OpenSees Integration Module

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Outline

❑ **OpenSees – OpenSees Multi-Platform Simulation**

◈ Communication Overview

◈ Example Structure

◈ Example Problem

❑ **OpenSees – MATLAB/C++ Multi-Platform Simulation**

◈ Communication Overview

◈ Example Structure

◈ Example Problem

❑ **OpenSees – VecTor2 Multi-Platform Simulation**

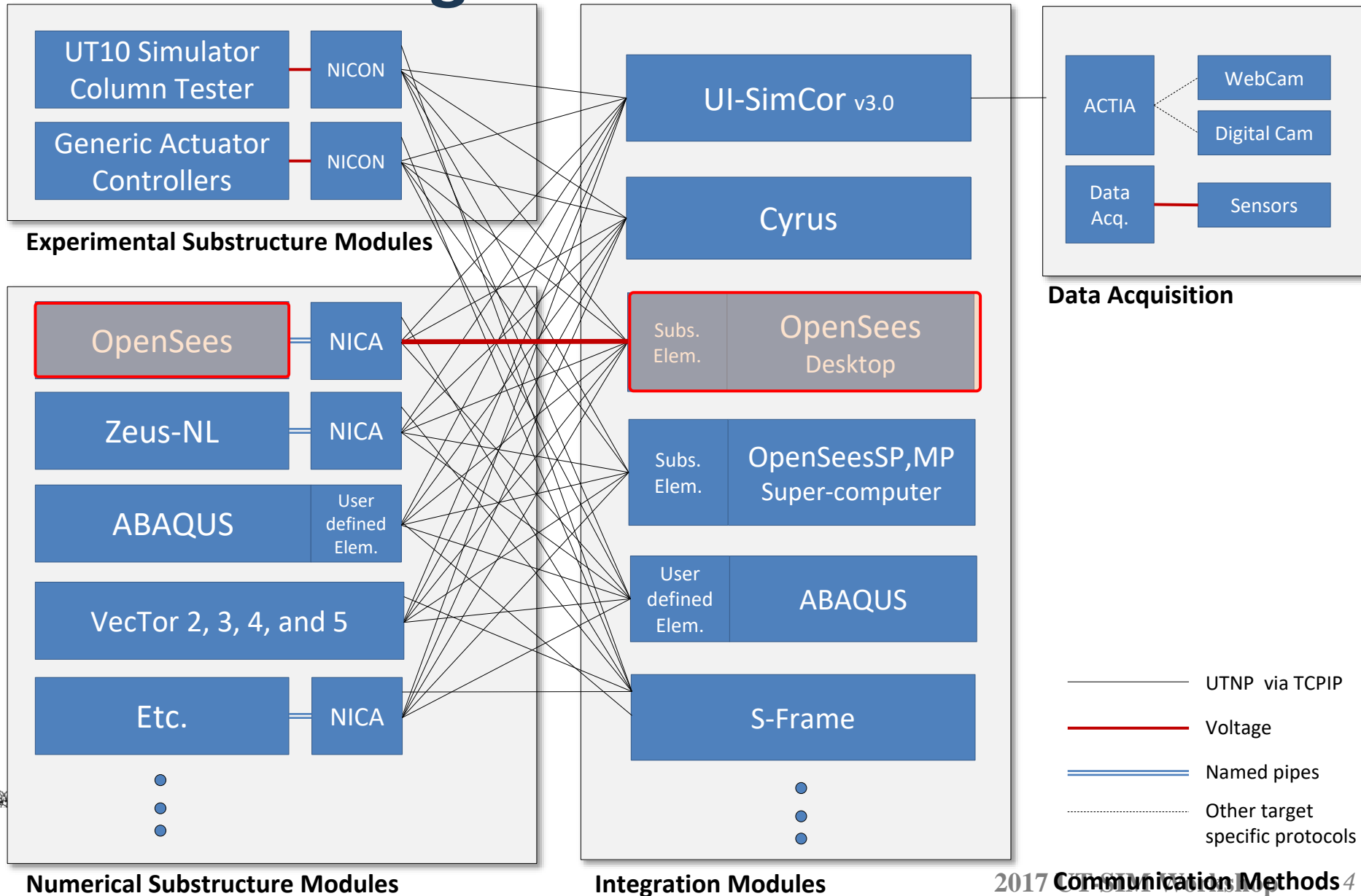◈ Communication Overview

◈ Example Structure

◈ Example Problem

Section 1

OpenSees – OpenSees Multi-Platform Simulation

UT-SIM Example Manual Chapter 3

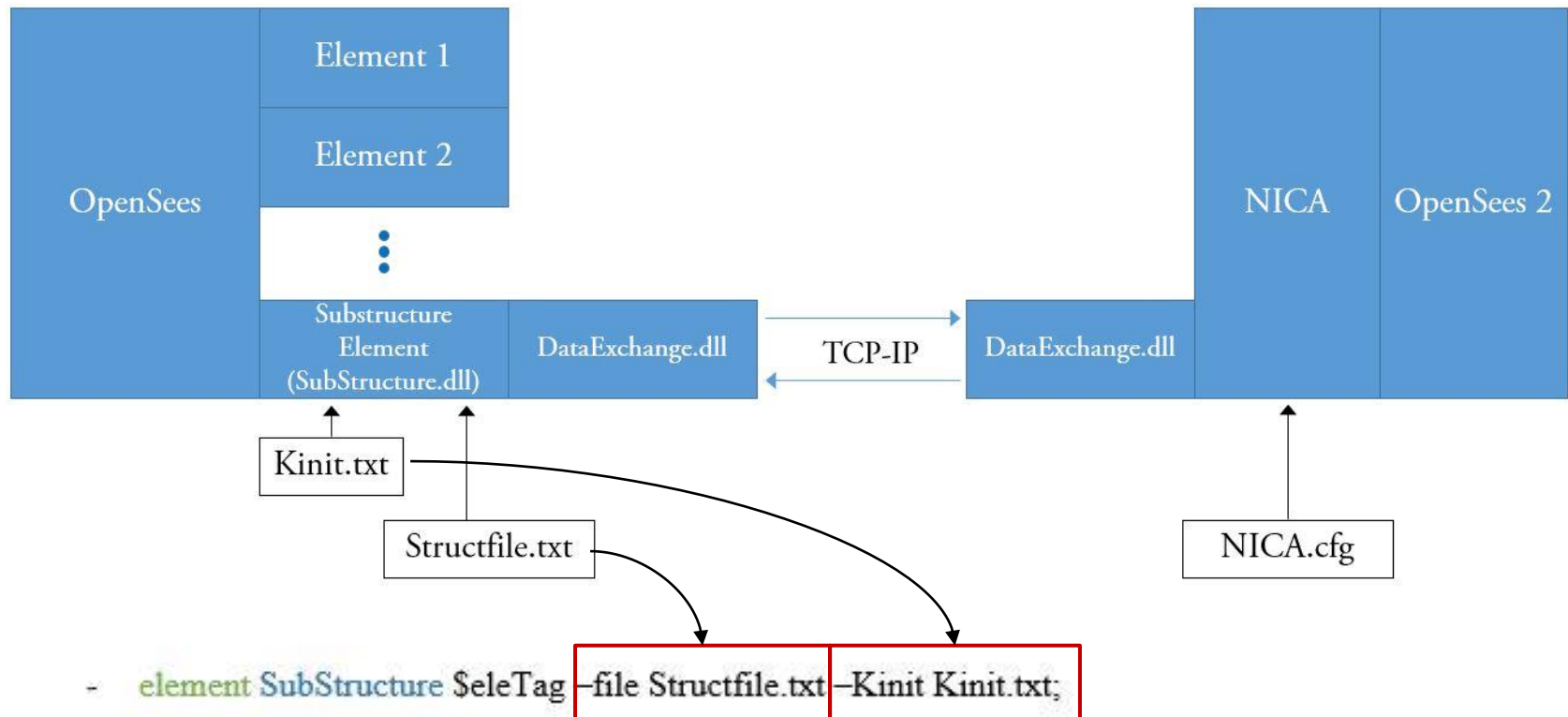# Model Integration Method

Experimental Substructure Modules

UT10 Simulator Column Tester — NICON

Generic Actuator Controllers — NICON

Numerical Substructure Modules

OpenSees — NICA

Zeus-NL — NICA

ABAQUS — User defined Elem.

VecTor 2, 3, 4, and 5

Etc. — NICA

Integration Modules

UI-SimCor v3.0

Cyrus

Subs. Elem. — OpenSees Desktop

Subs. Elem. — OpenSeesSP,MP Super-computer

User defined Elem. — ABAQUS

S-Frame

Data Acquisition

ACTIA — WebCam / Digital Cam

Data Acq. — Sensors

Communication Methods

——— UTNP via TCPIP

——— Voltage

===== Named pipes

········· Other target specific protocols
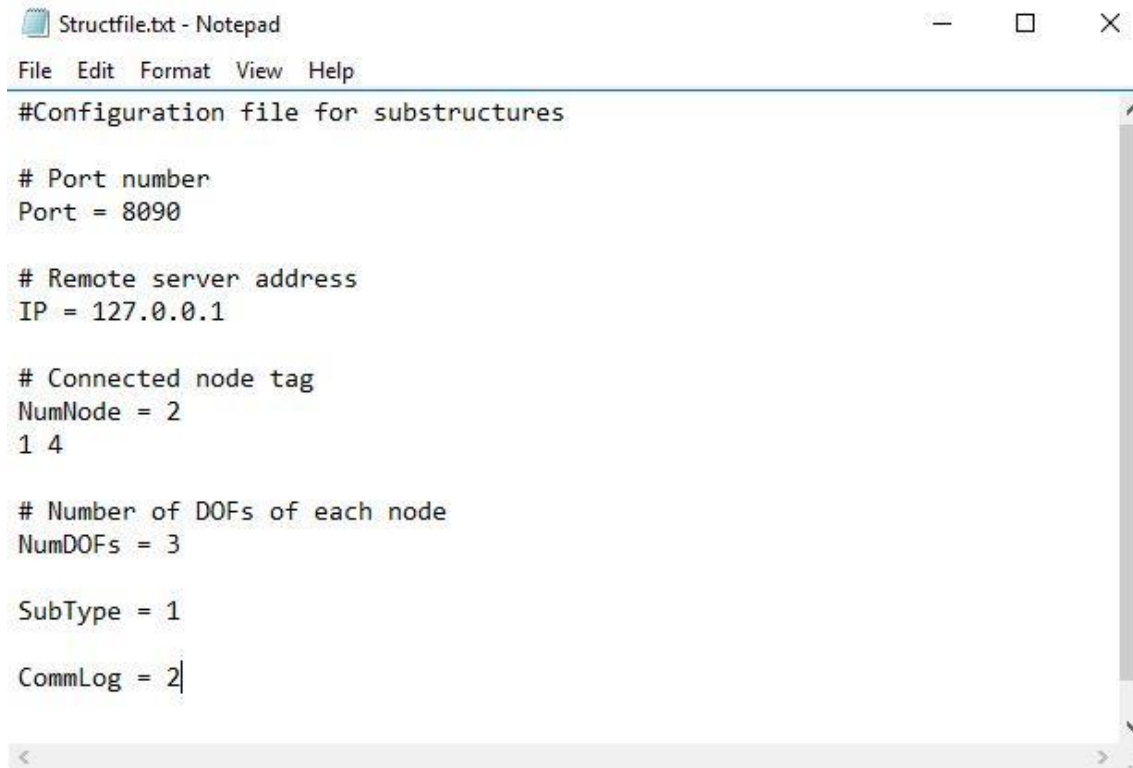
OpenSees – OpenSees Simulation

