

Anatomical Models in Organ Dose Evaluations

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Outline

- **Estimations**
 - Organ Dose
 - Deterministic Limits (Skin, Eye, BFO)
 - Stochastic Limits (Career)
- **CAM/CAF (Computerized Anatomical Male/Female)**
 - Kase/Billings/Yucker
 - Approach
 - Quad. Geometry
 - Interpolation Across Shield Distributions
 - Sizing/Scaling
 - Materials (H₂O, Al vs. Tissue, Bone, etc.)

Organ Doses

In order to assess crew exposure in terms of either “whole body dose equivalent” or “effective dose”, the starting point is organ absorbed dose

$$H = \int D(L) \cdot Q(L) dL$$

- Whole Body Dose Equivalent
Ref. NCRP, #98
 - Quantities assumed equal to those at the BFO (p. 160)
 - $Q(L)$ as defined in ICRP-26 (NCRP-98, p. 28)
- Effective Dose
Ref. ICRP, 1991b
 - $D_{T,R}$ is the absorbed dose due to incident radiation R in tissue/organ T
 - w_R is the radiation weighting factor for radiation R
 - w_T is the tissue weighting factor for tissue T

$$H = \sum_T w_T \sum_R w_R D_{T,R}$$

Organ Doses

- Calculational Process

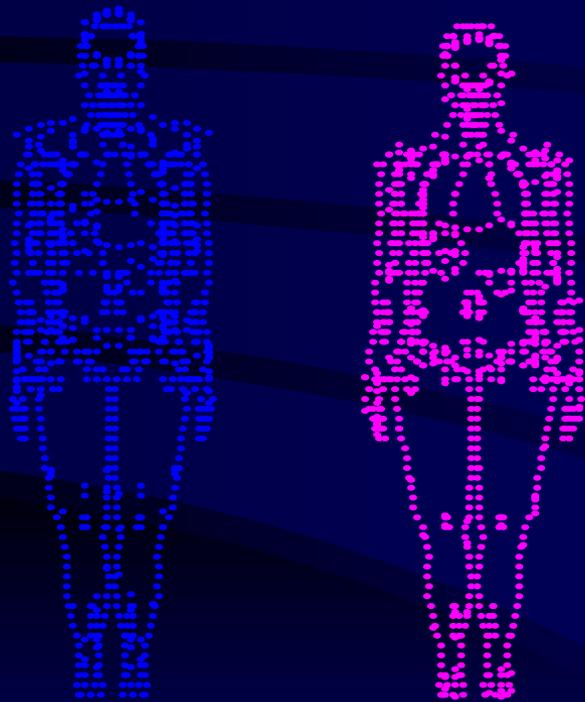
- Use 0-D transport codes developed at NASA, Langley Research Center (HZETRN, BRYNTRN) to generate dose vs. depth relations
- Divide space into N (typically 512) equal solid angle directions for each of M sample points per organ
- Along each direction, generate shield information (conventionally equivalent Al or water thicknesses)
- Fold dose-depth information into shield information
- Averaging accomplished by multiple point sampling

$$H = \frac{\sum_{M\text{Points}} \left(\sum_{N\text{Rays}} \int D_{M,N}(L) \cdot Q_{M,N}(L) dL \right) / N}{M}$$

The CAM/CAF Model

- Initially developed by Paul Kase ~1970 (AFWL) from anthropometric data developed by a sampling of the then current US Air Force cohort
- Has been maintained since (Kase, Billings, Yucker, etc., 1970, 1973, 1990, 1991, 1992) to ensure relevance and detail (.1 inch modeling resolution, within 5% of organ and body weight, chemical composition modeled for 11 tissue types)
- Constructed of ~1500 quadratic surfaces in a cartesian coordinate system yielding ~2500 closed volumes
- Skeleton (bone and marrow)/Muscle/internal organ/soft tissue/void (as in intestines, lungs)/fat, are accounted for
- Married to a ray-tracing routine (program CAMERA) yielding stackup (material vs. thickness) information

