Co-simulation in LS-DYNA
FMU & SyC

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LS-DYNA Users Conference
Nov. 2023

Ansys

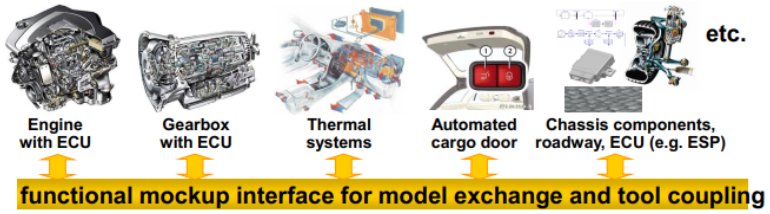
Agenda

- FMI, review and update
- SyC
  - Introduction to SyC
  - SyC in ls-dyna
  - How to run SyC
    - Using GUI
    - Using batch mode
- Summary and next steps

FMI

FMI Interface

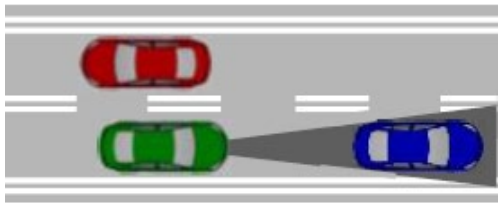
- Models of a system often have to be developed using different modeling and simulation environments. In order to simulate the complete system, the different programs have to interact with each other.
- The Functional Mock-up Interface (FMI) is a free standard that defines an interface to exchange dynamic models. It is supported by more than 150 tools.
- LDYNA/FMI integrates LS-DYNA with other tools and leads to new applications and business cases
  - Co-simulate with ANSYS/VRX, MOTION and Rigid Body Dynamics for the simulation of on-road vehicle dynamics, fatigue and active safety.
  - Co-simulation with Carmaker, MATLAB, Python, Adams etc. for AV design, controller design, optimization.
- Latest ls-dyna package: https://ftp.lstc.com/anonymous/outgoing/isheng/deliver/
  FMU_Manager_5.1_102823.zip 2023-10-28 12:32 219M

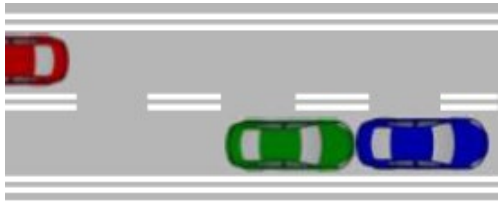


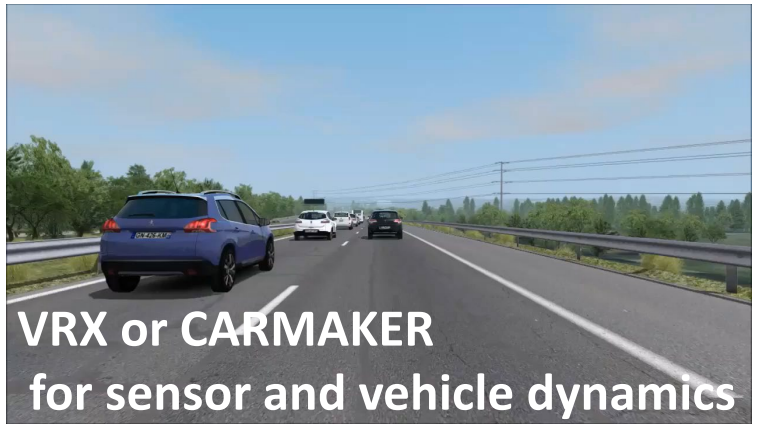
ANSYS CFX	$				2.0	
ANSYS DesignXplorer	$			1.0		
ANSYS SCADE Display	$		1.0 2.0	1.0 2.0		
ANSYS SCADE Suite	$		1.0 2.0	1.0 2.0		
ANSYS Simplorer	$		1.0 2.0	1.0 2.0	1.0 2.0	1.0 2.0
CarMaker	$				1.0 2.0	
CarSim	$		1.0 2.0		1.0 2.0	
LS-DYNA	$		1.0 2.0	2.0	2.0	2.0
MATLAB® Simulink®	$		2.0		1.0 2.0	1.0 2.0
PythonFMU			2.0			

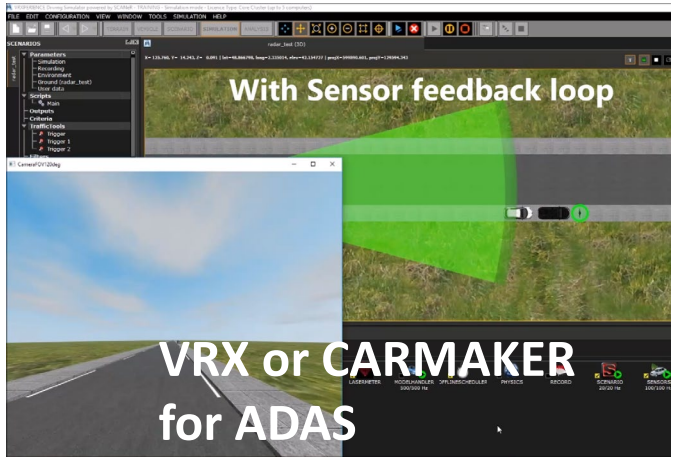
LS-DYNA/VRX/MOTION co-simulation for integrated safety & fatigue

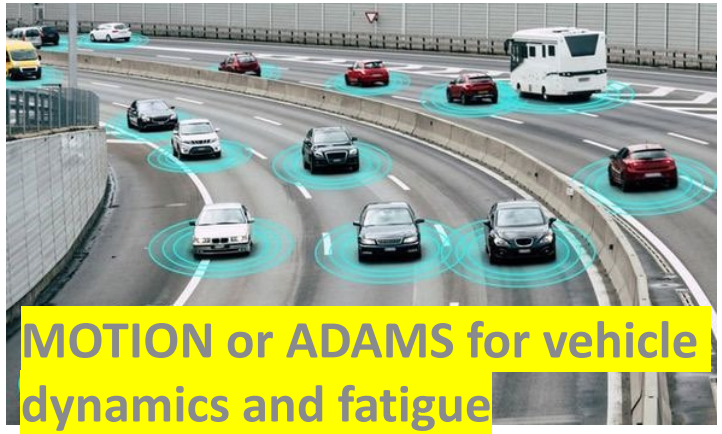
Norma/ADAS | ADAS & Active safety | Passive safety

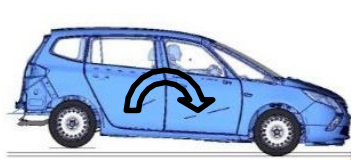


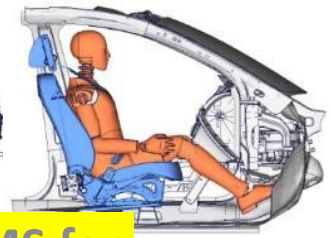


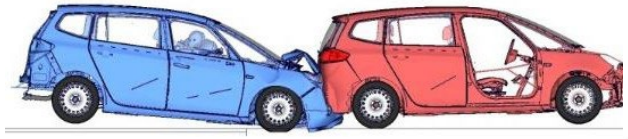












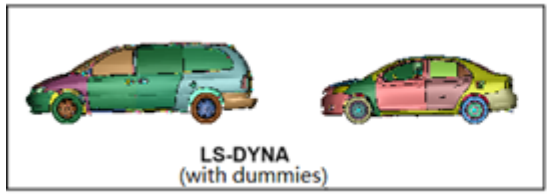
MOTION or ADAMS for
vehicle dynamics

LS-DYNA for ADAS

LS-DYNA for passive safety

LS-DYNA/VRX/MOTION co-simulation for integrated safety & fatigue

- Evaluation of active seatbelt



Acceleration/brake
Safety features control

Through FMI

Sensors, accelerometers:
Occupant kinematics, e.x..

