OpenSees Workshop

Brunel, May 2016

Presented by **Dr Liming Jiang & Xu Dai**

With acknowledgements to:
Jian Zhang, Yaqiang Jiang, Jian Jiang, Panagiotis Kotsovinos,
Shaun Devaney, Ahmad Mejbas Al-Remal, & Praveen Kamath & the IIT Roorkee and Indian Institute of Science teams, and China Scholarship Council!

& special acknowledgement to:
Frank McKenna at University of California, Berkeley for OpenSees

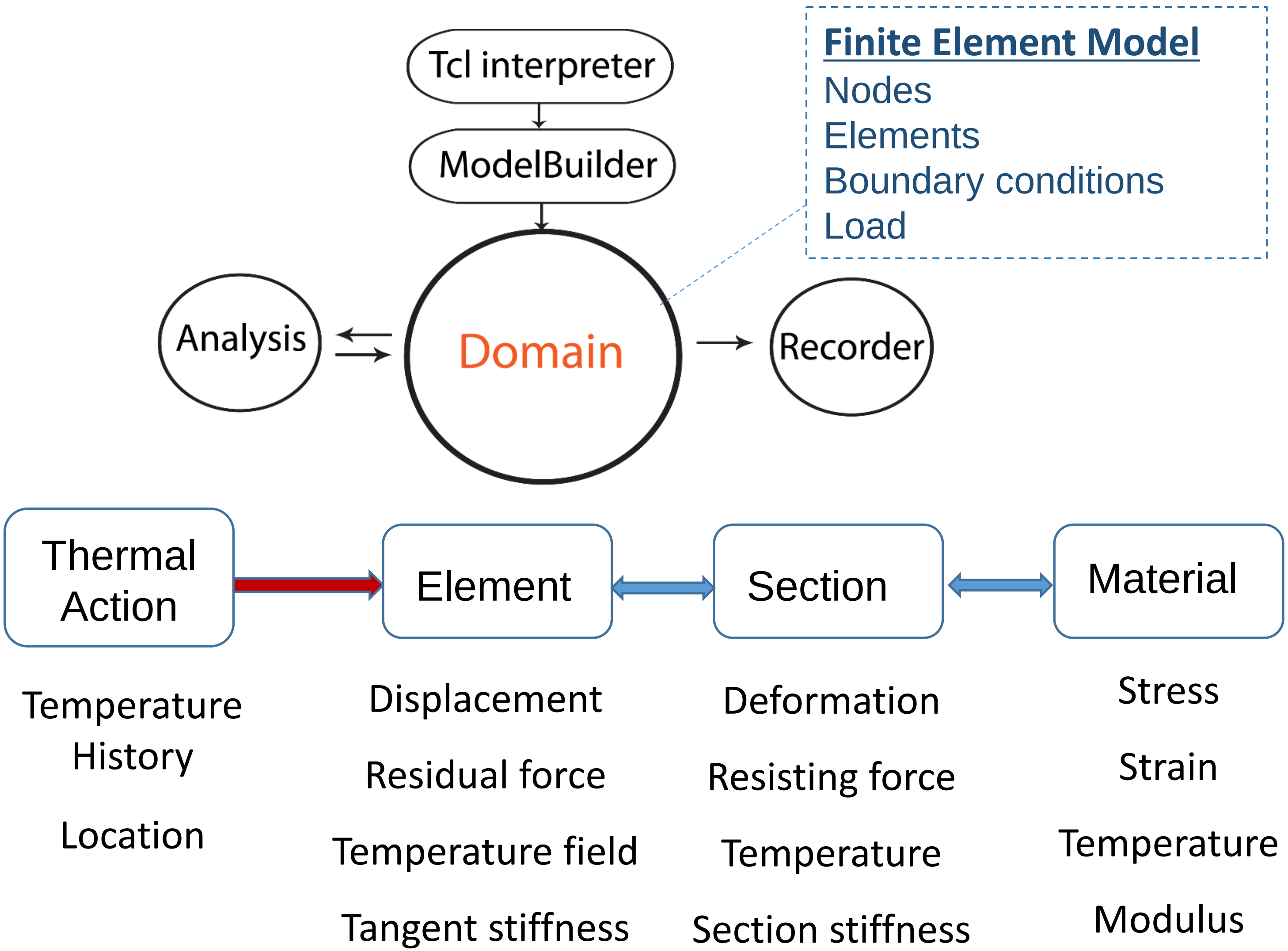
OPENSEES WORKSHOP DAY 3

1. Development for Thermomechanical Analysis
2. Development for Heat Transfer Analysis
3. Development for SIFBuilder
4. Extra exercise

