PAM-CSM Result File

ERF-HDF5 File Specification

ESI Software

Solver / Application	:	PAM-CRASH / VPS
Solver Version	:	2011
ERF-HDF5 Version	:	1.2
Release date	:	March 2011

Contents

1 Purpose of the File

The purpose of the described output file is to store simulation results for post-processing, result mapping or chaining of simulations. This file specification is complementary to the ERF-HDF5 format specification [1]. The file format is based on the open HDF5 binary format [2].

2 Filename Convention

The file name consists of three components: ROOT*_NATURE.SUFFIX*

with: *ROOT* users simulation project name
NATURE data indicator = RESULT
SUFFIX file extension = erfh5

Note: Eigenmode bases are stored in a special file with NATURE=EGM. For detailed information about Eigenmode files please refer to the VPS solver manual [3].

3 Space Dimensions and Coordinates

The model is embedded in the three-dimensional Cartesian space. The deformed geometry can be represented by:

- coordinates per state (ERF variable COORDINATE) or
- coordinates and displacements (variable COORDINATE and DISPLACEMENTS_NOD)

variable key	nature	ERF array storage order	description
COORDINATE	vector $\vec{x}$	$[x \quad y \quad z]$	Cartesian coordinates
DISPLACEMENTS_NOD	vector $\vec{u}$	$[u_x \quad u_y \quad u_z]$	displacements in Cartesian coordinates

4 Solver Options

The solver and analysis type options are stored in the ERF system block under the parameter 'solver_name'. The string consists of three qualifiers separated by colons (:) as follows:

solver_name = <Platform> : <Analysis_Type> : <Application_Option>

The following table lists all possible solver and analysis types.

ERF system block parameter solver_name	Description
'PAM-CSM:Explicit_Transient' 'PAM-CSM:Explicit_Transient:FPM' 'PAM-CSM:Explicit_Transient:Stamp'	explicit nonlinear transient analysis FPM solver results embedded stamping analysis
'PAM-CSM:Static_Linear' 'PAM-CSM:Static_Linear:Composite'	implicit linear static analysis with multi-layered output for composites
'PAM-CSM:Static_Nonlinear' 'PAM-CSM:Static_Nonlinear:Composite'	implicit non-linear static implicit analysis with multi-layered output for composites
'PAM-CSM:Heat_Steady_Linear'	implicit heat linear steady analysis
'PAM-CSM:Heat_Steady_Nonlinear'	implicit heat non-linear steady analysis
'PAM-CSM:Heat_Transient_Linear'	implicit heat linear transient analysis
'PAM-CSM:Heat_Transient_Nonlinear'	implicit heat non-linear transient analysis
'PAM-CSM:Acoustic_Eigen_Modes'	acoustic mode extraction
'PAM-CSM:Eigen_Modes'	structure mode extraction
'PAM-CSM:Frequency_Response'	NVH and acoustics
'PAM-CSM:Transient_Modal'	dynamic analysis based on modal superposition
'PAM-CSM:Buckling_Modes'	buckling analysis

5 Entity Types

5.1 Introduction

An ERF entity can represent a structural element (e.g. node, finite element, cell) or a non-structural object (e.g. model, contact, section). An entity can be referenced by its entity type key.

Notes:

1) An entity key may be any string of ASCII characters not containing a slash or a dot ("/" and ".", which are reserved as HDF path separators) and starting with a non-space character. The use of punctuation, non-printing characters and spaces should be avoided, as they may create problems for other software.
2) All identifiers (e.g. nodal, elemental, part identifiers) are one-based (greater than zero, ID > 0).

5.2 Generic Entities

entity type	description	visualization
NODE	FEM nodal points	point
PART	FEM parts	n/a
MODEL	Global model	n/a
INPUT	stripped input deck	n/a
FPMNODE	FPM points	point
FPMPART	FPM parts	n/a
SENPT	sensor points (attached to a node)	point
CONTACT	contact interfaces	n/a
SECTION	sections for force output	n/a
ELEMENT	any type of a finite element	depending on the element type
ACOUSTIC_NODE	acoustic node with 1DOF (acoustic pressure) in the fluid domain	point
PANEL	interface between fluid and structure domains	facets

