Response to Higher Ground's Technical Appendix Attached to Its Application and Waiver Request,
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1 Executive Summary

1.1 Background

On February 3 of 2017, Higher Ground, LLC (Higher Ground or HG) was granted a waiver and Experimental Radio Station Construction Permit and License, call sign WH2XHP, by the Federal Communications Commission (FCC). The Experimental License is valid for a little more than a year, and will expire on July 1, 2018. It allows HG to perform experimental “proof of concept” field tests on HG’s technologies and equipment, and ensure that its technology is sound.

This Experimental License is part of an overall process that Higher Ground has initiated that is intended to produce the grant of a full FCC license for HG’s proposed mobile technologies and applications. This waiver bypasses existing FCC licensing regulations in the 6 GHz fixed-station microwave frequency band with respect to frequency coordination, interference analysis, and prior coordination notification to incumbent users. Additionally, Higher Ground’s proposed technology has the vast potential to harmfully interfere with existing microwave communications systems of incumbent users. These incumbent users include many utility and critical infrastructure companies (electric, gas, railroad, etc.) involved in maintaining and operating critical national infrastructures, organizations directly involved in public safety and homeland security, as well as commercial telecommunications providers.

As part of their submission to the FCC, Higher Ground attached a Technical Appendix which discusses their proposed method of handling the possibility of harmful interference to incumbent users in detail. This document summarizes the findings of an independent evaluation of the Technical Appendix for potential oversights, confusions, incorrect assumptions, and incorrect conclusions contained in that document.

1.2 Tri-State Generation & Transmission

This document was specifically prepared for Tri-State Generation and Transmission Association (Tri-State). Tri-State is a wholesale supplier of electricity to 43 member distribution cooperatives in primarily rural areas of Colorado, New Mexico, Wyoming and Nebraska. Transmitting electric energy via high voltage transmission lines, safe and efficient control of coal, wind, solar and gas turbine generation and safely protecting the public while quickly restoring power during outages requires a very reliable communications and control system extending over this four state area. Tri-State also “shares” some of its communications capacity with other critical entities, such as the Colorado State Patrol. To accomplish this, Tri-State uses an extensive, Federal Communications Commission licensed 6 GHz digital microwave network. This network consists of
more than 200 stations throughout their service area. Tri-State has made a significant capital investment to build and maintain this highly reliable communications network.

In addition to high reliability operation, the microwave network must provide very low-latency end-to-end communications. Most of Tri-State’s high voltage electrical protection and control systems require repeatable millisecond response times. The microwave network is designed to reliably support these requirements and unplanned interruptions can damage or destroy equipment, impact safe operations, and cause loss of electricity to thousands of customers.

Companies like Tri-State and other critical infrastructure providers are able to use 6 GHz microwave to support these critical operations, in part because the decades-old FCC coordination and licensing process has guaranteed there will be no outside interference to these systems. The purposeful introduction of potentially harmful interference such as that being proposed by Higher Ground is unacceptable.

Like other electric utilities serving rural areas, there are few if any alternatives to this real-time microwave communications network. Therefore, its continued reliable, interference free operation is critical to providing the safe delivery of electric energy.

1.3 Significant Issues Found in the Technical Appendix

Following is a brief summary of the major issues that were found in Higher Ground’s Technical Appendix. These items are discussed in more detail in section 2 below. Also attached to this document is a spreadsheet containing detailed information extracted from the FCC ULS database pertaining to some of the items below.

It must also be stated that the Technical Appendix is somewhat incomplete, in that it does not include a detailed discussion of all potential 6 GHz frequencies that will be used by Higher Ground’s proposed network. The Technical Appendix does provide details of one specific frequency, which HG calls the Hailing Frequency. The findings summarized below, which discuss the Hailing Frequency specifically, will also apply to all Higher Ground frequencies generally. Because the specific details of those other (non-Hailing) frequencies have not been disclosed by Higher Ground, it is not possible to perform an adequate evaluation of them. However, by logical extension, it can be assumed that Higher Ground’s proposed 6 GHz mobile network has the potential to produce harmful interference to virtually all incumbent 6 GHz licensed fixed-station microwave systems across the country.

- **Security**: There is no discussion in the Technical Appendix of security, particularly with regard to the possibility of a SatPaq mobile unit being reprogrammed for possibly nefarious purposes.
• **Passive Antenna Repeater Systems:** There are many objects in the environment, both man-made and natural, which reflect and even amplify radio signals. The reflections are sometimes intentional and other times not. To avoid any possible interference to incumbent microwave systems, Higher Ground’s design analysis must account for all possible types of passive radio signal reflections, whether or not the reflecting objects appear on any FCC license.

• **True EIRP Level of Mobile (SatPaq) Units:** The transmitter EIRP level of SatPaq devices is listed as +9 dBW in the Technical Appendix but +10.4 dBW on the Experimental License. Only one of these two values can be correct.

• **True Bandwidth of the Hailing and Data Channels:** The overall emissions bandwidth of SatPaq devices is declared to be both 8 MHz and 4.9 MHz in the Technical Appendix, and 10 MHz on the Experimental License granted by the FCC. Only one of these three values can be correct. The correct bandwidth has a significant impact on the calculations and number of impacted incumbent users to be included in the analysis.

• **SatPaq DSSS Synchronization:** The additive interfering effect of multiple SatPaq devices transmitting from approximately the same location is not addressed in the Technical Appendix.

• **SatPaq Antenna Polarization Diversity:** The concept of SatPaq antenna polarization diversity is mentioned in the Technical Appendix, but never discussed and analyzed with due specificity.

