January 10, 2006

From: Dudley Raine (SAIC)

To: L3-Titan (Mr. Powell)
DTRA-TDND (Dr. Paul Blake, Major Kyle Reybitz)

Subject: Summary of Changes to the FIIDOS Software, 1985 - Present

The computer code, Fallout Inhalation and Ingestion Dose to Organs (FIIDOS)[1], is used by the Nuclear Test Personnel Review program to determine the dose to internal organs from exposure to fallout under various conditions common to participants in atmospheric nuclear testing. The original version of FIIDOS, created in 1985, was written in FORTRAN-IV for operation on a DEC PDP-11 mini-computer with problem input read from a keyboard and output directed to an off-line printer. The code required 32K of in-core memory and 100k of external, disk memory storage. A typical FIIDOS problem used 10 minutes of running time. Since 1985, with the substantial increases in the available computing power, FIIDOS has undergone a gradual evolution to a code that, though it still functions in much the same way, has substantially greater capabilities. This memorandum outlines those changes and assesses the impact of the changes to internal doses calculated for Nuclear Test Personnel Review program participants.

FIIDOS2

Significant Code Changes

SAIC's first revision to FIIDOS in 1995 included the following three significant changes: 1) ORIGEN2 - Oak Ridge Isotope Generation and Depletion Code, Version 2[2], was integrated into FIIDOS with initial fission product inventories from ENDF-B/VI (fast and 14-MeV fission), 2) new dose coefficients from Federal Guidance Report 11 (FGR-11)[3] were added to the existing tables of dose coefficients from ORNL TM-190[4] and ICRP-30[5], and 3) a plutonium bioassay prediction capability was included. In addition, an integrated exposure option was added to the original version's three discrete exposure options to assess internal doses in situations where the period of intake is long enough that significant changes occur in the radionuclide inventory; e.g., for an extended period on a residence island after an operation. The code was rewritten in Fortran 77 and compiled for various computing platforms, including UNIX, Macintosh, and MS-DOS compatible systems. Runtimes on the various platforms ranged from 20 seconds up to 9 minutes, depending on the speed of the system and the compiler options specified. This revised code was named FIIDOS2, and a report documenting the changes was drafted, but never completed.

Data Changes

The original FIIDOS used data tables containing time-dependent radionuclide and gamma spectral information for various fission radionuclides produced in a fast reactor that were generated by the original version of ORIGEN. FIIDOS interpolated between the standard times in the data tables to calculate the inventory and spectra at the times of interest. FIIDOS2 incorporated ORIGEN2, the latest available version of that code, as a

callable subroutine, with modifications to support the NTPR program needs. Thus, many of those data tables were no longer necessary because all of the required information was passed directly from ORIGEN2 into FIIDOS via common block variables, which eliminated the interpolation steps. The modifications to ORIGEN2 updated the radionuclide and gamma spectral data to use the latest fission product inventories available in ENDF-B/VI for U^{235}, U^{238}, and Pu^{239}, with a few corrections added to the inventory by Los Alamos and a few to the gamma production rates by SAIC. Including ORIGEN2 in FIIDOS2 produced minor differences (generally less than 1-2 percent at exposures more than an hour after detonation) in the resulting organ doses.

Dose Coefficients

The new dose coefficients added into FIIDOS2 were taken from FGR-11, which utilized the ICRP-30 methods and models and expanded the inventory of dose coefficients to 412 radionuclides. Additional large particle internal dose coefficients for a 10-micrometer activity median aerodynamic diameter (AMAD) particle distribution were created using the computer code, DFINT[6]. Inhalation dose coefficients were selected for each nuclide according to the respiratory clearance class associated with the oxide form of each element. It is not clear that the addition of this data set had any impact on the internal organ doses reported by the NTPR program since it was found that the organ doses resulting from using the original ORNL TM-190 dose coefficients tended to be greater than those from FGR-11, and thus the more veteran friendly data set continued to be the default choice, as directed by the Government.

