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Lunar Glovebox Balance with Wireless Technology

Ryan A. Zeigler
NASA JSC
2101 NASA Parkway
Houston, TX 77058

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Lunar Glovebox Balance with Wireless Technology

[Modified Section from Calaway, M.J. (2015) Lunar Processing Cabinet 2.0: Retrofitting Gloveboxes into the 21st Century; Jacobs JETS Technology Innovation Final Project Report section 3.1, Aug. 7, 2015, submitted to NASA]

April 18, 2019

The most important equipment required for processing lunar samples is a high-quality mass balance for maintaining accurate weight inventory, security, and scientific study. After careful review, a Curation Office memo by Michael Duke in 1978 chose the Mettler PL200 to be used for sample weight measurements inside the gloveboxes (Fig. 3). These commercial off-the-shelf (COTS) balances did not meet the strict accepted material requirements in the Lunar lab. As a result, each balance housing, weighing pan, and wiring was custom retrofitted to meet Lunar Operating Procedure (LOP) 54 requirements [for material construction restrictions]. The original design drawings for the custom housings, readout support stands, and wiring were done by the JSC engineering directorate. The 1977-1978 schematics, drawings, and files are now housed in the curation Data Center. Per the design specifications, the housing was fabricated from aluminum grade 6061 T6, seamless welds, and anodized per MIL-A-8625 type I, class I. The balance feet were TFE Teflon and any required joints were sealed with Viton A gaskets. The readout display and support stands outside the glovebox were fabricated from 300 series stainless steel with #4 finish and mounted to the glovebox with welded bolts. Wire harnesses that linked the balance with the outside display and power were encapsulated with TFE Teflon and transported through custom Deutsch wire bulk head pass-through systems from inside to outside the glovebox. These Deutsch connectors were custom fabricated with 316L stainless steel bodies, Viton A O-rings, aluminum 6061 with electroless nickel plating, Teflon (replacing the silicone), and gold crimp connectors (no soldering). Many of the Deutsch connectors may have been used in the Apollo program high vacuum complex in building 37 and date to about 1968 to 1970.

The sample weighing sensor and pan were located inside the glovebox while the majority of the electronics and readout display were located outside of the glovebox to mitigate cross-contamination risk to the samples. In addition, each balance was also given a special material wavier for being inside the glovebox, since there were still restricted materials inside the custom sealed housing and gold connectors on the wire harness bulk-head connectors. The original Mettler balances had a maximum capacity of 200 g with a readability of 0.001 g (1 mg) (Fig. 3). For heavier samples, the weight measurements would be conducted on a larger capacity balance outside of the glovebox with the sample sealed in a Teflon bag. In 1990, Sartorius balances were purchased for some of the cabinets as the Mettler balances began to break over time. The Sartorius balances increased the weighing capacity inside the glovebox to 3000 g with a 1 mg readability (Fig. 4). Again, the COTS Sartorius did not meet LOP 54 material requirements and the balance materials underwent a retrofit by in-house contractor staff to meet Lunar curation requirements. On both the Mettler and Sartorius balances, the weight tare is controlled by a foot pedal under the glovebox. The sample mass readout is then hand recorded on a paper form in the lab when working with a sample. The Mettler and Sartorius have digital outputs and could potentially be retrofitted to a computer system with the information uploaded to the current lunar database. However, the hardware and software is no longer supported and customizing would be difficult as well as require a significant amount of effort to maintain this aging equipment in the future. Therefore, the current Sartorius and

Mettler balances are required to be replaced in order to interface with modern computer hardware and software technology.

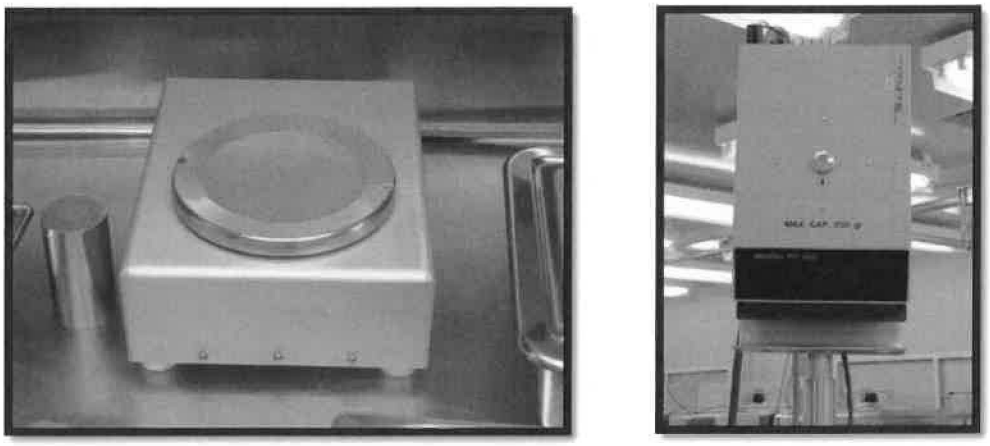


Fig. 3: Mettler PL200 balance from 1979. Left image is the weighing pan inside the glovebox and right image is the control box with display.

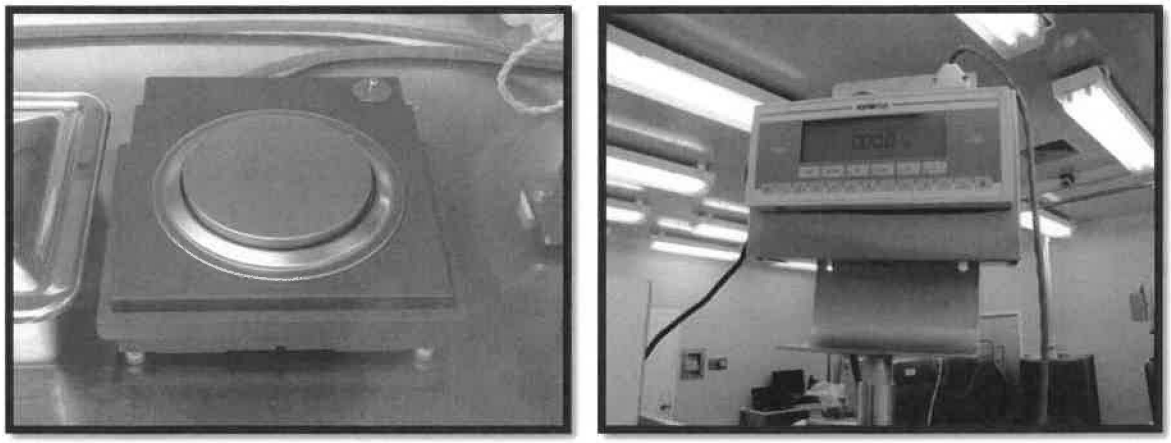


Fig. 4: Sartorius balance from 1990. Left image is the weighing pan inside the glovebox and right image is the control box with display.

For today's sample processing, laboratory sample processors desire the mass measurement to be directly uploaded to the existing Lunar database with an associated sample number and date/time of each measurement. This mass information would also be directly linked to the last calibration test for the balance. A computer interface and hands-free controls for the balance would also make processing samples easier. The following balance requirements were given to the project by Lunar curation for purchasing a new balance:

- Lunar sampling range is 0 to 6000 g; with 95% sample processing in the range of 0 to 200 g
- 1 mg readability
- 5 x 5 inch (127 x 127 mm) weighing pan

- Wireless data acquisition and control, if possible
- Foot petals are useful, if possible
- Electronics and displays out of the glovebox, if possible
- Meet current material requirements in LOP 54

After a thorough review of COTS balances that included A&D Weighing, Ohaus, Mettler-Toledo and Sartorius, Mettler-Toledo and Sartorius are still the only two manufactures of balances that meet most of these requirements. The most critical factor was that the control panel could be easily removed from the main balance unit. However, neither Mettler-Toledo nor Sartorius could meet all of the material requirements in LOP 54. A&D Weighing, Mettler-Toledo, and Sartorius all have balances with housings that meet most of the material requirements, but these models are not very sensitive at a readability of 1 mg and have too small of a pan size. In addition, most of these models have been discontinued. The closest match to the Lunar requirements with the least amount of required customization was the Mettler Toledo XP5003SDR:

- Maximum Capacity: 5,100 g; 1,000 g
- Readability: 0.01 g; 1 mg
- Repeatability: 0.006 g (2,000 g); 0.001 g (0 g)
- Weighing Pan Dimensions: 127 x 127 mm
- Ethernet or Bluetooth
- Housing: Die-cast aluminum, laquered, plastic and chrome steel
- Terminal: Die-cast zinc, chromed and plastics
- Weighing pan: Chrome-nickel steel X2CrNiMo-17-12-2 (SS-316L)



