

**Introduction**

Under contract to NASA, NanoLab developed a number of coating processes for the production of very high absorbance optical blacks for stray light suppression. NanoLab offers three products to meet the needs of optical engineers: adVANTA, IM-1.6, and Singularity LT. NanoLab offers both coating services and the paint itself for those interested in applying the coating in their own facilities.

**Singularity™ Black LT Overview**

Singularity is a carbon nanotube filled, solvent based paint that has exceptionally strong absorption in the visible, and is similar in performance to the vertically aligned arrays of nanotubes that are the blackest items known to mankind. Singularity has world class performance in the visible, NIR and IR (approaching 1% reflectance from 400nm to 3 microns), exceeding the optical properties of other commercially available products like Acktar's metal velvet and Martin Black. Singularity's grazing angle performance is unmatched. Special formulations are available for use as beam dump coatings, black body sources, etc.



**Singularity™ Black LT Application**

The paint is solvent based, and requires application in a spray booth or fume hood, or with protective solvent vapor/particulate masks suited to the task. Brushing or air brush spraying are the recommended application techniques, but parts can also be dipped. Substrates and spray guns should be resistant to chemical attack from solvents such as MEK and THF. We find that a Iwata Eclipse airbrush is well suited for small scale coating jobs. Coverage at ~10ml/in<sup>2</sup> results in a thick coating that performs well in the IR and visible. Thinner coats may perform well in the visible. After spray application, a heating step is required to crosslink the coating. Once crosslinked, it is a 'low-touch' surface, tough enough for gentle handling..

The heating step for original Singularity Black includes a ramp up to 100°C in air or in vacuum or inert gas, to crosslink the binders and create a durable coating. While fragile, Singularity coatings can be field repaired with an air brush and heat gun.





**Singularity™ Black, Properties**

**Cleanliness**

The coatings are cleanable using gaseous nitrogen at low to medium pressure (5 to 50 psi). The process removes stray fibers and dust, but not the coating. Once cleaned, the coatings were measured with a Clemex particle counter. Typical optical instruments have a requirement of Level 400 per Institute of Environmental Sciences and Technology (IEST) STD-CC1246E. Assemblies with slits or pinholes require Level 200. Painted hardware typically has a particle levels higher than 500. The IEST equivalent for the Singularity sample was 127.

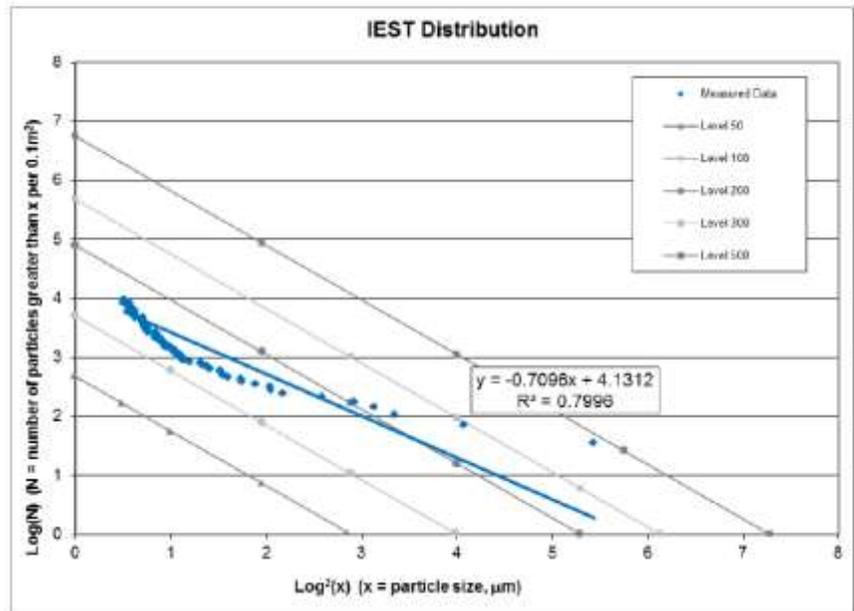
<b>Total Particles</b>	266	<b>Total Area Counted</b>						
<b>Background Particles</b>	0	<b>(<math>\mu\text{m}^2</math>)</b>		2.813E+09				
		<b>Area of Particles (<math>\mu\text{m}^2</math>)</b>		1.848E+04				
		<b>Percent Area Covered (PAC)</b>		6.571E-04				
<b>Particles Analyzed (total - background)</b>	266	<b>Background PAC</b>		0.000E+00				
<b>Particles Analyzed (total - background) per 0.1m<sup>2</sup></b>	9457	<b>PAC (total - background)</b>		6.571E-04				
		<b>PAC rate</b>						
		<b>Equivalent IEST Level*</b>		<b>127</b>				

