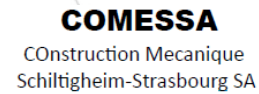


Simulation of the Next-CSP Solar Loop Including a Hybrid Gas Turbine

B. Grange, A. Le Gal, G. Flamant
CNRS-PROMES, France

September 28 - October 2, 2020
Online Event

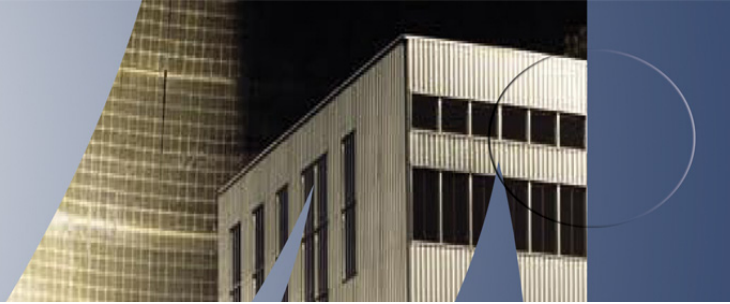
26th SolarPACES Conference



Outline

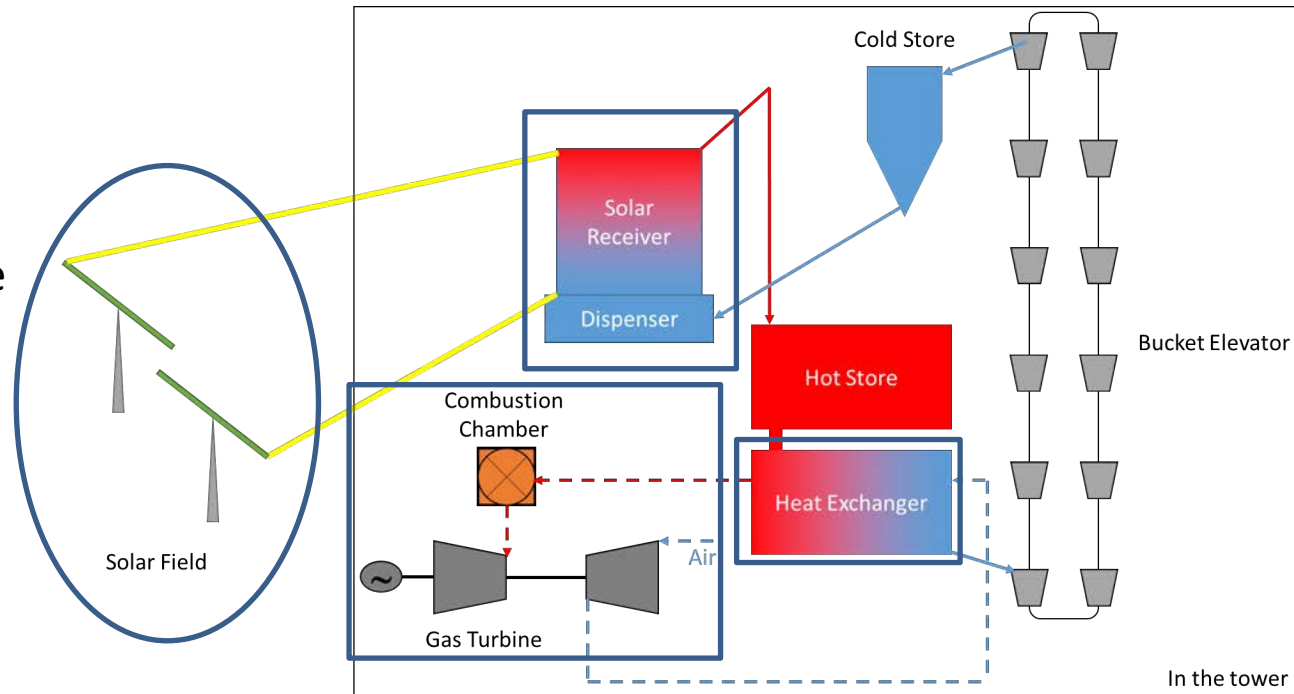
- Presentation of the Next-CSP project
- Modular Modelling Approach
 - Heliostat Field
 - Solar Receiver
 - Heat Exchanger
 - Gas Turbine
- Results & Discussion





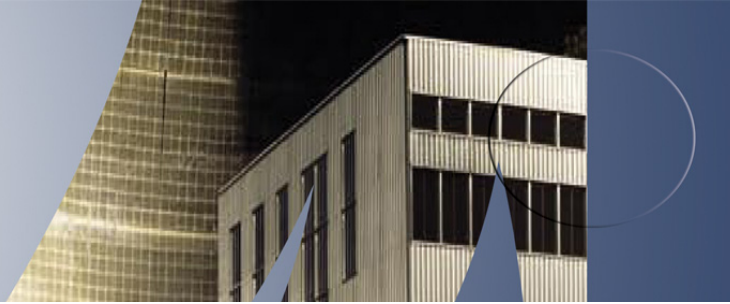
Next-CSP project

- Operation of the system
 - Solar Field
 - Dispenser
 - Tubular receiver
 - Hot and cold storage
 - Heat exchanger
 - Bucket elevator
 - Hybrid gas turbine