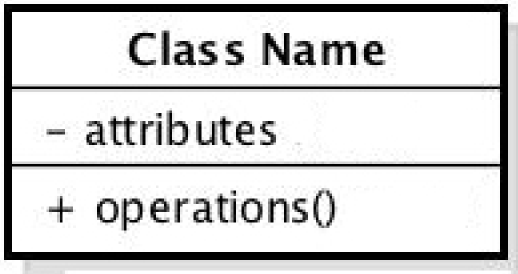
OPENSEES WORKSHOP

Day3:
Development for Thermo-mechanical Analysis

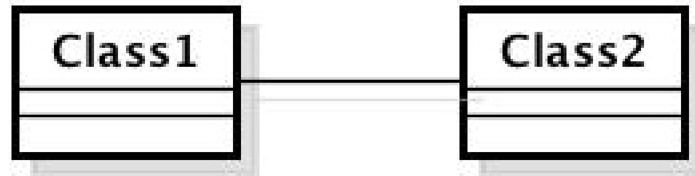
Thermo-mechanical Analysis



Thermo-mechanical Analysis

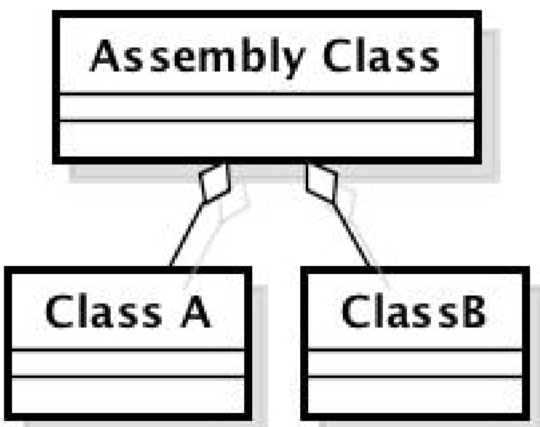


Class structure

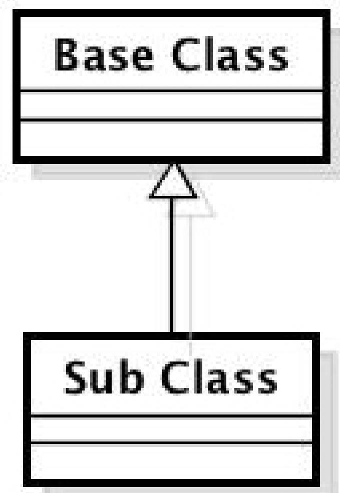


Association

UML Notation

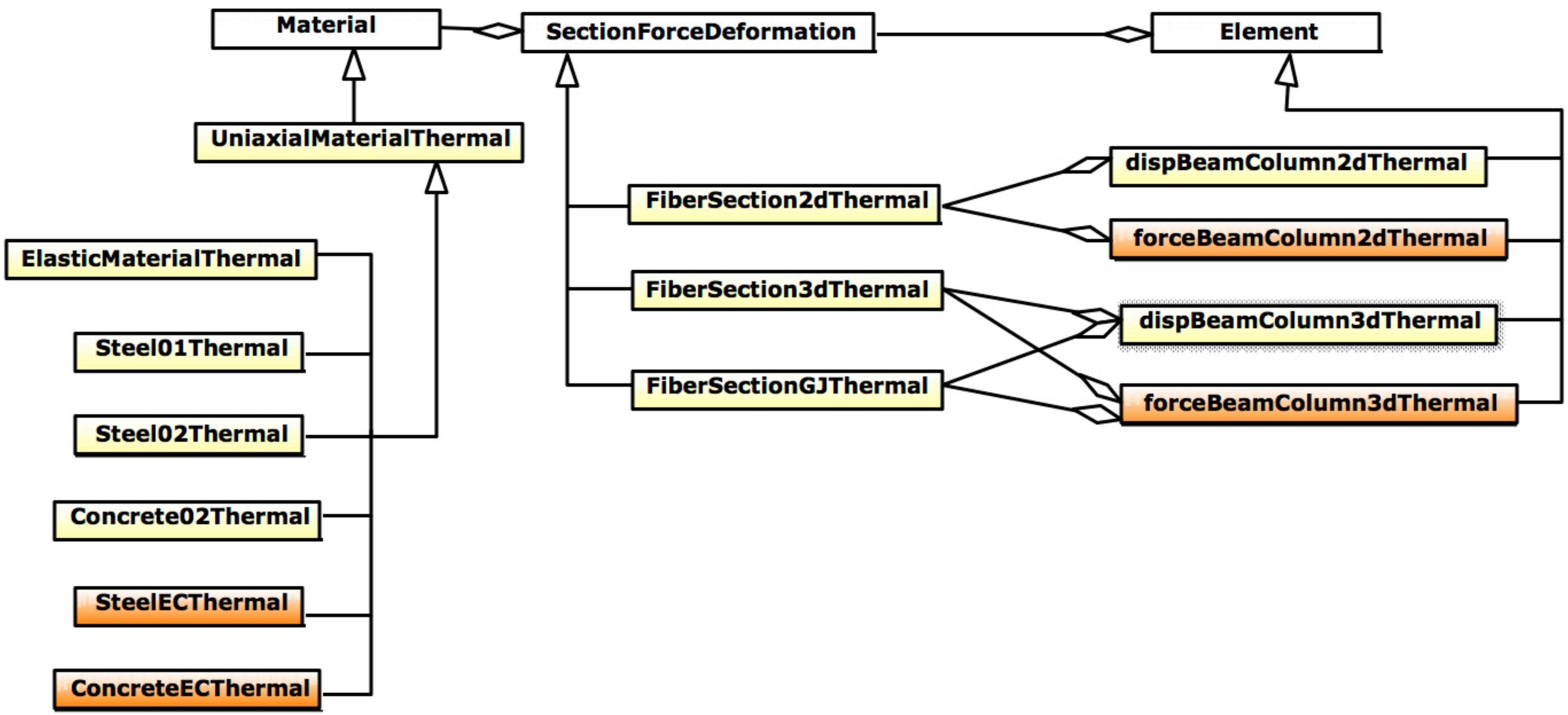


Aggregation



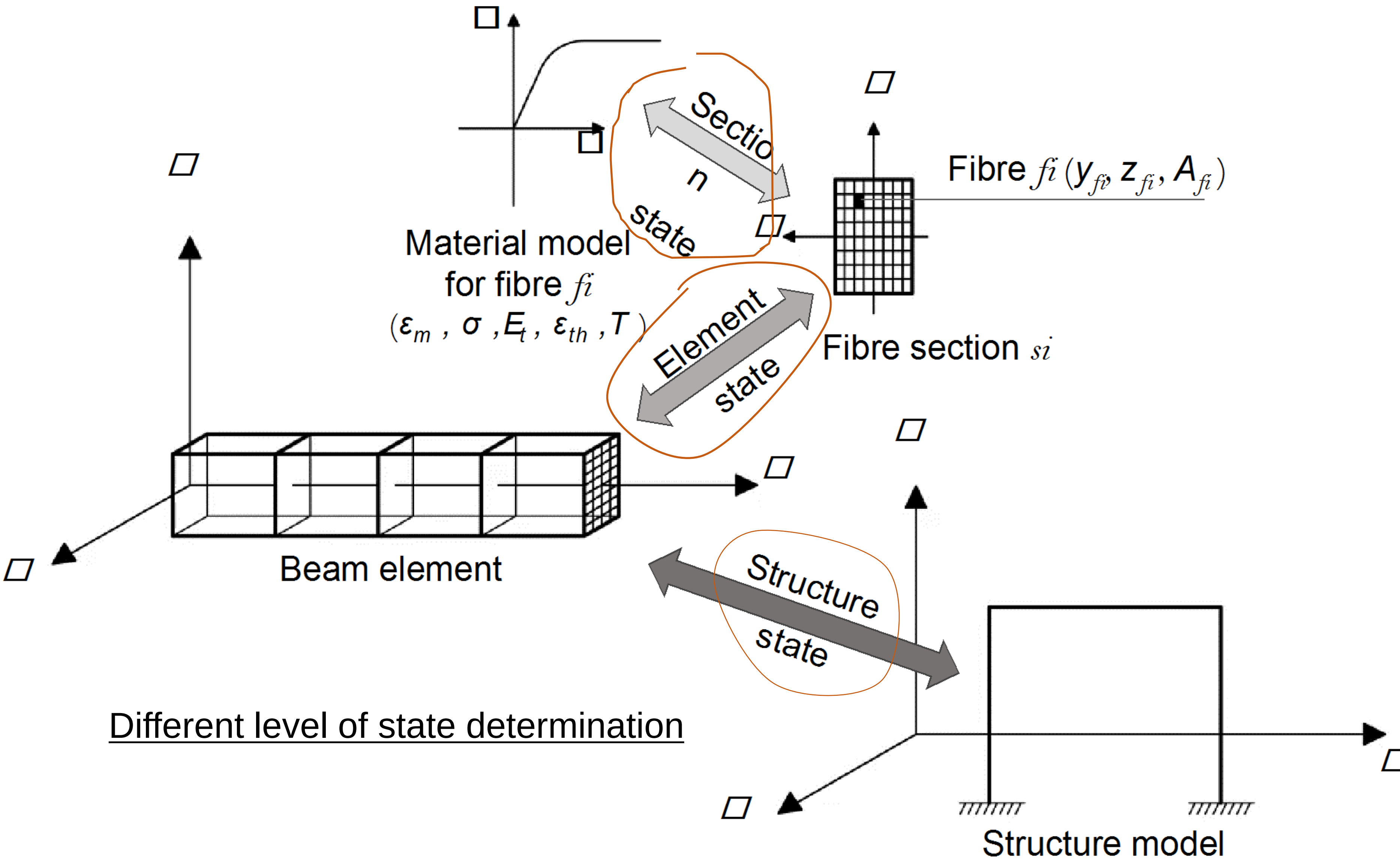
Generalisation

Thermo-mechanical Analysis



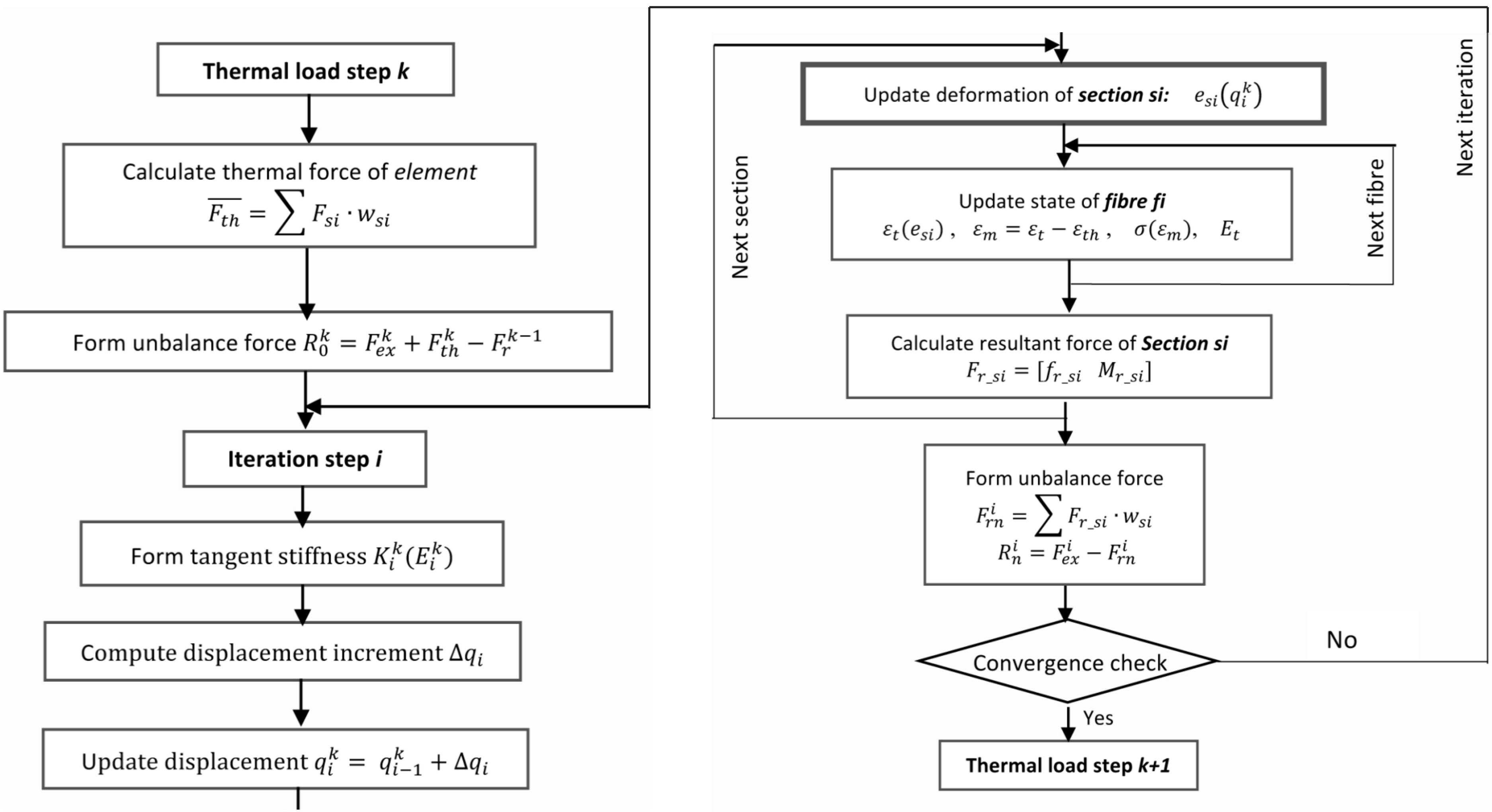
BeamColumn element

Thermo-mechanical Analysis



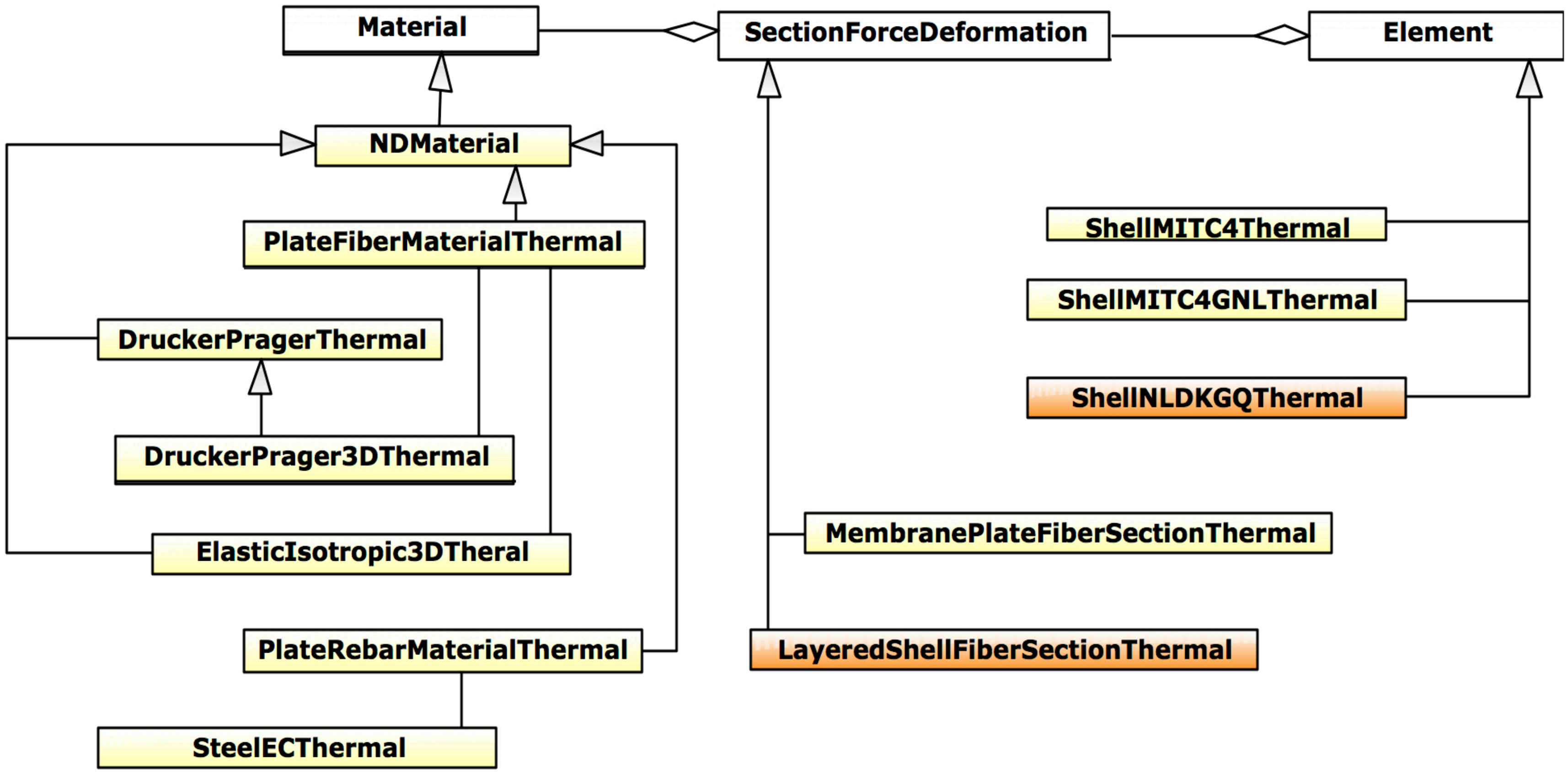
Different level of state determination

Thermo-mechanical Analysis



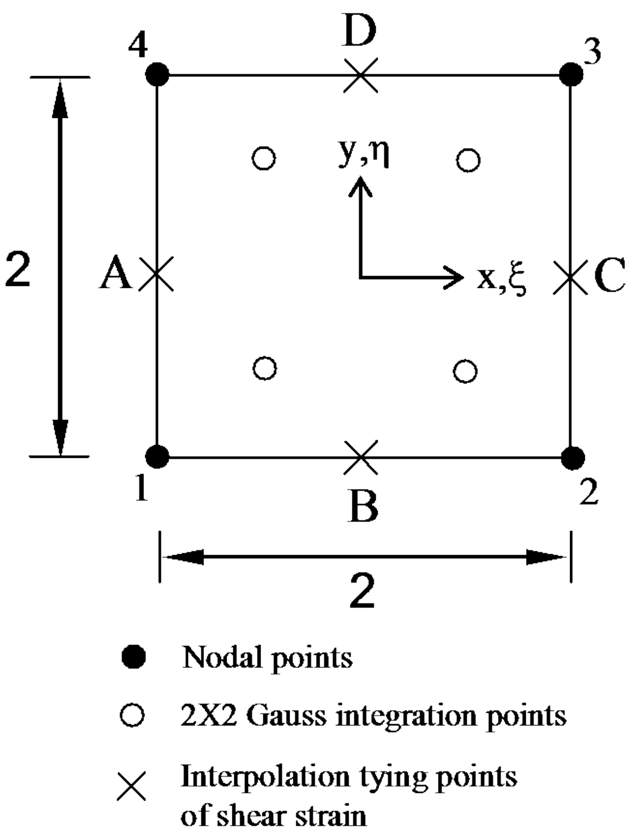
BeamColumn Element Flowchart