Particle Size $\mu\text{m}$	ALLOWABLE PARTICLES per 0.1m <sup>2</sup> BY IEST CONTAMINATION LEVEL					Number of Others per 0.1m <sup>2</sup>	Number of Fibers per 0.1m <sup>2</sup>	Total Particles per 0.1m <sup>2</sup>
	100	200	300	400	500			
>25	78.4	1230	7450	28800	86300	284	36	320
>50	10.7	169	1020	3950	11800	142	36	178
>100	1	15.8	95	367	1090	36	36	71
>200		1	6	23.3	69.6	0	36	36
>300			1	3.9	11.6	0	0	0
>400				1	3	0	0	0
>500					1	0	0	0

**Outgassing**

Aluminum foil samples were coated with SBLT for ASTM E-595-07 outgassing tests. Before testing, each foil was baked for 4 hours at 200°C. The Total Mass Loss (TML) was measured at 1.56%, Water Vapor Regain (WVR) was 1.18%, and the Collected volatile condensable material (CVCM) was 0.04%, with no visually detectable material on the collection plate.





# Singularity Black LT Aero Technical Data Sheet



CVCM Test Number	36675-22	36676-23	36677-24
Initial mass, holder and specimen, gm	0.108985	0.107163	0.108124
Mass of holder, gm	0.034706	0.034343	0.034245
Initial specimen mass @ 50 %RH, gm	0.072279	0.072820	0.073879
Final mass, holder & specimen, gm	0.105890	0.106119	0.106850
Total mass loss, specimen, gm	0.001095	0.001044	0.001274
Percent TML, specimen	1.51%	1.43%	1.72%
Average value TML	*****	1.56%	*****
Mass after 50 %RH re-soak, 23 C, 24hr, gm	0.106725	0.107020	0.107700
Total mass, water vapor regain, gm	0.000835	0.000901	0.000850
Percent water vapor regain	1.16%	1.24%	1.15%
Average value WVR @ 50 %RH	*****	1.18%	*****
Initial mass, collector, gm	1.796946	1.587363	1.630575
Final mass, collector, gm	1.796946	1.587371	1.630651
Collected mass – CVCM, gm	0.000000	0.000008	0.000076
Percent CVCM	0.00%	0.01%	0.10%
Average Value CVCM	*****	0.04%	*****

Remarks: CVCM (unweighable) on separator plate to: \_\_\_\_\_ mm diameter.

CVCM appearance as follows: **is not** detectable on collector plates.  Thin;  moderate;  heavy;  
 \_\_\_\_\_ Colored liquid;  clear liquid;  liquid runs in excess;  
 \_\_\_\_\_ Color;  transparent;  Opaque;  matte;  interference fringes;  foggy;  distorts eye reflection;  
 Smooth;  smoky;  splotchy;  partially opaque

Deposit covers \_\_\_\_\_ % of collector disc.

Specimen appearance after test: **No noticeable change.**

## Thermal Data

Samples were thermal cycled three times between -60°C and 85°C at a ramp rate of 10°C/minute, with 30 minute dwells at the extremes, in a nitrogen atmosphere. No damage or loss of particulate was noted. Also, thermal vacuum conditions, <1e<sup>-6</sup> torr at 100°C, did not affect the coating.

Safe upper operational limits for the coating is 450°C in air, 1200°C in vacuum, and safe lower operational limits for the coating are -200°C in vacuum.

The autogenous autoignition temperature for the coating is 600°C in air. Combustion products may include CO, CO<sub>2</sub>.

## Other

Odor-none, Immersion tests: No Visible Reaction to immersion 2hrs in 25C water, or ethanol.