5.3 Finite Elements

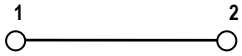
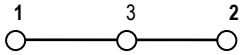
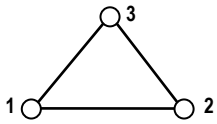
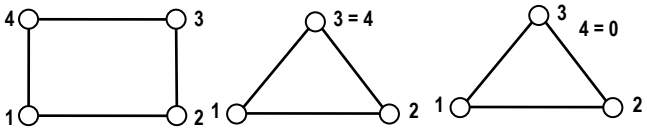
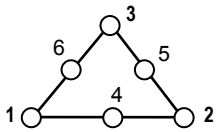
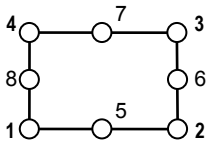
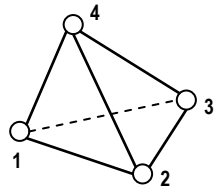
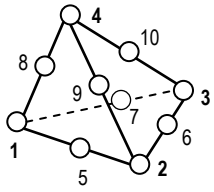
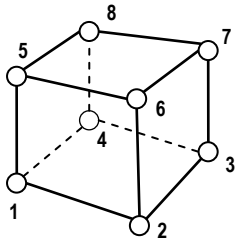
5.3.1 Overview

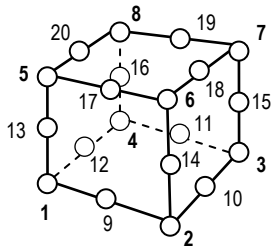
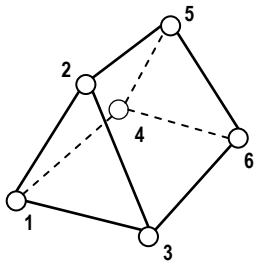
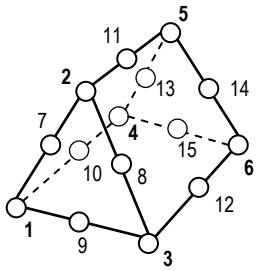
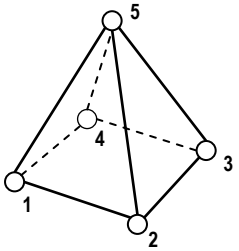
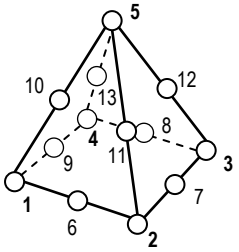
The finite elements are divided into four categories according to their dimensions in space. In addition to the classical bar and beam elements the structural link/joint elements are also considered as one-dimensional finite elements. The number of nodes and dimensions of each element type are stored as header parameter in the ERF connectivity blocks. It is highly recommended to use these parameters as primary information for visualization and extraction of faces. The purpose of the element key is to distinguish between different element formulations.

Note: The element identifiers (IDs) are unique over all types of elements. Therefore the generic type ELEMENT can also be used to refer to any type of element.

The following table shows all categories of elements used in CSM solvers. Note that an element family may consist of one or multiple element formulations, depending on the solver scheme.

Table: Types of elements

category	family	nodes	connectivity
particles - 0D	point	1	
beams – 1D	line2	2	
	line3 higher order	3	
shells – 2D	tria3	3	
	quad4	4	
	tria6 higher order	6	
	quad8 higher order	8	
solids – 3D	tetra4	4	
	tetra10 higher order	10	
	hexa8	8	

	hexa20 higher order	20	
	penta6	6	
	penta15 higher order	15	
	pyramid5	5	
	pyramid13 higher order	13	

5.3.2 0D Elements

element entity type	family	description	visualization
SPH	point	SPH particles	point
FPM	point	FPM points	point

5.3.3 1D Elements

element entity type	family	description	visualization
BEAM	line2	beam C0	line
BAR	line2	bar	line
SPRING6DOF	line2	spring with 6 DOF	line
SPHERICALJOINT	line2	spherical joint (mat 221)	line
FLEXTORSJOINT	line2	flexion-torsion joint (mat 222)	line
KJOINT	line2	kinematic joint	line
PLINK	line2	point link	line
MBSJOINT	line2	multi-body-system joint	line
MBSSPRING	line2	multi-body-system spring	line
SPRINGBEAM	line2	spring-beam	line
DRAWBEAD	line2	stamping drawbead	line
MTOJN	line2	multiple-to-one node kinematic joint	line
MUSCLE	line2	muscle	line
JET	line2	gas jet	line
SLINK	line2	surface link	line
MPCPLINK	line2	multi-point-constraint link	line
GAP	line2	contact gap element (implicit only)	line

5.3.4 2D Elements

element entity type	family	description	visualization
MEMBR	quad4	membrane (mat 150, 151, 152)	facet
THICKSHELL	quad4	thick shell (mat 161, 162)	facet
SHELL	quad4	shell based on various formulations	facet