• **Microwave Antenna Beamwidths:** The Technical Appendix recommends that the angular size of the Receiver Acceptance Cone (RAC) for a microwave receiver be 20°. We recommend the angular size be 20° if the actual microwave antenna beamwidth is 2° or less, and ten times the actual antenna beamwidth if it is more than 2°. In addition, at locations where a space diversity antenna system is being used, the beamwidth calculations must be based on the smallest antenna (the antenna with the largest beamwidth). Diversity antennas in the 6 GHz band can be as small as 3 feet in diameter, and can have beamwidths significantly larger than 2°. Beamwidth analysis must also include all possible passive antenna/repeater systems, even if not purpose-built to reflect 6 GHz microwave radio signals.

• **Close Proximity Circle Calculations:** The assumptions and units of measure used in the calculations to determine the size of the Close Proximity Circles (CPC’s) in section A.8.1.6 of the Technical Appendix are not clearly stated and confusing. In addition, the calculations are performed using the characteristics of a “typical” 6-foot (2-meter) microwave antenna. The calculations must use the worst-case scenario;
that is, they must use the smallest microwave antenna allowed by the FCC for 6 GHz microwave paths, which currently is 3 feet.

- **Microwave Path Distances:** The Technical Appendix recommends that the minimum length of the Receiver Acceptance Cone (RAC) for a microwave receiver be 50 miles. We recommend the minimum RAC length be 50 miles if the actual microwave path length is 25 miles or less, and twice the actual microwave path distance if it is more than 25 miles. There are also many other additional factors that must be taken into account in determining how far a SatPaq transmitter must be from a microwave receiver to guarantee no interference will be produced, including all potential passive antenna/repeater systems.

- **SatPaq Antenna Pointing Angles:** The Technical Appendix states that if a SatPaq antenna becomes misaligned with a satellite antenna by more than 15° in the middle of a transmission, it will disable the SatPaq transmitter within 100 milliseconds. The same basic algorithm must be used to determine if a SatPaq antenna becomes aligned with a microwave receiver in the middle of a transmission. For mission-critical electric utility operations, however, 100 milliseconds is an unacceptably long time to wait for a SatPaq to disable its transmitter. We also question the ability of a SatPaq to actually perform this function in under 100 milliseconds. And, the possibility of passive antenna/repeater systems potentially renders any meaningful analysis of antenna pointing angles completely moot, even if the passive antenna/repeater system is not purpose-built to reflect radio signals.

- **Potential Hailing Frequency Conflicts:** By querying the FCC ULS database directly, it is shown that the FCC ULS data contained in Table A-3 of the Technical Appendix is incorrect. This raises serious doubts as to Higher Ground’s ability to obtain correct and accurate data from the FCC ULS database as it pertains to interference prevention.

- **Validity of Experimental License Test Locations:** By comparing the locations of the microwave sites that Higher Ground could potentially interfere with on the Hailing Frequency (listed in Table A-3) of the Technical Appendix with the test area locations from HG’s Experimental License (WH2XHP), it can be shown that seven of the nine test areas are invalid. That is, those seven test areas cannot be used to test Higher Ground’s Hailing Frequency algorithm’s or methodologies, since there are no microwave sites in those areas containing the Hailing Frequency that can be used to test against. As a consequence, those seven test areas should be eliminated from the Experimental License.

- **Microwave Antenna Azimuths:** The Technical Appendix states that Higher Ground only needs to concern itself with north-facing microwave receive antennas, because SatPaq devices must always be pointed south to communicate with an orbiting geosynchronous satellite. There are
discrepancies in Higher Ground’s determination of what north-facing actually means. In addition, there are scenarios in which a SatPaq antenna can be pointed at, or physically very close to, a south-facing microwave receive antenna during a transmission. There is also the possibility of a man-made or natural passive antenna/repeater systems reflecting and redirecting the signal directly into a south-facing antenna. As a result, Higher Ground cannot simply “ignore” south-facing microwave receive antennas on a wholesale basis, but must account for them in all of their interference calculations.

- **Bandwidth Window Crossing vs. Carrier Center Frequency in a Bandwidth Window:** In determining which microwave paths could be affected by its Hailing Frequency, Higher Ground only looked at microwave paths where the microwave center frequency was within a 4.9 MHz uncentered emission window surrounding its proposed 5927.5 MHz Hailing Frequency. The correct methodology requires HG to look at microwave paths where the microwave emission bandwidth window and Higher Ground’s Hailing Frequency 8 MHz (or 10 MHz) emission bandwidth window overlap each other. The attached spreadsheet contains an evaluation of the FCC ULS database using these criteria, and the result is that the number of microwave paths that will potentially be interfered with by Higher Ground’s Hailing Frequency is 3590, not the 8 (or 18) as stated in the Technical Appendix, and three of the 3590 are licensed by Tri-State. 3590 is actually the minimum number of potential microwave channels that can be interfered with by the Hailing Frequency. There are also alternative methods of defining the bandwidth windows that increase the potential number of interfered microwave paths far beyond 3590. In addition, the overlap of emission bandwidth windows criteria must be used for all frequencies used by Higher Ground, not just the Hailing Frequency.

- **4 kHz (Analog Channel) Interference Calculation:** Higher Ground’s effective power level calculations are based on the assumption that the microwave receivers being interfered with are divided into 4 kHz analog frequency slots. This has been common satellite design practice since the 1960’s, but is really inapplicable to modern digital communications system. As the attached spreadsheet indicates, more than 99% of the microwave paths affected by the Hailing Frequency are digital, not analog. In addition, even if they were analog, 4 kHz frequency slots are not directly applicable to an analog microwave radio’s over-the-air signal from an interference perspective. As a result, the effective “interference power” being generated by the SatPaq mobile units in Higher Ground’s calculations is too low by a factor of 33 dB.

- **Interference Measurements:** In the real-life test environment created by Higher Ground and approved by the FCC, Higher Ground is being allowed to potentially interfere with critical infrastructure, real-time, operational
microwave systems. In addition, the test environment is set up in such a way that it is literally impossible to accurately determine if Higher Ground is actually causing interference. This is a totally unacceptable test environment.