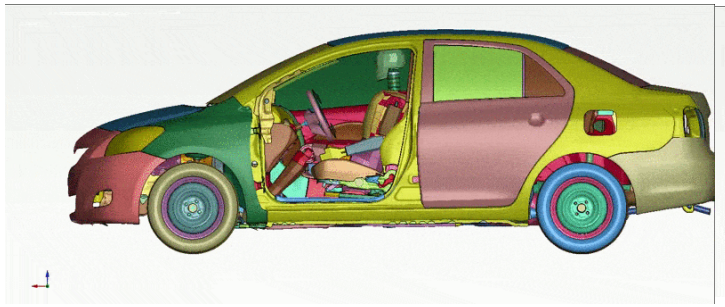
Acc/brake

Veh. kinematics

LS-DYNA
Interaction between Dummy, belt & bag

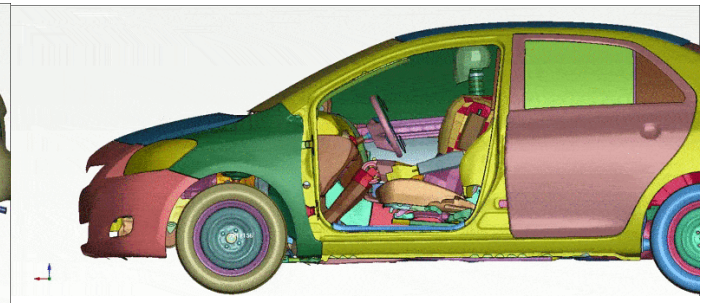
MATLAB
Control belt, bag, brake/acc

ANSYS/VRX
Vehicle dynamics before crash



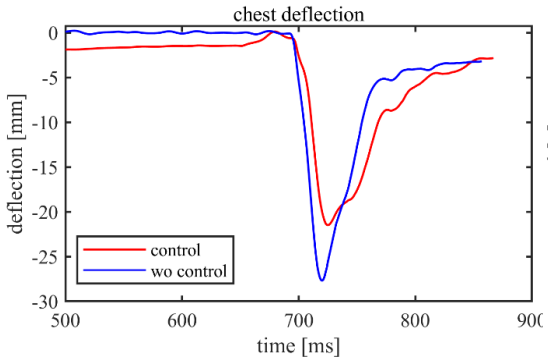
W/o active seatbelt

Occupant leans forward
due to deceleration

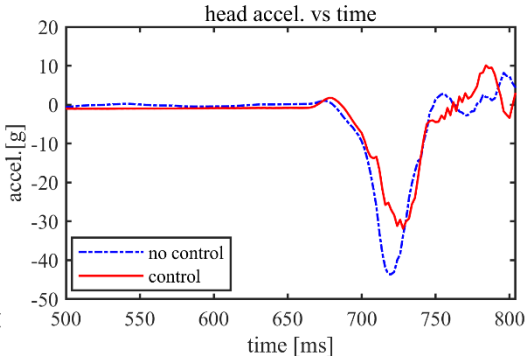


With active seatbelt

Occupant is secured in
position be active belt

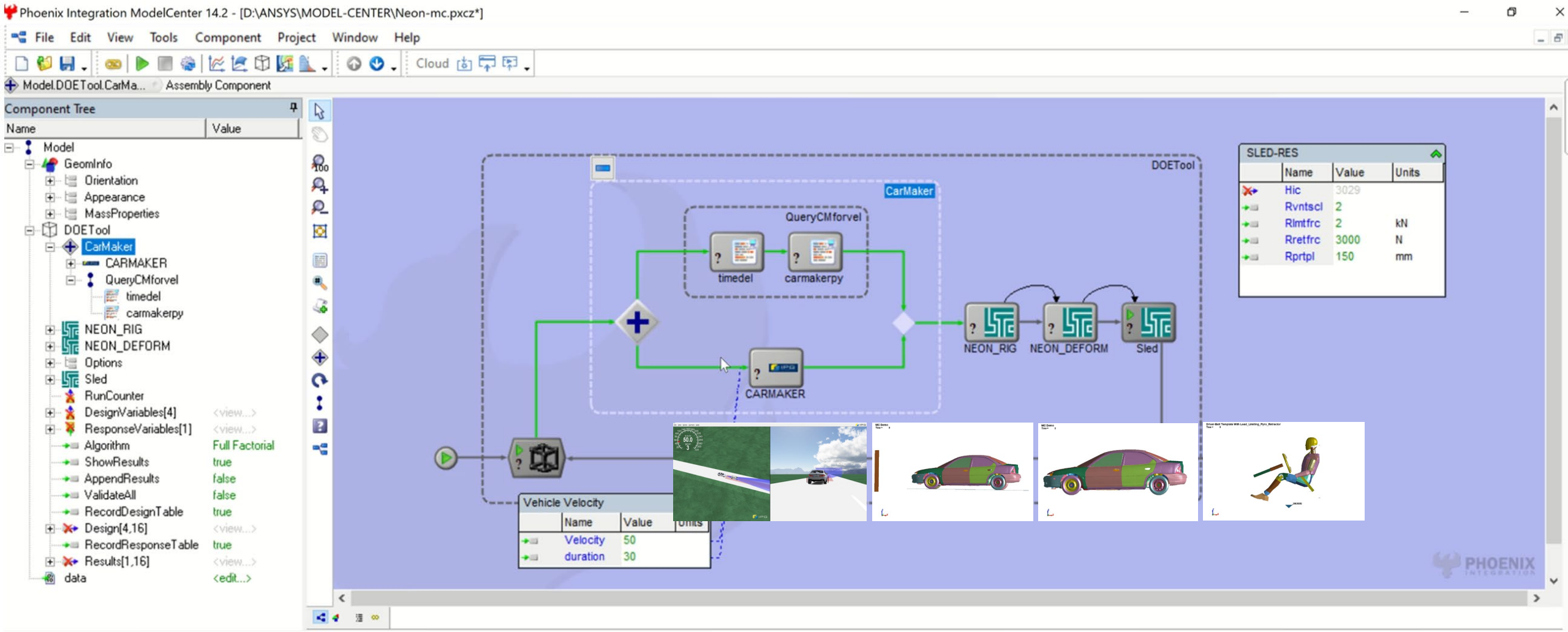


Chest compression



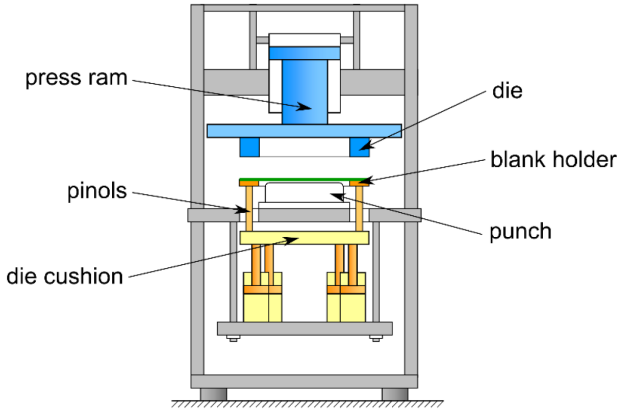
Head acceleration

Using Ansys **ModelCenter** to couple ls-dyna, Carmaker & PYFMI



See Amit for details

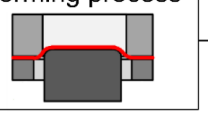
Coupled w. Virtuos using FMI for Virtual Commissioning of forming tools



