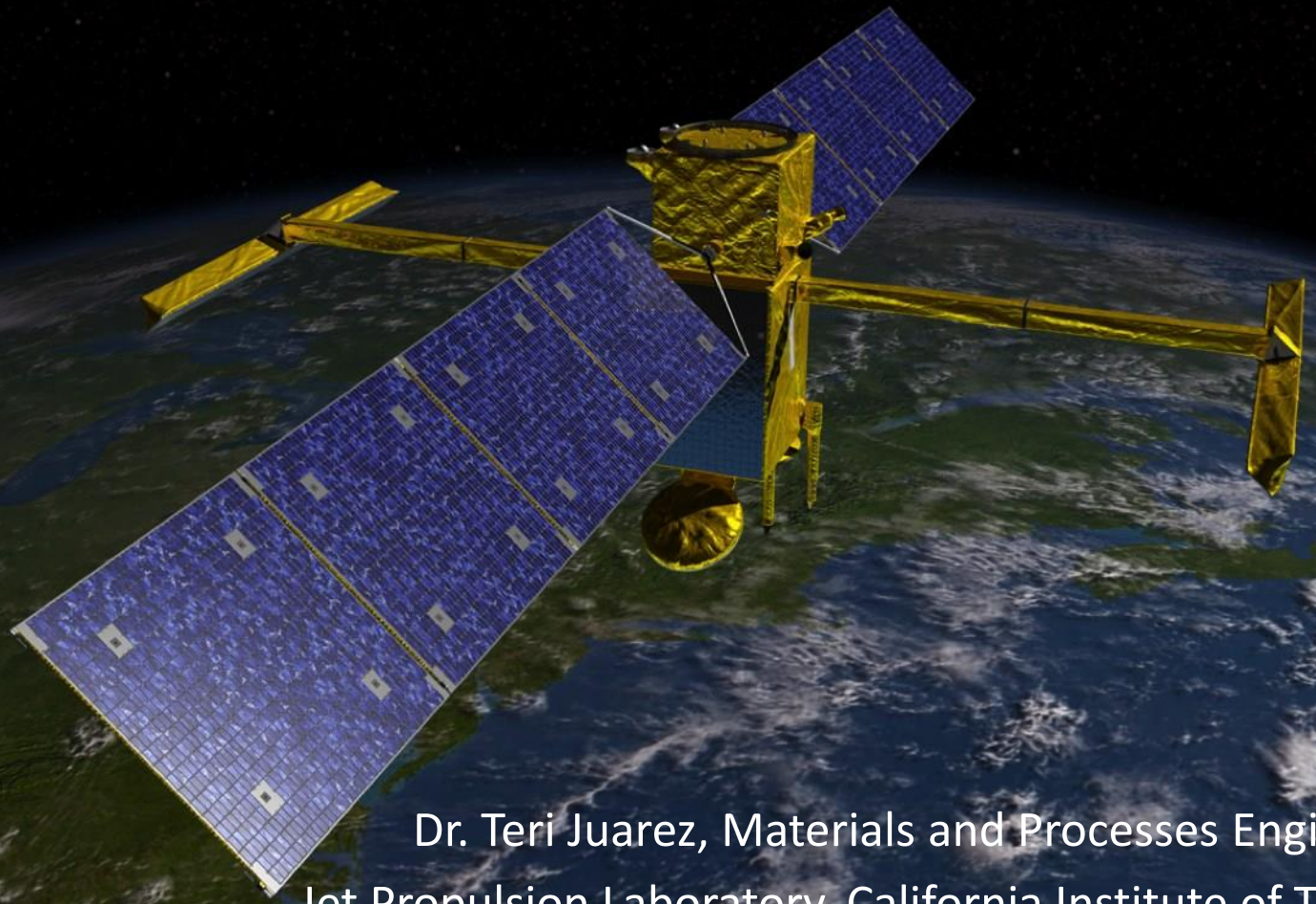
Thermal control coating patterns for thermo-optical property optimization



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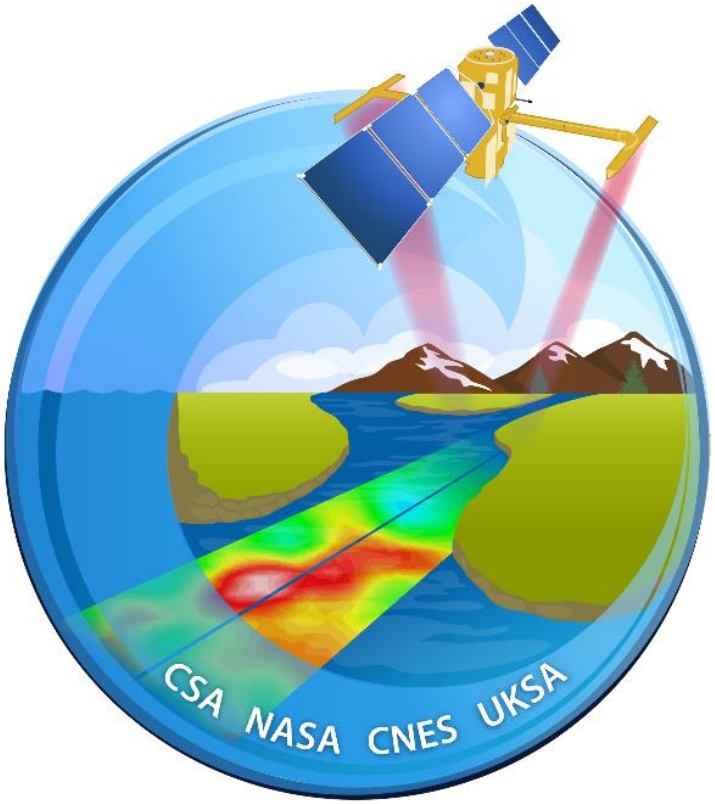
Contributors

