NIOSH OCAS Meeting Report
Presentation and Discussion with ACJ & Associates
on
The Integrated Modules for Bioassay Analysis Software (IMBA)

Date/Location of Meeting: May 8th, 2001 / Hamilton conference room A

Attendees (Affiliation):
Larry Elliott, Ted Katz, Greg Lotz, Jim Neton, Mary Schubauer-Berigan, Randy Smith, Henry Spitz (NIOSH)

Alan Birchall and Tony James (ACJ & Associates)

Objective: To learn about the capabilities and status of ACJ & Associates IMBA software for performing intake and internal dose assessments using the revised ICRP lung and biokinetic models.

Meeting summary: After a brief introduction of OCAS staff by Larry Elliott, Tony James provided an historical overview of internal dosimetry models / techniques and computer based analysis software. This was followed with a presentation by Alan Birchall who described the history of IMBA development. After this a brief computer demonstration of the software package was held, which was followed by a general discussion on how IMBA could be modified to meet OCAS' specific needs under EEOICPA. A copy of the overheads used for these presentations is attached.

It was concluded that IMBA had the desired capabilities, but some modification would be required to meet to meet our needs. Jim Neton agreed to develop a list of those features that would be absolutely essential for OCAS to use the IMBA program. ACJ & Associates would then respond with an estimate of the time and funding requirements necessary to implement these changes.

Agenda
ACJ & Associates Internal Dosimetry Meeting
Conference Room B
May 8th
9:00 A.M.

9:00	Introductions and brief discussion of EEOICPA and NIOSH's role	(OCAS Staff)
9:20	Overview of internal dosimetry techniques and computer based analysis software	(ACJ)
9:50	Interactive demonstration of Integrated Modules for Bioassay Analysis	(ACJ)
10:50	Discussion of IMBA/DOE	(ACJ)
11:20	Discussion of NIOSH's specific needs under EEOICPA	(ALL)
12:00	Lunch	
1:00	Review of specific exposure scenarios and potential IMBA modifications	(OCAS tech.team)
2:45	Adjourn	

IMBA: The UK's Integrated Modules for Bioassay Analysis - Development Strategies for "Expert" Software Applications

Presentation to HHS/CDC/NIOSH Office of Compensation Analysis and Services (OCAS) Staff on Software Needs for Implementing U.S. Legislation Related to DOE Worker Compensation

May 8, 2001

Anthony C. James, Ph.D.
ACJ & Associates, Inc.
129 Patton Street
Richland, WA 99352-1618, USA

And

Alan Birchall, Ph.D.
National Radiological Protection Board
Chilton, Didcot, OXON OX11 0RQ, UK

Scope of Presentation and Meeting - OCAS, May 8, 2001

- **James** - Overview of the evolution of ICRP internal dosimetry and dose assessment methodologies.
- **Birchall** - Development of NRPB's "Integrated Modules for Bioassay Analysis" **(IMBA)**.
- **Birchall** - Demonstration of IMBA methodology and capabilities.
- **James** - Strategy for developing ***"IMBA Expert"*** software applications tailored to users' specific requirements.
- **James** - ***IMBA Expert USDOE-Edition*** - content and timescale.
- **Meeting** - Discussion on how **IMBA methodology** could best be applied to meet the regulatory needs of OCAS/DOE Worker Compensation.

Overview I - Early Evolution of the Quantitative Regulation of Internal Dose

- **1959 - ICRP Publication 2 - "Permissible Dose for Internal Radiation"**
  - Introduced concept of calculating dose to individual body organ from radionuclide activity uniformly distributed within that organ.
  - Used "effective radius" of organ to calculate absorbed dose for γ-emitters.
  - Used simple compartmental clearance rate-constants to calculate retention and number of disintegrations in body organ.
  - Recommended values of "permissible" doses accumulated over specified time periods for several "critical" body organs, *e.g.*, D = 5×(N-18) rem for blood forming organs, gonads, and lens of the eye.
  - Recommended values of "maximum permissible concentration" in air (MPC_a) and water (MPC_w) for list of "important" radionuclides - corresponding to accumulation of the specified "permissible" dose in most highly irradiated organ.
  - Recommended "maximum permissible body burden" for each radionuclide -corresponding to accumulation of respective "maximum permissible [organ] dose."
  - Simple "by-hand" calculations.

