Collected LWA Engineering Memos
From the Development of the Electronics Shelter (SHL)

2008 March 13 – 2009 February 25

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Shelter Foundation Requirements

Version 0.5

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ARL:UT

March 13, 2008

Introduction

The foundation of the LWA Control Shelter (SHL) is deemed to be that collection of components and/or structures designed specifically to support and secure the shelter at an operational location. This could include but is not limited to; footings, piers, pads, anchors, straps, etc.

The primary objective of establishing a solid foundation is to limit the movement of the shelter relative to the various incoming cables and infrastructure. It is assumed that the cables and infrastructure will be subject to displacement over time, and that these systems, and their interfaces to the SHL will need to be designed to permit some degree of relative motion. The purpose of the foundation is to avoid large-scale shifts in the shelter location due to wind, snow, erosion and other natural forces. To this end, a notional tolerance of 0.25" has been assigned to the allowable movement/displacement in each axis. This value should be reviewed and adjusted as necessary in future versions of this document.

Shelter Background

The LWA Control Shelter is currently envisioned to be a 20 foot or 40 foot ISO container with a highly modified/customized interior. The ISO container is defined by the following standards:

- *ISO 668-1995 Series 1 freight containers -- Classification, dimensions and ratings*
- *ISO 1161-1984 Series1 freight containers -- Corners fittings, specifications*

In general, ISO containers are designed to have their entire weight distributed across the four corner blocks, which protrude approximately 0.5" below the floor frame of the container. Potential foundation designs should take this into account.

Exterior dimensions are: width – 8 feet, height – 8.5 feet, length – 20/40 feet. Empty weight on the 20 foot container is 4,850lbs. Empty weight on the 40 foot container is 8,380lbs. Modifications and equipment are estimated to add an additional 10,000 pounds, bringing the gross weight to 14,850lbs and 18,380lbs respectively.

Relevant Technical Requirements

The LWA foundation requirements are derived from "*LWA System Technical Requirements, Version: Draft#9*", prepared by Clint Janes, University of New Mexico, November 19, 2007. Excerpts from that document relevant to the foundation are provided below.

TR-15 Lifetime: Maintainability for ≥ 15 years
EN-1A Outside Temperature: Equipment exposed to the weather shall operate normally in temperatures of -20°F to 110°F and with daily temperature swings as high as 55°F
EN-1B Temperature survival: Survive temperatures from -50°F to 122°F.
EN-2A Precipitation: Equipment exposed to the weather shall survive without damage:

a. Rain falling at the rate of up to 6 inches/hour
b. A single rainfall of up to 2 inches
c. A snowfall of up to 2 feet
d. Hail up to 1 cm in diameter
e. Ice loading of up to 1 inch followed by a wind of 35mph

EN-2B Precipitation Drainage: Site drainage shall provide for a 2" rain over a 20 minutes period
EN-3A Relative humidity outside: Equipment exposed to the weather shall operate normally in RH of 10% to 90%
EN-3B Relative humidity survival: Survive RH of 5% to 99%
EN-4A Wind: Equipment exposed to weather shall survive horizontal winds up to 80 mph and 3 second gusts up to 100 mph and vertical winds up to 40 mph. Force shall be calculated for an altitude of no more the 3500' above sea level.
EN-4B Wind erosion: Structures shall be protected from wind erosion
EN-7A Fauna: …Crawl spaces, crevices, voids shall be avoided. Where unpreventable, ingress shall be blocked by screens of gnaw resistant materials to keep out insects and bats.
EN-9 Seismology: LWA equipment shall survive, without damage, horizontal and vertical accelerations to be expected in a magnitude 3.5 earthquake as rated by USGS.
PA-12 Safety: Safety hazards to be minimized and those remaining identified.

Several notes on these requirements are worth making.

1. EN-3A requires normal operation in RH of 90%. We assume that the foundations are required to operate normally in periods of 100% relative humidity.
2. EN-4A does not identify the direction of the vertical wind velocity (up or down). We assume that both may be required.
3. EN-4B includes the undermining of solid components resting on soil.

Shelter Foundation Requirements

Based on these technical and environmental requirements, the following shelter foundation requirements should be considered:

Construction

C-1: The foundation shall be pre-constructed on site to facilitate the placement of the shelter and minimize the on-site time of the heavy equipment required for transporting and lifting the shelter.

C-2: The foundation shall be designed and constructed so as not to obstruct or interfere with shelter cable penetrations.

C-3: The foundation shall be constructed such that all shelter contact points are co-planar and that the plane defined by the shelter contact points is level to within ¼ inch per 20 feet. Additionally, the local surface of the foundation structure surrounding the contact points shall be level to within 1/10 inch per 12 inches.

C-4: The foundation shall be constructed such that the shelter, when installed, is as close to grade as practical. (EN-7A)

C-5: The foundation shall be designed and constructed with a maintainable life of no less than 15 years, assuming periodic maintenance. (TR-15)

C-6: The foundation shall be designed and constructed so as not to impede or, should otherwise provide for, site drainage. (EN-2B)

Temperature

Tmp-1: The foundation shall not move, nor allow the shelter itself to move, more than 0.25 inches in any axis as a result of temperature fluctuations. This includes material expansion and/or contraction as well as frost heave and other such phenomenon. (EN-1A, EN-1B)

Rainfall

Rain-1: The foundation shall not move, nor allow the shelter itself to move, more than 0.25 inches in any axis as a result of rainfall, erosion caused by rainfall, standing water, soil expansion, and /or the weight of standing water upon the shelter roof. (EN-2A)

Snow

Snow-1: The foundation shall not move, nor allow the shelter itself to move, more than 0.25 inches in any axis as a result of snowfall, and/or the weight of snow upon the shelter roof. (EN-2A)

Hail
Hail-1: The foundation shall not move, nor allow the shelter itself to move, more than 0.25 inches in any axis as a result of hail. (EN-2A)

Ice
Ice-1: The foundation shall not move, nor allow the shelter itself to move, more than 0.25 inches in any axis as a result of ice and/or ice loading upon the shelter roof. (EN-2A)

Wind
Wind-1: The foundation shall not move, nor allow the shelter itself to move, more than 0.25 inches in any axis as a result of wind or erosion due to wind. (EN-4A, EN-4B)

Tornado
Tornados are not explicitly identified in the Technical Requirements. However, we note the following.

> "Tornados are storm containing the most powerful of all winds however, their probabilities of occurrence at any one location are low compared to those of other extreme winds. It has, therefore, been generally considered that the cost of designing structures to withstand tornado effects is significantly higher than the expected loss associated with the risk of a tornado strike." "For this reason, tornado-resistant design requirements are not included in current building codes or standards, for example, the Uniform Building Code, the Southern Building Code, or the American National Standard."[1]

Therefore, the foundation shall not be required to withstand tornadic winds.

Storms
Storm-1: The foundation shall not move, nor allow the shelter itself to move, more than 0.25 inches in any axis as a result of any combination of weather elements, i.e. "ice loading of up to 1 inch followed by a wind of 35mph". This shall not include tornados. (EN-2A, EN-4A)

Earthquake
EQ-1: The foundation shall not move, nor allow the shelter itself to move, more the 0.25 inches in any axis as a result of an earthquake of magnitude not greater than 3.5 as rated by the USGS. (EN-9)

Safety
Safe-1: The foundations, and any anchoring system or guy wires, shall be designed to minimize tripping or obstruction hazards. (PA-12)

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[1] Emil Simiu, P.E., Robert H Scanlan, P.E. 1986. *Wind Effects of Structures*, *Second Edition.* New York: Wiley-Interscience Publication.

SHL-0002

Long Wavelength Array

Shelter Foundation Options v 0.3

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ARL:UT

March 27, 2008

1 Introduction

This document presents a number of design options for a foundation suitable to support the LWA Control Shelter (SHL). The primary objective of any foundation is to provide an interface between the local terra firma and a structure. A foundation can be an integrated part of the structure or, as in this case, a separate, independent structure. Because the foundation must interface to the soil, it is important to have a full understanding of the soil composition and the overall geology of the area. At this point, since final site selection has not occurred, we do not have this understanding, and as a result this discussion should be considered preliminary. A description of the shelter and the requirements for the foundation have been outlined in an earlier memo [2].

2 Forces to be Reckoned With

We begin by considering the foundation requirements along with the sizes and weights offered for a 20 foot ISO container, and developing an initial analysis of forces that the foundation will have to withstand. As described in [2], the weight of the fully loaded 20 foot container is expected to be about 14,850 lbs (66150N). The surface area of the top of the container is $8 \times 20 = 160ft^2$, or $\approx 14.8m^2$. The surface area of the long side is $170ft^2$ ($\approx 15.8m^2$), while the shorter sides are $68ft^2$ ($6.3m^2$).

2.1 EN-2A-c: Snowfall of up to 2 foot accumulation

The density of wet snow, using figures given by University of Arkansas [6] and Cornell University [4], is about one-third that of water. Assuming a density $\rho \approx 330kg/m^3$, the maximum total mass of a 2ft (0.61m) snow load is

$$\rho \times 0.61m \times 14.8m^2 \approx 3000kg,$$

which yields a force of approximately 30000N (6720 lbs), which is a significant fraction (45%) of the total expected gross weight for the 20' shelter.

There are two issues that result from a load of this magnitude. First, this additional snow mass should be accounted for in foundation design, either directly or by an increased safety factor that should be used for foundation load calculations relative to the nominal gross weight. Second, this distributed roof loading should be checked against the ISO standard ratings for the container to be sure that this load can be supported safely without any permanent or significant deformation of the structure.

2.2 EN-2A-e: e. Ice loading of up to 1 inch.

The density of ice is approximately that of water, i.e. 1 gm/cm^3. With the area given in section 2, and with a 1" depth, ice accumulation on the roof gives a load of approximately 800 lbs. This is not a significant fraction of the nominal gross weight. If ice somehow also accumulates on all vertical exterior surfaces, it will add a further 2400 lb load. However, both of these figures are well below that required for snow accumulation, so ice buildup is not a factor in the foundation design.

2.3 EN-4A: Wind exposure at 100 mph gust.

Assumption of standard temperature and pressure gives reasonably conservative estimate of wind loading at higher elevation (= 3500 ft). Using an air density of 1.29 kg/m^3 gives a dynamic pressure of 1306 Pa. Stagnation pressure also includes a static pressure term which is relatively small compared to the dynamic pressure at these wind speeds. The drag coefficient, C_D, includes both upstream and wake effects. For a rectangular prism with the base/height aspect ratio of the ISO container, $C_D \approx 1.2$ [3]. Applying the wind pressure to the broad side of the shelter gives a total wind load force of 24762 N or 5567 lbf.

This wind load has two main effects on the shelter, both acting at the connection/support points between the shelter and the foundation. The first is a shear load, distributed among the support points, that acts to move the shelter laterally. The second force is a net moment, which acts to reduce the vertical force on the support points on the windward side of the shelter and increase it on the leeward side. A key point is to determine whether there is a transition from compression to tension on the windward side at maximum wind velocity (i. e. whether it is necessary to provide positive hold-down force on the shelter).

The wind loading on the side of the shelter from a 100 mph gust results in a reduction in the vertical load on the foundation on the windward side of 13,153 N and an equal increase in the vertical load on the foundation of 13,153 N on the leeward side. The net vertical loads on the foundation (or the reaction force of the foundation on the shelter depending on your point of view) are then 19,897 N on the windward side and 46,203 N on the leeward side. The key point here is that the wind force is not sufficient to lift/tip the shelter off of the foundation, and no hold-down device should be necessary.

However, the shear force between the shelter and foundation due to lateral loading from wind may indeed be a concern. For stability, the static coefficient of friction between the shelter and the foundation must satisfy

$$\mu > \frac{F_{lat}}{F_{Normal}}.$$

In this case, we have

$$\frac{F_{lat}}{F_{Normal}} = \frac{24762}{66150} \approx 0.374.$$

The coefficient of friction μ for clean steel on clean concrete is approximately 0.5. Thus it would only take a 25% reduction in μ, due to sand infiltration, moisture, or ice formation to reduce the frictional forces to the point where the shelter would slide. Accordingly, it would be prudent to have some form of connection between the shelter and the foundation specifically designed to resist lateral loads. A conservative design value for the total lateral load capacity of all anchoring devices would be half of the peak wind load, or roughly 12,400 N.

Again, it is necessary to check the ratings of an ISO container to ensure it will withstand this wind exposure.

2.4 EN-4A: Vertical wind exposure at 40 mph.

Assuming a downward wind, the resulting force on the shelter and foundation can be calculated in a similar manner to the horizontal wind case. A 40-mph pure upward wind will only be encountered in the case of a tornado, where there will likely be other, more significant and damaging effects to deal with. Upward forces resulting from vortex shedding due to horizontal winds redirected as they hit the side of the shelter are included in the drag force calculations, above. Because the roof of the shelter is horizontal, there is no net uplift force due to horizontal winds.

3 Foundation Options

This section provides a description of basic options for the shelter foundation. Drawings are available in [1]. In options that use pads we have made the important assumption that the soil on which the shelter is placed can be stabilized sufficiently to prevent settling, heaving and shifting. However, we have not addressed the steps, or the cost, required to do this. This assumption is not required for options involving piers or pilings. We have also assumed that all options lead to a level platform.

3.1 Concrete Pads

The most basic of foundations would be to simply set the shelter on concrete pads obtained from the local home store. Typical pads generally measure 2 feet by 2 feet by 4 inches thick. An ISO container is designed to rest on its corners, so one pad at each corner should be sufficient. These will allow the shelter to be kept low to the ground thus minimizing the crawl space (critter space) below the shelter. Assuming stabilization of the soil, the primary concern with this configuration is that, as discussed in section 2.3, the shelter would be vulnerable to movement in high winds.

Materials cost for this option is estimated to be $150 with minimal labor involved.

3.2 Pads and Tie Downs

From the discussion in section 3.1, some sort of additional restraint is likely advisable to prevent the shelter from being displaced in the X and/or Y direction by wind. In this option we utilize the same concrete pad arrangement as above, but add some type of soil anchor and tie down. Helical anchors are available in a number of configurations. The typical mobile home anchors are readily available, inexpensive, and assuming the soil into which they are placed does not move, are able to resist working loads of 3150 lbs (14031N) each. Anchors and tie downs can be appropriately placed to sufficiently increase both the hold down force and lateral force opposing the wind component. Initially, it would appear that two along each side of the shelter may be sufficient to provide adequate safety margin. The detailed arrangement of the anchors will be dependent on the site soil characteristics.

Shelter attach points for the tie downs are a bit more of a challenge. ISO shelters are designed to be both lifted and anchored by their corners and there is no framework beneath the shelter suitable for tie downs. Tie downs attached to the upper corners would likely present a hazard to personnel. The final design should include attention to mitigating the risks of personnel injury.

Materials cost for this option is estimated at $800. Labor costs should be small, since they are limited to driving the anchors and attaching tie downs.

3.3 Poured Concrete Pilings

This option provides for four poured bell-bottomed piers and takes advantage to the ISO container corner's designed ability to take both compression and tension. It also benefits from the fact that locking corner mounting devices are commercially available. The lower frame of the ISO container provide a mechanism that interlocks the four piers and prevents them from moving independently in the X and/or Y direction. Having the piers extending some distance below the surface make them less likely to be affected by ground swell, frost heave, or erosion. The bell-bottom provides for a greater distribution of the downward force, resists settling and conversely, heave. This option is more labor intensive possibly requiring contractor assistance to dig or drill the footing excavations to the appropriate depth, pour the concrete, and weld on the mounting clamps. While this option tends to be more invasive of the land, removal of the piers is a simple matter of digging them up.

Materials cost for this option is estimated at $1200. Labor costs remain to be estimated.

3.4 Driven Pilings

This option is very similar to, and has the same advantages, as the poured pilings option. Here steel, concrete, or timber driven piles rather than poured piers are used. This has the advantage of being a deep foundation that does not require any excavation. It would require working with a contractor to further design the foundation based on the site soil conditions and drive the piles.

We obtained an single quote from Hasse Construction regarding the cost of engineering and installation of a driven pile foundation. Assuming that we can provide soil and core sample analysis and all they have to engineer is pile length and cross-sectional size for our application, they can do the job with 1-3 days on site for $25K-$50K. We can request placement specifications on the order of ± 1 inch, however there is some drift possible if the pile encounters sub-surface obstructions (rocks, cars, etc.) so no guaranties on final dimensions. There may be less expensive ways of installing this type of foundation.

Contactors close to the proposed VLA site are:

- Hasse Construction, Albuquerque, NM
- Lawrence Construction, Littleton, CO
- Austin Bridge and Road, Irving, TX

4 Future Issues

- In section 2.1, it is clear that snow loading provides significant additional mass of the shelter roof. What are the ISO conditions for loading and structural deformation?
- What conditions does the earthquake requirement specified in [5] impose on the foundations?
- Establish all cost estimates, including labor costs.
- How is leveling of the shelter accomplished (and maintained) if fixed pile foundations are not used?
- What actions are required to prepare a stable bed for the shelter?

References

[1] J. Copeland, *Initial Shelter Drawings*, 2008, Drawings of pile/pad foundation options.

[2] ———, *Shelter Foundation Requirements v0.5*, Internal LWA Memo SHL-0001 (2008).

[3] R. W. Fox and A.T. McDonald, *Introduction to Fluid Dynamics*, John Wiley and Sons, 1985.

[4] Curt A. Gooch, *Heavy Snow Loads*, `http://emergencypreparedness.cce.cornell.edu//images//UserFiles//Heavy%20Snow%20Loads.pdf`, Cornell University Cooperative Extension.

[5] C Janes, *LWA Technical Requirements, Draft 9*, LWA SRR Documents (2007).

[6] Division of Agriculture University of Arkansas, *Ice and Snow Accumulation on Roofs*, `http://www.aragriculture.org//disaster//ice/_snow//ice_snow_accumulation.pdf`.

Response to
"Long Wavelength Array
Shelter Foundation Options v 0.3
John Copeland, Joel Banks
ARL:UT
March 27, 2008"

By
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Task Number SHL0003
April 7, 2008

In Section 2, I would recommend following the requirements of ASCE7-05 "Minimum Design Loads for Buildings and Other Structures". This document contains all loadings that need to be considered by law. It is referenced by the New Mexico Construction Industries Division Building Code.

Note that there are indeed wind uplift forces on flat roofs according to ASCE 7-05.

There should be some specification of allowable building deformations due to foundation settlement. My sense is that these allowable deformations are not very restrictive. We just want the building floor to be relatively level (say, within 2 degrees of horizontal).

Note that seismic loading can be a controlling design force. Seismic load requirements are provided in ASCE7-05.

The tie-downs from the roof at approximately 45 degrees from vertical provide a tripping hazard and are unsightly. If tie-downs are required, they should be less obtrusive.

The "poured concrete pilings" in Section 3.3 would be prohibitively expensive and are certainly not required considering the design forces. Also, removing such pilings would not be a simple matter.

Driven pilings might be a good option if uplift forces need to be resisted, especially if the antennas will be supported by driven posts as well, so the equipment will be available.

The shelter foundations should be designed to withstand all applicable forces for two extreme conditions, i.e., when:
the shelter is empty;
the shelter is maximally internally loaded.

Shelter leveling can be accomplished with a screw-type leveling system regardless of the foundation type being used. Alternately, wedges can be provided for this purpose.

Long Wavelength Array

Station Power Ground Side Interface (SHL-0004)

Version 0.3

Charles Slack, John Copeland, David Munton

3 April 2008

Introduction

The LWA station power requirements derive from the need to provide power to the LWA operational system components and support equipment. Following the nomenclature in [1], these components include, but are not limited to, FEE, ASP, DP1/2, DAC, MCS, and TCD elements, as well as lighting, heating, air conditioning, power conditioning. Additional power will also be required for a work area trailer.

Incoming Station Power

The LWA station power conditioning and distribution begins with the primary source power, provided by the local power company which will provide the high voltage incoming power from the nearest available service point to the control shelter local service point pad-mounted AC line step-down transformer. These incoming primary power lines must be buried, to National Electrical Code standards, so that no power lines are above ground any closer than 300 meters or more to the control shelter. The incoming primary power lines are connected to the pad-mounted step-down transformer through buried appropriate sized conduit. Output power to the shelter will be 120V/240V single phase.

The station power requirements have been roughly determined as shown below in Appendix A. These combined estimates project the single LWA station power to be 31 kW. Design guides suggest a safety factor of two over the maximum estimated capacity for the transformer. This takes into account power line source irregularities and provides an option for future expansion and unanticipated loads

Therefore the operational electronics, infrastructure power estimates, collective design experience, and the LWDA system power effectiveness, support a design capacity for the LWA control shelter main power distribution transformer of larger than 50 KVA. The LWA Control Shelter design requirements currently identify a 250-ampere service load center. A 50 KVA transformer is capable of a maximum of 208 - 220 amperes on the 120 V/ 240 V output side. Consequently, a 75KVA transformer appears preferable, although either of the following options may be reasonable depending on the final station power budget.

1. A 75 KVA transformer will supply 312 -320 amperes on the 120/240 V output side. The 75 KVA liquid filled, pad mounted, transformer will have dimensions of 34" X 49" X 24" and weigh 887 pounds. The concrete pad for the transformer will be approximately 4.5' x 4.5' x 4".
2. A 50 KVA transformer will be used, which would supply 208-220 A. In this case the shelter specification may be revised to reflect a smaller service load center.

Station Service

The AC power service point distribution load center boxes and power meter will be installed by a licensed electrician. All items that follow will be at the discretion of the electrician, and the final work should be done to local and national electrical codes as required.

The load center will be connected to the transformer by appropriate (buried) copper wire service lines enclosed in conduit from transformer to the meter/load center.