The CAM/CAF

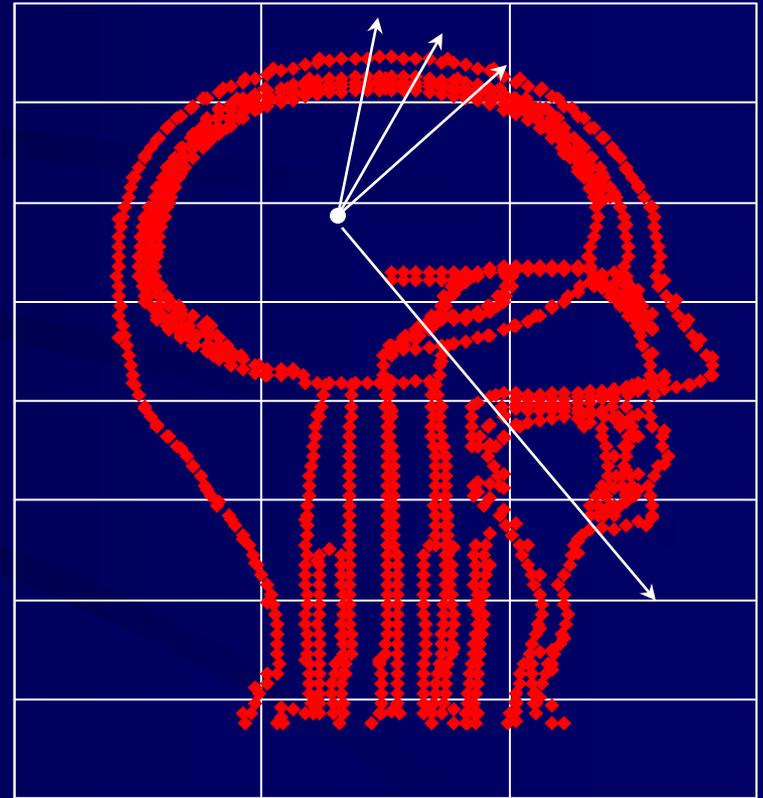


- CAM MODEL
- 5'9.25" TALL
- 155 LBS
- (Male Ast. ~5'11.1" ~80%)

- CAF MODEL
- 5'3.7"
- 142 LBS
- (Female Ast.~5'5" ~70%)

