Title: **Analysis of International Space Station Vehicle Materials on MISSE 6**

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The International Space Station Materials and Processes team has multiple material samples on MISSE 6, 7 and 8 to observe Low Earth Orbit (LEO) environmental effects on Space Station materials. Optical properties, thickness/mass loss, surface elemental analysis, visual and microscopic analysis for surface change are some of the techniques employed in this investigation.

Results for the following MISSE 6 samples materials will be presented:
deionized water sealed anodized aluminum; Hyzod™ polycarbonate used to temporarily protect ISS windows; Russian quartz window material; Beta Cloth with Teflon™ reformulated without perfluorooctanoic acid (PFOA), and electroless nickel.

Discussion for current and future MISSE materials experiments will be presented.
MISSE 7 samples are: more deionized water sealed anodized aluminum, including Photofoil™; indium tin oxide (ITO) over-coated Kapton™ used as thermo-optical surfaces; mechanically scribed tin-plated beryllium-copper samples for "tin pest" growth (α/β transformation); and beta cloth backed with a black coating rather than aluminization.
MISSE 8 samples are: exposed "scrim cloth" (fiberglass weave) from the ISS solar array wing material, protective fiberglass tapes and sleeve materials, and optical witness samples to monitor contamination.

Analysis of International Space Station Vehicle Materials on MISSE 6

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Analysis of International Space Station Vehicle Materials on MISSE 6

- **Background**
- **Results**
  - **Anodized aluminum, dependent on seal used.**
  - **Alodine**
  - **Electroless nickel**
  - **Multi-layer insulation materials**
  - **Window materials**
- **Summary**

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- **Anodized Aluminum**
  - **Most of ISS anodized aluminum is chromic acid anodize, MIL-A-8625 Type I tailored for specific range of solar absorptance and infrared emittance.**
  - **EPA restricted use of chromium, which eliminated both chromic acid anodize and the sodium chromate used to seal sulfuric acid anodize.**
  - **Sulfuric acid anodize, MIL-A-8625, Type II, is now usually processed with nickel acetate, unless boiling deionized water seal is specifically called out.**
    - **POSA-I data indicated darkening of sulfuric acid anodize with either nickel acetate or nickel fluoride seal.**
    - **Earlier MISSE SAA samples processed with nickel acetate were visibly yellow after only 800 ESH of UV radiation.**
    - **Darkening of ISS Photofoil labels shown to be dependent on presence of nickel.**
    - **Cobalt acetate has not been tested.**

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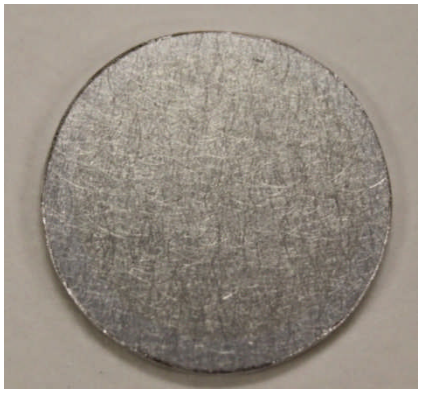
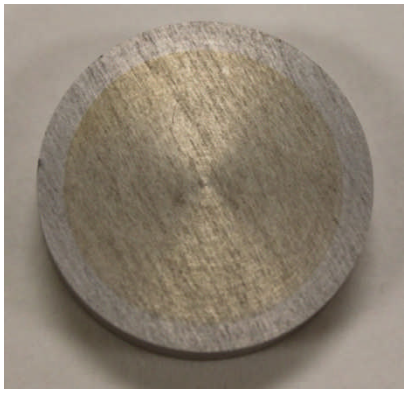
- **Anodized Aluminum**
  - **Four batches of sulfuric acid anodize processed at MSFC.**
    - **Fan blades, sample trays, small frames, samples**
  - **Hot deionized water seal specifically called out.**
  - **Three batches of 6061-T6 did not darken.**
  - **Fourth batch did darken. Post-flight analysis did not detect nickel, so no inadvertent use of nickel acetate. This batch was processed with samples and small frames made of AL 2195, an aluminum-lithium alloy**
  - **Other problems observed in anodizing aluminum-lithium alloys**
    - **Previous attempts to black dye anodize AL 2195 have failed**
    - **Black dye particles can be wiped off after processing**