Overview II - 1970/80's Evolution of Internal Dosimetry and Regulation

- **1977 - ICRP Publication 26 - "Recommendations of the International Commission on Radiological Protection"**
  - Established dose limitation system designed to prevent "non-stochastic" effects and to limit "stochastic" effects.
  - Non-stochastic limits based on the 50-year organ doses ($H_{50,T}$).

$$D_T = \frac{E_{abs,T}}{M_T} \quad [in\ gray\ (Gy), or\ rad] \ldots\ldots\ldots (1)$$

$$H_T = \sum_R w_R\, D_{T,R} \quad [in\ sievert\ (Sv), or\ rem] \quad \ldots\ldots\ldots (2)$$

  - Stochastic limits depend on total effects of organ doses on whole body.

$$E = \sum_T w_T\, H_T \quad [in\ sievert\ (Sv), or\ rem] \quad \ldots\ldots\ldots (3)$$

Overview III - 1970/80s Evolution of Internal Dosimetry and Regulation (contd.)

- **1979 - ICRP Publication 30 - "Limits for Intakes of Radionuclides by Workers"**
  - Adult (male) worker.
  - Dose coefficient - ***committed*** equivalent dose in organ ***T*** resulting from intake ***I***:

$$H_T(\tau) = \int_{t_0}^{t_0+\tau} H'_T(t)\,dt \quad \ldots\ldots\ldots (4)$$

$$H_T(\tau) = I\, h_T(\tau) \quad \ldots\ldots\ldots (5)$$

$$h_T = \sum_S \sum_j U_{S,j}\, SEE(T \leftarrow S)_j \quad \ldots\ldots\ldots (6)$$

$$SEE(T \leftarrow S; t) = \frac{1}{M_{T,t}} \sum_R E_R\, Y_R\, w_R\, AF(T \leftarrow S, E_R, t)_R \quad \ldots\ldots\ldots (7)$$

Overview IV - 1970/80s Evolution of Internal Dosimetry and Regulation (contd.)

- **1979 - ICRP Publication 30 - "Limits for Intakes of Radionuclides by Workers"**
  - ***Annual Limit on Intake*** (ALI) defined as largest value of ***I*** which satisfies:

$$I \sum_T w_T\, H_{50,T} \le 0.05\ Sv \quad \ldots\ldots\ldots (8) \quad \textit{for stochastic effects}$$

$$I\, H_{50,T} \le 0.5\ Sv \quad \ldots\ldots\ldots (9) \quad \textit{for nonstochastic effects}$$

  - ***Derived Air Concentration*** (DAC) in Bq m^{-3} for any radionuclide is that concentration in air which, if breathed by the Reference Man for a working year under conditions of light activity, would result in the intake of one ***ALI***:

$$DAC = \frac{ALI}{2000 \times 1.2\ m^3\ h^{-1}} = \frac{ALI}{2400\ m^3} \quad \ldots\ldots\ldots (10)$$

Overview V - 1970/80s Evolution of Internal Dosimetry and Regulation (contd.)

- **1979-85 - ICRP Publication 30 (Parts 1-4) - "Limits for Intakes of Radionuclides by Workers"** - ***Metabolic Models***
  - Simple, linear first-order equations describe translocation of material (from respiratory tract and body organ "compartments").
  - Contents of compartments mix in instantaneous, uniform manner.
  - Organ deposition from transfer compartment (blood) occurs rapidly.
  - Removal from each organ governed by specific retention times.
  - Direct excretion occurs from the organs and tissues after deposition.
  - Metabolic properties of a nuclide are described by a set of rate constants that are fixed for the 50-year integration period.
  - Daughter atoms born in the body following deposition of the parent are metabolized with the properties of the parent.
  - ***Limitation of Models*** - All ICRP30 models designed for dose limitation - not for individual dose assessment (bioassay).

Overview VI - 1990s Evolution of Internal Dosimetry and Regulation

- **1991 - ICRP Publication 60 - "1990 Recommendations of the International Commission on Radiological Protection"**
  - Revised overall radiation risk estimates - added consideration of "radiation detriment."
  - Revised tissue weighting factors, w_T - including more organs and "accounting" rules for "remainder tissues" and "rest of body."
  - Lowered dose limits.
- **1993-95 - New, More Realistic "Biokinetic" Models**
  - ***ICRP Publication 67 (1993)*** - including transuranics.
  - ***ICRP Publication 69 (1995)*** - including uranium.

Overview VII - 1990s Evolution of Internal Dosimetry and Regulation (contd.)

