Guidelines for Cleanroom Operations for Space-Flight Lasers

This a subsequent revision of the VCL/MBLA Building 33, 327A clean room procedures

Authorship/ review history

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ACROYNMS

- **MBLA-MUTI-BEAM LASER ALTIMETER**
- **VCL-VEGETATION CANOPY LIDAR**
- **HEPA-HIGH EFFICIENCY PARTICULATE AIR**
- **C.C.-CONTAMINATION CONTROL**
- **CCE-CONTAMINATION CONTROL ENGINEER**
- **NVR-NON-VOLATILE RESIDUE**
- **VOC-VOLATILE ORGANIC COMPOUNDS**
- **GSE-GROUND SUPPORT EQUIPMENT**
- **ESD-ELECTRO-STATIC DISCHARGE**
- **UV-ULTRA-VIOLET**
- **IPA-ISOPROPYL ALCOHOL**
- **THC-TOTAL HYDROCARBON CONTENT**
- **GN2-GASEOUS NITROGEN**
- **PCF-PRECISION CLEANING FACILITY**
- **GCF-GENERAL CLEANING FACILITY**
- **MEK –METHYL ETHYL KETONES**
- **MSDS-MATERIAL SAFETY DATA SHEET**
- **WOR-WORK ORDER REQUEST**
- **PPM-PART PER MILLIONTH**
- **IES-INSTITUTE OF ENVIRONMENTAL SCIENCES**
- **IR- INFRARED**

1.O PURPOSE

The purpose of this procedure is to define the cleanroom operational requirements, gowning protocol, equipment/hardware cleaning requirements, personnel rules protocol, and entrance/exit requirements for the laser build All users shall be required to don the same cleanroom garments, follow similar personnel rules, and pre-clean or bag items entering the facility.

1.1 Reference Documents

Document Number Document Title

FED-STD 209 , Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones
MSEC:09PC-FP03, Contamination Control
MSEC:09PC-WI07, Big Top Clean Tent ESD Floor Maintenance
MSEC:09PC-FP12, Clean room Operations & Multi-Projects
MBLA-CP-001, Cleaning Procedure For Plastics, Elastomerics Parts
MBLA-CP-002, Cleaning Procedure for Metallic Parts
MBLA-CP-004, Cleaning Procedure for Fasteners & Miscellaneous Small Parts
MBLA-CP-005, Cleaning Procedure for Support Tools and Equipment
MBLA-CP-006, Cleaning Procedure for Assemblies and Components
MBLA-CP-007, Optics Cleaning, Handling and Packing Procedure
MIL-STD-1246C, Product Cleanliness Levels and Contamination Control Program
NASA JSC SP-R-0022A Vacuum Stability, Requirements of Polymeric Materials for Space Out-gassing Data for Selecting Satellite Materials
Out-gassing Data for Selecting Spacecraft Materials Publication 1124
MSFC-HDBK-527, Materials Selection List for Space Hardware Systems, JSC 090604
SN-C-0005C, Contamination Control Requirements for the Space Shuttle Program

2.0 Re-Certification

During normal operations, conditions may exist which demand that the facility be re-certified. The Clean room Operations Group will be responsible for: review of the specific event, determining if the clean room needs to be re-certified and identifying the tests and activities necessary for certification. Certification or re-certification shall be performed in accordance with Certification and Monitoring WI 09PC-WI10. The following conditions or violations are examples of situations that would normally require re-certification: **NOTE: A RIBBON SHALL BE ATTACHED TO THE FILTER**

BANK, INDICATING POSITIVE FLOW AND FILTRATION SYSTEM IS OPERATIONAL.

Recertification of cleanrooms shall be required in all of the following situations:

1. Any time the airborne particulate count exceeds the associated class conditions (100,1000 or 10000) for a continuous 10-minute period. Note: Real-time particle counter monitoring required.
2. Any time structural changes are made in the clean room.
3. After any HEPA (High Efficiency Particulate Air) filter is repaired, removed or replaced.
4. If the facility is shut down for an extended period, the clean room must be thoroughly cleaned and certified prior to the initiation of operations.
5. Anytime power is interrupted, the cleanroom should be re-cleaned and re-certified. If power outage is planned, all critical hardware should be bagged in accordance with this document.
6.Anytime the ribbon attached to filter bank is not moving.

Clean room operations personnel contact list:
There shall be a list of personnel that can initiate Recertification of the cleanroom.

3.0 Maintenance

3.1 Routine Cleaning

Routine cleaning of a clean facility is essential in order to maintain the classification of the facility. Proper procedures, equipment and materials, as well as personnel are important in maintaining the cleanroom environment.

3.1.1 Only approved cleanroom operations group personnel and their designees will be allowed to participate in the cleaning of the facility.

3.1.2 All cleaning equipment must be cleaned to the same cleanliness standards as required for hardware entering the facility. Whenever possible, equipment used in "clean areas" will not be removed except for repair or replacement, and “clean area” equipment may not be used in a "non-clean" area. The Clean room Operations Group must approve all equipment and materials for use.

3.1.3 As a general rule, do not clean above un-bagged flight hardware. Remove or Double Bag Hardware before cleaning process

3.1.4 Limit movements during cleaning operations. The dragging of chairs, ladders, equipment, hoses, etc., should be kept to a minimum.

3.1.5 Cleaning of the facility may, but will not normally take place during any testing or integration activity and must be coordinated with users of the facility. Cleaning activities should be limited to off shifts where possible so as not to interfere with critical operations.

3.1.6 Cleaned areas must be reviewed by the senior technician, supervisor, or their designee and approved prior to the commencement of any certification. Reference Routine Facility Cleaning Procedure.

3.2 Equipment Repair

Maintenance activities can seriously stress and challenge the environment within a clean room. As a result, certain steps and precautions must be taken to limit the negative impact of any clean room maintenance program.

3.2.1 Maintenance activities should be scheduled so as not to interfere with critical operations. If it becomes absolutely necessary to make repairs during testing of experimental hardware, extreme care must be taken to protect the components from any "maintenance fall-out." Use distance and protective shields where applicable. Double bag hardware

3.2.2 In order to minimize unscheduled shutdowns, a good preventive maintenance program will be established.

- An adequate supply of spare parts will be kept on hand at all times.
- Maintenance shall perform periodic systems checks to prevent unforeseen equipment malfunction or systems failure.

3.2.3 All tools or equipment used for repair will be treated as GSE, i.e.; they must be cleaned prior to entry into the clean room. Reference: Support Hardware MBLA-CP-005 Cleaning Procedure.

3.2.4 Any repair activities must be coordinated with the Clean room Operations Engineer, supervisor, or their designee. This will prevent any negative impact on project activities within the facility.

3.2.5 High particle generating activities such as drilling and soldering are prohibited. However, if it becomes absolutely necessary, take care to protect the environment by:
Coordinating with the Cleanroom Operations Group,
Whenever possible, physically isolate the activity,
Using a vacuum at the point of contact to remove particles,
Use of a particle counter to monitor the activity may be required,
Clean and verify hardware once task is completed.

4.0 Rules and Regulations

4.1 Tools and Equipment

- Tools selected for the clean room should be chosen to minimize the generation of particulate matter.
- They should be of high quality.
- Rough surfaces should be coated with epoxy or polyurethane approved by a cognizant materials engineer.
- Tools should be inspected prior to use for wear or abrasion.
- Tools must be cleaned prior to entry into a clean facility. Reference MBLA-CP-005 for cleaning procedure.
- In order to control the generation of contamination, the facility monitor or Clean room Operations Representative may control Tool/Equipment entry.
- Any exhaust should be dumped outside of the room.
- Bearings should be self-lubricated.
- Permanent connections should be constructed of non-particulating, low-shedding materials.

- Any moving parts should be covered where possible to prevent particle generation the room.
- No drilling or sanding is allowed without prior knowledge and approval of all users of the room, cleanroom maintenance personnel, and management.

5.0 STANDARD CLEANROOM REGULATIONS FOR AEROSPACE APPLICATIONS

5.1 PERSONNEL REGULATION:

- Eating, drinking, smoking, or chewing gum is not allowed in the cleanroom or gowning room. If any of these things are done prior to entering the cleanroom, drink water to rinse mouth before entering the gowning room.
- No cosmetics, aftershave, perfume, or aerosols should be worn by anyone entering the cleanroom.
- No personal items are allowed in the gowning room or cleanroom.
- Cleanroom garments are to be worn at all times. Do not begin removing cleanroom garments until fully inside the gowning area.
- Cleanroom garments are not to be worn outside of the cleanroom and gowning area.
- Jewelry that may tear gloves or become caught on the coveralls or hood may not be worn in the cleanroom.
- Valuable personal items such as wallets may be brought into the cleanroom if they are secured within a pocket of the street clothing and concealed be the cleanroom garments.
- Do not touch any of the exposed part of the face. If this is necessary, return to the gowning area and change gloves.
- Personnel experiencing severe sunburn, a cold, or excessive coughing or sneezing may not be allowed in the cleanroom. The condition will be monitored and evaluated daily
- Avoid solvent contact with the bare skin as most solvents cause irritation and dryness. Skin lotions or lanolin-based soaps should be used to prevent excessive skin flaking.
- Personnel will move precisely and at a normal pace. Quick, sporadic movement or shuffling feet will disturb settled particulate matter.
- Latex gloves/Chemsoft CE/ or other approved gloves will be worn when working directly in the cleanroom. When working with solvents, polyethylene gloves will be worn over the latex gloves to prevent the latex from degrading.
- Cleanroom gloves to be used with laser hardware shall be selected in conjunction with contamination control engineering, and materials engineering to assure that the gloves will not present a significant contamination risk.
- If gloves or garments become soiled or torn, return to the gowning area and change gloves or garments.

5.2 Standard Cleanroom Operating Procedure:

- Keep flight hardware covered with bagging material during periods of inactivity or during contamination generating activities.

- Avoid direct contact with the flight hardware except when activities require. Use precision-cleaned drivers, wrenches or other precision-cleaned tools to manipulate parts.
- Personnel will be electrically grounded with ESD wrist straps and grounding cords before touching any flight hardware and/or when within three feet of the hardware.
- When working on clean benches, make sure that the HEPA filters are operating.
- Do not sit on work surfaces or stand on chairs.
- Before being taken into the clean area, parts and GSE will be cleaned. CC personnel will be responsible for cleaning flight items and GSE per defined Cleaning Procedure.
- Equipment that is being moved from one clean area to another may be double bagged while inside the first clean area to avoid re-cleaning.
- The bagging material will be cut with a razor and sealed with K102 Kapton tape or other approved cleanroom tape. Bagging material should not be torn open as tearing generates particles.
- If double bagged, the outer bag will be removed before being taken into the clean area. The inner bag will be removed inside the clean area.or staged on cleanbench.
- Any tool removed from the cleanroom must be re-cleaned upon re-entry into the cleanroom. Tools will be cleaned CC personnel.
- When bagging items with Llumalloy, the metal-coated side must face away from the hardware to prevent metal flakes from contaminating the clean item and to ensure protection from static charges.
- Minimize activity that obstructs the air flow from the HEPA filters to the flight hardware. Work "downstream of the flight hardware whenever possible to avoid contamination generated by movement.
- Contamination-generating activities must be directly followed by vacuuming with a HEPA-filtered vacuum and an alcohol wipe down with polyester cleanroom wipes or swabs. Vacuuming will be performed during the activity where possible.
- Any tool requiring compressed air or nitrogen must be connected to a filtered compressed air source in the cleanroom, exhaust from air tools should be vented outside of the cleanroom. All air lines and extension cords must be cleaned and bagged in approved bagging film before being brought into the cleanroom.
- When work requires contact with the floor, either cover the floor area with a piece of bagging film, or return to the gowning area after completing the work, to change into clean coveralls and gloves.
- Do not pick up and reuse an item that has dropped to the floor. The item must be precision cleaned before it is used again.
- Do not tear cleanroom paper or bagging material in the cleanroom or gowning area. These materials will be cut with a razor blade or scissors as tearing generates particles.
- Only non-retractable ball point pens will be used for writing in the cleanroom.
- Solvents needed in the cleanroom will be kept in Teflon or fluorocarbon bottles that will not leach molecular contaminants into the solvent.
- Solvents and detergents to be used in the cleanroom will be stored in Teflon or fluorocarbon bottles when inside the cleanroom. The solvents may be stored in other approved containers when outside of the cleanroom.

