Relap-3D IPSR Simulations

Presented by:

Emilian Popov

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

UT-BATTELLE

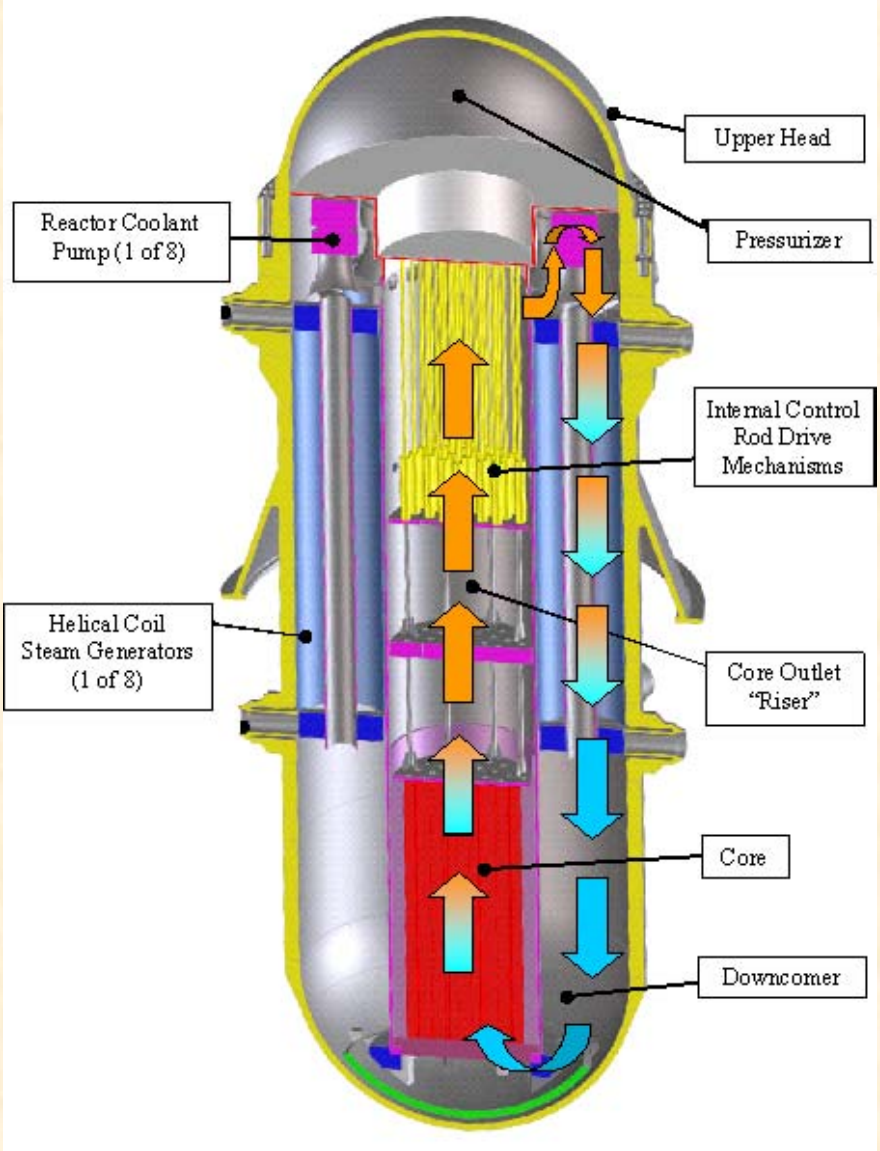
Presentation Outline

- ORNL Relap-3D activities
- IRIS reactor as a prototype IPSR
- Modeling and benchmarking
- Asymmetric transient example
- Conclusions and suggestions