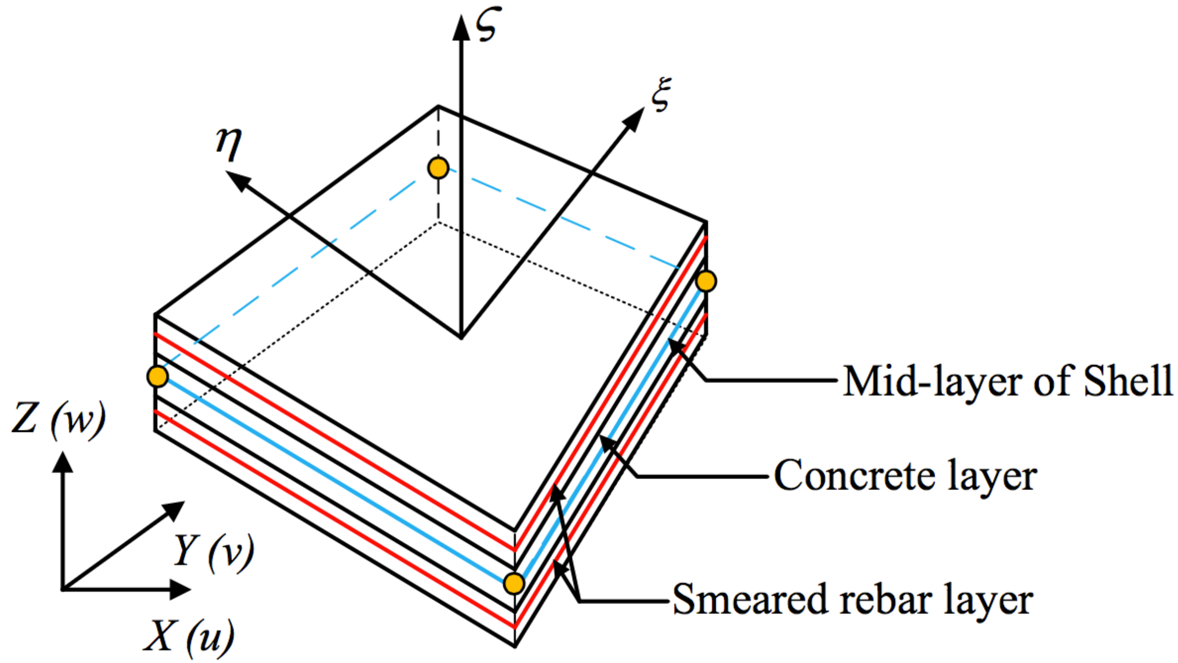
Thermo-mechanical Analysis



Shell element

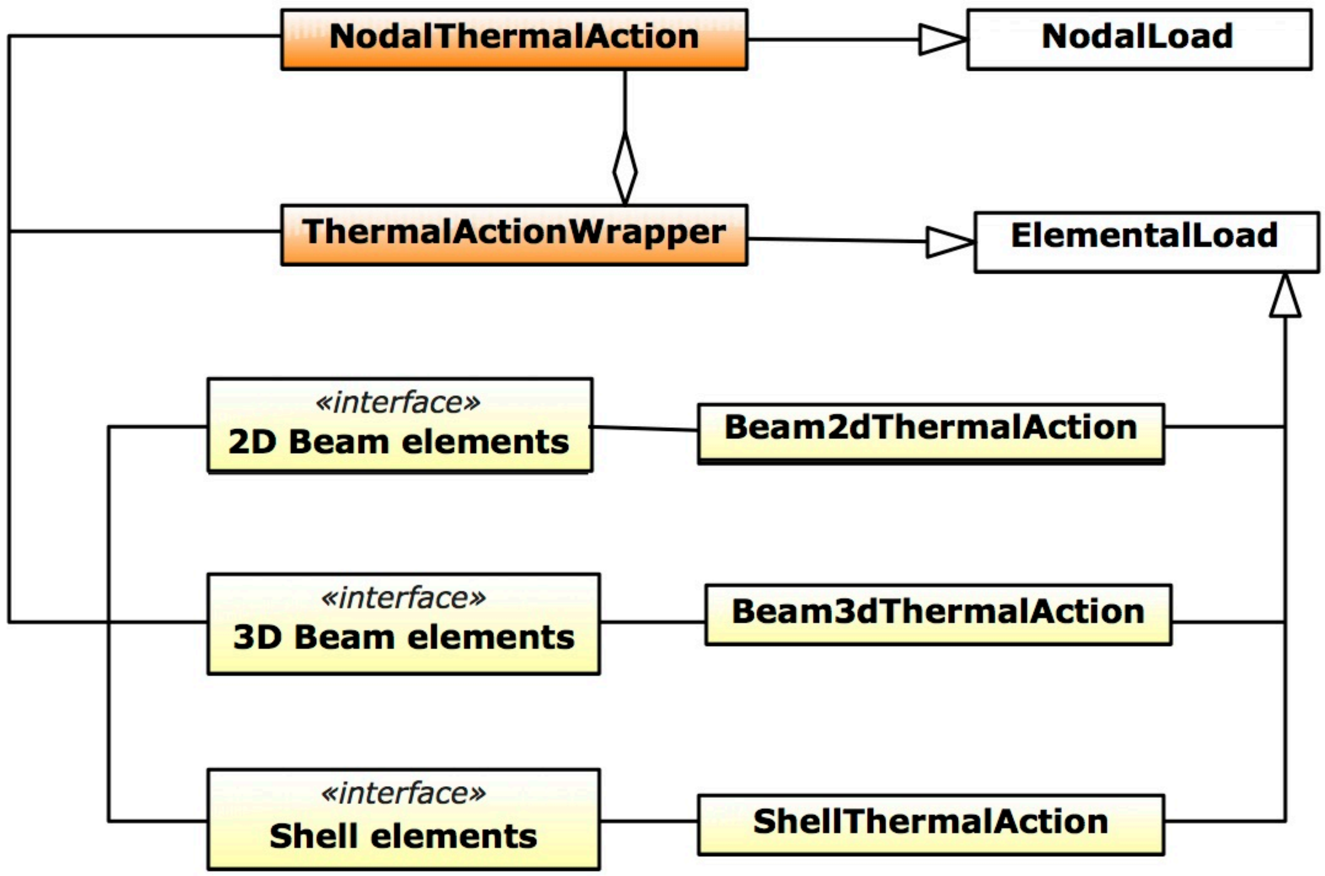
Thermo-mechanical Analysis





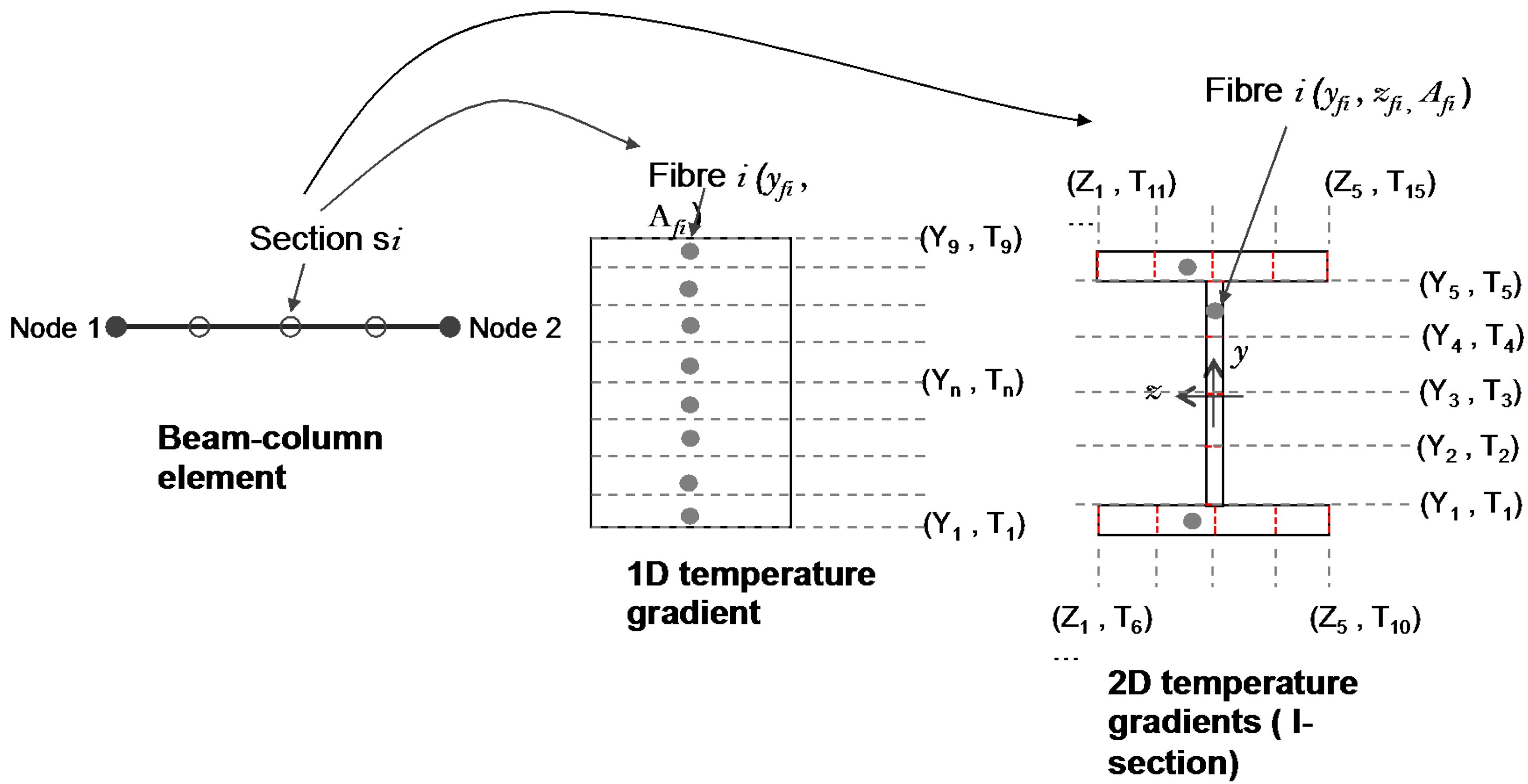
Shell element

Thermo-mechanical Analysis

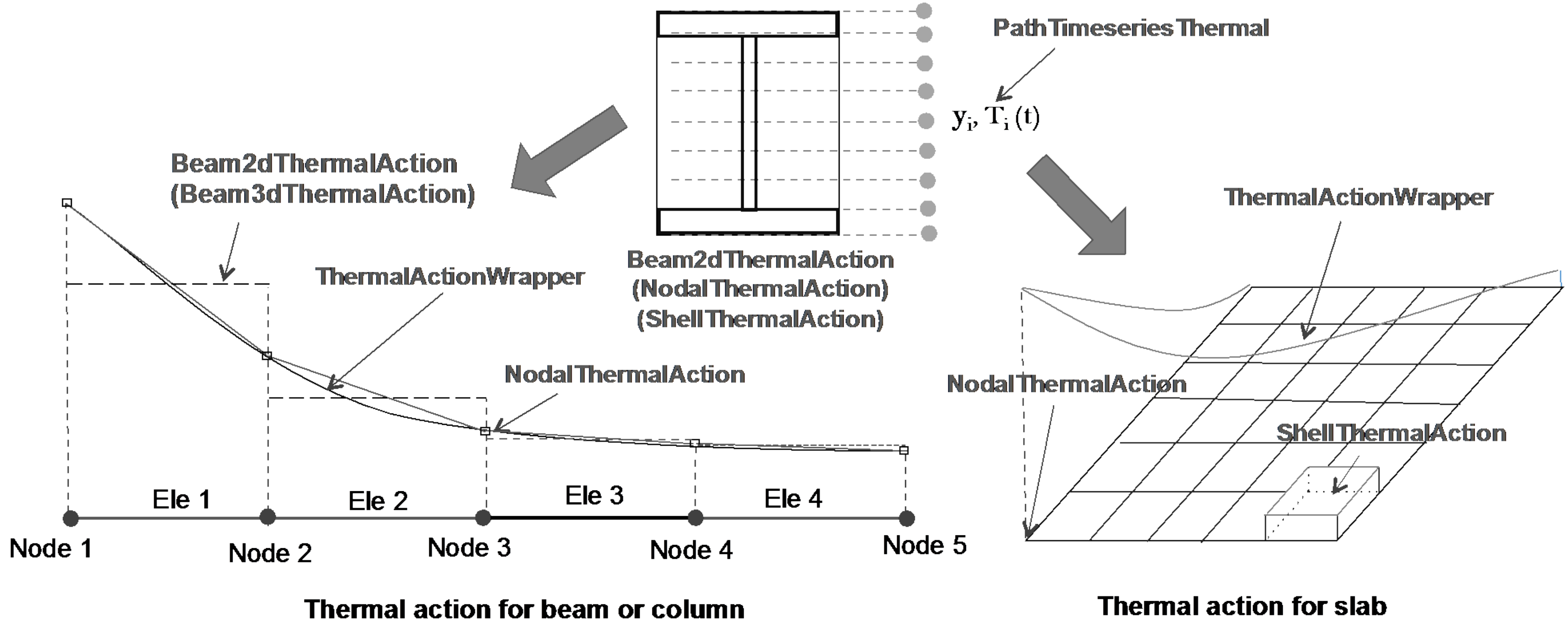


Thermal Action

Thermo-mechanical Analysis



Thermo-mechanical Analysis

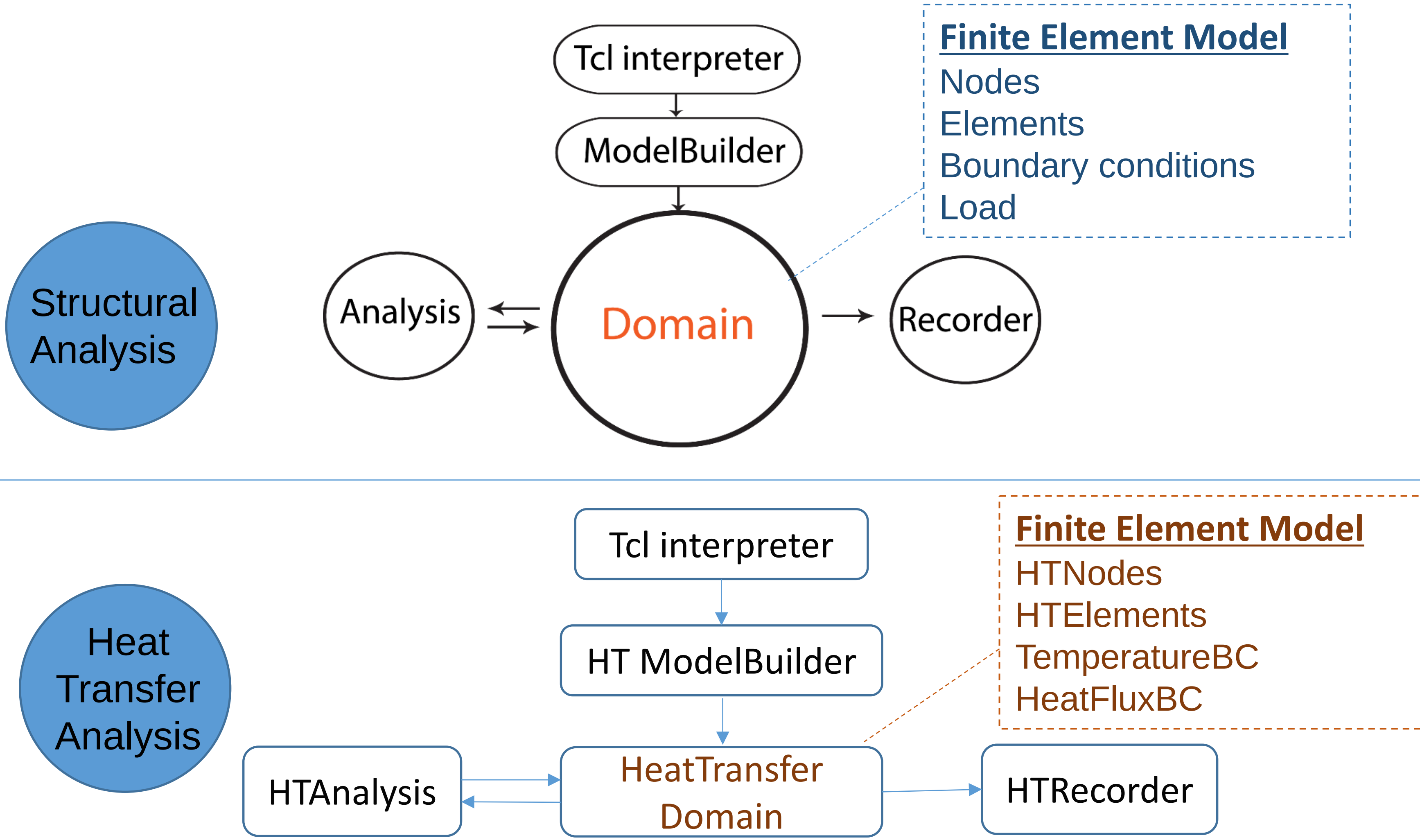


ThermalActionWrapper

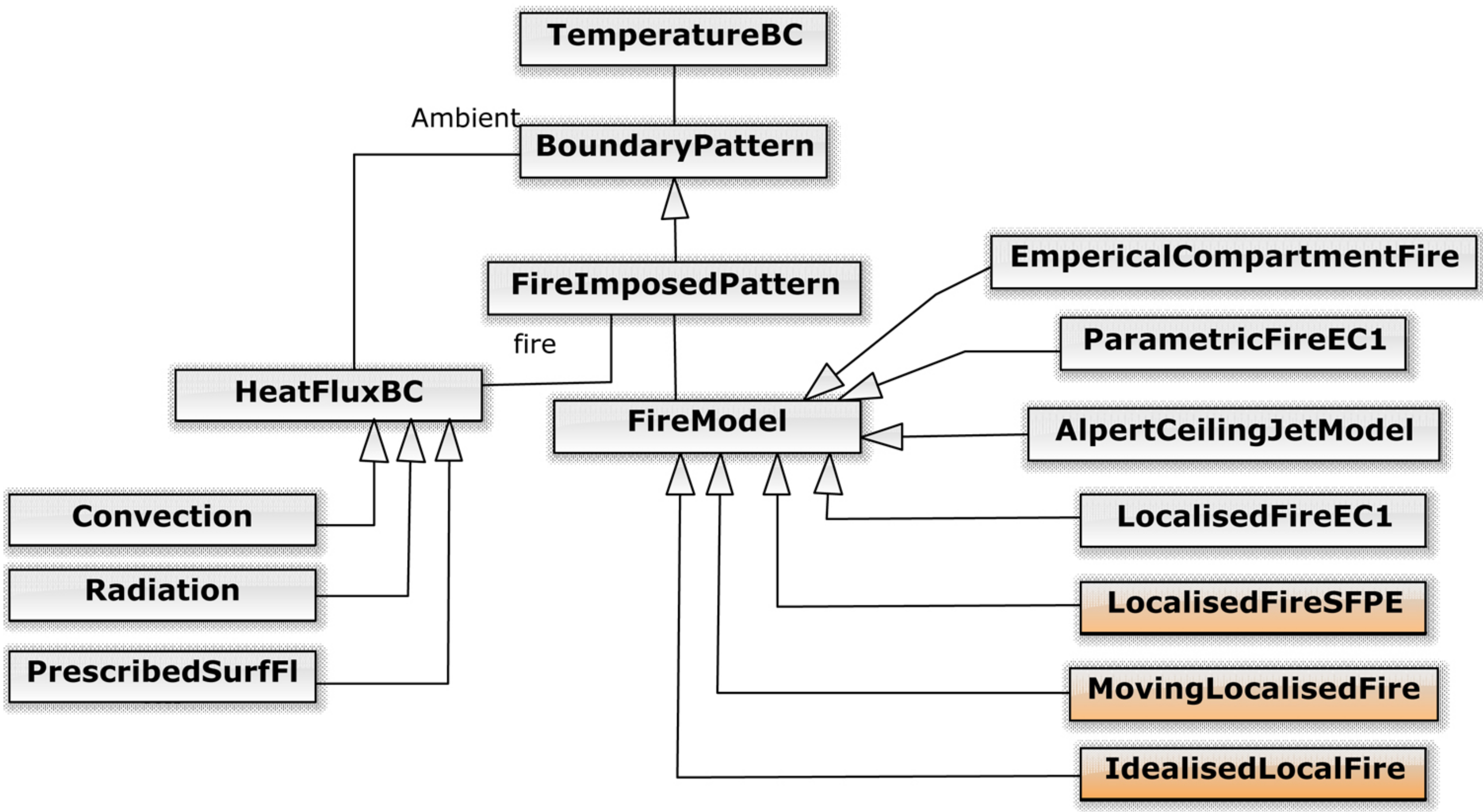
OPENSEES WORKSHOP

Day3:
Development for Heat Transfer Analysis

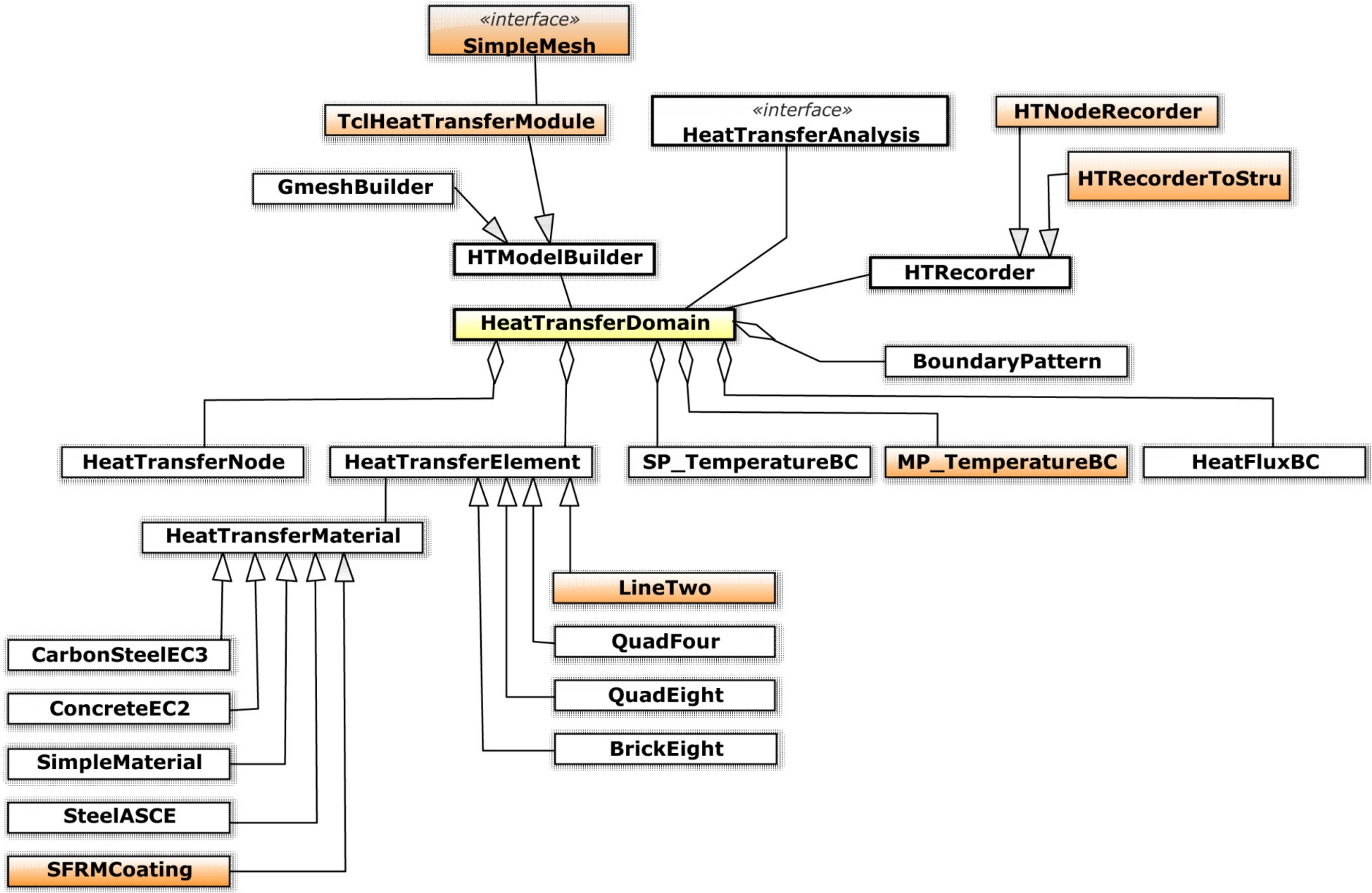
Heat Transfer Analysis



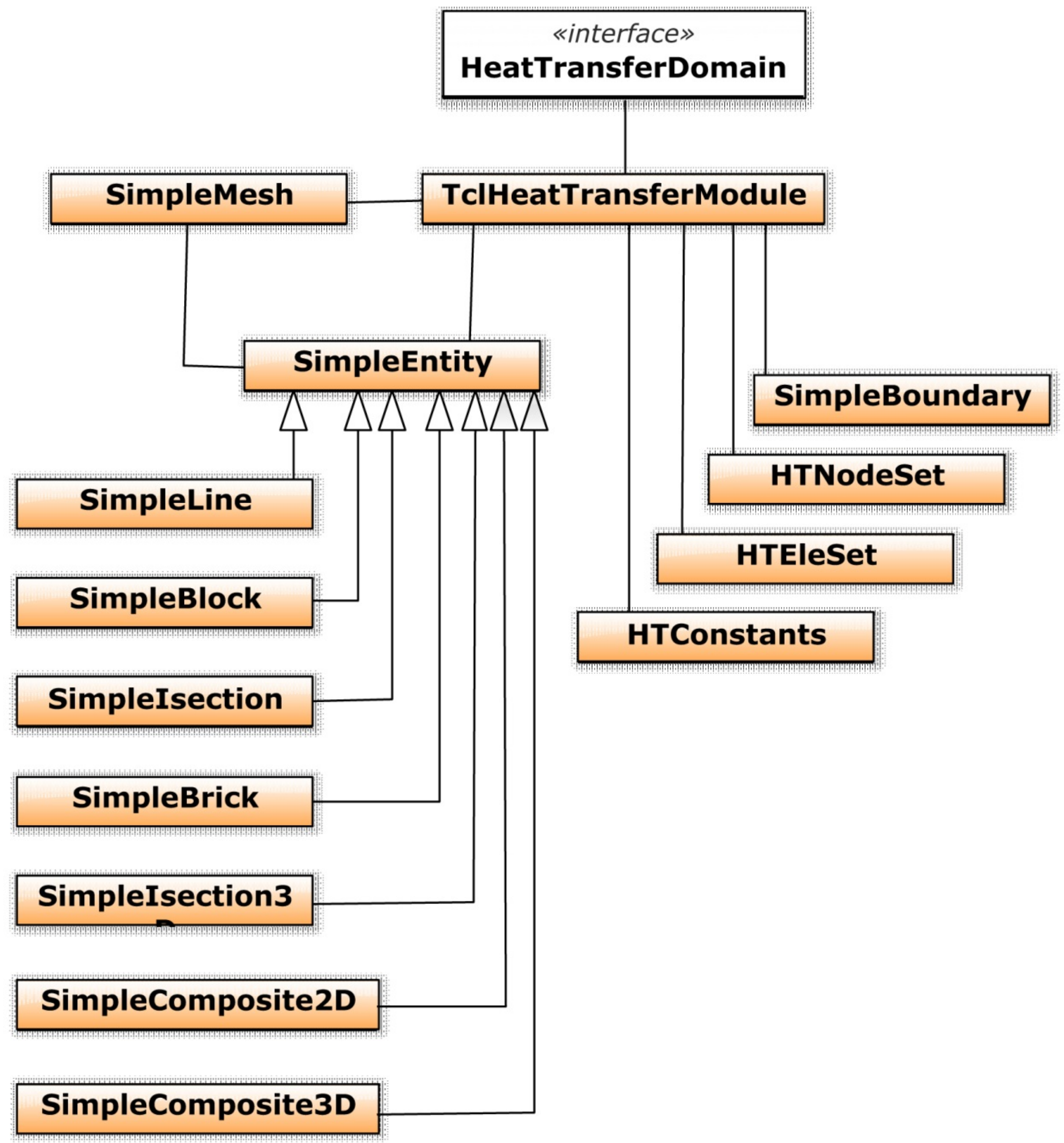
Heat Transfer Analysis



Heat Transfer Analysis



Heat Transfer Analysis

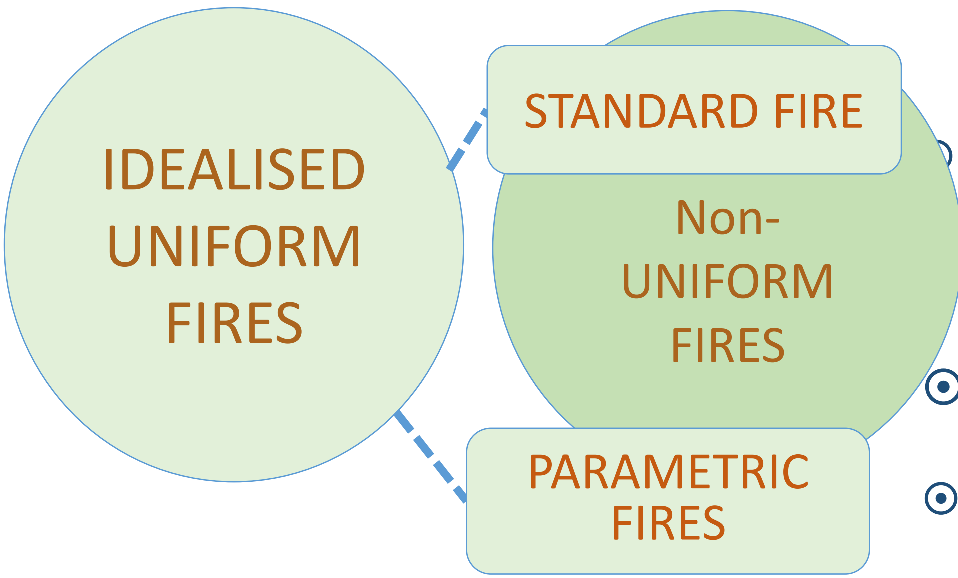