- **Fixed vs. Mobile Design Methodologies:** Higher Ground’s system is designed using fixed system design methodologies and techniques, and attempting to apply them on a quasi-real-time basis to a mobile environment. This is an untenable scenario. Higher Ground must redesign its system using mobile network principles, while still guaranteeing no interference to incumbent microwave systems in the same geographic areas and using the same frequencies.

2 Detailed Discussion of Significant Issues Found in the Technical Appendix

Following is a detailed discussion of the significant issues that were found in Higher Ground’s Technical Appendix.

It should also be noted that while this document focuses on the Technical Appendix, the Utilities Technology Council (UTC) is preparing a legal statement that addresses the FCC rulemaking and waiver process surrounding the Higher Ground Waiver. We will defer to the UTC regarding those matters.

The Technical Appendix only provides details on one specific frequency, which Higher Ground calls the Hailing Frequency. HG has not disclosed details of its intended use of frequencies in the rest of the 6 GHz fixed-station licensed microwave band. However, it is assumed that Higher Ground intends to use all available portions of the 6 GHz band, and will use the same basic operational approach to mitigate interference on all frequencies. The technical issues discussed below, which address the Hailing Frequency specifically, also apply to all potential Higher Ground frequencies generally. Even though it is not possible to perform an evaluation of all potential frequencies in this document due to the lack of detail provided by HG, by logical extension it can be shown that Higher Ground’s proposed 6 GHz mobile network has the potential to produce harmful interference to virtually all incumbent 6 GHz licensed fixed-station microwave systems across the entire country. That is, the potential for harmful interference is far beyond the specific scope addressed below, and specifically far more than the three Tri-State microwave paths identified in the Hailing Frequency analysis.

2.1 Security

The Technical Appendix does not discuss security aspects associated with the SatPaq devices. For example, what would happen if someone “hacked into” a SatPaq phone and reprogrammed it for nefarious purposes? Such a scenario
could involve purposely interfering with a 6 GHz microwave radio path that is used to monitor and control a nuclear power plant, for example. What measures / safeguards / procedures does Higher Ground propose to prevent, detect, mitigate, or eliminate such possibilities?

2.2 Passive Antenna/Repeater Systems

There is no discussion whatsoever in the Technical Appendix of passive antenna/repeater systems (Passives) and the detrimental and unpredictable effect they can have on microwave interference from SatPaq devices.

Passives are intentionally constructed and used in some microwave paths as a cost-effective alternative to constructing an active repeater location which requires buildings, towers, power, access, continual maintenance, etc. Most purpose-built Passives are in the form of a large, flat “billboard” several tens of square feet in size, which redirects and amplifies virtually any radio signal that comes in contact with its face.

In addition to purpose-built Passives, there are also other structures that unintentionally reflect and redirect microwave signals. Almost any metallic or water-based surface, particular if it is relatively flat, can act as a Passive. This includes man-made structures such as buildings, fences, utility pedestals, road signs, and motor vehicles, but can also include naturally occurring structures such as rock formations and lakes. There are Passives almost everywhere, and their precise locations are unknown (and even mobile) and their effects on radio signals, and in particular their effects on mobile radio signals, are impossible to predict with any degree of accuracy.

With respect to mobile applications such as SatPaq, for all practical purposes a Passive (whether man-made or natural) can be considered to be an antenna with a 180° beamwidth. That is, any radio signal (such as from a SatPaq) which is directed into the face of the Passive is reflected and redirected. To further complicate the issue, the VAST majority of Passives a SatPaq may “bounce” signals off of (such as buildings and cars) will not appear on any FCC license, even though they must be accounted for in some fashion if Higher Ground is to guarantee it will not interfere with any incumbent microwave system.

Passives also inject gain into a microwave signal. That is, the transmitted signal after it has bounced off of the Passive can actually be “stronger” than the signal that was received and redirected by the Passive. This means that a signal reflected by a Passive can actually be transmitted much farther than a signal that has not been reflected.

In the discussions in other sections below, particularly those that involve antenna beamwidths, pointing angles, and microwave path distances, the effects of Passives must be included (they currently are not). This must also include the
effects of “unlicensed” Passives, including natural and man-made devices which are not specifically purpose-built to reflect radio signals.

2.3 True EIRP Level of Mobile (SatPaq) Units

Throughout the Technical Appendix document, particularly in section A.5 (Earth Station Pattern), HG states that the Effective Isotropic Radiated Power (EIRP) level of the SatPaq devices is 9 dBW (7.9 Watts). This is calculated from a transmitter output power level of 1 Watt (0 dBW) plus an antenna gain of 9 dBi. However, in the Experimental License, the EIRP level of the mobiles is listed as 11 Watts (10.4 dBW). While this relatively minor difference in power level should not be significant to most of the documented calculations, the SatPaq power levels should be consistent in all documentation, calculations, and licensing.

2.4 True Bandwidth of the Hailing and Data Channels

Throughout the Technical Appendix document, it states that the bandwidth used by Higher Ground’s Direct Sequence Spread Spectrum (DSSS) technology is 8 MHz. However, in the Experimental License the emission designator used is 10M0G1D, which indicates that the actual bandwidth used is 10 MHz, not 8 MHz. In addition, in the discussion of the Hailing Frequency (section A.8.1.5), the bandwidth used in the calculations is only 4.9 MHz (it uses a “window” of 5925.1 to 5930 MHz to search for potential microwave signals). The true required and potentially interfering bandwidth must be used in all calculations and licensing, whether that is 4.9, 8, or 10 MHz.