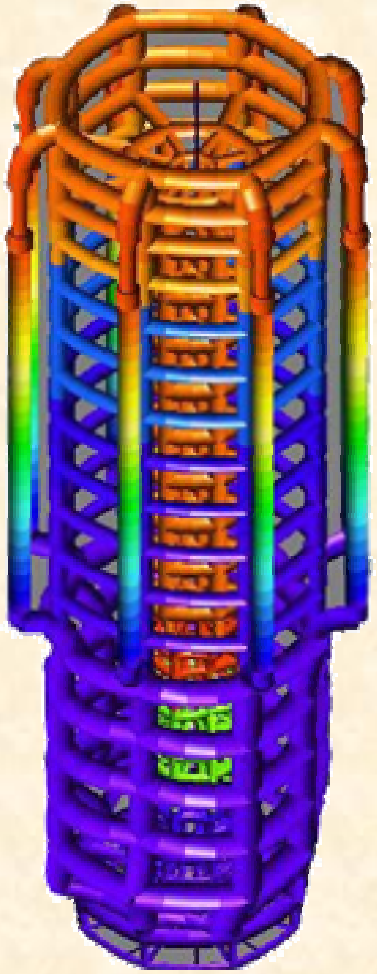
Relap 3-D activities at ORNL

- Integral PRZ NERI Project
- FMDP VVER-1000 Analyses
- Neutron XS development
- OECD Benchmarks

IRIS used as Prototype



Steady State Simulation



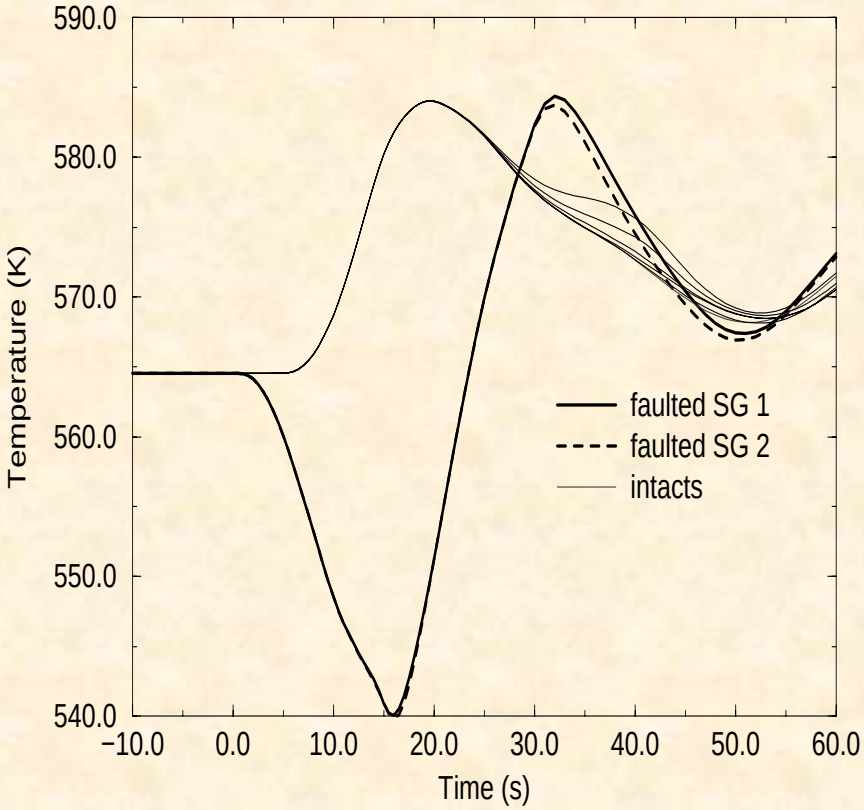
Parameter	Unit	Reference	Relap5 3-D
Pressurizer pressure	MPa	15.5	15.52
BE vessel flow	kg/s	4707	4693
BE core flow	kg/s	4504	4530
Core inlet temperature	K	565.2	564.4
Core outlet temperature	K	601.5	601.2
SG pressure	MPa	5.8	5.8
Steam exit temperature	K	590.2	590.5
Total steam flow	kg/s	502.8	502.2
Dp core	KPa	52.0	72.7
Dp SG1 prim/sec	KPa	72/296	14/315
RCP head	m	19.1	20.0