OPENSEES WORKSHOP

Day3:
Development for SIFBuilder

What fire models ?

IDEALISED **UNIFORM FIRES**



- Based on tests dating back over 100 years spe... ...ed temperature-time curve ;
- still ... ...s a "PR... ...ch for ALL typ...

Design Fires

- Initiate... ...widely in Eurocode o... ...gn;
- Parameters include fuel load, ventilations and compartment dimensions;
- Limited to 500m^2 and 4m height by EN1991;
- Beginning to be used in "PERFORMANCE-BASED" approach, often disregarding limits

IDEALISED **NON-UNIFORM FIRES**

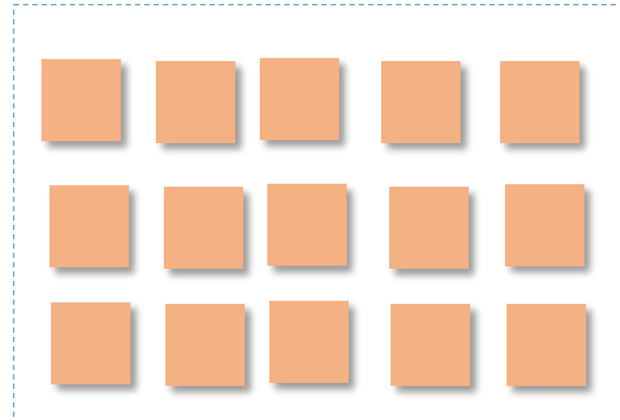
IDEALISED Non-UNIFORM FIRES

Continuous fuel distribution

- Large plan office
- Post-flashover
- Fire spread / Travelling fire

Discontinuous fuel distribution

- Car park, bridge fire
