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A Digital Twin of an Operating Theater

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Outline

HEALTHY BUILDINGS 2023 EUROPE
BEYOND DISCIPLINARY BOUNDARIES

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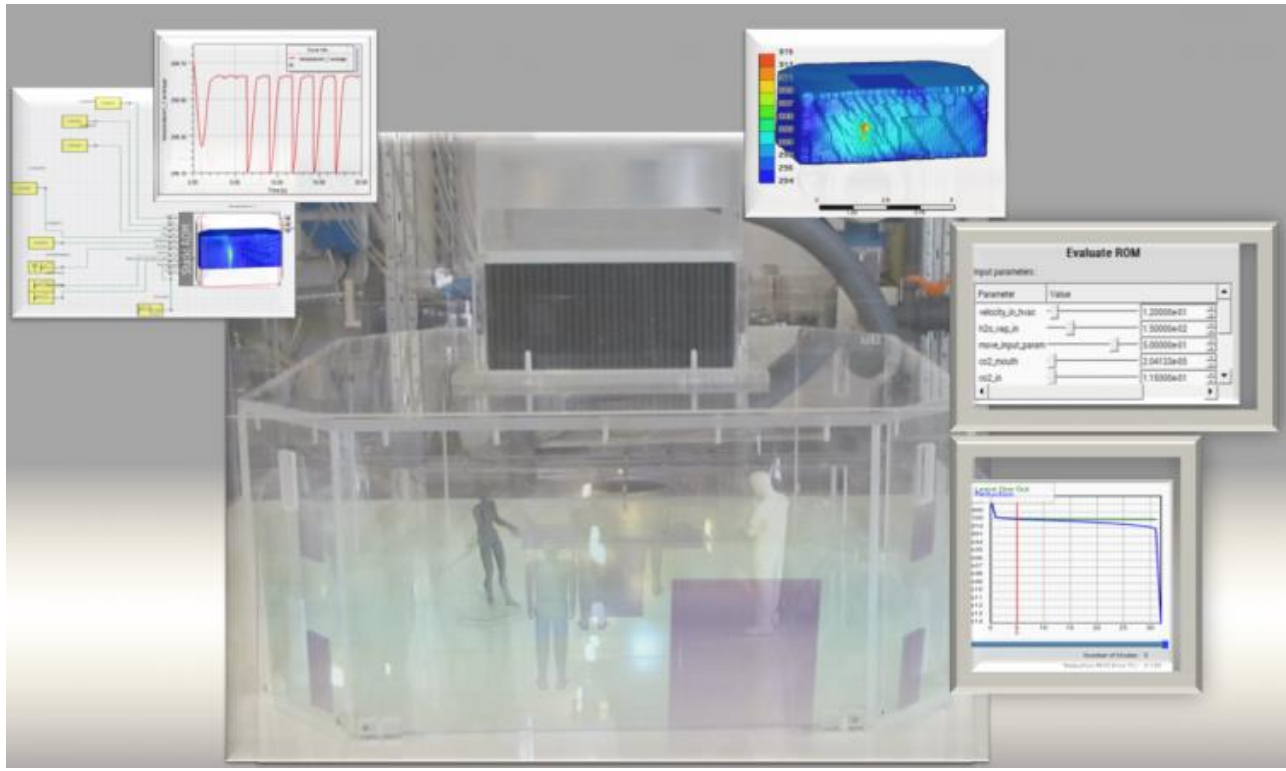
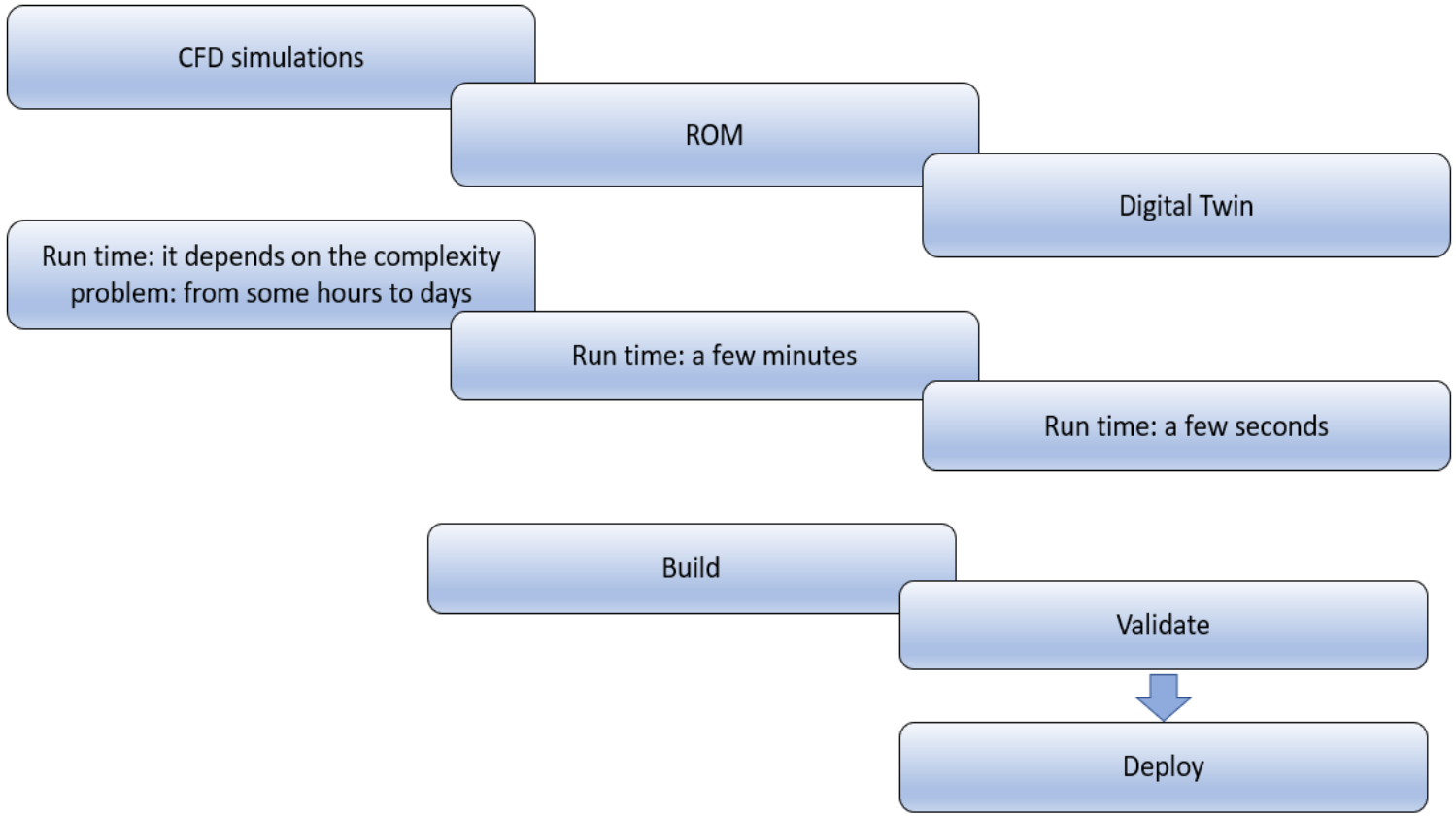
- Digital Twin & CFD and workflow
- Case study: S. Gerardo operating theatre
- ROM setup
- CFD vs ROM
- Twin Builder – Digital Twin
- Mock-up
- Conclusions



