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delivering transport safety solutions

FE Coupling Workshop

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www.tass-safe.com

Day Schedule

	Welcome with tea and coffee
09h00-09h30	General introduction
09h30-10h00	Coupling main overview
	Coffee break
10h30-11h15	MADYMO part of coupling
11h15-11h30	PARTNER part of coupling
11h30-11h45	Running a coupling model
11h45-12h00	Tips & tricks, importing a foreign code
	Lunch break
13h30-14h30	Exercises
	Coffee break
15h00-16h30	Exercises, discussion, feedback & closure

General Introduction

- Workshop Set-up
- Some Coupling Examples
- Why Coupling
- Stand alone vs. Coupling
- Coupling Development
- Coupling Download Site

Coupling Workshop Set-Up

Objective

- To provide guidelines for coupling between MADYMO and FE codes.

Theoretical sessions

- Explain coupling set-up

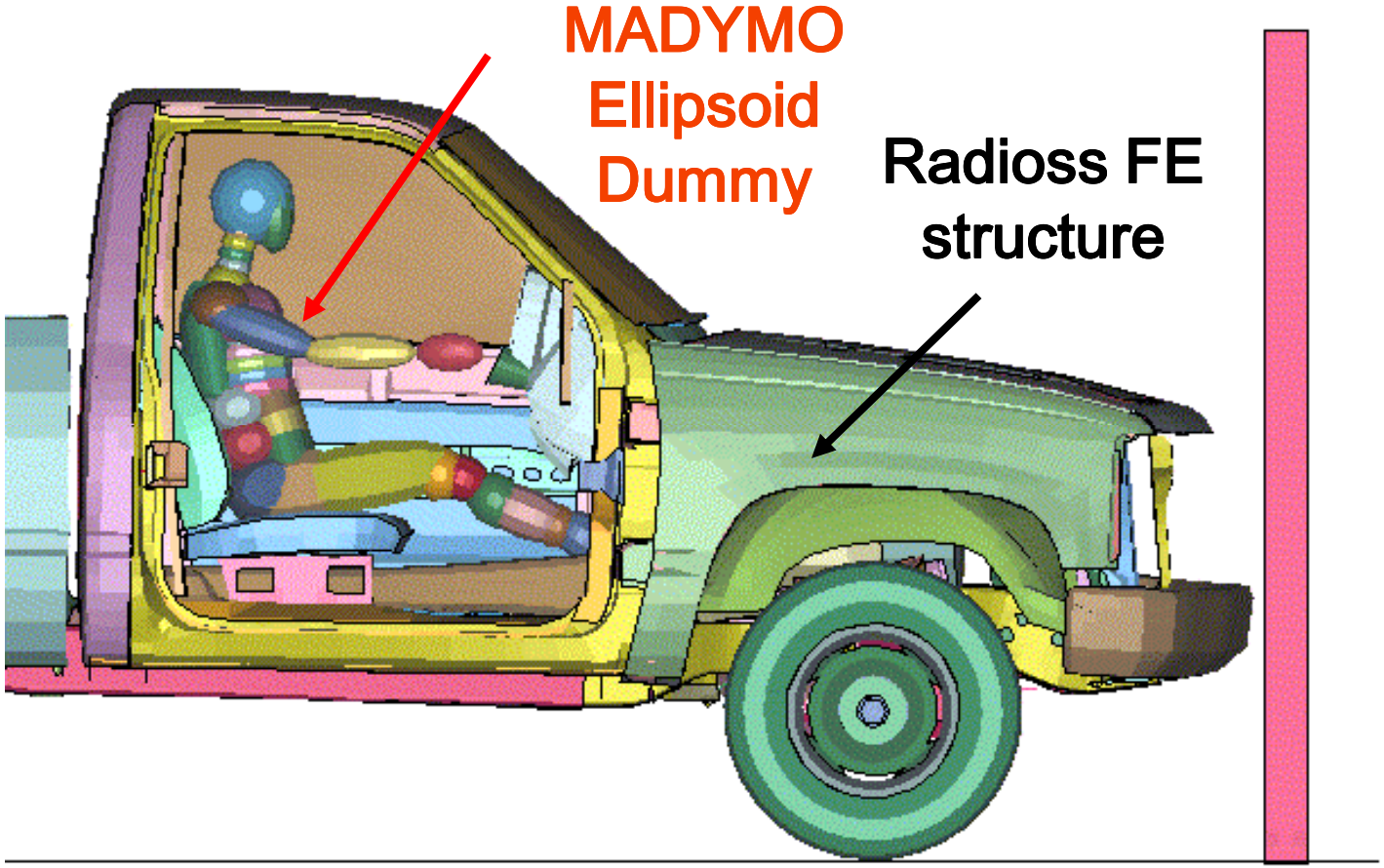
Practical sessions

- To obtain better understanding of the theoretical part

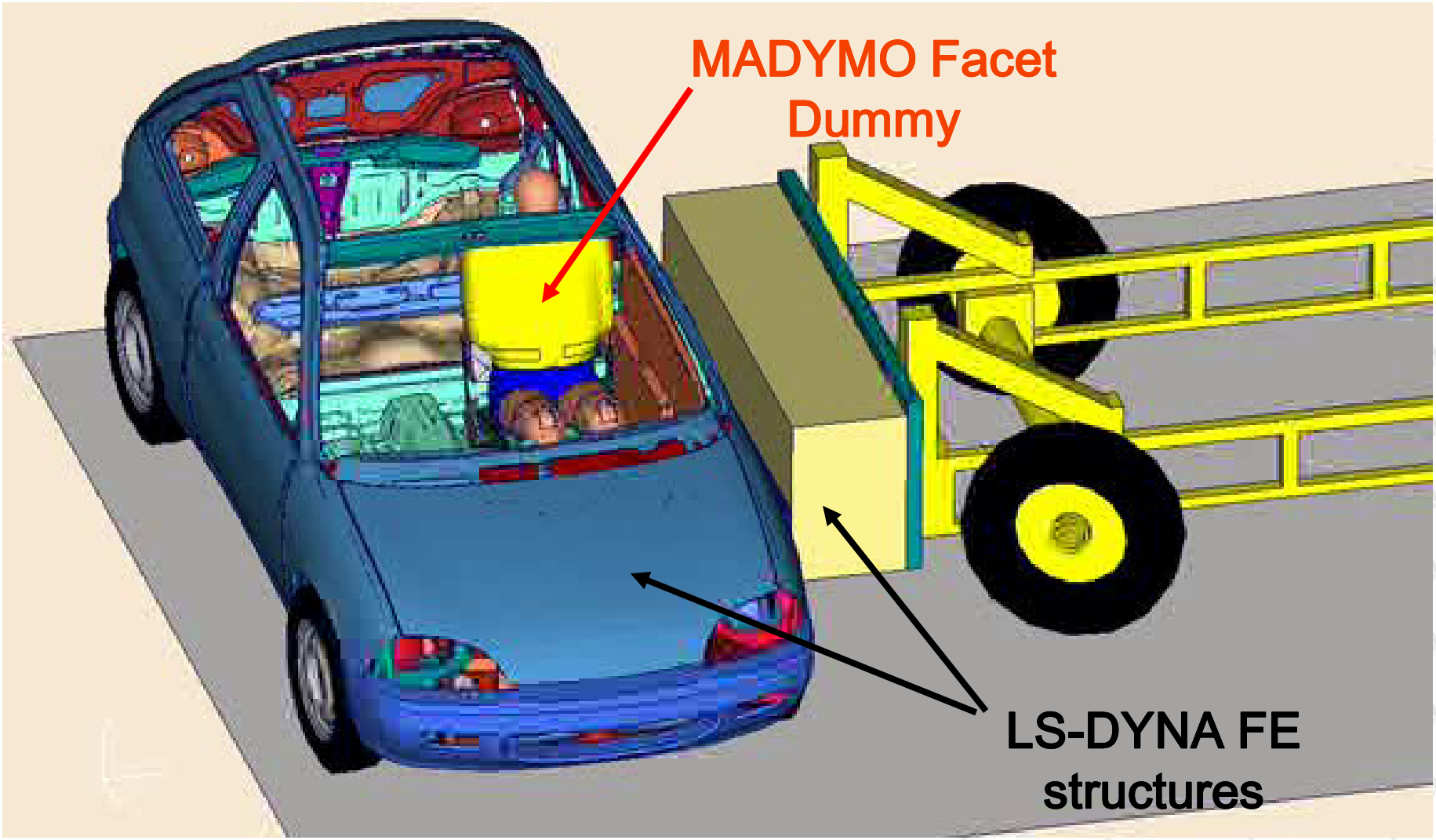
Available Software

- MADYMO R6.4
- LS-DYNA 971
- Text editors: nedit & vi
- Xmadgic 5.1
- MADPOST 3.2B
- Pdf viewer for the MADYMO & LS-DYNA manuals
- Xdiff program

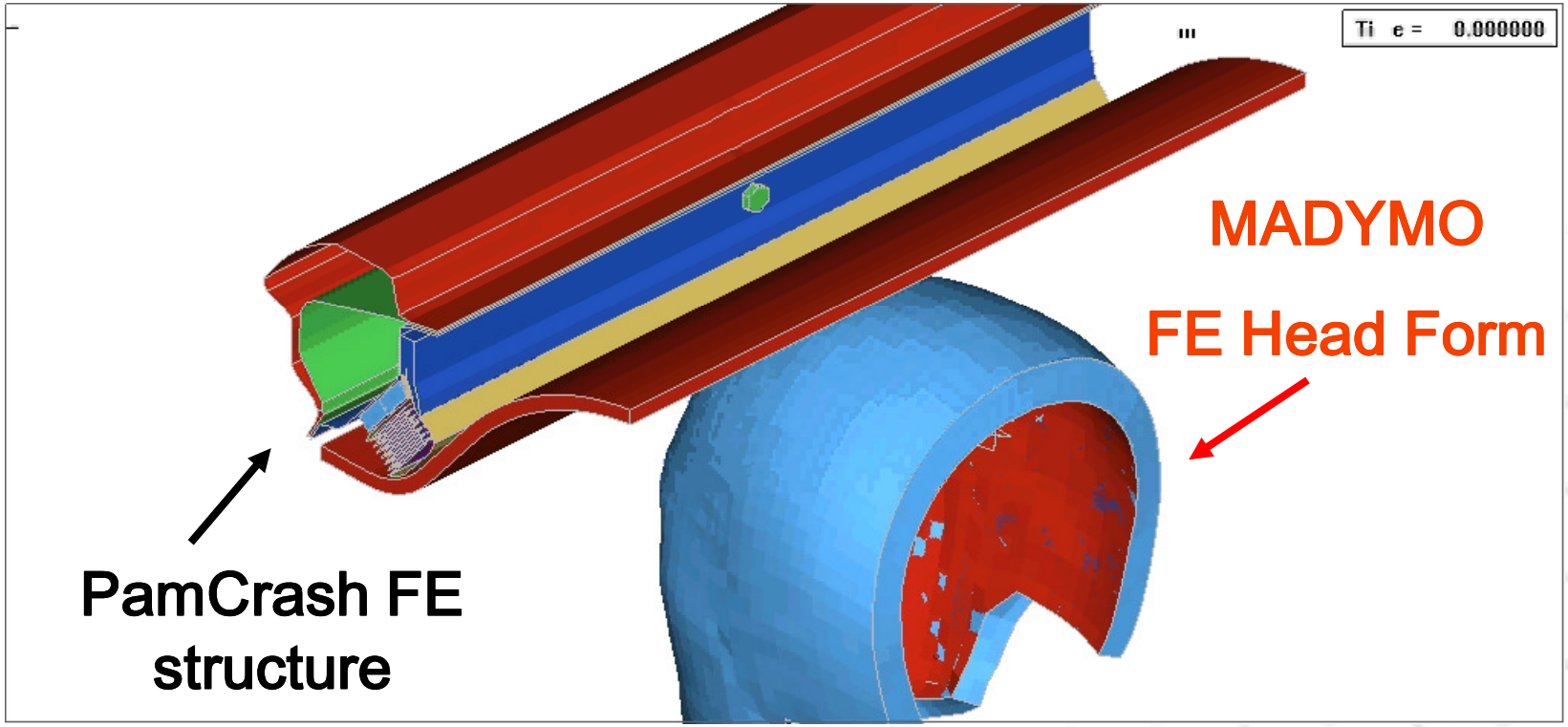
Example of a Frontal Impact Coupled Analysis



Example of a Side Impact Coupling Analysis

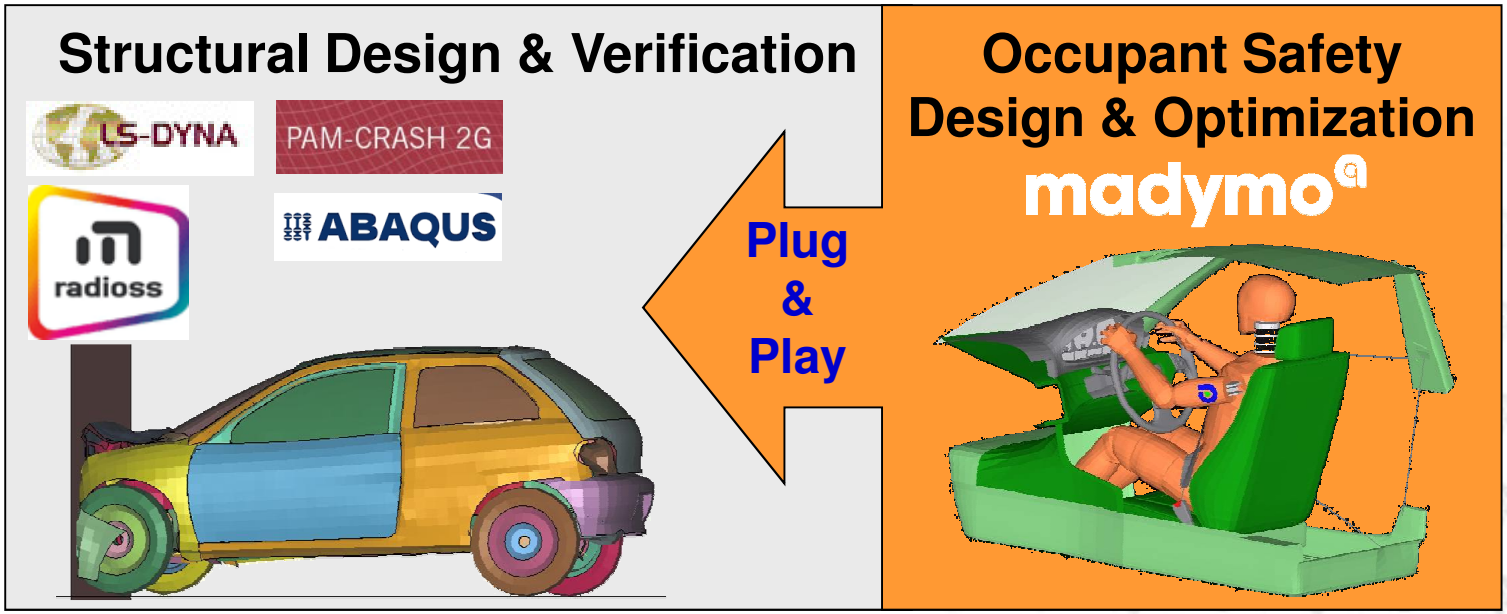


Example of a FMVSS201 Headform Coupling Analysis



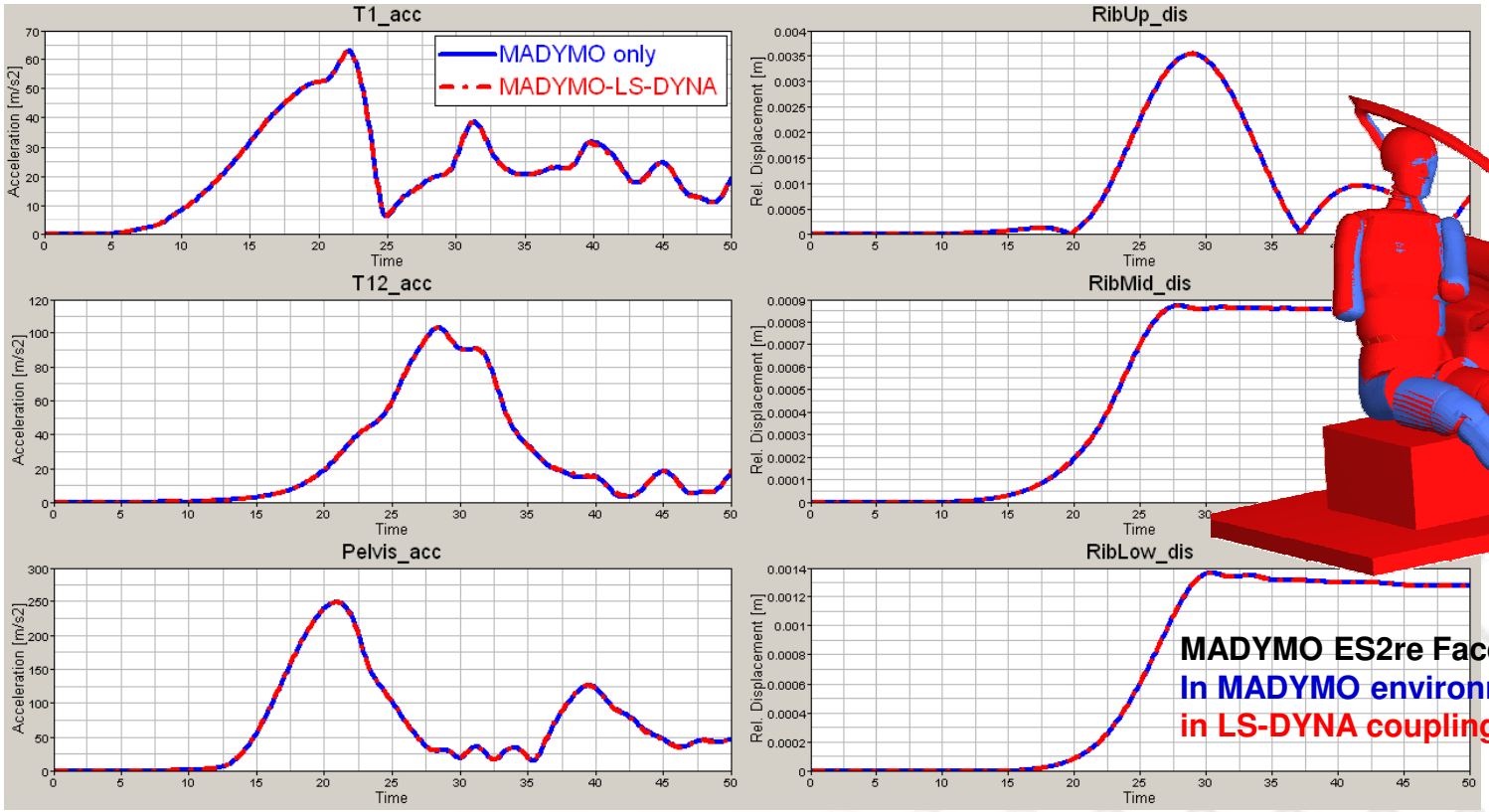
Why coupling

- FE crash codes are typically used for structural design
  - accurate predictions of deformations, but long run times
- MADYMO is specialized in restraint design & optimization
  - very fast run times & accurate dummy models
- TASS aims to offer its customers the best of both worlds by harmonizing MADYMO with FE crash codes through a plug & play coupling solution



Stand Alone vs. Coupling

- Performance of MADYMO Dummy models is a constant factor regardless of code of execution if extended coupling is used, because the contacts are handled in MADYMO



Stand Alone vs. Coupling

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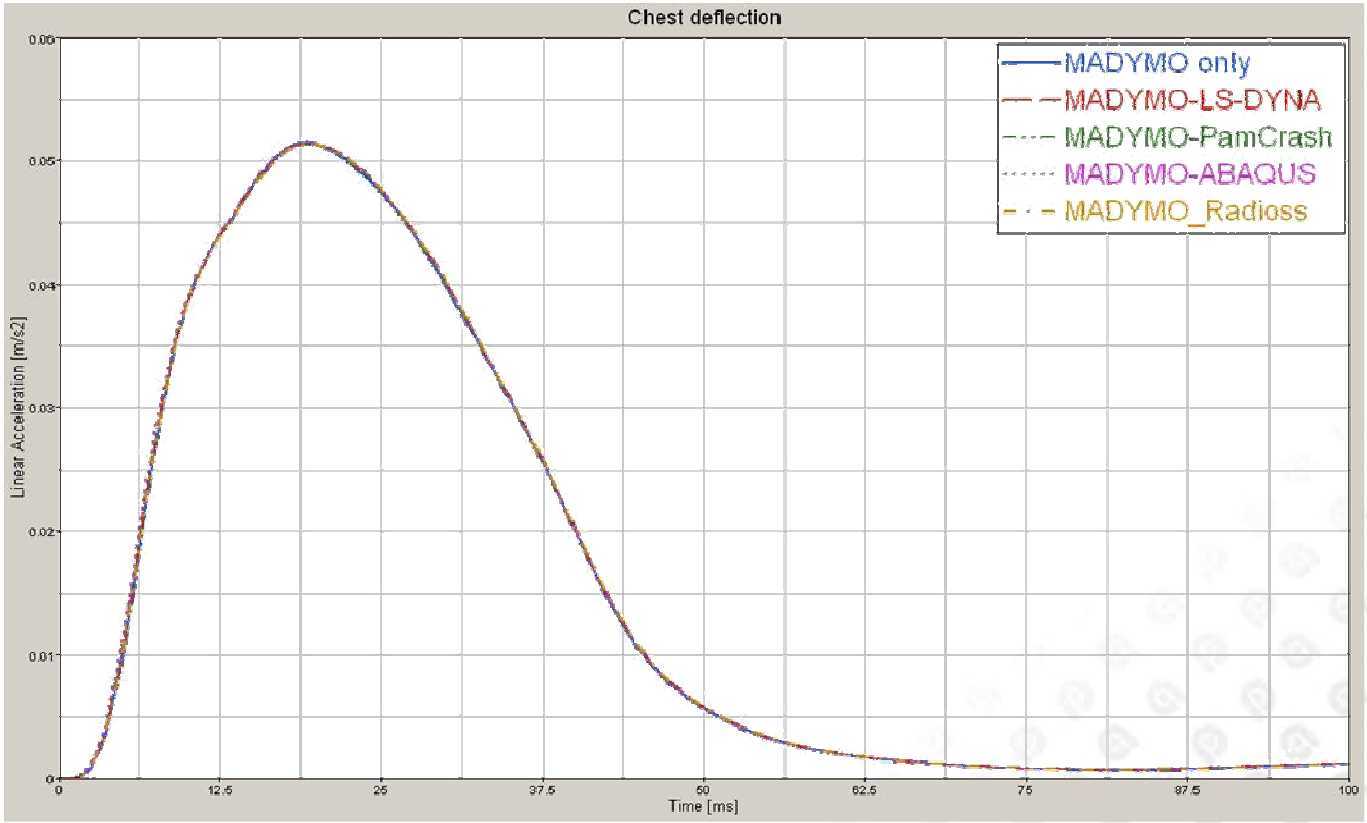

