CLEAN AIR SHOWER CURTAIN FOR PROTECTION OF CONTAMINATION SENSITIVE TELESCOPES ON THE ARIANE 5 LAUNCHER

SPIE Optics + Photonics 2022
21 - 25 August 2022, San Diego

Marco Calcabrini, Alan C. Abeel, Amelia Simon, Eve M. Wooldridge, Bruno Erin

01

LAUNCH OF JAMES WEBB SPACE TELESCOPE WITH ARIANE 5

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

01. GUIANA SPACE CENTER – CENTRE SPATIAL GUYANAIS (CSG)

Geographic position

Ideal launch base for launching satellites into geostationary or quasi-equatorial orbit

- Extensive launch azimuth possibilities
- Latitude very close to the equator (5 degrees North) which requires a reduced correction of the orbital inclination
- Benefit from the slingshot effect linked to the Earth's rotation

Satellites from the CSG

Commercial and institutional missions

- More than 90 launches to put satellites in GTO
- Specific adaptations for scientific missions such as *Automated Transfer Vehicle*, *Rosetta*, space telescopes such as the *X-ray Multi-Mirror Mission* and *Herschel* and *Planck* before launching *James Webb Space Telescope* (JWST)

arianespace
arianegroup

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

01. SPACECRAFT PROCESSING FACILITIES FOR VA256 CAMPAIGN

S5C
Payload Preparation Facility

S5B BAF
Hazardous Processing Facility

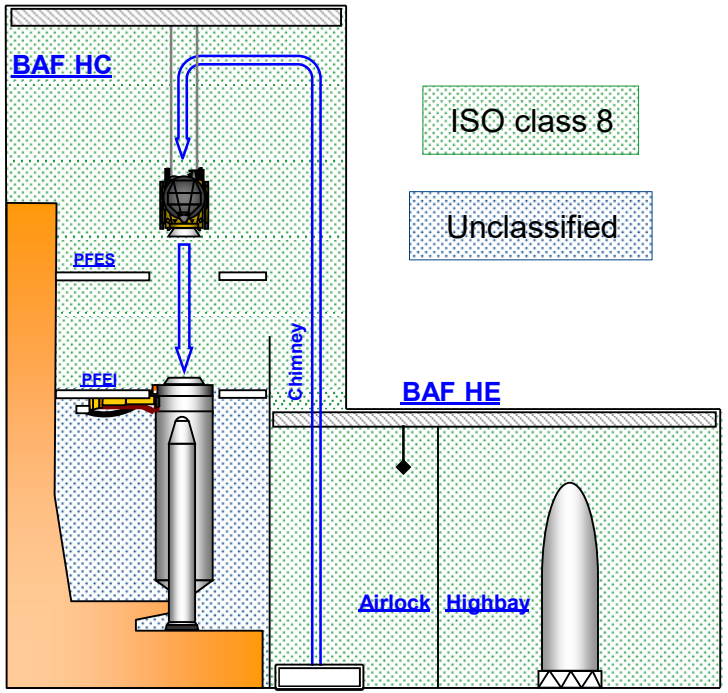
Launch Pad
Lift-off

S5C ISO Class 8	CCU3 ISO Class 7	S5B ISO Class 8	CCU3 ISO Class 7	BAF ISO Class 8	Launcher Fairing ISO Class 7