Digital Twin: where to use it?

- DT (Digital Twin) is defined as a **mega model**, device shadow, mirrored system, avatar, or synchronized virtual prototype
- In Air Quality control, a DT can be a fundamental help in the:
- operating theater to prevent infections, recircle flows, and obtain a comfortable environment for the medical staff and patients
  - offices
  - waiting rooms
  - common areas
- by providing technology for air quality control, energy saving in buildings, regulation and management of people flow, maintenance, detection, and management of plant failures.

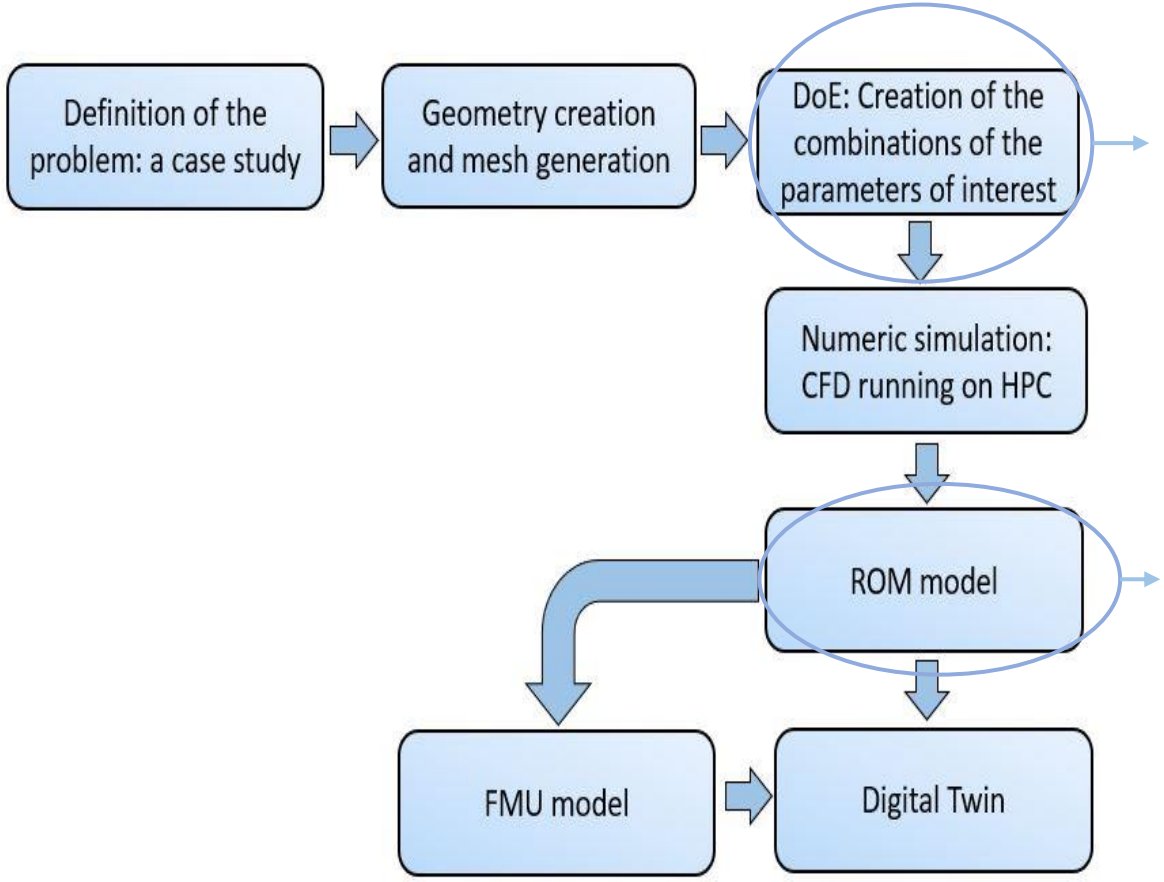
Digital Twin & CFD



The advantages of DT compared to only CFD are:

- the capability of DT to obtain the results in every point of parameter field used to create it, in a few seconds after the construction
- the possibility to deploy the DT and use it on IIoT (Industrial Internet of Things) interface or a device

Toward the digital twin: the workflow



The definition of :

- set of parameters
- range of interest of parameters
- creation of parameter combinations to give to CFD