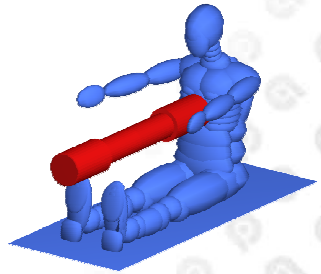

MADYMO code
PARTNER code

Stand Alone vs. Coupling

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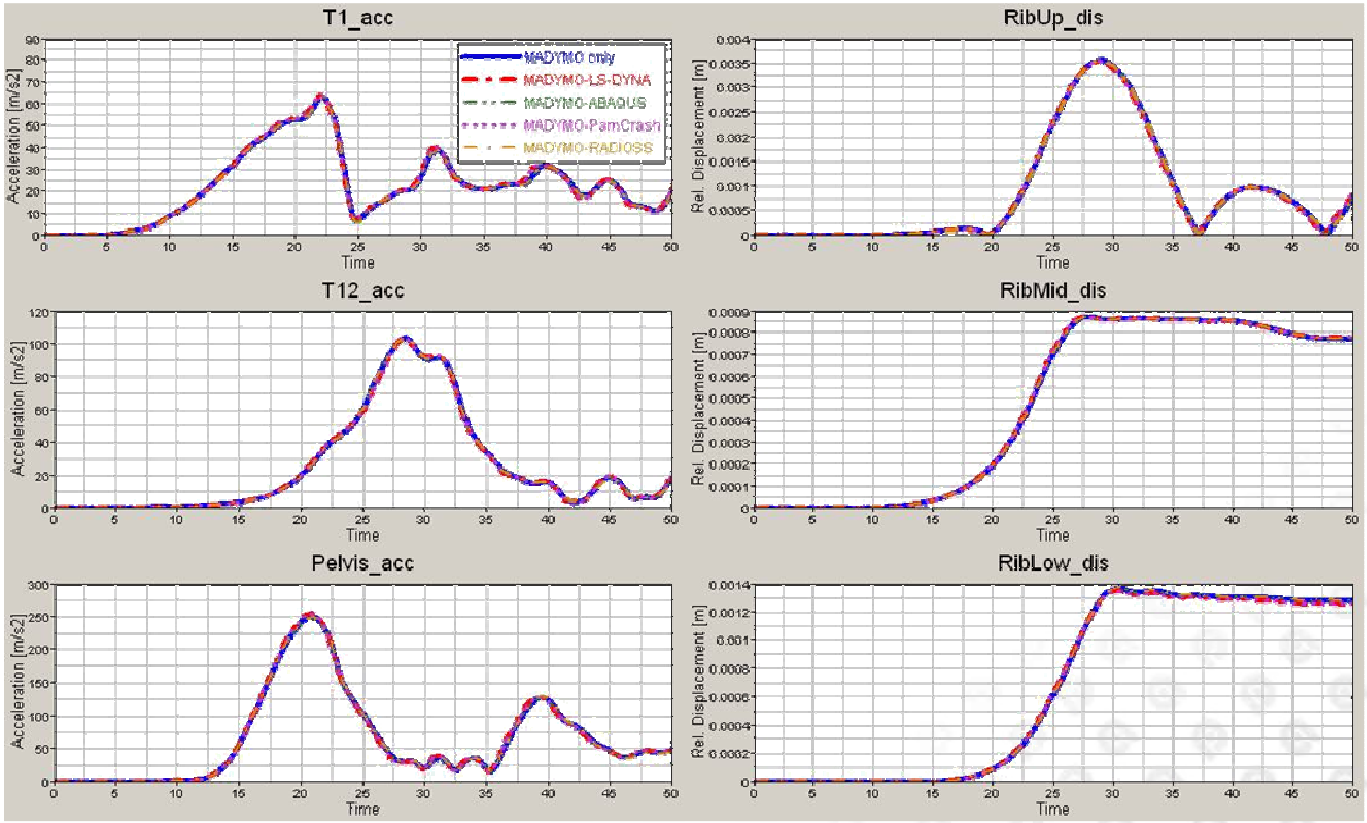
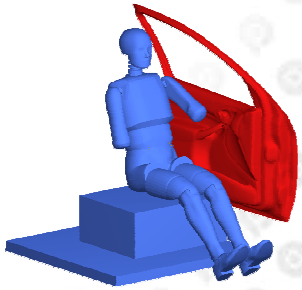




MADYMO code
PARTNER code

Coupling Development

- LS-DYNA - MADYMO Coupling was first released with MADYMO v5.0. This gave LS-DYNA Users access to MADYMO dummy models for safety simulations

- Later also coupling functionality was added to enable:
  - MADYMO - PamCrash
  - MADYMO - Radioss
  - MADYMO - Abaqus

Coupling Version Overview

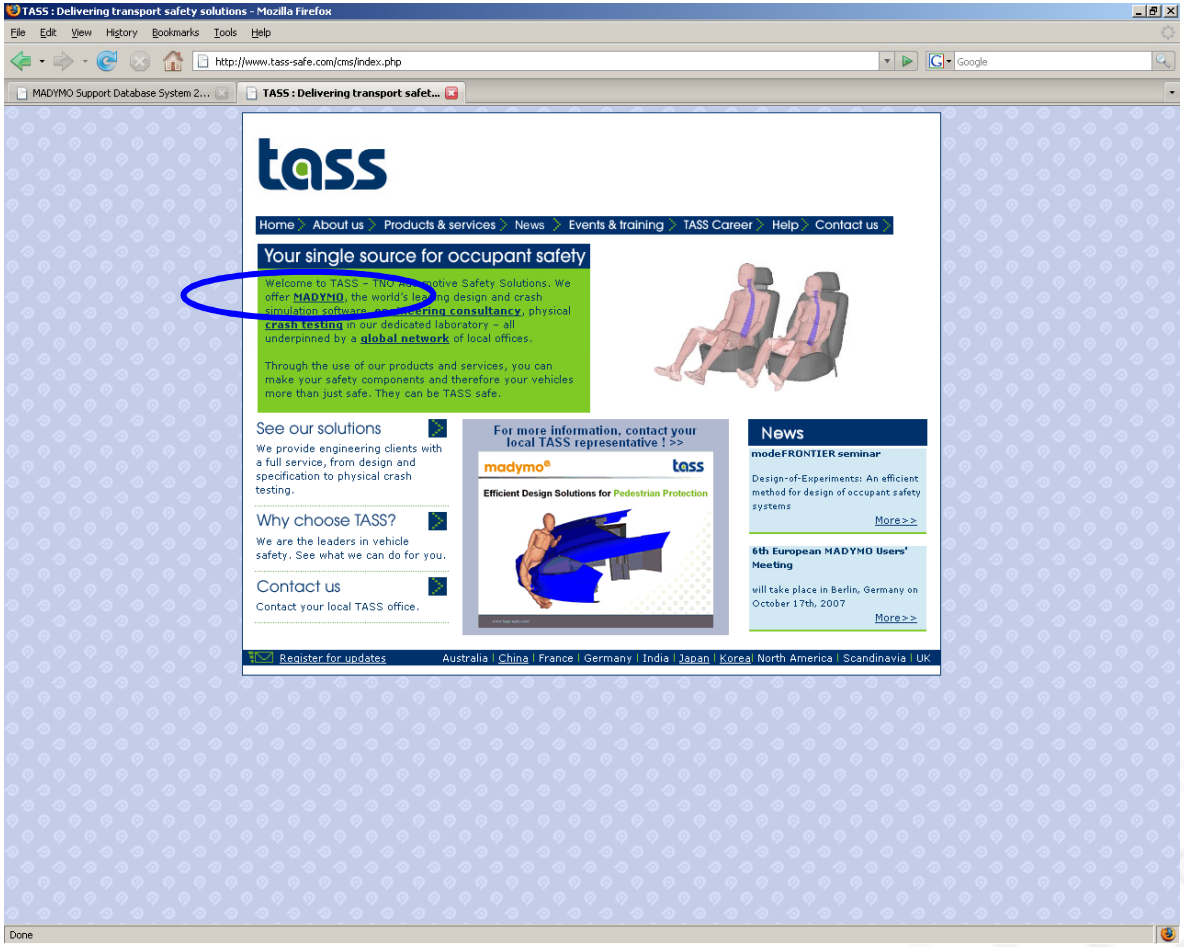
Coupling versions released with R6.4.x and older version, per October 4th, 2007

MADYMO R.6.4								
Partner / Platform	LS-Dyna		MPP-Dyna		PamCrash		Radioss	ABAQUS
	970-6763	971-7600	970-6763	971-7600	2007 SMP	2007 MPP	5.1 G	6.7PR3E
hpl100pa20	✔ [1 Jun 2007]	🛠	✔ [1 Jun 2007]	🛠	?	?	?	?
hpl100ia64 (HP Itanium)	✔ [1 Jun 2007]	🛠	Q [1 Jun 2007]	🛠	?	?	?	🛠
sgi64r10k	✔ [1 Jun 2007]	🛠	🛠	🛠	?	?	?	?
ibmrs51	✔ [1 Jun 2007]	🛠	Q [1 Jun 2007]	🛠	?	?	?	?
linux32E	✔ [1 Jun 2007]	🛠	🛠	🛠	✔ [1 Sep 2007]	✔ [1 Sep 2007]	?	?
linux64 (SGI Altix)	🛠	🛠	Q [1 Jun 2007]	🛠	✔ [1 Sep 2007]	✔ [1 Sep 2007]	?	🛠
x86_64- SLE9 (AMD Opteron)	✘ [Compiler Conflict]	🛠	✘ [Compiler Conflict]	🛠	✔ [1 Sep 2007]	✔ [1 Sep 2007]	✔ [1 Dec 2006]	🛠
x86_64-RHEL3 (AMD Opteron)	✘ [Compiler Conflict]	🛠	✘ [Compiler Conflict]	🛠	✔ [1 Sep 2007]	✔ [1 Sep 2007]	✔ [1 Dec 2006]	🛠
em64t-RHEL3	✘ [Compiler Conflict]	🛠	✘ [Compiler Conflict]	🛠	✔ [1 Sep 2007]	✔ [1 Sep 2007]	?	🛠
sun4UHI	?	?	?	?	?	?	?	?
ppc64-SLE9	?	?	?	?	?	?	?	?
win32	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]
em64t-win	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]	✘ [security issue]

- ? - Not Requested: Platform is not requested by customers.
- 🛠 - Under Development: Agreement between MADYMO and partner to start development. No commitment yet to deliver this version.
- Q - Validated: Validated by MADYMO and partner but not yet released by partner (date of validation mentioned)
- ✔ - Released: Validated by MADYMO/partner and (officially) released by partner (date of release by partner mentioned).
- ✘ - Not Possible: Not possible to create a version due to technical reasons (reason mentioned).

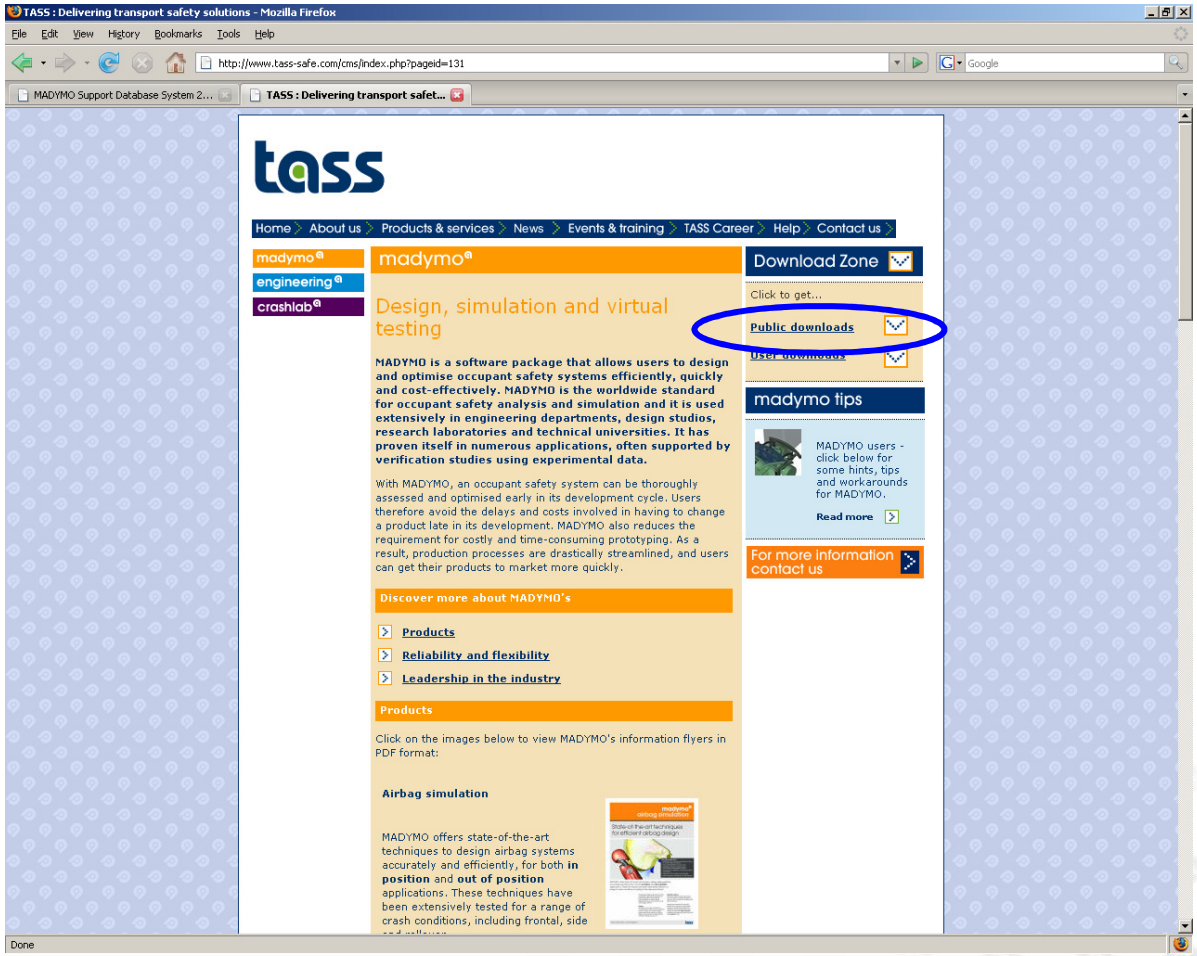
Coupling Info Download Area

http://www.tass-safe.com , click on MADYMO



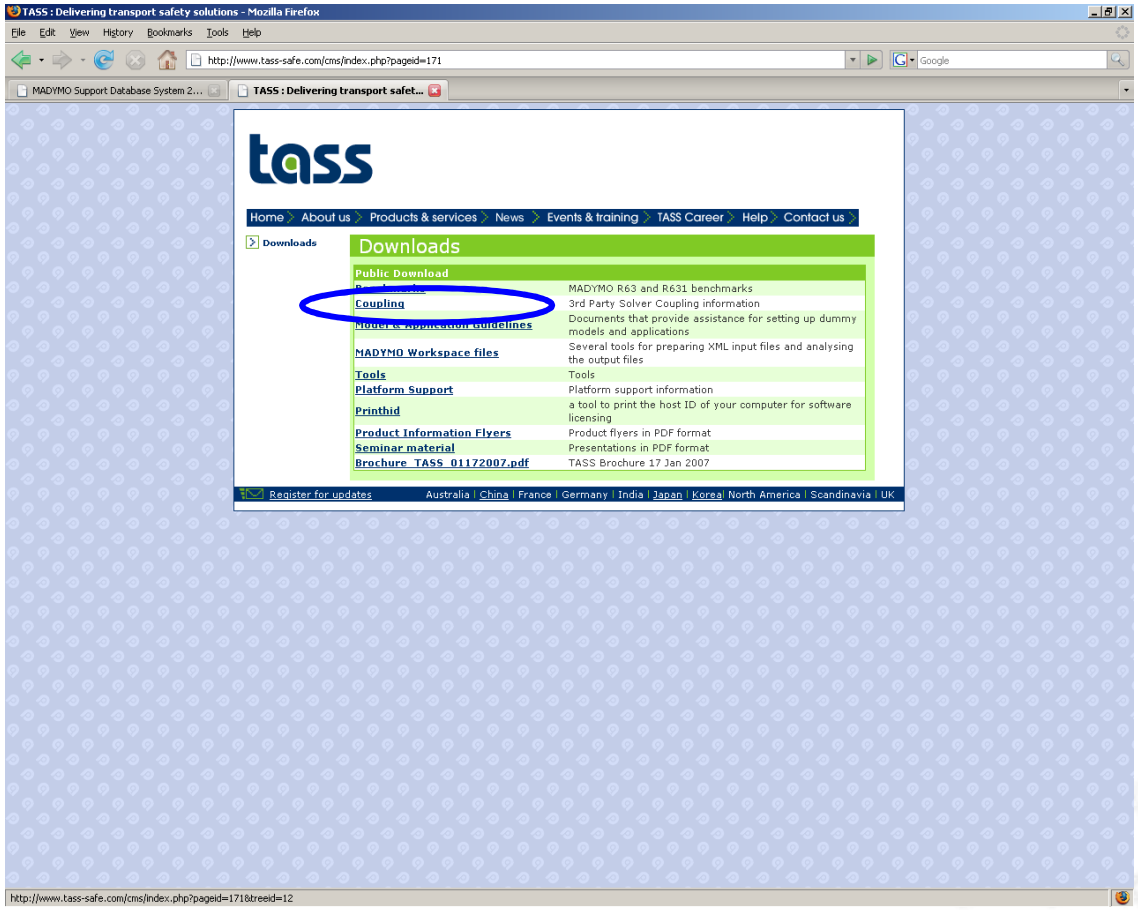
Coupling Info Download Area

Click on Public Download



Coupling Info Download Area

Click on Coupling



Also information can be found in the Coupling.pdf manual.

Coupling Main Overview

- Basic Idea of Coupling
- Types of Coupling
- Type of Dummies
- General Coupling Items

Basic Idea of Coupling

- By slight adjustments and adding some additional elements in both input decks (MADYMO and PARTNER) both models are merged to “one model”.

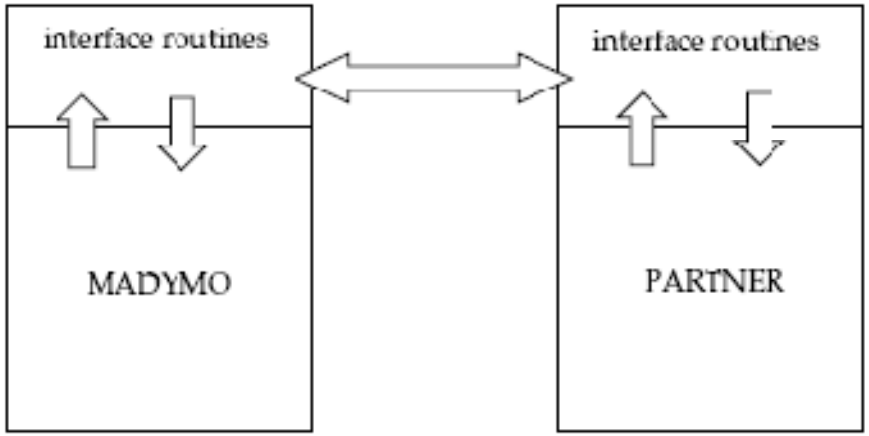
- Loop: MADYMO sent data to PARTNER. The partner performs calculations including the provided MADYMO data. Adjusted MADYMO data is sent back. Now MADYMO performs a new calculation including the adjusted data. Once ready, a new loop starts.

- Of special attention is the contact handling. This can be realized in two ways:
  - MADYMO MB data can be “sent” to the PARTNER such that the contact is handled in the partner code. This is called BASIC coupling.
  - PARTNER FE data is “send” to MADYMO such that the contact is handled in MADYMO. This is called EXTENDED coupling.