The load center will be mounted on suitable structure constructed of 14 gauge galvanized strut material in close proximity to the actual shelter (10 to 20 feet from control shelter). The service point load center boxes & power meter may be installed as close as five to ten feet from the large incoming primary power step-down transformer.

The service point load center will house the following.

1. A 250A circuit breaker for the shelter service.
2. A 50A circuit breaker for the working area trailer service.
3. Two 20A GFCI circuit breakers for auxiliary external weather proof power receptacles located at the load center.

All connections from the load center to either the shelter, or to the working area trailer, will be by weatherproof cable. In the case of the shelter, this cable may be buried. It is anticipated that the shelter may be hardwired to the service point load center.

References

[1] Ellingson, S. “LWA Station Architecture V1”, LWA Memo Series 119

Appendix A - Power Budget

The approximate power budget for the LWA equipment racks are estimated using numbers from the LWDA power budget to compute a comprehensive power per stand value, with approximations about the number of each component present. This estimate should be refined as the system develops.

Component	Number	Power per Unit (W)	Total Power (W)
Rack Fan	6	100	600
Computer/Monitor/Keyboard	4	250	1000
Network UPS	4	200	800
GPS Timing Receiver	1	150	150
DC Power Supplies			10000
Receive Chains	512	10	5100
Internal Lighting	6	60	360
Total			**18010**

Here we have assumed the following.

1. DC Power supplies operate at 50% efficiency, and supply power for the receive chain.
2. The LWA receive chain power requirement is 10W across all devices per polarization per stand.
3. The GPS power requirement is taken from a Symmetricom XLi Time and Frequency system.

The station / shelter will also require heating, ventilation, and cooling (HVAC) that must also be included in the power estimate. In order to estimate the HVAC needs of the LWA shelter, estimates for several quantities in addition to the power generated by the LWA receive chains and other electronics must be considered. These include: 1) the thermal heating due to the sun, and 2) the heating due to additional equipment and people in the shelter. For the purposes of this estimate, we calculate that the thermal heating results in a power transfer as given in Appendix A, and allow 130W of power per person in the shelter with at most three personnel inside.

Component	Number	Power per Unit (W)	Total Power (W)
Solar Heating	1	450	450
People	3	130	390
Total			**840**

Thus, equipment, solar heating, and personnel will generate just about 19kW of power.

Choosing 13 SEER AC units, which have the capability of removing 3.4 units of heat energy per unit of energy expended (input power), means that the AC will require ~ 5.5kW of power.

In addition, a trailer serving as a working area, with a 50A electrical service, could potentially require 6kW.

Thus, total station power requirements are on the order of 6kW+5.5kW+19kW ~ 31kW.

Appendix B - Heat Transfer through Shelter Walls

Heat transfer through the shelter walls represents one source of heating that must be accounted for. An estimate of this transfer under summer conditions represents the minimal load an AC unit must remove to maintain a constant temperature. In order to estimate this we begin with the U-value for insulation, defined by

$$U = \frac{Power(W)}{\delta T(K) \times m^2}$$

U is related to the standard R-value via the equation $U = 5.682/R.$ Energy will be transferred through the shelter walls, which have an area of about (8.5*20*2) + (8.5*8*2) ~ 476 square feet, and the ceiling which is (8.5*20)~ 170 sq. ft. The floor will be ignored in these computations.

During the summer, with AC running, it is not hard to imagine a 15C difference between the internal and external temperatures. So we end up with a power transferred of:

$$P = (\delta T * m^2 * 5.682)/R$$

Current thoughts are that the shelter walls will have an R value of 10, leading to a power transfer of 375 W through the walls. The ceiling will have an R-value of 20, and the power transferred would be ~ 70W. Thus the total power would be about 450W.

May 9, 2008

LWA Lightning Protection System

John Copeland, David Munton

SHL-0008

The purpose of the lightning protection system should be two-fold: To provide a safe place for field technicians to take shelter in an electrical storm and to protect the electronics to the greatest extent possible. It should protect the electronics from not only a direct strike but also from the electromagnetic wave produced by strikes in close proximity.

As stated in the preface to the National Fire Protection Association's standard for the installation of lightning protection systems, "…lightning is a stochastic, if not capricious, natural process. Its behavior is not yet completely understood." Even within the current state of knowledge, lightning protection is a complicated problem. However, mitigation of lightning consequences can be achieved with the use of a detailed systems approach which includes an integrated set of grounding techniques, protectors, and safety procedures. The severity of a lightning strike is a statistically predictable event. The lightning protection/grounding system should be designed to take into account a typical-to-large strike. Components common to most lightning protection systems are described below in general terms.

Air Terminal – "Lightning Rods" installed on the structure as sacrificial attachment points intending to conduct direct flashes to earth. This does not however, provide protection for electronics or people inside the structure. Inductive and capacitive coupling from lightning-energized conductors can result in significant voltages and currents on interior power, signal, and other conductors. For the LWA shelter, an overhead shield wire and mast system may be a better alternative.

Shield Wire - Shield wire, sometimes referred to as a static wire, is a wire that is generally installed above the phase conductors in high tension power lines. Its purpose is to intercept a lightning strike before it can attach to a phase wire. After striking the shield wire, the lightning current is diverted to ground through the pole ground lead. Shield wires can also be suspended above a structure to intercept a lightning strike. It is most often seen above explosive handling and storage facilities.

Downconductors – Downconductor pathways are generally installed outside the structure. With the LWA shelter being a metal building, the shelter itself may serve as a downconductor and may, in fact, emulate a faraday cage.

Bonding – Bonding assures that unrelated conductive object are at the same electrical potential. Without proper bonding, lightning protection systems will not work. All metallic conductors, including AC ducts, entering the shelter should be electrically referenced to the same ground potential.

Grounding – The grounding system must address low earth impedance as well as low resistance. Some soils, (such as sandy soils), have such high resistivities that conventional ground rods or ground electrode systems may be unable to attain the desired ground resistance requirement. Enhanced ground electrodes or ground enhancement materials may be required to meet the grounding specification.

Corrosion – Corrosion and cathodic reactance issues should be considered and addressed.

Transients and Surges – Ordinary fuses and circuit breakers are not capable of dealing with lightning inducted transients. AC power main panel, secondary distribution panels, equipment racks, and all valuable plug-in-devices should be protected with surge protection devices (SPD). Surge protection devices for the incoming RF cables are being considered as part of the RPD subsystem. These transient limiting devices should be test to ANSI/IEEE/ISO9000 standards. Care should be taken to avoid the low-priced, bargain products which proliferate the market (caveat emptor) Additionally, it should be noted; UPSs are not surge protection devices.

Testing – Modern diagnostic testing is available to mimic the performance of lightning conducting devices as well as to indicate the general route of lightning through the shelter. This testing is low power, 50 watts or less. It is traceable, but will not trip metal oxide varistors (MOVs), gas tube arrestors, or other SPDs. This should be discussed with a lightning contractor.

Maintenance - The lightning protection/grounding system should be maintained on a monthly or at least yearly basis. This should include testing protectors, measuring the ground system, pulling on ground rods, and protection grounding connections for corrosion and tightness. It should also involve a re-evaluation of the overall system design each time new equipment is installed, moved, or modified.

In the United States there is no single lightning safety code or standard providing comprehensive guidance. The following is a list of relevant standards and codes. This list is by no means exhaustive. IEC, IEEE, MIL-STD, FAA, NASA and similar documents are supported by background engineering, the peer-review process, and are technical in nature.

- NFPA 70 National Electric Code
- IEEE Std C2 National Electric Safety Code
- NFPA 780 Standard for the Installation of Lightning Protection Systems
- ANSI/J-STD-607-A-2002 Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications
- ANSI T1.313-2003 Electrical Protection for Telecommunications Central Offices and Similar Type Facilities
- IEEE Std 80 Guide for Safety in AC Substation Grounding
- IEEE Std 142 (Green Book): Recommended Practice for Grounding of Industrial and Commercial Power Systems

- IEEE Std 1100 (Emerald Book): Recommended Practice for Powering and Grounding Electronic Equipment
- IEC 62305: The European International Electrotechnical Commission series for lightning protection

Organizations dedicated to lightning protection include:

- National Lightning Safety Institute, (www.lightningsafety.com)
- Lightning Protection Institute, (www.lightning.org)
- United Lightning Protection Association (www.ulpa.org)
- Underwriters Laboratories (www.ul.com)

Risk Assessment – The following is the National Lightning Safety Institutes short version of risk assessment. While it is included in somewhat of a humorous vein, it reiterates some important points.

1. Lightning behavior is not fully understood. In another 100 years, science may roll back the "unknown" to the "known." Today we can only agree that lightning is arbitrary, capricious, random, stochastic, and unpredictable.
2. From a perspective of statistical probability, the likelihood of lightning striking your facility or structure is remote. Perhaps a one-in-a-million chance?
3. If lightning did strike your operations, damage from a lightning strike is calculable. Consequences range from "mild" to "catastrophic."
4. Your options are:
    a. Do nothing. Run with the odds. Take your chances.
    b. Do something. Get some information. Perform a safety assessment. Install defenses for people and for the facility.
5. Lightning doesn't care what you do.

While it would certainly be possible to research, design, and integrate lightning protection to some degree, it may be more prudent and cost effective to seek out advice from a commercial lightning contractor familiar with the techniques that are most effect in the high desert area of Socorro County, New Mexico. To that end, a list of Albuquerque area lightning contactors has been included as an appendix to this memo. (See Appendix A)

One of the shelter manufacturers, SeaBox, has as a factory installed option, a halo lighting protection system. This is entirely external to the shelter and provides air terminals connected to a single point ground lug and/or pigtail. Any discussions with a lightning protection contractor should include whether or not this $3K option is a worthwhile investment.

References

1. 21st Century Lightning Safety for Environments Containing Sensitive Electronics, Explosives, and Volatile Substances., Richard Kithil, President & CEO, NLSI, 2005
2. NFPA 780 Standard for the Installation of Lightning Protection Systems, 2008 Edition.
3. Fundamentals of Lightning Protection, Richard Kithil, President & CEO, NLSI
4. Grounding and Bonding – The Foundation for Effective Electrical Protection, Harger Lightning and Grounding, 2003
5. Halo Grounds, Comm-Omni International, www.comm-omni.com, 2008
6. Polyphaser Application Guide, Appendix A Part 1, Grounding Overview, Comm-Omni International, www.comm-omni.com, 2008

Appendix A

Lightning Protection Contractors in Northern New Mexico

Baca Lighting Protection
2887 Cooks Road
Santa Fe, NM 87507
505-473-1615
www.bacalightningprotection.com

B&D Industries
9720 Bell SE
Albuquerque, NM 87123
505-299-4464
www.b-d-electric.com

Gorman Lightning Protection
324 Palomino Street
Santa Fe, NM 87505
505-989-3564
www.gormanlightning.com

Echo Electric Company
610 Dekalb Avenue
Farmington, NM 87401
505-327-0881

KSL Services
PO Box 80
Los Alamos, NM
505-667-5061

Sonshine Enterprises
232 Muriel Street NE
Albuquerque, NM 87123
505-296-2461

Preferred Lightning Protection
2100 East First Street
Maryville, MO 4468
866-299-7406
www.preferredlp.com
Installations Nationwide

LWA Station Power Conditioning and Distribution

Sky Side Interface

SHL0009, Rev 1

John Copeland, 29 May 2008

The primary function of the power conditioning and distribution (PCD) subsystem is to make electrical power available to the other various subsystems; ARX, DRX, DP1, DP2, MCS, and FEE. This power should be clean and to the extent affordable, uninterruptible.

As outlined in SHL-0004, power comes to the shelter from a transformer installed by Socorro Electric Cooperative (SEC). The output of the transformer will be 120/240VAC, single phase. Behind this transformer will be the contractor installed power meter and a site power distribution panel. The site power distribution panel will house circuit breakers for and provide service to the following:

1. Shelter main power distribution panel
2. Weatherproof convenience outlet
3. Exterior work lights

The shelter main power distribution panel will be supplied by the shelter manufacturer and house circuit breakers for and provide service to the following:

1. Shelter sub-panel via EMI filters
2. Air conditioning unit #1
3. Air conditioning unit #2
4. Convenience outlet located in shelter entry panel access area
5. Work light located in shelter entry panel access area.

The shelter sub-panel will be supplied by the shelter manufacturer and house circuit breakers for and provide service to the following:

1. Interior lighting
2. Convenience outlets
3. Rack power outlets

Table 1 contains a summary of the estimated circuit loads and circuit protection. It is important to note that the primary job of circuit breakers is to protect the wiring. For each circuit, wire and breakers are sized based on a number of factors such as average current, in-rush current, and locked rotor current. The sum of the circuit breakers ratings may exceed to total power available because not all circuits are expected to carry the full load all the time.

Circuit Number	Name	Breaker	Voltage	Estimated Load
Site Power Panel				
1	Site Main	300A	240	241A
2	Shelter Main	250A	240	206A
3	Conv-1	15A	120	10A
4	Work Lights	15A	120	5A
5	Conv-2	30A	120	20A
Shelter Main Panel				
6	AC-1	30A	240	13A
7	AC-2	30A	240	13A
8	Work Lights	15A	120	5A
9	Conv-3	15A	120	10A
10	Shelter Sub	200	120	160A
Shelter Sub Panel				
11	Lights	15A	120	10A
12	Conv-4	20A	120	15A
13	Conv-5	20A	120	15A
14	Rack-1	30A	120	20A
15	Rack-2	30A	120	20A
16	Rack-3	30A	120	20A
17	Rack-4	30A	120	20A
18	Rack-5	30A	120	20A
19	Rack-6	30A	120	20A

Table 1.

The National Electrical Manufactures Association (NEMA) is the most popular set of standards used in America for the construction of power cords and their connectors. The NEMA nomenclature describes both the connectors rating and the pin configuration. The following table list the connectors suggested for use in the shelter.

NEMA Configuration	Location	Grainger PN:
5-20R	Convenience Outlets	6A702
L5-30R	Rack Outlets	1PKJ7
L5-30P	Rack Outlets Mating	4HD30
Non-NEMA	Rack Inlets (Metal Case)	3D326
Non-NEMA	Rack Inlets Mating	3D323

Table 2.

Each equipment rack will house a UPS rated at 3.0KVA. A proposed unit would be:

American Power Corporation
SU series
Model number SUA3000RMXL3U $1300
LAN card w/temp PN:AP9619 $460

This unit will provide approximately 18 minutes and run time at 50% of the rated load and is LAN capable. The UPS can be programmed for a synchronized turn-on delay to avoid branch circuit overload following a power outage. If connected to the shelter network, the outputs from the UPS can be switched via the LAN interface. This will allow for the power cycling of individual systems connected to the UPS. Rear mounted power distribution units (PDUs) or "power strips", can be connected to the UPS outputs as required for further distribution. PDUs can also be LAN controlled for further network control of sub-systems.

American Power Corporation
Power Distribution Unit (PDU, Rack Mount, 1U
Model Number AP7900, $509

Ultimately, the vast majority of electronic systems, including computers, operate on direct current (DC) power. How and when to make the conversion from the line supplied alternating current (AC) to DC is one of the issues to be resolved. At this juncture, there are two basic methods:

1. Do a bulk conversion from AC-to-DC and provide a common DC voltage to each sub-system. It would then be up to the sub-system to do any DC-to-DC conversion it requires.

2. Provide clean, stable AC and allow each subsystem to provide its own AC-to-DC converters.

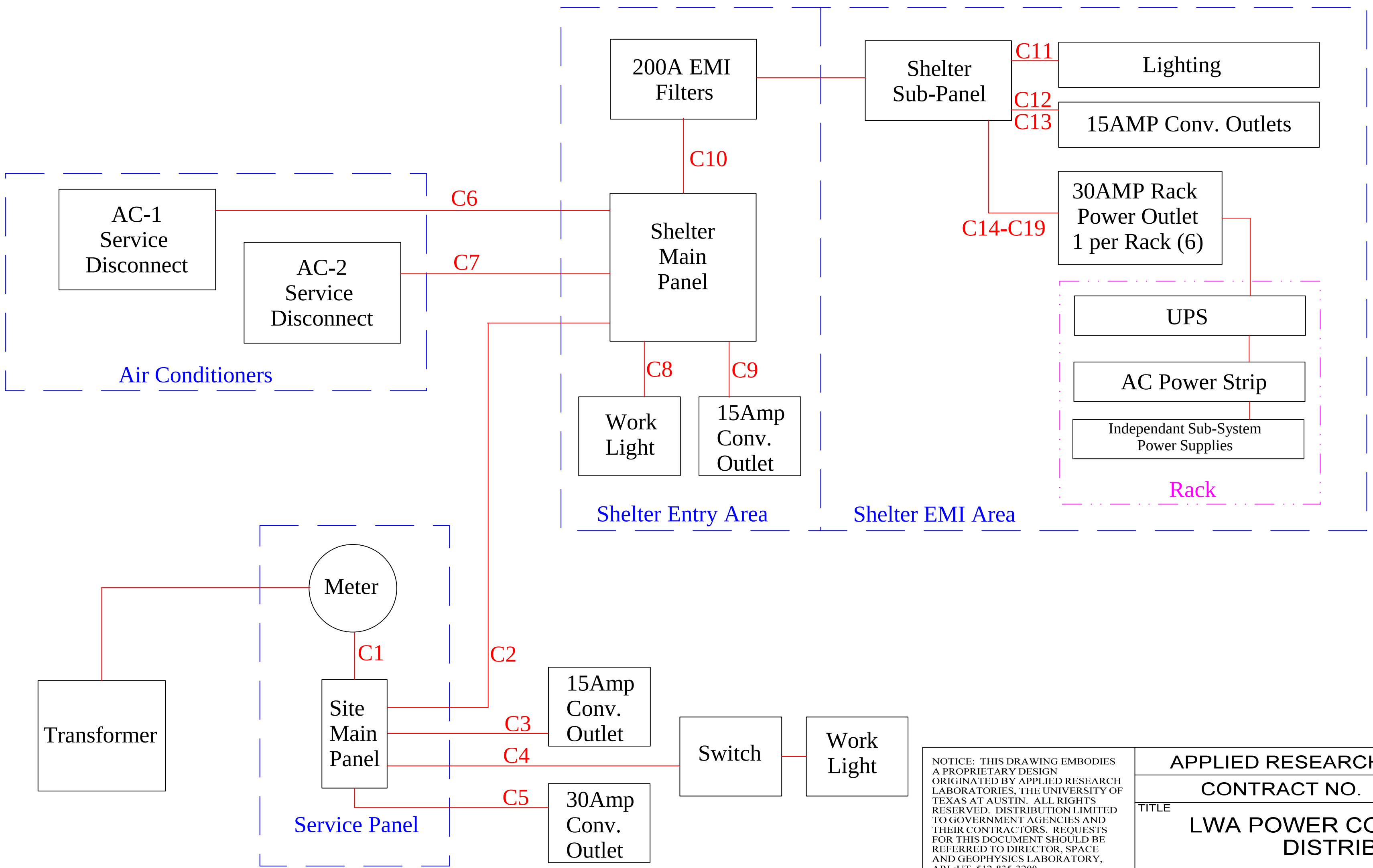
There are several things to consider in choosing which method to pursue. One thing to consider is system efficiency, or the lack thereof. Voltage conversions, whether from AC to DC or DC to DC, are not 100% efficient. With a switching power supply, as much as 30% of the input power is consumed in the conversion itself. With a linear supply this number can reach 50%. Therefore, as repetitive conversions take place, additional power is lost.

Another issue is linear conversion vs. switching conversion. While most digital circuits are not bothered by some switching noise, analog RF and amplifier circuits could be easily contaminated by the electrical noise from switching power supplies. This would mandate that the main source of a common DC supply be extremely clean. This, in turn, would subject all DC power to a steep penalty in efficiency.

In today's electronics, a wide range of DC voltages in both polarizations are utilized. A few of the more common voltages are ±15, ±12, ±5, and ±3.3. By providing a common DC Voltage of say, ±24volts, each sub-system will be inducing a further power loss with each additional conversion.

LWA sub-systems are being designed and fabricated all over the country. It may be in the best interest of the program to simplify the power distribution by providing 120 volt AC from the rack and allowing each sub-system to determine whether it requires linear or switching power and at what voltage. The power conversion can then be done from AC, directly to the required voltage. This also allows the various power supplies to be switched via networked UPS outlets and PDUs. Additionally, commercial off-the-shelf (COTS) items such as rack-mount computers, network switches and GPS receivers already designed to operate on 120 volt AC power will require no special consideration to fit into the power distribution scheme.

Power cords can be standardized to cords of appropriate wire gauge with a PH-386 grounding connector (commonly referred to as 'HP' connector) and a NEMA 5-15P grounding plug. This will also ensure an earth ground for each chassis. It could be further stipulated that each chassis PH-386 compatible power entry module be fused to the appropriate level for that chassis.



NOTE: Circuit indentifiers (Cx) refer to the circuits define in SHL0009, Table 1.

J COPELAND

24 APRIL 08

APPLIED RESEARCH LABORATORIES

CONTRACT NO. UNM-874F

TITLE

LWA POWER CONDITIONING & DISTRIBUTION

SIZE	CAGE CODE	DWG NO	REV
B		SHL0009	

SCALE		SHEET	
	DO NOT SCALE		1 OF 1

Shelter Entrance Panel Initial Design – SHL0010a
Shelter Entrance Panel Requirements and Design Options

Joel Banks

June 8, 2008

Introduction

This document discusses the performance requirements for the Shelter Entrance Panel (SEP), identifies the issues involved in evaluating the different design options for the structures and components relative to those requirements, and presents recommendations for the preferred design options.

The SEP is the main signal and power interface between the antenna array and the data processing and control electronics in the shelter. The main function of the SEP is to provide the physical interface between external cabling and internal shelter cabling. The SEP also provides a location for the electrical service connection to the shelter, along with data networking cables and/or optical fibers. In addition, it provides a centralized location for suppression of electrical surges in the antenna cables due to lightning strikes and similar disturbances.