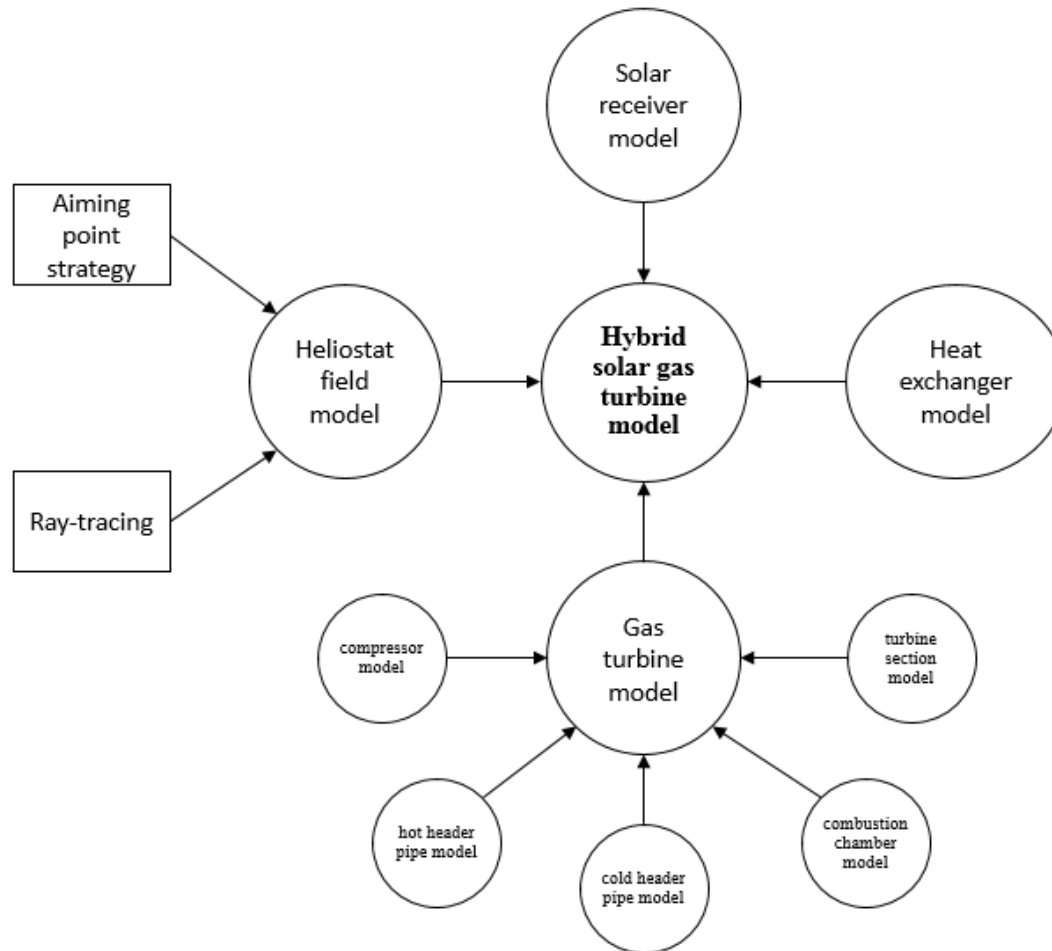


- Nominal Power (21st of March at noon):
 - on Receiver Aperture: ~3.8 MW
 - Transferred to the Particles in Solar Receiver: ~2 MW
 - Transferred to the Air: ~1.75 MW





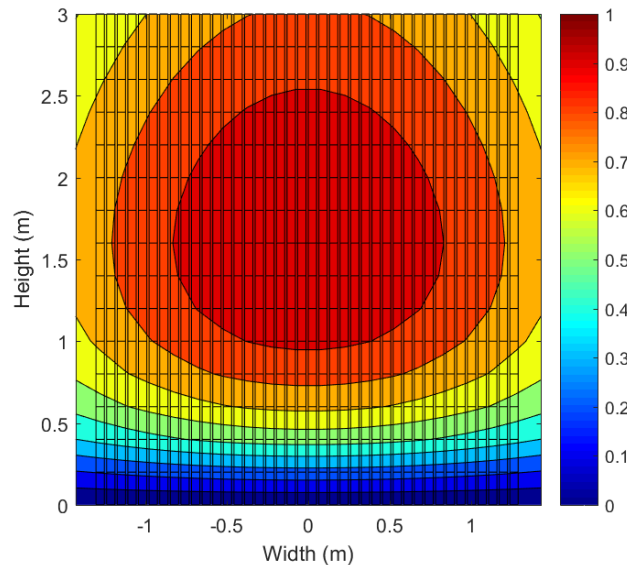
Modular Modelling Approach *Global Vision*





Modular Modelling Approach *Heliostat Field*

- TABU search coupled with convolution-projection optical model Unizar



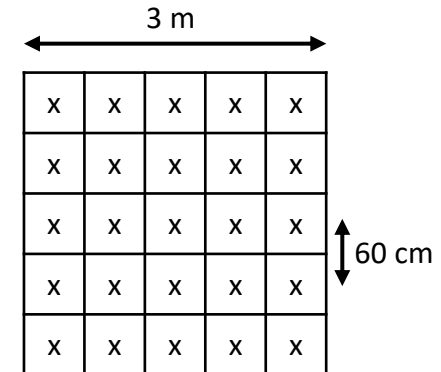
Objective normalized flux distribution

Horizontally → Gaussian distribution

Vertically → $y = \left(\frac{x}{x_{peak}} \right)^{x_{peak} \cdot b} \exp(b(x_{peak} - x))$

$$\longrightarrow \varphi_{inc} \leq 500 \text{ kW/m}^2$$

Number of aiming points = 25



Cost function

Root-Mean-Square Deviation

Constraint

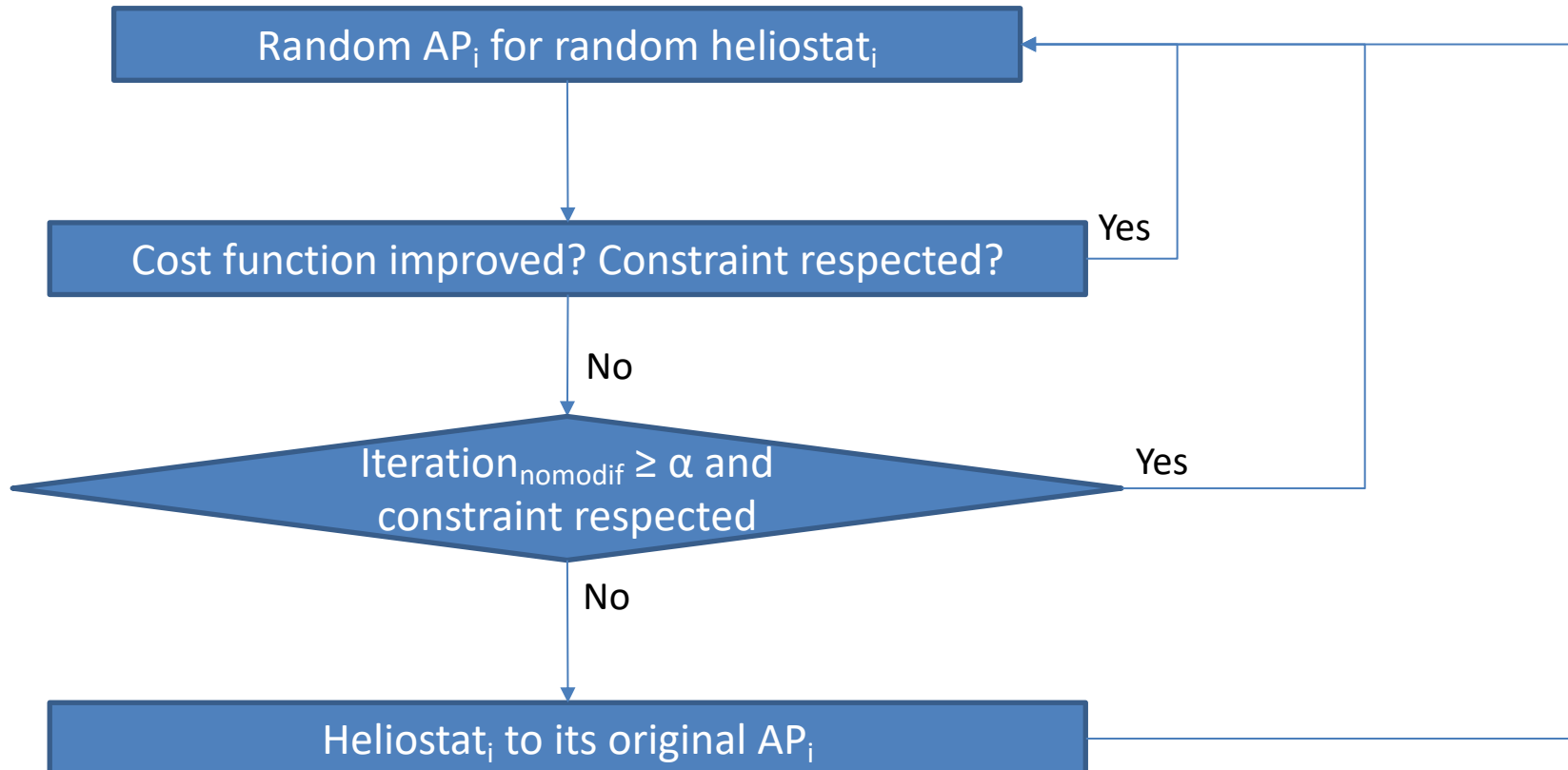
Not more than 30% of flux loss
relative to base case

