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Re: Request for information
Correspondence reference # 7918
From: Jose Trevino (Jose.Trevino@fcc.gov)

Dear Jose,

This note is in response to your request for additional details of the calculations on our proposed system to support a demonstrated compliance with Section 8.3.28(6) of the NTIA Manual. We have investigated input data and present the detailed calculations that we believe demonstrates compliance. In addition, as we do wish to be good radiation stewards, we demonstrate below that the proposed arrangement of the repeater system will provide a significant safety margin in the power that might be received by an isotropic antenna at a distance of 100' from the building.

Please let me know if there is any additional information that you require and I will respond as quickly as possible.

Best Regards
Brian

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Detailed Calculations

Introduction

During investigation of the manufacturer's website calculation table, as submitted previously, some mistakes were discovered. (The manufacturer is now rectifying the errors in their web posting.) It is therefore easy to see that the justification previously presented, that being from a non-expert, "user" point of view, could give you cause for query. It is SAIC's strong desire to be good radiation stewards. The FCC concern for, and guidance in ensuring that SAIC meets the NTIA standard is greatly appreciated. The following discussions are presented in support of the FCC request for further information and detailed calculations.

System Gain Inventory

The signal inventory shown in Table 1 is used to calculate the total radiated power from the repeater antenna. The antenna gains and cable losses are data supplied by the manufacturer for the equipment specified in the license application. This inventory shows that the effective radiated power emanating from the repeater will be -73.9 dBm. The paragraphs to follow discuss in more detail the input data to Table 1. It will be seen that the estimates we provide are all overestimates of the anticipated performance. The goal here is to be sure that there is a reasonable safety margin in meeting the NTIA requirements.

Table 1 System gain inventory leading to total radiated power

average reciever power (L1 - North America)		-130	(dBm)
reciever antenna gain	33		(dB)
antenna cable insertion loss	-2.6		(dB)
repeater amplifier gain	20		(dB)
repeater antenna gain best case	5.7		(dB)
total system gain		56.1	(dB)
effective radiated power		-73.9	(dBm)

Table 1 uses the value of -130 dBm as the maximum North American average surface flux for the received GPS signal. The value -130 dBm (-160 dBW) is the average value that can be expected when measured at the Earth's surface. Please refer to Section 2.1.1 of the US Coast guard document "Global Positioning System Standard Positioning Service Signal Specification", 2nd Edition June 2, 1995 [http://www.navcen.uscg.gov/pubs/gps/sigspec/gpssps1.pdf]. In section 2.3.4, Signal Coverage and Power Distribution, the received power (dBW) is graphed as a function of satellite elevation angle (see Figure 1). The signal level shown is what is measured at the output of a 3 dBi reference receiving antenna. This makes the distribution of the received signal power in the range of -161 dBW to -163 dBW. The section also maintains that the maximum received signal levels along with a set of unpredictable environmental and technical factors can never exceed -153 dBW (-156 dBW without the reference antenna gain). As a result, an average of -160 dBW [-156 dBW,-163 dBW] is an accurate indication of the received signal power at the input of the receiving antenna.