The reasons for this selection over Sartorius balances was that the Mettler-Toledo XP5003SDR meets the full weight range and readability requirements. This essentially limits the need for multiple balances that would increase costs. The housing is die-cast aluminum that has been painted and lacquered. Before choosing a balance, we contacted Mettler and Sartorius to see if we could purchase a housing without paint and lacquer. Unfortunately, both Mettler Toledo and Sartorius will not customize their housings to meet Lunar material requirements, nor would they pull an unpainted housing off the assembly line. For reducing costs, we also investigated if either the Sortorius or Metller balance COTS die-cast aluminum housing could be stripped, polished, and anodized, similar to the 1990 Sartorius retrofit. Again, unfortunately, the complex shape and type of die-cast aluminum housing prevented this option. In addition, we could not confirm the aluminum grade of the die-cast. The most common aluminum die-cast grade is A380 and this would not meet LOP 54 approved materials. Even if we were able to use these COTS housings, the intricate shapes would trap contaminates over time and would be difficult to clean. Therefore, the only option left was to design and fabricate a custom housing, similar to the original Mettler PL200. Mettler also offered a data transfer wireless Bluetooth option to link to the Dell XPS computer which only had a USB, Bluetooth, and wireless 2.4 GHz solution. This Bluetooth capability was not offered by any other balance manufacturer at the time. The control screen and draft shield were already removable. This means that we could duplicate the older models with the weighing pan inside the glovebox and the majority of electronics outside the glovebox limiting the risk of cross-contamination.

The design of the housing for the Mettler-Toledo XP5003SDR was to follow a similar design from the PL200. We were also very fortunate to have the Mettler-Toledo engineers in Germany supply us with a full 3D CAD model of the XP5003SDR that could be manipulated in Pro Engineer Wildfire 5.0 CAD software.

This 3D CAD model was used to take critical measurements and conduct a model fit check with the newly designed housing part models. This also allowed for < 1.0 mm precision on the design to fit snug around the existing balance base housing. Our original design, just like the PL200, was to have seamless aluminum welds to make the rectangular box. However, the cost for aluminum welding and anodizing were approaching $10k in costs. A more economical solution was found that would have Zero Manufacturing (the machining branch of the company who makes the famous zero cases) use a standard COTS Zero stamped rectangular box: part number Z136-164A; Al Alloy = 6061-0; Heat Treat Temper = T4; Clear Anodized MIL-A-8625 Type 2. This standard stamped box bottom would be cut to size and holes drilled to our specifications at their standard tolerance of ± 0.01 inch. They could also provide material certifications to meet metal grade requirements for the LOP 54 material requirements. The stamping process would also provide smooth flat surfaces and rounded corners for reducing contamination over a welded box and provide excellent cleanability. The bottom plate for the Zero housing cover would be fabricated in-house by ARES technicians and made from aluminum 6061. This bottom plate would bolt-down to the bottom of the Mettler balance housing. Teflon PTFE would be used for the balance feet of the housing with stainless steel button screws to attach the cover. The seam of the rectangular box would also be oriented on the bottom to limit contamination build-up and the surface would be very smooth for cleanability.

At the time of the Mettler-Toledo XP5003SDR purchase, we did not know how the Bluetooth signal would work inside a stainless steel glovebox, nor how an aluminum balance housing would affect the signal strength. After some Bluetooth signal loss calculations, we experimented with many LOP 54 approved materials and thicknesses. The experimental results showed that the close proximity of the aluminum housing would significantly degrade the signal. In order to allow for the Bluetooth signal to get through the aluminum housing, a PTFE Teflon back cover was designed to allow for a good amount of signal to penetrate the material. The secondary plan would have been to use an Ethernet cable through a secondary Deutsch connector (this would have been even more difficult than making the needed wire harness). This Teflon back cover would provide adequate signal strength as well as allow for the entry of the primary wire harness sealed by Mosites #1028 Viton.

For viewing the balance level, a new level viewing window was designed and fabricated in-house with Lexan polycarbonate MR10. This new window was then recessed smooth with the top of the housing and screwed into place. The COTS balance plate was manufactured to be 316L stainless steel. However, the thin steel was of poor manufacturing quality, the back of the plate had welding that potentially could produce particulate contamination, and the plate would be difficult to clean. Since this plate would be used for Lunar samples, the plate would need to be routinely cleanable and of high quality. Therefore, we designed a new 316L stainless steel plate. We found a machining service in Colorado that could fabricate the plate design for $570.00 as well as offer a high mirror polish. This plate would be easily cleanable and reduce contamination over time. In addition, we used the existing welded bolts on the glovebox from the old balance display and fabricated in-house a new display stand. For reducing costs and limitations in the ARES machining facilities ability to fabricate stainless steel parts, we were forced to make the stand out of anodized aluminum 6061, over the original 300 series stainless steel. Dissimilar metals over time will experience galvanic corrosion; and in our case aluminum and stainless steel. To mitigate this, we compressed Mosites Viton between the metal parts. Fig. 5 – 7 show images of the balance.



Fig. 5: Mettler-Toledo XP5003SDR balance custom housing, weighing pan, and wire harness integrated into the Lunar Processing Cabinet. The Right image shows the balance control screen and computer.

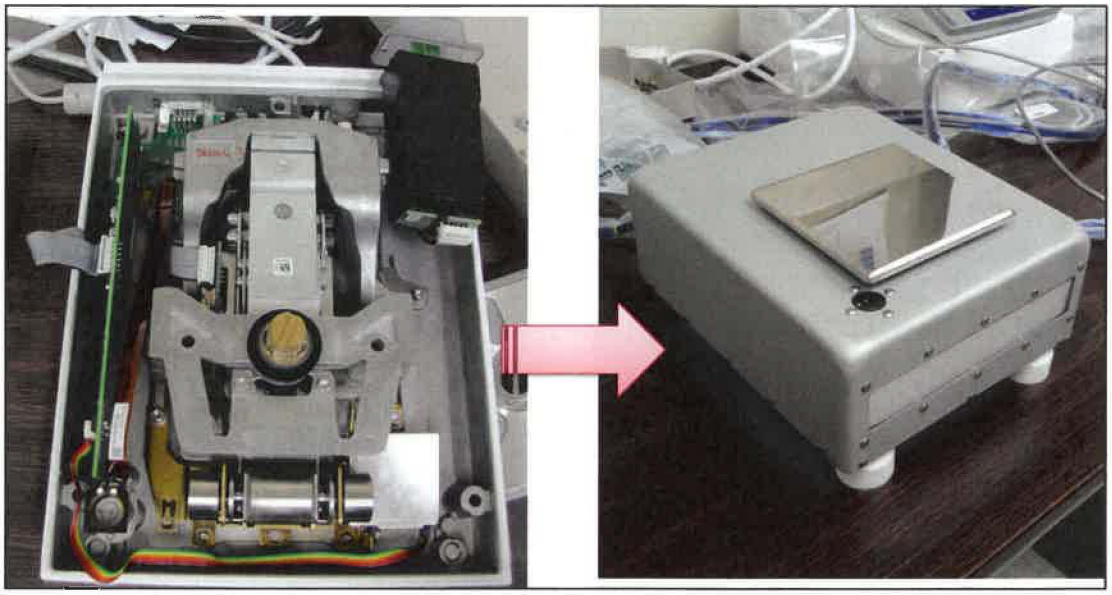


Fig. 6: Left image shows the inside of the Mettler-Toledo XP5003SDR balance and custom housing of the right.



Fig. 7: Left image shows the custom 316L stainless steel weighing plate. Right image shows the back cut-out for the wire harness and Bluetooth. During operations, this is enclosed with the PTFE and Viton seals.

