SELECTING CLEANROOM CONSTRUCTION MATERIALS FOR THE OSIRIS-REX AND HAYABUSA2 CURATION FACILITY AT NASA JOHNSON SPACE CENTER

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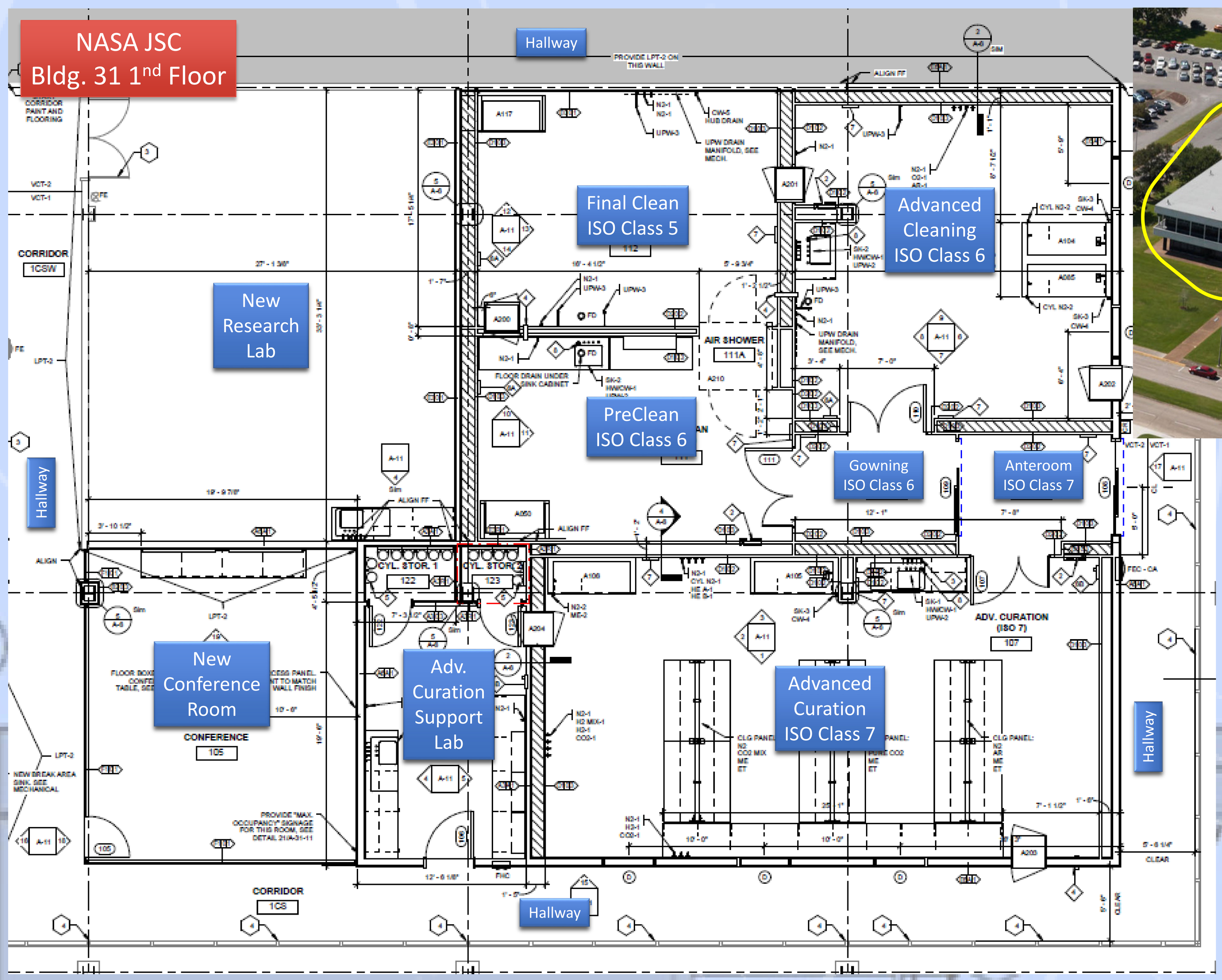
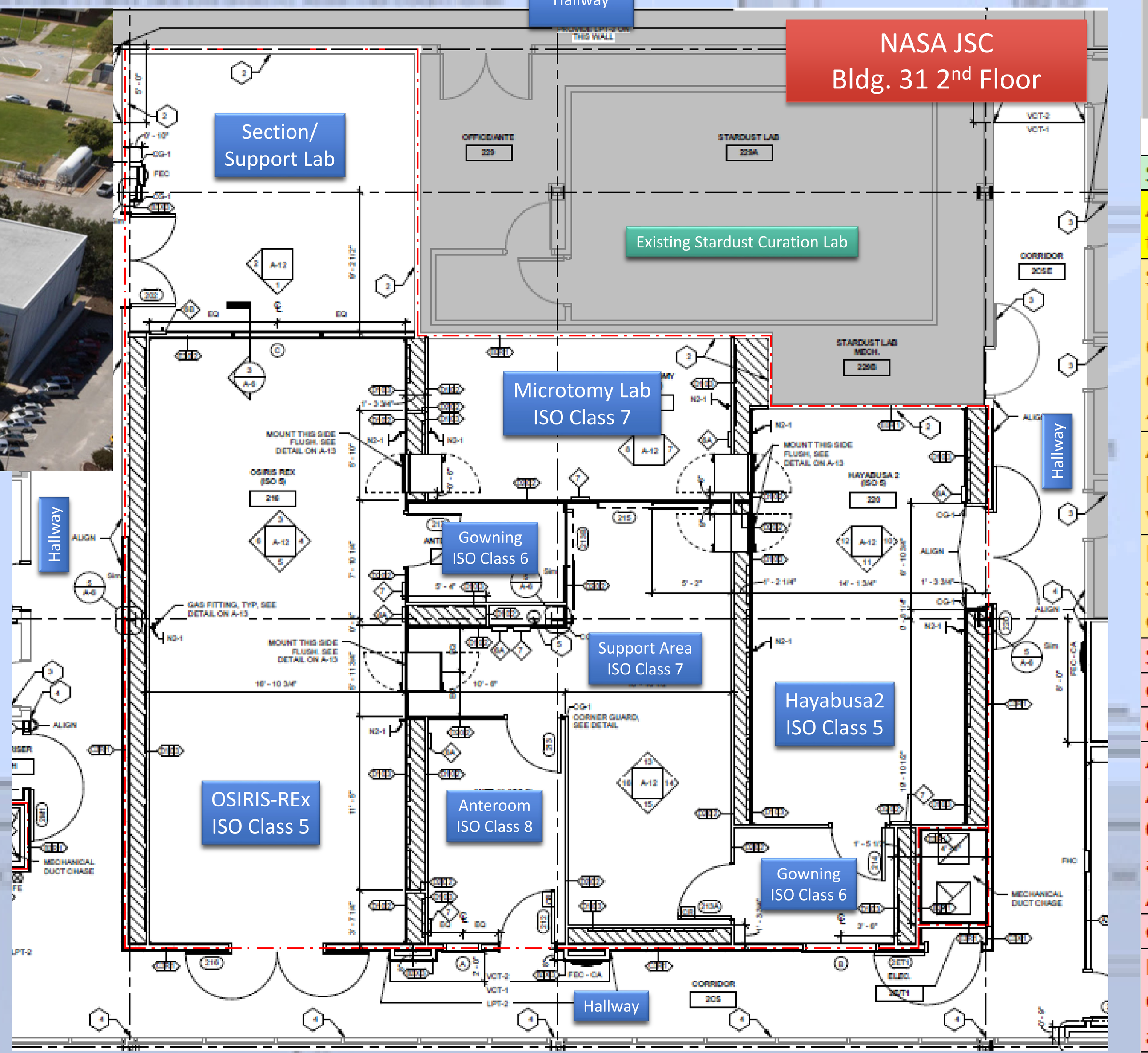