Surface Water and Ocean Topography (SWOT) Mission



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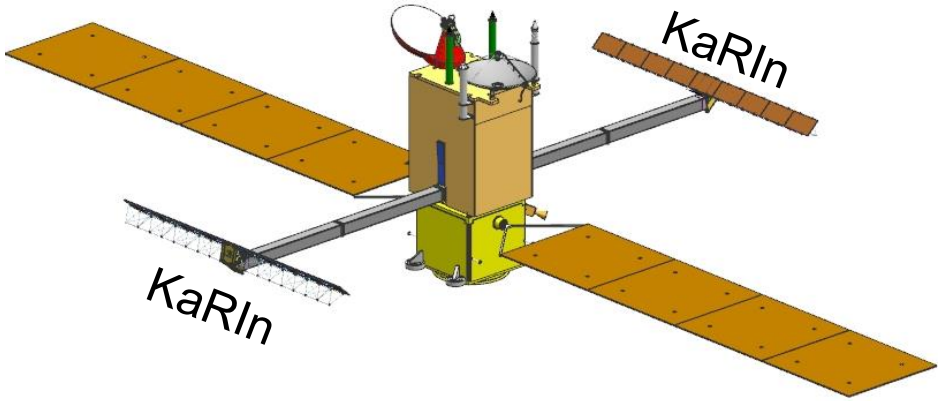
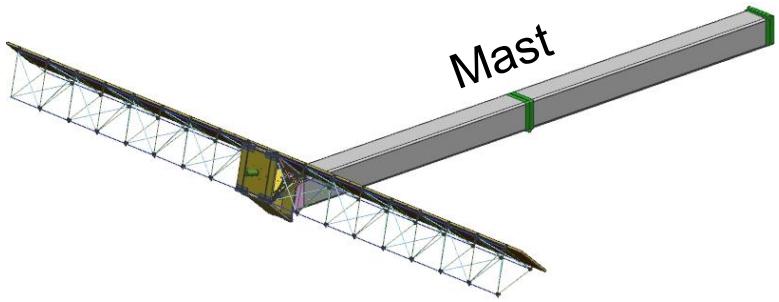
Outline

- Overview
- Objectives
- Success Criteria
- Test Coupons and Basic Coating Results
  - Adhesion and Thermal shock
- Pattern Results
  - Recommended Procedures
- Conclusion

Overview

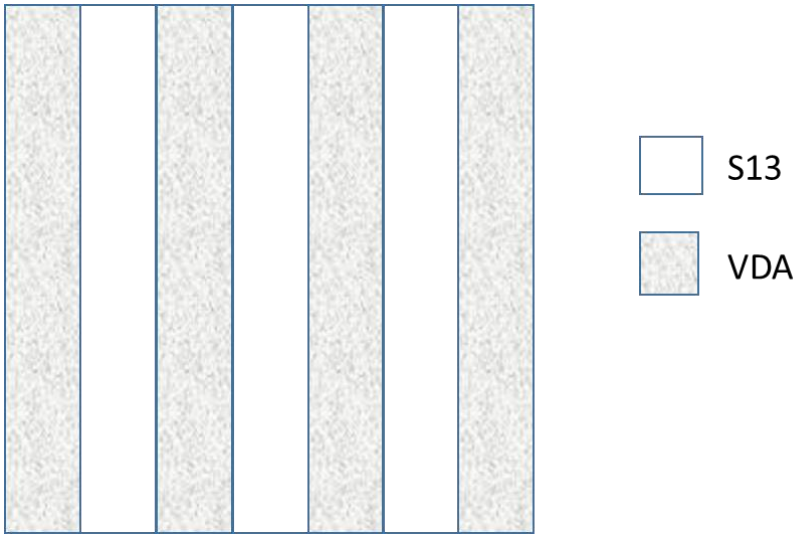
- SWOT (Surface Water and Ocean Topography) satellite mission will complete the first global survey of Earth's surface water
- SWOT measures water levels with a deployable instrument (KaRIn) that is mounted onto a mast assembly
- Thermal analysis of the structure showed that exterior carbon composite panels on the mast require both low emissivity (ε) and low absorptance (α) to meet thermal requirements
- Thermal control coatings are typically used to address passive thermal control needs, but a single coating with the required thermo-optical properties does not exist





Overview Cont.

