

# Coupling Experiences with RELAP5-3D and S5K

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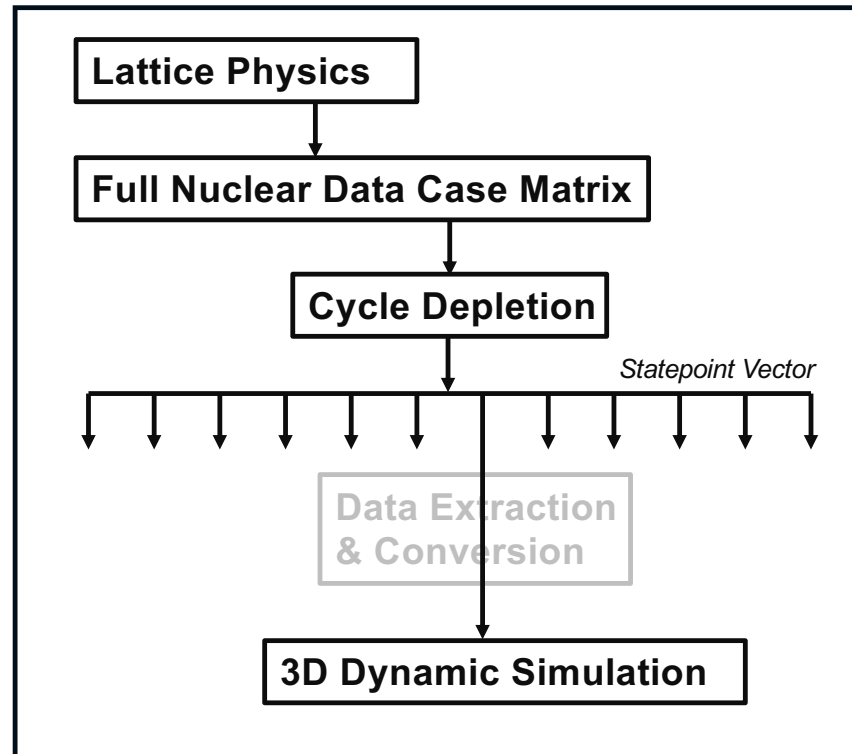
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# Studsvik SIMULATE5-K Dynamic Solver

- ***SIMULATE5-K*** is the 3D, Dynamic core model Studsvik Core Management System.
- A ***mated pair*** of
  - reactor physics core data.
  - and 3D, advanced nodal method dynamic core simulation
- Seamless Data Transfer From Core Design Model
- Easy To Analyze Anywhere In Cycle
- Easy To Analyze On The Current Cycle