❑ **Communication Overview**

OpenSees – OpenSees Simulation

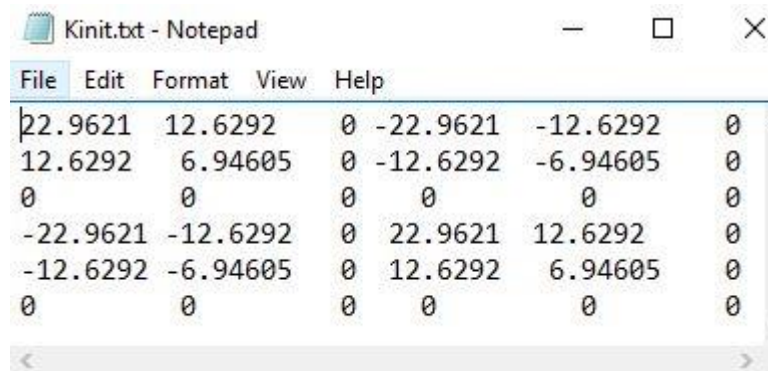❑ **Communication Overview**

◈ Located in the folder containing the integration module

OpenSees – OpenSees Simulation

❏ Communication Overview
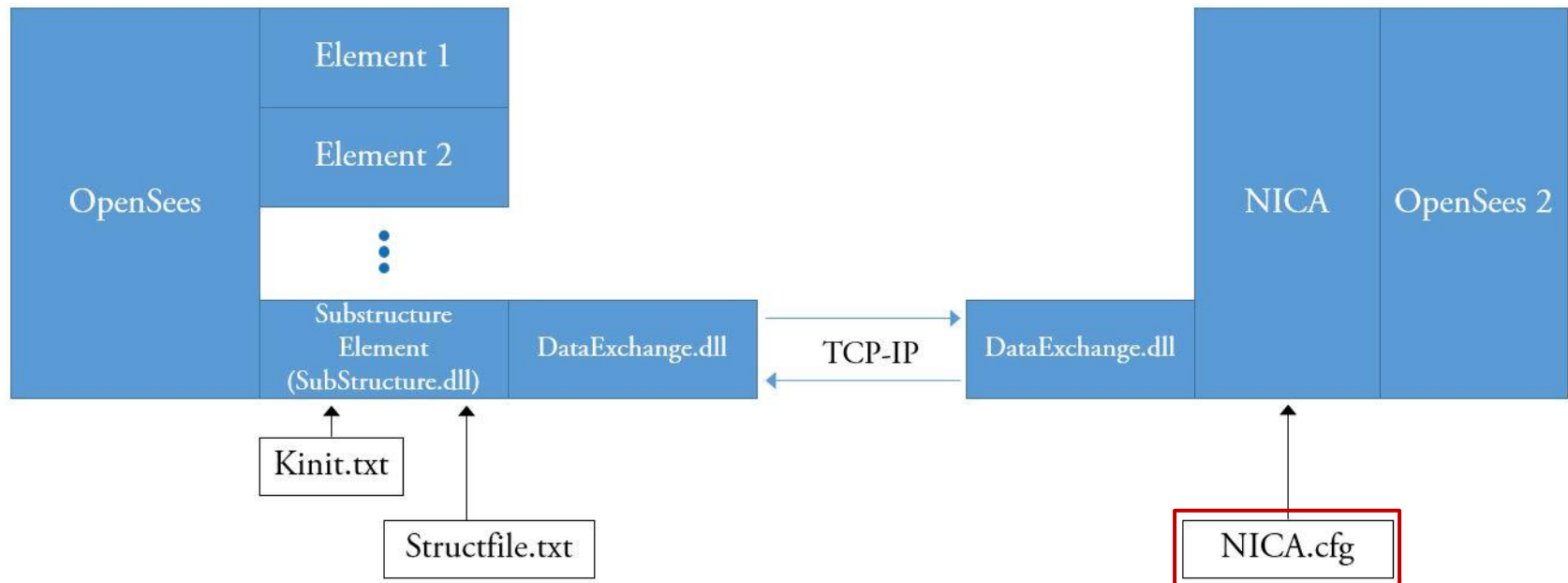
◈ Located in the folder containing the integration module

OpenSees – OpenSees Simulation

❑ **Communication Overview**

OpenSees – OpenSees Simulation

❑ Communication Overview

◈ Located in the folder containing the NICA.exe file

```
NICA.cfg - Notepad                                                    —    □    ×
File  Edit  Format  View  Help
|
# Connection port to NICA
Port = 8090

# Application: 1 for Zeus-NL, 2 for OpenSees, 3 for Abaqus, 4 for Vector,
#              and 9 for generic console-in console-out application. Vector has
#              not been implemented yet.
MDL_Type = 2

# Control node numbers
# Note: The sequence of nodes should be consistent with Nodes in SimCor.
MDL_Node = [1 4]

# Model dimension
# Note: This tag is used only for OpenSees and Abaqus. Ignore for other analysis types.
#       In the current version, 2D 3DOF system and 3D 6DOF system are supported.
MDL_Dim = 2

# Effective DOFs in control point.
# Note: 1.The sequence of DOFs should be consistent with sequence of DOFs in UI-SimCor.
#             2.Use one line per each controlled node.
#       2.For 2D 3DOF model, use DOF 1, 2, 6 (not 1, 2, 3) for x, y, rz DOFs.  It is set as x,y,z,Rx,Ry,Rz
EFF_DOF =
1 1 0 0 0 1
1 1 0 0 0 1

# Model file name (include extension)
MODEL = Sub.S2(BRB).tcl
```

OpenSees – OpenSees Simulation

❑ **OpenSees Script Example**

◈ Standalone model

```
puts "Define Elements";

element corotTruss 1 1 4 1 ; # BRB defined as a truss element
element elasticBeamColumn 2 1 3 $Ac $E $Ic $TFrame; # Column Element Between Nodes 1 & 3
element elasticBeamColumn 3 2 4 $Ac $E $Ic $TFrame; # Column Element Between Nodes 2 & 4
element corotTruss 4 3 4 2 ; # Beam Element Defined
```
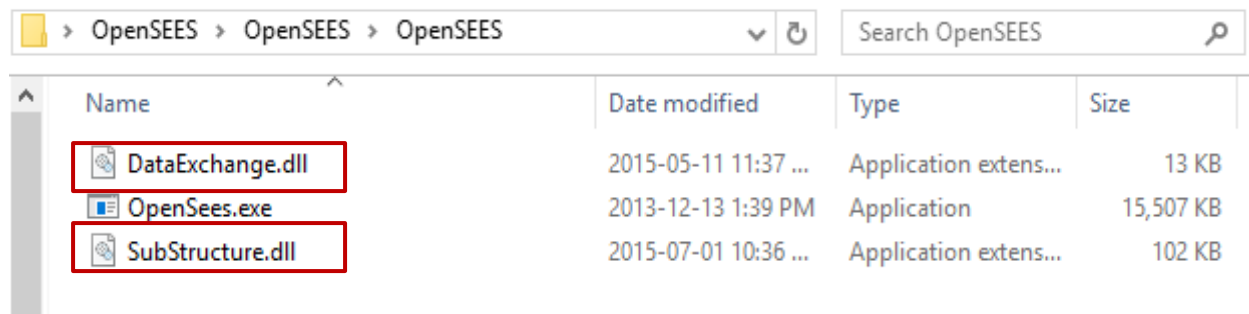
◈ Integration model

```
puts "Define Elements";

element SubStructure 1 -file Structfile.txt -Kinit Kinit.txt
element elasticBeamColumn 2 1 3 $Ac $E $Ic $TFrame; # Column Element Between Nodes 1 & 3
element elasticBeamColumn 3 2 4 $Ac $E $Ic $TFrame; # Column Element Between Nodes 2 & 4
element corotTruss 4 3 4 2; # Beam Element Defined
```