- SWOT thermal team proposed an alternating striped pattern, using S13GP:6N/LO-1 (S13) and Vapor Deposited Aluminum (VDA), to achieve thermal requirements
- JPL M&P developed a comprehensive qualification study to address processing challenges arising from the surface preparation and application of two distinct coatings
- Developed an adaptable procedure that can be applied to other similar applications for optimizing thermo-optical properties



Objectives

Basic Requirements

- Develop process for satisfactory adhesion of both coatings on MH55J cyanate ester composites
  - Also investigated adhesion of S13 on VDA
- Achieve acceptable thermo-optical properties for each coating

Pattern Requirements

- Identify order of coating process
  - ♦ VDA must be applied first, S13 is silicone based and undesirable in VDA vacuum systems
- Masking strategy, including tape selection to minimize contamination/residue → stripe intersections and overlapping
- Stripe thickness and spacing – Information provided by thermal

Success Criteria

Basic Requirements

- Coatings must pass adhesion testing with a minimum of 3A rating using ASTM D3359 Method A
- Demonstrate acceptable thermo-optical properties
- Survive five thermal shock cycles (150 ℃ to LN_2) followed by adhesion testing to same standards above

Pattern Requirements

- Coatings in pattern configuration must pass adhesion testing with a minimum of 3A rating using ASTM D3359 Method A, including across the interface
- Survive ten thermal cycles to expected mission thermal extremes, followed by adhesion testing to same standards above

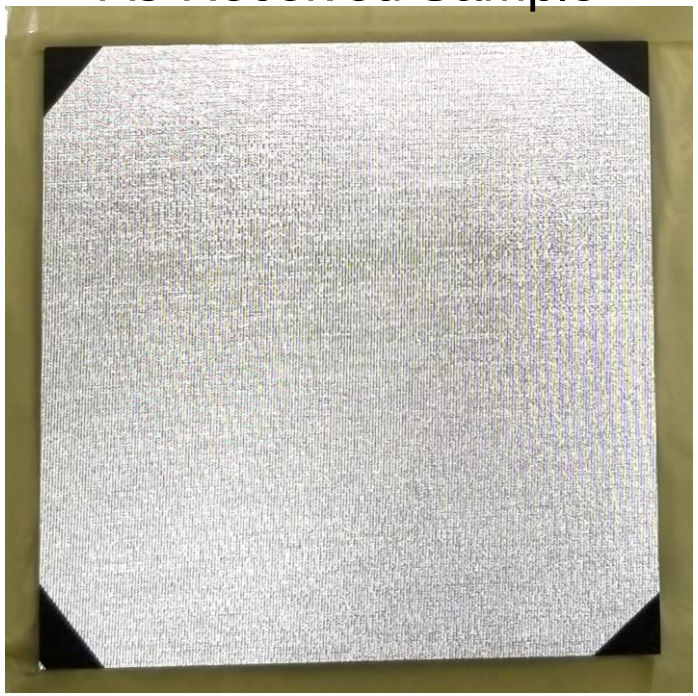
Thermal Requirements – slightly flexible since pattern can be adjusted to compensate for deviance from expected values

	VDA	S13
α	0.12	0.31 (EOL)
ε	0.03	0.88

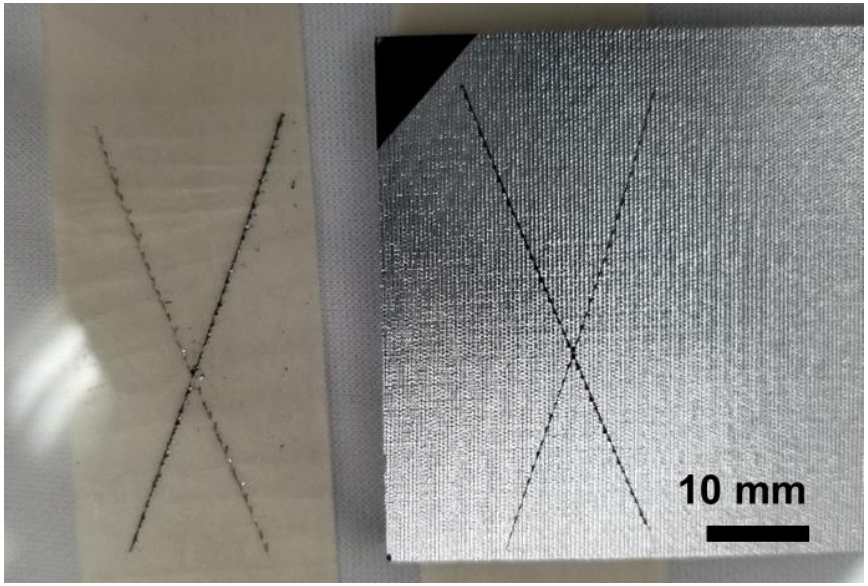
Results of VDA Assessment (1/2)