- **1994 - ICRP Publication 66 - "Human Respiratory Tract Model for Radiological Protection"**
  - More realistic (mechanistic) than ICRP30 model for ***deposition***, ***clearance*** and ***dosimetry*** (target cells at risk).
  - Designed for both ***dose limitation*** and ***dose assessment***.
  - Aerosol size range 0.0006- μm-AMTD through 100- μm-AMAD - including "inhalability."
  - Mechanistic treatment of particle clearance - competition between "mechanical" clearance processes and material "dissolution/absorption" to blood.
  - ICRP30 "solubility classifications" (D, W and Y) replaced by "absorption types" (F, M and S).
  - Ability to represent absorption behavior of specific materials.
  - New dosimetry of alveolar-interstitial (AI), bronchiolar (bb), bronchial (BB), thoracic lymph nodes (LNTH), and extrathoracic tissues (ET_1, ET_2, and LNET).
  - Extrathoracic tissues recognized as potentially "at risk."
  - Lung tissue weighting factor ($w_{lung} = 0.12$) sub-divided into fractions: 0.333 for AI; 0.333 for bb; 0.333 for BB, and 0.001 for LNTH.

Overview VIII - 1990s Evolution of Internal Dosimetry and Regulation (contd.)

- ***1995 - ICRP Publication 70*** - "Basic Anatomical and Physiological Data for Use in Radiological Protection: The Skeleton."
- ***1994 - ICRP Publication 68*** - "Dose Coefficients for Intakes of Radionuclides by Workers."
- ***1997 - ICRP Publication 78*** - "Individual Monitoring for Internal Exposure of Workers: Replacement of ICRP Publication 54 (1988)."
- ***1999 - EPA issued Federal Guidance Report #13*** adopting ICRP Publication 60 risk factors and current ICRP respiratory tract and biokinetic models.

Use of ICRP's New Respiratory Tract Dosimetry and Biokinetic Modelling Concepts in Radiation Litigation

Dr. James has applied ICRP's current modelling concepts for expert dose assessments in 11 litigated cases (to date)

- In UK - Since 1989 in Rae and Hope *vs.* BNFL (English High Court).
- In US - Since 1993 in Billingsley *vs.* Dow Chemical *et al.* (Colorado Industrial Compensation Court).

Current Status of ACJ & Associates, Inc./NRPB Co-development Projects for IMBA-based Bioassay Application Software

- ***Defence Evaluation Research Agency (DERA), UK*** - ***IMBA-URAN*** project commenced.
- ***DOE, EH-52 (US)*** - awaiting contract for ***IMBA Expert USDOE-Edition*** project (Phase I).
- ***Canadian Nuclear Safety Commission (CNSC)*** - negotiating contract for ***IMBA-CANDU.***
- ***IMBA Expert Uranium-Edition*** - mining and nuclear industry clients "in waiting."

Deliverables Schedule for *IMBA Expert USDOE-Edition*

▪ Phase I - "alpha version"	Sep, 2001
▪ Phase I - "beta version"	Dec, 2001
▪ Phase I - final version with documentation	Mar, 2002
▪ Phase II - "alpha version"	Jul, 2002
▪ Phase II - "beta version"	Sep, 2002
▪ Phase II - final version with documentation	Dec, 2002

Aims of *IMBA Expert USDOE-Edition* Project

Provide USDOE Sites With Standardized Methods for Dealing With Bioassay Measurements - More Powerful And Flexible Than Existing Software

- Develop user-friendly, quality-assured software to enable USDOE sites to use IMBA modules automatically for intake and dose assessment.
- Extend the use and applicability of the IMBA modules.
- Customize use of IMBA modules for specific USDOE-site regulatory purposes.

Planned Capabilities of *IMBA Expert USDOE-Edition*

Phase I

- The software will deal with the following routes of intake:
  - Inhalation (Acute, Chronic);
  - Ingestion;
  - Injection (i.v.);
  - Trans-dermal (Wound).

- The software output will include:
  - Equivalent doses to each organ;
  - Committed effective dose;
  - Organ retention at specified times;
  - Bioassay quantities over specified timescale;
  - Best estimate of intake.

Planned Capabilities of *IMBA Expert USDOE-Edition*

Phase I

- The parameter fitting method will be based on the maximum likelihood method, and the software will therefore be able to deal with:
  - More than one data point simultaneously;
  - Data recorded as below a minimum level of detection;
  - Positive data points with different errors on each measurement;
  - More than one intake regime simultaneously.

