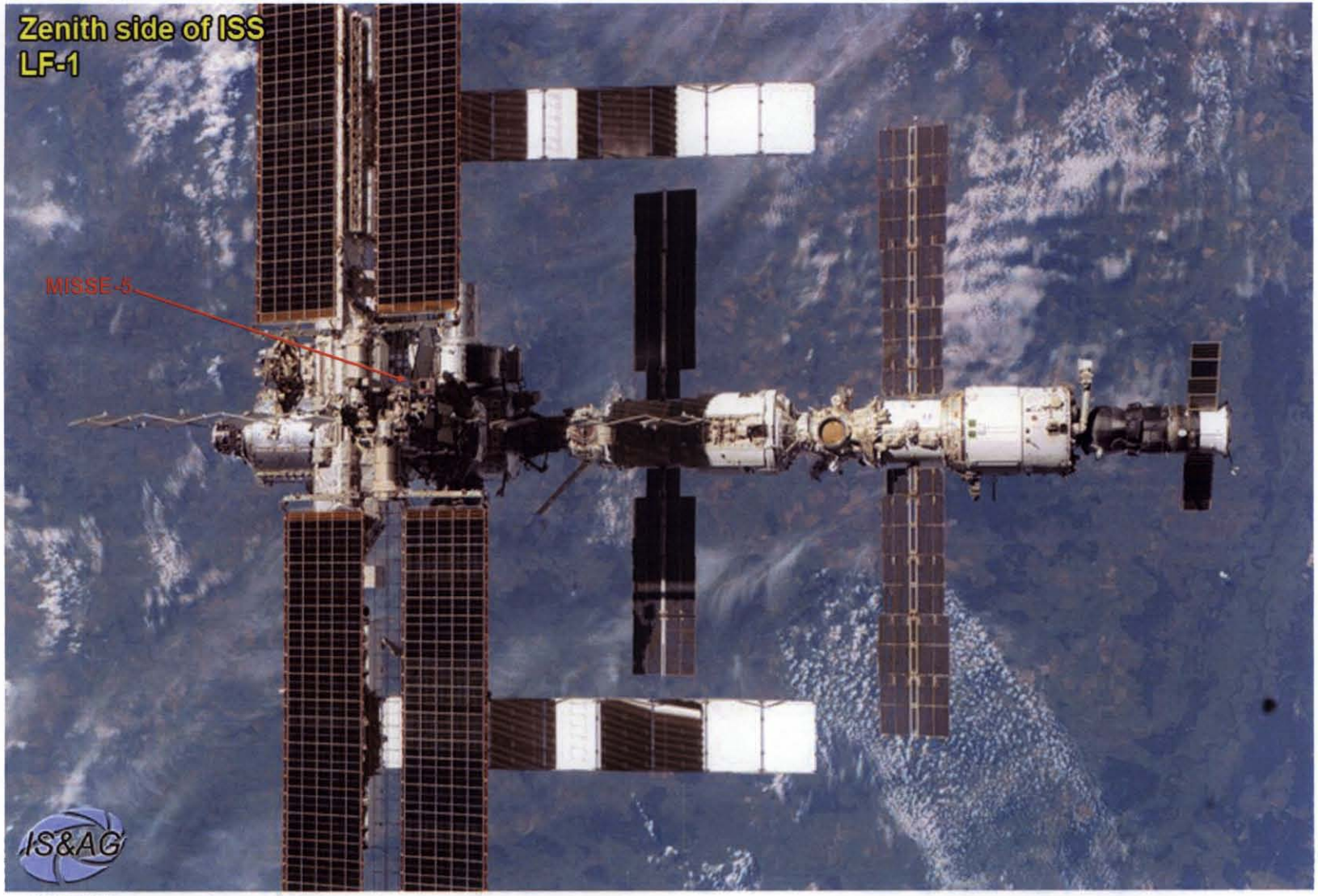
ISS View showing MISSE-5 location



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MISSE-5 deployed on ISS, NASA Image