- The amount of cleanroom paper in the cleanroom should be kept to a minimum. Documents needed in the cleanroom will be on lint-free cleanroom paper and bagged for transport. If this is not possible, the documents will be bagged in clean bagging material and remain so while in the cleanroom. Paper should be kept downstream of flight hardware.
- Wipes/swabs will not be dipped into a container of solvent--this practice contaminates the solvent. Solvent will be stored in cleanroom approved squirt bottles and used to wet wipes/swabs.
- Check with the CCE before drilling, abrading or soldering.
- When drilling, abrading or soldering:
  - Cover as much of the flight hardware as possible with bagging material.
  - Vacuum contamination with a HEPA filtered vacuum as it is generated during drilling or abrading.
  - Vacuum the floor area. Wipe the surfaces clean with solvent soaked wipes or swabs.
- The CCE should be consulted concerning special cases that are not covered in this document.

5.3 Specific Regulations:

- No aerosol spray cans are allowed in the cleanrooms. These include pressurized air cans for dusting and/or cooling purposes. The aerosol cans contain molecular contaminants, and may contain particles that deposit on the surfaces.
- ESD protection and ground straps must be worn when touching ESD hardware or any time you are within three feet of the item.
- Oxygen sensors shall be placed near each purged instrument for personnel safety.
- Anytime a screw or other fastener is tightened, removed, loosened, a HEPA Vacuum should be used to pick up any particle shedding.
- Whenever an optic mount is moved or removed, the location of that optic should be wiped down with solvent (IPA) moistened swabs until no free particles are removed.
- When fasteners are removed from a flight article in a laser optical cavity, the threaded holes should be swabbed with a moistened swab to remove shed particles.
- Optic cells and cell holders should be damp swabbed prior to installation and whenever the optic cell is removed from the cell holder.
- The Laser Optical Bench is sensitive to contamination for various reasons. It must be kept bagged or closed at all times unless testing or integration requires access. The Hardware will be immediately bagged up once the testing or integration activity is complete.
- All GSE prior to entering the cleanroom must pass through CC personnel to access its compatibility with a clean environment and the laser hardware.

5.4 Personnel Discipline

- Before you enter the changing room, there are several things you must follow:
  - Bathe before coming to work.
  - Do not use any powder.

- Do not use hairspray.
- Use skin lotions or lanolin-based soaps. They provide a good means of tightening skin pores and minimizing flakes.

- Note: Clean facilities offer no guarantee of security for personal items. Highly valuable personal items MUST be stored in a secure area away from clean facilities.

6.0 Access Patterns

6.1 Personnel Access

6.1.1 All personnel requiring access to the Cleanroom facilities shall read, understand and comply with the cleanliness requirements and all cleanroom operating procedures for the project.
6.1.2 Exceptions to the above because of one time or infrequent entry may be made by special authorization. A certified individual must accompany personnel who have received a special exception.
6.1.3 All personnel, and cleaned-bagged hardware should access room through one gowning room and air shower. Only one entrance/exit shall be used in accessing a cleanroom, unless the entrances are interlocked to prevent simultaneous opening. Wipe exterior bag lightly with IPA and recommended wipes before entrance into air-shower, to remove contamination accumulation during transport.

6.2 Gowning Procedure

PERSONNEL ENTERING THE CLEAN ROOMS MUST WEAR FULL CLEANROOM GARMENTS. THIS INCLUDES COVERALLS, HOODS, BOOTS, MASK AND GLOVES.

Hang up your lab coat or outer jacket outside the change area in a separate office area.

- Remove all jewelry and personal items from your pockets and store them in the office area.
- Sign the clean room entry log.
- Use the shoe cleaner. Clean one shoe, and then clean the other shoe.
- Retrieve a hood, coverall, and boots from the garment storage area. Cut the bags open with a scissors. As you don each garment, inspect them for damage and cleanliness. Return soiled or damaged garments to the appropriate container. Discard any mask or glove which may fall on the floor during the gowning procedure.
- Hood: Put on the hood first, making sure all your hair is covered. Snap shut for a snug fit.
- Coveralls: Next, remove the coverall from the bag. Unzip the coverall and step into the garment, taking care to prevent the uniform from excessive dragging on the floor. Insert your arms into the sleeves and pull up the zipper. Be careful to not get the garment stuck in the zipper. Tuck the hood flap inside the garment and snap all the snaps at the neck, wrist and ankles.
- Booties: sit down on the clean bench. Remove the Boots from the bag. Slip a bootie over one shoe. Place the bootied foot into the designated clean area without touching the floor outside the clean area. Repeat for the other shoe.

- Face Mask: put on a mask, completely covering the mouth and nose. All personnel having a beard and/or mustache must wear a beard cover. Make sure that all the hair is covered.
- Dispose of opened plastic bags into the waste cans.
-
- Gloves: Put on a pair of latex gloves/Chemsoft CE Nitrile.
- Inspect clothing, make sure garments are tucked in and all snaps are closed, perform visual inspection.
- Step on the tacky mat and then enter the air shower.
- Once the air shower has stopped, open the door and enter the cleanroom.
- Gowning room is divided by bench, clean side/dirty side.(Booties/street shoes)

6.3 Ungowning Procedure

- Re-enter the change room. One person at a time.
- Remove the garment in the opposite order as put on:
- Remove the gloves and mask and discard.
- Sit on the gowning seat and unfasten the boots. Remove one boot and then the other.
- Place the boots on the boot rack at the base of the clean garment storage rack.
- Remove the coverall and place on your hanger(label the hanger) on the clean garment storage rack. NOTE: Do not allow the garment to touch the floor.
- Remove the hood and snap to the coverall in the closet.
- The coverall and hood may be placed in the "dirty" uniform container if they are not to be reused. Boots may be placed at the base of the clean garment storage rack.
- Sign out on the log sheet.

NOTE: Cleanroom garments may be reused only during the same workday. The Contamination Control Engineer may designate longer periods of use depending on use, activity, and schedule.

7.0 QUICK REFERENCE GUIDE

Note: The following tables provide a quick references defining, cleaning techniques, specific cleaning procedure, cleanliness requirements, inspection and verification methods for all flight and associated hardware for laser project. See Appendix A for a list of detailed procedures, cleanliness requirements, inspection and verification methods.

TABLE I CLEANING GUIDE

METALLIC STRUCTURES Aluminum, stainless steel, copper		Procedure A Refer to MBLA-CP-002			Bake-out required
OPTICAL ASSEMBLIES Metallic mounts			Procedure B Refer to MBLA-CP-006		Bake-out required
Plastics/Elastomers				Procedure B Refer to MBLA 001	Bake-out required
O-rings/Gaskets: Viton		Procedure A Refer to MBLA-CP-001			Bake-out required
Large Metal Components/ Small parts		Procedure A Refer to MBLA-004/006			Bake-out required
Support tools/tool boxes				Refer to MBLA-005	Bake-out not required
Electrical/Solder Components, (water sensitive)				Procedure D Refer to MBLA-005	Bake-out required
Non-metal components Teflon, Delrin, ceramic		Procedure A Refer to MBLA-001			Bake-out required

TABLE II CLEANING PROCEDURE

Procedure A	Inspection Method	Verification Method	Particulate/Molecular Levels
Ultrasonic cleaning using deionized water and Alconox solution. If items are greasy or contain oil, use Simple Green Crystal instead of Alconox. Leave submerged in ultrasonic cleaner for 30 minutes. Remove from ultrasonic cleaner; thoroughly rinse items with deionized water. Rinse part in a fresh container in the ultrasonic bath for 15 minutes in deionized water. Rinse part in Optima grade IPA, Dry hardware with filtered GN2/ Compressed air. Or manual cleaning with IPA and extracted wipes.	Qualitative inspection methods should include; high intensity white light and UV light inspection for particulate and molecular contamination. Inspect from a distance of 2-4 inches from hardware wearing safety goggles. Particles may be removed by vacuuming, fluorescing compounds maybe removed by wiping with solvents (IPA, Acetone). Repeat Procedure A if fluorescing compounds are difficult to remove.	Critical Hardware, ie. laser components will require quantitative verification. A NVR rinse should be performed to verify surface cleanliness level for molecular contamination. Tape sample should be performed for verification of particulate surface cleanliness level. These verification methods should be performed before bake-out.	Particulate Surface cleanliness levels <50 per Mil-Std-1246. Molecular Surface cleanliness level < $0.1\mu g/cm^2$ In the absence of a surface area measurement, the mass of NVR in the rinse shall be reported.
Procedure B			
Optical Components, mount structures that cannot be immersed should be vacuumed and IPA wiped. Extracted swabs and IPA or Acetone may be used for small crevices or screw holes. Refer to	Perform visual inspection methods.	Perform Tape lift and NVR analysis, prior to bake-out.	Particulate surface cleanliness level <50 per Mil-Std-1246. Molecular NVR analysis $<0.1\mu g/cm^2$

MBLA –006 Component Procedure			
Procedure C Coated Optics, cleaning coated optics should be performed only by laser project personnel. Refer to Optics Cleaning Procedure MBLA-007	Perform visual Inspection methods using 30x magnification or higher and multiple lighting conditions. Document optics using photomicrographs	NA	NA
Procedure D Items that cannot be immersed should be vacuumed, then wiped with wipes moistened with IPA, then dry with filtered GN2/compressed air.	Perform visual Inspection methods.	Perform Tape Lift/NVR Verification prior to bake-out.	Particulate surface cleanliness level <50 per Mil-Std-1246 NVR Analysis <0.1μg/cm2

Appendix ZERO: Cleaning Procedure-000 Cleaning Supplies and Equipment

1.0 This is the Zeroth appendix, Upon which the document stands

2.0 Cleaning Supplies

- Swabs and Wipes used in Precision Cleaning Operations Shall be soxhlet extracted in the solvent in which they will be used, and a known number of swabs or wipes analyzed for extractables quantitatively and qualitatively.
- Swabs that clump or degrade in a solvent shall not be used in that solvent. If the swabs are NASA approved, and use with the solvent is not prohibited by the manufacturer, a NASA alert or Advisory should be issued.
- Extracting polyester clean room wipes and swabs in multiple solvents frequently results in the degradation of the wipe, resulting in particulate generation.
- Solvents of the highest purity available shall be used for final precision cleaning of optics, and certificates of analysis/compliance should be obtained.
- Fluoropolymer wash bottles shall be used for all solvents used in final precision cleaning of laser parts.
- Polyethylene Gloves should be used for all solvent operations. A solvent wetted wipe should be used to wipe down the polyethylene gloves after donning to remove solvent removable contamination from the gloves.
- Tongs or forceps should be used when possible with wipes when carrying out final cleaning to prevent extracting material from gloves.

3.0 Rules for Cleaning Apparatus

All cleaning supplies exposed to flight hardware or solutions, which contain or have contained flight hardware, shall be considered single use until their cleanliness is verified by this procedure.

- Any cleaning apparatus to be utilized for cleaning laser hardware shall be inspected visually for signs of contamination.
- All cleaning supplies shall be stored in a manner consistent with maintaining cleanliness of the cleaning supplies.
- Beakers and other containers shall be kept inverted and covered when not in use to prevent inadvertent contamination.
- Tongs, forceps, etc. shall be blown dry and bagged an bags that have been solvent wiped.
- Containers used for NVR testing shall be made of borosilicate glass and have ground glass stoppers. These containers shall be baked clean in a laboratory furnace in air at 550-600° C for at least two hours to remove

any molecular contamination. Verification of furnace cleaning adequacy is carried out using a black permanent marker, a mark on the glassware entering the oven must be gone at the end of the cleaning cycle. The glassware so cleaned should be placed into the furnace with the furnace at 150°C or below and then heated to temperature. The furnace and glassware should then be allowed to cool to 150°C or below before removing. Stoppers should be placed in the container and covered with food-grade aluminum foil for storage.

4.0 Verification of Cleaning Apparatus

All hard surface cleaning equipment shall be verified clean by one of two ways.

- For metallic and glass cleaning equipment that poses a potential for transfer of material by direct or solution contact with laser components shall be rinsed three times with clean deionized water, the water shall be allowed to flow out or off of the piece and it shall be verified that the water sheets off of the surface of the equipment without beading. A lack of sheet flow from the surface indicates that the surface is contaminated. Any contaminated cleaning apparatus shall be rigorously cleaned until water sheets from the surface. Water used for testing that has detected contamination shall be disposed of immediately, and its container re-verified by the above procedure.