- Unlikely fire spread
- Localised fire



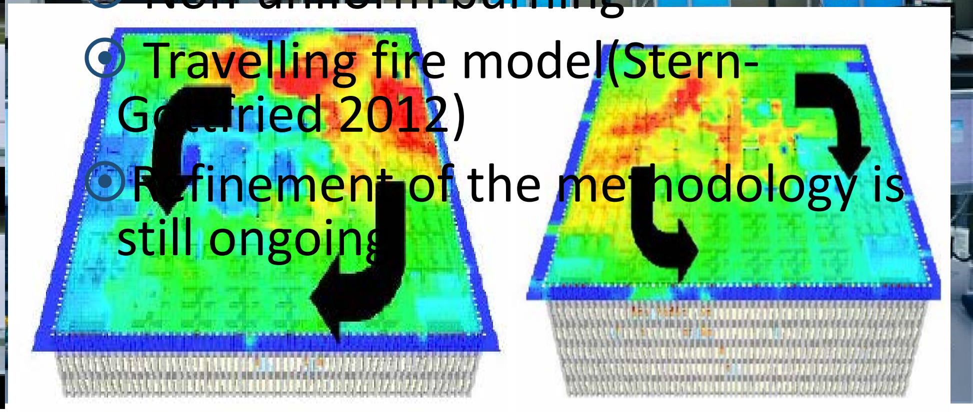
- **Fuel distribution**

OPEN-PLAN OFFICE

Horizontally travelling fires

Still spatially uniform

- Distributed fuel load (office furniture)
- Non-uniform burning
- Travelling fire model (Stern-Gottfried 2012)
- Refinement of the methodology is still ongoing

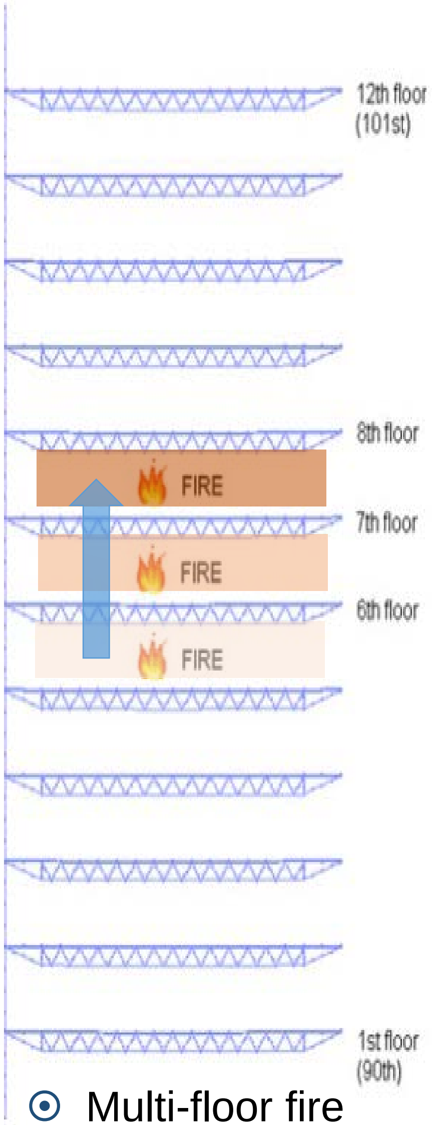


WTC 1, Floor 94

WTC 1, Floor 97

Tall building fires

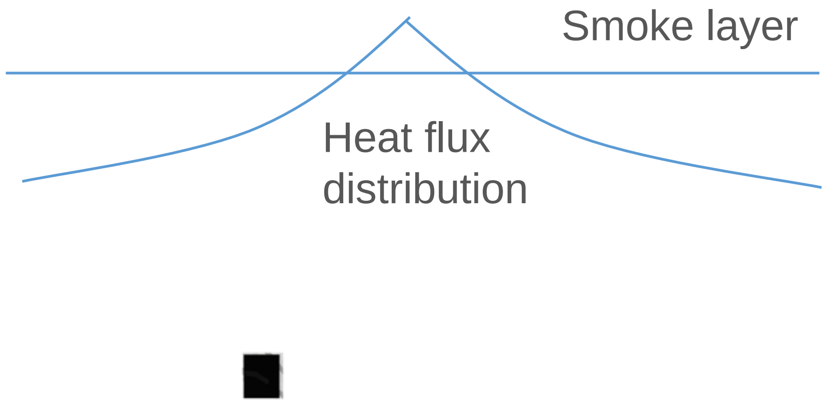
--Vertically travelling fires



- Multi-floor fire model for WTC collapse

- Fire spread through adjacent floors
- Delays of ignition associated with compartment fire models
- A sub-structure model of WTC tower subjected to Multi-floor fire (Kotsovinos & Usmani 2013)

