



Thinking outside the sphere

Report on Coverage Analysis of 5 Craig Road Tower Application

January 23, 2014



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At the January 7, 2014 session of the hearing on the SBA/AT&T application for a tower at 5 Craig Road, the Board sought additional information about coverage for the record. Isotrope has worked with the applicant to obtain the new information and perform an assessment within the limited two week time between meetings. Some misunderstandings between the applicant and Isotrope required additional time to clear up. This was completed on January 17th. The applicant offered and agreed to extend the reporting and review period beyond the scheduled January 21st session of the public hearing.

New Information

Three categories of information were required by the Board for the next meeting:

1. AT&T Raw drive test data to be delivered to Isotrope for evaluation in lieu of Isotrope conducting an independent formal drive test of the same type.
 - a. Only PCS drive test data was supplied.
2. LTE cell site information to be delivered to Isotrope to perform peer review of the AT&T LTE coverage maps.
 - a. Received by Isotrope (for PCS band)
3. Population counts based on computer estimated coverage from existing, proposed and hypothetical alternative sites.
 - a. Received by Isotrope

Isotrope has prepared coverage plots and corroborated the results with the AT&T PCS drive test data to the extent practicable. They are included in the Appendices to this report.

In a separate memo, Isotrope has shown how the drive test data and drive test map provided by AT&T are seriously flawed. The drive test lacks documentation of the coverage of two critical sectors. As a result, the drive test data and the AT&T drive test map are not indicative of AT&T



PCS coverage in the area. With careful reconstruction, the drive test data was employed by Isotrope to validate the general propagation model Isotrope used to map coverage.

Bylaw Focus of Report

Based on the information provided in this report, the Board has several forms of evidence on the existing and proposed AT&T coverage in the area of the proposed facility. The following questions may help the Board focus on the subject material in this report and in its deliberations:

- 1) Does the proposed facility “provide in the most community-compatible method practicable Service Coverage to a Significant Gap within the Town” by “clear and convincing evidence”?
[§3.10.6.17 b) – Mandatory Findings]
 - a. Addressing the question of Significant Gap as defined in the bylaw¹, before addressing community-compatible methods, the Board may need to decide if it is sufficient to consider only the AT&T PCS spectrum without consideration of the other bands employed by AT&T in Acton (e.g. Cellular and 700 MHz).
 - b. Similarly, the Board may need to decide if it is necessary to consider 3G coverage and 4G coverage independently.

¹ § 3.10.3.16 Significant Gap – A Coverage Gap in a Carrier’s Personal Wireless Service network within a specific geographic area shall be considered to be a “Significant Gap” if such specific identified geographic area is so large in physical size and/or affects or is predicted to affect such a large number of remote users of Compatible User Service Devices as to fairly and reasonably be considered “significant” as opposed to merely being a small “dead spot”. In determining whether or not a particular Carrier’s Coverage Gap is significant, a relatively small or modest geographic area may be considered a “Significant Gap” if such geographic area is densely populated or is frequently used by a large number of persons for active recreational or similar purposes who are, or are predicted to be, remote users of Compatible User Service Devices, and/or such geographic area straddles one or more public highways or commuter rail lines regularly traveled, or predicted to be traveled, by remote users of Compatible User Service Devices, while a larger geographic area may be considered not to be a “Significant Gap” if such geographic area does not straddle any public highways or rail lines and/or is sparsely populated. Whether or not a Significant Gap exists is to be determined separately for each Carrier’s Personal Wireless Services network, regardless of whether or not any other Carrier(s) have Service Coverage in such geographic area.