- Other features will include:
  - Built-in database of all ICRP default parameters;
  - Built-in database of all bioassay retention functions;
  - Ability to enter user-specified retention functions;
  - Ability to enter user-specified particle transport parameters;
  - Built-in biokinetic models for each radionuclide considered.

Planned Capabilities of *IMBA Expert USDOE-Edition*

Phase I

- Other features (continued):
  - On-screen graphical and statistical output;
  - Ability to download data to spreadsheets;
  - Ability to deal simultaneously with doses from combinations of radionuclides;
  - Ability to use both ICRP 26 and ICRP 60 weighting factors;
  - Built-in nuclear decay database, and ability to display it on-screen;
  - Ability to exclude individual data points;
  - Ability to deal with large data sets (hundreds of points);
  - Ability to change error assumptions (normal or lognormal);
  - Ability to change all aerosol parameters (*e.g.*, including particle density, shape factor;
  - Recommend one single best estimate;
  - Ability for user to enter specific absorption parameters;
  - Ability to toggle units between pCi and Bq;
  - Ability to dump output as ASCII file;
  - Ability to toggle between date and days.

Planned Capabilities of *IMBA Expert USDOE-Edition*

Phase II

- This will enhance the power of the Phase I software significantly, while retaining its flexibilty and ease of use. The main enhancements will be:
  - Extension of the fitting routine to enable the user to fit more than one data set simultaneously, *e.g.*, the ability to determine the best estimate of an intake from both lung counts and urine samples;
  - Extension of the fitting routine to enable the user to take into account previous measurement history of other individuals (group members) using a Bayesian approach;
  - Ability to deal with bioasssay data taken over different periods of time;
  - Inclusion of an IMBA module dealing with tritium;
  - Resolution of any user problems with, and suggested enhancements to, the Phase I software;
  - Extension to additional radionuclides.

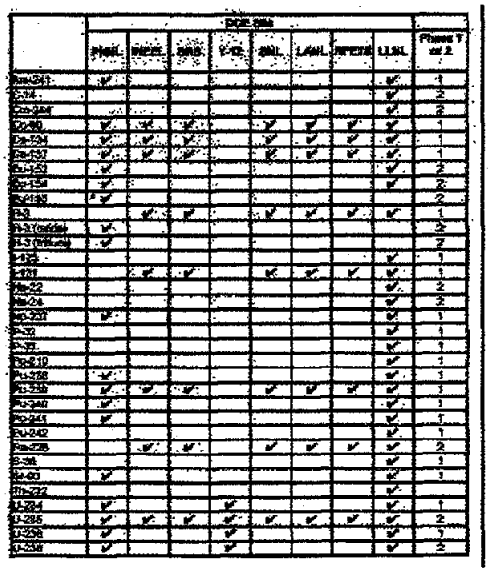
Planned Capabilities of *IMBA Expert USDOE-Edition*

Phase II

- Other additional features:
  - Ability for user to over-ride program's best estimate;
  - Download graphical output to spreadsheets;
  - Evaluate uncertainty on the estimate of intake;
  - Estimate intakes of ^{241}Pu from measured ^{241}Am;
  - Ability to use tissue weighting factors from 10 CFR 835;
  - Ability to extrapolate fitted bioassay function to enable user to design future monitoring program;
  - Inclusion of Jones and Durbin excretion models for plutonium;
  - Ability to deal with chelated intakes.

Planned Capabilities of *IMBA Expert USDOE-Edition*

Radionuclides Required by Contributing USDOE Sites



Development Plan for IMBA-based Software Products - Canada and the United States

The ***NRPB*** has appointed ***ACJ & Associates, Inc.*** to serve as "AUTHORISED NRPB SOFTWARE CO-DEVELOPER AND DISTRIBUTOR" for North & South America and the Pacific Rim Countries

- ACJ & Associates, Inc. will co-develop and license to "end-users" software products utilizing NRPB's proprietary IMBA© modules and methodology for application to bioassay analysis and dose assessment.

