SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Personal Dosimetry of Workers without a physical dosimeter

"An Innovative Application Using Computational Methods"

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LIÈGE université

Personal Dosimetry: Back to Basics

- **Personal dosimetry** is the act of measuring radiation doses to workers exposed to ionizing radiation

Organ Absorbed Dose (Gy) → Equivalent Dose (Sv) → Effective Dose (Sv)

W_R Radiation Weighting Factor

W_T Tissue Weighting Factor

$$H_T = \sum_R w_R D_{T,R}$$

$$E = \sum_T w_T \left[\frac{H_T^M + H_T^F}{2} \right]$$

Physical Quantities

KERMA (Gy)

Kinetic energy released in matter

Protection Quantities **Non-mesurable**

→ Need for Operational Quantities

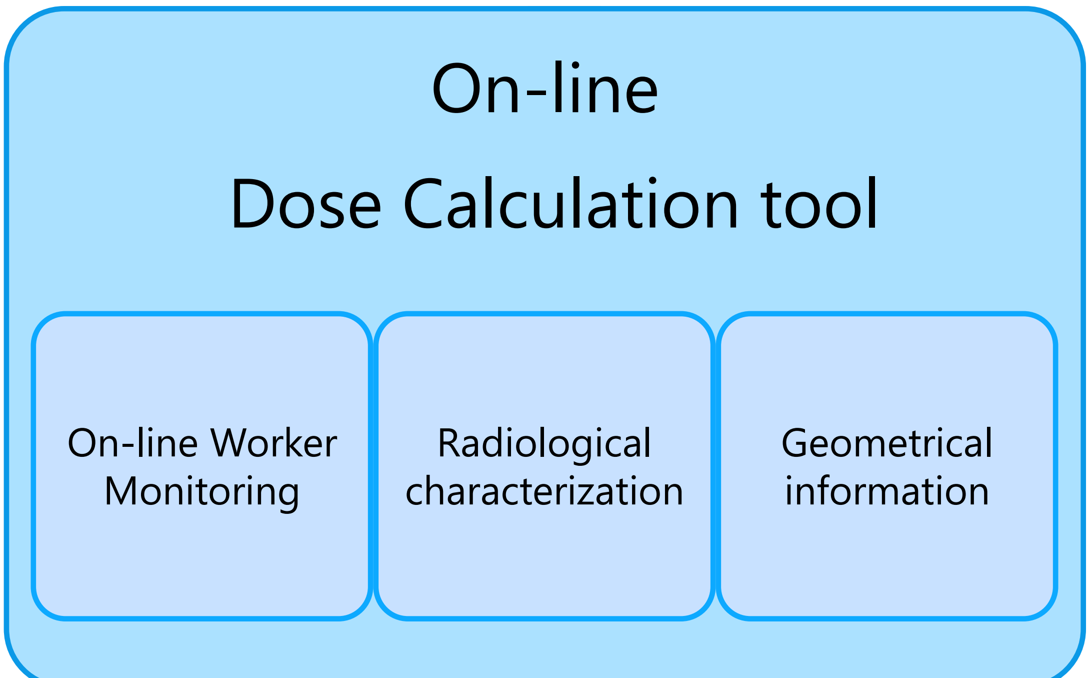
Personal Dose Equivalent $H_p(d)$ with d: 10, 3, 0.07 mm



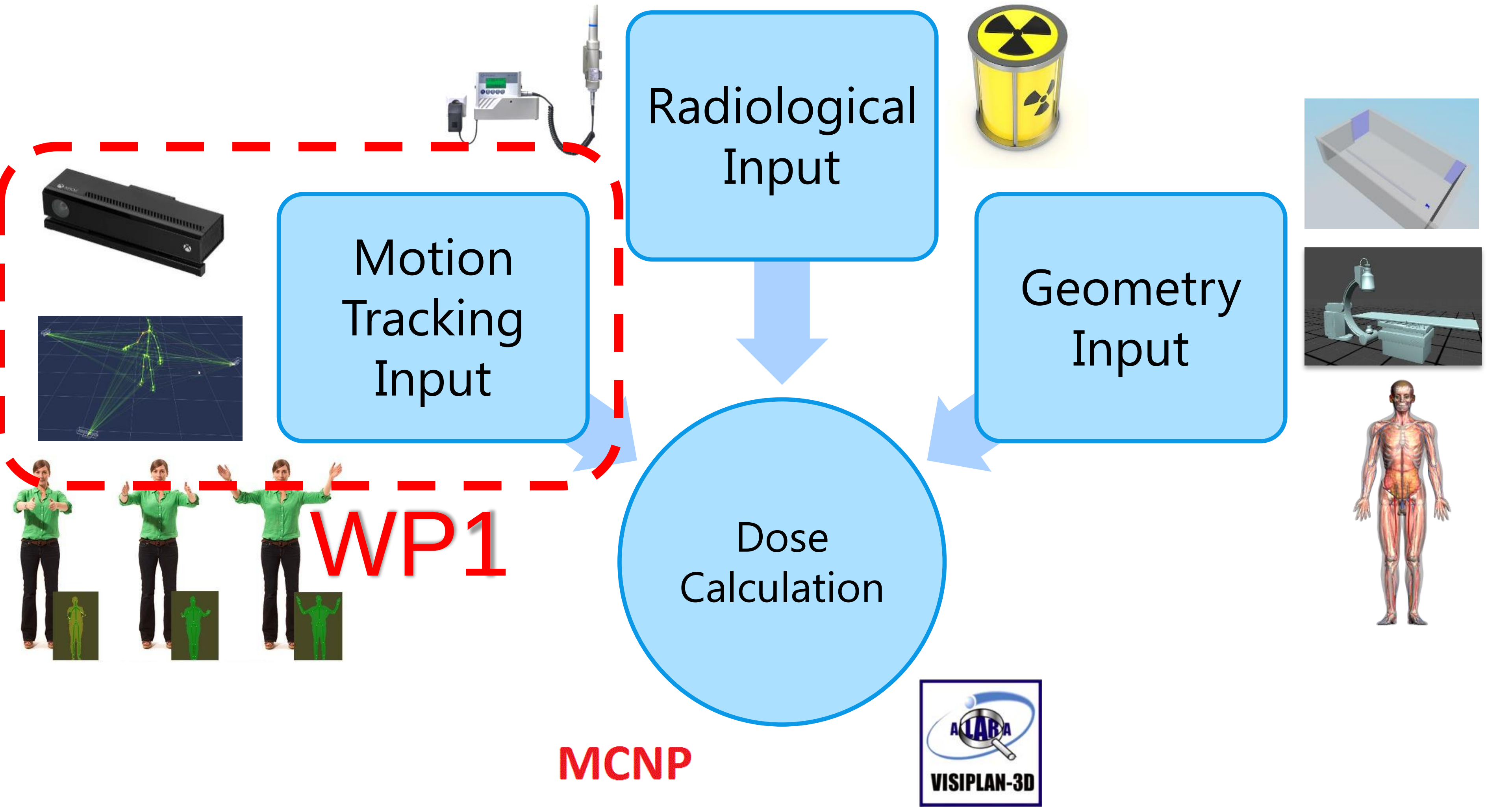

***ICRP Publication 103 (2007)**

Personal Dosimetry: Future

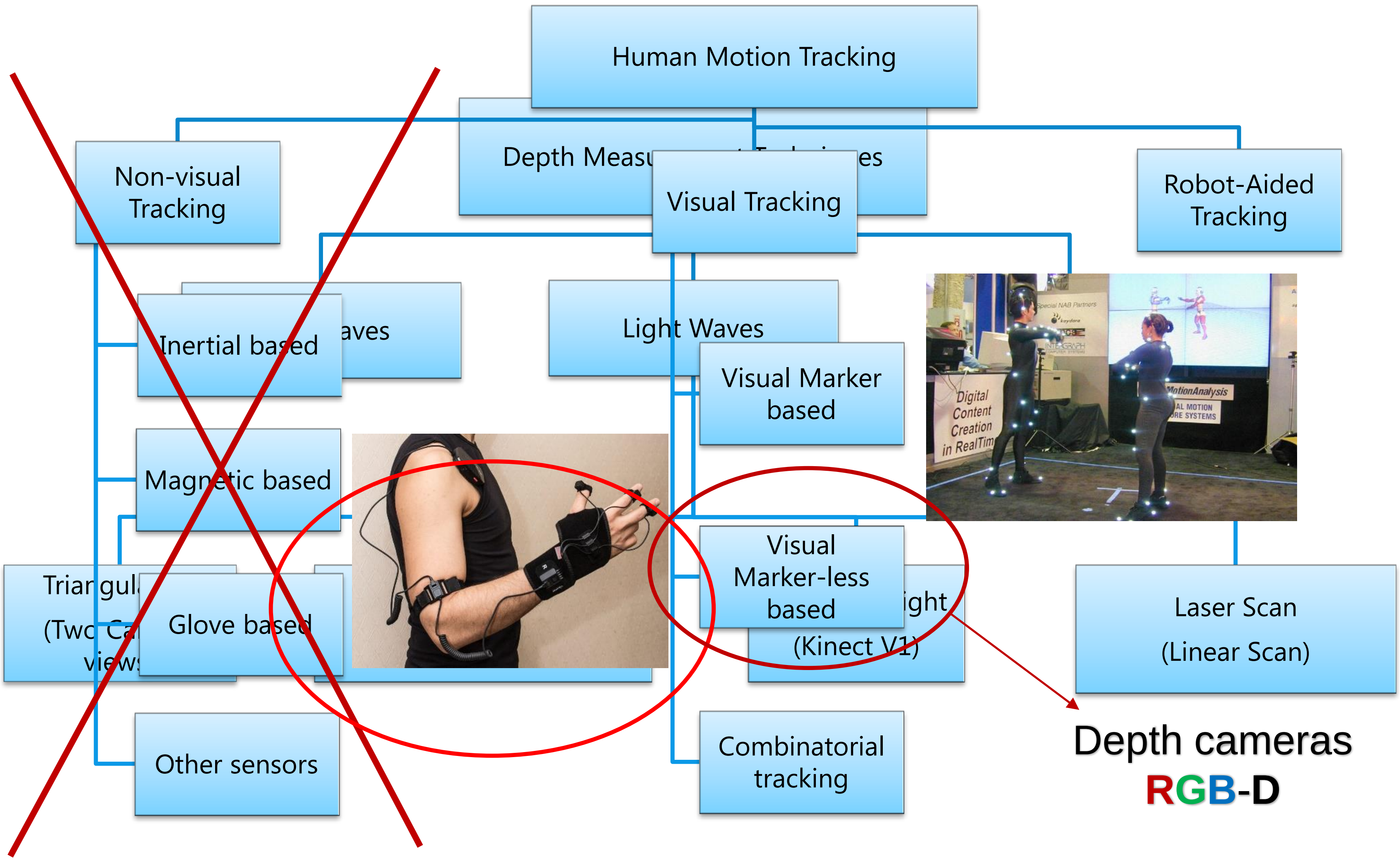
- Development in direction of wireless, small, active dosimetry systems (Cost?? Reliability??)
- Is $H_p(10)$ adequate quantity for dosimeters? Individualized dosimetry
- May be no need for physical dosimeters



