by the launch vehicle final stage in the applicant’s launch vehicle trajectory analysis done in accordance with paragraph (b)(1)(ii).

(ii) An applicant shall define the final stage impact dispersion area by using a dispersion factor [\(\text{DISP}(H_{\text{ap}})\)] as shown below. An applicant shall calculate the impact dispersion radius \(R\) for the final launch vehicle stage. An applicant shall set \(R\) equal to the maximum apogee altitude \(H_{\text{ap}}\) multiplied by the dispersion factor as shown below:

\[
R = H_{\text{ap}} \cdot \text{DISP}(H_{\text{ap}}) \quad \text{(Equation B70)}
\]

where: \(\text{DISP}(H_{\text{ap}}) = 0.05\)

(5) An applicant shall combine the launch area and downrange area flight corridor and any final stage impact dispersion area for a guided suborbital launch vehicle.

(i) On the same map with the launch area flight corridor, an applicant shall plot the latitude and longitude positions of the left and right sides of the downrange area of the flight corridor calculated in accordance with subparagraph (d)(3).

(ii) An applicant shall connect the latitude and longitude positions of the left side of the downrange area of the flight corridor sequentially starting with the last IIP calculated on the left side and ending with the first IIP calculated on the left side. An applicant shall repeat this procedure for the right side.

(iii) An applicant shall connect the left sides of the launch area and downrange portions of the flight corridor. An applicant shall repeat this procedure for the right side.

(iv) An applicant shall plot the overflight exclusion zone defined in subparagraph (c)(7).

(v) An applicant shall draw any impact dispersion area on the downrange map with the center of the impact dispersion area on the launch vehicle final stage impact point obtained from the applicant’s launch vehicle trajectory analysis done in accordance with subparagraph (d)(3)(ii).

(e) Evaluate the Launch Site

(1) An applicant shall evaluate the flight corridor for the presence of populated areas. If no populated area is located within the flight corridor, then no additional steps are necessary.

(2) If a populated area is located in an overflight exclusion zone, an applicant may modify its proposal or demonstrate that there are times when no people are present or that the applicant has an agreement in place to evacuate the public from the overflight exclusion zone during a launch.

(3) If a populated area is located within the flight corridor, an applicant may modify its proposal or complete an overflight risk analysis in accordance with appendix C.
### TABLE C–1—OVERFLIGHT ANALYSIS DATA REQUIREMENTS

<table>
<thead>
<tr>
<th>Data category</th>
<th>Data item</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Data</td>
<td>Total population within a populated area (N).</td>
<td>Within 100 nm of the launch point: U.S. census data at the census block-group level. Downrange from 100 nm beyond the launch point, world population data are available from: Carbon Dioxide Information Analysis Center (CDIAC) Oak Ridge National Laboratory Database—Global Population Distribution (1990), Terrestrial Area and Country Name Information on a One by One Degree Grid Cell Basis (DB1016 (8–1996))</td>
</tr>
<tr>
<td></td>
<td>Total landmass area within the populated area (A).</td>
<td>N/A.</td>
</tr>
<tr>
<td></td>
<td>Failure probability—P_f = 0.10 N/A.</td>
<td>See table C–3.</td>
</tr>
<tr>
<td></td>
<td>Effective casualty area (A_c)</td>
<td>Determined by range from the launch point or trajectory used by applicant.</td>
</tr>
<tr>
<td></td>
<td>Overflight dwell time</td>
<td>See appendix B, table B–1.</td>
</tr>
<tr>
<td>Launch Vehicle Data</td>
<td>Nominal trajectory data (for an appendix B flight corridor only).</td>
<td>See figure C–1, which shows an area considered for probability of impact (P_i) computations.</td>
</tr>
</tbody>
</table>

### (c) Estimating Corridor Casualty Expectation

1. A corridor casualty expectation (N_i(Corridor)) estimate is the sum of the expected casualty measurement of each populated area inside a flight corridor.
2. An applicant shall identify and locate each populated area in the proposed flight corridor.
3. An applicant shall determine the probability of impact in each populated area using the procedures in subparagraphs (5) or (6) of this paragraph. Figures C-1 and C-2 illustrate an area considered for probability of impact (P_i) computations by the dashed-lined box around the populated area within a flight corridor, and figure C-3 illustrates a populated area in a final stage impact dispersion area. An applicant shall then estimate the N_i for each populated area in accordance with subparagraphs (7) and (8) of this paragraph.

