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Development of Computational Code for Internal Dosimetry

by

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"Learning from Plutonium and Uranium Workers"

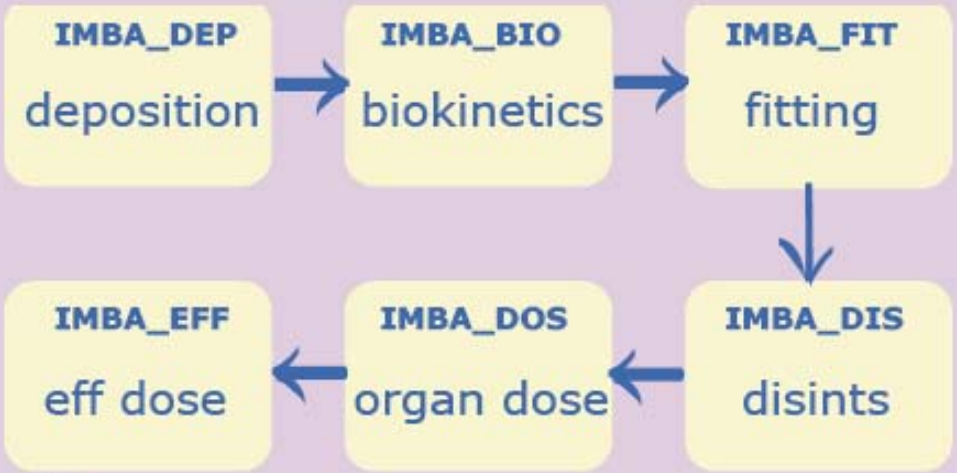
What Is the UK NRPB/HPA's "IMBA"?

- The acronym "IMBA" stands for Integrated Modules for Bioassay Analysis.

- During 1997-1999, the UK National Radiological Protection Board (NRPB), in collaboration with British Nuclear Fuels plc (BNFL) and Westlakes Research Institute developed IMBA:
  - a suite of software modules that implement the ICRP Publication 60 (1991) recommendations and ICRP Publication 68 (1994) models for estimation of intakes and doses.

- The resulting product, NRPB's "IMBA modules," went through extensively documented quality assurance, and:
  - By 2000 were adopted for routine formal dose assessment by Approved Dosimetry Services (ADS) throughout the UK – to convert the ADS' own software codes from implementing ICRP26/30 to implementing the 2000 UK Regulations (under the 1996 Euratom Directive).

How Do the IMBA Modules Function?



Program Modules	Function
IMBA_DEP	calculates fractional deposition in each region of the repiratory tract
IMBA_BIO	predicts values of bioassay quantity per unit intake (lung or whole body retention, daily urinary or faecal excretion)
IMBA_FIT	estimates intake by comparing measured activity and predicted retention or excretion
IMBA_DIS	calculates disintegrations in each organ per unit intake
IMBA_DOS	calculates organ doses using the estimated intake
IMBA_EFF	calculates weighted organ doses using tissue weighting factors from ICRP Publication 60 as updated in ICRP Publication 68

Six independent modules – integrated via standard ASCII INPUT/OUTPUT data sets – can be run in any order to perform ALL required dose calculations:

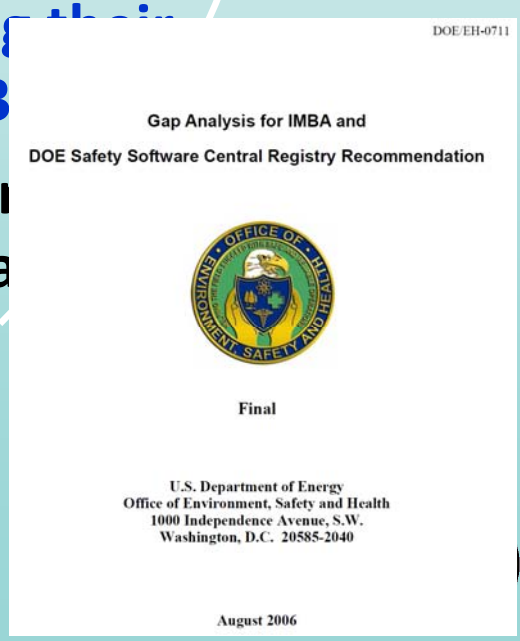
Prospective – dose per unit intake
Retrospective – dose from bioassay measurements

Advantages of Modular Design

- Symbiotic relationship with quality assurance – the same (generic) modules act for ALL elements (and individual radionuclides).
- Readily enables each component of complex dose calculation to be validated.
- Applies previously quality assured code, e.g., the Lung Dose Evaluation Program (LUDEP) – the code used to generate the reference regional deposition values for the HRTM (ICRP 66).
- The original IMBA modules were developed independently by separate teams (using different mathematical and coding approaches) – results were rigorously compared with NRPB's PLEIADES code (one of the codes used to generate ICRP reference dose coefficients).
- The same modules can be run in different orders – for different types of calculation (prospective or retrospective).
- The modules can readily be controlled by external code, e.g., by treating them as subroutines in existing (or specially developed) software.