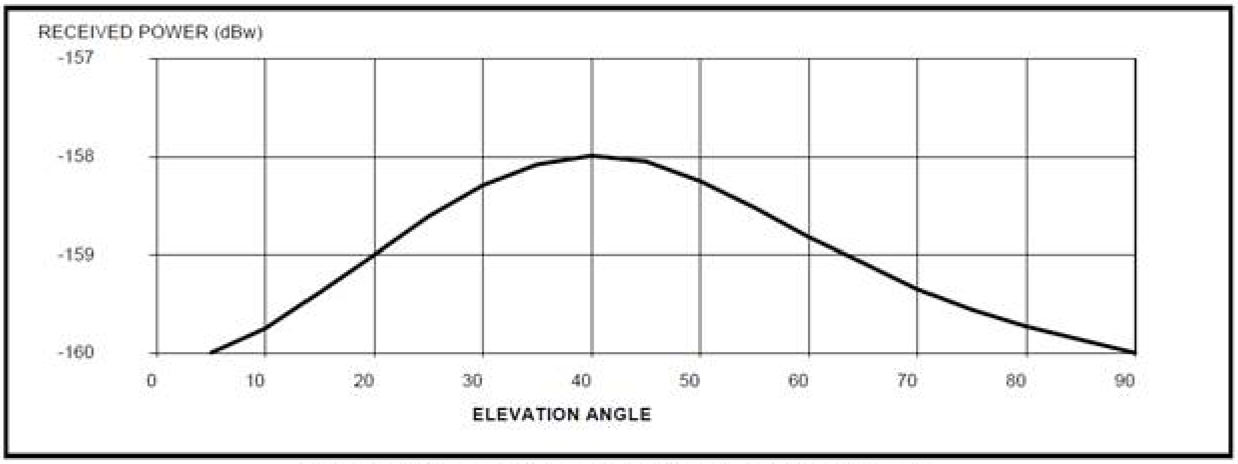

Figure 2-6. User Received Minimum Signal Levels

Figure 1 US Coast Guard specification of North American average user received signal power as measured at the output of a 3 dBi reference receiving antenna.

The SACI receiver antenna gain is measured and documented by the manufacturer, GPS Source, Inc. Figure 2 is provided for the specific antenna to be used, Model 3G1215A-XN-1. Using a gain of 33 dB in the signal inventory is seen to be an accurate, if not slight overestimate of the antenna gain for the L1/L2 bands.

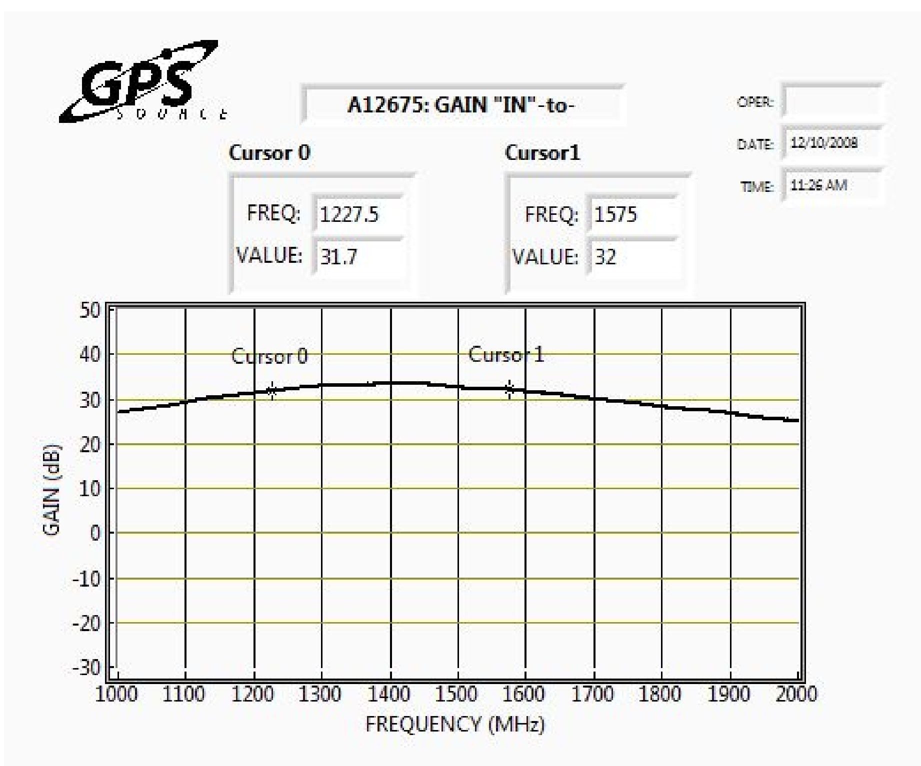

Figure 2 Gain measurements for the model 3G1215A-XN-1 reciever antenna.