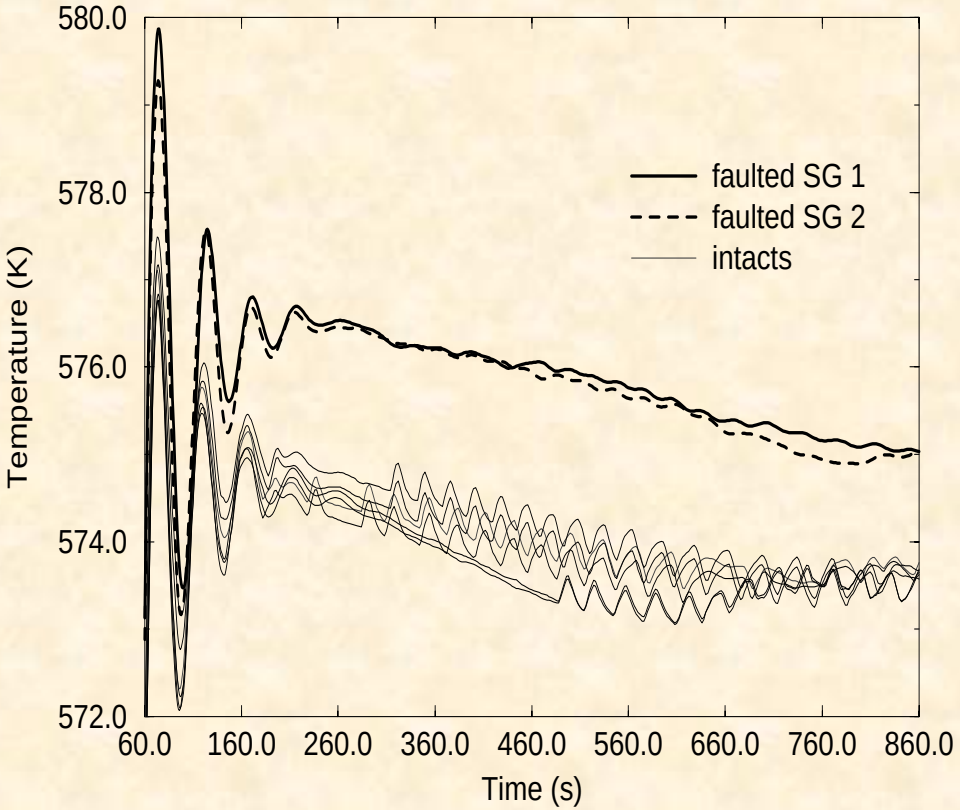
Asymmetric Transient example

- Inadvertent opening of a SD valve

System function	Time of occurrence	Set point/signal
Reactor Shutdown	At time 0	Low steam line pressure, S-signal
Turbine isolation	5 sec	Normal delay after a reactor trip
Normal Feedwater to intact SGs	Gradually reduced to zero by the control system	
Normal Feedwater to faulted SGs	Terminated 5 sec after turbine trips	Assumption, no particular signal available
Intact SGs Steam dump operation	Calculated	Follow a predefined primary average temperature
Startup feedwater	Comes on when MFW unavailable	Maintains SG level