- Coupons were processed by Surface Optics Inc. (San Diego)
- Layer of vapor deposited aluminum (VDA) applied to two sides of coupon per proprietary process
- Samples successfully **passed adhesion testing** in the as-coated condition and after thermal shock

As-Received Sample



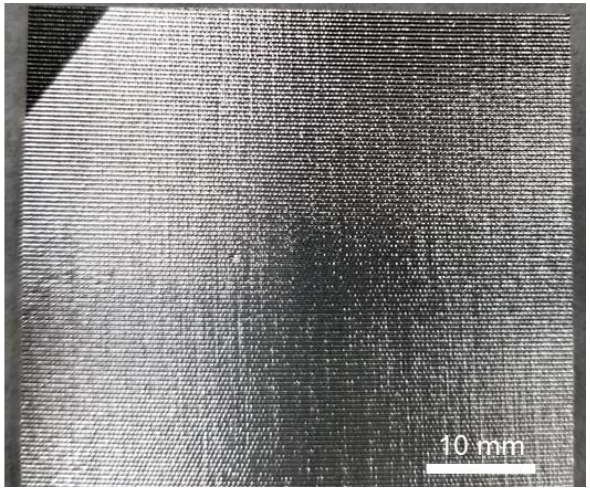
Adhesion Test



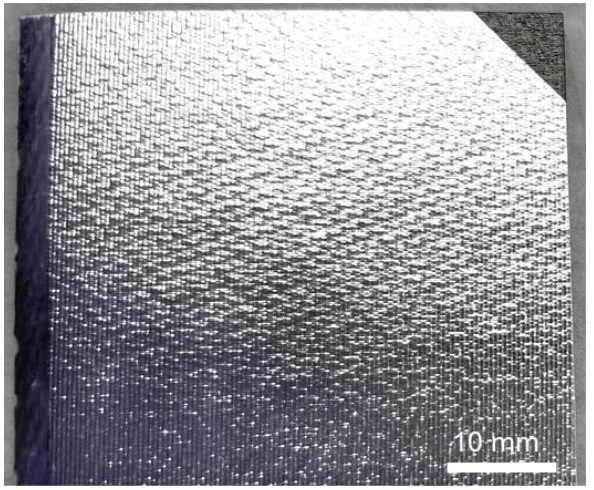
Results of VDA Assessment (2/2)

- Textural difference was observed between the two sides of the flight-like coupons. Sides are designated as bag and tooling side.
- Absorptance measurements differences were observed depending on the orientation of the sample during measurement
  - Measurements were made at different orientations by rotating the coupons to 45 degrees and 90 degrees
- Average emissivity was higher than target value
  - Properties were deemed acceptable by thermal team

Tooling Side



Bag Side



	Bag Side	Tool Side	Target
Average Absorptance*	0.12 ± 0.03	0.14 ± 0.05	0.12
Average Emissivity*	0.03 ± 0.03	0.05 ± 0.05	0.03
Coupon F, Absorptance 0°	0.12	0.08	-
Coupon F, Absorptance 45°	0.13	0.08	-
Coupon F, Absorptance 90°	0.07	0.11	-

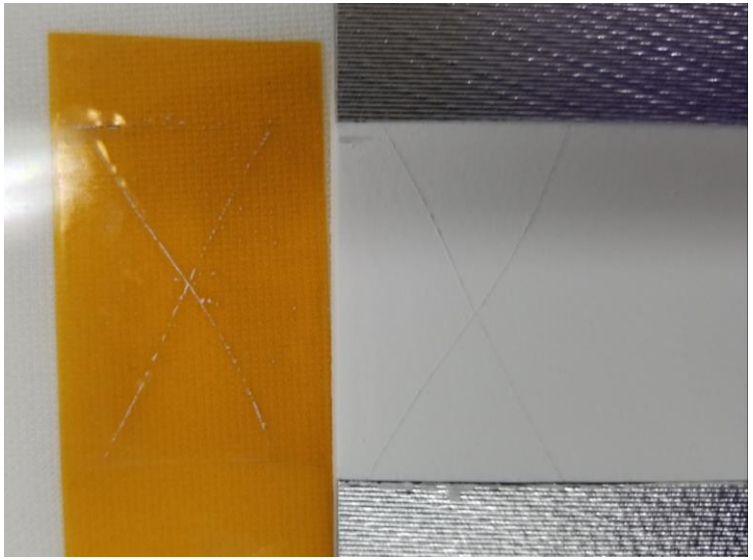
*Values determined with at least 9 measurements

Results of S13 Assessment (1/2)

- Coupons were processed at JPL per internal processes
  - Bare M55J composite surfaces were abraded and primed
  - VDA surface was solvent wiped and primed
- S13 coatings on abraded and primed composite had mixed results. Some coupons failing adhesion testing in the as-coated condition and after thermal shock → result of poor surface preparation
- S13 coatings applied to VDA successfully passed adhesion testing in the as-coated condition and after thermal shock

S13 on composite

S13 on VDA



Results of S13 Assessment (1/2)

