TOP C S P

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Towards, Competitive, Reliable, Safe and Sustainable Concentrated Solar Power (CSP) Plants

Midterm meeting REA, 18-19 April 2024

DC1: Universal flux density measurement system for large-scale external and cavity receivers with high-performance image processing

Author: Sergio DÍaz Alonso

Supervisor: Christian Raeder

Institution: DLR

- **Education**
  - Bachelor’s Degree in Industrial Technologies Engineering (UC3M)
  - Master’s Degree in Industrial Engineering (UC3M)
  - Honours in:
    - Master’s thesis: Optimization of a baby feeding bottle using CAE techniques
    - Applied Thermal Engineering
    - Electronic Engineering Fundamentals
    - Material Technologies

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    - Applied Thermal Engineering
    - Electronic Engineering Fundamentals
    - Material Technologies

- **Experience**
  - Research fellow (UC3M) Proceeding in CNIT12 + paper in “Results in Enginnering”
  - Process Engineer in Exera
  - CAE Engineer in Andaltec R&D of automotive lighting devices
  - PhD candidate in DLR

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- Introduction to the task and changes proposed
- Current status
- Future steps

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- **Introduction to the task and changes proposed**
  - Increasing variety of central receivers in CSP systems

Receivers

Cavity

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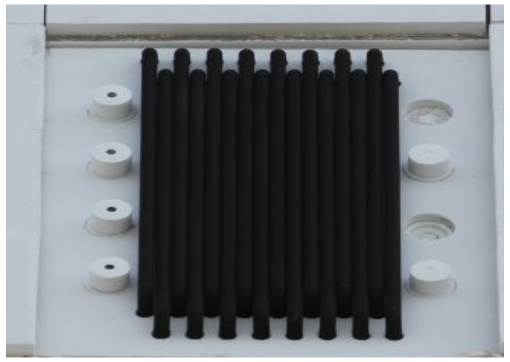
Receivers

Cavity

Tube



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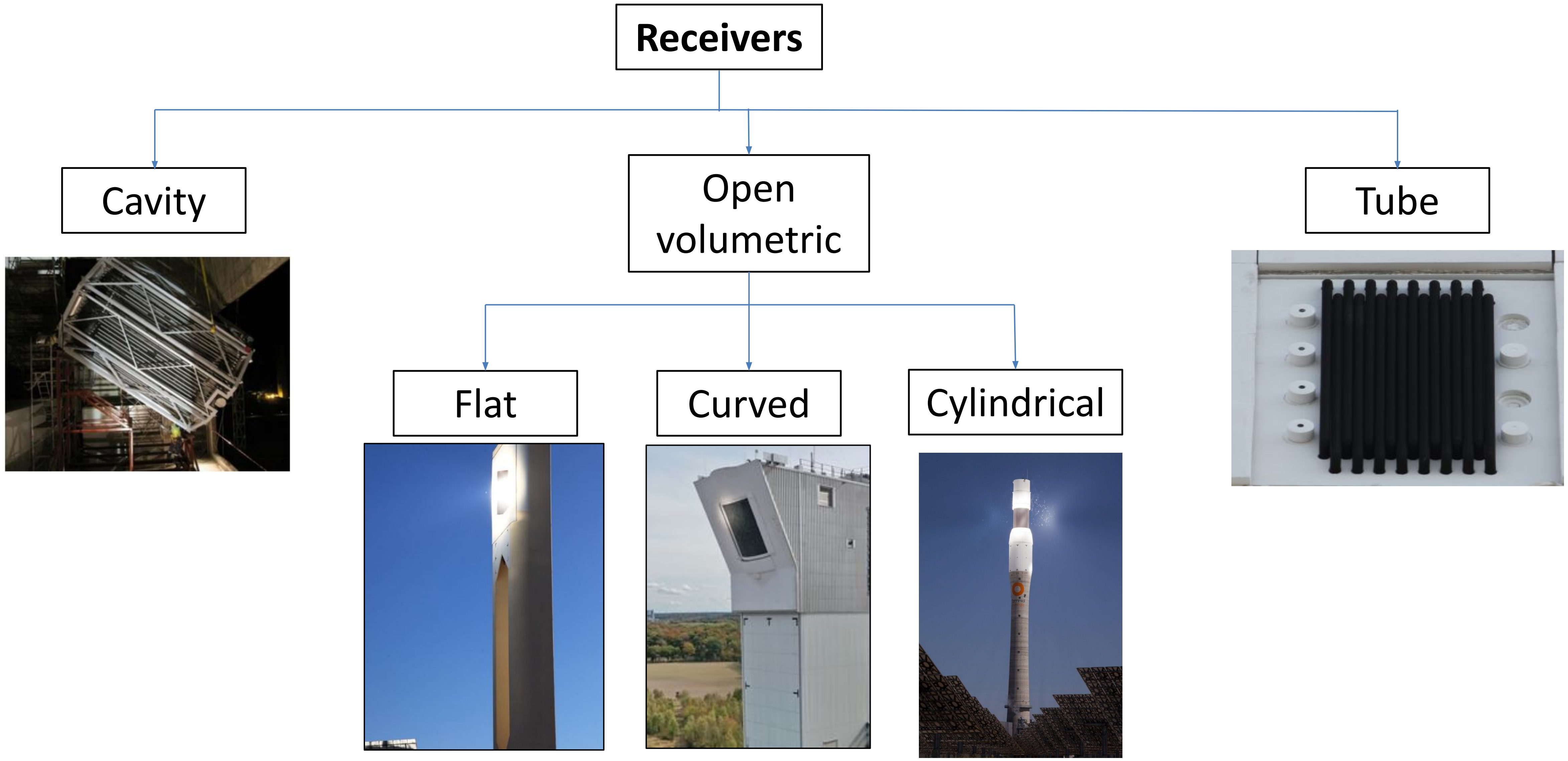

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- **Introduction to the task and changes proposed**
  - Increasing variety of central receivers in CSP systems

Receivers

Cavity

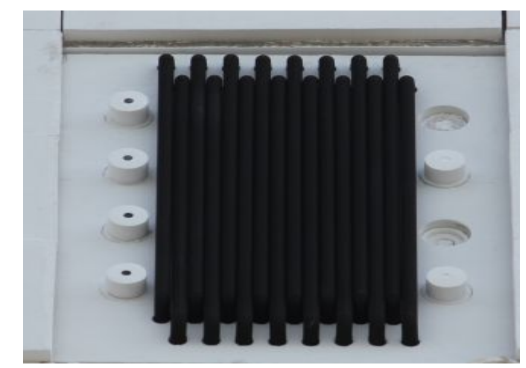
Open volumetric

Flat

Curved

Cylindrical

Tube



- **Motivation:** universal flux density measurement (FDM)
- **Ad-hoc approach**

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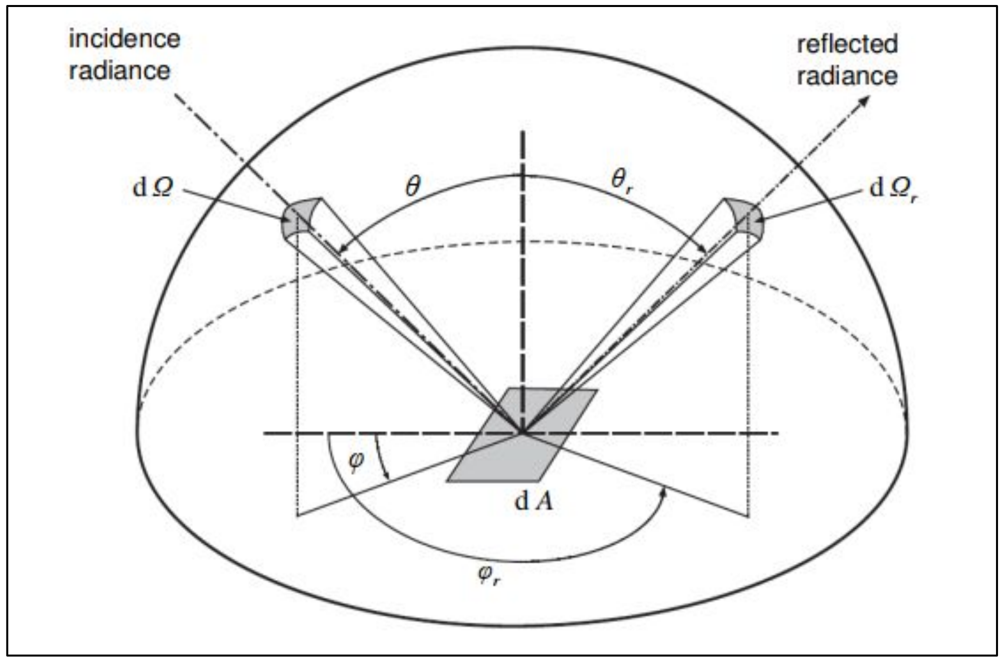
• **Introduction to the task and changes proposed**



$$\rho(\theta,\varphi,\theta_r,\varphi_r)=\frac{L_r(\theta,\varphi,\theta_r,\varphi_r)}{L(\theta,\varphi)\cos\theta\,\mathrm{d}\Omega}$$

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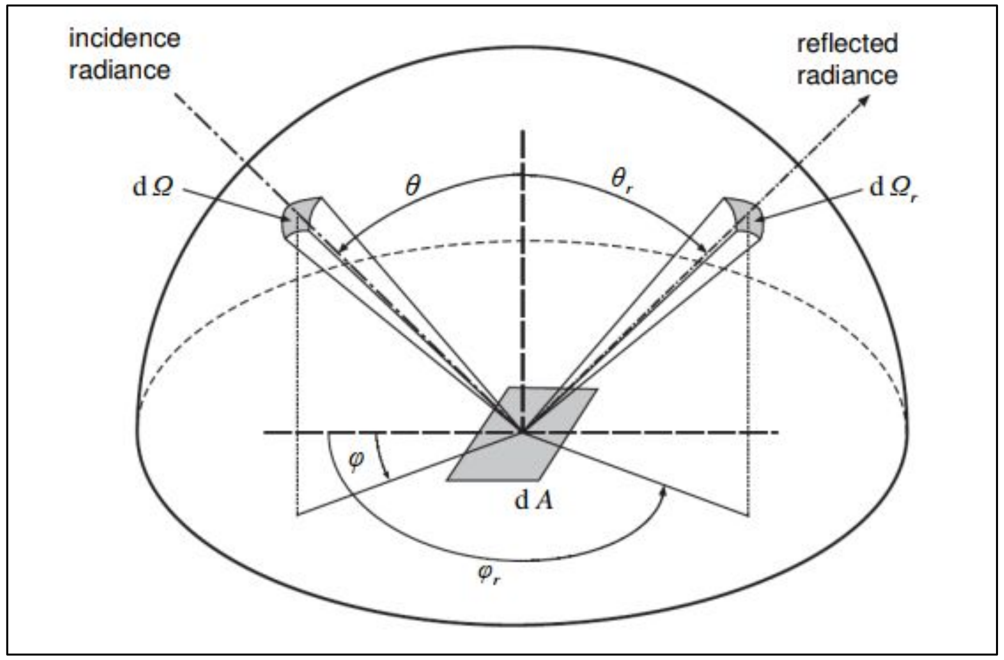