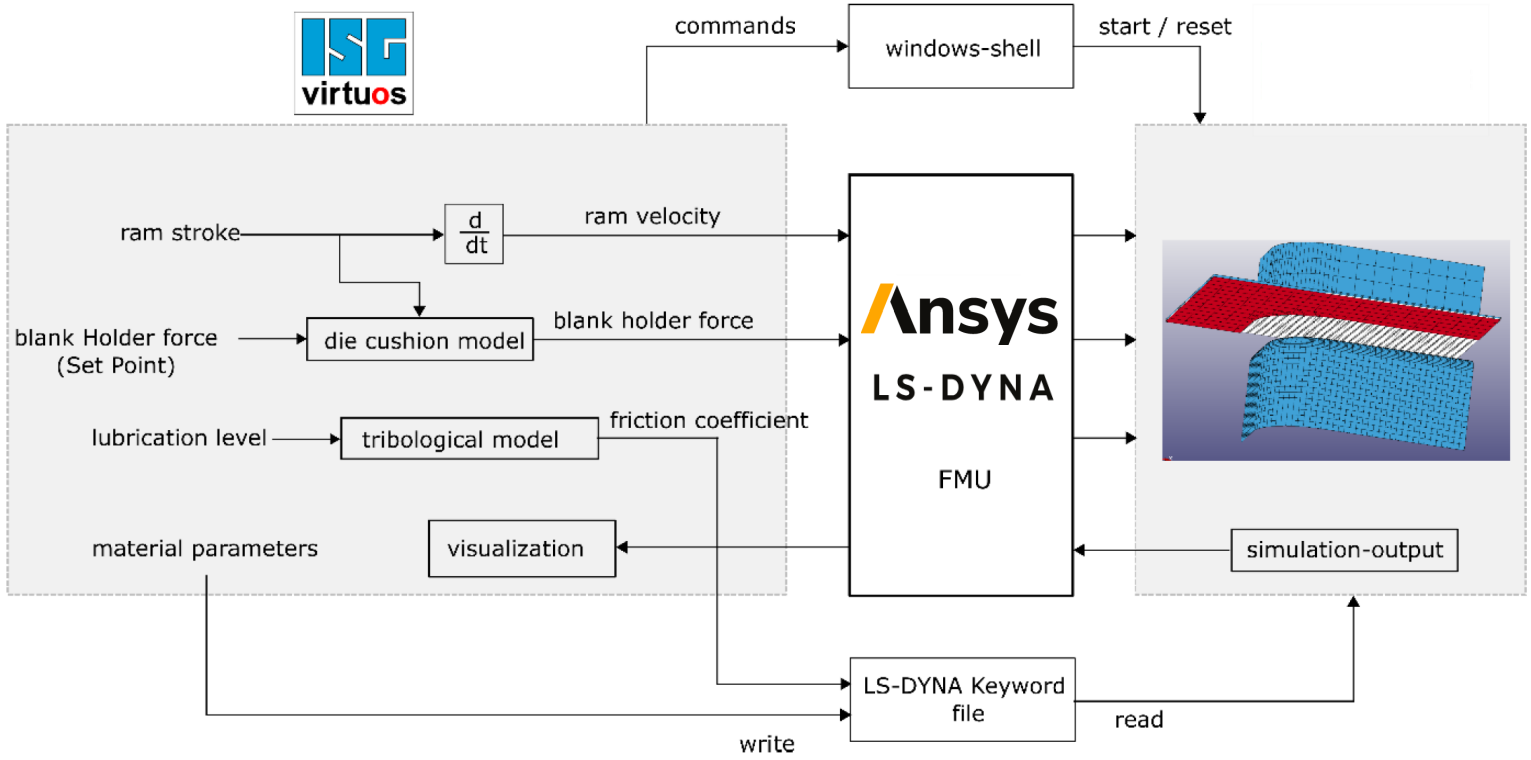
machine influences:
- elastic compliance of press and die
- dynamic influences of the drive and die cushion control

material fluctuations:
- thickness of the metal blank
- elastic-plastic behavior
- temperature

process parameters:
- blank holder force
- ram speed
- lubrication of the blank

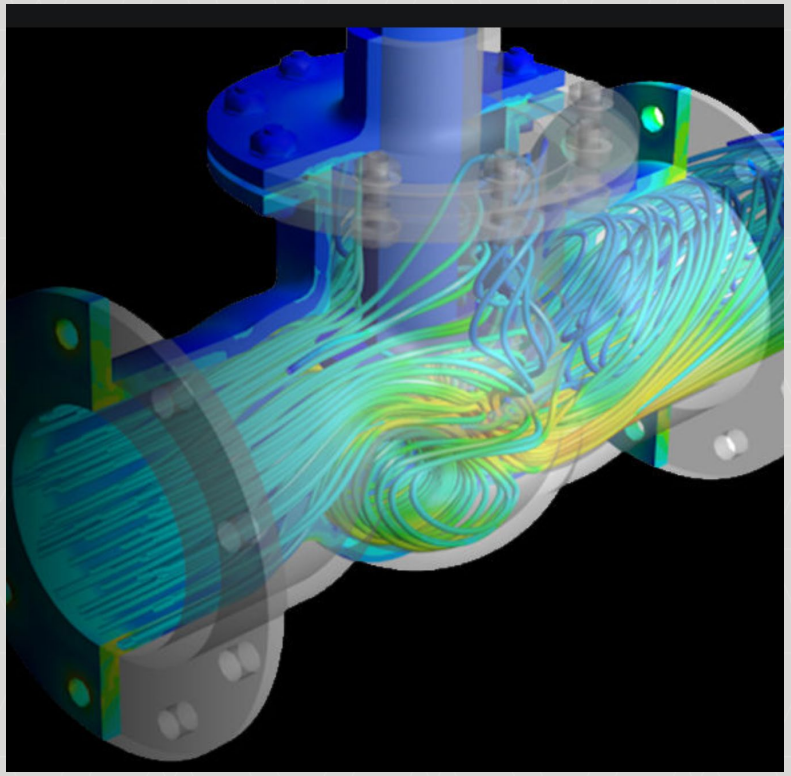


forming parameters:
- stress-stain state
- metal thinning
- material flow



S. Heiland, etc. Technische Universität Dresden, Institute of Mechatronic Engineering "**13th European LS-DYNA Conference 2021, Ulm, Germany "**