CAM/CAF

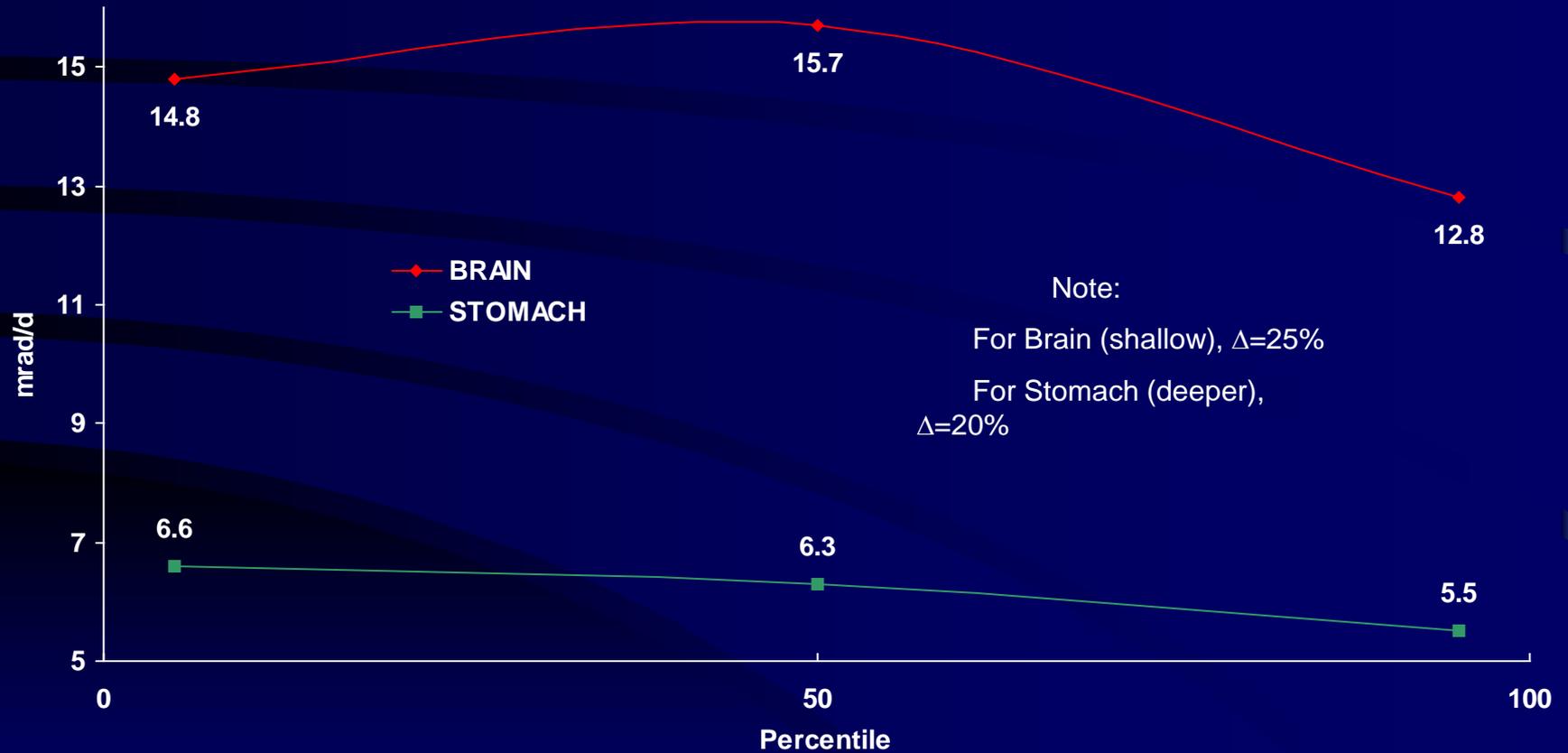
- CAMERA Routines
(~5 MB with model files)
begin at a dose point, and trace n directions over the 4π solid angle to an outer surface, yielding material vs. thickness information.
- Has been successfully modified to allow a full 3-D scaling
(more individual modeling)