2.5 SatPaq DSSS Synchronization

The Technical Appendix does not discuss the effect of multiple SatPaq devices operating in the same vicinity. Specifically, it does not address the additive nature of power when multiple signals are being transmitted at the same time from approximately the same location. Such a scenario may increase the possibility of interference to a microwave receiver, since the power levels and transmission distances are not the same as for a lone, isolated transmitter.

2.6 SatPaq Antenna Polarization Diversity

On page 17 of the Technical Appendix, in the last sentence of the first paragraph of section A.8.1.7 (Diversity Techniques), it states that, “Polarization diversity involves switching to the opposite antenna diversity to reduce coupling, a common technique.” However, the concept of polarization diversity is not discussed in appropriate detail anywhere else in the document. More specifically, the document does not discuss how it is even possible to change the SatPaq antenna polarization, whether by the SatPaq user or in an automated fashion.
2.7 Microwave Antenna Beamwidths

In section A.8.1.2 (Protection Zones), the first paragraph states, “Whereas the typical angle of receiver acceptance for a typical microwave dish is 2 degrees, we will define our protection acceptance angle to be ten times larger and set it at 20 degrees (1/18 of a 360 degree circle).” In the paragraph previous to that (the last paragraph of section A.8.1.1) it states, “PtP microwave antennas are typically two or three meters in diameter, which defines a 1.7 degree (or less) acceptance angle (3 dB), although ULS contains information regarding smaller or larger receiver dishes and this data will be accounted for as well.”

There are two items of discrepancy here: first, is a “typical” 6 GHz microwave antenna beamwidth angle 1.7° or 2°, and second, what exactly does “accounted for” actually mean in this context? We concur that if the 3 dB beamwidth of the microwave antenna is less than 2°, the angle of the Receiver Acceptance Cone (RAC) be 20°, However, if the 3 dB antenna beamwidth is more than 2°, the angle of the RAC should be ten times the antenna beamwidth (that is, more than 20°).

In addition, it is very common practice for microwave paths to use space diversity antenna systems. In such cases, there is usually a larger antenna (with a small beamwidth) and a smaller antenna (with a larger beamwidth). Higher Ground must in all cases perform worst-case interference calculations with the smaller antenna (the one with the largest beamwidth). The FCC currently allows diversity antennas as small as 3 feet in diameter for the 6 GHz microwave band, which have beamwidths much larger than 2°.

As is also discussed above in section 2.2, antenna beamwidth analysis must include the possibility of passive antenna/repeater systems, whether man-made or natural, and whether or not purpose-built to reflect radio signals in the 6 GHz microwave band.

2.8 Close Proximity Circle Calculations

In section A.8.1.6, starting on page 16 of the Technical Appendix, it discusses how the size of the Close Proximity Circle (CPC) around a microwave receive antenna is determined. The Close Proximity Circle is referenced in multiple places throughout the Technical Appendix, and is the “quiet zone” around the sides and back of a microwave antenna where a SatPaq transmitter cannot be used. The exact sources of data used in the calculations are unstated (for example, what assumptions/units-of-measurement are used to equate 8 MHz of bandwidth to 69 dB of gain) and must be clarified.

The calculations in the Technical Appendix determine that the size of the Close Proximity Circle should be 6300 meters (approximately 3.9 miles). However, the calculations are based on a “typical” 2-meter (6-foot) microwave antenna. As
discussed above in section 2.7, however, antennas are used in microwave paths that are both much smaller and much larger than 6 feet. These size of the CPC must be recalculated using a worst case analysis; that is, using antennas as small as 3 feet in diameter (the smallest currently allowed by FCC regulations for 6 GHz microwave paths).

As discussed out in other sections, the CPC’s must be applied to all microwave antennas, whether they be north-facing or south-facing. It is perfectly possible for a SatPaq to be in close proximity to a south-facing microwave antenna and transmit an interfering signal into the sides or back of the antenna.

2.9 Microwave Path Distances

Section A.8.1.2 (Protection Zones), first paragraph states, “Whereas the typical microwave link has a communications distance of 20 to 30 miles, we will define our exclusion zone triangle to be twice as long and set it at 50 miles long (or longer if necessary).”

There are two items of discrepancy in this statement. Firstly, it indirectly states that, “50 is twice as big as something that has a ‘typical’ range of 20 to 30,” which is incorrect. Secondly, the “if necessary” point is further defined in a footnote, and essentially states that if the difference in height between the two antennas at each end of a microwave path is large enough it may warrant a longer Receiver Acceptance Cone (RAC), with no defined / distinct criteria.

We suggest that if the microwave path length is 25 miles or less, the minimum length of the RAC be 50 miles, and if the microwave path length is more than 25 miles the minimum length of the RAC be twice the microwave path length. Additional RAC length may also be required for large differences in antenna heights at the ends of the microwave path, though the criteria needs to be specifically and clearly stated.

It should also be noted that due to the potential of atmospheric ducting and other factors, even this is not an absolute guarantee that a SatPaq transmitter cannot interfere with a microwave receiver. For example, it is a very common practice for microwave systems to use space diversity antenna systems to overcome the reduction in path reliability associated with atmospheric ducting. Also, reliability criteria in microwave paths are almost never designed assuming the true earth radius as the limiting factor. That is, they assume that the earth is actually smaller (making the “bulge” in the middle of the microwave path larger) or larger (making the “bulge” in the middle of the microwave path smaller) than the earth actually is. Simply stated, the assertion in section A.8.1.1 that a microwave signal can never go past the earth’s horizon is incorrect.

In addition, a microwave signal that is “trapped” in an atmospheric duct is not attenuated with distance to the same degree it us under “normal” circumstances.
As a result, the signal can end up traveling much further than it would under non-ducting conditions.

In addition to atmospheric ducting, path distance analysis must include the possibility of passive antenna/repeater systems, whether man-made or natural, and whether or not purpose-built to reflect radio signals in the 6 GHz microwave band. Refer to section 2.2 above.