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

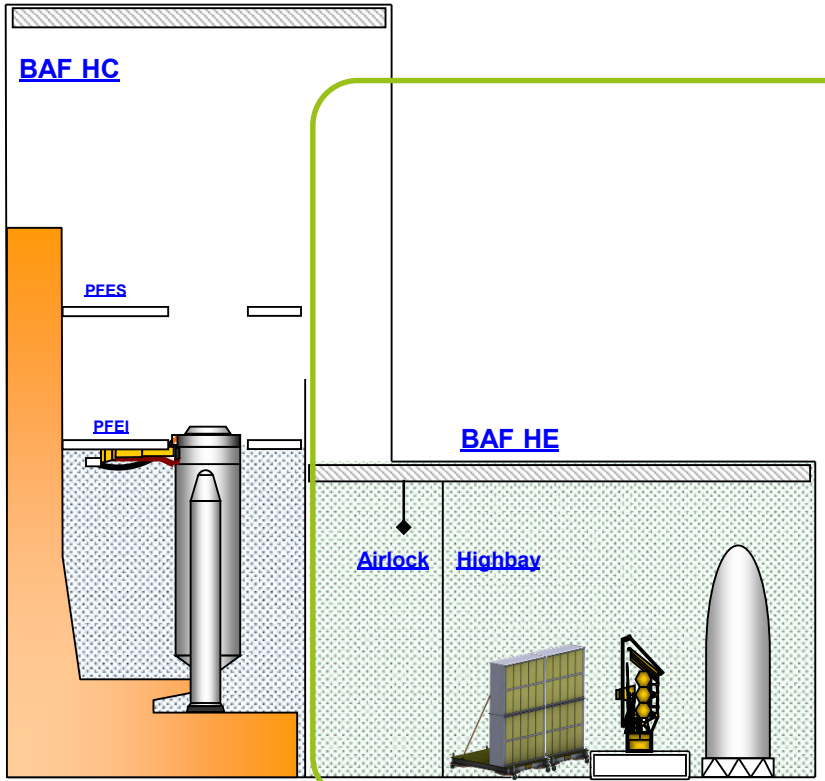
01. UPGRADES TO MEET THE ISO CLASS 7 REQUIREMENT

S5C – S5B + HEPA Filters
ISO Class 7



THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

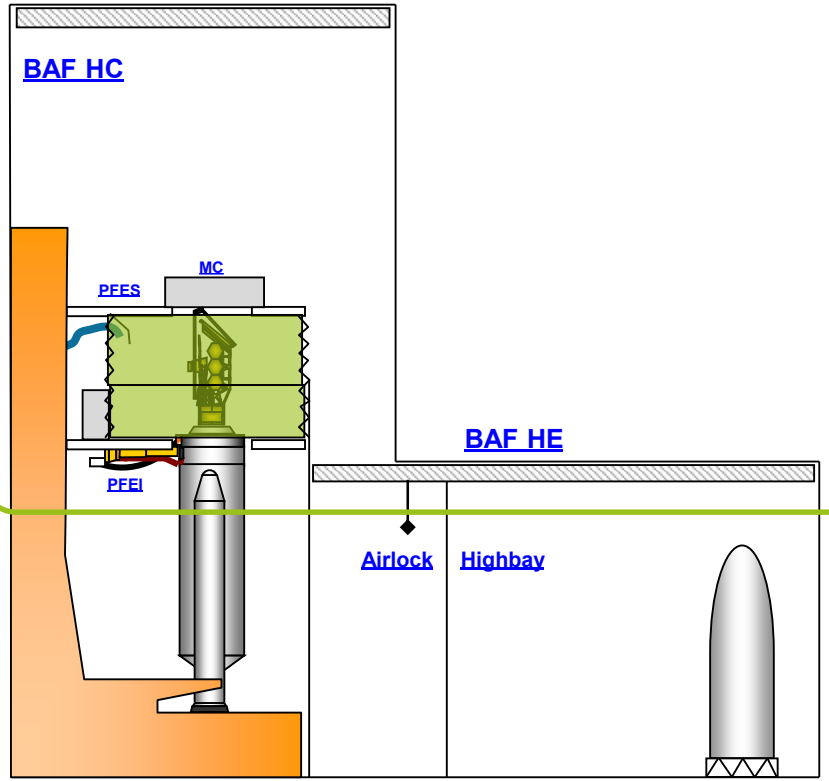
01. UPGRADING THE BAF-HE

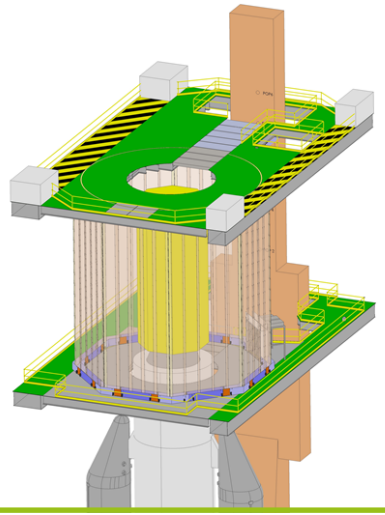


BAF-HE + HEPA Filters
ISO Class 7

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

01. UPGRADING THE BAF-HC





BAF-HC + AShC
ISO Class 7

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

02

AIR SHOWER CURTAIN DESIGN

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

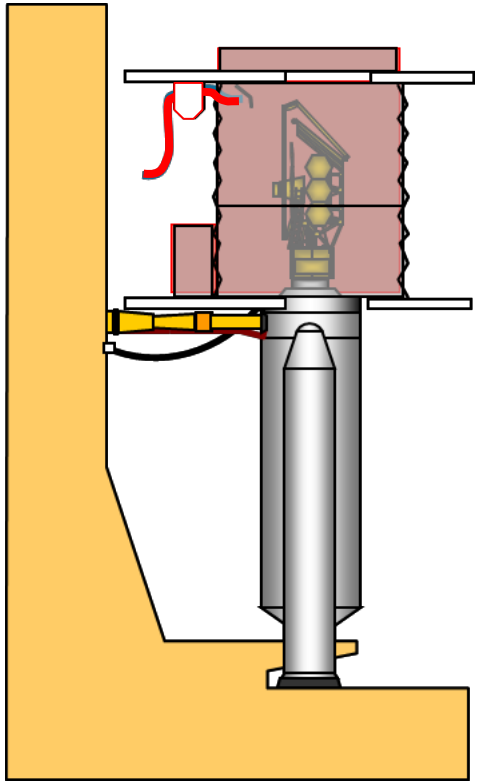
02. AIR SHOWER CURTAIN CONCEPT

Curtain

Manhole Cover

Anteroom

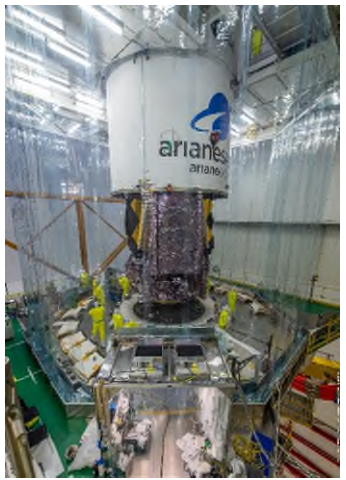
Air supply system

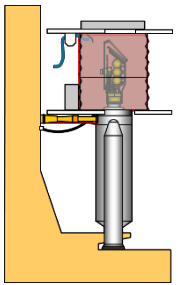


THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

AIR SHOWER CURTAIN CONCEPT

- Multiple soft panels 15 m high, attached to the Platform-AShC Connection Structure (PACS), screwed onto the bottom surface of the PFES
- Simple folding-unfolding operation by lowering the PFES closer to the PFEI
- Stowing boxes around the JWST at the edge of the ATEX zone
- Dry and safe mechanical fastening systems only (no adhesive tape authorized avoiding contamination and unexpected fragments, including Foreign Object Debris (FOD), falling onto JWST)
- Structures and boxes entirely made of aluminum to limit the total weight of the installation
- The design consistent with that required in an ISO Class 7 cleanroom:
  - Less and easy accessible horizontal surfaces
  - No boxed elements or sealed boxed elements to prevent from accumulating dust