Summary of the Roles of ACJ & Associates, Inc. and NRPB in Co-developing IMBA-based Software Products

Territory of North & South America and Pacific Rim Countries

ACJ & Associates, Inc. :

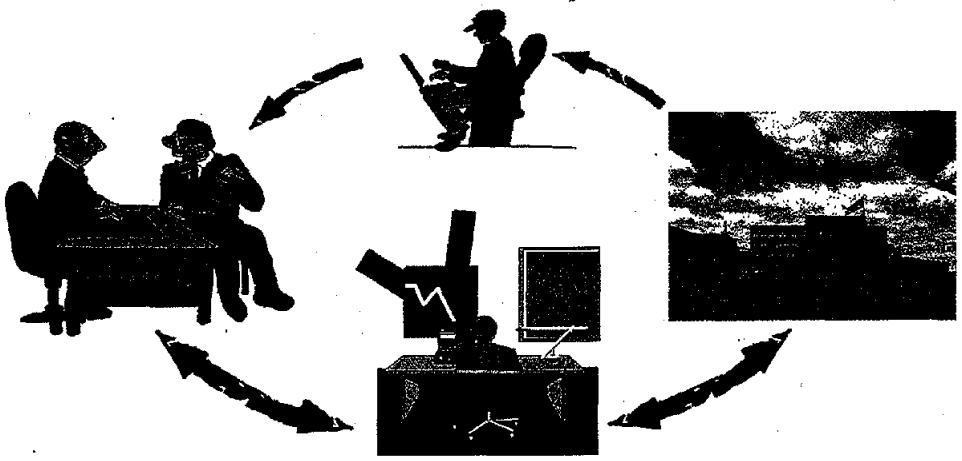
- Marketing and identification of customer requirements.
- Liaison with customer to develop detailed technical specification of software function and user-interfaces, and documentation requirements.
- Liaison with NRPB to cost any necessary coding development, and provision of quotation for cost and delivery to customer.
- Documentation and testing of software product against technical specification, delivery of software and user-license(s) to customer.
- Provide customer with appropriate technical support.

NRPB:

- Develop and quality assure any necessay new software coding to interface with IMBA© modules.
- Provide scientific oversight of new methodologies or applications.
- Maintain close links with ICRP Dose Calculations Task Group (DOCAL) and developments in ICRP Committees and other Task Groups.

Co-development Process for IMBA-based Software Products

Customer/End-User **ACJ & Associates, Inc.** **NRPB**



Acknowledgements

Naomi Jarvis (NRPB) is the principal programmer of the IMBA© interface codes.

M. S. Peace (BNFL) carried out a substantial part of IMBA development and quality assurance;

M.-D. Dorrian, J. W. Marsh and S. L. Thrift (NRPB) assisted with the implementation of biokinetic models;

A. W. Phipps and T. J. Silk (NRPB) provided the ICRP SEE data and ran many calculations with PLEIADES;

R. K. Bull (AEAT) assisted with quality assurance;

A. E. Riddell (Westlakes) assisted with many parts of the IMBA project in its early stages;

Members of the UK Internal Radiation Dosimetry Group provided the original inspiration for the IMBA project, and support and encouragement as the project progressed;

Financial support (to NRPB) was provided by BNFL, AEA Technology, AWE and DERA, and;

DERA have kindly permitted NRPB to describe and demonstrate IMBA-CALC.

IMBA: Concepts & Capabilities

by
Dr A Birchall and Dr A C James

Meeting with the Internal Dosimetry Working Group,
Canadian Nuclear Safety Commission (CNSC)

CNSC Headquarters
280 Slater Street
Ottawa, Ontario

October 3rd, 2000

NRPB

IMBA: Concepts & Capabilities

Contents

1. Introduction
2. Description of IMBA Suite
3. Advantages of Modularity
4. Quality Assurance
5. Organisation of Effort
6. Methods of Applying IMBA Modules
7. Time Scales and Progress
8. Conclusions

1. Introduction to IMBA Project

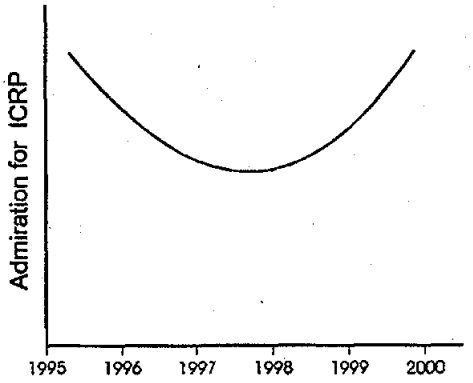
- When? - started in 1997.
- Why? - ICRP has revised many of its biokinetic models, including that for the respiratory tract.
  - Use of new models required by UK regulations (January, 2000).
  - Although corresponding dose coefficients are published by ICRP, UK Approved Dosimetry Services need to implement new models to interpret monitoring data, and calculate doses under non-standard conditions.
  - Appropriate user-friendly software not currently available.
- What? - IMBA modular system (Integrated Modules for Bioassay Analysis) was developed jointly by NRPB and the UK Nuclear Industry to provide well QA'd code modules and methodologies to implement new ICRP models for estimation of intakes and doses.