Plutonium Bioassay

A plutonium bioassay capability was added that uses the available radionuclide inventory data in FIIDOS to determine the total intake of Pu^{239} based on the inhaled or ingested total number of curies as calculated during the internal dose calculations. The Pu^{239} excretion rate is represented by a five-term exponential function[7], which is used to predict the Pu^{239} activity excreted in urine during any 24-hour period at specific times after uptake. While this modification had no effect on the resulting organ doses calculated by FIIDOS, it provided a tool to assess radiological uptake if a participant had a bioassay result greater than the population average during the period of the NTPR-sponsored Pu^{239} bioassay program (1998-1999).

FIIDOS3

The next revision of FIIDOS, created from the FIIDOS2 version of the source code in 1999, changed the program flow so that multiple discrete or integrated exposures with multiple measurements (all from the same detonation) could be handled in a single run. Previously, each measurement could have multiple exposure times associated with it, but only one measurement time could be used in a given run. This change enabled the user to include up to 50 measurement/discrete exposure pairings (or a combination of measurements and exposures adding up to 100) or up to 33 measurement/integrated exposure pairings. Also, the plutonium bioassay capability was expanded to be more flexible and allow the user to specify the number of excretion times to be evaluated and the specific times after detonation at which those excretions would be calculated. Because of the substantial increase in computer power available by that time, even longer

runs with a full input deck of 100 (measurement plus exposure) times usually took less than 1 minute on a PC. No other technical changes were made and the code output was verified to be consistent with the output from FIIDOS2. Internally, this version of FIIDOS was referred to as FIIDOS3, but no report or other documentation was assembled for it.

FIIDOS4

Two modifications have been made to FIIDOS since 1999. In 2001, internal dose coefficients for inhalation and ingestion from FGR-13[8] were added to the code. The dose coefficients presented in FGR-13 use the latest methods and models from the ICRP, including the ICRP-66 lung model. Only one set of inhalation dose coefficients for a particle size distribution of 1 micrometer AMAD was incorporated into FIIDOS along with a new set of ingestion dose coefficients. Because these dose coefficients did not result in appreciable increases or decreases in the total reported organ doses for most participants relative to those calculated using the existing ICRP-30 or FGR-11 tables, the FGR-13 tables were only used in situations involving a specific internal organ that was not contained in the other dose coefficient tables. The second change, which is in preliminary development, allows the reporting of alpha doses separately from beta and gamma doses to satisfy the Department of Veterans Affairs requirement for calculating the probability of causation using the Interactive RadioEpidemiological Program. This modification assumes that the alpha-particle dose to an organ equals the total organ dose for the few alpha particle emitting radionuclides in the FIIDOS inventory.

The changes noted above outline the major differences between the original version of FIIDOS and the current version. Since FIIDOS2, no changes have been made that affect the way the doses are calculated; the only changes involve the dose coefficients, program flow, options, and output presentation. Other than completing the change to report alpha doses separately, SAIC does not envision any additional modifications for FIIDOS.

References

1. "FIIDOS - A Computer Code for the Computation of Fallout Inhalation and Ingestion Dose to Organs, Computer User's Guide," DNA-TR-84-375, Defense Nuclear Agency, December 12, 1985.
2. "ORIGEN2 - A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code," ORNL-5621, Oak Ridge National Laboratory, Oak Ridge, Tennessee, May 1980.
3. "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," Federal Guidance Report 11, EPA Report 520/1-88-020, Environmental Protection Agency, Washington, D.C., 1988.
4. "Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities,"

ORNL/NUREG/TM-190, Oak Ridge National Laboratory, Oak Ridge, TN, October 1981.

5. “Limits for Intakes by Workers, A Report of Committee 2 of the International Commission on Radiological Protection” ICRP Publication 30, Annals of the ICRP, Volume 2, No. 3/4, 1979.
6. Eckerman, K. F., “DFINT Version 4.0 - A Code to Preview the Dosimetric Data of ICRP Publication 30, Parts 1-4,” Oak Ridge, TN, June 19, 1993.
7. Jones, S. R., “Derivation and Validation of a Urinary Excretion Function for Plutonium Applicable Over Tens of Years Post Uptake, Radiation Protection Dosimetry,” Vol. 11 No. 1 pp 19-27, Nuclear Technology Publishing, 1985.
8. “Cancer Risk Coefficients for Environmental Exposure to Radionuclides,” Federal Guidance Report 13, EPA Report 402-R-99-001, Environmental Protection Agency, Washington, D.C., September 1999.