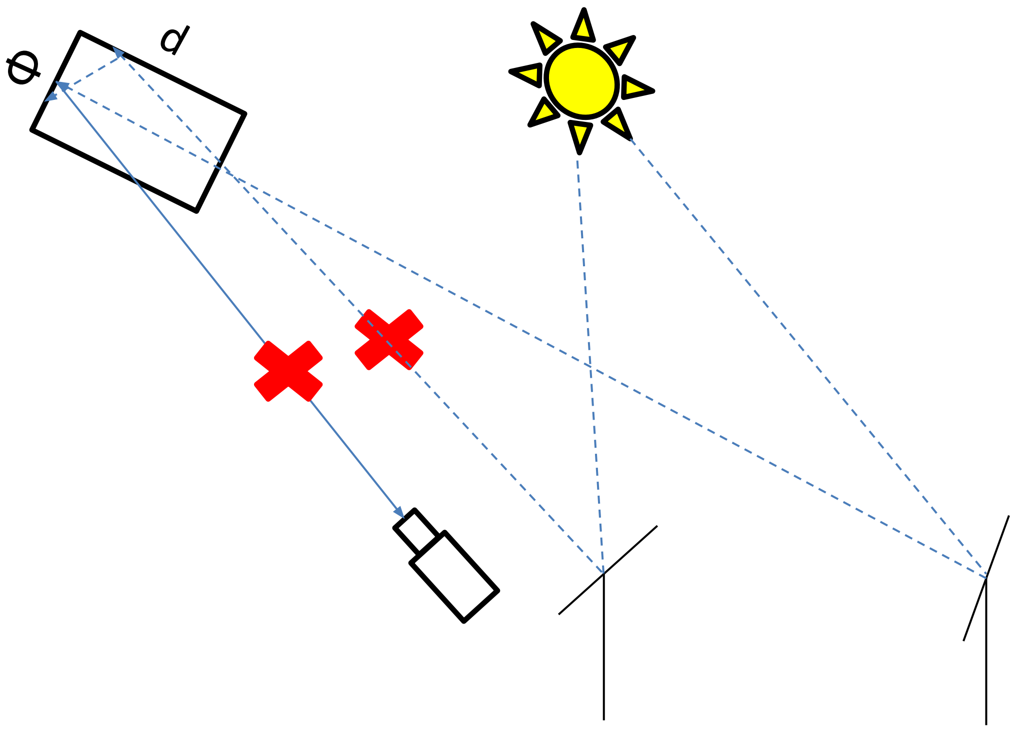

$$\rho(\theta,\varphi,\theta_r,\varphi_r)=\frac{L_r(\theta,\varphi,\theta_r,\varphi_r)}{L(\theta,\varphi)\cos\theta\,d\Omega} \longrightarrow \rho(\theta,\varphi,\theta_r,\varphi_r,d,\phi)=\frac{L_r(\theta,\varphi,\theta_r,\varphi_r,\boxed{d,\phi})}{L(\theta,\varphi)cos\theta d\Omega}$$

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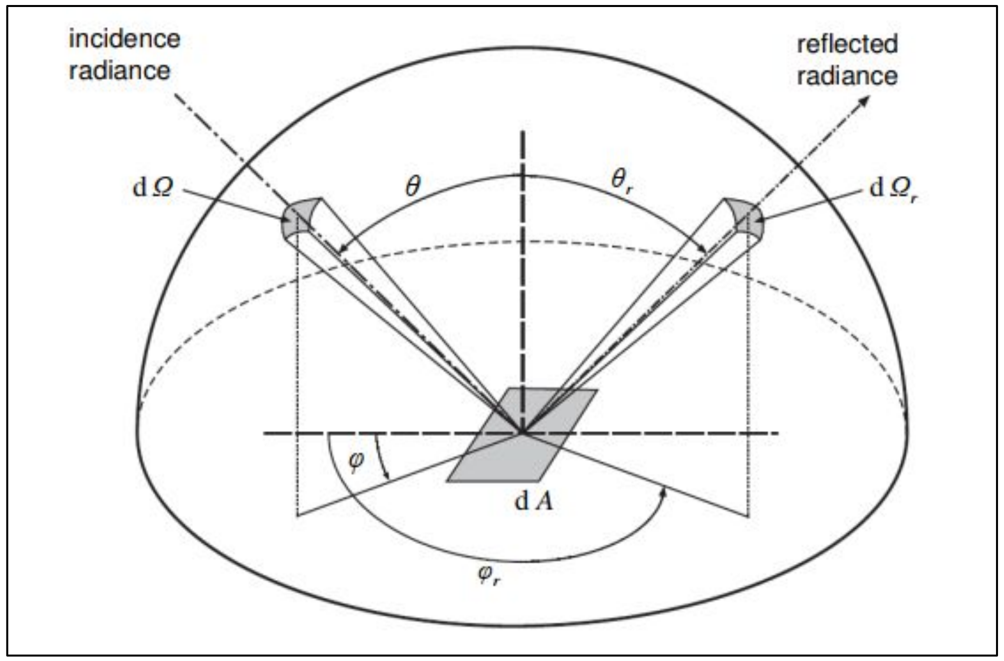
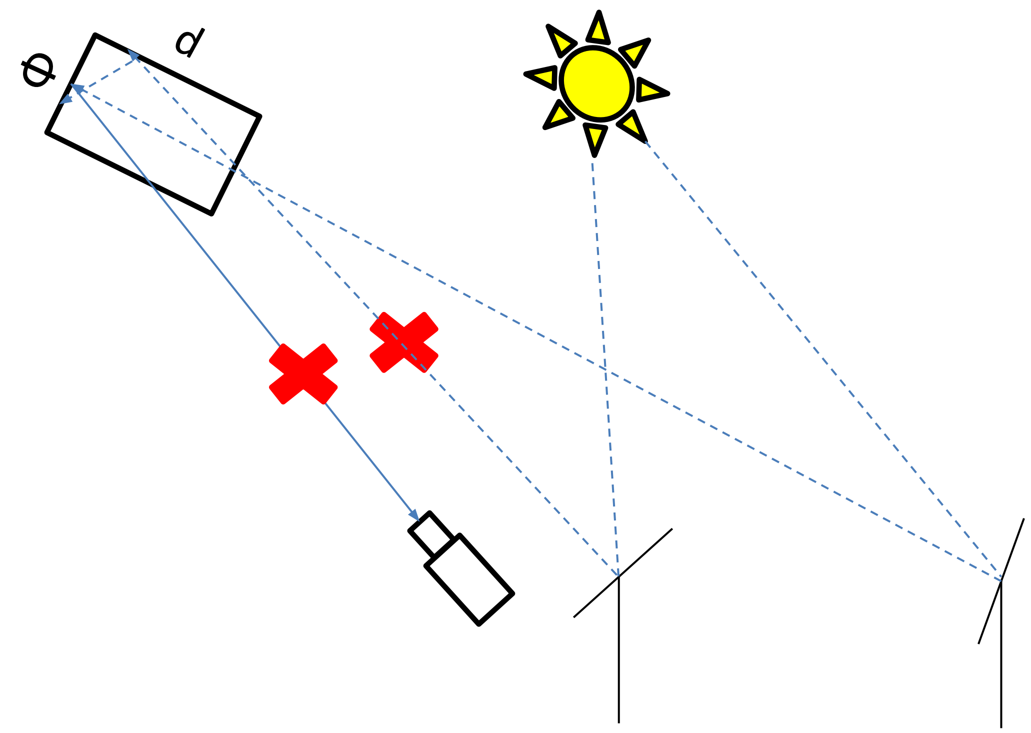
Introduction to the task and changes proposed





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Now the BRDF is also a function of the geometry of the cavity (depth, aperture diameter) □ Discarded use, difficult characterisation

- Inherent perspective problems: most of the fraction reflected can‘t be captured in camera
- Some heliostat reflection is reabsorbed by other walls

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Design principles

- Real-time measurement

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- Real-time measurement
- Non-disruptive

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- Real-time measurement
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- Connection between conventional measurements and possible future trends (data-driven models)

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- Real-time measurement
- Non-disruptive
- Connection between conventional measurements and possible future trends (data-driven models)
- Self-corrected with AI enhancement

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Design principles

- Real-time measurement
- Non-disruptive
- Connection between conventional measurements and possible future trends (data-driven models) “Stepping on the shoulders of giants”
- Self-corrected with AI enhancement
- *Towards Smart CSP”*

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- Introduction to the task and changes proposed
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- **Real-T**ime **Im**age **E**nhanced **Data-D**riven **D**igital **T**win **(Real-TImE 3DT)**

Data platform → Python interface → STRAL2 simulation in the aperture plane of the cavity → Fluxmap

(Online real time data of the power plant)

Image obtention in the cavity aperture plane (e.g. FMAS) → Fluxmap

Stage 1: validation in aperture plane

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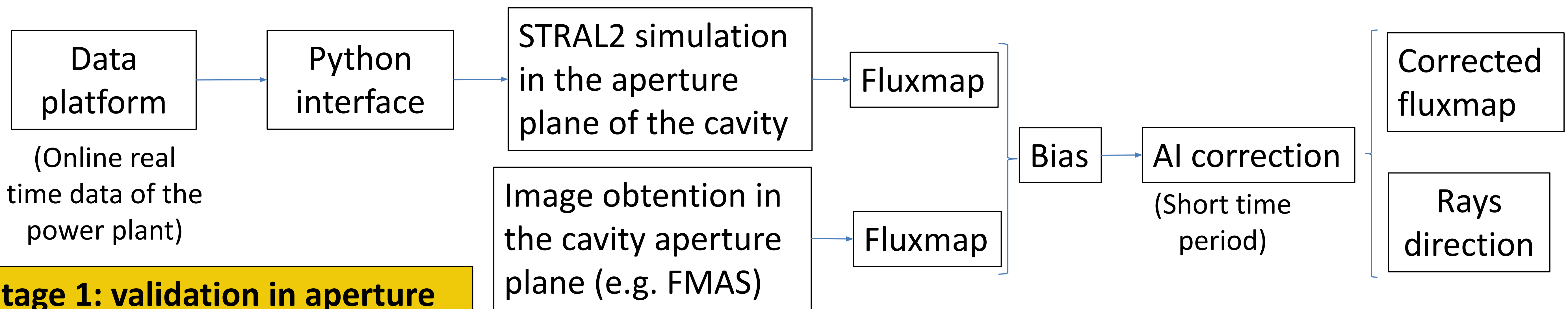
•**Real-T**ime **Im**age **E**nhanced **Data-D**riven **D**igital **T**win **(Real-TImE 3DT)**