1. Introduction (contd.)

Publication Sequence of New ICRP Models, Recommended Dose Coefficients, and Practical Guidance on Bioassay Led to Confusion

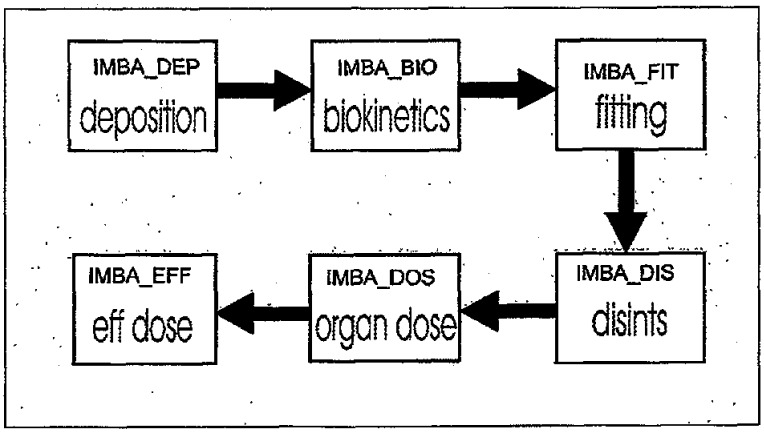
1. Introduction (contd.)

Introduction of the "IMBA" Methodology in the UK Has Eased the Practical Transition From Old to New ICRP Models - and to Implementation of New Ionising Radiation Regulations



2. Description of Modular IMBA Suite

The IMBA Suite Consists of Six Independent Code Modules Which Communicate *via* ASCII Data Files -and Can be Run in Any Order



2. Description of IMBA Suite (contd.)

Deposition Module

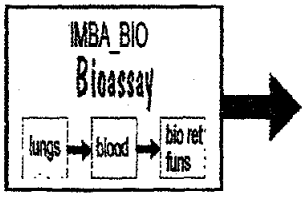
IN
AMAD
AMTD
σ_g
Shape factor
Density
Exposure Type
Subject

OUT
$D(ET_1)$
$D(ET_2)$
$D(BB_f)$ $D(BB_s)$
$D(bb_f)$ $D(BB_s)$
D(AI)

2. Description of IMBA Suite (contd.)

Bioassay Module

IN
Deposition (7)
Solubility (5)
Bioassay Type
Ret/Exc Function
Intake Regime (T_1, T_2)
Radioactive Decay,
f_1, $t_{½(blood)}$, λ, $t_{i\ (data)}$



OUT

Bioassay
Quantity
At each t_i

2. Description of IMBA Suite (contd.)

Summary of Key Functions

- ***Estimates intakes from bioassay data - and predicts committed doses.***
  - By running modules in specific order, it is possible to perform many different types of calculation.
  - Modules are run from user-friendly "interface" which can be customised to user's specific requirements.
- ***Abillty can be incorporated in design of interface for user to vary environmental and other parameters of models.***
- ***IMBA system is designed to analyse simultaneously multiple intake regimes - which can include different acute and chronic intakes, by different pathways (e.g., inhalation, ingestion, or direct uptake to blood).***
- ***All types of bioassay data can be analysed, e.g., whole body or organ counts, urinary or faecal excretion - and IMBA incorporates sophisticated fitting methods, e.g., unbiassed treatment of observations < MDA, varying MDAs, and different error types for individual data points.***

2. Description of IMBA Suite (contd.)

Radionuclides

- Phase I Development (completed)
  - ^{239}Pu, ^{131}I, ^{234}U, ^{137}Cs, ^{3}H
- Phase II Development (completed)
  - ^{35}S, ^{90}Sr, ^{60}Co, ^{106}Ru, ^{241}Am, ^{227}Ac, ^{241}Pu, ^{238}Pu, ^{144}Ce, ^{210}Po
- Phase III Development (in progress)
  - Various

