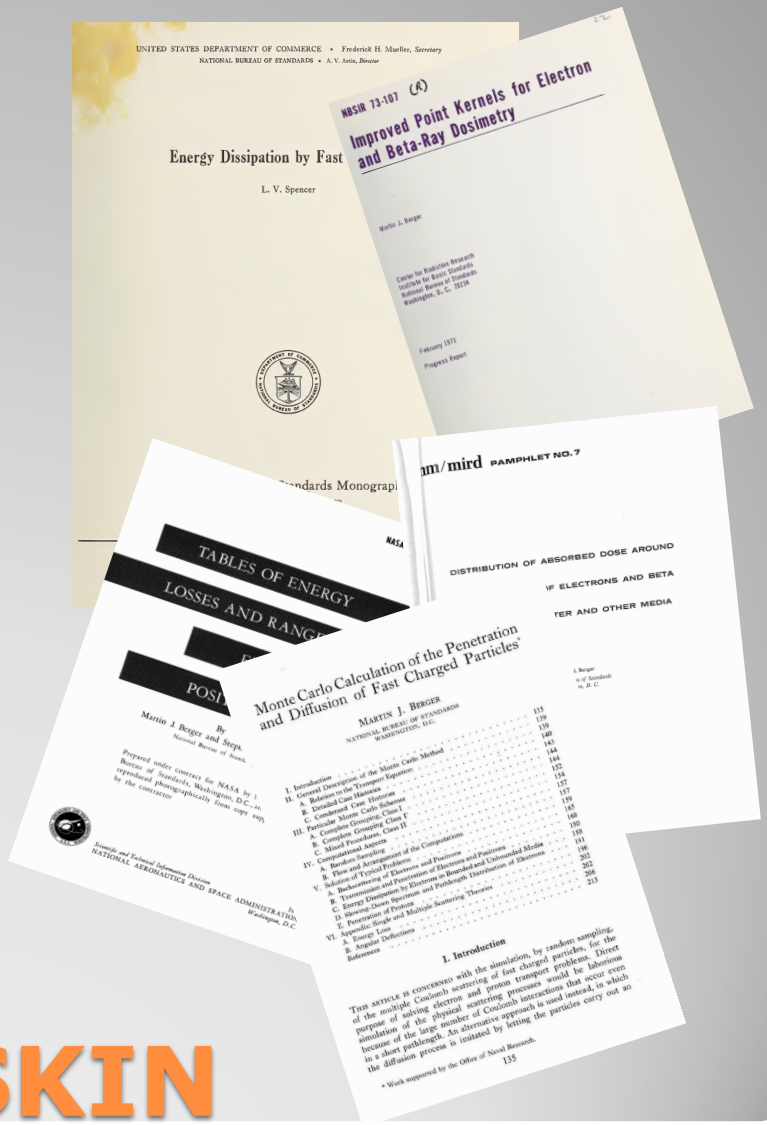
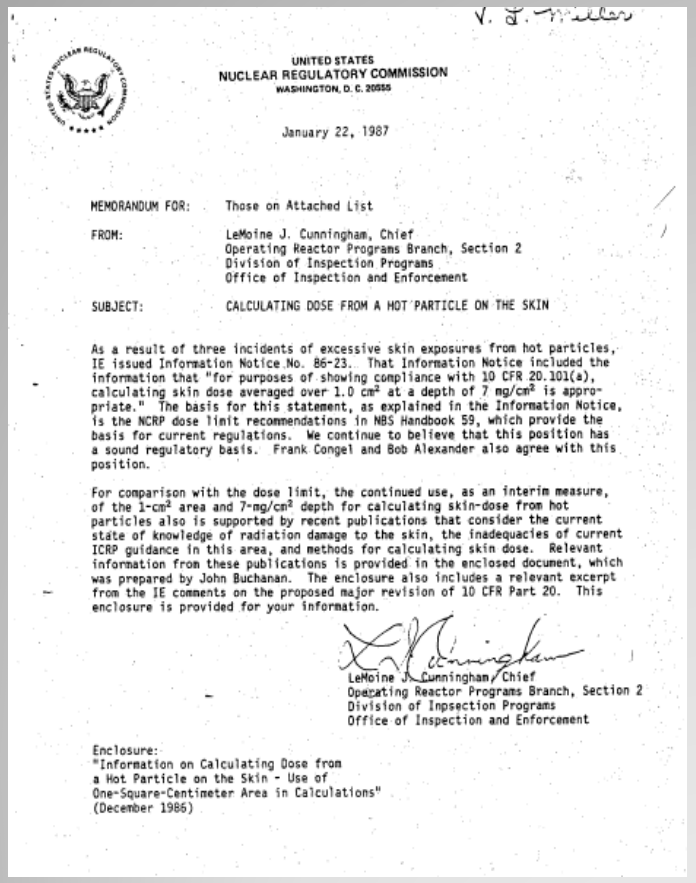
30 Years of VARSKIN:

Evolution and Improvements

- 1955 – Spencer
  - Theory of Electron Penetration
- 1959 – Spencer
  - Energy Dissipation by Fast Electrons
- 1963 – Berger
  - MC Calculation of the Penetration and Diffusion of Fast Charged Particles
- 1964 – Berger and Seltzer
  - Tables of Energy Losses and Ranges of Electrons and Positrons
- 1971 – Berger
  - MIRD Pamphlet No. 7
- 1973 – Berger
  - Improved Point Kernels for Electron and Beta-Ray Dosimetry



30 Years of VARSKIN



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

January 22, 1987

MEMORANDUM FOR: Those on Attached List

FROM: LeMoine J. Cunningham, Chief
Operating Reactor Programs Branch, Section 2
Division of Inspection Programs
Office of Inspection and Enforcement

SUBJECT: CALCULATING DOSE FROM A HOT PARTICLE ON THE SKIN

As a result of three incidents of excessive skin exposures from hot particles, IE issued Information Notice No. 86-23. That Information Notice included the information that "for purposes of showing compliance with 10 CFR 20.101(a), calculating skin dose averaged over 1.0 cm^2 at a depth of 7 mg/cm^2 is appropriate." The basis for this statement, as explained in the Information Notice, is the NCRP dose limit recommendations in NBS Handbook 59, which provide the basis for current regulations. We continue to believe that this position has a sound regulatory basis. Frank Congel and Bob Alexander also agree with this position.

For comparison with the dose limit, the continued use, as an interim measure, of the 1-cm^2 area and 7-mg/cm^2 depth for calculating skin-dose from hot particles also is supported by recent publications that consider the current state of knowledge of radiation damage to the skin, the inadequacies of current ICRP guidance in this area, and methods for calculating skin dose. Relevant information from these publications is provided in the enclosed document, which was prepared by John Buchanan. The enclosure also includes a relevant excerpt from the IE comments on the proposed major revision of 10 CFR Part 20. This enclosure is provided for your information.

LeMoine J. Cunningham, Chief
Operating Reactor Programs Branch, Section 2
Division of Inspection Programs
Office of Inspection and Enforcement

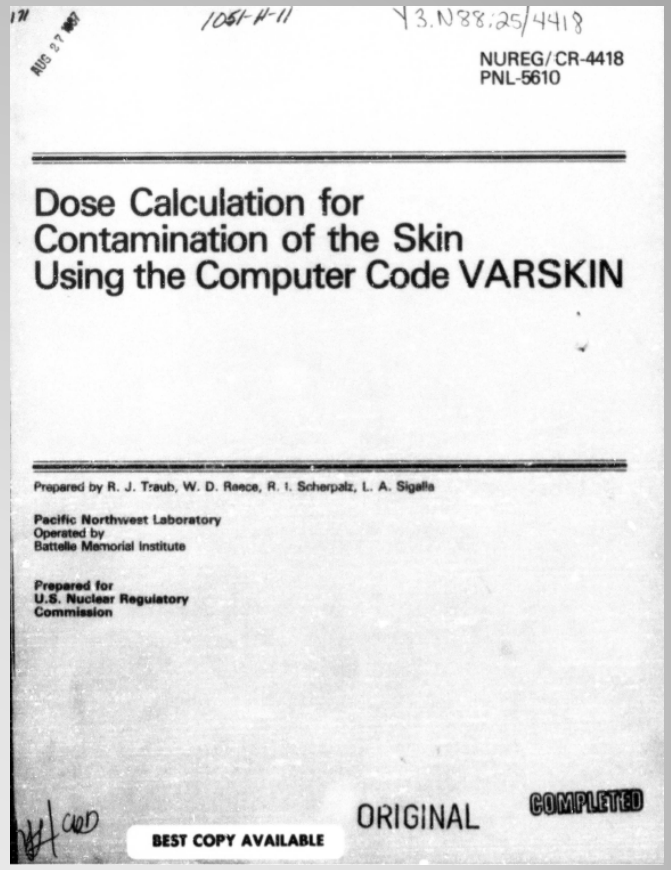
Enclosure:
"Information on Calculating Dose from
a Hot Particle on the Skin - Use of
One-Square-Centimeter Area in Calculations"
(December 1986)