The P_i computations do not directly account for populated areas whose areas are bisected by an appendix A flight corridor centerline or an appendix B nominal trajectory ground trace. Accordingly, an applicant must evaluate P_i for each of the bi-sections as two separate populated areas, as shown in figure C–4, which shows one bi-section to the left of an appendix A flight corridor's centerline and one to its right.

5. Probability of impact (P_i) computations for a populated area in an appendix A flight corridor. An applicant shall compute P_i for each populated area using the following method:

\[
P_i = \frac{|y_2 - y_1|}{\sigma_y} \exp \left( -\frac{y_1 - y_2}{2\sigma_y} \right)^2 \cdot \exp \left( -\frac{y_1 + y_2}{2\sigma_y} \right)^2 + \exp \left( -\frac{y_1 - y_2}{2\sigma_y} \right)^2 + \exp \left( -\frac{y_1 + y_2}{2\sigma_y} \right)^2 + \frac{P_f (x_3 - x_1)}{C R} \]  

(Equation C1)

where:
- \(x_1, x_3\) = closest and farthest downrange distance (nm) along the flight corridor centerline to the populated area (see figure C-1)
- \(y_1, y_2\) = closest and farthest cross range distance (nm) to the populated area measured from the flight corridor centerline (see figure C-1)
- \(\sigma_y = \) one-third of the cross range distance from the centerline to the flight corridor boundary (see figure C-1)
- \(\exp = \) exponential function \(e^x\)
- \(P_f = \) probability of failure = 0.10
- \(R = \) IPP range rate (nm/sec) (see table C-2)
- \(C = 643\) seconds (constant)
### TABLE C–2—IIP RANGE RATE VS. IIP RANGE

<table>
<thead>
<tr>
<th>IIP range (nm)</th>
<th>IIP range rate (nm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–75</td>
<td>0.75</td>
</tr>
<tr>
<td>76–300</td>
<td>1.73</td>
</tr>
<tr>
<td>301–900</td>
<td>4.25</td>
</tr>
<tr>
<td>901–1700</td>
<td>8.85</td>
</tr>
<tr>
<td>1701–2600</td>
<td>19.75</td>
</tr>
<tr>
<td>2601–3500</td>
<td>42.45</td>
</tr>
<tr>
<td>3501–4500</td>
<td>84.85</td>
</tr>
<tr>
<td>4501–5250</td>
<td>154.95</td>
</tr>
</tbody>
</table>

(ii) For each populated area within a final stage impact dispersion area, an applicant shall compute \( P_i \) using the following method:

(A) An applicant shall estimate the probability of final stage impact in the x and y sectors of each populated area within the final stage impact dispersion area using equations C2 and C3:

\[
    P_x = \frac{k_2 - k_1}{\sigma_x} \exp \left( -\frac{(x_1/\sigma_x)^2}{2} \right) + 4 \exp \left( -\frac{(x_1 + x_2)/2\sigma_x)^2}{2} \right) + \exp \left( -\frac{(x_2/\sigma_x)^2}{2} \right) \tag{Equation C2}
\]

where:
- \( X_1, X_2 = \) closest and farthest downrange distance, measured along the flight corridor centerline, measured from the nominal impact point to the populated area (see figure C–3)
- \( \sigma_x = \) one-third of the impact dispersion radius (see figure C–3)
- \( \exp = \) exponential function \((e^*)\)

\[
    P_y = \frac{k_1 - k_1}{\sigma_y} \exp \left( -\frac{(y_1/\sigma_y)^2}{2} \right) + 4 \exp \left( -\frac{(y_1 + y_2)/2\sigma_y)^2}{2} \right) + \exp \left( -\frac{(y_2/\sigma_y)^2}{2} \right) \tag{Equation C3}
\]

where:
- \( y_1, y_2 = \) closest and farthest cross range distance to the populated area measured from the flight corridor centerline (see figure C–3)
- \( \sigma_y = \) one-third of the impact dispersion radius (see figure C–3)
- \( \exp = \) exponential function \((e^*)\)

(B) If a populated area intersects the impact dispersion area boundary so that the \( x_2 \) or \( y_2 \) distance would otherwise extend outside the impact dispersion area, the \( x_2 \) or \( y_2 \) distance should be set equal to the impact dispersion area radius. The \( x_2 \) distance for populated area A in figure C–3 is an example.