- c. Based on a determination of what services and spectrum are considered collectively and/or independently to evaluate a potential Significant Gap in Service Coverage:
 - i. Is there a Significant Gap, as defined in the Bylaw, in AT&T Service Coverage in the area targeted by the proposed facility?
 1. If so, does the proposed facility meet the following standards:
 - a. The “most community-compatible method practicable” [§3.10.6.17 b)],
 - b. “other methods preferred by the Town are not feasible for providing Service Coverage to satisfy Such Significant Gap” [§3.10.6.17 c)],
 - c. “cannot be located at any other practicably available site that is less objectionable to the general public...” [§3.10.6.17 e)],
 - d. “cannot for technical or physical reasons be located on an existing Personal Wireless Facility or Tower that would be expected to provide comparable Service Coverage” to all or a portion of a Significant Gap [§3.10.6.17 d)]

Overview of this Review

PCS-only versus Holistic View

In summary, the applicant is relying solely on AT&T coverage information regarding its PCS-licensed spectrum. AT&T has declined to provide any information on the existing coverage of other components of its existing wireless network, in the Cellular and 700 MHz licensed spectrum bands. AT&T subscriber phones are routinely switched among the various bands available based on signal quality and the shared traffic demands of other users on the network. In other words, the user employs the whole of the AT&T network and is unaware of the actual spectrum the phone is operating on at any moment.



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According to AT&T, its 3G service is available in the PCS and Cellular licensed bands, while the newer 4G services (not presently supporting voice communications) provide data services in the 700 MHz and PCS bands.

The AT&T PCS coverage is less robust than the AT&T Cellular and 700 MHz coverage in the area around the proposed facility at 5 Craig Road. This is a natural result of how vegetation affects radio signals, and other factors. In short, every suburban and rural cell site that employs multiple frequency bands (as AT&T cell sites do) will inherently have better coverage from its cellular and 700 MHz bands than in its PCS band (assuming equivalent settings and equipment for each band at the cell site). PCS coverage, therefore, will almost always look poorer than Cellular or 700 MHz coverage from the same site. Cell phones on the edge of coverage will tend to be moved to the lower frequency spectrum to maintain service from a given cell site (assuming a cell site offers the same service on two frequency bands).

3G and 4G Distinction

AT&T also distinguishes between its 4G and 3G services, because they employ different technologies and power levels to evaluate performance. AT&T asserts that if either of these services experiences a gap in coverage, the Acton Zoning Bylaw's gap criterion is met. AT&T has provided separate maps for 3G and 4G coverage. Isotrope submits coverage maps primarily for 3G PCS coverage in this report. Isotrope's analysis of the 4G PCS existing coverage (Appendix 6) indicates that it is equivalent to the 3G coverage, therefore the 4G coverage needs not be fully mapped at additional time and expense.

AT&T Analysis Is Pessimistic

Isotrope analysis of existing AT&T 3G PCS coverage shows more existing coverage than AT&T's analysis (Isotrope employs the same thresholds as defined by AT&T, to keep the comparison simple). The Isotrope coverage model was validated in this area by drive testing data supplied by AT&T. Isotrope analysis of AT&T 4G PCS coverage is nearly identical to that of the 3G PCS service, because while the 4G transmitted reference power levels are lower, the 4G thresholds are lower as well, more than compensating for the difference between 3G and 4G transmitted



power. Isotrope finds the AT&T 4G coverage maps presented by AT&T understate 4G coverage even more than the AT&T 3G maps understate 3G coverage.

Relying on the Isotrope analysis, the question remains, is there a significant gap, as defined under the Bylaw, in AT&T service in the vicinity of the proposed facility? To address the facts upon which the Board may render an informed opinion, here is a summary of analysis of the state of AT&T PCS coverage. Following that will be an analysis of AT&T coverage in general.

PCS Coverage Analysis

Difficulty with Data Acquisition and Analysis

In our September 13 report, we noted that the AT&T coverage maps were not labeled as to the frequency band depicted; labeled only “Current Coverage in Acton MA.” The *Report of Radio Frequency Engineer* submitted with the application (Tab 4) states unequivocally “10. ...it is my professional assertion that there is inadequate network service available to AT&T customers within the Town of Acton, especially along Route 2 and surrounding neighborhoods.” The original application made no distinction between PCS coverage and any other band of coverage. Only upon inquiry was it revealed that the coverage maps related only to PCS coverage, rather than “network service available.” The application also did not distinguish between 3G and 4G coverage, only asserting “4. AT&T is also designing a network to provide high speed data services commonly referred to as “long term evolution” service (“LTE”).”