- 1981 – 10 CFR 20.101(a)
  - whole body skin dose <7.5 rem/qtr
- 1983 – NRC Notice 83-59
  - skin of the "hands, forearms, feet and ankles" can receive 18.75 rem/qtr
- 1986 – NRC Notice 86-23
  - "… for purposes of showing compliance with 10 CFR 20.101(a), calculating skin dose averaged over 1.0 cm^2 at a depth of 7 mg/cm^2 is appropriate."
- 1987 – NRC Branch Chief
  - "The continued use of a 1-cm^2 area for calculating skin dose from a hot particle is supported by recent scientific publications."

30 Years of VARSKIN

AUGUST 1987

- VARSKIN (NUREG/CR-4418)
- R.J. Traub; W.D. Reece; R.I. Scherpalz; and L.A. Sigalla
- PNNL, Richland, WA
- "NRC requested PNNL to devise a method to compute the radiation dose to the skin from radioactive material on the skin."
- At the time, even though the Federal Regulations limited skin dose, "There [were] no regulatory guides … to ensure that radiation doses to the skin [were] properly computed."



30 Years of VARSKIN

30 Years of VARSKIN

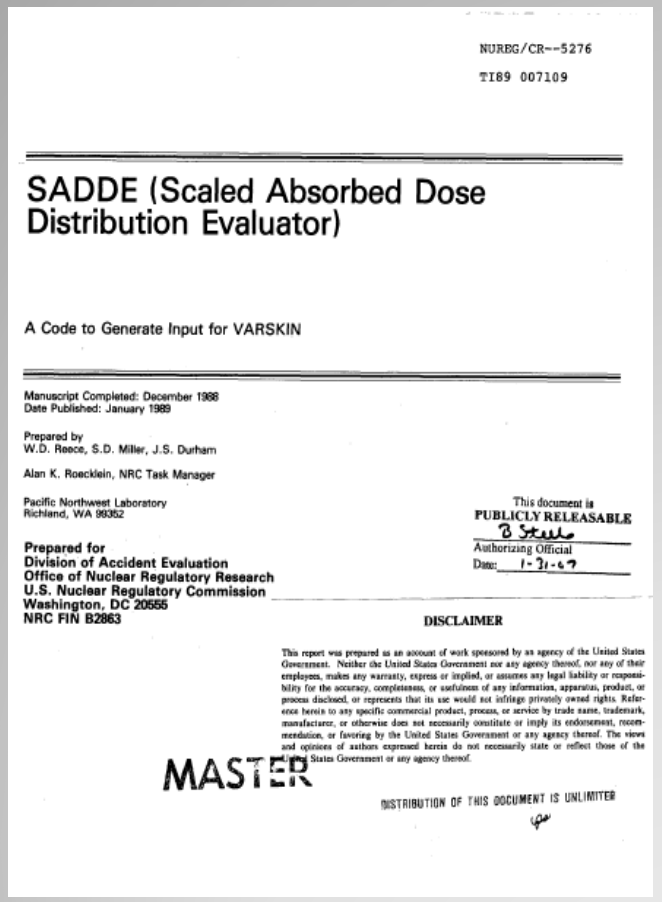
VARSKIN [1]