The SEP bulkhead must be as EMI-tight as possible to minimize emissions from the LWA processing equipment, which could generate self-interference, or generate interference for the VLA. The exterior of the SEP should be enclosed to protect the antenna cables and connectors from ambient environmental conditions, in order to provide better system reliability and durability. In addition, the SEP should be designed to make maintenance and repair of cables, connectors, and related equipment, straightforward.

Many of these requirements are interrelated, and the design choices to meet one requirement may be primarily driven by other requirements. Each of the requirements will be discussed in turn, with the issues involved and design options presented in detail. Suggestions for preferred design options are made when practical; cases where further exploration is needed are also identified.

SEP and EMI shielding

The SEP must minimize propagation of EMI from the LWA processing equipment to the exterior of the shelter. This requires full electrical continuity and sealing of all joints between the SEP structure and components and the structure of the shelter. There are 3 main ways to achieve this goal:

- Continuous welding of all structural seams
- EMI gasketing at all demountable (non-welded) connections
- Sealing of all joints and seams with metal-foil tape

It is also possible to combine two or more of these methods.

Continuous welding of all components into an integral structure may provide the best shielding performance, but this can be difficult to achieve and limits the ability to easily perform maintenance and repair of the SEP. (Maintenance and repair requirements are discussed later in this document.) Because the connector panels of the SEP must be weather-resistant and also provide good electrical continuity with the shield braid of the antenna cables for static dissipation and surge suppression, they cannot be made of painted plain steel (the material used for standard ISO cargo containers, which will be used for the main shelter structure). Stainless steel and aluminum are thus better material choices for the connector panels. It is very difficult to weld stainless steel to plain steel; it is impossible to weld aluminum to steel.

A better approach is to have a steel structural framework for the SEP, with the framework welded to the shelter structure. The connector panels would be attached to the framework with closely-spaced threaded fasteners, EMI gasketing or metal foil tape would then be used to ensure shielding.

Another aspect of EMI shielding involves the penetration of the antenna signal leads through the SEP. This is best done with RF-tight bulkhead connectors mounted to the connector panels. There must be a close fit between the connectors and the panels, with precisely machined openings that eliminate gaps. The connectors must be designed to provide good continuity and shielding with the panels, preferably with a compression nut and washer, along with a sealing gasket. Any bulkhead connectors that are not connected to antenna leads must be capped with terminating resistors to prevent radiation through the unused conductors.

If surge suppressors with integral bulkhead connectors are used for the panel penetrations, the connection between the suppressor and panel must be EMI-tight. Typical surge suppressors do not provide this capability; it is essential to ensure that this requirement is met, which may require additional EMI gasketing at the connection.

SEP and electrical continuity between antenna cables and ground

The SEP must provide electrical continuity between the shield braid of the antenna cables and ground for purposes of static dissipation and electrical surge suppression. This path goes from the braid, through the cable connector to the entrance bulkhead connector (possibly with an intermediary surge suppression device), into the connector panel, thorough the shelter structure and then to an earth ground terminal. The impedance of this path must be sufficiently low to prevent significant potential differences between the antenna cable and ground.

It may also be necessary and desirable to provide additional grounding conductors between sections of the connector panels and from the panels to the main grounding conductor in order to minimize the overall impedance of this path, provide sufficient current capacity for surge suppression, and isolate the grounding path from the main shelter structure.

As with EMI shielding, there must be good continuity between the bulkhead connector and the panel, and low resistance within the panel itself. The panel should therefore be bare metal; stainless steel and aluminum are reasonable options. Aluminum has lower resistance and thus better conductivity than stainless, but it can be susceptible to surface oxidation which can increase contact resistance. This is not a problem in low-current applications such as simple grounding and static dissipation, but may be an issue in higher-current surge suppression situations. It may therefore be desirable to use a standard, commercial anti-oxidation compound between the bulkhead connectors and aluminum connector panels.

If the surge suppression devices do not use the grounding (common) side of the RF connectors for discharge of surge power, additional conductors must be provided for this purpose. One approach would be to use a framework of bus bars, which would minimize the wiring between the individual surge suppression devices and ground, and also improve access for maintenance and repair.

SEP interface between antenna cables and receiver chain

The SEP also provides a physical interface between the cables from the antennas and the receivers in the equipment racks. The antenna cables are fairly long and must potentially withstand environmental exposure and physical loading. Therefore, they must be low-loss and robust, which mandates a minimum size and connector type. Cable with a diameter of approximately 0.25” to 0.5” with type N connectors is common for this application. In contrast, the cables to the receivers are relatively short, and the size limitations of the equipment racks mandate a much denser packing of the connections. For this application, small-diameter cable (approximately 0.1” diameter) with SMA connectors are more suitable.

Therefore, between the interface at the SEP and the racks a transition to different connector types is required. There are three ways to accomplish this.

1. The SEP bulkhead connectors may in themselves be adapters, with different connector types on each end.
2. The internal SEP to rack cables might have different connectors at each end.
3. Adapters separate from the bulkhead adapters could be used.

The integral bulkhead adapter approach is preferable, as it minimizes the number of components required, reducing cost, mechanical complexity, and the potential for signal degradation at connections.

Another issue to consider is the provision of electrical power to the antennas through the cables. If the power supplies are integrated into the receivers, no additional requirements are imposed on the SEP components. However, if discrete, connectorized bias-Ts are used, selection of the SEP connectors must consider the physical demands of these devices. The weight and mechanical loading of the power devices on the bulkhead connectors would require the use of larger (type N) connectors for robustness and reliability. The power devices should then be configured with smaller (SMA) connectors on the side towards the receivers, or adapters must be fitted. Additionally, the spacing of the connectors on the SEP panels must accommodate not only the size of the power components and their connectors, but must allow hand or tool access to the connectors for installation or maintenance. Furthermore, provision must be made for the power wiring to the devices, to ensure adequate space and prevent interference with access to other components.

SEP assembly, maintenance, and repair

The design of the SEP must provide for easy assembly, maintenance, and repair of all related structures, cables, and components. Modular design provides several advantages, particularly for maintenance and repair. It is preferable to use several small panel sections, each with a set of connectors, rather than a single, large panel. The SEP is thus broken down into a set of smaller, simpler subassemblies. While the number of parts increases slightly, the cost of fabrication and assembly is reduced. As noted above, this approach also leads to mounting the panels to the shelter structure with threaded fasteners, rather than welding them in place.

Cable management is a major consideration, as there will be over 500 cables attached to each side of the SEP. Using cable trays or brackets to group and route cables between the shelter entrance and the SEP, and between the SEP and the receivers, will greatly help in keeping things orderly, prevent interference, and improve access to the individual connections and components. It is essential to label the ends of the cables and each bulkhead connection (on both sides of the panels). Grouping the cables and connectors according to the physical location of the antennas, corresponding to the main trunk lines of the cable runs, will simplify both initial configuration and troubleshooting of the system.

Designing for ease of maintenance also strongly suggests the use of standard bulkhead connectors for the panel penetrations, rather than using bulkhead-mount surge suppressors. When the suppressors need to be replaced after a strike, the work can be done without needing simultaneous access to both sides of the panel, reducing manpower demands. Furthermore, the EMI shielding of the panel will not be compromised, and there will be no need to evaluate the effectiveness of the shielding after the repair.

SEP entrance area

The entrance area of the SEP, where the antenna cables enter the shelter structure, must be enclosed to protect the antenna cables and connectors from ambient environmental conditions, in order to provide better system reliability and durability. This area does not need to be EMI shielded. However, because the space will not have climate control, it is likely that measures will need to be taken to prevent condensation, which can lead to corrosion and degradation of the connection between the antenna cables and the SEP. Ventilation of this area will probably be sufficient to prevent this problem.

Ventilation options include simple passive vents placed in the walls of the shelter, allowing natural convection, and forced ventilation, using one or more small fans to ensure a continuous flow of air through the area. Due to the generally low relative humidity of the LWA area, condensation potential may be relatively minor, but more study is needed before selecting ventilation components. The seasonal (and diurnal) variation of temperature in the area, along with the controlled temperature of the equipment enclosure, will result in the surface of the SEP alternately being colder and warmer than ambient conditions, leading to condensation potential on both surfaces of the SEP. However, only the exterior surface is of concern; the high internal cooling load from the equipment will result in the air conditioning system running with a high duty cycle and keeping interior humidity very low. It will likely be necessary to ensure a certain amount of air circulation through the entrance area to prevent condensation on the exterior surface of the SEP.

Shelter structure and cable entrance to SEP

The shelter structure must provide means for passing the antenna cable from the exterior to the SEP. This can be as simple as sleeved openings in the entrance area floor. A better approach would be to use conduit, which would provide additional sealing against environmental conditions and better protect the cables physically.

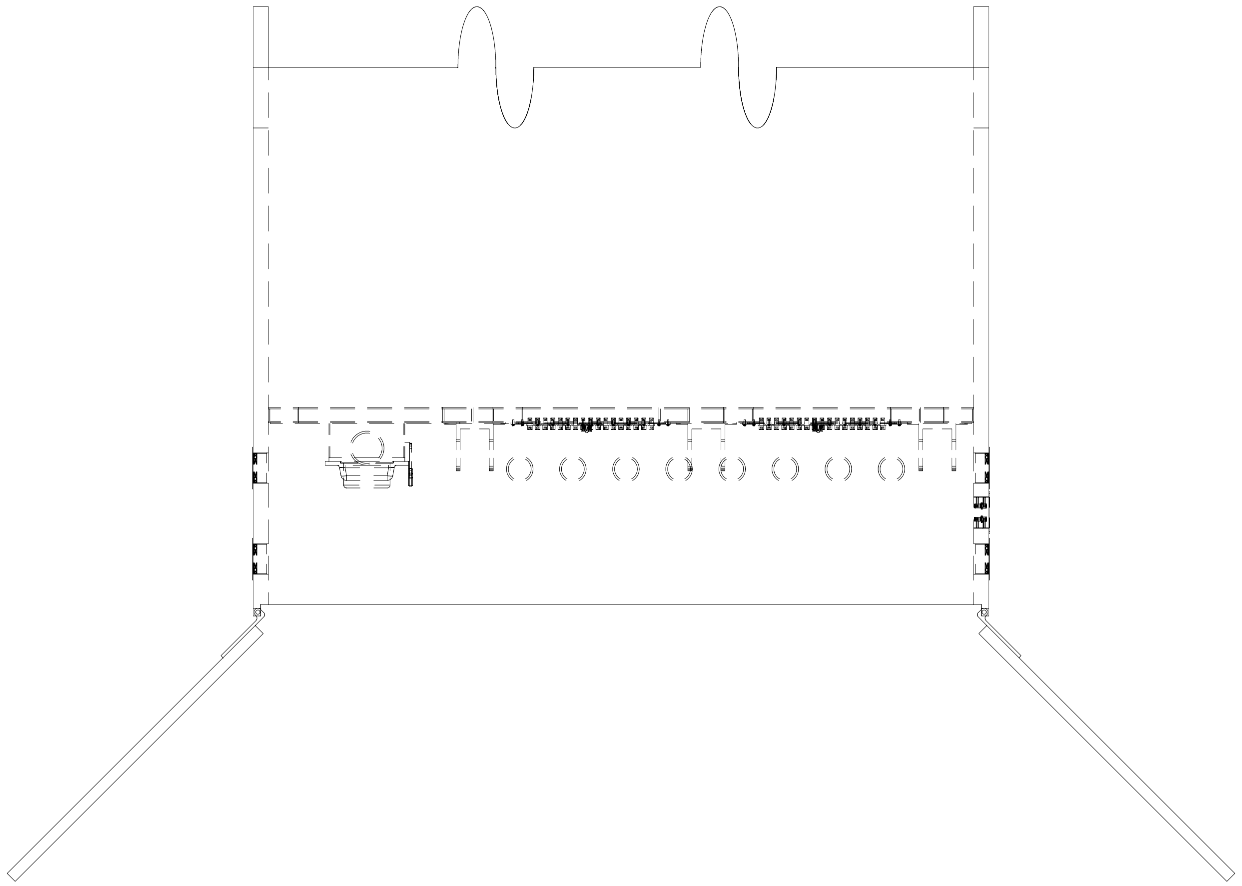
If simple sleeves are used, access underneath the shelter must be provided for feeding the cables through the inlets. If conduit is used, exterior access ports will be helpful. Any conduit connection to the shelter must also accommodate minor misalignments between the main conduit run and the inlet sleeves, or relative movement between the shelter and the ground due to humidity changes or freeze/thaw cycles. One approach is to connect the ends of horizontal, buried conduit runs to the vertical inlet sleeves with a section of flexible conduit. This approach will accommodate relative movement in all three dimensions.

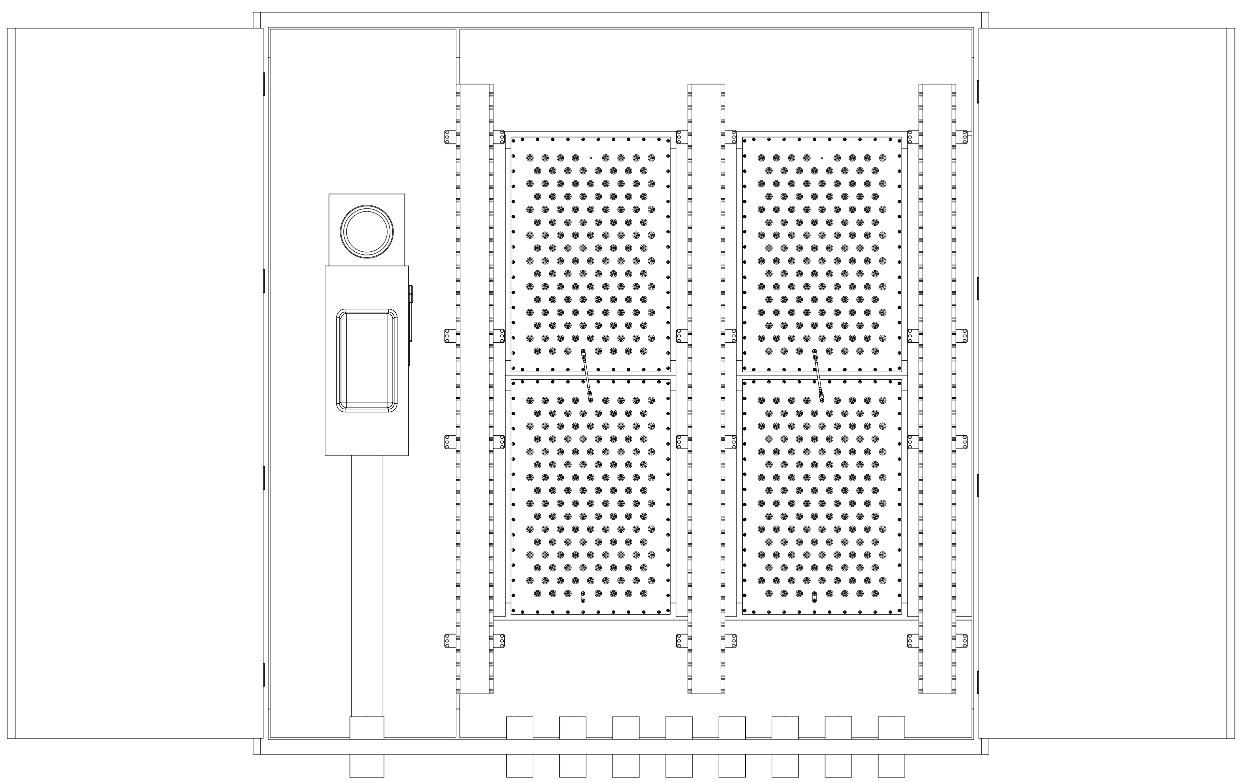
Summary

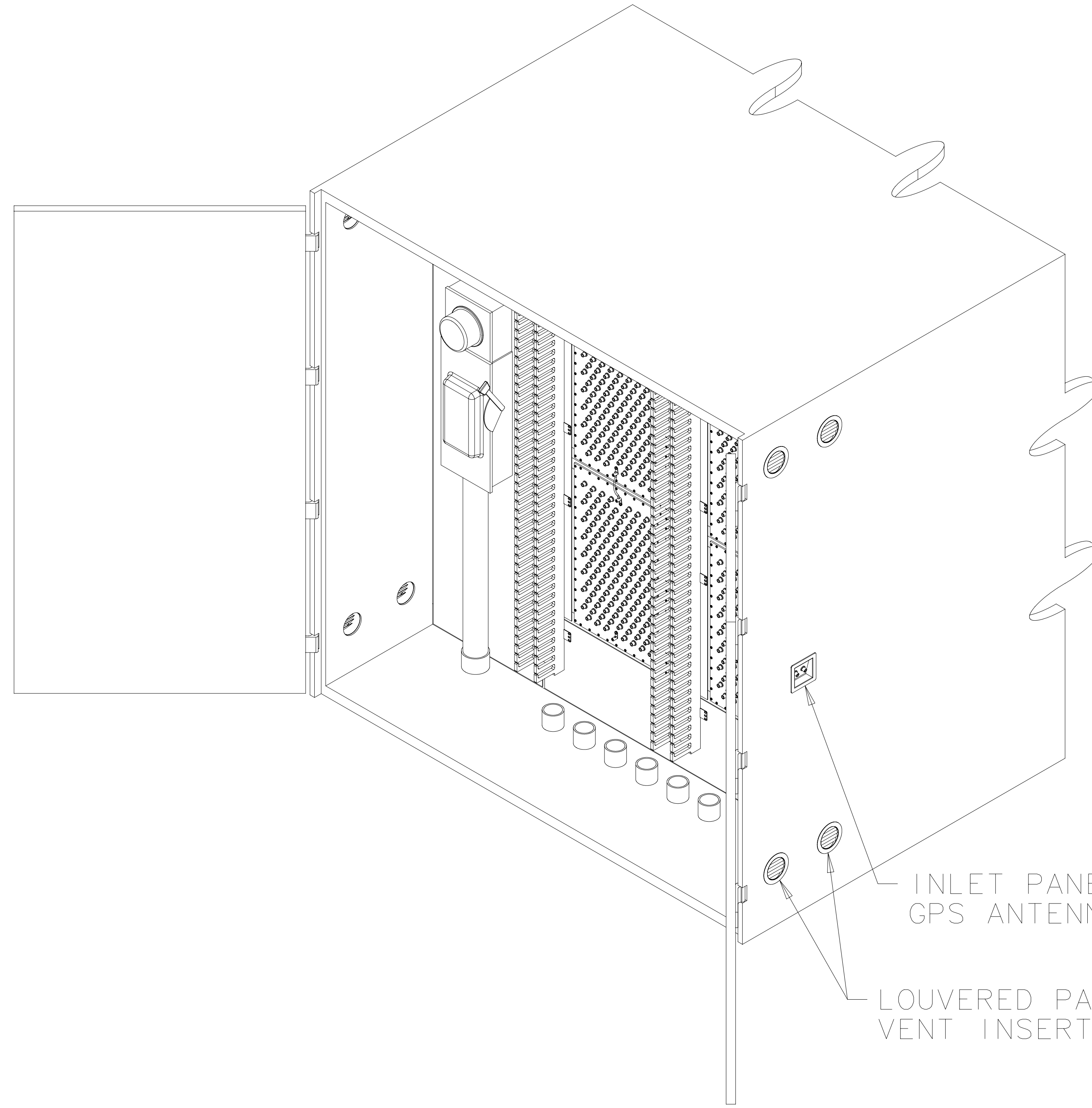
In this memo a number of considerations for the SEP design have been discussed, with the intent of outlining the important requirements and major issues. Of the different approaches that have been discussed, it is worth summarizing what would be the initial choices in the approach to the SEP design.

1. The SEP will be attached to a plain steel frame, which will be welded to the main shelter body.
2. The entry panels will be bolt-in aluminum panels with EMI gasketing.
3. To promote adequate ground, heavy copper jumpers will connect panels and panel-to-frame.
4. N-type surge suppressors, mounted to N-type bulkhead connectors are preferred. Bulkhead surge suppressors might be considered if cost becomes an issue.
5. N-to-SMA-type transition on the inside of the SEP.
6. Factory installed weather resistant, insect resistant vents in the SEP service area for increased ventilation.
7. And 6' of flexible conduit connecting the SEP service area to the antenna field conduit.