OpenSees – OpenSees Simulation

❏ **Required Steps for the Analysis**

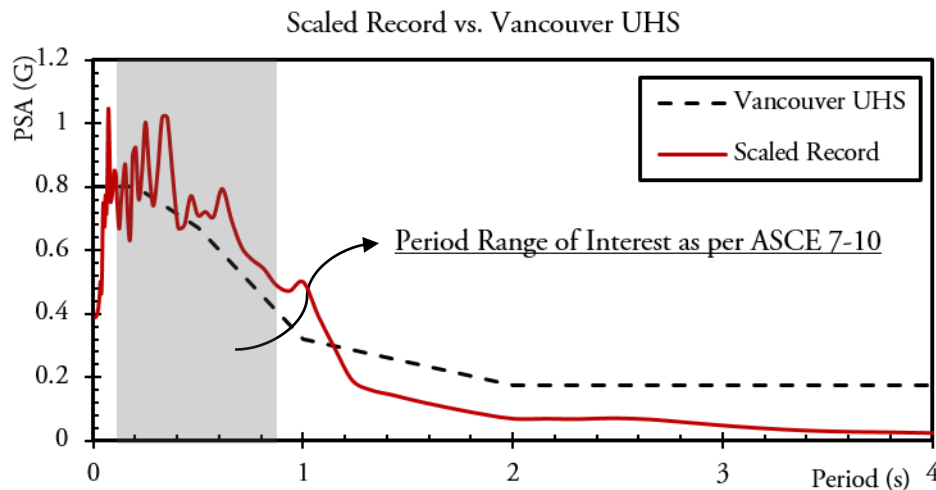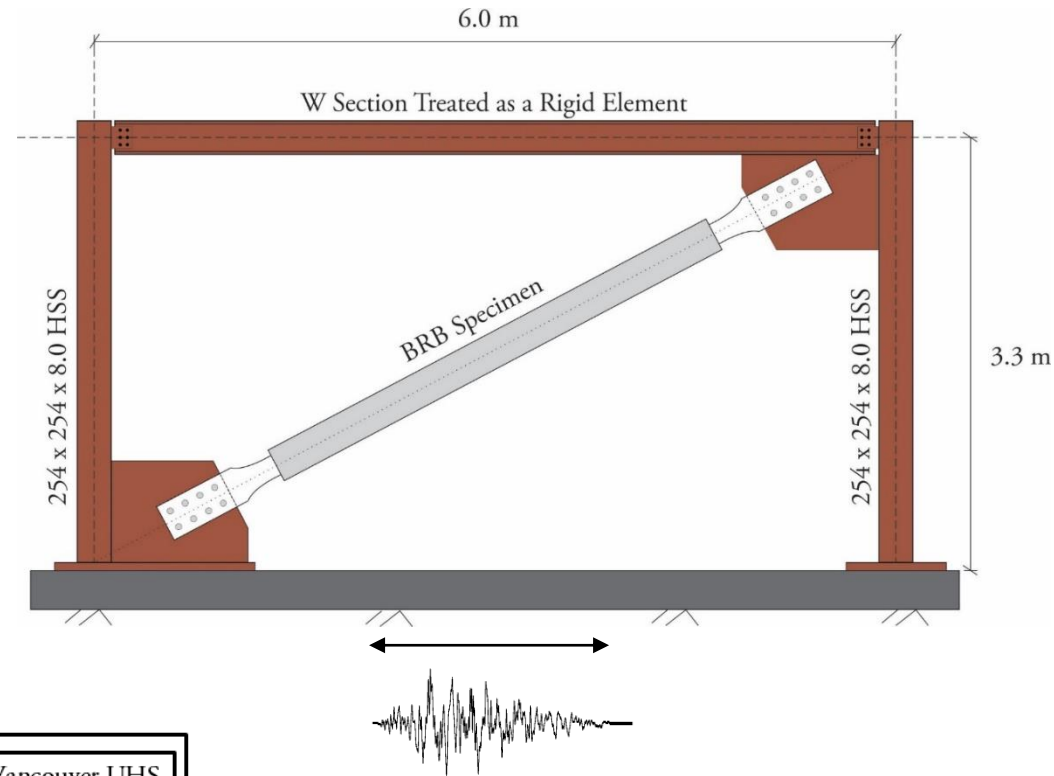1. Place the DataExchange and the SubStructure .dll files in the OpenSees folder.

2. Place a copy of the HSF zip folder on the C drive.

OpenSees – OpenSees Simulation

❑ **Example Structure**

◈ Vancouver, Canada.

◈ Site Class 'C'

6.0 m

W Section Treated as a Rigid Element

254 x 254 x 8.0 HSS

BRB Specimen

254 x 254 x 8.0 HSS

3.3 m

Scaled Record vs. Vancouver UHS

- – – Vancouver UHS
- —— Scaled Record

Period Range of Interest as per ASCE 7-10

OpenSees – OpenSees Simulation

❑ **Analytical Modelling**
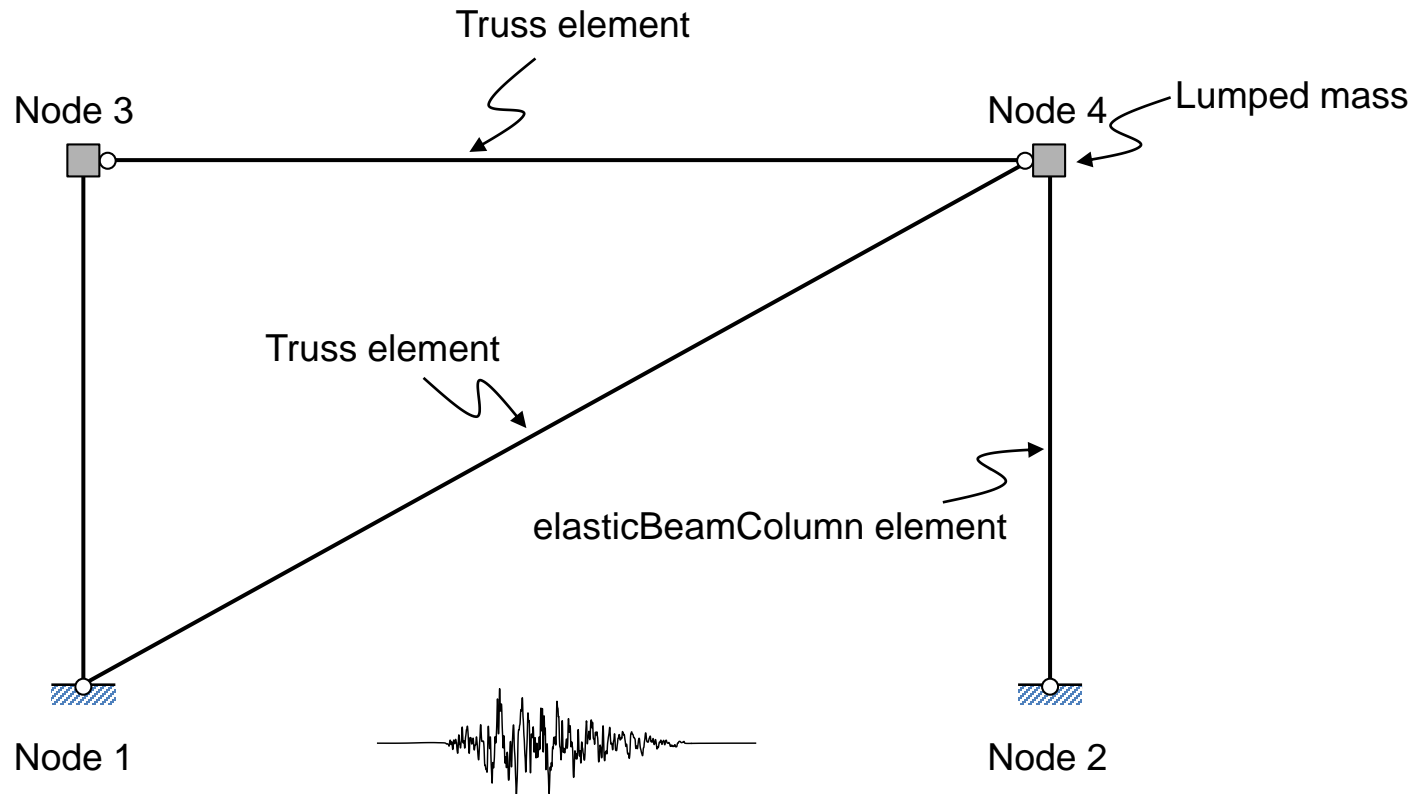
OpenSees – OpenSees Simulation
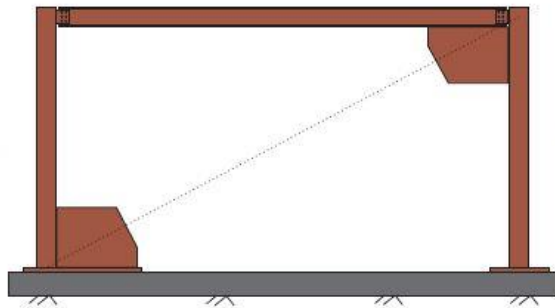
❑ **Analytical Substructures**
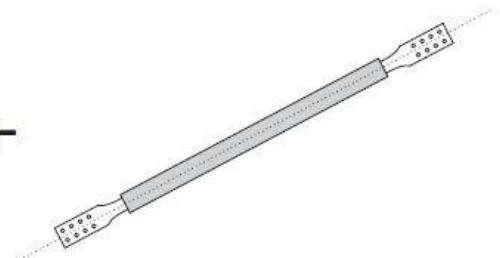
Integrated Numerical Model   Integration Module   Substructure Module

Multi-Platform   OpenSees   OpenSees
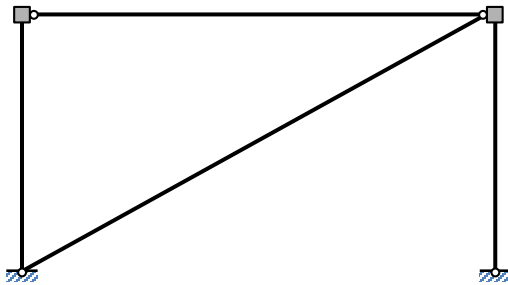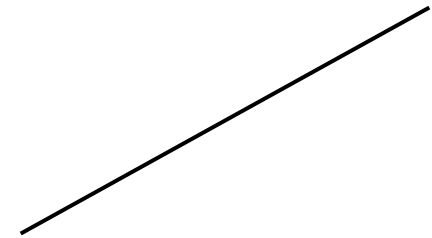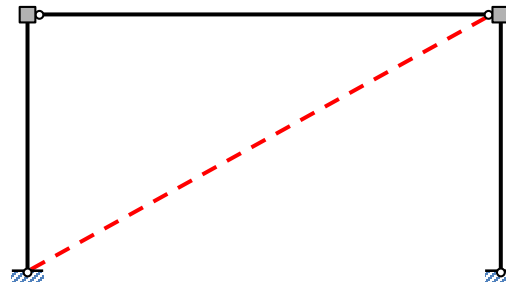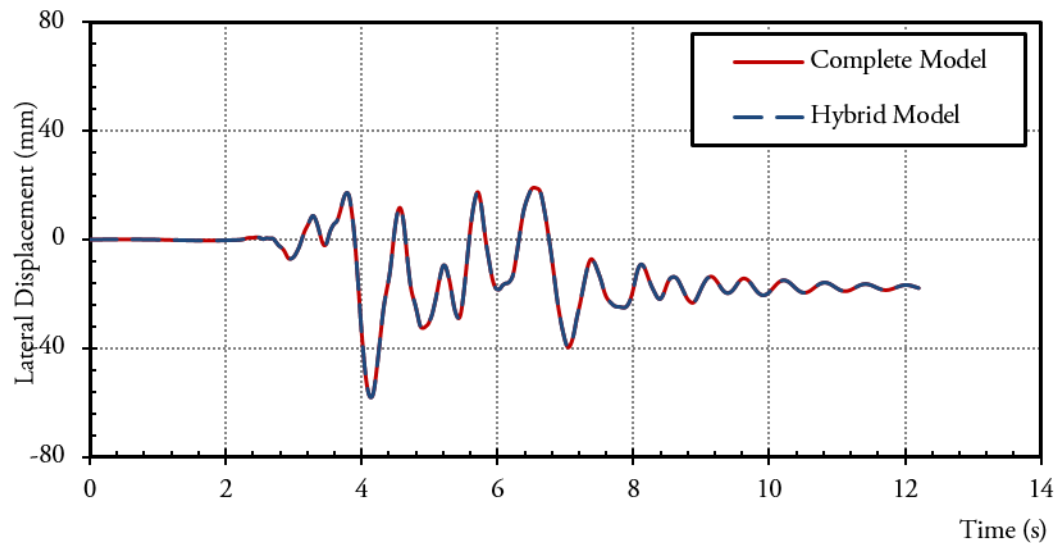
OpenSees – OpenSees Simulation