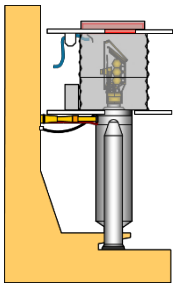




THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

02. MANHOLE COVER

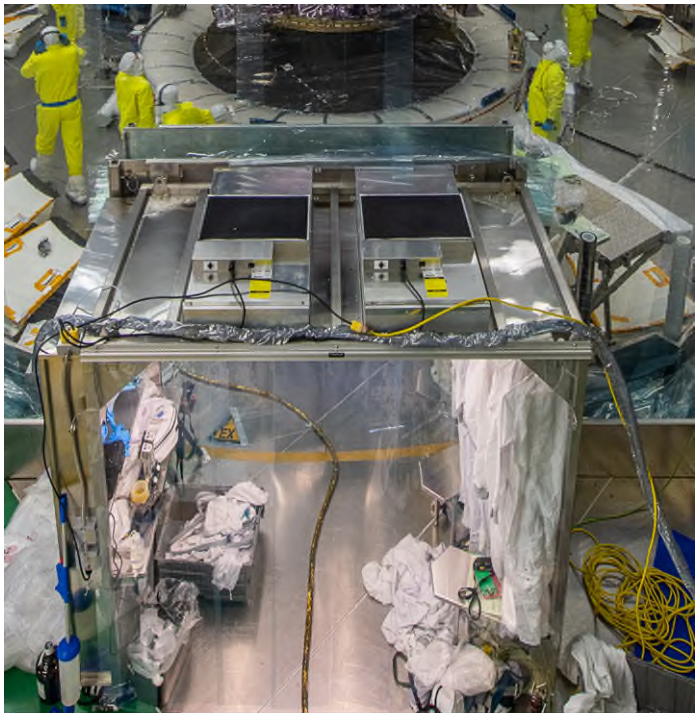
- NASA provided tarp to close out the opening on the PFES and create an enclosed volume in tandem with the AShC.
- Fabricated with a polyvinyl fluoride bagging material that accommodated Atmospheres Explosible (ATEX) restrictions affixed to heavy-duty sawhorses at the corners using hooks and reinforced cutouts.
- Used both after the initial cleaning prior to and after JWST's integration with the Launch Vehicle (LV).
- Easy installation and removal in a rolling fashion
- The Manhole Cover was designed, built, and tested at the Goddard Space Flight Center in the Space Systems Development and Integration Facility (SSDIF).
- A series of rollout installations and removals inside the SSDIF to identify and mitigate any concerns with the process and perfect its execution.
- The rollouts also allowed for extensive cleaning and cleanliness inspections of the tarp prior to packaging for shipment to CSG. Once verified by the teams, NASA double-bagged the rolled-up Manhole Cover in polyethylene to protect it from contamination during shipment and handling.

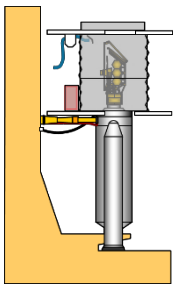


THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

02. ANTEROOM

- A HEPA-filtered, stainless steel anteroom at the entrance of the AShC to facilitate the ingress and egress of personnel.
- The mechanical design of the AShC base accommodated an unattached mating of the anteroom with the AShC that fostered an easy entrance and exit. The anteroom was used to change from Arianespace to NASA cleanroom garments that incorporated additional pieces, including cleanroom hoods, boots, and gloves. Changing allowed for the use of fresh garments around JWST and the LV as an additional layer of contamination control by avoiding flight hardware exposure to garments potentially soiled during passage from the BAF changing room up to the PFEI.
- The anteroom included storage compartments for new gloves, beard covers, facemasks, sweatbands, waste bins, and other contamination control consumables. The anteroom also included a rack of stainless steel hangers for storing used garments, two deployable seats to assist with changing, electrical outlets, and built-in overhead lighting. It was further equipped with curtains made of the same PolySim® material as the AShC to control its own interior cleanliness.