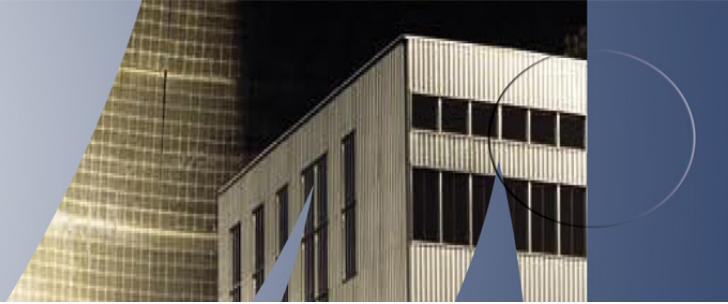




Modular Modelling Approach *HelioStat Field*

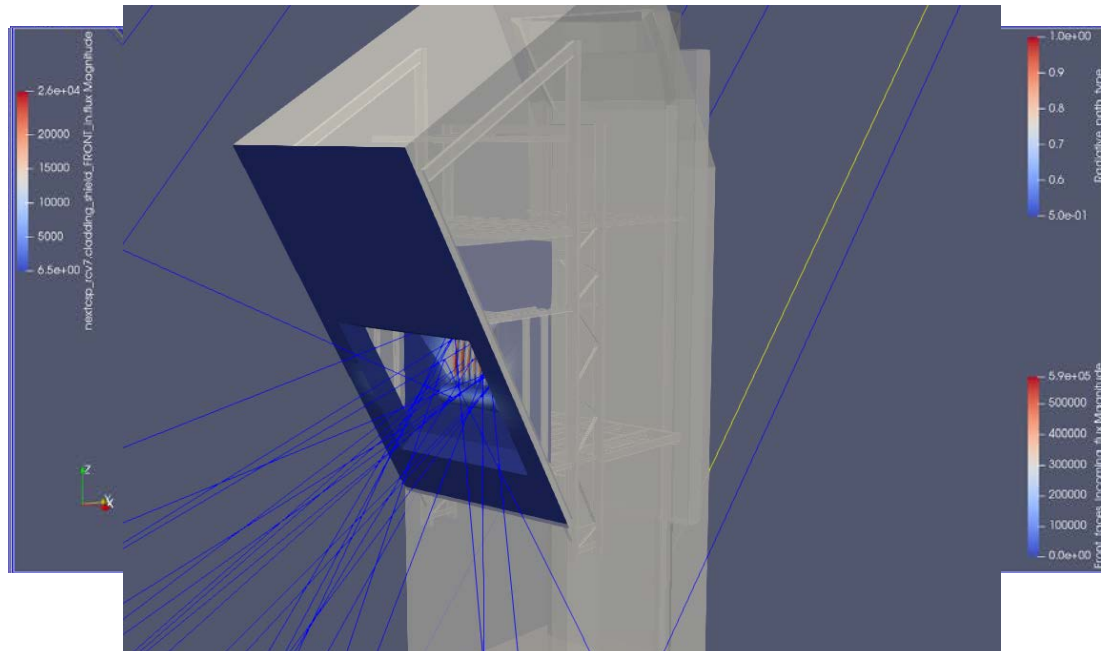
- Algorithm

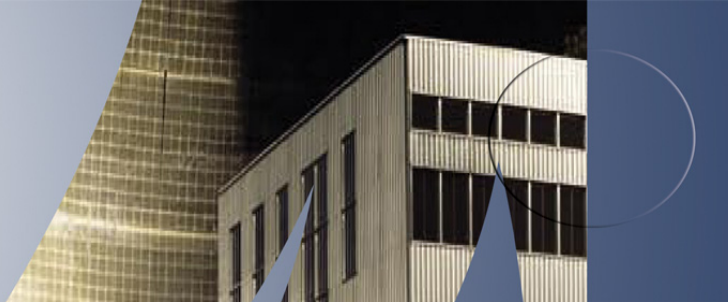




Modular Modelling Approach *Heliostat Field*

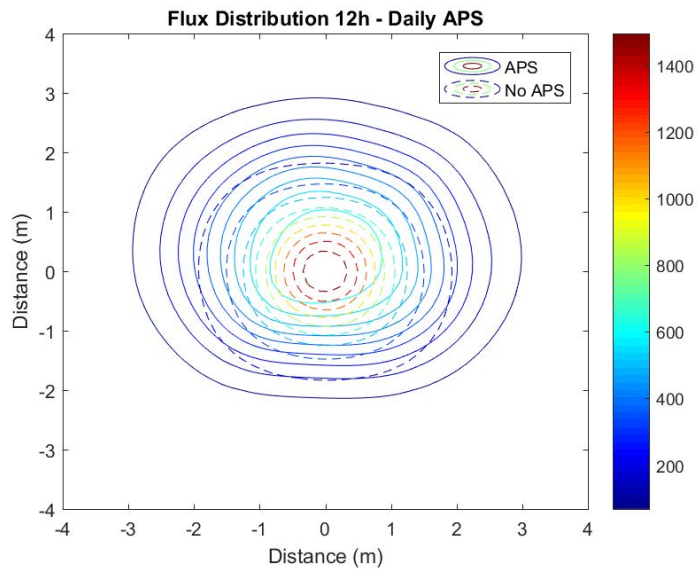
- Presentation of *Solstice*
 - New open-source ray-tracing software developed by the CNRS-PROMES laboratory and Meso-Star SAS
 - YAML (Yet Another Markup Language) language to create geometries
 - Import CAD model → Ray's path in complex geometry
 - Access to performance of the solar field