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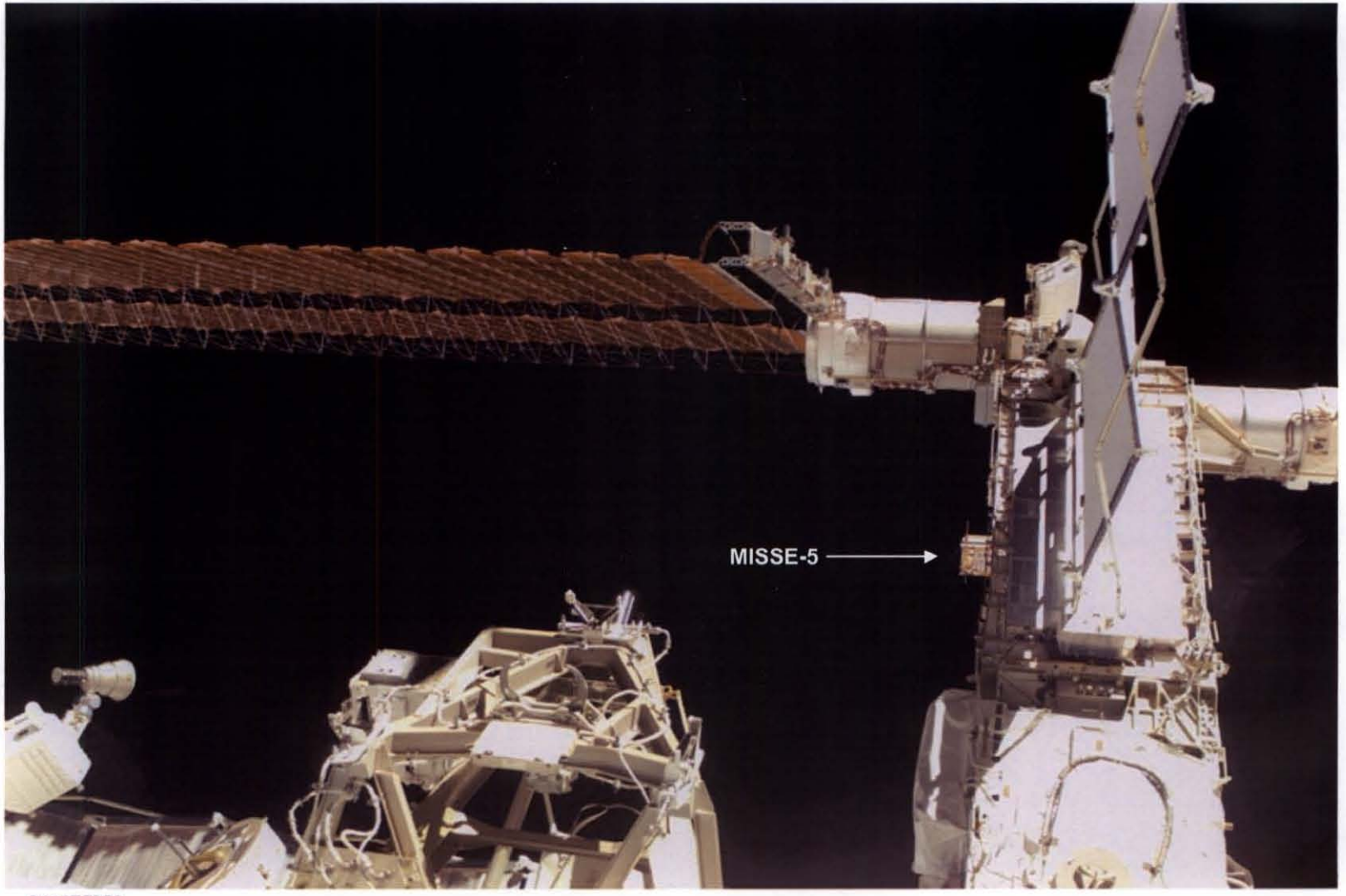
ISS View showing MISSE-5 on P6 Truss