As previously reported, attenuation in the cable is specified as the minimum loss expected for our system of a 50' length of the LMR-400 cable. This represents the minimum theoretical losses and assumes pristine cable with no conductor or contact oxidation to give additional attenuation.

The repeater amplifier is to be operated at 20 dB gain to drive the 2G1215P-XN-4 repeater antenna manufactured by Antcom Corporation and distributed by GPS Source. The radiation pattern for this antenna is given in Figure 3. The gain shown represents that in the horizontal plane, relative to the forward direction, and the gain is cylindrically symmetric about the forward axis. Figure 4 translates this data into relative power flux distribution, P_w, vs. angle from the forward direction. It will be noted that this antenna radiates predominantly in the forward direction in approximately a 60° cone angle. In order to reference this data to the equivalent isotropic radiated power, P_i the radiation pattern is integrated over an arbitrary spherical surface centered on the antenna and normalized to the area of this reference surface:

$$P_i = \frac{1}{4\pi r^2}\int_0^\pi P_w(\vartheta)\cdot 2\pi r^2 \sin(\vartheta) d\vartheta = \frac{1}{2}\int_0^\pi P_w(\vartheta)\cdot \sin(\vartheta) d\vartheta \qquad \text{Equation 1}$$

Given the data for repeater antenna we find that the equivalent isotropic power, $P_i = 0.268\ W/m^2$. This equates to a peak gain for this antenna of 5.7 dBi in the forward direction. For the purposes of ensuring there is a reasonable margin in the overall calculations, this gain has been included in estimating the total gain inventory (Table 1) of the repeater system.

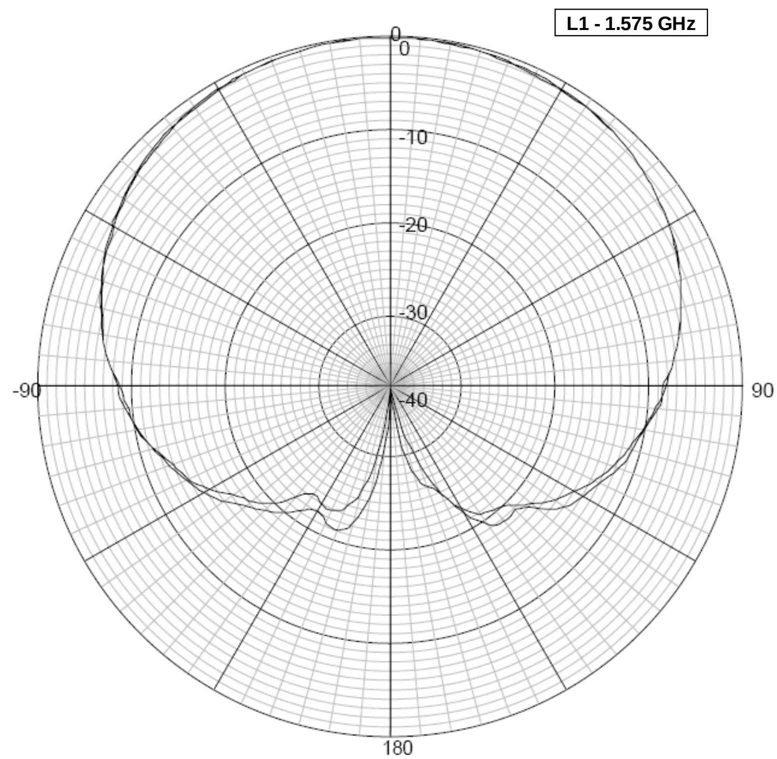

Figure 3 Radiation pattern for Antcon 2G1215P-XN-4 antenna. Radiated power is given in units of dB. The pattern is rotationally symmetric about the forward direction.