SyC, System Coupling



The Ansys Product Portfolio

Connect
- Granta MI
- Granta Selector
- Granta MDS
- optiSLang
- Minerva
- ModelCenter

Cloud
- Ansys Cloud Direct
- Ansys Gateway powered by AWS

Digital Twin
- Twin Builder

Mission Engineering
- STK
- ODTK
- TETK

Embedded Software
- SCADE Suite
- SCADE Display
- SCADE Architect
- SCADE Test
- SCADE Lifecycle

Safety Analysis
- Digital Safety Manager
- medini analyze
- medini analyze for Cybersecurity
- medini analyze for Semiconductors

AV Simulation
- AVxcelerate Headlamp
- AVxcelerate Sensor

Structures
- Mechanical
- LS-DYNA
- Forming
- Motion
- Sherlock
- Additive Solutions
- nCode DesignLife
- Autodyn

Acoustics Simulation
- Sound

3D Design
- Discovery

Fluids
- Fluent
- CFX
- Chemkin-Pro
- Forte
- Rocky
- FENSAP-ICE
- EnSight
- Turbo Tools
- Polyflow
- Model Fuel Library
- Thermal Desktop

Electronics
- HFSS
- Maxwell
- SIwave
- Icepak
- Motor-CAD
- Q3D Extractor
- NuHertz
- EMC Plus
- Charge Plus

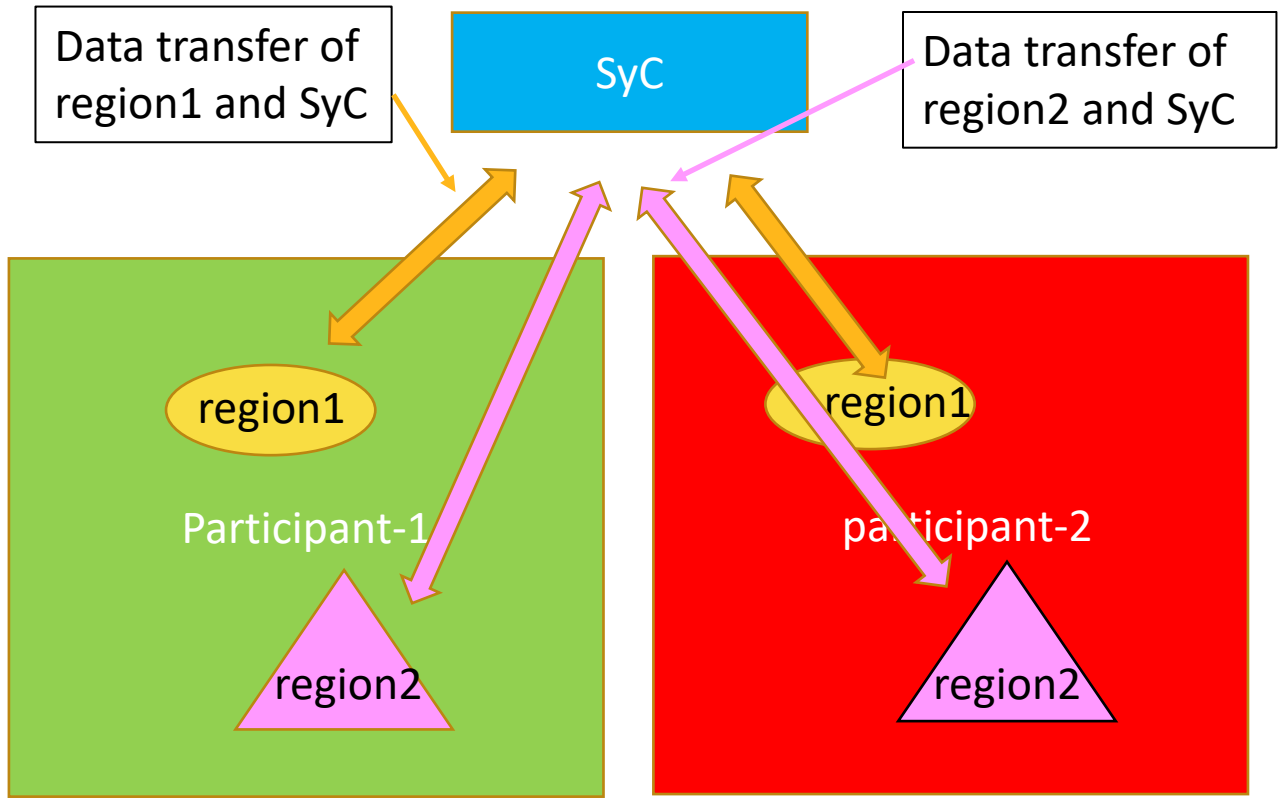
Photonics
- Lumerical FDTD
- Lumerical FDTD Accelerator
- Lumerical MODE
- Lumerical Multiphysics
- Lumerical INTERCONNECT
- Lumerical CML Compiler

Semiconductor
- RedHawk-SC
- RedHawk-SC Electrothermal
- Totem
- PowerArtist
- RaptorH
- RaptorQu
- Exalto
- VeloceRF
- PathFinder
- Path FX
- Clock FX

Optics
- Zemax OpticStudio
- Zemax OpticBuilder
- Speos

Concept of SyC, System Coupling for Ansys software

- Ansys software supporting SyC: Fluent, CFX, Forte, AEDT, Maxwell, MAPDL, Fensap, …



- Regions is mesh-based. In ls-dyna it can be defined through *SET_SEGMENT_N8.

N1	N2	N3	N4	N5	N6	N7	N8

- Meshes of solvers don't have to be exactly the same. However, they have the represent the same geographical regions..
- *COSIM_SYC_INTERFACE is used to define data to be transferred from/to ls-dyna.

EQ.FORCE: Nodal force, import only.