Overall, this path seems to optimize flexibility while keeping parts count and cost low.
Future work will focus on preparing detailed drawings and specifications of the SEP for the vendors







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PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS ± DECIMALS .XX=±0.03 .XXX=±0.010 ANGLES ±1/2°
DO NOT SCALE DRAWING

CONTRACT NO. XXXX-X-XXX-X

APPROVALS		DATE
DRAWN	J. BANKS x3463	8/7/08
CHECKED		
ISSUED		

TREATMENT

FINISH

SIMILAR TO | ACT. WT | CALC WT

APPLIED RESEARCH LABORATORIES
SPACE AND GEOPHYSICS LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

TITLE
SHELTER @ ENTRANCE PANEL
LWA SHELTER

SIZE B | FSCM NO. | DWG NO. SEP-10000

SCALE: NONE | SHEET 1 OF 1

REVISIONS				
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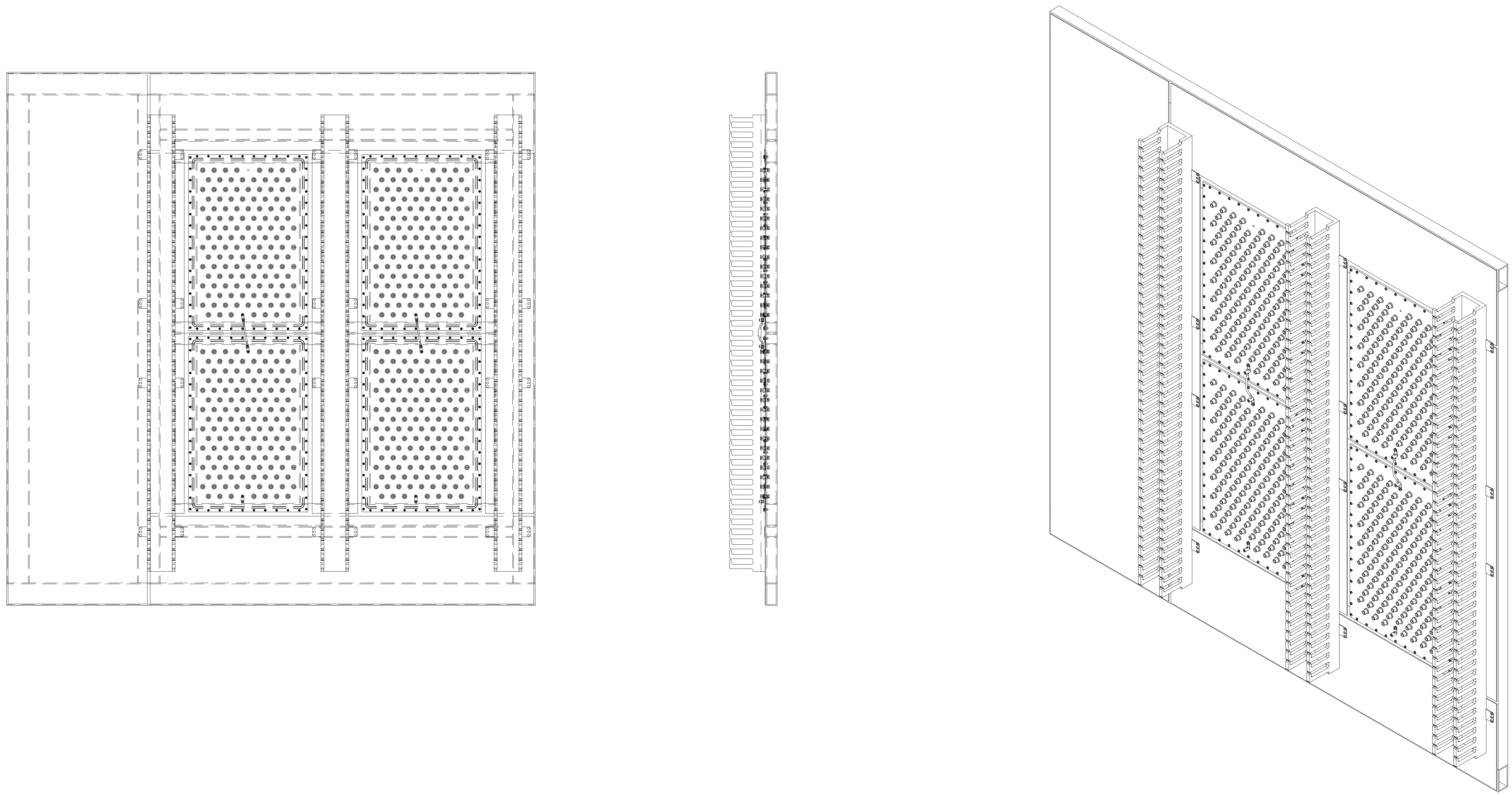

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PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS ±
DECIMALS .XX=±0.03 .XXX=±0.010
ANGLES ±1/2°
DO NOT SCALE DRAWING

CONTRACT NO. XXXX-X-XXX-X

APPLIED RESEARCH LABORATORIES
SPACE AND GEOPHYSICS LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

APPROVALS	DATE
DRAWN J. BANKS x3463	7/22/08
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ISSUED	

TREATMENT

FINISH

SIMILAR TO | ACT. WT | CALC WT

TITLE
ENTRANCE PANEL ASSEMBLY
LWA SHELTER

SIZE B | FSCM NO. | DWG NO. SEP-20000

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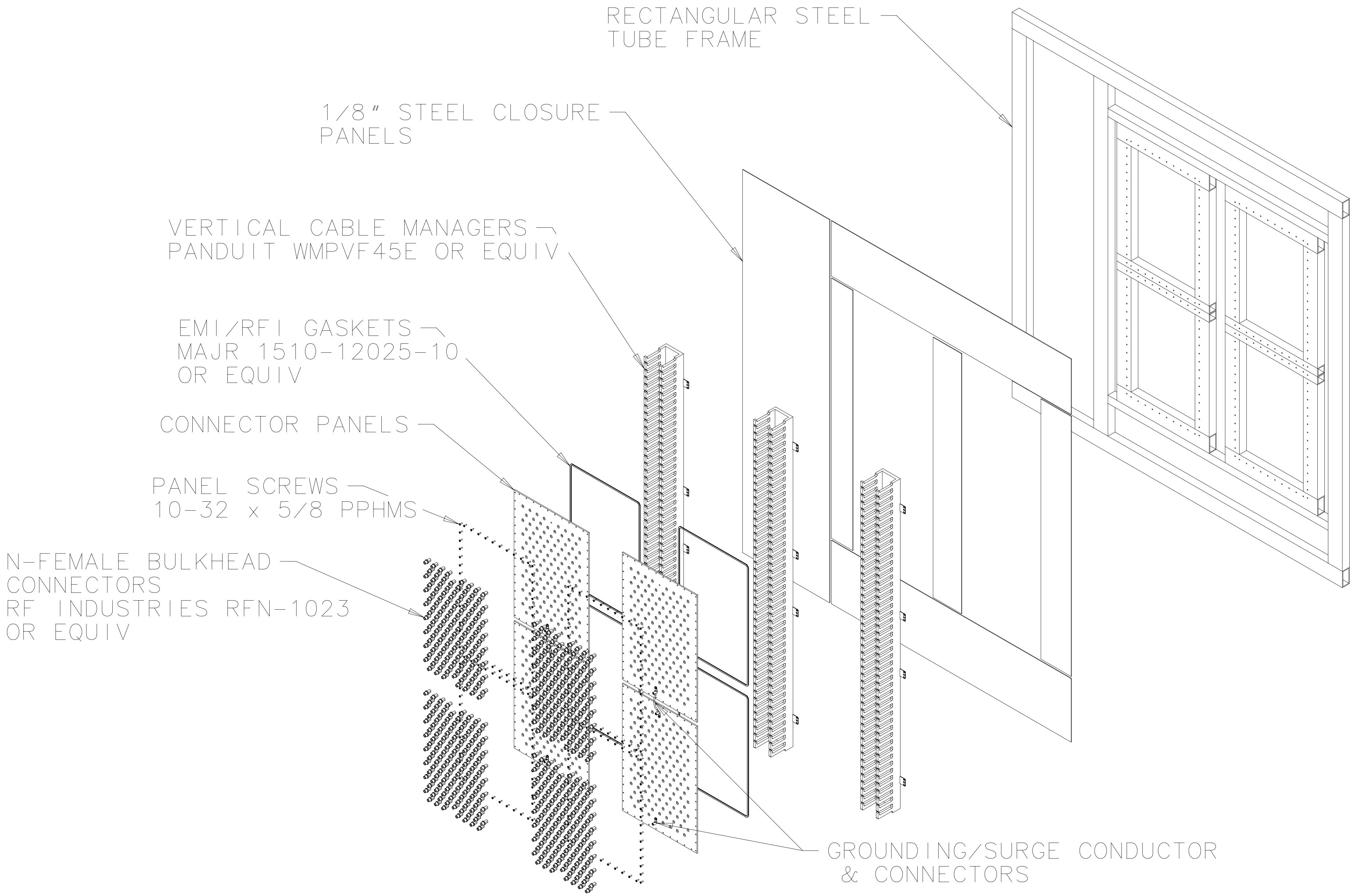

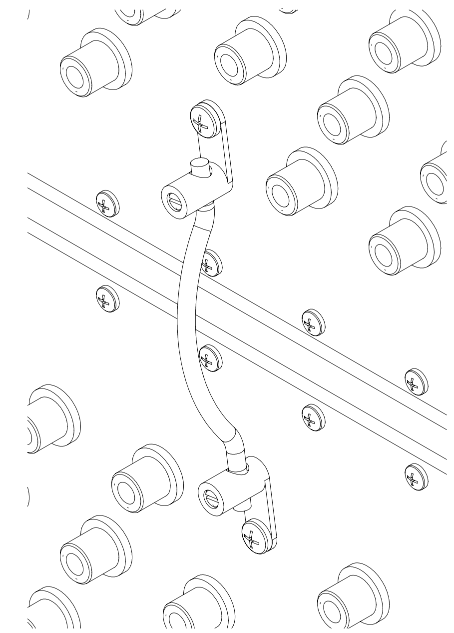

DETAIL OF GROUNDING/SURGE CONDUCTOR & CONNECTORS

THOMAS & BETTS L70 OR EQUIV, 4 AWG THHN

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

X	X	XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX
QTY REQD	ITEM NO	NEXT ASSEMBLY	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS ± DECIMALS .XX=±0.03 .XXX=±0.010 ANGLES ±1/2°
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | ACT. WT | CALC WT

CONTRACT NO. XXXX-X-XXX-X

APPROVALS	DATE
DRAWN J. BANKS x3463	7/22/08
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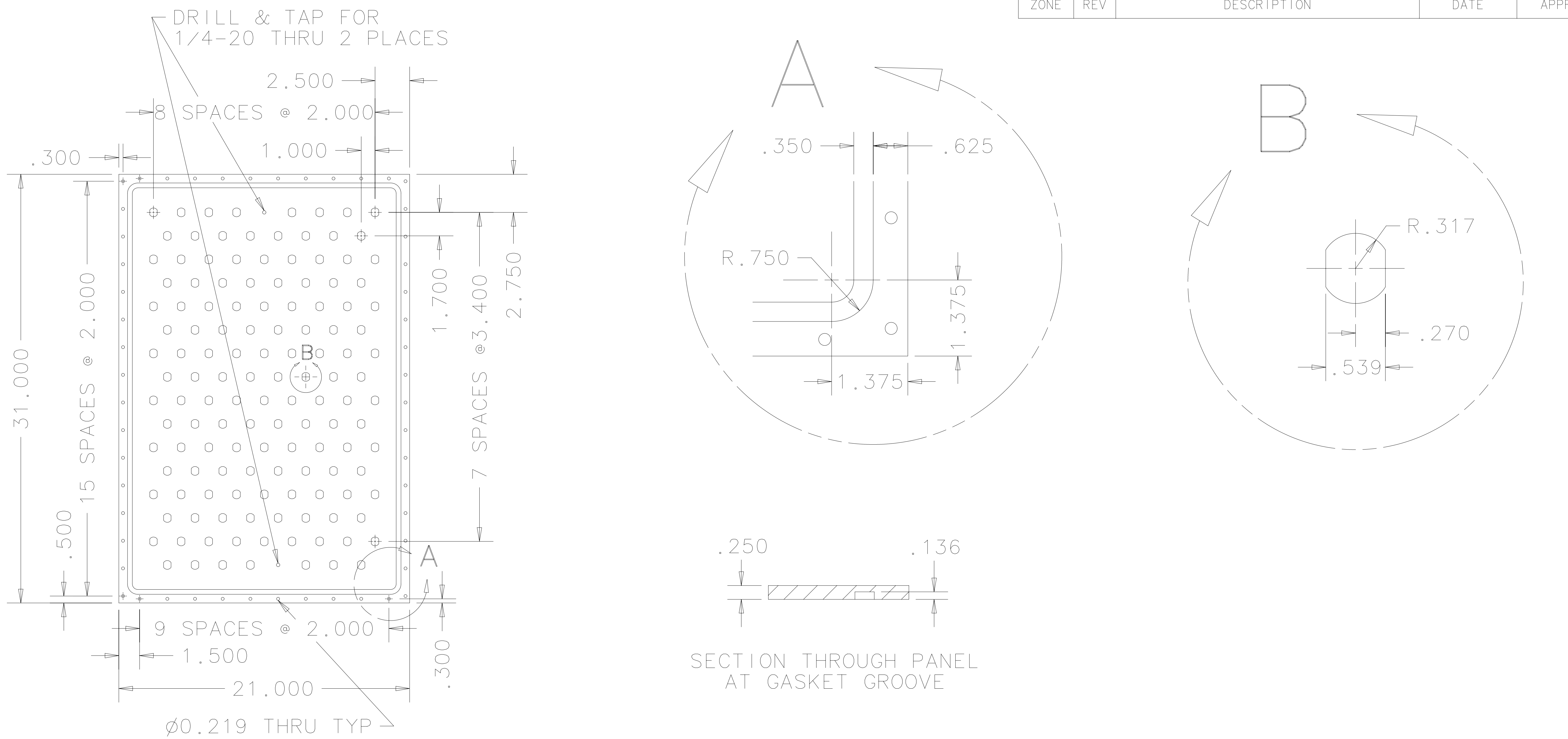
ISSUED	

APPLIED RESEARCH LABORATORIES
SPACE AND GEOPHYSICS LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

TITLE
ENTRANCE PANEL ASSEMBLY
LWA SHELTER

SIZE B | FSCM NO. | DWG NO. SEP-20000

SCALE: NONE | SHEET 2 OF 2



REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

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QTY REQD	ITEM NO	NEXT ASSEMBLY	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
±	.XX=±0.03 .XXX=±0.010	±1/2°

DO NOT SCALE DRAWING

CONTRACT NO.
XXXX-X-XXX-X

APPLIED RESEARCH LABORATORIES
SPACE AND GEOPHYSICS LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

APPROVALS	DATE
DRAWN J. BANKS x3463	7/23/08
CHECKED	
ISSUED	

TREATMENT

FINISH

SIMILAR TO | ACT. WT | CALC WT

TITLE
CONNECTOR PANEL
LWA SHELTER

SIZE B | FSCM NO. | DWG NO. SEP-20001

SCALE: NONE | SHEET 1 OF 1

REVISIONS				
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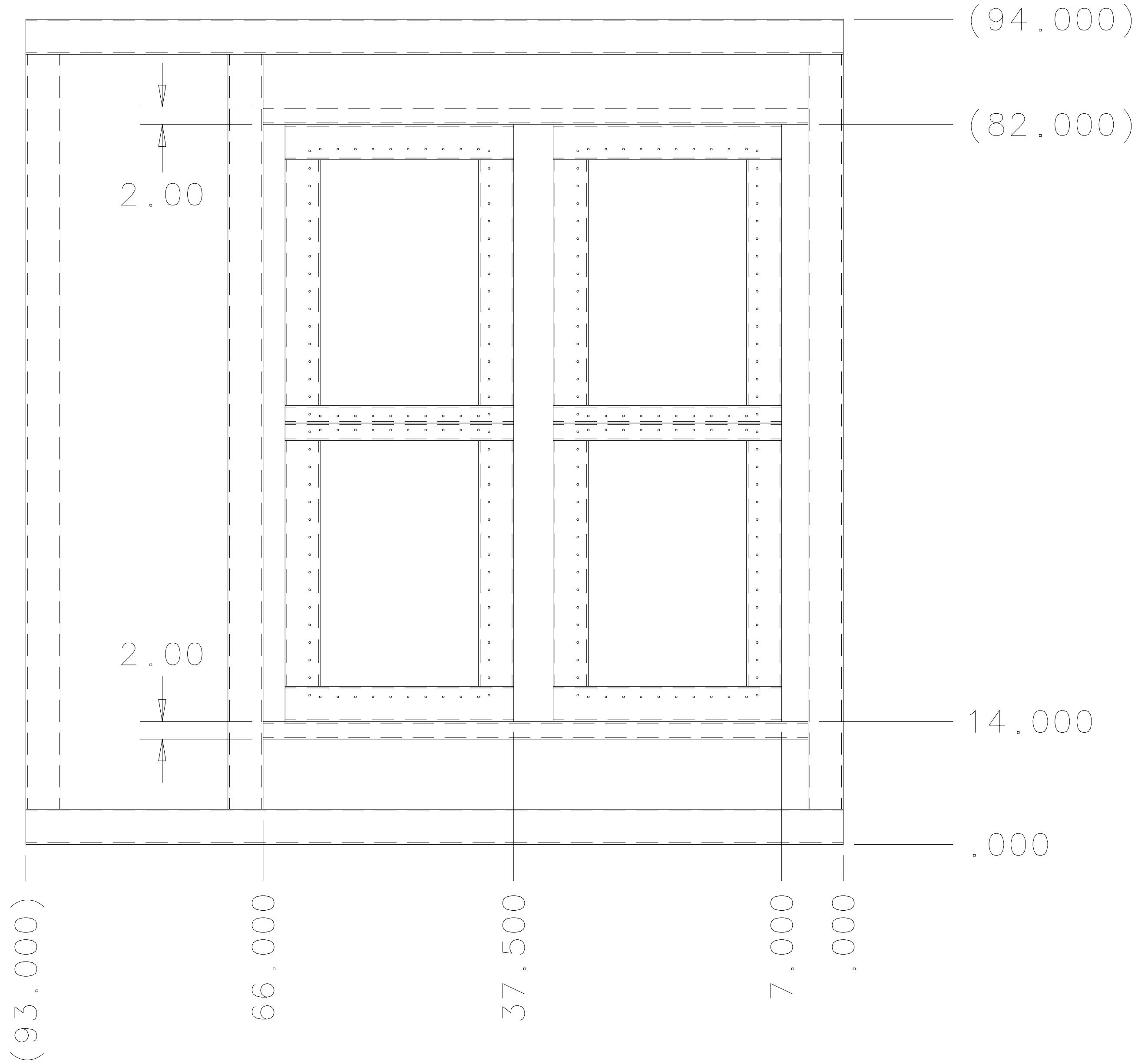


NOTE: ALL MATERIAL 4" X 2" X 3/16" RECTANGULAR STEEL TUBE, EXCEPT 2" X 2" X 3/16" WHERE NOTED.

OVERALL DIMENSIONS AND CORNER DETAILS SHALL MATCH ACTUAL ISO CONTAINER USED FOR SHELTER BODY.

ASSEMBLE WITH CONNECTOR PANELS ATTACHED TO FRAMES TO PREVENT DISTORTION WHILE WELDING.

QTY REQD	ITEM NO	NEXT ASSEMBLY	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
4			SEP-21001	CONNECTOR PANEL FRAME	
X	X	SEP-20000		ENTRANCE PANEL ASSEMBLY	

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
±	.XX=±0.03 .XXX=±0.010	±1/2°

DO NOT SCALE DRAWING

CONTRACT NO. XXXX-X-XXX-X

APPLIED RESEARCH LABORATORIES
SPACE AND GEOPHYSICS LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

APPROVALS	DATE
DRAWN J. BANKS x3463	7/22/08
CHECKED	
ISSUED	

TREATMENT

FINISH

SIMILAR TO | ACT. WT | CALC WT

TITLE

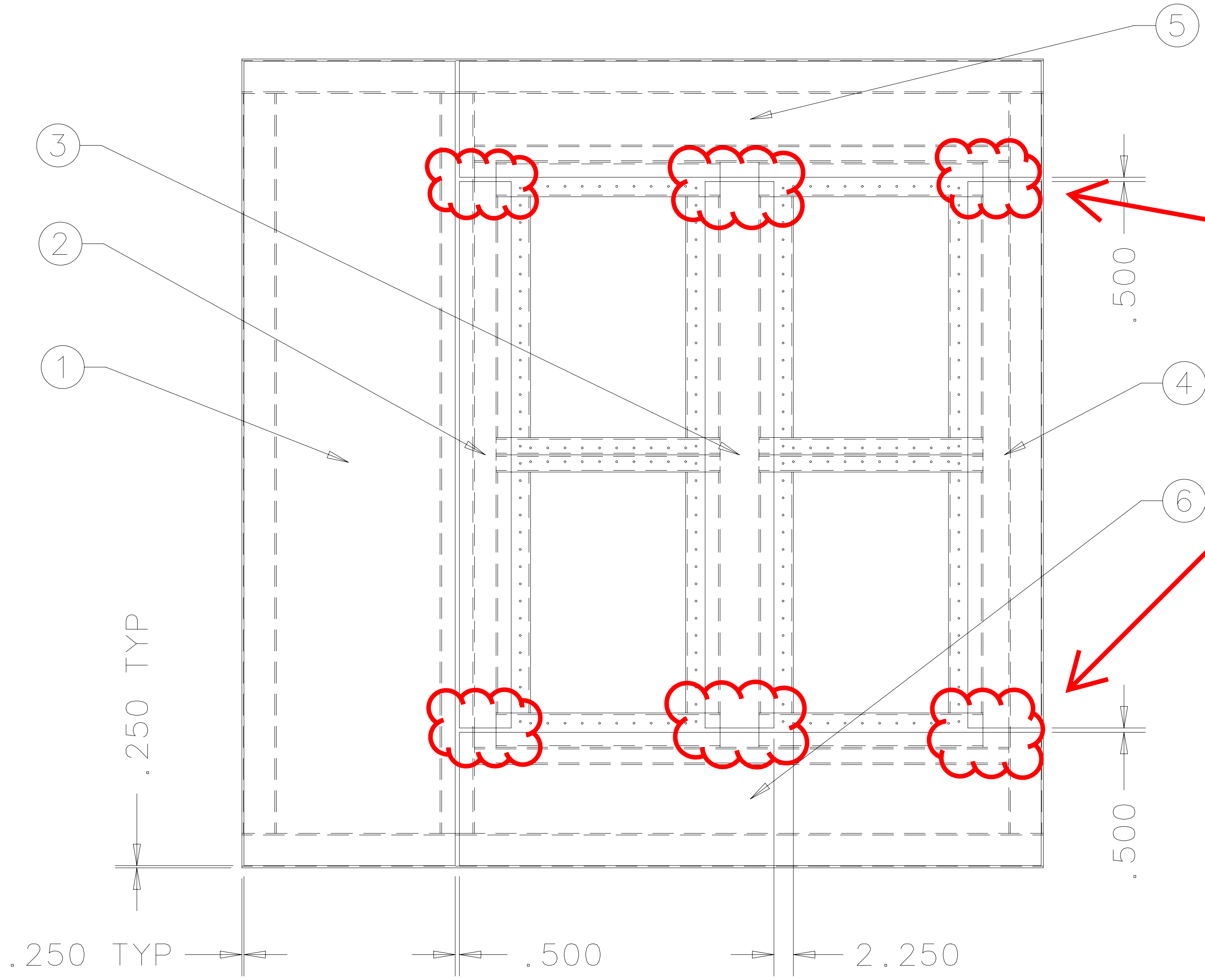
ENTRANCE PANEL FRAME

LWA SHELTER

SIZE B | FSCM NO. | DWG NO. SEP-21000

SCALE: NONE | SHEET 1 OF 2

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



SEAMS BETWEEN CLOSURE PANELS AT AREAS WITH NO UNDERLYING FRAME TUBING SHALL HAVE 1-1/2" WIDE X 1/8" THICK FILL PLATES WELDED TO REAR FACES OF PANELS.