Example Demonstration
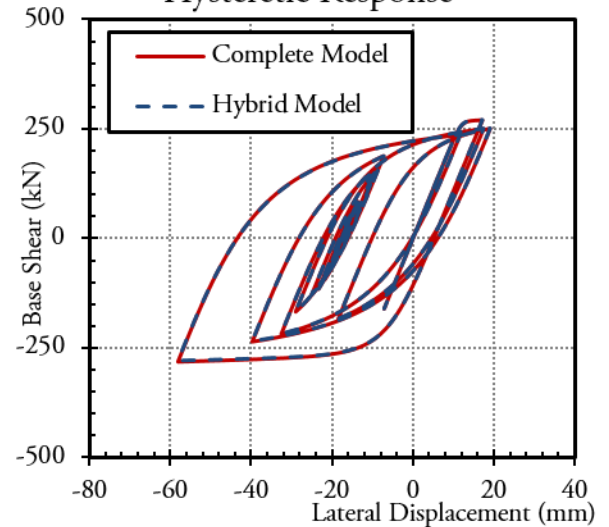
OpenSees – OpenSees Simulation

❑ Results

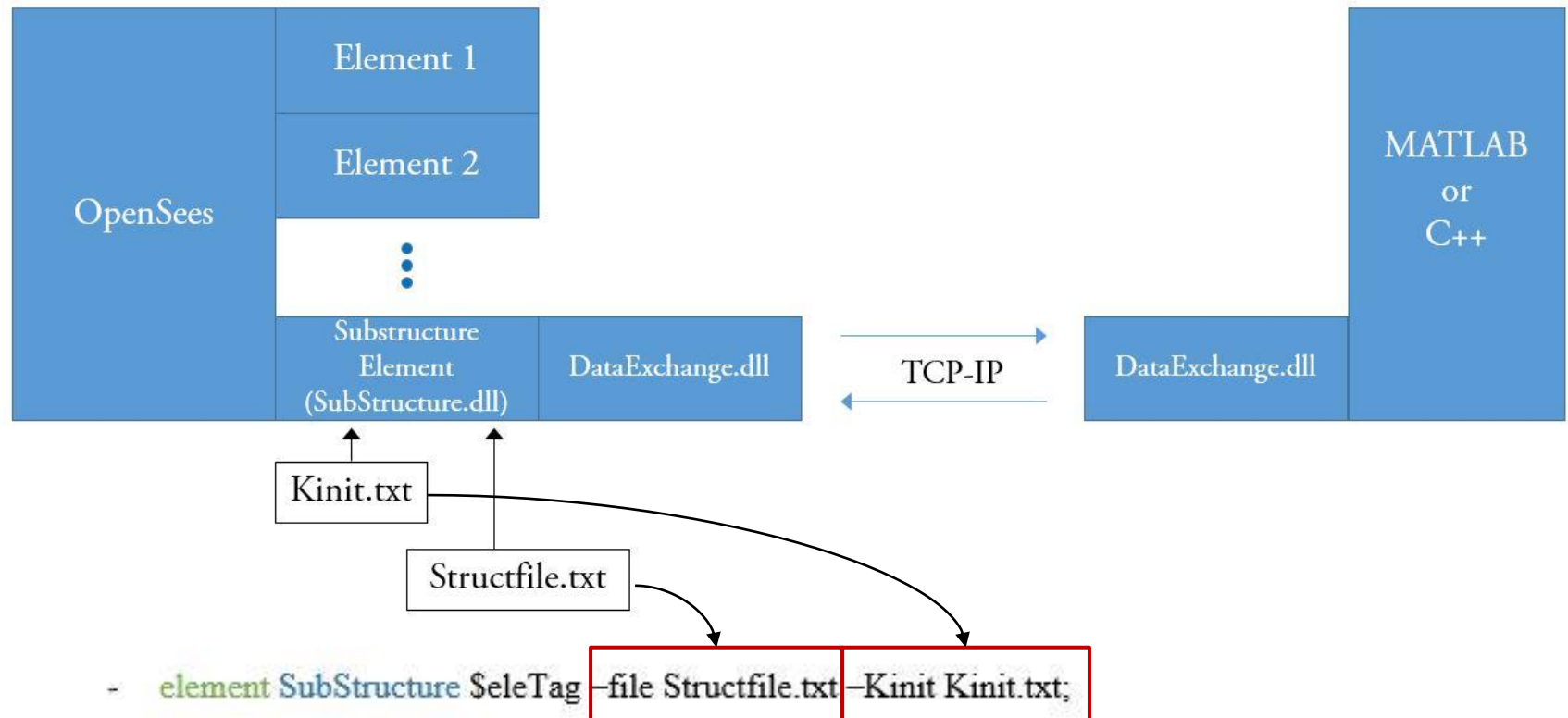Top Story Lateral Displacement Time-History

Hysteretic Response

Section 2

OpenSees – MATLAB/C++ Multi-Platform Simulation

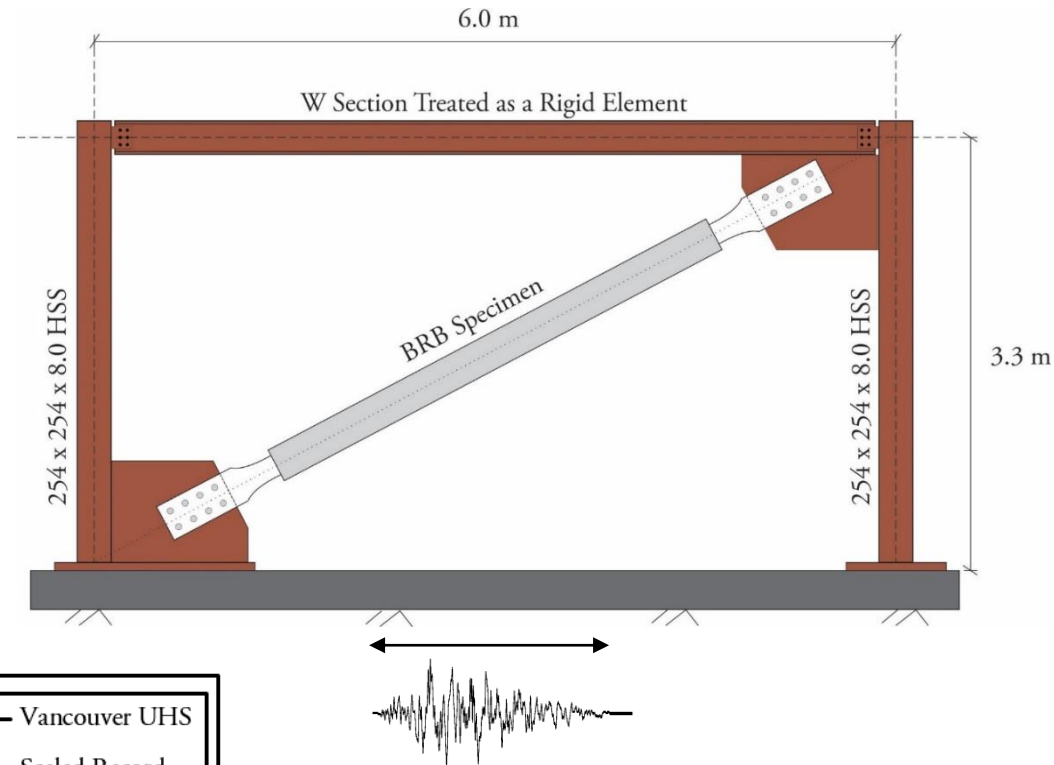**UT-SIM Example Manual Chapter 4 and 5**

OpenSees – MATLAB/C++ Simulation
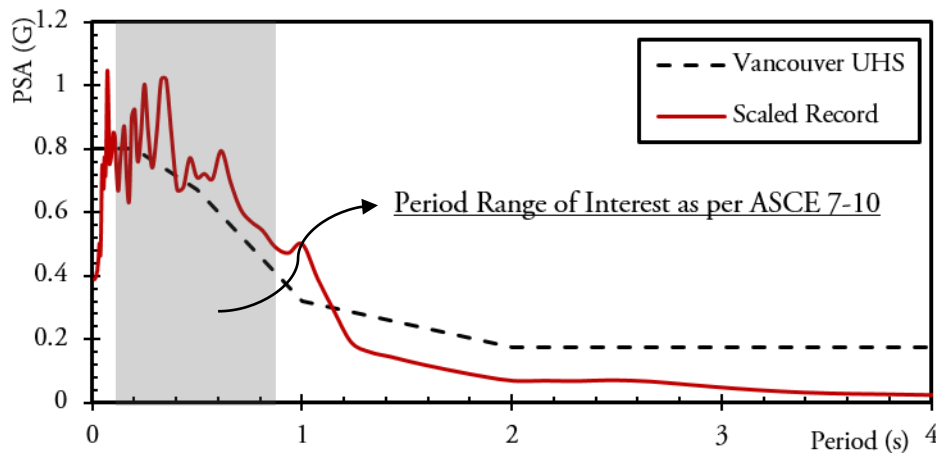
❑ **Communication Overview**

OpenSees – MATLAB/C++ Simulation

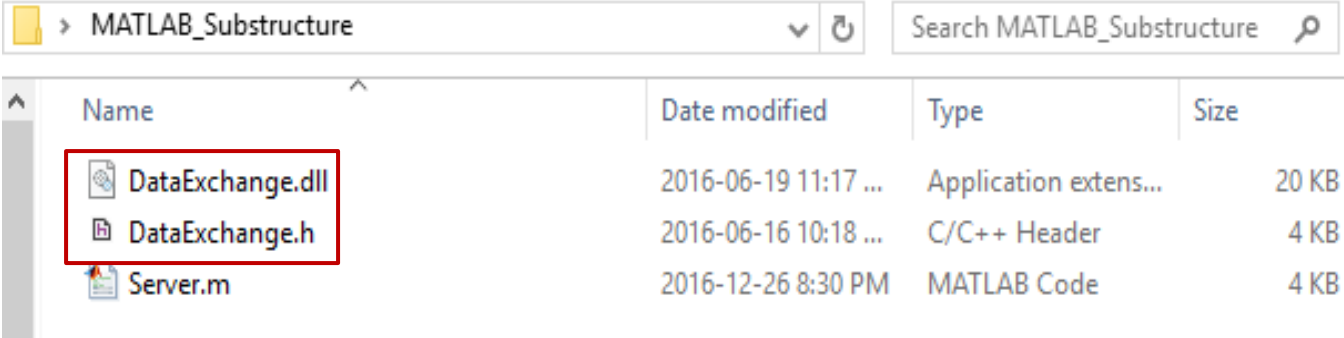❑ **Example Structure**

◈ Vancouver, Canada.