The fabrication of the wire harness proved to be rather difficult and required multiple testing before designing. We first tried to remove all circuit boards from the balance to the outside of the glovebox to reduce cables going into the glovebox. This required the signal testing of COTS circuit boards where we had no schematics. The Molex digital ribbon connectors were rather small and we did not have the proper electrical testing equipment in our lab to make a test easy. However, with improvisation, we were able to signal test all the ribbon connectors and found out that we would require several signal boosters for the Molex digital connectors. After consultation with an electrical engineer, we decided that the complexity of this would dramatically increase costs. Fortunately, the PS/2 data cable signal test did not show a significant signal loss over the needed 10 to 20 feet. Therefore, a wire harness would need to include two foot petals cables, PS/2 data cable, and power cables. Ideally, a customized four foot wire harness encapsulated with PTFE wire casing would be needed and directly link to bulk head connector. A cost estimate from several vendors resulted in quotes ranging from $2.5k to $3k. Therefore, we decided to splice all the wires in-house. Since a 100 ft. minimum spool of PTFE jacketed wire was $2.7k and we would have needed three types of wire sizes at a total cost of about $8k, we chose to use PTFE Teflon heat shrink for the wire bundle at a cost of $157.00. In addition, a new bulk-head connector was considered to replace the 40 year old Deutsch connectors; each glovebox has four connectors. Deutsch connectors are no longer made for our application and are considered old technology. After cost estimates from several vendors, Douglas Electrical had the most economical solution that would fit the glovebox cut-out and meet customized material requirements. Each new Pot-Con connector would be $2,570.00 per connector (with price lowering with quantity). Due to the limited budget, the project could not incur the cost of new connectors. Afterwards, we decided that we would reuse the 40 year old spare parts with the existing Deutsch connectors. This was extremely difficult since the 1970 Deutsch connectors were manufactured for large power wires at size 12 AWG and the PS/2 cable was 26 AWG. To make this connection, we carefully built up the wires to be able to make the 12 AWG crimp connection. In the original glovebox design, soldering was not approved due to contamination. We did attempt to solder the 26AWG and then encapsulate the solder in Teflon, however, the wires were prone to breaking.

We were also fortunate that the existing 12-pin Deutsch connector was the exact pin count we required and all twelve connections were used. Fig. 8 provides a wire connection diagram where 7 wires (26 AWG) were used for the PS/2 data cable, 2 wires (18 AWG to 3.5 mm stereo jack) for foot petal 1, 2 wires (18 AWG to 3.5 mm stereo jack) for foot petal 2, and 2 wires (16 AWG) for power wires. The PS/2 data cable would also have to be spliced to a circuit board Molex connection. After all wires were spliced on both sides of the bulk-head connectors, bundled, and tested, the wire harnesses were fitted with Zeus PTFE heat shrink.

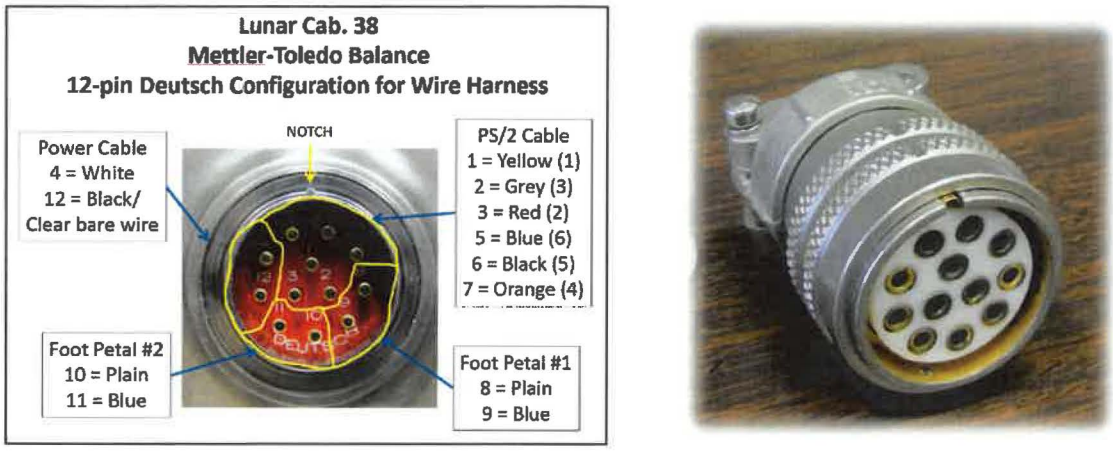
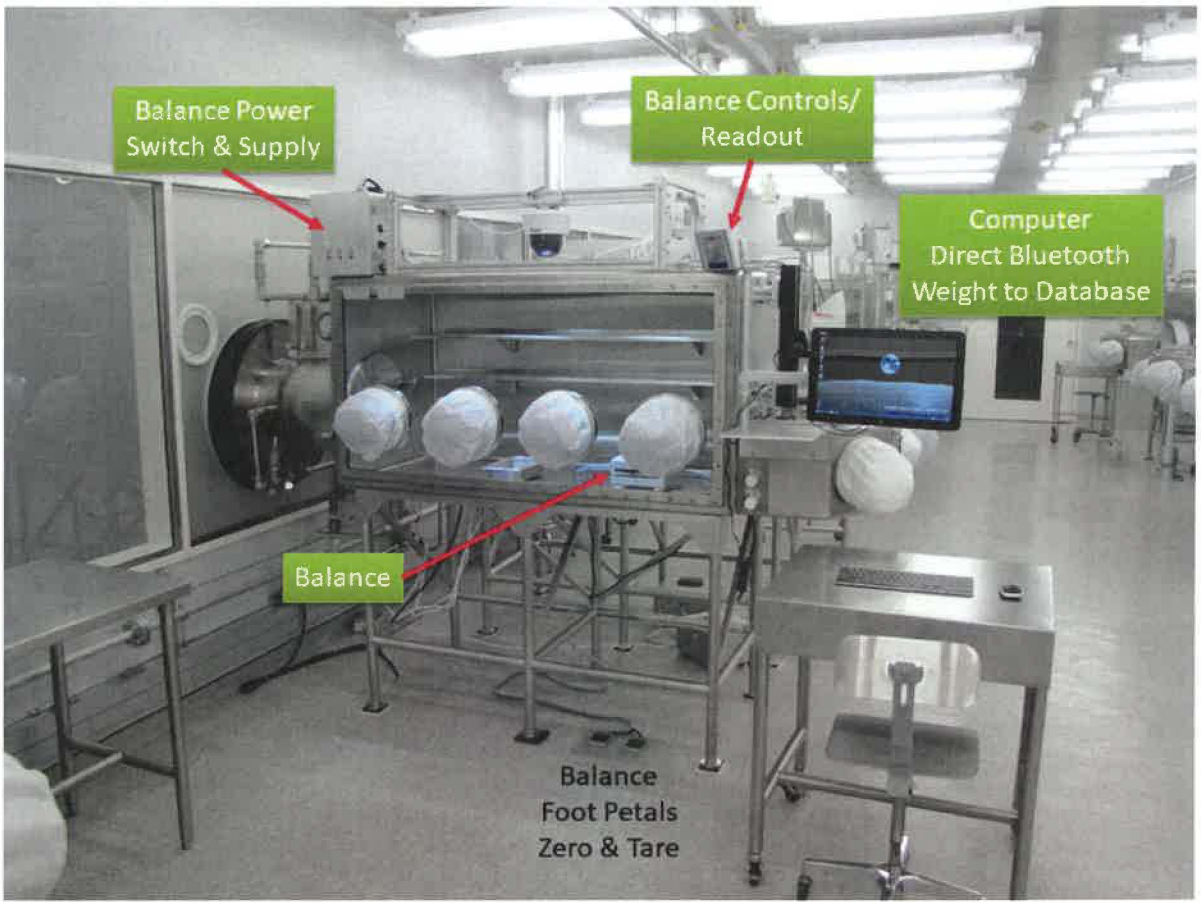


Fig. 8: Image of a Deutsch bulk-head connector with pin layout (Left). Wire harness snap connector (Right).

Power transformer for the balance was integrated into an aluminum electrical enclosure outside of the glovebox. The power cable was also spliced and attached to a power ON/OFF toggle switch. Mettler-Toledo Balance Link COTS software was also purchased for automatically transmitting weight data to the Dell XPS computer via the Bluetooth connection. This software would run in the background when entering information into the Lunar database. For transferring balance readings, the existing Lunar database would use a web based browser. When the mass entry box would be highlighted, the balance data would be directly populated by a designated command. In the future, the planned new upgraded Lunar database could easily use this COTS software to build a fluid process for entering mass data with integrated times and sample ID.