- For polymeric material with a surface energy less than water, i.e. Teflon, Viton, Polyethylene, the article shall be rinsed with IPA, and the rinse tested for NVR. Solvent rinse bottles and storage containers shall be allowed a minimum of 24 hours leaching time with a solvent prior to the NVR test.

5.0 Contaminated Cleaning Apparatus

All cleaning hardware indicted, as being contaminated, shall be immediately segregated from other cleaning equipment to be removed from the cleaning area, and marked as contaminated. Any flight hardware cleaned using these items shall also be indicted as contaminated, back to the last verification of cleanliness per this procedure.

Cleaning equipment found to have strongly adhered hydrophobic contamination shall be cleaned utilizing appropriately rigorous cleaning methods, or be removed from use to assure no cross-contamination of flight hardware.

APPENDIX A MBLA-CP-001 Plastics, Elastomerics Parts

CLEANING PROCEDURE
FOR PLASTIC, ELASTOMERIC PARTS

1.0 SCOPE

This document describes the cleaning procedure to be used for plastic and elastomeric parts, such as Viton o-rings, bumpers, and gaskets, Delrin moldings, Teflon insulators, rod seals, and gaskets, using solvent wiping cleaning methods.

In general, the solvent wiping methods described in these cleaning steps will utilize Optima Grade isopropyl alcohol (IPA) for most operations. Acetone may be used for hard-to-remove contaminants only on Delrin and Teflon. Other solvents such as MEK and toluene shall not be used on these materials (except for Teflon) because of susceptibility to degradation. Check surface compatibility with any solvent prior to use.

All cleaning of plastic and elastomeric parts shall take place in a Class 100 clean bench or in the PCF.

2.0 REQUIRED MATERIALS AND EQUIPMENT

Optima grade IPA (isopropyl alcohol)
Optima grade Methylene Chloride
Extracted cleanroom wipes
Chemsoft CE and Polyethylene gloves
Optima grade acetone (For Delrin and Teflon Parts ONLY)
Grade B GN_2 with 0.5 μm particle filter, or filtered compressed air
Stainless steel mesh strainer
100 watt inspection lamp (white light)
Long-wave UV inspection lamp
Hepa Filtered Vacuum Cleaner

Restrictions

No solvent should be used on a polymeric or elastomeric part with out prior approval by a cognizant Materials Engineer. Failure to comply with this mandate may result in destruction of the part or failure of the laser system.

Note: Viton Components

Each lot of Viton components shall be wiped down with methylene chloride solvent wipes and then baked out under vacuum oven at 190°C for 24 hours per 2 mm thickness, either with a scavenger plate or a nitrogen purge to remove plasticizers, residual surface lubricants, and other NVR materials. Following bakeout, the parts should be solvent wiped with methylene chloride a second time. The adequacy of the bake out of each lot is to be verified by high temperature solid

probe mass spectrometry. Only trace levels of volatile material present prior to the decomposition of the Viton polymer shall be acceptable.

Viton Components shall then be surface cleaned and verified per the existing procedure prior to use.

3.0 CLEANING STEPS

These cleaning steps are to be performed on a Class 100 clean bench or in a precision cleaning facility.
Note: All personnel shall wear safety goggles and be familiar with the MSDS for all solvents/cleaners used during the cleaning operations.

Note: No MEK or Toulene shall be used on any laser hardware without the approval of the Materials Engineer. This approval shall include the scope and location of the use of MEK or Toluene.

Note: If acetone is used to clean Delrin or Teflon hardware surfaces, a final solvent wipe with IPA, as in Steps 3.1.2 and 3.1.3 above, is required in order to remove any residuals. Again, do not use MEK or toluene without approval.

3.1 Ultrasonic cleaning

Ultrasonic Cleaning should be performed on plastic and elastomer parts whenever possible, especially those parts which have crevices, holes, etc. Ultrasonic cleaning provides a good mechanism for removing molecular films, soils, and particulate matter from hardware by loosening action. Ultrasonic cleaning is effective in removing particles of 50 microns in size or larger and is effective in cleaning difficult to reach areas such as screw threads and items with threaded blind holes. All cleaning personnel shall wear polyethylene gloves when using solvents on hardware.

- 3.1.1 Items should be placed in a glass beaker with enough solvent to immerse the items and then the beaker placed in the ultrasonic cleaner tank filled with water.
- 3.1.2 Glass containers should be used instead of plastic containers because glass is a better conductor of sound.
- 3.1.3 Items are not to be densely packed in the cleaning container to ensure the solvent is in contact with the hardware's surface as much as possible.
- 3.1.4 Determine which solvent is best for the plastic/elastomeric part (check cert log).
- 3.1.5 Immerse item in solvent and place in ultrasonic cleaner filled with water.

- 3.1.6 Turn on cleaning unit, and allow to clean for at least 10 minutes. Experience with cleaning different types of parts may lead to different minimum cleaning times.

- 3.1.7 Rinse the hardware with a stream of clean solvent collecting the rinse into the solvent used in the ultrasonic cleaner.

- 3.1.8 Recycle the parts through the procedure from steps 3.1.5 through 3.1.7, then continue to step 3.1.9

- 3.1.9 The processed item should not be allowed to air dry when the ultrasonic cleaning operation is completed. This may cause loosened soil or particulates to redeposit on item surfaces or hard to reach areas such as crevices.

- 3.1.10 Blow off the excess solvents immediately after the ultrasonic cleaning using clean filtered compressed air or filtered GN_2.

3.2 Solvent Wipe Cleaning :

- 3.2.1 Obtain solvent wash bottles filled with IPA and extracted cleanroom wipes. Teflon bottles are ideal. All cleaning personnel shall wear polyethylene gloves when using solvents on hardware.

- 3.2.2 Lightly saturate an extracted wipe with Optima Grade IPA.

- 3.2.3 Wipes shall be used over hardware surfaces in a slightly overlapping unidirectional pass in either vertical or horizontal direction.

- 3.2.4 Wipes shall be folded and refolded several times during a cleaning operation so that a clean section of the wipe is exposed.

- 3.2.5 Change wipes as they become contaminated.

- 3.2.6 Change gloves as they become contaminated

- 3.2.7 Repeat the cleaning steps rotating the direction of the wiping 90 degrees to account for structure contamination retention.

- 3.2.8 Rinse the suspended part with a stream of IPA from a wash bottle. Assure that the area used to suspend the part is not wetted.

- 3.2.9 Allow the solvent to sheet off , then blow of solvent with filter GN2.

- 3.2.10 Invert the part, rinse the previous suspension point, and blow off solvent.

- 3.2.11 Aspiration of the solvent from the holes is preferable; aspiration equipment can be specified if required.

- 3.2.12 Continue cleaning until there is no residue that shows up on the swab.

- 3.2.13 Dry hardware thoroughly using filtered compressed air or filtered GN_2.

4.0 Verification

The hardware that has been cleaned shall receive an inspection, qualitative and quantitative verification prior to double bagging.

4.1 QUALITATIVE VERIFICATION:

Personnel should wear safety goggles and appropriate cleanroom attire.
Inspect with a 100W white light inspection lamp for any visible particles. For reflective surfaces, hold the light and view the surface at an angle. Inspection that detects localized molecular contamination should be followed by a solvent stream rinse or recycling through the modified ultrasonic cleaning process.

- Remove particles using a HEPA-filtered vacuum.
- Turn on the UV inspection lamp and allow to warm up. Turn off the lights in the cleanroom or clean tent. Alternately, item may also be placed in a darkened inspection box.
- Inspect cleaned hardware for particles and for any molecular contaminants that fluoresce in UV light. Use solvent dampened wipe to remove molecular contamination or repeat steps for Ultrasonic and Solvent Wipe cleaning, as listed above. Use HEPA-filtered vacuum to remove any particles.

4.2 QUANTITATIVE VERIFICATION:

For quantitative verification of surface particulate levels, a tape lift sample may be taken and analyzed. To obtain a quantitative verification for determination of cleanliness levels of hardware cleaned, and NVR rinse sample should be taken.

- Estimate 1 sq.ft., or more, or hardware, if possible, and note surface area estimate. In the absence of the surface area estimate, note the number of parts.
- Rinse with clean Optima IPA collecting rinsate in a clean glass jar. (this can be done in a number of ways, e.g. using strainer and aluminum foil, but all collecting aids used must be pre-cleaned with IPA.
- Provide rinsate and an IPA control sample to analysis lab. NVR control sample shall come from the same wash bottle used for the collection of the NVR sample. The volume in the control shall be approximately the same volume as the NVR sample.
- Results for sensitive hardware should be (at most) <0.1mg/sq.ft.($\mu g/cm^2$) NVR, with no silicones present. If these levels are not obtained, repeat cleaning process. If the surface area estimate is not provided, report the net mass of contaminant. Note: IPA control sample should have <<0.1 mg NVR.

4.3 PACKAGING

After cleaning and verification, hardware should be double bagged in Llumalloy bagging film that has been IPA wiped and blown dry. Bagged hardware may transported under the project guidelines for controlled hardware.

APPENDIX B MBLA-CP-002 Metallic Parts

CLEANING PROCEDURE FOR METALLIC PARTS- 002

1.0 SCOPE

This document describes the cleaning procedure to be used for large metallic structure piece parts or hardware, such as base plates, bars, structures, enclosures, housings, clamps, and lens cells, using solvent wiping cleaning methods. In general, the solvent wiping methods described in these cleaning steps will utilize Optima Grade isopropyl alcohol (IPA) for most operations. Acetone, MEK or toluene may be used for hard-to-remove contaminants. There should be no material compatibility problems with the use of these stronger solvents since the metallic hardware materials are generally aluminum, stainless steel and copper. Chlorine, bromine, iodine and fluorine containing solvents should not be used without prior approval of the cognizant materials engineer, to prevent degradation due to corrosive residue or stress corrosion issues.

All cleaning of metal parts will take place in a controlled environment.

2.0 REQUIRED MATERIALS AND EQUIPMENT

Optima grade IPA (isopropyl alcohol)
Extracted cleanroom wipes
Extracted Swabs
Polyethylene gloves
Optima grade acetone
Certified grade MEK
Optima grade toluene
Grade B GN_2 with 0.5 micron particle filter, or filtered compressed clean dry air
Stainless steel mesh strainer
100 watt inspection lamp (white light)
Long-wave UV inspection lamp
HEPA filtered vacuum cleaner

3.0 CLEANING STEPS

ALL PERSONNEL SHALL WEAR SAFETY GOGGLES AND BE FAMILIAR WITH THE MSDS FOR ALL SOLVENTS/CLEANERS USED DURING THE CLEANING OPERATIONS.

ALL CLEANING PERSONNEL SHALL WEAR POLYETHYLENE GLOVES WHEN USING SOLVENTS ON HARDWARE.

NOTE : NO MEK OR TOLUENE SHALL BE USED EXCEPT WITH PRIOR APPROVAL.

3.1 Obtain solvent wash bottles filled with IPA and approved cleanroom wipes. Teflon wash bottles are ideal.

3.2 Lightly saturate a cleanroom extracted wipe with solvent. Wipes shall be used over hardware surfaces in a slightly overlapping unidirectional pass in either vertical or horizontal direction. Wipes shall be folded and refolded several times during a cleaning operation so that a clean section of the wipe is exposed. Rotate wipe direction 90° for each subsequent wiping cycle.

3.3 Repeat Step 3.2 until there is no residue that shows up on the wipe.

NOTE: If acetone is used to clean hardware surfaces a final solvent wipe with IPA, as in Steps 2 and 3 above, is required in order to remove any residuals. No MEK or toluene except by prior approval as noted above. A mixture of 3 parts Optima Hexane or Heptane and 2 parts Optima IPA can be substituted for Toluene or MEK.

3.3 If any drilled or tapped holes are in the hardware, use cleanroom approved extracted swabs wetted with acetone to remove residue from these holes. Continue cleaning until there is no residue that shows up on the swab. Perform a final cleaning of these holes with cleanroom approved swabs wetted with IPA.

3.4 Dry hardware thoroughly using filtered compressed air or filtered GN_2.

4.0 Verification:

The hardware that has been cleaned shall receive an inspection, qualitative and quantitative verification prior to bagging for transportation.

4.1 Qualitative Verification:

Inspect with a 100W white light inspection lamp for any visible particles. Remove particles using a HEPA filtered vacuum.
Turn on the UV inspection lamp and allow to warm up. Turn off the lights in the cleanroom or clean tent.