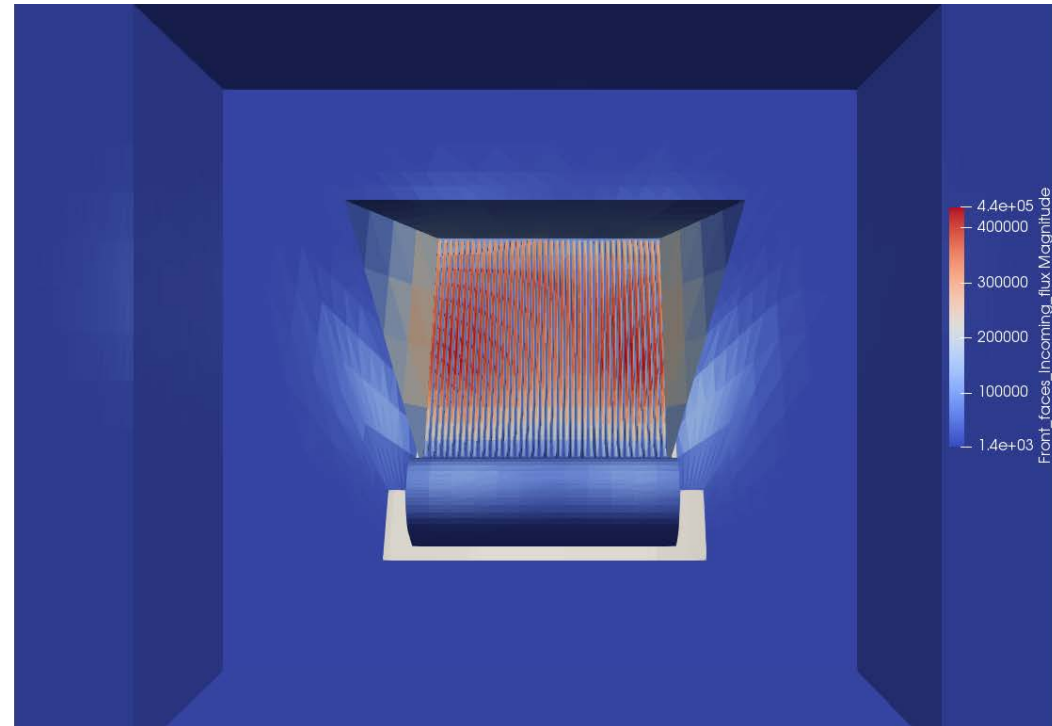


Modular Modelling Approach *Heliostat Field*

- Typical Optical Results

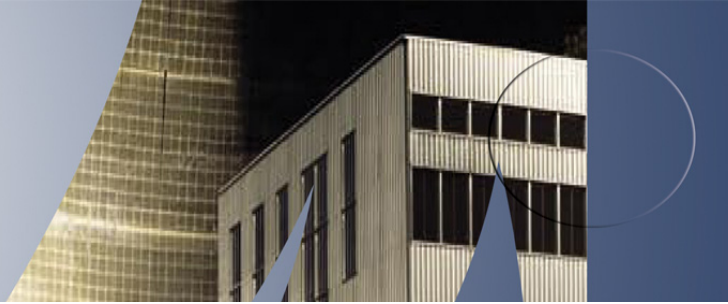


TABU + Unizar



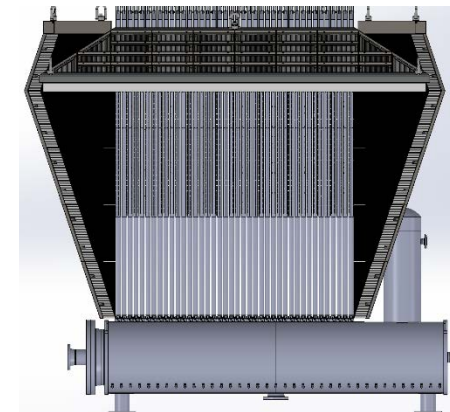
Solstice





Modular Modelling Approach *Solar Receiver*

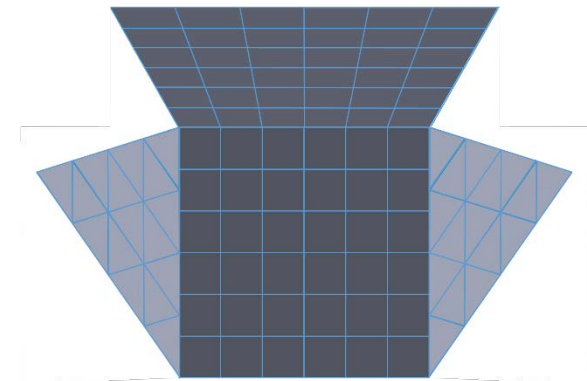
- Inputs from *Solstice*'s results
- 30 elements per tube (15 back of tubes, 15 front of tubes) → 1200 elements
- 104 elements for the cavity
- Visible from 0.3 to 3 μm carried out in *Solstice* and IR above 3 μm in thermal model
- Calculation of all the view factors
- Maximum Wall Temperature of 900°C
- Model Based on Net Radiation Method