◈ Site Class 'C'

OpenSees – MATLAB/C++ Simulation

❑ **Required Steps for the Analysis**

In addition to the previous steps required for the OpenSees – OpenSees case, place the DataExchange files in the folder containing the MATLAB substructure.

OpenSees – MATLAB/C++ Simulation

❑ MATLAB/C++

◈ MATLAB SubStructure Script

```
clear all; close all; clc

loadlibrary('./DataExchange.dll', './DataExchange.h');

% define socket variables
PortNumber = 8090;
machineInetAddr = libpointer('cstring','0.0.0.0');

sockfd = 0;
flag = 2;

% define initial stiffness matrix

Kinit = [22.9621   12.62920     0 -22.9621   -12.6292    0
         12.6292    6.94605     0 -12.6292   -6.94605    0
            0          0        0    0          0        0
        -22.9621  -12.6292      0  22.9621    12.6292    0
        -12.6292   -6.94605     0  12.6292     6.94605   0
            0          0        0    0          0        0];
```
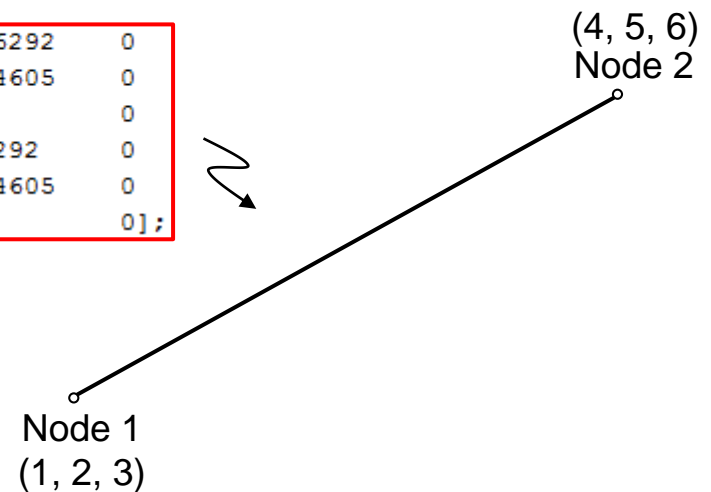
(4, 5, 6)
Node 2

Node 1
(1, 2, 3)

OpenSees – MATLAB/C++ Simulation

❑ **MATLAB/C++**

◈ Main loop (i.e. MATLAB)

- Receive displacement

```matlab
case Impose_TargetValues

    % calculate the size to be appended to the message header
    lens = calllib('DataExchange', 'indicator');

    %receive displacement from OpenSees
    rdata = libpointer('doublePtr', zeros(lens,1));
    calllib('DataExchange', 'RecvData', sockfd1, rdata, lens, TCP_IP);
    displ = get(rdata, 'value');
```

- Send restoring force

```matlab
case Report_Values

    % calculate the size to be appended to the message header
    lens = calllib('DataExchange', 'indicator');

    % calculate restoring force
    force = Kinit * displ;
    sdata = [displ; force];
    sdata1 = libpointer('doublePtr', sdata);

    % send force to OpenSees
    calllib('DataExchange', 'SendData', sockfd1, sdata1, lens, TCP_IP);
```

Can be replaced with the algorithm for nonlinear elements
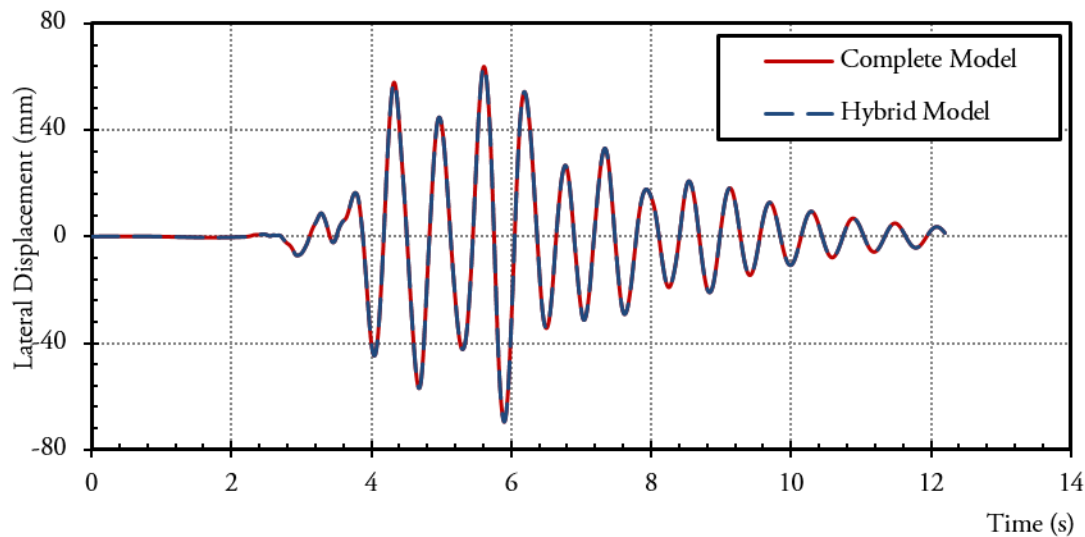
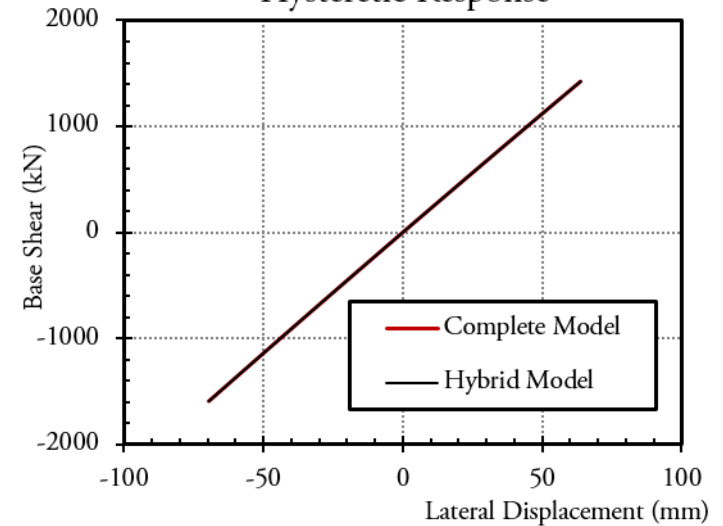# OpenSees – MATLAB/C++ Simulation

Example Demonstration

OpenSees – MATLAB/C++ Simulation

❏ **Results**

Top Story Lateral Displacement Time-History
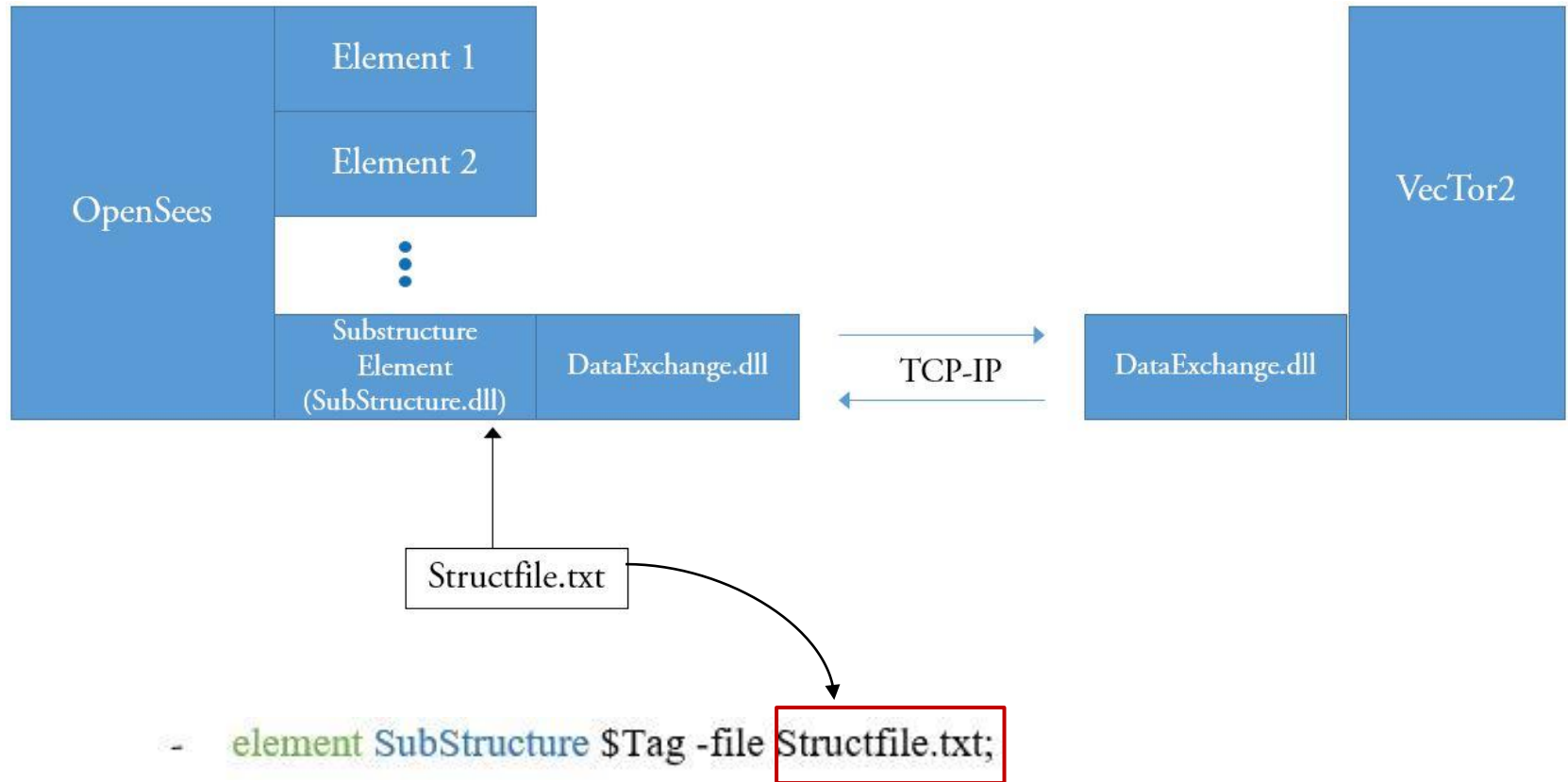