Inspect cleaned hardware for particles and for any molecular contaminants that fluoresce in UV light. Use solvent dampened wipe to remove molecular contamination (first try IPA, then, 3 parts mixture Optima Hexane or Heptane and 2 parts Optima IPA) or repeat steps 1-5. Use HEPA filtered vacuum to remove any particles.

4.2 Quantitative Verification:

Perform quantitative verification for determination of cleanliness levels of hardware cleaned.

- Estimate 1 sq.ft., or more, of hardware and note surface area estimate, or part count.
- Rinse with clean IPA collecting rinsate in a clean glass jar. (this can be done in a number of ways, e.g. using strainer and aluminum foil, but all collecting aids used must be pre-cleaned with IPA. See NVR analysis instructions for sampling procedure.
- Provide rinsate and an IPA control sample to analysis lab.
- Results for sensitive hardware should be <1.0 mg/sq.ft. NVR, with no silicones present. If this is not obtained, repeat steps 1-5. If silicones are present, toluene may be required if approved in place of the IPA in steps 1-5. Note: IPA control sample should have <0.1 mg NVR. **If surface area measurement is not available, the actual mass of NVR per part must be reported.**

4.3 Packaging:

All cleaned and inspected hardware must be double bagged, using approved Llumalloy bagging material. The cert-log should be updated, and responsible person notified for pick-up.

APPENDIX C MBLA-CP-004 FASTENERS & MISCELLANEOUS SMALL PARTS

CLEANING PROCEDURE
FOR FASTENERS AND MISCELLANEOUS SMALL PARTS

1.0 SCOPE:

This document describes the cleaning procedure to be used for small piece parts such as nuts, bolts, washers, helicoils, and other miscellaneous parts that can fit into a beaker to be placed in the ultrasonic cleaner. In general, the ultrasonic cleaning described in these cleaning steps will utilize Optima Grade isopropyl alcohol (IPA), Alconox or Simple Green Crystal for cleaning in most operations. Check surface compatibility with any cleaner prior to use.

2.0 REQUIRED MATERIALS AND EQUIPMENT

600 or 800 ml glass beakers
Simple Green Crystal(clear) or Alconox detergent
De-ionized or distilled water
Optima grade IPA (isopropyl alcohol)
Extracted cleanroom wipes
Polyethylene gloves
Optima grade toluene
Grade B GN_2 with 0.5 μm particle filter, or filtered compressed air
Ultrasonic cleaner (e.g. Branson) and timer
Stainless steel mesh strainer
100 watt inspection lamp (white light)
Long-wave UV inspection lamp
HEPA-filtered vacuum cleaner

3.0 CLEANING STEPS

Note: All personnel shall wear safety goggles and be familiar with the MSDS for all solvents/cleaners used during the cleaning operations.

3.1 Prepare Simple Green (clear) or Alconox and de-ionized water solution per manufacturer's directions, dilute further if undissolved detergent particles are present.
3.2 Place hardware into a clean beaker and add Simple Green Crystal (clear) or Alconox solution to immerse hardware.
3.3 Prepare ultrasonic cleaner per manufacturer's specifications, assuring the water level is adequate.
3.4 Insert beaker into cleaner, turn on heater and set timer for 30 minutes.
3.5 After 30 minutes, remove beaker from bath and pour entire contents into mesh strainer.
3.6 Flush contents with water.
3.7 Place hardware into a fresh clean beaker and immerse hardware in de-ionized water.
3.8 Prepare ultrasonic cleaner per manufacturer's specifications.

3.9 Insert beaker into cleaner, turn on heater and set timer for 30 minutes.
3.10 After 30 minutes, remove beaker from bath and pour entire contents into mesh strainer.

3.10.1 Immerse the strainer into a clean beaker of de-ionized water and agitate, if bubbles remain on the water after agitation stops, repeat rinse is clean water until no foam is observed after agitating again.

3.11 Place hardware in beaker, immerse with isopropyl alcohol (IPA) and allow to soak for at least 20 minutes, ultrasonic agitation can be used.
3.12 Swirl beaker around and observe fluid. If fluid looks clear continue with step 13, if not, repeat steps 1-12.
3.13 If fluid looks clear, remove one piece of hardware and wipe with IPA-dampened extracted cleanroom wipe. If hardware surface and wipe look clean, continue with step 14, if not repeat steps 1-13
3.14 Pour entire contents of beaker into mesh strainer and flush with IPA.
3.15 Perform Qualitative Verification.
3.16 Proceed to quantitative verification if required (see verification steps below.)

3.16.1 Assure that the parts are blown dry before packaging.

3.17 Package cleaned and inspected parts in cleanroom approved IPA wiped Llumalloy. Double bag parts.
3.18 Proceed to transportation and storage.

4.0 Verification:

The hardware that has been cleaned shall receive an inspection / qualitative verification prior to entering the cleanroom.

4.1 Qualitative Verification:

Dry hardware thoroughly using filtered, compressed air or filtered GN_2.
Inspect with a 100W white light inspection lamp for any visible particles. Personnel must wear safety goggles for light inspections. For reflective surfaces, hold light and view surface at an angle.

- Remove any observed particles using a HEPA-filtered vacuum.
- Turn on the UV inspection lamp and allow instrument to warm up. Turn off the lights in the cleanroom or clean tent. Alternately, item may be placed in a darkened inspection box.
- Inspect cleaned hardware for particles and for any molecular contaminants that fluoresce in UV light. For reflective surfaces, hold light and view surface at an angle.
- Use solvent dampened wipe to remove molecular contamination or repeat cleaning steps 1-14. Use a HEPA-filtered vacuum to remove any particles.

4.2 QUANTITATIVE VERIFICATION:

Perform quantitative verification for determination of cleanliness levels of hardware cleaned. This method does not give instantaneous results.

- Estimate 1 sq.ft., or more, of hardware and note surface area estimate, or not the quantity of parts.

- Rinse with clean IPA collecting rinsate in a clean glass jar. (this can be done in a number of ways, e.g. using strainer and aluminum foil, but all items used must be pre-cleaned with IPA. Submit for NVR analysis.
- Provide rinsate and an IPA control sample of similar volume to analysis lab.
- Results for sensitive hardware should be <0.1mg/sq.ft. ($\mu g/cm^2$) NVR, with no silicones present. If this is not obtained, repeat cleaning steps 1-16. If silicones are present, 3 parts Optima Hexane and 2 parts Optima IPA, may be required in place of the IPA in steps 1-14. Note: IPA control sample should have <<0.1 mg NVR.

5.0 PACKAGING:

After cleaning and verification, hardware should be double bagged in Llumalloy bagging film that has been IPA wiped and blown dry, and cert-log updated. Notify proper personnel for pick-up.

APPENDIX D MBLA-CP-005, SUPPORT TOOLS AND EQUIPMENT

CLEANING PROCEDURE FOR
SUPPORT TOOLS AND EQUIPMENT

1.0 INTRODUCTION

The purpose of this procedure is to provide an overall set of contamination-related recommendations and instructions on cleaning techniques for support tools and general support equipment for all cleanrooms needed for the laser project. The cleaning methods will reduce the transfer of molecular and particulate contaminants from support tools and support equipment to the critical hardware, during integration and assembly operations.

The recommendations and procedures contained herein are based on Swales Aerospace experience with maintaining aerospace hardware cleanliness levels during integration and assembly.

The recommendations discussed herein are applicable to all support tools and support equipment needed for assembly and integration of the laser systems. The procedure will address the necessary steps required for cleaning tools and equipment to minimize the generation and transfer of contamination during handling and integration.

All tools and support equipment used laser builds will benefit by implementing the cleaning procedures recommended in this document. Tools and equipment within the cleanroom contribute to contamination accumulations within the cleanroom environment. Contamination from these materials may affect the cleanroom environment by outgassing (vaporization and condensation processes), by contact transfer of contaminants, and by direct application of materials.

All tools and support equipment pose a contamination threat if not properly cleaned. The use of support tools and equipment can directly affect critical hardware and the cleanroom environment. The transfer of contamination in the forms of oils, particulate matter, or out-gassed species is a threat to the required cleanliness levels.
Shadow toolboxes provide safe storage environment, and a means of tracking tools, and verifying the return of each item after usage.

2.0 CLEANING MATERIALS AND EQUIPMENT

Class 100 Clean Bench
Ultrasonic Cleaner
Optima Grade Isopropyl Alcohol (IPA)
Optima Grade Acetone
Cleanroom Wipes
Extracted Wipes
Clean GN2/Compressed Filter Air
Cleanroom Tapes, Kapton, Mylar and Polyethylene

Llumalloy Material
HEPA Filter Vacuum or House System
Extracted Swabs
De-ionized (DI) Water
Simple Green (Crystal) or Alconox Detergent
Cleanroom Garments
Polyethylene and Chemsoft CE Gloves
UV or High Intensity White light
NVR Rinse Sample Kit
Shadow Toolboxes for storage of cleaned tools

3.0 SUPPORT TOOLS and BASIC EQUIPMENT CLEANING PROCEDURE

All support tools and support equipment (screw drivers, sockets, wrenches, ball drivers, consoles, and oscilloscopes) required within the cleanroom must be cleaned and inspected prior to being used in cleanroom facilities. Cleaned tools must be accompanied by proper documentation prior to cleanroom entry, to ensure that proper cleaning and packaging methods have been performed. Trained technicians performing this process will familiarize themselves with all cleaning materials and proper usage. Safety equipment (goggles) should be worn at all times when solvents and detergents are in use. Eye wash station and Material Safety Data Sheets (MSDS) should be readily available for referencing solvent flash points and other precautions for solvents and cleaners being used. The cleaning facilities (GCF/PCF) should be Class 10,000 or better and well ventilated.
Swales Aerospace recommends that shadow toolboxes of high quality be designated and implemented for laser programs. After tools/toolboxes undergo the cleaning and verification process, the items should be used only for integration and assembly of critical hardware. If an item is removed from the cleanroom, it must be re-cleaned and inspected before being taken into the cleanroom and used on flight hardware.
It is recommended that whenever possible, support equipment that contain fans be located outside of the critical integration clean areas. It is recognized that there are instances where fan-containing equipment will be required in the clean area. In these instances, steps must be taken to minimize the risk of contaminating critical hardware. Fan-containing equipment should be placed as far away from the critical hardware as possible, and should be located "downstream" (in the airflow) from the critical items. Exhaust from equipment should be ducted outside of the cleanroom, whenever possible. All equipment must be thoroughly cleaned and inspected prior to entry into the cleanroom.

3.1 Cleaning Support Tools and Equipment (which do not contain fans)

Support tools used in the cleanrooms should be of high quality, and furnished by reputable vendors. Any tool rough surfaces should be coated with approved epoxy or polyurethane encapsulents which minimize particulate generation and out-gassing. Equipment requiring lubricants must be cleaned and sealed in order to minimize the potential of out-gassing and molecular transfer. Workers are responsible for evaluating

the condition of each tool, and determining whether tool is excessively worn, or degraded. All degraded tools and equipment should be replaced with new equipment.

3.1.2Ultrasonic Cleaning

Ultrasonic cleaning may be done on any item, which can be immersed in liquid. The ultrasonic cleaner thoroughly cleans areas that are hard to reach, crevices, blind holes, and threaded screws. It will remove dust, oils, oxides, fingerprints, and greases. It is compatible with stainless steel, aluminum, brass, copper, glass, and most plastics. The combination of the ultrasonic frequency and the recommended cleaning solution on submersed items provides a uniform and cleaning method.

Trained personnel should inspect each item, and verify item compatibility with immersion cleaning and solvents. The ultrasonic cleaner should be cleaned and prepared per the manufacturer specifications. If the ultrasonic cleaner has a vapor degreaser or heat cycle, allow sufficient time to for the bath to reach operating temperature, prior to insertion of item to be cleaned.

- Small tools, screwdrivers, box wrenches, sockets, etc., should be placed in a stainless steel beaker containing a 10% solution of Simple Green (clear) or Alconox detergent and DI water.
- Immerse items in ultrasonic bath.
- Set ultrasonic timer for 30 minutes.
- Once time has elapsed, remove beaker from ultrasonic cleaner.
- Wear polyethylene gloves over Chemsoft CE gloves.
- Pour contents into a stainless steel mesh strainer; rinse thoroughly with DI water.
- After DI rinsing, flush item with Optima Grade IPA.
- Items should be dried immediately with filtered GN_2/Compressed Air.
- Remove hardware from strainer and place on Class 100 Cleanbench or clean stainless steel table in cleaning facility.
- To ensure that the ultrasonic cleaning method has effectively removed contaminants, take an extracted wipe, lightly saturated with IPA. Manually clean tool to ensure that all residues are removed. If wiping method still shows visible contaminants are present, repeat steps 2-9.
- Once all visible contamination is removed proceed to next step.
- Perform Inspection and bagging per section 4.0.
- Reclean, as necessary, until desired cleanliness level is achieved.
- After inspection, double bag item and transfer to cleanroom or clean storage area.