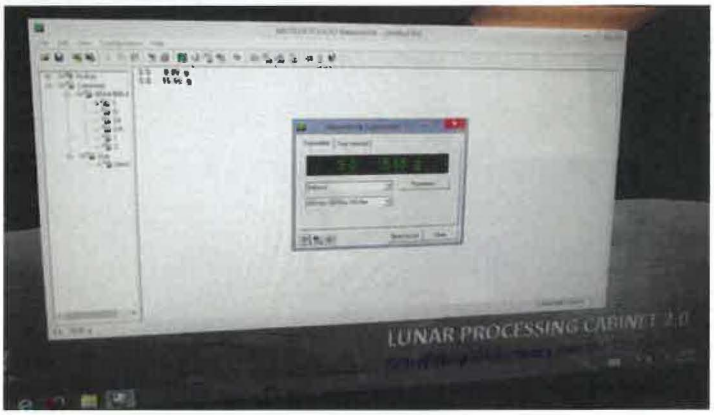

Balance Power Switch & Supply
Balance Controls/ Readout
Computer Direct Bluetooth Weight to Database
Balance
Balance Foot Petals Zero & Tare



Remote Touchscreen Controls

Deutsch Connector Wire Pass-through

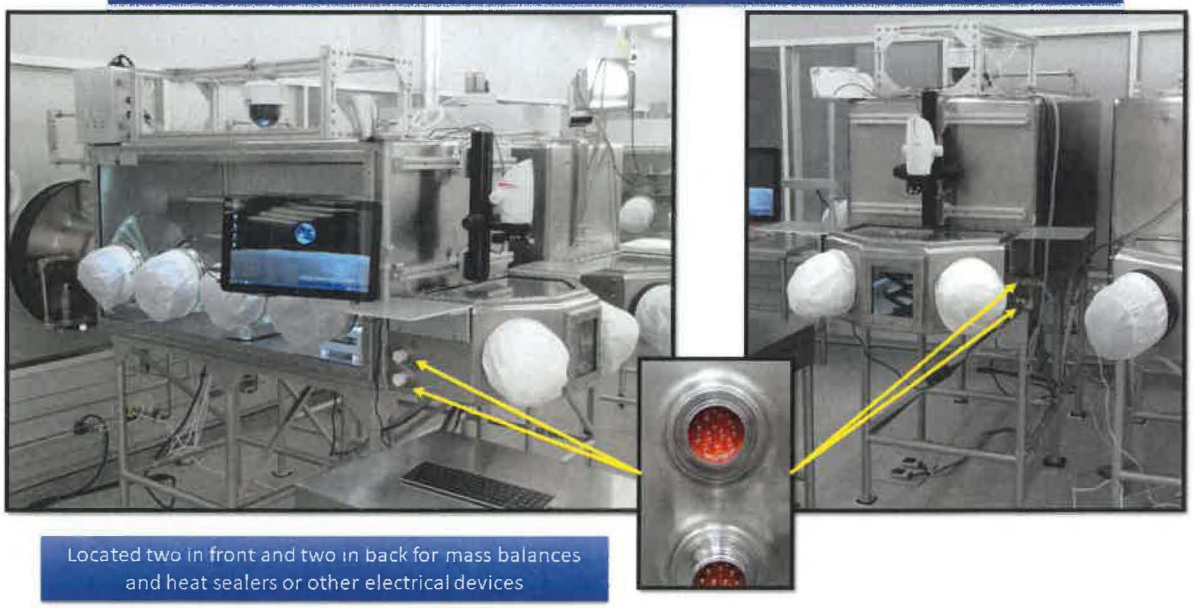
Wireless Data Bluetooth Connection







Lunar Processing Glovebox with 4 original Deutsch Electrical Bulkhead pass-thru



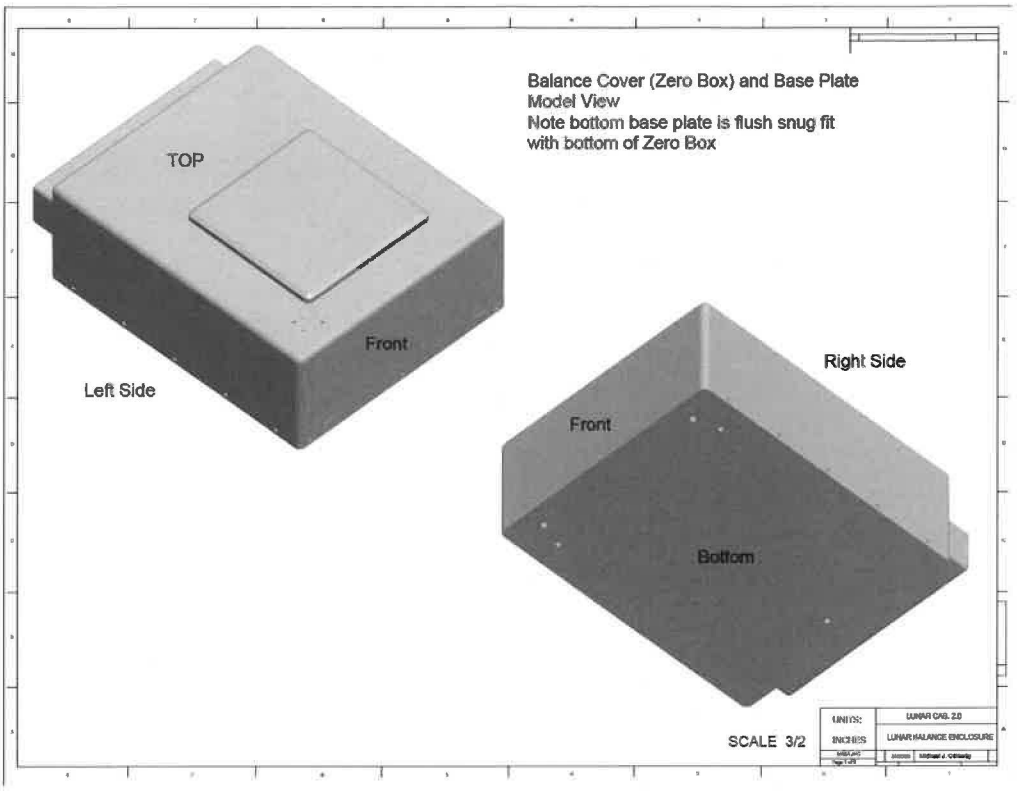
Located two in front and two in back for mass balances and heat sealers or other electrical devices

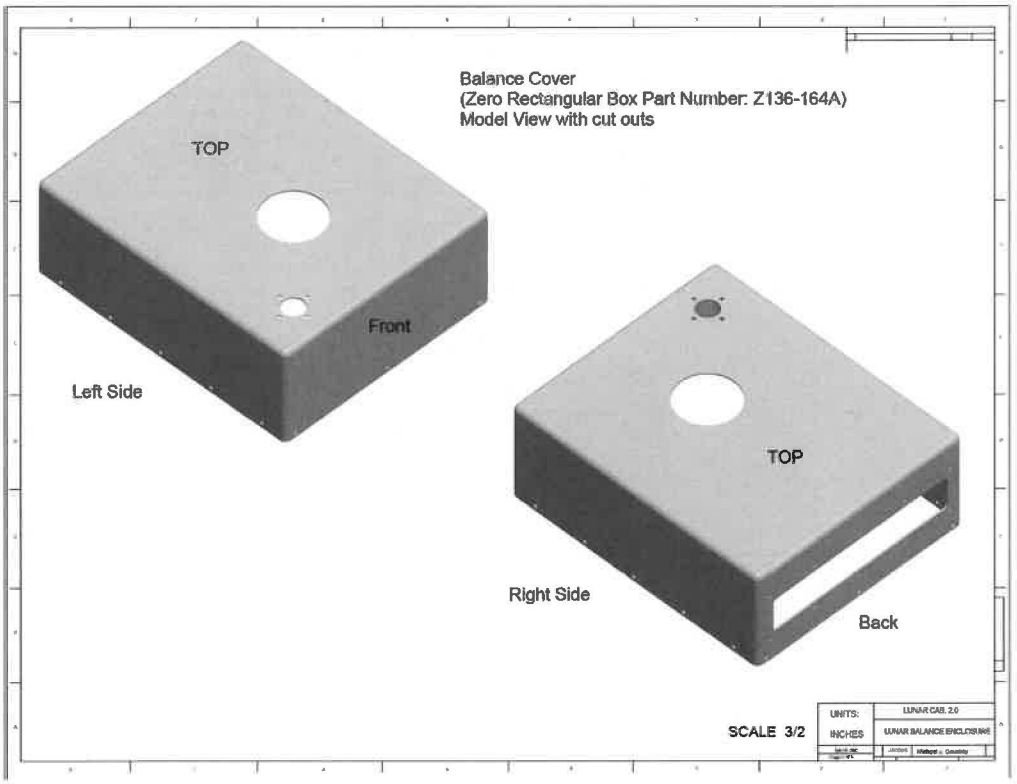
Replacement Part for Deutsch would be Glenair 233-103-H7 with cutom FEP/PTFE wire harness:

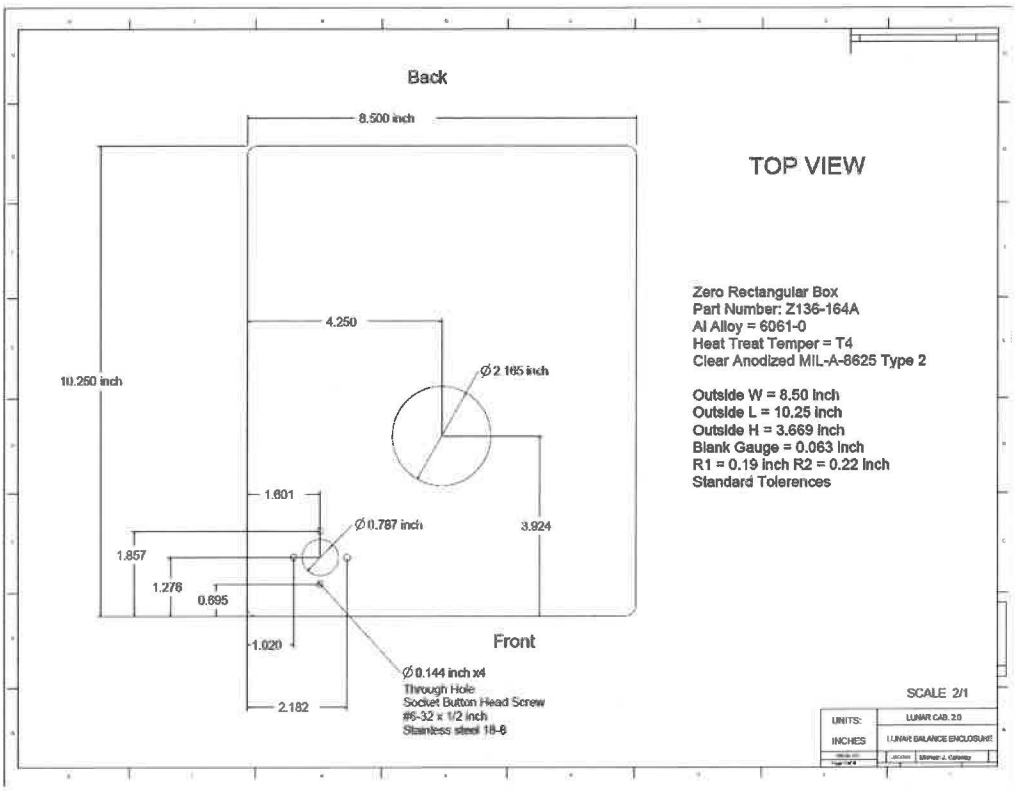
Glenair 233-103-H7
Jam Nut Mount Hermetic Bulkhead Feed-Thru
MIL-DTL-38999 Series III Type

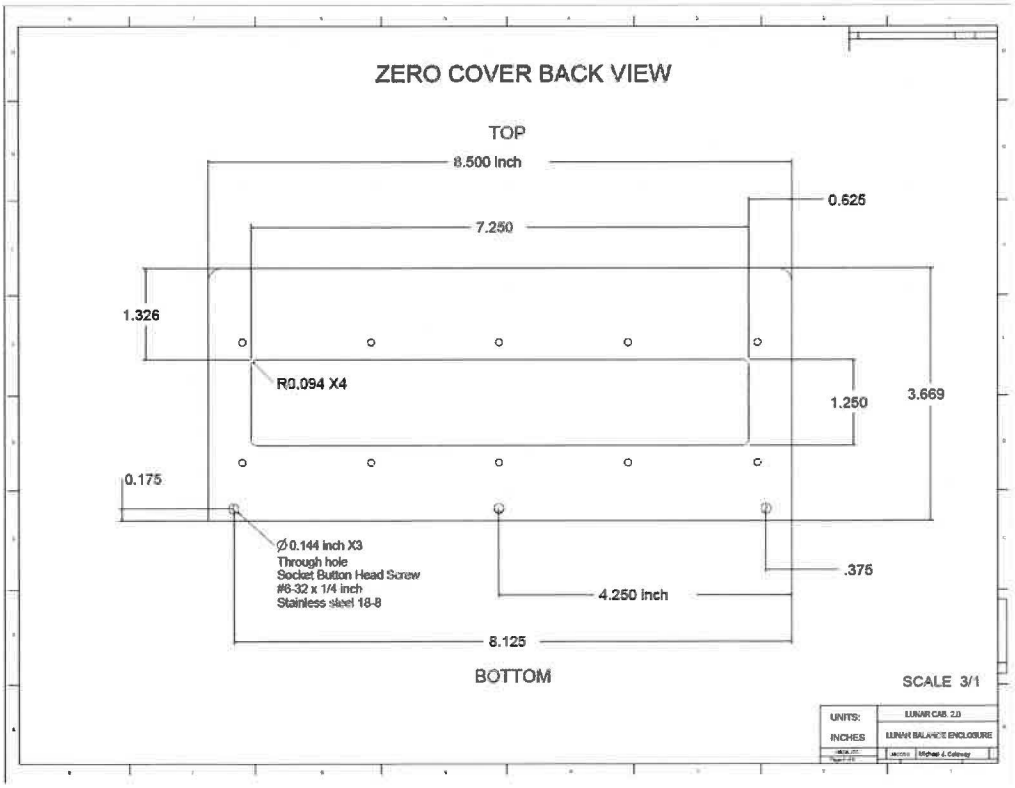
- Housing and nut: 316L Stainless Steel, passivated
- Connector Arrangement: 26 of size 20 AWG
- Shell Size: 17 (code: E26 or 17-26), 1.259" F thread
- Viton seals
- Gold Plated sockets and pins
- Fused Vitreous Glass hermetic insulator
- Hermetic seal leak rate: 1×10^{-7} cc He/sec.