Extension of the IMBA Modules to Accommodate Different Dosimetry Rules and Regulatory Practices: The IMBA Expert™ Concept

- In 2000, USDOE's Office of Worker Protection Policy and Programs (EH-32) recognized the benefits of the "IMBA modular" approach:
  - To develop an intuitive (i.e., user friendly) MS Windows®-based interface that can be customized for any dose assessment application or methodology.
  - To give USDOE nuclear facilities (sites) the capability of applying "uniformly" the currently recommended (ICRP 68) biokinetic models and the ICRP 66 HRTM – whilst preserving their compliance with US federal regulations (10CFR83
  - To provide simultaneous statistical analyses (fitti bioassay data and different types of bioassay qua


DOE/EH-0711

Gap Analysis for IMBA and

DOE Safety Software Central Registry Recommendation

Final

U.S. Department of Energy
Office of Environment, Safety and Health
1000 Independence Avenue, S.W.
Washington, D.C. 20585-2040

August 2006

Parallel Developments to *IMBA Expert™ USDOE-Edition*

- ***IMBA Expert™ NIOSH-Edition*** – **custom-developed for CDC/NIOSH/OCAS as a 'bread-board' calculator for them to carry out preliminary assessments in support of the 2000 Energy Employees Occupational Injury Compensation Program Act (EEOICPA). Delivered in 2002.**

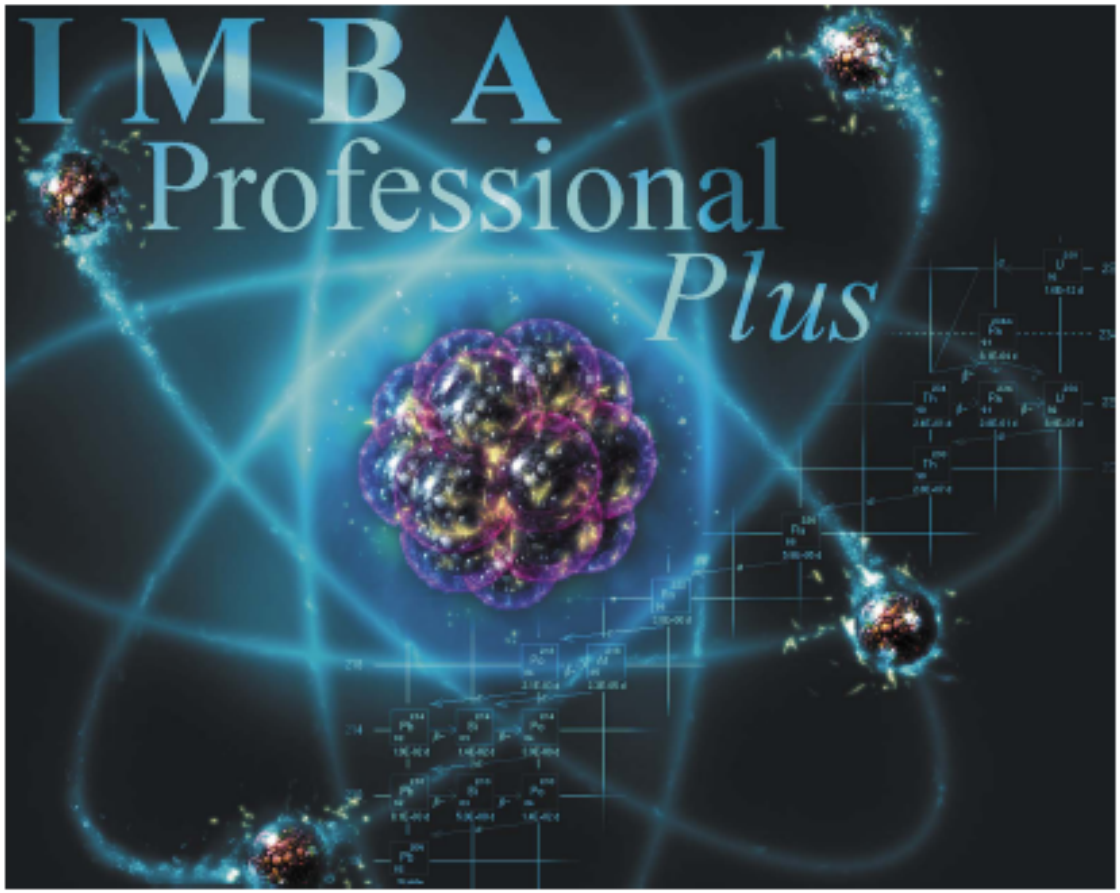
- ***IMBA Expert™ CANDU-Edition*** – **custom-developed for the (Canadian) CANDU Owners Group, Toronto, Ontario. Delivered in 2004.**