NOTE: PANELS TO BE WELDED TO FRAME MEMBERS ALL AROUND, FRONT & BACK, TO PROVIDE EMI/RFI SEAL.

QTY REQD	ITEM NO	NEXT ASSEMBLY	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
1	6		SEP-21002-6		1/8" STEEL SHEET
1	5		SEP-21002-5		1/8" STEEL SHEET
1	4		SEP-21002-4		1/8" STEEL SHEET
1	3		SEP-21002-3		1/8" STEEL SHEET
1	2		SEP-21002-2		1/8" STEEL SHEET
1	1		SEP-21002-1		1/8" STEEL SHEET
X	X	SEP-20000		ENTRANCE PANEL ASSEMBLY	

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS ± DECIMALS .XX=±0.03 .XXX=±0.010 ANGLES ±1/2°
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | ACT. WT | CALC WT

CONTRACT NO. XXXX-X-XXX-X

APPROVALS	DATE
DRAWN J. BANKS x3463	7/22/08
CHECKED	
ISSUED	

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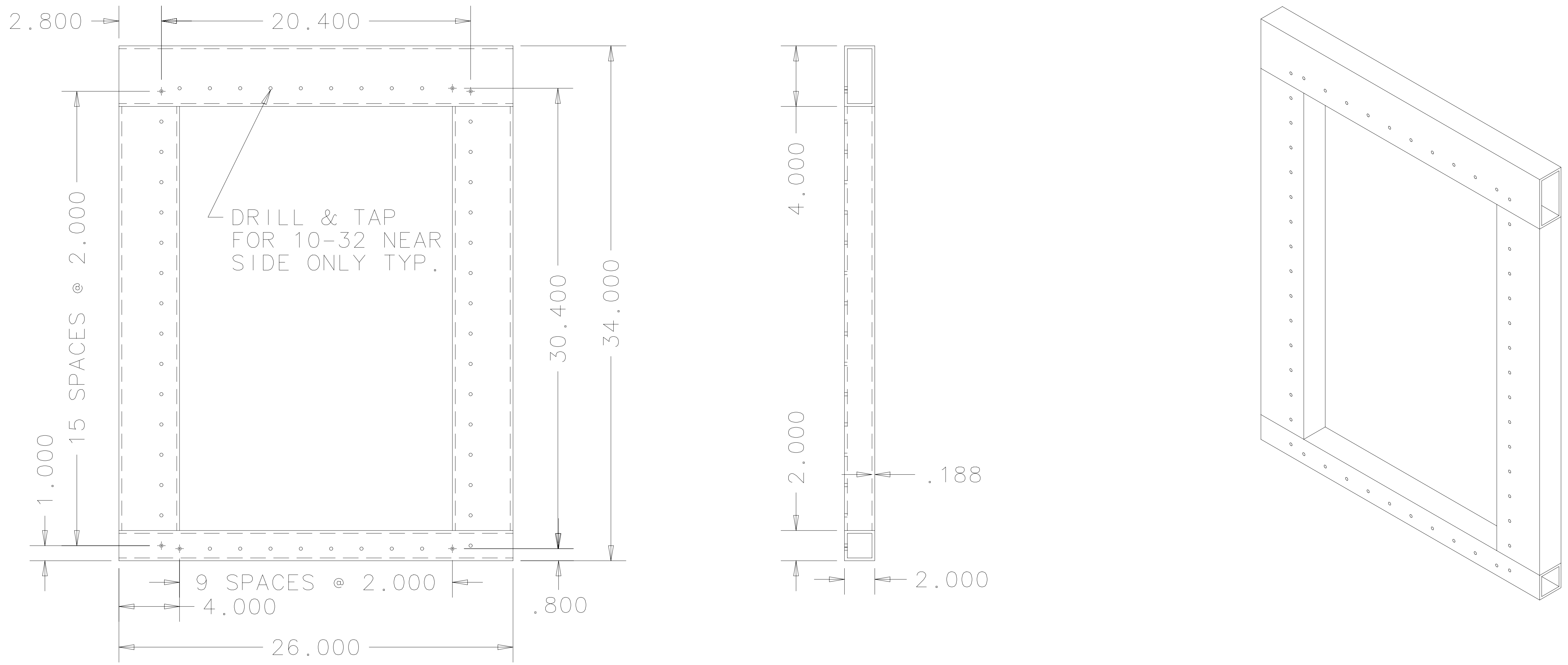
THE UNIVERSITY OF TEXAS AT AUSTIN

TITLE
ENTRANCE PANEL FRAME
LWA SHELTER

SIZE B | FSCM NO. | DWG NO. SEP-21000

SCALE: NONE | SHEET 2 OF 2

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



NOTE: MACHINE HOLES AFTER WELDING FRAME.

4	X	SEP-21000	XXXXXXXX	ENTRANCE PANEL FRAME	STEEL TUBE
QTY REQD	ITEM NO	NEXT ASSEMBLY	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
±	.XX=±0.03 .XXX=±0.010	±1/2°

DO NOT SCALE DRAWING

CONTRACT NO. XXXX-X-XXX-X

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THE UNIVERSITY OF TEXAS AT AUSTIN

APPROVALS	DATE
DRAWN J. BANKS x3463	7/22/08
CHECKED	
ISSUED	

TITLE
CONNECTOR PANEL FRAME
LWA SHELTER

TREATMENT

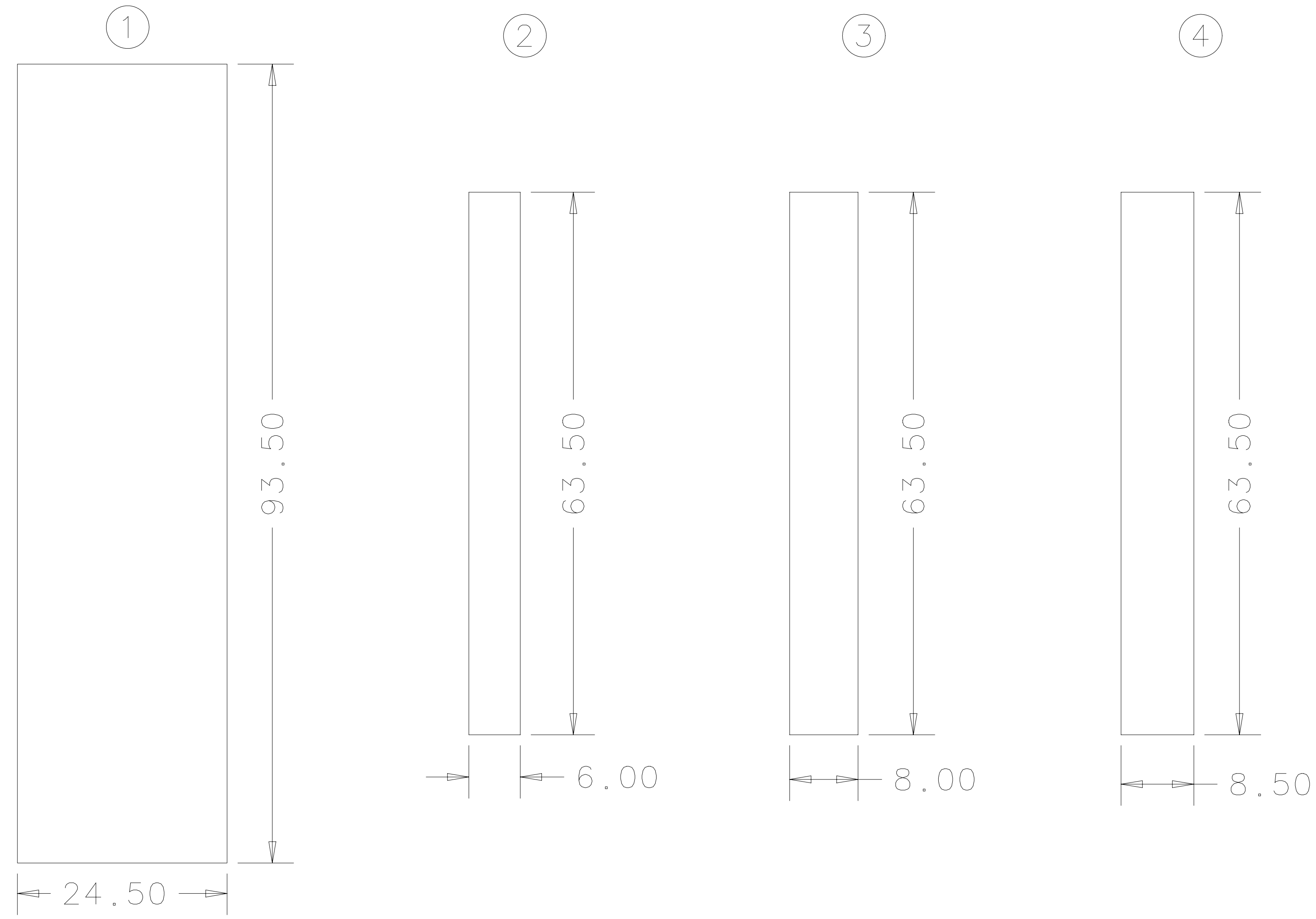
FINISH

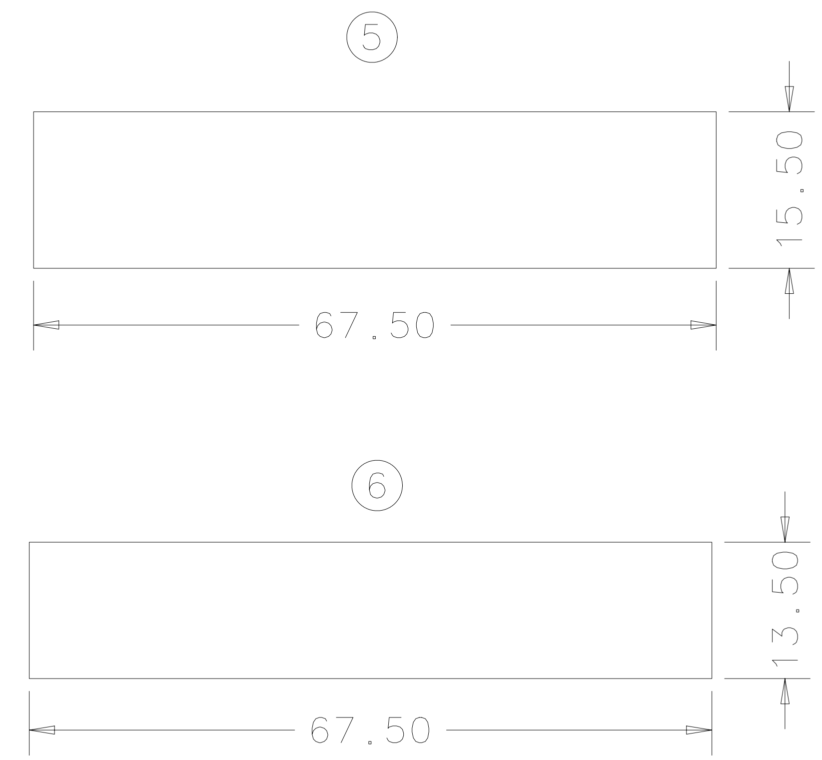
SIMILAR TO | ACT. WT | CALC WT

SIZE B | FSCM NO. | DWG NO. SEP-21001

SCALE: NONE | SHEET 1 OF 1

REVISIONS





NOTE: DIMENSIONS OF PANELS 1 & 5 MAY NEED TO BE ADJUSTED TO MATCH ISO SHIPPING CONTAINER. SEE DWG SEP-21000 SHEET 1 FOR DETAILS.

QTY REQD	ITEM NO	NEXT ASSEMBLY	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
1	6		SEP-21002-6		1/8" STEEL SHEET
1	5		SEP-21002-5		1/8" STEEL SHEET
1	4		SEP-21002-4		1/8" STEEL SHEET
1	3		SEP-21002-3		1/8" STEEL SHEET
1	2		SEP-21002-2		1/8" STEEL SHEET
1	1		SEP-21002-1		1/8" STEEL SHEET
		SEP-10000		ENTRANCE PANEL ASSEMBLY	

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:

FRACTIONS ± DECIMALS .XX=±0.03 .XXX=±0.010 ANGLES ±1/2°

DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | ACT. WT | CALC WT

CONTRACT NO. XXXX-X-XXX-X

APPROVALS	DATE
DRAWN J. BANKS x3463	7/22/08
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APPLIED RESEARCH LABORATORIES
SPACE AND GEOPHYSICS LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN

TITLE
CLOSURE PANELS
LWA SHELTER

SIZE B | FSCM NO. | DWG NO. SEP-21002

SCALE: NONE | SHEET 1 OF 1

Long Wavelength Array

Equipment Rack Specification and Options

SHL-0011 & SHL-0017

Revision 1.0

John Copeland

1 July 2008

The equipment rack in the LWA shelter must serve two basic functions: Provide and convenient and standardized mounting system for the electronic equipment and, contribute to the overall reduction in electromagnetic and radio frequency emissions from the LWA shelter. The racks, if appropriately configured, could also provide a level of EMI/RFI Isolation between the various subsystems within the LWA as required. A list of Equipment rack specifications are included as appendix A. A list of vendors that advertise some level of EMI isolation is included as Appendix B.

Rack Size

The first requirement, equipment mounting, can be easily met by any number of equipment rack manufacturers. While equipment racks are available in only two standard widths, 19 and 21 inch, they are available in any number of heights and depths. 19 inch is the more accepted width with a large number of accessories and equipment mounting kits available. The large majority of commercially available units such as network routers, network switches, GPS time clocks, computers and UPSs are manufactured in a 19 inch rack mount configuration.

The rack height is limited by the interior height of the shelter. This finished height should be verified with the shelter vendor. In general, the shelter inside height is considered to be 94 inches. Allow 3 inches for flooring, ceiling insulation and covering. Another 3 inches should be allowed for lighting fixtures. This leaves a working height of 88 inches. A rack with 72 inches of interior height (41 Rack-units) generally has an external dimension of around 76 inches. This leaves 12 inches that can be used to accommodate a mounting system as well as ventilation above and below the rack.

The rack depth can be determined based on the deepest piece equipment to be installed. In order to maintain EMI/RFI integrity, the rack will have to accommodate all equipment with front and back doors in place and closed. Generally, the longest piece of equipment will be the rack mounted UPS. The unit suggest in SHL-0009, the American Power model number SUA3000RMXL3U, is listed as 26 inches deep. Therefore, a 30 inch deep rack, measured from front rail to back rail, should allow sufficient clearance for cabling at the rear. This will result in an overall (outside) frame depth of 36 inches.

Level of Shielding Required

The largest factor in determining which brand of rack or which model of a particular brand to use, is the level of shielding that will have to be provided by the rack. The more shielding that is required, the more expensive the rack will be and fewer vendors will be available to provide. There are a number a factors that affect the level of shielding the a rack can provide. These include but are not limited to: type of steel used, thickness of steel, welded construction and quality of weld seems, quantity of ventilation required and quality of screens. One manufacturer, Equipto, has a full line of EMI/RFI racks with five levels of shielding performance. Their racks are tested to the MIL-285 Standard and the results are published on their website. A summary of the results at the frequencies of interest can be found in the following table:

Level Designation	Minimum Attenuation, 10MHz to 100Mhz	Minimum Attenuation, 100MHz to 400Mhz
R1	38dB	25dB
FCC	85dB	45dB
R3	70dB	50dB
R4	63dB	60dB
R5	85dB	70dB

Table 1

The FCC rack is a cold-rolled steel rack. All other racks are 400 series stainless steel. The R3 rack costs is roughly 3 times the FCC rack cost.

Panels and Doors

In the 6-rack configuration depicted in the modified container sketches (Specification for LWA Control Shelter, 12 October 2007), the rack frames are joined to form one, 6-rack bay. This was done primarily to conserve space but it has several other advantages as well. Joining the racks can eliminate up to 10 side panels at an estimated cost of $400 each. This configuration allows cabling to pass between instruments located in different racks without having to add additional external penetrations. A joining frame is use to create an RFI-tight seal between racks. Should the isolation a single bay be required, a divider frame is available. See figure 1.

Doors should be hinged front and back to allow access to both ends of any piece of equipment. I/O panels are available in various heights up to 21 inches. These are frame mounted either above or below a shortened door. It is recommended that each rack contain at least 1, 7 inch I/O panel to provide for power entry. The doors can be ordered with grill openings and EMI filters to aid in thermal management as required.

Top and Bottom panels are available either solid or with grill openings for air flow. Openings would again be covered with brass honeycomb EMI/RFI filters.

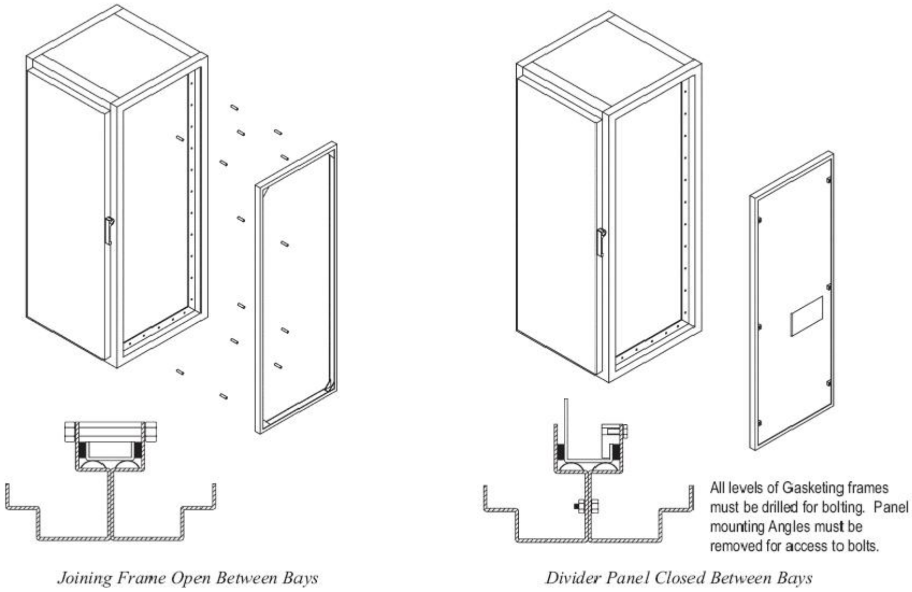

Figure 1.

Cable Entry

Cable are generally brought into closed equipment racks via bulkhead or flange mounted connectors installed in an input/output panel. An example of a custom I/O panel is shown in figure 2.

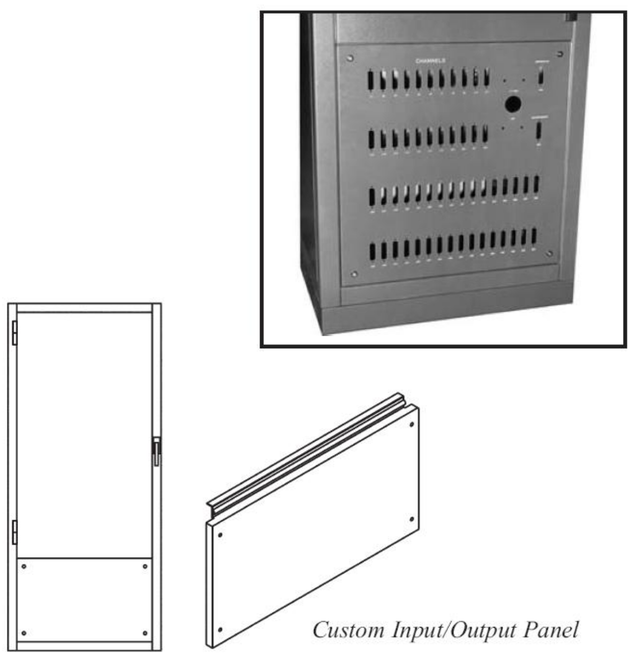

Figure 2.

The large number (512) of RF cables entering the racks, the ARX in particular, and the cables running from the ARX to the DP1 subsystem require some special consideration. With this in mind, there are several additional I/O options:

1. A custom I/O panel could be manufactured that would encompass the entire back of the rack. This could be hinged or not.
2. The rack top panel can also be used as an I/O panel provided that grilling is not required for thermal management. A small I/O panel can be accommodated with the grill and filter.
3. The ARX chassis could be designed to protrude through the back door of the rack, eliminating the need for an I/O panel.

Vertical Mounting Rails

The vertical mounting rails should extend from top to bottom and be movable front-to-rear. Rails are available with the holes punched or threaded. Threaded is generally more versatile as it allows for slides to be mounted to the back side so as not to interfere with chassis front panels.