So, even with the added “safety margin” provided by doubling the actual microwave path length and accounting for differences in antenna elevations, there is still not a 100% guarantee that no harmful interference can occur.

2.10 SatPaq Antenna Pointing Angles

In the last paragraph of page six (section A.7.1 -- Compliance with FCC’s Off-axis EIRP Mask) it states, “With regard to antenna pointing, the SatPaq transmitter will be activated only when it is within 15 degrees of the required pointing angle to the satellite.” It also states that the SatPaq will stop transmitting within 100 milliseconds if the SatPaq detects that its antenna is no longer within this 15° pointing angle (azimuth) envelope.

There are at least three separate, major sub-items involved in this scenario: the detection of the antenna azimuth, the determination of whether or not it is correct, and the disablement of the transmitter if the antenna azimuth is incorrect. It is not specifically stated in the document exactly which of the three major sub-items is included in the 100 milliseconds. Given the lack of sufficient detail, it is assumed that the 100 milliseconds only applies to the third sub-item (disablement of the transmitter). It is unclear, and is certainly questionable, whether it is really possible to shut down the transmitter within 100 milliseconds of when the antenna first becomes misaligned.

In addition, this same basic methodology should be used to determine if the SatPaq antenna becomes pointed at a microwave receive antenna that it was not pointed at when the transmission began, and to disable the SatPaq transmitter as a result. This is necessary whether the microwave antenna is north- or south-facing. A SatPaq that is accidentally dropped to the ground, swung around as the user turns his/her head, or various other scenarios, can have its antenna azimuth change by tens or even hundreds of degrees in less than 100 milliseconds. This could potentially cause interference to multiple microwave systems that were not affected when the transmission was initiated.

It must again be also be noted that even 100 milliseconds is an unacceptably long time for interference to occur in a real-time control environment such as an electric utility delivery system.
None of this analysis addresses the possibility of passive antenna/repeater systems (Passives). For example, a SatPaq antenna can be pointed in a completely different direction than the satellite antenna, up to and including the exact opposite direction (180° out of whack), but be pointed at a Passive that will reflect the signal back towards the satellite. However, the SatPaq will never recognize this is happening because it is only concerned with the direction of the antenna, not with the radio signal itself.

Likewise, it is possible for a SatPaq antenna to not be pointed directly into the Receiver Acceptance Cone (RAC, discussed more fully in section 2.7 above) of a 6 GHz incumbent microwave radio, but be pointed at a Passive that will reflect the signal into one or more RAC’s. The SatPaq is unable to recognize this situation, and may unknowingly generate an interfering signal into one or more microwave receivers. Passive are discussed in more detail above in section 2.2.

For all practical purposes, the possibility of Passives, whether man-made or natural, and whether purpose-built to reflect radio signals or not, renders all discussion and calculation of antenna pointing angles as fruitless. There is simply no way to accurately predict the influence of Passives on the directions of radio signals in a mobile environment like SatPaq.

### 2.11 Potential Hailing Frequency Conflicts

A query of the FCC ULS on-line database was conducted in mid-February 2017, to find all of the active, regular licenses that use the Hailing Frequency “window of concern” (5925.1 MHz to 5930 MHz) around the Hailing Frequency (5927.5 MHz). This was done to provide a validity check of the data contained in Table A-3 (page 14, section A.8.1.5) of the Technical Appendix. The results of that query are quite disturbing as they relate to the accuracy of the data in Table A-3.

Table A-3 lists only 18 entries, yet the FCC ULS database query produces 80. The vast majority of the 80 entries returned by the FCC query are area licenses. For example, the licensee of call sign KAH90 is Qwest Corporation, based in Oregon. The license is not for a specific site or frequency, but covers a total of 14 entire western states (Qwest’s service territory) and 10 different frequency bands, including the 5925 MHz to 6525 MHz band. While these types of area licenses are not directly applicable to utilities in general or Tri-State in particular, Higher Ground must demonstrate or explain how they will not interfere with incumbent microwave paths associated with these types of licenses when there is no site-specific data whatsoever to reference.

Of the 80 licenses from the FCC database query, 10 (not 18, as shown in Table A-3 of the Technical Appendix) are site-specific licenses that could potentially be of value to Higher Ground’s Haling Frequency calculations. The 10 "correct" data points are listed below in Table 2.1. For example, the second entry in Table A-3 of the Technical Appendix is call sign WGF58. This is indeed a valid license (the
licensee is AlasCom), but the license does not (at least currently) have any center frequency in the 5925.1 MHz to 5930 MHz band. Using Higher Ground’s stated criteria for determining the entries in Table A-3, it is unclear how Higher Ground identified this call sign as a potential problem for its Hailing Frequency.

Table 2.1 - FCC ULS Hailing Frequency Conflict Query Results

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<tr>
<th>Call Sign</th>
<th>Licensee</th>
<th>City</th>
<th>State</th>
<th>Freq MHz</th>
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<td>COLERAINE</td>
<td>MN</td>
<td>5928.750</td>
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<td>WLR549</td>
<td>Nevada Bell Telephone Company d/b/a AT&amp;T Nevada</td>
<td>LUNING</td>
<td>NV</td>
<td>5926.250</td>
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<td>ECKLEY</td>
<td>CO</td>
<td>5927.500</td>
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<td>DOBBINS</td>
<td>CA</td>
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<td>CO</td>
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<tr>
<td>WPTD331</td>
<td>Western Farmers Electric Cooperative</td>
<td>COMANCHE</td>
<td>OK</td>
<td>5929.575</td>
</tr>
<tr>
<td>WQKZ948</td>
<td>MADISON, COUNTY OF</td>
<td>RICHMOND</td>
<td>KY</td>
<td>5928.750</td>
</tr>
</tbody>
</table>

While this may on the surface appear to be “good news,” in that there are only 10 instead of 18 incumbent licensees to be concerned with regarding the Hailing Frequency, that is actually not the case. This actually raises a fundamentally disturbing question of how accurate or reliable Higher Ground’s queries into the FCC ULS database actually are. Since the foundation of HG’s entire methodology is based on accurately querying the FCC ULS database, and they have clearly demonstrated that they do not seem to be able to do it correctly, this absolutely must be addressed.