(C) An applicant shall determine, first, the probability between \( y_1 = 0 \) and \( y_2 = a \) and, second, the probability between \( y_1 = 0 \) and \( y_2 = b \), as depicted in figure C–4. The probability \( P_y \) is then equal to the sum of the probabilities of the two parts. If a populated area intersects the line that is normal to the flight azimuth on the impact point, an applicant shall solve equation C2 by obtaining the solution in two parts in the same manner as with the values of \( x \).

(C) An applicant shall calculate the probability of impact for each populated area using equation C4 below:

\[
    P_i = P_x \cdot P_y \tag{Equation C4}
\]

where: \( P_x = 1 - P_y = 0.90 \)
(6) Probability of impact computations for a populated area in an appendix B flight corridor. An applicant shall compute $P_i$ using the following method:

$$P_i = \left( \frac{y_2 - y_1}{\sigma_y} \right) \frac{1}{6\sqrt{2\pi}} \exp \left( \frac{-(y_1^2 + y_2^2)}{2\sigma_y^2} \right) + 4 \exp \left( \frac{-(y_1^2 + y_2^2)}{2\sigma_y^2} \right) + \exp \left( \frac{-(y_1^2 + y_2^2)}{2\sigma_y^2} \right) \left( \frac{P_f}{t} \right) \right) \left( t_d - t_d \right)$$

(Equation C5)

where:
- $y_1, y_2 =$ closest and farthest cross range distance (nm) to a populated area measured from the nominal trajectory IIP ground trace (see figure C-2)
- $\sigma_y =$ one-third of the cross range distance (nm) from nominal trajectory to the flight corridor boundary (see figure C-2)
- $\exp =$ exponential function ($e^x$)
- $P_f =$ probability of failure $= 0.10$
- $t =$ flight time from lift-off to orbital insertion (seconds)
- $t_d =$ overflight dwell time (seconds)

(i) For the launch and downrange areas, but not for a final stage impact dispersion area for a guided suborbital launch vehicle, an applicant shall compute $P_i$ for each populated area using the following method:

(A) An applicant shall estimate the probability of final stage impact in the x and y sectors of each populated area within the final stage impact dispersion area using equations C6 and C7:

$$P_i = \left( \frac{y_2 - y_1}{\sigma_y} \right) \frac{1}{6\sqrt{2\pi}} \exp \left( \frac{-(y_1^2 + y_2^2)}{2\sigma_y^2} \right) + 4 \exp \left( \frac{-(y_1^2 + y_2^2)}{2\sigma_y^2} \right) + \exp \left( \frac{-(y_1^2 + y_2^2)}{2\sigma_y^2} \right) \left( \frac{P_f}{t} \right) \right) \left( t_d - t_d \right)$$

(Figure C-1: Analysis of an Appendix A Flight Corridor)
where:

\[ x_1, x_2 = \text{closest and farthest downrange distance, measured along nominal trajectory IIP ground trace, measured from the nominal impact point to the populated area (see figure C-3)} \]

\[ \sigma_x = \text{one-third of the impact dispersion radius (see figure C-3)} \]

\[ \exp = \text{exponential function (e^x)} \]

\[ P_x = \frac{(x_2 - x_1)}{6\sqrt{2\pi}} \exp \left( -\frac{(x_1)^2}{2} \right) + 4 \exp \left( -\frac{(x_2 + x_1)^2}{2} \right) + \exp \left( -\frac{(x_2)^2}{2} \right) \]  

(Equation C6)

where:

\[ y_1, y_2 = \text{closest and farthest cross range distance to the populated area measured from the nominal trajectory IIP ground trace (see figure C-3)} \]

\[ \sigma_y = \text{one-third of the impact dispersion radius (see figure C-3)} \]

\[ \exp = \text{exponential function (e^x)} \]

\[ P_y = \frac{(y_2 - y_1)}{6\sqrt{2\pi}} \exp \left( -\frac{(y_1)^2}{2} \right) + 4 \exp \left( -\frac{(y_2 + y_1)^2}{2} \right) + \exp \left( -\frac{(y_2)^2}{2} \right) \]  

(Equation C7)

(B) If a populated area intersects the impact dispersion area boundary so that the \( x_2 \) or \( y_2 \) distance would otherwise extend outside the impact dispersion area, the \( x_2 \) or \( y_2 \) distance should be set equal to the impact dispersion area radius. The \( x_2 \) distance for populated area A in figure C-3 is an example.