3.1.2 Solvent Wiping

- Tools containing sealed lubricants (socket wrenches, drills, etc.) should not be immersed. Items as such must be manually cleaned with extracted wipes, swabs and Optima Grade IPA. The method includes removing any excess lubricants, by wiping extracted swabs saturated with IPA around socket adapter area, drill vent holes, etc. Then, the entire item is wiped with extracted wipes and IPA, until no visible residue is detectable on wipes.

- This method uses the approved extracted cleanroom wipes and swabs to remove molecular and particulate contamination from surfaces. Swabs prove to be very effective with the removal of both contaminant types from difficult to reach areas, such as blind holes, crevices and grooves.
- Take care to choose a solvent that will remove the contaminant without harming the surface that is being cleaned. Optima grade IPA is the solvent recommended for general use. If a stronger solvent or DI water/detergent mixture is used, follow with an IPA wipe to remove solvent residue and dry the surface.
- The solvent wipe cleaning procedure is as follows:
- Wipes/swabs should be lightly dampened with solvent.
- Do not moisten a wipe or swab by dipping it into a container of solvent. Moisten the wipe or swab from a squeeze bottle. This will help avoid contaminating the solvent in the bottle.
- Wipe with slightly overlapping unidirectional passes.
- The wipe should be folded and refolded several times during a cleaning operation so that a clean section of the wipe is exposed as often as possible. This will help in removing as much residue as possible but not allow the contamination to be redistributed on the surface being cleaned. Wipe in successive wiping cycles at 90° rotation to account for surface effects.
- Dispose of contaminated wipes and replace with fresh wipes, as necessary, during cleaning process.
- Continue using the wipe, lightly wetted with solvent, until no residue is evident on the wipe.
- When using swabs, inspect the swab frequently for visual cleanliness and damage or tearing.
- Replace the swab, during the cleaning operation, as required.
- Continue swab cleaning until no residue is evident.
- Visually inspect hardware and bag as described in Section 4.0.
- Re-clean as necessary, until item passes visual inspection.

3.2.2 Cleaning Support Tools and Equipment (which contain fans)

Whenever possible, support equipment that contains fans should be externally located, outside of the clean area, and as far away from the critical hardware, as possible. It is recognized that there are instances where fan-containing equipment will be required in the clean area.

Cleaning personnel must treat equipment-containing fans on a case-by-case basis. Items such as oscilloscopes or console racks containing blower fans, which cool the instrument, must be bagged in a way such that the generation of particulate and molecular matter in the cleanroom is minimized. Note: For some equipment, it may be possible to filter the exhaust.

During operations within the cleanroom, any tool or support equipment, which contains fans, must be modified such that the air produced by fan exhaust will be directed outside of the cleanroom. The air generated from these fans produce particulate and molecular matter. The clean environment, and all surfaces in close proximity, may be detrimentally affected by these contaminants. The combination of special bagging techniques, exhaust

redirection, and cleaning processes will minimize the production of any molecular or particulate matter.
Most fan-containing tools and equipment consoles are constructed of metal with threaded hole perforations on each side, allowing for adjustment of shelves for electronic equipment. The back of the console is usually open, allowing for cooling, fan dispersion, and access for power cords or data cables. These items require manual cleaning methods and special bagging requirements.
The basic procedure for cleaning of fan-containing tools and equipment is as follows (please note that each item must be evaluated for compatibility with this procedure):

- Remove all electronic equipment from shelves.
- Vacuum all interior surfaces; start at top and work down.
- After vacuuming, use filtered GN_2 or compressed air spraying to ensure particle removal from crevices and perforated holes.
- Wear polyethylene gloves over Chemsoft CE gloves.
- Saturate wipe with Optima Grade IPA.
- Wipe all interior surfaces of console until wipes show no visible contaminants. Change wipes frequently.
- Once interior is cleaned, extracted swabs and IPA should be used to clean all perforated openings.
- Change swabs until perforated opening and swab shows no visible contaminants.
- Repeat vacuuming of perforated holes. This will ensure removal of any fibers generated during swab cleaning.
- Once interior is clean, repeat the same process for the exterior of the console.
- Wipe all exterior surfaces with extracted wipes and IPA. Starting from top and work down.
- Repeat the same process for cleaning the perforated holes. Working from the exterior side in.
- For electronic equipment cleaning, vacuum all surfaces with house or HEPA filtered vacuum system.
- Using filtered air, point directly at fan unit, and allow pressurized air to circulate fan. This will remove dust particles trapped near fan.
- Wipe all surfaces with extracted wipes and IPA. Note: Minimize solvent contact on monitor screens or oscilloscopes. Surface is clean when wipe shows no visible contaminants.
- Dry item with filtered air.
- Inspect per section 4.0.

After item passes inspection, install all equipment in console.
Proceed to step 4.1, for special bagging requirements.

4.0 INSPECTION AND VERIFICATION METHOD

Inspection and Verification Procedure:

- Inspector will don safety goggles and inspect items with high intensity white light first. Best results are obtained with lights off.
- Wear Chemsoft CE gloves.
- Visually inspect items for contamination from a distance of 2-4".

- Inspector should begin by inspecting item with white light. Any particulate matter should be removed by vacuuming or wiping with IPA. Once all particulate matter is removed, white light inspection is complete.
- Next visually inspect item with UV light. Lights must be off or item must be placed in a darkened inspection box for UV light inspection. Fluorescing compounds may be removed by vacuuming or by wiping with extracted wipes, IPA or Acetone. If wipe shows any residue, repeat cleaning process until fluorescing compounds are removed. Note: Some materials naturally fluoresce and should not be considered contaminants.
- An item passes inspection when visible contamination is absent using visual aids. Note: NVR rinse may be required, if applicable.
- Once item has passed inspection, double bag, and transfer to cleanroom or clean storage area.

4.1 Special Bagging Requirements for Consoles and Tools with Fans

- For consoles, seal entire back of console with two sheets of Llumalloy.
- Cuts out two access holes in Llumalloy material: one for power cord, data cables, etc. and the other for the exhaust duct.
- Re-enforce access holes with Mylar or polyethylene tapes, which keeps material from tearing.
- Double bag the rest of the console, but do not attach Llumalloy material to back of the console.
- Item may be brought into cleanroom after first bag is removed. Consoles and similar items (e.g. computer equipment) should be located as far away, and "downstream" from the critical hardware, as possible.
- Remove second bag.
- Console may be plugged into power supply located within the tent. Clean tent air will be exhausted outside the cleanroom using Llumalloy ducting.
- If clean tent is not being used, air from console may be exhausted out of cleanroom by attaching Llumalloy sleeving to the second access hole, creating a tunnel, which will remove air to the outside the cleanroom.

Note: If console rack is warm to the touch, exhaust hole needs to be enlarged. Return item to designated cleaning area in order to perform hole enlargement.

APPENDIX E MBLA-CP-006, ASSEMBLIES AND COMPONENTS

ASSEMBLY AND COMPONENT CLEANING PROCEDURES

1.0 Introduction

1.1 Purpose

The purpose of this document is to provide a set of cleaning procedures for the major assemblies and components of the laser program. These procedures provide the steps necessary to meet the cleanliness contamination requirements.

Key laser parts require cleaning at the assembly, sub-assembly and component level, a set of cleaning guidelines/instructions for each of the key assemblies and components was developed, and is addressed in this document.

The recommendations and procedures contained herein are based on Swales Aerospace experience with assembly, integration, process flow, and maintaining contamination-sensitive hardware cleanliness levels.

1.2 Scope

The recommendations presented in this document are applicable to handling, packaging and storage of all Critical Hardware for the laser program.

Optics are to be handled differently than other hardware, and that the general cleanroom worker will not be handling sensitive optics. Therefore, the optics are not included in this document.
All optics are to be handled only by the responsible optical engineer, or designee. The Optics Cleaning, Packaging and Handling document, MBLA-CP-007 shall dictate by responsible optical engineer and optics handling.

All laser hardware must be certified clean prior to installation into the laser. There are no exceptions. All laser optical cavity components should be inspected at each subassembly level for contamination, damage, or other degradation. After each subassembly is bonded, it should be baked out in an instrumented vacuum bake out system as described elsewhere.

1.3 Reference

It is recommended that all personnel involved in the assembly, integration, and testing of the laser program, read and understand the requirements and procedures which have been developed for the program. This list includes:

2.0 LASER SURFACE CLEANLINESS REQUIREMENTS

BASED ON:
THE FOLLOWING, SURFACE CLEANLINESS REQUIREMENTS ARE RECOMMENDED FOR KEY LASER HARDWARE ELEMENTS:

Cleanliness levels required of the laser optic system are significantly more stringent than IR telescopes etc. The levels need to approach levels below all non-laser optic requirements, with the possible exception of far ultraviolet and some x-ray instruments in order to assure adequate life of the laser. Molecular and particulate contamination will result in virtually no obvious degradation in performance until catastrophic failure occurs in the optical system. Typical infrared systems have light intensities many orders of magnitude less than this instrument. Additionally, typical front surface infrared mirrors are significantly more contamination tolerant than dielectric mirrors.

> *MOLA 2 experienced contamination related optical damage twice when cleaned to a level between 100A and 100A2. These correspond to 100A and 100 (A/100) per Steve Monroe (Boeing). 50A3 should the target and the 100A2 should be considered the minimum acceptable level of cleanliness. Where 50 A3 corresponds to a particulate level of 50 and an NVR level of less than 1 microgram per square foot. The 100A2 corresponds to 100 and an NVR level of A/100.*

Surface Contamination Minimum Requirements

MBLA Hardware Element	Allowable Surface Particulate Contaminants	Allowable Surface Molecular Contaminants
Optics	TBD	TBD
Optical Mounts and Mount Hardware	< Level 50 per MIL-STD-1246	<0.1μg/cm^2 of Non Volatile Residue; no silicones
Major Components and Assemblies	< Level 150 per MIL-STD-1246	<0.1μg/cm^2 of Non Volatile Residue; no silicones

3.0 General Cleaning Methods

All rough cleaning will be performed in a General Cleaning Facility (GCF), and all precision cleaning will be performed in a Precision Cleaning Facility(s).

All solvents used will be high purity (e.g. Optima Grade), and only cleanroom approved wipes and extracted wipes and swabs will be used for cleaning

3.1 Rough Cleaning

Rough cleaning is done in the General Cleaning Facility (GCF) upon receipt of hardware. This cleaning method is used to remove gross contamination from the surface so that an item may be brought into the Precision Cleaning Facility (PCF).

For rough cleaning, items are cleaned with wipes lightly dampened with solvent or a detergent/distilled (or de-ionized) water solution. The wipes do not have to be extracted for this use. Heavy build-up of oils, greases, etc., should be removed. Items should be cleaned until no contamination is visible when viewed at a distance of 6-12 inches under general room light. After cleaning, the item may be single bagged for storage or transport to the Precision Cleaning Facility.

Hardware must be taken to the Precision Cleaning Facility (PCF) and precision cleaned before it can be taken into the cleanroom.

3.2 Precision Cleaning

This process is used to fine clean all accessible hardware surfaces to the cleanliness level required by the most sensitive element for the laser. Standard precision cleaning methods are described below. Responsible engineers for each assembly and component must with the support of Contamination Control Engineering, and Materials Engineering choose the cleaning method appropriate for the hardware, and document it on the hardware cert log, and supply appropriate procedures and explicit instructions to the cleaning personnel so that cleaning personnel are informed how the hardware is to be cleaned to avoid risk of damage.

3.2.1 Solvent Wiping

Surfaces are cleaned with extracted wipes that have been lightly dampened with a high purity solvent. A HEPA-filtered vacuum should be used to remove particles prior to solvent wiping. Wipes should be folded for use, with each surface only used once to avoid spreading contaminants. Wipes should be changed frequently. Rotate wipe direction 90° for each subsequent cycle. Surfaces should be cleaned from top to bottom. Isopropyl alcohol is the base solvent recommended. Solvent wiping should be followed by solvent steam rinsing. Other solvents may be used as needed. Always check solvent compatibility, with the responsible engineer before use on any surface. Use of additional or alternative solvents must be documented. Items should then be dried using filtered nitrogen or clean, compressed air.