# The Multi-Physics Problem

Simulation of complex interactions between physical domains and phenomena

- Detailed transient thermal-hydraulic conditions in power plant systems

**RELAP5, RETRAN-3D,**

- Power distribution and kinetic response of nuclear reactor

**SIMULATE5-K (S5K)**

- Coolant flow and heat transfer within subchannels between fuel rods

**VIPRE-01, COBRA/CTF**

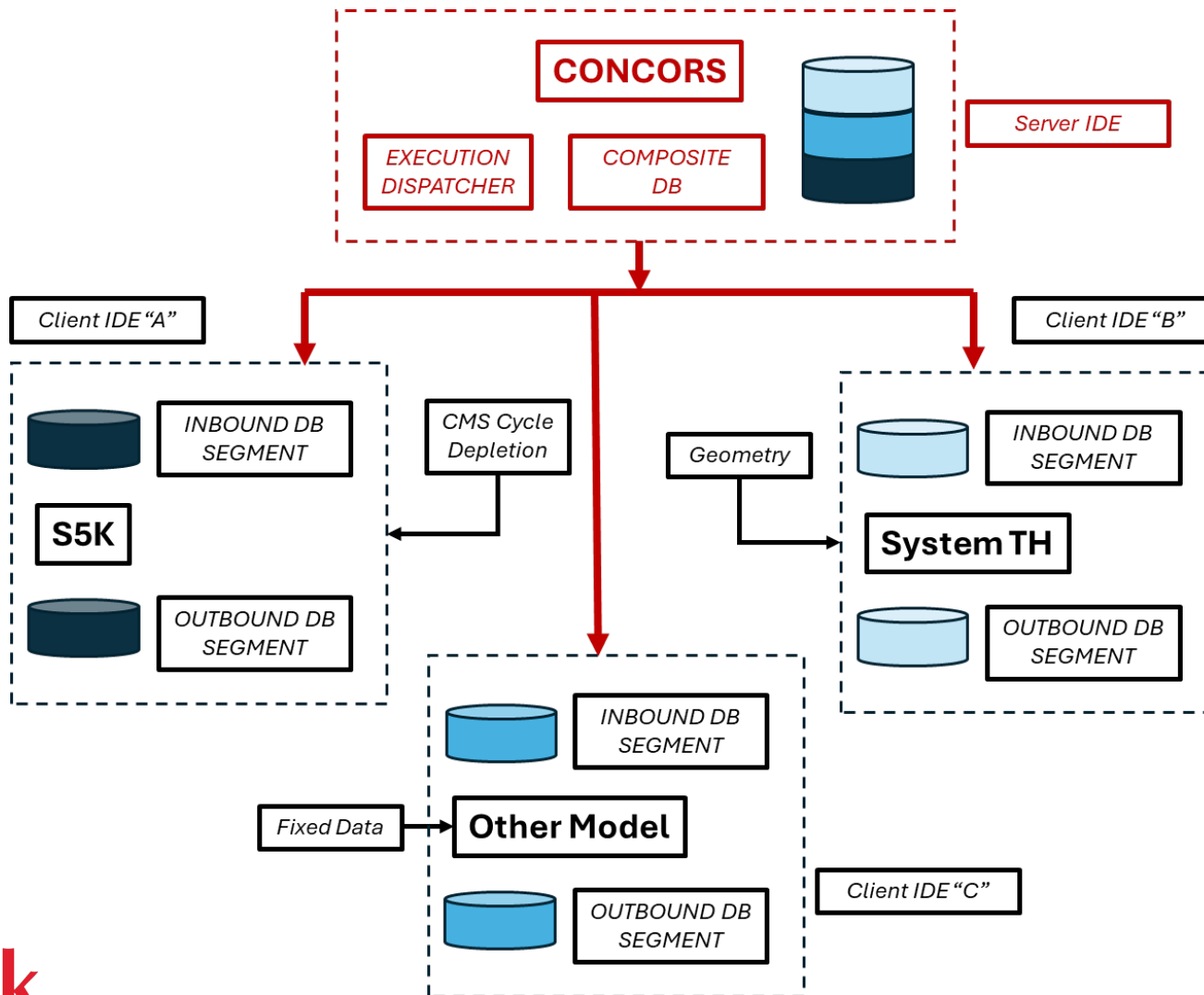
Coupled code simulation is a software solution for Multiphysics problems

# CONCORS Project Goals



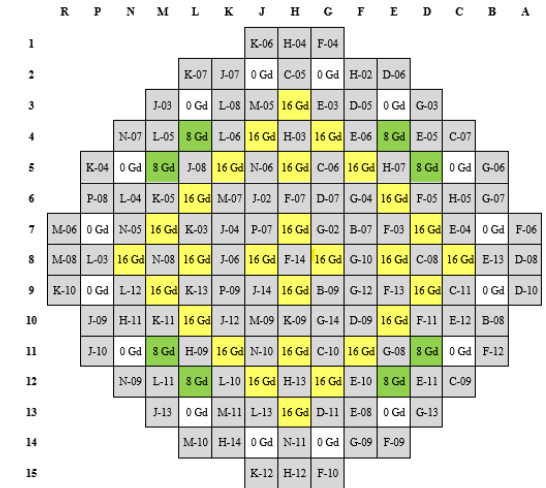
- Focus on engineering grade simulation codes
- Neutral Interface Coupling Method
  - Maintain independent build environments for constituent codes
  - Reduction in “ad hoc” or custom development in constituent codes
  - Generalized approach to data transfer between codes
  - Extend coupling capability to three (or more!) codes
  - Engineering flexibility for coupling techniques
    - Time step negotiation?
    - Sequential vs. parallel?
    - Problem discretization? Overlapping physical domains?
- Allow departure from the “Linear” licensing analysis model