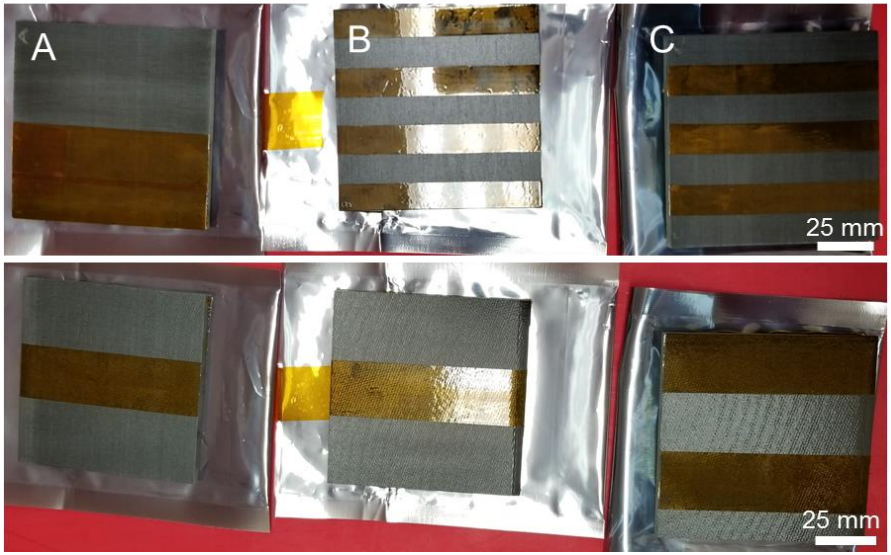
- S13 coating layer is thick enough to mitigate any textural influence of the composite substrate
- Thermo-optical property measurement differences based on orientation or surface texture were not observed
- Properties were in line with anticipated results and accepted by SWOT thermal team
  - No standard deviations listed because values were within known instrument error

	Bag Side*	Tool Side*	S13 on VDA**	Target
Average Absorptance	0.19	0.19	0.18	0.20
Average Emissivity	0.89	0.89	0.88	0.88

*Values determined with at least 9 measurements
**Values determined with 4 measurements

Pattern Sample Overview

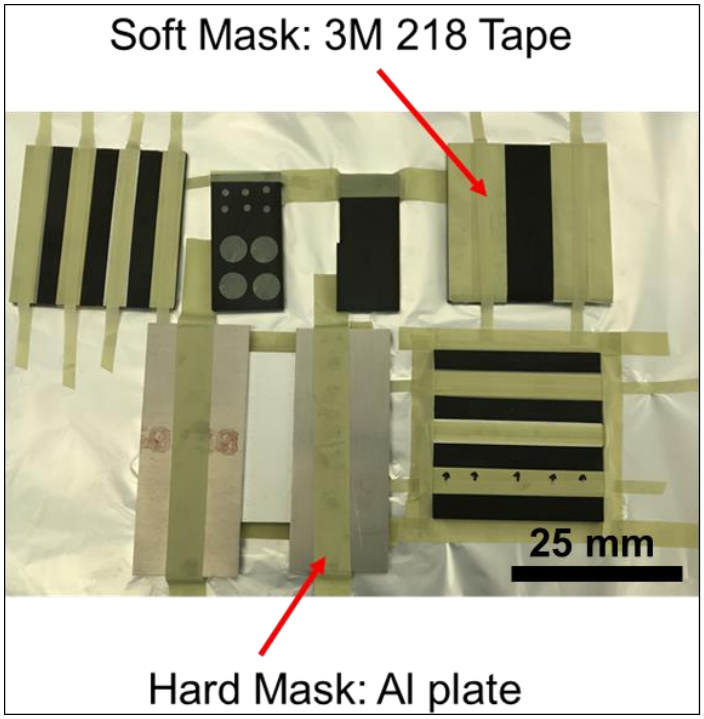
- Four square coupons with alternate Kapton tape (low outgassing) masking schemes were coated with VDA on both sides
- Areas underneath VDA masking tape were pre-abraded & cleaned prior to masking → decided not to abrade between VDA stripes
- Area under masking was thoroughly cleaned after VDA application and subsequent masking removal
- VDA surfaces were masked with 3M 218 tape or Al as a non-adhesive option for coating with S13 between VDA stripes