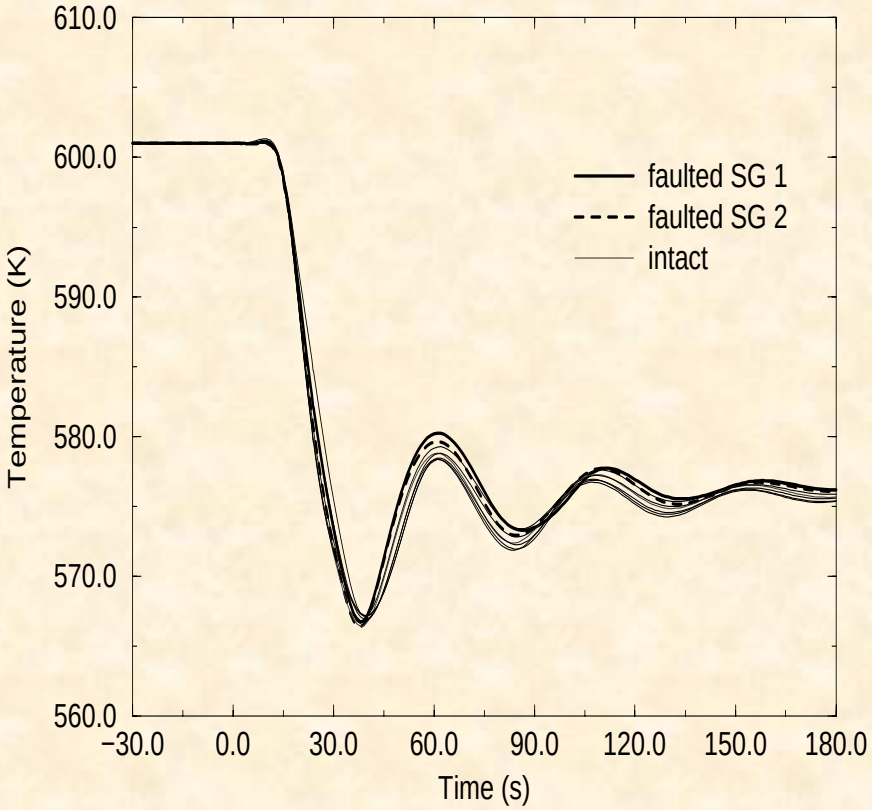
SD opening selected graphs (1)

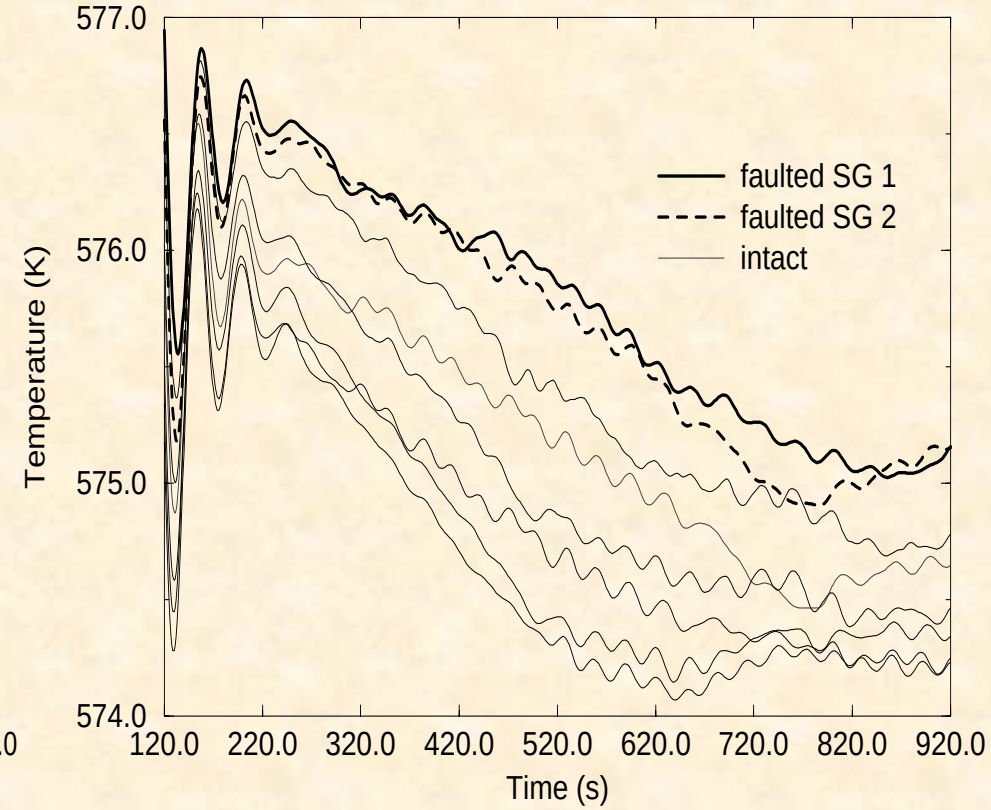




Cold leg temperatures (SG outlet)

SD opening selected graphs (2)