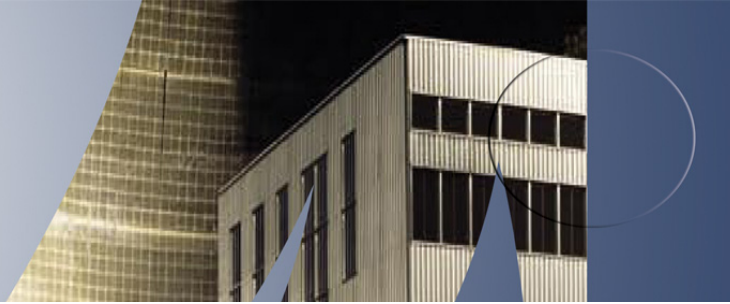


$$\dot{Q}_i^{net} = A_i \cdot \left(\dot{\phi}_i^{inc} + \sum_j F_{ij} \cdot J_j - J_i \right)$$

$$\dot{Q}_i^{res} = \dot{Q}_i^{net} - (\dot{Q}_i^{tr} + \dot{Q}_i^{loss})$$

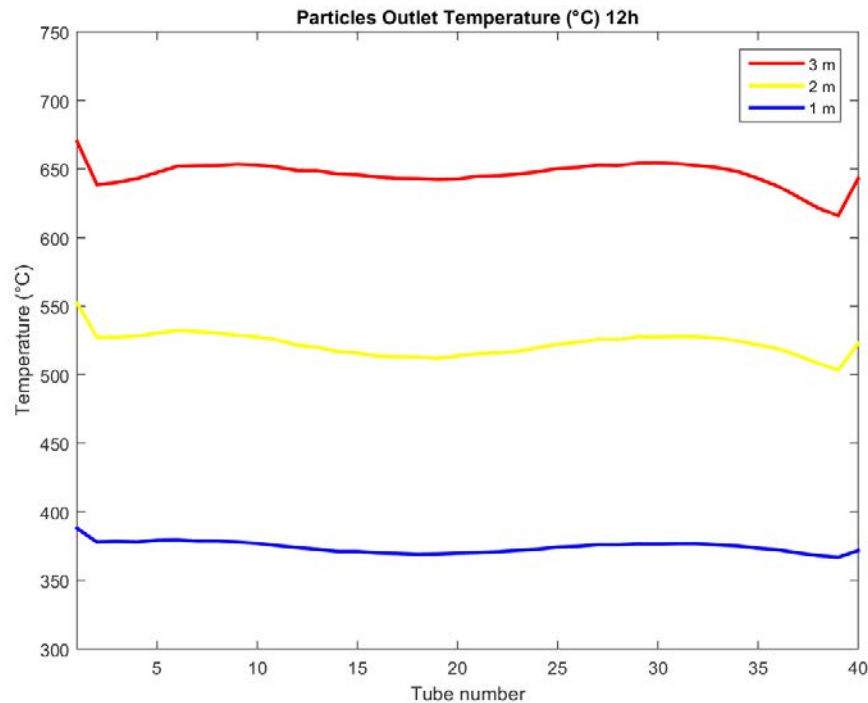
$$T_{i,t+dt}^w = T_{i,t}^w + \frac{\dot{Q}_i^{res} \times \Delta t}{m_i^{rec} \cdot c_p^{rec}}$$





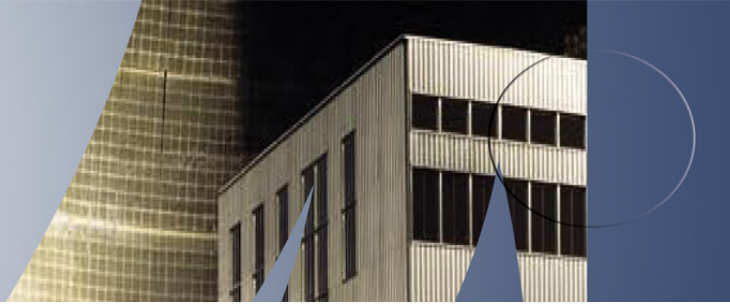
Modular Modelling Approach *Solar Receiver*

- Typical Results



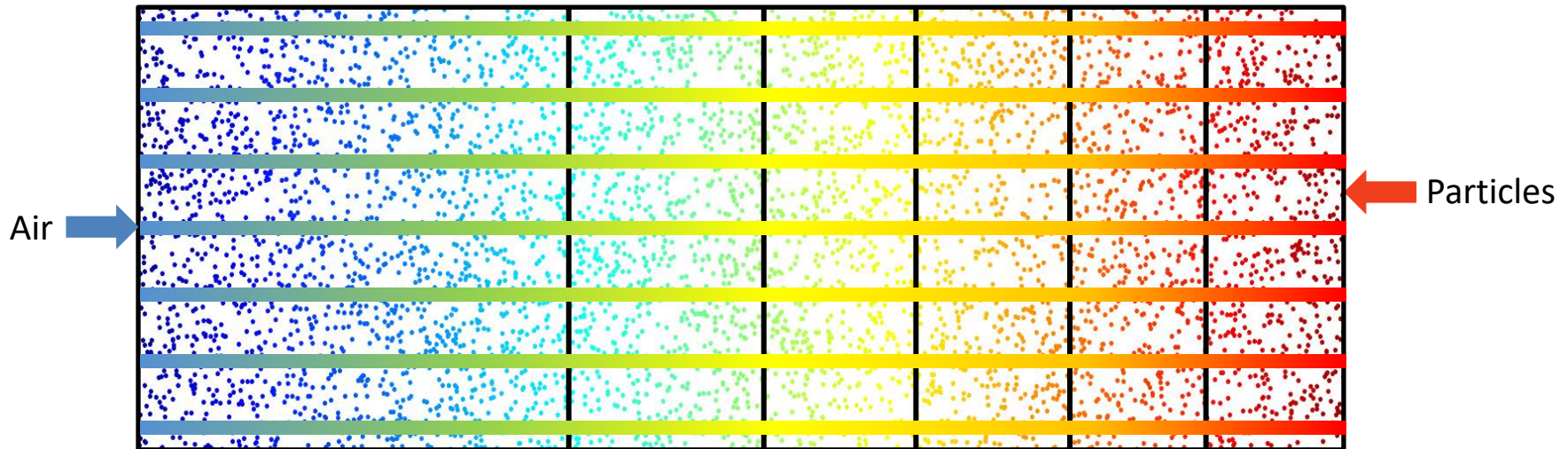
Maximum Temperature too high
BUT possibility to decrease the number of operating heliostats