NASA JSC Bldg. 31 New Construction On Front Core 1st and 2nd Floor

Started March 2019

Completed in 2020



In early 2019, NASA Johnson Space Center (JSC) Astromaterials Acquisition and Curation Office [1] in JSC bldg. 31 will commence construction of two ISO Class 5 cleanroom laboratory suites for the Hayabusa2 and OSIRIS-REx sample return missions as well as new cleanroom facilities for curation precision cleaning and advanced curation work. The two new curation labs are designed for initial receiving, preliminary examination, and basic characterization and processing of small particles. The labs were also designed to enable long-term pristine sample storage and preservation of their scientific integrity to promote decades of future research by the international scientific community.

The scientific study of organics in general including biologically abundant compounds, like amino acids, is critical for both missions. In an effort to mitigate terrestrial contamination and preserve any organic signature, the OSIRIS-REx mission implemented a stringent contamination control plan [2] where all sample hardware at time of sample acquisition would be at Level 100 A/2 per IEST-STD-CC1246D (non-volatile residue (NVR) < 500 ng/cm^2). In addition, the mission imposed a requirement of <180 ng/cm^2 for amino acids (and hydrazine) [2]. Given these mission requirements, long-term storage preservation requirements, and information from the Organic Contamination Baseline Study at JSC [3], JSC Curation team decided to carefully select cleanroom construction materials that would not hinder the scientific search for amino acids and the study of organics in the samples.

A year prior to final cleanroom design with RS&H Inc., we began researching cleanroom candidate construction materials that have low particulate shedding and outgassing properties along with good mechanical properties for cleanability, chemical resistance, and minimizing electrostatic charges (e.g., conductive flooring). After the literature and industry search, our team narrowed several candidate materials that would be further tested for their specific outgassing characteristics using ASTM E-595 as well as better understanding the organic compounds using DART-MS analyses. The information gained from these two analyses provided the foundation for the selection of the cleanroom materials for the OSIRIS-REx and Hayabusa2 labs on 2nd floor as well as materials used for the new precision cleaning and advanced curation labs on the 1st floor.

Flooring Systems: Traditionally, epoxy floor systems have been used extensively in the semiconductor industry due to low outgassing characteristics. Conversely, the biotech/pharmaceutical industry widely use vinyl flooring for good microbial control and resistance to many biocide cleaning chemicals [4, 5]. However, Stonchem 441, a new 100% solids polyurea-polyurethane hybrid lining system provided the lowest outgassing results. It uses no adhesives and is applied like epoxy in liquid form and then allowed to cure. This immersion grade lining provides a durable, flexible, waterproof membrane that can withstand significant impact and abrasion. While the DART-MS results showed more diversity in the organic compounds when compared to vinyl flooring systems, Stonchem 441 had significantly lower outgassing characteristics.

Wall Systems: Cleanroom walls are typically designed as a modular panel or epoxy painted gypsum board (drywall). For ISO Class 5 cleanrooms, drywall is difficult to seal penetrations and can add particulates overtime. In addition, traditionally applied cleanroom paints usually outgas more than composite panels, which use advanced coil coating paint system with high temperature curing ovens [4, 5]. The Lasco wall panel (Larson aluminum composite wall panel with Duracoat XT-20S corporate white paint) offered the best results. The DART-MS spectra showed very few peaks for the Lasco panel.

Paint Systems: The lowest outgassing cleanroom paint systems are two-part epoxy paints [4, 5]. While epoxy paint will not be used inside these working cleanrooms, parts of the cleanroom air plenum walls will require paint. Sherwin Williams 2-part epoxy paint was chosen based on the lowest outgassing result.

Summary: All selected material systems were rated for ISO Class 5 or below for particulate shedding and long-term durability, including the use of heavy gloveboxes and equipment on the floor. The DART-MS results were useful for identifying material with the least organic compound diversification as well as classes of compounds that could affect amino acid research. However, in some cases, the team chose a lower outgassing material to minimize the total organic carbon (TOC) load of the laboratory. The DART-MS spectra peak heights also correlate well with E-595 outgassing results.