- Calculates beta radiation dose rate to skin from contamination directly on the skin
- Based on absorbed-dose distributions published in MIRD Pamphlet No. 7 (Burger 1971)
- Limited to the 75 nuclides included in the pamphlet
- Source sizes from a point to a 100 cm^2 disc
- "Source is treated as homogeneous", and there is no mention of backscatter correction (thus, assumed water/water interface)
- A given run could handle a 'single nuclide', but dose could be calculated for a mixture of up to 5 radionuclides
- No gamma-ray dose computed

30 Years of VARSKIN

QUINCE

- M. Williams (Union Electric Co., St. Louis) developed a method to interpolate between nuclides with similar energy spectra
  - Williams, M.C. A method for adding nuclides to VARSKIN and QUINCE skin dose calculation software. *Radiation Protection Management.* 4(6):25-34; 1987
- At some point in the mid- to late-80's, he developed QUINCE, "an enhanced version of the VARSKIN code"
  - with a revised dose-integration method and the ability to handle five separate nuclides in one run



NUREG/CR--5276

TI89 007109

SADDE (Scaled Absorbed Dose Distribution Evaluator)

A Code to Generate Input for VARSKIN

Manuscript Completed: December 1988
Date Published: January 1989

Prepared by
W.D. Reece, S.D. Miller, J.S. Durham

Alan K. Roecklein, NRC Task Manager

Pacific Northwest Laboratory
Richland, WA 99352

This document is
PUBLICLY RELEASABLE
B Stein
Authorizing Official
Date: 1-31-97

Prepared for
Division of Accident Evaluation
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN B2863

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MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

- SADDE (NUREG/CR-5276)
- W.D. Reece; S.D. Miller; and J.S. Durham
- Pacific Northwest National Lab Richland, WA
- January 1989

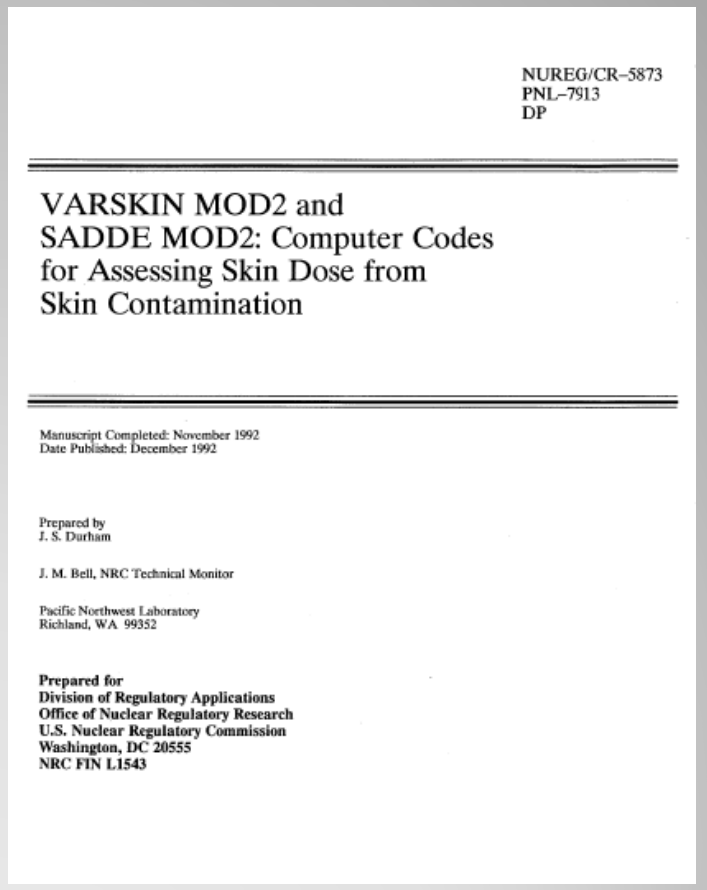
- To calculate the Scaled Absorbed Dose Distribution (SADD) for radionuclides other than those listed in MIRD 7

30 Years of VARSKIN

30 Years of VARSKIN

- VARSKIN MOD2 and SADDE MOD2 (NUREG/CR-5873)
- J.S. Durham
- Pacific Northwest National Lab Richland, WA
- December 1992

- SADDE MOD2 allows the generation of scaled absorbed dose distributions "for mixtures of radionuclides and internal conversion and Auger electrons"