S114E7356

MISSE-5 deployed on ISS, early August, 2005, NASA Image

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MISSE-5 Nadir Side

S114E7353

MISSE-5 Nadir-facing surface, August 2005, NASA Image

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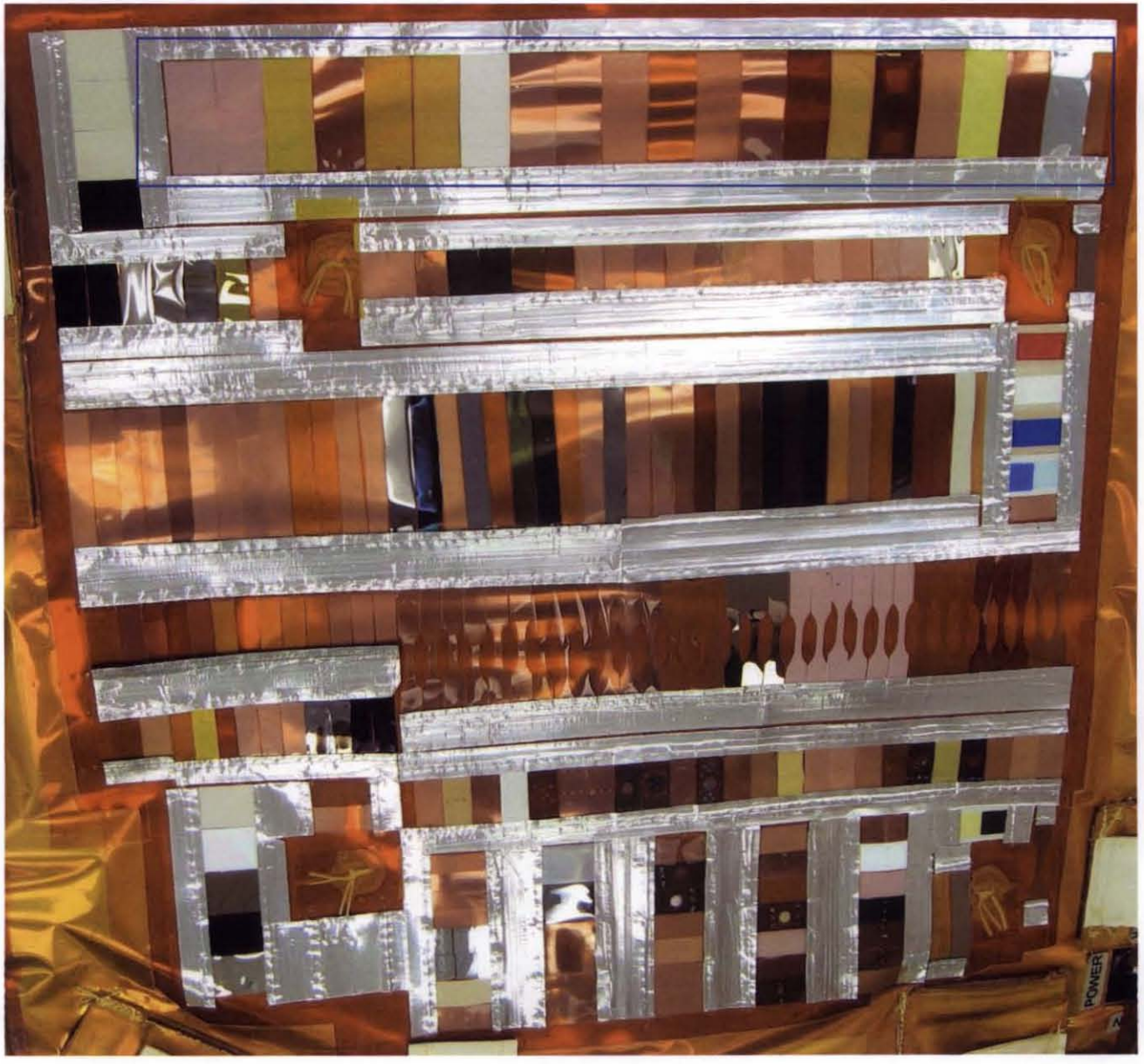
MISSE 5 Thermal Blanket Materials Experiment - Post-Flight



NASA Image

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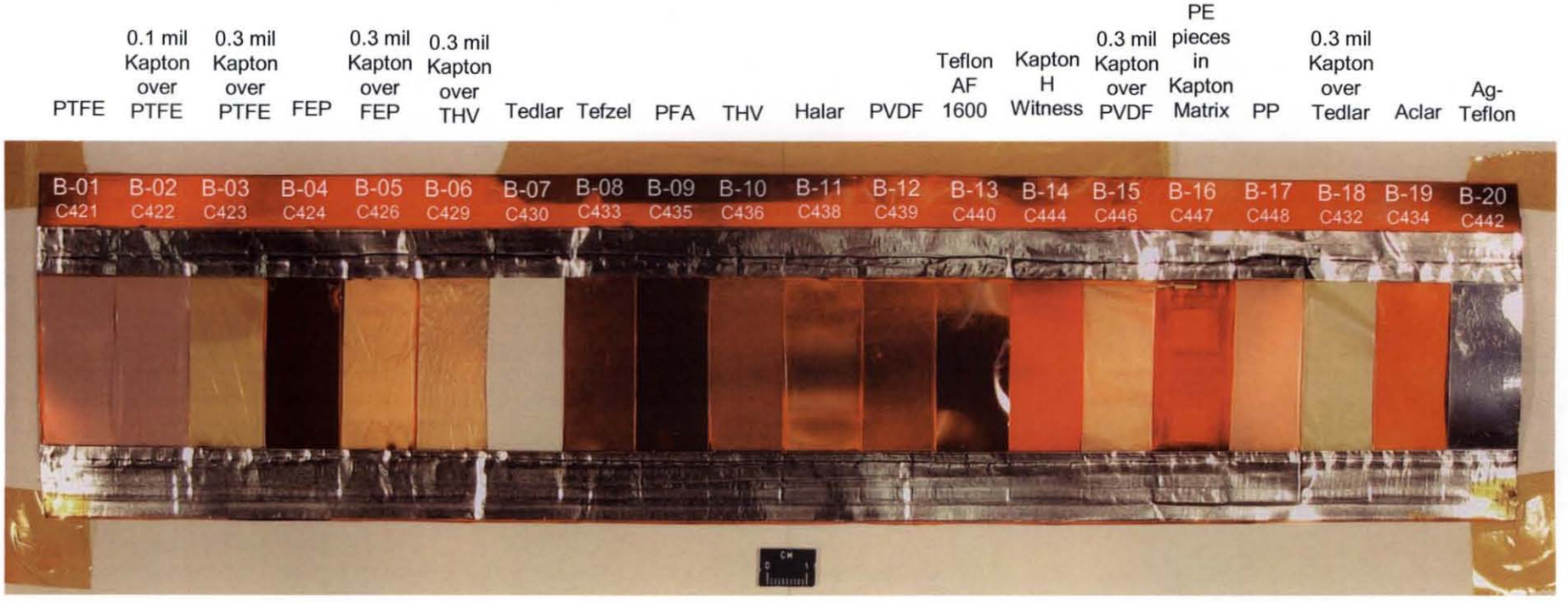
MISSE 5 Team Cooperative Samples

