The Development of the new XJ Jaguar in Advanced Aluminium; Opportunities and Challenges

Zeguer, T., Jaguar Cars

CONTENTS

The XJ Saloon

- Flagship Jaguar, essence of the brand
- Over 800,000 sold - over half of all Jaguars ever made
- Seventh generation XJ since 1968

34 Years of the Jaguar XJ Saloon

XJ Series I
1968-73

XJ Series II
1973-79

XJ Series III
1979-86

XJ 40 1986-94

X300 1994-1997

X308 1997-2002

New XJ LWV Targets

- 40% body weight saving for complete body and increase torsional stiffness .
- Meet world safety standards
- Ease of repair. Bolt-on front end for low speed damage repair
- Improved performance, economy, emissions
- Enhanced feature specification
- Improved interior/ luggage space.
- Durability to be at least as good as steel

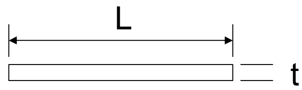
New XJ Delivers

- 40% body weight saving - 60% increase in stiffness
- Up to 200kg reduction in vehicle weight (3.0 v 3.2)
- Excellent safety and corrosion performance
- Reduced cost of ownership with competitive insurance ratings
- Improved performance, economy, emissions
- Improved headroom, legroom, luggage space
- Instantly recognisable Jaguar design
- Acknowledged Jaguar ride & handling balance

Gauge Reduction Rationale

Basic equation to convert steel gauge to aluminium gauge :-

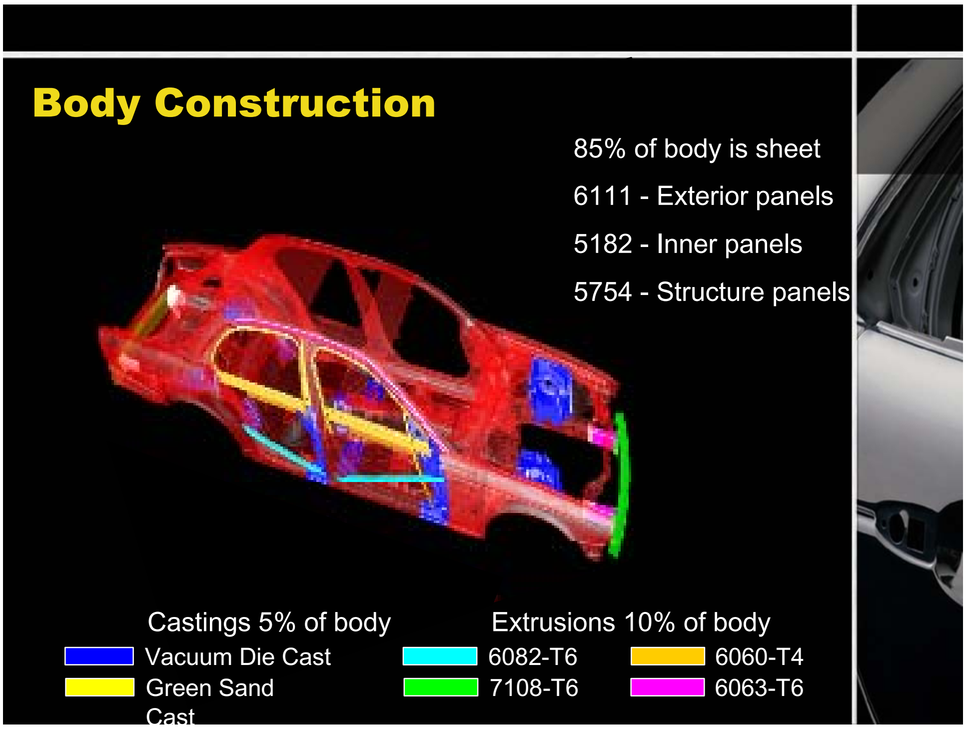
$$Gauge_{Al} = \sqrt[3]{3(Gauge_{St})^3}$$



Conversion results in stiffness match between steel & aluminium

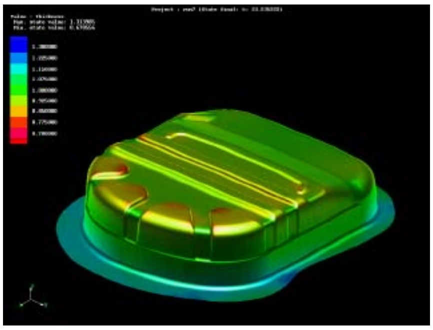
Steel gauge	Al. Gauge	% Weight Save
0.75 mm	1.08 mm	52%
1.00 mm	1.44 mm	52%
1.20 mm	1.73 mm	52%