Analysis of International Space Station Vehicle Materials on MISSE 6

- **MISSE- 6 Anodized Aluminum Results**

MISSE-6		Preflight	Postflight	Δ	Environment
CAA on 6061-T6	α	0.32	0.34	+0.02	1,950 ESH
	ε	0.49	0.46	-0.03	1.2E20 O atoms/cm^2
SAA on 6061-T6 #1 Hot deionized water seal	α	0.44	0.43	-0.01	2,600 ESH
	ε	0.85	0.85	-	2.0E21 O atoms/cm^2
SAA on 6061-T6 #2 Hot deionized water seal	α	0.43	0.43	-	1,950 ESH
	ε	0.85	0.85	-	1.2E20 O atoms/cm^2
SAA on 2219-T851 Processed with AL2195	α	0.39	0.45	+0.06	1,950 ESH
	ε	0.77	0.76	-0.01	1.2E20 O atoms/cm^2
SAA on 7075 Processed with AL2195	α	0.35	0.42	+0.07	1,950 ESH
	ε	0.72	0.76	+0.04	1.2E20 O atoms/cm^2
SAA on 2195	α	0.29	0.37	+0.08	1,950 ESH
	ε	0.78	0.77	-0.01	1.2E20 O atoms/cm^2

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- **Chromate conversion coatings**
  - **12-4 Iridite conversion coating on aluminum-lithium**
  - **Metalast TCP-HF is a trivalent chromium alternative to the more toxic hexavalent chromium conversion coating**

MISSE-6		Preflight	Postflight	Δ	Environment
12-4 Iridite on 2195	α	0.31	0.31	-	1,950 ESH
	ε	0.05	0.04	-0.01	1.2 E+20 O atoms/cm^2
Metalast on 6061 5 minutes	α	0.52	0.53	+0.01	1,950 ESH
	ε	0.04	0.04	-	1.2 E+20 O atoms/cm^2
Metalast on 6061 10 minutes	α	0.54	0.55	+0.01	1,950 ESH
	ε	0.04	0.04	-	1.2 E+20 O atoms/cm^2

Analysis of International Space Station Vehicle Materials on MISSE 6

- **Results**
  - **Electroless nickel**
    - **Used on fluid and electrical connectors**
    - **Usually covered by MLI for thermal control**
    - **Ground testing at MSFC included both near and vacuum UV radiation exposures.**

Electroless Nickel		Pre-exp	Post-exp	Δ	Environment
MISSE-6 Ram	α	0.42	0.41	-0.01	2,600 ESH
	ε	0.09	0.09	-	2.0 E+21 O atoms/cm^2
MISSE-6 Wake	α	0.39	0.39	-	1,950 ESH
	ε	0.09	0.09	-	1.2 E+20 O atoms/cm^2
Ground test	α	0.40	0.40	-	>4,000 ESH
	ε	0.08	0.08	-	No AO

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Beta Cloth

- Aluminized beta cloth from same batch as ISS insulation blankets
- Unaluminized beta cloth with Teflon processed without perfluorooctanoic acid (PFOA)
  - Ground testing at MSFC included near UV radiation
- Unaluminized beta cloth with grounding thread from same batch as Gamma-Ray Burst Monitor on Fermi Gamma-Ray Space Telescope
  - Formerly known as Gamma-ray Large Area Space Telescope (GLAST)
  - 550 km, 28.5^{o} orbit
- Dutch glass cloth used on European hardware on ISS

Analysis of International Space Station Vehicle Materials on MISSE 6

MISSE-6 Results for Beta Cloth

		Pre-exp	Post-exp	Δ	Environment
ISS batch ram facing	α	0.36	0.41	+0.05	2,600 ESH
	ε	0.87	0.88	+0.01	2.0 E21 O atoms/cm^2
ISS batch wake facing	α	0.36	0.42	+0.06	1,950 ESH
	ε	0.87	0.89	+0.02	1.2 E20 O atoms/cm^2
PFOA-free ram facing	α	0.35	0.37	+0.02	2,600 ESH
	ε	0.89	0.89	-	2.0 E21 O atoms/cm^2
PFOA-free wake facing	α	0.36	0.39	+0.03	1,950 ESH
	ε	0.89	0.89	-	1.2 E20 O atoms/cm^2
PFOA-free Ground exposure	α	0.35	0.37	+0.02	532 ESH
	ε	0.89	0.89	-	No AO

ISS beta cloth results approx. the same as previous MISSEs with shorter and longer exposures