Post-Flight



NASA Image

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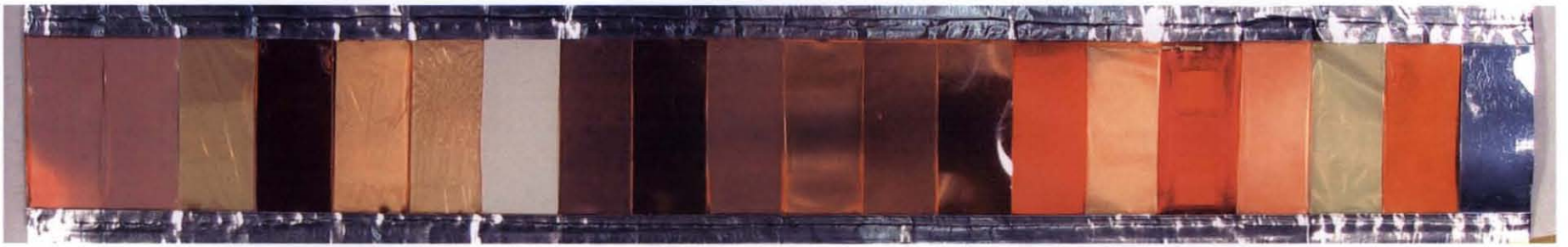
MISSE 5 Team Cooperative Samples

Pre-Flight

Post-Flight



NASA Image

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Erosion Information

Sample	Name	Chemical Formula	Step Height / microns
B-01	PTFE	$(CF_2\text{-}CF_2)_n$	not detectable
B-02	0.1 mil Kap over PTFE	$(CF_2\text{-}CF_2)_n$	not detectable
B-03	0.3 mil Kap over PTFE		
B-04	FEP	$[(CF_2\text{-}CF_2)_n\text{-}CF_2\text{-}C(CF_3)F]_m$	not detectable
B-05	0.3 mil Kap over FEP		
B-06	0.3 mil Kap over THV		
B-07	**Tedlar**	**$(CH_2CHF)_n$**	**not detectable, yellowed surface, looks smoother**
B-08	Tefzel	$[(CF_2\text{-}CF_2\text{-})\text{-}(CH_2\text{-}CH_2)]_n$	~0.8
B-09	PFA	$[(CF_2\text{-}CF_2)\text{-}(CF_2\text{-}CF(OCF_3)]_n$	difficult to measure, seems to be < 0.5
B-10	THV	$[(CF_2\text{-}CF_2)\text{-}(CF_2\text{-}CF_2\text{-}CF_2)\text{-}(CH_2\text{-}CF_2)]_n$	difficult to measure, seems to be < ~1
B-11	Halar	$[(CH_2\text{-}CH_2\text{--}(CFCl\text{-}CF_2)]_n$	~4.5, obvious yellowing
B-12	PVDF	$[(CF_2\text{-}CH_2)]_n$	~1.5, obvious yellowing and undercutting
B-13	Teflon AF 1601	see below	not detectable
B-14	**Kapton witness**		**5.4 ± 0.2 (1.8 ± 0.007 O atoms cm^{-3})**
B-15	0.3 mil Kap over PVDF		
B-16	**Polyethylene**	**$(CH_2\text{-}CH_2)_n$**	
B-17	Polypropylene	$[CH(CH_3)\text{-}CH_2]_n$	not detectable, obvious change in transparency (cloudy now)
B-18	0.3 mil Kap over Tedlar		
B-19	Aclar	$[(CF(Cl)\text{-}CF_2)]_n$	difficult to measure, may have eroded slightly though
B-20	Ag/FEP		not detectable