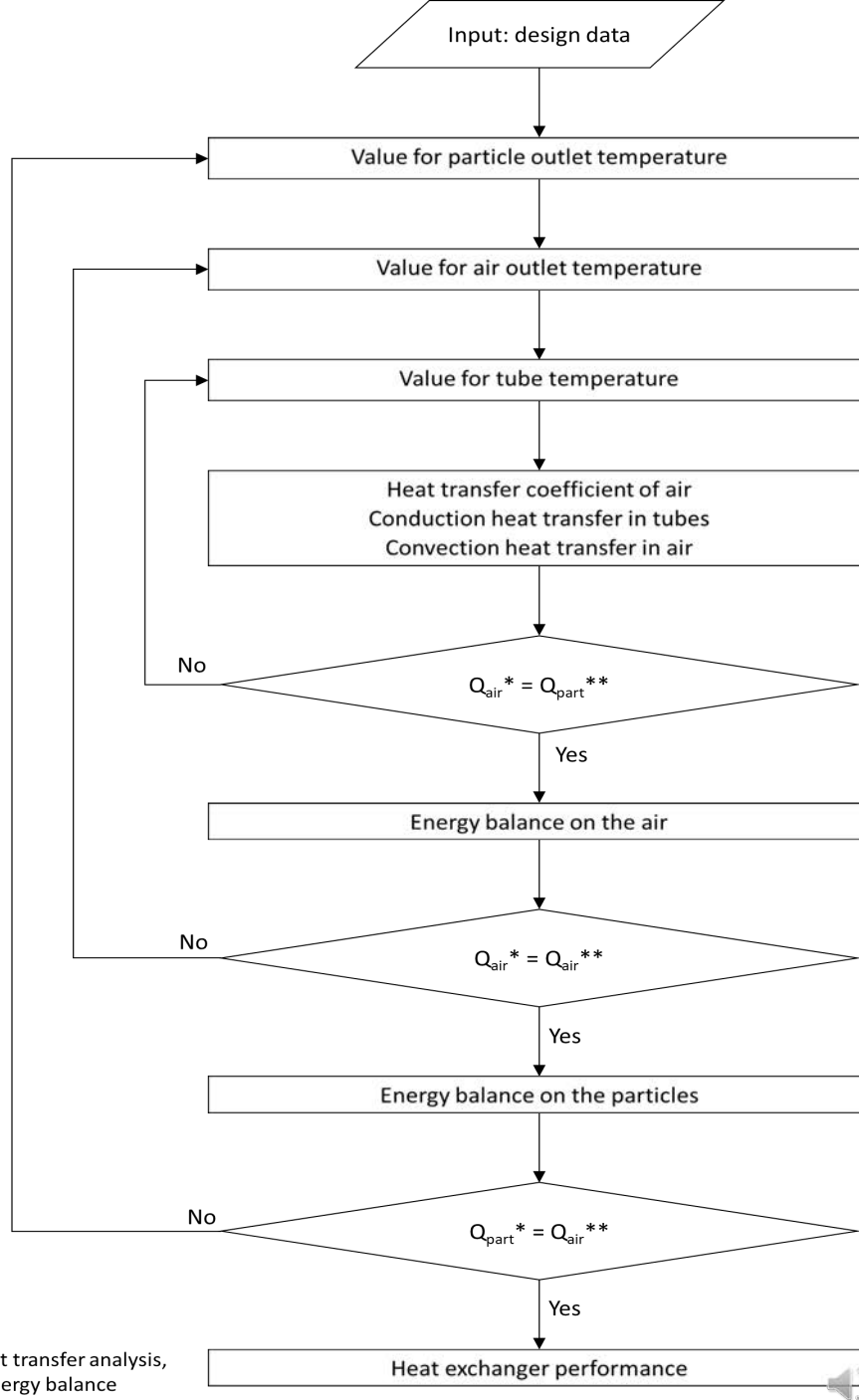


Modular Modelling Approach *Heat Exchanger*

- 6 stages – Counter current
- Inputs from thermal model (Particles Inlet Temperature) and from gas turbine model (Air Inlet Temperature)



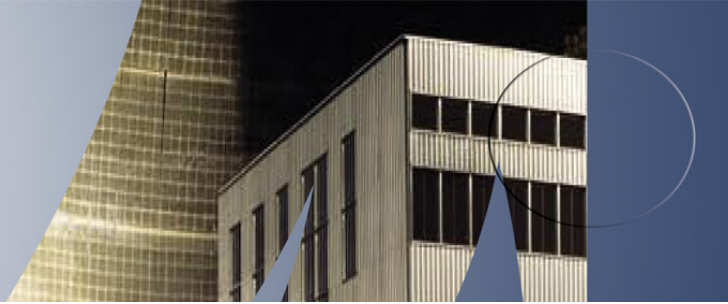
Modular Modelling Approach *Heat Exchanger*



$$F_{friction} = (1.82 \times \log_{10}(Re) - 1.64)^{-2}$$

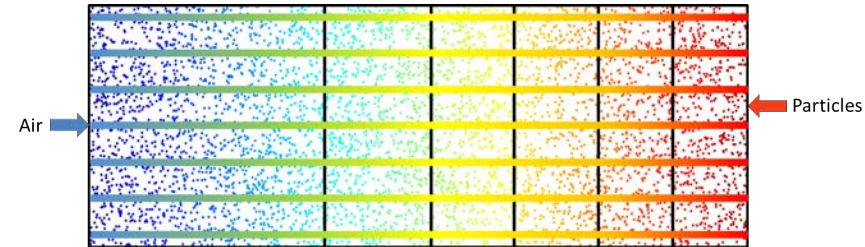
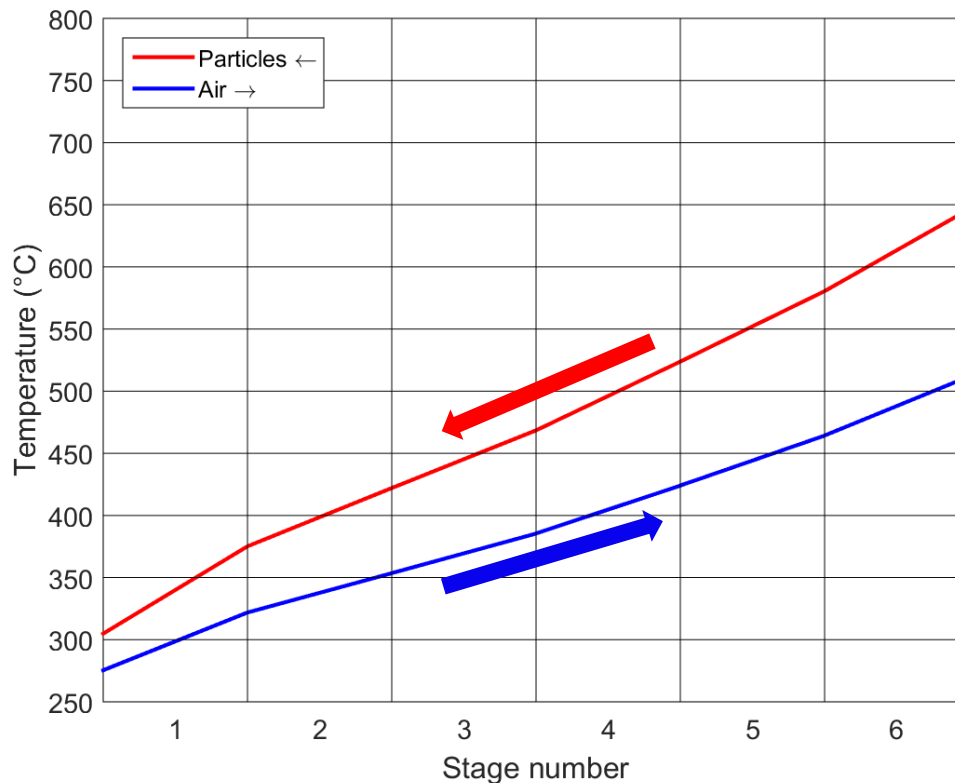
(*) heat calculated based on heat transfer analysis,
(**) heat calculated based on energy balance
(inlet and outlet of the FB-HEX stage)