Localised fires



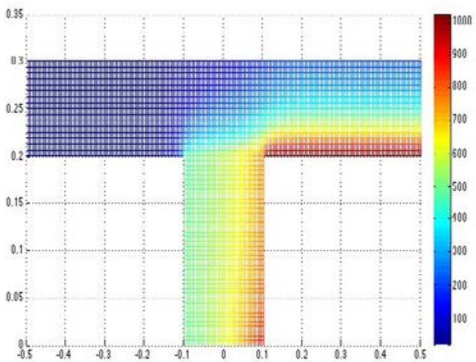
- **Localised fire plume**

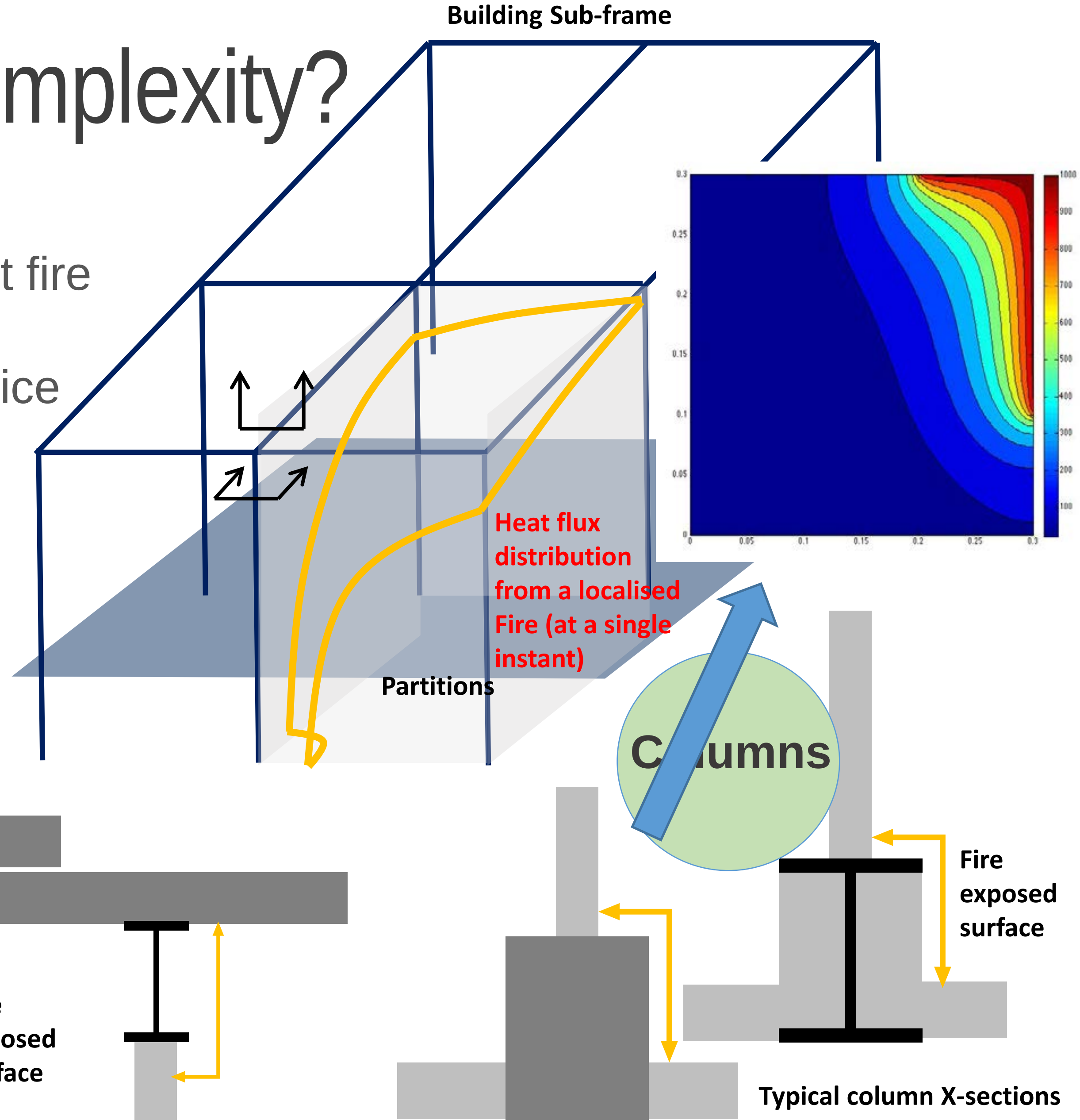
- Fuel load controlled
- Sufficient ventilation
- No fast fire spread

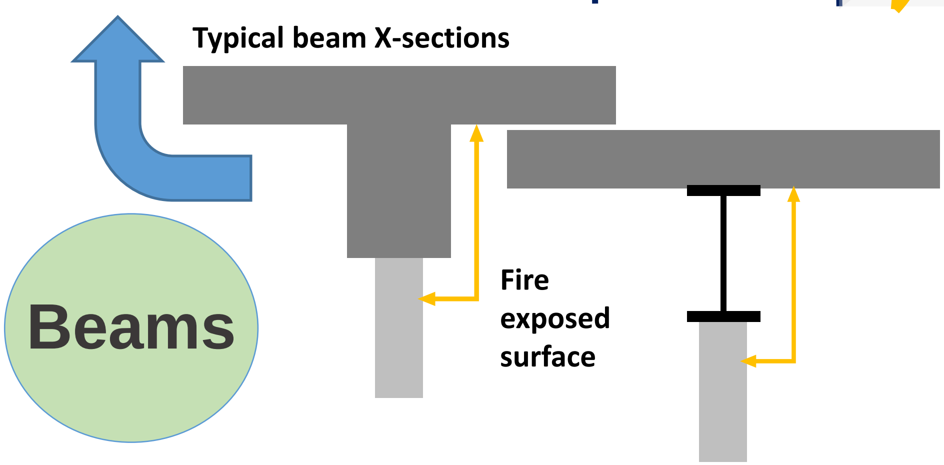
- Car park building / atriums/ bridges
- Hasemi fire tests
- Eurocode model / SFPE model
- Ceiling fire plume / steel beam underneath ceiling /smoke layer

What is the complexity?

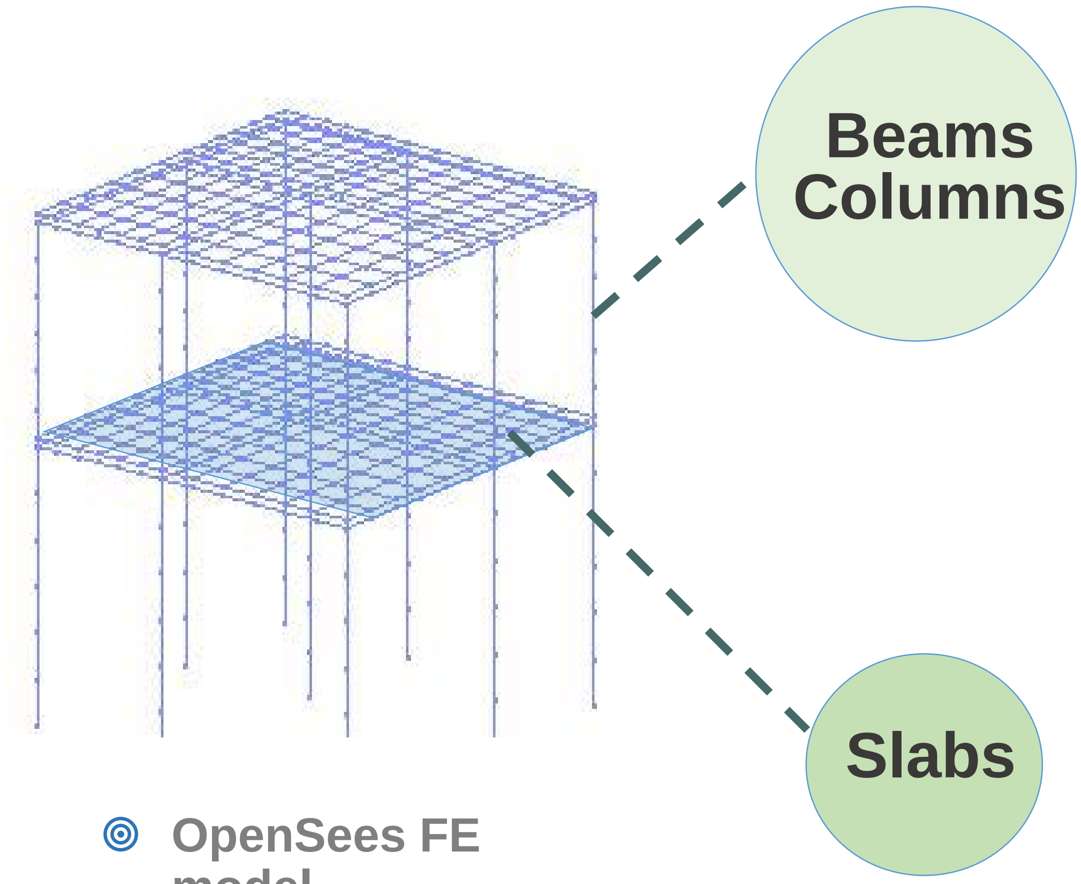
- Localised compartment fire
- Partial exposure
- Mostly ignored in practice







Modelling structural behaviour in fire using OpenSees



Beam-column elements

- Uniaxial materials
- Fibre based sections
- Displacement based / force based

Shell elements

- Multi-axial materials
- Multi-layered plate sections

- **OpenSees FE model**

Integrated computation in OpenSees

SIFBuilder

User-friendly interface for creating (regular) structural models and enable consideration of realistic fire action

Fire

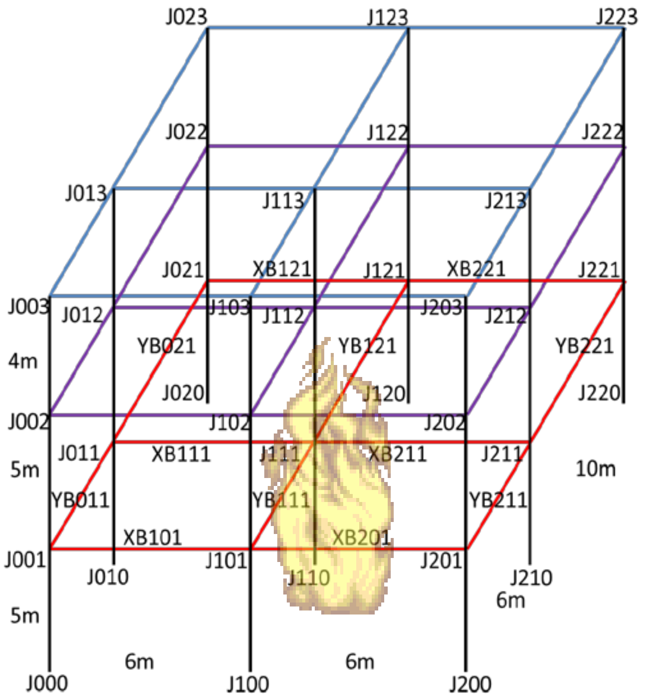
Models of fire action (only ***idealised*** fires), i.e., Standard fire, Parametric fire, EC1 Localised fire, Travelling fire