2.12 Validity of Experimental License Test Locations

The Experimental License, WH2XHP, granted by the FCC, contains a list of 9 Test Areas across the United States where Higher Ground SatPaq units will be allowed to “roam” for the duration of the Experiment (between February, 2017 and June, 2018). For purposes of evaluating the effectiveness of their Hailing Frequency methodologies/algorithms, Higher Ground’s Experimental License Test Areas (ELTA’s) should correspond to the identified Hailing Frequency locations identified in Table A-3 of the Technical Appendix. That is, if HG is not actually Experimenting with their mobile SatPaq units in areas where they do not believe there could be a potential Hailing Frequency interference, the results of the Experiment will be invalid.
Therefore, it is necessary to evaluate the geographical relationship between the ELTA’s and the potential Hailing Frequency conflict locations identified in Table A-3 of the Technical Appendix. If there are no potential Hailing Frequency “problem sites” within a particular ELTA, that ELTA cannot yield valid/useful experimental data, and should be eliminated from the Experimental License (or at least from the experiments themselves). We have performed this evaluation, as described below.

Firstly, we can only use 10 of the 18 locations identified in Table A-3 of the Technical Appendix, because 8 of them are invalid (they do not currently exist in the FCC ULS database). The ten “valid” Hailing Frequency sites are listed in Table 2.1 above. We then ran a query to see if any of those 10 sites are completely enclosed by or within 50 miles of the edges of the ELTA’s, and only found four “hits” (see Table 2.2 below).

### Table 2.2 - Valid Experimental Areas for Hailing Frequency Tests

<table>
<thead>
<tr>
<th>Call Sign</th>
<th>Licensee</th>
<th>City</th>
<th>State</th>
<th>Freq MHz</th>
<th>Experimental Area Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>WLR549</td>
<td>Nevada Bell Telephone Company d/b/a AT&amp;T Nevada</td>
<td>LUNING</td>
<td>NV</td>
<td>5926.25</td>
<td>Sierra Nevada Mtns, CA</td>
</tr>
<tr>
<td>WMQ270</td>
<td>NEW CINGULAR WIRELESS PCS, LLC</td>
<td>DOBBINS</td>
<td>CA</td>
<td>5927.50</td>
<td>Palo Alto, CA</td>
</tr>
<tr>
<td>WMQ270</td>
<td>NEW CINGULAR WIRELESS PCS, LLC</td>
<td>DOBBINS</td>
<td>CA</td>
<td>5927.50</td>
<td>Sierra Nevada Mtns, CA</td>
</tr>
<tr>
<td>WPNJ399</td>
<td>Nevada Bell Telephone Company d/b/a AT&amp;T Nevada</td>
<td>LOVELOCK</td>
<td>NV</td>
<td>5926.25</td>
<td>Sierra Nevada Mtns, CA</td>
</tr>
</tbody>
</table>

We used an area that included an “extension” of 50 miles outside the ELTA to handle the possibility of a SatPaq mobile unit being on the edge of a test area but still being able to interfere with a microwave receiver 50 miles away. This is consistent with criteria from section A.8.1.2 of the Technical Appendix. As can be seen from the data in the Table, only two of the nine ELTA’s (Sierra Nevada and Palo Alto) can even be used to test the validity of the Hailing Frequency methodology proposed by Higher Ground.

Using Higher Ground’s own criteria, any test performed in the seven Experimental Licenses test areas not listed in Table 2.3 will produce invalid results, since they cannot test interference associated with the Hailing Frequency. The other seven test areas should be eliminated from the Experimental License and potentially replaced with appropriate ELTA’s where interference effects of the Hailing Frequency can actually be tested.
2.13 Microwave Antenna Azimuths

In Table A-3 on page 14 of the Technical Appendix document, it discusses 18 microwave paths that are within its “window of concern” (5925.1 MHz to 5930 MHz) around the hailing frequency of 5927.5 MHz. As section 2.11 above shows, the data in Table A-3 does not match the current FCC database, so is highly questionable. Nonetheless, we will assume it is correct for purposes of discussion in most cases throughout this document, and particularly in this section.

The Technical Appendix states that the only microwave paths that can potentially be interfered with are those that have a north-facing receive antenna, and highlight 8 of the 18 entries in Table A-3 as being north-facing. The document never actually defines what north-facing really means, but it is assumed to be any antenna with an azimuth of more than 270° or less than 90°. This is somewhat consistent with the highlighted entries in the Table, but unfortunately there are some entries in Table A-3 that do not conform to a recognizable pattern. For example, the next to last entry in the table (WPTD331) has an azimuth of 276.8° or only 6.8° north of due West, and is marked as north-facing. However, the fourth item from the bottom of Table A-3 (WNJY326) has an azimuth of 68.5° (21.5° north of due East). This is significantly “more north” (by 14.7°) than WPTD331, but is not marked as north-facing. This is perhaps just an oversight on the part of Higher Ground, but is obviously an area of concern. At a minimum, Higher Ground must state exactly how north-facing is defined.

In addition, Higher Ground appears to consider a tolerance level of 15° in SatPaq antenna azimuths to be acceptable (see section 2.10 above), at least when pointing at geostationary satellite antennas. Applying the same criteria to microwave receivers in addition to satellite receivers, it would be necessary to define north-facing as anything South of due East/West by an additional 15°, creating the north-facing boundaries as anything more than 255° (instead of 270°) and less than 105° (instead of 90°). And, as discussed in section 2.10 above, south-facing microwave receive antennas are not by default totally exempt from the possibility of harmful interference due to a SatPaq transmitter.

