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Technical Facilities Management, Loan Pool, and Calibration

Introduction

My work at JPL for the SURF program began on June 11, 2012 with the Technical Facilities Management group (TFM). As well as TFM, I worked with Loan Pool and Metrology to help them out with various tasks. Unlike a lot of other interns, I did not have a specific project rather many different tasks to be completed over the course of the 10 weeks.

The first task to be completed was to sort through old certification reports in 6 different boxes to locate reports that needed to be archived into a digital database. There were no reports within these boxes that needed to be archived but rather were to be shredded. The reports went back to the early 1980's and up to the early 2000's. I was looking for reports dated from 2002 to 2012

Updating Databases and Creating Pivot Tables for Metrics

After going through the old certification reports I began working with excel to create pivot tables and pivot charts. These were put together to help automate cleanroom metric development. All of the data collected from our cleanrooms is collected into a database on our TFM web tool and then put into an excel spreadsheet so the data can be manipulated. This is where the pivot tables come into play and help to organize the data so we can see trends in our data. Examples would be whether room is considered a cleanroom or a clean environment, the cleanliness classification for each cleanroom, the division that owns the cleanroom, the project that currently uses it; and whether a room is certified and not certified. We can see how many of each we have as a total. To go along with the pivot tables and pivot charts the cleanroom database on the excel spreadsheet was a bit off and outdated. I updated the database and reorganized it for better aesthetics and flow.

Another database that was to be updated was the pre-filter database. The pre-filter database contains information on pre-filters such as when they are due, where they are located, and the type of pre-filter to name a few. The basic use of a pre-filter is in the name it is the "pre" filter. A pre-filter's primary purpose is to filter out the larger particulates from the air before they reach the finer and much more expensive HEPA and ULPA filters. I noticed a problem with this database; all of the data was offset and mixed up. What needed to be done was a cross check with other databases such as the TFM Web Tool and the cleanroom database which had just been updated. The pre-filter database was completed in a couple days. After finishing the Pre-filter database I updated the clean bench database; adding a column for the bench's specific project, and created pivot tables for the clean bench database.

After the pre-filter database was updated I was to go out and change pre-filters in cleanrooms, clean benches, and air showers. All pre-filter jobs tasked to TFM require the procurement of pre-filter's from General stores. The pre-filters are then taken to their respective location. For some much work is required to get to them. One such pre-filter is located in an air shower that was due for a change. It required entering the ceiling and unscrewing about a dozen bolts to access the filters. Others simply slide in such as on a clean bench. There are a few clean benches on lab that require a different type of filter called skuttle which is simply a blue filter like material that can be cut to the specific shape necessary for the respective slot.

Certification

Certifications are required when working with mission critical or flight hardware and the same applies to clean benches. Equipment and rooms that I have been certifying are:

- Cleanrooms
- Highbays
- Airlocks
- Airshowers
- Gowning rooms
- Gowning cabinets
- HEPA vacuums
- Clean benches

Certifications of cleanrooms consist of five steps and they must occur in a specific sequence to verify that certain certification requirements are met before moving on to the other tests:

1. The first step is to perform a surface cleanliness inspection which consists of performing a visual inspection of surfaces to check for surface contaminants. A common technique used for this inspection is a black wipe.
2. Filter media inspection is performed by visually verifying that the HEPA filters are not damaged.
3. Air velocity measurements are taken using a VelGrid which is a velocity meter that takes 16 measurements over a one square foot area and averages them to give you an accurate flow rate of each HEPA filter in a cleanroom. The flow rate that each HEPA should be putting out is 90 fpm +/- 20% for individual readings and an average of 90fpm +/- 10%. On occasion a room with an incorrect flow rate is found which I will discuss later. Some rooms have 20+ HEPA's and each filter has two measurements.

4. Differential pressure of the room is measured to determine the magnitude and direction of facility pressurization in between two rooms. In a clean room you want a positive pressure so that there is only flow out of the room through useable holes rather than a flow into the room. When measuring the differential pressure you use the same equipment that you attached the VelGrid to except one hose would go outside of the room and the other inside the room. If a negative pressure is found there is not enough air flow out of the HEPA filters and airflow must be increased.
5. Ambient particle counts of the room are measured using a particle counter. Depending on the size of the room the amount of samples will vary. The samples in a room are calculated by taking the square root of the Area of the cleanroom. As an example, an ISO 8 room or 100,000 can have no more than 100,000 of the 0.5 micron particles per cubic foot. The purpose of this test is to verify that the required cleanliness classification is being met. The particle counter not only counts the amount of particles but the sizes of the particles that are in the air. The sizes are 0.3 micron, 0.5 micron, 1.0 micron, 10.0 micron, and 25.0 micron. Using the example above; if only one 10.0 micron or 25.0 micron particle were found in the room the test would automatically fail. In which case you double check all connections make sure everything is clean and run it again. Typically rooms score for cleaner than what they are rated for. Table 1 shows the maximum concentration limits allowed for each type of cleanroom.