Computational Personal Dosimetry
General Methodology

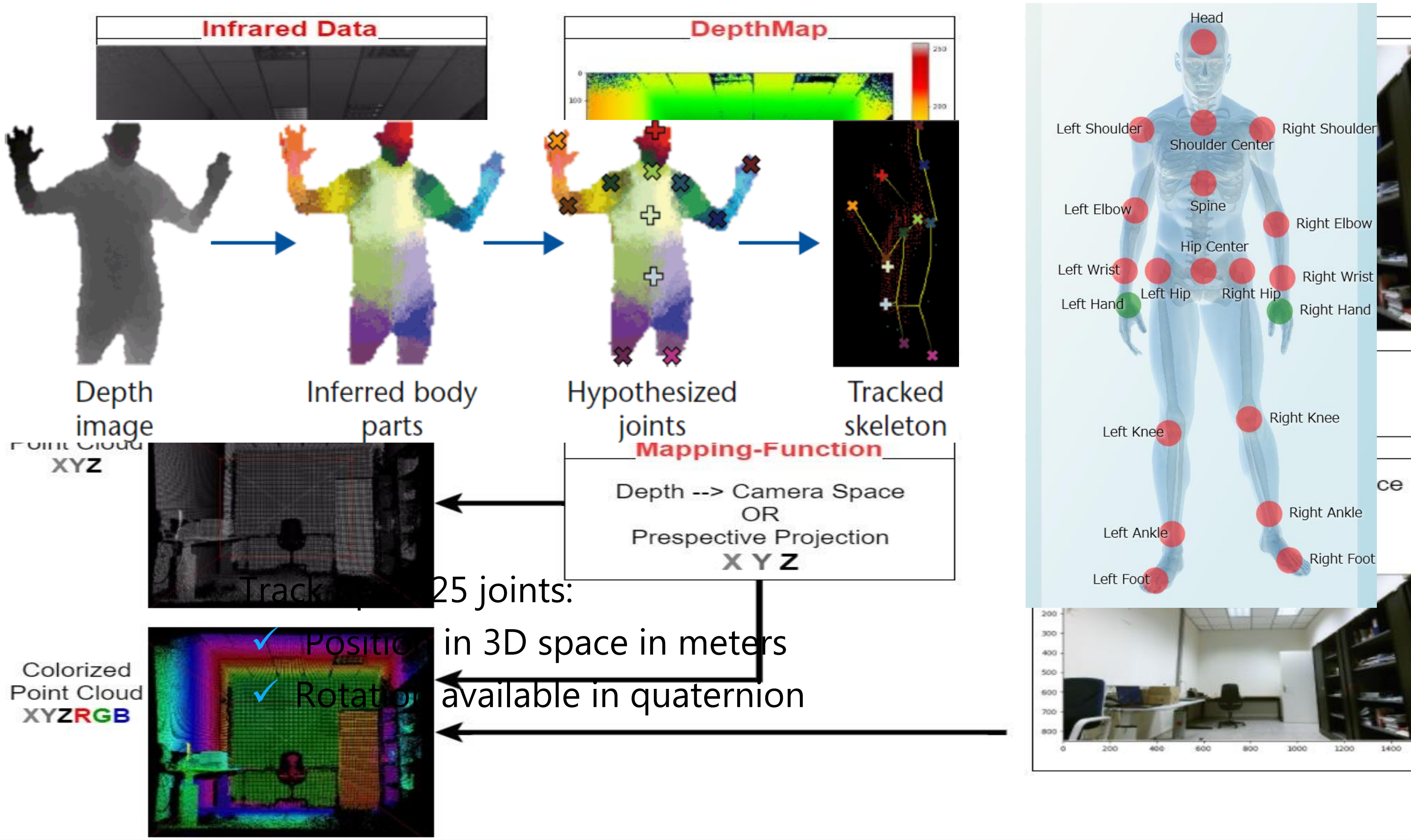


WP1: Motion Tracking



Microsoft® Kinect V2: How it works?

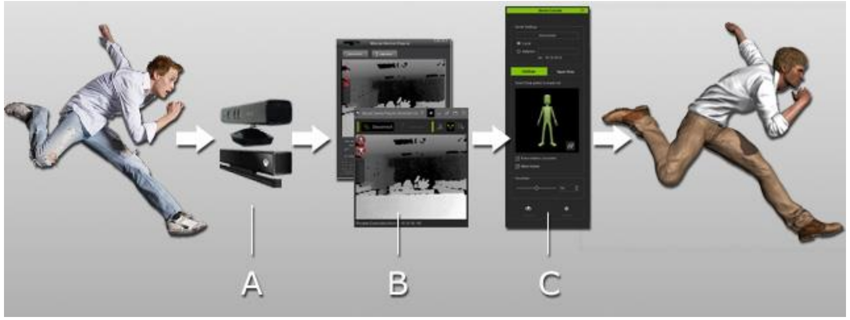
- Basic principles: Skeleton Tracking
- Basic principles: ToF (Time-of-Flight)

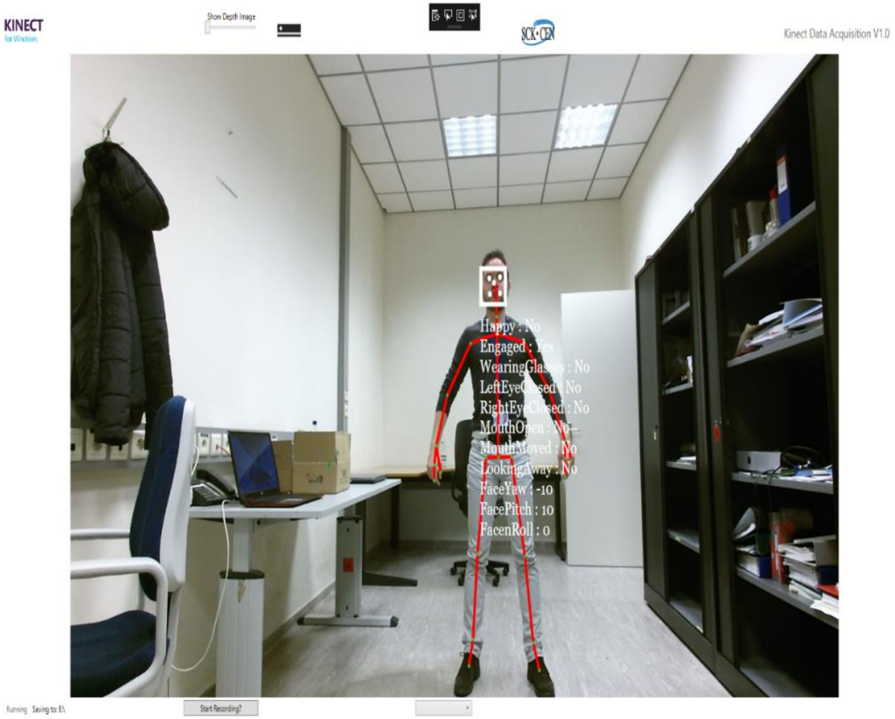


Track … 25 joints:

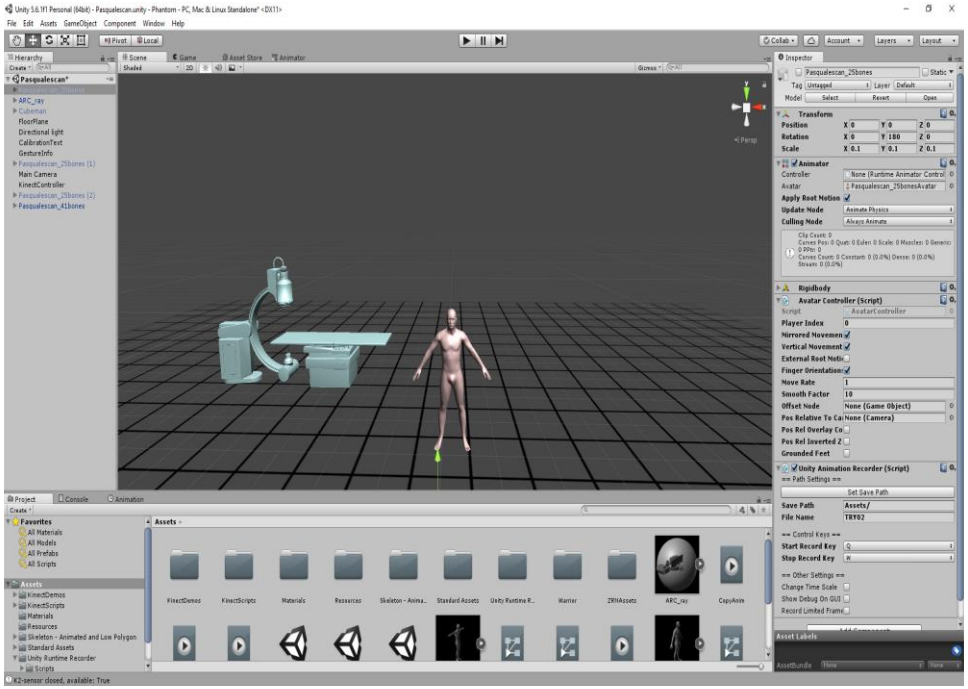
- ✓ Positio… in 3D space in meters
- ✓ Rotatio… available in quaternion

3D Motion Tracking



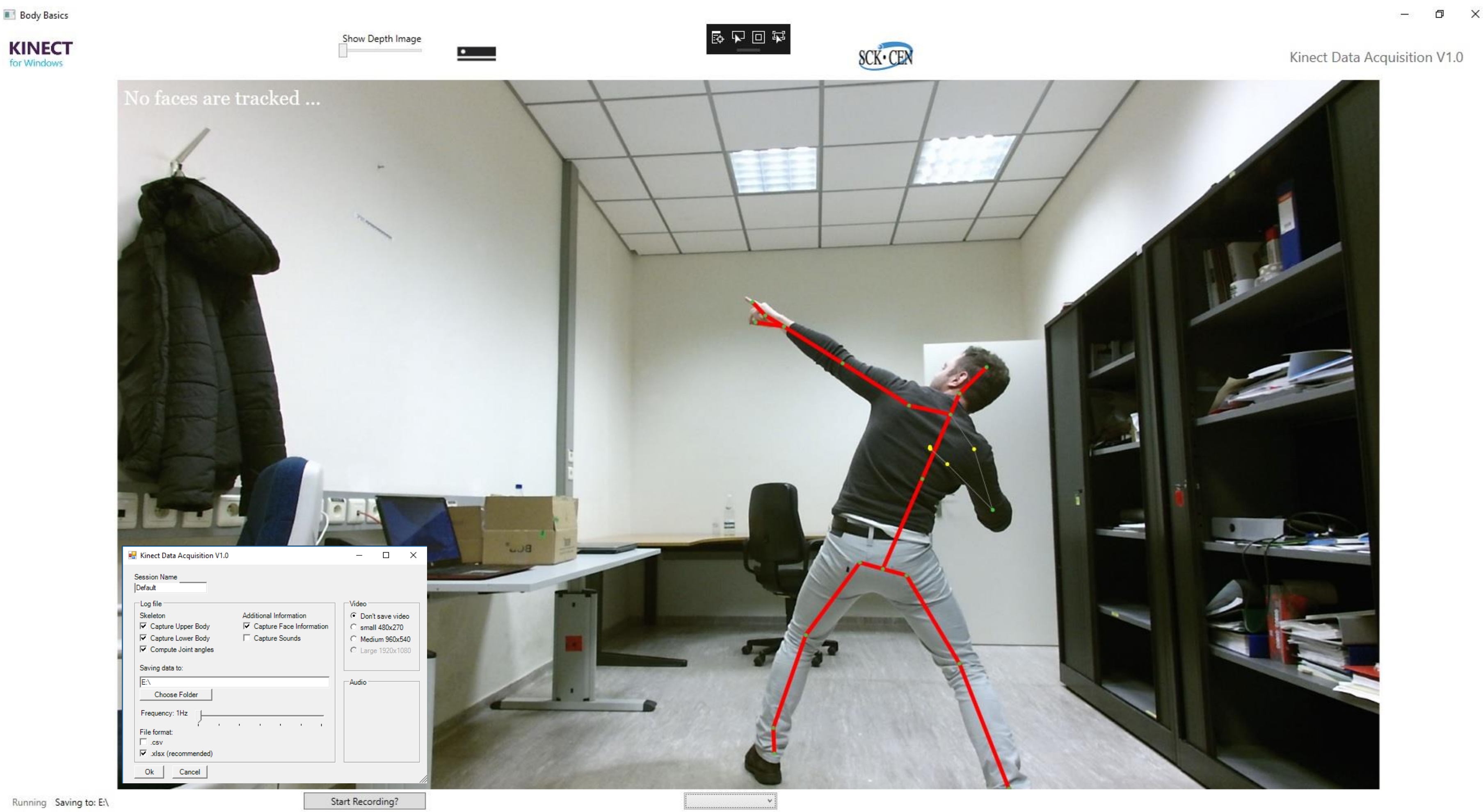


B



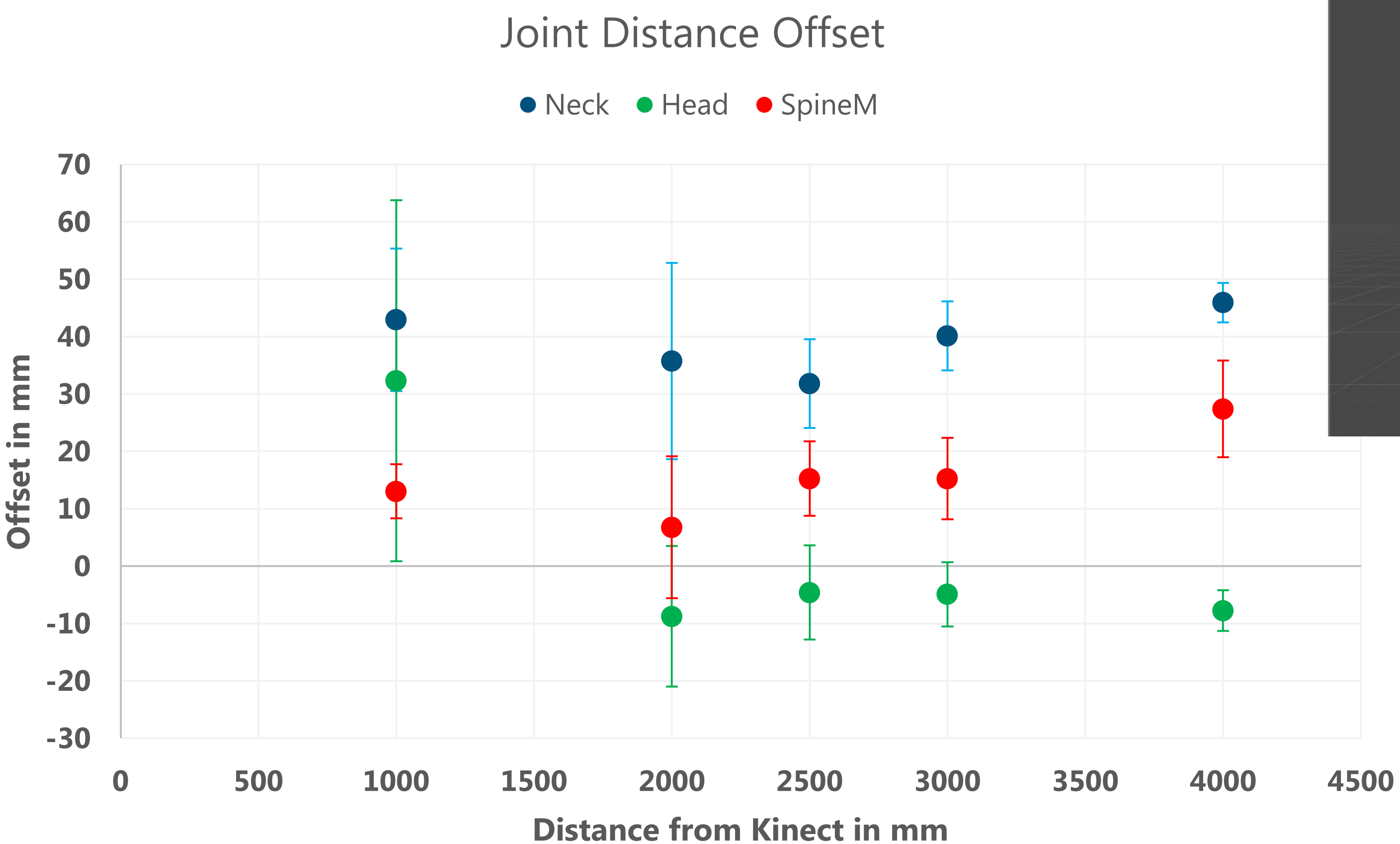
C

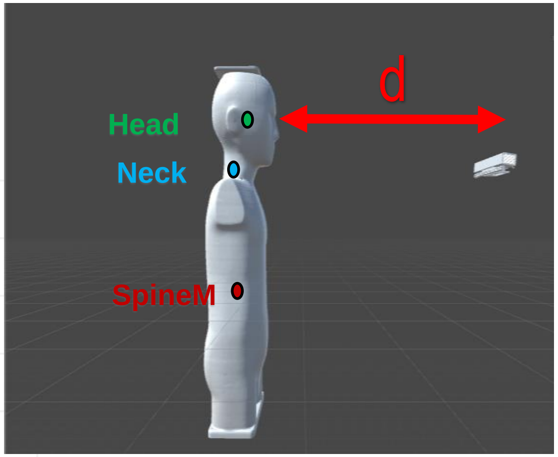
Kinect Data Acquisition V1.0



Skeleton Tracking Accuracy

Comparison of the captured depth value of skeletal joints with the ground truth distance from Kinect V2