Basic Idea of Coupling

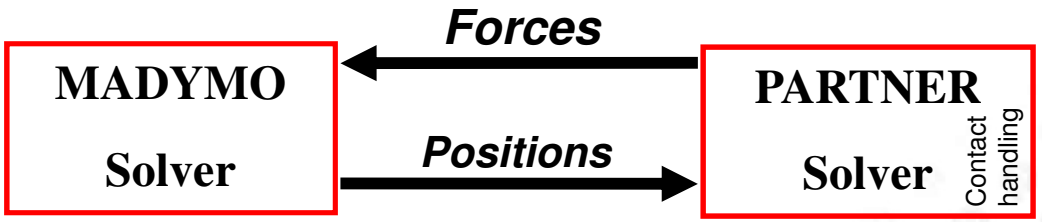
- Every time step information is exchanged between the two solvers

- These exchanges are performed by interface routines



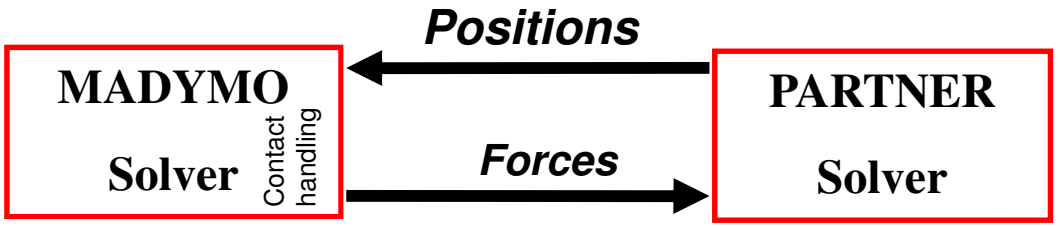
Types of Coupling

- Basic Coupling:
  - Each integration time step MB object data is sent to partner
  - Partner code makes a copy of the MADYMO MB objects and transforms these into partner FE objects.
  - These objects are also visible in the partner animation output.
  - Contact evaluations / constraints are performed in partner code
  - (Contact) forces are sent back to MADYMO
  - Useful e.g. to support FE partner pieces to MADYMO bodies.
  - Contact Char's of ellipsoid dummies can't be transferred to partner
  - Not applicable for e.g. MADYMO Facet/FE dummies, FE belts and airbags.



Types of Coupling

- Extended Coupling:
  - Each integration time step FE data (nodal positions) is sent to MADYMO
  - MADYMO makes a copy of the coupled PARTNER FE objects
  - These objects are visible in the MADYMO animation output
  - Contact evaluations / Constraints are performed in MADYMO
  - Forces are sent back to PARTNER
  - Contact char's of dummies can be used.
  - Partner FE pieces can be "TIED" to MADYMO.



Types of Coupling

- Combined Coupling:
  - Combining both basic and extended coupling in one simulation is also possible. This is called a Combined Coupling.
  - Do not define contacts double.
    - Example: Airbag (MADYMO) – Steering wheel (PARTNER)

      Define this contact either in MADYMO or in the PARTNER but not in both codes.

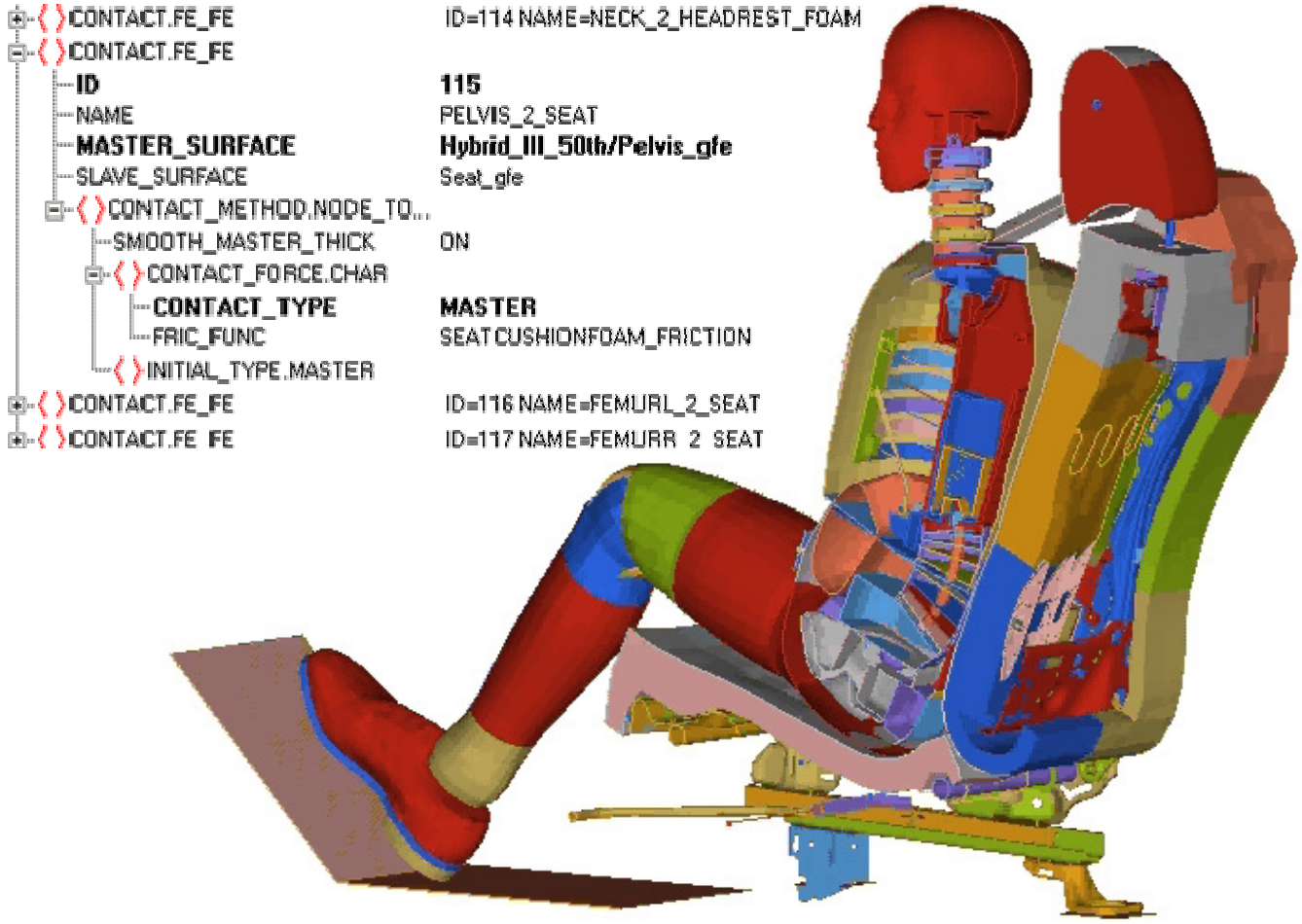
Types of Coupling

•Short Summary

Basic coupling	Extended coupling
Contact between MADYMO rigid body surfaces and PARTNER surfaces No contact possible between MADYMO FE/Facet surfaces and PARTNER surfaces	Contact between MADYMO rigid body surfaces and PARTNER mesh Contact possible between MADYMO FE/Facet surfaces and PARTNER surfaces
Contact definition is in PARTNER model and contact is handled in PARTNER	Contact definition is in MADYMO model and contact is handled in MADYMO
Rigid body compliance (defined in MADYMO dummy model) is not used for contact	Rigid body or facet surface compliance (defined in MADYMO dummy model) is used for contact
Only possible with ellipsoid dummy models (no facet or FE)	Possible for all MADYMO dummy models
Not possible to couple MADYMO FE belts and airbags	Possible to couple MADYMO FE belts and airbags

Because of contact compliance of MADYMO dummies it is recommended to use the extended coupling. Also the set-up is more easy.

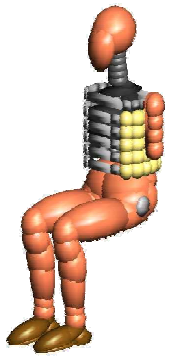
Extended Coupling Example with CHAR contact



MADYMO Dummy Models

- MADYMO is renowned for its efficient ellipsoid dummy models
- Ellipsoid models are starting to reach the top of their performance due to the lumped classical MB approach
- MADYMO is investing significantly in next generation dummy models to continue to meet our customers (increasing) demands:
  - Speed
  - Accuracy
  - Reliability
  - Ease of use

The Different Methods for Crash Safety Models

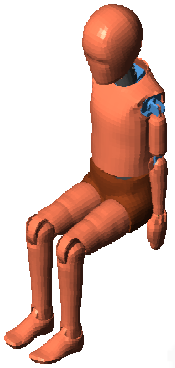


ellipsoid

- Fast
- Robust
- Easy to use
- Accurate
- DOE

facet

- Fast
- Robust
- Easy to use
- Accurate
- DOE



FE

- Fast
- Robust
- Easy to use
- Accurate
- DOE

Concept design

Prototyping

Verification

Characteristics Dummy Models

	MB	Facet	FE
Speed			
Typical timestep	1.0 E-4	1.0 E-5	1.0 E-6
Simulation time	++	+/-	-
Accuracy			
Geometry	-	++	++
Modelling detail	-	+	++
Validation set	+	++	+
Reliability (robustness)	++	+	+/-
Ease of use			
Modelling time	+	+	+
Visual analysis	-	+	++
Quality reports	-	++	-

General Coupling Items

- All coupling types synchronize their time step
  - used time step=min(MADYMO, PARTNER).
  - Generally this results in a smaller MADYMO MB time step
- End time of simulation*:
  - Used end time=min(MADYMO,PARTNER)
- Animation output time step of both codes need to be consistent since otherwise the animations will be out of phase
- Generally: Do not use command line options but specify these options, like MADYMO's *RSIZE*, in the input decks

* Except Radioss

MADYMO Part of the Coupling

- General
  - Coupling Types
  - Memory Allocation
  - Integration Method
  - Coupling Interface Version
  - Animation Output Scaling
- Coupling Adjustments to Input Decks
  - Basic
  - Extended
  - Combined
- Verification
- Limitation/Known Issues

GENERAL: MADYMO Main Adjustment Steps

- For both basic and extended coupling:
  - Add *COUPLING* element
    - to activate the coupling
  - Synchronize animation output time step

- For basic coupling:
  - Define *COUPLING_BODY* and/or *COUPLING_SURFAC*E elements under the *COUPLING* element.

- For extended coupling:
  - Define an empty *FE_MODEL* in MADYMO for “storing” the external parts.
  - Refer under the *COUPLING* element to this *FE_MODEL*
  - Define *GROUP_FE*s and *CONTACT*s
  - Check memory allocation

Note: Input cards based on MAD64 format. See MADYMO manuals for syntax details.

General: Coupling Types

• MADYMO supported coupling types.

	BASIC	Extended
LS-DYNA	√	√
PamCrash	√	√
Radioss	√	√
Abaqus	X	√

• Basic coupling is divided into two sub-types: Rigid Bodies and Surfaces (Ellipsoids/ Planes)

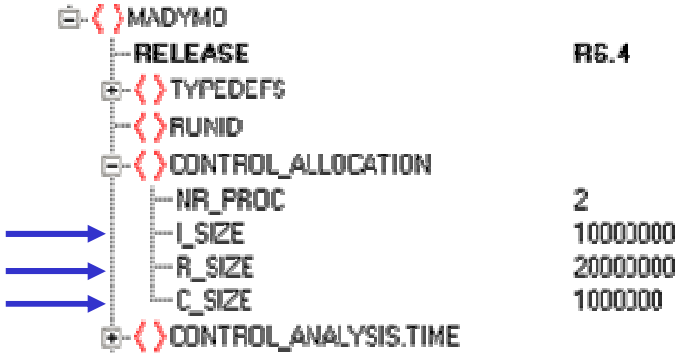
	RB	SURFACES
LS-DYNA	X	Ell & Pla
PamCrash	√	Ell & Pla
Radioss	√	Ell*
Abaqus	X	X

*Planes can be exported as well but no contact definition is possible within Radioss

General: Memory Allocation

- Depending on the size of the partner FE data that is sent to MADYMO it can be necessary to increase the double precision and integer space of MADYMO using *R_SIZE* and *I_SIZE* in the MADYMO .xml file under *CONTROL_ALLOCATION*. Adjusting the *C_SIZE* is generally not needed.

Input deck

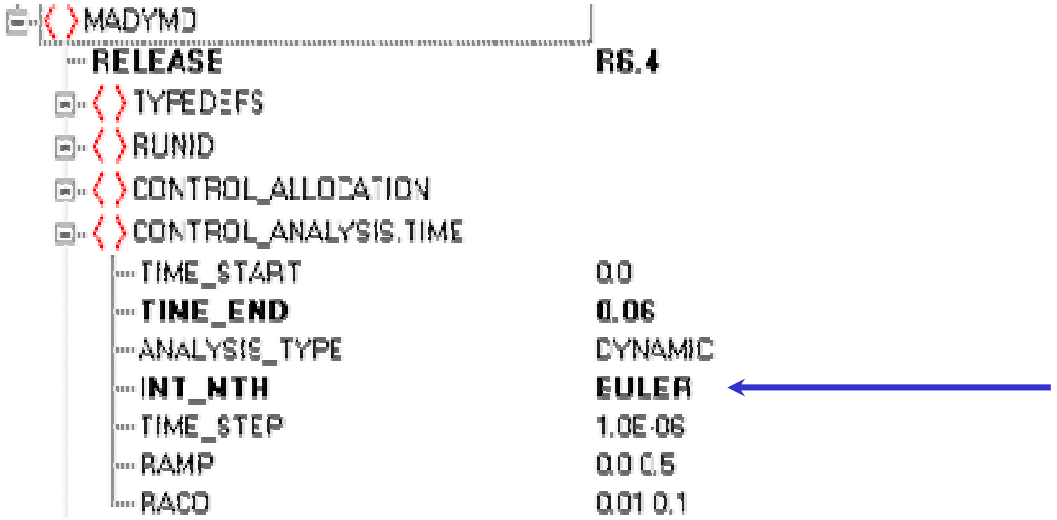


Reprint file

```
*******************************************************
 MODEL STORAGE REQUIREMENTS ESTIMATE
 *******************************************************

            |  AVAILABLE  |   CLAIMED   |  PERCENTAGE
 ------------------------------------------------------
 INTEGER    |   10000000  |    3436117  |     34.36
 REAL       |   20000000  |    4862751  |     24.31
 CHARACTER  |    1000000  |     255043  |     25.50
```

General: MADYMO Integration Method

- The integration method in coupling runs has to be EULER



- The reprint file will generate a warning if EULER is not defined. So the solver will activate it automatically. However, for clear reprint warning overview it's better to define this option in the input deck.

```
** WARNING ** ID=(COUP04/3D/INCOUP)
Integration method set to EULER due to coupling.
```

General: Coupling Interface Version

- In MADYMO R6.3.1 a new coupling interface is introduced*, enabling:
  - Automatic length unit scaling of MADYMO animation output by activating *AUTO_SCALE_ANI*
  - Communication of failure/abort to other code.
    - MADYMO to Partner
    - Partner to MADYMO

- Which version of interface is used can be seen in the reprint file under *COUPLING_INTERFACE*. Version 1 contains this new functionality, version 0 not.

- Used coupling interface version: min(MADYMO,PARTNER)

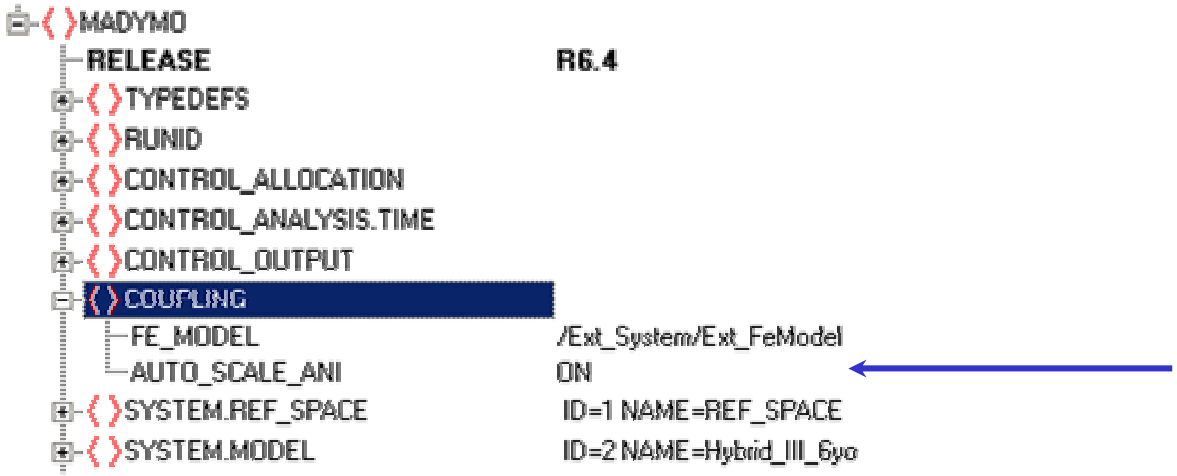
- Example of reprint file

```
---------- COUPLING ----------
EFFECTIVE INTERFACE VERSION .....:       0
```

*Not yet supported by all PARTNER executables.

General: MADYMO Animation Output Scaling

- The attribute *AUTO_SCALE_ANI* has been added under the *COUPLING* element to allow automatic scaling of the MADYMO animation to the 3rd party codes unit of length. (Not yet supported by all coupling partners)



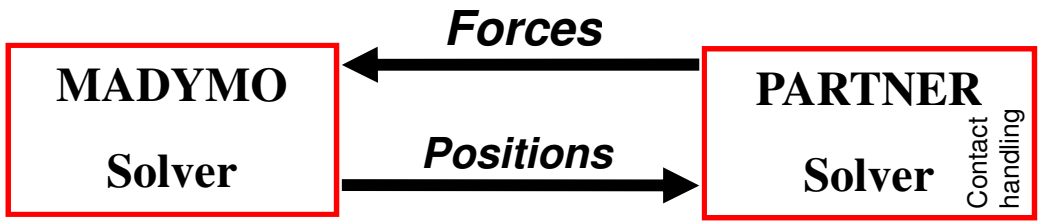
Notes:

- If *AUTO_SCALE_ANI* is ON, the attribute *SCALE_FACTOR_ANI* under *CONTROL_OUTPUT* is ignored.
- Also a script is available at the public coupling download, named scale_kin.zip, that can assists in converting MADYMO units

Basic Coupling Adjustments to MADYMO Input Deck

- Basic Coupling
  - Rigid Bodies: Define *COUPLING_BODY* under the *COUPLING* element.
  - Surfaces: Define *COUPLING_SURFACE* under the *COUPLING* element.

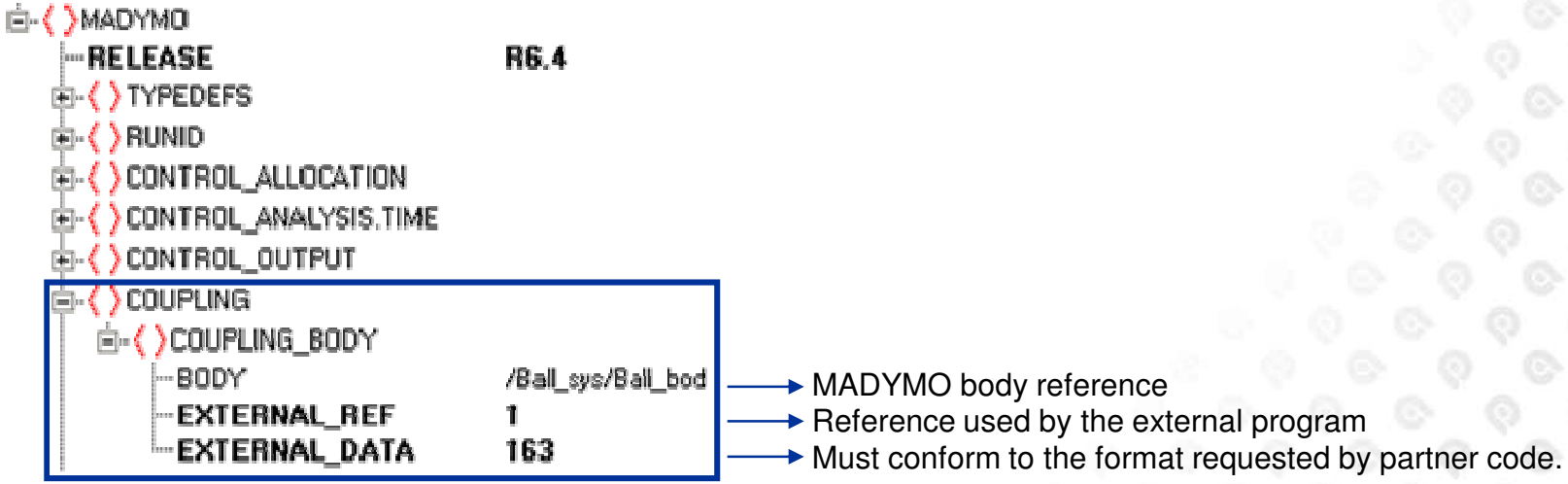
- Cycle



Notes: Abaqus support no basic coupling

Basic Coupling Adjustments to MADYMO Input Deck

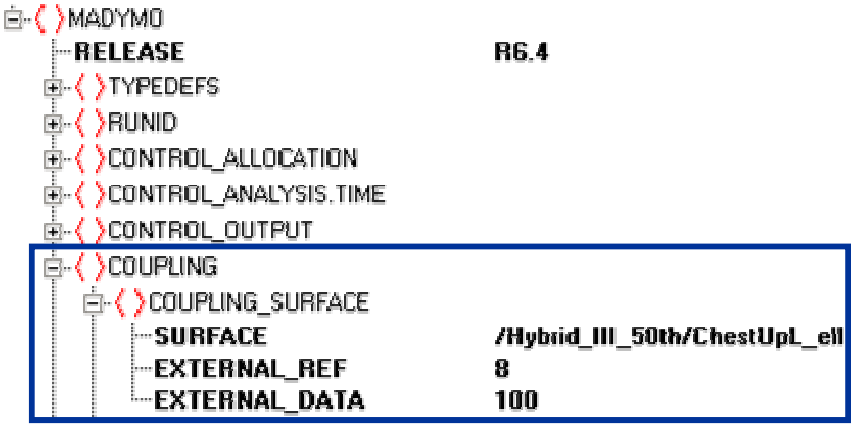
- Basic Coupling of Rigid Bodies
  - Rigid Bodies: Define *COUPLING_BODY* under the *COUPLING* element.
  - Rigid body data passed to the partner. The partner will calculate interactions with these bodies according to its algorithms.