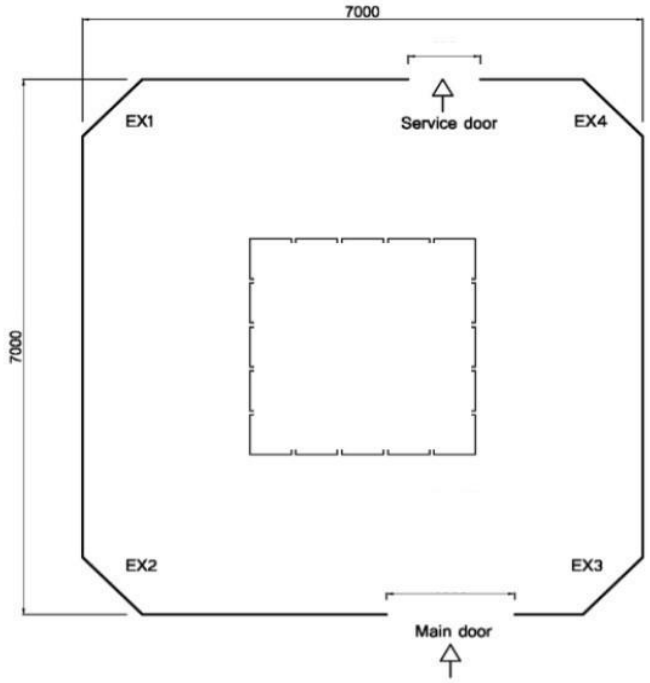
The definition of :

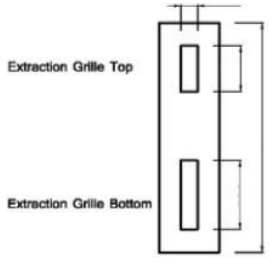
- CFD set of snapshots and split in two set:
  - learning set
  - Validation set
- Creation of a Reduced Order Model (ROM) by
  - SVD (Singular Value Decomposition)
  - GARS (Genetic Aggregation Response Surface)

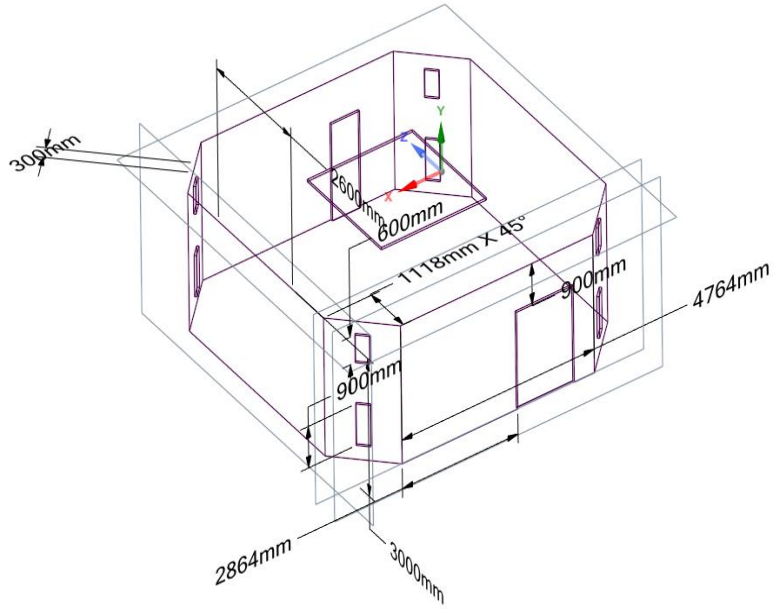
Model export to obtain the Digital Twin(DT)

Case study:
S. Gerardo Hospital

The geometry is the one of the San Gerardo Hospital in Monza with a central HVAC system, and 8 discharge grilles, 4 upper 4 lower.