Evolution of Computational Phantoms

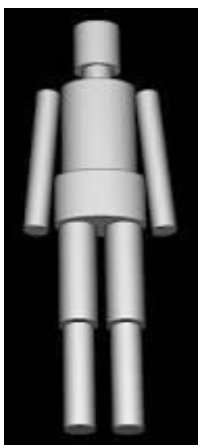
Computational phantoms development of very detailed and realistic anatomy

1950's Simple phantoms

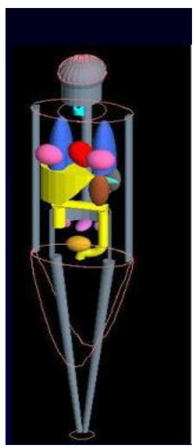
1960's Stylized phantoms

1980's Voxel phantoms

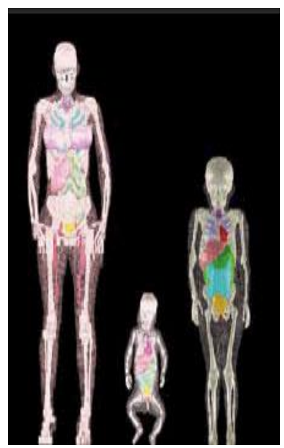
2000's Hybrid phantoms



BOMAB Phantom



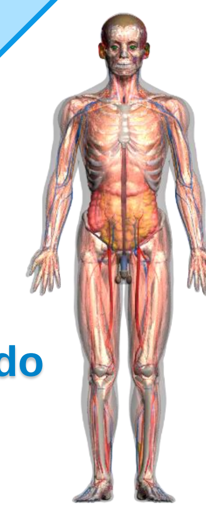
ORNL Phantom



Irene, Baby & Child Voxel Phantoms

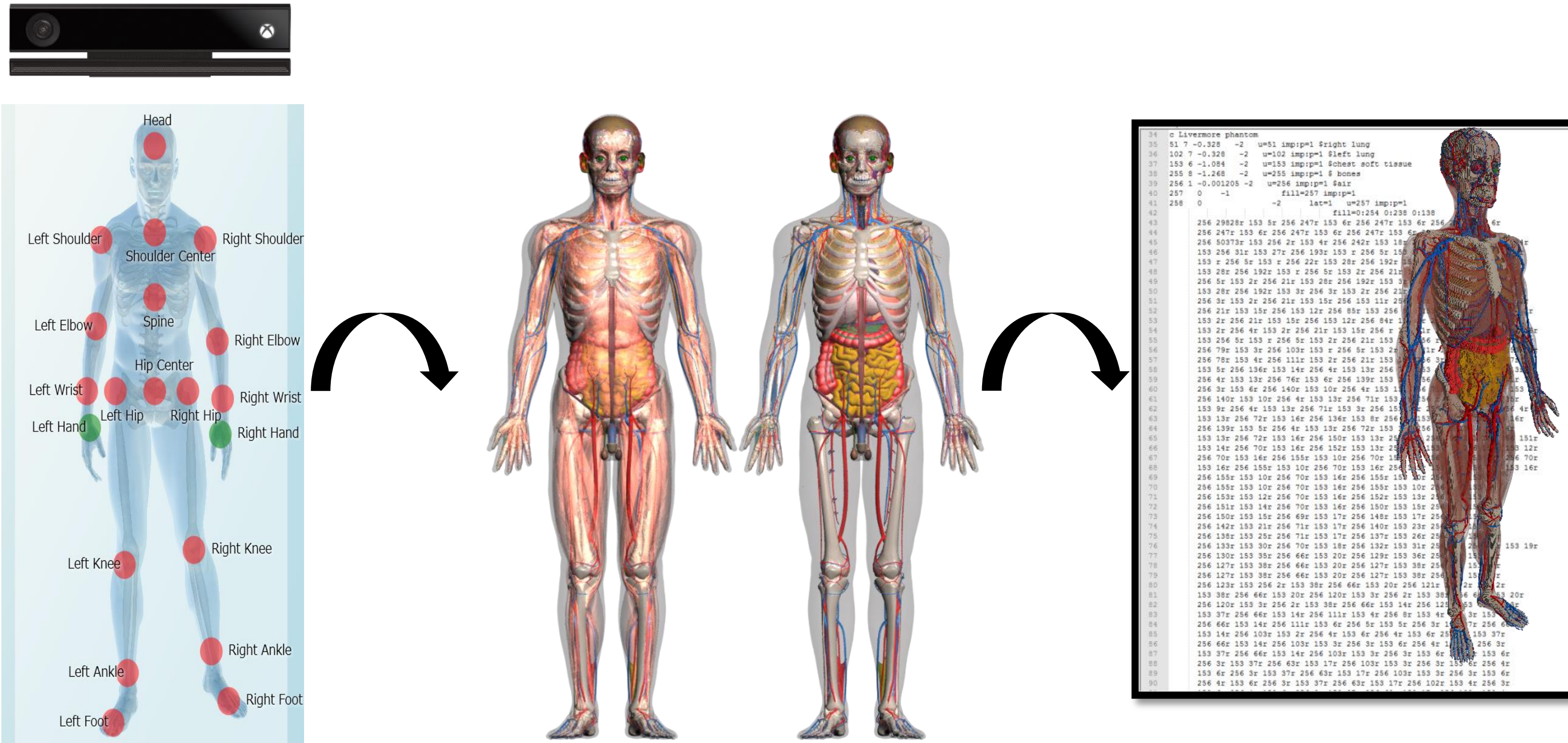
Adult male Phantom

PhD P. Lombardo



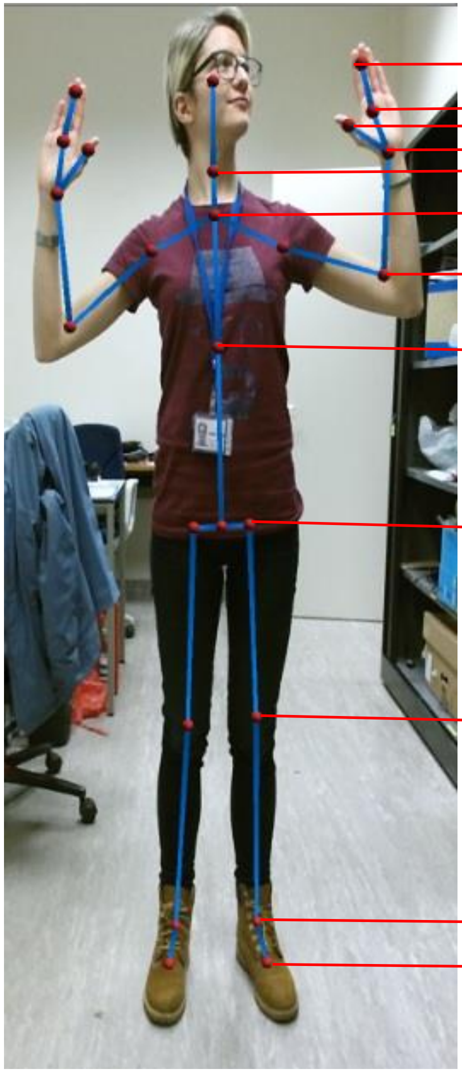
Realistic Anthropomorphic Flexible Phantom