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# Testbed Problem 2025

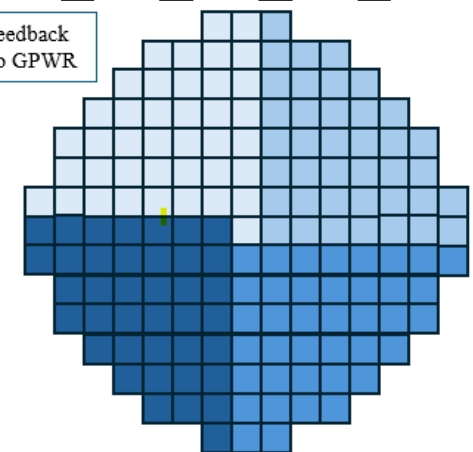
- Testbed demonstrations of null transient at 100% power
- Two-code explicit, sequential coupling
  - RELAP5/MOD3 – 4 core region coolant channels
    - Boundary conditions at core plena
  - SIMULATE5K – Generic PWR Equilibrium core.
    - Internally expands channel T/H distributions to node/assembly mesh based on nodal powers.



RELAP5 Volumes / Heat Structures

Channel Feedback Mapping To GPWR

+ 3 Identical



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## Progress 2026

- Commercial Utility Procurement of CONCORDS w/ RETRAN (& S5K)
- **INL RELAP5-3D Licensing Agreement**
- Concurrent Application of CONCORDS Generically to RELAP5-3D (& S5K)

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# Application of CONCORS to RELAP5-3D

- It's Done
- REALLY Straightforward
- What Does That Mean:

*Generally, the CONCORS Method links external code Component ID's and/or node volumes to the S5K core knowing only the system code inputs. The relationship between the RELAP5-3D input and its memory addressing is "really straightforward."*

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# TMI MSLB: YAML Input Sample (“ATRIUM”)

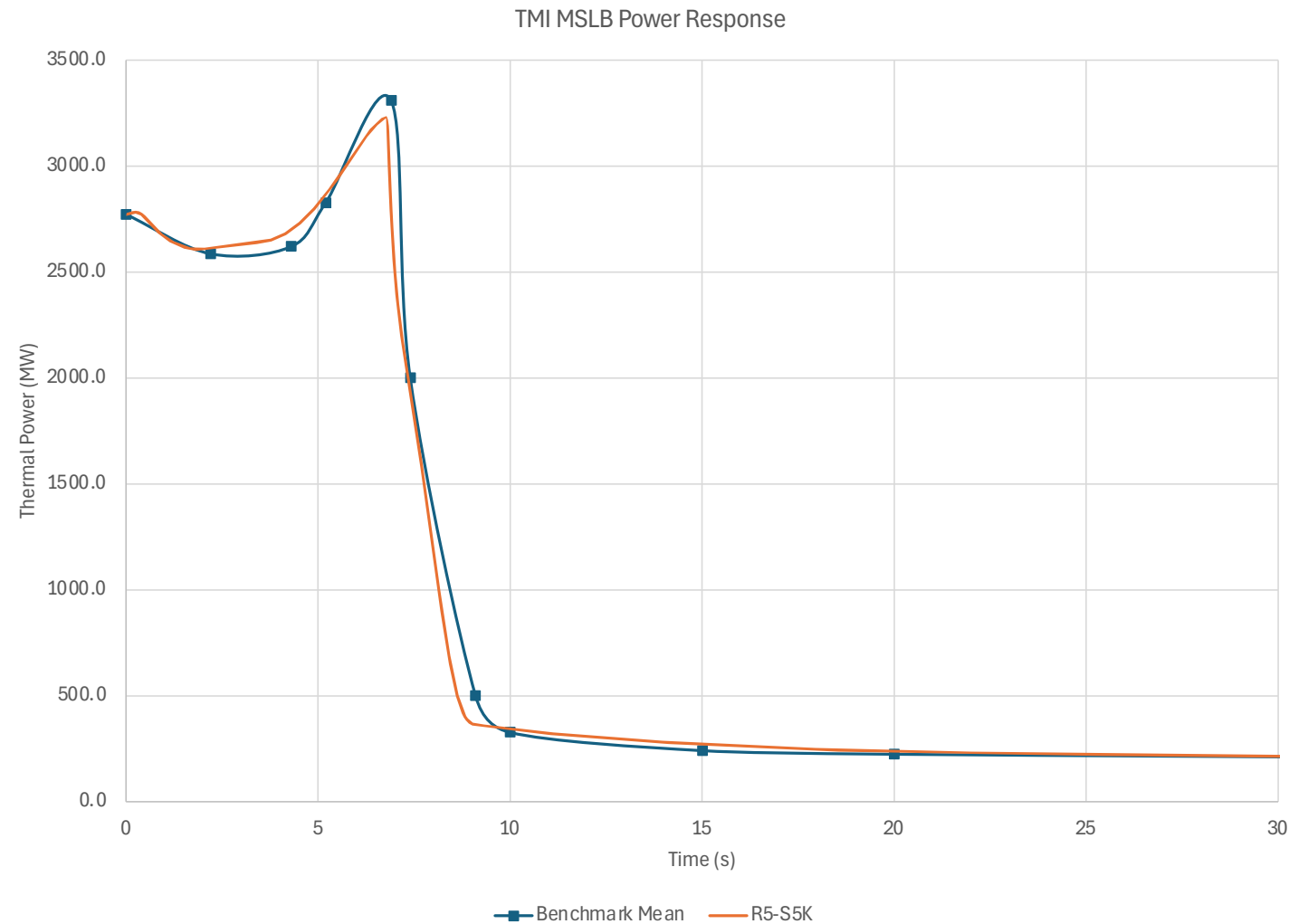
```
Requests:
# -----
# Syscode sends core hydraulic data to S5K
# -----
- label: "Thermal Hydraulic Data for Neutronic Feedback"
  datatypes: [double,double,double,double,double,double,double,double,double,double]
  sender:
    process: r53d
    when: hydro
    attributes: [ 'avol', 'vvol', 'voidg', 'rhof', 'rhog', 'velf', 'velg', 'p', 'tempf', 'uf', 'ug']
    units: [ 'm**2', 'm**3', 'none', 'kg/m**3', 'kg/m**3', 'm/s', 'm/s', 'Pa', 'degK', 'J/kg', 'J/kg']
    component:
      comptype: pipe
      x:
        dim: "1-26"
        compids: "1-18"
  receiver:
    process: s5k
    when: sys_thtop
    attributes: ['sys_fa','sys_vol','sys_void','sys_rhof','sys_rhog','sys_velf','sys_velg','sys_pres','sys_tmo','sys_uf','sys_ug']
    units: [ 'm**2', 'm**3', 'none', 'kg/m**3', 'kg/m**3', 'm/s', 'm/s', 'Pa', 'degK', 'J/kg', 'J/kg']
    component:
      comptype: sys_chan
      x:
        dim: "1-26"
        compids: "1-18"
```