NUREG/CR–5873
PNL–7913
DP

VARSKIN MOD2 and
SADDE MOD2: Computer Codes
for Assessing Skin Dose from
Skin Contamination

Manuscript Completed: November 1992
Date Published: December 1992

Prepared by
J. S. Durham

J. M. Bell, NRC Technical Monitor

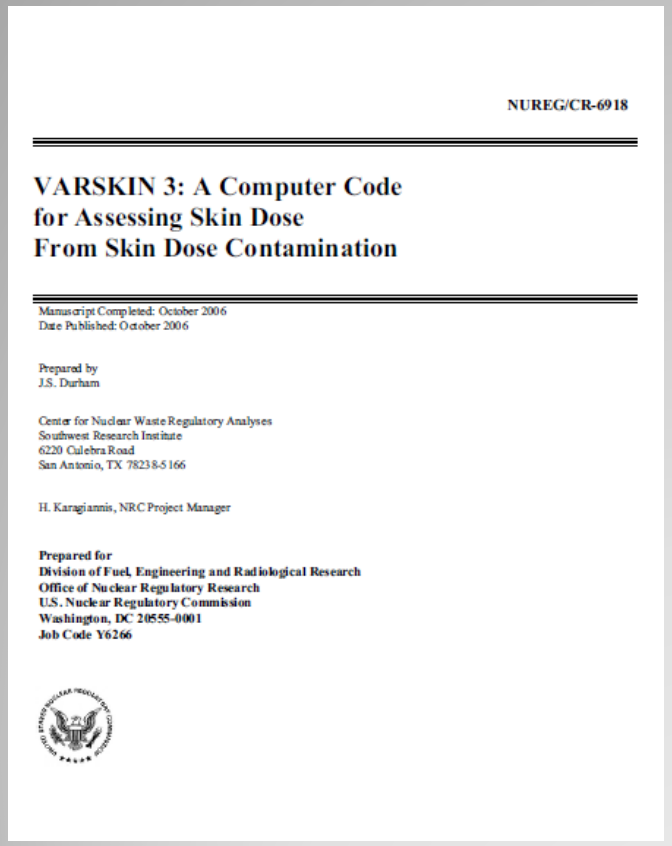
Pacific Northwest Laboratory
Richland, WA 99352

Prepared for
Division of Regulatory Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN L1543

30 Years of VARSKIN

VARSKIN MOD2

- MOD2 introduces 3D source geometries (thick disk, sphere, slab) to account for self-shielding and absorbing media (including air gap)
- Volume-averaged dose at depth can now be estimated
- Backscatter correction for point and disk sources to 1 cm^2
- Offset particle model made available
- "Hot particle gamma dose" from certain radionuclides added
- Only a few select gamma-emitters are included
- Users cautioned not to use MOD2 to calculate positron dose
- The code runs on DOS systems and must be "installed"



NUREG/CR-6918

VARSKIN 3: A Computer Code for Assessing Skin Dose From Skin Dose Contamination

Manuscript Completed: October 2006
Date Published: October 2006

Prepared by
J.S. Durham

Center for Nuclear Waste Regulatory Analyses
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78238-5166

H. Karagiannis, NRC Project Manager

Prepared for
Division of Fuel, Engineering and Radiological Research
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
Job Code Y6266

- VARSKIN 3 (NUREG/CR-6918)
- J.S. Durham
- Southwest Research Institute
  San Antonio, TX
- October 2006

- June 4, 2002
  - NRC Regulatory Issue Summary 2002-10 changes the skin dose averaging area from 1 cm^2 to 10 cm^2