Table 1: Cleanroom Classifications

ISO Classification Number (old FED-STD-209 Classification)	Maximum concentration limits (Particles/cubic feet of air) for particles equal to and larger than the considered sizes shown below					
	0.1μ	0.2μ	0.3μ	0.5μ	1.0μ	5.0μ
Cleanrooms						
ISO 4 (10)	284	67	29	10	2	
ISO 5 (100)	2,840	672	289	100	24	
ISO 6 (1,000)	28,400	6,720	2,890	1,000	236	8
ISO 7 (10,000)	284,000	67,200	28,900	10,000	2,360	83
ISO 8 (100,000)			289,000	100,000	23,600	831
Controlled Environment						
ISO 8.5 (300,000)				300,000	74,700	2,630
Note: Uncertainties related to the measurement process require that concentration data with no more than three significant figures be used in determining the classification level.						

After the room is certified the respective report generated is submitted into the TFM Web Tool which keeps track of what is certified, location of cleanroom, customer name, cleanroom classification, and informs of what needs to be certified.

Before you can enter a cleanroom you have to go through an Air shower which also must be certified. The certification of an Air shower uses a different particle counter than the one mentioned above because certifying an air shower requires a particle counter that uses a heavy-duty pump. Air showers throw a high amount of air that creates pressure on the pump of a particle counter and only a heavy duty pump can continue without failure. When certifying an Air shower a tube is placed inside one of the shower's blower holes and the particles inside are counted. The particle count in an air shower should be zero or close to zero for all sizes. There cannot be any 10 micron or 25 micron particles in any counts however. Clean benches are certified differently. The first step is to change the pre-filters if necessary, and then perform a

visual inspection of the HEPA filter media to verify that it is not damaged. After, air velocity measurements are taken to verify the air flow. The air velocities for the clean benches follow the same requirements as the HEPA filters in the ceiling of a cleanroom. Finally a filter media scan test is performed by attaching a probe to the particle counter and scanning the filters to verify that they meet cleanliness requirements and that there are no leaks.

HEPA vacuums are also certified to verify that they meet cleanliness requirements and are not leaking particles when used inside cleanrooms. When certifying a HEPA vacuum it is placed inside of the clean bench so that the particle counter does not pick up particles from the ambient or other sources. Attached to the particle counter is the same probe used to certify the clean bench. The probe is waved on one side of the vacuum for one minute and the other side for one minute to scan the HEPA filter and verify that it is not leaking particles. Typically the particle count for all sized particles is zero since HEPA vacuums are required to be a class 100.

Lastly are the gowning cabinets that are used to store cleanroom garments for use later that day or week. These cabinets have their own specific HEPA filtration systems. Again the same probe is used as with clean benches and HEPA vacuums. The probe is placed inside the cabinet and the door is closed. The particle counts for these are typically low or zero.

Break-Out Box and Break-Out-Cable Inventory

TFM is also responsible for the storage and inventory of break-out-boxes (BOB) and break-out-cables (BOC). BOB's and BOC's are loaned to different projects and customers have visibility to the type of cables and boxes that are available. A request to borrow a cable or box can be made through the TFM Group website under Break-Out-Boxes and cables. The first task that I was assigned was to organize, label, and input information on Breakout cables (BOC) that had been recently returned to TFM by a project that no longer needed them. These were cables left over after Mars Science Laboratory had left JPL and these cables needed to be checked off in the system, as well as add some new ones to the system.

Metrology and Instruments Group

When the BOC were inputted into the system there was new work found for me with the Metrology and Instruments group. Within the Metrology and Instruments group is Loan pool. Loan pool "*provides instrumentation and measurement support including metrology, measurement standards, measurement analysis, the Instrument Loan Pool and repair/calibration of general purpose test equipment and gas monitors.*" My first work with loan pool was a yearly inventory of all Loan pool owned items. After a couple weeks of inventory work I began looking for missing equipment which, like pre-filters and certifications, I will work on for the duration of the summer.

One of my first tasks with Metrology and Instrument services was the inventory of flammable cabinets. I went around to all the flammable cabinets and checked all of the contents of them. On the flammable cabinet sheet I updated:

- Name of the item (where necessary)
- Added new items
- Size of item
- Quantity of an item
- The health, flammability, and special rating for the item
- Updated the MSDS book

Once all of the information was updated, a new data sheet showing the contents of the cabinet with the categories included above was placed on the outside of the cabinet and another was placed inside the MSDS book. After I completed these flammable cabinets for Metrology, TFM had me help them inventory all of their cabinets. Another task that I had for Loan pool was archival work.