# TMI MSLB: Intrinsic S5K Expansion Module\*

```
'HYD.BEX'  'FLAT' , , , , , , , , , 10 , 'FIRST' /
'HYD.VHZ'  18 26 /
'HYD.MAP'
0 0 0 0 0 0 0 0 0 0 0 14 14 14 14 14 14 14 14 14 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 14 14 14 14 14 14 14 14 14 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 15 15 14 14 14 14 14 14 14 14 14 14 14 14 14 14 13 13 0 0 0 0 0 0
0 0 0 0 0 0 15 15 14 14 14 14 14 14 14 14 14 14 14 14 14 14 13 13 0 0 0 0 0 0
0 0 0 0 15 15 15 15 9 9 8 8 8 8 8 8 8 8 8 8 8 7 7 13 13 13 13 0 0 0 0
0 0 0 0 15 15 15 15 9 9 8 8 8 8 8 8 8 8 8 8 8 7 7 13 13 13 13 0 0 0 0
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0 0 15 15 15 15 15 15 9 9 8 8 8 8 8 8 8 8 8 8 8 7 7 13 13 13 13 13 13 0 0
0 0 15 15 9 9 9 9 9 9 3 3 2 2 2 2 2 2 2 2 1 1 7 7 7 7 7 7 13 13 0 0
0 0 15 15 9 9 9 9 9 9 3 3 2 2 2 2 2 2 2 2 1 1 7 7 7 7 7 7 13 13 0 0
15 15 15 15 9 9 9 9 3 3 3 3 2 2 2 2 2 2 2 2 1 1 1 1 7 7 7 7 13 13 13 13
15 15 15 15 9 9 9 9 3 3 3 3 2 2 2 2 2 2 2 2 1 1 1 1 7 7 7 7 13 13 13 13
15 15 15 15 9 9 9 9 3 3 3 3 3 3 2 2 1 1 1 1 1 1 1 1 7 7 7 7 13 13 13 13
15 15 15 15 9 9 9 9 3 3 3 3 3 3 2 2 1 1 1 1 1 1 1 1 7 7 7 7 13 13 13 13
15 15 15 15 9 9 9 9 3 3 3 3 3 3 2 2 1 1 1 1 1 1 1 1 7 7 7 7 13 13 13 13
16 16 16 16 10 10 10 10 4 4 4 4 4 4 5 5 6 6 6 6 6 6 6 12 12 12 12 18 18 18 18
16 16 16 16 10 10 10 10 4 4 4 4 4 4 5 5 6 6 6 6 6 6 6 6 12 12 12 12 18 18 18 18
16 16 16 16 10 10 10 10 4 4 4 4 4 4 5 5 6 6 6 6 6 6 6 6 6 12 12 12 12 18 18 18 18
16 16 16 16 10 10 10 10 4 4 4 4 5 5 5 5 5 5 5 5 6 6 6 6 6 6 12 12 12 12 18 18 18 18
0 0 16 16 10 10 10 10 10 10 4 4 5 5 5 5 5 5 5 5 6 6 6 6 12 12 12 12 18 18 0 0
0 0 16 16 10 10 10 10 10 10 4 4 5 5 5 5 5 5 5 5 6 6 6 6 12 12 12 12 18 18 0 0
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0 0 0 0 0 0 0 0 0 0 0 17 17 17 17 17 17 17 17 17 17 0 0 0 0 0 0 0 0 0 0 /
```