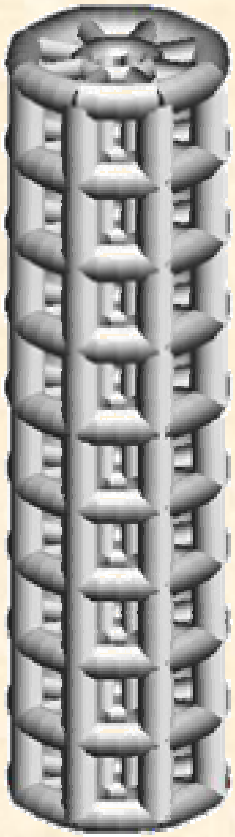


Hot leg temperatures (SG inlet)

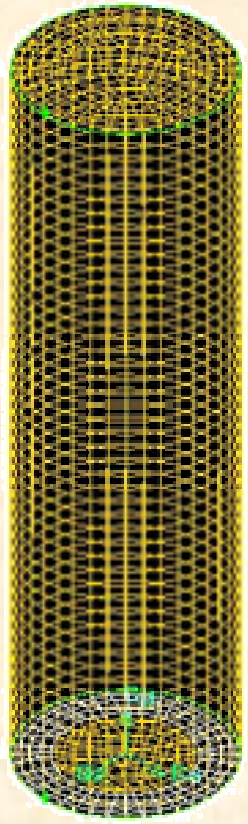
Riser Flow Benchmarking

- FLUENT code used
- Boundary conditions taken from Relap run
- Purpose is to verify the degree of mixing
- Optionally reactor internals will be included
- Two conditions were considered:
  1. Steady state operation – radial asymmetry
  2. A dried out pair of SGs– azimuthal asymmetry
- Temperature and velocity profiles compared

Reactor upper plenum (Riser)