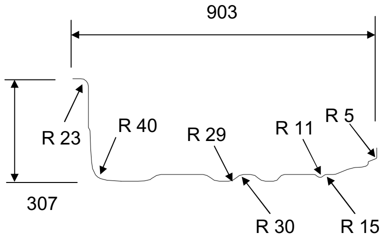
Multiply by 1.48 for aluminium gauge (for thin sheet bending stiffness)



Structural Panel Development

- Aluminium design & stamping guidelines used on all parts.



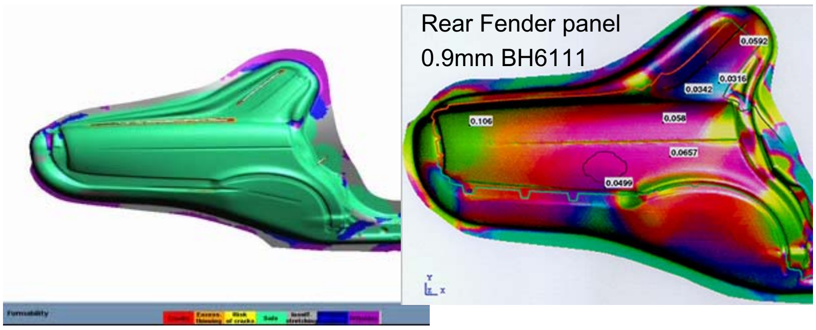


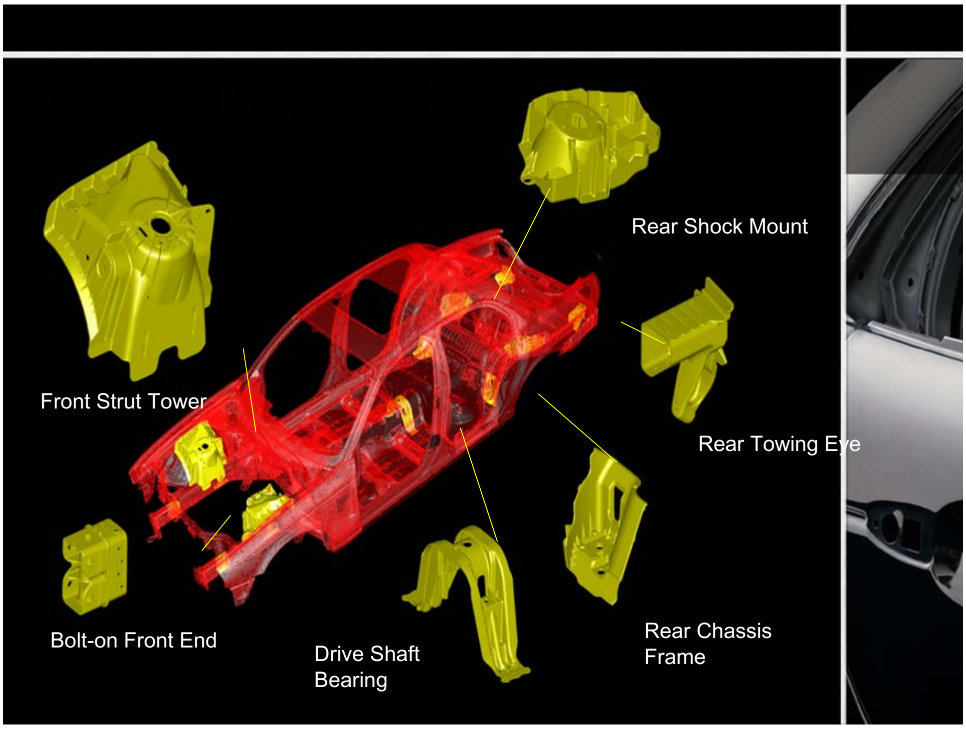
Structural Castings

- Castings selected in key areas for:-
  - Complex geometry - unfeasible as stamped parts
  - Local stiffness in high load input areas
  - Improve part integration
  - Reduce tooling investment
  - Reduce multiple sheet stack-up issues
  - Self pierce rivet joining to other parts