5.3.5 3D Elements

element entity type	family	description	visualization
HEXA8	hexa8	8-node hexahedral FI	facets
BRICKSHELL	hexa8	8-node brick shell	facets
TETRA10	tetra10	10-node tetrahedron	facets
TETRA4	tetra4	4-node tetrahedron	facets
PENTA6	penta6	6-node penta	facets
PENTA15	penta15	15-node penta	facets
HEXA20	hexa20	20-node hexahedral	facets

5.4 Collectors

5.4.1 Introduction

A collector is a compound of entities of different types including the collector itself. Collectors are used to visualize and access associated nodes and elements, e.g. of spotwelds, airbags or rigid body definitions. Since the collector is considered as a regular entity like an element or node, it can be used for result output (entityresults blocks).

5.4.2 Kinematic Constraints

collector entity type	description	visualization
RBODY	rigid body	spider between master and slave nodes
MTOCO_COLLECTOR	multiple-to-one kinematic constraint	spider between master and slave nodes
OTMCO_COLLECTOR	one-to-multiple constraint	spider between slave and master nodes

5.4.3 Airbags

collector entity type	description	visualization
AIRBAG	Airbag	highlighted CHAMBER collectors
CHAMBER	Airbag chamber	highlighted elements, VENTs, WALLs
VENT	Airbag vent hole	highlighted elements and nodes
WALL	Airbag chamber wall	highlighted elements

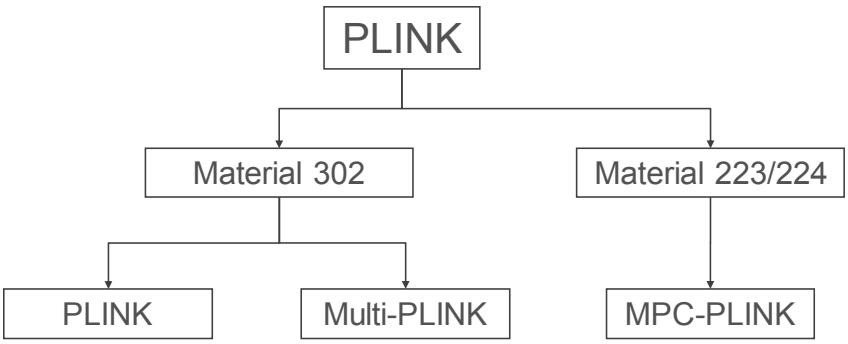
5.4.4 Muscle Collector

collector entity type	description	visualization
MUSCLE_COLLECTOR	Human Model Muscle	highlighted MUSCLE elements

5.4.5 PLINK Collectors

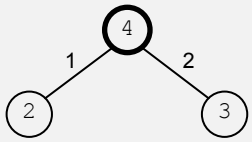
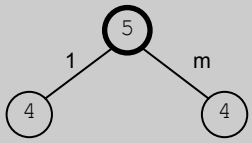
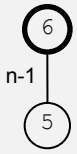
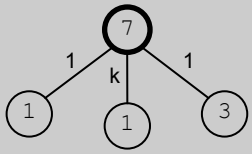
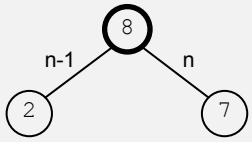
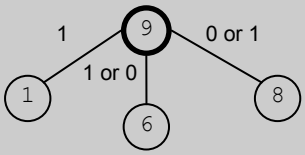
The introduction of PLINK-collectors was motivated by user requests to improve the MPC-PLINK output. The purpose of these collectors is to standardize the output of all PLINK entities and to improve their visualization in post-processors.

The family of PLINKS can be presented as follows:



The following table shows all PLINK collector types and their dependencies.

Important Note: The collector IDs are unique within a collector type only, i.e. the IDs are not unique considering all collector definitions in the file.