arianespace
arianegroup

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

02. AIR SUPPLY SYSTEM

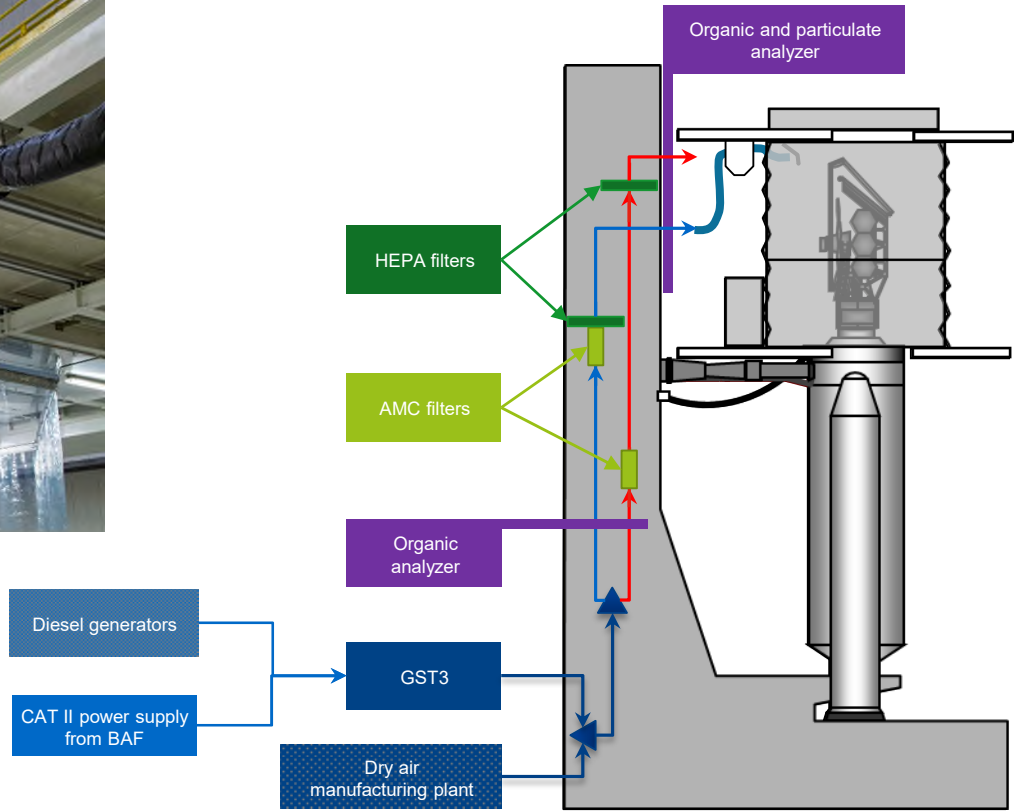
Dry Air

HEPA fiters

Organic filters and analyzer

Hygrometry higher than 30%

Functioning inside a building



THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

03
QUALIFICATION AND TEST

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

03. QUALIFICATION PLAN – GOWG AND VA254 CAMPAIGN

Targets

- Mechanical interfaces
- Duration of operations
- Ventilation performance
- Methodology and instruments for contamination measurement
- Actual contamination status to be compared with applicable requirements

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

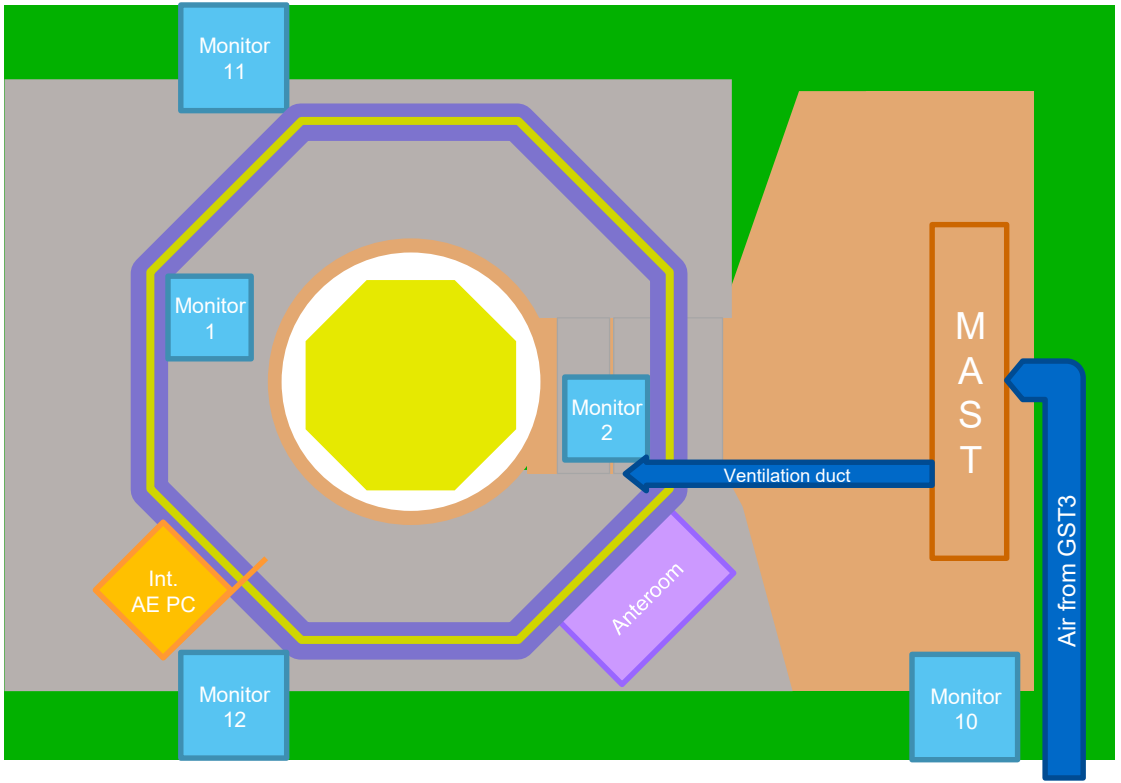
03. SENSOR LAYOUT DURING GOWG – VA254 CAMPAIGN

Monitor 10-11-12:
Particles Fallout (PFO) and Witness Plates standard positions on PFEI

Monitor 1-2:
Particles Fallout (PFO) and Witness Plates specific positions inside the AShC

AE Internal Particle Counter (PC):
Environment parameters continuous monitoring inside the AShC (T, R.H., PC) connected to the control bench under AE responsibility