Exterior Panel Development

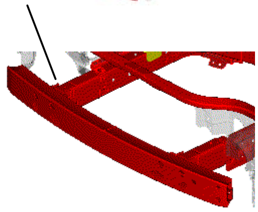
- Extensive use of CAE & development die program to validate style
- Spring back compensation major issue with aluminium





Extrusions

- Extrusions selected in key areas for:-
  - Weight save & reduced part count
  - Reduced tooling investment
  - High strength applications
  - Ability to form simple shapes/profiles
- Application includes:-
  - Cant Rails, Bumper Beams, Side Impact Beams, Door Frames & Crush cans
- **Material selected**
  6063-T6, 6060, 6082, 7108-T6



Front Bumper Beam

Door Assembly

Hybrid of aluminium grades, processes and joining technologies

Sheet Material
Outer AA6111-T4
Inner AA5754-H0
AA6060 Extrusion
Upper Frame
Waist Rail
Side Impact Beam
Die Casting C446
Hinge Reinf. Panel

•MIG welding
•Rivets
•Adhesive

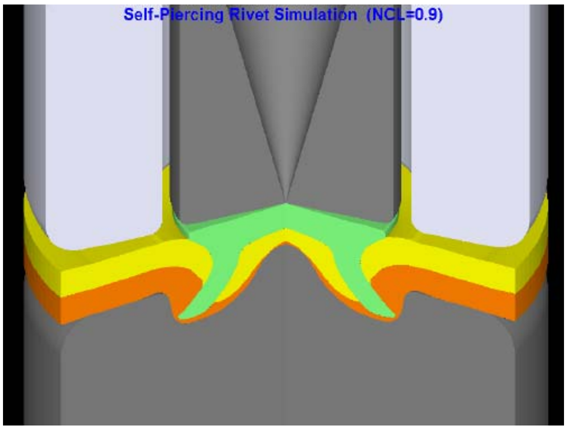
	Equivalent steel	XJ alu hybrid	Weight saved
Front Door	19Kg	10.48Kg	***45%***
Rear Door	15Kg	8.72Kg	***42%***

Henrob Self-Piercing Rivets

- SPRs selected as the best joining technology for the LWV structure:
  - Preferred joining technology of the aircraft industry
  - Increased performance versus welding
  - Cold joining process – no heat distortion of parts
  - Material thickness & stack-up combinations
  - Compatible with adhesive bonding process

Riveting Process Simulation

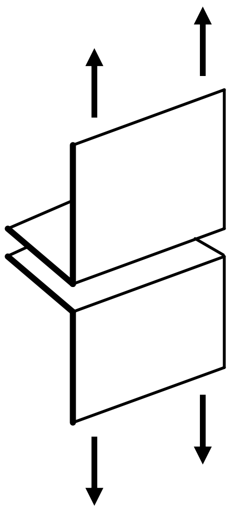
New Jaguar XJ - the world's first volume riv-bonded monocoque vehicle



Adhesive Bonding

- Challenge was to find the best joining technology for the LWV structure:-
  - FEA used to select optimum joints for adhesive bonding
  - Enhances Strength, Durability & Stiffness - selective bonding
  - Single part heat curing epoxy
  - Pumpable paste applied in BIW assembly
  - Compatible with PT2 surface pre-treatment & AL070 stamping lubricant