3.2.2 Ultrasonic Cleaning

Ultrasonic solvent cleaning is good for metal and other non-porous materials. An ultrasonic cleaner uses warmed solvent to remove contaminants through cavitation. If a solvent other than isopropyl alcohol is used in the ultrasonic cleaner, a high purity IPA rinse should follow to remove remaining residue. Items should then be dried using

filtered nitrogen or clean, compressed air. Composites, harnesses and other porous materials will require a bake-out after immersion cleaning to thoroughly dry the material.

3.2.3 Solvent (Pressure) Spray

Pressure spray cleaning may be used on large, solvent resistant items. Porous materials may only undergo pressure spray cleaning prior to vacuum bake-out. This method is best as a rough cleaning if the hardware is heavily contaminated. This method uses large quantities of solvent and should only be used when necessary. Most high pressure solvent spray systems are now recirculating and thus risk adding contaminants to the hardware.

3.2.4 Vacuuming

A HEPA-filtered vacuum can be used to remove particles from most surfaces. The tip of the vacuum should not be allowed to touch easily scratched surfaces. Small, shaped Teflon vacuum tips are available to permit vacuuming of small items or into tight crevices. Vacuuming is usually done in conjunction with solvent wiping.

3.2.5 GN_2 Spray

Clean, certified gaseous nitrogen is used to dry a solvent-cleaned surface or remove particles from a surface that cannot be touched. The gas used should be filtered to Grade 6.0 or better. All regulators valves, etc., shall either be verified clean or trapped and filtered.

Clean air, certified to the required cleanliness level, may be substituted for GN_2 if necessary for safety reasons. If bottled gas is being used, the gas quality must be verified at the point of use each time the bottles are replaced. Note: typically, gas suppliers certify gas at their fill manifold only, unless the customer requests (and pays for) individual cylinder certifications.

4.0 Cleaning Methods for Components and Assemblies

NOTE: ALL HARDWARE IN EXPOSED TO THE LASER CAVITY SHALL BE VERIFIED CLEAN BY THE APPROPRIATE METHODS PRIOR TO ASSEMBLY.
The following guidelines are for the cleaning of laser subassemblies and components.

Some of the recommendations for all laser hardware include:

- Perform all cleaning in authorized cleaning facilities (GCF and PCF(s)).
- Use only high purity solvents (e.g. at least Optima Grade).
- Use only approved wipes/swabs and extracted wipes/swabs.
- Use only clean filtered gaseous nitrogen and compressed air.
- Perform visual inspections of parts, assemblies, and components continually.
- If contaminants are noticed, take the time to clean contaminants, or send item back to the cleaning facility, prior to continuing with assembly and integration activities.

- ❖ Protect cleaned items, within the cleanroom, during times when item is not being worked on - during operational downtimes.
- ❖ Use cleanroom covers during downtimes to protect hardware from the normal cleanroom environment, and from other activities within the cleanroom.
- ❖ Ascertain the highest possible bake-out temperature for each assembly and component; a higher temperature bake-out is more effective and more efficient at out-gassing materials.

4.1 Optical Assemblies

The optical mounts and assemblies should be precision cleaned, then placed in vacuum bake-out prior to mounting the optics.

Simple metallic mount structures may be cleaned by immersion in an ultrasonic cleaner, followed by drying with a GN_2 spray. The preferred practice is detergent, deionized water, IPA as described above. Some pure metal pieces may not require a vacuum bake-out. For porous materials, immersion cleaning may only be done prior to bake-out. For cleaning after bake-out, solvent wipe the hardware with extracted wipes and an appropriate solvent. Isopropyl alcohol is the basic solvent recommended and should be used after a wipe with any other solvent. The hardware may be vacuumed to remove particles at any point in the assembly process.

Mount structures that cannot be immersed in solvent should be vacuumed and solvent wiped. Hardware should be cleaned from the top down, so that personnel do not lean over the newly cleaned surfaces. The extracted wipes should be folded for use and a new surface exposed after each pass over the surface. This will minimize the spread of contaminants over the surface.

After cleaning, the mount hardware should be visually inspected. Tape lift samples may be taken to verify the particulate cleanliness level. Most mount hardware usually does not have enough surface area to allow for a square foot NVR rinse, if desired, a rinse analysis should be performed on a part count basis. The structure should only undergo an NVR rinse prior to vacuum bake-out. After bake-out, solvent rinses should be avoided.

Mount hardware should undergo vacuum bake-out prior to the installation of the optical elements.

CP-007 REV B, Guidelines for OPTICS Inspection, CLEANING, HANDLING AND PACKAGING

OPTICS CLEANING, HANDLING, AND PACKAGING PROCEDURES

1.0 Purpose

The purpose of this document is to establish guidelines for the inspection, cleaning, handling, packaging, and storage of the optics for laser transmitters.

1.01 SCOPE

The scope of this document covers procedures and processes to be performed by NASA personnel and contractors working on the VCL/MBLA laser transmitter units under the control of NASA Goddard Space Flight Center's VCL/MBLA Project. The document is not intended to establish step by step instructions for processes but adherence to the standards set forth in this document is mandatory, unless specific exceptions are approved by the project.

1.1 Overview:

To eliminate possible contamination sources on coated optical surfaces, it is recommended that the optics be packaged in individual containers made of non-scratching, Class 100 cleanroom-compatible materials that comply with surface cleanliness requirements, such as Teflon or polycarbonate. The optics should not be wrapped in tissues. The optics shall be held to prevent contact of the active surfaces with any packaging material. The containers may then be bagged in Llumalloy HSC film. Extracted wipes may also be used as a protective cover or padding for optics. **No contact of dry solid material with the optics should be permitted unless deemed absolutely necessary.** Contact with dry solid materials will result in hard particles from the surface of the solid or on the optic abrading the surface of the optic.

Coated optics should be kept clean by the preventive measures being recommended, throughout the testing and integration phase.

1.2 Highlights:

The following highlights of the optics contamination control recommendations are offered, to aid in ensuring that optics cleanliness requirements are met:

- Any operation involving the coated optics involves a risk to the optic, therefore handling and other process shall be kept to a minimum.
- All operations carried out on the optics shall be documented on an individual basis to assure traceability.
- Optics must be kept at Level <50 (particulate) and Level <0.1μg/cm^2 (molecular) cleanliness levels.

- Optics mounts, containers and all materials/parts used with the optics must be kept at the same cleanliness levels as the optics, Level <50 (particulate) and Level <0.1μg/cm^2 (molecular) cleanliness levels.
- All optics and optical mounts, packaging materials, containers, etc. shall have no detectable silicones.
- Choose low outgassing, non-particle shedding materials for use in facilities and near optics.
- Minimize handling of optics.
- Implement PROTECTION OF OPTICS as the primary method of achieving optical cleanliness.
- Package, inspect, handle and integrate optics in a Class 100 environment.
- Train personnel in Class 100 cleanroom practices.
- Perform precision cleaning and certification of all critical hardware associated with the optics.
- Bake-out all primary hardware to reduce bulk materials out-gassing levels and to clean hardware.
- Store optics in cleaned, purged containers where possible.
- Optics shall be stored in a desiccated environment (electric desiccators or dry gas purge.)
- Electric desiccators are only suitable for short term storage (one week or less.)
- Purge gases should have <5ppm hydrocarbons, and be further purified with filters, hydrocarbon traps and desiccants.
- Closely monitor hardware, support hardware and facility cleanliness.
- Implement an optical witness sample monitoring program to track optics cleanliness throughout the assembly and integration process. Witness samples should be placed in the immediate proximity of the optics and should remain in that location until replaced with a new witness samples.
- Carefully package all optics for shipment.

1.3 Applicable Documents:

1.0 IES 1246, Product Cleanliness Levels and Contamination Control Program

2.0 NASA JSC SP-R-0022A, Vacuum Stability, Requirements of Polymeric Materials for Space Outgassing Data for Selecting Satellite Materials

3.0 Outgassing Data for Selecting Spacecraft Materials Publication 1124

4.0 MSFC-HDBK-527, Material Selection List for Space Hardware Systems, JSC 09604 Rev E. or later

5.0 SN-C-0005C, Contamination Control Requirements for the Space Shuttle Program

6.0 551-WI-8072.1.7 Optical Component Cleaning

7.0 545-WI-8072.1.2 Contamination Control procedure for the Tape Lift sampling of Surfaces.

8.0 Procurement specifications for VCL/MBLA laser optics.

2.0 Description of Optical Elements

Coated optics used in the path of the laser are the most sensitive to contamination. Such optics are extremely sensitive to even minor scratches, dust, debris, very thin films of molecular contamination, or any other surface feature that can cause the laser energy to be locally intensified. Such intensification can cause latent damage, or catastrophic damage, which reduces optic life and redirects the laser energy to nearby surfaces, which could degrade and cause further contamination. Contamination can also change the focus of the laser beam.

Some of the optics are highly sensitive or are pre-assembled and as such cannot be cleaned easily. Unless specified otherwise all such optics shall meet, as a minimum, Level 50 (particles) and $<0.1\mu g/cm^2$ (molecular) requirements as per IES-1246. Handling and packaging are critical. All of the procedures in this document were prepared with this requirement in mind.
We recommend that all optical elements be packaged, handled and cleaned to these stringent requirements for three reasons:

- Use of a single procedure decreases the chance of a mistake in handling.
- Uniformly clean hardware decreases the chance of cross-contamination during assembly.
- It is standard cleanroom practice to use procedures that meet the requirements of the most contamination-sensitive element.

2.1 Coated Optic

A coated optic is an optic that has been coated with a special purpose coating. Surfaces shall be kept as free as possible from debris, dust, or thin-film molecular contamination sources. Handling and packaging become critical, handling of the laser optical system components will be carried out only by persons who have been trained by the laser staff and/or their designees for handling the components.

Different coatings have different properties, and should be treated as such. Each optic should have adequate documentation with it to assure that the properties of the coatings and base optic are known.

3.0 Materials Requirements for handling and packaging

NOTE: VIRTUALLY ALL MATERIALS WILL HAVE SUFFICIENT CONTAMINATION POTENTIAL TO AFFECT THE REQUIRED LEVELS OF

CLEANLINESS OF THE OPTICS. EXCEPTIONS ARE CERTIFIED DRY ULTRA ZERO AIR, AFTER PASSING THROUGH ABSORBENT AND SUBMICRON FILTER, AND FILTERED LIQUID NITROGEN BOIL OFF.

This section describes the criteria used to choose packaging materials and contains a table of materials that may be used to package the optics. Materials are described by use: as primary packaging materials, secondary packaging materials and mount materials.

Primary packaging materials are the materials that immediately surround the optical element. These materials are most critical, as they can easily transfer contaminants to the optic within.

Secondary packaging materials are used outside of the primary packaging materials. These materials are used as cushioning or to provide an airtight seal around the optic.

Mount materials are those materials used to create the optical mounts that hold the optical elements in place.

3.1 Basic Materials Selection

Materials used shall not degrade the surface cleanliness of the optic. Alternate materials may only be used with the approval of the Program and Quality Assurance Managers.

3.1.1 Particle Cleanliness

Materials used shall not shed particles or contain particles that can scratch or otherwise damage optic surfaces. All material immediately surrounding the optical elements shall be compatible with Class 100 cleanroom use (per FED-STD-209). Surface cleanliness shall meet a minimum level 50 (particles) and $<0.1\mu g/cm^2$ (molecular) per IES-1246 (formerly MIL-STD-1246C).

3.1.2 Molecular (Organic Film) Cleanliness

- All materials (with the exception of solvents) used for primary packaging shall be screened to 1.0% Total Mass Loss (TML) and 0.1% Collected Volatile Condensed Material (CVCM)) and $<0.1\mu g/cm^2$ (molecular) per IES-1246 (formerly MIL-STD-1246C.)
- ASTM E1559 testing is required on all polymeric materials used within the laser cavity in order to predict the outgassing effect.
- Additionally, materials shall not deposit contamination through surface contact with the optic. Contact transfer testing should be carried out.
- When a material may contact a solvent, that material shall be tested for extractables with that solvent. Extractable levels shall be compatible with the surface cleanliness level of the optic exposed to the material.

3.2 Approved Materials

Approved materials are listed in the sections below as an aide to selecting materials that can be used for packaging.

3.2.1 Primary Packaging Materials

All materials used in packaging of the optics after any cleaning, shall be verified by physical testing prior to use. This is due to the inherent variability of polymeric materials.