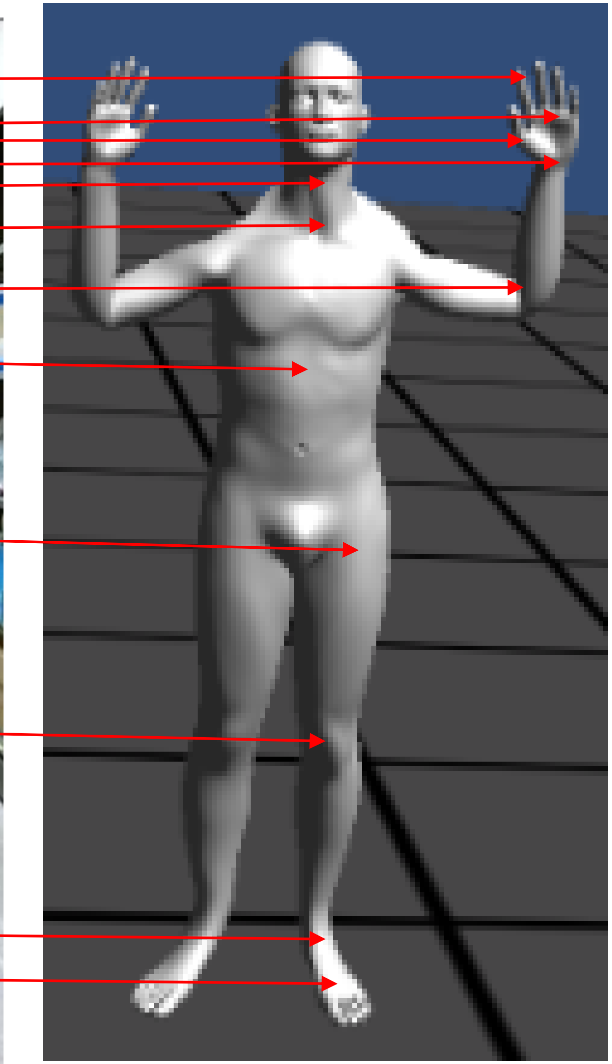
Tracking to computational phantom

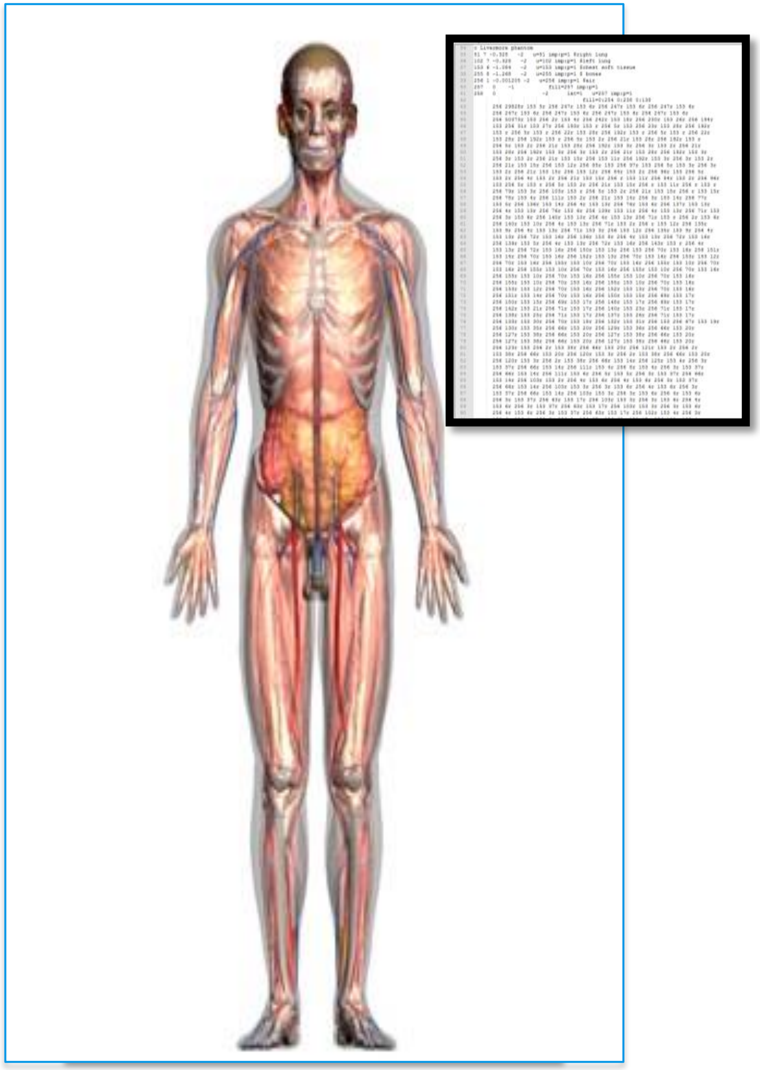


Realistic Anthropomorphic Flexible Phantom

From Tracking to MCNP

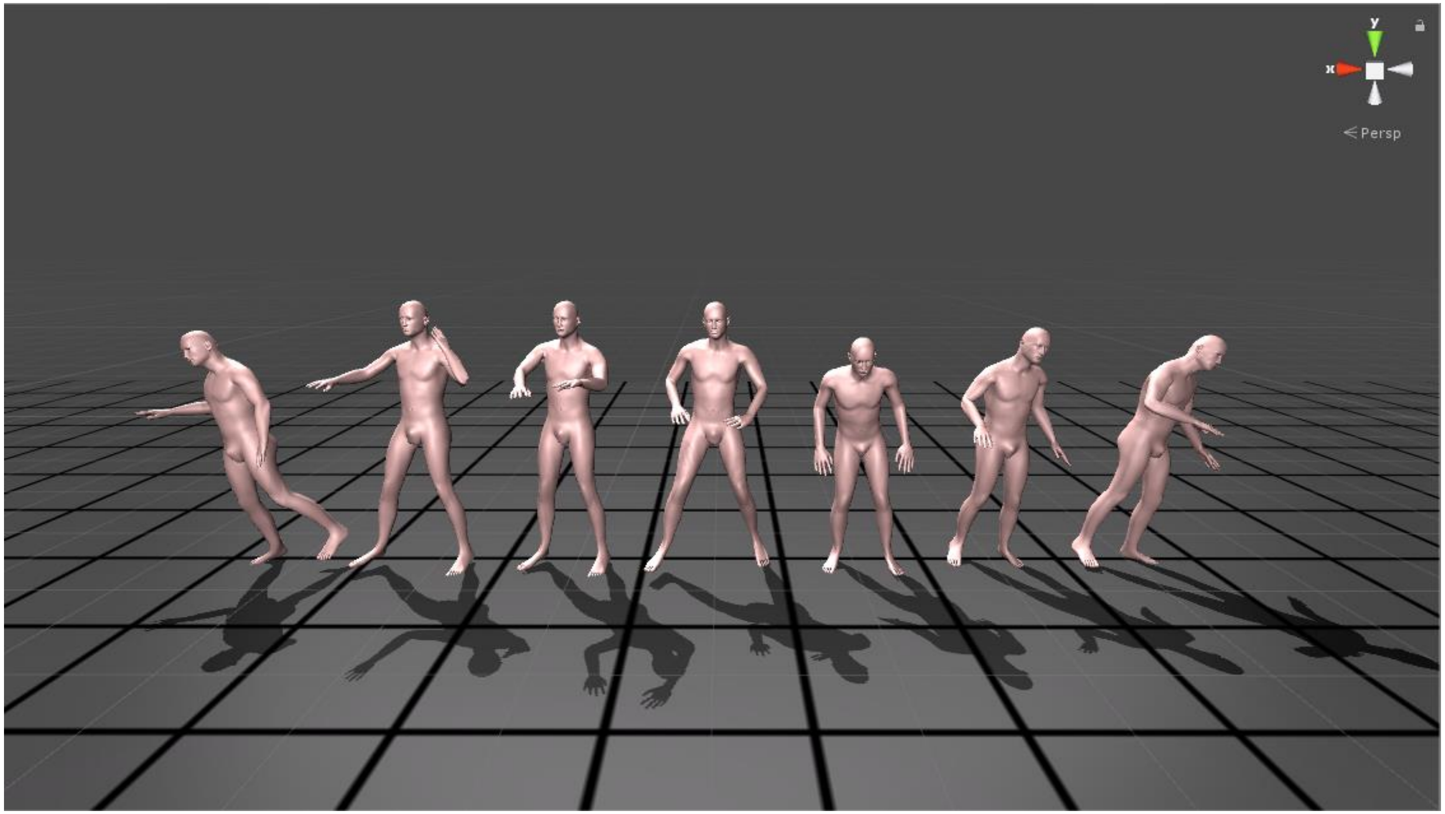




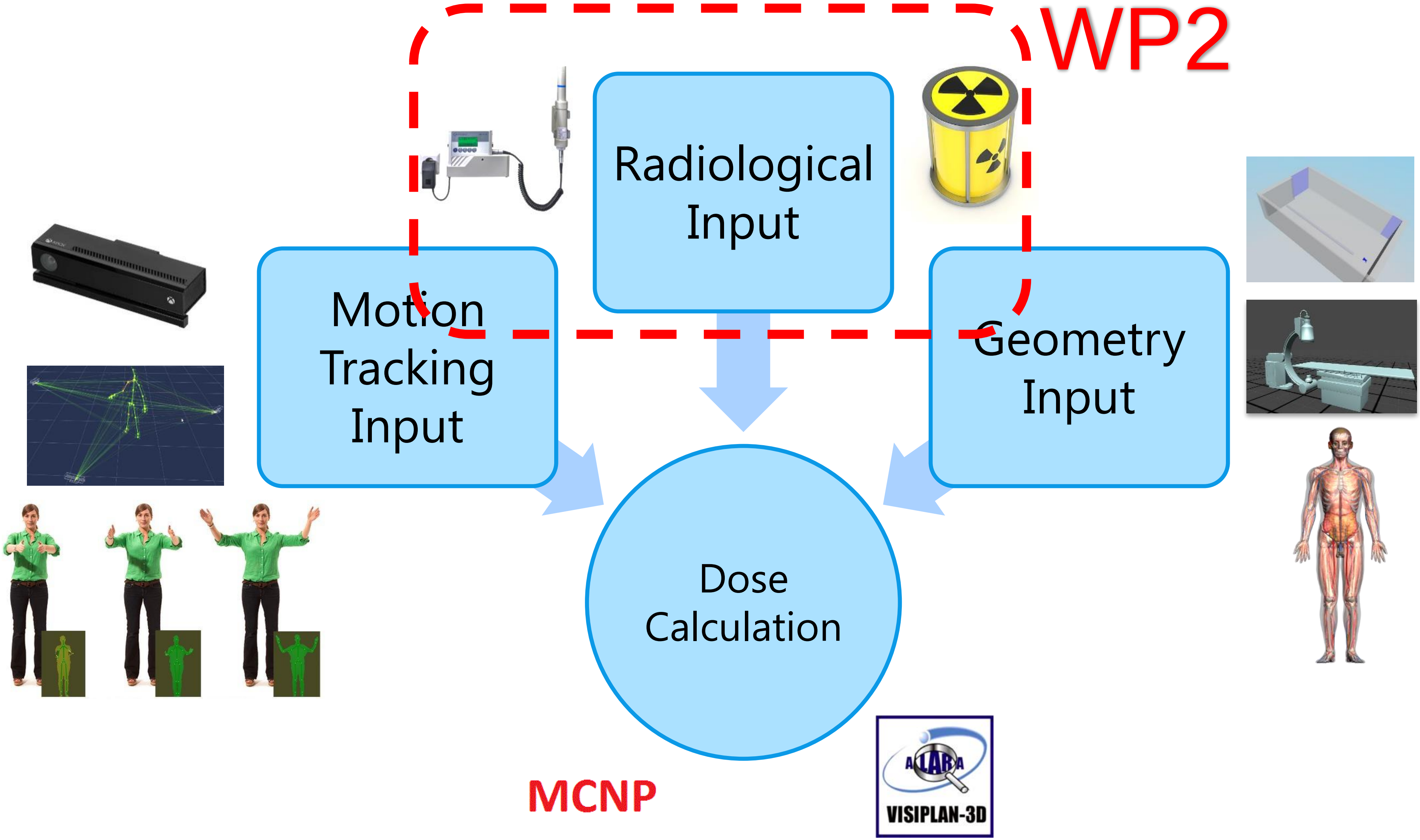


Flexible Phantom Animation

- Motion is captured frame by frame
- Every frame, an input file can be generated
  - Investigation of optimum frequency and accuracy

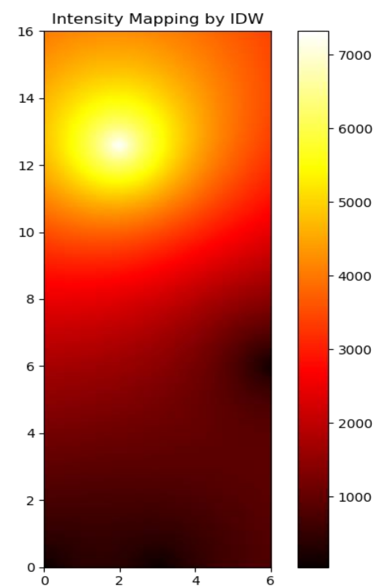


General Methodology



Radiological Input

- Definition of the radiation field in the calculation tool: source geometry, spectrum, activity,...etc.
- Two types of fields:
  - Stable radiation fields
    - Field mapping using Monte-Carlo calculations
  - Radiation field change with time
    - Periodical MC simulation for field characterization and normalization
- Two scenarios:
  - Known source data
  - Unknown source data