Modular Modelling Approach *Heat Exchanger*

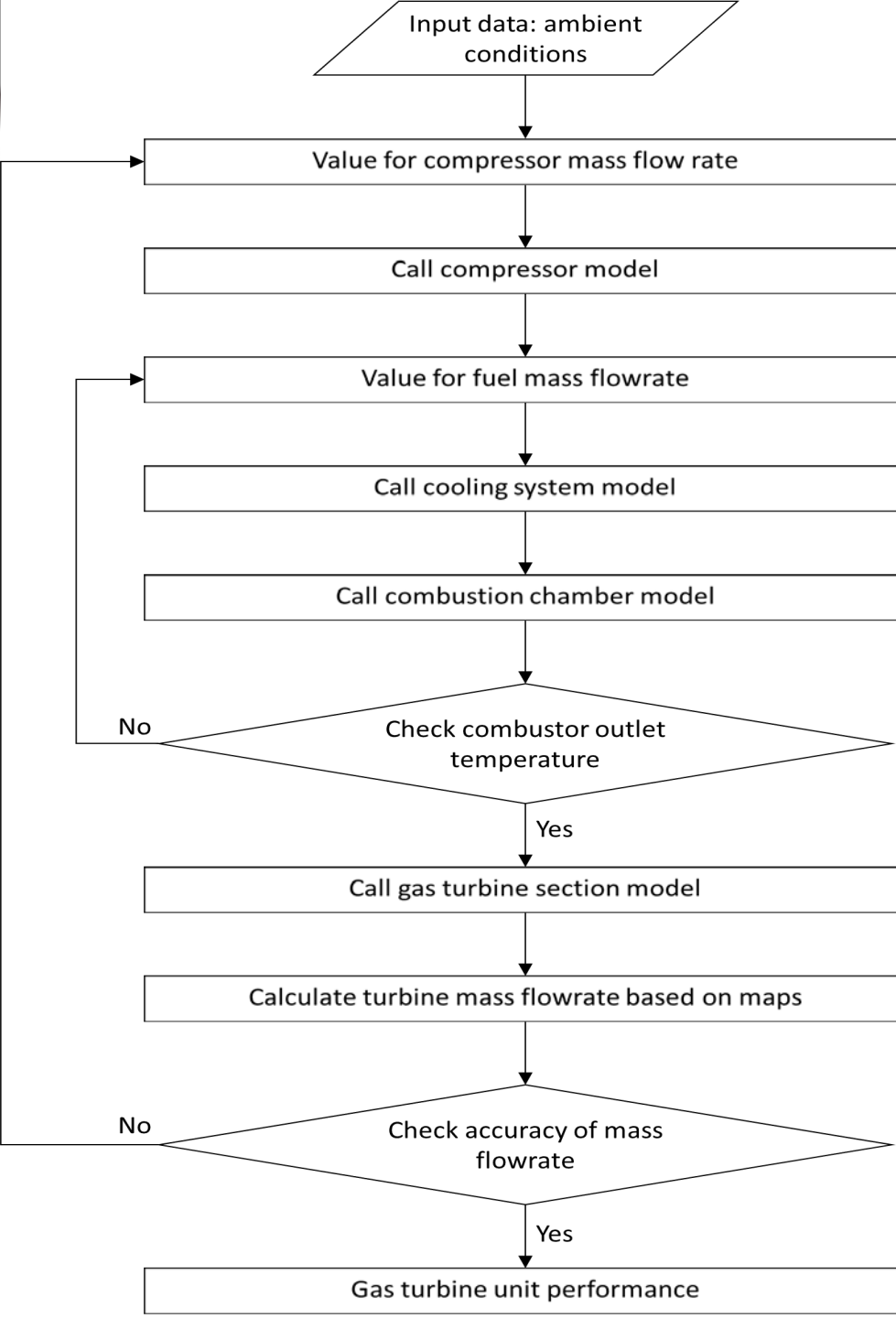
- Typical Results



- The outlet gas temperature is limited by the heat transfer coefficient inside the tubes (air side)
- A better design is possible