Primary packaging materials are any packaging materials that cannot molecularly contaminate the air within the first air tight seal of the package. Because this air is in contact with the optic there is risk of a build-up of outgassing molecules that may adsorb or condense on the optic due to temperature changes or by exceeding air solubility thresholds. The materials listed in the table below are acceptable for primary packaging applications.

All materials used in critical applications shall be tested and evaluated per the molecular and particulate levels listed above. Problems with outgassing and surface contact cross contamination have occurred when bulk material is not 100% virgin or when manufacturers change formulations, processes or raw material lots.

All molded plastics must be cleaned using a cleaning process that can remove silicones (i.e., a Simple Green or similar detergent solution or suitable solvent). Other organics must be 100% virgin material. Have the material lot tested for transferable contaminants.

Table 1 provides a summary of the characteristics associated with primary optics packaging materials.

3.2.2 Secondary Packaging

All polymeric materials used in the secondary packaging of the optics after any cleaning shall be lot verified prior to use. This is due to the inherent variability of polymerics.

Secondary packaging provides a shock cushioning and an impact protection for the optics. All primary packaging materials are acceptable for use as secondary packaging materials. It is recommended that contamination critical optics be stored in the cleanest materials possible. Non-primary packaging materials should not be stored in bulk near contamination critical surfaces. Table 2 provides a summary of the characteristics of secondary optics packaging materials.

Table 2. Secondary Packaging (Cushioning) Materials for Optics

Table 1. Primary Packaging Materials for Optics MATERIALS	COMMENTS
Teflon	PFA has lowest moisture transmittance. The surface finish must be smooth.
Delrin	Delrin is a hard material that is difficult to machine. It is a good spacer or mount material.
Viton	Gaskets should be made from sheet material that has been tested for NVR and outgassing. Viton properties vary greatly between vendors. Alternately, material should be baked out prior to use.
Gore-Tex	100% expanded PTFE sheet from W.L. Gore, Inc.
Kel-F	3M Chlorotrifluoroethene with 1,1-Difluororethene. Similar to Teflon
Polycarbonate	One commercial name is Lexan. It is softer than Delrin and easier to machine.
Polypropylene	Should be extracted or multiply rinsed
Polyester film	Should be wiped, surface contact should be minimized
Polyethylene	Acceptable versions are labeled Food grade, microwaveable, 100% pure and virgin. Do not use LDPE.
Llumalloy	Keep metal side facing out to maintain ESD protection.
Polyimide (Kapton)	Not for hydroscopic or humidity sensitive materials
Teflon film	DuPont trade name: PFA, PTFE, FEP
Aluminum foil, food-grade	Rinsed foil provides little or no potential molecular contamination potential, can act as a holder, should not contact active surfaces.
Tefzel	Also made by DuPont. It is similar to Teflon.
Electro-polished stainless steel	Electro-polished has the smoothest finish.
Anodized Aluminum	Clear anodize is preferred because some dyes leach when cleaned.
Braycote 600, 601 lubricant	Lubricant use should be avoided. These may be used sparingly if absolutely necessary. Can only be removed with a perfluorinated solvent.
Nickel plated aluminum	Inspect to verify that there are no breaks in the plating as it will act as galvanic cell. Nickel plating creates a durable, easy to clean surface finish.
Titanium	Do not use methanol or other chlorinated solvents that can cause stress corrosion cracking.
Adhesives	Use should be minimized. Acrylics are recommended.

Table 2. Secondary Packaging (Cushioning) Materials for Optics

MATERIALS	COMMENTS
Polypropylene containers	Food grade, microwaveable containers and 100% virgin polypropylene containers
Polypropylene films and bubble wrap	100% pure preferred
Polyester film	
Polyethylene	High density is preferred for contamination critical optics. Must be labeled clear, laboratory or food grade, 100% pure and virgin. Verify that lid is made of same material. Do not use LDPE.
Polyurethane foam	Pure virgin polyurethane foam for cushioning. Verify properties of specific material; some urethanes have high outgassing rates or high NVR levels.
Polystyrene	It is acceptable when there is a double airtight seal to protect the optics. Polystyrene should be avoided.
Paper and corrugated cartons	Paper is not preferred, but acceptable for less critical, less costly, or lightweight optics with enough cushioning. Must be sulfur-free.
Viton foam	Verify properties of specific material, some Viton products have high outgassing rates.
Llumalloy (HSC)	Keep metal side facing out to retain ESD protection.
Polyimide(Kapton)	Not for hydroscopic or extremely humidity sensitive materials
Teflon film	
Tefzel	
316 stainless, other high quality stainless	electropolished preferred
Anodized Aluminum	Only for optics which are not hydroscopic or damaged by humidity, or when sufficient purging is performed to remove surface absorbed H_20. Anodize must be type 3 sealed. Dye must not leach when cleaned.
Containers fabricated from metals with baked enamel finishes	
Metals painted with low outgassing paints	
Polycarbonate containers	Also known as Lexan. This material may be machined for use as a custom insert.
Nickel plated aluminum	Inspect to verify that there are no breaks in the plating, as it will act as a galvanic cell. Nickel coating creates a durable, easy to clean surface finish.
Titanium	Do not use methanol or other chlorinated solvents that can cause stress corrosion cracking.
Adhesives	All adhesives must meet outgassing requirements. Use should be minimized. Acrylic adhesives are preferred.

3.3 Other Materials issues

Other materials issues not covered here may present a threat to the laser optic system.

Polymeric materials that might be exposed to the laser cavity or the laser optical components should be specifically evaluated to stricter guidelines than the ASTM E-595 out-gasing procedure. These items shall be evaluated on a case by case basis.

Lubricants should be avoided if possible. Molybdenum disulfide, if used should be burnished into surfaces then loose material removed with light cleaning.

ESD handling techniques should be used to minimize particle pick-up due to charging of dielectric optic material.

4.0 Cleanroom Requirements for Handling and Storage of Optics

4.1 Garment Requirements

Personnel handling optics should wear cleanroom hoods, masks, smocks (or coveralls and boots as required in the facility) and ChemSoft CE nitrile gloves or Latex gloves. Polyethylene gloves should be worn over either glove when using solvents, when feasible. Gloves must be rinsed before use to remove surface molecular and particulate contaminants. Teflon, Teflon coated, or other suitable polymeric surfaced forceps or fixtures should be used for handling optics when feasible.

4.2 Cleanroom Requirements for Optics Handling

Handling of completed optics should be minimized. When handling is necessary, the optics should be in a Class 100 environment. Clean benches are ideal for processing individual optics or small optical assemblies. The clean benches should be placed in an area containing cleanroom-compatible, low-outgassing materials. The clean benches should be equipped with carbon filters if placed in areas not already equipped with hydrocarbon filtration. It should be noted that the carbon filters will lower the pressure at the face of the HEPA-filters.

Inspecting and packaging should take place in a Class 100 or better environment.

4.3 Assembly

If an epoxy must be used to mount an optical element, a clean air or nitrogen purge should be used to direct out-gasing species away from the optical surface. The purge and/or vacuum must be used throughout the required epoxy cure time.

If an epoxy must be used near an optical element during assembly, the optical assembly should be bagged or otherwise covered with clean material. The covered assembly should be purged with clean air or gaseous nitrogen. The flow rate must be sufficient to

maintain a positive pressure within the cover. The cover should remain in place during the entire epoxy cure.

Optics should be integrated in a Class 100 or better environment.

Purge flow should be maintained over or through critical assemblies whenever feasible, particularly when the assembly is covered or stored for an extended period.

4.4 Cleanroom Requirements for Optics Storage

4.4.1 Coated Optics

Optical elements must be placed in storage containers, and then placed in an appropriate environment. Coated optics may be stored short term in a dry Class 100 environment. For long-term storage, there are two alternatives:

- The optical elements, in their storage containers, may be stored in a Grade 6.0 air- or GN_2-purged cabinet, which is placed in a Class 10,000 or cleaner cleanroom.
- The optics, in their storage containers, may be stored in containers that are pressurized and meet consistent cleanliness levels for one to two months.

4.5 Cleaning Methods for Optical Elements

If cleaning is required, as determined by the project assigned optics inspector, only project approved suitably trained personnel shall perform the cleaning. The cleaning should be carried out by a person suitably trained to perform optics handling and testing, following these guidelines.

Warning: Electro-optic Q-Switches are not to be cleaned using this procedure. The Q-Switches contain elements that could be irreparably damaged during generalized cleaning. Contamination of the Q-Switches will be addressed on a case by case basis.

4.5.1 Contact Cleaning Methods

We do not recommend contact cleaning the coated optics except when absolutely required. The Goddard Work instruction 551-WI-8072.1.7 procedure fits normal industry standards for cleaning coated optics.

4.5.1.1 Ultrasonic Cleaning

Ultrasonic cleaning of parts is generally acceptable. Specific contraindications for some parts are to be noted.

Ultrasonic cleaning shall be done using verified clean glass beakers as reservoirs for the cleaning and rinsing solvents. Precautions shall be taken to assure no contact of the active surfaces with solid surfaces will occur. Teflon holders shall be used to prevent contact of

the optic with the glass container. Ultrasonic cleaning times will be determined in a case by case basis. Cleanliness will be determined by inspection or surface sampling.

Cleaning will typically include cleaning with detergent and deionized water solution, followed by rinsing with a stream of deionized water, followed by ultrasonic rinsing of the part, followed by an additional deionized water rinse. The parts, assuming the water rinse sheets off of the part, will then be sequentially rinsed with isopropyl alcohol, acetone and isopropyl alcohol again. The part will then be blown dry with dry gas and inspected.

4.5.1.2 Manual Cleaning

Manual cleaning is defined herein as the use of a hand held solid phase wiping or cleaning product to apply energy to remove contaminants from an item.

Dry Manual cleaning is strictly prohibited, with the exception of where indicated by the item's manufacturer or other qualified optical system specialist. This shall be only carried out by an approved designated individual.

Wet manual cleaning is to be carried out with the optic thoroughly wetted with the liquid cleaning solution. The base document for this application is 551-WI-8072.1.7. Only those persons who have been trained in the use of this procedure shall be allowed to carry out contact cleaning of flight optics.

Known source soft (soft is defined as lint, paper fiber, organic matter,…) particulate contamination or known source molecular contamination may be removed by approved trained individuals utilizing solvent extracted and wetted cleanroom wipes or extracted and wetted cotton swabs following procedures that will prevent optical damage. This process can be used for in process cleaning during integration steps. This cleaning will be followed with verification of the cleanliness and integrity of the optic.

NOTE: Specific optics may have contraindications. The Q-switch will dissolve in water; it will fog in a condensing environment, keep it clean with a dry gaseous purge flow, at an elevated temperature if feasible.

4.5.2 Non-Contact Cleaning Methods

4.5.2.1Gaseous Nitrogen

Particles may be blown from the surface with clean and dry gaseous nitrogen or air. Cleaned, certified Teflon tubing should be used. The nitrogen should be filtered to Grade 6.0 or better, with the THC level <1ppm. The gas should be further purified near the purge outlet with appropriate filters and contaminant traps.

4.5.2.2 Solvent Vapor Cleaning

Solvent vapor cleaning of instrument components is a low impact way of obtaining extremely clean surfaces. The recommended solvent is isopropyl alcohol. This is to be carried out in a small apparatus with fresh solvent. A volume of solvent is heated in a

covered container in which the parts to be cleaned are suspended above the liquid level. The solvent is maintained below its boiling point, and is allowed to condense on the surfaces of the part to be cleaned. The sub-boiling distillation of the solvent generates ultra-high purity solvent vapor that then condenses on the surface of the part and then runs off. The solvent will condense most rapidly on contaminants. This will continually extract the contaminants until either the part is removed or the surface is clean.

The parts to be vapor cleaned will be pre-cleaned using alternate methods to remove the bulk of the contamination. This will generally be washing with deionized and/or distilled water and detergent.

The parts are then suspended in the headspace above the solvent in the solvent vapor cleaner. The method of suspension shall allow free access and egress of the vapor to the part. Typically either a basket or wire suspension, also pre-cleaned is used for this application.

The vapor cleaning should continue until the surface of the optic and/or mounting assembly is uniformly wetted with solvent condensate, or has reached a sufficient temperature to allow the part to be removed without condensation of water on the surface of the part. With thick cross section optics this may be achieved by slowly raising the optic and holder assembly from the cleaning apparatus, watching the surface of the optic.