- Few dose area monitors to estimate unknown source parameters
- Algorithm to locate unknown radioactive source and estimate source strength with 3 dose rate meters using IDW/kriging interpolation



Geometry Input

- Define of the workplace geometry for the calculations

Geometrical input

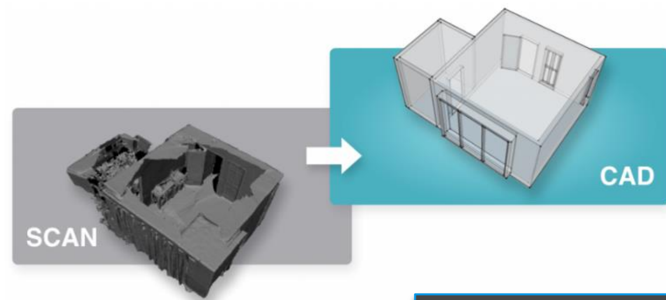
From Technical Drawings
Survey Techniques
Photogrammetry
Laser Scanning

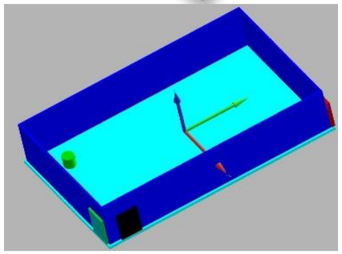
Primitive Volumes

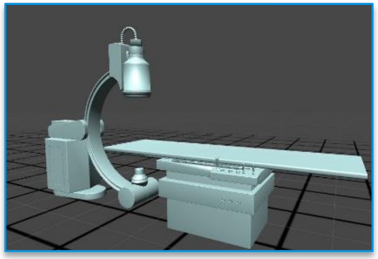
Material input

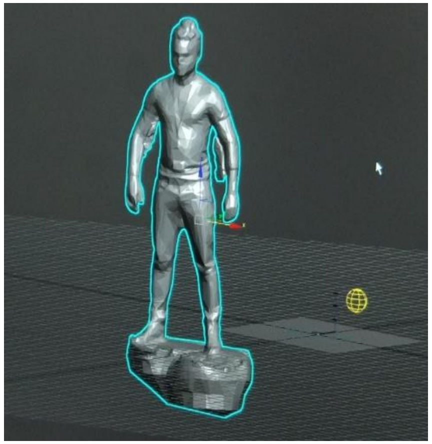
Technical Data
Experts on site

Material Dataset









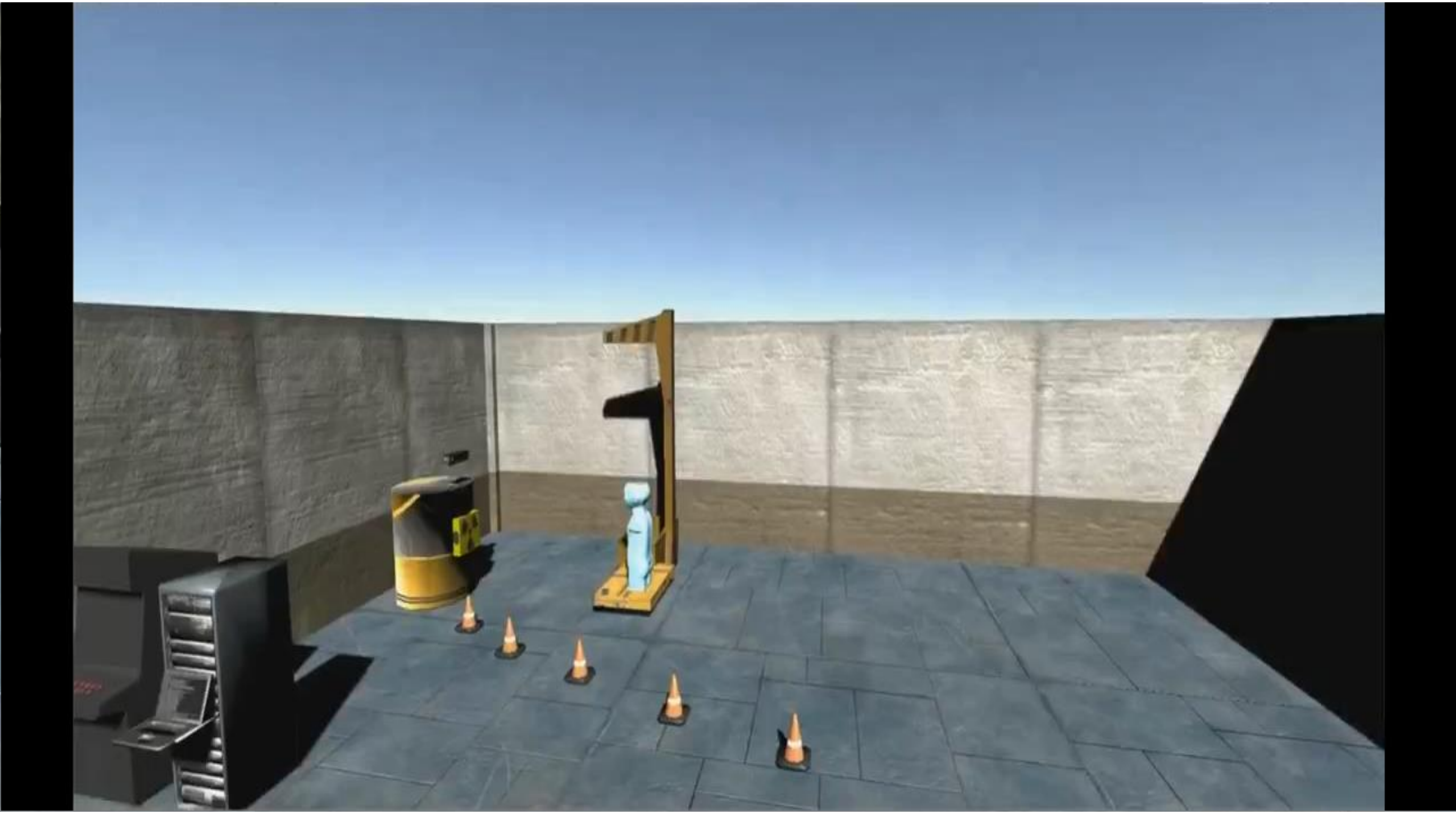
- Simple geometries can be easily modeled
- Complex geometries can be prepare by:
  - converting CAD files to different formats
  - by scanning of the workplace
- Modeling of important moving objects (shielding) will be investigated