There is also the possibility of a SatPaq device being physically very close to a south-facing microwave receive antenna (close enough to cause interference, and perhaps even directly on the same frequency). However, since all south-facing receive antennas are effectively ignored by Higher Ground, there would be no indication in Higher Ground’s control system of the potential interference.

The discussion thus far has not even addressed the possibility of passive antenna/repeater systems (Passives, discussed in more detail above in section 2.2). A SatPaq transmitter antenna can be facing south, but be pointed at a Passive that reflects and redirects the radio signal to the north and directly into
one or more south-facing microwave receive antennas, potentially causing interference.

As a result, south-facing microwave receive antennas cannot simply be ignored on a wholesale basis, but must be accounted for in all interference calculations.

This particular discussion also points out the issue of the possible use of 6 GHz terrestrial frequencies near the Canadian or Mexican borders, and SatPaq’s potential interference with terrestrial communications systems in those foreign countries. Higher Ground must also address this in their interference analysis.

2.14 Bandwidth Window Crossing vs. Carrier Center Frequency in a Bandwidth Window

Throughout the Technical Appendix document, particularly in section A.8.1.5 (Haling Frequency), it is stated that Higher Ground uses a Direct Sequence Spread Spectrum (DSSS) modulation scheme with a bandwidth of 8 MHz around the center frequency. As discussed above in 2.4, Higher Ground is not consistent in always using 8 MHz as the emission bandwidth, but for the rest of this section we will assume it is 8 MHz.

In section A.8.1.5 of the Technical Appendix, the determinations of microwave paths that could potentially be interfered with (Table 8.3) only looked at microwave entries in the FCC ULS database with a center carrier frequency within a 4.9 MHz bandwidth window (between 5925.1 MHz and 5930 MHz). Not only does this bandwidth window not extend out to the 8 MHz required by HG’s own criteria, but it is not even centered on HG’s stated Haling Frequency of 5927.5 MHz.

In addition, HG did not take into consideration the bandwidth window of the microwave signals. The vast majority of microwave paths in the 6 GHz band have an emission bandwidth of 30 MHz (as manifested by the Emission Designators contained in the FCC Licenses). For a proper analysis, Higher Ground must consider all FCC ULS licenses where the bandwidth windows of the two signals (the microwave signal and Higher Ground’s signal) overlap and interfere with each other. It is completely invalid to only look at data where the center frequency of one is within the bandwidth window of the other.

Attached to this document is a Microsoft Excel spreadsheet which contains data from the FCC ULS database where the microwave bandwidth window and the Higher Ground Hailing Frequency bandwidth window overlap. This data was taken from the FCC ULS database in early February 2017, and assumes that the HG bandwidth window is 8 MHz (5723.5 MHz to 5931.5 MHz), even though the emission designator on Higher Ground’s Experimental License states that the window is even larger (10 MHz). This data also assumes that the emission designator of the microwave license is correct and corresponds to the actual bandwidth window of the microwave path.
In the spreadsheet, there are a total of 3590 microwave paths that Higher Ground’s Hailing Frequency could cause harmful interfere to, three of which are licensed to Tri-State. This is FAR more than the 18 stated in the Technical Appendix. Additionally, if Higher Ground’s bandwidth window is extended out to 10 MHz to correspond with the emission designator declared in its Experimental License, the number of potentially harmed microwave paths increases by more than 7% from 3590 to 3847. Note that the attached spreadsheet only contains the 8 MHz bandwidth data, not the 10 MHz bandwidth data.

There has also been some concern raised in the industry regarding interference to adjacent channels in the 6 GHz microwave band. Microwave systems are protected via the standard coordination process not only from co-channel interference (a microwave carrier on the exact same center frequency), but also from adjacent channel interference (the “next” microwave center frequency channel, typically offset by 30 MHz either higher or lower). In other words, in microwave systems it is generally recognized that adjacent channels, not just co-channels, can and will cause interference to each other. This means that from an interference perspective, one must consider frequencies that are actually outside what the emission designator on the FCC license may say is “safe”.

It is not really possible to apply standard adjacent channel evaluation methodologies to this situation, since SatPaq devices do not use standard microwave channel spacing or modulation techniques. However, we can provide a “simulation” of this that can provide an estimate of the potential scope of the problem. We can do this by extending the bandwidth window of each microwave channel out by 30 MHz in both directions from what the emission designator says (both higher and lower). For example, if the emission designator on the microwave license indicates a bandwidth of 30 MHz we will use a bandwidth window of 90 MHz (45 MHz on either side of the carrier, not just 15). Similarly, if the emission designator says 10 MHz, we will use 70 MHz (35 MHz on either side of the carrier instead of just 5).

This simulation indirectly provides a way to estimate the number of adjacent channels that could potentially be affected by Higher Ground’s Hailing Frequency. It must be emphasized that this is not an exact measurement, but is simply an estimate of the potential scope of the situation. Using the criteria of an 8 MHz Higher Ground bandwidth window and an incumbent microwave bandwidth window of what is stated by the emission designator plus 60 MHz (30 MHz on either side), the total number of microwave paths potentially affected by the Hailing Frequency more than doubles from 3590 to 7971 (this data is not contained in the attached spreadsheet).

The spreadsheet also does not contain details of which microwave paths are north- or south-facing. As discussed in previous sections, not only is the very definition of what is north-facing vs. south-facing at question, but also at question is whether the distinction between north-facing vs. south-facing microwave receive
antennas is even relevant to the interference discussion at all, and if so, to what extent.