Based on the material specifications, mechanical properties, DART-MS analyses, and outgassing results, the RS&H cleanroom design incorporated:

- ***Walls/Ceilings:*** **Lasco Wall Panel**
- ***Floor:*** **Stonchem 441**
- ***Plenum Wall/Door Paint:*** **Sherwin Williams Epoxy System**

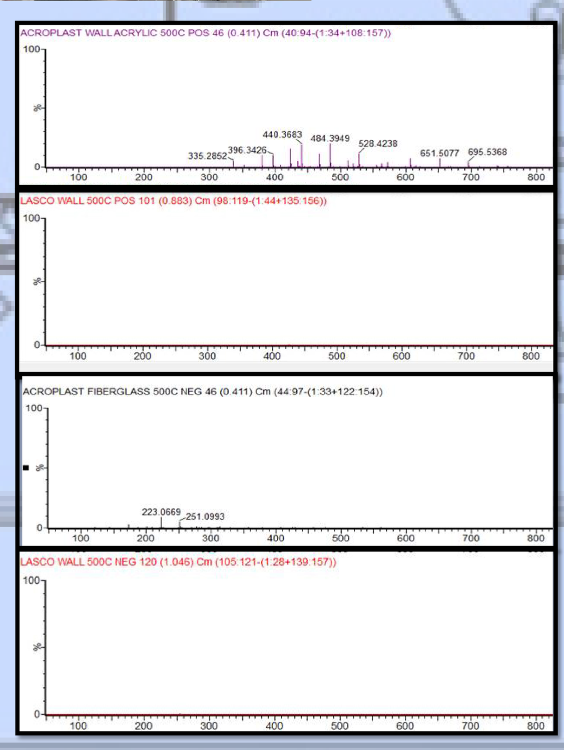
ASTM E-595 Testing: "Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment" uses a vacuum chamber at 125 ˚C for 24 hours. Product outgassing is reported in Total Mass Loss (TML%), Collected Volatile Condensable Materials (CVCM%), and Water Vapor Regain (WVR%). While this test was originally intended for spaceflight hardware, the curation office adopted the test for a qualitative comparison of ground hardware for 50 years.

NASA Low Outgassing Materials Limit < 1.0 TML% and < 0.10 CVCM%

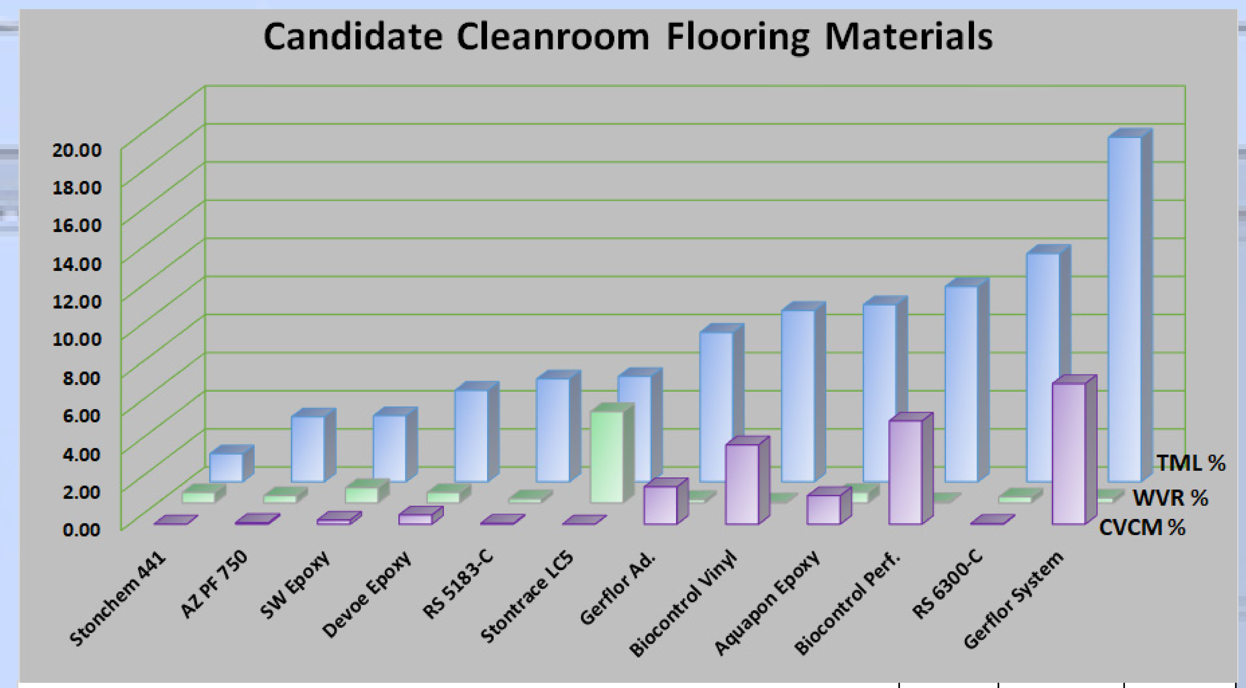
NASA WSTF E-595 Test Chamber: 5 identical samples and one control are placed into Al pods and loaded into thermal mount. Mount can hold 2 sample sets per run in thermal-Vac Chamber.