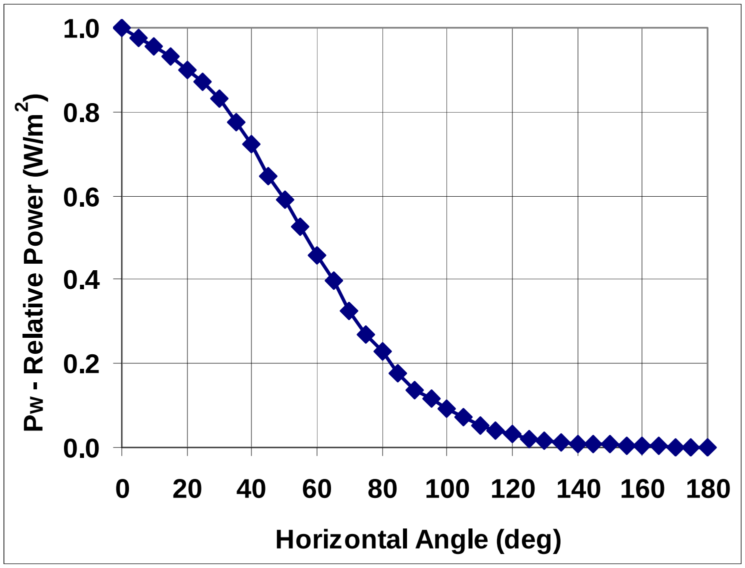

Figure 4 Relative distribution of radiated power flux for the Antcom repeater antenna.

The next step is to examine the re-radiated power levels at some distance from the repeater antenna with the goal of ensuring that the equivalent isotropic radiated power remains at or below -140 dB as prescribed in Section 8.3.28(6) of the NTIA Manual. It will be noted that by retaining the gain of the re-radiator antenna, these calculations will ultimately overestimate the equivalent isotropic radiated power at range by a minimum of approximately 5.7 dB. Further, it will be seen that an additional margin in excess of 10 dB is realized as a result of the high directionality of the antenna coupled with the physical arrangement and orientation of the antenna within the Manassas facility.

Free Space Loss Factor

The decay of the signal intensity at various distances from the antenna is described by the so-called one way radar equation. The full details of this equation are reproduced in Table 2. For the present purposes it is the free space loss term, α_1, which describes the signal decay:

$$\alpha_1 = K_1 + 20\log(Rf) \quad \text{[dB]}. \qquad \text{Equation 2}$$

Here, R is the distance from the antenna and f is the operating frequency. In evaluating α_1, the constant K_1 is determined by the units used for R and f. To the listing in Table 2 a value of K_1 = 36.58 can be included when the following units are used: R [miles] and f [MHz].

Table 2 Details of the calculations for the one-way radar equation.

ONE-WAY RADAR EQUATION

Peak Power at Receiver Input, $P_r \text{ (or } S) = P_D A_e = \frac{P_t G_t A_e}{4\pi R^2}$ and Antenna Gain, $G = \frac{4\pi A_e}{\lambda^2}$ or: Equivalent Area, $A_e = \frac{G\lambda^2}{4\pi}$

So the one-way radar equation is:

$$S \text{ (or } P_r) = \frac{P_t G_t G_r \lambda^2}{(4\pi R)^2} = P_t G_t G_r \left[\frac{c^2}{(4\pi f R)^2}\right]^{*} \qquad \left(\text{Note: } \lambda = \frac{c}{f}\right)$$

* keep λ, c, and R in the same units

On reducing to log form this becomes:

$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r - 20\log fR + 20\log(c/4\pi)$

or in simplified terms:

$10\log P_r = 10\log P_t + 10\log G_t + 10\log G_r - \alpha_1$ (in dB)

Where: α_1 = one-way free space loss = $20\log(fR) + K_1$ (in dB)

and: $K_1 = 20\log[(4\pi/c)$(Conversion factors if units if not in meters, m, and Hz)]

Note: To avoid having to include additional terms for these calculations, always combine any transmission line loss with antenna gain.