\*Pre-existing Feature, there are other syntaxes similar to HYD.VHZ that are more complex

# TMI MSLB: Power Results



## Other Input Example(1)

```
# -----  
# S5K Sends power fractions to R5 Heat Structures  
# -----  
- label: "S5K Sends Local Power Fractions"  
  datatypes: [double, double]  
  sender:  
    process: s5k  
    when: sys_advance  
    attributes: ['sys_pffue', 'sys_pfact']  
    component:  
      comptype: sys_power  
      x:  
        dim: "2-25"  
        compids: "1-18"  
  receiver:  
    process: r53d  
    when: 3dkin  
    attributes: ['htfctr', 'htftrn']  
    component:  
      comptype: htsrc  
      x:  
        dim: "1-24"  
        compids: "10,20,30,40,50,60,70,80,90,100,110,120,130,140,150,160,170,180"
```

## Other Input Example(1)

```
# -----  
# S5K Sends power fractions to R5 Heat Structures  
# -----  
- label: "S5K Sends Local Power Fractions"  
  datatypes: [double, double]  
  sender:  
    process: s5k  
    when: sys_advance  
    attributes: ['sys_pffue', 'sys_pfact']  
    component:  
      comptype: sys_power  
      x:  
        dim: "2-25"  
        compids: "1-18"  
  receiver:  
    process: r53d  
    when: 3dkin  
    attributes: ['htfctr', 'htftrn']  
    component:  
      comptype: htsrc  
      x:  
        dim: "1-24"  
        compids: "10,20,30,40,50,60,70,80,90,100,110,120,130,140,150,160,170,180"
```

## Other Input Example(2)

```
# -----  
# S5K Sends reactor thermal power to r53d  
# -----  
- label: "Thermal Power - Reactor"  
  datatypes: [double]  
  sender:  
    process: s5k  
    when: sys_advance  
    attributes: ['ctp']  
    component:  
      comptype: reactor  
      compids: "1"  
  receiver:  
    process: r53d  
    when: convar  
    attributes: ["cntrlvar"]  
    component:  
      comptype: ctrlsys  
      compids: "12"
```

*Also, CONCORS by design preserves all the inherent I/O of its client processes. However, the meeting point “edits” can send data to CONCORS as watchpoints.*

# CONCORS Next

- Three Real Project (S5K + others)
  - Two 2-client processes
  - One 3-client processes
- All “the stuff” that comes with real projects
- Graphics?

*BTW, if  $N = \text{\#clients}$ , the number of “coupled codes” publications grad students could generate scales as  $(N-1)^2$ .  
CONCORS could be tenure machine!*

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