- ***IMBA Expert™ UK-Edition*** – **custom-developed for UK ADs. Delivered in 2004.**

- ***IMBA Expert™ OCAS/ORAU-Edition*** – **custom-developed for Oak Ridge Associated Universities (ORAU) to enable HP dose-assessors to perform standardized calculations of annual tissue doses required for substitution in the *Interactive RadioEpidemiology Program* (*IREP*) – for calculation of cancer causation probability. Delivered in several phases (through 2005).**

"Internationalizing" the IMBA Concept: The UK HPA-RPD's *IMBA Professional Plus (IPP)*

IMPA Professional Plus is the successor of the IMBA Professional and IMBA Expert™ series. It is more flexible, more powerful and 6 - 10 times faster. The central concept behind the software is that the nucleus of the program (called the Base Unit) can be installed and run as a separate entity, enabling basic internal dosimetry calculations to be performed. More powerful capabilities (called Add-ons) can be added to the Base Unit as required. Each Add-On can be installed independently, and increases the functionality of the software. The users can thus build up the software to meet their precise requirements.



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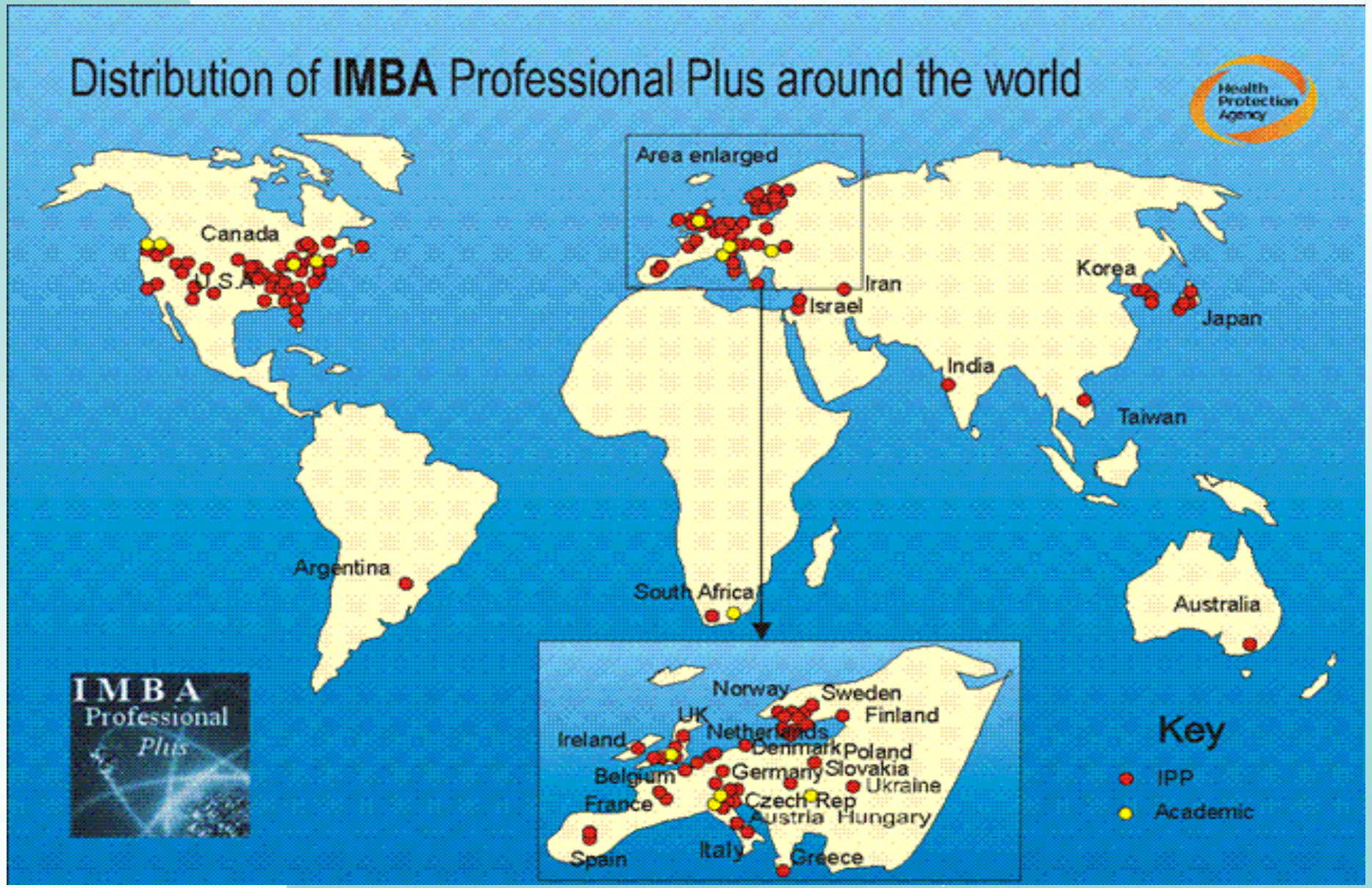
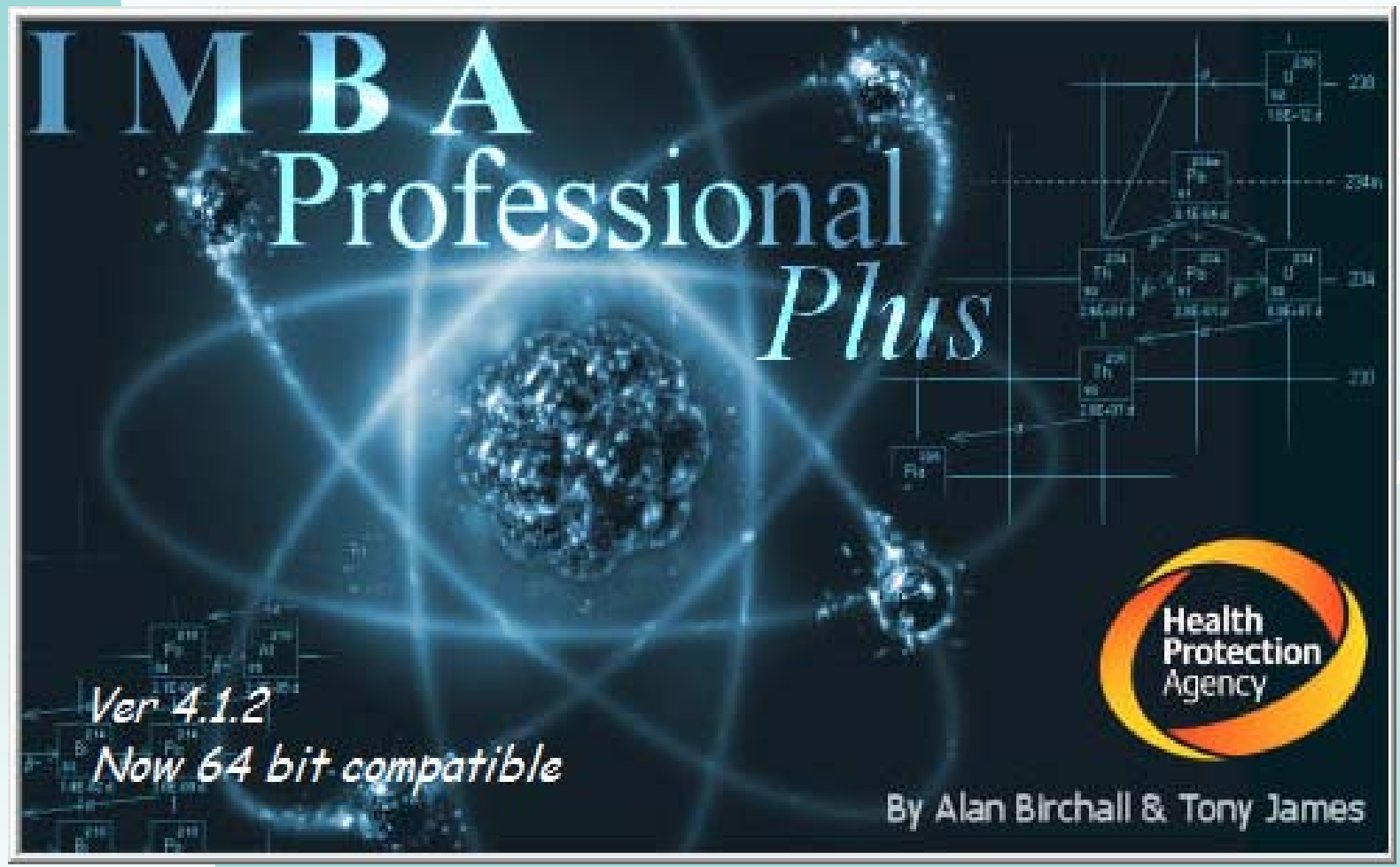
IPP Has Been Adopted Very Widely!

