Comparison of Organ Dosimetry for Astronaut Phantoms

Earth-Based vs. Microgravity-Based Anthropometry and Body Positioning

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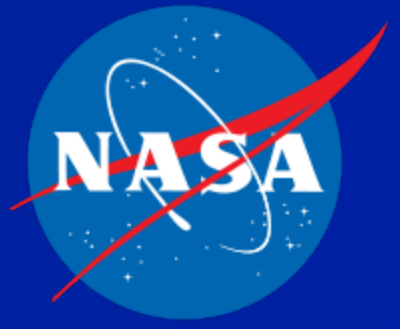
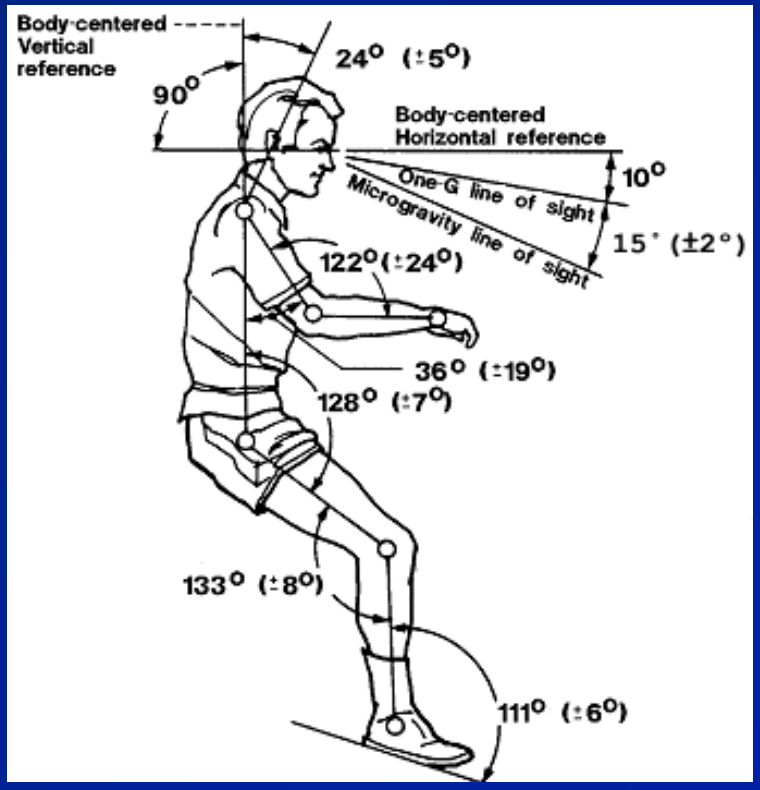