3. Advantages of IMBA Modularity

- ***Flexibility***
  - *Can use modules in any order to perform different functions -e.g., calculate intakes, doses, or deposition of multi-modal aerosols, or perform parameter sensitivity analyses.*
- ***Can be Incorporated into Existing Software***
  - *BNFL (UK) have incorporated IMBA modules into their in-house dose assessment software - to preserve operator familiarity with, and functionality of, their in-house user interface.*
  - *As "Add-in" to counter analysis packages - such as ORTEC®'s Renaissance® software.*
  - *As "Add-in" to aerosol size analysis packages - such as JABASoft™'s IMPACTOR EXPERT software.*
- ***Each Module Can be Written Independently***
- ***Easier to Develop "Front End" Interfaces***
- ***Aids Quality Assurance***

4. Quality Assurance

- ***Modularity***
  - *Each module is easier to test since it is small - with well defined input/output.*
  - *Same modules are used for all calculations (e.g., for different radionuclides and biokinetic models) - therefore code is smaller.*
  - *Can readily test each stage of a calculation.*
  - *Once a module works - it works.*
- ***Used Previously QA'd Code Whenever Possible***
- ***Each Module Developed Twice - by Independent Authors, with Different Programming Languages***
- ***Multi-Institutional Comparisons***
  - *With ICRP tabulations, plus ICRP CD-ROM.*
  - *With other existing codes, e.g., LUDEP and PLEIADES (NRPB's code used to calculate ICRP's published dose coefficients).*
  - *Used in internal dosimetry and bioassay intercomparison exercises.*

5. Organisation of Effort (Phase I)

Independent Authorship of IMBA Modules

Module	NRPB	BNFL	Westlakes Research Institute
Deposition	✔		✔
Biokinetics	✔	✔	
Fitting	✔		✔
Disintegrations	✔	✔	
Dosimetry	✔	✔	

5. Organisation of Effort (Phases II & III)

- ***Phase II***
  - *Completed April, 1999.*
  - *Major technical contributions from NRPB, BNFL, AEAT, and AWE.*
  - *Each organisation also contributed substantial funding.*
- ***Phase III***
  - *In progress, 2000 - 2001.*
  - *Continuing developments and improvements of IMBA modules, e.g., the bioassay data fitting module.*
  - *Continuing development, implementation, and quality assurance of model and radiation data files.*

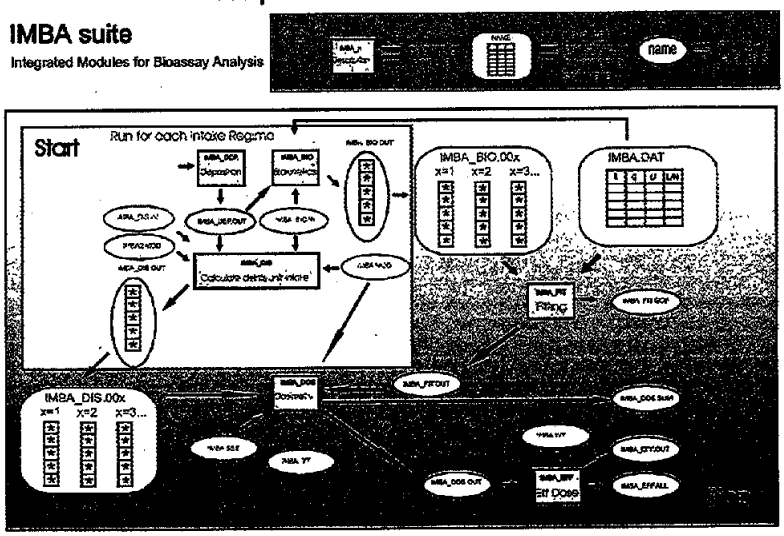
6. Methods of Applying IMBA Modules

(For Contributing Organisations in the UK)

- ***Distribution of IMBA Modules Themselves***
  - *British Nuclear Fuels Limited (BNFL), Atomic Weapons Establishment (AWE), and Atomic Energy Authority Technology (AEAT) have incorporated IMBA modules into their own "in-house" software for bioassay analysis, internal dose assessment and reporting.*
- ***NRPB Development of User-Friendly Software for Automatically Implementing the IMBA Modules***
  - *This method of applying the IMBA modules and methodologies was preferred by the Defence Evaluation Research Agency (DERA) - and other UK Approved Dosimetry Services (ADS).*