4.6 Cleaning Materials and Supplies

4.6.1 Alternate Cleaning Solvents

For recommendations of alternate solvents for use in the removal of stubborn molecular contamination contact a cognizant materials engineer. A mixture of 3 parts Optima Hexane or Heptane and 2 parts Optima isopropyl alcohol can be substituted for toluene or MEK.

4.6.2 Cleaning Materials

Only wipes and swabs extracted with the wiping solvent are to be used. Multiply extracted wipes and swabs are suitable for use provided either the swabs have been extracted with the cleaning solvent, or that the use of the swabs has been approved by the Materials Engineer and Contamination Control Engineer.

4.6.3 Cleaning Equipment Verification

Any cleaning apparatus to be utilized for cleaning flight hardware shall be inspected visually for signs of contamination.

CP-000 shall be followed implicitly for any operations involving optics. All cleaning supplies shall be stored in a manner consistent with maintaining cleanliness of the cleaning supplies. Beakers shall be kept inverted and covered when not in use to prevent inadvertent contamination. Tongs, forceps, etc. shall be blown dry and bagged. This is especially important for the jars used for the NVR testing.

All hard surface cleaning equipment shall be verified clean by one of two ways.

1. For metallic and glass cleaning equipment that poses a potential for transfer of material by direct or solution contact with MBLA laser components shall be rinsed three times with clean deionized water, the water shall be allowed to flow out or off of the piece and it shall be verified that the water sheets off of the surface of the equipment without beading. A lack of sheet flow from the surface indicates that the surface is contaminated with a hydrophobic contaminant. Any contaminated cleaning apparatus shall be rigorously cleaned until water sheets from the surface. Water used for testing that has detected contamination shall be disposed of immediately, and its container re-verified by the above procedure.

2. For polymeric material with a surface energy less than water, i.e. Teflon, Viton, Polyethylene, the article shall be rinsed with IPA, and the rinse tested for NVR. Solvent rinse bottles and storage containers shall be allowed a minimum of 24 hours leaching time with a solvent prior to the NVR test.

All hardware indicted, as being contaminated shall be immediately segregated from other cleaning equipment to be removed from the cleaning area, and marked as contaminated. Any flight hardware cleaned using these items shall also be indicted as contaminated, back to the last verification of cleanliness per this procedure.

Cleaning equipment found to have strongly adhered hydrophobic contamination shall be cleaned utilizing appropriately rigorous cleaning methods, or be removed from use to assure no cross-contamination of flight hardware.

All cleaning supplies exposed to flight hardware or solutions that contain or have contained hardware shall be considered single use until their cleanliness is verified by this procedure.

5.0 CLEANLINESS VERIFICATION AND MONITORING METHODS

The optical elements should be inspected upon arrival and prior to installation. All inspections should take place within a Class 100 cleanbench.

Continuous monitoring via optical witness plates is recommended during storage and assembly.

Optics that have been exposed to an unknown or uncontrolled environment should be packaged appropriately and returned to for inspection and analysis.

5.1 Visual Inspection

The optics should be visually inspected on a Class 100 clean bench using high intensity white and long-wave UV light. Microscopic inspection of the active surfaces is also recommended. Personnel must wear safety goggles and appropriate cleanroom attire during inspections. Inspections must take place in a darkened cleanroom or certified clean inspection box. Lenses must be placed over a dark surface for inspection. Be sure to inspect both sides of each lens. The optics should be held to prevent contact between

the optical surface and other hard surfaces. Optical witness samples received with the optics should also be inspected so that they may later be used to track the cleanliness level of the optical elements throughout processing.

Note: Spot cleaning may be done as necessary.

To inspect optical surfaces, hold the light at an angle and view the surface at the same angle. Particles and films will not always be visible when viewed at a normal angle. This effect is most pronounced on mirrors. The angle used will change based on the shape and surface of the optic.

The white light inspection should be done first, followed by the UV light inspection.

Microscopic inspection shall be carried out at 30 power or higher.

Other methods of verifying the cleanliness may be used or required at the discretion of the laser build/ development staff.

No contaminants or defects should be visible in the clear aperture of the optics, as defined in the procurement specification for the optic, from a distance of 2-4 inches, or visible through the microscope at 30 power. Acceptability of the optical surface cleanliness will be determined by inspection and testing as described above and in other documentation as applicable.

5.2 Optical Witness Plates

During storage, assembly and operations, optical witness plates should be used to monitor changes in the contamination level of the optics. It is standard procedure to have at least two witness plates with each set of optics. One is changed at regular intervals during storage, assembly and operations. This plate tracks deposition from individual operations. The other witness sample remains in place throughout processing and is removed at the latest possible time. This plate is used to track the cumulative deposition on the optics and can be used to estimate the cleanliness level of the optics at the start of operations. Another method is to use numerous witness samples, which are removed one by one at set intervals, with the last plate giving the cumulative deposition.

Optical witness samples shall be included in the multiple lens storage boxes that will be used. Appropriate sized holders must be available in the storage boxes.
Plates shall be analyzed to measure contaminant deposition, as appropriate to the sample type.

5.3 NVR testing

5.3.1 Surface Rinse Samples

Non-volatile residue analyses will be carried out utilizing rinse samples of surfaces. Wipe samples will not be used. Wipe samples do not provide adequate or reliable information.

NVR analyses should be carried out measuring the sample mass to 0.01mg. For residue levels less than 0.2mg, GC/MS utilizing an internal standard addition shall be used for quantitation of contamination.

5.3.2 Thermal Vacuum Bakeout

Qualification of the hardware with respect to outgassing shall be carried out via thermal vacuum bakeout. The thermal vacuum bake out shall occur in a thermal vacuum chamber equipped with a box oven that can be independently heated in a controlled manner separate from the surrounding chamber. It must be equipped with at a minimum: one temperature controlled quartz crystal microbalance (QCM), One cryogenic QCM, and an independently controlled cold finger and scavenger plate, each with its view constrained to a port from the box oven.

5.3.3 Purged Bakeout

In circumstances where thermal vacuum facilities are not available, purged bake out can be carried out. Quantification of the off gassing can be achieved through various means. Details will not be given here.

5.3.4 Qualification

Qualification should be defined as an outgassing rate such that the contamination budget of the laser is not entirely consumed prior to the nominal end of mission at either upper operating temperature, or upper survival temperature. This can be estimated by measuring the deposition rate on the QCM at temperature at the nominal end of the bake out.

5.4 Optics Cleaning Process

Should it be determined that cleaning of an optic is required, the cleaning process shall follow this progression.

5.4.1 Particulate Blow Off: The use of a clean dry nitrogen blow off utilizing an ionizer equipped blow gun shall be used in attempts to remove particulate contamination from the surface of the optics.

5.4.2 Light Wet Swabbing: The use of wet, extracted swabs for removal of adhered particles and/or minor molecular contamination shall be used if nitrogen blow off in unsuccessful. Acceptable solvents are isopropyl alcohol or acetone, providing the swabs being used have been extracted with the solvent being used i.e. acetone may be used providing acetone was used to extract the swabs.

5.4.3 If additional cleaning is still warranted, next step would be to flush optical surfaces with alcohol or double distilled acetone while holding the substrate with teflon tweezers, followed with clean dry nitrogen blow-off. The blow off process shall be carried out so as to sweep the solvent from the optical surfaces in a sheet, preventing evaporation of the solvent from the surface.

5.4.4 If satisfactory results cannot be obtained with the above methods, then the optics will undergo standard (coated optic) washing procedure, as outlined in WI: 551-WI-8072.1.7 Rev A/Optical Component Cleaning.

5.4.5 If satisfactory results are not obtained, the optic will be segregated and identified as non-conforming and appropriately documented for later determination of disposition.

5.4.6 Inspection as outlined above in section 5.1 shall be carried out after each cleaning step to determine the status of the optic.

6.0 Optical Component processing Cleanroom Controls

6.1 Equipment Access

Proper control of equipment and materials entering the clean room is necessary in order to prevent contamination of the environment.

6.1.1 Materials prepared for immediate entry into a clean facility may be moved directly into the facility by the Clean room Operations Group or responsible engineer. Materials that have been cleaned and/or prepared for later or delayed entry into a clean facility may be draped or double-bagged using proper anti-static material.

6.1.2 All documentation entering clean facilities must be on clean room paper or submitted to the clean room operations group for encapsulation to protect the hardware and environment. Clean room paper may be cleaned by dusting with pressurized gas or wiping lightly with isopropyl alcohol.

6.1.3 The drape shall be removed from items so covered just prior to entry into a clean facility.

6.1.4 Double-bagged items shall have the outer bag removed just prior to entry into the clean facility. Once in the facility the item shall be moved to the workplace and the inner bag removed.

> NOTE: Only a person working in the clean room can touch the material once the outer bag has been removed.

6.2 Large Items

6.2.1 Larger components will be handled on a case by case basis.

6.2.2 The Clean room Operations Group must be notified in order to coordinate the cleaning and movement of large items into clean facilities.

6.2.3 Items requiring entry will be cleaned by vacuum, pressurized gas, and/or wiped with approved solvents to remove any visible contamination.

6.2.4 During preparation for entry, traffic in the area may be restricted.

NOTE: ALL ENTRY PREPARATION ACTIVITIES SHALL TAKE PLACE

IN A DESIGNANTED AREA.

7.0 Tool Control

All tools and small hand-carried equipment must be verified clean prior to entry into the clean facility.

7.1 Tools will be inspected and cleaned by the clean room monitor or clean room operations personnel.

7.2 Tools will be cleaned by: Procedure MBLA-CP-005,Support Tools.

- vacuuming to remove coarse particles (if needed).

- wiping with approved solvents to remove molecular and particulate

contaminants.

8.0 Safety

In order to provide a safe working environment and to assure that all systems work as defined, certain precautions must be taken.

8.1 Some facilities may have specific limits on the amounts and types of solvents that may be stored or used in specific areas. Any such limits will be complied with. All solvents must be stored in the appropriate container and clearly marked as to its contents. Disposal of waste solvents and other hazardous materials shall be per GSFC Hazardous Waste Program. Safety goggles must be worn when using solvents. Before using any hazardous solvent, review the MSDS and the specific safety procedure for that solvent, if required.

8.2 All spills, no matter how small, must be picked up immediately. Large spills must be reported to the safety office.

8.3 Keep aisles and work station clearances at least 3 feet wide to allow easy escape in case of an emergency.

8.4 Waste/Wash solvent collection containers should minimize the exposed surface area of the solvent to minimize the quantity of solvent vapors released during use.

8.5 Solvent containers should be kept closed when not in use to prevent contamination and solvent vapor release.

9.0 Materials

In order to protect the integrity of the facility, only approved equipment and materials are allowed in the clean room. Although the lists below are not meant to be all-inclusive, if an item is not on the approved list below, the Clean room Operations Group must approve it for use prior to entry. Depending upon the project within the clean room, certain solvents or other materials may be prohibited from use in clean rooms or facilities. The use of solvents containing aromatic compounds (toluene, xylene, MEK, 200 proof absolute alcohol), and denatured alcohol is prohibited with laser hardware unless a specific documented exception is made.

Prohibited Materials

Any adhesive tape not marked adequately marked with its composition.
Pencils, erasers or retractable pens
Abrasives, such as files and crocus paper
Masking tapes
Cardboard, paper, and other porous materials
Tygon or silicone tubing
Neoprene
Vinyl films
Exposed greases and oils
Exposed or uncoated wood
Toluene
Xylene
Methyl ethyl ketone
Absolute ethanol
Silicone oil
Silicone Grease
Silicone adhesive or sealant

Approved Materials: ♦

Isopropyl Alcohol Spectroscopic Grade or better *
Bagging material to be individually approved by each specific project
Polyester clean room uniform
Latex and polyethylene gloves
Polyethylene tubing
Kapton tape, Well Documented Acrylic adhesive
Trichlorotrifluroethane (freon) Spectroscopic Grade or better *
Polyester-cellulose wipes and swabs
Low shedding cellulose, nylon, polyurethane or PVA sponge mops
Tools and tool boxes that have been cleaned and inspected for cleanliness
Acetone Spectroscopic Grade or better *
Hexane Spectroscopic Grade or better *
Heptane Spectroscopic Grade or better *
Acrylic based tape, similar to Mylar 3M #850 or Polyethylene 3M #480
PVA sponge precision cleaning supplies

♦ **Verification of suitability Must be carried out, this is not Carte Blanc.**

* These solvents will be of equivalent to or higher purity than Fisher Scientific Optima Grade solvent.