Notes: Rigid Bodies can't be coupled to LS-DYNA

Basic Coupling Adjustments to MADYMO Input Deck

- Basic Coupling of Surfaces: ellipsoids, planes and cylinders
  - Define *COUPLING_SURFACE* under the *COUPLING* element.
  - Surface data passed to the partner. The external program will calculate contact interactions with these surfaces according to its own algorithms

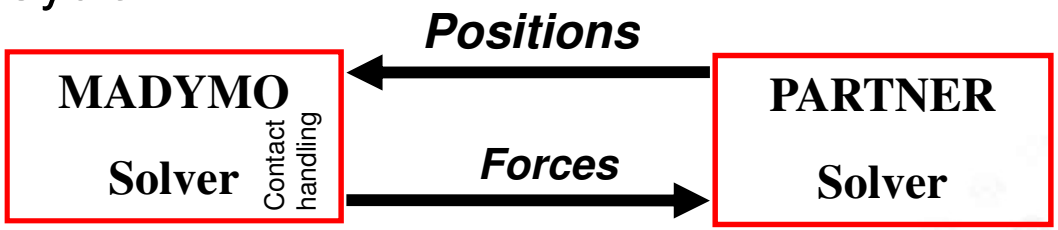


→ MADYMO Surface reference
→ Reference used by the external program
→ Must be conform to the format requested by partner code.

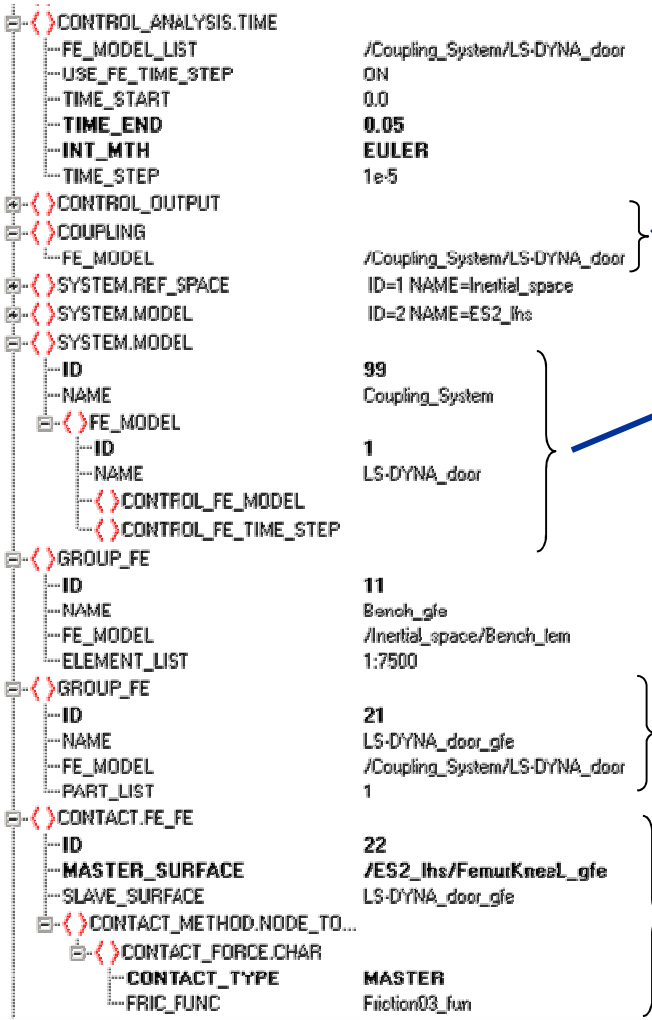
Extended Coupling Adjustments to MADYMO Input Deck

- Extended Coupling
  - FE data from partner code is transferred to MADYMO.
  - Also define an empty *FE_MODEL* under a system. This *FE_MODEL* will be used to “store” the partner FE data.
  - Refer under the *COUPLING* element to this *FE_MODEL*
  - Define *USE_FE_TIME_STEP* to ON and select minimal the coupling *FE_MODEL*
  - Partner FE part, element and node numbers within MADYMO are identical to the partner one’s.

- Cycle



Extended Coupling Adjustments to MADYMO Input Deck



If *FE-MODEL* is defined:

- Extended coupling is used
- The coupled external solver sends selected FE model data to MADYMO.

Empty *FE_MODEL* to assemble received partner data

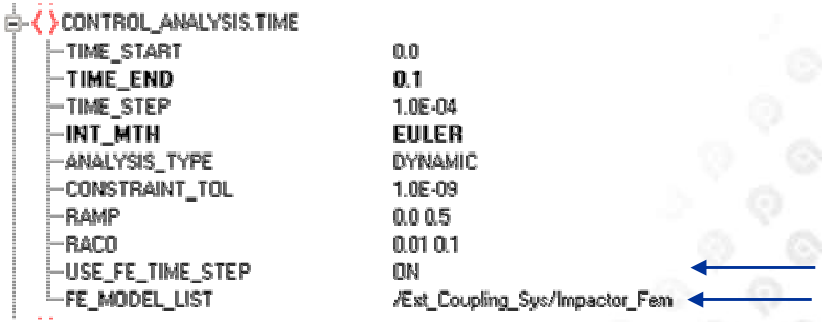
- All other data specified in this specified *FE_MODEL* will be overwritten by the data from the external program.

- This new data can be used in e.g. *GROUP_FE* or *OUTPUT_NODE*.

- The coupled parts can be used to define contacts or tied surfaces in MADYMO .

Extended Coupling Adjustments to MADYMO Input Deck

- Set the *USE_FE_TIME_STEP* to ON in the *CONTROL_ANALYSIS.TIME* element and select, at least, the *FE-MODEL* defined for coupling MB time synchronization purpose.



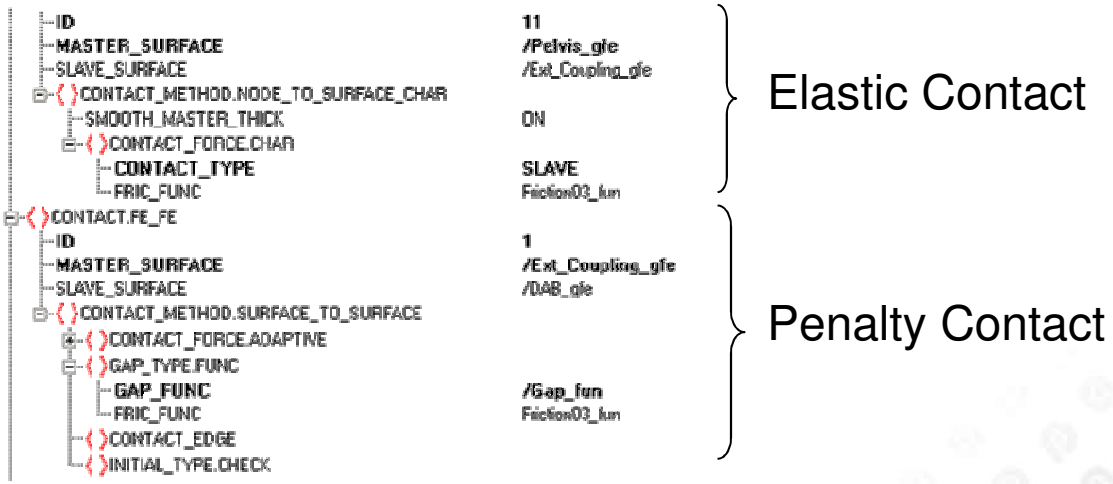
- The reprint file will generate two warnings if *USE_FE_TIME_STEP* is not ON. So the solver will activate it automatically. However, for clear reprint warning overview it's better to define this option in the input deck.

```
** WARNING ** ID=(COUP07/3D/INCOUP)
USE_FE_TIME_STEP under CONTROL_ANALYSIS_TIME set to ON, needed for
Extended Coupling.

 ** WARNING ** ID=(COUP08/3D/INCOUP)
External FE model: /12/1 ( /Coupling_System/nine_pins_fem ) added to
FE_MODEL_LIST under CONTROL_ANALYSIS_TIME.
```

More Extended Coupling FE-MODEL

- Kinematic constraints (like supports, kinematic contacts, spotwelds, prescribed motion and rigid_elements) can not be defined to the external FE model within the MADYMO input deck

- Elastic as well as penalty based contacts can be defined, including damping. (So no kinematic contact)



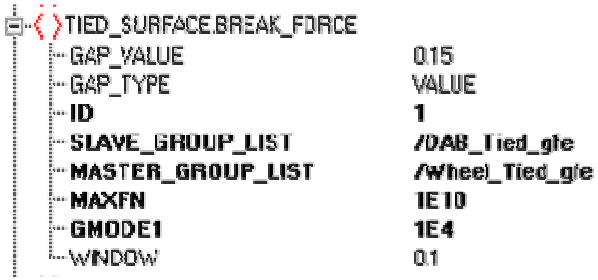
More Extended Coupling FE-MODEL

- *TIED_SURFACE.** between MADYMO and partner can be defined
  - *MASTER_GROUP_LIST*: select from partner *FE_MODEL*
  - *SLAVE_GROUP_LIST*: select from MADYMO *FE-MODEL*

- Example

  add groups to show master = dyna

  - Input deck

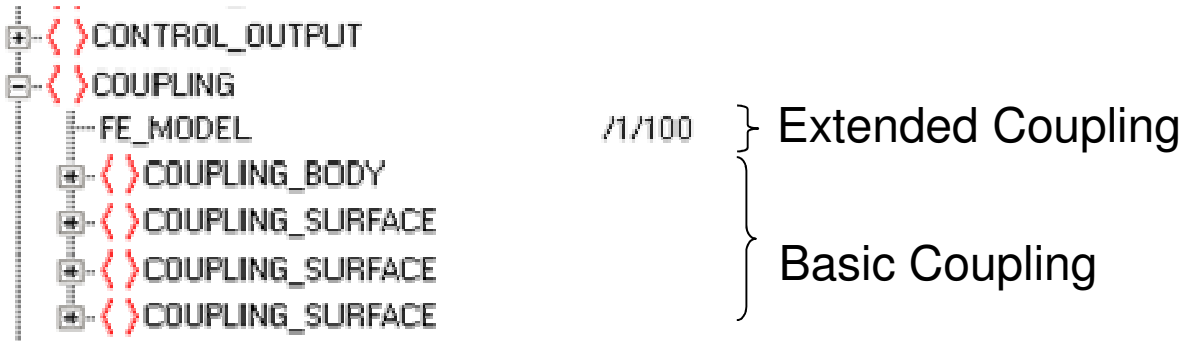


  - Reprint Example

```
Tied_surface : /1 (    )
Due to this tied surface the coordinates of slave node 97 are modified:
Old coordinates :   0.27654E+01  0.41200E+00  0.86685E+00
New coordinates :   0.27698E+01  0.41203E+00  0.86497E+00
```

Combined Coupling Adjustments to MADYMO Input Deck

- Since Combined Coupling is a combination of Basic and Extended Coupling both the "*FE_MODEL*"and "*COUPLING_**" have to be defined. Also the other elements for extended coupling have to be defined.



Verification: REPRINT File Info

- Reprint File shows:
  - Is coupling used

```
------------- GENERAL-TOTAL -------------
 Number of system.ref_space ........... :          1
 Number of system.model ............... :          2
 Number of FE-models .................. :          2
 ..
 Number of states ..................... :          0
 Coupling ............................. :         ON
 Number of user-defined gasses ........ :          0
 Number of output_energy .............. :          0
 ..
----------- END GENERAL-TOTAL -----------
```

Verification: REPRINT File Info

- Check the reprint to see whether the correct coupling data is defined in MADYMO
  E.g. for Basic Coupling

```
---------------------- COUPLING ----------------------------
COUPLING
    FE_MODEL ....................................:
    OUTPUT SCALING...............................: OFF
    SURFACE .....................................: /2/2
      EXTERNAL REFERENCE ........................:          2
      EXTERNAL DATA .............................:
        NUMBER ..:          1  DATA ..:      1.0000E+01
     SURFACE .....................................: /2/110
      EXTERNAL REFERENCE ........................:        110
      EXTERNAL DATA .............................:
        NUMBER ..:          1  DATA ..:      1.1800E+02
    COUPLING TYPE ...............................: BASIC
--------------------- END COUPLING -------------------------
```

The COUPLING TYPE reflects the coupling data defined in MADYMO: BASIC, EXTENDED or COMBINED

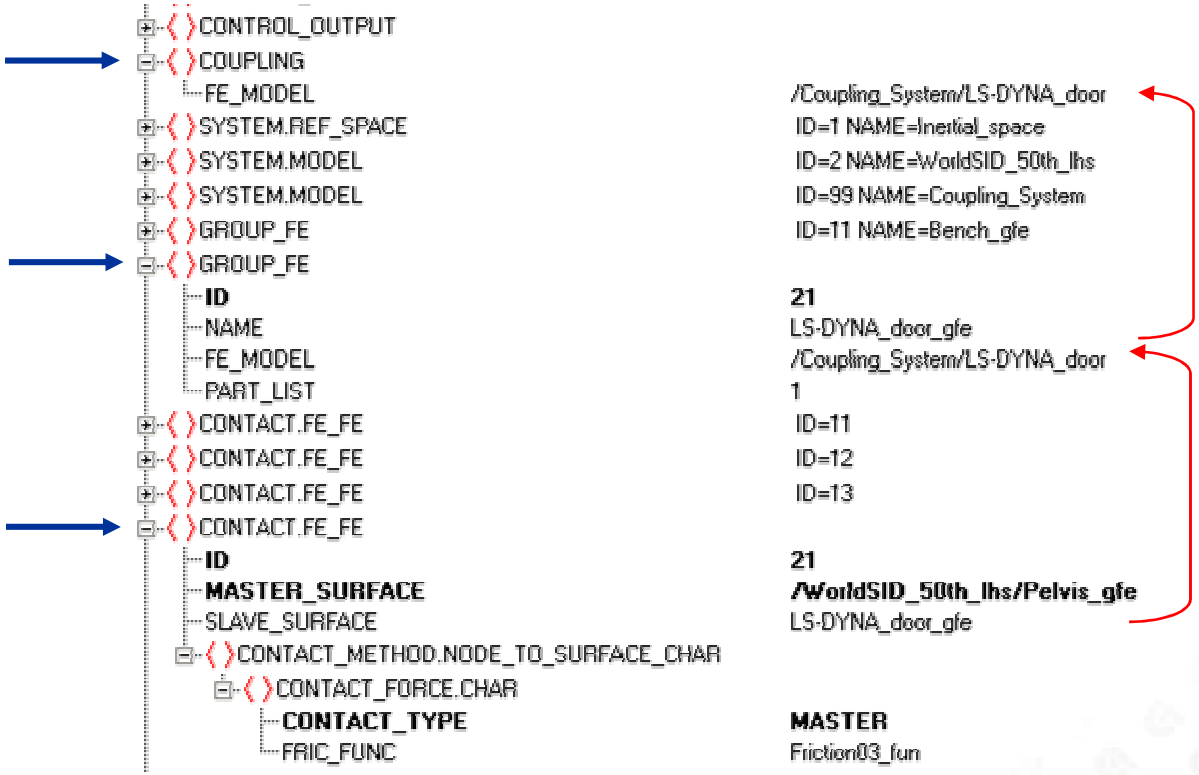
Verification: REPRINT File Info

- Check the reprint to see whether the correct data is received from the PARTNER.
  E.g. for Extended Coupling

```
---------COUPLING INTERFACE-----------
 EFFECTIVE INTERFACE VERSION ..........:          0
 NUMBER OF NODES ......................:        256
 NUMBER OF PARTS ......................:          1
   PART ID (FROM COUPLED PROGRAM) .....:          1
     THICKNESS ........................:      1.0000E-03
     BULK MODULUS .....................:      1.5682E+11
 NUMBER OF ELEMENTS ...................:        225
   NUMBER OF TRIADS ...................:          0
   NUMBER OF QUADS ....................:        225
   NUMBER OF SOLIDS ...................:          0
--------- ELEMENT.QUAD4 ---------
       NO |  PARTNR |        N1 |        N2 |        N3 |        N4 |    THICKNESS |
         1         1           1           2          18          17     0.0000E+00
..
       225         1         239         240         256         255     0.0000E+00
--------- END ELEMENT.QUAD4 ---------

-----------------------------------------------
 SELECTED ELEMENTS/NODES IN GROUP_FE :

 GROUP_FE ID ..........................: /16 (   )
    FE-MODEL ..........................: /1/100 (   )
    SELECTED ELEMENTS .................:
         1:225
    SELECTED NODES ....................:
         1:256
-----------------------------------------------
--------- END COUPLING INTERFACE ---------
```

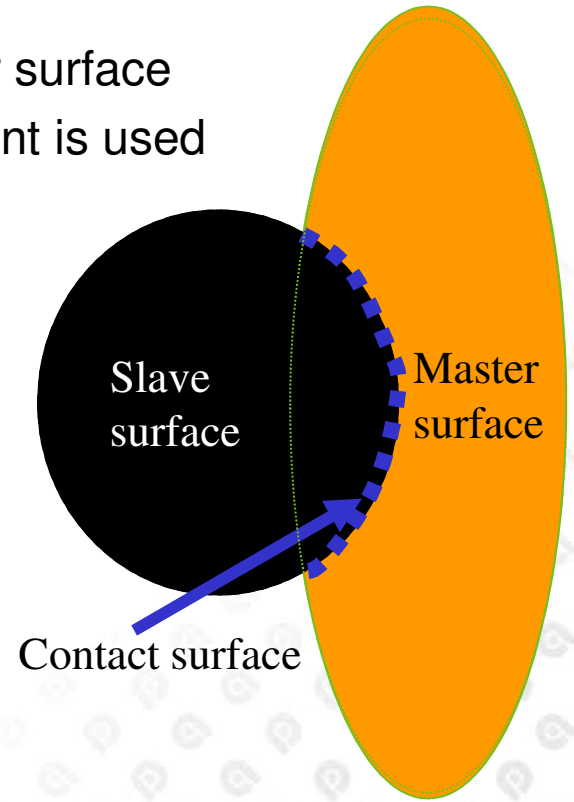
(Facet) Contact Definition

- Example of contact definition in extended coupling



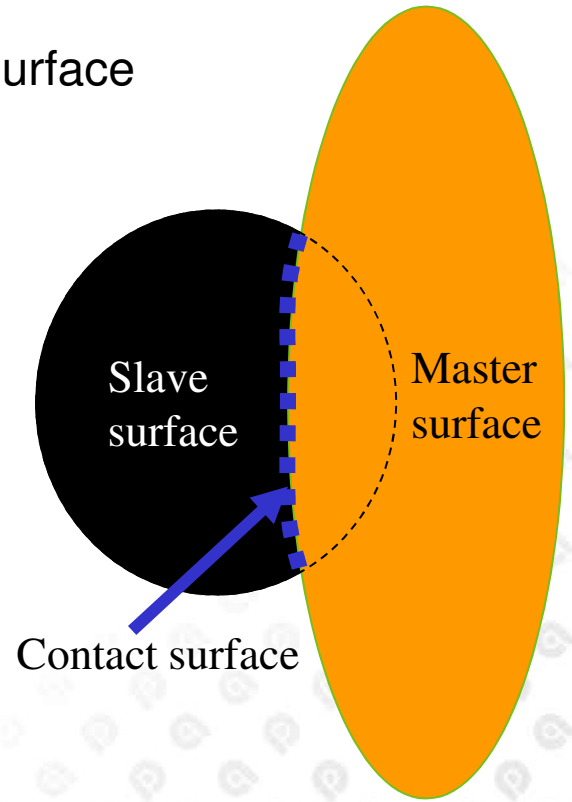
(Facet) Contact Definition

- ***CONTACT_TYPE* = MASTER**
  - Master surface is assumed to be deformable
  - Slave surface is assumed to be rigid
  - Contact hysteresis is stored for master surface
  - Maximum nodal penetration per element is used



(Facet) Contact Definition

- ***CONTACT_TYPE* = SLAVE**
  - Slave surface is assumed to be deformable
  - Master surface is assumed to be rigid
  - Contact hysteresis is stored for slave surface



Limitation and Know Issues

- For coupling Interface version 0: Partner sometimes write out “NORMAL TERMINATION” although MADYMO terminated abnormally.
- Extended coupling requires at least one element, only providing nodes is not allowed.
- For SMP-MPP runs the screen output can be out phase. This is normal behavior.

Abaqus Part of the Coupling

- General
- Extended Coupling
- Verification
- Known Issue

General

- No Basic Coupling is supported for Abaqus
- For Extended Coupling

  *CO-SIMULATION, PROGRAM =MADYMO

  Optional unit scaling

  *CO-SIMULATION REGION, REGION ID=n

  Surface_A, Surface_B,

- Coupling only works with Abaqus/Explicit

Note: Input cards based on Abaqus 6.7 format. See Abaqus manuals for syntax details.

General: Units

- *CO-SIMULATION, PROGRAM=MADYMO

  Mass unit conv. factor, length unit conv. factor , time unit conv. factor

- Example

  *CO-SIMULATION, program=MADYMO

  1, 0.001 , 1

  Means: Used Abaqus Units: kg, mm, seconds

  Abaqus dat file:

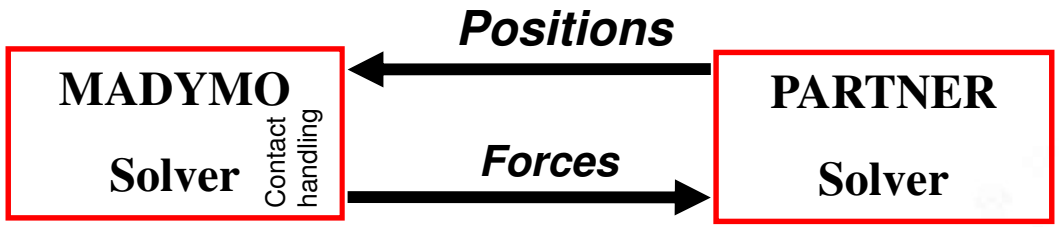
```
 EXTERNAL PROGRAM:                                    MADYMO

     ALL QUANTITIES EXCHANGED MAY BE IN DIFFERENT UNITS IN THE TWO PROGRAMS.
     THE SCALE FACTORS FOR THE BASIC UNITS ARE LISTED BELOW.
       AN ABAQUS VALUE WHEN MULTIPLIED BY THE APPROPRIATE SCALE FACTOR WILL
       CONVERT TO A VALUE IN UINTS USED BY THE EXTERNAL PROGRAM.
          UNIT CONVERSION SCALE FACTOR FOR MASS   =    1.000
          UNIT CONVERSION SCALE FACTOR FOR LENGTH =   1.0000E-03
          UNIT CONVERSION SCALE FACTOR FOR TIME   =    1.000
```

Extended Coupling Adjustments to Abaqus Input Deck

- Define co-simulation cards
  - Surfaces are passed to MADYMO by ID number. Multiple Surface regions can be defined to allow multiple part IDs within MADYMO.
  - *GROUP_FE*s in MADYMO can select these Abaqus ID's, node and/or element numbers of these surface IDs.