Introduction

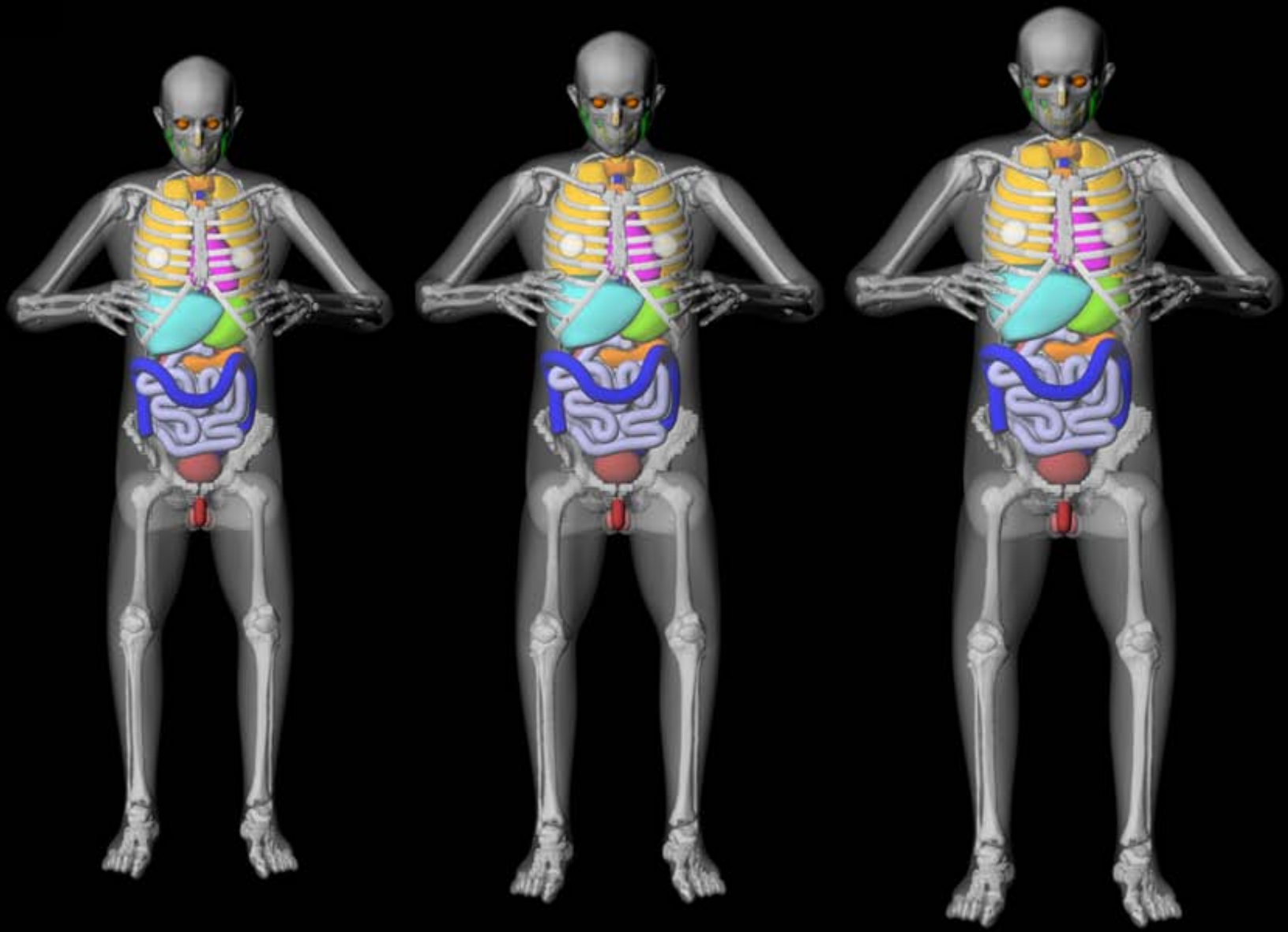
- Space Radiation Exposure
  - Trapped protons
  - GCR
  - SPE
- Computational phantoms
  - CAM (1973)
  - CAF (1992)
  - UF phantoms
- Transport and Dosimetry
  - BRYNTRN
  - HZETRN