Hysteretic Response

Section 3

OpenSees – VecTor2 Multi-Platform Simulation

UT-SIM Example Manual Chapter 10

OpenSees – VecTor2 Simulation

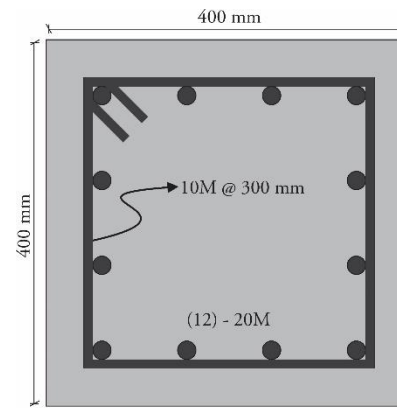❏ **Communication Overview**
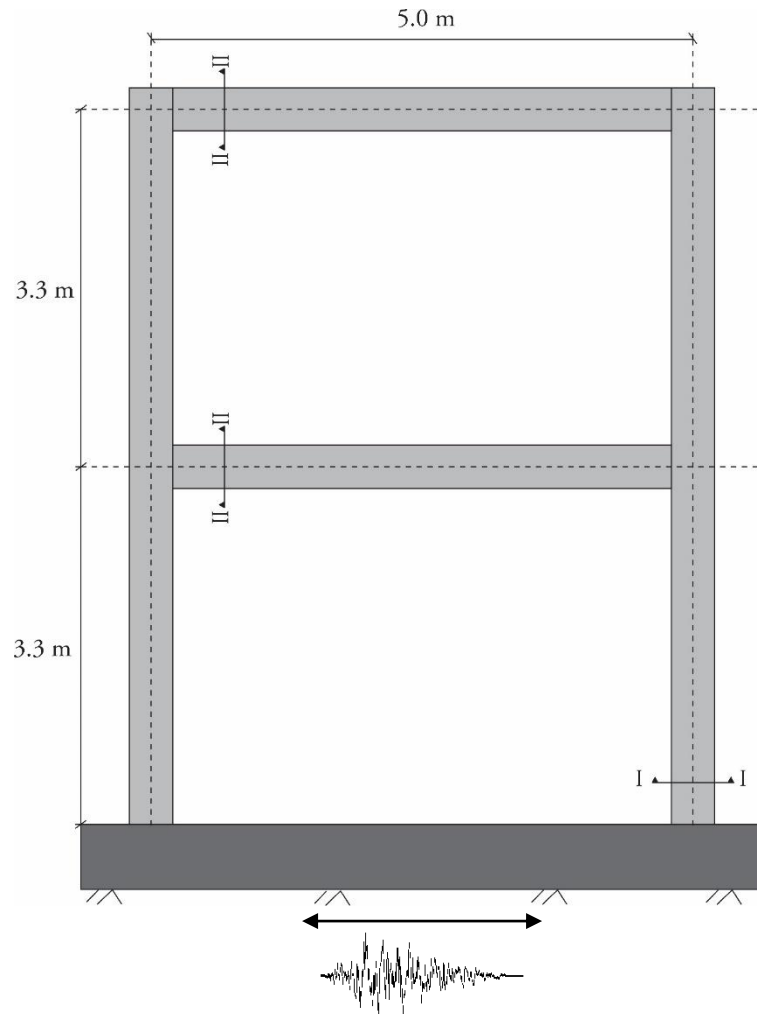
OpenSees – VecTor2 Simulation

❏ **PARDISO Solver Project**

1. Go to http://www.pardiso-project.org/.

2. Download the academic license.

3. When completing the forms, the website asks for a user name. Specify the computer username as the user name.

4. After completing the procedure, the user will receive an email from the PARDISO project with the download link, and the license key.

5. Copy the license key into a .txt file named 'pardiso.lic'. This file must be placed in the same folder where the VecTor2 substructure is located.
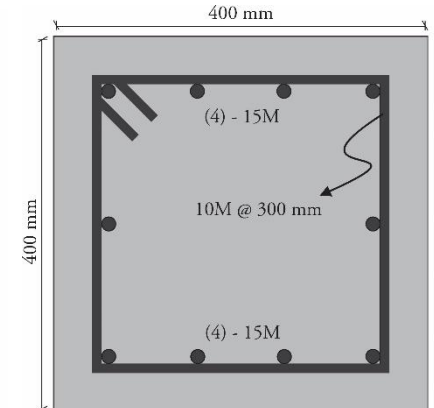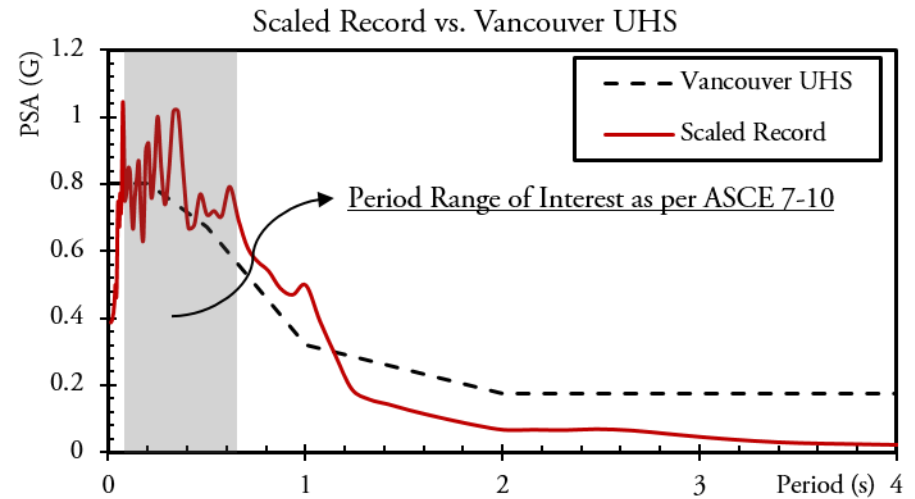
OpenSees – VecTor2 Simulation

❑ **Example Structure**

5.0 m

3.3 m

3.3 m

I — I
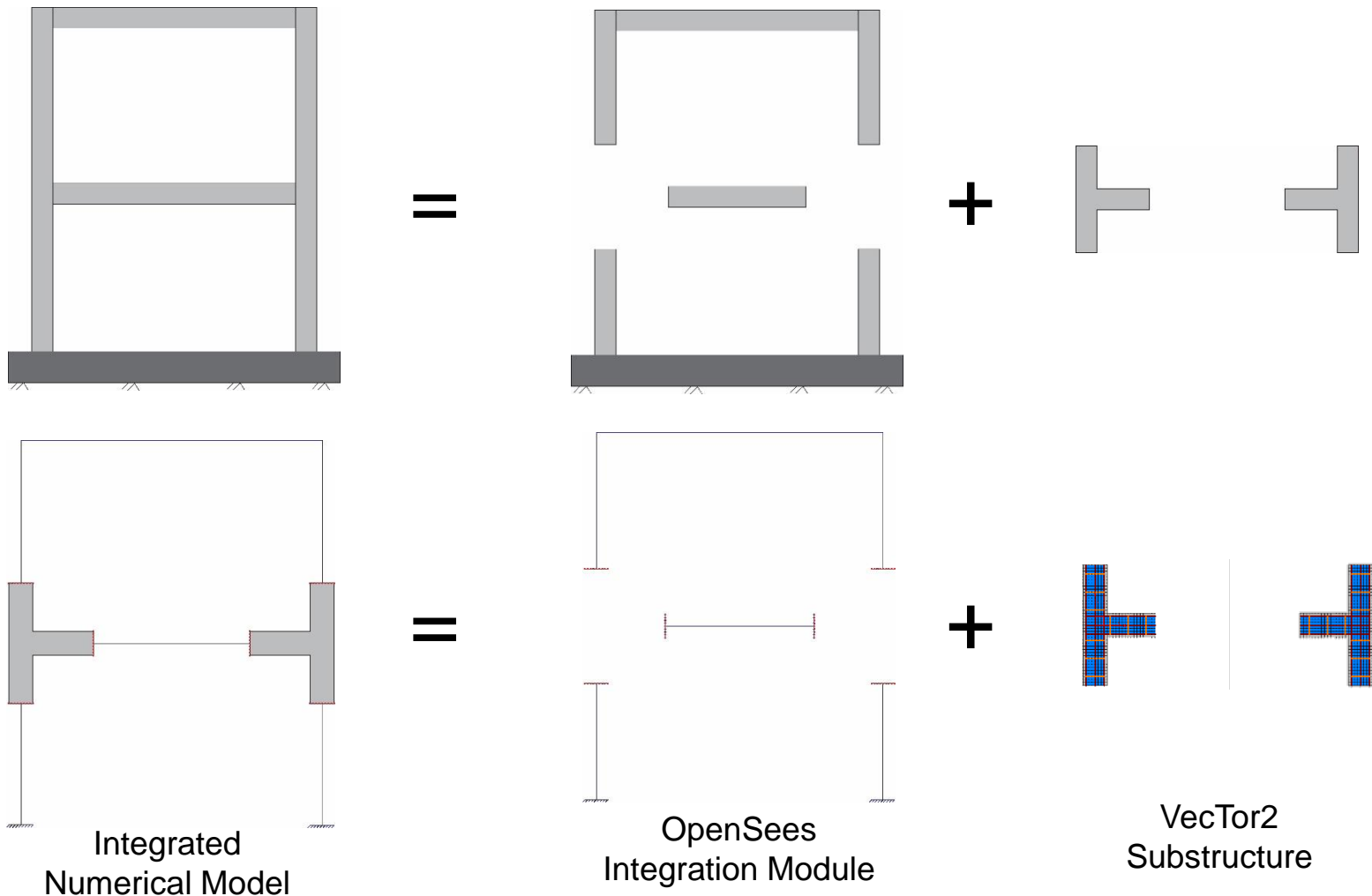
II

II

II

400 mm

400 mm

10M @ 300 mm

(12) - 20M

SECTION I - I : COLUMN DETAIL

400 mm

400 mm

(4) - 15M

10M @ 300 mm

(4) - 15M

SECTION II - II : BEAM DETAIL

Scaled Record vs. Vancouver UHS

PSA (G)

Period Range of Interest as per ASCE 7-10

- - - Vancouver UHS
—— Scaled Record

Period (s)