Air inlet from GST3 through Mast, POP3, duct and air diffuser



THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

03. MEASUREMENT REPORT - GOWG

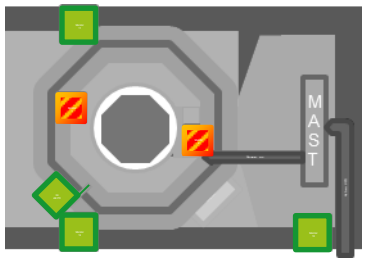
	Particles fallout [ppm/week]		Organic Contamination [mg/mm²/week]	Particle Counters [ISO Class]	Volatile Organic Contamination [ppm methane equivalent]
	Inside AShC	Outside AShC			
Requirement	< 1925	< 1925	< 0,5	8	< 15
Target	< 364	< 1925	< 0,5	7	< 15
Measured values	Monitor 1** 1265 Monitor 2** 1612	Monitor 10 1354 Monitor 11 172 Monitor 12 94	Monitor 1** 0,76 Monitor 2** 0,71	Int. AE PC Avg. value 5,29*	< 1,8

* witness plates exposed less than the two weeks required by the qualified measurement process* no information is available on particles smaller than 0,5 µm
** no information is available on particles smaller than 0,5 µm

AE Internal Particle Counter (PC):
Environment parameters continuous monitoring inside the AShC. Output provided in ISO Class largely compliant with the ISO Class 7 requirement

Particles Fallout (PFO)
Values close to ISO Class 8

Organic Contamination
Values slightly out of specification



THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

03. QUALIFICATION REPORT

Targets

The test provided good general indications and confirmed the feasibility of the proposed solution

Open points

Some problems (e.g., on the AShC inlet flow rate) were encountered and resolved during the test phase, and others were addressed in preparation for the launch campaign as improvement actions, such as:

- To seal out around the air duct diffuser and between the AShC and the PFES,
- To eliminate the fiber sources inside the AShC, such as the vinyl pads around the launcher,
- To reinforce the cleanliness process by using sealed edge wipes,
- To deeper clean the PFES before MC installation and JWST hoisting onto the launcher,
- To wear full ISO 7 garmenting

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

04
LAUNCH CAMPAIGN

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

04. LAUNCH CAMPAIGN SEQUENCE

Nov 29th
Launcher transferred to the BAF

Dec 6th
AShC deployment

Dec 11th
JWST integration on launcher

Dec 18th
Encapsulation

5 additional working days for launcher finalization

Launcher finalization and ventilation configuration

5 additional working days for JWST finalization

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

04. SENSOR LAYOUT DURING VA256 CAMPAIGN

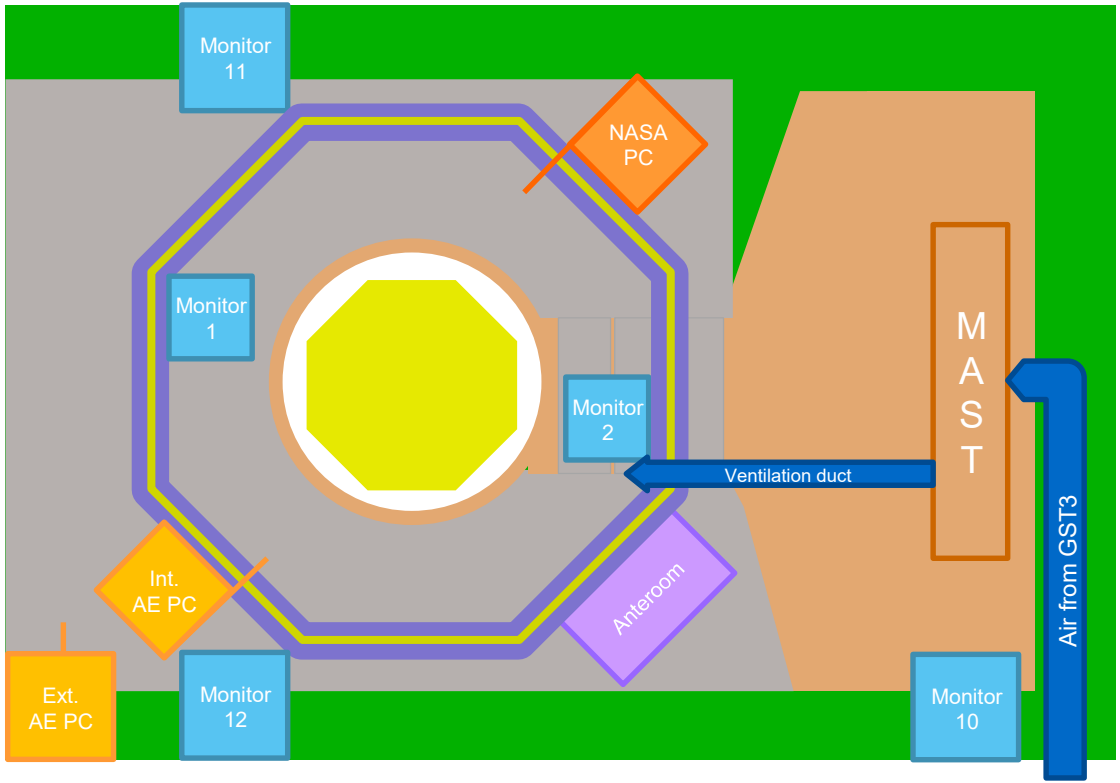
Monitor 10-11-12:
Particles Fallout (PFO) and Witness Plates standard positions on PFEI

Monitor 1-2:
Particles Fallout (PFO) and Witness Plates specific positions inside the AShC

AE Internal Particle Counter (PC):
Environment parameters continuous monitoring inside the AShC (T, R.H., PC) connected to the control bench under AE responsibility