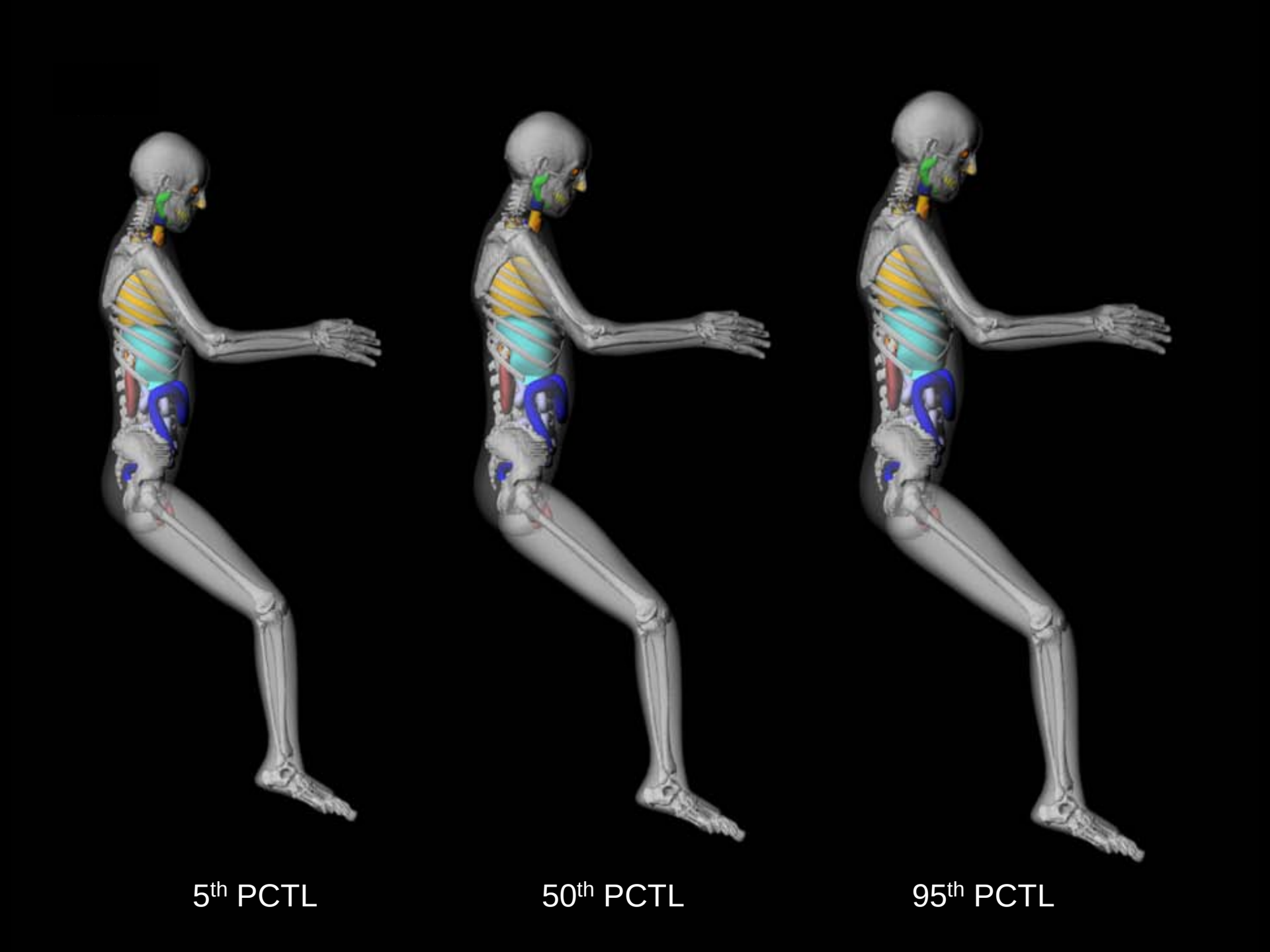
NASA MSIS (1995)

Microgravity-Induced Changes

Microgravity Effect	*UF Hybrid Phantom Change*
Loss of leg volume	Scale thighs in 2D to reduce leg volume by 10%
Sitting height increase	Scale torso outer body contour and spine by a factor of 1.03 in z-direction
Cardiac atrophy	Reduce overall heart volume by 10%
Bone mineral density loss	Reduce bone density of trabecular bone by 10% for spine, hips, and proximal femora
Overall mass loss	Remove mass from lower torso, targeting 4-5% mass loss
Neutral body posture	Reposition arms, legs, and head, using NASA MSIS as a guide