- Validated contact characteristics of MADYMO dummy models can be used

- Cycle



Example: Extended Coupling Adjustments to Abaqus Input Deck

- Example
  - MADYMO

  - Abaqus

```
*Co-simulation, program=MADYMO
*Co-simulation Region, region id=11
Ball,
Plane,
```

The surface Ball and Plane, with id 11, are transferred to MADYMO to FE_MODEL /1/100 and get MADYMO part number 11.

Extended Coupling Verification

- The reprint file shows all data sent to Abaqus file shows all data sent to MADYMO. E.g.
  - reprint file:

```
------------------COUPLING INTERFACE--------------------
 NUMBER OF NODES                        :          92
 NUMBER OF PARTS                        :           1
   PART ID (FROM COUPLED PROGRAM)       :           1
     THICKNESS                          :      3.5000E-04
     BULK MODULUS                       :      1.1111E+09
 NUMBER OF ELEMENTS                     :          90
   NUMBER OF TRIADS                     :           0
   NUMBER OF QUADS                      :          90
   NUMBER OF SOLIDS                     :           0
```

  - Abaqus .dat file (define *Preprint):

```
  C O - S I M U L A T I O N    R E G I O N S
    REGION NAME: PLANE
      REGION ID:       11
      REGION TYPE: SURFACE
      IMPORTED QUANTITIES:
                         CF
      EXPORTED QUANTITIES:
                         COORD
                         NODALMASS
                         THICKNESS
                         BULKMOD
```

Know Issues

- Surfaces defined for co-simulation must be such that no nodes are shared with each other.

- Abaqus/Explicit analysis will continue, after the co-simulation has finished, until the Abaqus end time is reached.

LS-DYNA Part of the Coupling

- General
- Basic Coupling
- Extended Coupling
- Verification
- Known Issue

GENERAL: LS-DYNA Main Adjustment Steps

- For both basic and extended coupling:
  *CONTROL_COUPLING,
    - to define the units relation between both codes
  *CONTROL_PARALLEL
    - to define the number of CPU's for SMP jobs

- For basic coupling:
  *PART, *SECTION_SHELL, *MAT_RIGID and *CONTACT_ENTITY
    - to define the ellipsoids and/or planes
    - Contacts between LS-DYNA FE and MADYMO ellipsoids/planes are evaluated in LS-DYNA

- For extended coupling:
  SET (*SET_PART,*SET_SHELL,*SET_SOLID)
  *CONTACT_COUPLING
    - to define the elements to be used in the contact interaction within MADYMO

Note: Input cards based on LS-DYNA 971 format. See LS_DYNA manuals for details on LS_DYNA syntax.

General: LS-DYNA Units

- Three consistent unit ranges are available in LS-DYNA.
  1. m, s, kg and N
  2. mm, s, tonne and N
  3. mm, ms, kg and kN

- A unit correction needs to be made if a LS-DYNA model does not have SI units within the *CONTROL_COUPLING element.

  Example see next slides:

General: LS-DYNA Units

Example:

***CONTROL** ***CONTROL_COUPLING**

***CONTROL_COUPLING**

Purpose: Change defaults for MADYMO3D/CAL3D coupling, see Appendix I.

Card 1

1	2	3	4	5	6	7	8
Variable	UNLENG	UNTIME	UNFORC	TIMIDL	FLIPX	FLIPY	FLIPZ	SUBCYL
Type	F	F	F	F	I	I	I	I
Default	1.	1	1.	0.	0	0	0	1

VARIABLE	DESCRIPTION
UNLENG	Unit conversion factor for length. MADYMO3D/GM-CAL3D lengths are multiplied by UNLENG to obtain LS-DYNA lengths.
UNTIME	Unit conversion factor for time, UNTIME. MADYMO3D/GM-CAL3D time is multiplied by UTIME to obtain LS-DYNA time.
UNFORC	Unit conversion factor for force, UNFORC. MADYMO3D/GM-CAL3D force is multiplied by UNFORC to obtain LS-DYNA force.

General: LS-DYNA Units

Example:

*CONTROL *CONTROL_COUPLING

*CONTROL_COUPLING

Purpose: Change defaults for MADYMO3D/CAL3D coupling, see Appendix I.

Card 1	1	2	3	4	5	6	7	8
Variable	UNLENG	UNTIME	UNFORC	TIMIDL	FLIPX	FLIPY	FLIPZ	SUBCYL
Type	F	F	F	F	I	I	I	I
Default	1000	1	1.	0.	0	0	0	1

Means: Used LS-DYNA Units: mm, seconds and N

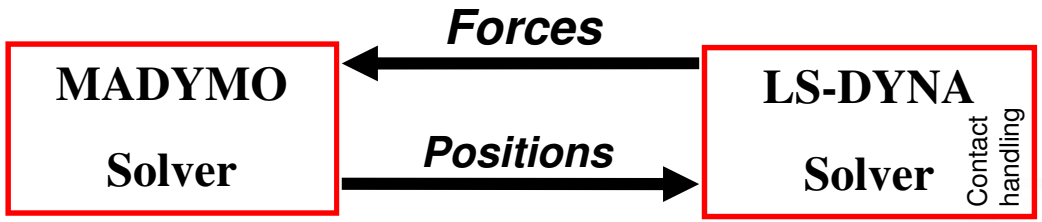
General: LS-DYNA Units

Defined units are listed in the LS-DYNA d3hsp file

```
CONTROL CARD 17. Computation Options-Coupling

    length conversion factor coupling.............    0.1000E+04

    time conversion factor coupling...............    0.1000E+01

    force conversion factor coupling..............    0.1000E+01
```

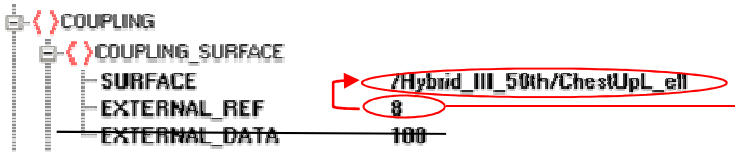
Basic Coupling Adjustments to LS-DYNA Input Deck

- For each MADYMO ellipsoid and/or plane a separate PART, MATERIAL and CONTACT_ENTITY has to be defined.
- The SECTION_SHELL can, optional, be re-used
- The DEGREE (shape) of the MADYMO ellipsoid is taken into account automatically in LS-DYNA.
- Cycle



Basic Coupling Adjustments to LS-DYNA Input Deck

- MADYMO Coupling Definition



EXTERNAL_DATA is ignored, although mandatory

- Define *MAT_RIGID for the parts that represent ellipsoids/planes

```
*MAT_RIGID
$#      MID          RO           E          PR           N     COUPLE          M   RE/ALIAS
$       mid          ro           e          pr   ellipsd#   mesh/y/n    system#   re/alias
         57.8199E-09   206800.0.30000001        -2.         2.         1.         8.
$#      CMO         CON1         CON2
         0.           0.           0.
$#       A1           A2           A3          V1          V2          V3
         0.           0.           0.          0.          0.          0.
```

- Define *SECTION_SHELL for the ellipsoid/plane parts

```
*SECTION_SHELL
$#    SECID     ELFORM       SHRF        NIP      PROPT         QR      ICOMP
          2          2       0.83         0.         0.         0.          0
$#       T1         T2         T3         T4
         1.         1.         1.         1.
```

- Define for each ellipsoid and/or planes a *PART

```
*PART
$#
$#      PID      SECID        MID      EOSID      HGID       GRAV    ADPOPT       TMID
          3          2          5          0         0          0         0          0
```

to *CONTACT_ENTITY

Basic Coupling Adjustments to LS-DYNA Input Deck

```
*MAT_RIGID
$#      MID        RO         E        PR         N    COUPLE         M  RE/ALIAS
$       mid        ro         e        pr  ellipsd#  mesh/y/n   system#  re/alias
          57.8199E-09    206800.0.30000001       -2.         2.        1.         8.
$#      CMO      CON1      CON2
          0.         0.        0.
$#       A1         A2        A3        V1        V2        V3
          0.         0.        0.        0.        0.        0.
```

- COUPLE: Set to 2 to generate a mesh in LS-DYNA of MADYMO ellipsoids/planes and write these out in the d3plot files
- RE/ALIAS: MADYMO External Reference number. This number must match the EXTERNAL_REF number of the MADYMO ellipsoid or plane. This must be a unique number for each coupled entity.

Basic Coupling Adjustments to LS-DYNA Input Deck

- Define *CONTACT_ENTITY to enable contact for the parts representing the MADYMO ellipsoid/plane

```
$--------|---------|---------|---------|---------|---------|---------|---------|
*CONTACT_ENTITY
$#      PID     GEOTYP      SSID      STYP        SF        DF        CF    INTORD
         3          7         1         2        1.        0.        0.         0
$#       BT        DT        SO        GO
         0.        0.         0         0
$#       XC        YC        ZC        AX        AY        AZ
         0.        0.        0.        1.        0.        0.
$#       BX        BY        BZ
         0.        1.        0.
$#    INOUT        G1
            0        0.
```

- PID: Part ID of the ellipsoid/plane
- GEOTYP: Geometric entity;6=Plane, 7=Ellipsoid
- SSID/STYP: The Slave set ID of selected LS-DYNA elements for contact purpose.
- SO: Contact Stiffness;
  - 0:Rigid MADYMO ellipsoid or plane (*Commonly used*)
  - 1:Contact stiffness from E of *MAT_RIGID
  - 2:User defined force-penetration curve

Basic Coupling Adjustments to LS-DYNA Input Deck

- Element *CONSTRAINED_EXTRA_NODES_NODE
  - This element supports LS-DYNA (nid) nodes to MADYMO MB surface (pid)
  - E.g. to connect a LS-DYNA steering column to a MADYMO airbag

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$$$$   *CONSTRAINED_EXTRA_NODES_NODE
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$  Rigidly attach nodes 285 and 4576 to part 14.  (Part 14 MUST be a rigid body.)
$
*CONSTRAINED_EXTRA_NODES_NODE
$
$...>....1....>....2....>....3....>....4....>....5....>....6....>....7....>....8
$      pid       nid
         14       285
         14      4576
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
```

Example from a d3hsp file:

```
e x t r a   n o d e s   f o r   r i g i d   b o d i e s

 the  following nodes have been added to part        14:
   285  4576
```

Basic Coupling Adjustments to LS-DYNA Input Deck

- Element *CONSTRAINED_RIGID_BODIES
  - To connect LS-DYNA (slave) rigid bodies to a MADYMO (master) MB surfaces.

Card	1	2	3	4	5	6	7	8
Variable	PIDM	PIDS						
Type	I	I						
Default	none	none						

VARIABLE	DESCRIPTION
PIDM	Master rigid body part ID, see *PART.
PIDS	Slave rigid body part ID, see *PART.

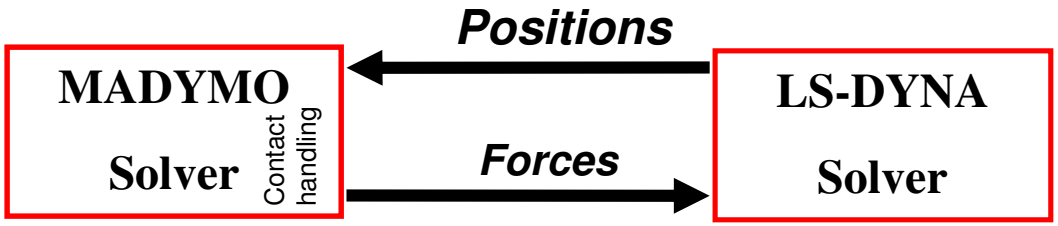
Example from a d3hsp file:

```
r i g i d   b o d y   m e r g e   c a r d s

     rigid body       143 becomes part of rigid body         3
```

It's recommended not to use this option.

Extended Coupling Adjustments to LS-DYNA Input Deck

- Define a SET_PART/SOLID/SHELL and a CONTACT_COUPLING card
- Validated contact characteristics of MADYMO dummy models can be used
- Cycle



Extended Coupling Adjustments to LS-DYNA Input Deck

- Define *SET_PART, *SET_SHELL and/or SET_SOLID in LS-DYNA for contact interaction purpose within MADYMO.
  - *SET_PART

Card 1	1	2	3	4	5	6	7	8
Variable	SID	DA1	DA2	DA3	DA4			
Type	I	F	F	F	F			
Default	none	0.						
Remark		1	1	1	1			

Card 2, 3, 4, ... (*OPTION*=LIST or <BLANK>) (The next "*" card terminates the input.)

Card 2,...	1	2	3	4	5	6	7	8
Variable	PID1	PID2	PID3	PID4	PID5	PID6	PID7	PID8
Type	I	I	I	I	I	I	I	I

SID: Unique SET_PART ID
PID*: selected part numbers

Example:

```
*SET_PART
                1
$--------|---------|---------|
                1         5         4
```

  - *SET_SHELL and SET_SOLID do work in a similar way: See LS-DYNA reference manual

Extended Coupling Adjustments to LS-DYNA Input Deck

- Define *CONTACT_COUPLING in LS-DYNA

Card 1	1	2	3	4	5	6	7	8
Variable	ID							
Type	I							
Default	required							

Cards 2, 3, 4, ... Define as cards as necessary. The next "*" card terminates this input.

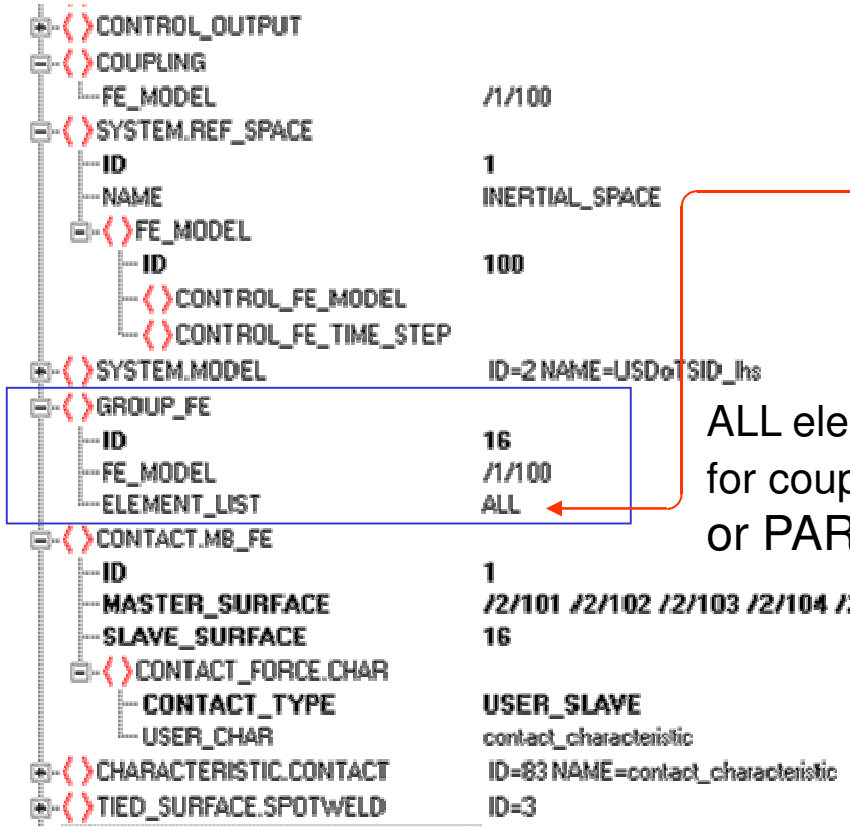
Cards 2,3,..	1	2	3	4	5	6	7	8
Variable	SID	STYPE						
Type	I	I						
Default	required	0						

VARIABLE	DESCRIPTION
SID	Set ID for coupling. See Remark 1 below.
STYPE	Set type: EQ.0: part set EQ.1: shell element set EQ.2: solid element set EQ.3: thick shell element set

Note: Only one coupling surface can be defined.
Additional defined surfaces are added to the first set.

Extended Coupling Adjustments to LS-DYNA Input Deck

Example



LS-DYNA input: part nr 1 is defined in set part nr 10, this set is supplied to the contact coupling nr 2. LS-DYNA Part nr 1 can be used in MADYMO.

```
*SET_PART
10
1
*CONTACT_COUPLING
2
10
```

ALL elements are selected that are defined in LS-DYNA for coupling. However, also selection by NODE _LIST or PART_LIST or element sub-selection is possible e.g.

Basic Coupling Verification

- The reprint file shows all data sent to LS-DYNA, d3hsp file shows all data received from MADYMO. E.g.
  - reprint file:

```
SURFACE ....................................: /2/2
     EXTERNAL REFERENCE .....................:          2
     EXTERNAL DATA ..........................:
       NUMBER ..:          1  DATA ..:      1.0000E+01
```

  - d3hsp

```
part     id .....................          3
 section  id .....................           2
 material id.....................           3
..
..
 madymo external number             = 2.00000E+00
 madymo coupling flag ............. = 2.00000E+00
```

Note:d3hsp contains more info regarding the coupling

Extended Coupling Verification

- The reprint file shows all data received from LS-DYNA, d3hsp file shows all data sent to MADYMO. E.g.
  - reprint file:

```
NUMBER OF NODES .....................:        256
NUMBER OF PARTS .....................:          1
  PART ID (FROM COUPLED PROGRAM) .....:          1
    THICKNESS ........................:     1.0000E-03
    BULK MODULUS .....................:     1.5682E+11
NUMBER OF ELEMENTS ..................:        225
  NUMBER OF TRIADS ..................:          0
  NUMBER OF QUADS ...................:        225
  NUMBER OF SOLIDS ..................:          0
```

  - d3hsp

```
c o n t a c t   c o u p l i n g

contact coupling interface ID     =       1
number of part IDs                =       1
number of shell element IDs       =       0
number of solid element IDs       =       0
number of solid-shell element IDs =       0

shell element ID list for coupling:
        1         2         6       ..  225
```

    - ???