Stage 1: validation in aperture plane

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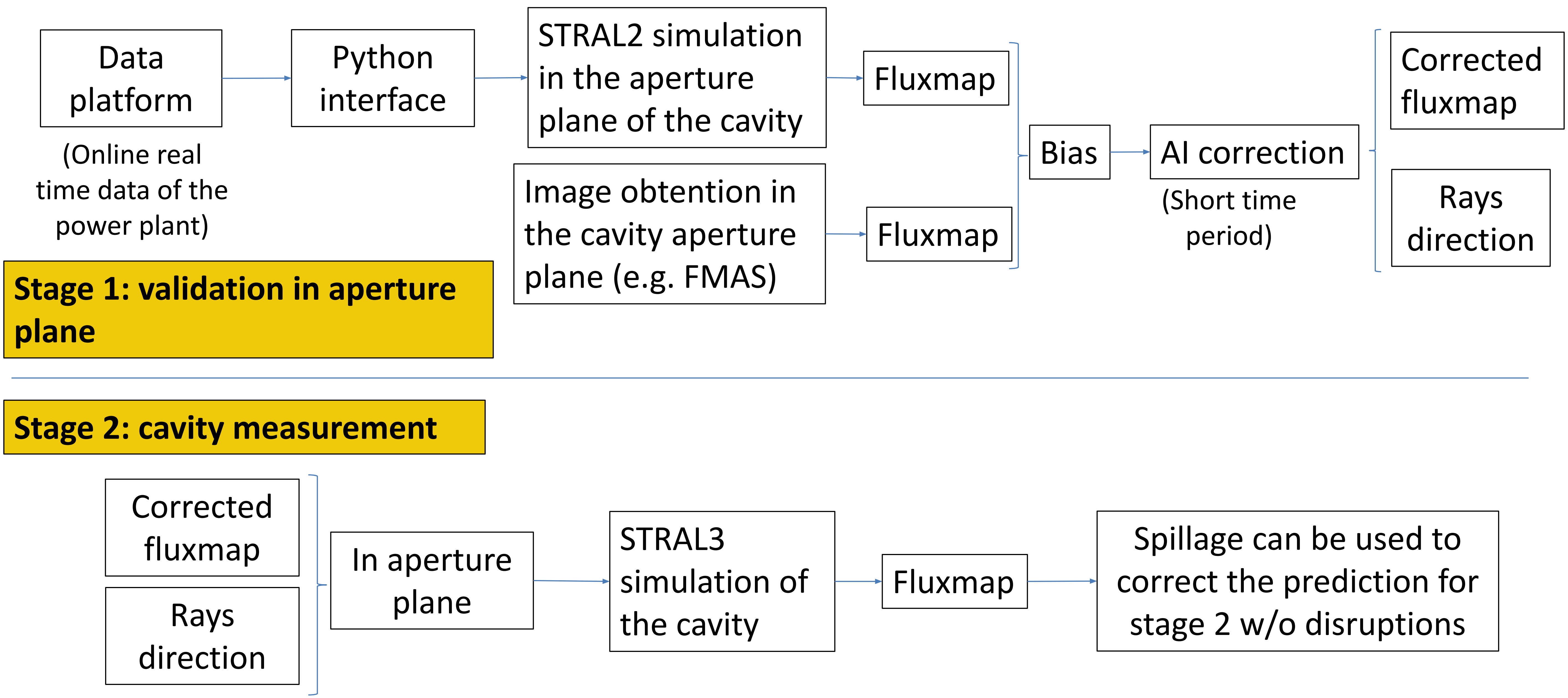
- **Real-Time Image Enhanced Data-Driven Digital Twin (Real-TImE 3DT)**



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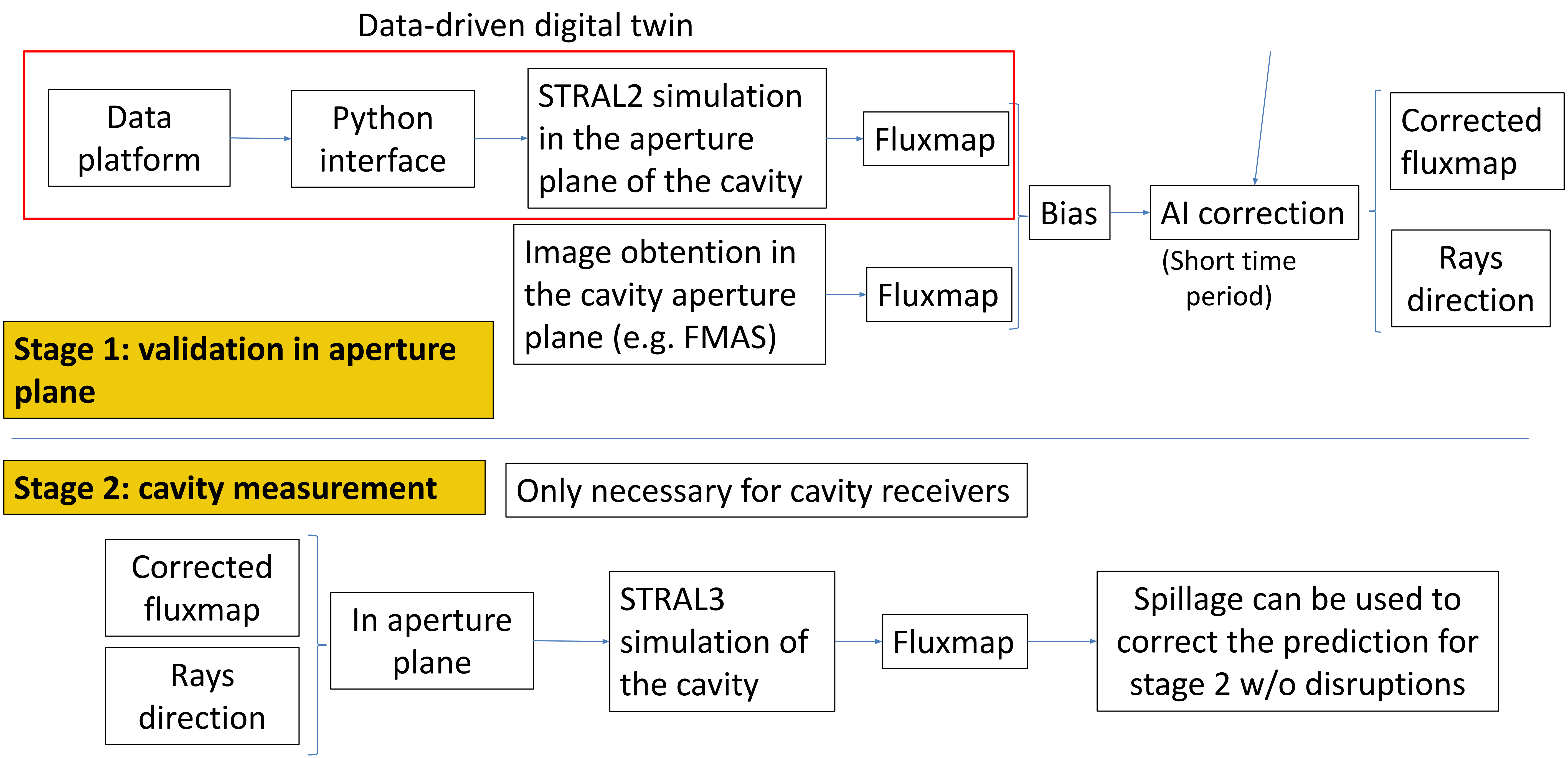

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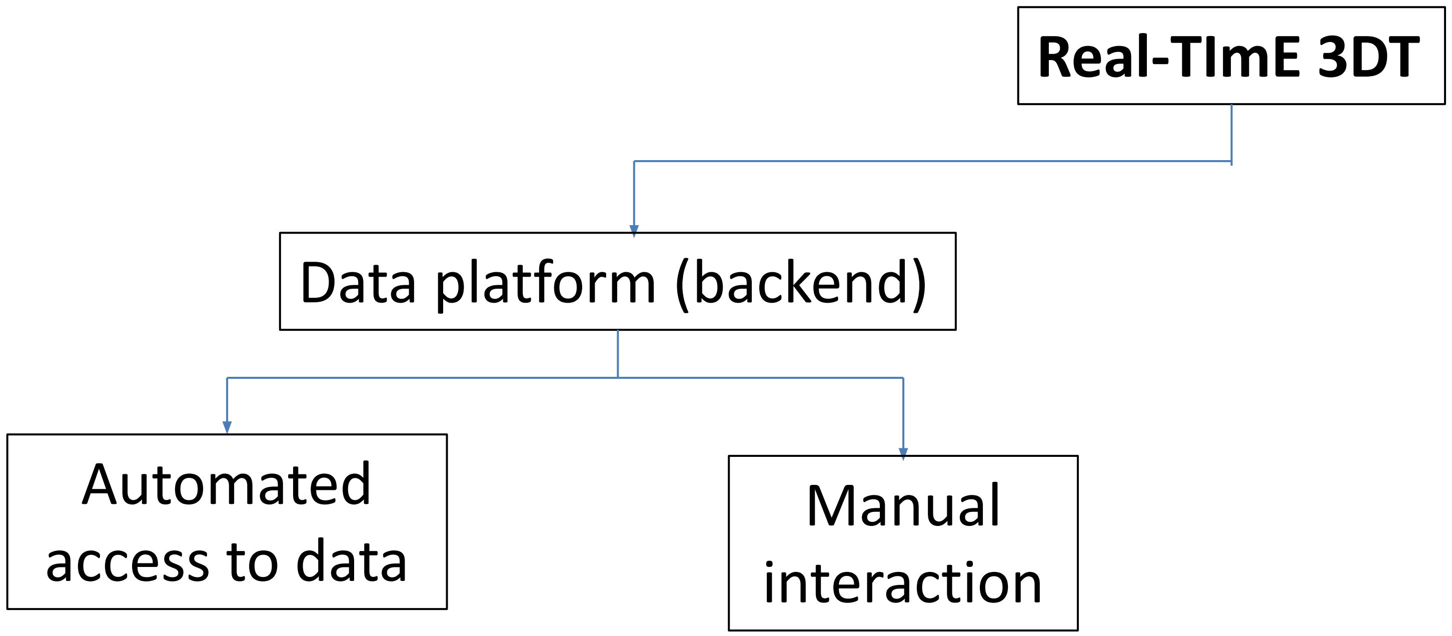
- **Technical approach**