Accessories

A number a various accessories are available for equipment racks. These include by are not limited to; shelves - sliding and fixed, fan trays with flow rates up to 945cfm, vertical rail mounted blowers with flow rates up to 800cfm, top or bottom panel mounted fans with flow rates up to 750cfm, copper buss bars for internal grounding, Power strips, chassis supports and slides. Fans and/or blowers will require some amount of rack space. How much will depend on the type and size of device installed. This must be accounted for in the layout of each rack.

Rack Mounting Options

Equipment racks can be mounted is a number of different configurations depending on a number of different factors. Does the rack need to be accessible front and rear? Does the rack need to be mobile? Does the rack have to be transportable while populated? Does the rack need to endure shock loads?

The three basic rack base configurations are,

1. Fixed base/pedestal
2. Mobile base with casters
3. Slide rails.

The fixed base option can be the rack frame itself sitting at floor level or the rack sitting up on a fixed pedestal. The pedestal raises the rack approximately 4 inches. If the 3 foot deep racks were positioned in the center of the 8 foot wide shelter, this would leave 2-1/2 feet in front of and behind the racks. This would allow the 19 inch wide door to open however, it would preclude removal and replacement of deep equipment.

Adding casters to the bottom of the rack would allow the rack to be moved forward and back although caster tend to travel sideways as well. One way to eliminate this is to use v-groove casters and have them ride on floor mounted rails. 4 inch V-groove casters rated at 550 pound each are available at a cost of $50 each.

Slide rails provide a very elegant solution to the problem of being able to service both the front and the rear of the rack in a confined space. Bottom mounted slide rails are available with a capacity of 1270 pounds each and an extension length of 18 inches are available. On the locking model that locks at both ends of travel, list price from Newark is $705.90 each. (Newark PN: 95F1030).

Summary

All the options presented here will combine and interact to determine the actual cost of the racks. An optimized rack configuration would consider all the EMC, space, and thermal issues and design a rack system to address them. Some racks would have more or less ventilation than others based on installed equipment. Some racks may require internal dividers to address inter-rack EMC issues. Unfortunately, the equipment to be housed in the racks is itself, under development. The full extent of thermal and EMC issues is, as yet, unknown.

Appendix A

Electronic Equipment Rack Standards

EIA RS-310-D Cabinets, Racks, Panels, and Associated Equipment

IEC 60297-1 Mechanics for Racks – 19 inch common standard

IEC 297-x Dimensions of Panels and Racks

MIL-STD-461E Requirements for the control of electromagnetic interference characteristics of subsystems and equipment [EMI/EMC]

Appendix B

Equipment Rack Manufacturers

901D

http://www.901d.com
COTSREADY™ Shelter Racks and Consoles
Steel or Aluminum
"Up to 60dB shielding (MIL-STD-461)"

AMCO Engineering Co.

http://www.amcoengineering.com
Commercially shielded cabinets
Sheilding 120dB@10KHz to 30dB@10GHz

American Rugged Enclosures

http://www.areinc.com
COTS and Custom Enclosures
EMI/RFI Power Ready Chassis

APW

http://www.apw.com
Built-to-Order Custom Solutions

Bud Industries

http://www.budind.com
Standard Racks and Enclosures

CMP Enclosures

http://www.enclosures.com
Standard, Heavy Duty and Modified Racks, Consoles and Enclosures

Great Lakes Cabinets

http://www.greatcabinets.com
Racks, Enclosures, and Accessories

Quantum Scientific

http://www.eia-rackmount-case.com
Rack Mount Cases

Electrorack

http://www.electrorack.com
EMI Racks – FCC through Tempest

Elma

http://www.elma.com//Americas/English/Products.aspx#
EMI Racks – FCC Part 15, Subpart J, class A and B
46dB 30MHz to 1GHz
(Optima EPS is an Elma subsidiary)

Emcor

http://www.emcorenclosures.com
Emission Control EMI/RFI Shielded Enclosures
“38dB@1GHz”

Equipto Electronics Corp.

http://www.equiptoelec.com
Five levels of Shielded Rack; R1, FCC, R3, R4, Tempest
Up to 80dB, 200MHz to 1GHz. 60dB, 1GHZ to 10GHz

General Devices

http://www.gendevco.com
Medium Duty Commercial Cabinets
Slides and Rack hardware

Hammond Mfg Co. Inc.

http://www.hammondmfg.com
Welded Frame Racks – no mention of EMI

Hoffman

http://www.hoffmanonline.com
EMC Enclosures
No Racks

Knurr USA Inc.

http://www.knuerr.com
EMC Racks, Steel, Single and Double Paneled
Manufacturing and Sales are in Germany

Schroff North America

http://www.schroff.us
EMC/RFI Tecnorack; 40dB@1GHz

Long Wavelength Array

Station Fiber Interface Specification

SHL-0016

Revision 1.0

John Copeland

3 July 2008

This document discusses the handling of the fiber optic cable once it has been laid out to the site. This is based on the LWDA experience of working with NRAO, and assumes that the fiber installation will be similar. It is possible that if a contractor such a Western New Mexico Telephone Company installs the fiber, they may have their own standards for utility panels and termination.

Routing

The fiber optic cable laid out to the LWA site should terminate initially at the site utility panel. An outdoor rated fiber optic junction box such as the American Product model show in figure 1, should be mounted on the utility panel. This utility panel is available at a cost of $211.67 in quantities of 1-3. A conduit riser should be provided to protect the fiber cable from the junction box to some appropriate distance beneath the ground. If the incoming cable is armored with metal jacketing, sufficient earth ground should be provided for lightning protection.

Conduit should be installed to carry a fiber optic patch cord from the junction box to the Shelter Entry Panel (SEP).

Figure 1. American Product AP1012

A bulkhead or flange mount connector should used to pass the signals through the SEP. Once inside the shelter, additional patch cords should be used to route the fiber from the SEP to the appropriate rack. Another bulkhead penetration should be used to pass the signal through the rack I/O panel. The cable should be well supported and protected against tight bends, kinks, compression or any other situation that might damage the glass core.

Cable

Due to the relatively long cable run out to the LWA site, it is assumed that single mode fiber will be used. This will continue up to the initial network switch which should be capable of translating the single-mode input to multi-mode outputs. The fiber optic patch cables should be duplex, single-mode, 8.3/125, and of the appropriate length. These are available from a number of suppliers at an average cost of $3.00 per meter, including the connectors.

Connectors

In order to maintain the EMI/RFI integrity of the SEP, a connector with a full metal housing should be used. The "ST" connector shown in figure 2 is one such type. ST stands for Straight Tip. This is a quick release bayonet style connector developed by AT&T.

ST Connectors are among the most commonly used fiber optic connectors in networking applications. They are cylindrical with twist lock coupling, 2.5mm keyed ferrule. ST Connectors are used both short distance applications and long line systems. The ST connector has a bayonet mount and a long cylindrical ferrule to hold the fiber. They are easily inserted and removed due to their design. The ST connector has been standardized as FOCIS 2 (Fiber Optic Connector Intermateability Standards) in EIA/TIA-604-02.

ST connectors come in two versions: ST and ST-II. These are keyed and spring-loaded. They are push-in and twist types. They are rated for 500 mating cycles. The typical insertion loss for matched ST connectors is 0.25 dB.

Figure 2. ST Connector

A typical part would be the AMP #504034-1, available through Allied Electronics (PN:512-6549) at a cost of $9.40 each, $6.70 each in quantities of 100+. These are epoxy-less and can be installed on site.

Bulkhead Fittings

Bulkhead fittings will facilitate the fiber connection through the SEP and through the rack I/O panel. They will also be used in the junction box. While these are available in plastic and nickel plated plastic, metal should be used to maintain the EMI/ RFI integrity of the SEP. These are available in a bulkhead mount as shown in figure 3, or a flange mount.

A typical part would be the AMP #504021-1, available through Allied Electronics (PN:512-6565) at a cost of $2.04 each, $1.57 each in quantities of 100+.

Figure 3. ST Bulkhead Connector

Initial Network Device

The incoming fiber will terminal at some type of network device. This will be either a router or a switch. Regardless, the device should be able to accept the single-mode input and provide for multi-mode outputs. All subsequent devices such as switches and network interface cards (NIC) can be multi-mode.

LWA Site Soil Characteristics - A Test Plan
SHL - 0014 Version 0.3
August 5, 2008

David Munton, John Copeland (ARL:UT), Walter Gerstle (UNM)

Introduction

The LWA station sites will be spread over a large area, with the final configuration anticipated to contain 50 stations [1], spread over an area 400 km in diameter. As a result of this geographic diversity, it is anticipated that the characteristics of the soil at each site will vary widely, and that this will affect choices made in the installation procedures for each station. This memo develops an initial list of in-situ tests of the soil conditions at the first station locations. These tests will provide data that will aid in making decisions about the way in which the elements of the station are installed. However, where existing standards provide guidance in the interaction of the station elements with the soil, without the additional cost of conducting tests, these standards should be adopted.

Issues to be Addressed

The following are open design issues that the soil tests are intended to help address.

- A number of possible foundation designs have been suggested for the station shelter [2]. At this point it is unknown which of these designs are reasonable at the station locations.
- A low cost solution is to simply place the shelter on concrete blocks. Regardless of the foundation used, a potential issue is the movement of soil out from under (or around) the foundation.
- Information on the soil should help with antenna and ground screen hold-down issues that are currently unresolved. Since there will be far more antennas and ground screen hold-downs than shelters, this may be more important than the shelter foundation issues alone.
- The issue of the mobility of the soil under erosive forces such as wind and rain is one that should be addressed during the tests, in order to determine if there is a potential problem with soil migrating out from under the foundations. In addition, experience at the LWDA site suggests that animal burrowing could potentially combine with erosion to be a problem.
- A second issue that needs to be considered is the load bearing capacity of the soil. This is true regardless of whether concrete piles or pads are used as a foundation. The testing should address the question of whether pre-compaction of the soil is required in order to avoid settling of the shelter.
- Since soil is inherently very strong in compression, it may be that anchorage of the shelter, antennas and ground screens against uplift forces is the more important issue.
- In addition to the foundations, there may be additional tie downs used to hold the shelter in place. While the use of mobile home tie downs is one approach to this, alternate approaches have been suggested [6]. If tie downs are used, testing should establish the maximum

allowable force that an anchor can sustain before shifting within the ground renders the anchor useless.

- Currently the nominal RF and Power Distribution network (RPD) design □[5] envisions cable carried within conduit, buried at some depth, nominally 40". An implicit assumption has been made that trenching at the site is possible using conventional tools. Tests should be constructed to verify that this is a reasonable assumption.
- The moisture profile in the soil should be monitored for both civil infrastructural and electrical performance reasons.

It is worth noting that future LWA sites may be on alluvial cobbles or directly on bedrock. These sites may pose unique challenges involving rock mechanics. This is currently considered to be beyond the scope of this initial effort.

Shelter Footing Allowable Bearing Pressures

A basic calculation provides some insight into the problem. As discussed in □[5], the fully loaded weight of a 20 ft shelter is anticipated to be 14,850 lb (6736 kg). The IS0 compliant modified shelters under consideration have four corner mount points, each of which supports $F_{c,N}$ ~ 14,850 lb /4 = 3,713 lb (1684 kg).

The allowable soil bearing pressure for sandy soils is 1500 PSF (71.8 kPa) minimum, according to the International Building Code [9]. Thus the area required for each footing is 3,713 lb/1500 PSF = 2.47 sq. ft. A 1'-8" by 1'-8" concrete pad footing should be adequate under each corner of the shelter.

The manufacturer of the footing forms suggested in □[4] suggests they are capable of supporting a 14134 lb (62.9 kN) load in sandy soil for the 36" diameter size, or an 8560 lb (38.1 kN) load in the smaller 28" diameter size. In either case, the soil bearing pressure should be below the 1500 PSF mentioned above.

Shelter Tie Downs

In □[3], it was estimated that the total horizontal force exerted on the shelter by a 100 mph wind, was approximately 5620 lb (25 kN). Assume four tie down cables, anchored at the four upper corners of the shelter and descending at an angle θ^o angle as shown in □[4].

In order for the shelter to remain in place, we must have the following, assuming the wind is broadside to the shelter.

$$F_w < \mu(F_N + 4F_t\cos(\theta^o)) + 2F_t \sin(\theta^o)\cos(\theta^o)$$

where F_w is the force exerted by the wind, F_N is the normal force due to the shelter weight, μ is the coefficient of friction between the shelter and the pads, and F_t is the total force along the tie down cables (assumed identical between all cables).

If we assume an angle $\theta^o = 45^o$, and use the numbers in □[3], we have that

$$25\text{ kN} < 23\text{kN} + 4 * 0.35 * F_t\cos(45^o) + 2F_t \sin(45^o)\cos(45^o).$$

Solving this for F_t we find that $F_t > 277$ lb (1230 N). This force will be directly exerted on the anchor, and so translates into a requirement on the forces that the anchors can resist. Allowing for a safety factor of 5, we might require that tie down anchors have an ultimate capacity of $F_t > 1348$ lb (6000 N).

Failure in mobile home anchors is related to the amount of movement between the cable tie and the anchor head, and a 2 inch movement is considered failure ([7]). We may wish to adopt a similar notion of failure here. It is worth noting that the cable forces indicated above appear to be well below the requirements on anchoring equipment for mobile homes ([7]).

Suggested Tests

The following tests are suggested.

- **Soil Load Bearing Tests** - A test should be conducted to determine the load bearing characteristics of the soil at the LWA site.
- **Post and Anchor Driving** - The means by which posts and anchors are driven into the ground is very important, and likely to be one of the more time consuming installation activities. Tests need to be conducted to determine the required equipment and procedures for doing this effectively.
- **Anchor Failure Tests - Along Axis** - A test should be conducted to determine the amount of along axis force necessary to move possible shelter anchor two inches along axis. It may be desirable to test multiple types of anchor. Anchors should be placed using standard installation tools in a manner similar to the anticipated actual shelter installation.
- **Anchor Failure Tests - Off Axis** - For some anchoring mechanisms there may be off-axis forces present. In this case a test should be conducted to determine the amount of a force necessary to shift the anchor head four inches (this number is adopted from \cite{mobile}. It may be desirable to test multiple types of anchor. Anchors should be placed using standard installation tools in a manner similar to the anticipated actual shelter installation.
- **Trenching Tests** - A series of test trenches should be dug using a rented trencher, in order to establish whether the nominal 40 inch depth is a reasonable trenching depth.
  This is largely a subjective exercise.
- **Soil Moisture Test** – Soil moisture content should be monitored as a function of soil depth and time.
- **Miscellaneous Anchor and Post Tests** – As the antennas and ground screens are developed, testing will be required to ensure that the soil hold-downs employed are adequate.

The details of the way in which the tests are conducted will be dependent on the personnel and equipment available at the time of the tests. Where standard geotechnical engineering tests exist, those should be adopted.

Conclusions

In the design of the LWA stations, we should use existing standards like ASCE 7-05 [8], the International Building Code [9], and the Uniform Building Code [10] whenever possible to ensure that the soil-structure interactions will be acceptable. We believe it is not necessary to do soil tests for every aspect of the design. Whenever the cost of doing a soil test and the resulting design solution would exceed the cost of a more conservative design solution without the soil test, the conservative design solution with no soil test should be preferred. However, there are certain obvious tests that should be done at each site; these tests have been listed above.

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Specification for LWA Control Shelter (SHL0026)

Revision 2.5

John Copeland, Joel Banks, David Munton

This document provides a specification for the Long Wavelength Array (LWA) station equipment shelter (SHL). The purpose of this specification is to provide vendors with the specific information needed for estimating the construction costs and lead time of LWA SHL.

1.1 Introduction

This section, 1.1, provides descriptive material about the LWA project, the shelter, and the remainder of this document. Nothing in this section should be construed as a specification for the LWA SHL. Specifications will be detailed in the remaining sections of this document.

1.1.1 Overview

The LWA will be a radio telescope, located in central New Mexico, and operating in the frequency range 20-80 MHz. The LWA will consist of multiple stations, each of which will consist of an antenna array, an RF distribution network, support electronics, and a shelter (SHL) which houses the electronics. The LWA SHL serves several purposes.

1. The SHL houses the LWA station electronics in an environment that is protected from weather, and provides a level of thermal stability.
2. The SHL contains the power distribution system for the station electronics.
3. The SHL provides a level of RF shielding, attenuating RF emissions from the station digital electronics.
4. The SHL provides an interface between incoming RF cables from the antenna field and the interior electronics. This interface is referred to as the Shelter Entry Panel (SEP)
5. The SHL provides an interface between the externally provided power and the internal power distribution system. This interface also occurs at the SEP.
6. The SHL is NOT intended to serve as a maintenance area. A small amount workbench area may be available, but it is intended to only provide room for a small amount of equipment, or tools. In general, the SHL is intended to be unoccupied during most operations.

The SHL is intended to be a modified ISO compliant shipping container.

1.1.2 Contents and Drawings

This specification consists of this document and four drawing packages. These drawing packages are intended to provide additional detail to the specifications. In many cases, the drawings are not dimensioned, in order to allow modification by the SHL manufacturer.

The drawing packages are as follows.

1. Drawings of the intended configuration of the shelter are provided in SHL drawing package 1.
2. Electrical layout of the shelter is provided in drawing package 2.
3. Drawings of the SEP are provided in drawing package 3.
4. Drawings of the mechanical interface supporting the racks are provided in drawing package 4.

It should be noted that, where necessary, variations from these drawing packages are permissible, provided that these are noted and detailed. Where components are specified, replacement with equivalent components is permitted if the replacement results in cost savings and equivalent performance.

1.2 Physical Dimensions

This section provides specifications for the physical dimensions of the shelter structure.

1. The overall length of the SHL shall be ~20 feet
2. The dimensions shall comply with the following ISO standards:
    a. *ISO 668-1995 Series 1 freight containers -- Classification, dimensions and ratings*
    b. *ISO 1161-1984 Series1 freight containers -- Corners fittings, specifications*

1.3 Entry

The SHL shall have an entrance, no less that 30 inches or more than 36 inches in width, placed in accordance with customer supplied drawing package 1. The entrance must be at least 78 inches high.

In the entrance, possibly inset, shall be an RFI/EMI sealed entrance, outward opening door. This door must be able to be grounded to the frame of the shelter. If such a door cannot be rendered weather tight, then a second exterior, weather tight door must be provided.

The exterior entry door shall have an exterior lock, and an interior means to defeat the exterior lock.

During normal operations this exterior door will remain in the open position. The SHL must provide a mechanism for locking the exterior door in the open position in order to avoid movement in a breeze.

The entry door shall support emergency egress.

1.4 RF Shielding

The SHL shall provide no less than 60dB of attenuation between the frequencies of 150 KHz and 12 GHz. The manufacturer is required to provide evidence that the shielding level has been met across this frequency range. For testing purposes, it will be considered appropriate that the SEP RF cable entry panels described in Section 1.6, Appendix A, and in drawing package 3, be blank panels, i.e. prior to be having RF bulkhead connection holes placed.

RF shielding modifications shall include but are not limited to:

1. Power line filters
2. Honeycomb filters on all HVAC ducts and returns
3. Metal floor or floor covering
4. Welded seams

1.5 Insulation

Modified Container shall have an R value of no less than 10.

1.6 Shelter Entry Panel

The SHL shall have any internal EMI tight bulkhead positioned approximately 12 inches from the original end doors. This bulkhead will provide access for the power and RF cables to the interior. A detailed discussion is provided in Appendix A on page 8 and is intended to complement drawing package 3 which contains a proposed design and component list.

1.6.1 Exterior of the SHL – SEP: Vents

The SHL shall have at least one or more louvered vent panels on each vertical wall between the original SHL external doors and the SEP. These vents are intended to provide for passive circulation in this area. In drawing package 3, a total of 4 vents are shown on one side. These external vents should be placed so as not to allow the incursion of water into the SEP area.

1.6.2 Exterior of the SHL – SEP: Cable Pass Through Panel

An external, recessed patch panel which is of sufficient size to hold four (4) N-type bulkhead connectors, should be positioned on the side of the SHL, between the original external doors and the SEP, as shown in drawing package 2. The patch panel should be welded in place. This will allow connections from roof mounted instrumentation to be easily routed to the SEP.

1.6.3 Exterior of the SHL – SEP: Fiber Patch

Fiber Optic cable to the site will terminate at the main site utility panel, located away from the shelter. From there the FO cable should run, in conduit, to the SHL and enter the SEP alcove through a dedicated penetration in the floor, and from there to the designated connectors on the SEP. Additional details are covered in SHL-0016.

1.6.4 Exterior of the SHL: SEP Entry Doors

During installation and maintenance operations the exterior doors opening onto the SEP will remain in the open position. The SHL must provide a mechanism, such as a cane bolt, for locking the exterior doors in the open position at an arbitrary angle. If a cane bolt type mechanism is used, it must be of sufficient length to extend at least two feet below the base of the modified container.

1.7 Floor Covering

Modified container shall have industrial grade tile or vinyl floor covering.

1.8 Rack Rails

1.9 External Finish

All exterior seams shall be caulked to prevent rust bleeding.
Modified Container shall be primed with a marine or industrial grade coating.
Modified Container shall be finished with a marine or industrial grade coating, white in color.

1.10 Interior

Modified Container shall be equipped with universal mounting rails (Unistrut) as per customer drawing in drawing package 1.

Walls shall be finished with fiber reinforced panels (RFP) or similar product.

Modified container shall be equipped with a work bench/station as per customer drawing.

1.11 HVAC

The modified container will be used to house electronic equipment and personnel generating ~30KWatts of heat energy. The container will be located in Socorro, NM and will be required to operate in temperatures from -20°F to 110°F. Radiant heating through the walls and ceiling surfaces must be accounted for in the cooling budget.