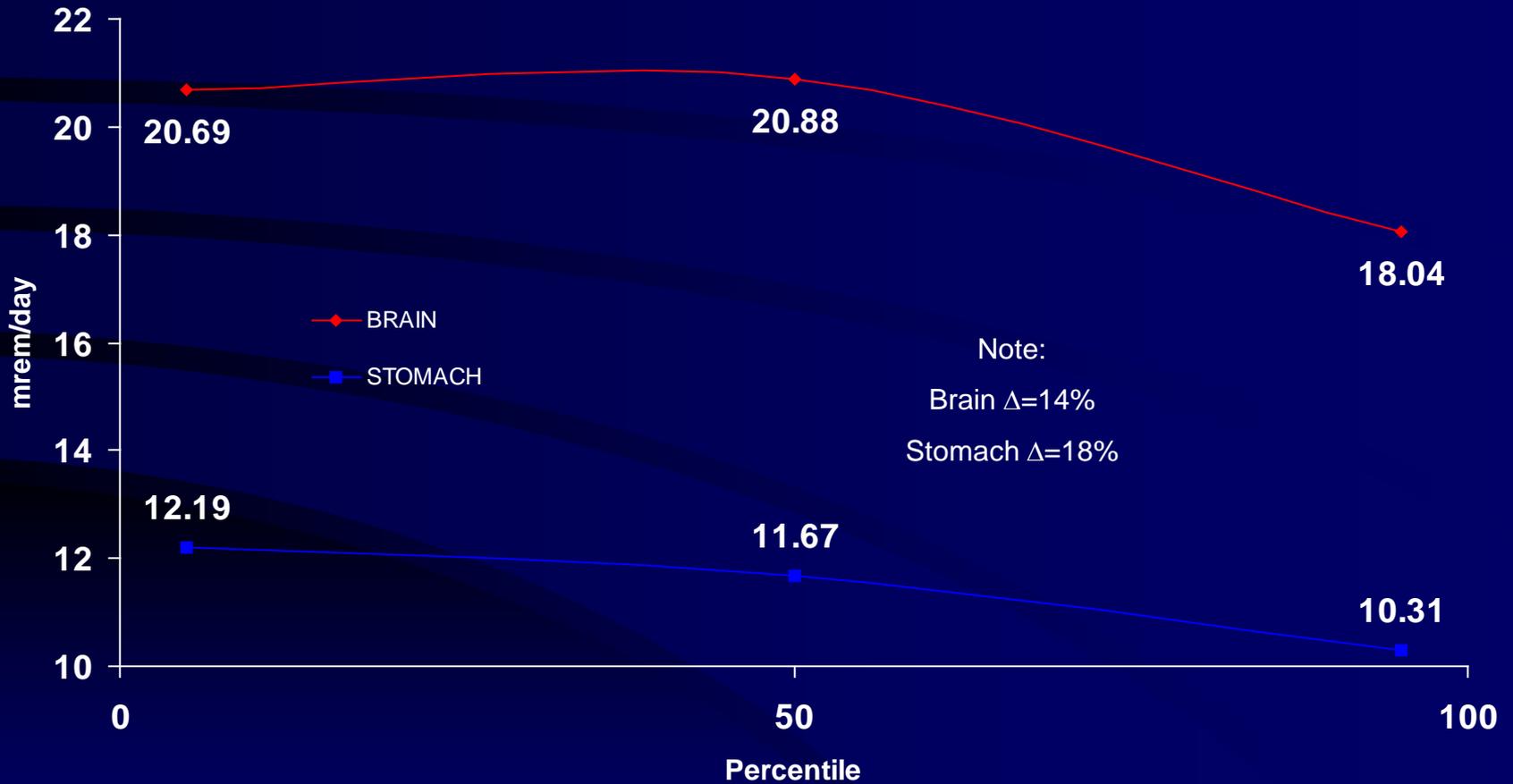
Scaling

- CAM was originally based on the 50th percentile AF male
- With the work of Billings and Yucker (1992), and with recent additions to the CAMERA driver program by Atwell (1998), the CAM/CAF models can be sized selectively to more accurately reflect crewmembers' body sizing/type