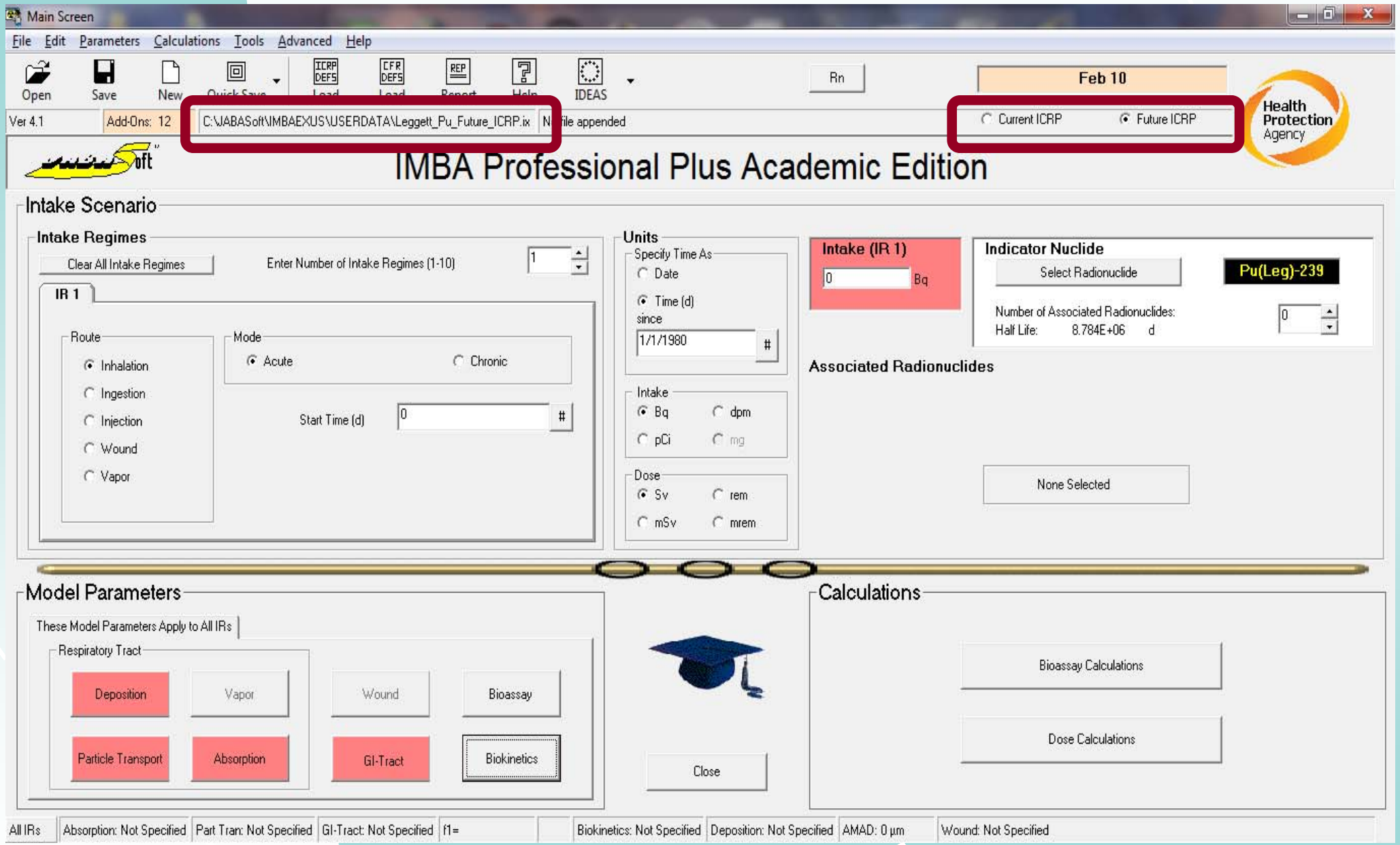


The Future of "IMBA" – Ongoing Research & Development

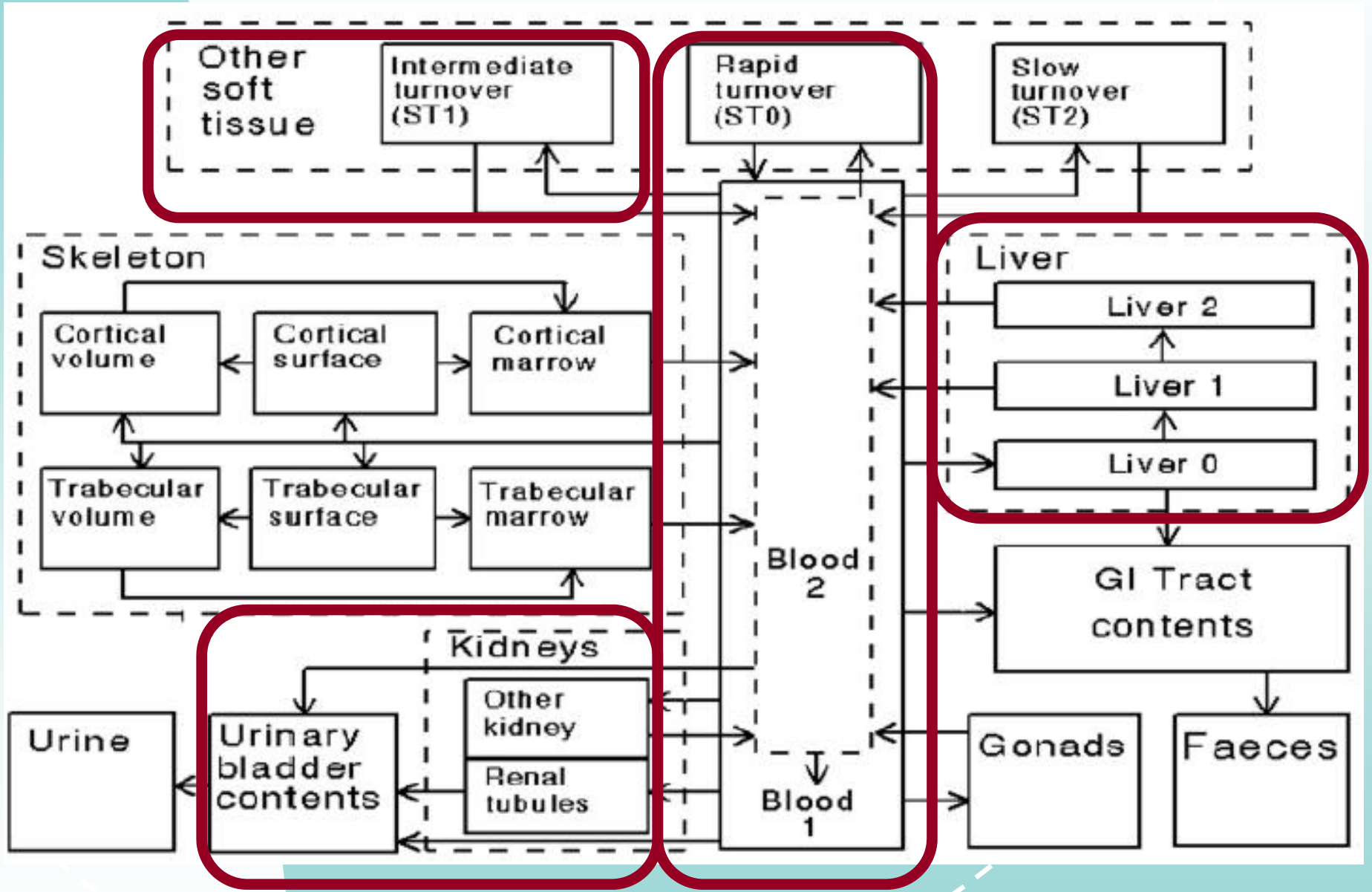


The U.S. Transuranium & Uranium Registries are actively collaborating with Drs. Birchall and Puncher (UK HPA) to TEST novel (IMBA-based) analytical capabilities and methods with Registries case studies.