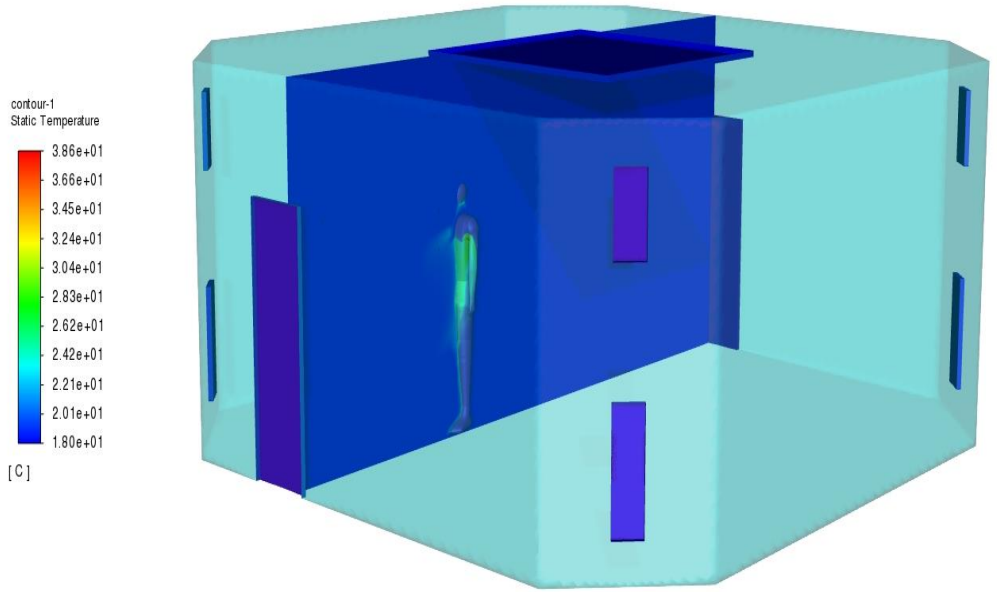


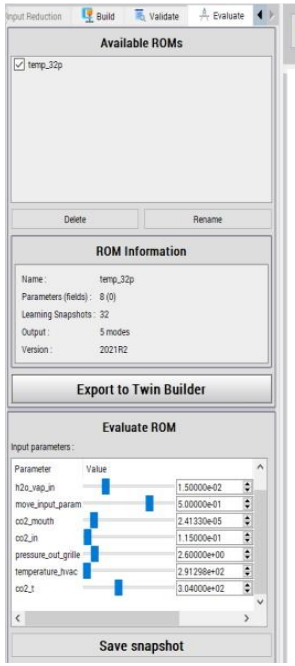


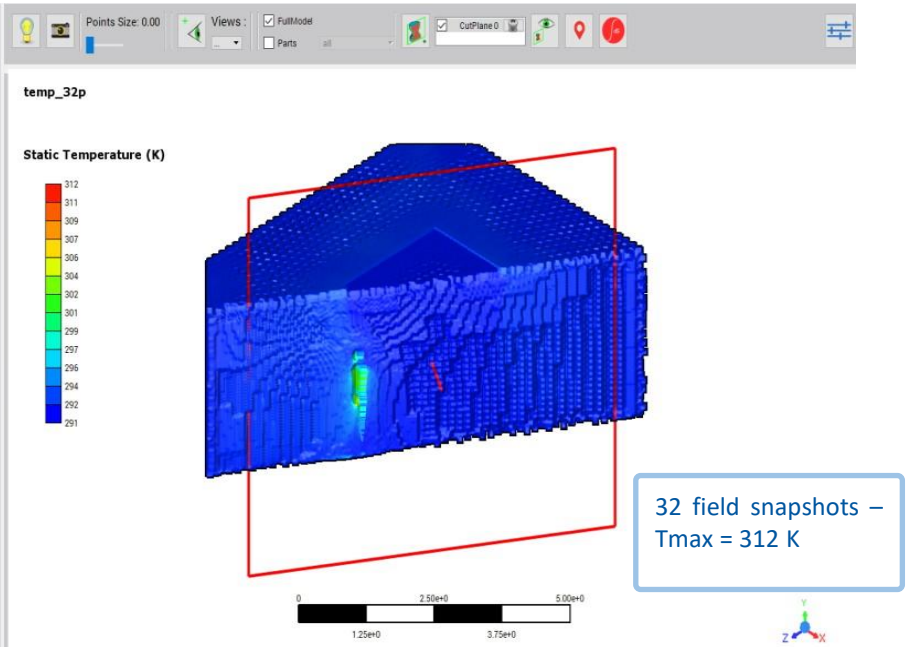


CFDvsROM: Temperature comparison

Comparison of CFD (left) and ROM (right) results constructed with 50% of the different sets of snapshots (64 snapshots – reference solutions). The variation of the temperature field between CFD and ROM is underestimated by about 0.64%.