All measurements made with black background

Analysis of International Space Station Vehicle Materials on MISSE 6

MISSE-6 Results for Beta Cloth

		Preflight	Postflight	Δ	Environment
GBM batch	α	0.27	0.31	+0.04	2,600 ESH
	ε	0.89	0.89	-	2.0 E21 O atoms/cm^2
GBM batch	α	0.27	0.28	+0.01	1,950 ESH
	ε	0.89	0.89	-	1.2 E20 O atoms/cm^2
Dutch glass cloth	α	0.23	0.26	+0.03	2,600 ESH
	ε	0.87	0.88	+0.01	2.0 E21 O atoms/cm^2
Dutch glass cloth	α	0.23	0.27	+0.04	1,950 ESH
	ε	0.87	0.88	+0.01	1.2 E20 O atoms/cm^2

GBM beta cloth backed with aluminized Kapton

Dutch glass cloth adhesively backed with aluminized Kapton

MISSE-6 Results for Metallized Teflon

		Preflight	Postflight	Δ	Environment
2 mil Al / Teflon Ram facing	α	0.12	0.12	-	2,600 ESH
	ε	0.65	0.65	-	2.0 E21 O atoms/cm^2
2 mil Al / Teflon Wake facing	α	0.12	0.12	-	1,950 ESH
	ε	0.65	0.65	-	1.2 E20 O atoms/cm^2
10 mil Ag / Teflon with 966 adhesive	α	0.07	0.09	+0.02	2,600 ESH
	ε	0.85	0.85	-	2.0 E21 O atoms/cm^2

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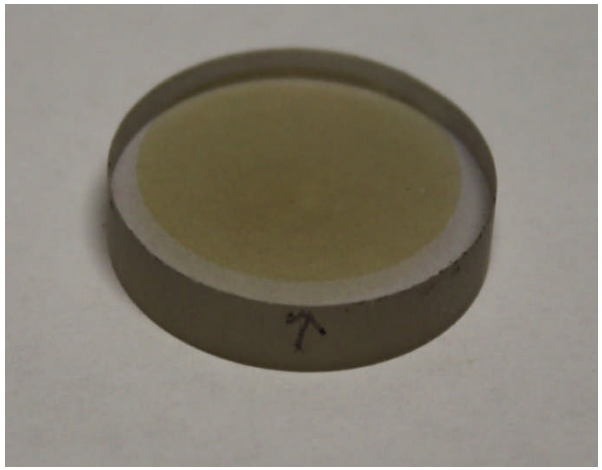
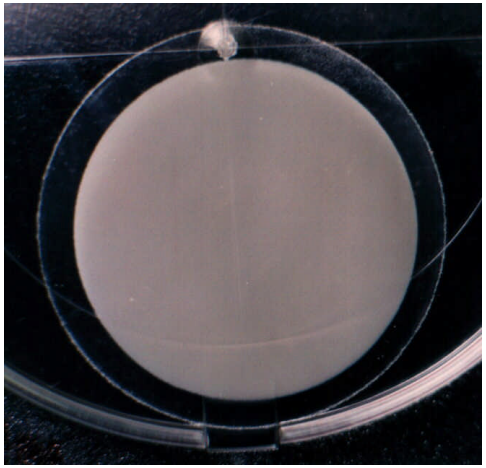
Hyzod polycarbonate

- Used as scratch panes or debris panes protecting ISS windows
- Protective coating applied for atomic oxygen resistance
- Mass loss was 1.34 mg for ram sample, 0.86 mg for wake