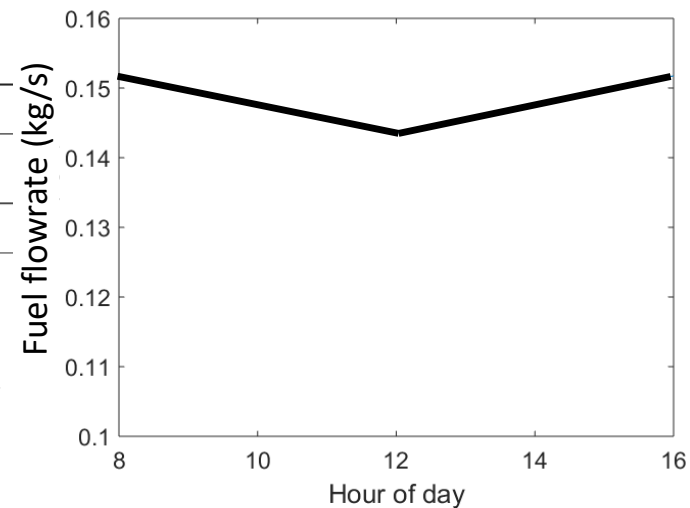


Modular Modelling Approach *Gas Turbine*

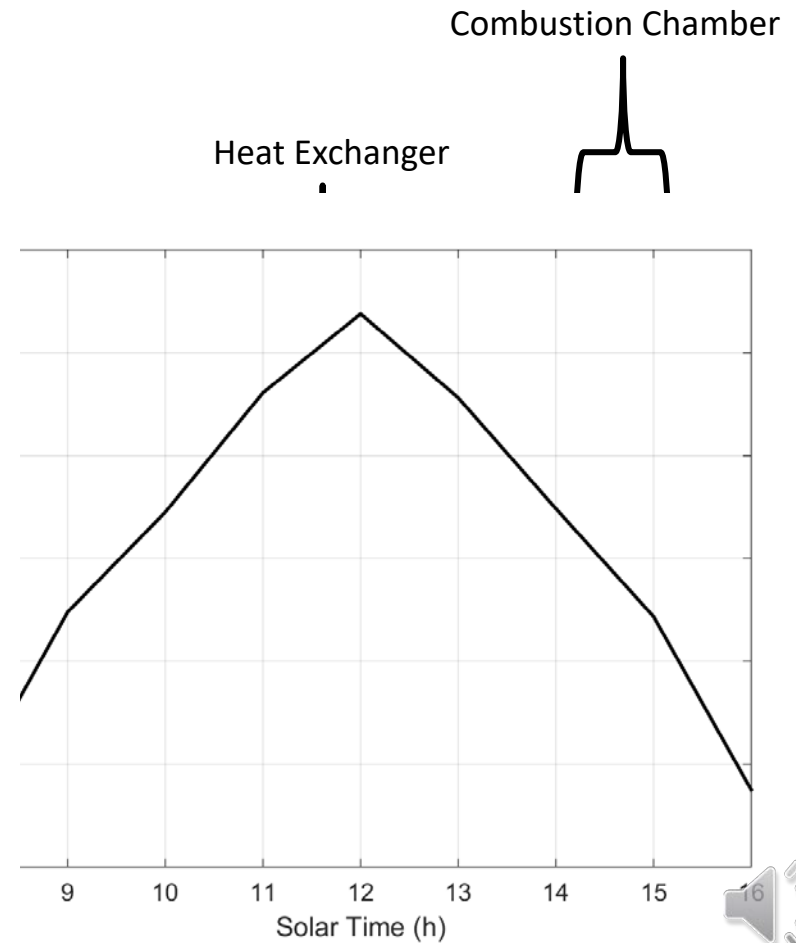
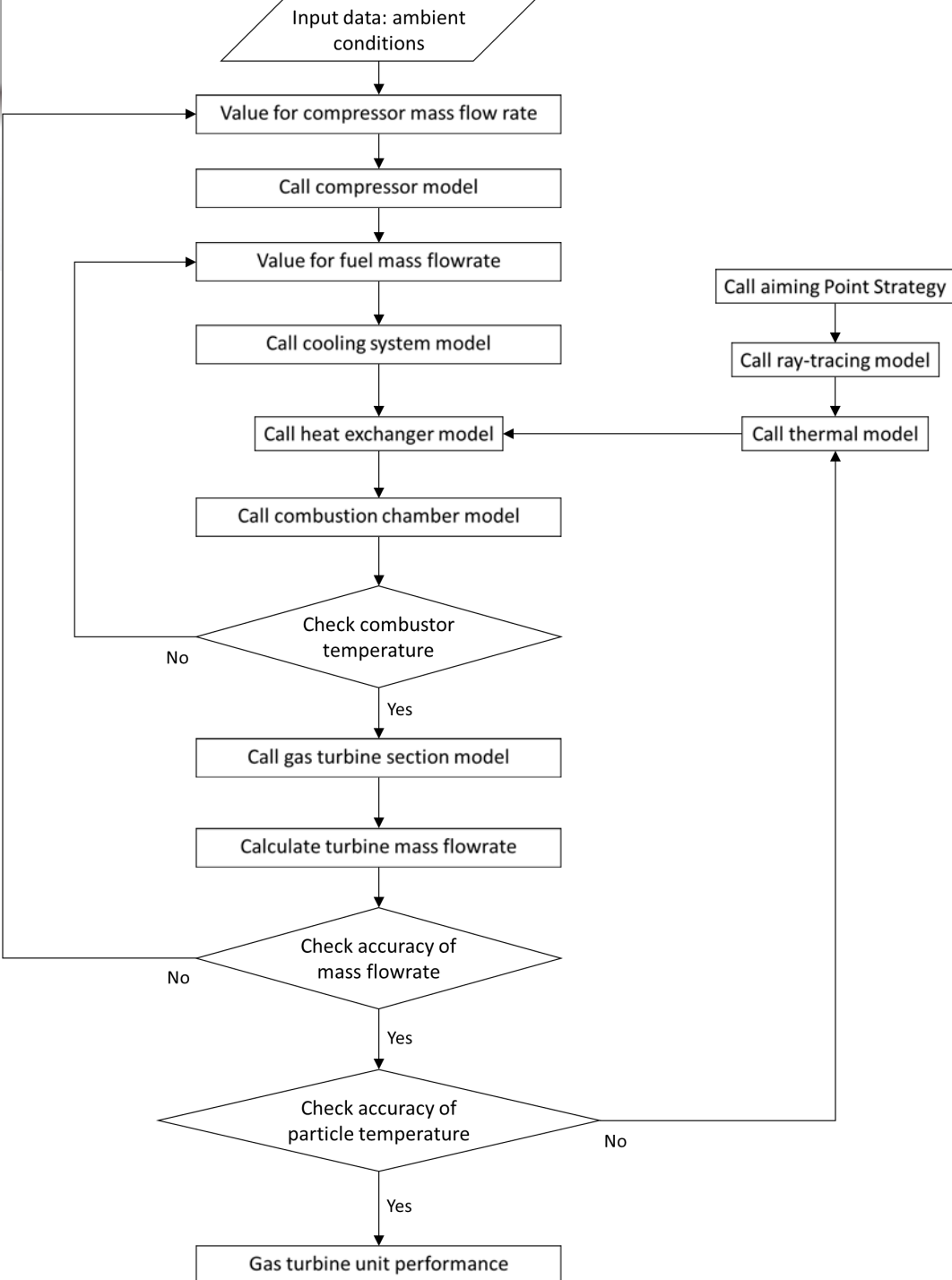


$$\frac{P_2}{P_1} = Q \frac{\sqrt{T_1/288,15}}{P_1/1013,25} = \frac{N}{\sqrt{T_1/288,15}}$$

$$\frac{P_3}{P_4} = Q \frac{\sqrt{T_3/288,15}}{P_3/1013,25} = \frac{N}{\sqrt{T_3/288,15}}$$



Modular Modelling Approach *Global Model*



- Low solar share BUT can be increased with:
 - Better heat transfer wall/particles in receiver
 - Better HEX design
 - Optimized solarized turbine (current one is off-the-shelf)
- Major objectives of this project is to gain experience in the particle solar loop and in the hybridisation

Thank you for your attention

Any Questions?

- This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 727762, project acronym NEXT-CSP.
- This work was supported by the French "Investments for the future" program managed by the National Agency for Research, under contract ANR-10-EQPX-49-SOCRATE (Equipex SOCRATE).