Upon our inquiry, the applicant followed up with an explanation that the coverage maps were of AT&T PCS band, 3G technology. The applicant declines to submit coverage information on the network as a whole, including other frequency bands. Also, 4G PCS coverage was said to be



different, and additional AT&T coverage maps were submitted² before the January meeting to establish the purported distinction.

In our December 3, 2013 memorandum, we summarized the then-open questions, including a request for backup description of the methods employed to make the drive test map included in the October 29th Supplemental Information, “Applicant provided a supplemental map of a scan test. Map was not accompanied by any description of methodology, date of survey, adjustment factors (normalizations) applied to the raw data, if any. Was an external antenna used? If so, what gain and line loss? Was data adjusted accordingly? What band and air interface technology employed? What type of signal strength measurement? If internal to vehicle, was a consumer phone used? How mounted?” A January 2, 2014 response from AT&T was forwarded by email, with methodology information, including a statement by the third party drive tester, “There were no adjustments to the raw data, prior to submission to AT&T.” AT&T proffered no information to the contrary. At the January 7th meeting, we relied on the assertion that the AT&T drive test map depicted the raw data from the drive test and made suggestions and opinions based on that understanding.

At the conclusion of the January 7 meeting, the applicant was tasked by the Board to present the raw drive test data and certain other things, discussed below, to Isotrope. In transferring the first drive test data file to Isotrope, AT&T indicated the drive test data had been adjusted before presentation on the drive test map, “Please advice Mr. Maxson to consider first column of Ec (signal strength) parameters and when propagation plots are created the computer model take in account minimum of 6Db loss associated with the clutter so please advice to consider the loss to have apple to apple comparison.”(sic) On a telephone conference on January 8th, Isotrope inquired about the meaning of this statement, to resolve its ambiguity. On further inquiry, Isotrope determined that AT&T meant the drive test data was penalized by 6 dB to

² Unfortunately, the computer filenames make the distinction between the 3G and 4G coverage maps, but the map labels, when printed out, do not make the distinction. Readers are cautioned to keep track of the 4G and 3G maps separately.



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account for some “clutter loss” anomaly before it was depicted on the map (map is in Sec. 2 Supplemental submission of SBA/AT&T). Upon second inquiry to another AT&T representative who joined the call, the drive test data was described as having been penalized by 6 dB to account for “body losses.” Appendix 1 discusses best practices in making coverage maps and drive test maps, concluding that such an adjustment unnecessarily reduces the drive test results.

Isotrope then used the raw, unadjusted drive test data as a new point of comparison to Isotrope’s modeling of the existing coverage. This required rerunning many of the propagation maps that Isotrope had already prepared. Upon comparison of the drive test data against our normally reliable computer modeling, there appeared to be a significant anomaly in the drive test results. This is the subject of a separate memorandum. In summary, the drive test data lacks reliable data on two cell site sectors that are critical to the understanding of existing PCS coverage in the Craig Road area.

Isotrope requested further information to assess this anomaly, and performed additional analysis of drive test server data and computer model most-likely-server data. This effort confirmed the anomaly and Isotrope proceeded to rerun its mapping one more time to accommodate the flaws in the drive test data.

Isotrope’s computer estimated coverage map of existing AT&T PCS coverage (less the two sectors not represented in the drive test) is shown in Appendix 2, with an overlay of the two-channel AT&T 3G PCS drive test data. It confirms visually what Isotrope confirmed statistically – that there is a good correspondence between the Isotrope coverage model and the drive test data.

Roads

Within the area targeted by the proposed facility, there is already a substantial area that receives coverage that exceeds the AT&T preferred threshold for in-vehicle coverage on Route 2 and northeastern School Street (Isotrope Existing AT&T PCS 3G coverage in Appendix 3; AT&T drive test). The proposed facility does not substantially increase this in-vehicle service area



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(Isotrope Existing plus Proposed PCS coverage in Appendix 4). The proposed facility does substantially increase the AT&T 3G PCS “in-building” coverage on Route 2; however, in-building service to Route 2 is not relevant, as there is no development to speak of along Route 2 in the area under the influence of the proposed facility. School Street, and by proximity, Craig Road, enjoys substantial in-vehicle coverage (3G PCS) without the proposed facility.