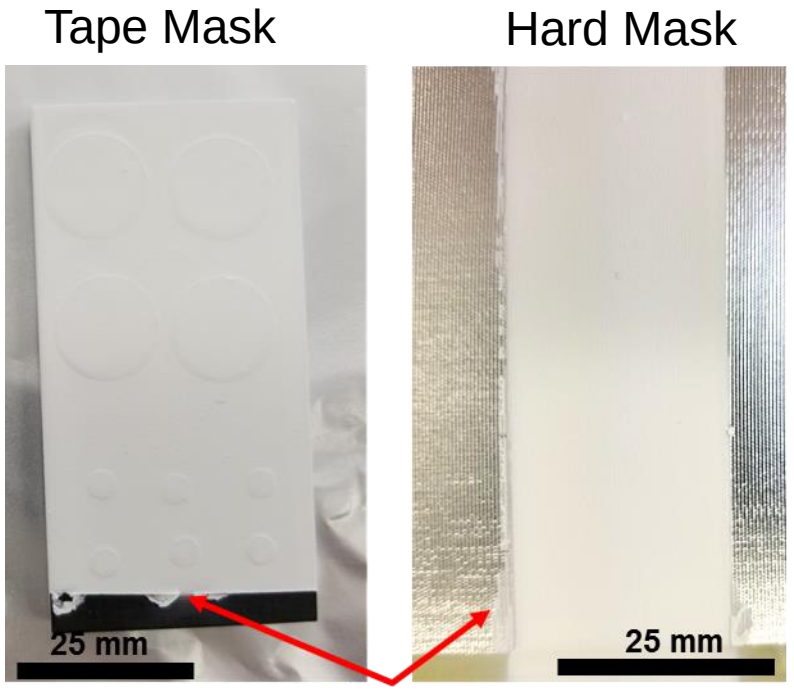


Note: Coupon D not shown. Coupon was coated with VDA on both sides, no masking

Masking results

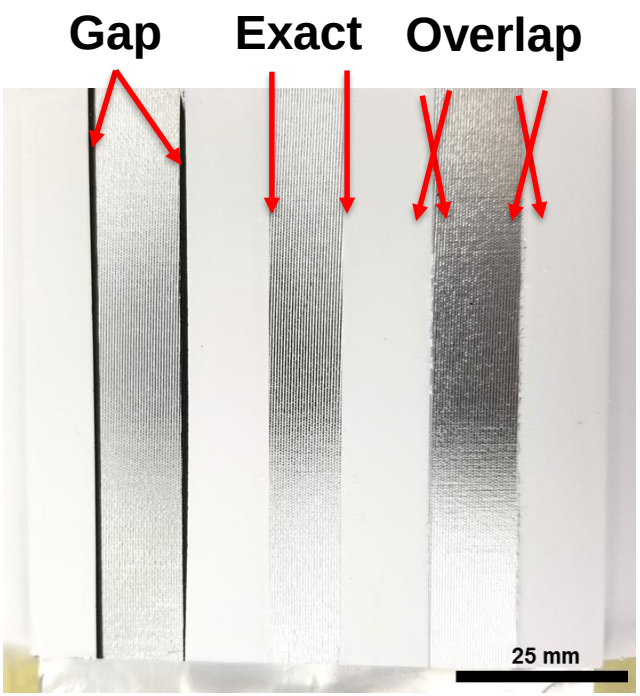
- Paint was observed seeping under both hard masks and tape masks, likely due to composite panel texture
- Tape residue and small areas of VDA removal were observed when masking was removed after painting



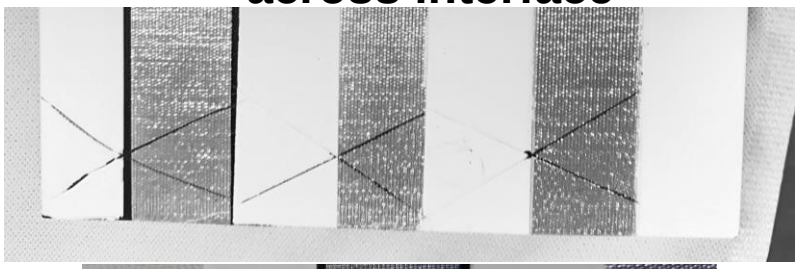


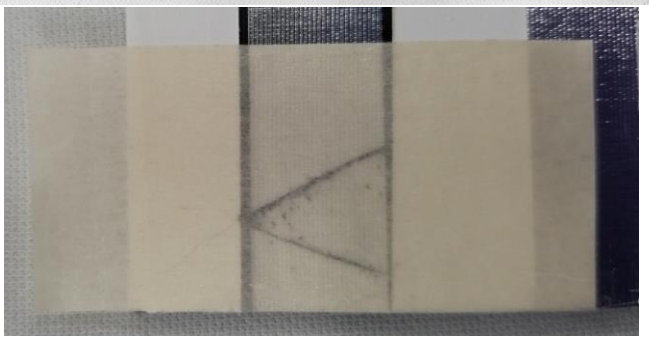
Interface results

- Coupons B1 and C1 were used to investigate coating transitions at the stripe intersections and feasibility of ½” stripes
  - Interface options include: gap between coatings, attempt at exact interface, overlap of S13 onto VDA
- Adhesion tests performed across the interfaces were all successful
- Overlapping scheme was selected → provided same coverage, no peeling at interface, and less time consuming than exact masking