OpenSees – VecTor2 Simulation

❑ **Analytical Substructures**
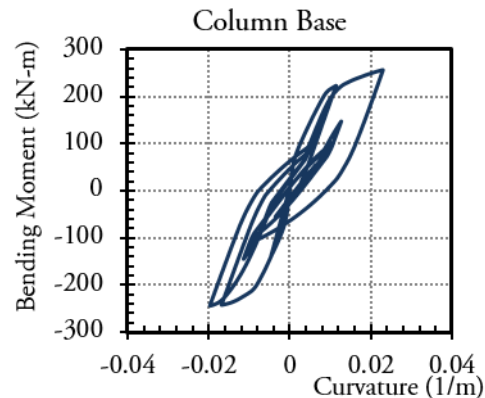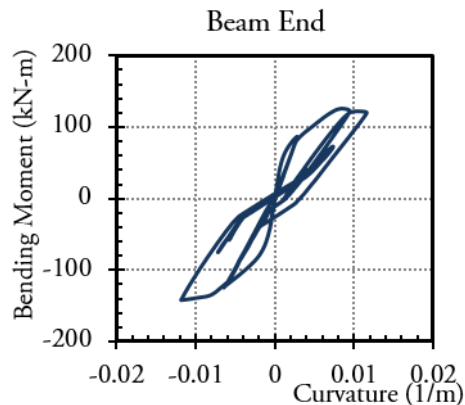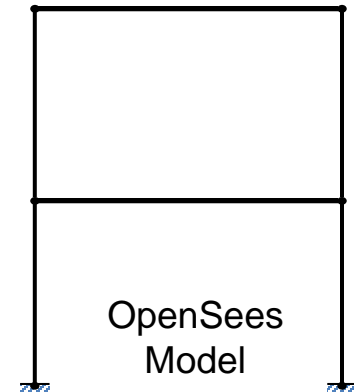

Integrated
Numerical Model

OpenSees
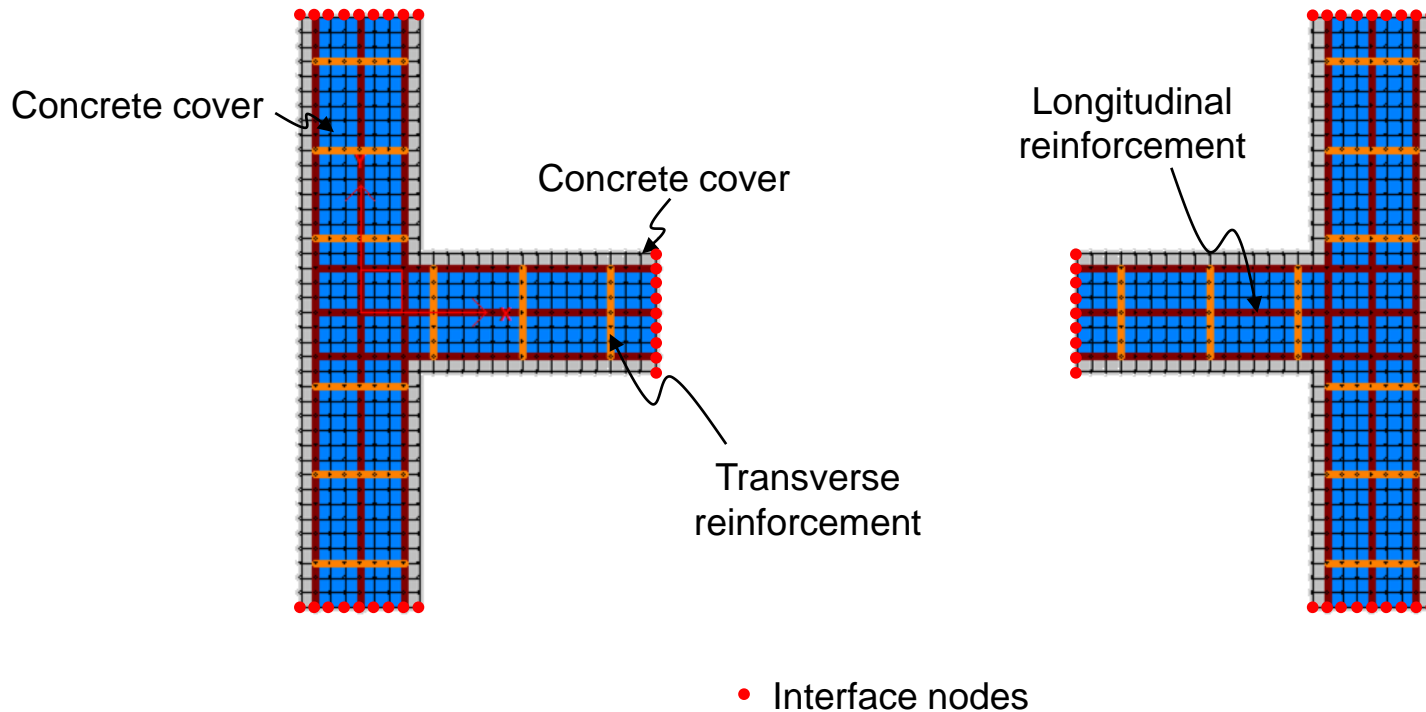Integration Module

VecTor2
Substructure

OpenSees – VecTor2 Simulation

□ **Standalone OpenSees Model**

1. Fiber Model.

2. Linear shear behaviour.

3. Confinement taken into account (Kupfer/Richart).

OpenSees
Model

Beam End

Column Base

Top Story Lateral Displacement Time-History

First Story Displacement
Second Story Displacement
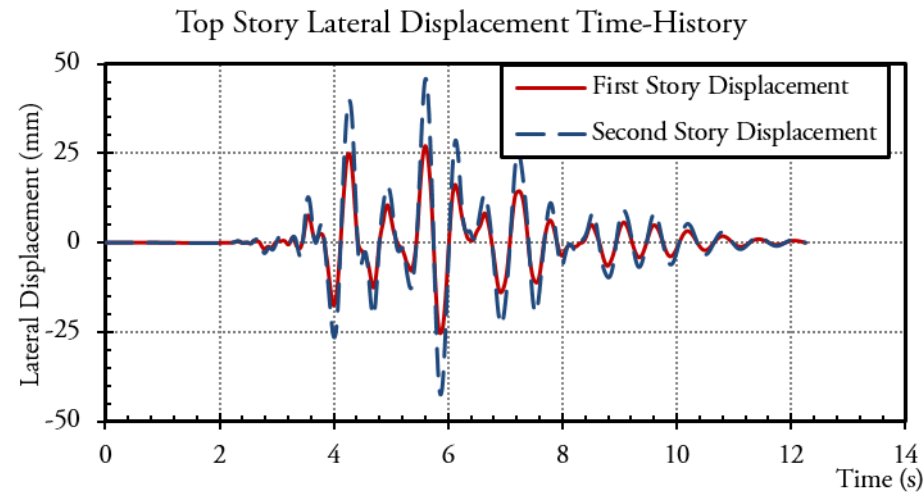
OpenSees – VecTor2 Simulation

❏ VecTor2 Substructure Module

Concrete cover

Concrete cover

Transverse reinforcement

Longitudinal reinforcement
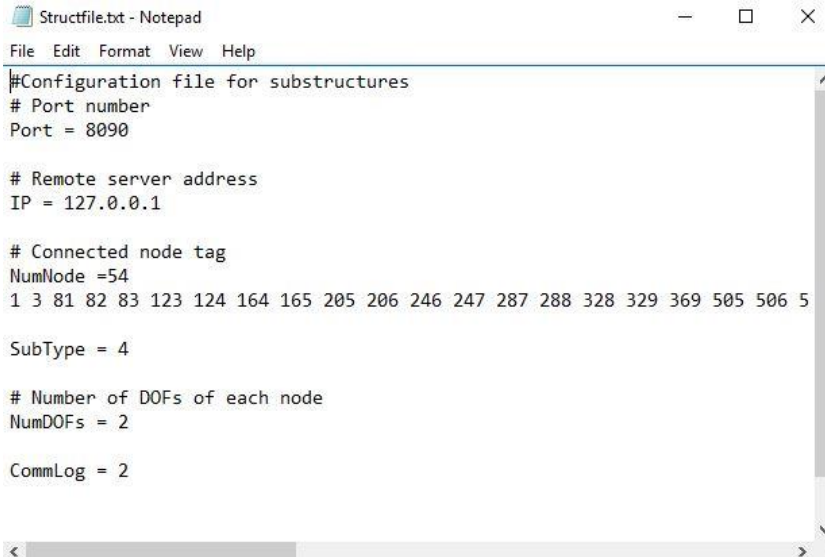
● Interface nodes

OpenSees – VecTor2 Simulation

❑ **OpenSees Integration Module**

Structfile.txt - Notepad

File   Edit   Format   View   Help

```
#Configuration file for substructures
# Port number
Port = 8090

# Remote server address
IP = 127.0.0.1

# Connected node tag
NumNode =54
1 3 81 82 83 123 124 164 165 205 206 246 247 287 288 328 329 369 505 506 5

SubType = 4

# Number of DOFs of each node
NumDOFs = 2

CommLog = 2
```
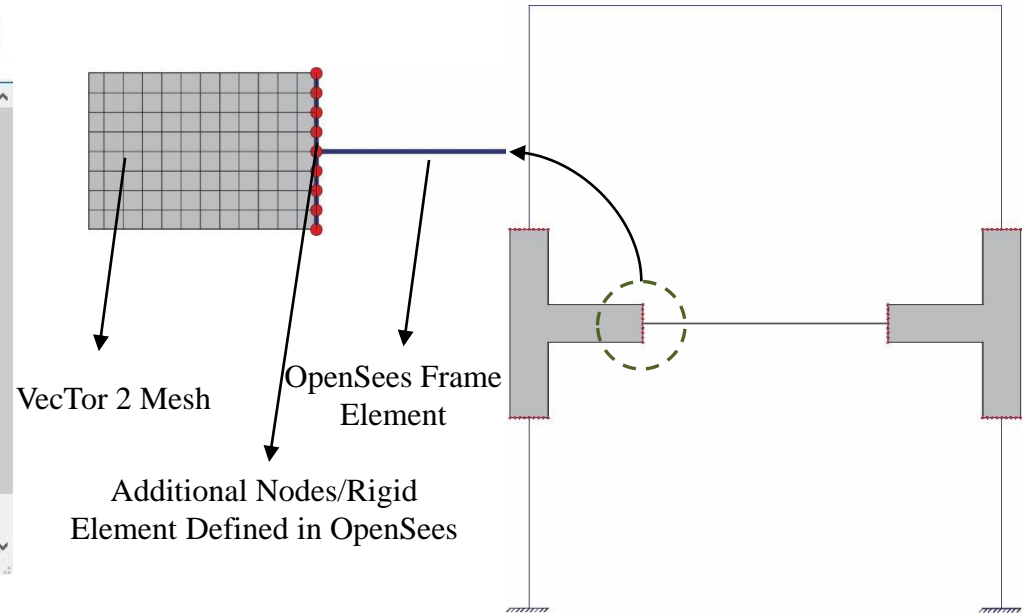
VecTor 2 Mesh

OpenSees Frame
Element

Additional Nodes/Rigid
Element Defined in OpenSees

- element SubStructure $Tag -file Structfile.txt;

OpenSees – VecTor2 Simulation

❑ **Simulation Steps**

- ◈ Save the 'pardiso.lic' in the SS Folder.