The applicant showed a Massachusetts Department of Transportation traffic count table to Isotrope. Isotrope does not dispute the fact that Route 2 is a major artery, and the applicant is invited to submit the data to the record if it desires. Traffic counts alone do not measure the impact of a proposed facility. Fundamentally, there must be a substantial extent of in-vehicle service that is substantially unreliable along Route 2, and that a proposed facility would substantially improve.

Only the AT&T Current Coverage map of 3G PCS service shows negligible “in-vehicle” service (blue) along Route 2 near School Street. Even the flawed drive test map, including the unnecessary 6 dB penalty on mapped data and the apparent loss of a key sector of the Annursnac Hill cell site, shows an appreciable extent of “in-vehicle” service on Route 2 and School Street.³ Isotrope’s computer model is also supportive of the presence of substantial “in-vehicle” service in these road segments.

In addition, we have made the point that while the signal level used as an in-vehicle threshold is -82 dBm, there remains a substantial degree of in-vehicle service at lesser signal levels approaching the -90’s (negative numbers mean -92 is weaker than -82). The Isotrope model shows that more than half of the relevant segment of Route 2 is presently served by better than -82 dBm “in-vehicle” service. Most of the rest of the Route 2 segment, to Hosmer St, still has at least -92 dBm service (3G, PCS).

³ The drive test was conducted in the fall while the foliage had not reached its local color peak, and leaves, missing much chlorophyll, were still hydrated. The drive test is a reliable indication of received signal strength with foliage present.



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Isotrope coverage analysis indicates that the proposed facility would add about ¼ mile of additional coverage above the “in-vehicle” threshold along Route 2, nearer to Hosmer Street. Along School Street about 1000 feet would enjoy a promotion to the PCS “in-vehicle” threshold where it is not available. The most relevant road improvements in coverage would be along much of the southern part of Hosmer Street (below Route 2) (about 1/3 mile) and along much of Laws Brook Road between the Town line and School Street (about ½ mile). These road segments are projected to receive a threshold improvement to the “in-vehicle” grade of service. At the reduced height of 80 feet (Appendix 4), the new signal improves service to Laws Brook Road, but not to the point of crossing into the “in-vehicle” threshold. Hosmer St sees a threshold increase, to a lesser degree than from 100 feet.⁴

Isotrope analysis of a hypothetical alternative location, the DOT parcel on the corner of Route 2 and Hosmer Street (Appendix 5) shows a substantial increase in the “in-vehicle” grade of coverage on Hosmer and School Streets and Laws Brook Road. It also provides in vehicle service on Route 2 that fully complements existing in-vehicle coverage there. Any parcel in the general area of this hypothetical alternative would provide similar improvements, provided a similar antenna elevation can be obtained.

Residents speaking to the Board offered anecdotal testimony plus a video of a drive test conducted by one resident continuously displaying the number of “bars” on his telephone, asserting that AT&T does not have a significant gap in the area served by the existing AT&T facilities. As we explained in the hearing, it is generally understood among the technical community that bars on a telephone are indicative of a combination of signal strength and noise/interference, resulting in a general quality indicator. Phones with three bars of signal

⁴ The height difference of 20 feet in computer modeling is a relatively small difference and the comparative results may vary substantially with actual performance in the field. Consequently, the comparison serves most powerfully to illustrate if a terrain obstruction would occur with a height reduction (nothing significant). Secondly, the prediction of the impact of increased losses due to land cover is not so precise. The population counts provide a ratio of change in performance between the two heights that help quantify the differences.



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quality, as was apparently the worst case in the resident drive test, are typically able to make, receive and maintain calls reliably. The commentary from residents should not be summarily dismissed,⁵ as it includes a systematic attempt to illustrate AT&T network performance in the form of the drive video. It is a reasonable indication of a concern that merits further analysis.