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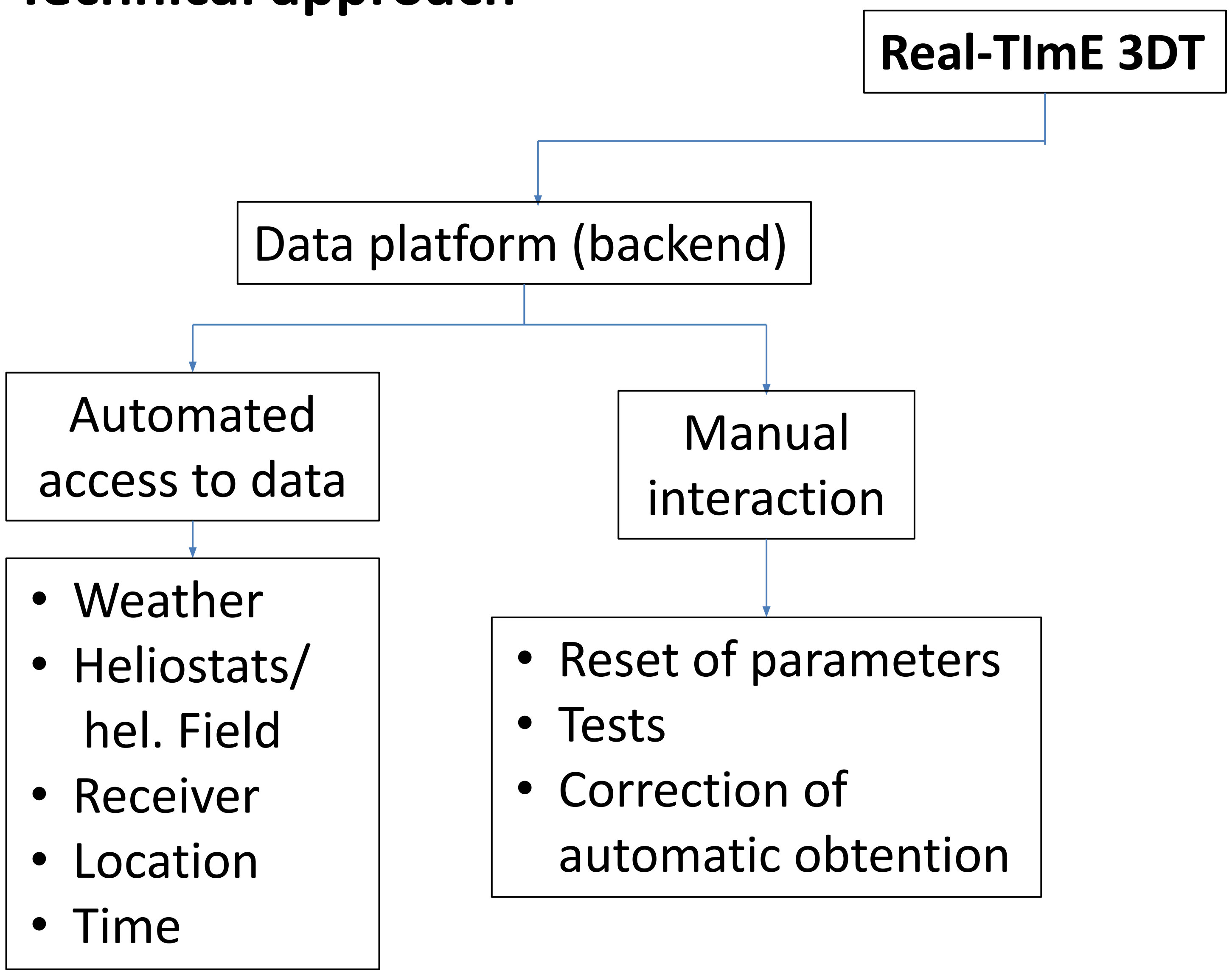

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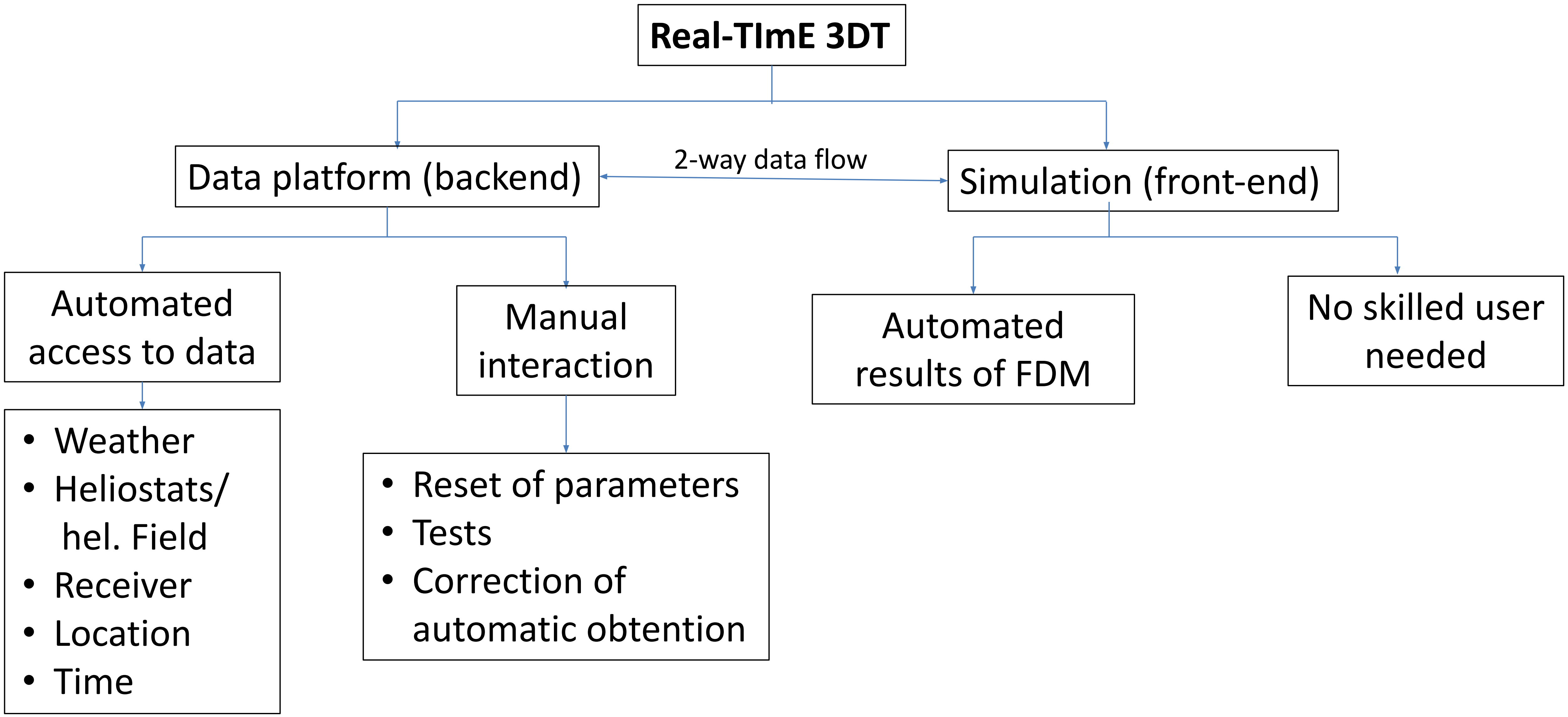

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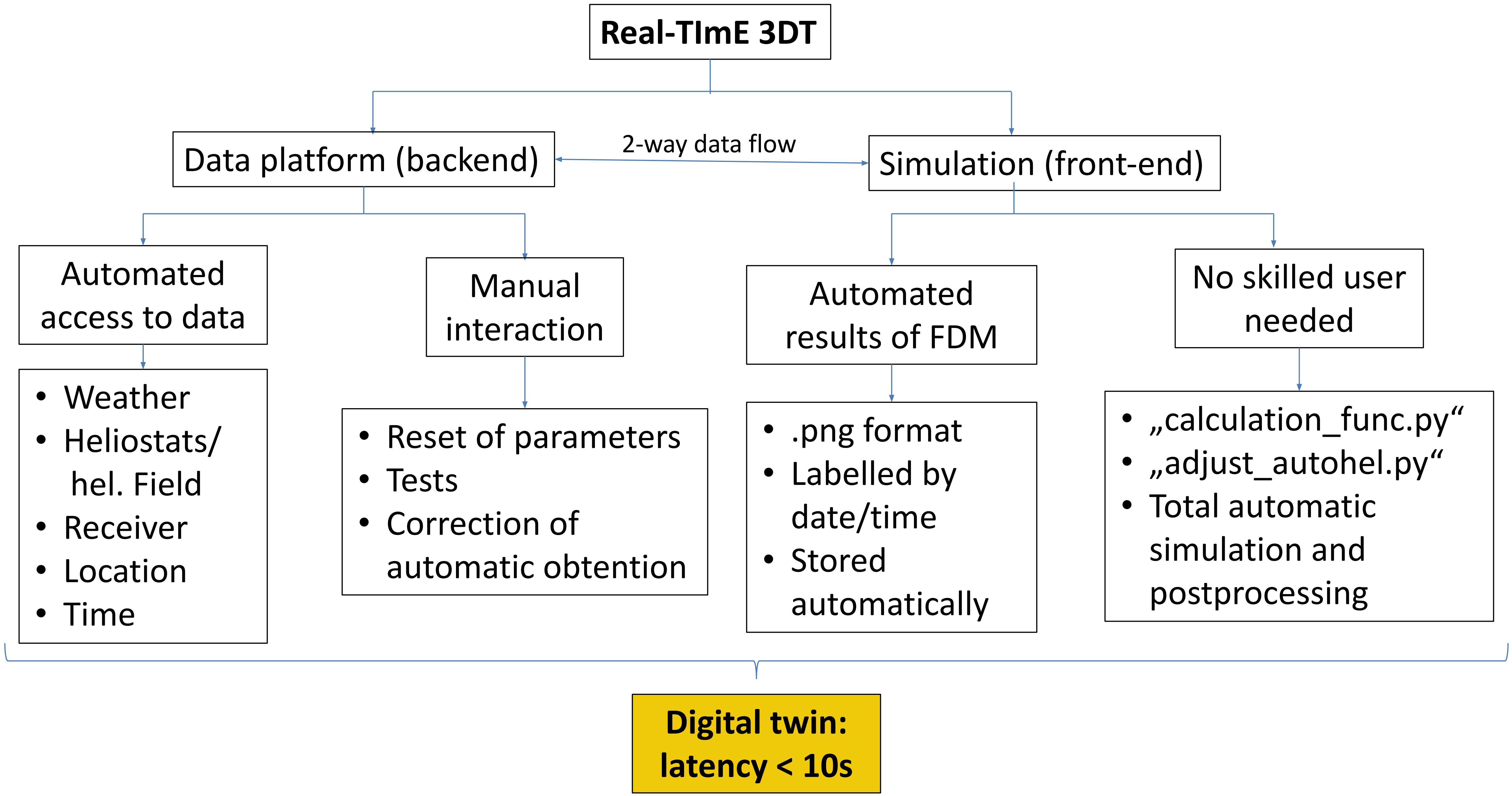

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- **Results (DT)**

Adjustment

- List of heliostats to be modified
- Modification
  - Live defocus
  - Live change of tracking error
  - New aimpoint
- Time auto adjustment