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High Resolution XPS

Sample	Name	Chemical Formula	C atom%	O atom%	F atom%	Si atom%	Cl atom%
B-01	PTFE Teflon	$(CF_2\text{-}CF_2)_n$	34.5	3.0	62.5		
B-02	0.1 mil Kap over PTFE	$(CF_2\text{-}CF_2)_n$	33.6	1.6	64.8		
B-03	0.3 mil Kap over PTFE						
B-04	FEP Teflon	$[(CF_2\text{-}CF_2)_n\text{-}CF_2\text{-}C(CF_3)F]_m$	36.5	4.2	59.3		
B-05	0.3 mil Kap over FEP						
B-06	0.3 mil Kap over THV						
B-07	**Tedlar**	**$(CH_2CHF)_n$**			**contaminated**		
B-08	Tefzel	$[(CF_2\text{-}CF_2\text{-})\text{-}(CH_2\text{-}CH_2)]_n$	52.9	7.7	39.4		
B-09	PFA	$[(CF_2\text{-}CF_2)\text{-}(CF_2\text{-}CF(OCF_3)]_n$	34.6	2.8	62.7		
B-10	THV	$[(CF_2\text{-}CF_2)\text{-}(CF_2\text{-}CF_2\text{-}CF_2)\text{-}(CH_2\text{-}CF_2)]_n$	43.4	9.4	44.8	2.4	
B-11	Halar	$[(CH_2\text{-}CH_2\text{--}(CFCl\text{-}CF_2)]_n$	55.9	14.9	25.6		3.6
B-12	PVDF	$[(CF_2\text{-}CH_2)]_n$	53.9	11.1	32.9	2	
B-13	Teflon AF 1601	see below	33.9	1.2	64.9		
B-14	Kapton witness		49.1	37.3	N% 5.0	8.6	
B-15	0.3 mil Kap over PVDF						
B-16	**Polyethylene**	**$(CH_2\text{-}CH_2)_n$**			**did not measure**		
B-17	Polypropylene	$[CH(CH_3)\text{-}CH_2]_n$	64.9	28.3		6.8	
B-18	0.3 mil Kap over Tedlar						
B-19	Aclar	$[(CF(Cl)\text{-}CF_2)]_n$	57.1	17	17.6	6	2.3
B-20	Ag/FEP						

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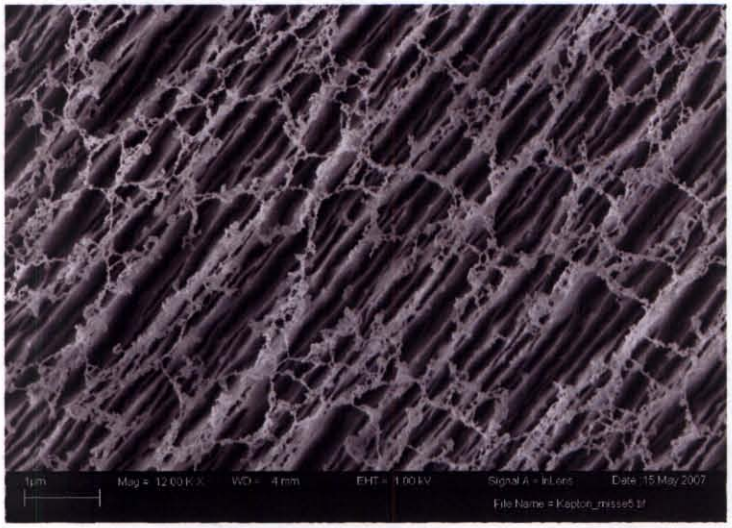
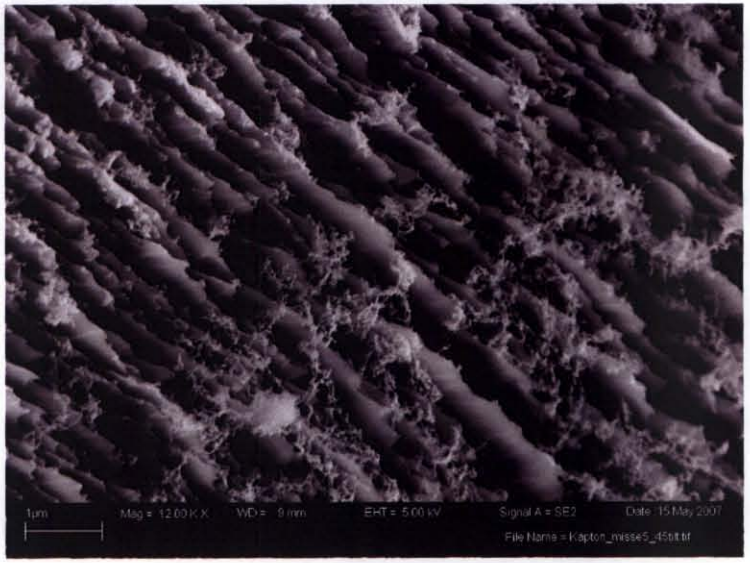
Post-Flight SEM images of Kapton