Isotrope offered to conduct a more detailed formal drive test at the previous meeting in September and the January 7 meeting. On January 7, the Board decided that a review of the applicant's drive test data was in order before considering commissioning a formal independent drive test.

Following the September meeting, AT&T had a drive test of existing coverage performed⁶ and provided a map of one data set from that drive test in its supplement submitted in November. Without seeing the raw data, we did not want to assume anything. Consequently, we indicated at the January 7 meeting that it was not certain that the drive test measurements were of the same signal characteristic that the computer model was set up to predict, with a risk that the drive test map was an "apples and oranges" comparison to the computer predicted map. After that meeting we have obtained an answer to that concern that revealed other shortcomings of the drive test.

After the January 7th meeting, Isotrope returned home via the Craig Road area. Isotrope conducted an informal drive test in two brief trips around the School Street, Hosmer Road,

⁵ Webster defines the scientific method: "principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses." The residents' hypothesis was that based on experience that there is AT&T service in the targeted area. The problem was that this hypothesis conflicts with the assertion of the applicant. The residents' method was to systematically observe and record a measure of signal availability using the bars on a cell phone and a video camera. In essence, a drive test was conducted with a video data point every 30th of a second. The result is compelling information about the availability of AT&T service in an automobile on the roads driven. The test is repeatable, verifiable and systematic.

⁶ According to published foliage maps, the drive test was conducted in medium to high (but not peak) color, indicating that most trees were still in leaf, having lost most chlorophyll and not dried out.



Route 2 loop. On the first pass, a telephone call was made on the AT&T network that connected to a music service to monitor the continuity of the call. The phone was a smartphone that was held to the head of the user. Throughout the entire loop the music was never interrupted or garbled and the call was not dropped. Figure 1 illustrates the Isotrope informal drive test.