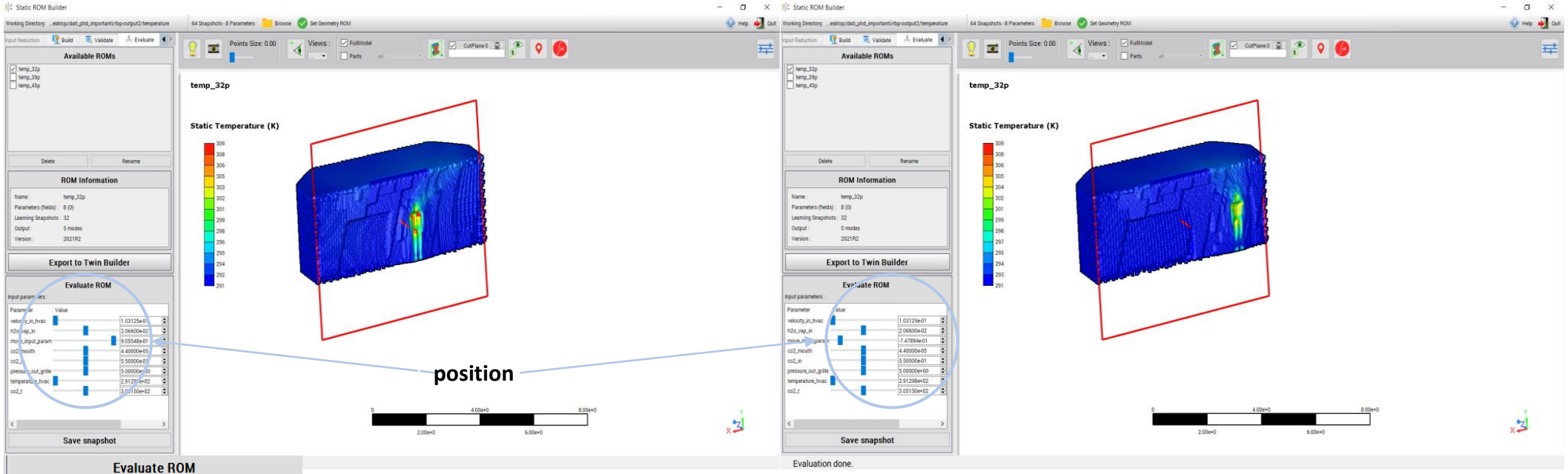


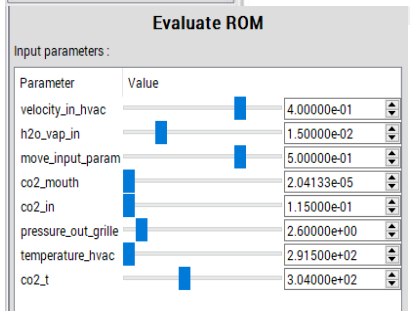




32 field snapshots – Tmax = 312 K

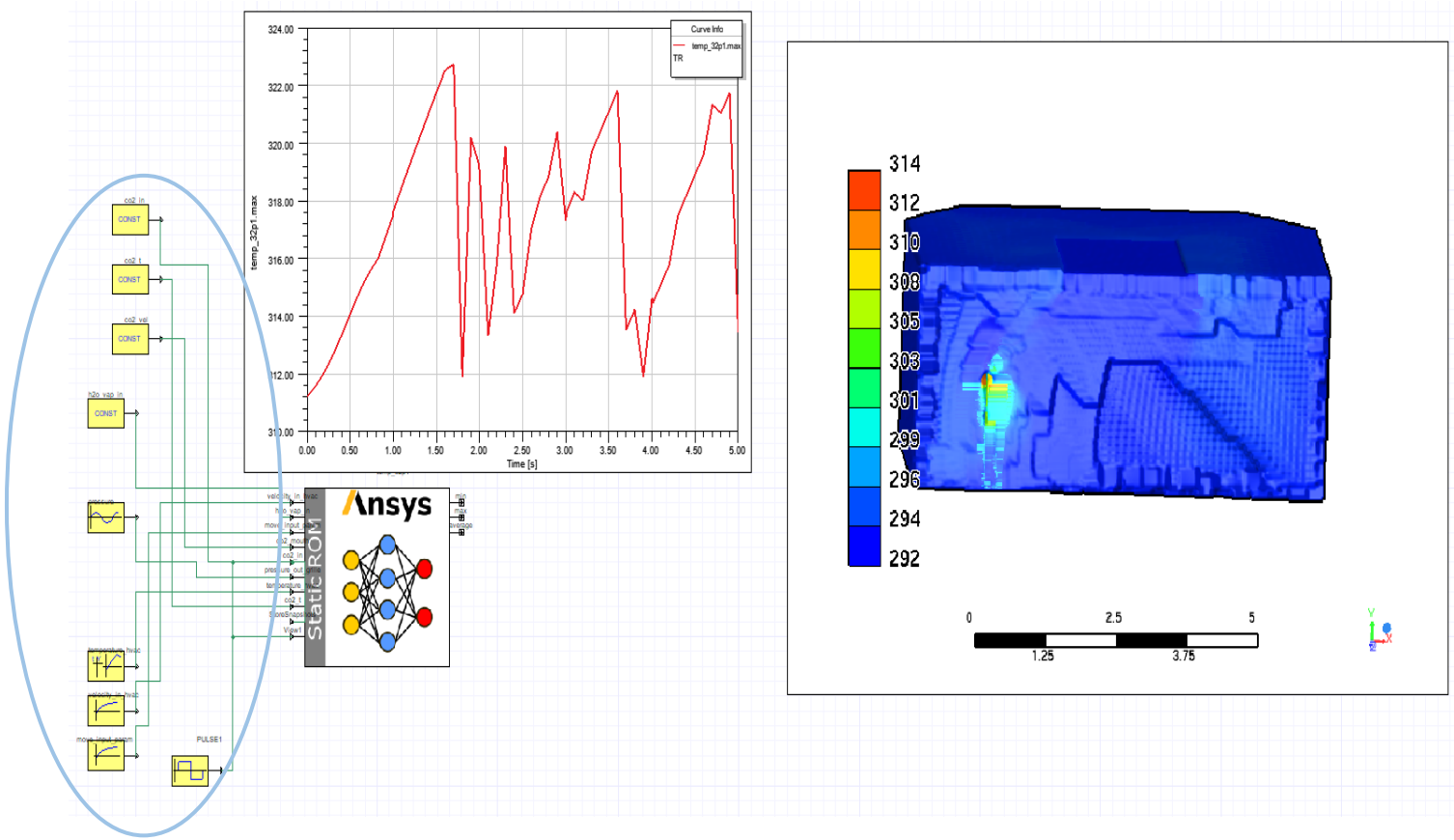
ROM with geometrical parameter change





Variation of the temperature field upon changing the human dummy position only

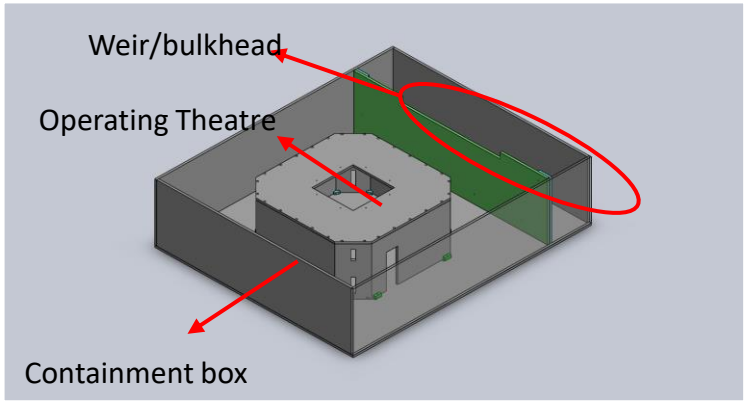
Digital Twin

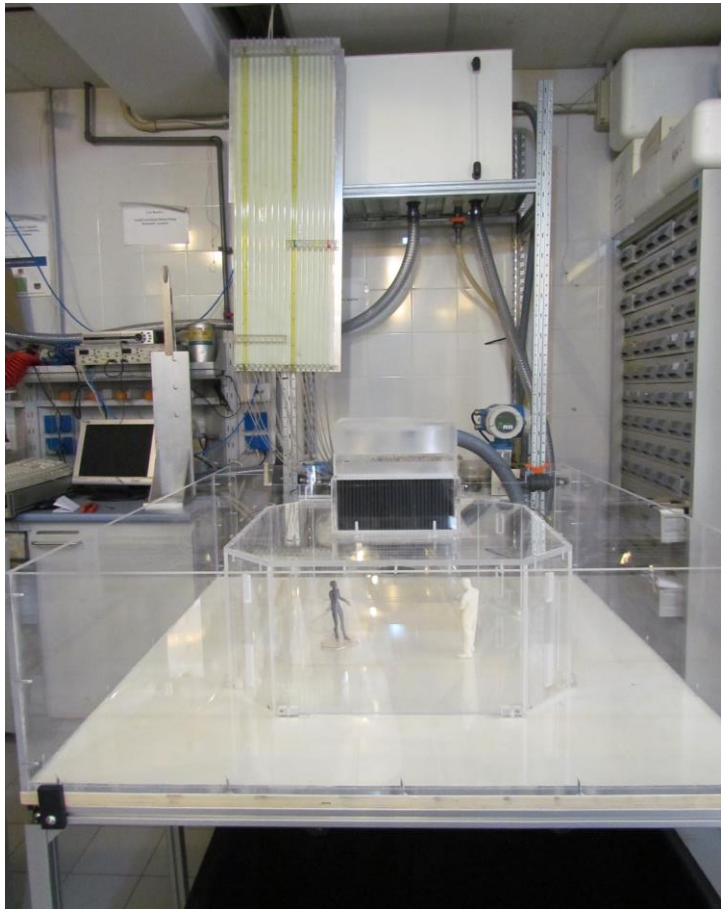


- The ROM result was exported in TB.
- Trend (left) of the temperature in the operating theatre when the input parameters change.
- Images (right) of the temperature field, in some instants in time.

Mock-up

- 1:10 scale model
- Material: 10 mm thick plexiglass
- Operating Theatre
- Containment box
- Weir/bulkhead
- Box designed to have ACH≈15 and volumetric flow 18 l/min





Conclusions

- We obtain:
  - CFD steady state simulations for an operating room with a human dummy
  - comparison to CFD results and ROM results: good approximation of ROM and digital twin in relation to the temperature
  - the ROM returns the values of the field of the variables or the scalars and can provide good indications of the influence of one parameter concerning another concerning the problem considered.
  - the ROM responds in real-time to the variation of the variable values: instantaneous evaluation of the quantities of interest
  - the result of the ROM was exported to the Twin Builder software to obtain a digital twin.
- Further developments:
  - complete an operating theatre
  - possibility to simply change the geometry of the operating theatre
  - experiments on the mock-up

Thanks for your attention

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