DART-MS Analyses: Instrument Parameters

- Waters Xevo G2-XS QToF, with IonSense DART-MS, set up for TLC plate mode
- Positive ionization performed at 3.0 kV
- Negative ionization performed at 2.5 kV
- Bazooka tube (129 mm) set at 1-2 mm above material surface
- DART source at 9.6 cm
- Acquisitions were performed by collecting by scanning across TLC plate → material → TLC plate to ensure background could be collected before and after material
- DART spectra were collected in positive mode at 300, 400, and 500°C, then a new area was selected for negative mode which was also analyzed at 300, 400, 500°C

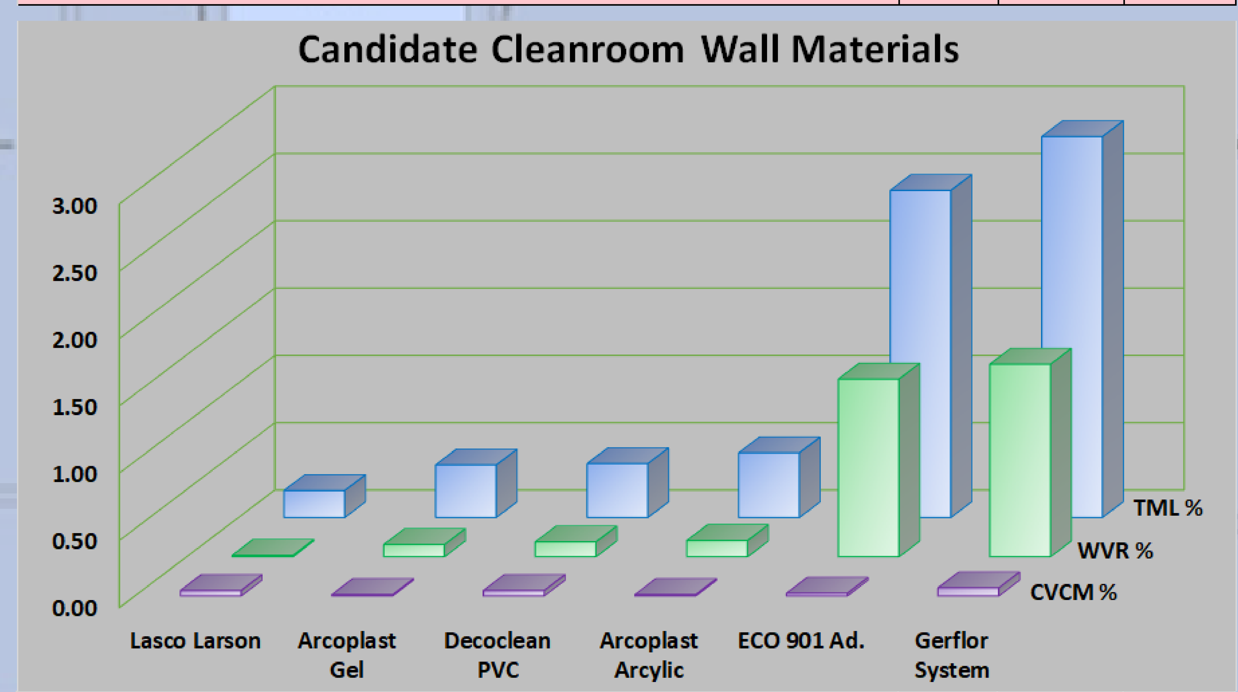


Candidate Cleanroom Flooring Materials



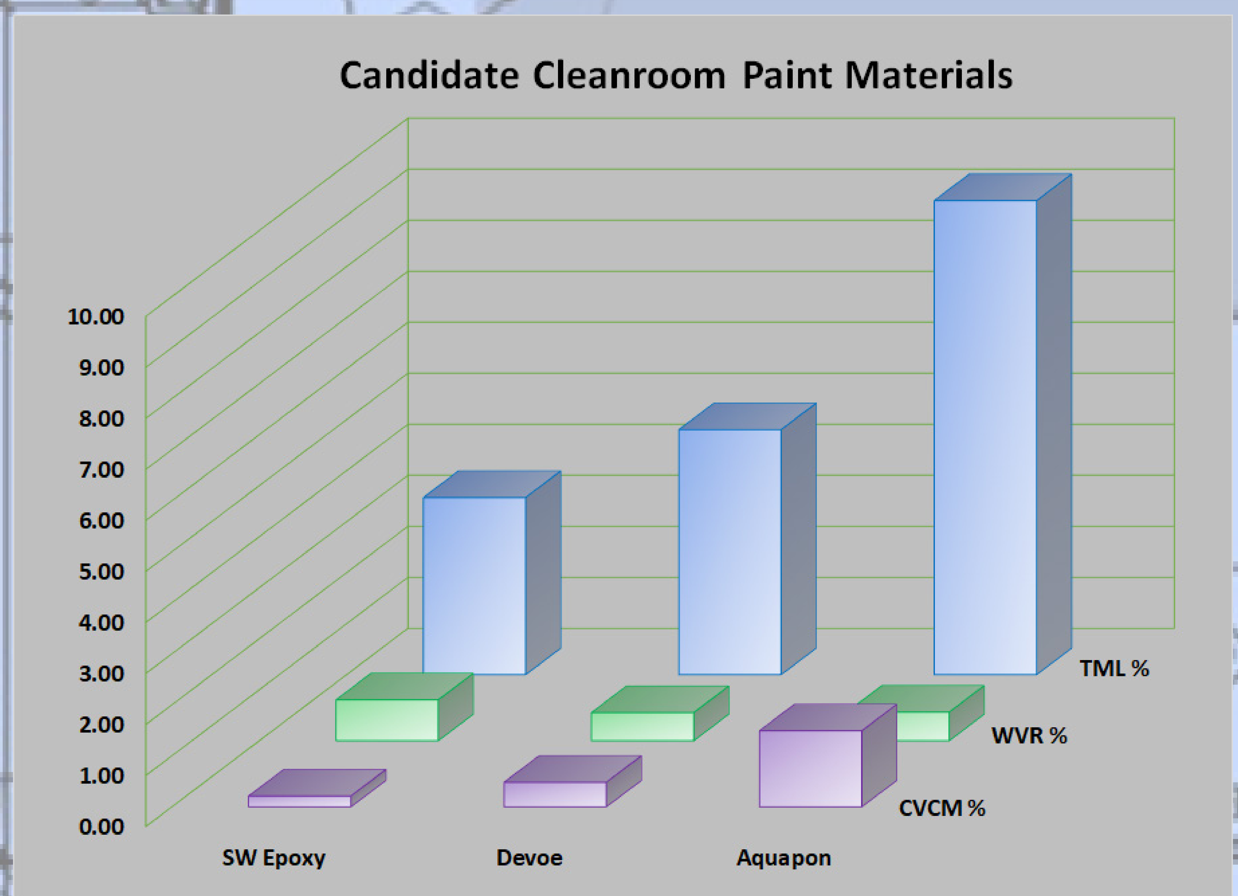
Material	TML %	CVCM %	WVR %
STONCHEM 441 BACKLESS FLOOR SYSTEM	1.47	0.00	0.55
Arizona PF Epoxy Floor System: Epoxy 750, Seattle Red; applied to 1 mm thick Stainless Steel	3.41	0.08	0.38
SHERWIN WILLIAMS PRO INDUSTRIAL WATER BASED EPOXY SYSTEM: Pro Industrial Waterbased Catalyzed epoxy, extra white B73 W 311, 6501- 17203 glass white COMP A and Pro Industrial Waterbased Catalyzed epoxy hardener, B73 V 300, 6501-17278 COMP B; MIX RATIO 4:1	3.47	0.21	0.80