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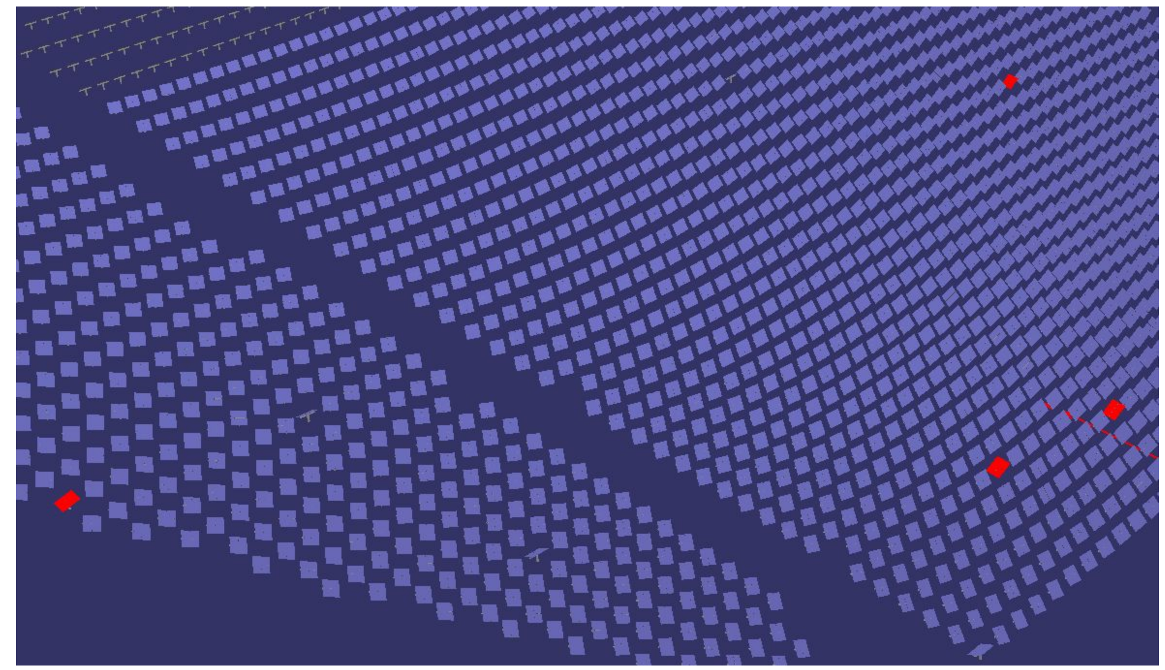
Real time influence



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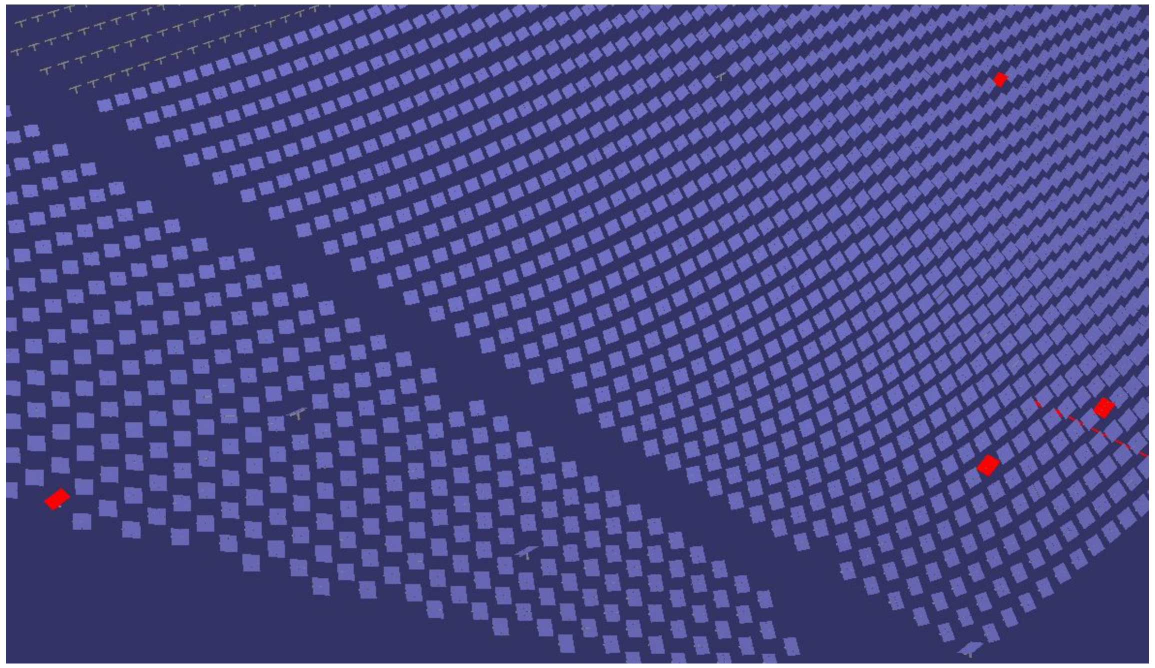

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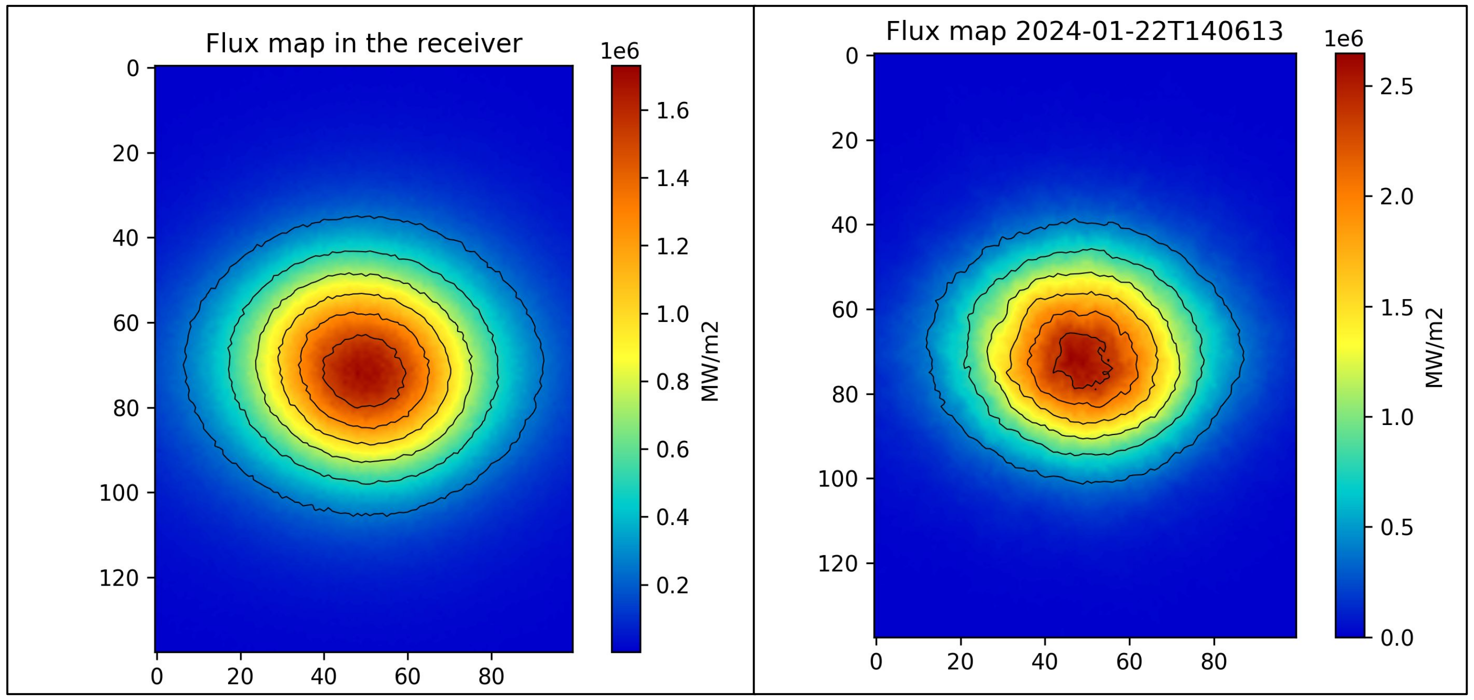

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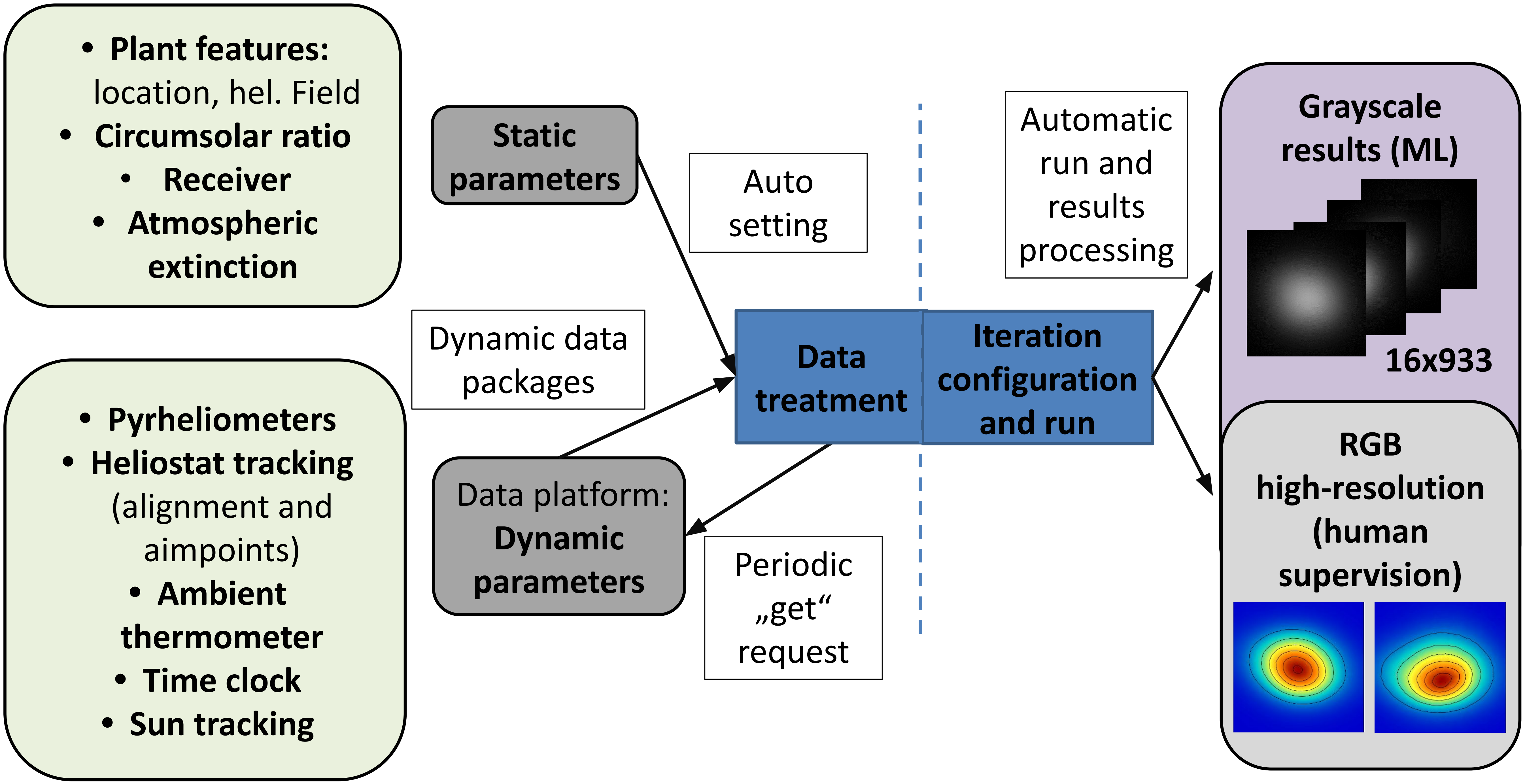