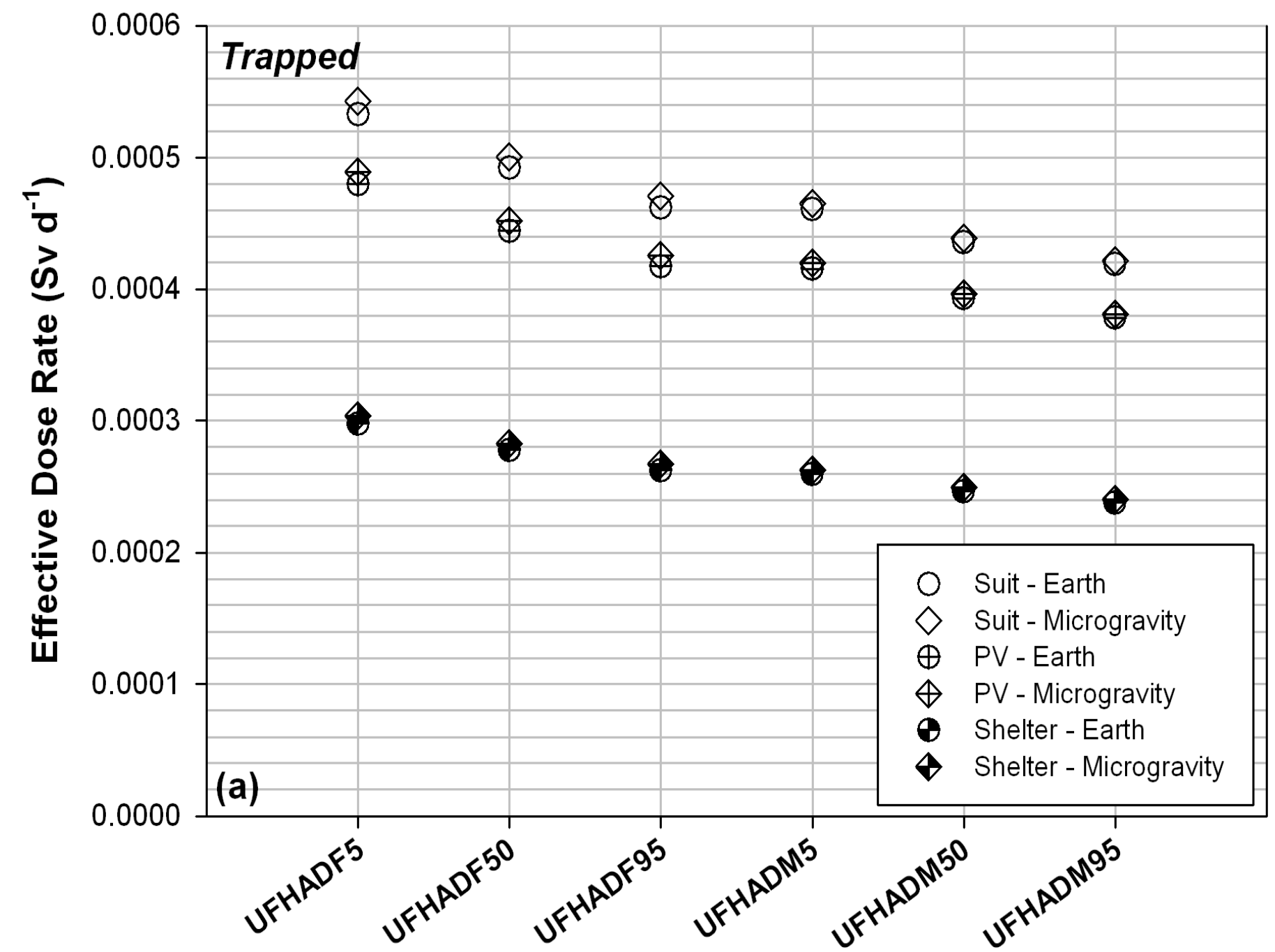


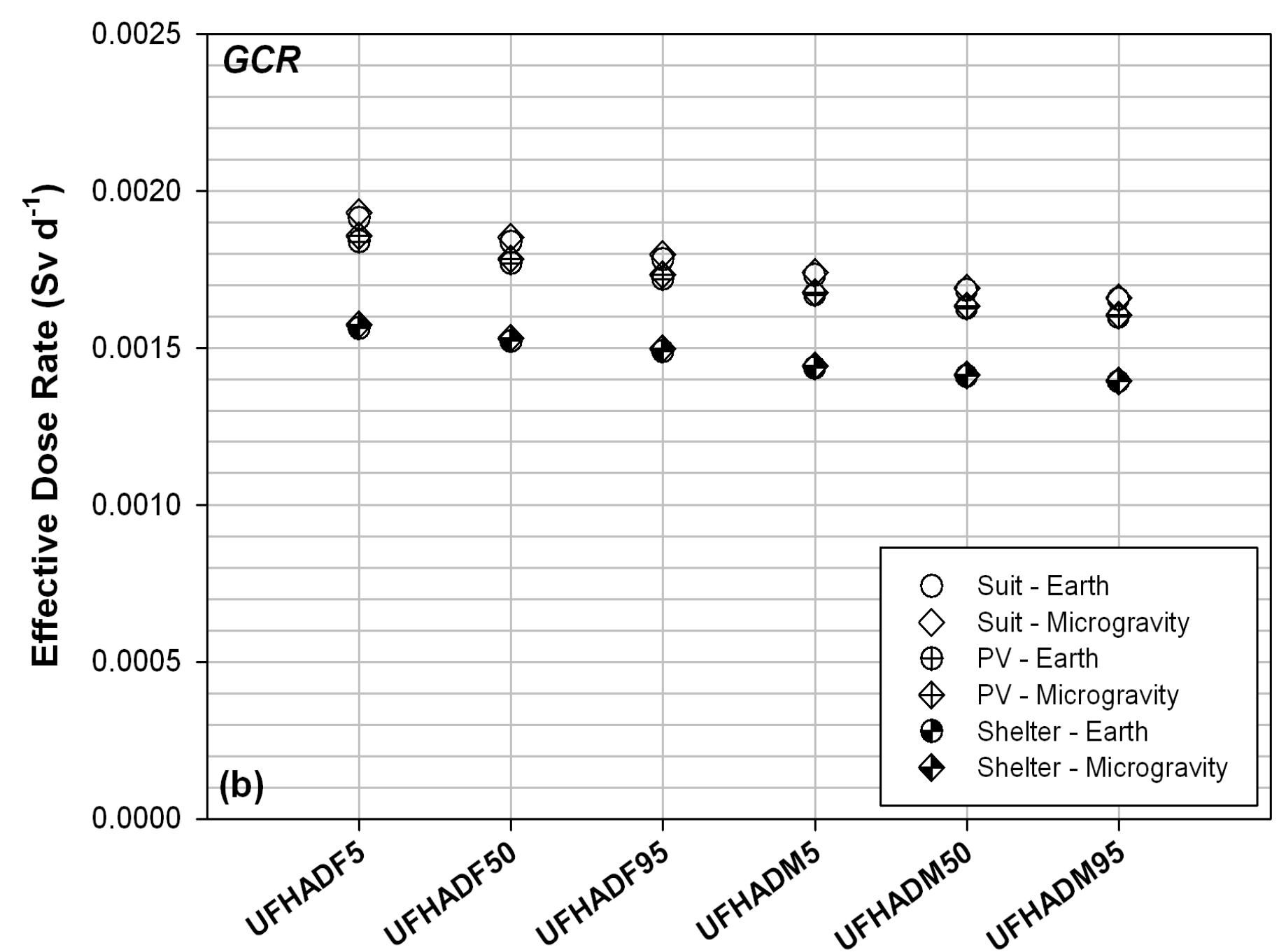
5th PCTL 50th PCTL 95th PCTL

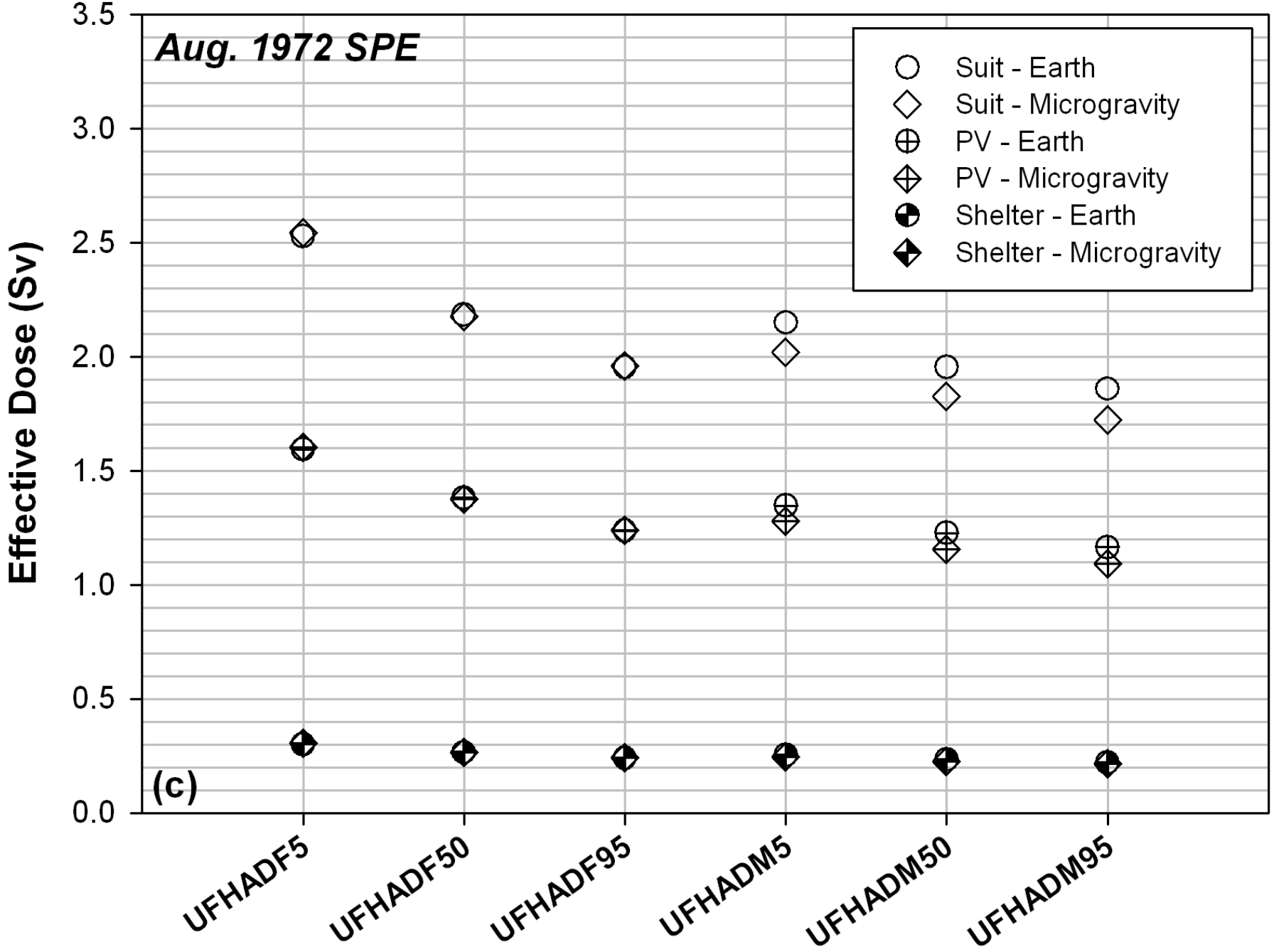

5th PCTL
50th PCTL
95th PCTL

Transport and Dosimetry

- Transport
  - One-dimensional deterministic
  - Straight-ahead approximation
  - Convert 3D geometry to 1D
- Dosimetry
  - ICRP 60 quality factor
  - Dose and dose equivalent vs. aluminum and water depth
  - Isotropic irradiation