AkzoNobel Devoe High Performance Coatings Tru-Glaze Water Based Epoxy System: Tru-Glaze-WB 4420 Part A (DV44200100) and Tru-Glaze-WB 4428 Part B DV44289999); Mix Ratio 1:1	4.80	0.48	0.55
HooverWells High Performance Floor System: Rez-stone Epoxy Floor System with Prime 5017-BK at 20 min. and Topcoat 5183-C 28 min. Light Grey. Coated on Aluminum	5.40	0.04	0.22
Stontrace LC5 Charcoal Floor System	5.53	0.00	4.79
Gerflor Gerfix Spray Adhesive for Gerflor Vinyl Flooring	7.84	1.96	0.19
Gerflor Mipolam Biocontrol Vinyl Flooring (NOT performance grade)	8.99	4.16	0.06
AQUAPON WB 2-PART EPOXY SYSTEM: Aquapon WB Gray Primer COMP A 98- 46/01, 00338318 and Aquapon WB Primer COMP B 98-99/01, 00338339; Aquapon WB Porcelain White COMP A 95-1/05, 00338303 and Aquapon WB COMP B 98-101/05, 00338308; applied to 3 mm thick Aluminum	9.29	1.49	0.56
Gerflor Mipolam Biocontrol Performance Vinyl Flooring	10.24	5.41	0.07
Rez-Stone Epoxy Floor System: Prime Rezstone 5017 MCT: Base Build Coat 5056, Conductive Base Coat 5365-C, Top Coat Conductive 6300-C; applied to 3 mm thick Aluminum	11.98	0.03	0.32
Gerflor Combined with adhesive	18.08	7.37	0.26