- ◈ Generate and Save the VecTor2 *Structure* File in the SS Folder.

- ◈ Generate and Save the VecTor2 *.job* File in the SS Folder (can change modelling Assumptions).

- ◈ Check the Number of Analysis Steps.

- ◈ Change Modelling Format to 3.

- ◈ Create/Copy the NICON.txt file to the SS Folder.

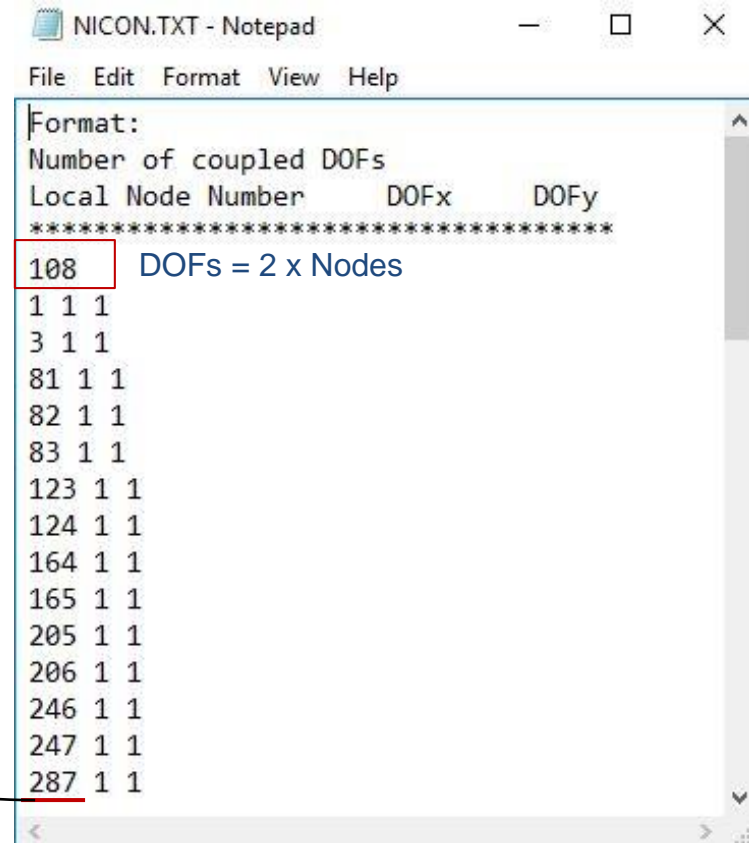# OpenSees – VecTor2 Simulation

❑ V2 Job File

OpenSees – VecTor2 Simulation

❑ NICON.txt File

NOTE: THE INTERFACE NODES MUST BE SPECIFIED WITH THE SAME SEQUENCE, IN THE INTEGRATION MODULE AND THE SUBSTRUCTURE MODULE, AND IN AN <u>ASCENDING</u> ORDER.

'287 1 1' : At node 287 force/displacement are communicated in the X and Y directions

VecTor2 Node#

NICON.TXT - Notepad

File Edit Format View Help

```
Format:
Number of coupled DOFs
Local Node Number      DOFx     DOFy
*****************************************
108          DOFs = 2 x Nodes
1 1 1
3 1 1
81 1 1
82 1 1
83 1 1
123 1 1
124 1 1
164 1 1
165 1 1
205 1 1
206 1 1
246 1 1
247 1 1
287 1 1
```

OpenSees – VecTor2 Simulation

❑ **SS Folder**

Name

Case1.L2E
Struct.S2E
VecTor.job
NICON.TXT
Struct.s2r
pardiso.lic
VT2-14JAN16.exe
Debug.txt
cccccc.TXT
Case1.l2r
VecTor.job.bak
VT2.AUX
DataExchange.dll
msvcr110d.dll
VECTOR.SFD
libpardiso500-WIN-X86-64.dll
libpardiso500-WIN-X86-64.exp
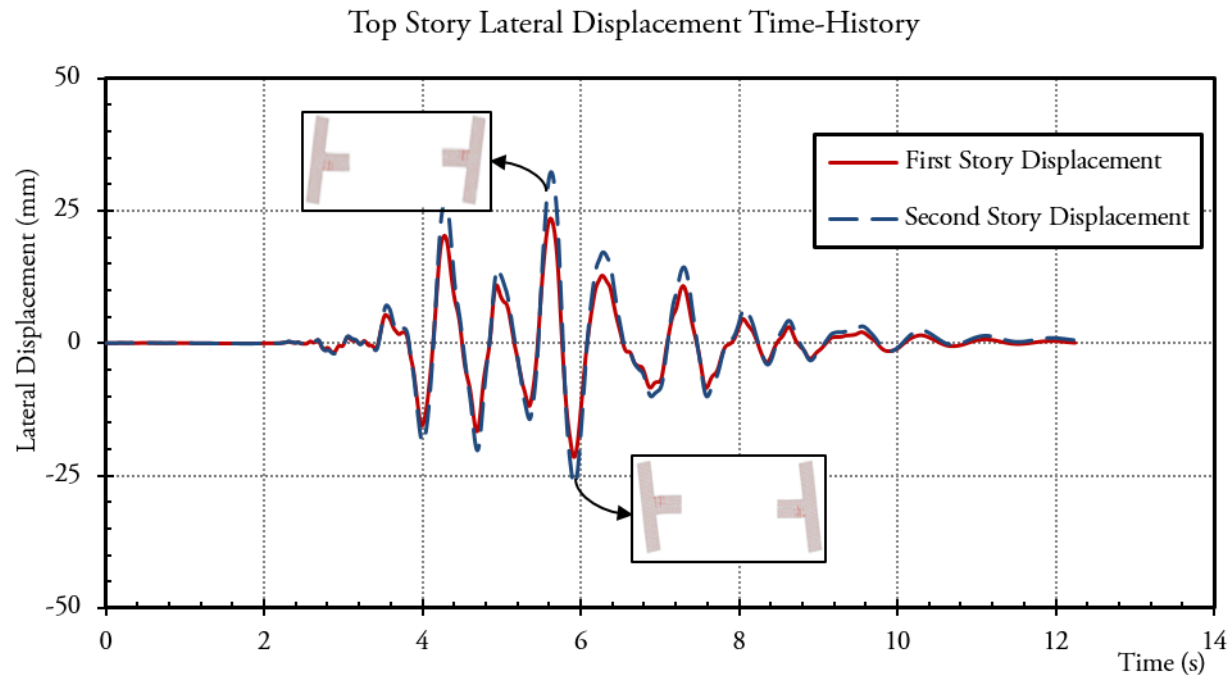libpardiso500-WIN-X86-64.lib
libiomp5md.dll

OpenSees – VecTor2

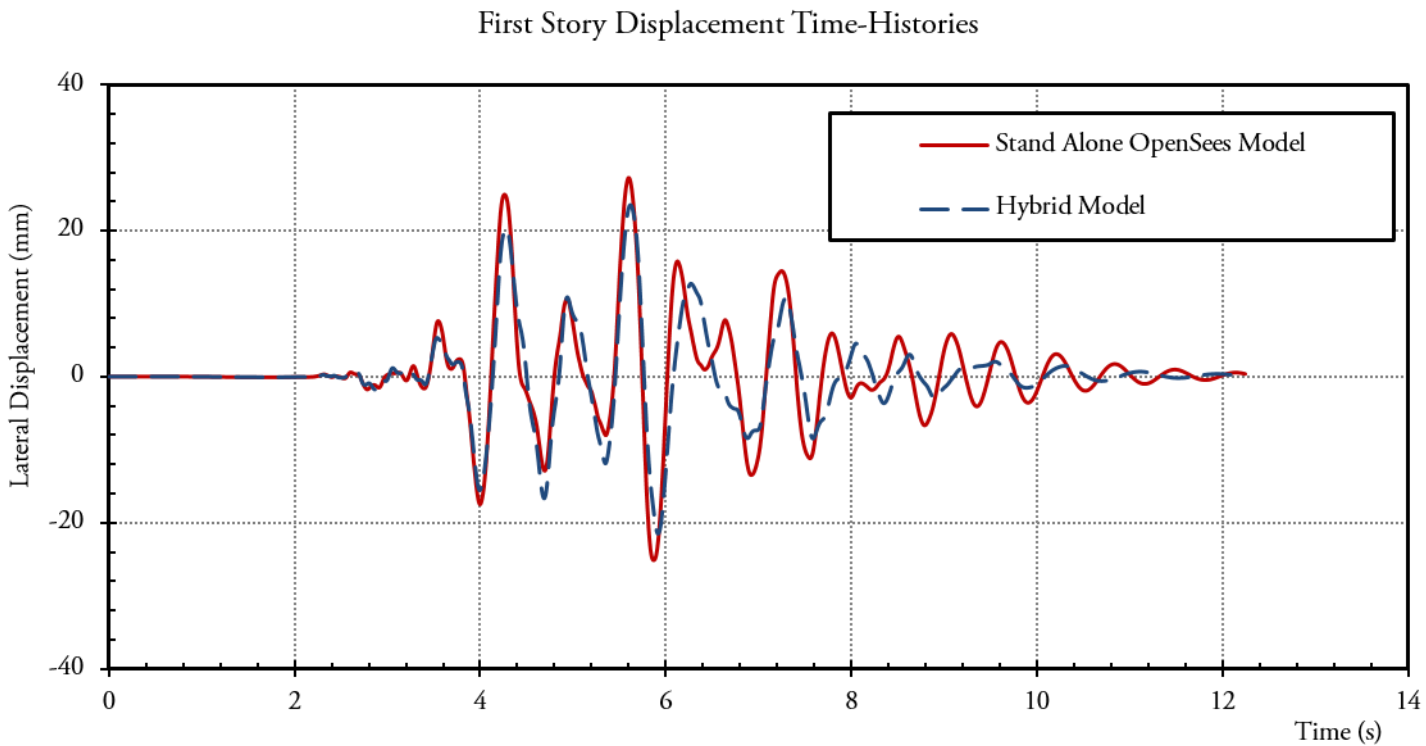**Example Demonstration and Results**

OpenSees – VecTor2 Simulation

❑ **Results can be viewed in:**

  ❖ Augustus

  ❖ Comm_log.log File

  ❖ OpenSees Displacement Recorders

Top Story Lateral Displacement Time-History

OpenSees – VecTor2 Simulation

❑ **Comparison**

First Story Displacement Time-Histories

OpenSees Integration Module

Thank you

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