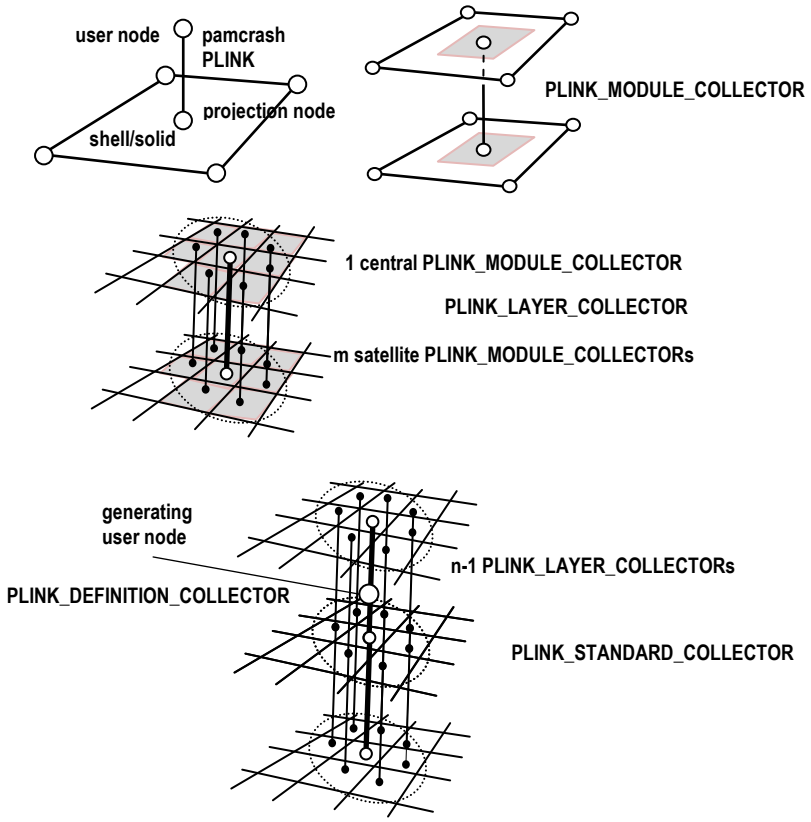
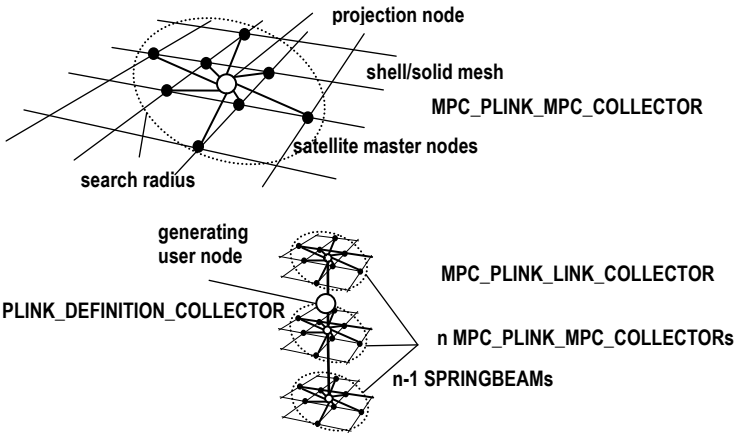
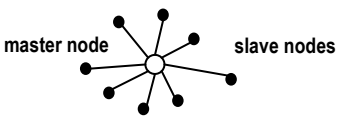
collector entity type	description	dependencies (see legend below)
PLINK_MODULE_COLLECTOR	PLINK Module Definition	
PLINK_LAYER_COLLECTOR	Layer of a Standard-PLINK Definition	
PLINK_STANDARD_COLLECTOR	Standard-PLINK Definition	
MPC_PLINK_MPC_COLLECTOR	MPC-PLINK Constraint Defintion	
MPC_PLINK_LINK_COLLECTOR	MPC-PLINK Link Definition	
PLINK_DEFINITION_COLLECTOR	MPC-/Multi-/Standard-PLINK Definition	

Legend for diagrams of collector dependencies:

symbol	entity type	definition	Identifier
1	NODE	Node	ID(1) = User NODE ID
2	ELEMENT	1D Element (beam or bar)	ID(2) = User ELEMENT ID
3	ELEMENT	2D or 3D Element (shell or solid)	ID(3) = User ELEMENT ID
4	PLINK_MODULE_COLLECTOR	1 connecting beam/bar ELEMENT 2 shell/solid ELEMENTs	ID(4) = ELEMENT ID(2)
5	PLINK_LAYER_COLLECTOR	1 central PLINK_MODULE_COLLECTOR m satellite PLINK_MODULE_COLLECTOR	ID(5) = central ID(4)
6	PLINK_STANDARD_COLLECTOR	n-1 PLINK_LAYER_COLLECTORs	ID(6) = ID(9)
7	MPC_PLINK_MPC_COLLECTOR	1 central NODE k satellite NODEs 1 ELEMENT containing central NODE	ID(7) = central NODE ID(1)
8	MPC_PLINK_LINK_COLLECTOR	n MPC_PLINK_MPC_COLLECTORs n-1 connecting beam ELEMENTs	ID(8) = ID(9)
9	PLINK_DEFINITION_COLLECTOR	1 generating NODE 0 or 1 PLINK_STANDARD_COLLECTOR 1 or 0 MPC_PLINK_LINK_COLLECTOR	ID(9) = PLINK User ID

The following table illustrates the visualization of collectors as compounds of different entity types.