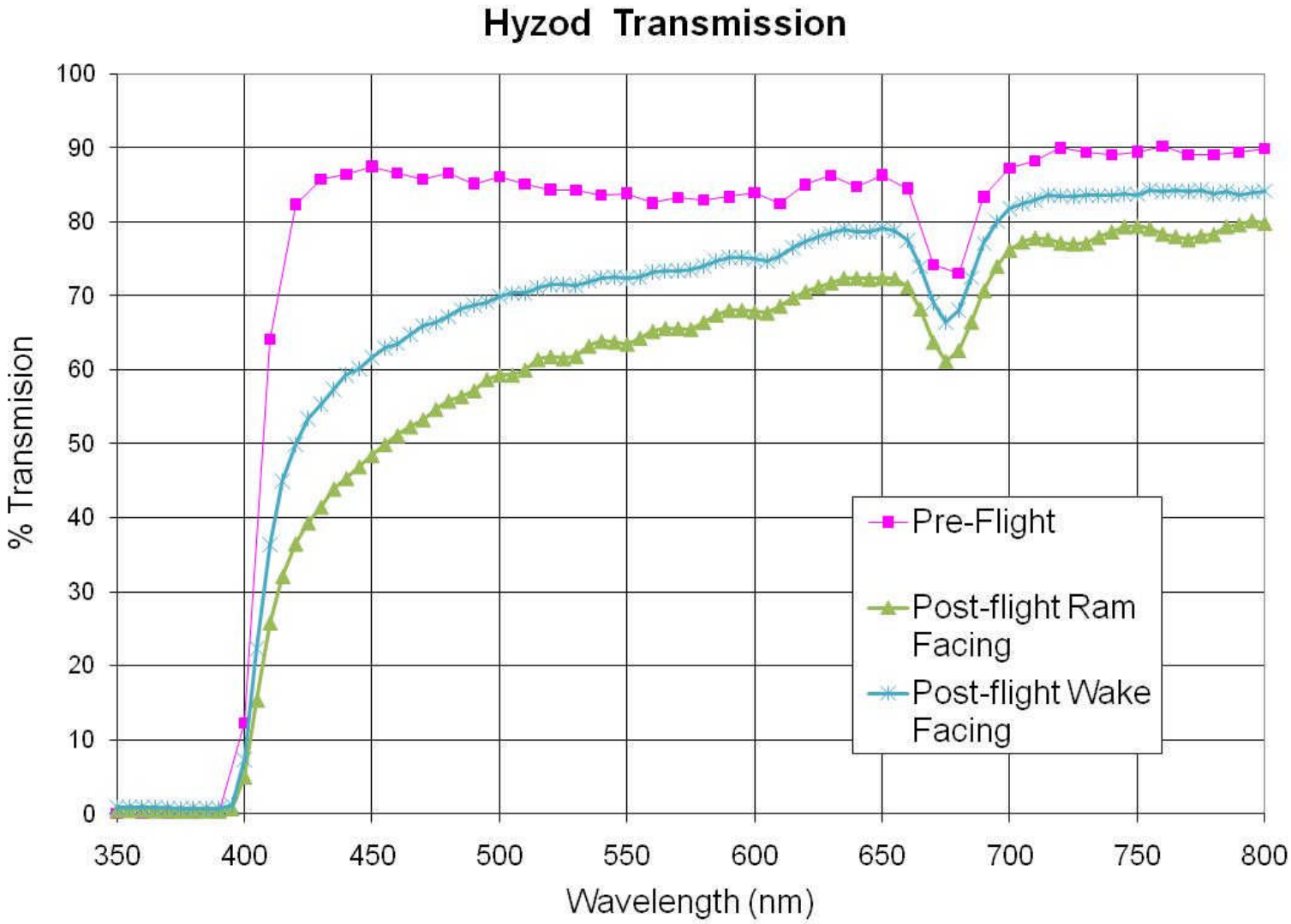
With protective coating.

Some UV darkening.



Polycarbonate from previous flight experiment, no coating, heavily eroded by atomic oxygen