```
input summary including part IDs:
number of part IDs                =     256
number of unique nodal points     =       1
number of shell elements          =     225
number of solid elements          =       0
number of solid-shell elements    =       0
```

Know Issue

- If MADYMO end time is larger than the LS-DYNA end time, MADYMO writes out twice a termination line to the log file, although the reprint file only write out the first line.
  - First: MADYMO TERMINATED NORMALLY
  - Secondly: MADYMO TERMINATED ABNORMALLY, because of errors

- Workaround: Make both end times identical

Normal/Abnormal Termination Issue

```
Directory          : /mnt/usr4/people/montfos/iedereen/coupling/ex03-NewStyle_R64/03a
User               : Sjef van Montfort  <montfos@wtma58>
Total CPU time     :          23.7 sec (    0 hours  0 minutes 23 seconds)
Total elapsed time :          29.4 sec (    0 hours  0 minutes 29 seconds)

MADYMO TERMINATED NORMALLY, but    1 warning(s) were found
Terminated by MADYMO at time = 5.00000E-02

MADYMO received TERMINATION request by external program

MADYMO TERMINATED ABNORMALLY, because of ERRORS.
   3949 t 5.0017E-02 dt 1.24E-05 write d3dump01 file
   3949 t 5.0017E-02 dt 1.24E-05 write d3plot file

N o r m a l    t e r m i n a t i o n


Memory required to complete solution   :       819814
Additional dynamically allocated memory:        31863
                                 Total:       851677

T i m i n g   i n f o r m a t i o n
                     CPU(seconds)    %CPU  Clock(seconds) %Clock
 ================================================================
 Initialization ..... 5.9000E-01    2.35     1.0964E+00    3.70
 Element processing ... 1.1140E+01   44.29     1.1871E+01   38.02
 Binary databases ..... 3.5000E-01    1.39     4.0381E-01    1.36
 ASCII database ....... 3.3000E-01    1.31     3.5435E-01    1.20
 Contact algorithm .... 1.9999E-02    0.08     2.8532E-02    0.10
 Contact entities ..... 0.0000E+00    0.00     0.0000E+00    0.00
 Rigid bodies ......... 9.5500E+00   37.97     9.5718E+00   32.28
 Implicit Nonlinear ... 0.0000E+00    0.00     0.0000E+00    0.00
 Implicit Lin. Alg. ... 0.0000E+00    0.00     0.0000E+00    0.00
 Coupling MADYMO ...... 3.1700E+00   12.60     6.9227E+00   23.35
 ================================================================
 T o t a l s            2.5150E+01  100.00     2.9649E+01  100.00

Problem time       =    5.0017E-02
Problem cycle      =      3949
Total CPU time     =        25 seconds (   0 hours  0 minutes 25 seconds)
CPU time per zone cycle  =       774 nanoseconds
Clock time per zone cycle=       899 nanoseconds

Number of CPU's    1
NLQ used/max     253/  253
Start time   08/21/2007 18:15:42
End time     08/21/2007 18:16:12
Elapsed time      30 seconds(  0 hours  0 min. 30 sec.) for    3949 cycles

N o r m a l    t e r m i n a t i o n
```

PamCrash Part of the Coupling

- General
- Basic Coupling
- Extended Coupling
- Verification
- Known Issue

GENERAL: PamCrash Main Adjustment Steps

- For both basic and extended coupling:
  - Add COUPLING MADYMO
    - to activate the coupling
  - Set OMP_NUM_THREADS PamCrash environment variable
    - Must be identical to MADYMOs nr_proc
- For basic coupling:
  - Define PART and MATERIAL cards for each MADYMO entity.
  - Define contact
- For extended coupling:
  - Define MDBODY card for each PamCrash entity.

Note: Input cards based on PC/SAFE 2005 format. See PamCrash manuals for syntax details.

General: Coupling

- Define COUPLING MADYMO within the PamCrash control section.

Coupling Keyword Card (Optional)

Columns	Item	Format	Name	*version/option*
1	**COUPLING MADYMO** **MADYMO**: for coupling with MADYMO (TNO)	free		

Notes:

- **COUPLING MADYMO** will couple PAM-CRASH / PAM-SAFE V2004 or higher and MADYMO 6.2 or higher
- If the **COUPLING** card is omitted no coupling but a standard solver run is carried out.
- **MADYMO** keyword is mandatory.
- For further information, see also additional documentation or contact your local ESI Group support team.

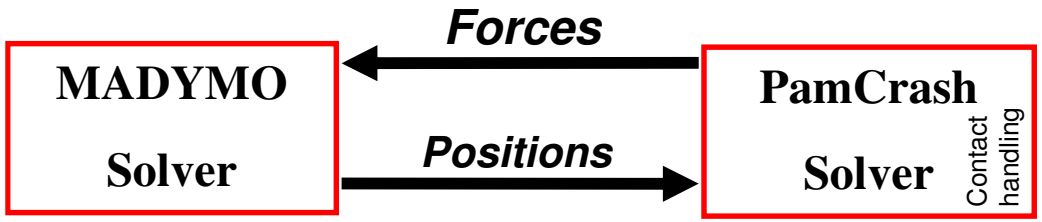
- Only SI-units allowed

- From the MADYMO/PamCrash log file

```
OPTIONS USED :
------------

      1.  SOLVER        : CRASH
      2.  ANALYSIS      : EXPLICIT
      3.  FILE          : boule3
      4.  COUPLING      : MADYMO
```

Basic Coupling Adjustments to PamCrash Input Deck

- For MADYMO ellipsoids and/or planes a PART, MATERIAL and contact has to be defined.
- The DEGREE (shape) of the MADYMO ellipsoid is taken into account automatically in PamCrash.
- Cycle



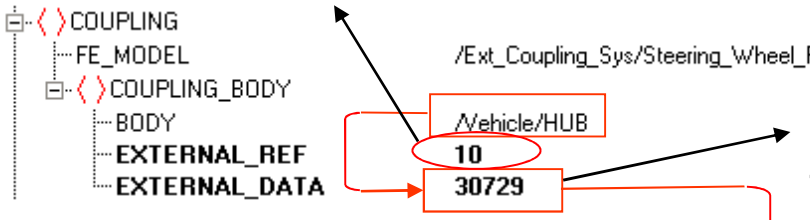
Basic Coupling Adjustments to PamCrash Input Deck

- Define a COUPLING_BODY in MADYMO.
  - 1st value in EXTERNAL_DATA refers to PamCrash node number that will be tied to the Body centre of Gravity.
- Define a COUPLING_SURFACE in MADYMO.
  - PART identifier should be identical to the first EXTERNAL_DATA value.
  - 2nd value in EXTERNAL_DATA refers to the mesh density of an ellipsoid.
- Define a PART and MATERIAL (type 100) in PamCrash for the surfaces to be received from MADYMO
- Define contacts in PamCrash

Basic Coupling Adjustments to PamCrash Input Deck

- Example Rigid Body
  - MADYMO

EXTERNAL_REF is ignored, although mandatory



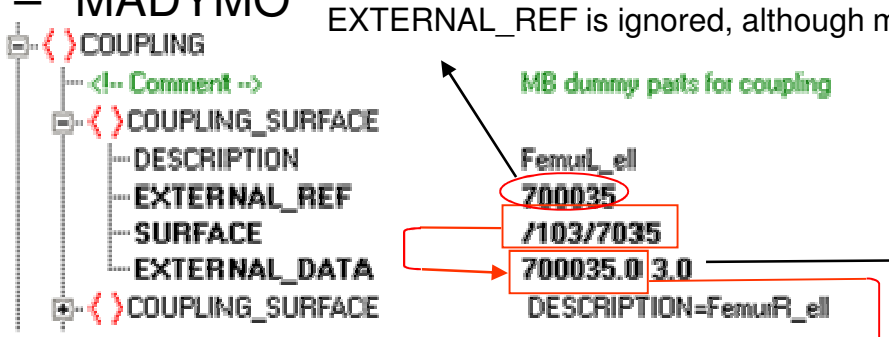
PC Node number that will be tied to the Body centre of Gravity

  - PamCrash

```
NODE   /     30729        2.7479956        0.3514169       0.82089777          0
SHELL  /     30023      143   30720    30721    30729    30728        3 0.0
SHELL  /     30024      143   30721    30722    30730    30729        3 0.0
SHELL  /     30031      143   30728    30729    30737    30736        3 0.0
SHELL  /     30032      143   30729    30730    30738    30737        3 0.0
```

Basic Coupling Adjustments to PamCrash Input Deck

- Example Surfaces
  - MADYMO



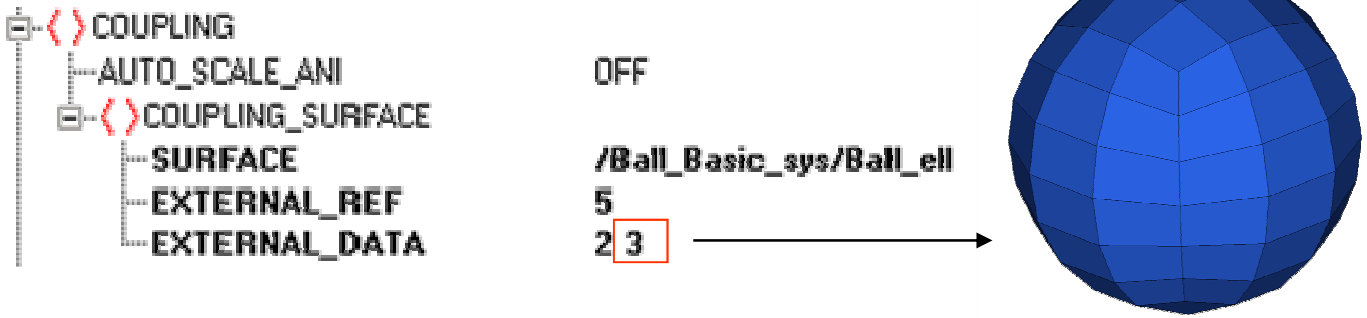
  - PamCrash

```
PART  /   700035   SHELL  700001
NAME MADYMO FemurL_ell
0.0
0.0
 1.730E-06    1

END_PART
$ ---5---10----5---20----5---30----5---40----5---50----5---60----5---70-
MATER /   700001     100 999.999              0       0       1       0
                                                    1.0             0

NAME MADYMO ellipsoid 1
 1.000E+09           0.35
```

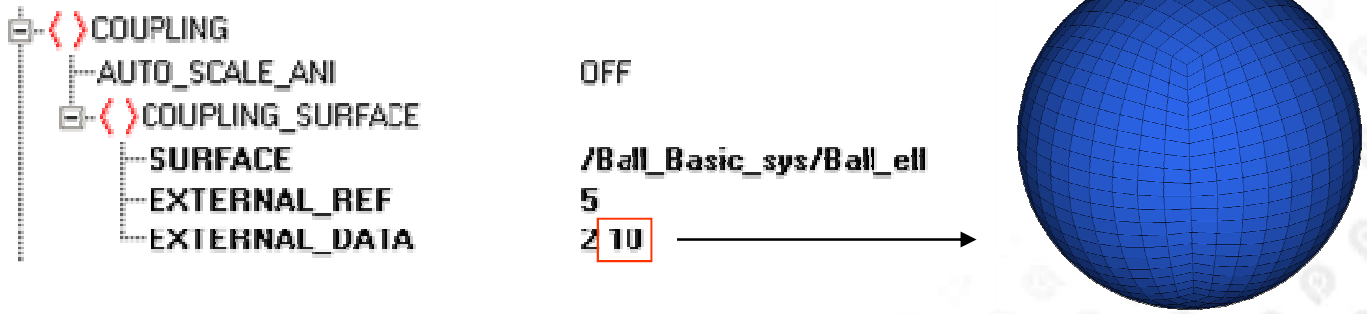
Material type 100

Basic Coupling Adjustments to PamCrash Input Deck

- Example
  - Density 3



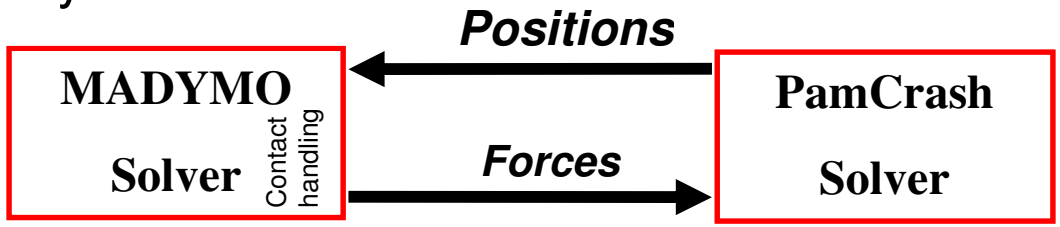
  - Density 10



Note: A finer mesh will result in a smoother surface but also in longer CPU times

Extended Coupling Adjustments to PamCrash Input Deck

- Define MBBODY cards
- Validated contact characteristics of MADYMO dummy models can be used
- Cycle



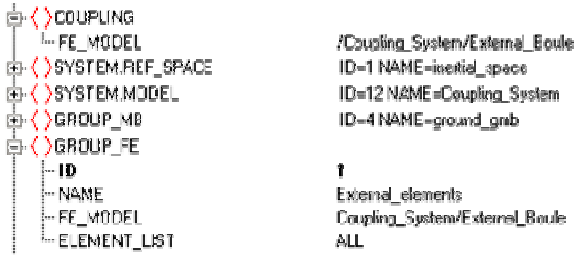
Extended Coupling Adjustments to PamCrash Input Deck

- Define MDBODY cards in PamCrash
  - The MDBODY card has to be defined for each deformable body
  - If no thickness or bulk modulus is defined within the MDBODY card, PamCrash will calculated average values for these
  - The IDCVS nr of MDBODY can be used e.g. within a GROUP_FE of MADYMO
  - IDCVS nr does not work if the CTYPE is NODE. Refer within MADYMO to the individual PamCrash nodes.

- Define contacts in MADYMO

Extended Coupling Adjustments to PamCrash Input Deck

- Example
  - MADYMO



  - PamCrash

```
$---5---10----5---20----5---30----5---40----5---50----5---60----5---70----5---80
MDBODY/         1SHELL
NAME boule
        PART 1
        END
$
```

Part one of type shell is sent to MADYMO with id nr. 1

CARD 1

Columns	Item	Format	Name	version option
1-8	Keyword **MDBODY/**	A8		
9-16	FE deformable body identification number	I8	IDMDBO	
17-24	Body's FE mesh type: **SHELL** **SOLID** **NODE**	 A5, 3X A5, 3X A4, 4X	CTYPE	
25-32	Average Bulk Modulus to be used by MADYMO contact	E8.0	BULK	
33-40	Average thickness to be used by MADYMO contact	E8.0	THICK	
41-48	External identifier to be referenced in MADYMO	I8	IDCVS	

CARDS 2 for FE Deformable Body Title

Columns	Item	Format	Name	version option
1-4	Keyword **NAME**	A4		
5-80	Title	A76	TITLE	

Note:PamCrash calculate (and provides to MADYMO) average values for BULK and/or THICK if not user defined

Basic Coupling Verification

- The reprint file shows all data sent to PamCrash, PC log file shows all data received from MADYMO. E.g. for Rigid Bodies
  - reprint file:

```
----------------- COUPLING ------------------------------

 COUPLING
    FE_MODEL ..................................: /3/100 ( /Ext_Coupling_Sys/Steering_Wheel_Fem )
    OUTPUT SCALING.............................: OFF
    BODY ......................................: /Vehicle/HUB
      EXTERNAL REFERENCE ......................:         10
      EXTERNAL DATA ...........................:
        NUMBER ..:          1  DATA ..:      3.0729E+04
    COUPLING TYPE .............................: COMBINED

-------------- END COUPLING ------------------------------
```

  - PC log file (e.g. readable in the MADYMO log file)

```
*** SETUP MODE SUCCESSFULLY READ FROM MADYMO **


      NUMBER OF COUPLED ENTITIES .........         1
      NUMBER OF COUPLED ELLIPSOIDS .......         0
      NUMBER OF TIED NODES  ..............         1
      NUMBER OF PLANES ...................         0

      COUPLING ENTITY NO .................         1 (TIED NODE)
      SYSTEM NUMBER ......................         1
      BODY NUMBER ........................         1
      NODE NUMBER TO BE TIED TO THE BODY .     30729

      TOTAL NUMBER OF GENERATED NODES.....         0
      TOTAL NUMBER OF GENERATED SHELLS....         0
```

Basic Coupling Verification

- The reprint file shows all data sent to PamCrash, PC log file shows all data received from MADYMO. E.g. for surfaces
  - reprint file:

```
---------------------------------- COUPLING ------------------
 COUPLING
    FE_MODEL .....................................:
      SURFACE ....................................: /2/1
    EXTERNAL REFERENCE ...........................:         10
    EXTERNAL DATA ................................:
    NUMBER ..:          1  DATA ..:      1.0000E+00
    NUMBER ..:          2  DATA ..:      3.0000E+00

---------------------------------- END COUPLING ----------------
```

  - PC log file (e.g. readable in the MADYMO log file)

```
 *** SETUP MODE SUCCESSFULLY READ FROM MADYMO **


NUMBER OF COUPLED ENTITIES .........         1
NUMBER OF COUPLED ELLIPSOIDS .......         1
NUMBER OF TIED NODES  ..............         0
NUMBER OF PLANES ...................         0

COUPLING ENTITY NO .................         1 (ELLIPSOID)
SYSTEM NUMBER ......................         1
ELLIPSOID NUMBER ...................         1
ASSIGNED MATERIAL NUMBER (TYPE 100).         1
AUTOMATIC MESH GENERATION DENSITY ..         3
NUMBER OF GENERATED NODES ..........        92
NUMBER OF GENERATED NULL SHELLS ....        90

TOTAL NUMBER OF GENERATED NODES.....        92
TOTAL NUMBER OF GENERATED SHELLS....        90
```

Extended Coupling Verification

- The reprint file shows all data received from PamCrash, PamCrash log file shows all data sent to MADYMO. E.g.
  - reprint file:

```
----------------------------COUPLING INTERFACE-----------
 NUMBER OF NODES                          :          92
 NUMBER OF PARTS                          :           1
   PART ID (FROM COUPLED PROGRAM)         :           3
     THICKNESS                            :      3.5000E-04
     BULK MODULUS                         :      1.1111E+09
 NUMBER OF ELEMENTS                       :          90
   NUMBER OF TRIADS                       :           0
   NUMBER OF QUADS                        :          90
   NUMBER OF SOLIDS                       :           0
```

  - PC log file (e.g. readable in the MADYMO log file)

```
F E   B O D Y   F O R   M A D Y M O


    FE DEFORMABLE BODY ID ............ =           2
    FE DEFORMABLE BODY NAME .......... = boule
    BODY MESH TYPE ................... = SHELL
    REFERENCE ID IN MADYMO CONTACT ... =           3
    AVERAGE BULK MODULUS ............. =  0.1111E+10
    AVERAGE THICKNESS ................ =  0.3500E-03


    NUMBER OF ASSOCIATED SHELLS ...... =          90

              LIST OF SHELLS TRANSFERRED TO MADYMO:
```

Known Issue

- Increase MADYMO simulation end time if the animation file DSY does not write the last frame.

Radioss Part of the Coupling

- General
- Basic Coupling
- Extended Coupling
- Verification
- Restart
- Known Issue

GENERAL: Radioss Main Adjustment Steps

- For both basic and extended coupling:
  - Add /MADYMO/ON in D01 Radioss ENGINE file.
    - to activate the coupling
  - Define the Radioss units. Lunit Tunit Munit

- For basic coupling in the D00 file:
  - Contacts: INTER/TYPE14* and/or /INTER/TYE15
  - Support of Radioss node to MADYMO RB: /MADYMO/LINK/
  - Transfer of a MADYMO ellipsoid to Radioss: /SURF/MDELLIPS/

- For extended coupling in the D00 file:
  - Define /MADYMO/EXFEM/exfem_id/exfem_title
    - exfem_id is the FEM identification number
    - exfem_title is the FEM identification number
  - Define the parts that needs to transfer data

Notes: -Input cards based on Radioss 5.1 format. See Radioss manuals for syntax details.
-TYPE 15 is less CPU friendly than TYPE 14

GENERAL

- The simulation end time of MADYMO is used. The Radioss end time is ignored.

- Radioss /MODIF option is not supported in the coupling

Note: Input cards based on Radioss 2005 format. See Radioss manuals for syntax details.

General: Radioss Units

- Radioss Input in D01 file

/MADYMO/ON

l_{unit} t_{unit} m_{unit}

- Activates MaDyMo-RADIOSS coupling.

- l_{unit} Length unit conversion factor, must be 1 meter in RADIOSS model unit
- t_{unit} Time unit conversion factor, must be 1 second in RADIOSS model unit
- m_{unit} Mass unit conversion factor, must be 1 Kg in RADIOSS model unit

- Example (Radioss Input & output)

```
/MADYMO/ON      =>   MADYMO TO RADIOSS LENGTH SCALE FACTOR  . . . . .   0.10E+04
1000 1 1
                     MADYMO TO RADIOSS TIME SCALE FACTOR  . . . . . .   0.10E+01
                     MADYMO TO RADIOSS MASS SCALE FACTOR  . . . . . .   0.10E+01
```

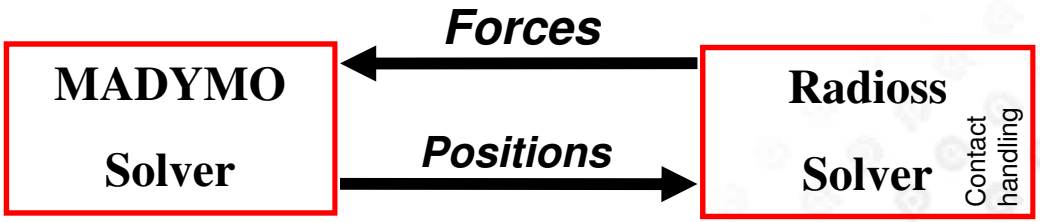
Means: Used Radios Units: mm, seconds and kg

Basic Coupling Adjustments to Radioss Input Deck

- To be defined in the D00 Radioss file:
  - /INTER/TYPE14 defines contact between an ellipsoid an a node set. Elastic based contact. High penetrations allowed but requires a fine mesh.
  - /INTER/TYPE15 defines contact between an ellipsoid an a element set. Penalty based contact. Able to handle a coarser mesh better
  - /MADYMO/LINK/ enables to support a Radioss node to a MADYMO Body.
  - /SURF/MDELLIPS/ transfers a MADYMO ellipsoid to Radioss.
  - To visualize a MADYMO plane within Radioss only a COUPLING_SURFACE element of the plane within MADYMO is needed. No definition within Radioss.

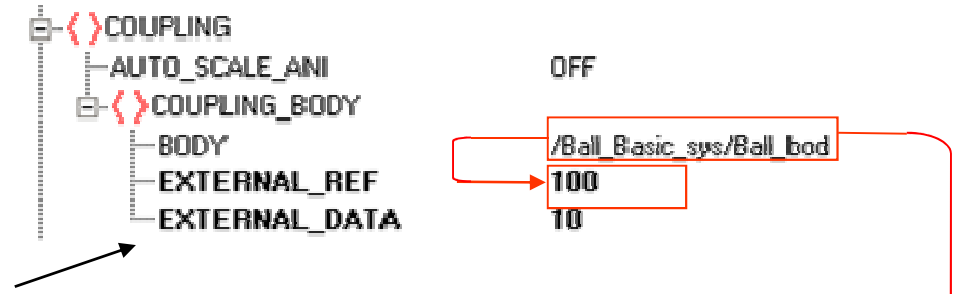
- The DEGREE (shape) of the MADYMO ellipsoid is taken into account automatically in Radioss.

- Cycle



Example: Basic Coupling Adjustments to Radioss Input Deck

- Example Rigid Body
  - MADYMO



  - Radioss

```
/MADYMO/LINK/3/connecter
     100      41
/NODE
 41              40.0            40.0            0.0
```

The MADYMO body Ball_bod is communicated to Radioss the external ref number 100. Within Radioss this refers to node 41

Example: Basic Coupling Adjustments to Radioss Input Deck

- MADYMO RB and Radioss node are one entity. Mass, Inertia and COG of this entity are identical to MADYMO RB. For that, the Radioss node mass has to be small compared to the MADYMO RB mass.

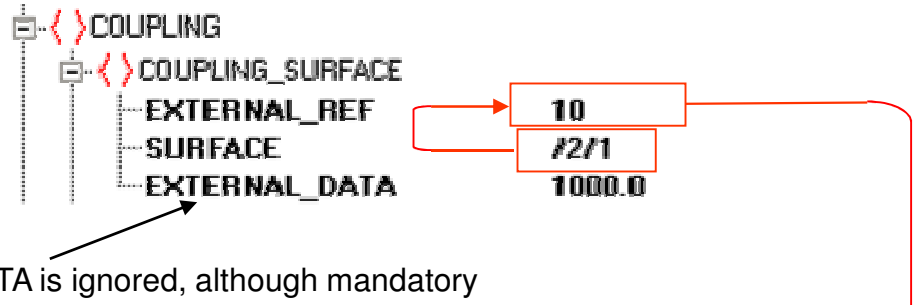
- Since the movement of the Radioss node is set by the MADYMO body the “LINK” is a kinematic condition. For that no other kinematic constraint is allowed of this Radioss node.

- If the linked node is the master node of a rigid body within Radioss as well, the inertia of this RB must be set to spherical.

- An error will be generated by Radioss if a “LINKED” node is also defined within extended coupling data exchange.

Example: Basic Coupling Adjustments to Radioss Input Deck

- Example Surface
  - MADYMO



  - Radioss

```
#--1---|---2---|---3---|---4---|---5---|---6---|---7---|---8---|---9---|--10---|
/SURF/MDELLIPS/1010/The first madymo coupl'd surface
      10
#--1---|---2---|---3---|---4---|---5---|---6---|---7---|---8---|---9---|--10---|
/INTER/TYPE15/  427/ball-plane-cnt
1         1010
      0.10000E+04     0.40000
/SURF/SEG/      1/Plane_cnt
#--1---|---2---|---3---|---4---|---5---|---6---|---7---|---8---|---9---|--10---|
       1       1       10      11       2
       2       2       11      12       3
```

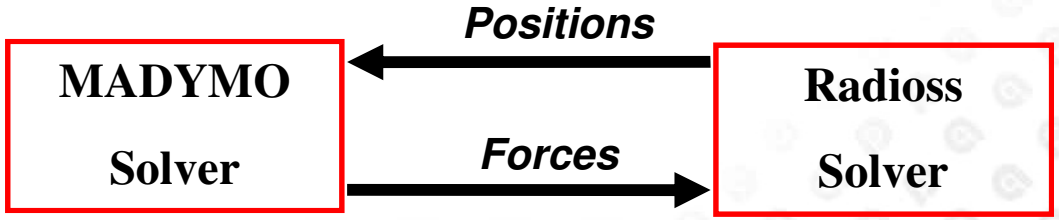
The MADYMO ellipsoid /2/1 is communicated to Radioss by the external ref number 10. Contact nr 427 is defined between the MADYMO ellipsoid and Radioss Plane.

Extended Coupling Adjustments to Radioss Input Deck

- Define /MADYMO/EXFEM/exfem_id/exfem_title
  - exfem_id and exfem_title are not transferred to MADYMO
  - Contact can be defined between Radioss parts and MADYMO MB and FE. The Radioss parts must be either 4 node shell, 3 node shells or 8 node bricks.
  - /MADYMO/LINK cannot select a node belonging to these parts. Radioss STARTER generates an error for that.
  - Nodes of the selected parts can not be a slave node of an interface TYPE 2 or a rigid body within Radioss if these nodes receive contact forces from MADYMO. Radioss starter will write out a warning.