Modified Container will have sufficient cooling to sustain the interior volume temperature at 72°F and sufficient to control the heat energy load described above.

The cooling will be distributed across 2 HVAC units and controlled by a lead/lag controller. Controller and thermostat to be placed according to drawing package 1.

HVAC unit power will be routed exterior to the modified container.

HVAC units shall be added to the exterior and therefore not contained within the ISO footprint.

1.12 Electrical

The overall electrical layout is shown in drawing package 2.

1.12.1 Main Distribution Panel

The shelter main power distribution panel shall have no less than 120/240 volt, 250 amp main service, single phase, 60Hz, located in the SEP area.

The shelter main power panel shall provide the following service.

1. 200A service, via EMI filters located in the SEP area, to the shelter subpanel located in the shelter interior.
2. 30A service to air conditioning unit #1
3. 30A service to air conditioning unit #2
4. 15A convenience outlet located in shelter entry panel access area
5. 15A service for work light located in shelter entry panel access area.

1.12.2 Shelter Interior Subpanel

The shelter subpanel located in the interior of the shelter shall provide the following service.

1. Utility circuits. Modified container shall have two (2), 120 volt, 15A, quad. receptacles on individual circuits, placed according to drawing package 1.
2. Rack Circuits. Modified container shall have six (6), 120 volt, 30 amp, single, twist lock receptacles on individual circuits, placed according to drawing package 1.
3. Lighting circuit.: Modified container shall have a single 15A lighting circuit

1.12.3 Lighting

Lighting inside the shelter, provided by the electrical service specified in 1.12.3, will consist of the following.

1. Three (3), 4 foot, 2-bulb fluorescent fixtures with customer approved electronic specification, placed according to drawing package 1. These will serve as general lighting

2. Two (2), 4 foot, 2-bulb fluorescent fixtures with customer approved electronic specification, placed according to drawing package 1. These will serve as work lighting when servicing equipment racks.

3. Two (2), 4 foot, 3-bulb track lighting fixtures with customer approved electronic specification, placed according to drawing package 1. These will serve as a "soft light" option for personnel.

1.13 Grounding System Attachment Points

The SHL shall have at least two external lugs which will serve as attachment points for an external grounding system in the event of a lightning strike on the SHL.

1. The lugs shall be 3/8"-16 x 1-1/2", grade 5, hex head bolts.
2. Lugs shall be welded, by the head only, to the skin of the long sides, 6 inches above the top of the frame rails, on diagonally opposite corners.
3. Lugs shall be centered (left to right) in the recess closest to the corner.
4. *Lug threads shall not be painted*

1.14 Safety

Modified container shall have no less than 1 battery powered emergency lighting fixture.

Modified container shall have no less than 1 smoke detector and 1 carbon monoxide detector. These may be combined into a single unit.

Alarms shall provide audio and visual cues.

Alarm devices shall be network enabled.

1.15 Acceptance Testing

Modified container shall be tested and certified to meet the RF shielding specification given in this document.

Modified container shall be tested to ensure all lighting and power receptacles work properly.

Modified container shall be tested to ensure all emergency and safety features work properly.

Modified container shall be tested to ensure that any exterior doors can be locked in place.

Testing shall be conducted with blank (no holes for bulkhead connecters) connector panels in place.

1.16 Delivery

Quotes shall include delivery charges to Socorro, NM.

Appendix A. Shelter Entry Panel

The SEP is located at the open end of the ISO shipping container which is the main structure of the shelter, at a position determined by the space requirements of the processing equipment. The SEP is also positioned to provide the best continuity with the interior walls of the container. That is, at a point where the interior dimensions of the corrugated walls and roof are at a minimum. The overall dimensions of the SEP frame and the details of the corners must be adjusted to match the actual container used for the shelter.

The main structure of the SEP is designed to provide EMI shielding. The frame is made of rectangular steel tube, with 1/8" steel closure plates covering the openings of the frame except where the cable connector panels are attached. The plates are welded to the frame with continuous fillet welds all around, front and back. The edges of the plates are spaced 1/2" apart to ensure that the plates are welded to the frame rather than each other. Similarly, the frame is to be continuously welded to the structure of the shelter walls all around, front and back, ensuring that there are no gaps. Because there must be electrical continuity between the panels and the frame, the steel frame may not be painted where the connector panels are located. The SEP frame and closure panels should otherwise be painted after assembly and installation to prevent rust formation.

Type N female bulkhead connectors are mounted to the connector panels, with the fixed flange of the connector on the exterior side of the panel. There must be sufficient continuity and contact between the connector and the panel to ensure proper EMI shielding. If the connector itself does not provide sufficient performance, EMI gaskets or washers must also be used. EMI gaskets provide continuity and shielding between the connector panels and the SEP frame. The gaskets fit into a groove milled into the rear face of the panels, and are compressed against the frame as the panel is attached. The holes for the mounting screws are drilled and tapped into the face of the frame only, to ensure that the screws do not become EMI radiating elements.

One of the functions of the bulkhead connectors and panels is to provide a pathway for electrical discharge due to static buildup or lightning surges. To ensure a low-impedance path to ground, the connector panels include fittings for jumper connectors, which run between the panels and connect to the shelter grounding system.

Because cable management is a major consideration, the exterior face of the SEP is provided with three cable riser trays. These risers have slotted sides (with a slot by each row of connectors) which aid in separating and guiding the cables as they are routed to the bulkhead connectors. With three risers, there will be no more than five cables in each group running horizontally from the riser to the connectors, which will greatly simplify both installation and maintenance of the cables. Retaining clips fit across the fingers of the cable risers to hold the cables in place while allowing access to individual cables. Similar cable trays will be fitted to the rear of the SEP to help guide the cables between the SEP and the receiver equipment rack. Details of this arrangement will be determined later.

One bay of the SEP is intended for electrical power distribution equipment, which will filter the incoming electrical service and pass it to the interior of the shelter. Any penetrations of the SEP for these electrical conductors must also be shielded for EMI protection. This will probably require the use of EMI gaskets at the covers of the equipment enclosures, and between the enclosures and the SEP panels.

The end of the shelter exterior to the SEP is not a conditioned space, so louvered vents are provided in the side walls for passive ventilation. In addition, there is an inlet panel fitted into one wall of this compartment to bring the signal cable from an external GPS antenna to the main connector panels.

This design presents a proposed design configuration for the SEP which is almost fully developed. While some details must still be determined, the proposed design meets all of the performance requirements, and provides parts specifications and dimensions for fabrication where possible. Integration with the design for the interior shelter equipment space will result in a final design which can then be built and deployed.

Shelter Production Guidance
SHL - 0028 Version 1.0

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ARL:UT

September 17, 2008

1 Introduction

The LWA shelter (SHL) provides a weatherproof environment in which the LWA electronics can be housed ([1]). Initial work on the SHL has largely been handled by Applied Research Laboratories: The University of Texas at Austin. This work will be transitioned to the the LWA Program Office, The University of New Mexico at the end of September 2008. This memo outlines some of the issues that may be expected to arise between the end of September 2008 and the completion of the production of the LWA shelter (SHL). In this memo our intent is to address the following.

- Issues that remain to be resolved in the development of the shelter.
- Steps that may need to be taken prior prior to PDR.
- Steps that may need to be taken after PDR, but prior to procurement.
- Information and materials to provide to vendors.
- Steps that might occur after vendor selection and during construction

2 Development - Remaining issues

The following subsections identify some issues that we feel have not been completely resolved. Each of these issues has the potential to modify some feature of the SHL design.

2.1 Lightning Protection - Grounding

Lightning protection is a critical component in ensuring the longevity of the LWA array, as was discussed in [5]. Generally, the skin of the SHL serves as a conduit to a ground cable for any currents induced by an electrical surge. Such surges may be produced by a lightning strike on, or near, the shelter. Alternatively, a lightning strike at, or near, one or more antennas, produces a surge through the RF cables that reaches the shelter. At the SEP, bulkhead mounted lightning arrestors ensure that the path of the surge is onto the skin of the shelter. In either case, a clear path to ground must exist.

At this point, the SHL specification ([14]) requires two lugs that will be connected to the grounding system. Two are specified for flexibility. The resistance between any point on the shelter and these lugs must be small ($< 25\Omega$). An alternative connection point would be to connect the grounding clamps to the body at some edge.

The unresolved question revolves around the nature of the grounding system. An idea from Eddie Baca, of Baca Lightning Protection ([5]) would be to provide one or more copper plates buried approximately 6' deep, each connected to one of the lugs by class I lightning protection cable. A second method might involve using one or more long runs of buried copper cable connected to the lugs. We recommend that any plans be reviewed by an experienced lightning protection professional knowledgeable about conditions in the central New Mexico region. The details of this plan and the professional review should occur prior to PDR.

An additional system component that may require grounding is the incoming fiber line. A potentially relevant study was conducted in [6], and recommendations offered for the grounding configuration. At this point in time, we are unaware of any LWA work that considers the grounding requirements of the incoming fiber line.

2.2 RF Attentuation Level

The current shelter specification requires a signal attentuation of 60dB between 15kHz and 12GHz. Based on our discussion with potential vendors ([7, 8]) this appears to be within the realm of some vendors experience ([7]). However, it may be a difficult undertaking for other vendors without similar resources. The following should be reviewed and settled on prior to PDR.

- What, if any, is the minimum acceptable attenuation level that should be present in the shelter specification.
- What are the manufacturers obligations with respect to meeting this specification?
- Should the manufacturer be responsible for testing as is currently called out in the specification? If not, who is and how does that affect the manufacturers obligations?
- Currently, the specification requires testing should take place with blank panels in place (i.e., before bulkhead holes are placed in the panels). This ensures that any RF leaks are the results of a manufacturing defect, and not due to the significant number of bulkhead penetrations that the SEP must contain. To obtain measurements for a field level of performance, these tests may be repeated with the fully populated bulkhead panels in place, either at the manufacturers or at some other location. However, we do not think it is reasonable to require the manufacturer to meet a specific level of performance with the fully populated SEP.

2.3 RPD to Rack Connection

At this time the nature of the ARx packaging remains unknown, or conceptual. The 512 RF connections into the rack place high demands on the design of this interface, since space is limited. This deserves significant design attention. It is worth noting that the ARx will also have 512 RF output connections that must reach the digitization stage, and that these represent an additional 512 exit points from the ARx rack(s). There are a number of possible approaches to the handling of the cables and it is worth assigning resources as early as possible to consider this issue.

2.4 Overall Power Consumption

At this time, the overall power consumption of the LWA station remains uncertain. An initial power distribution scheme has been outlined in [10]. Revisions in the estimated power consumption have the potential to modify the requirements for the SHL internal power circuits, internal power subpanel, the main SHL panel, the site power panel, and the incoming transformer. As a result, when a more detailed power budget is known, the documents [9, 10, 12], may need to be reviewed and their conclusions may need to be altered.

2.5 Shelter Rack

The specific equipment rack that will used in the LWA SHL still needs to be determined. A detailed look at possible options was provided in [13]. It is important to note that no attention has been paid to the important issue of cooling within the racks, and no discussion has occurred on whether fans will need to be installed in the racks. We believe that this will be an important issue to consider in the coming months.

2.6 Shelter Internal Rack Mounts

Current design plans call for the racks inside the SHL to be bolted to each other ([15, 16]), and to a dolly which will enable the racks to move for maintenance purposes. This non-dimensioned design is tied to the specifics of the racks chosen for use in the LWA shelter. To complete this, or any other effective mounting system, the manufacturer will need to know the specific equipment rack that will be used.

Certain choices made in the design of the rack mounts will depend on the weight of the populated racks. At this point, no good estimate exists of the weight of the populated racks.

2.7 Shelter Siting

The SHL will need to be situated in a level area, with sufficient room for any tie down anchors and cables. The location will need to be in the vicinity of the incoming LWA station power.

2.8 Foundations

Shelter foundations have been discussed in references [2, 3, 4]. Current understanding of the site usage rules may preclude some of the options discussed there. If a final decision is to proceed with a concrete pad and tie down approach, then the following considerations apply.

- The site needs to be level following the requirements in [2], or some revised criteria.
- The specific type of anchor, and the required number of anchors, for the tie downs needs to be decided upon.
- The materials for the tie down, and the method by which it attaches to the shelter have not been identified.
- Tie-downs and anchors represent tripping hazards, as well as hazards at body and head level. A method of preventing personnel from inadvertently coming into contact with the tie downs and anchor wires must be devised.

- Tie-down locations need to be considered in relation to the exterior shelter doors, which will need to be opened and locked in place for maintenance.

A related, but relatively minor issue, is how to prevent the underside of the SHL from being used as a habitat by snakes or other wildlife. If the SHL sits on pads, there will be an approximately 1 inch gap between the bottom edge of the shelter and the ground. We would recommend considering how this area might be sealed off from wildlife.

2.9 Fiber and Networking

At this point, design issues surrounding the incoming fiber that will tie the LWA SHL equipment to the outside world have been addressed in [11]. As noted in section 2.1, there may be a possible grounding issue with the incoming fiber line. In addition, the overall design described in [11] should be reviewed prior to PDR, and the overall shelter design reviewed to ensure that an appropriate number of penetrations into the shelter exist.

No discussion has occurred on whether an internal network is required within the shelter, but outside of the racks. Such a network might require the use of shielded conduit. The current shelter specification does not call out this feature. This may not be a necessary feature, but it might be useful if additional computer resources will be present outside of the equipment racks.

2.10 SHL Door Anchors

As currently envisioned, the SEP access doors will need to be open for the installation of shelter power, for the installation of the RPD cable system, and for maintenance. The SEP is intended to be inside the exterior doors of the shelter. Thus, these doors must be open throughout the installation. In order to ensure that these doors will not move in a breeze, there will need to be an anchoring system in place. In addition, if tie downs are to be used, the anchoring system must not allow the doors to swing into contact with the tie down wires. Currently, the shelter specification suggests the use of cane bolts for this purpose, with a specification that they reach 2 feet below the base of the shelter. It is not clear if this depth will be sufficient to anchor the doors in the open position. Planned site soil tests may provide some useful information on this topic.

2.11 GPS Antenna Mount

Currently there is nothing in the specification for a GPS antenna mount. Our intent is to use a magnetic antenna mount avoiding the need for a permanent installation on the shelter. MFJ Enterprises has a three-magnet antenna mount for $40, part number is MFJ-339S (`http://www.mfjenterprises.com`). An example is shown in Figure 1. The antenna cable would be run from rooftop mount to the small patch panel on the side of the shelter, and from there to the SEP panel and into the shelter.

There will need to be an adapter fabricated which will attach to the magnetic base, and to which the actual antenna can then be attached. This should be a straightforward job.

3 Prior to PDR

The current plan is to procure the shelter at some point after PDR. For this reason, we feel it is appropriate to treat PDR for the shelter as if it were a critical design review. Thus, we recommend

Figure 1: MFJ Enterprises MFJ-3398S Magnetic Antenna Mount

that the issues identified in sections 2.1, 2.2, 2.4, 2.7, 2.5, 2.6, 2.9 and 2.8 be resolved prior to PDR. The issues addressed in sections 2.10 and 2.11 are relatively minor and can be resolved at later times.

4 Prior to Procurement

Prior to procurement, all issues identified by the PDR must be resolved. A final, updated, version of [14] must be prepared. All drawing packages should be updated. A final delivery point should be determined and specified in the revised specification. Assuming a competitive bid process is required, an updated list of vendors should be prepared. A list of vendors was provided in [17], and is available on the LWA Basecamp site.

4.1 Shelter Racks

Once a specific shelter rack is identified, it may be appropriate to purchase one or more units. Lead time on these can be expected to run 4 to 8 weeks. Once available, the racks can be used for several purposes. They can be provided to the SHL manufacturer, they can be used for integration testing, and they can be used to test packaging strategies. Current plans call for six racks in the SHL. In addition there may be the need for the program office to have one or two for there own use.

5 Information and Materials to Provide to Vendors

The information vendors can receive will be determined by the particular purchasing rules that are in force and the mechanism used to procure the shelter. At ARL:UT a procurement for the LWA shelter would need to be handled by competitive bid. A "sole source" procurement would not be possible because, as we have identified in [7, 8], multiple vendors appear capable of producing the shelter. Alternative approaches to procuring the shelter, such as a ”best value” or ”Request for Proposal” approach, will depend on the rules and regulations governing the purchasing entity. For this reason, we believe it is inadvisable to provide a specific vendor with any information about the shelter prior to the initiation of a formal procurement process, or without specific written advice from the purchasing department.

We would anticipate that as part of the overall procurement process, each vendor should receive the specification, and a set of associated drawing packages.

5.1 Long Lead Time Items

If long lead items need to be procured for the development of the shelter, and the approriate items have been identified, then the program office may wish to trade risk for schedule and purchase and provide these items to the vendor. In doing so, the Program Office will assume the risk that the purchased components are inappropriate, or become damaged before being transferred to the manufacturer. However, this would allow schedule compression.

5.2 Providing the Vendor with the Shelter Racks

A significant portion of the effort expended in developing the shelter will be in ensuring that the racks can easily be mounted and moved. As noted above, this will depend on the details of the rack that is chosen. For this reason, we believe the the vendor should be provided with, or required to purchase, one or more of the racks chosen by the LWA project. It is unclear which approach would be more cost effective. The racks will fall into the category of long lead time items.

6 After Vendor Selection and During Construction

Depending on the vendor selected, the level of commitment of LWA program personnel will vary. There will need to be a single person responsible for understanding the role of the LWA shelter and the implications of any fabrication decisions that need to be made. We would expect one or more full days at the onset spent reviewing the specification with the vendor, and discussing the vendors constructions plans. We would expect a half to a full day per month spent reviewing the construction as it progresses, and dealing with the inevitable questions that will arise.

7 Summary

In this note, we have have identified important remaining design issues associated with the LWA SHL, and sketched out the issues we see with the overall procurement process. None of these issues should be immediately critical in the development of the shelter, and all appear to be straightforward to resolve. As the other system components develop, the dependencies identified in this document, and elsewhere, will need to be dealt with in a timely fashion.

At this point, the single largest risk in the transfer of this work to the University of New Mexico appears to be that the overall development of the SHL will become stalled as new personnel take up this effort and are unfamiliar with the work that has been done. We hope that this memo will provide some guidance on the important remaining issues.

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DRAFT v0.2

Initial Estimate of Shielding Required for the LWA Shelter

Aaron Kerkhoff (ARL:UT)

November 9, 2007

1 Introduction

It is critical to minimize the electromagnetic emissions due to LWA electronic equipment so that they do not interfere with measurements taken by the LWA itself and those taken by VLA antennas, which are located near the LWDA and other proposed LWA sites. In addition to low emission circuit board design techniques, multiple layers of shielding will be required to meet emission limits in order to prevent harmful interference. The electronics shelter, which houses the electronics at an LWA site is one component of this shielding scheme. The purpose of this document is to provide an initial estimate of the shielding that will be required for the LWA shelter. The emission limits for both the LWA and VLA will first be reviewed. A simple model for LWA electronics emissions is then presented, which is used to develop a preliminary shielding budget and estimate the required shielding for the shelter. Finally, a discussion of the results is provided.

2 Emission Limits for the LWA and EVLA

The threshold power flux density (PFD) levels, which will cause harmful interference to the EVLA are specified in [1] and repeated in Table 1 for convenience. The threshold PFD for LWA is calculated using expressions given in [1], the minimum channel bandwidth and maximum integration time specified for LWA, 100 Hz and eight hours respectively, and the expected system temperature based on a 250 K electronics temperature and a 6 dB sky to electronics noise ratio. This results in a PFD of -232.5 dB(Wm^{-2}) at 20 MHz. Although the calculated limit is approximately 12 dB higher at 80 MHz, the value at 20 MHz will be assumed to hold over the entire LWA band in this analysis in order to be conservative. This limit is required to protect total power radiometry measurements taken by the LWA. As noted in [1], the limit may be relaxed by a significant factor (possibly 20 to 30 dB) due to imaging de-coherency and fringe phase winding effects with RFI if the goal is only to protect the instrument for interferometry. To be conservative, the limit required to protect total power radiometry will be assumed in this analysis. The EVLA and LWA PFD limits, F_h, can be converted to the maximum allowed EIRP at the emissions source, $P_{e,MAX}$, using the following expression

$$P_{e,MAX} = F_h(4\pi r^2) \tag{1}$$

where r is the standoff distance between the emissions source and the victim antenna. The LWA shelter is assumed to be at most 20 m from the closest antenna element in the station. The minimum spacing between an LWA station and an EVLA antenna is assumed to be 300 m (which is the case for the LWDA site.) The resulting maximum allowed $P_{e,MAX}$ values due to LWA electronics in each frequency band are given in Table 1. For simplicity, values are only given out through U-band, which encompasses frequencies up to 18 GHz. Since the power limit for the LWA is so much higher than that for the EVLA 4 m band, the LWA limit will be used for all frequencies between 20 to 80 MHz in subsequent analysis.

Table 1: Harmful threshold power flux density for LWA and EVLA and maximum allowed EIRP due to LWA electronics for specified standoff distances

Band	Center freq. [GHz]	F_h [dBWm^{-2}]	$P_{e,MAX}$ [dBW]
LWA	0.050	-232.5	-195.5
4 m	0.074	-195	-134.5
P	0.327	-189	-128.5
L	1.5	-172	-111.5
S	3.0	-163	-102.5
C	6.0	-154	-93.5
X	10.0	-147	-86.5
U	15.0	-141	-80.5

3 LWA Electronics Shielding Budget

In order to determine the total shielding required to meet the power limits given in Table 1, it is necessary to estimate the actual power that will be emitted by LWA electronics. A simple model for LWA electronics emissions was developed and is described by the following:

1. It is assumed that the emissions by an LWA station will be dominated by system components which consist of high-speed digital circuitry. This includes custom circuitry developed for LWA such as the digitizer (DIG), the beamformer (BFU), transient buffer systems (TBN and TBW), digital receiver (DRX), and the data aggregation and communications system (DAC), as well as commercial equipment such computers and networking components.