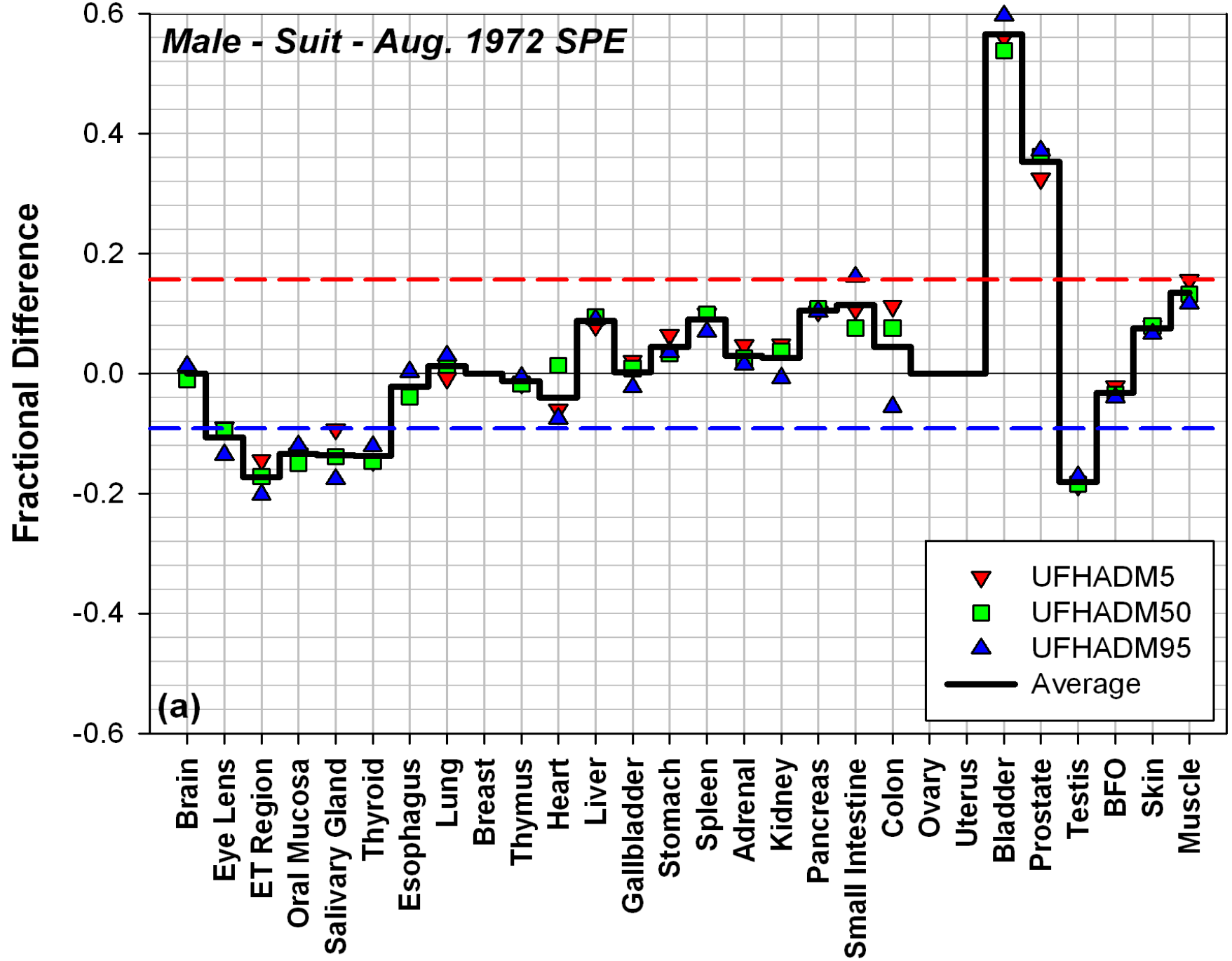

Trapped
Effective Dose Rate (Sv d-1)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
(a)
UFHADF5
UFHADF50
UFHADF95
UFHADM5
UFHADM50
UFHADM95
Suit - Earth
Suit - Microgravity
PV - Earth
PV - Microgravity
Shelter - Earth
Shelter - Microgravity


GCR
(b)
Effective Dose Rate (Sv d-1)
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
UFHADF5
UFHADF50
UFHADF95
UFHADM5
UFHADM50
UFHADM95
Suit - Earth
Suit - Microgravity
PV - Earth
PV - Microgravity
Shelter - Earth
Shelter - Microgravity


Aug. 1972 SPE
Suit - Earth
Suit - Microgravity
PV - Earth
PV - Microgravity
Shelter - Earth
Shelter - Microgravity
Effective Dose (Sv)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
(c)
UFHADF5
UFHADF50
UFHADF95
UFHADM5
UFHADM50
UFHADM95

Implications for Space Dosimetry

- Effective dose
  - Very small differences seen for GCR and trapped protons
  - Slight decrease for male in Aug. 1972 SPE due to shielding of testes
- Organ dose equivalent differences
  - GCR: < 5%
  - Trapped: < 15%
  - Aug. 1972 SPE: up to 60%
- Body position optimization during SPE


Male - Suit - Aug. 1972 SPE
Fractional Difference
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
(a)
UFHADM5
UFHADM50
UFHADM95
Average
Brain
Eye Lens
ET Region
Oral Mucosa
Salivary Gland
Thyroid
Esophagus
Lung
Breast
Thymus
Heart
Liver
Gallbladder
Stomach
Spleen
Adrenal
Kidney
Pancreas
Small Intestine
Colon
Ovary
Uterus
Bladder
Prostate
Testis
BFO
Skin
Muscle

Comparison with Ion Therapy

