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February 21, 2002

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Washington, DC 20555

Dr. Peter S. Lam
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Dr. Jerry Kline
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U.S. Nuclear Regulatory Commission
Washington, DC 20555

Re: In the Matter of Private Fuel Storage L.L.C. (Independent Spent Fuel Storage Installation) Docket No. 72-22-ISFSI

Dear Administrative Judges:

The State of Utah notifies the Board and parties of errata in the Prefiled Testimony of Dr. Marvin Resnikoff for Contention Utah K/Confederated Tribes B, filed February 19, 2002. Most of the changes relate to formatting errors in formulas where regular letters were used instead of Greek letters.

Enclosed are the corrected pages 6, 10, 12, 23, 24, and 26. Please replace your pages with the enclosed corrected pages. The specific corrections are as follows:

I. Page 6, A. 8: the formula for F should have a capital Greek sigma (Σ) not capital S, so that the formula reads: $F = \Sigma_{ijk}(N_{ijk}*P_{ijk}*f_{ijk}(x,y)*A_{ij})$;

II. Page 10, Q. 15: the word "averaging" should appear after 10-year, so that the question reads: **Q. 15: Do F-16 crash rates for 3-year, 5-year or 10-year averaging periods show a continuing decrease in the accident rate over the life of the F-16?**;

III. Page 12, A. 16: all capital Ss without subscripts should be Greek capital sigma, so that the formulas read:

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SECY-02

$$S_{xy} = \sum (xy) - [\sum x][\sum y]/n$$
$$S_{xx} = \sum x^2 - [\sum x]^2/n$$
$$S_{yy} = \sum y^2 - [\sum y]^2/n$$

IV. Page 23, A. 43: in the explanations at the top of the page, r_{air} should have a Greek rho (ρ) instead of the r, so the r_{air} reads ρ_{air};

V. Page 23, A. 43: in the middle of the page capital Ds in the formulas should be Greek capital deltas (Δ), so that the paragraph and formulas read:

> Because I am going to use a spreadsheet to estimate the path of a falling object, I estimate $dt = \Delta t$ such that:
>
> $$V_x(t + \Delta t) = V_x(t) - bV_xV\Delta t.$$
>
> Similarly for the y-component:
>
> $$V_y(t + \Delta t) = V_y(t) - g\Delta t - bV_yV\Delta t.$$

VI. Page 24, A. 45: the formula for T should not have parentheses, so that the formula reads:

$$T^{1.5} = 0.5MV^2 / 17{,}400K_s D^{1.5}$$

VII. Page 26, A.47: the last two complete paragraphs are affected where a certain m in formulas should be Greek lower case mu (μ), so that the affected sentences read:

> The expected CRUD surface density in a PWR-containing rail cask can be estimated at 140 μCi/m^2, and from this the total inventory in a HI-STORM cask holding 24 fuel assemblies is estimated to be 522.4 Ci. Id. For a cask holding 62 BWR fuel assemblies, the expected amount of CRUD inventory would be greater.
>
> Employing the computer code HOTSPOT (Homann, SG, "HOTSPOT Health Physics Codes for the PC," Lawrence Livermore National Laboratory, UCRL-MA-106315, March 1994), I calculated the downwind exposures due to a puff release from the HI-STORM cask. The program assumes a Gaussian distribution, 1 μm AMAD.

Copies of the enclosed documents are also being transmitted by electronic mail.

Sincerely,

Denise Chancellor
Assistant Attorney General

Enclosures: as stated
cc: PFS Service List

N = number of flights per year along the airway
A = effective area of plant in square miles

NUREG-0800 at 3.5.1.6-3. This is the commonly recognized method of calculating the probability of impact to nuclear facilities from aircraft.

Q. 8: Is the NUREG-0800 methodology consistent with DOE methodology?

A. 8: Yes. DOE Standard 3014 gives the following formula for an aircraft crash probability calculation:

$$F = \Sigma_{ijk}(N_{ijk} * P_{ijk} * f_{ijk}(x,y) * A_{ij})$$

Where:

F	=	estimated annual aircraft crash impact frequency for the facility of interest (no./y)
N_{ijk}	=	estimated annual number of site-specific aircraft operation takeoffs, landings, and in-flights) for each applicable summation parameter (no./y)
P_{ijk}	=	aircraft crash rate (per takeoff or landing for near-airport phases and per flight for the in-flight (nonairport) phase of operation for each applicable summation parameter
$f_{ijk}(x,y)$	=	aircraft crash location conditional probability (per square mile) given a crash evaluated at the facility location for each applicable summation parameter
A_{ij}	=	the site-specific effective area for the facility of interest that includes skid and fly-in effective areas (square miles) for each applicable summation parameter, aircraft category or subcategory, and flight phase for military aviation
i	=	(index for flight phases): i=1, 2, and 3 (takeoff, in-flight, and landing);
j	=	(index for aircraft category or subcategory): j=1, 2,..., 11;
k	=	(index for flight source): k=1, 2,..., K (there could be multiple runways, and nonairport operations)