2. The primary interference mechanism addressed here involves radiated emissions from LWA digital electronics being picked up by a victim antenna (either LWA or EVLA), so that they are directly injected into a receive chain. Another possible mechanism involves LWA digital electronics emissions being coupled into the LWA analog receive chain through an analog cable or some other analog component. It is assumed that sufficient shielding / isolation will be placed between LWA analog and digital components so that this interference mechanism can be neglected in this analysis.

3. The dominant emissions from commercial equipment are assumed to be due to four identical computers (one for the master monitor and control system (MCS) and three for control of other sub-systems) and one network router (between the DAC and the station fiber connection). Each of these devices, as delivered (that is, with standard cases installed), is assumed to exhibit emissions exactly equal to FCC Part 15 limits for unintentional radiators over all frequencies. These limits are given in Table 2 in terms of field strength at 3 m and the EIRP

at the emissions source as a function of frequency. The total power emitted by the four computers and the network router is assumed to be $P_{com} = \sqrt{5}*P_e$ where P_e is the power limit from Table 2 for each frequency band. This expression indicates an assumption that the emissions from commercial equipment aggregate in power with the square root of the number of devices. The square root factor was chosen (somewhat arbitrarily) to acknowledge that the aggregation of power due to these devices will be less than linear since the devices are not synchronized.

4. Due to the large number of channels (512), the dominant emissions from custom LWA electronics are expected to be due to the DIG's and the three BFU's. Each channel in each of these components is assumed to radiate exactly at the Part 15 limits in Table 2 over all frequencies *without any shielding applied.* This implies that the PCB's in each of these components have been designed for low emissions. It seems reasonable to assume such "bare-board" emission levels can be achieved since the emissions from the revision 3 LWDA receiver PCB were found to be roughly -80 dBW or less [2] and emissions from EVLA PCB's are typically -90 dBW or less [3]. It is anticipated, however, that since all of these devices are synchronized, their emissions will aggregate in power in a roughly linear fashion. This was found to be the case when comparing the emissions of the LWDA aggregator PCB, which contains 8 digital signal channels to those of the LWDA receiver PCB, which contains just one [4]. The TBN and TBW may exhibit similar emission levels as the DIG's and BFU's since they both involve 512 digital channels. However, these devices are ignored in this analysis for simplicity. Since the number of DRX's relative to the number of channels in a BFU is expected to be relatively low and there is only one DAC, the emissions due to these components are neglected in this analysis. Thus, the total power emitted by all of the unshielded BFU's and DIG's is assumed to be $P_{dig} = 4*512*P_e$ where the factor of four results from three BFU's and one set of DIG's. This factor could be increased to six to include the emissions due the TBN and TBW, but will not significantly change the results of this analysis.

5. Apart from shielding provided by the standard component case, the only additional shielding provided to each computer and network router within the shelter is a rack. The shielding provided by a rack is denoted by S_{rack}; this is assumed to be constant among all LWA racks. While custom shielding modules which reduce computer emissions have been developed for the EVLA effort, it is assumed in this analysis that such modules would not be used for LWA to reduce costs.

6. It is anticipated that a layer (or layers) of shielding will be applied to each channel in all custom LWA digital electronics in addition to the shielding provided by a rack. In the context of this analysis, this additional shielding compensates for the aggregation of emissions due to the large number of signal channels. This shielding is also necessary, however, to maintain isolation between different channels. While the shielding applied to the DIG's and BFU's is of primary interest for the purposes of this shielding analysis, it is assumed that a similar level of shielding will be applied to other components such as the DRX's and the DAC so that it is reasonable to neglect their emissions. The additional shielding applied to custom LWA electronics is denoted by S_{dig}, and is common among all processing channels.

7. As it is difficult to anticipate at this point, the emissions due to cabling carrying high-speed digital data between modules within racks and between racks is not explicitly considered in this analysis, though it is addressed in the ensuing discussion.

It is also necessary to estimate the levels of shielding that can be provided by racks and any additional shielding modules applied to custom digital electronics. For the purposes of this analysis, results from the LWDA are used. The rack used for LWDA is an Equipto FCC/VDE level shielded

Table 2: FCC Part 15 emission limits for unintentional radiators

Band	Freq. range [GHz]	E-field at 3 m [μV/m]	EIRP at source (P_e) [dBW]
LWA / 4m	0.030-0.088	100	-88.2
P	.216-.960	200	-82.2
L and up	$\geq$ .960	500	-74.3

cabinet. The shielding provided by this rack after it was fully modified to accommodate sufficient airflow and all connectors was measured between 0.1 to 4.0 GHz [5], and the results are provided in Table 3. The shielding provided by the rack at other frequencies is estimated based upon these measurements and the rack specifications. It is expected that with more time for design and testing than was available in the LWDA effort, the shielding provided by this rack could be improved compared to the values given in Table 3 particularly above L-band. Additionally, the rack model used for LWDA provides less shielding than other models offered by the vendor. Note that increasing the shielding provided by the rack, either by using a higher quality rack model and/or by other measures such as adding RF absorbing foam to the interior walls of the rack, will certainly increase its cost. Therefore, in order to be conservative, and to anticipate a low-cost design, the rack shielding values given in Table 3 are used in this analysis.

As an example of a PCB level shielded enclosure, the rev. 3 LWDA receiver enclosure is considered. The measured shielding provided by this enclosure between 1.0 to 6.0 GHz [4] is given in Table 3; estimates of the shielding provided in other frequency bands are also provided in the table. Since this enclosure is a catalog item from Compac, it is expected that at least this level of shielding could be achieved in a board level shielding module for LWA components.

Table 3: Shielding provided by LWDA rack and receiver enclosure. Values with an * are estimated while others are measured.

Band	Center freq. [GHz]	LWDA rack shielding [dB]	LWDA DRX enclosure shielding [dB]
LWA	0.050	50*	40*
P	0.327	34	30*
L	1.5	26	30
S	3.0	20	20
C	6.0	15*	20
X	10.0	10*	10*
U	15.0	5*	5*

The total emissions due to all LWA electronics with all shielding except that due to the shelter is given by

$$P_{e,tot} = P_{com,sh} + P_{dig,sh} \tag{2}$$

where

$$P_{com,sh} = P_{com}/S_{rack} \tag{3}$$

$$P_{dig,sh} = P_{dig}/(S_{dig}S_{rack}) \tag{4}$$

and all quantities are expressed in a linear format. The required shielding for the LWA is then given by

$$S_{shelter} = P_{e,tot} - P_{e,MAX} + M \tag{5}$$

where M is a design margin and all quantities are now expressed in log format. Using the assumed parameter values given above, calculated values for $P_{com,sh}$, $P_{dig,sh}$, and $S_{shelter}$ are given in Table 4 for each frequency band. The shielding values given assume a design margin of 10 dB at all frequencies, which is the recommended minimum value.

Table 4: Shielding requirement for LWA shelter

Band	Center freq. [GHz]	$P_{com,sh}$ [dBW]	$P_{dig,sh}$ [dBW]	$S_{shelter}$ [dB]
LWA	0.050	-134.7	-145.1	71.1
P	0.327	-112.7	-113.1	28.6
L	1.5	-96.8	-97.1	27.5
S	3.0	-90.8	-81.1	31.8
C	6.0	-85.8	-76.1	27.8
X	10.0	-80.8	-61.1	35.4
U	15.0	-75.8	-51.1	39.3

4 Discussion

The required shelter shielding at LWA frequencies is high due to the close proximity of the LWA electronics to the LWA antennas and the relatively low harmful threshold PFD level assumed for LWA. For perspective, the shielding provided by the LWDA shelter at these frequencies is roughly 45 dB. Such a high level of shielding can be attained by commercially available shielded chambers [6], though it comes at a significant cost. Therefore, it is highly desirable to reduce the shelter shielding requirement. Given that the total power due to emissions in this band is dominated by commercial electronic equipment, the required shelter shielding can only be reduced by increasing the shielding provided to this equipment within the shelter. One way to do this is to increase the shielding provided by the racks. Results are provided in [3], which indicate that the LO rack developed for EVLA exhibits at least 60 dB of shielding at LWA frequencies. This is only a 10 dB improvement over the estimate provided in Table 3, however. Additionally, the racks developed for EVLA are generally much more expensive (by well over a factor of two) than the rack used for LWDA. Given that it is estimated that at least six such racks will be required per LWA station, the additional cost of improved racks may be significant. Although it was assumed in this analysis that no additional shielding would be applied to commercial equipment apart from the standard case provided, it might make sense to consider components which can be provided by the vendor with increased shielding or to build custom shielded enclosures for standard components. Achieving an increase in shielding of 20 dB here might be more cost effective than trying to increase the shielding of the shelter by that amount. Finally, further consideration of the harmful PFD level for LWA may be warranted to determine if such low levels as those assumed here are absolutely necessary. In particular, it should be determined if it is necessary to protect the LWA for total power radiometry assuming the minimum channel bandwidth and maximum integration time specified for LWA. If it is only necessary to protect the system for interferometry, the shelter shielding requirements can be reduced significantly.

From P band up through C band, the shielding requirements for the shelter are much lower, roughly 30 dB. This seems to be a reasonable goal for this frequency range. The shelter shielding requirements at X and U bands are somewhat higher due to the reduced shielding offered by the racks and custom electronics shielding modules at these frequencies as assumed in Table 3. It is acknowledged that the intensity of the emissions will tend to reduce with increasing frequency. This was shown to be the case with electronics developed for LWDA [4]. Despite the fact that higher clock rates will be used in LWA, it is probably not reasonable to assume that the emissions above 8 GHz are the same as those at 1 GHz as was assumed in the analysis presented in the previous section. Therefore the required shelter shielding in X and U bands can likely be reduced compared with the values given in Table 4. However, it is recommended that a shelter shielding of 30 dB be maintained at these frequencies to provide some safety margin.

In summary, given the preceding analysis, initial shielding goals for the LWA shelter are set at 70 dB for the LWA band and 30 dB for P band through U band.

As was mentioned earlier, the analysis presented here has not addressed emissions due to cables carrying high-speed digital data. Of particular concern are any digital data cables connected between racks, that is, not subject to the shielding provided by the racks. As only preliminary design work has been completed on some of the LWA digital processing components, it is not clear how many inter-rack digital data links may be necessary, though there will certainly be at least a few. In order to avoid cable emissions, it is assumed that all such links will be fiber-optic. If this is the case, then the shelter shielding requirements should be unaffected by digital data transmission between racks. If for some reason, these links are implemented by electrical signalling instead (e.g. LVDS over Infiniband cables) it will likely be necessary to provide some additional shielding to suppress cable emissions either by routing the cables through a conduit between the racks or by adding more shielding to the shelter.

References

[1] R. Perley, B. Brundage, D. Merteley, "RFI Emission Limits for Equipment at the EVLA site", *EVLA memo No. 106*, Sept. 8, 2006.

[2] A. Kerkhoff, "Status of LWDA Electronics RF Emissions Measurements", *LWA memo No. 43*, May 16, 2006.

[3] R. Ridgeway, "Highly Shielded Boxes for the EVLA Project", *EVLA memo No. 59*, June 4, 2003.

[4] A. Kerkhoff, "Status of LWDA Electronics RF Emissions Measurements, Part II", *LWA memo No. 44*, July 7, 2006.

[5] A. Kerkhoff, "LWDA Emission Measurements", presentation, Nov. 13, 2006.

[6] see for example http://www.ets-lindgren.com/page/?i=Series-81.

Shelter HVAC Calculations
Steve Tremblay
2/12/09

To calculate the amount of refrigeration required for a stations shelter we need to sum up the heat created by the components in the shelter and the heat that enters the shelter through the exposed surfaces. Using the given container dimension (20' X 8' X 9.5') the surface area of the four walls and the roof sum up to 64.29 m^3. Using the R-value of 7.5 Maloy quoted, this means that at most 1.03 kW of heat will enter through the walls (using the specified extreme values of 110 F outside temp and 43.33 C). Adding this to the heat generated by the components yields 11.9 kW of heating needed. This is then converted into 'tons' of refrigeration to yield 3.4 tons. This, however, assumes that the density of air is that of "sea level" so we still need to account for the elevation of the site. Using the elevation of Pie Town, NM as a standard (~7500 ft) we multiply the cooling needed by the Volume Correction Factor (1.28 @ 7500 ft) to get 4.4 tons. This still does not include solar conducted heat, or account for pulling down the temperature of the shelter after the door has been opened, so we will want to raise this up to ~5 tons of refrigeration split between the two specified HVAC units.

LWA Shelter Specifications

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February 25, 2009

Contents

1 Introduction

Here we describe the preliminary design review specifications for the Long Wavelength Array (LWA) shelter. These specifications include cooling requirements and RF shielding modifications, in addition to other structural modifications needed to make the shelter functional for housing the LWA electronics. An outline of the interface for the Environmental Control System is also presented. This is a revised shelter plan, building on information provided in SHL0026 [1].

2 Shelter overview

The shelter will be a modified shipping container, of size $8' \times 9.5' \times 20'$. A $9.5'$ height is preferred over the more commonly sized container height of $8.5'$ due to the following reasons:

a It will provide extra room for cables, and light between electronics racks and the ceiling.

b The extra room will improve the airflow and thus cooling capabilities of the HVAC units to be installed (Sect. 2.6).

c) It will be easier to install a second door (Sect. 2.2).

A conceptual drawing of the shelter is provided in Fig. 1, reproduced from [1]. Note that this drawing is intended to indicate the general layout of the shelter, and is not meant to be used for fabrication. In the following sections we describe the modifications that needs to be done to the container. These modifications will ensure the functionality of the shelter, in addition to provide ~ 60 dB of RF shielding.

2.1 Modifications floor and walls

The container will have a metal sheet covering the entire floor of the shelter, to be welded to the metal sides of the shelter (required for RF shielding). No additional cover floor on top of the metal floor will be needed.

If the walls in the container initially have vents at the sides, these vents must be closed and sealed. The interior walls will be covered with a simple wall insulation. A suggestion of a suitable interior wall material is standard melamine of $5/8''$ thickness.

A foldable work table will be installed at the same wall at which the entry door is located at.

2.2 Modification entry door

The entry door will be equipped with an RF tight door, rated for 60 dB shielding [2]. A second door will be installed outside the RF door, with the aim of protecting the entrance from weather and dust which otherwise significantly can decrease the shielding properties of the door over extended time scales.

2.3 Shelter entry panel (SEP)

Access for power and RF cables into the shelter will be through a bulkhead, located about 12 inches from the original end doors of the container (the exact positioning to be determined by container wall corrugation structure). This SEP must be constructed so that RF shielding is achieved. The frame will be welded to the shelter structure with no gaps.

The SEP will have a connector panel, with 512 N-type female bulkhead connectors mounted, and special care taken to ensure proper RF shielding. The design of the SEP will further allow for additional connectors (e.g., for outlier antennas). Details of the structure of this entry panel will be worked out with the vendor.

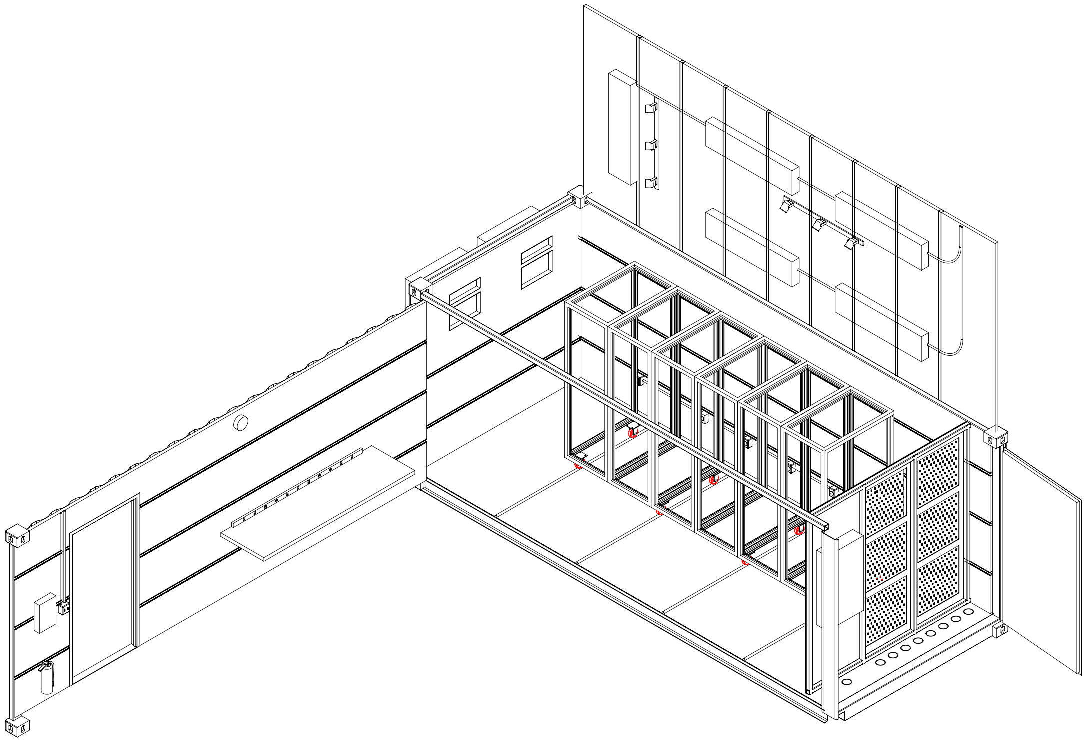

Figure 1: Conceptual drawing of the LWA shelter. This is not a drawing intended for fabrication purposes, but indicates the general layout of the shelter.

At least 9 penetrations in the floor of the SEP will be required, out of which one will be for power cables and the remaining 8 for RF cables. The size of the penetrations (with sleeves) must be matched to the size of the incoming cable conduits.

2.4 Electronics racks

Arrangement for placement of 6 electronics racks inside the shelter will be provided. If possible the preferred arrangement would be to construct a simple dolly system for moving the racks back and forth slightly, for easier access. The racks will however lock into a central position. One rack (Equipto R3) will be provided to the vendor to allow vendor to construct this dolly system.

2.5 Cable rack

The ceiling of the shelter will have a cable management system mounted, such as a cable tray.

2.6 HVAC

The combined shelter equipment is estimated to draw between 10-15 kW. Heating of the interior of the shelter due to outside temperature is estimated to contribute another ~ 1 kW, resulting in an estimated cooling need of of 3.4 ton [3]. This will be distributed over 2 HVAC units, mounted on the short side of the container. A lead/lag controller will be included for the units. For RF shielding purposes, the HVAC units will need Honeycomb filters on all ducts and returns.

The HVACs constitute the Environmental Control System (ECS) and will be monitored and controlled remotely (see Sect. 4.1).

2.7 Power

Assuming the LWDA site will be the location of the LWA1, the power distribution scheme will be adapted to fit with existing power distribution. The Power Conditioning and Distribution (PCD) subsystem is described in [5], and the parts directly connected to the shelter of the PCD are:

- The two HVAC units will run off 240 VAC at 30 A each.
- The entry of the power cable into the SEP will be via one of the cable pentrations in the SEP (Sect. 2.3).
- The SEP main panel will provide service outlets in the SEP access area and a work light.
- A subpanel will be located inside the shelter, providing circuits for lighting, racks and utilities [5].

The power lines leading into the shelter must be equipped with EMI filters (exact type to be determined with the chosen vendor).

2.8 Lighting

Lighting in the shelter will be provided and installed such that optimum light conditions are obtained while working with equipment in the racks. This probably means installing lighting at the walls of the shelter.

2.9 Grounding

The shelter will be grounded via two metal rods of about 8ft length. Grounding points will be determined with vendor.

2.10 Safety

The shelter will have at least one smoke detector, enabled to a network for remote monitoring.

3 Delivery

Any quotes shall include delivery charges to the LWA site (the VLA site) in NM, with an expected delivery in August 2009.

4 ECS Interface Control

The ECS will cool the shelter and shelter electronics. We here provide the main outline of the Interface Control for the Environmental Control System (ECS). The Interface Control between the Power Conditioning and Distribution (PCD) and the MCS is outlined in [5].

4.1 ECS interface

The following are defined as the ECS interfaces:

- The interface between the ECS and the PCD is via one power port (240 VAC, 50 A).
- The ECS connects to the SHL-MCS, which is single node on the station MCS command hub. The SHL-MCS translates the specific software interface of the ECS into the common ICD interface defined in teh MCS Common ICD [4].

Depending on what brand of HVAC units are purchased, there will likely be a control unit included which is assumed to provide at least the following monitoring points:

1. Room temperature: within a temperature range not yet specified
2. Airflow sensor: On/Off
3. Compressor current: On/Off

Additional monitoring points may include a sensor for dirty filter, humidity etc. The control points will include:

1. Room temperature setpoint: specifying maximum allowed room temperature
2. Reset

Details of the monitoring and control set points together with their detailed physical interface will be presented in later versions of this document once the shelter vendor has been identified, and subsequently the HVAC units.

5 Schedule for procurement

The procurement of the shelter is to begin promptly. During February 2009, we will collect bids from vendors. The procurement will be started immediately after the bids are received, with the final purchase to be made in May 2009 at the latest. Scheduled delivery of the shelter is August 2009.

6 References

[1] Copeland et al., 2008, LWA Engineering Memo SHL0026
[2] Kerkhoff, A., 2008, LWA Engineering Memo SHL0027A
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[4] Ellingson, S., 2008, LWA Engineering Memo MCS0005
[5] Craig, J., 2009, PCD Common ICD