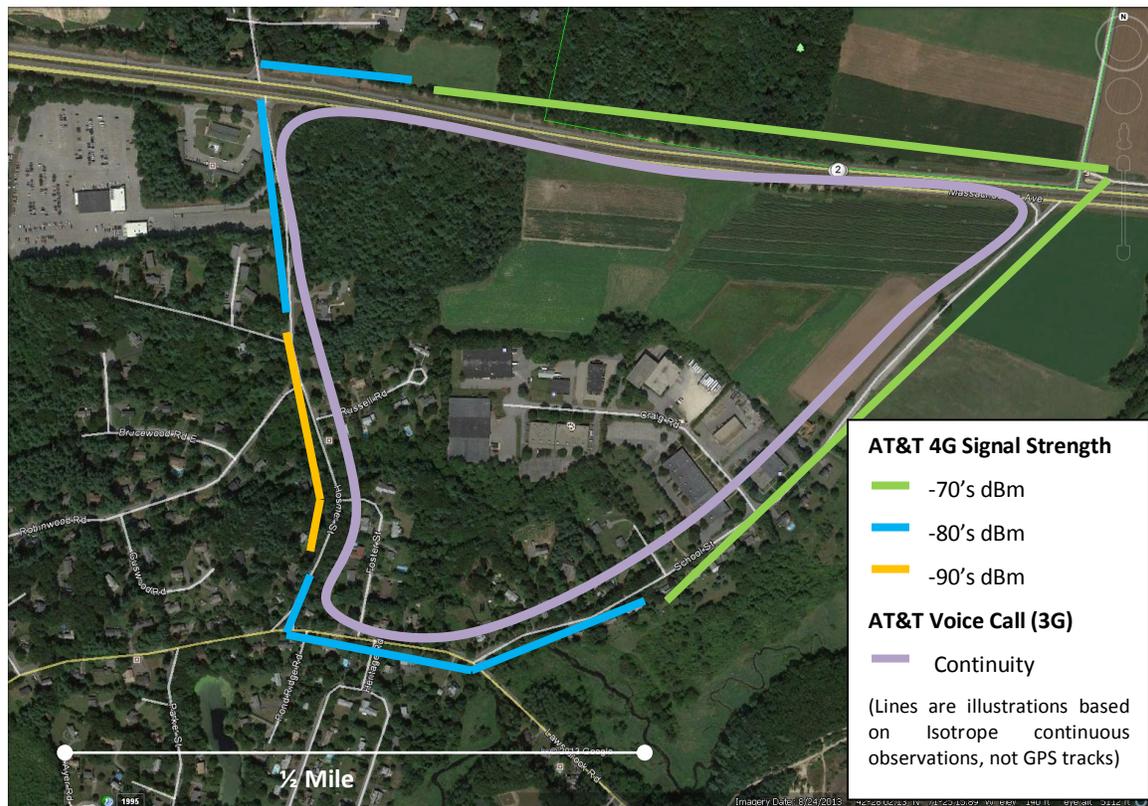


Figure 1 –Isotrope Informal Drive Test Jan 7, 2014

On the second pass, the phone was switched to a network monitoring mode and the received signal level of the 4G service was monitored. On Route 2 and much of School Street the signal level remained above -80 dBm. Near Hosmer Street on School Street and on Route 2, the signal level dipped into the -80s. On Hosmer Street, the signal level was mostly in the -80s, with a ¼ mile segment where the signal dipped below -90, with a minimum level of -96 dBm. The AT&T threshold for in-vehicle coverage of 4G service is -96 dBm. That is the outdoor signal strength AT&T seeks for highly reliable in-vehicle service. The phone was inside the vehicle, so a



measured level of as low as -106 dBm would have been acceptable to AT&T.⁷ Based on this informal drive test, the AT&T network is functional within vehicles in the targeted area of the proposed facility. It is likely that the phone was at least in part using the 700 MHz band for 4G signal level measurement, and the Cellular band for 3G voice connectivity. This test does not indicate exclusively PCS performance.⁸

Residential Population

Isotrope prepared population counts based on Isotrope drive-test-confirmed coverage modeling. These counts show the Acton residential population that receives an improvement in service to a higher threshold is less than 1% of the total population of Acton (less than 220 people). The AT&T count of population receiving a threshold improvement to “in-building” coverage is about double Isotrope’s count, and still at or below 1% of the Town population. Below is a table of Isotrope population counts.

Population Counts	Existing	Proposed 100 ft	Net Increase	Proposed 80 ft	Net Increase	DOT 100 ft	Net Increase
PCS -74 dBm	2511	2620	109	2542	31	2749	129
PCS -92 dBm	12979 ⁹	13163	184	13020	41	13614	635

⁷ It should be noted that there is no foliage in January, so there is a bias toward overstating the network performance at this time of year. It is reassuring that the signal level was obtained within the vehicle, at some penalty of vehicle penetration loss, and the lowest signal level received was some 10 dB above the threshold.

⁸ It should also be noted that the practice in measuring wireless network performance includes using regular user equipment (phones) to collect data. Companies such as ZK Celltest, among others, sell professional measurement technology that employs cell phones. The phones are externally controlled and/or run with applications on them to perform professional data collection and to run automated call continuity testing. The use of a handheld phone without the test platform for the same purpose is substantially no different, except that the data is observed and noted, and not electronically collected.

⁹ Total population counts are made within the Acton coverage area of the AT&T facilities included in the coverage analysis. Since not all facilities serving Acton north of Post Office Square are included in the map, the total population served on the maps is less than the total population of Acton. What matters is the difference between the before- and after-counts, which are highlighted in the table.



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- AT&T estimates indicate an increase of 215.87 persons to Acton's AT&T in-building coverage with the proposed facility. The estimation method may overstate the number of residents.
- AT&T estimates indicate an increase of 453.50 persons to Acton's AT&T outdoor coverage with the proposed facility. The estimation method may overstate the number of residents.

Buildings

There are about nine (9) industrial buildings in the 20± acre Craig Road area that would see an increase in AT&T PCS coverage to AT&T's "in-building" grade of service. According to Isotrope coverage data, 36 residences would obtain AT&T's grade of "in-building" service with the proposed facility. Reduced to 80 feet, the residence increase is 11.