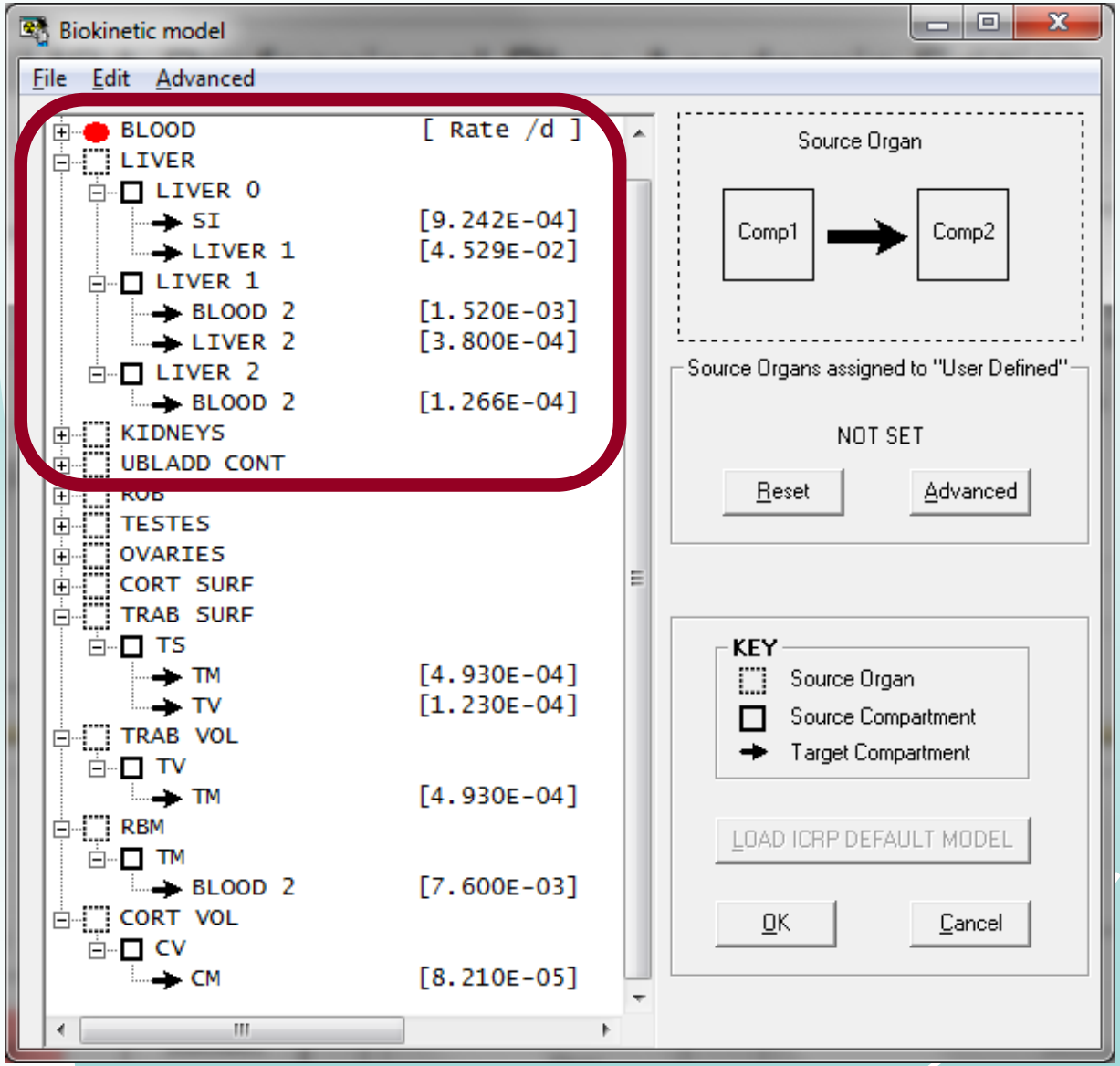
Implementation (and Testing) of Proposed New ICRP Models



Leggett et al. (2005) – Revised (Improved?) Pu Biokinetics

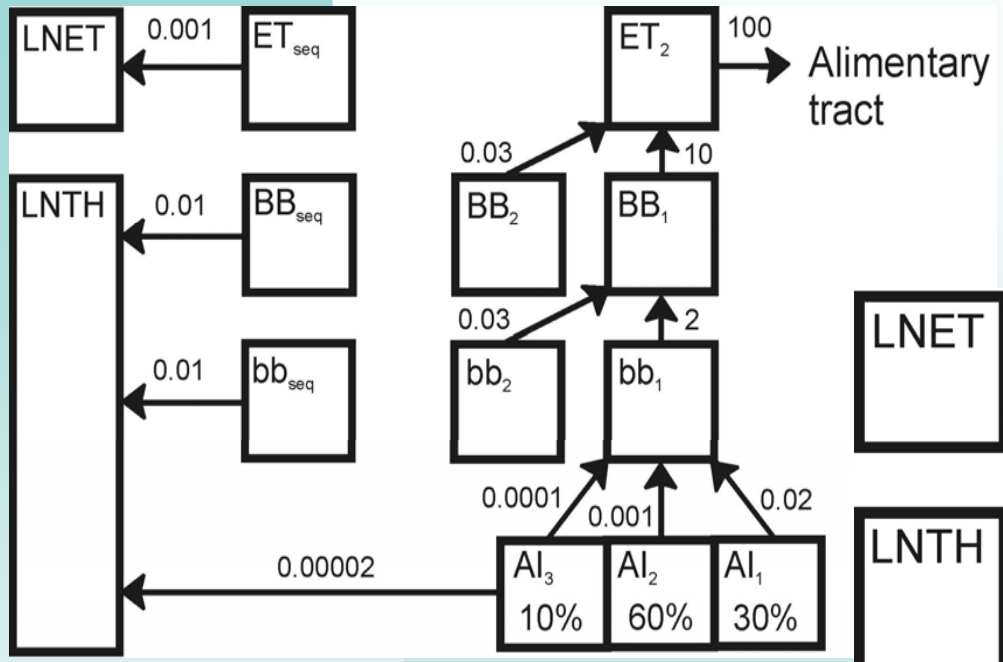


New Capability: "Build Your Own" Biokinetic Model in IPP!