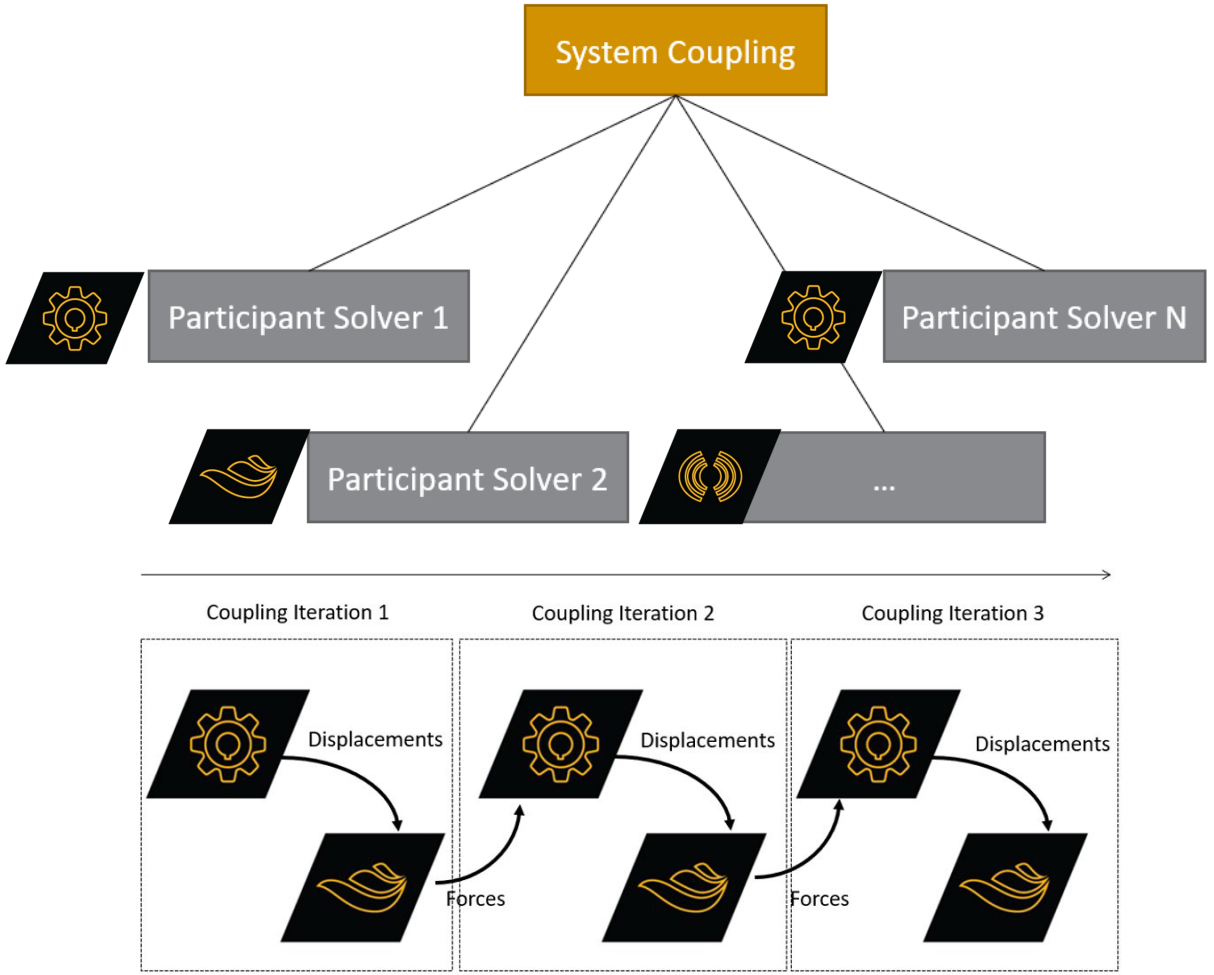
EQ.PRESS: pressure for segments, import only.

EQ.INCDIS: Incremental nodal displacement from the last SYC time step, export only.