Adhesion test across interface

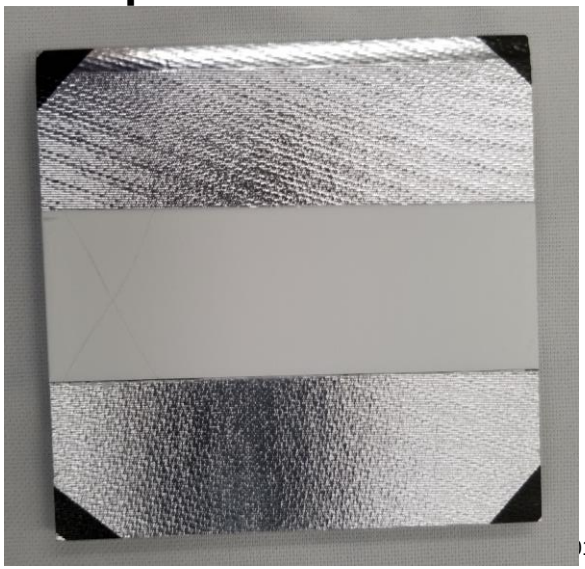




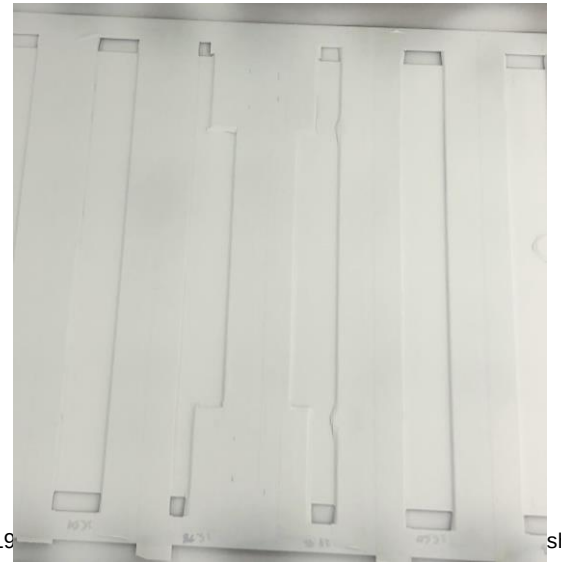
Final Recommendations & Results

- Recommend coating the entire panel surface with VDA
  - S13 adheres well to the VDA surface
  - Eliminates masking for VDA and minimizes surface preparation
- Hard mask in combination with the 3M 218 tape to minimize the adhesive in contact with the VDA
  - Custom hard masks were generated using sheet metal and water jet
  - Small strips of tape used to hold edges down
- Larger panel processed with these recommendations successfully completed adhesion testing and thermal cycling