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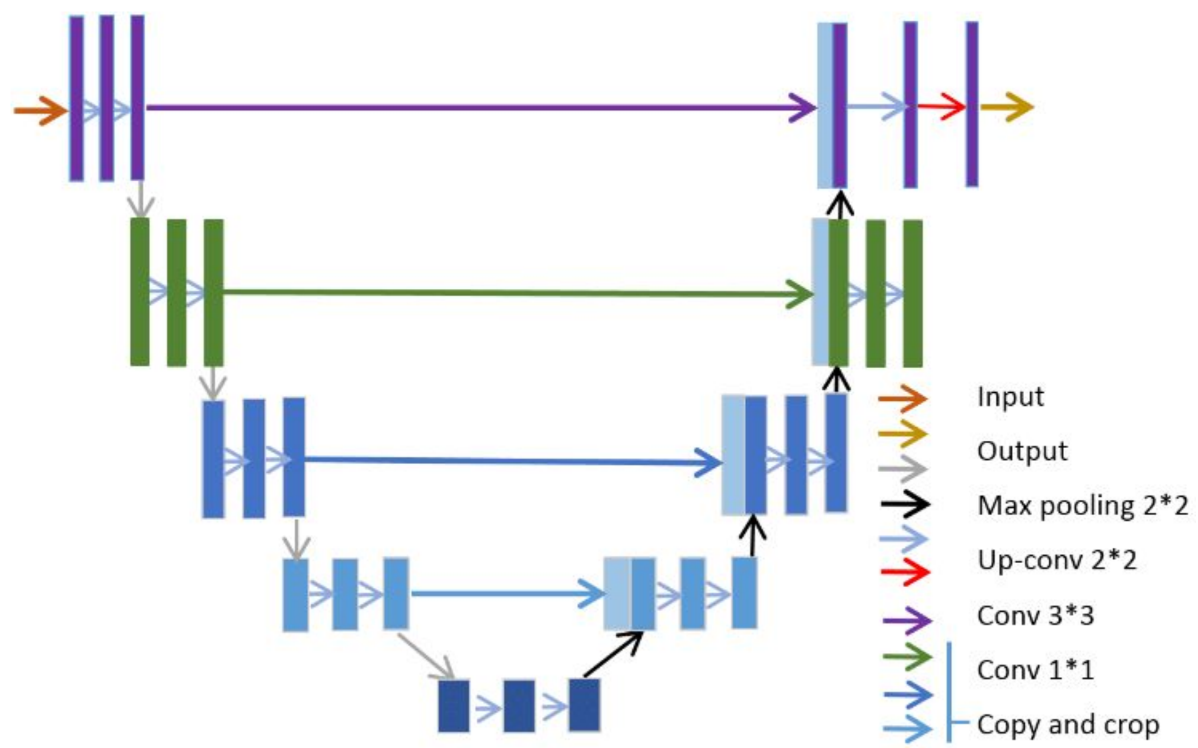
- **Neural network module**
  - UNet3+
    - Mapping from image space to image space
    - Real values known (from image processing methods) □ Generate predicted value
    - Real data batch known from past experiments in STJ (w/ ambient conditions and heliostats)



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- **Training Using the digital twin**
  - Two stages:
    - Pre-training with synthetic normalized augmented data Refine the neural net (933 cases in 16 combinations)
      - Compensation of the lack of data
      - Mapping from an ideal simulation to a realistic simulation w/ all errors

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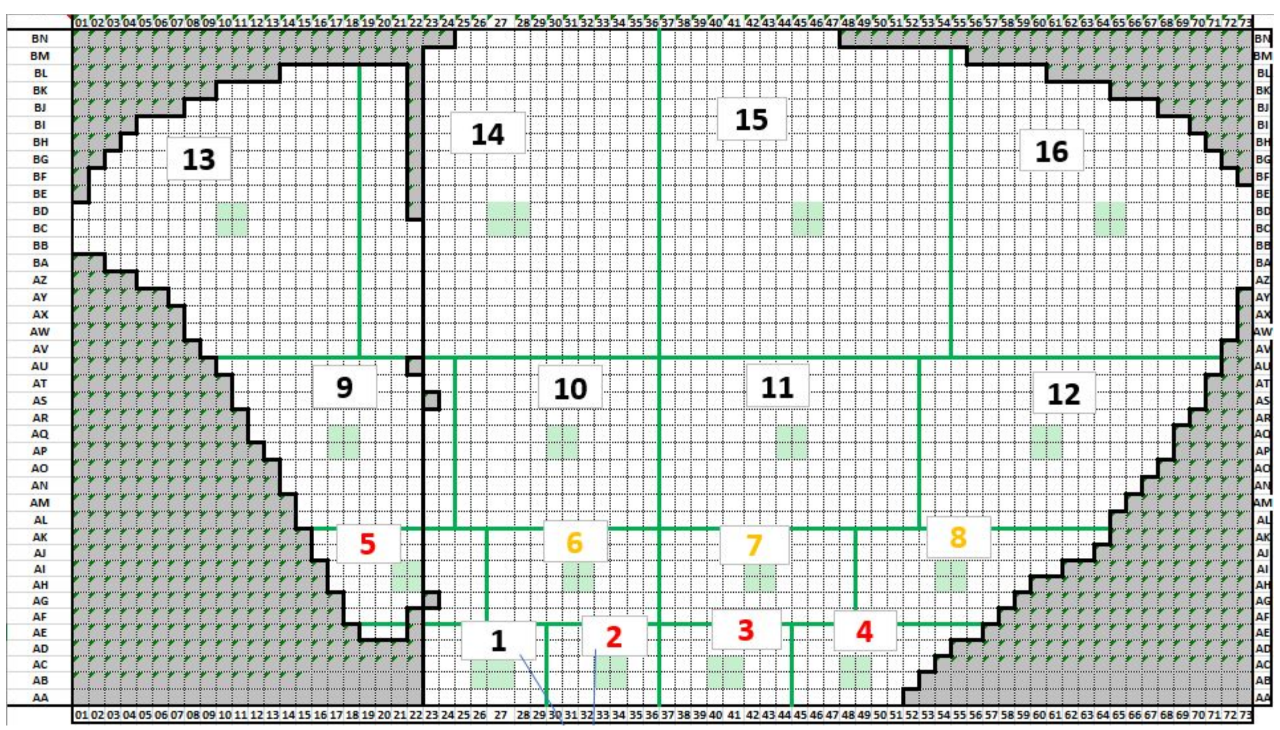
Augmentation technique



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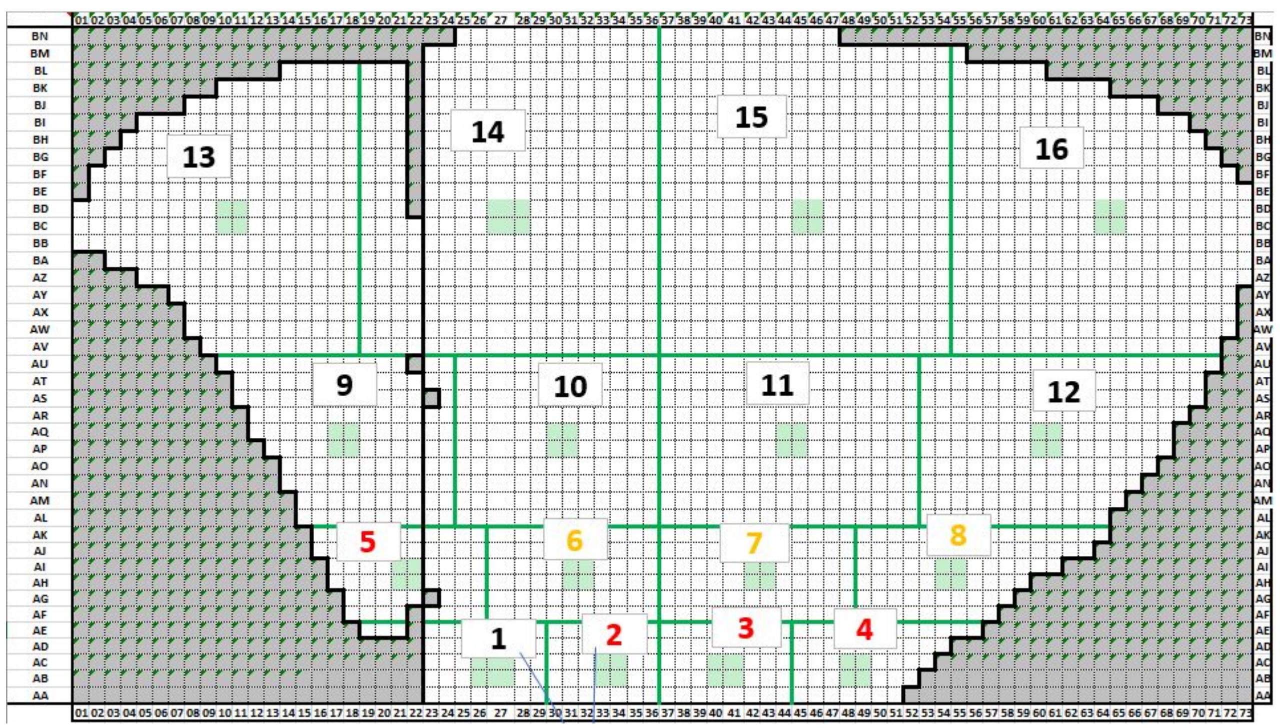
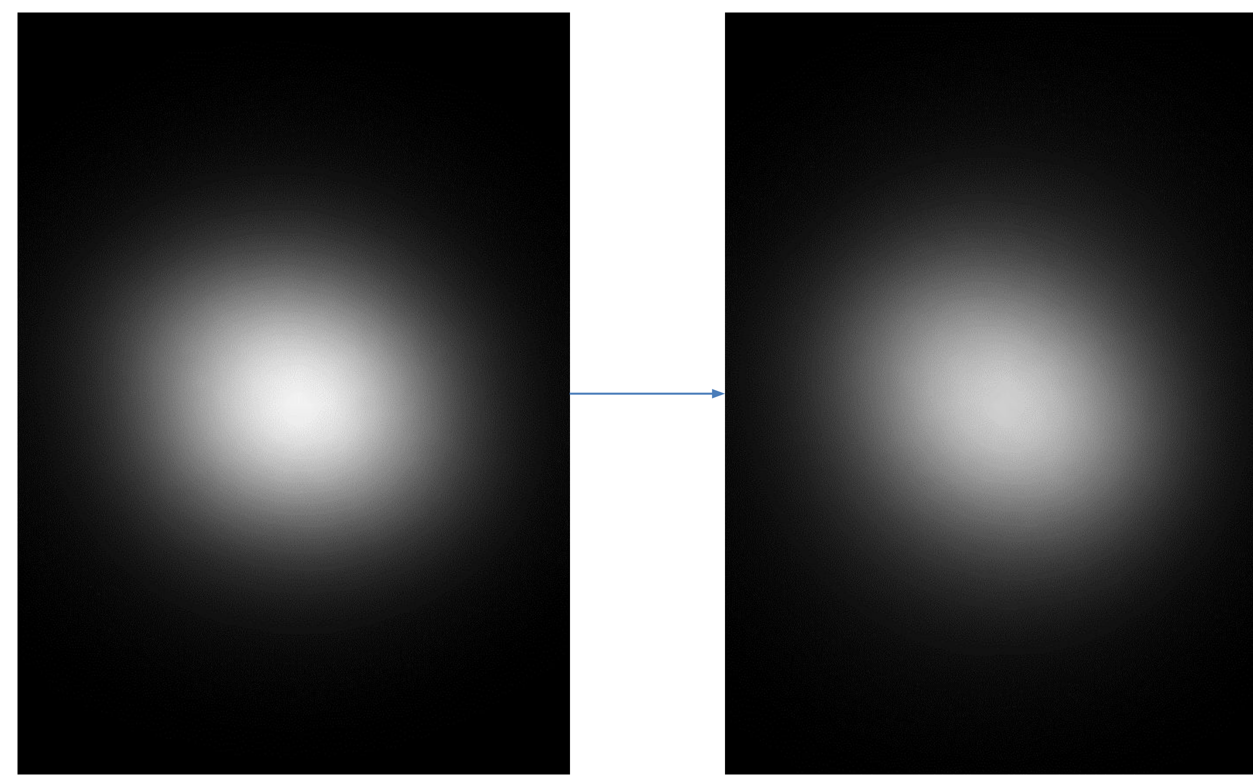