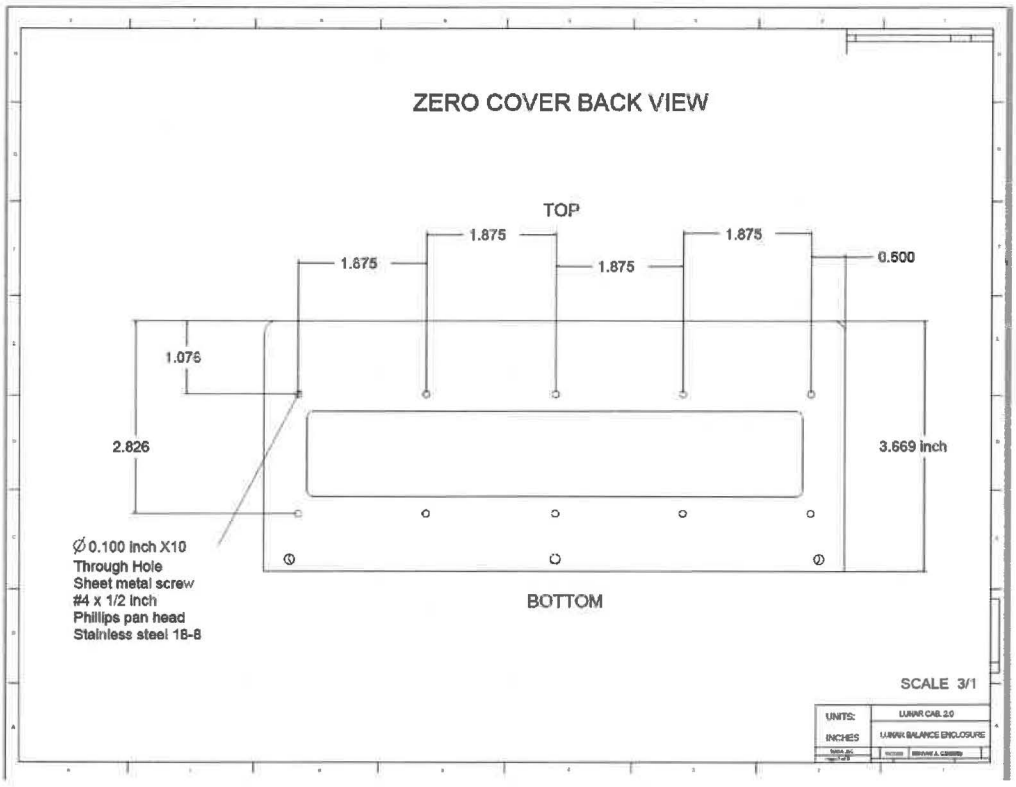


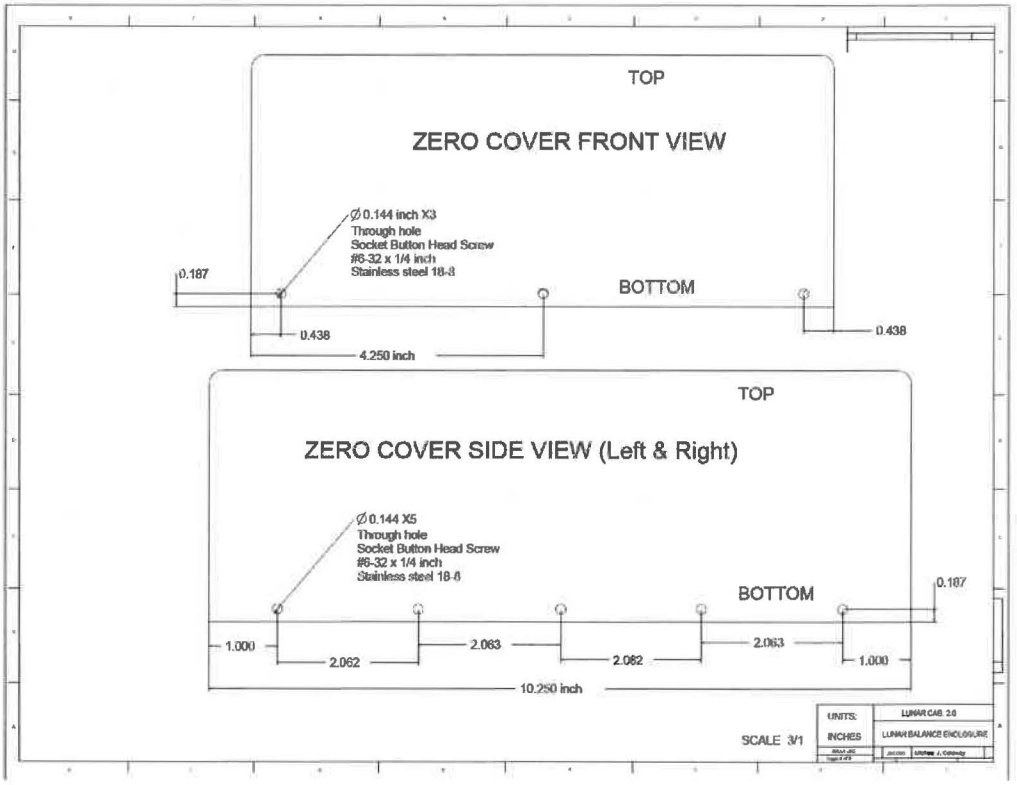

Balance Cover (Zero Box) and Base Plate
Model View
Note bottom base plate is flush snug fit
with bottom of Zero Box
TOP
Front
Left Side
Right Side
Front
Bottom
SCALE 3/2
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE

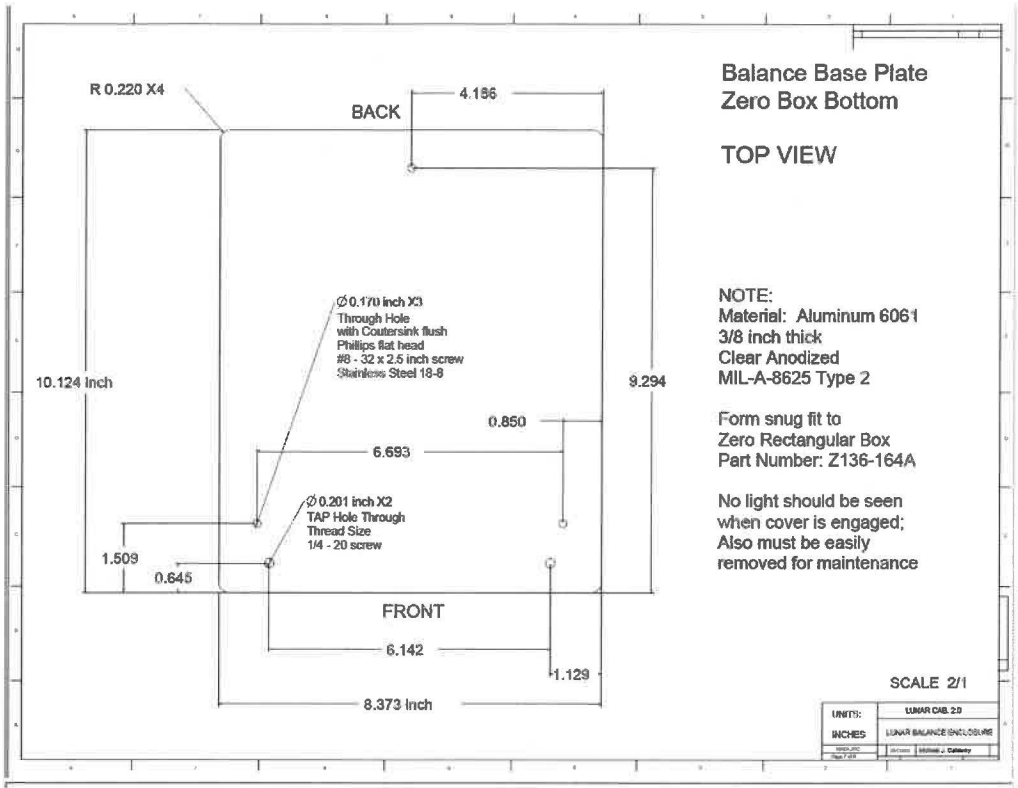

Balance Cover
(Zero Rectangular Box Part Number: Z136-164A)
Model View with cut outs
TOP
Front
Left Side
TOP
Right Side
Back
SCALE 3/2
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE

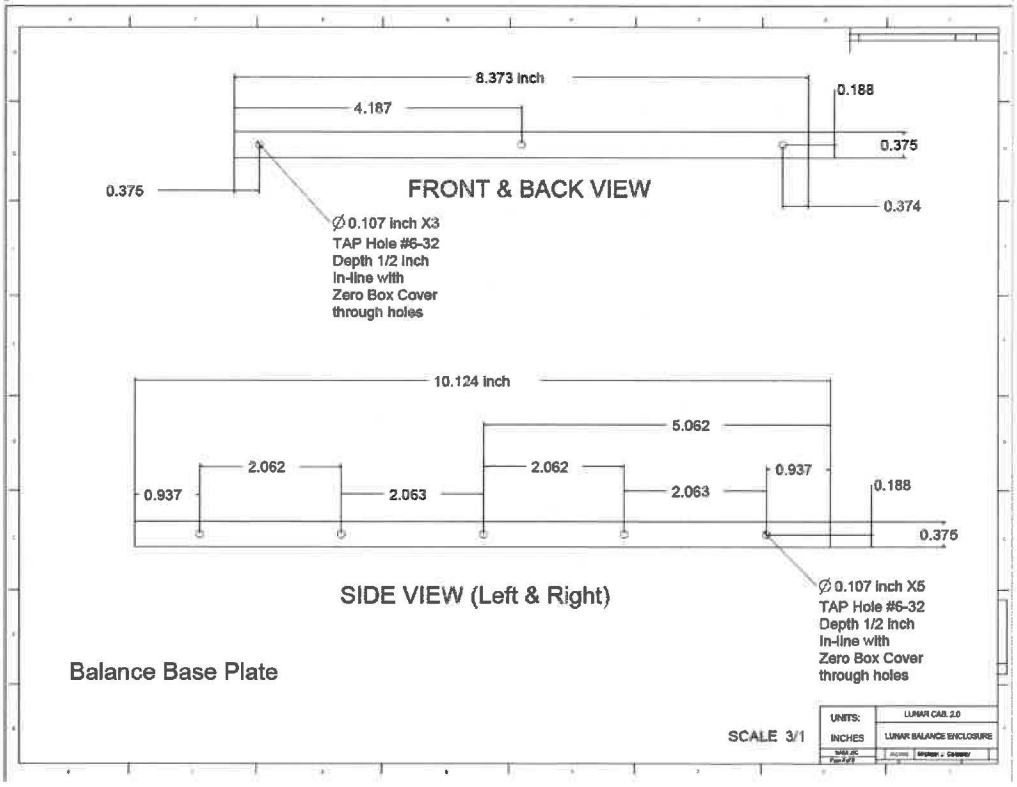

Back
8.500 inch
10.250 inch
4.250
Ø 2.165 inch
1.601
Ø 0.787 inch
3.924
1.857
1.278
0.695
1.020
2.182
Front
Ø 0.144 inch x4
Through Hole
Socket Button Head Screw
#6-32 x 1/2 inch
Stainless steel 18-8
TOP VIEW
Zero Rectangular Box
Part Number: Z136-164A
Al Alloy = 6061-0
Heat Treat Temper = T4
Clear Anodized MIL-A-8625 Type 2
Outside W = 8.50 inch
Outside L = 10.25 inch
Outside H = 3.669 inch
Blank Gauge = 0.063 inch
R1 = 0.19 inch R2 = 0.22 inch
Standard Tolerences
SCALE 2/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE

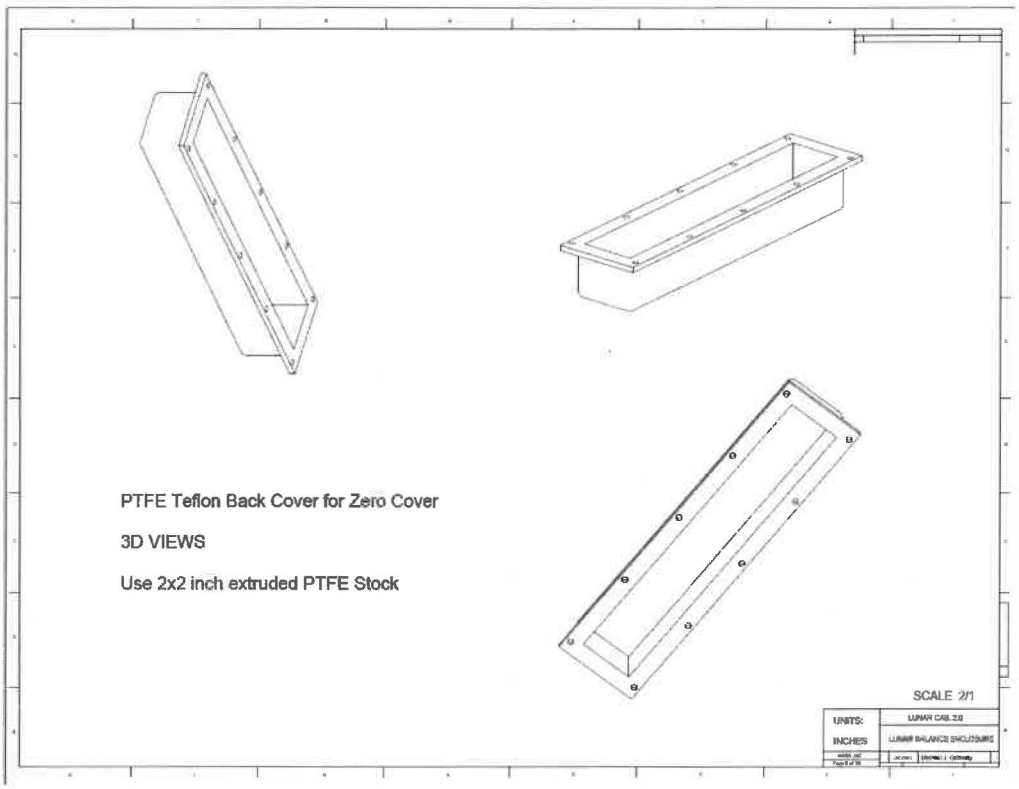

ZERO COVER BACK VIEW
TOP
8.500 inch
0.625
7.250
1.326
R0.094 X4
1.250
3.669
0.175
Ø 0.144 inch X3
Through hole
Socket Button Head Screw
#6-32 x 1/4 inch
Stainless steel 18-8
.375
4.250 inch
8.125
BOTTOM
SCALE 3/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE

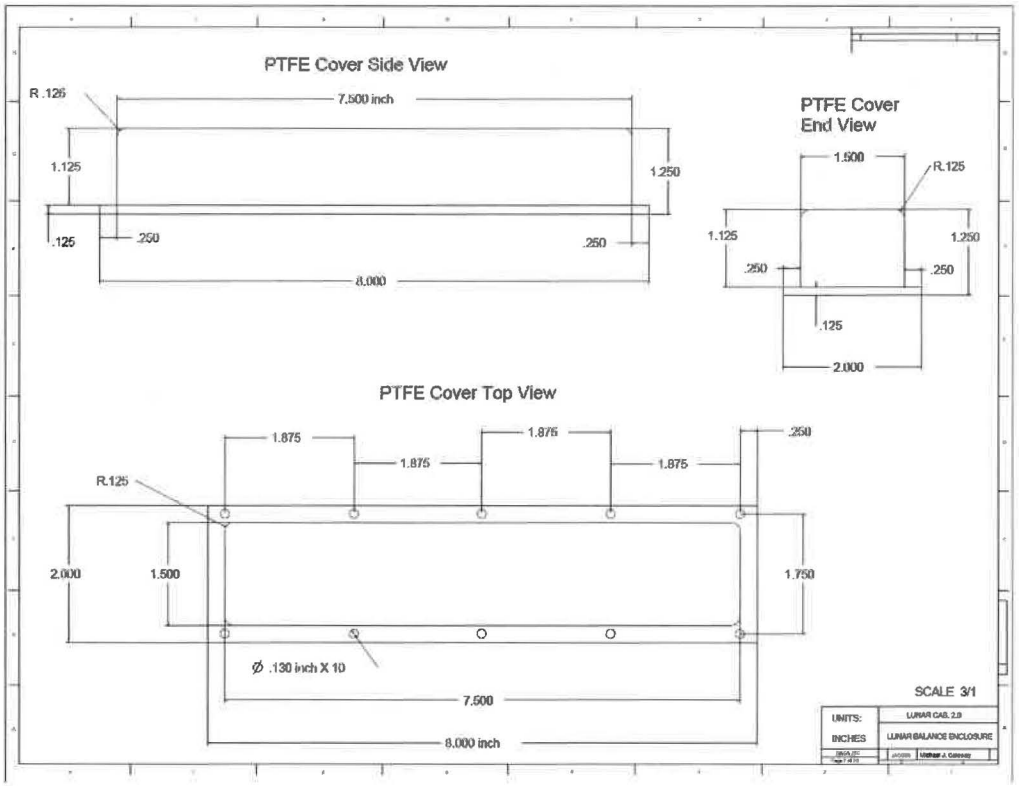

ZERO COVER BACK VIEW
TOP
1.875
1.875
1.875
1.675
0.500
1.076
2.826
3.669 inch
Ø 0.100 inch X10
Through Hole
Sheet metal screw
#4 x 1/2 inch
Phillips pan head
Stainless steel 18-8
BOTTOM
SCALE 3/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE

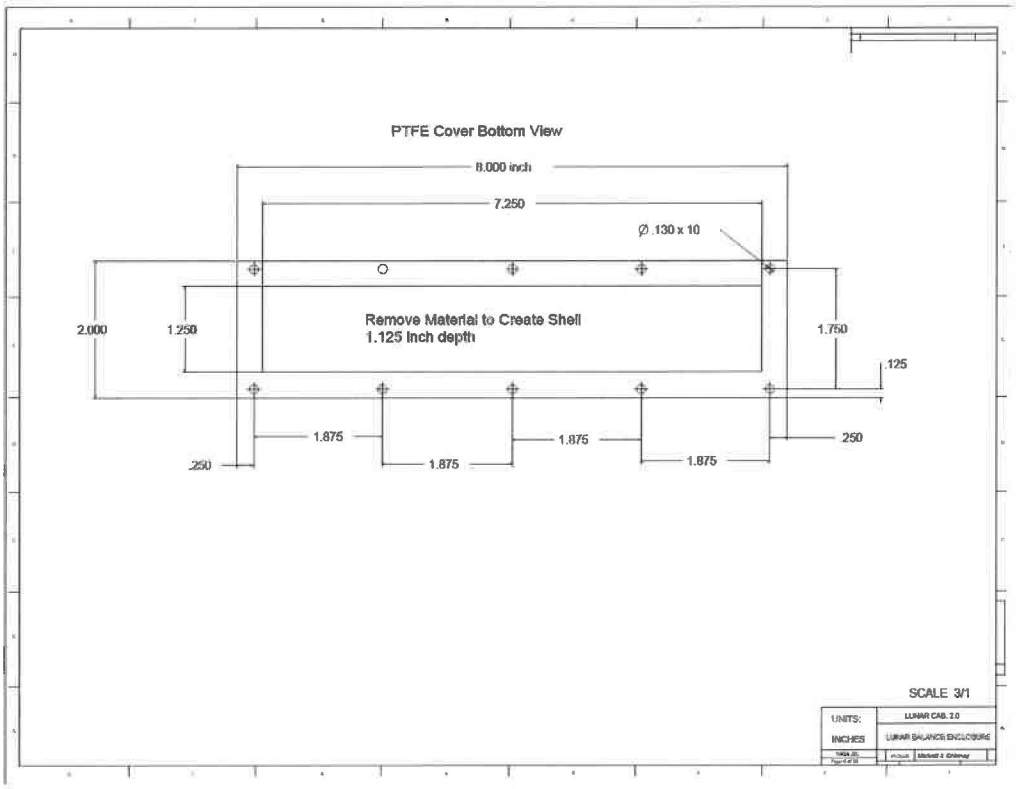

TOP
ZERO COVER FRONT VIEW
Ø 0.144 inch X3
Through hole
Socket Button Head Screw
#6-32 x 1/4 inch
Stainless steel 18-8
0.187
BOTTOM
0.438
0.438
4.250 inch
TOP
ZERO COVER SIDE VIEW (Left & Right)
Ø 0.144 X5
Through hole
Socket Button Head Screw
#6-32 x 1/4 inch
Stainless steel 18-8
BOTTOM
0.187
1.000
2.062
2.063
2.062
2.063
1.000
10.250 inch
SCALE 3/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE

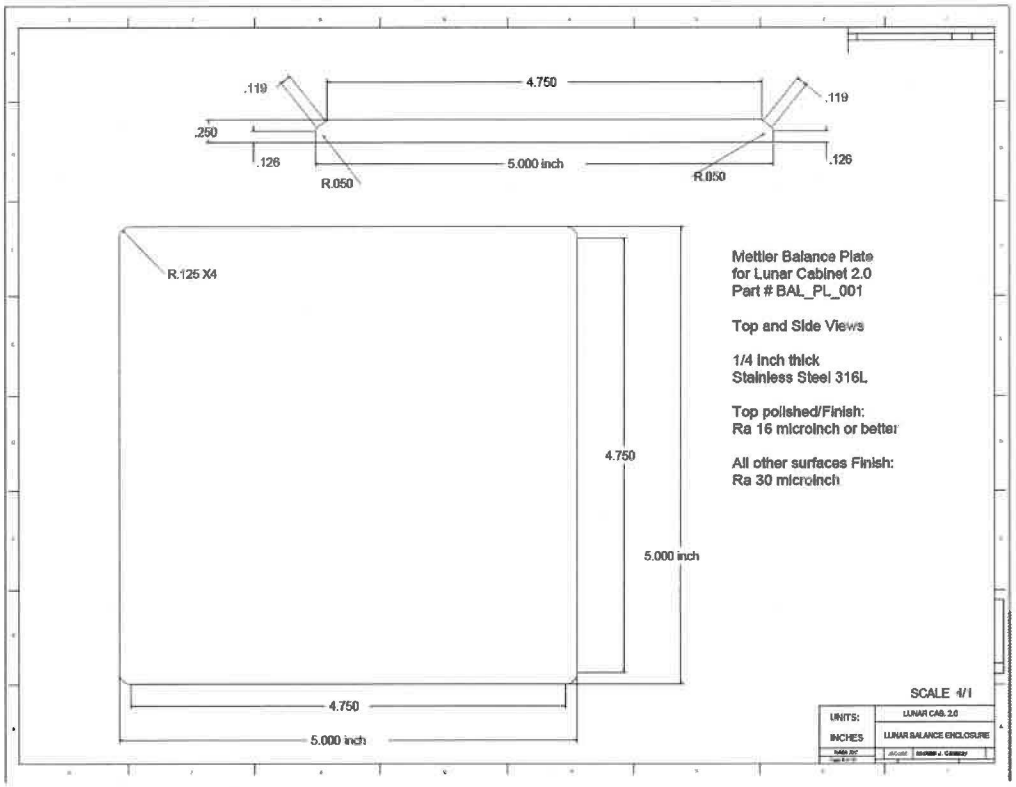

Balance Base Plate
Zero Box Bottom
TOP VIEW
R 0.220 X4
BACK
4.186
10.124 inch
9.294
Ø 0.170 inch X3
Through Hole
with Coutersink flush
Phillips flat head
#8 - 32 x 2.5 inch screw
Stainless Steel 18-8
0.850
6.693
Ø 0.201 inch X2
TAP Hole Through
Thread Size
1/4 - 20 screw
1.509
0.645
FRONT
6.142
1.129
8.373 inch
NOTE:
Material: Aluminum 6061
3/8 inch thick
Clear Anodized
MIL-A-8625 Type 2
Form snug fit to
Zero Rectangular Box
Part Number: Z136-164A
No light should be seen
when cover is engaged;
Also must be easily
removed for maintenance
SCALE 2/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE

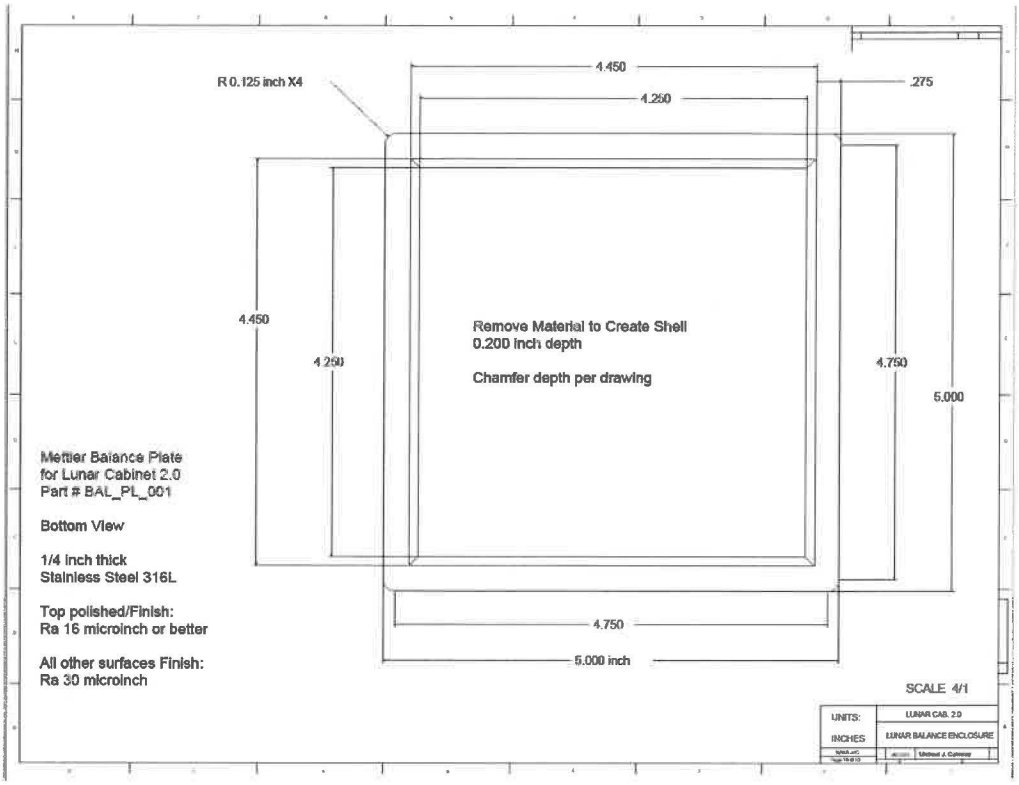

8.373 inch
4.187
0.188
0.375
0.375
FRONT & BACK VIEW
0.374
Ø 0.107 inch X3
TAP Hole #6-32
Depth 1/2 inch
In-line with
Zero Box Cover
through holes
10.124 inch
5.062
2.062
2.062
0.937
0.188
0.937
2.063
2.063
0.375
SIDE VIEW (Left & Right)
Ø 0.107 inch X5
TAP Hole #6-32
Depth 1/2 inch
In-line with
Zero Box Cover
through holes
Balance Base Plate
SCALE 3/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE


PTFE Teflon Back Cover for Zero Cover
3D VIEWS
Use 2x2 inch extruded PTFE Stock
SCALE 2/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE


PTFE Cover Side View
R .125
7.500 inch
1.125
1.250
.125
.250
.250
8.000
PTFE Cover
End View
1.500
R.125
1.125
1.250
.250
.250
.125
2.000
PTFE Cover Top View
1.875
1.875
1.875
1.875
.250
R.125
2.000
1.500
1.750
Ø .130 inch X 10
7.500
8.000 inch
SCALE 3/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE


PTFE Cover Bottom View
8.000 inch
7.250
Ø .130 x 10
Remove Material to Create Shell
1.125 inch depth
2.000
1.250
1.750
.125
1.875
1.875
1.875
1.875
.250
.250
SCALE 3/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE


.119
4.750
.119
.250
.126
5.000 inch
.126
R.050
R.050
R.125 X4
4.750
5.000 inch
4.750
5.000 inch
Mettler Balance Plate
for Lunar Cabinet 2.0
Part # BAL_PL_001
Top and Side Views
1/4 inch thick
Stainless Steel 316L
Top polished/Finish:
Ra 16 microinch or better
All other surfaces Finish:
Ra 30 microinch
SCALE 4/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE


R 0.125 inch X4
4.450
4.250
.275
4.450
4.250
Remove Material to Create Shell
0.200 inch depth
Chamfer depth per drawing
4.750
5.000
4.750
5.000 inch
Mettler Balance Plate
for Lunar Cabinet 2.0
Part # BAL_PL_001
Bottom View
1/4 inch thick
Stainless Steel 316L
Top polished/Finish:
Ra 16 microinch or better
All other surfaces Finish:
Ra 30 microinch
SCALE 4/1
UNITS:
INCHES
LUNAR CAB. 2.0
LUNAR BALANCE ENCLOSURE