Even if it is determined that north-facing vs. south-facing is relevant to the discussion, it would be very safe to assume that approximately one-half (1795 of 3590, 1924 of 3847, or 3985 of 7971, depending on exactly how the *bandwidth windows* are defined) of the microwave paths would be north-facing and the other half south-facing. This would mean that the scope of the interference is *substantially* more than the Technical Appendix declares (8 vs. 1795, 1924, or 3985).

In addition, this *bandwidth window* overlap model must be used on all interference calculations, not just those involving the Hailing Frequency. It is simply incorrect to only look at *center frequencies* in one direction and *bandwidth windows* in the other direction. It is also invalid to use incorrectly-sized *bandwidth windows* in either direction.

### 2.15 4 kHz (Analog Channel) Interference Calculation

Throughout the Technical Appendix document, Higher Ground states that their +9 dBW SatPaq transmit signal continuously operates across an 8 MHz bandwidth window (using Direct Sequence Spread Spectrum or DSSS technology). Also throughout the document HG states that this signal does not actually interfere with microwave signals at +9 dBW, but rather only at -24 dBW. The basic line of reasoning is as follows.

The +9 dBW SatPaq transmit signal is spread across 8 MHz of bandwidth. The microwave path that will potentially be interfered with is divided into 4 kHz analog channels. Therefore, we can divide the total 8 MHz of SatPaq bandwidth into 2000 individual 4 kHz channels, and therefore also divide the total +9 dBW of power by 2000 to calculate the amount of “interference power” we are generating into each 4 kHz channel. To divide +9 dBW of power by 2000, we subtract 33 dB from it (dividing by 2000 is equivalent to subtracting 33 dB), resulting in a “interference power” of only -24 dBW to each individual 4 kHz microwave channel.

This methodology has been a common practice in satellite communications design since the 1960’s when communications satellites were first developed. However, there are several major faults with this line of reasoning, particularly with respect to modern digital microwave communications systems.

The first is the assumption that the signal transported on an analog (or digital) microwave radio carrier is divided into 4 kHz channels. It is true that an analog microwave *baseband* signal is divided into 4 kHz channels, but the over-the-air signal that is transported on the microwave carrier itself is not. The microwave signal is composed of many elements besides the baseband component, the most significant being the deviation.
The second fault is the assumption that because an individual channel is only being affected by an interference power level of -24 dBW, the entire microwave path is only being affected by -24 dBW. That is simply untrue. There are 2000 (or some large quantity of) individual channels being affected, not just one. All calculations in the Technical Appendix which directly or indirectly use/assume an interference level of -24 dBW are invalid.

The third fault is the (unstated, yet underlying) assumption that all microwave radio paths are analog and therefore can logically be divided into discrete channels separated by frequency. The attached spreadsheet, first discussed above in section 2.14, also contains details on whether the 3590 microwave paths potentially interfered with by the SatPaq Hailing Frequency are analog, digital, or other (combination of analog and digital). As with the emission bandwidth window discussed in that section, this information is embedded in the emission designator on the FCC License.

As the spreadsheet indicates, only 33 of the 3590 microwave paths listed (fewer than 1%) contain some analog elements (shown as “Analog” or “Other” in the spreadsheet). More than 99% of the paths are purely digital. In a digital microwave path, interference with any part of the signal generates errors on the entire signal stream and any or all of the applications being transported, not just certain “frequency slices” of it.

It should also be noted that digital microwave paths often include mechanisms to increase overall reliability, such as Forward Error Correction (FEC). These mechanisms are intended to help overcome issues such as inadvertent or random interference, but are not intended to help overcome intentional interference. The presence of these mechanisms cannot be used to justify the purposeful introduction of harmful interference into the microwave radio receivers. In addition, any test procedures developed must disable FEC (or other similar mechanisms specifically designed to mitigate interference issues) in the microwave radios to properly assess the SatPaq interference impact.

2.16 Interference Measurements

In the Technical Appendix, there is no methodology discussed as to how to actually measure, or really even know, if the SatPaq devices are causing interference to the critical microwave systems. Because the SatPaq’s are mobile, frequency-agile, untraceable, and only used for sporadic communications, it is a practical impossibility to determine if any interference encountered in a microwave system is due to SatPaq or some other truly “random” environmental source. In essence, Higher Ground has created a test bed for itself where they cannot fail. It is literally impossible for incumbents to determine or prove if SatPaq is causing interference. Likewise, it is impossible for Higher Ground to determine or prove that they are not causing any interference.
This test environment has been established using fully operational critical infrastructure microwave systems as the “guinea pigs,” and no way to accurately determine if the Higher Ground technology actually harms the “guinea pigs.” This is an unacceptable scenario.

2.17 **Fixed vs. Mobile Design Methodologies**

The SatPaq environment is actually a mobile radio environment, not a fixed point-to-point environment. Higher Ground sometimes calls the SatPaq units “Handheld Mobile Earth Stations,” but they are not earth stations in any sense of the term except for the fact that they communicate with satellites. They are, in actuality, mobile/cellular radios. The SatPaq network must be modeled and engineered as a mobile environment, similar to a two-way Land Mobile Radio (LMR) system. Mobile environments and fixed environments use very different modeling, engineering, and design methods, and the two are generally incompatible.

Higher Ground is attempting to use engineering design principles for a fixed environment and apply them in quasi-real-time to a mobile environment. This simply does not, and cannot, work with any degree of predictable accuracy. A prime example of this is Higher Ground’s analysis which completely ignores passive antenna/repeater systems, particularly ones that are not purpose-built to reflect radio signals.

Higher Ground must redesign their network using mobile principles, not fixed principles. Such a system will also need to meet the requirement of guaranteeing that it will never interfere with fixed systems in the same geographic areas and using the same frequencies as incumbent microwave systems.

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