16-04-2014 @12:00:00

Input (prediction) **Label („real“ image)**



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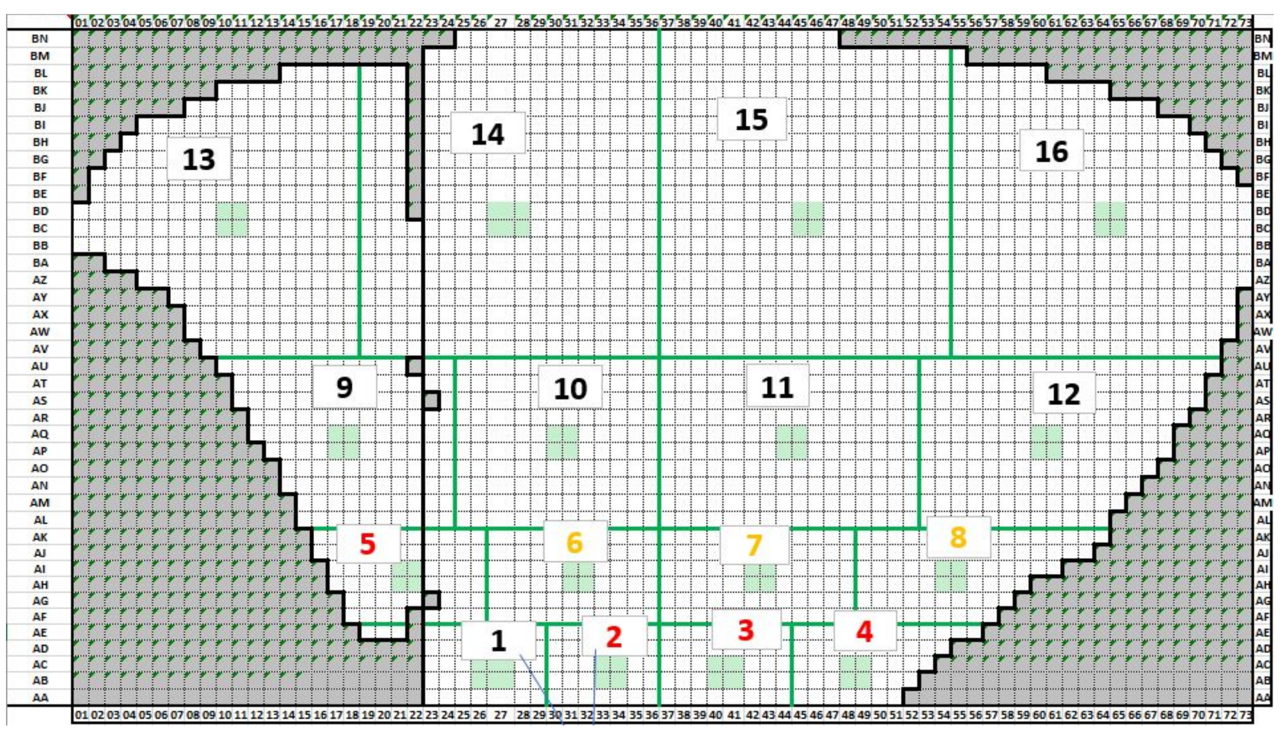

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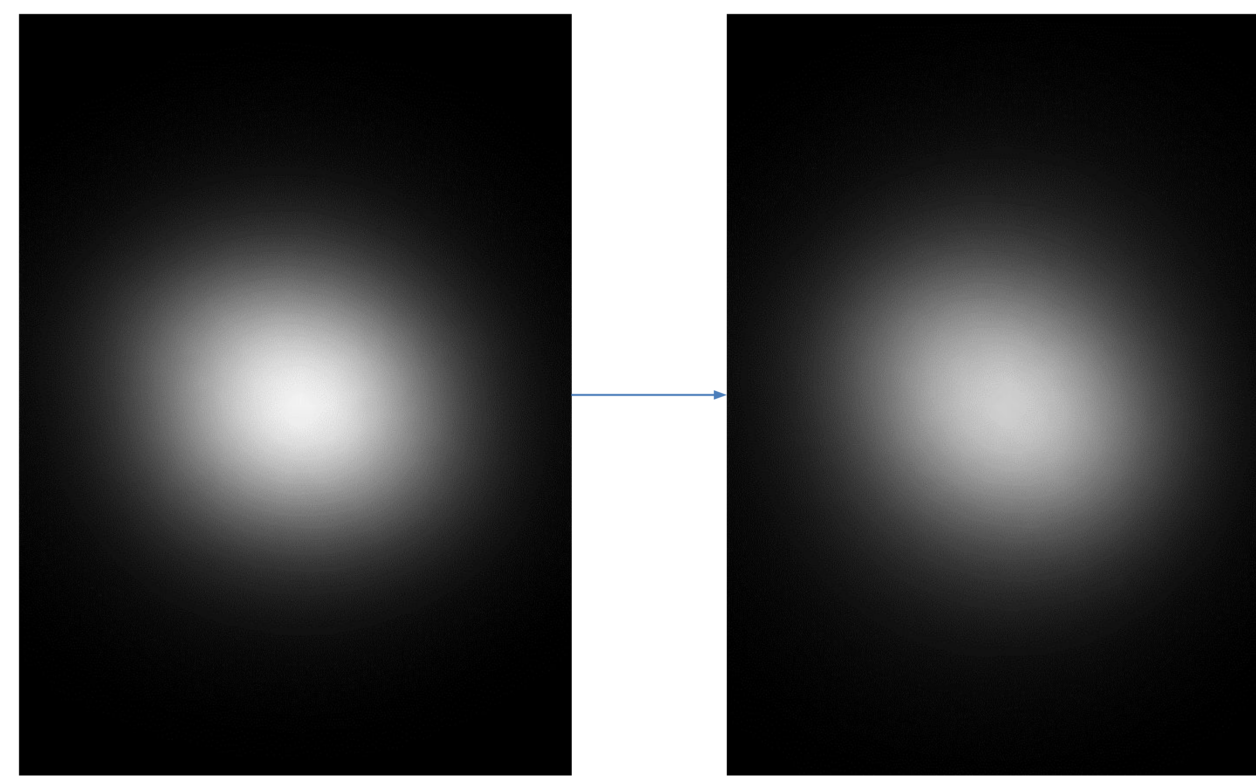

- Training with old experiments

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Summary

- Current synergies with S2L2 project and HEHTRES
- New intern hosted from 2nd may Master's thesis: "Pre-training of a Graphic Neural Network with Synthetic Data on CSP context"
- 1st paper on-going "CSP data-driven digital-twin for FDM"
- Planned participation in SOLLAB and SolarPACES

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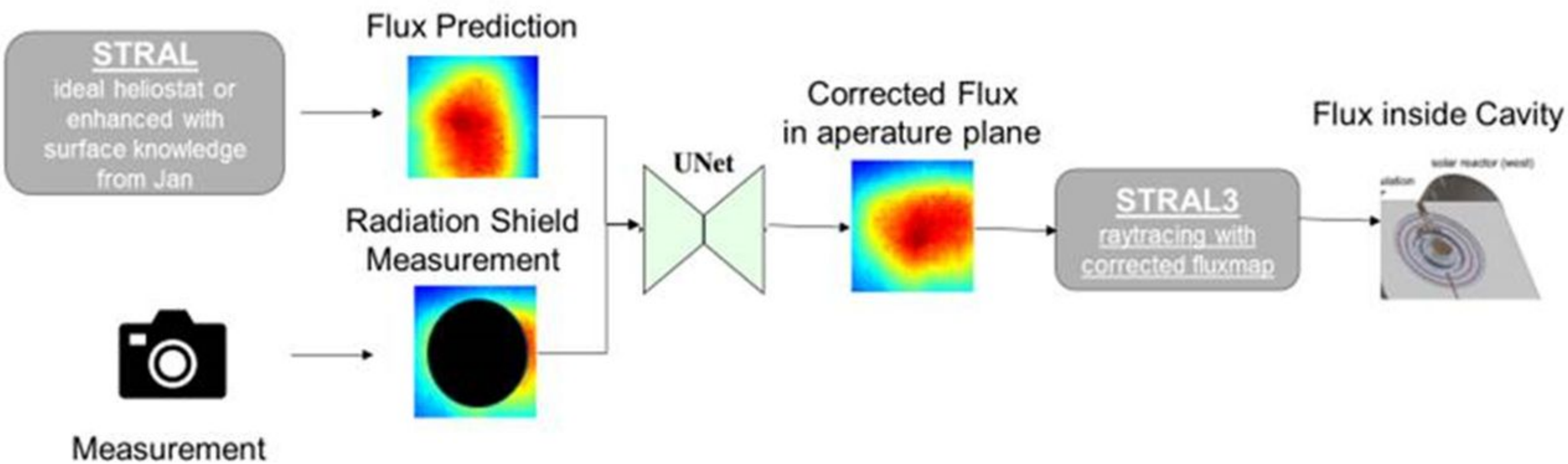
- **On-duty control strategy**



Thanks to the hybrid focus between data driven models and state-of-the-art measurement technologies, two key points are achieved:

- FDM without operation disruption
- FDM inside of a cavity receiver

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THE END

Thanks for listening!