Scaling - Sample Doses



Scaling-Sample Dose Equivalent



Materials

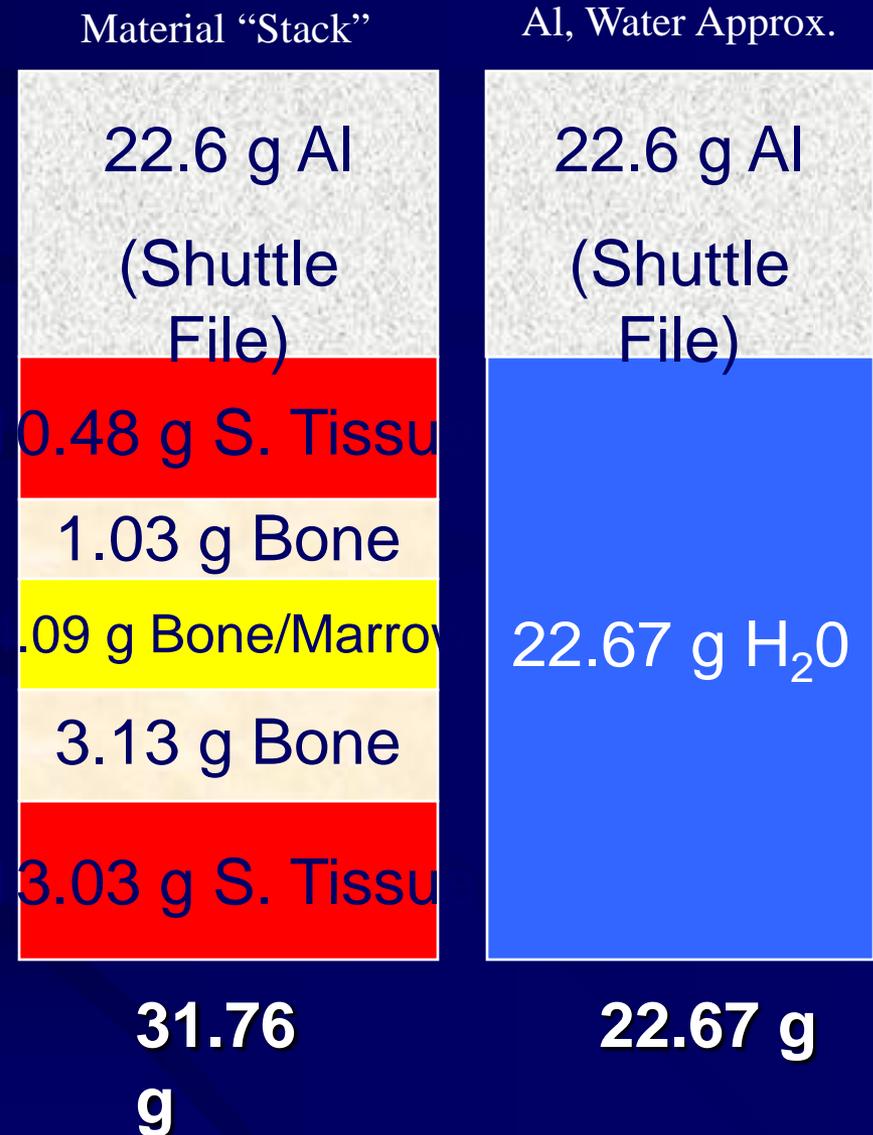
- By convention, materials are assumed to be either Al, or Water (or converted by 50 MeV proton range scaling)
- CAM/CAF, CAMERA are constructed to provide material information
- Different Computational Approach, instead of interpolating over a dose vs. depth array, transport model performs the calculation along each of the n directions in space separately
- Increases computational time by ~X60
 - Parallel Computing?