I began archive work for Loan Pool to organize all of the instruction manuals and various books and resources for all the equipment owned by loan pool. Everything has a paper copy and is stored on shelves. Some of these paper copies were out of order or not even inputted into the archival system. My job was to help another intern with the archival work. The work was completed within a couple weeks of when I began helping the other intern with about 5 hours a week dedicated to that work.

Another task that Loan pool has had me working on is instrument calibration. The calibration work has ranged from Mechanical to Electrical calibration with more focus on the Electrical portion. To date with Electrical calibration I have calibrated air ionizers, Fluke multimeters, oscilloscopes, frequency counters, power sources, and waveform generators. In the Mechanical area of calibration I calibrated a pin set using a super micrometer. In this pin set there were 184 different sized pins that each had to have their diameter measured and fit within the specified tolerance. The values that the pins should be are specified on a calibration sheet with the tolerances on the pins.

Electrical calibration was where I spent the bulk of my time. The equipment that I calibrated the most was air ionizers. The calibration process is simple for an air ionizer and involves a set of known distances and a charged plate. The plate is charged 1000 Volts and the time that it takes for the air ionizer to dissipate the charge to a certain value is measured. This value has to fit within the specified standard for the distance that you are performing the test at. The distances begin at one foot and continue in one foot increments to four feet. The item that I calibrated the second most was Fluke Multimeters.

These multimeters ranged from older ones to the new out of box. The calibration process for the multimeters is very different than that of the air ionizers. The calibration is semi-automated in that the person doing the calibration has to input the data and manipulate the multimeter to the programs specified process. All of the precise voltages, currents, frequencies, and capacitances were provided by a very accurate Fluke Calibrator. Many of the newer items have a much more automated calibration process such as the oscilloscopes, frequency counters, and waveform generators. For these equipment, an adapter is plugged into the back and the process runs itself for the most part. The only thing that you need to be present for is changing the channels such as an oscilloscope or changing the calibration equipment that the power meter is plugged into. The power source that I have calibrated was different than a newer one; it is a black box with switches to give you precise measurements. When calibrating this type of power meter you connect it to a very sensitive multimeter. This helps to precisely measure the output of the power meter. These machines are accurate to the micro scale. After I got squared away within Loan Pool and calibration services I started jumping back and forth between TFM and Metrology completing work with both.

HEPA Filters

Seven weeks into the ten weeks of my internship I began going out on HEPA servicing jobs with TFM. HEPA filters located in air handlers and cleanrooms are serviced by TFM. On occasion rooms have either high airflow or low airflow out of the filters. When the airflow is too high the HEPA filters can be damaged if it is too low the room is not going to be as clean as it should and there could be a negative pressure in the room. One room that I helped to service had low air flow on all filters and one filter with no power to it. Using the VelGrid, all velocities were measured and found to be 50 to 60 fpm. After going through the ceiling near all of the pre-filters to the HEPA's the problem was found. The pre-filters were all clogged up from the recent construction on the floor in adjacent rooms. Once all of the pre-filters were replaced the speed on all filters increased by about 20 fpm. The filter with no air flow appeared to have an electrical problem. The loss in power appeared to occur after the breaker box. After flipping the switch from off to on the HEPA began working again but had a low air flow. We simply had to increase the flow rate of the filter on a high / low / off switch on the HEPA itself.

Cleanroom Garments

One of my final tasks given to me, besides the summer long tasks, was a cross check of two databases so we could understand exactly how many cleanroom garments were on inventory:

- Bunny suits

- Hoods
- Boots
- Frocks

The two databases were Prudential Cleanroom Services and our TFM database. We had a different count of each item than Prudential had said they sent us. I cross checked our database to find out the actual numbers that matched and those that did not. The numbers were not significant but there were enough to add up to a larger number as a whole that was off.

Conclusion

This summer internship at JPL was one of the best summers that I have ever had. I have learned so much and reconnected with some old friends and made some new friends. I will definitely work on coming back here next summer possibly working with the calibration lab as an intern. Last summer I started here with TFM and once again I worked with TFM summer but with a little twist, I also worked with the Metrology and Instruments group. This opportunity has really been of great benefit to me and I cannot thank everyone I met enough for the chance to work here. As far as my future goes this summer has played a huge role in helping to carve out my own path for the near future being college, and the distant future as far as work goes. I have changed my mind from Mechanical engineering, to Aeronautical engineering, and now Physics. I would like to work here at JPL after I graduate from college and pursue a higher degree at Cal Tech. I would be interested in an academic part time job here for the near future so that I could work during the school year and not have to leave this wonderful place. Thank you for the great experience.

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Bibliography

"Metrology and Instrumentation." http://loanpool.jpl.nasa.gov/. Aug 8, 2012.

"Test and Certification for Cleanrooms, Benches, and Controlled Environments" Rev. 3 JPL Rules! DocID 42636. Aug 13, 2012