If a populated area intersects the flight azimuth, an applicant shall solve equation C7 by obtaining the solution in two parts. An applicant shall determine, first, the probability between \( y_1 = 0 \) and \( y_2 = a \) and, second, the probability between \( y_1 = 0 \) and \( y_2 = b \), as depicted in figure C-4. The probability \( P_y \) is then equal to the sum of the probabilities of the two parts. If a populated area intersects the line that is normal to the flight azimuth on the impact point, an applicant shall solve equation C6 by obtaining the solution in two parts in a similar manner with the values of \( x \).

(C) An applicant shall calculate the probability of impact for each populated area using equation C8 below:

\[ P_i = P_x \cdot P_x \cdot P_y \]  

(Equation C8)

where: \( P_i = 1 - P_t = 0.90 \)
Figure C-2: Analysis of an Appendix B Flight Corridor
(7) Using the $P_i$ calculated in either subparagraph (c)(5) or (6) of this paragraph, an applicant shall calculate the casualty expectancy for each populated area within the flight corridor in accordance with equation C9. $E_{ck}$ is the casualty expectancy for a given populated area as shown in equation C9, where individual populated areas are designated with the subscript "k".

$$E_{ck} = P_i \cdot \left( \frac{A_x}{A_k} \right) N_k$$

(Equation C9)
An applicant shall estimate the total corridor risk using the following summation of risk:

\[ E_{C(\text{Corridor})} = \sum_{k=1}^{n} E_{C_k} \]  

(Equation C10)

An applicant may employ specified variations to the analysis defined by subparagraphs (c)(1)–(8). Those variations are identified in subparagraphs (9)(i) through (vi) of this paragraph. Subparagraphs (i) through (iv) permit an applicant to make conservative assumptions that would lead to an overestimation of the corridor \( E_{C} \) compared with the analysis described by subparagraphs (c)(1)–(8). In subparagraphs (v) and (vi), an applicant that would otherwise fail the analysis prescribed by subparagraphs (c)(1)–(8) may avoid (c)(1)–(8)’s overestimation of the probability of impact in each populated area. An applicant employing a variation shall identify the variation used, show and discuss the specific assumptions made to modify the analysis defined by subparagraphs (c)(1)–(8), and demonstrate how each assumption leads to overestimation of the corridor \( E_{C} \) compared with the analysis defined by subparagraphs (c)(1)–(8).

(i) Assume that \( P_i \) and \( P_j \) have a value of 1.0 for all populated areas.

(ii) Combine populated areas into one or more larger populated areas, and use a population density for the combined area or areas equal to the most densely populated area.

(iii) For any given populated area, assume \( P_i \) has a value of one.

(iv) For any given \( P_i \) sector (an area spanning the width of a flight corridor and bounded by two time points on the trajectory IIP ground trace) assume \( P_i \) has a value of one and use a population density for the sector equal to the most densely populated area.

(v) For a given populated area, divide the populated area into smaller rectangles, determine \( P_i \) for each individual rectangle, and sum the individual impact probabilities to determine \( P_i \) for the entire populated area.

(vi) For a given populated area, use the ratio of the populated area to the area of the \( P_i \) rectangle from the subparagraph (c)(1)–(8) analysis.

(d) Evaluation of Results

(1) If the estimated expected casualty does not exceed 30×10⁻⁶, the FAA will approve the launch site location.

(2) If the estimated expected casualty exceeds 30×10⁻⁶, then an applicant may either modify its proposal, or, if the flight corridor used was generated by the appendix A method, use the appendix B method to narrow the flight corridor and then perform another appendix C risk analysis.


APPENDIX D TO PART 420—IMPACT DISPERSION AREAS AND CASUALTY EXPECTANCY ESTIMATE FOR AN UNGUIDED SUBORBITAL LAUNCH VEHICLE

(a) Introduction

(1) This appendix provides a method for determining the acceptability of the location of a launch point from which an unguided suborbital launch vehicle would be launched. The appendix describes how to define an overflight exclusion zone and impact dispersion areas, and how to evaluate whether the public risk presented by the launch of an