```
** WARNING :        1 INCOMPATIBLE CONDITION(S) ON NODE EXCHANGED WITH MADYMO     1302:
                                                                    - RIGID BODY
```

- Define the integer parts ID's of Radioss to be exchanged to MADYMO
- Validated contact characteristics of MADYMO dummy models can be used
- Cycle



Example: Extended Coupling Adjustments to Radioss Input Deck

- Example
  - MADYMO

  - Radioss

```
/MADYMO/EXFEM/1/
       2
```

Radioss part 2 is communicated to MADYMO. This part number can be used within MADYMO.

Basic Coupling Verification

- The reprint file shows all data sent to Radioss, Radioss log file shows all data received from MADYMO. E.g.: Rigid Body
  - reprint file:

```
---------------------- COUPLING -------------------------------

  COUPLING
    FE_MODEL .....................................:
    OUTPUT SCALING................................: OFF
    BODY .........................................: /Ball_Basic_sys/Ball_bod
      EXTERNAL REFERENCE .........................:        100
      EXTERNAL DATA ..............................:
        NUMBER ..:           1  DATA ..:      1.0000E+01
    COUPLING TYPE ................................: BASIC
------------------- END COUPLING -----------------------------
```

  - Radioss .lis file

```
 RIGID LINKS TO MADYMO DEFINITIONS
      ---------------------------------

 ** INFO : SPECIFIC DATA RELATED TO MADYMO WILL BE CHECKED IN RADIOSS ENGINE.

          LINK IDENTIFIER . . . .         3
          RADIOSS NODE ID . . . .        41
          MADYMO BODY REFERENCE .       100
```

Basic Coupling Verification

- The reprint file shows all data sent to Radioss, Radioss log file shows all data received from MADYMO. E.g. Ellipsoid
  - reprint file:

```
---------------------- COUPLING ------------------------------

COUPLING
   FE_MODEL ....................................: /1/100
     SURFACE ...................................: /2/1
   EXTERNAL REFERENCE ..........................:          10
   EXTERNAL DATA ...............................:
   NUMBER ..:           1  DATA ..:       1.0000E+03
     SURFACE ...................................: /4/1
   EXTERNAL REFERENCE ..........................:          11
   EXTERNAL DATA ...............................:
   NUMBER ..:           1  DATA ..:       2.0000E+03

------------------ END COUPLING ------------------------------
```

  - Radioss .lis file

```
EXTERNAL COUPLING TO SURFACE:     1001 The first madymo coupl'd surface
----------------------------

          SURFACE DEFINITION :
          --------------------
          REFERENCE TO MADYMO COUPLING SURFACE :        10
          CORRESPONDING DATA WILL BE READ IN RADIOSS ENGINE.
```

Extended Coupling Verification

- The reprint file shows all data received from Radioss, Radioss log file shows all data sent to MADYMO. E.g.
  - reprint file:

```
--------------------COUPLING INTERFACE------------------
 NUMBER OF NODES                          :        5776
 NUMBER OF PARTS                          :           1
   PART ID (FROM COUPLED PROGRAM)         :           2
     THICKNESS                            :      8.1000E-04
     BULK MODULUS                         :      6.9608E+10
 NUMBER OF ELEMENTS                       :        5625
   NUMBER OF TRIADS                       :           0
   NUMBER OF QUADS                        :        5625
   NUMBER OF SOLIDS                       :           0
```

  - Radioss .lis file

```
 FEM INTERFACED TO MADYMO DEFINITION
-----------------------------------

      FOLLOWING PARTS         WILL BE SENT TO MADYMO
         2

      FOLLOWING 4-NODES SHELL WILL BE SENT TO MADYMO
      2453      2454      2455      2456      2457      2458      2459      2460      2461      2462
      8073      8074      8075      8076      8077

      FOLLOWING 3-NODES SHELL WILL BE SENT TO MADYMO

      FOLLOWING BRICKS        WILL BE SENT TO MADYMO

      FOLLOWING NODES         WILL BE SENT TO MADYMO
      4308      4309      4310      4311      4312      4313      4314      4315      4316      4317
      4318      4319      4320
```

Restart

- Restart of a coupled MADYMO Radioss run is possible.
- More info how to enable a restart can be found in the MADYMO or RADIOSS coupling manual.

Known Issues

- Last animation file is not written if the simulation end time is a multiple of the output time step . If so, increase the end time slightly.

- A coupling run through RADTOOL is not possible

Running a Coupling Model

- General
  - Plug-In Approach
  - Command Line Interface
  - Performance
  - Licence Requirements
- MADYMO
- MADYMO-Abaqus
- MADYMO-LS-DYNA
- MADYMO-PamCrash
- MADYMO-Radioss
- Restart

Running a Coupling Model

- General
  - Plug-In Approach
  - Command Line Interface
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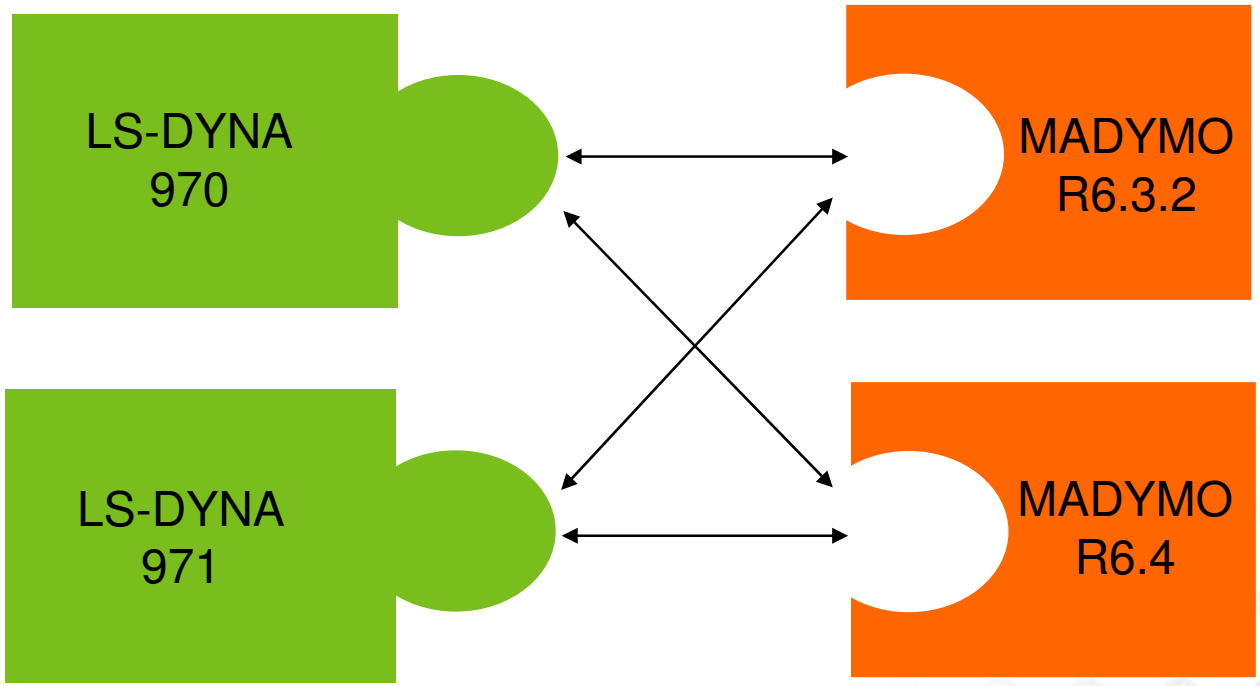
- MADYMO
- MADYMO-LS-DYNA

General: Plug-In Approach

- Combining MADYMO/PARTNER versions
  - As of R6.3, coupling is built as a plug-in for the partner executable.
  - This concept enables easy exchange of MADYMO and/or PARTNER versions.
  - The plug-in is a so-called shared library.
  - This shared library is now part of the MADYMO release, so it is directly available for each new MADYMO release, including patches
  - Example:
    - Customers that have a working MADYMO R6.4 / LS-DYNA 971 coupling can simply install a new MADYMO release to upgrade the coupling to this release.
      Similar, when LSTC releases a new version, customers can simply install that version to upgrade the coupling to this new version.

General: Plug-In Approach

- Plug-in approach allows easy coupling between different versions of codes.
  - Example



General: Plug-In Approach

- All MADYMO supported platforms are enabled except windows, PPC and Sun.
  - Security reasons currently prevent a coupling to be released on the windows platform.
  - PPC and Sun not requested by customers.
- Plug-in approach enables daily in-house QA-testing on both MADYMO and PARTNER side.
- All MADYMO coupling shared libraries are SMP.
- Can be used for coupling with SMP or MPP versions of the partner programs.

General: Command Line Interface

- The MADYMO command line interface madymo_cli can now generate an environment file (.madymo_env)
  - Generated by the command **madymo64 -show**
  - Should be done in the same directory as where MADYMO will be run

- The MADYMO executable will read the environment settings it needs from .madymo_env when it can't find the settings in the environment variables
  - This makes it easier to run MADYMO without the command line interface (e.g. for coupling and/or MPP)
  - When MADYMO is run without command line interface, or when the third party mpi (message passing interface) environment does not communicate these environment variables

General: Command Line Interface Example

.madymo_env contents:

MADETCPATH=/mnt/usr7/people/projects/DS/R64/DAB:/usr/local/tno/madamo_64/share/etc

MADINCPATH=/mnt/usr7/people/projects/DS/R64/DAB:/usr/local/tno/madymo_64/share/dbs/human/3d:/usr/local/tno/madymo_64/share/dbs/dummies/3d:/usr/local/tno/madymo_64/share/dbs/barriers:/usr/local/tno/madymo_64/share/dbs/tyres/inc:/usr/local/tno/madymo_64/share/etc

MADBINPATH =/mnt/usr7/people/projects/DS/R64/DAB:/usr/local/tno/madymo_64/x86_64-SLE9/bin

General: Performance

- Reducing the amount of data (nodes) to be exchanged between both codes will increase the performance significantly.

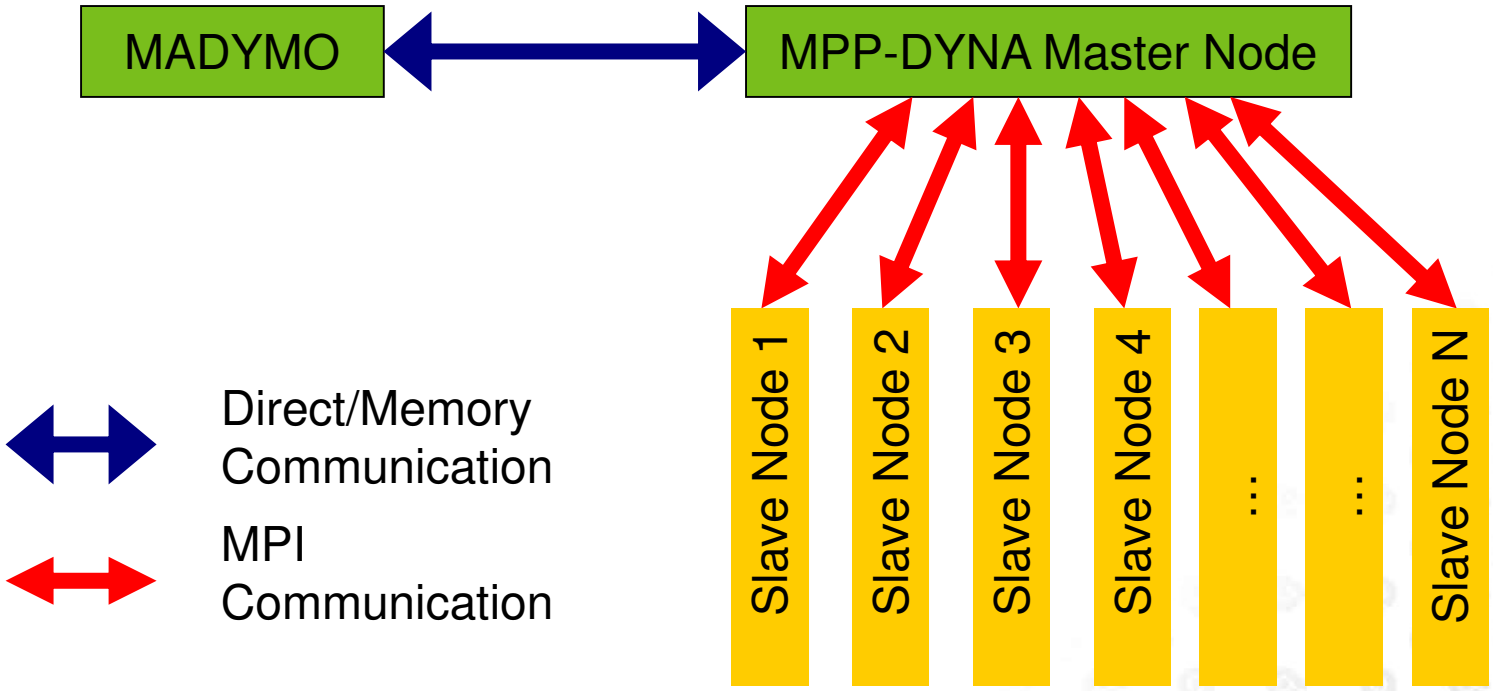
- Check Log/reprint file to see if simulation is well balanced.
  - MADYMO typically takes 5 to 15 % CPU time.
  - Example from reprint

```
Total Finite Element.....................    3109.3(  5%)      13.1(  1%)
Total Multi Body ........................      69.7(  0%)       0.7(  0%)
External program in coupling ............   63121.7( 95%)    2532.9( 99%)
Output ..................................      12.5(  0%)       0.7(  0%)
Filtering and injury ....................       0.8(  0%)       0.1(  0%)
```

- SMP-MPP especially: the ratio CPU/Wall clock time should be > 90%
  - Example from reprint

```
Total CPU time     :       66317.2 sec (   18 hours 25 minutes 17 seconds)
Total elapsed time :       74266.8 sec (   20 hours 37 minutes 46 seconds)
```

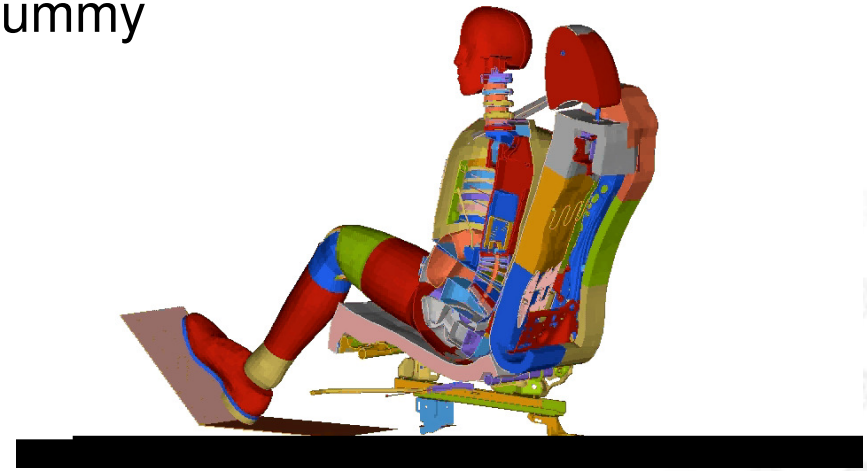
    - Ratio ≈ 0.9


MADYMO
MPP-DYNA Master Node
Slave Node 1
Slave Node 2
Slave Node 3
Slave Node 4
...
...
Slave Node N
Direct/Memory Communication
MPI Communication

Performance 2

Originally:

- 10k elements madymo facet dummy
- 70k elements seat
- 16 hours on 8cpu mppdyna



Changes:

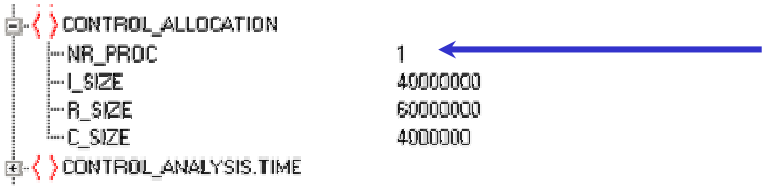
- Send half of the elements
  (only the 'dummy sided' elements)
- Replace solids by shells
  (4 nodes in stead of 8 nodes per element)
- Result: 9 hours

General: Performance

- If performance is not as expected:
  - More nodes allocated than available?
  - Bad network connection?
  - Wrong MPI version?
  - Large size of data exchange between codes?
    - Improvements e.g.:
      - Overlay solids in PARTNER with shell material and transfer only the shells.
      - Only the “contact surface” of a seat i.s.o. whole seat.
  - Test stand alone runs?
  - Total size of partner model compared to size of data sent to MADYMO small? **???**
  - Number of used CPU OK?

General: Performance

- For SMP-SMP runs the number of CPU's defined must be identical for both codes.



- SMP calculations are efficient to ~ 8 CPUs max.

- For SMP-MPP (MADYMO-PARTNER) the performance depends both on the used hardware and the input decks
  - Generally it's recommended to run MADYMO on 1CPU. However, it's best to test.

- MPP-MPP (MADYMO-PARTNER) not yet supported.

General: License Requirements

- In order to run a coupling run required are:
  - MADYMO software including coupling libraries and licenses
  - PARTNER software including coupling executable and licenses

- Example from the reprint file (MADYMO license part displayed only):