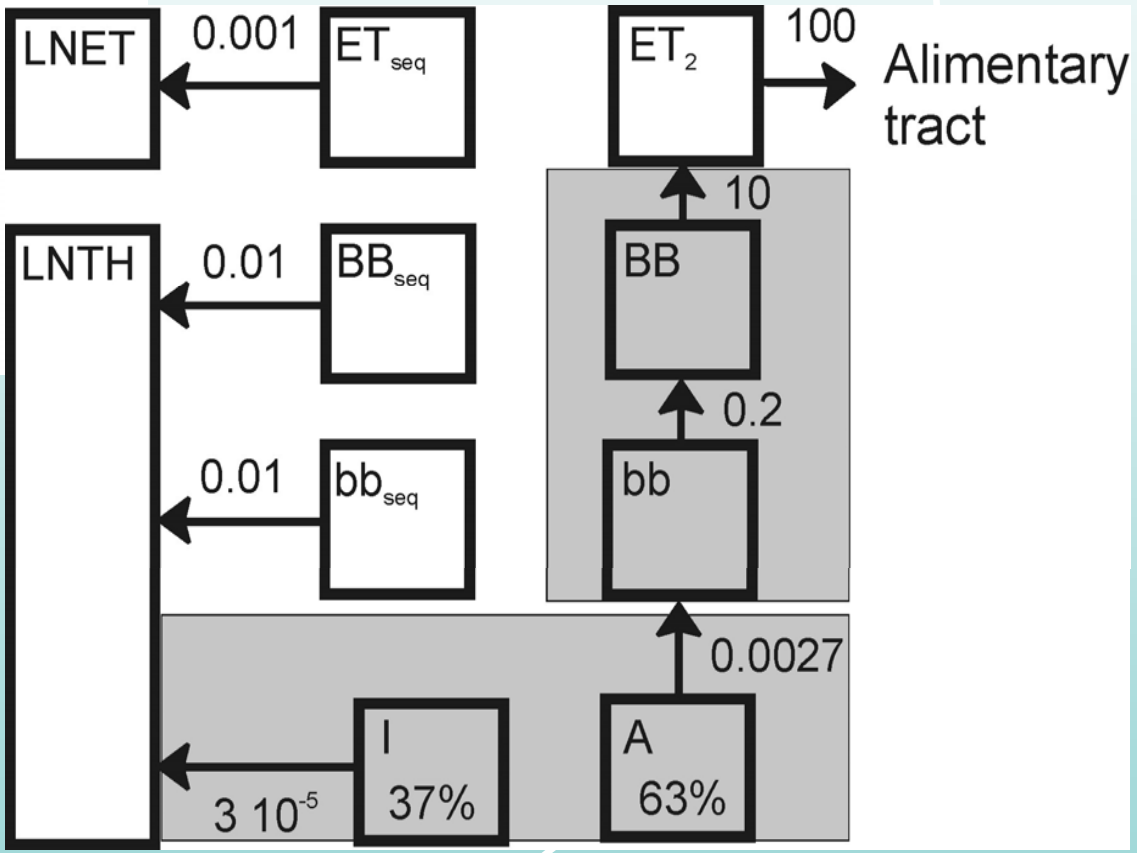


Recycling model now solved "live" – does not require "pre-cooked" equivalent set of exponential terms (non-recycling approximation)

Proposed Improvement of HRTM



ICRP Publication 66 (1994)



Gregoratto et al. (in press)

ICRP Publication 103 Has Changed the Treatment of Lymph Nodes – and Remainder Tissue – Dose!

ICRP Publication 103

Table 3. Recommended tissue weighting factors.

Tissue	w_T	Σw_T
Bone-marrow (red), Colon, Lung, Stomach, Breast, Remainder tissues*	0.12	0.72
Gonads	0.08	0.08
Bladder, Oesophagus, Liver, Thyroid	0.04	0.16
Bone surface, Brain, Salivary glands, Skin	0.01	0.04
	Total	1.00

* Remainder tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (male), Small intestine, Spleen, Thymus, Uterus/cervix (female).

Some Potential Issues with New ICRP 103 "Dosimetry"

- **Not stated whether Thoracic Lymph Nodes (LNTH) are included in the "lymph node dose average" – or how to calculate axillary lymph node dose (for a "wound" intake).**

- **If LNTH are included, their w_T value would increase by an order of magnitude – from 0.001 (ICRP 66) to about 0.01 (one-fourteenth of the 0.12 "remainder" value).**

- **At least for the actinides, the radionuclide concentrations (tissue doses) for the Breast, Brain, Salivary glands, Skin, Adrenals, Gall bladder, Heart, Pancreas, Prostate, Spleen, Thymus, Uterix/cervix are not "modeled" – and autopsy data indicates substantial differences from Massive Soft Tissue (MST).**

However, the IMBA Expert™/IMBA Professional Plus design concept can be applied to incorporate whatever new recommendations ICRP may come up with – and adapted to comply with specific national regulatory requirements!

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Thank you for your attention!

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