- 10 CFR 20.1201(c) changes area of skin dose calculation to 10 cm^2

30 Years of VARSKIN

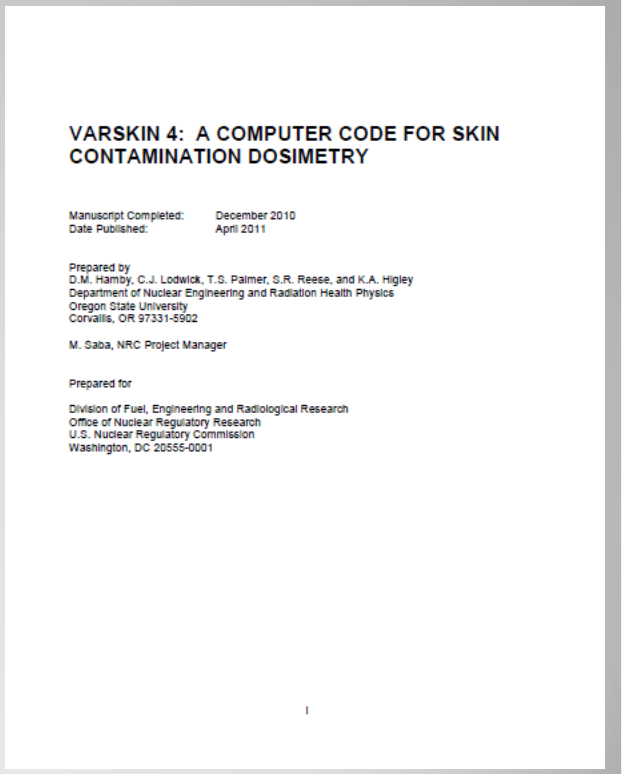
30 Years of VARSKIN

VARSKIN 3

- Now in Windows platform (installation still necessary)
- Single screen data entry with a variety of unit options
- Still using Berger (1971) point kernels
- Distributed source option now available
- ICRP 38 nuclear data w/o progeny (up to 20 per run)
- Addition of a syringe geometry model and help files
- Database files and structure changed a bit
- "Dummy" spectrum for nuclides not transitioning through beta decay
- Limited electron backscatter model developed
- Photon dosimetry upgraded
- V3.1 released in 2009 to fix a bug with the gamma database

- NUREG/CR-6918, Rev 1
- D.M. Hamby et al.
- Oregon State University
  Corvallis, OR
- April 2011

varskin 4.0



VARSKIN 4: A COMPUTER CODE FOR SKIN CONTAMINATION DOSIMETRY

Manuscript Completed: December 2010
Date Published: April 2011

Prepared by
D.M. Hamby, C.J. Lodwick, T.S. Palmer, S.R. Reese, and K.A. Higley
Department of Nuclear Engineering and Radiation Health Physics
Oregon State University
Corvallis, OR 97331-5902

M. Saba, NRC Project Manager

Prepared for

Division of Fuel, Engineering and Radiological Research
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

- The NRC charged us with: "Enhance the photon dosimetry model"
  - "… but DO NOT TOUCH the beta model!"

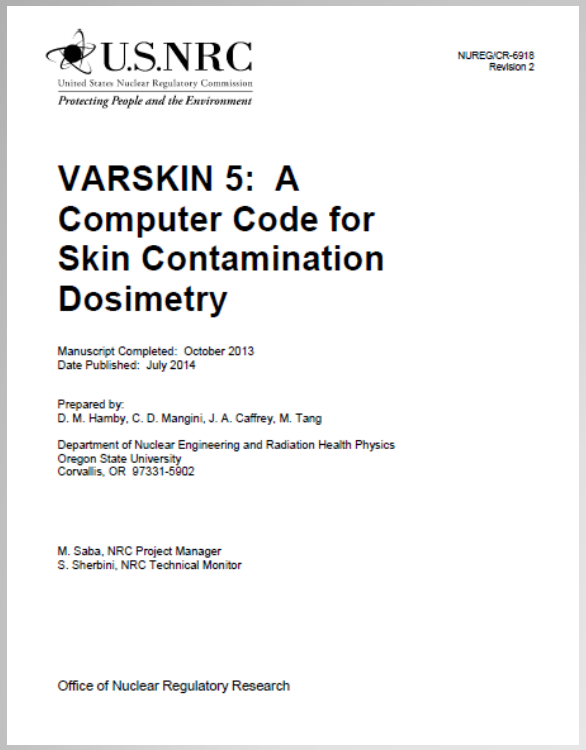
30 Years of VARSKIN

30 Years of VARSKIN

VARSKIN 4

- Rigorous treatment of photon dosimetry
- Five geometries included for photon dosimetry
- Syringe model ‘eliminated’
- Photon model now uses a point kernel method and accounts for attenuation, charged particle buildup, transient equilibrium, and electron scatter correction near the surface
- Geometric and material attenuation considered
- Charged particle equilibrium (CPE) fractions determine
- An off-axis scatter factor was employed
- Convergence studies conclude best integration method
- No longer is it necessary to “install” the code