Table: Visualization of collectors

PLINKs	
MPC_PLINKs	
RBODY, OTMCO_COLLECTOR	

5.5 Zones

The purpose of zones is to divide a single entity (e.g. an element) into multiple domains to attach results to each of these domains. A typical example is a multi-layered shell element that is used to model a composite structure.

zone type	description	visualization
ZONE	default zone type – also used for single-zone entities	n/a
LAYER	Composite applications	n/a

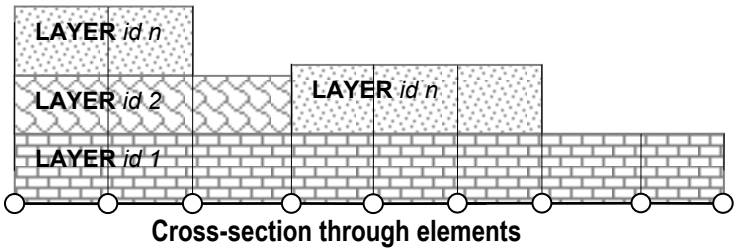


Figure: Multi-layered Shell Elements to model composite structures

Note: For detailed information about the simulation and output of composite structures please refer to the VPS solver manual [3] and the Functional Specification [4].

5.6 Local Frames

Vector or tensor coordinates may refer to local frames. A local frame can be referenced by the frame type key and an indentifier.

frame type	description	visualization
FRAME	local frame	lines
ELEMENT_FRAME	local frames for shell elements	lines

The three-dimensional vector basis $\vec{R}, \vec{S}, \vec{T}$ of a local frame is stored as an entity result under the ERF variable BASIS3X3. In order to place the frame in space, the coordinates of the origin are stored under the ERF variable COORDINATE.

Note: Frames are not necessarily orthonormal or orthogonal.

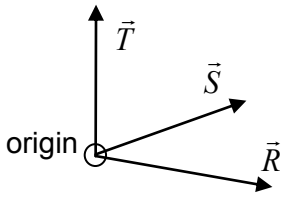


Figure: Local frame

variable key	nature	ERF array storage order	description
COORDINATE	vector $\vec{x}$	$[x \quad y \quad z]$	Cartesian coordinates to store the origin
BASIS3X3	matrix $\underline{B}$	$[R_x \quad R_y \quad R_z \quad S_x \quad S_y \quad S_z \quad T_x \quad T_y \quad T_z]$	vector basis in Cartesian coordinates

6 File Storage Scheme

6.1 Introduction

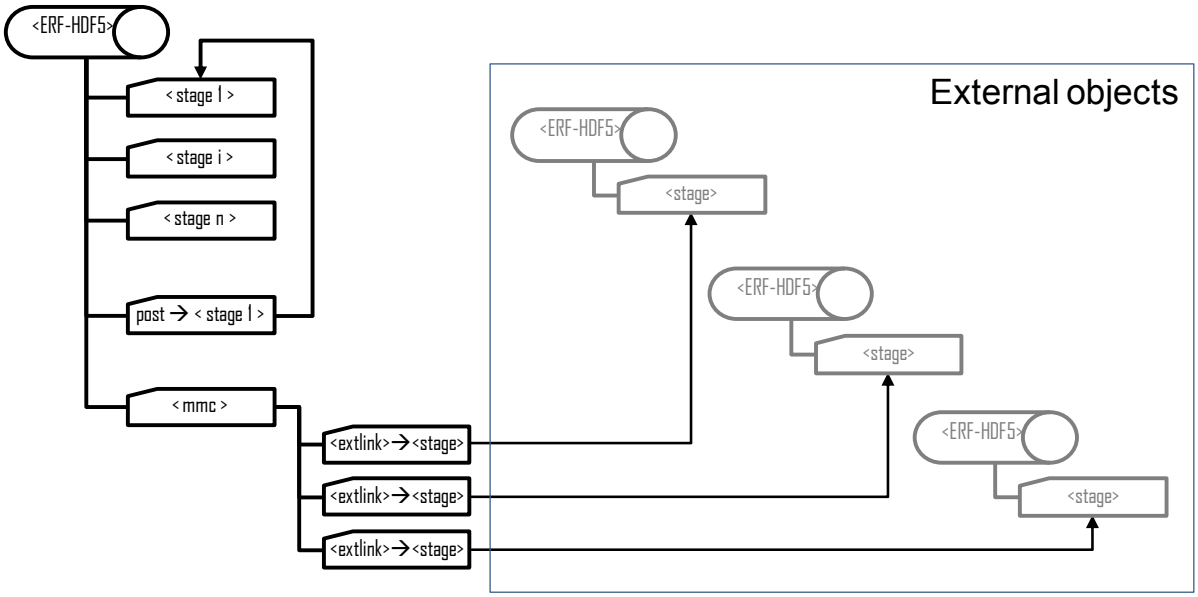
The file storage scheme defines the hierarchy of the data blocks being stored in the ERF file.