## Vibration

The Singularity coated panels successfully passed vibration testing. The GEVS vibration level is a low level input of 14.1 Grms that comes from a widely accepted government document called "General Environmental and Verification Specification for STS and ELV Payloads, Subsystems and Components", GEVS-SE, June 1996, Table 2.4-4. The BPL test is from a Ball Aerospace Structural Guideline and the vibe levels (also called Power Spectral Density or PSD) are fairly high to account for design cases where responses cannot be predicted. It includes a combination of vibe levels that account for acoustic vibration, random vibration, and quasi-static loading. This level is higher than most flight applications. No visible particles were removed during these tests. Some particles were generated by the vibration testing, and characterized using the Clemex particle analyzer.



## Singularity Black LT Aero Technical Data Sheet



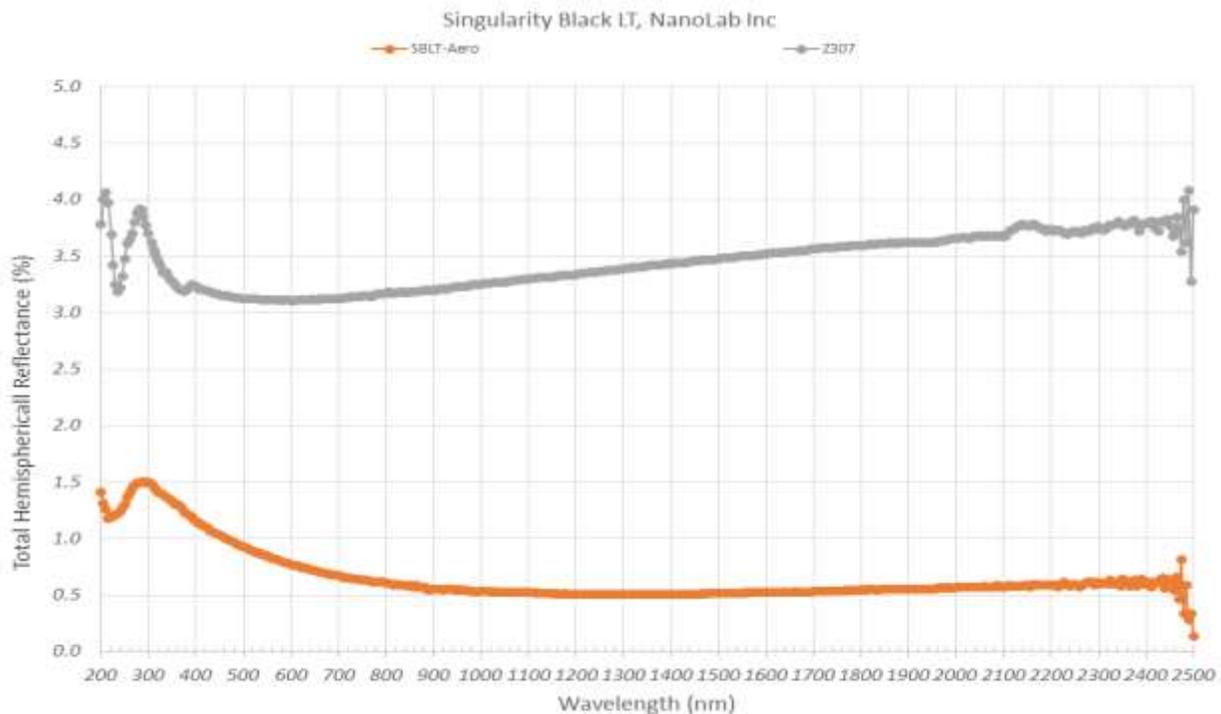
Vibe Level	GEVS				BPL			
Test Order	1	2	3	4	5	6	7	8
Sample	129-6	140-5	129-6	140-5	129-6	140-5	129-6	140-5
Axis	X	X	Z	Z	Z	Z	X	X
PC Test	15-0705	15-0708	15-0706	15-0707	15-0704	15-0703	15-0701	15-0702
micrometers	Particles per 0.1 m <sup>2</sup>							
>25	1201	426	543	659	504	465	1783	1473
>50	271	155	155	116	116	155	426	426
>100	0	116	0	78	0	116	310	194
>250	0	39	0	78	0	78	78	78
>500	0	0	0	78	0	78	78	39
Percent Area Covered (PAC)	2.86E-03	4.19E-03	1.19E-03	1.36E-02	1.19E-03	1.46E-02	2.53E-02	1.83E-02
IEST-CC-1246 Level	100	200	148	262	248	266	300	280
Comments	Dark	Dark	Mostly dark	Mostly black + 2 Blue	Mostly dark	Dark	None	Mostly black

Particle fallout levels during vibration testing were between IEST Levels 100 and 300, which are lower than what is observed for Martin Black and other black paints.