AE External Particle Counter (PC):
Environment parameters continuous monitoring outside the AShC (T, R.H., PC) connected to the control bench under AE responsibility

Air inlet from GST3 through Mast, POP3, duct and air diffuser



THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

04. MEASUREMENT REPORT VA256

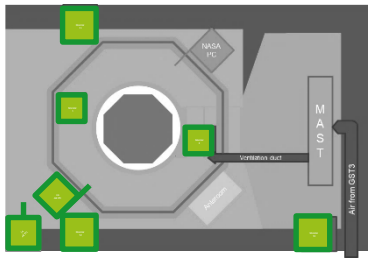
	Particles fallout [ppm/week]		Organic Contamination [mg/mm²/week]		Particle Counters [ISO Class]		Volatile Organic Contamination [ppm methane equivalent]
	Inside AShC	Outside AShC	Inside AShC	Outside AShC	Inside AShC	Outside AShC	
Requirement	< 1925	< 1925	< 0,5	< 0,5	8	8	< 15
Target	< 364	< 1925	< 0,5	< 0,5	7	8	< 15
Measured values	Monitor 1* 867	Monitor 10 1735	Monitor 1* 0,13	Monitor 10 0,14	Int. AE PC Average value 5,76**	Ext. AE PC Average value 6,23**	< 1,8
	Monitor 2* 668	Monitor 11 137	Monitor 2* 0,06	Monitor 11 0,05			
		Monitor 12 99		Monitor 12 0,16			

* witness plates exposed less than the two weeks required by the qualified measurement process* no information is available on particles smaller than 0,5 µm
** no information is available on particles smaller than 0,5 µm

AE Internal Particle Counter (PC):
Environment parameters continuous monitoring inside the AShC. Output provided in ISO Class largely compliant with the ISO Class 7 requirement

Particles Fallout (PFO)
Values between ISO Class 8 and ISO Class 7

Organic Contamination
Values conform to specification



arianespace arianegroup

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

04. PARTICLE COUNTER

Particle contamination

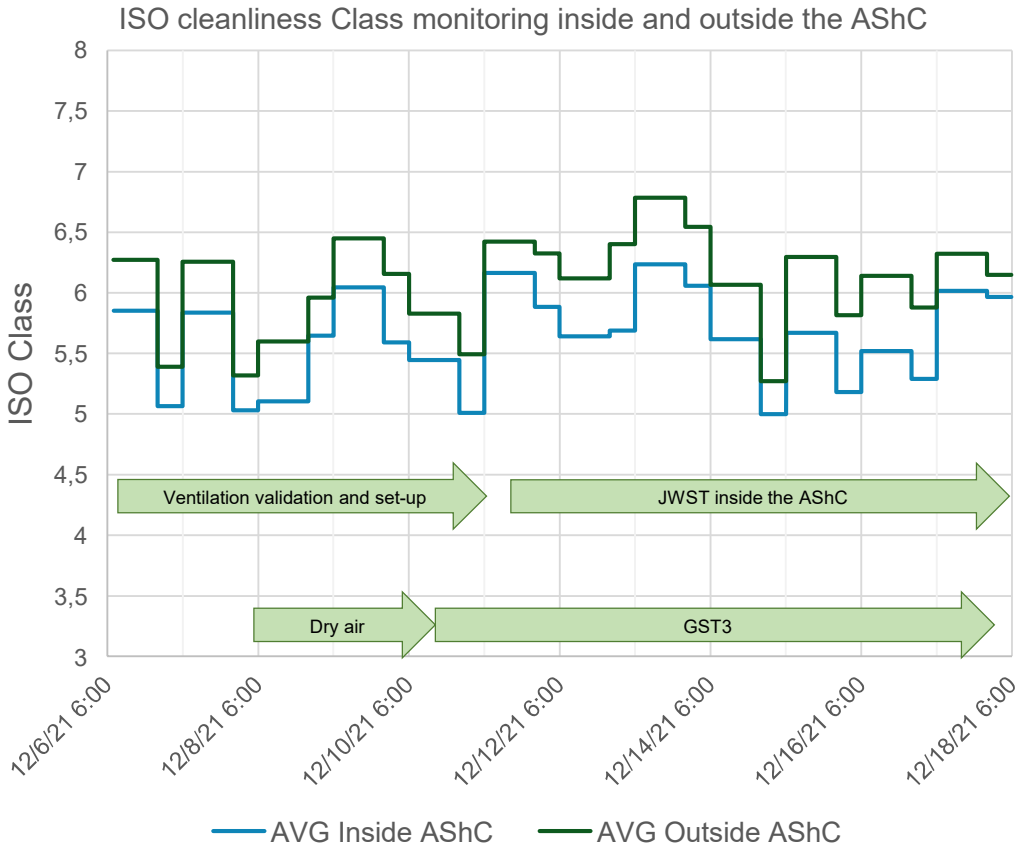
- A constant gap is evident between the measurements inside and outside the AShC.
- For several prolonged phases, the amount of particles smaller than 0,5 µm inside the enclosure was below the instrument's lower detection threshold (ISO Class 5). It is not possible to state that an ISO Class 6 cleanliness was achieved but only to certify that better than ISO Class 7 was met.