surface

45° tilt



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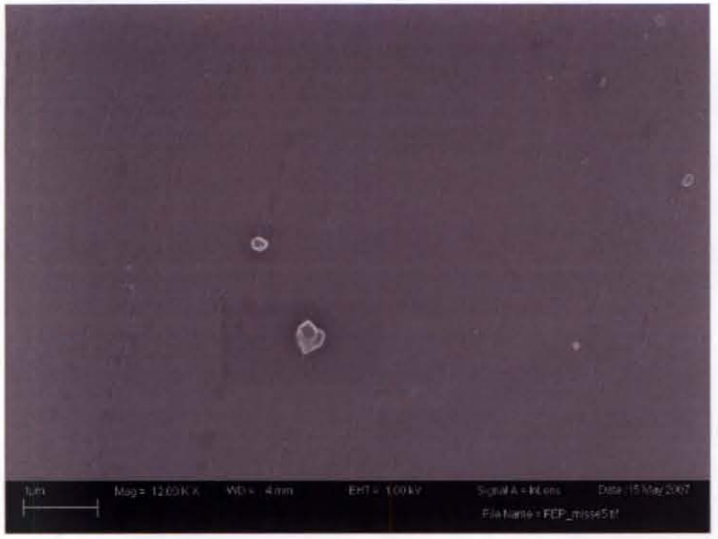
Post-Flight SEM Images of FEP Teflon



Salt crystal

45° tilt

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MISSE-5 atomic oxygen fluence determination

Recession rate measurement using Kapton, ~1.8 x 10^{20} atoms/cm^2

Model results account for variation in orientation, but not all shielding
Model predictions give "maximum likely values"

- **Nadir ~2.4 x 10^{20} atoms/cm^2**
- **Zenith ~1 x 10^{20} atoms/cm^2**

Accounting for docked Space Shuttle time periods – no direct shielding

MISSE-5 Exposure Summary

Surfaces received about the same fluence of atomic oxygen as STS materials experiments from 1980's and 1990's

Solar exposures ranged from ~525 to 2700 ESH,
including both direct and Earth-reflected
Nadir side only received ~160 ESH of direct solar

Thermal cycling was mostly between +40 C and –40 C.