```
LICENSE MODULES USED FOR HOSTID 56A3E1E3 :
        MADYMO/Solver (Multibody)
        MADYMO/Solver (FEM)
        MADYMO/Dummy Models/Side
        MADYMO/Coupling/Extended LS-DYNA
        MADYMO/CPU ( 1)
```

MADYMO Installation

- Brief IT MADYMO installation summary
  - Install MADYMO according to the MADYMO Installation instructions.
  - Install the license file madymo.lic for MADYMO, necessary to run a (coupled) simulation.
  - Make the MADYMO run-script available to the user, e.g. by an alias or soft-link. This makes the coupling run commands shorter.

MADYMO-Abaqus coupling executable

- Contact the Abaqus support for the applicable coupling software package.

- This coupled analysis can be run in serial and parallel mode.

MADYMO-Abaqus Analysis Serial

- Install coupling executable from Abaqus Simulia:
- Arrange Abaqus licenses
- Convert the XML file to a SAF file
  - Madymo64 –sh
  - $MDPATH/bin/bsaf madymofile.xml madymofile.saf
  - exit
- E.g.: If the coupled executable, MADYMO and Abaqus input file are in the current directory in the current directory:

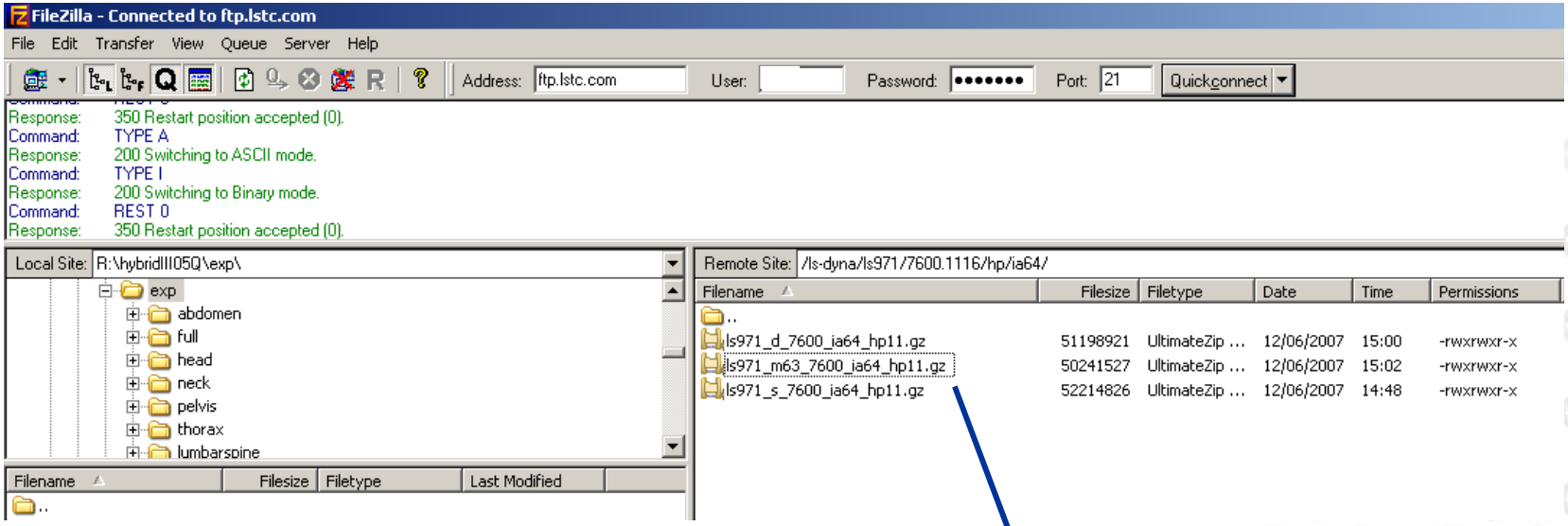
  abq66pr7b.exe job=Abaqusfile madymo=madymofile.saf

  Note: Abaqusfile is without .inp suffix

  Also use can be made of scripts to facilitate the starting procedure.
  Details can be found in the Abaqus coupling manual

MADYMO-LS-DYNA coupling executable

- For downloading the partner executable for coupling: ftp.lstc.com.



MADYMO Coupling for hp

- Or contact LS-DYNA support

LS-DYNA PARALLEL

- The number of CPUs is defined for an SMP job with the element: NCPU of *CONTROL_PARALLEL

*CONTROL_PARALLEL

Purpose: Control parallel processing usage for shared memory computers by defining the number of processors and invoking the optional consistency of the global vector assembly.

Card	1	2	3	4	5	6	7	8
Variable	NCPU	NUMRHS	CONST	PARA				
Type	3	I	I	I				
Default	1	0	2	0				
Remarks		1	2	3				

- The number of CPUs defined for an MPP job is defined by the MPI command line option.

MADYMO-LS-DYNA Analysis

- Install coupling executable from PARTNER: e.g. ls971_m63_7600_amd64_redhat40
- Arrange LS-DYNA licenses
- E.g.: If the coupled executable, MADYMO and LS-DYNA input file are in the current directory:

madymo64 –coupling direct -x ./ ls971_m64_7600_1224_ia64_hp11 madymofile.xml -arg i=ls-dynafile.k y=madymo memory=10000000

The -arg option transfers all parameters following it to LS-DYNA, so the –arg option must be the last MADYMO command option on the command line. Also use can be made of scripts to facilitate the starting procedure. See e.g. coupling manual: Example Startup Scripts

Note:LS-DYNA memory allocation *KEYWORD 10000000

MADYMO-PamCrash coupling executable

- The PamCrash distribution contains all essentials for a coupling simulation.

PamCrash Parallel

- SMP and MPP (from v2007) versions available
- For SMP jobs the environment variable OMP_NUM_THREADS needs to be defined. It specifies the number of CPU's for PamCrash. If this number is not identical to the number of MADYMO CPU's, the simulation will abnormally terminate .
  - Example: setenv OMP_NUM_THREAD 2
- For MMP jobs use PAMworld
  - For details contact your system administrator and/or PamCrash support.

MADYMO-PamCrash Analysis

1. Install PamCrash

2. Arrange PamCrash licenses

3. E.g.: If the coupled executable, MADYMO and PamCrash input file are in the current directory in the current directory:

   define environment variables:
   PAMEXE=/path/to/pam/psolid.x
   PAMLIB=/path/to/pam/lib
   LD_LIBRARY_PATH=$PAMLIB

   madymo64 –coupling direct -x $PAMEXE madymofile.xml –arg pamcrash.pc

   Also use can be made of scripts to facilitate the starting procedure. See e.g. coupling manual: Example Startup Scripts

Note: for v2007 also PAMworld can be used to start a coupling simulation

MADYMO-Radioss coupling executable

- Contact the Radioss Support for the applicable coupling executable.

- This coupled analysis can be run in MPP mode only.

MADYMO-Radioss Analysis

- Install coupling executable from Altair:
- Arrange Radioss licenses
- E.g.: If the coupled executable, MADYMO and Radioss input file are in the current directory in the current directory: (1 cpu only, also in Radioss inputdeck needs to be define 1 cpu)
- Define environment variables:
  - RADSTRT=/path/to/radioss_starter
  - RADENG=/path/to/radioss_engine

Next run:

```
Echo `hostname` > ./procgrp
$RADSTRT < input.D00
madymo64 -coupling direct -x $RADENG mad.xml -arg -p4pg ./procgrp -p4wd `pwd` < input.D01
```

Note: -p4pg and –p4wd are needed for Radioss MPI settings

Also use can be made of scripts to facilitate the starting procedure. See e.g. coupling manual: Example Startup Scripts

General: Coupling Restart Functionality

– Since MADYMO R631 Coupling restart functionality is available for Radios 51G and higher.

Tips and Tricks & Importing a foreign code

- Tips and Tricks
- Importing a foreign code

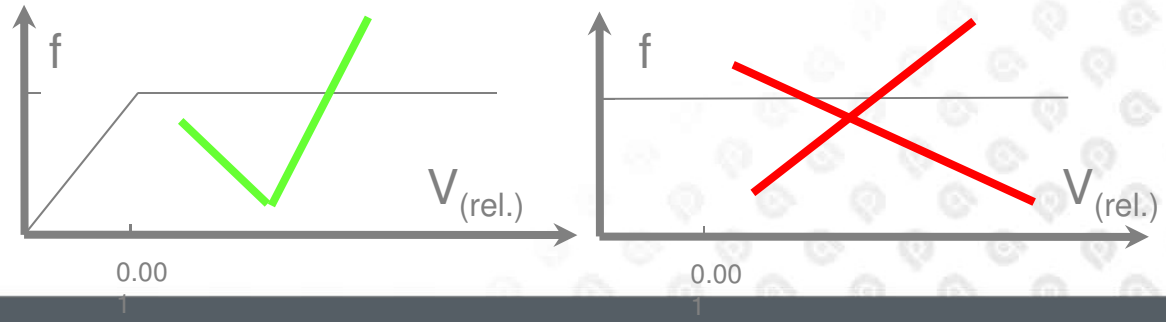
Tips and Tricks

- Perform a “zero run” and check reprint file and partner info-file to e.g.
  - Built up the model step wise i.s.o. the whole model at once.
  - Is coupling selected
  - Which partner components are selected
  - Not too much data selected for transfer (CPU performance)
  - Minimizing data exchange: shells i.s.o. solids by overlaying shell elements “over” solids with comparable stiffness as the solids.
  - Define CONTACT_SURFACE=ON within CONTACT.FE_FE if solids are exported to MADYMO
  - Warnings /errors
  - Appropriate (SI)units (length, mass etc.)
  - SMP-MPP runs: Is correct MPI installed
  - Euler Integration
  - Sufficient memory

Tips and tricks

- Overlay both animation files.
  - No identical behavior:
    - Incorrect units
    - Constraints (Master/Slave reversed e.g.)
    - Initial conditions (displ, vel or acc)?
- Check MADYMO manual: Coupling.pdf, but also other manuals do contain relevant info w.r.t. coupling
- Try to use equal mesh density for both codes
- Check chapter 1 of the model manual (Model.pdf) e.g.

  closed meshes are preferred
  surface with edge should be slave (belts)
  most curved surface should be slave
  highest mesh density should be slave
- Friction curves



Tips and tricks

- Check required time step of dummy model.
- Check reprint file and partner code output on warnings
- View the animation and check behaviour
- Define more output to simplify the analysis of a model
  - Mind the partner units if they are not in SI-units.
- Try to simplify the model or generate a stand alone model to isolate the cause if behaviour is unexpected
- Contact your local MADYMO or PARTNER local office for support.

Miscellaneous

Observations

- Basic coupling:
  - Density of imported MADYMO surfaces has no effect on results in LS-DYNA.
  - Density of imported MADYMO surfaces has effect on results in PamCrash.
  - MADYMO planes can be exported to Radioss. However, no contact definition possible within Radioss.
  - MADYMO does send cylinder data to PamCrash but this data is not processed by PamCrash, although stated in manual.
  - Gravity is applied to MADYMO items within LS_DYNA or PamCrash if e.g. all parts are selected for gravity in LS_DYNA or PamCrash. Radioss does not apply a gravity to exported MADYMO items. (Abaqus has no basic coupling)

Miscellaneous

Observations

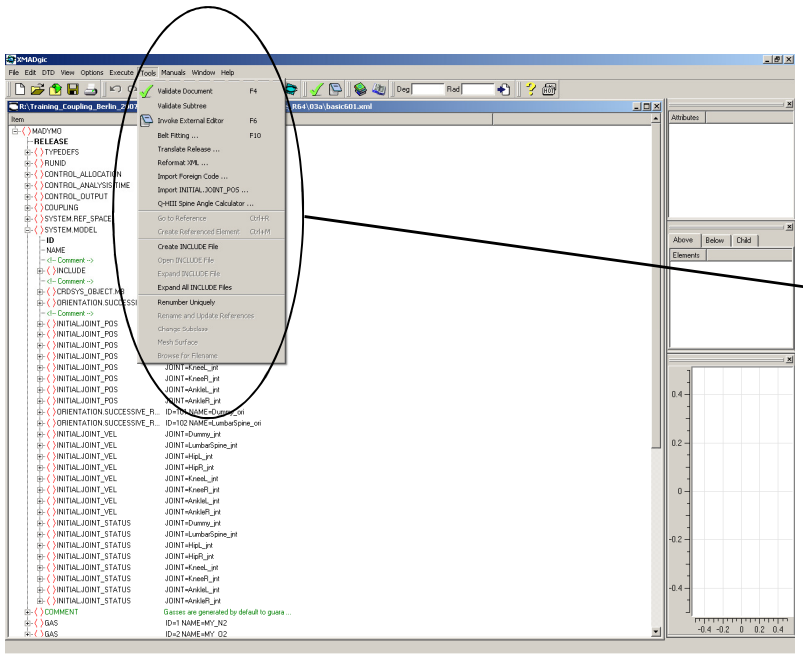
- Extended coupling:
  - No gravity is applied to PARTNER items within MADYMO.

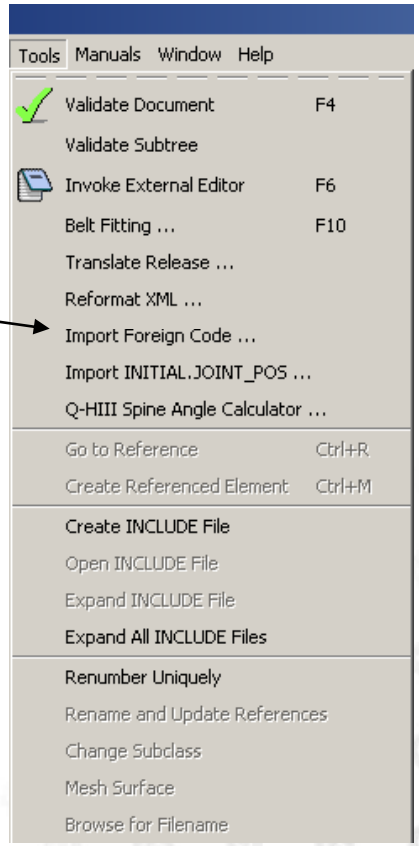
General: Importing Foreign Code

- Assists e.g. the user to display the partner side in XMADGIC (temporarily) to gain better graphical overview.
- Also use can be made by evaluation of the animation output files to check e.g. the correct initial position.
- Not all partner data is converted. This is listed in the log file in XMADGIC.
- Detailed info can be found in the converter_user_guide manual.

Importing Partner Input Deck

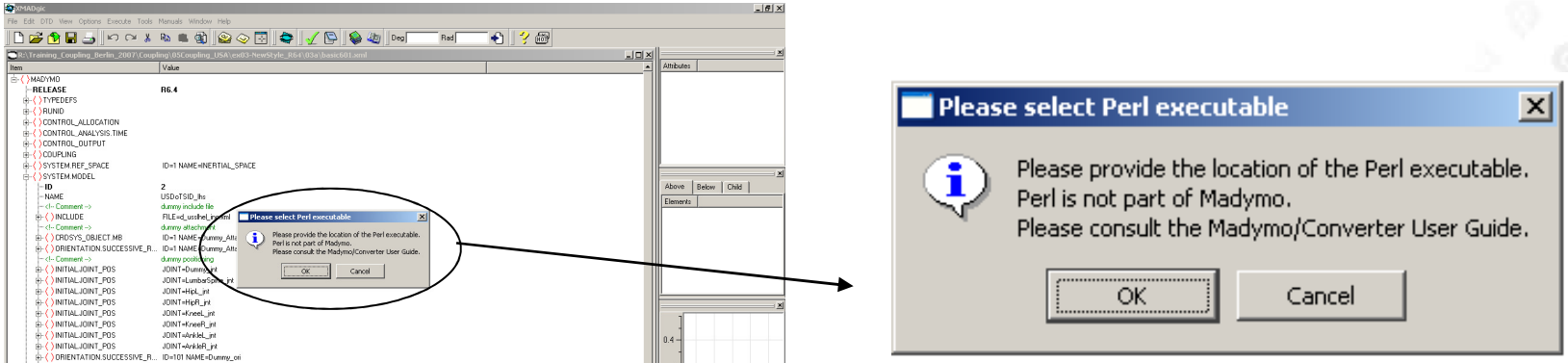
- Select Import Foreign Code under Tools





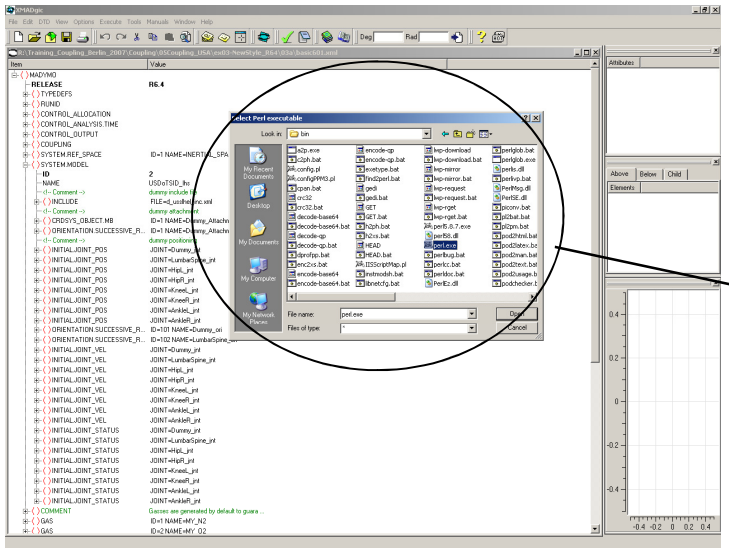
Importing Partner Input Deck

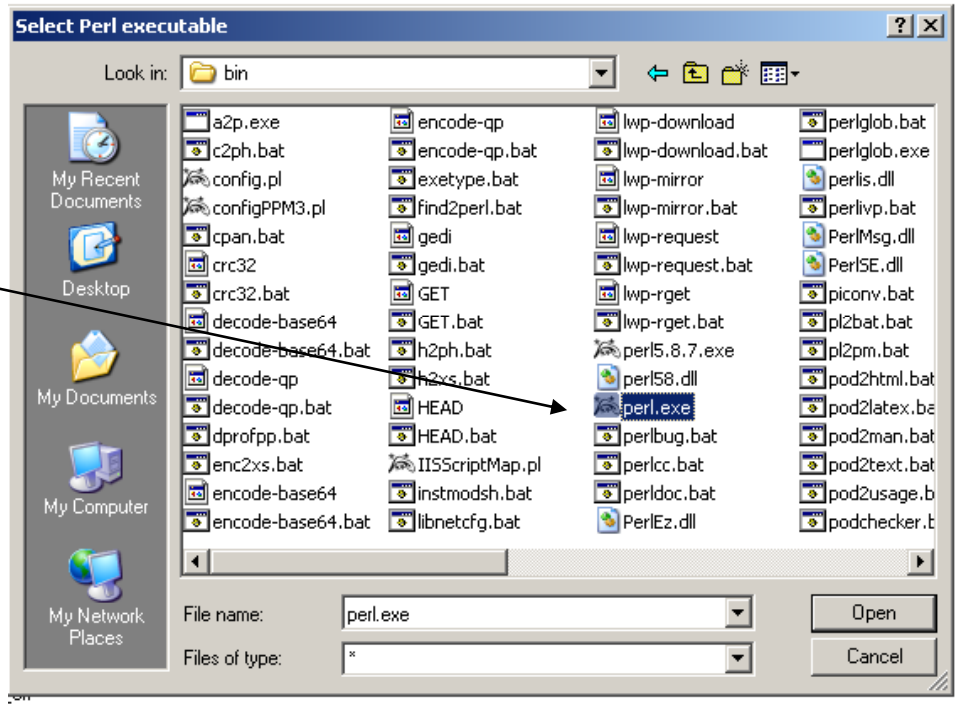
- Define perl, if not defined
- If not installed: download the applicable executable at the Perl site: http://www.perl.org



Importing Partner Input Deck

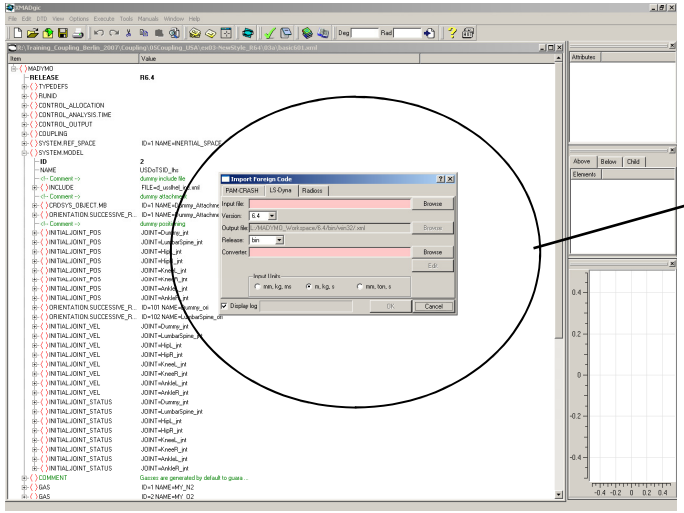
- Define perl, if not defined

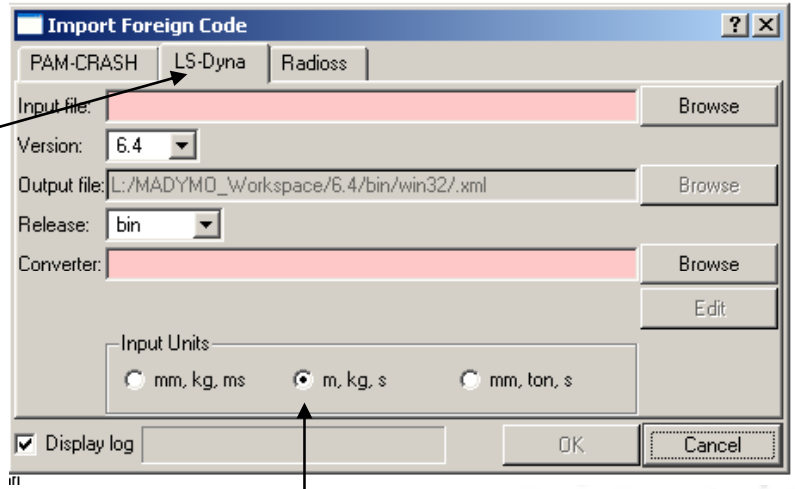




Importing Partner Input Deck

- Select PamCrash/LS-DYNA or Radioss





Unit selector

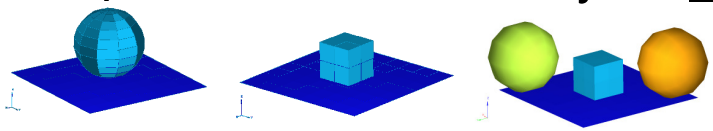

Thank you for your attention!
Question ?

Exercises

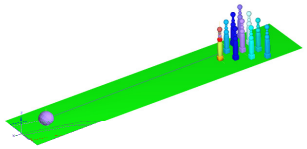
- Simple Models
  (basic vs extended vs combined)
- Bowling Alley
- Dummy Impacts
  - Impactor to Chest of Ellipsoid Dummy
  - Door to ES2 Facet dummy impact
- Support Airbag to Steering Wheel

Exercises

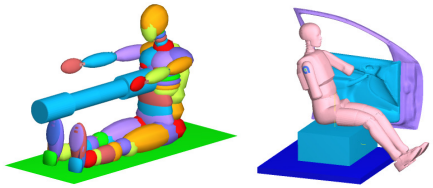
1. Simple Models, Directory: 01_basic_vs_extended_vs_combined



2. Bowling Alley, Directory: 02_Bowling_Alley



3. Dummy Impacts, Directories: 03a_Ell_Frontal_Impact and 03b_Facet_Side_Impact



4. Support Airbag to Steering Wheel Directory: 04_Airbag_Wheel_Support