Dose Calculations tools

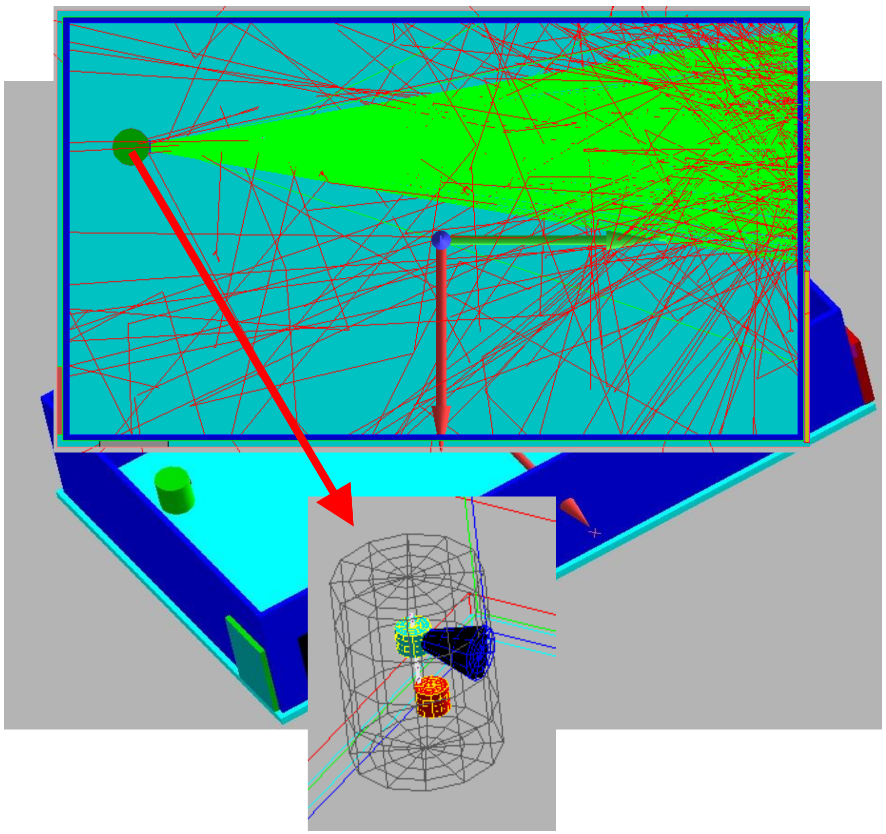
- **VISIPLAN**
  - is a dose assessment tool developed at SCK for ALARA pre-job studies based on analytical point kernel calculation method
  - Coordinates extracted by KDA inserted into the trajectory definition
  - Effective dose derived using conversion coefficients for different irradiation geometries from ICRP-116

- **MCNP**
  - Monte-Carlo radiation transport code
  - Calculation using the coordinates from KDA every simulation time
  - Using $H_p(10)/Ka$ conversion coefficients (1st approach)
  - Calculating absorbed dose in a cell centered at the tracked point and positioned at 10 mm within the ICRU slab phantom (2nd approach)

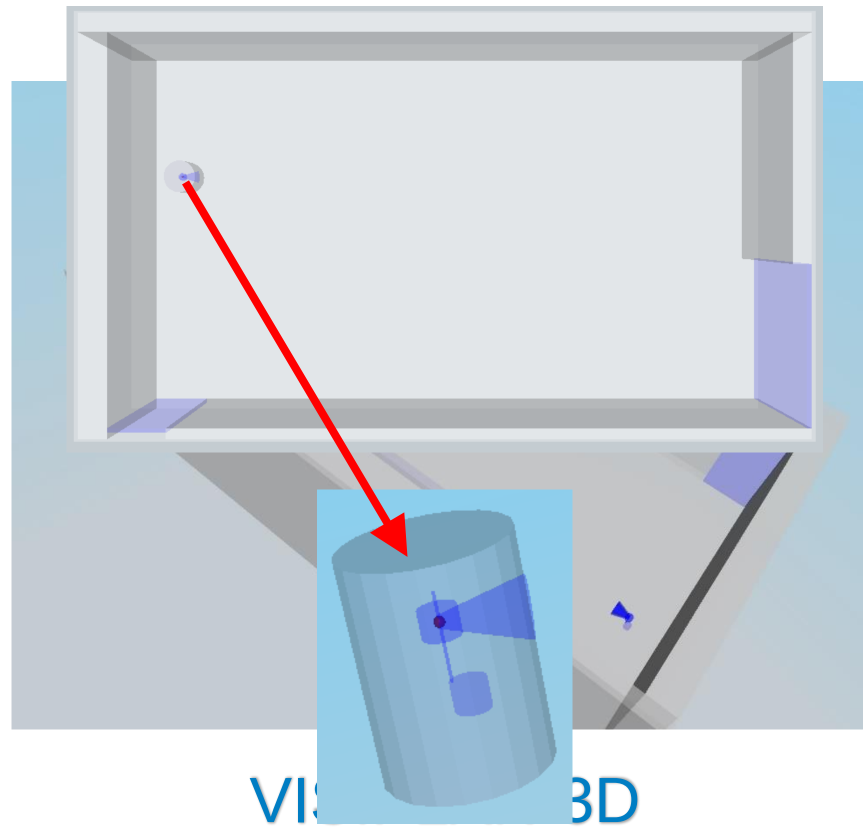
First Practical Test



Geometry Input
Source Input



MCNP

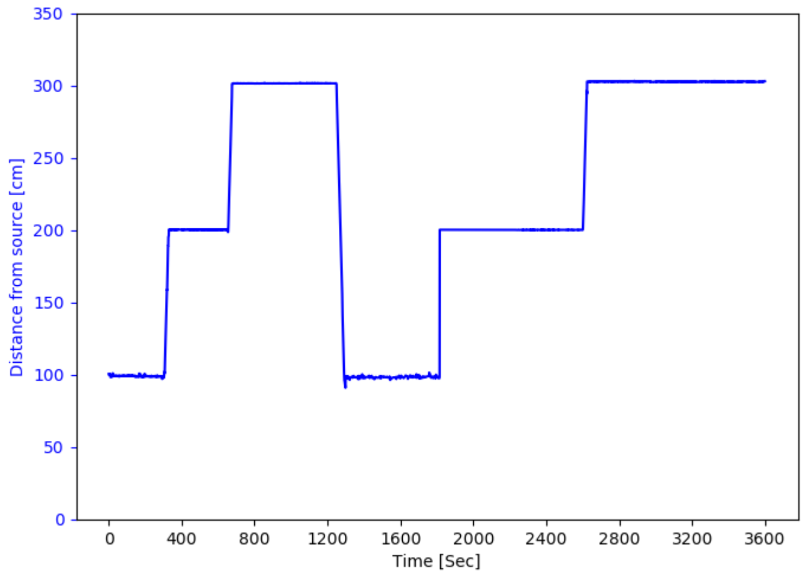


VISIPLAN-3D
VISIPLAN-3D

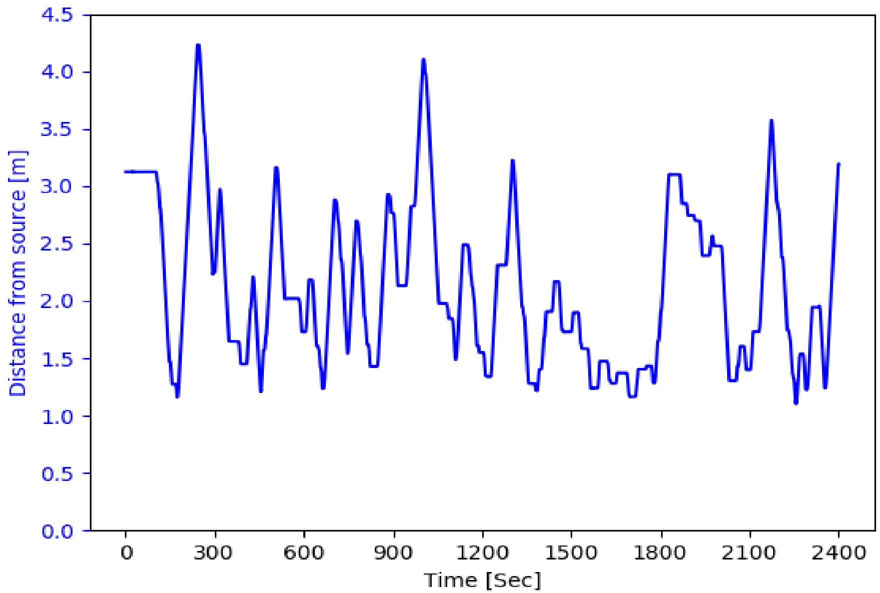
First Practical Test

- Test A: Reference test / Fixed position at 2m for 1H
- Test B: Different positions 1m/2m/3m at slower rate
- Test C: Random movements test