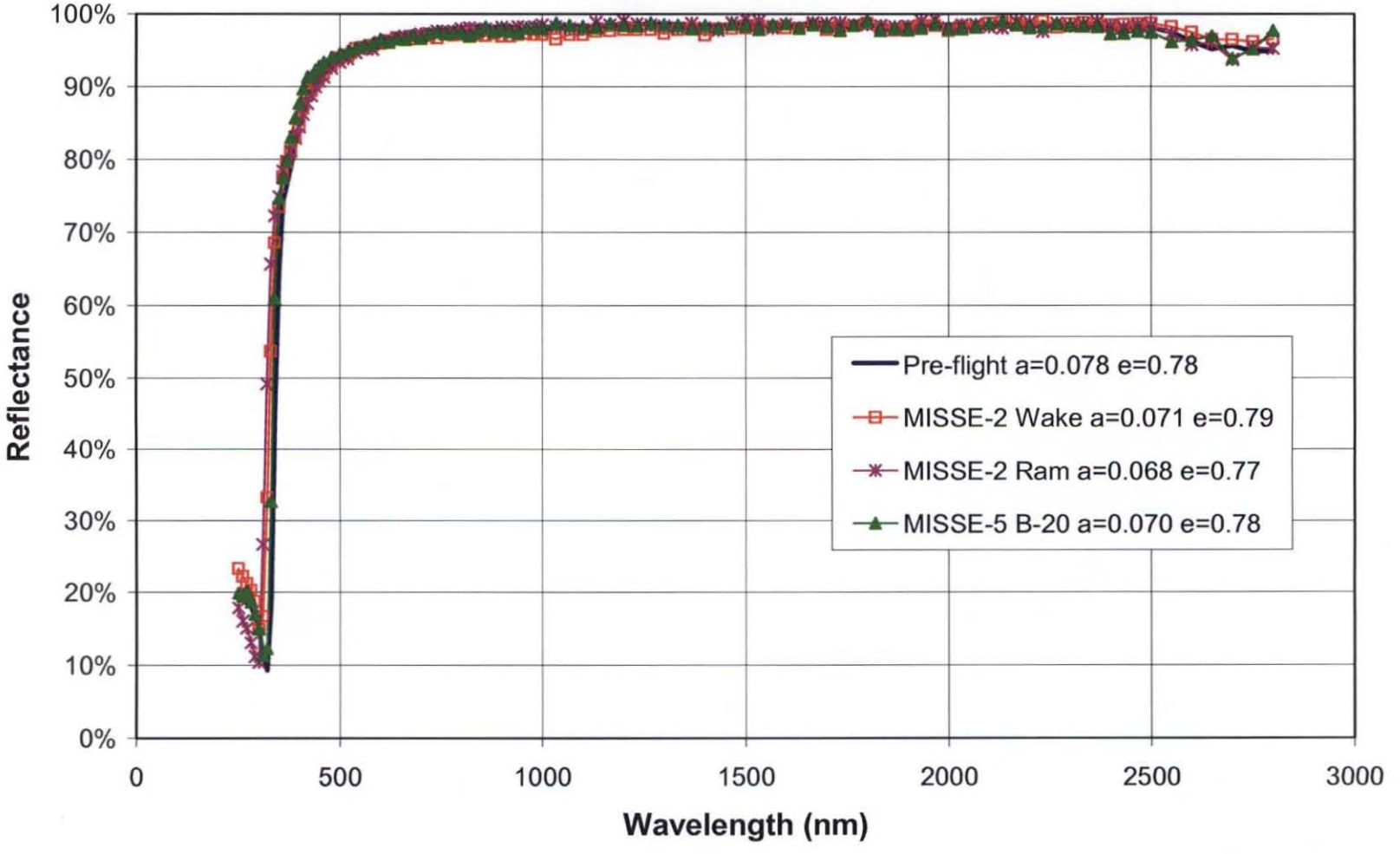
Relatively few impacts observed

Shielding by ISS structure minimal for MISSE-5 solar-exposed (Zenith) side

Molecular contamination levels appear generally low, not much analysis yet

MISSE 5 Material Specimens Optical Property Measurements

MISSE 5 mil Silver/Teflon



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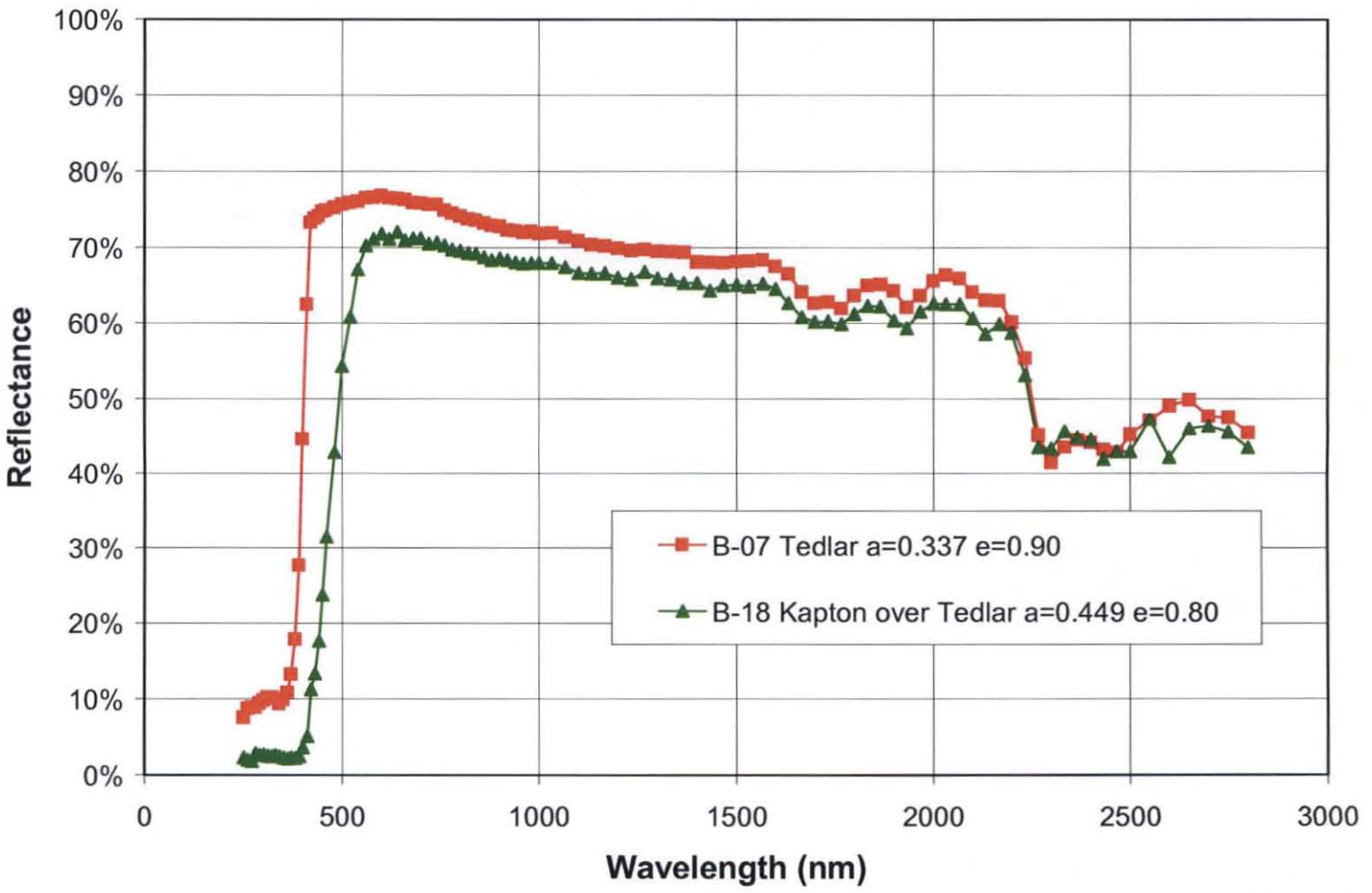
MISSE 5 Material Specimens Optical Property Measurements