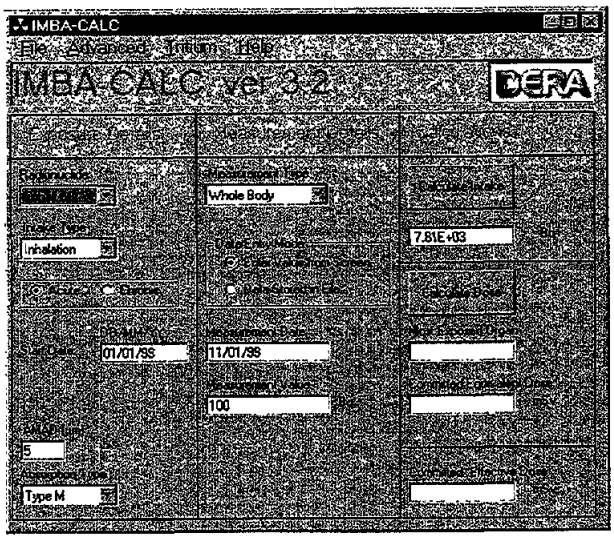
6. Methods of Application (contd.) - "In-House" Incorporation of Modules

Required Functional Structure



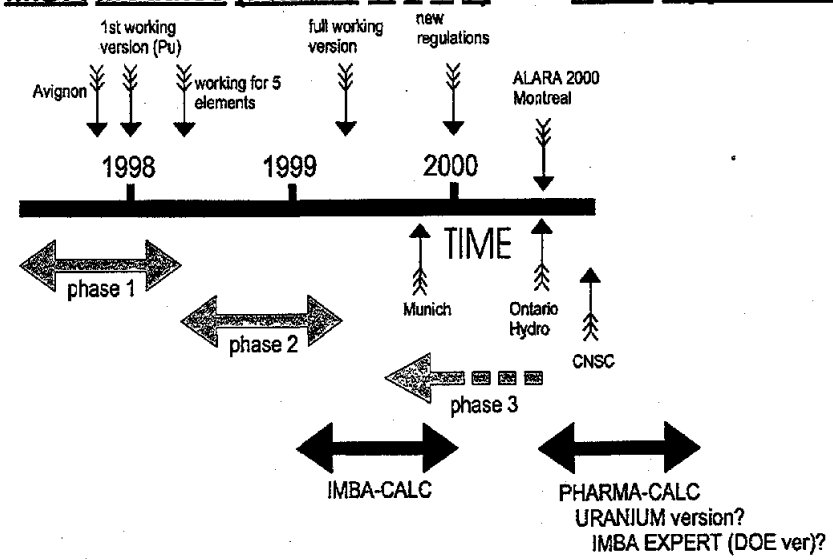
6. Methods of Application (contd.) - NRPB Developed User-Friendly Software Package

For High Throughput, Regulatory Purposes, DERA Required a Simplified User Interface



7. Time Scales and Progress

IMBA Modules (Phases 1, 2 & 3) and **IMBA Applications**



7. Time Scales and Progress (contd.) - IMBA Applications

Currently Proposed Developments

- ***PHARMA-CALC***
  - *Application of IMBA modules to dose assessment for radiopharmaceuticals.*
  - *Software would facilitate user entry of specific biokinetic models - for a very large number of radiopharmaceuticals.*
  - *Under consideration for development by NRPB - with funding from radiopharmaceutical industry*

- ***IMBA Applications Outside of UK***
  - *IMBA EXPERT USDOE-Edition being considered by USDOE Headquarters, Office of Worker Protection Programs and Hazards Management (EH-52), in collaboration with principal USDOE Laboratories and Field Sites.*
  - *IMBA EXPERT Canadian-Edition being considered by Canadian Nuclear Safety Commission (CNSC), in collaboration with potential user groups, e.g., Ontario Power Generation.*
  - *Interest in NRPB-developed application software in Nordic countries, and in other parts of Europe.*

8. Conclusions

- "IMBA" has proved to be the way forward for internal dosimetry in the UK - by facilitating a smooth transition to implementing new ICRP models for dose assessment within the framework of new Ionising Radiation Regulations.
- IMBA modules have been extensively QA'd - and the methodology has been shown to work.
- Ongoing developments and enhancement of the IMBA modules are currently funded in the UK, and are underway.
- Such fundamental developments and enhancements are likely to receive continued support in the UK, and are likely to keep pace with future developments of ICRP models and recommendations.
- The proposed development of an IMBA EXPERT USDOE-Edition tailored to meet the current and future technical requirements of participating USDOE sites is timely - and has been welcomed by the USDOE "community."