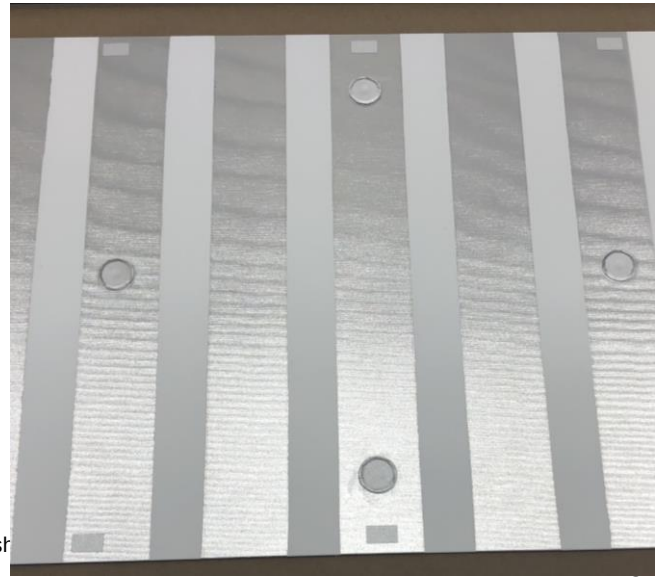
Coupon w/ S13 on VDA



Hybrid Mask After Paint

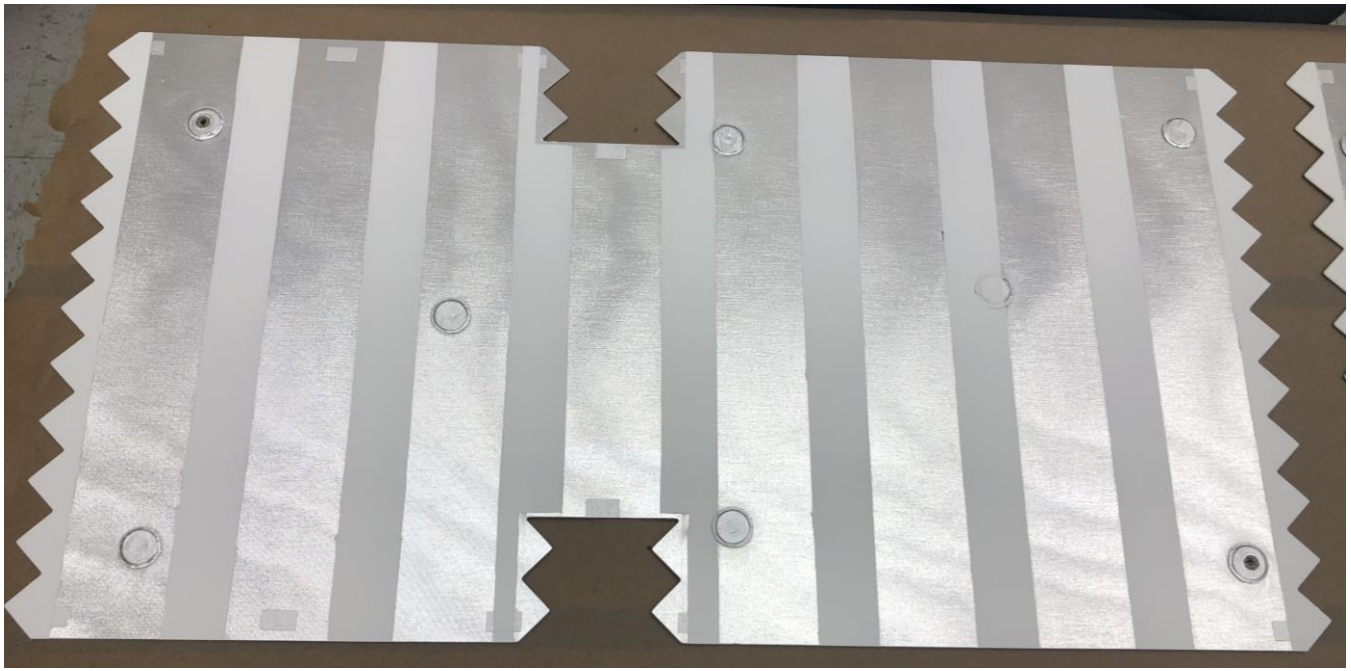


Coated Full Size Panel



Conclusions

- The results yielded a design that met thermal requirements and survived anticipated thermal environments in low cycles tests
- Identified procedure provides a customizable process for optimizing thermo-optical properties
  - Particularly surfaces requiring low emissivity (ε) and absorptance (α)

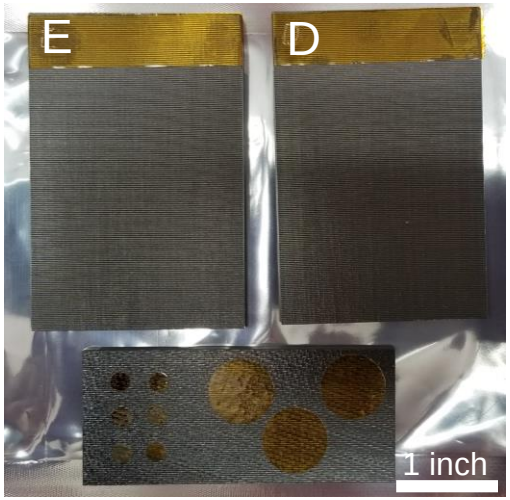


Questions?

Backup slides

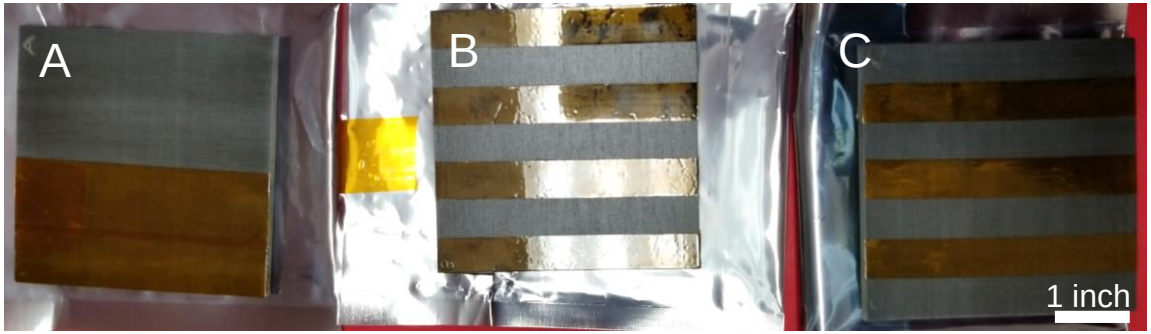
Test Coupons

Witness coupons for VDA only



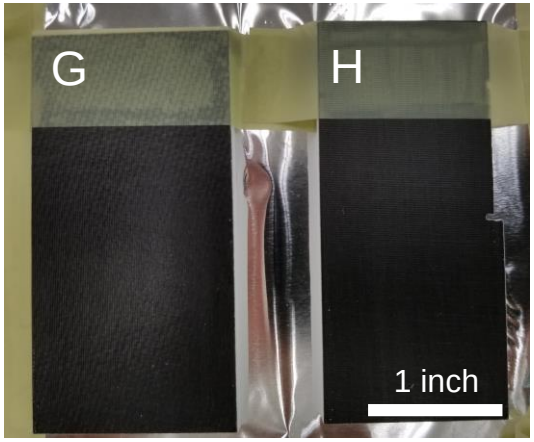
Coupons for striping

Side 1



Side 2

Witness coupons for S13 only



Note: Coupon F is not shown, but was coated with VDA on both sides, no masking