Values of K_1 (in dB)

Range (units)	f_1 in MHz K_1 =	f_1 in GHz K_1 =
NM	37.8	97.8
km	32.45	92.45
m	-27.55	32.45
yd	-28.33	31.67
ft	-37.87	22.13

Note: Losses due to antenna polarization and atmospheric absorption are not included in any of these equations.

Reradiated Power at Range

With the above data in hand, the power flux, P, at various distances from the antenna can be calculated:

$$P(R) \text{ [dBm]} = P_{antenna} \text{ [dBm]} + \alpha_1(R) \text{ [dB]}, \qquad \text{Equation 3}$$

where $P_{antenna}$ is the effective radiated power as given in Table 1 at a frequency of 1575 MHz.

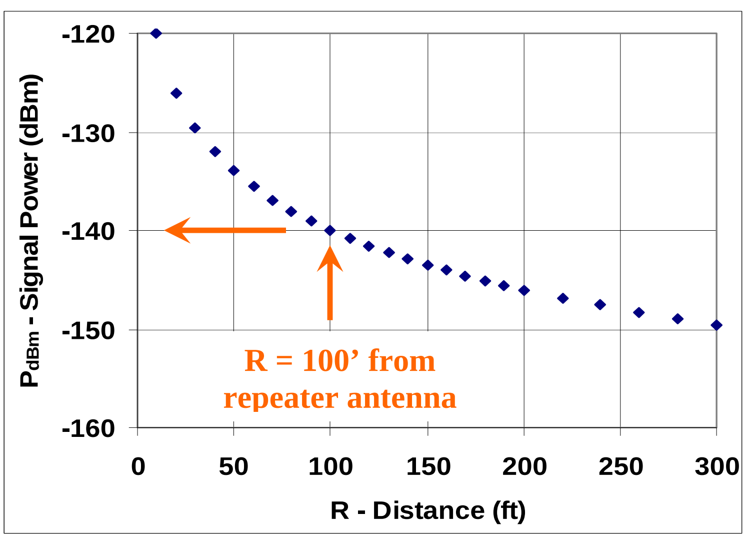

Figure 5 Plot of the on-axis signal strength at various distances from the re-radiator antenna. The maximum signal strength at a distance of 100' would be -140 dBm.

Note again that the reradiated power given in Figure 5 is that in the direction of maximum gain and therefore provides an overestimate for the purposes of meeting the requirements of NTIA Section 8.3.28(6).

Overview of the Manassas Facility

This section provides an overview of the Manassas facility and surrounding area as well as a description of the orientation of the repeater antenna with respect to the exterior walls of the building. Figure 6 and Figure 7 shows the location of SAIC's Manassas laboratory in relationship to the surroundings. The laboratory is located in an industrial park, surrounded by the grounds of the Manassas National Battlefield Park. All local streets are in excess of 500' form the laboratory with the closest major highway being over 2000' from the proposed location of the repeater antenna.