### Singularity™ Black Optical and IR performance

#### Total Hemispherical Reflectance (THR)

SBLT samples were measured at GSFC, using a research grade UV-Vis-NIR spectrometer equipped with an integrating sphere, and measured referenced to a Spectralon white sample.

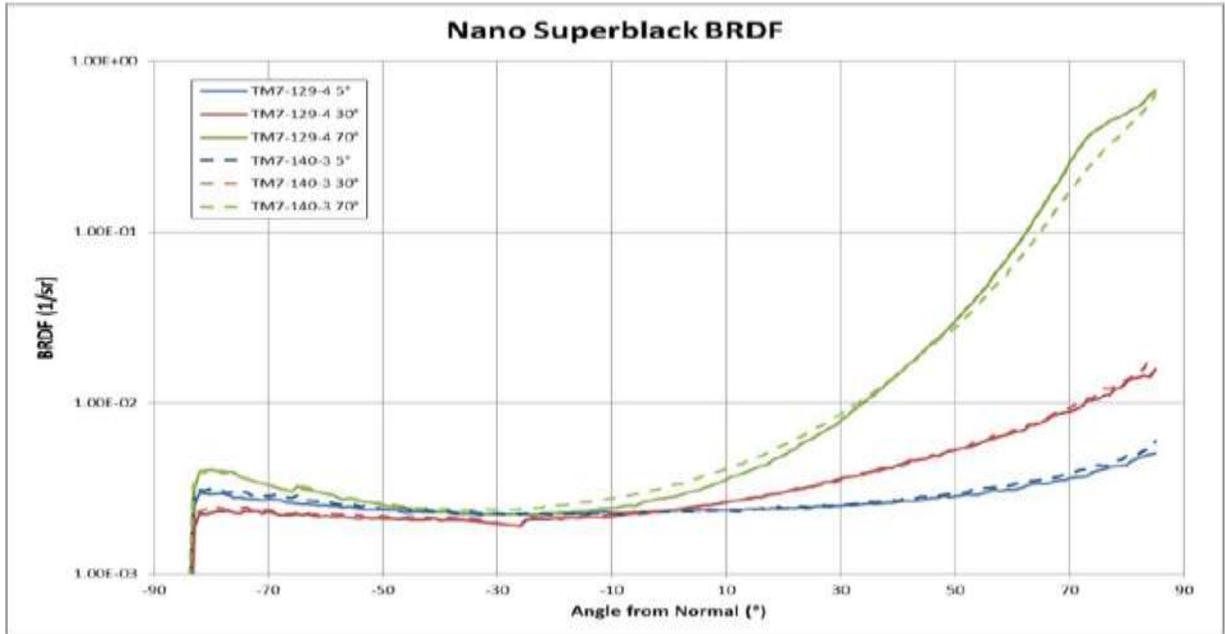




Coatings had a measured absorptivity of 0.99, and emissivity of 0.86.

**BRDF**

Reflectance measurements were taken using a Complete Angle Scatter Instrument (CASI) with the source at incidence angles of 5, 30, & 70 degrees. The detector scan radius covers the range +/- 90 degrees to the surface normal. The test wavelength was 633 nm.



**Singularity™ Black LT Training & Packaging**

For those interested in painting components, we offer a Singularity School where students will learn safety protocol, and application techniques to make the deepest blacks possible. These courses can be held at NanoLab, or at your facility. We sell Singularity Black in four sizes: 20ml, 250ml, 500ml & 1000ml. Coverage is ~1cm<sup>2</sup>/ml.

**Singularity™ Black LT Coating Services and Contact Information**

NanoLab provides coating services for baffles, telescope components, and other optical parts. Parts are handled in a class 100 clean space to prevent particulate contamination during the coating process. All work is done domestically, by US citizens in an ITAR compliant facility.