Note that the HDF5-group names – except ‘post’ and ‘mmc’, which are described below - are not part of the specification and could be changed. Therefore the reader should only rely on the block contents and not on the group/path names.

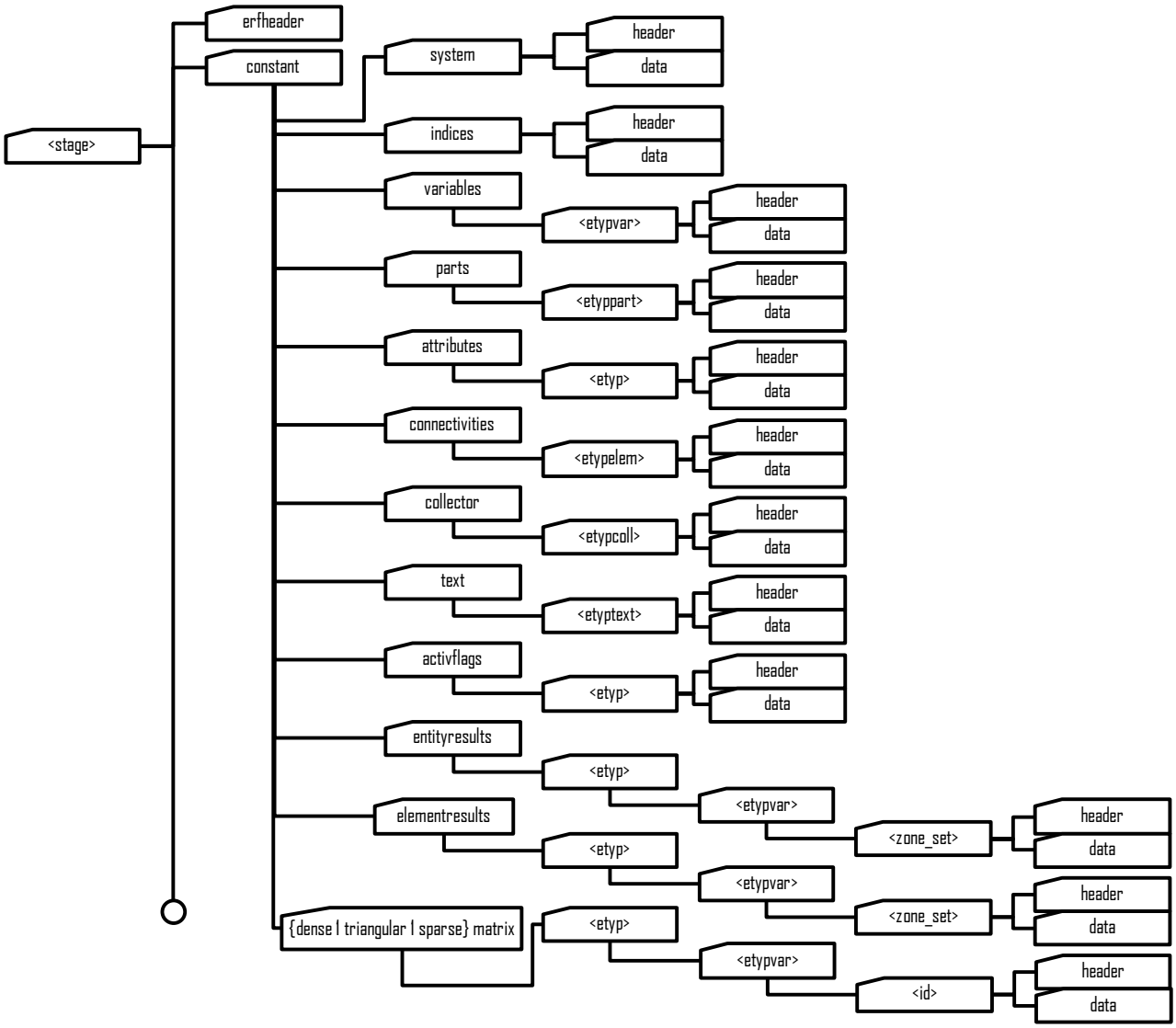
There are two optional top-level groups, ‘post’ and ‘mmc’:

- The group ‘post’ represents a symbolic link to a selected stage (default stage)
- The group ‘mmc’ (optional) contains external links to stage groups in other ERF files. These stages could be considered as sub-models of the same global model (MMC - Multi-Model Coupling). The post-processor may visualize these sub-models simultaneously (overlay mode).

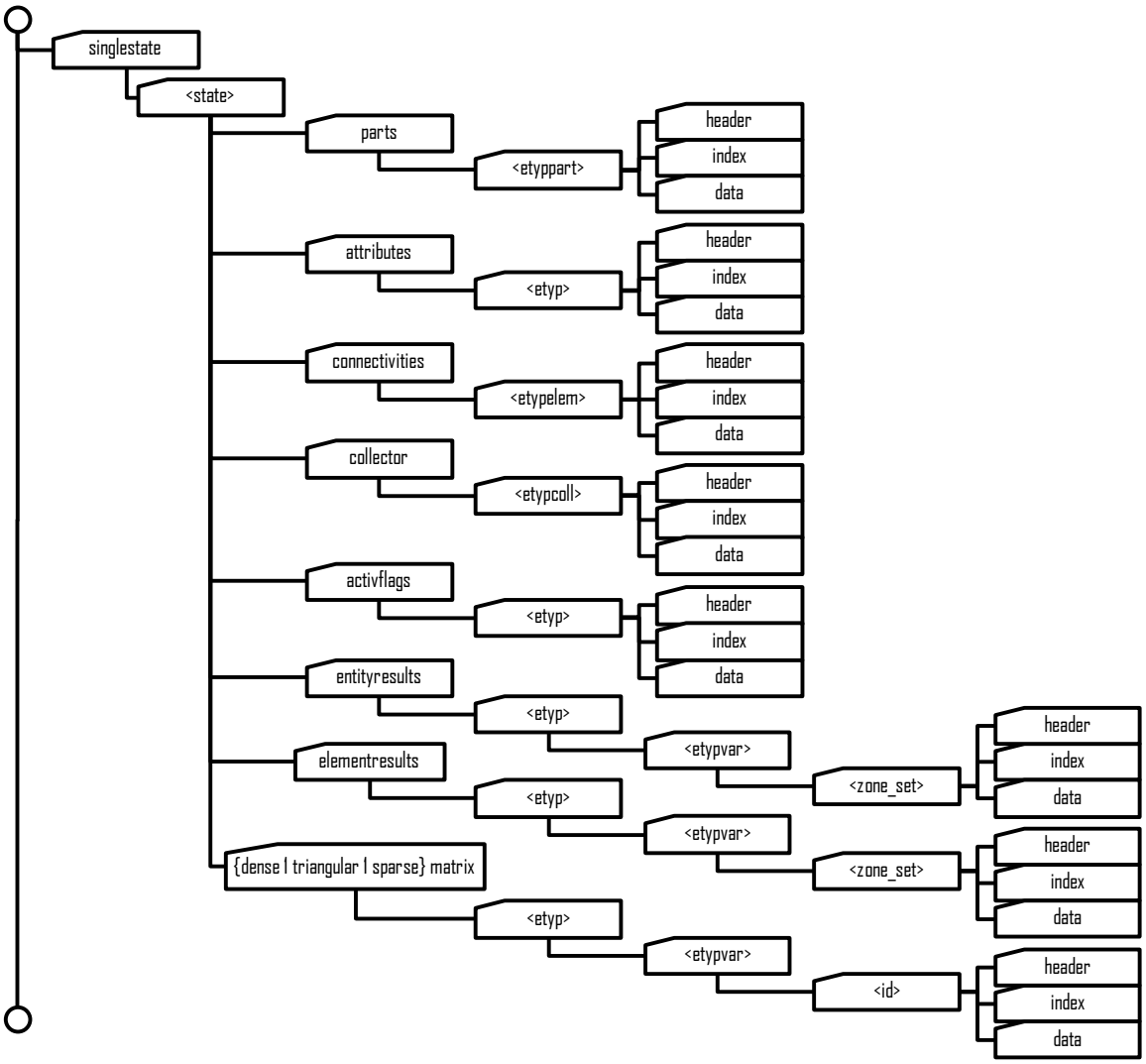