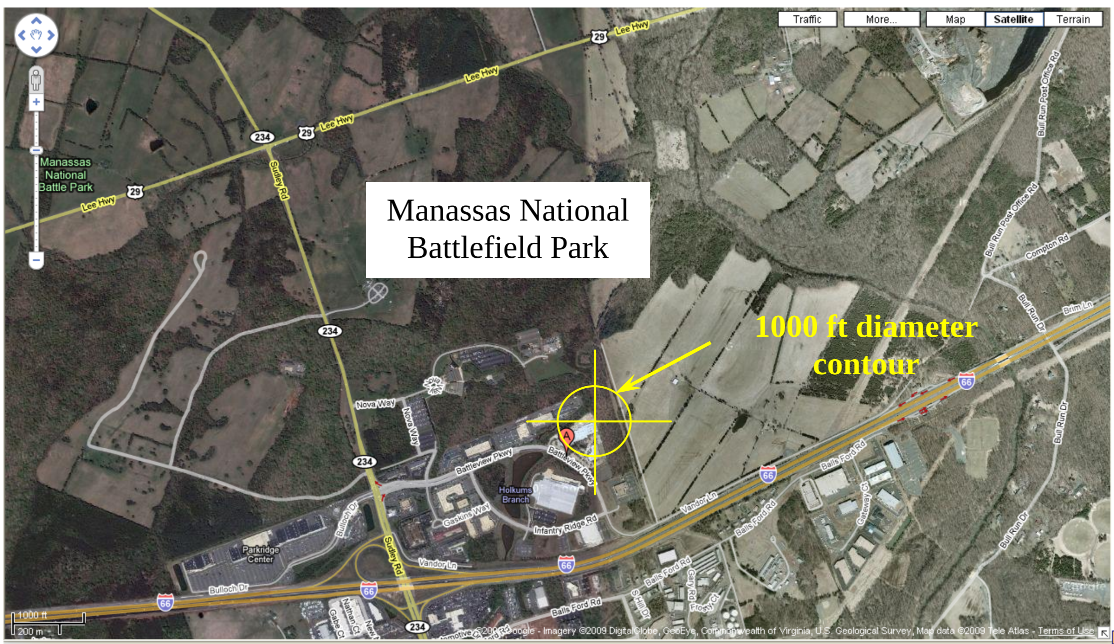

Figure 6 Satellite view of area surrounding SAIC's Manassas laboratory. The building location is highlighted to identify its location with respect to the surroundings.

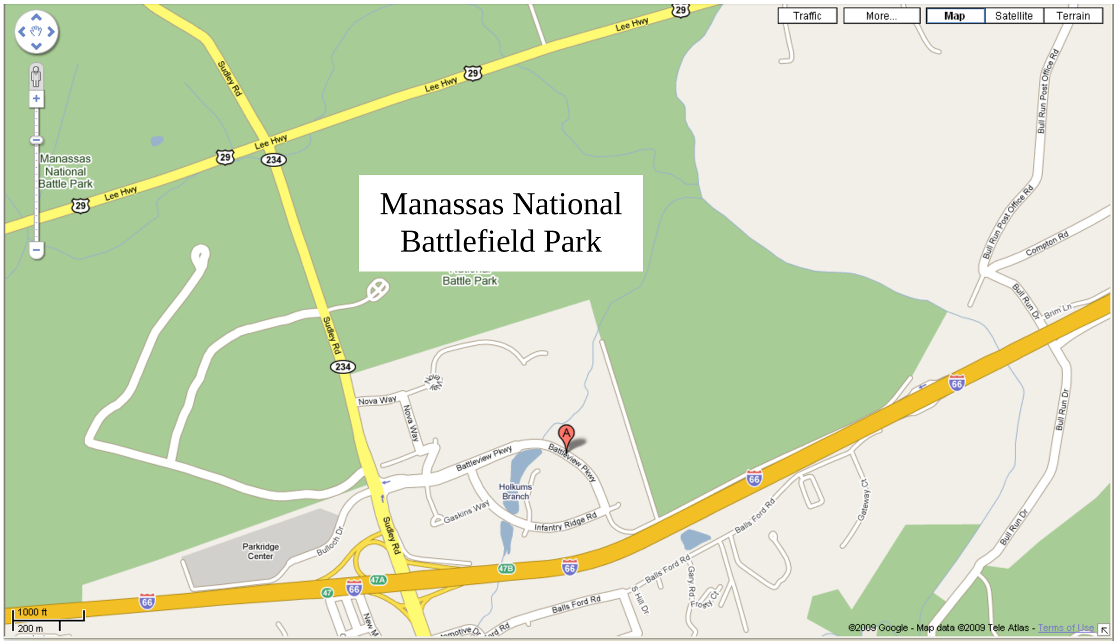

Figure 7 Area map showing the location of SAIC's laboratory in relation to the Manassas National Battlefield Park, shown in green.

Figure 8 provides a close-up aerial view of the building. The repeater antenna would be mounted inside the laboratory on the exterior wall as shown. It would be oriented to radiate such that the forward direction is inwards from the wall and the 180°, or rearward direction, faces the adjacent park grounds (see also Figure 3). A circle of over 200' radius would contain portions of the building itself, the front and rear parking lot area, and the heavily wooded area of the park.