Materials

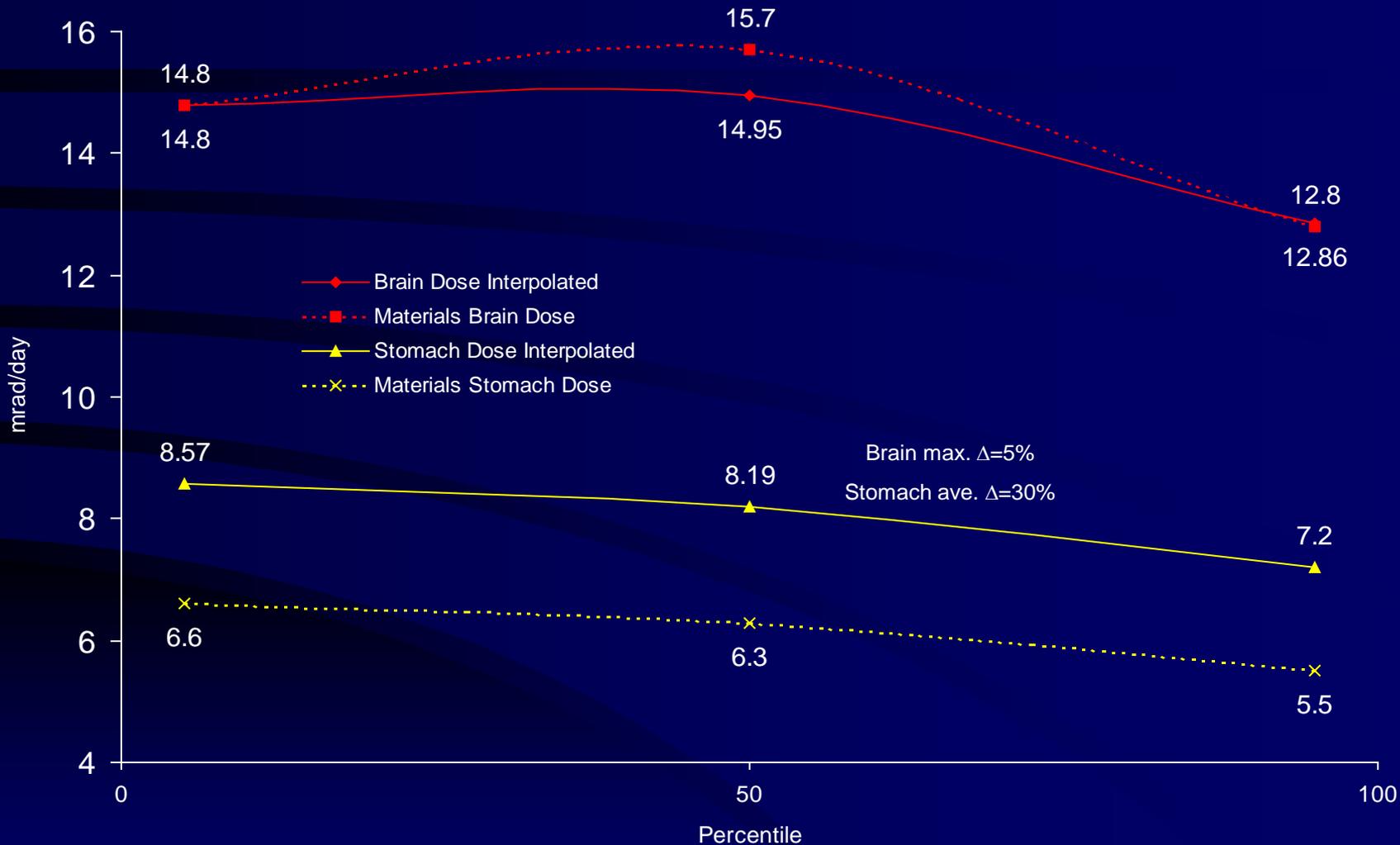
- Body structures modeled to the tissue/organ level

| <i>water/stack</i> | <u>DOSE</u> | <u>DOSE EQ</u> |
|------------------------|-------------|----------------|
| 200 MeV p, | 155% | 147% |
| 500 MeV p, | 90% | 101% |
| 1000 Mev p, | 70% | 106% |
| SPE, | 106% | 91% |
| Trapped p, (STS-91) | 170% | 165% |