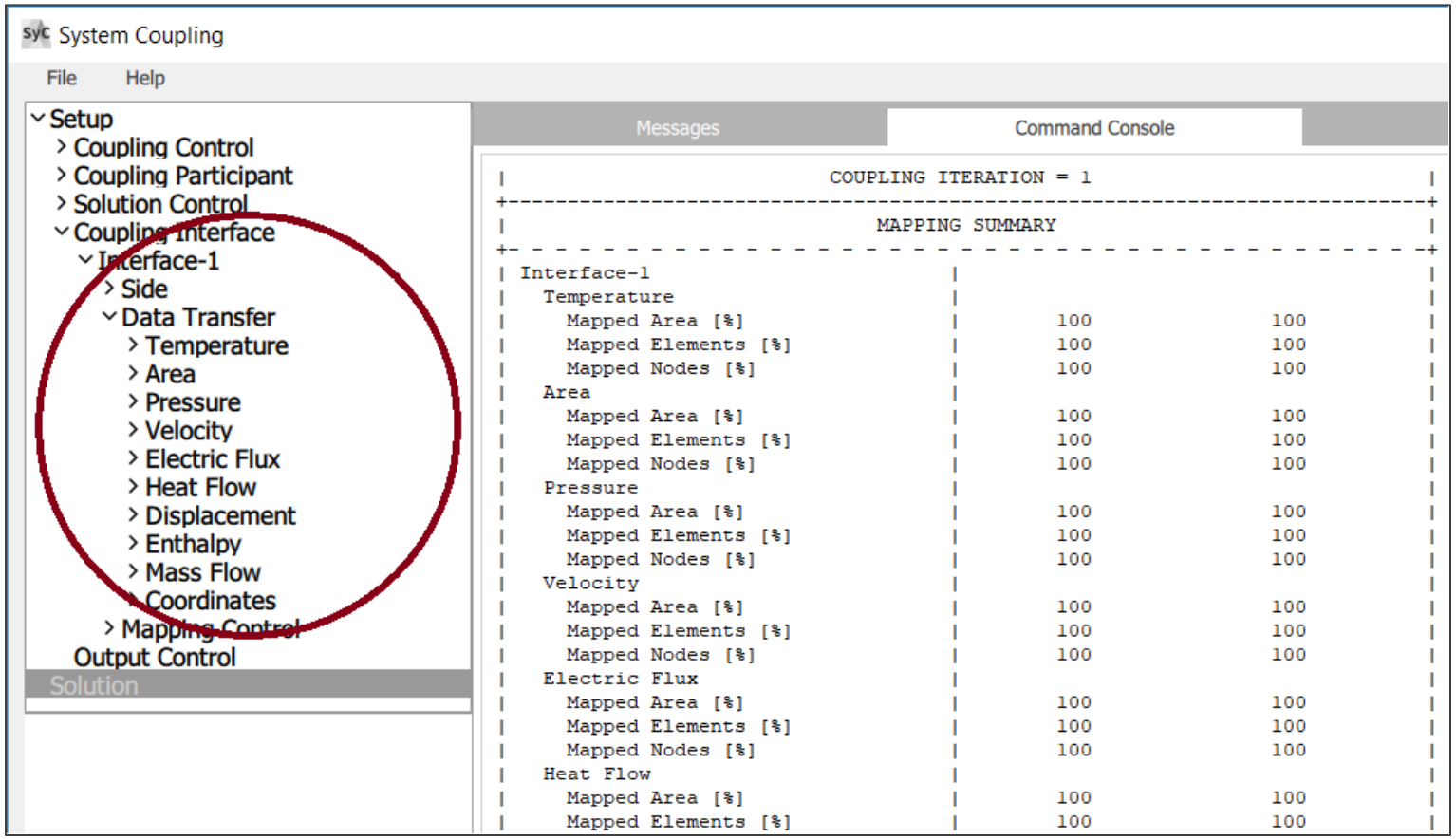
EQ.VEL : nodal velocity, export only

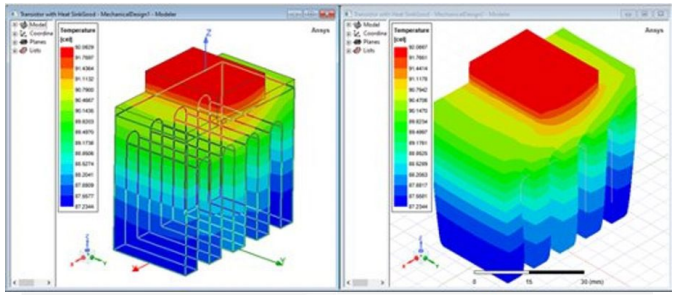
SyC Co-Simulation Management

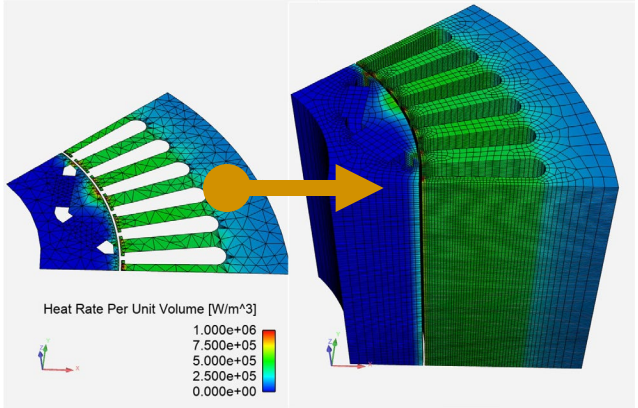
- Execution synchronization
- Analysis evolution
  - Coupling Step
    - Coupling Iteration
      - Solver Step
        - Solver Iteration
- Collect, map and serve data
- Solution stabilization & acceleration
- Convergence checking
- Result & restart point creation and synchronization
- Error handling

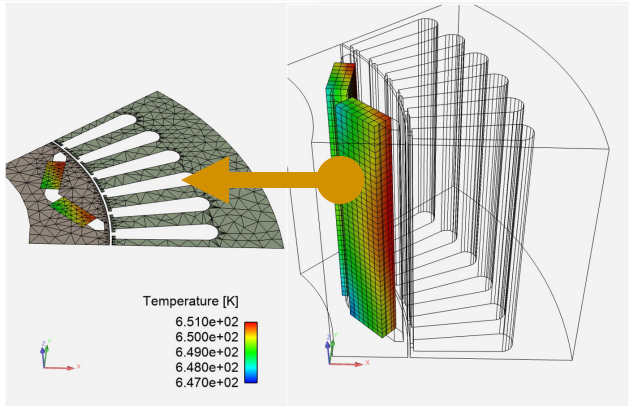


Map Any* Scalar or Vector Variable in various ways





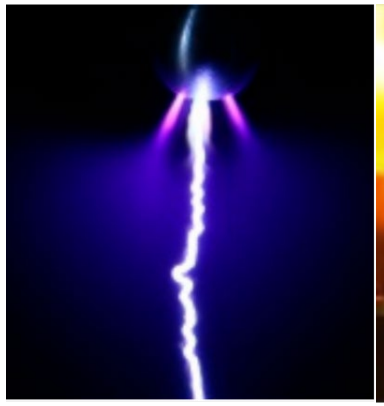




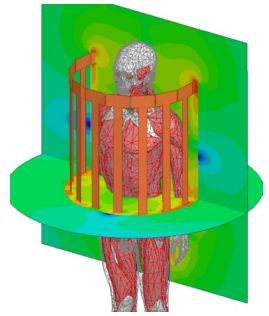
*Any variable supported as input or output by participants

Possible application of SyC

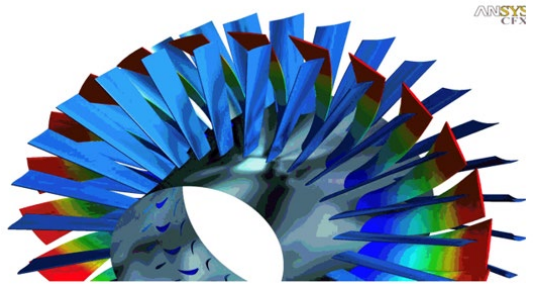
- Electric arc:
  - An electric arc is an electric breakdown of a gas that produces a prolonged electric discharge.
  - Needs for simulation
    - Accurate predicate the current limiting effect
    - Accurate simulate the behavior of the running arc with Lorentz force
    - Accurate predicate the arc voltage
    - Accurate predicate the structure deformation