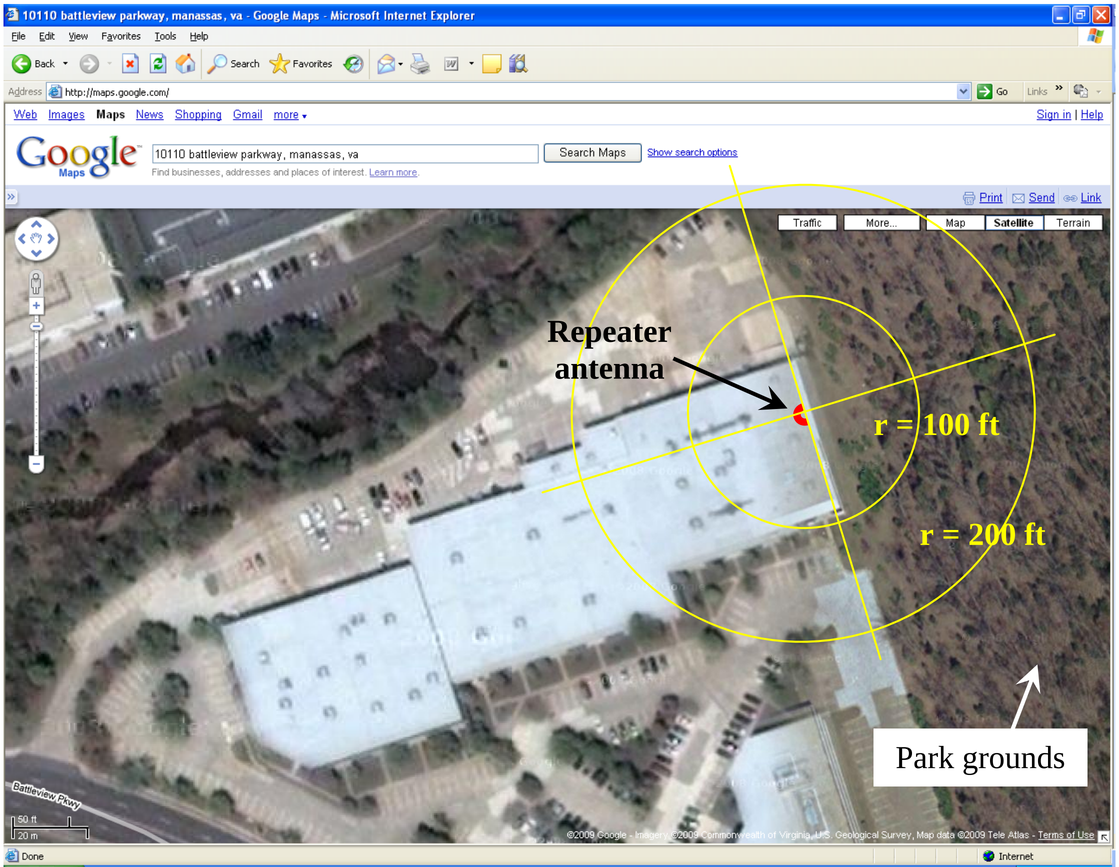

Figure 8 SAIC's laboratory in relation to industrial building complex and surrounding National Park. Repeater antenna will be located inside the building near the exterior wall as indicated.

Summary

As per Figure 5, at a distance of 100' radius from the antenna, the maximum radiated power would be -140 dBm assuming free space propagation and therefore no attenuation in the exterior walls of the building or other structures. This power level has been calculated as the peak value for the forward direction and as such it provides a minimum margin of 5.7 dB in the power levels that would be measured at a distance of 100' from the building. In particular, since the repeater is mounted directly on an exterior wall the antenna orientation will be such that these calculations would provide a minimum margin in excess of 15 dB for the half-sphere constituting the rearward direction for the repeater antenna.