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

04. PARTICLE COUNTER

Particle contamination

- A constant gap is evident between the measurements inside and outside the AShC.
- For several prolonged phases, the amount of particles smaller than 0,5 µm inside the enclosure was below the instrument's lower detection threshold (ISO Class 5). It is not possible to state that an ISO Class 6 cleanliness was achieved but only to certify that better than ISO Class 7 was met.
- Particle contamination, which is directly related to the presence of operations

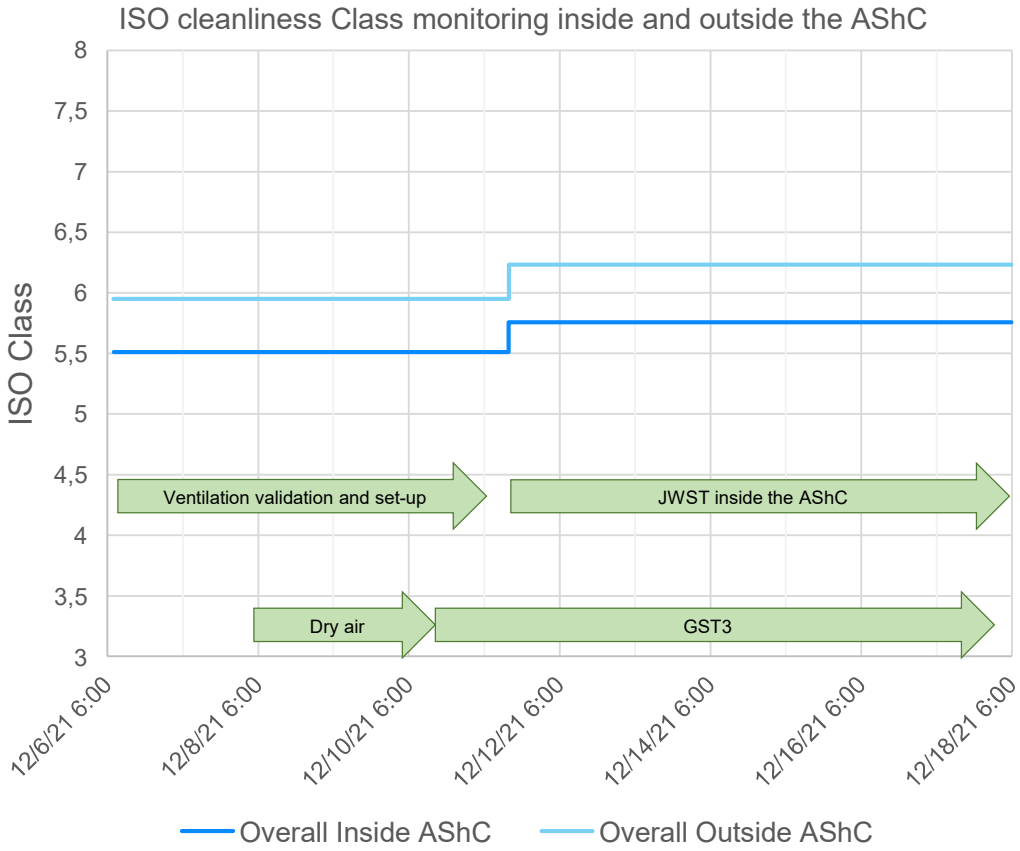


THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

04. PARTICLE COUNTER

Particle contamination

- A constant gap is evident between the measurements inside and outside the AShC.
- For several prolonged phases, the amount of particles smaller than 0,5 µm inside the enclosure was below the instrument's lower detection threshold (ISO Class 5). It is not possible to state that an ISO Class 6 cleanliness was achieved but only to certify that better than ISO Class 7 was met.
- Particle contamination, which is directly related to the presence of operations
- The improvement was conspicuous and measurable as approximately 0,46 ISO cleanliness classes.



THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

05
DISCUSSION

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

05. LESSONS LEARNED AND FUTURE APPLICATIONS

Lessons learned

- Stringent cleanliness and hygrometry requirements not only imposed new devices but also led us to seek excellence in all the processes, tools, and operations
- The selection of approved products/materials as well as the strict controls during all phases of processing
- Sealed-edge wipers along with regular UV inspections are now an option for any fiber-sensitive mission.
- Proper dimensioning of means and resources and involvement and cooperation among all teams involved are essential in cases such as these, where the requirements are so stringent.
- Essential during the prolonged and unexpected anomaly troubleshooting phase and allowed for easier management of operations on the PFEI outside its perimeter. Finally, it implicitly changed the behavior of people entering the AShC.
- The joint effort provided valuable results: Arianespace has been able to adapt to the very stringent requirements of the customer, and the collaboration with NASA and ESA has increased our expertise in contamination control, which is a priority for our future customers

Use of upgrades for future Arianespace campaigns

- Environmental management systems and contamination control methodologies developed during the VA256 campaign are now part of the Arianespace standard operating procedures, contributing to the provision of excellent service and continuous improvement for satellite processing. These improvements will namely serve the coming Jupiter Icy Moons Explorer - JUICE launch campaign (cleanliness process, garmenting, Payload fairing specific seal, etc.).
- The Ariane 5 launcher will soon be replaced by its successor, Ariane 6, and consequently, the BAF-HC will no longer be used for future launch campaigns in French Guiana. Nevertheless, the AShC developed for JWST could be adapted for any other project, such as Vega-C, where temporary cleanliness requirements are necessary.