Heat Transfer

Heat transfer to the structural members due to fire action

Thermo-mechanical

Structural response to the elevated temperatures

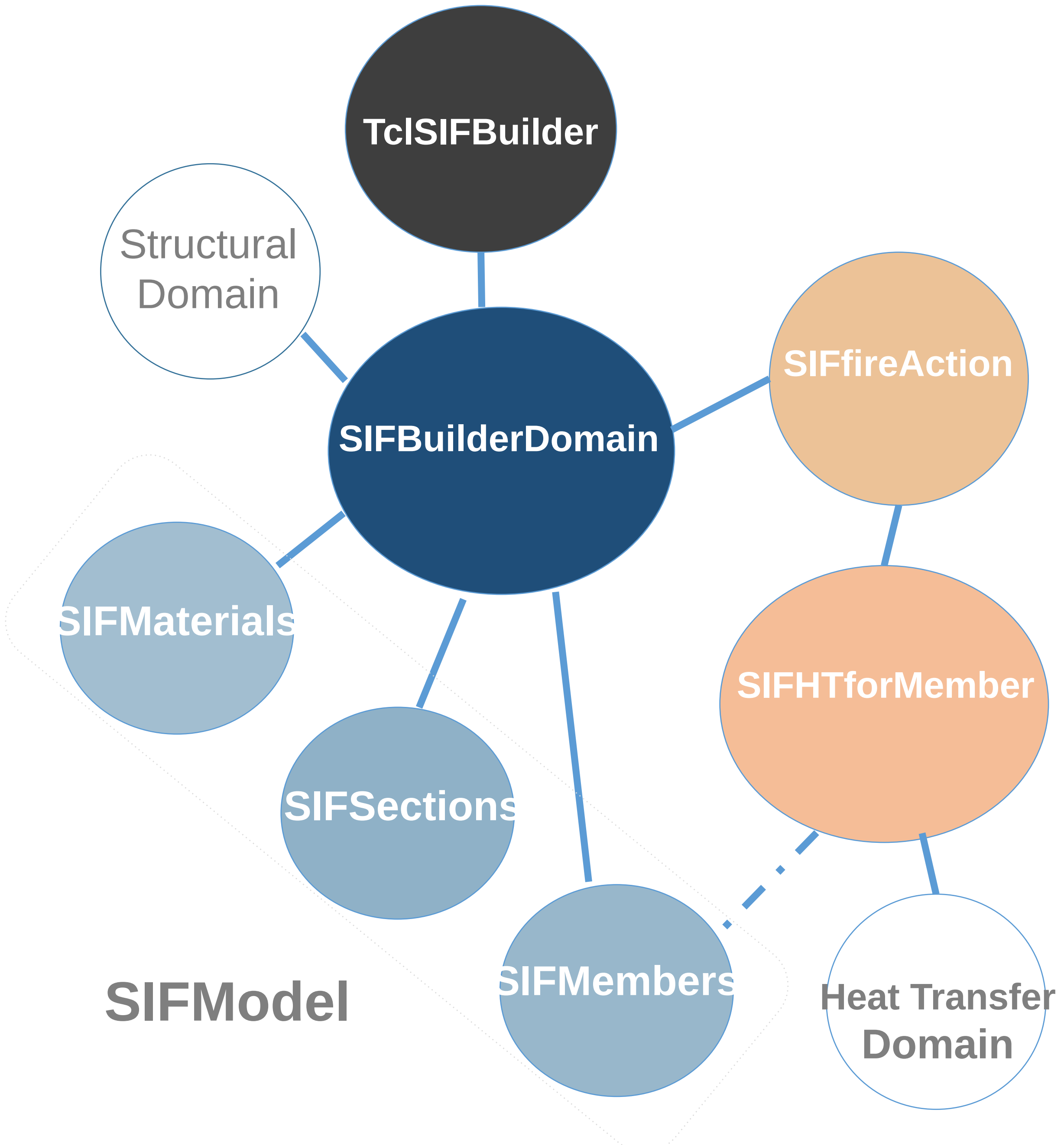


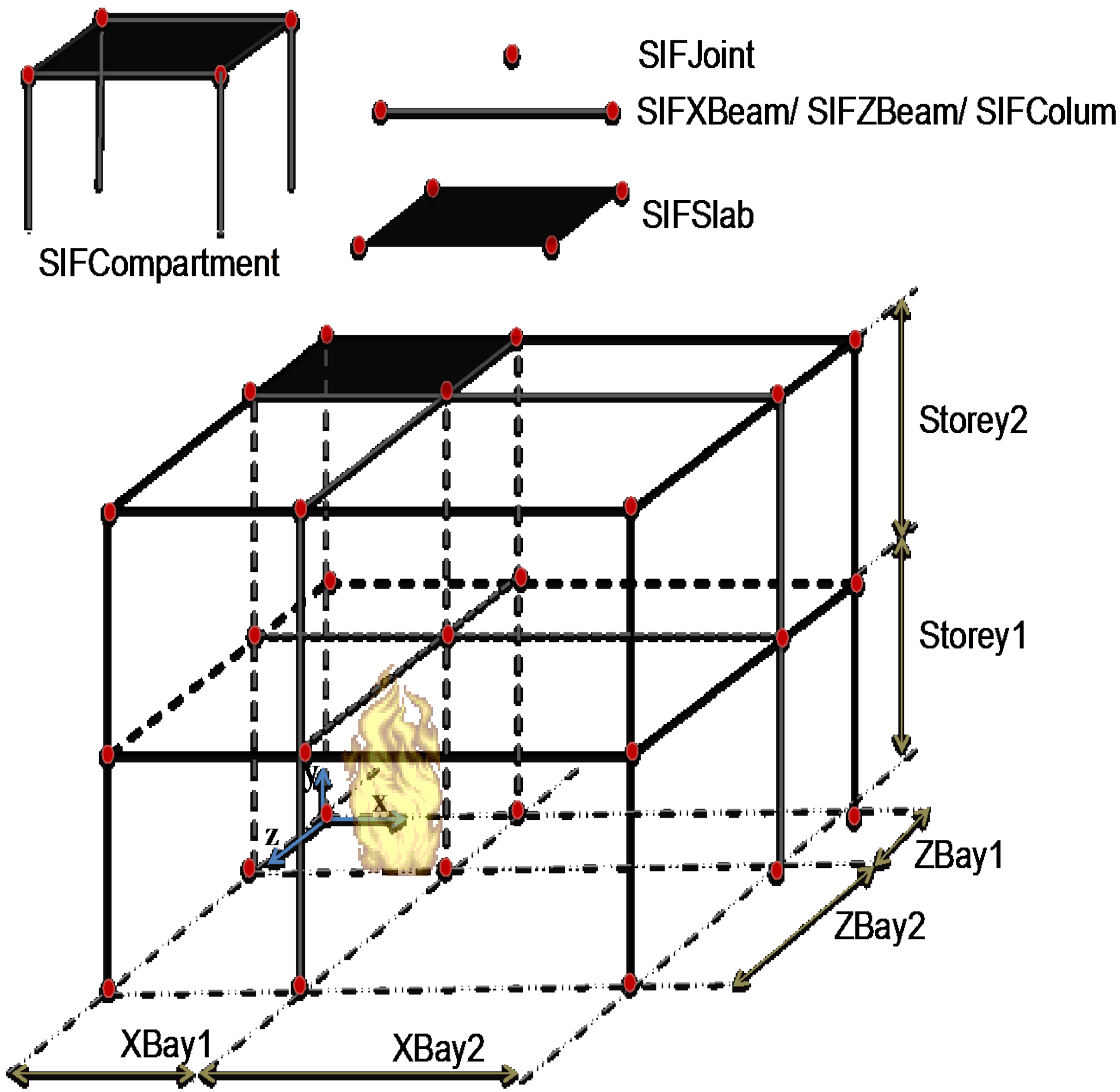
- **Tcl** supported

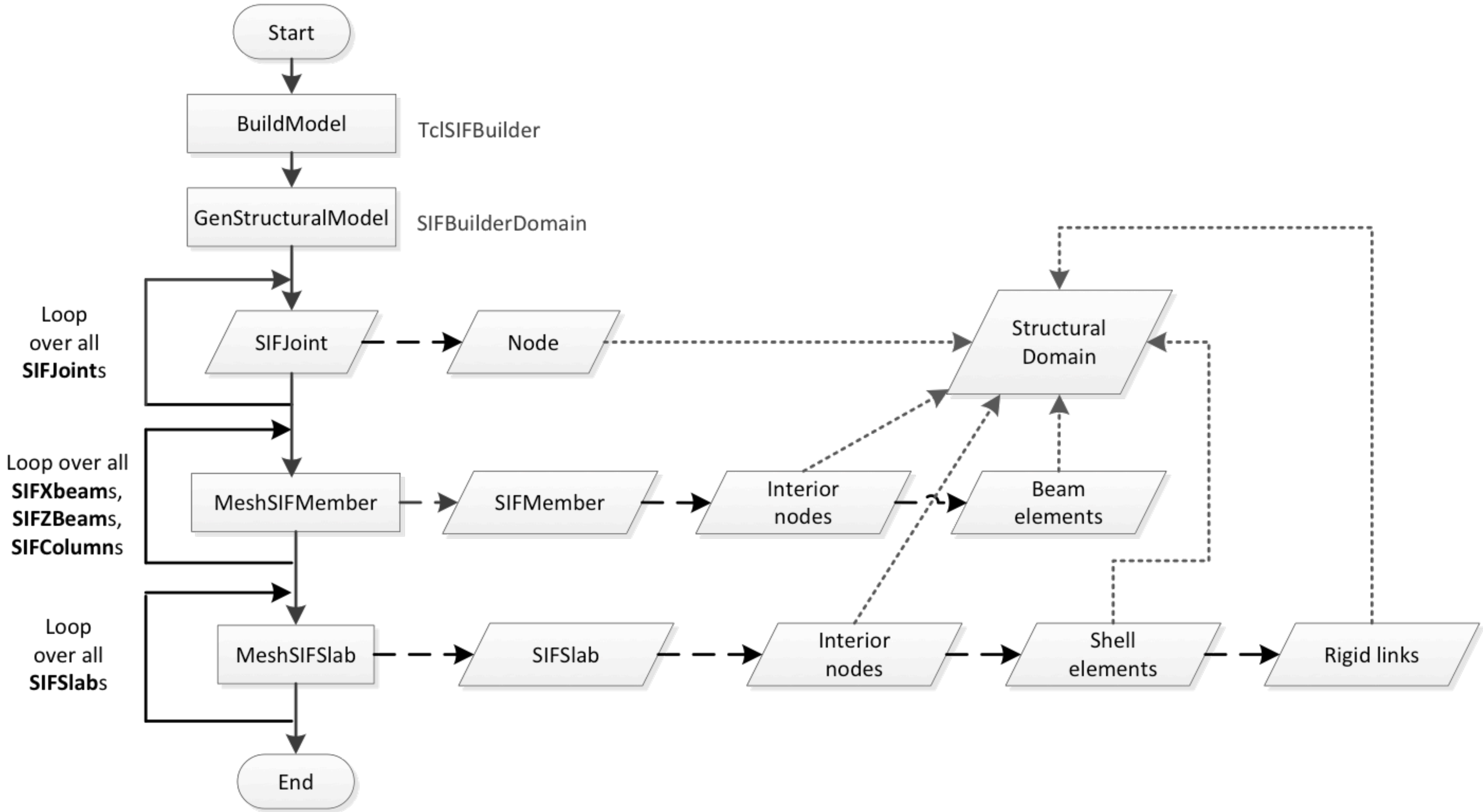
  (Tool command language)
- SIFBuilderDomain as main storage
- SIFModel created for building info

  (material, section ,members)

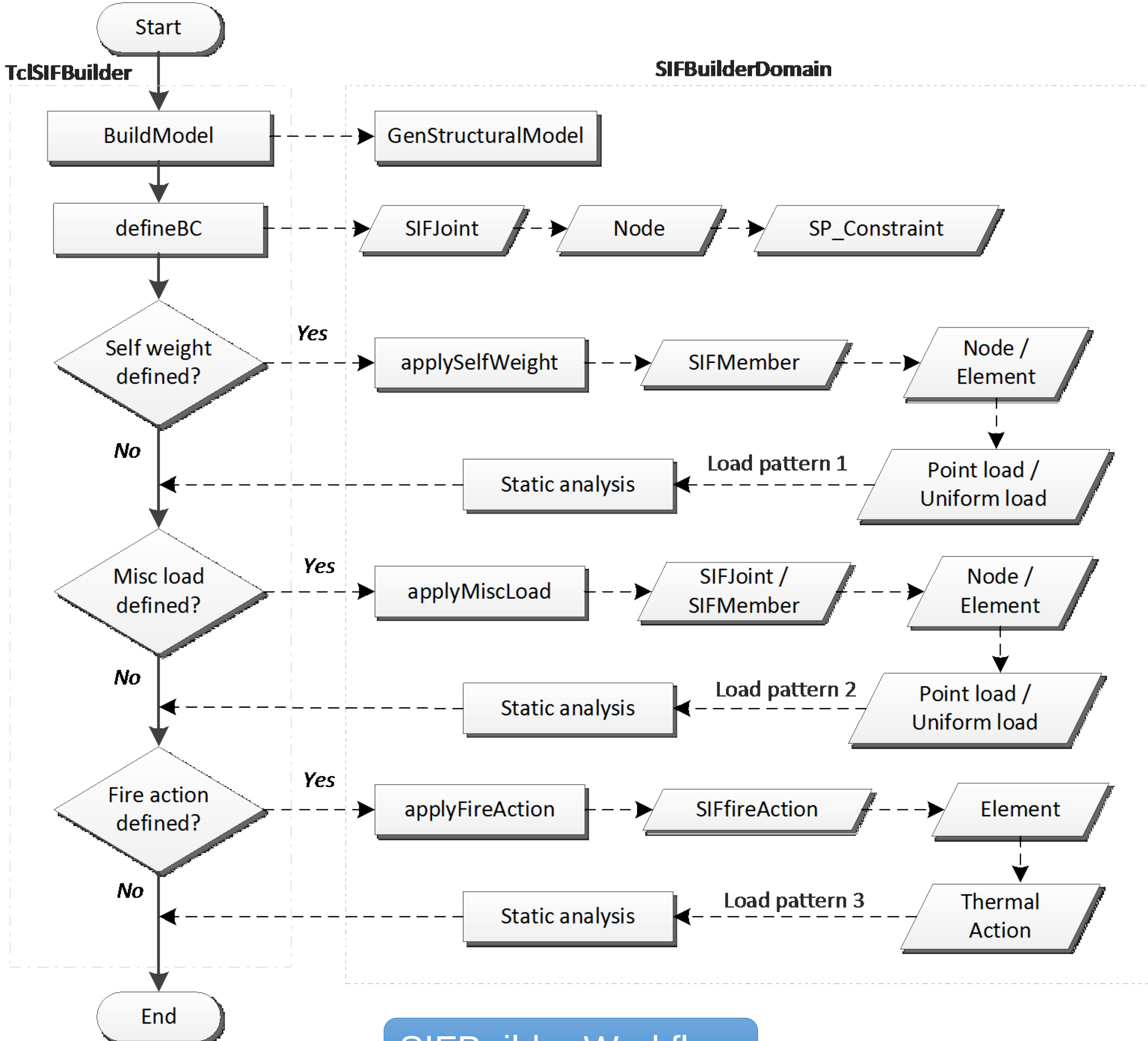
- Various types of Imposed loads
- Various types of fire action
- Automated heat transfer analyses
- Automated implementation of thermal action