So, for example, for an F-16 traversing Skull Valley under "normal" flight

A. 14: Yes. The NRC licensing proceeding regarding the Three Mile Island 2 ("TMI-2") reactor (Docket 50-320) is the most extensive investigation of aircraft crash probability. In a post hearing memorandum before an NRC Appeal Board, NRC Staff acknowledged that even though there appeared to be a trend in that air carrier service had "become significantly safer over the past 22 years":

> it is not reasonable to quantify such improvements in safety for purposes of either limiting the data base to establish the current accident rate or to develop a rate for future projections. Thus, it is reasonable to use data for the entire 22-year period in computing an accident rate.

State's Exhibit 73, *NRC Staff Posthearing Memorandum Regarding Aircraft Crash Probability Issue*, Docket No. 50-320 (dated April 30, 1980) at 10.

Q. 15: Do F-16 crash rates for 3-year, 5-year or 10-year averaging periods show a continuing decrease in the accident rate over the life of the F-16?

A. 15: No. If the Class A and B accident rates are combined, as is shown in the following table, then the 10-year averages show a decreasing rate, followed by a steadying, followed by an increase in the most recent years. The past five years show a steadily increasing trend. In fact, the 3-year average rate of FY98-00 is the highest since 1990, the 5-year average rate is the highest since 1994, and the 10-year average rate is the highest since 1997.

Table 1: Class A+B Mishap Rate per 100,000 Miles Flown.

Year Ending	3-Year Average	5-Year Average	10-Year Average
FY-91	4.30	5.15	5.62
FY-92	4.41	4.96	5.07
FY-93	4.55	4.36	4.91
FY-94	4.45	4.47	4.86
FY-95	4.01	4.23	4.67
FY-96	3.62	3.97	4.53
FY-97	3.21	3.78	4.38
FY-98	3.65	3.67	4.03
FY-99	4.38	3.87	4.19
FY-00	4.93	4.30	4.26

Correlation Coefficient, R_s, is given by the following formula:

$$R_s = (S_{xy}) / (S_{xx}S_{yy})^{0.5}$$

where,

$$S_{xy} = \sum (xy) - [\sum x][\sum y]/n$$
$$S_{xx} = \sum x^2 - [\sum x]^2/n$$
$$S_{yy} = \sum y^2 - [\sum y]^2/n$$

The rankings in Table 2 result in the following value for Rs:

Table 3: Spearman Rank Correlation Coefficient for F-16 Crash Rate, FY95-FY00

S_{xy}	S_{xx}	S_{yy}	R_S
15.5	17.5	17.5	0.886

For samples containing a small number of data points (<10) and n=6, an R_s value of 0.886 is significant at the 95% confidence level.[1] The results show a correlation between increasing crash rate and increasing year since 1995, with approximately a 95% level of significance.

In addition, I have performed a linear regression on the data points from FY1995-FY2000 in order to test the hypothesis that the crash rate is dependent on the Fiscal Year (which can be thought of as a surrogate for the age of the plane, etc.), and that the dependence shows a positive correlation. To do this, I used the Rank Correlation Coefficient, which uses the same formula as the Spearman Rank Correlation Coefficient, but uses the actual numbers of the data points instead of their rankings. This test differs from the Spearman Rank Correlation Coefficient in that it assumes a linear relationship between the two variables. Using this relationship, an R_s value of 0.895 was obtained, suggesting a strong positive linear correlation between F-16 crash rate and increasing year.

Q. 17: Have you done any analysis to determine if the F-16 annual crash rate is

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[1] Woodbury, George. 2002. *An Introduction to Statistics.* Canada: Duxbury/Thomson Learning, 2002.

Where:

b	=	air resistance (m^{-1})	=	$C_d \rho_{air} A/m$
m	=	mass of bomb		
ρ_{air}	=	density of air (kg/m^3)		
A	=	cross-sectional area of bomb (m^2)		
C_d	=	drag coefficient		

These equations can be simplified by dividing by the mass, and substituting:

$$a_x = dV_x/dt$$

$$a_y = dV_y/dt$$

Because I am going to use a spreadsheet to estimate the path of a falling object, I estimate $dt=\Delta t$ such that:

$$V_x(t + \Delta t) = V_x(t) - bV_xV\Delta t.$$

Similarly for the y-component:

$$V_y(t + \Delta t) = V_y(t) - g\Delta t - bV_yV\Delta t.$$

Using these equations, a spreadsheet was set up which computed V_x, V_y, X, and Y for discrete timesteps, given the specific initial conditions. I assume the projectile is released horizontally at a speed of 472 mph from a height of 1000-3000 ft above ground level. The spreadsheet calculations and projectile path are shown in State's Exh. 80.