varskin V5



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG/CR-6918
Revision 2

VARSKIN 5: A Computer Code for Skin Contamination Dosimetry

Manuscript Completed: October 2013
Date Published: July 2014

Prepared by:
D. M. Hamby, C. D. Mangini, J. A. Caffrey, M. Tang

Department of Nuclear Engineering and Radiation Health Physics
Oregon State University
Corvallis, OR 97331-5902

M. Saba, NRC Project Manager
S. Sherbini, NRC Technical Monitor

Office of Nuclear Regulatory Research

- NUREG/CR-6918, Rev 2
- D.M. Hamby; C.D. Mangini; J.A. Caffrey; and M. Tang
- Oregon State University
  Corvallis, OR
- July 2014

- NRC: "Now, you can work on the beta dosimetry model."

30 Years of VARSKIN

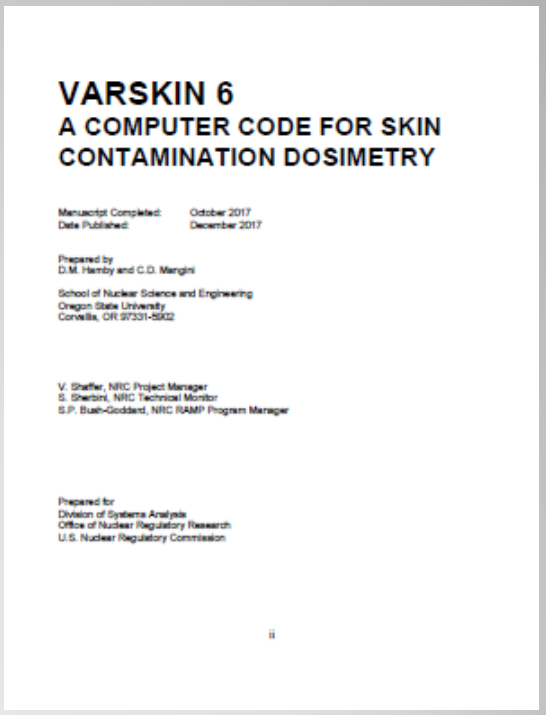
VARSKIN 5

- Enhancements to electron dosimetry
- Berger's point kernel method fundamentally unchanged
- Created new SADD values based on MC simulations for wide ranging source materials and electron energies
- Introduced two SADD scaling models (depth and energy)
- An effective-Z for source material is now required when adding a nuclide to the user library
- Comprehensive MC backscatter model
- Backscatter factors applied to each dose kernel

30 Years of VARSKIN

VARSKIN 6

- NUREG/CR-6918, Rev 3
- D.M. Hamby and C.D. Mangini
- Oregon State University
  Corvallis, OR
- December 2017



VARSKIN 6
A COMPUTER CODE FOR SKIN CONTAMINATION DOSIMETRY

Manuscript Completed: October 2017
Date Published: December 2017

Prepared by
D.M. Hamby and C.D. Mangini

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Prepared for
Division of Systems Analysis
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