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Project number 101072537).

Marie Skłodowska-
-Curie Actions

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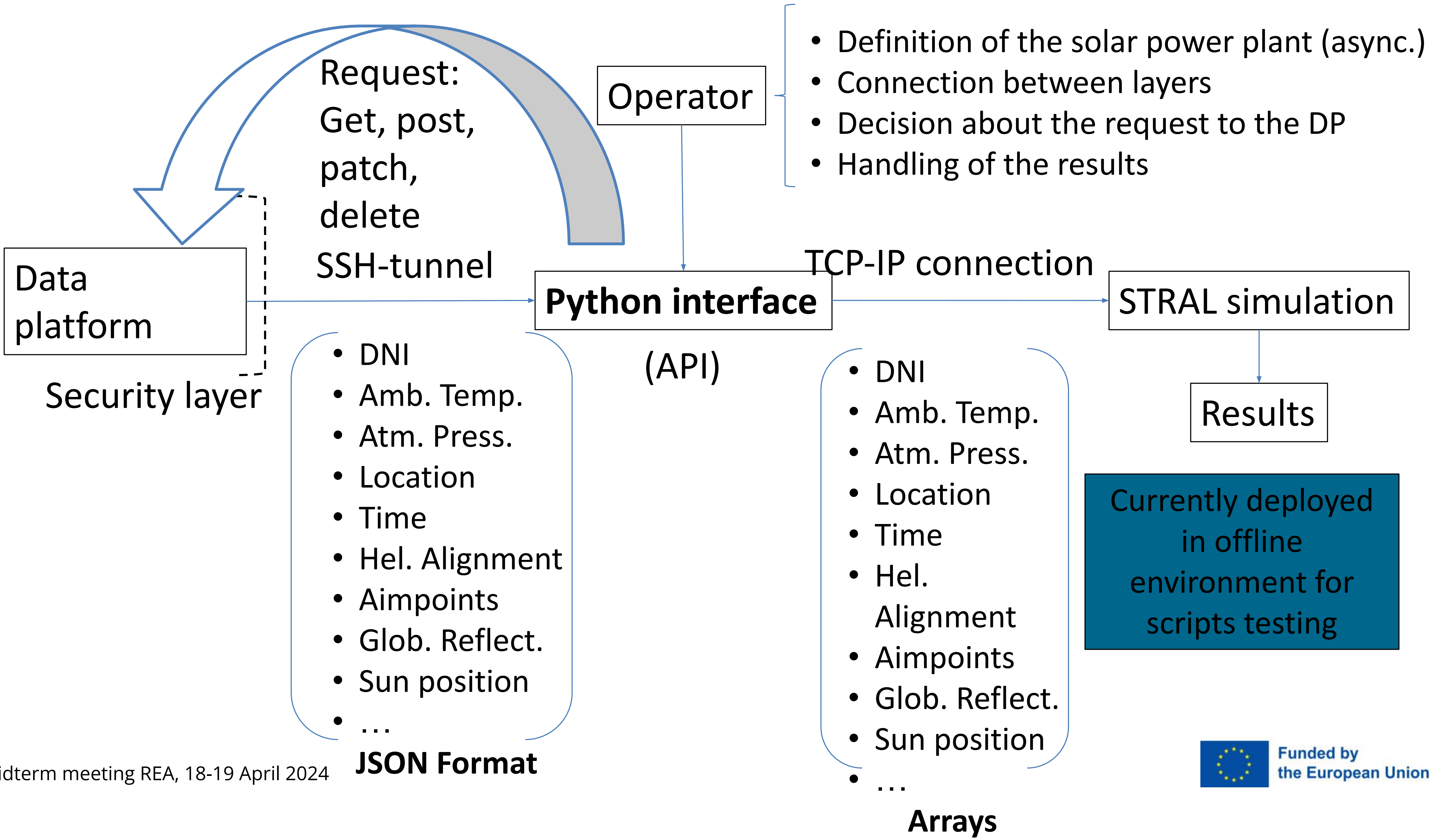
CURRENT STATUS: DT WORKFLOW



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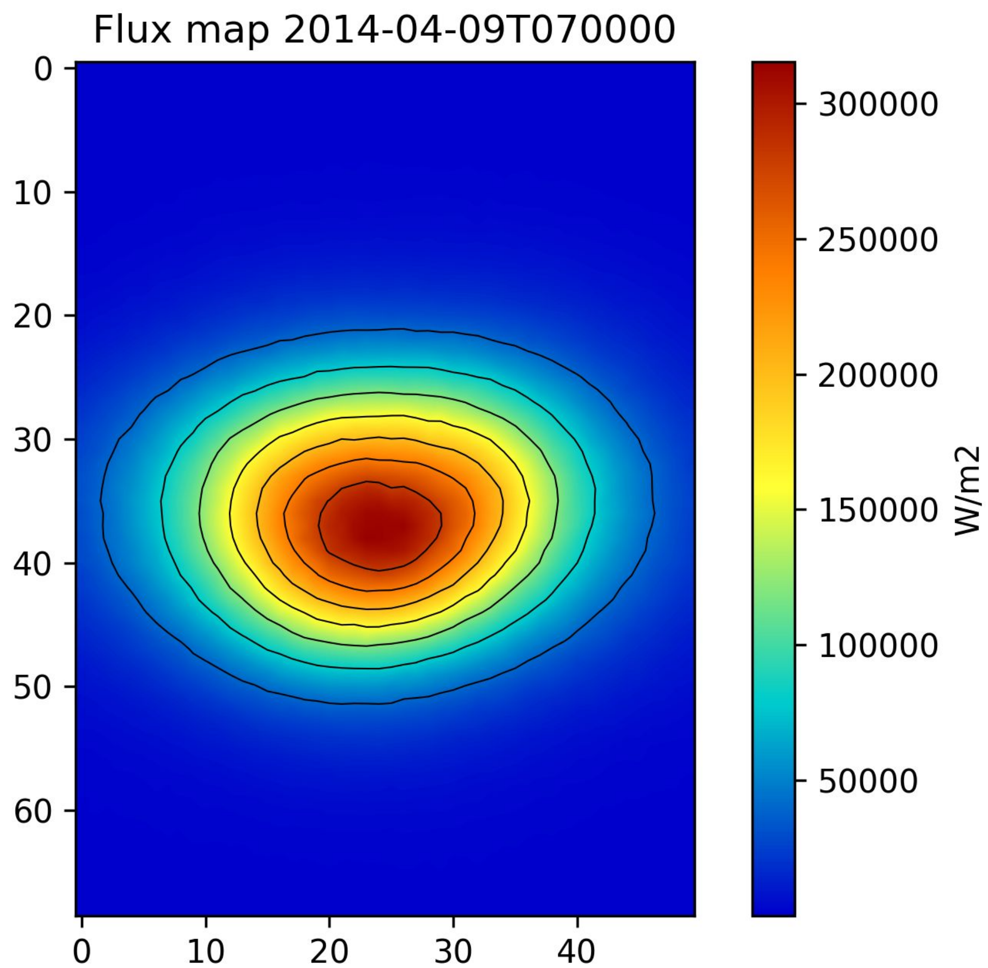
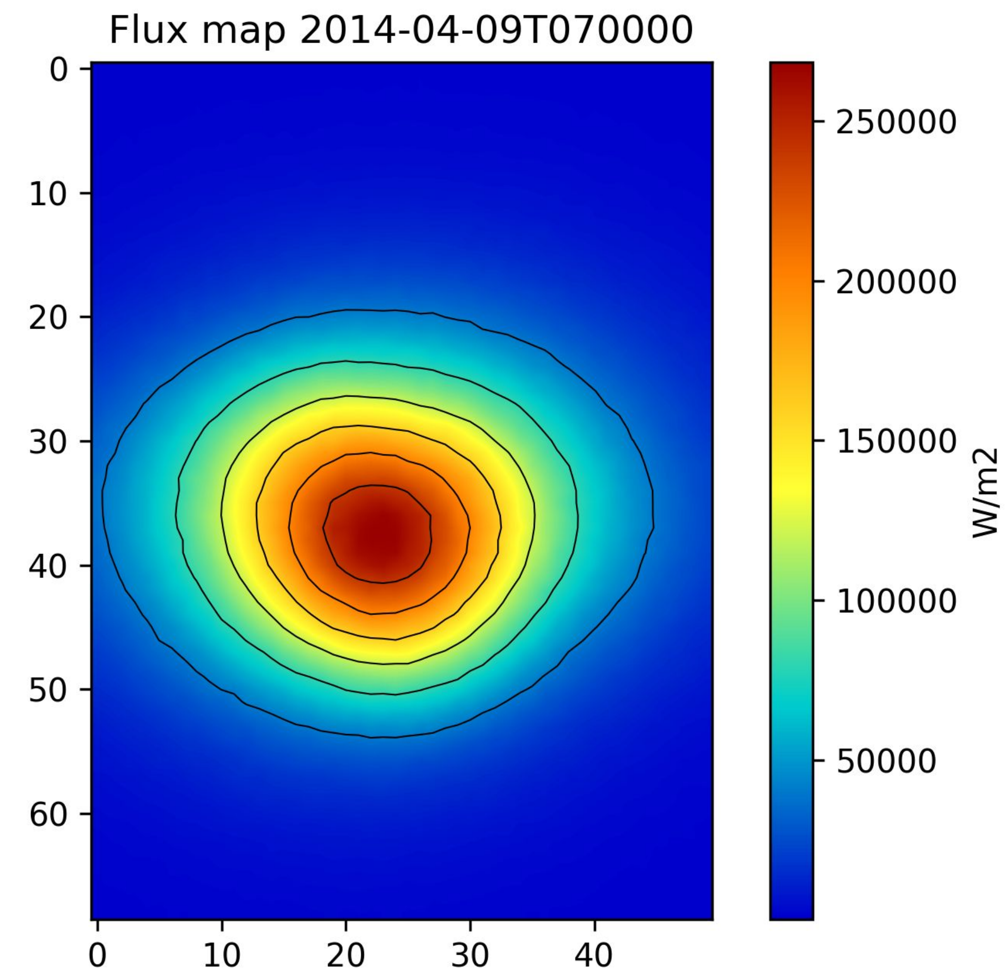
- RGB images □ Grayscale images for ML





Scale adapts to the peak value □ Need to adapt the scale to the intensity □ Normalization w/ peak value

Max DNI		Conditions			
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