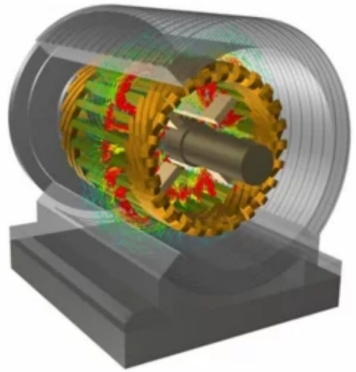
- MRI induced heating of a pacemaker



- Flutter analysis for wings, risers, blades



- Electric motor analysis

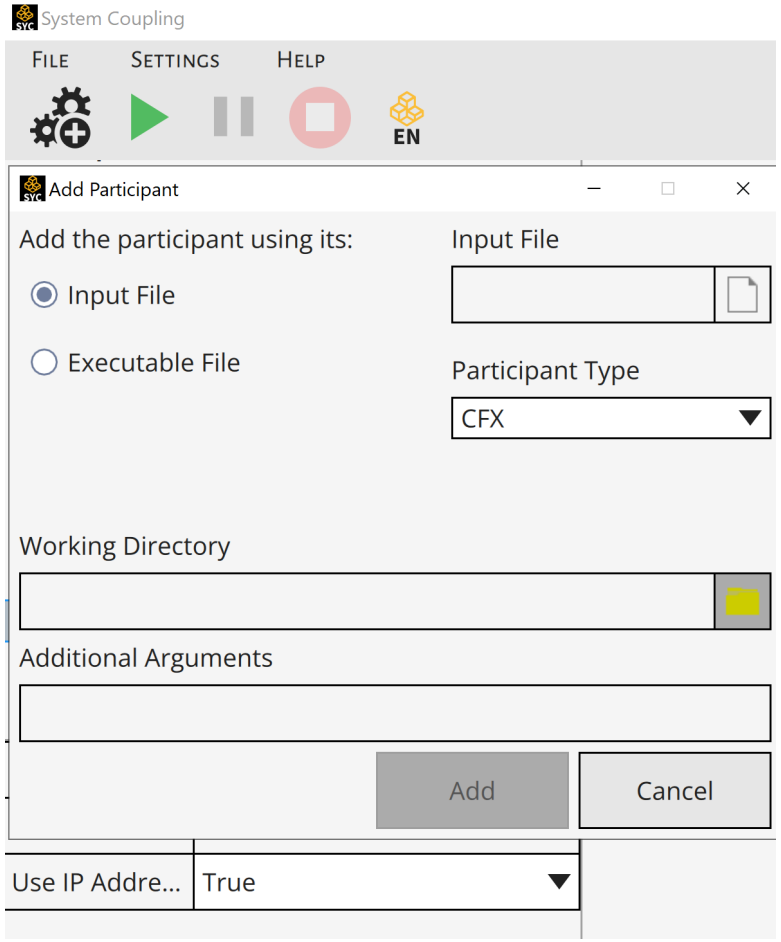


SyC in LS-DYNA

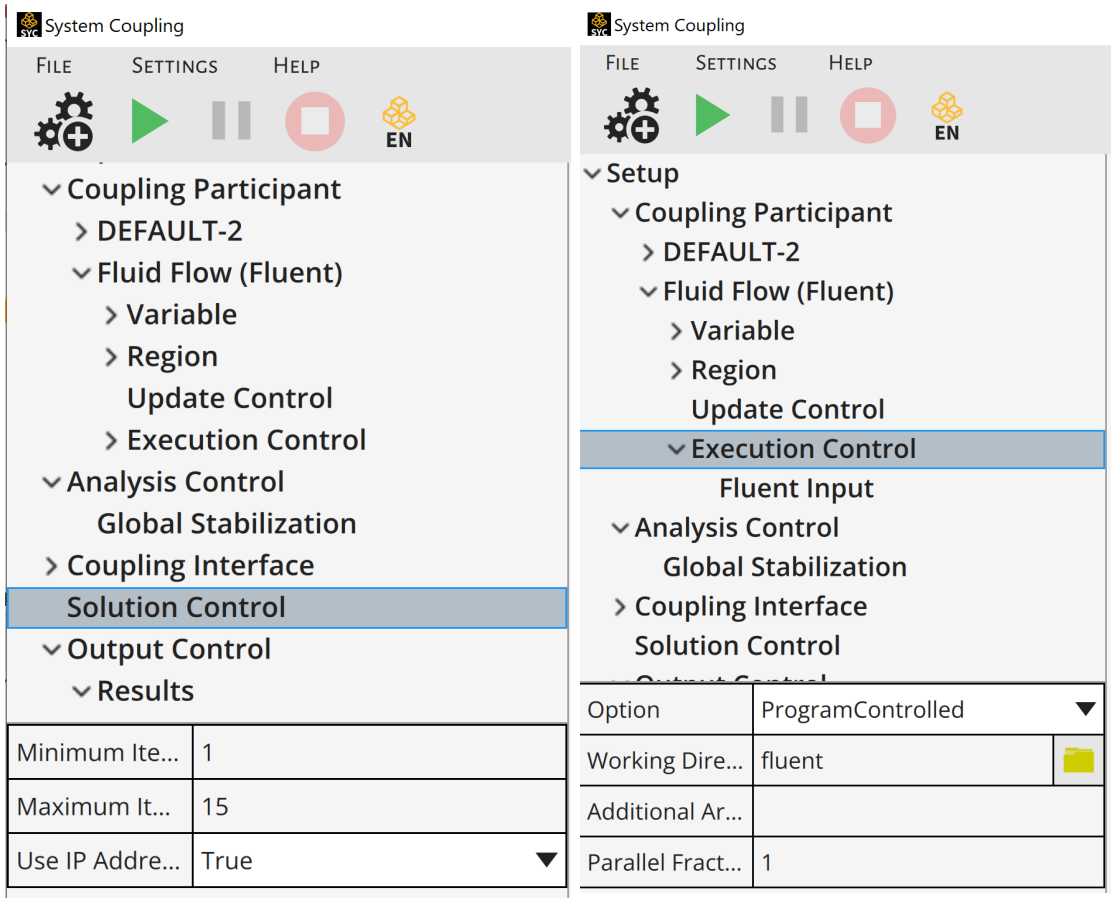
- Implicit: do data transfer for every implicit step, set the TimeStepSize in the PY file to ls-dyna's implicit time step.
- Explicit: no iteration for explicit, set the MaximumIterations=1 in SyC's PY file.
- Works for Linux and Windows; smp & mpi
- The results from the sample decks show that the SyC speed of Fluent/LS-DYNA and Fluent/APDL are about the same.
- Available in Ansys R222 & R241, see https://ftp.lstc.com/anonymous/outgoing/isheng/syc/
- R222 - syc2user083023.zip
  - Use dynamic library. Therefore, not available in general version of lsdyna
  - The lsd-yna executables with SyC features are part of the package.
  - Can co-simulate with other Ansys solvers up to R232.
- R241 syc2user_v241_110323.zip
  - Use static library.
  - Coding is done and tested, waiting to be ported to the general version of ls-dyna

SyC GUI as a pre-processor

- Participants are added by poking 

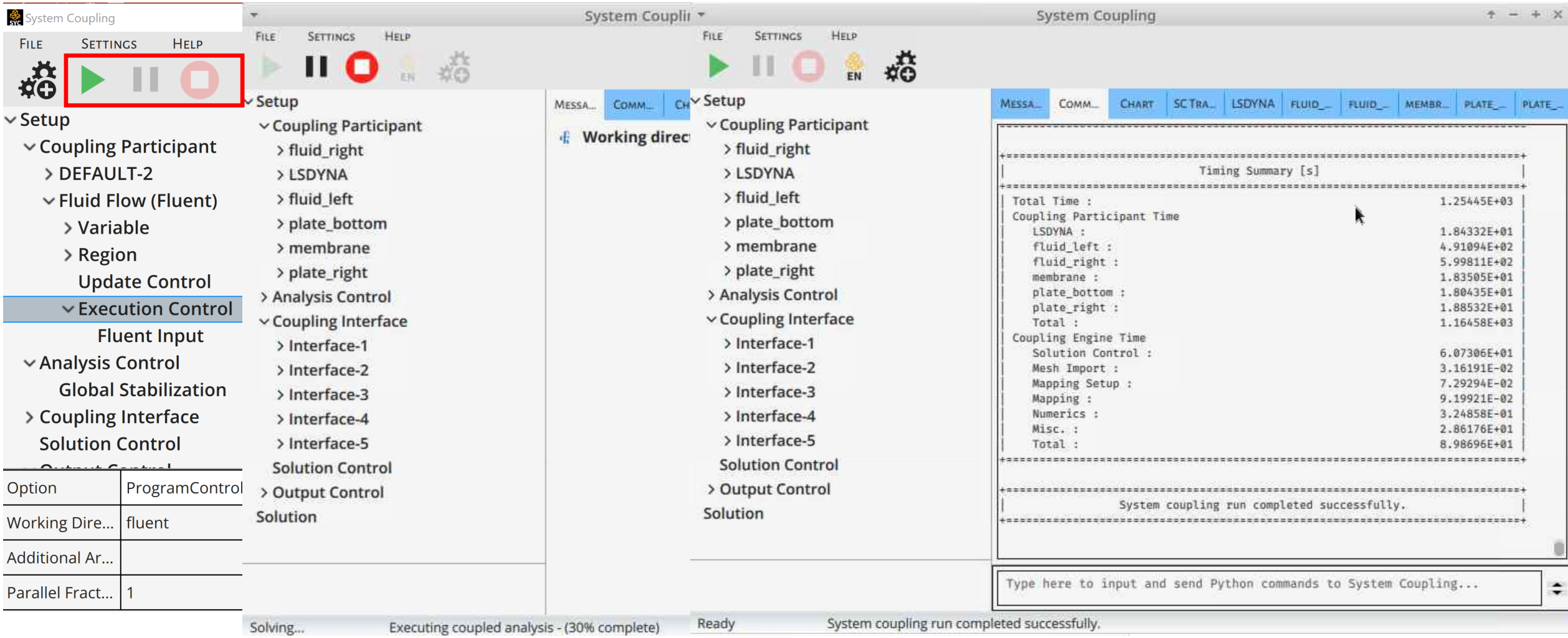


- Participant coupling interface, execution , solution & output control can be defined