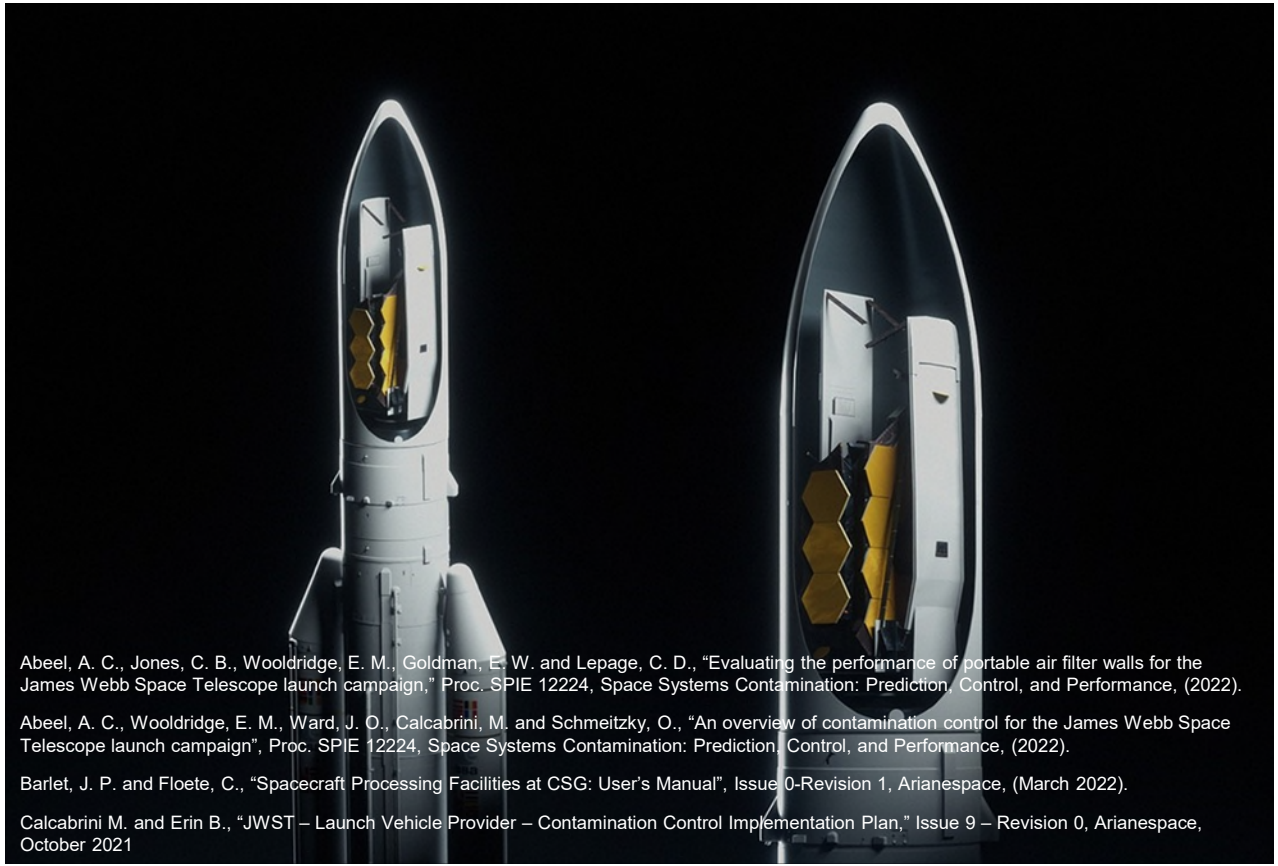
THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

05. ACKNOWLEDGMENTS

David Baran, Lauren Bayet, Killian Beuret, Marie Bussman, Mario Camacho, Larkin Carey ,Adam Carpenter, Damien Castille, Daniel DaCosta, Genevieve Dede, Charles Diaz, Nathalie Dinge, Jason Durner, Guillaume Faure, Alessia Fazi, Adrien Frantzen, Juan Gomez, Courtney Gonzales, Bruce Haines, Azuka Harbor, Kelly Henderson-Nelson, Cole Horton, Asanka Jayawardena, Frank Jenkins, Peter Jensen, Craig Jones, Zachary Kemp, Morgane Laffont, Jon Lawrence, Colette Lepage, Jack Marshall, Jeremy McFarlane, Dr. Michael Woronowicz, Sylvain Michel, Sanclair Montoute, Kimberly Morales, Benjamin Morin, Maria Odriozola, Nilesh Patel, Leonardo Perez, Cyrille Ponroy, Laurent Poulain, Laurence Renaudon, Helene Requiston, Beatriz Romero, Peter Rumler, Olivier Schmeitzky, Klaus Sell, Elaine Stewart, Pascal Studer, Wafaa Tabibi, Joelle Tephany, Michael Wilks, Harry Willems, Thierry Wilmart

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER'S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.

05. REFERENCES



Abeel, A. C., Jones, C. B., Wooldridge, E. M., Goldman, E. W. and Lepage, C. D., “Evaluating the performance of portable air filter walls for the James Webb Space Telescope launch campaign,” Proc. SPIE 12224, Space Systems Contamination: Prediction, Control, and Performance, (2022).

Abeel, A. C., Wooldridge, E. M., Ward, J. O., Calcabrini, M. and Schmeitzky, O., “An overview of contamination control for the James Webb Space Telescope launch campaign”, Proc. SPIE 12224, Space Systems Contamination: Prediction, Control, and Performance, (2022).

Barlet, J. P. and Floete, C., “Spacecraft Processing Facilities at CSG: User’s Manual”, Issue 0-Revision 1, Arianespace, (March 2022).

Calcabrini M. and Erin B., “JWST – Launch Vehicle Provider – Contamination Control Implementation Plan,” Issue 9 – Revision 0, Arianespace, October 2021

THIS DOCUMENT AND ITS CONTENTS ARE PROPERTY OF ARIANESPACE.
IT SHALL NOT BE COMMUNICATED TO ANY THIRD PARTY WITHOUT THE OWNER’S WRITTEN CONSENT | ARIANESPACE – ALL RIGHTS RESERVED.