Q. 44: Describe the parameters that you use for a jettisoned MK-84 that would strike the PFS facility.

A. 44: The calculations show that the MK-84 strikes the ground at a speed of 243 meters per second, assuming a drag coefficient of 0.1 and a release from 3,000 ft. above ground level at an angle of 15 degrees with the horizontal. Under these conditions, the MK-84 strikes the ground at an angle of 36° with the horizontal. For a drag coefficient of 0.5, the impact speed and angle are 219 meters per second and 40°, respectively. If the MK-84 were released from a greater height, its impact speed and angle with respect to the horizontal would be greater. If a pilot did not "zoom" before jettisoning ordnance, the speed and

impact angle would be 245 meters per second and 33° for $C_d = 0.1$, and 225m/s and 35° for $C_d=0.5$. There exist numerous release points, velocities and angles with the horizontal. In my calculation of the impact angle for jettisoned ordnance, I chose 35° with the horizontal because it represents a central value calculated for initial heights in the range of those typically flown in Skull Valley.

Q. 45: Describe how you determined whether a jettisoned 2,000 MK-84 bomb could breach the HI-STORM 100 cask?

A. 45: Using the following formulas[2], I calculated the penetration depth in concrete and steel:

Concrete

$$t_p = (U/V)^{0.25} (MV^2/Df_c)^{0.5}$$

where,

t_p = perforation thickness, just great enough to allow a missile to pass through without any exit velocity,
U = reference velocity (200 ft/sec),
V = missile impact velocity (ft/sec),
M = mass of the missile (in slugs, pounds divided by gravitational acceleration 32.2 ft/sec2),
D = missile diameter (ft)
f_c = ultimate compressive strength of concrete (4,000 –5,000 psi or 648,000-720,000 lb/ft^2)

Steel

$$T^{1.5} = 0.5MV^2 / 17{,}400K_s D^{1.5}$$

where,

[2] Davis, P. R., D. L. Strenge, and J. Mishima, 1998, *Final Accident Analysis for Continued Storage*, Revision 0, Jason Technologies Corporation, Las Vegas, Nevada. [244118].

Further, in the high-speed impact and subsequent toppling of the cask and taking into account depressurizing of the fuel rods, I assume all Chalk River Unidentified Deposits ("CRUD") and volatile fission products located in the gap between the pellet and cladding would be released to the cask cavity. However, because the cask metal is thermally hot, I do not assume plateout of cesium on the cask metal surface. Though tests with high energy explosives in the early 1980s by Sandia and Battelle Columbus showed that up to 1% of the uranium fuel fragments were lost, I have not assumed 1% of the fuel fragments, particularly Ru and Pu, are released. Release of these fuel fragments would greatly increase the immediate lung dose due to the passing radioactive cloud.

The percentage inventory of cesium in the gap ranges from 0.6% to 27%. This is based on my review of references concerning cesium build-up in the rod gap. A summary of my literature review is included as State's Exhibit 83. Next, I assume that 0.2% to 10% of cesium is in the rod gap, and assume that 100% of this is released from the cask into the external environment. This assumption is based on a paper published by Argonne National Laboratory ("CSNF Waste Form Degradation," ANL-EBS-MD-000015 Rev 00, 2000). Then, consistent with RISKIND (YC Yuan, *et al*, "RISKIND – A Computer Program for Calculating Radiological Consequences and Health Risks from Transportation of Spent Nuclear Fuel," ANL/EAD-1, 1995), I assume 100% of the CRUD (Co-60) is released.

The expected CRUD surface density in a PWR-containing rail cask can be estimated at 140 $\mu Ci/m^2$, and from this the total inventory in a HI-STORM cask holding 24 fuel assemblies is estimated to be 522.4 Ci. Id. For a cask holding 62 BWR fuel assemblies, the expected amount of CRUD inventory would be greater.

Employing the computer code HOTSPOT (Homann, SG, "HOTSPOT Health Physics Codes for the PC," Lawrence Livermore National Laboratory, UCRL-MA-106315, March 1994), I calculated the downwind exposures due to a puff release from the HI-STORM cask. The program assumes a Gaussian distribution, 1 μm AMAD. I further assume a deposition velocity of 1 cm/sec, a wind speed of 4 m/s and Pasquill Stability Category D meteorological conditions. These are the most likely meteorological conditions in Skull Valley. *See* PFS SAR Section 2.3. The program calculates radiation dose due to inhalation and submersion in a passing radioactive cloud. The program also calculates ground surface deposition of particulates. Tables and diagrams showing the radiation plume are included in State's Exhibit 84.

Thus, at a distance of 100 m from the impact location, the committed dose equivalents due to inhalation range from 70 rems to 3,300 rems due to the release of cesium