SyC GUI for simulation control

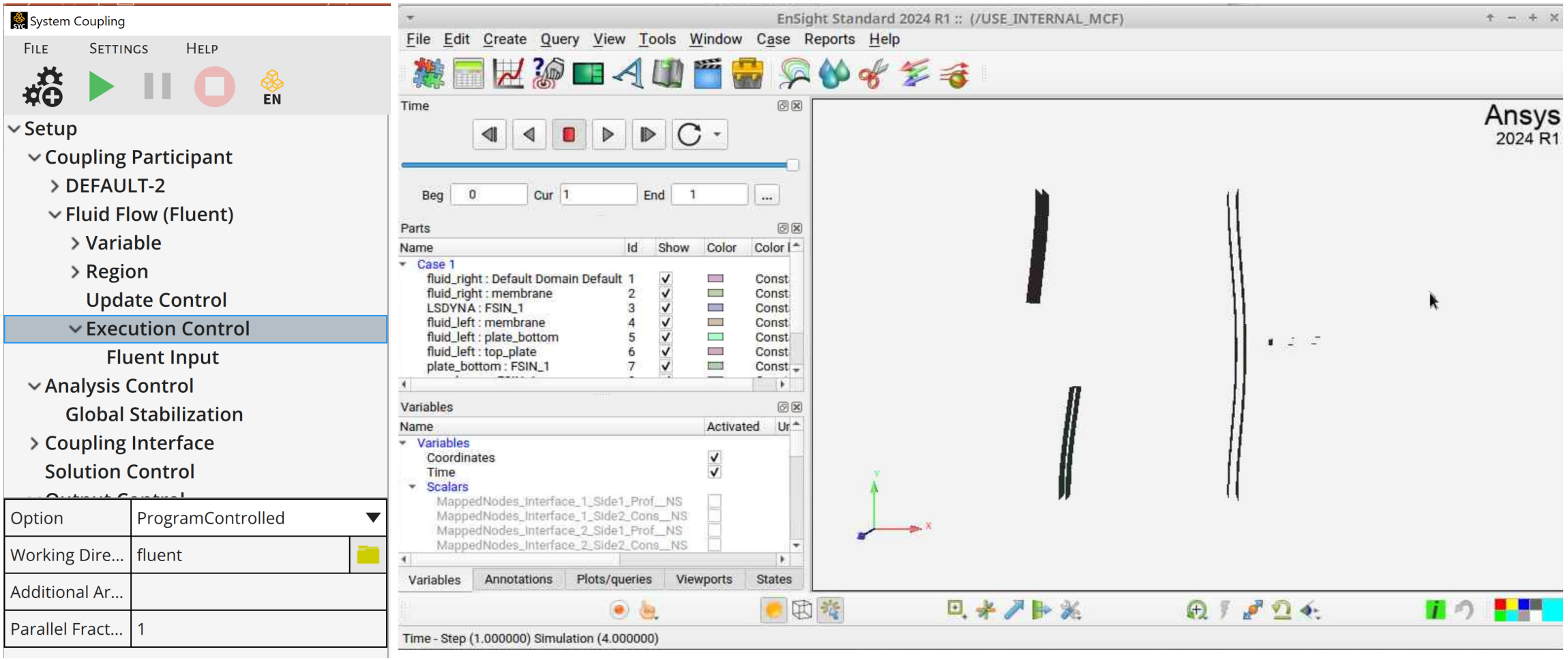
- Co-simulation can be controlled by



SyC GUI for post processing

- Poking 

to bringing in Ensight for post-processing co-simulation results



Run SyC in batch mode, before GUI for lsd-dyna is available

- Syc of Ansys V222
  - SyC Executable: C:\Program Files\ANSYS Inc\v222\SystemCoupling\bin\SystemCoupling.bat
- SyC input file in PY format that defines
  - Convergence criterion and Max/min number of iterations
  - How often data transfer will take place, *DatamodelRoot().SolutionControl.TimeStepSize = "0.0001 [s]"*
  - Participants, or solvers, by their execution script and scp files:

    FluentPart=AddParticipant(InputFile = os.path.join('Fluent_2', 'fluent.scp'))
  - Interface: regions of which data transfer will take place

    interfaceFM = AddInterface(
    SideOneParticipant = FluentPart, SideOneRegions = ['fsi'],
    SideTwoParticipant = LsdynaPart, SideTwoRegions = ['FSIN_1'])
  - Data to be imported/exported

    AddDataTransfer(Interface = interfaceFM, TargetSide = 'One',
    SideOneVariable = 'displacement', SideTwoVariable = 'INCD')
    AddDataTransfer(Interface = interfaceFM, TargetSide = 'Two',
    SideOneVariable = 'force', SideTwoVariable = 'FORC')

A scp file and an execution script for each solver

- Each solver needs a scp file, in xml format, to
  - define the “regions” and their data to be exported or imported.
  - Specify the analysis type
  - LS-DYNA’s scp file can be created by setting OPT of *COSIM_SYC_CONTROL to G

Variable	SYCID	OPT		

- an execution script to specify its executable and input deck, e.g.,

```
# Run the application

/opt/intel/compilers_and_libraries_2018.3.222/linux/mpi/intel64/bin/mpirun -n "$NPROCS"
/data1/iyeh/impi18_syc/mppdyna i=input.k "$@"
```

Scp file

```
<CouplingParticipant>
  <CosimulationControl>
    <Type>DEFAULT</Type>
   <AnalysisType>Transient</AnalysisType>
    <DisplayName>LSDYNA</DisplayName>
    <Variables>
      <Variable>
        <Name>INCD</Name>
        <QuantityType>Incremental Displacement</QuantityType>
      </Variable>
      <Variable>
        <Name>FORC</Name>
        <QuantityType>Force</QuantityType>
      </Variable>
    </Variables>
    <Regions>
      <Region>
        <Topology>Surface</Topology>
        <Name>FSIN_1</Name>
        <OutputVariables>
          <Variable>INCD</Variable>
        </OutputVariables>
        <InputVariables>
          <Variable>FORC</Variable>
        </InputVariables>
      </Region>
    </Regions>
  </CosimulationControl>
</CouplingParticipant>
```

Contents of tutorial package

- Tutorial package

executables	: ls-dyna executable
Manual	: user manuals
multiple-participants	: SYC deck: ls-dyna, mapdl, Fluent and CFX
OscillatingPlate	: SYC deck: ls-dyna and a user-defined Fortran file
ReedValve	: SYC deck: ls-dyna and Fluent
syc2user	

Summary and Next Steps for SyC

- Summary
  - The latest FMI application was presented.
  - SyC, a new co-simulation tool in LS-DYNA was introduced.
  - The differences between these tools were addressed.
  - Single-code simulation is still preferred, if available.
- Next Step
  - SyC is being implemented in general version of ls-dyna
  - SyC's GUI will include LS-DYNA, that will lessen the effort of running SyC.
  - Dependent on the interest of ls-dyna customers, more interface definitions and variables to be exchanged can be added.

Thank you