6.2 ERF File Top-Level Groups



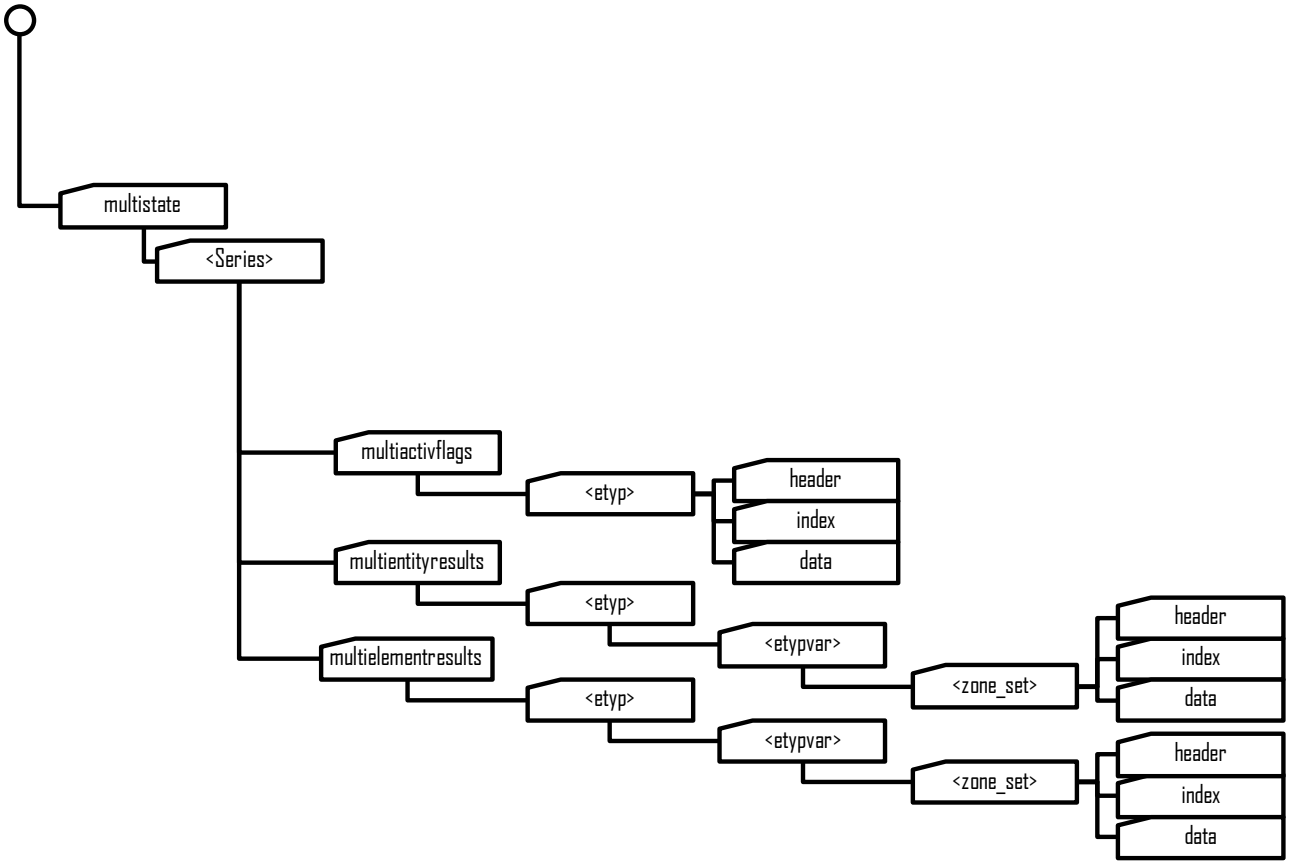
6.3 ERF-Header and Constant Blocks



6.4 Single-State Blocks



6.5 Multi-State Blocks



7 References

[1] ERF-HDF5 Specification Version 1.2, ESI Group, 2011
[2] http://www.hdfgroup.org/HDF5/, HDF Group
[3] VPS Solver Reference Manual Version 2011, ESI Group, 2011
[4] Functional specification COMP09 Visual Composite Solution Phase2, ESI Group, 2009