Candidate Cleanroom Wall Materials



Material	TML %	CVCM %	WVR %
Lasco Wall Panel; Larson Aluminum Composite with Polyester Paint	0.20	0.04	0.01
Arcoplast Gel-coat on Fiberglass Composite Wall Panel	0.39	0.01	0.09
Gerflor Decoclean PVC Wall Panels	0.40	0.04	0.11
Arcoplast Arcylic Wall Panel	0.48	0.01	0.12
Ultrabond ECO 901 Adhesive for Gerflor PVC Wall Panels	2.43	0.02	1.32
Gerflor Decoclean PVC Wall Panels with adhesive	2.83	0.06	1.43

Candidate Cleanroom Paint Materials



Material	TML %	CVCM %	WVR %
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Acknowledgements: Thanks to Susan Harper and Brenton Woods at NASA WSTF for help conducting the ASTM E-595 testing and all material manufactures for suppling samples for the analyses and funding via task NNH09ZDA007O and contract NNM10AA11C issued through the New Frontiers Program.

Reference: [1] Allen et al. (2011). Chemie der Erde-Geochemistry, 71(1), 1-20. [2] Dworkin et al. (2018) Space Sci Rev, 214: 19. [3] Calaway et al. (2014). NASA/TP-2014-217393. [4] Whyte, W. (Ed.). (2000). Cleanroom design. Wiley. [5] Whyte, W. (2010). Cleanroom technology: fundamentals of design, testing and operation. Wiley.