Analysis of International Space Station Vehicle Materials on MISSE 6



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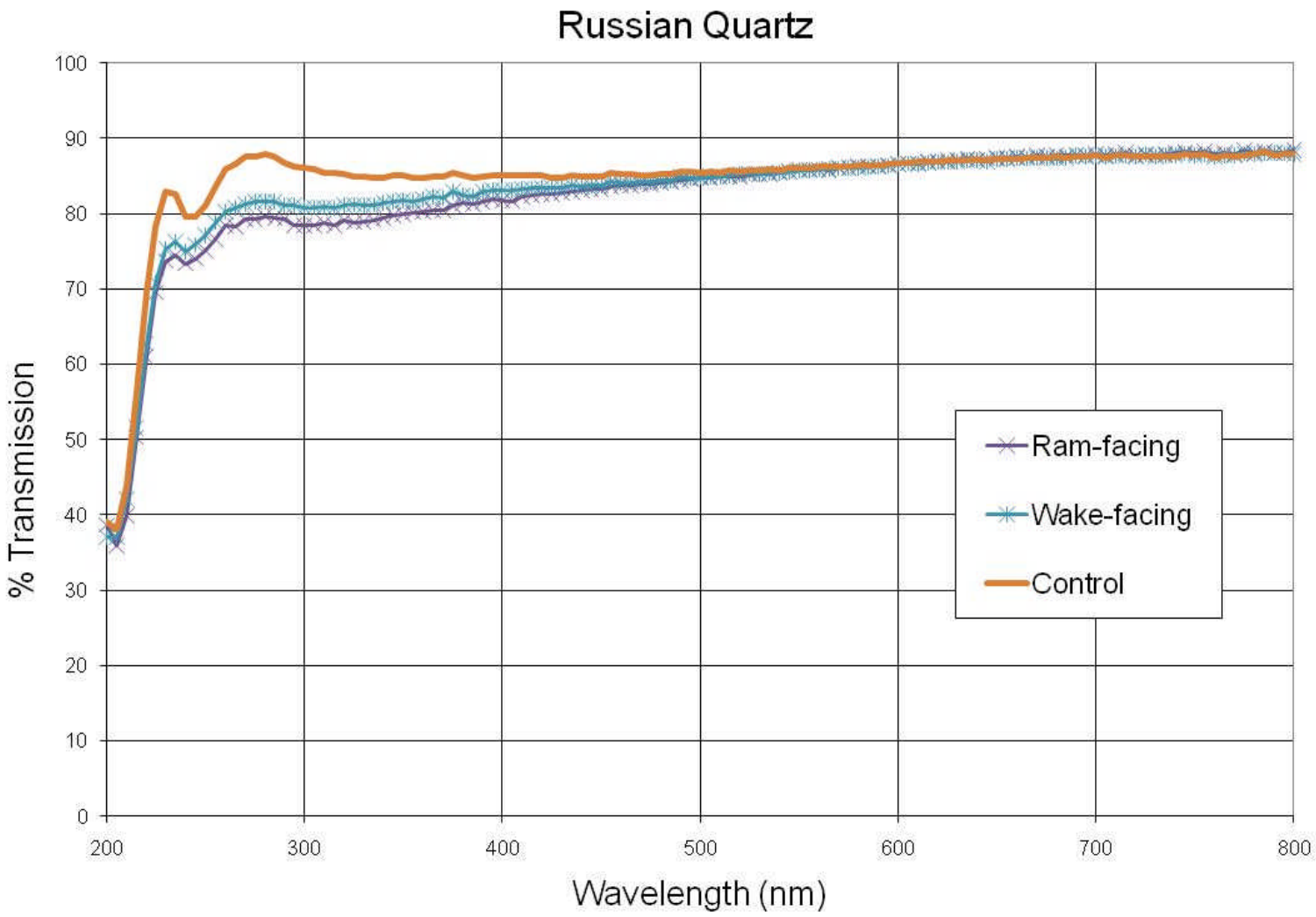
Russian quartz window

- **Used on Zvezda Service Module**
- **Earth observation**
- **Slight decrease in transmission in UV wavelengths**
- **No visible change in appearance**

Analysis of International Space Station Vehicle Materials on MISSE 6



Analysis of International Space Station Vehicle Materials on MISSE 6

- **Summary**
  - **Provided data for sustaining engineering of ISS**
    - **Should not use nickel acetate in anodize seal**
    - **Hot water seal of anodize showed durability in 17-month exposure**
    - **Concern over processing of aluminum-lithium alloy**
      - **Alodine appeared durable, anodize darkened in UV**
    - **Other materials also showed durability**
      - **Electroless nickel**
      - **Russian quartz window material**
    - **PFOA-free beta cloth, static-dissipative beta cloth, and Dutch glass cloth demonstrated same or better durability as ISS-batch beta cloth**
  - **Contamination control plan working**
    - **Most darkening due to UV degradation, not contaminant deposition**

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- **MISSE 7 on ISS now**
  - Deionized-water sealed anodized aluminum foil samples
  - Evaluation of tin pest / tin whisker growth
  - Indium tin oxide on Kapton with different resistances
  - Germanium on black Kapton
  - Stamet on black Kapton – developed to have the same properties as germanium except better corrosion resistance
  - Environmentally-friendly chemical conversion coatings
  - PFOA-free beta cloth
  - Beta cloth manufactured with black backing rather than aluminization
  - Optical witness samples

Analysis of International Space Station Vehicle Materials on MISSE 6

- **MISSE-8 scheduled to fly on STS-134**
  - **Continue contamination monitoring with optical witness samples and AZ93 white coating**
  - **Indium tin oxide on Kapton**
  - **ITO / SiOx / Kapton**
  - **Permacel and Intertape protective fiberglass tapes on Kapton**
  - **Fiberglass sleeve material**
  - **Solar array scrim cloth**
  - **Sheldahl G4280 glass cloth**
  - **Re-flight of sulfuric acid anodize on 2219 and 7075 with hot water seal**
  - **Environmentally-friendly chemical conversion coatings**