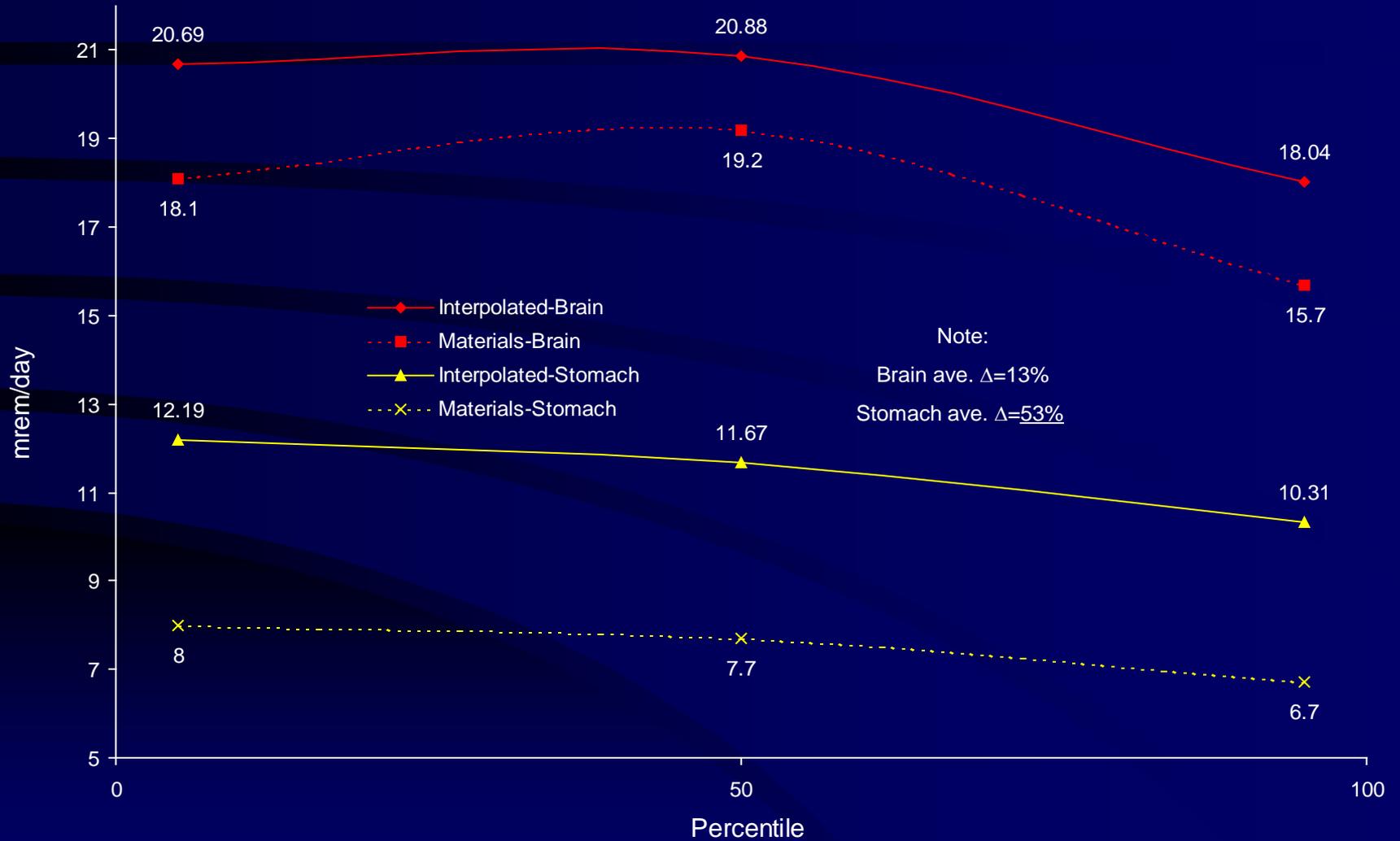
- Note: This is an example of a thick shield value, and so yields a much larger difference than the average of a shield distribution.



Materials-Sample Doses



Materials-Sample Dose Equivalent



Conclusions/Ideas

- The maximum (CAM, trapped proton) difference in D. Eq., taking into account both scaling and materials, is $\sim X2$ (stomach \sim deeper organ). CAF results are $\sim 110-115\%$ of CAM, show the same trends.
- The CAM model system is a useful, relatively (geometrically) accurate model.
 - Strengths- resolution, ease of modification, independence on platform/software, and simplicity
 - Weakness' - difficulty of visual representation (error detection), standardization, maintenance, and method of deriving material equivalence
- Future work - Benchmarking, (PTE, Accelerators, etc.)