AT&T Network Analysis

Considering the AT&T network as whole, AT&T has substantial coverage for its 3G and 4G services in the locus of the proposed Craig Road facility. In addition to the PCS coverage analysis presented above, Isotrope employed customary facility characteristics that it has successfully employed in other zoning matters and produced an existing AT&T Cellular coverage map and an existing AT&T 700 MHz coverage map (Appendix 7). Cellular coverage was modeled for 3G services and 700 MHz coverage was modeled for 4G services. The Isotrope informal drive test, described above, illustrates that call continuity (3G) and data service coverage (4G) is robust on the loop of roads around Craig Road, without considering whether the user device is on one radio band or another. The fact that the Isotrope informal drive test was conducted without a data collection apparatus does not diminish the reliability of the results. Signal strength was measured continuously and call continuity was monitored continuously. Moreover, the fact that the survey was conducted in the dead of winter is not dispositive of the results. Only a drive test taken when foliage is present would be sufficient to corroborate, modify or dismiss the results.



Isotrope makes no recommendation with respect to whether the applicant's request to consider only AT&T PCS coverage is the most appropriate way to evaluate the potential for a significant gap under the Acton Zoning Bylaw. The facts of both the PCS-only case and the holistic total-network case are presented here.

Isotrope Conclusions Summary

PCS Analysis

- SBA/AT&T relies solely on predicted and measured coverage from the AT&T PCS spectrum to assert that there is a significant gap in AT&T service. The Board should consider whether it is the entirety of AT&T's services in Acton, or a specific band of AT&T frequencies that should be the standard for evaluation of a gap in service under the bylaw (or under the Telecommunications Act).
- AT&T computer estimated coverage maps understate the actual coverage of the AT&T 3G and 4G PCS systems.
- Based on drive test data prepared for AT&T and supplied to Isotrope, Isotrope's computer estimated coverage mapping of PCS coverage is more realistic.
- AT&T adjusted by 6 dB the data displayed on the drive test map submitted in the Supplemental filing. Consequently, the AT&T drive test map understates the coverage of the cell sites that were measured.
- The AT&T drive test map is based on data that failed to represent the coverage of two key sectors facing the Craig Road area – Annursnac Hill Gamma sector and Post Office Square Beta sector. The result is an indication of a deficiency in coverage in locations where the coverage is not deficient. The measured coverage in the Craig Road locus is affected by this flaw.
- AT&T Drive test data of PCS coverage mapped by Isotrope and Isotrope mapping of PCS coverage indicate there are large areas of substantial coverage and pockets of substantially unreliable PCS service (orange on Isotrope maps) around the area to be served by the proposed facility.



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- With the proposed facility, 9 Industrial buildings on Craig Road would receive improved PCS coverage to the level satisfying the AT&T PCS “in-building” threshold.
- The present analysis is based on AT&T-stated thresholds for in-building, in-vehicle, and outdoor coverage.
 - Isotrope has explained that the signal levels given by AT&T as thresholds are target values.
 - There is still substantial suburban in-building service in areas in a band outside the threshold – e.g. the in-vehicle region (blue) on the maps is expected to provide reliable in-building service under most circumstances, just to a lesser degree than in the higher threshold area.
 - The same is true when considering in-vehicle coverage outside the target blue zone (into the yellow zone).
 - Consequently, AT&T in-vehicle PCS service along Route 2 and eastern School Street in Acton appears to be able to be substantially reliable without the proposed facility.
- PCS-only population estimates suggest ½% to 1% the Acton population receives the benefit of an increase to AT&T’s desired PCS “in-building” threshold.
- PCS-only population estimates suggest that between less than 1% and 2% of the Acton population receives the benefit of an increase to AT&T’s desired “outdoor” threshold.
- A facility at the DOT site, or some location nearby using a similar antenna height, would produce a substantially larger population increase in all coverage categories.

Network Analysis

- When considering the entire AT&T network, including also Cellular and 700 MHz spectrum AT&T uses, there is substantial AT&T voice and data coverage already available in the general area of the proposed facility. AT&T has declined to provide any data on service bands other than PCS.
- An Isotrope drive-through of the road loop around the proposed site successfully maintained a voice call with an AT&T phone without disruption or audible artifacts.