Test B

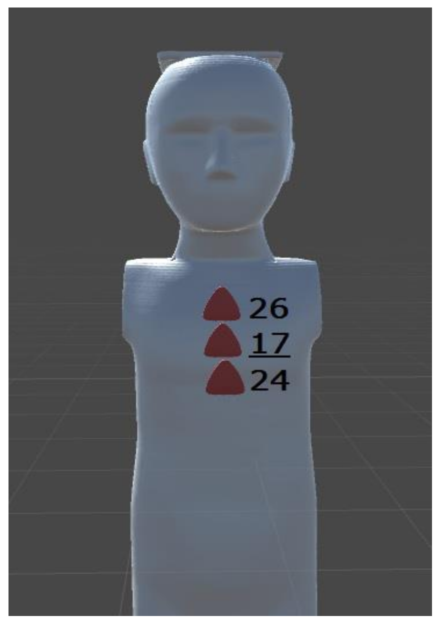


Test C

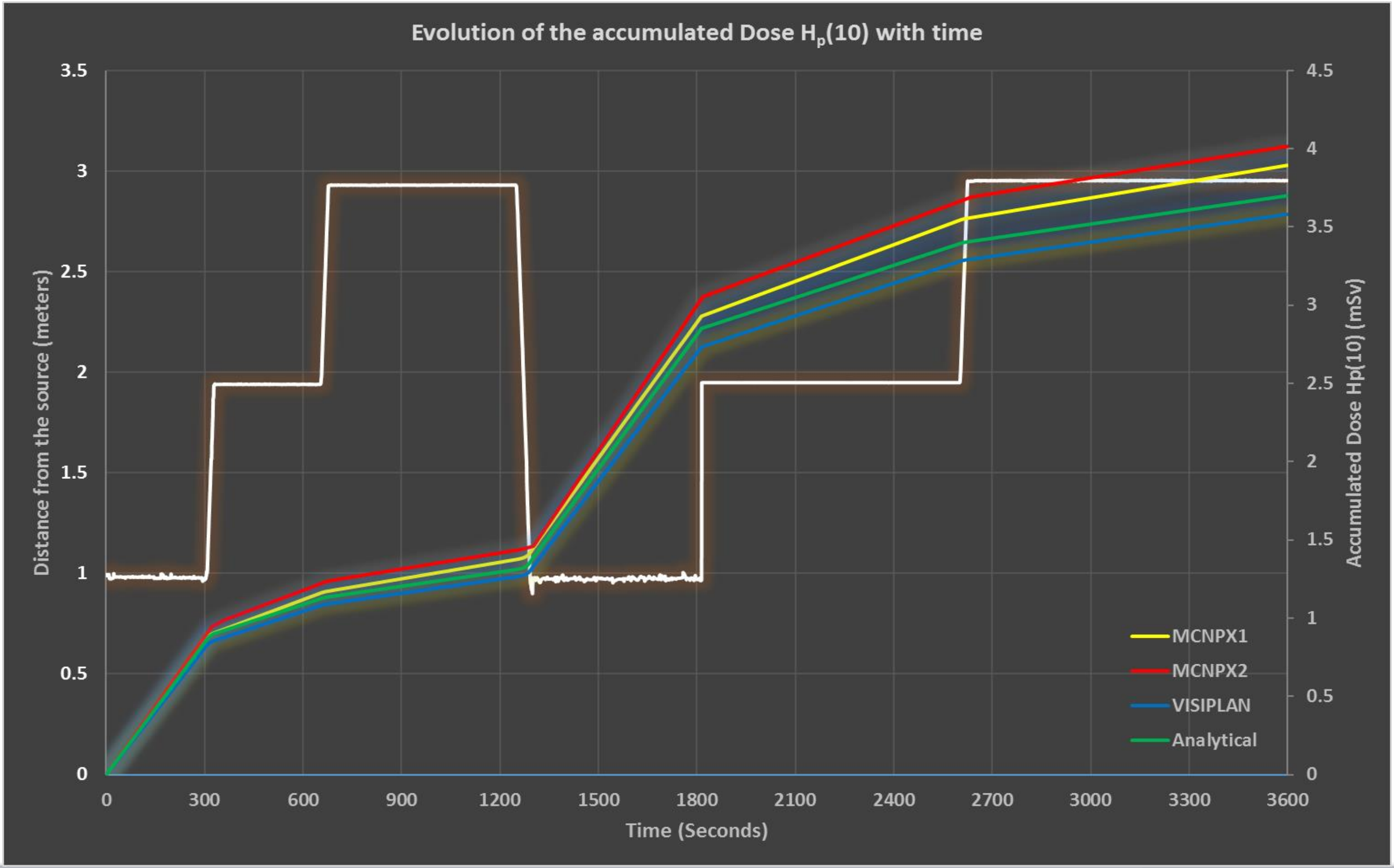


- Test A: Reference test / Fixed position at 2m for 1H

Calculated **Analytical** $H_p(10)$ mSv	Calculated **VISIPLAN** $H_p(10)$ mSv	Calculated **MCNPX 1st** $H_p(10)$ mSv	Calculated **MCNPX 2nd** $H_p(10)$ mSv	Measured **InstaDose** $H_p(10)$ mSv
2.48	**2.38**	**2.60**	**2.58**	**2.40**

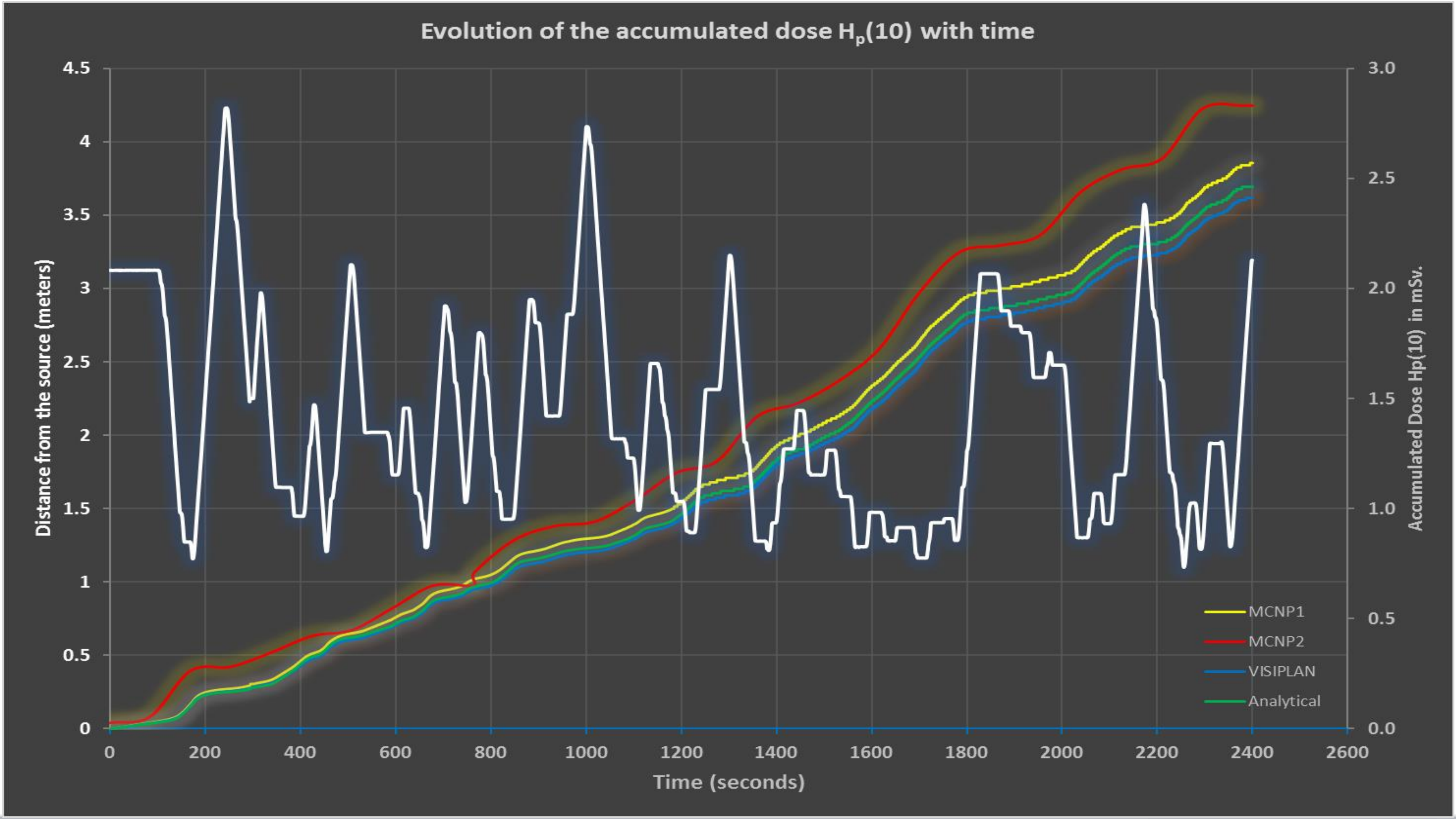


- Test B: Different positions 1m/2m/3m at slower rate



Test C

- Test C: Random movements test



Conclusion

- The first practical test shows the validity of the method in simple simulated scenario
- Very good agreement between calculated, measured and reference dose → Dose value every 25s within ~5-15% error
- VISIPLAN → sufficient for simple radiation fields, limited in more complex scenarios
- The two approaches used in MCNP are valid, one over another depends on the workplace/scenario

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