Characteristic	Space Radiation	Ion Therapy
Health Status	Very healthy	Afflicted with disease
Occurrence	Undesirable	Intentional
Radiation Species	Protons Heavy ions up to U	Protons Heavy ions (C, Ne)
Energies	Spectrum < 1 AMeV to 50 AGeV	Discrete 100s AMeV
Dose Deposition	Depth dose curve	Bragg Peak
Geometry	Isotropic	Highly directional
Fragmentation	Shielding difficulty	Dose to critical organs
Morphometry changes	Small impact on *E* Varying effect on *H*	Very important Clinically relevant

Conclusion

- In terms of effective dose, little change is seen from incorporating microgravity-induced morphometry changes
- Larger effects observed on organ dose equivalent
- Overlap in interest between space radiation and ion therapy (2011 NCRP Annual Meeting)
  - Cross-sections
  - Transport
  - Epidemiology
- Other areas of common interest should also be explored

References

- Bahadori AA, Van Baalen M, Shavers MR, Dodge C, Semones EJ and Bolch WE 2011 Effect of anatomical modeling on space radiation dose estimates: A comparison of doses for NASA phantoms and the 5th, 50th, and 95th percentile male and female astronauts *Physics in Medicine and Biology* **56** 1671
- Billings M P and Yucker W R 1973 The Computerized Anatomical Man (CAM) Model Final Report (Houston, TX: NASA)
- Yucker W R and Huston S L 1990 Computerized Anatomical Female Final Report *MDC H 6107 (Huntington Beach, CA: McDonnell Douglas Space Systems Company)*
- NASA 1995 Man-Systems Integration Standards Revision B *NASA-STD-3000 (Washington, DC: NASA)*