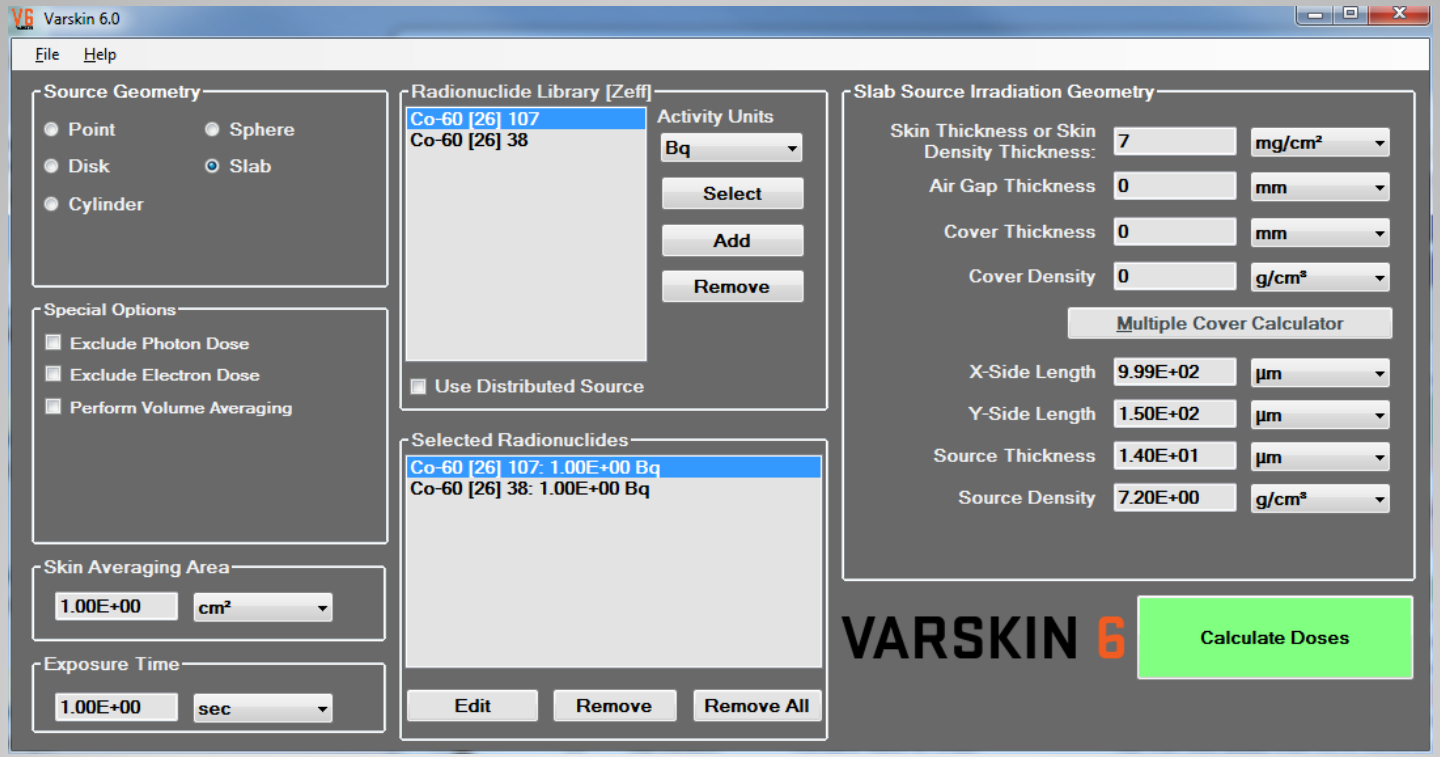
ii

- Selection of decay database
  - ICRP 38 or ICRP 107
- Option to include decay-progeny
- Minor bug fixes

- … enhancements for VARSKIN VII
  - discussion tomorrow afternoon

30 Years of VARSKIN

- As a simple example, hot particle on skin surface:
  - Co-60 in iron, slab geometry (999 x 150 x 14 μm thick)
  - measured density of 7.2 g/cm^3
  - shallow dose (7 mg/cm^2) averaged over 1 cm^2



30 Years of VARSKIN

	Electron Dose	Photon Dose	Total Dose (pGy/nt)
VARSKIN [1]	238*	-	-
VARSKIN MOD2	-	-	230#
VARSKIN 3	154	27.2	181
VARSKIN 3.1	154	14.9	169
VARSKIN 4	154	6.48	160
VARSKIN 5	188	6.48	194
VARSKIN 5.1	188	6.48	194
VARSKIN 5.2	199	5.25	204
VARSKIN 5.3	199	5.25	204
VARSKIN 6 (38)	199	5.25	204
VARSKIN 6 (107)	199	5.25	204

*dose estimated from V6 ratio with NUREG/CR-4418 Table 3.1 (beta only; water/water interface)
#dose estimated from V6 ratio with NUREG/CR-5873 Table 4 (beta and gamma; air/water interface)

30 Years of VARSKIN