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Comparison with FEP results from previous flights

STS flight results	
STS-8	**<0.05 x 10-24 cm3/atom**
EOIM-III	**<0.05 x 10-24 cm3/atom**
LDEF	**0.34 x 10-24 cm3/atom**
HST	**1 x 10-24 cm3/atom**
MISSE-1 & -2	**0.3 x 10-24 cm3/atom**

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Acknowledgements

The MISSE-5 secondary materials experiment was a cooperative effort between several organizations

NASA LaRC, NASA MSFC, NASA GRC,AFRL, Boeing, Montana State University

Specimens also supplied by Sheldahl, AZ Technology, University of Pittsburgh

Thanks to Mr. Casey Knight , Montana State University for supporting post-flight measurements

Particular thanks to the Naval Research Laboratory for allowing this experiment to be added

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Team Cooperative Sample Fabrication Notes

Kim de Groh (NASA GRC)

MISSE 5 Team Cooperative Flight Samples					
ID #	MISSE-5 #		Chemical Name	Trade Name	Flight Material
C421	**B-01**	**PTFE**	Polytetrafluoroethylene (PTFE)	Teflon PTFE	3 mil PTFE T-100 Virgin Skived Sintered Film from Furon
C422	**B-02**	0.1 mil Kapton over PTFE			3 mil T-100 PTFE
C423	**B-03**	0.3 mil Kapton over PTFE			3 mil T-100 PTFE
C424	**B-04**	**FEP**	Fluorinated ethylene propylene (FEP)	Teflon FEP	2 mil "round robin" FEP from DuPont
C426	**B-05**	0.3 mil Kapton over FEP			2 mil "round robin" FEP
C429	**B-06**	0.3 mil Kapton over THV			3.5 mil AMD 313 from 3M (Gary)
C430	**B-07**	**Tedlar**	Polyvinyl fluoride (PVF)	Tedlar	2.0 mil white Tedlar (Gary)
C432	**B-18**	0.3 mil Kapton over Tedlar			2.0 mil white Tedlar (Gary)
C433	**B-08**	**Tefzel**	Ethylene-tetrafluoroethylene (ETFE) or Tetrafluoroethylene-ethylene copolymer	Tefzel	5.0 mil Tefzel LZ from DuPont (Gary)
C434	**B-19**	**Aclar**	Polychlorotriflfuoroethylene (PCTFE)	Aclar or Neoflon (prev."Kel-F")	5.0 mil PCTFE Neoflon M-300 from Plastic Profiles Div.
C435	**B-09**	**PFA**	Perfluoroalkoxy (PFA)	Teflon PFA	5.0 mil PFA 500 LP from DuPont (Gary)
C436	**B-10**	**THV**	Tetrafluoroethylene/ hexafluoro propylene/vinylidene fluoride (THV)		3.5 mil AMD 313 from 3M (Gary)
C438	**B-11**	**Halar**	Ethylene-chlorotrifluoroethylene (ECTFE)	Halar	3.0 mil Halar 300 from Westlake Plastics
C439	**B-12**	**PVDF**	Polyvinylidene fluoride (PVDF)	Kynar	3.0 mil Kynar 740 from Westlake Plastics
C440	**B-13**	**Teflon AF 1601**	Amorphous fluoropolymer (AF)	Teflon AF	2.0 mil Teflon AF 1601 from DuPont
C442	**B-20**	**Ag/FEP Teflon**	Ag/Fluorinated ethylene propylene (FEP)	(Ag-Teflon)	5.0 mil FEP/Ag/Inconel from Sheldahl
C444	**B-14**	**Kapton** environment witness sample	Polyimide (PMDA)	Kapton	5.0 mil Kapton H
C446	**B-15**	0.3 mil Kapton over PVDF			3.0 mil Kynar 740
C447**	**B-16**	**Polyethylene**	Polyethylene (PE)	Alathon	2.0 mil "Round robin" low oxygen PE
C448	**B-17**	**Polypropylene**	Polypropylene (PP)	Profax	20 mil Type C 28 PP from Goex
1). All sampes have 1/4" wide salt-sprayed area (next to 1/4" adhesion area at the sample end with the corner cut mark), except C442 Ag-FEP, which has no salt					
2). The 0.1 mil Kapton is actually 0.3 mil Kapton with four 0.1 mil thick Kapton windows (1/4" x1/4" in size) with Kapton covers					
3). Kapton covers are adhered with 1/4" wide strips of Y966 adhesive at each end					
4). All samples with Kapton covers only have Kapton covers on the flight samples (F), the back-up samples (B) do not have Kapton covers					
** C447 originally shipped to LaRC as full size PE samples, Flight sample is a "button/sandwich" sample w/ 2 pieces of PE btw 2 pieces of 5 mil Kapton H (1 PE piece is salt-sprayed)					

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