SIFJoint
SIFXBeam/ SIFZBeam/ SIFColum
SIFSlab
SIFCompartment
Storey2
Storey1
y
x
z
ZBay1
ZBay2
XBay1
XBay2



SIFBuilder Workflow



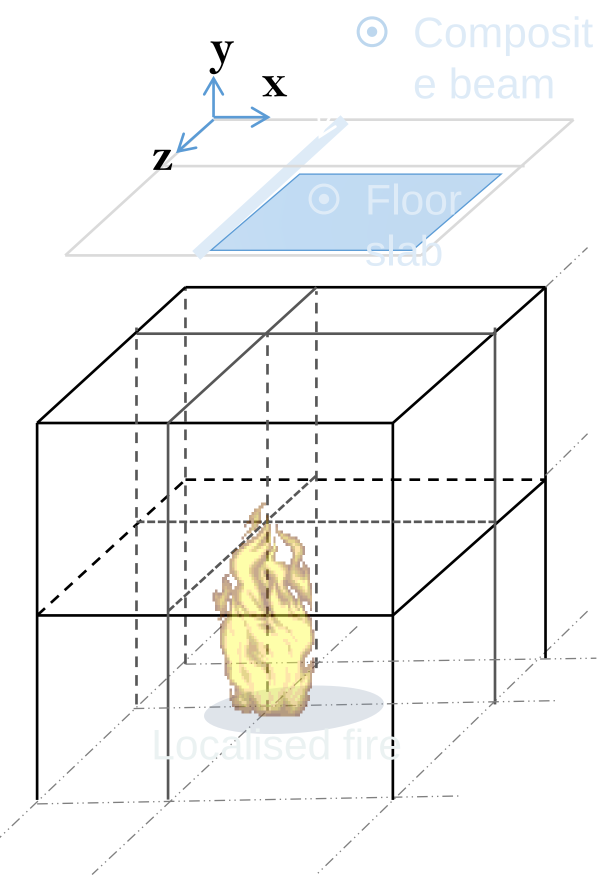
SIFBuilder Workflow

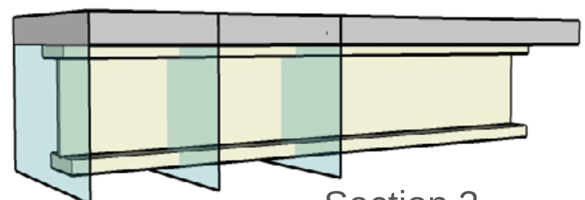
SIFBuilder
-Implementation of Fire Action

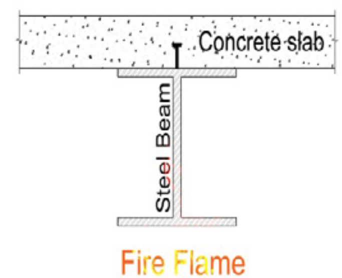
Strategy for efficient heat transfer modelling

---Idealised non-uniform fires, T(x,y,z,t)

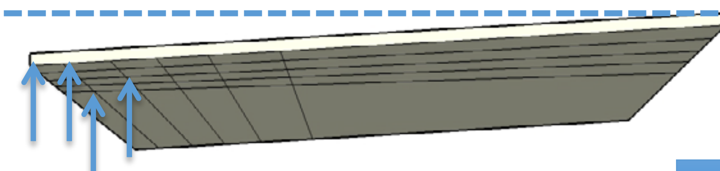
- Heat flux input varies with the location ;
- Composite beam: a series of 2D sectional analyses
- Concrete slab : using localised1D Heat Transfer analyses







- **Composite beam**
- 2D section with localised BC



q convection + radiation

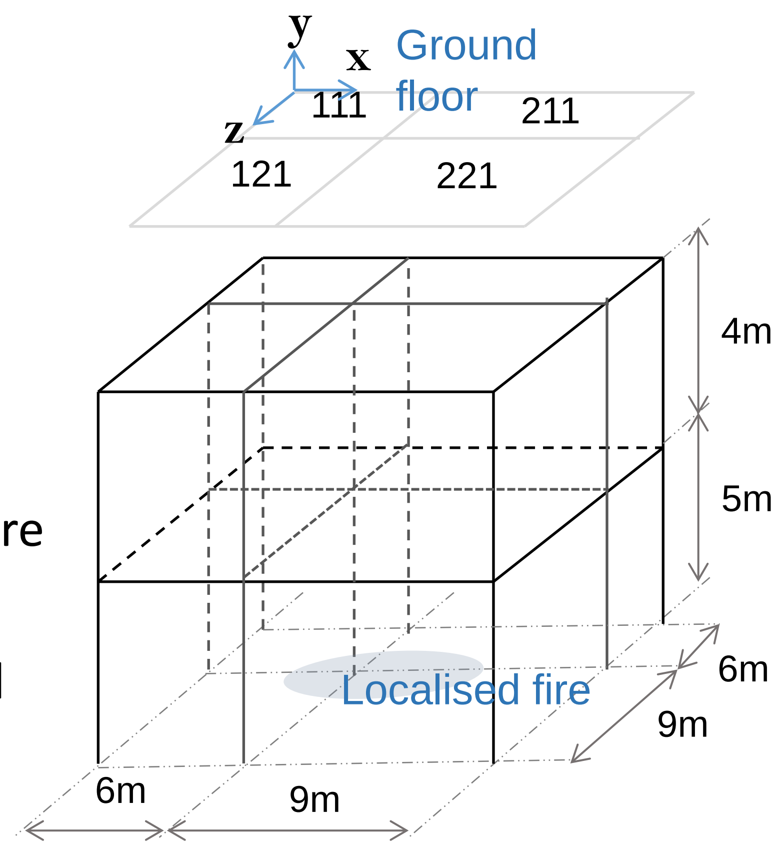
- 1D section with localised BC

q heat flux input

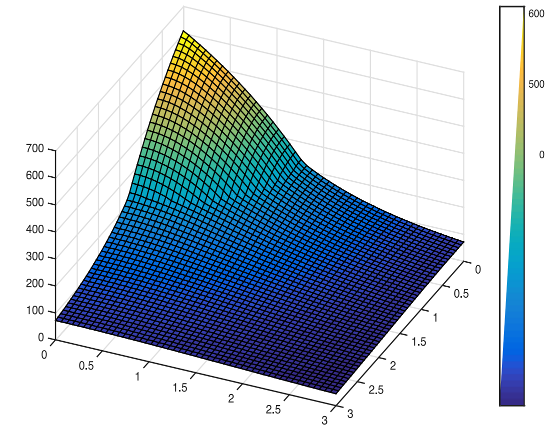
- **Floor slab**

SIFBuilder

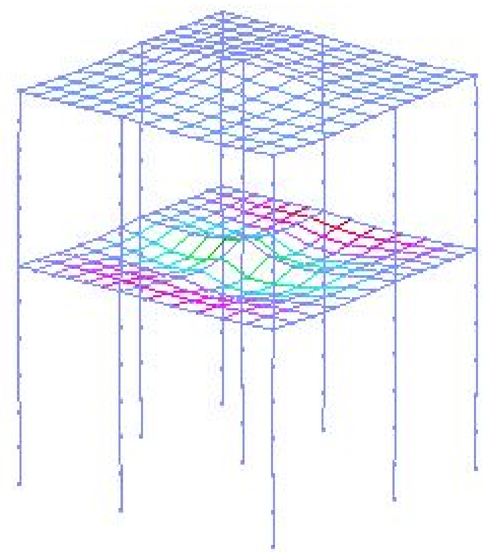
- Fire surrounding centre column
- EC1 Localised fire
- Unconfined ceiling
- Horizontally Non-uniform temperature distribution
- Localised structural deformation



- Configuration



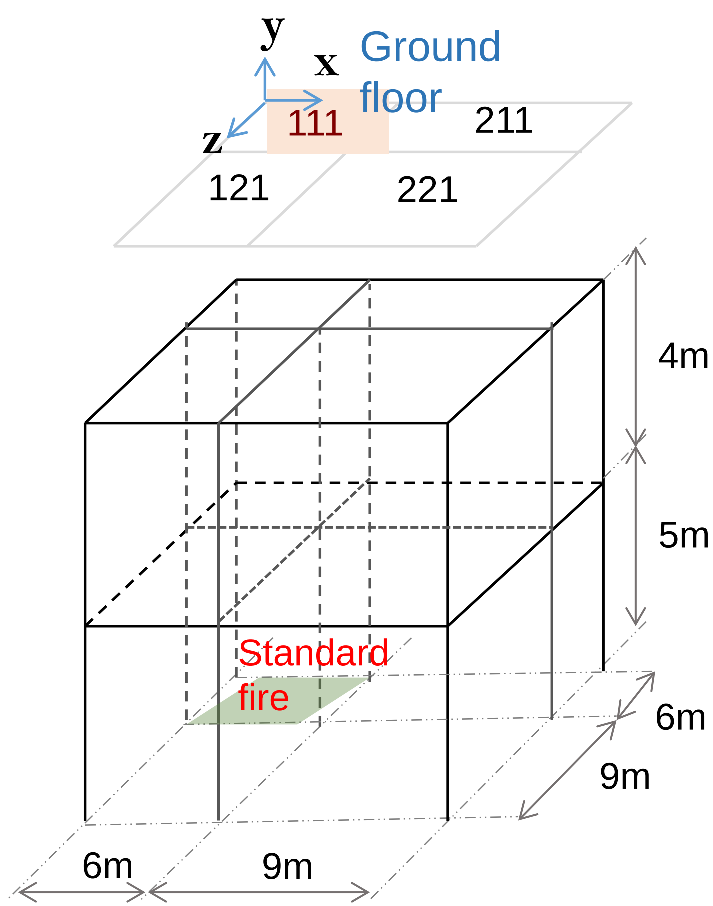
- Slab temperature distribution



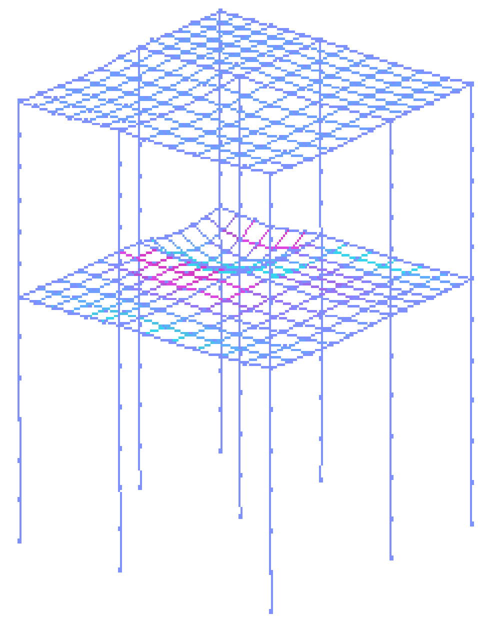
- Structural Deformation

SIFBuilder
-Idealised uniform fires

- Compartment fire
- Standard fire curve
- Confined in one corner compartment (111)
- Wall partitions considered



- Configuration



- Structural deformation

OPENSEES WORKSHOP

Day3:
Extra Exercise?

OPENSEES WORKSHOP

THANK YOU!