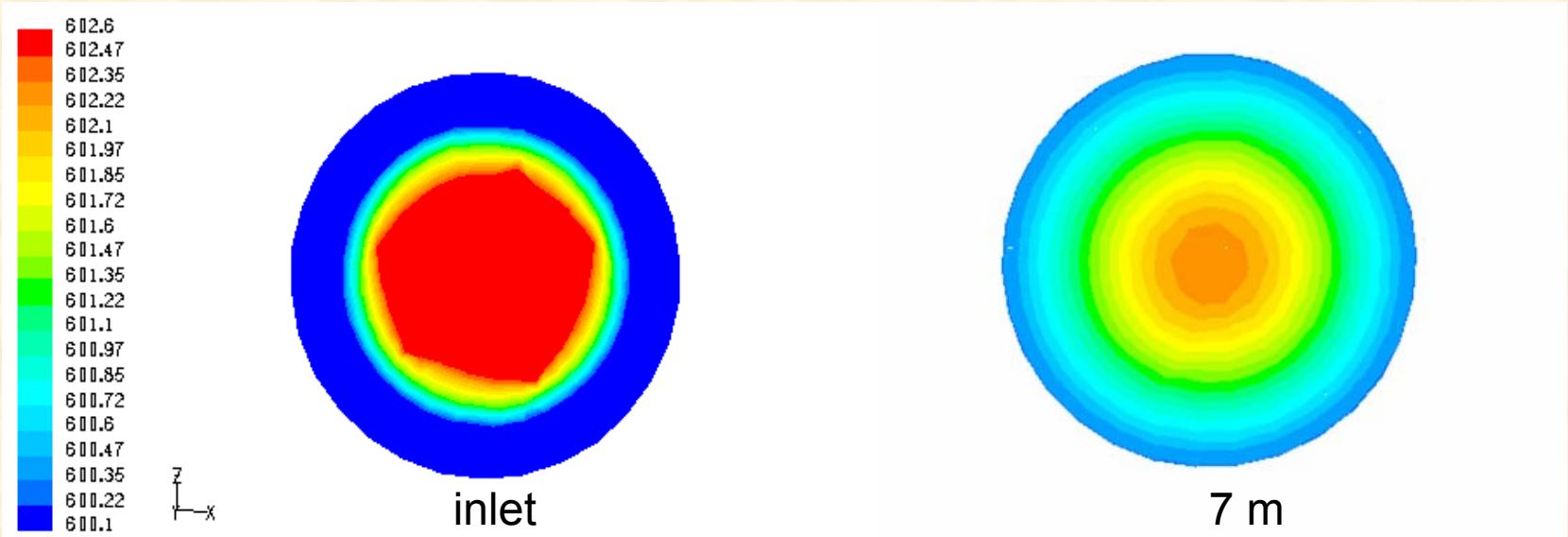


RELAP



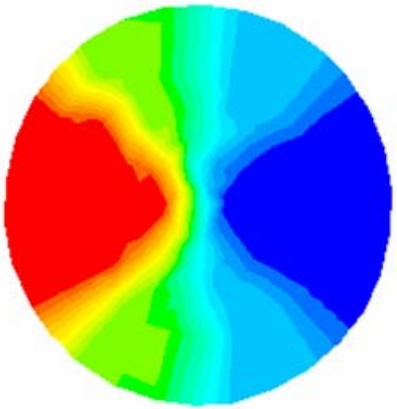
FLUENT

Nominal Operation Temperature Profile
(no internals)

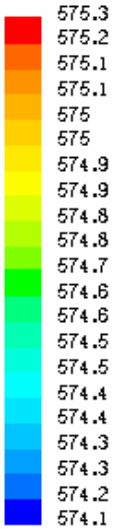


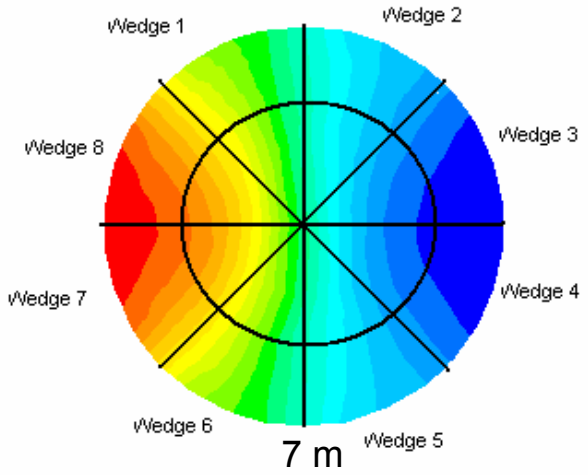
Location	Temperature Fluent, K		Temperature Relap, K	
	Inner ring	Outer ring	Inner ring	Outer ring
Inlet of component	602.6	600.1	602.6	600.08
At 7 m elevation	601.8	600.7	602.1	600.11

Two SGs out of service temp. profile
(no internals)



inlet





7 m

Location		Temperature Fluent, K				Temperature Relap, K			
		1&6	2&5	3&4	7&8	1&6	2&5	3&4	7&8
Inlet (average)		574.70	574.35	574.15	575.25	*574.70*	*574.35*	*574.15*	*575.25*
At 7 m	inner	574.72	574.46	574.29	574.98	No identifiable change			
	outer	574.73	574.40	574.20	575.14				

Summary of findings

- No substantial flow mixing occurs (structures not taken into account)
- Basically, the CFD confirms Relap results
- Temperature unevenness in the riser is negligible for most limiting anticipated events

Conclusions and suggestions

- Relap-3D is appropriate for Integrated Reactor System Analysis
- 3-D flows are explicitly present because of the lack of piping (loops)
- Suitable range of parameters and fluid properties already exists
- Operating regimes and expected events similar to typical PWR

Conclusions and suggestions (cont'd)

- GUI requires significant improvement
  1. Separate component display
  2. Component alignment (multiple junct.)
  3. Handling data after a restart
  4. Printing/saving is not always reliable
  5. Representing vectors, etc.

Conclusions and suggestions (cont'd)

- Relap 3D problematic findings
  1. Swirl flows generation
  2. Boron model malfunction in some versions
  3. Limited number of nodes (running out of words)
  4. Ability to model structures in the flow seems necessary
  5. Connection of components with different meshing