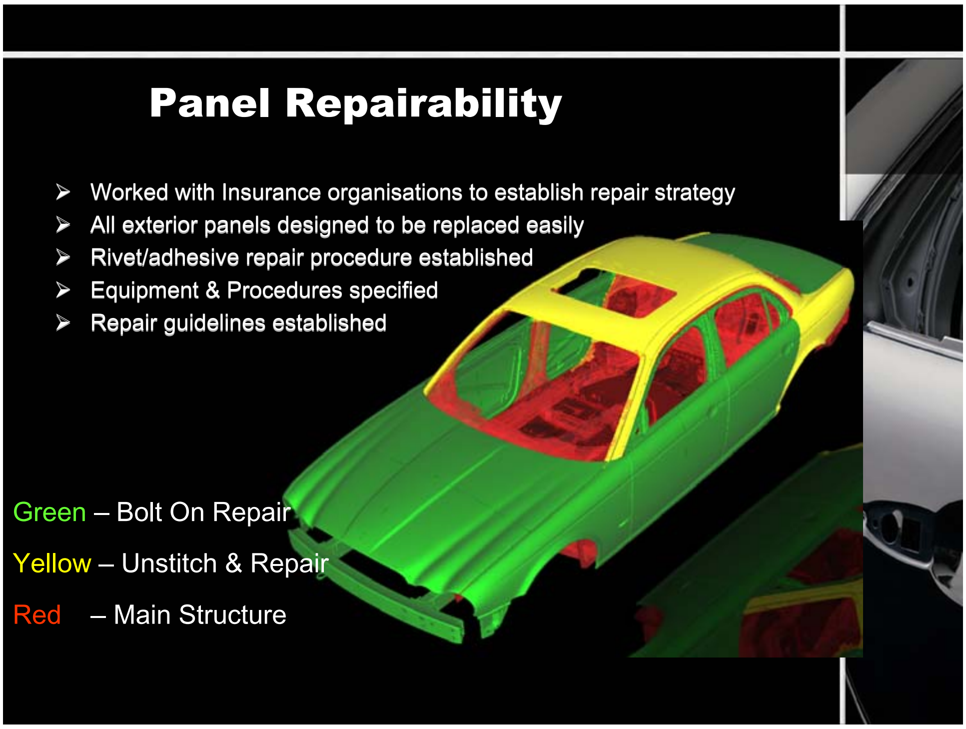
Riv-Bonding Rationale



	Pull Strength	Vibration (fatigue)
Spot welded steel (1.2 mm CR2)	74 Kg	12 Kg
Spot welded aluminium (2.0 mm 5754-0)	78 Kg	5 Kg
Riveted aluminium (2.0 mm 5754-0)	215 Kg	17 Kg
Bonded aluminium (2.0 mm 5754-0)	174 K	62 Kg

New XJ BIW information

Self pierce rivets	3204
Clinch spots	78
Structural adhesive (m)	104
MIG weld (metres)	2
Weld studs (trim fix)	40
Weld studs (ground)	26
Blind rivets	180
Cast parts	15
Extruded parts	35
Stamped parts	284



New XJ Safety Philosophy

- **Engineered to be amongst the worlds safest vehicles**

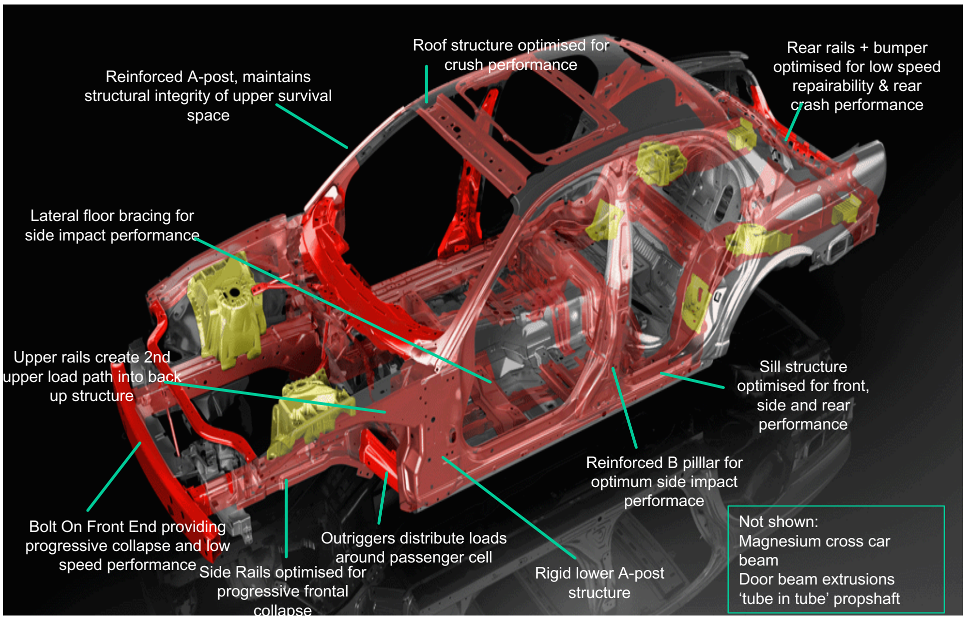
- World safety standards Proven via:
  - 1000+ CAE virtual crash tests using 175,000 hrs of computing power
  - 79 full vehicle crash tests

Crash Requirements have formed a 3D array

- **By impact configuration**
  - **Front Impact**
  - **Side Impact & Side Pole Impact**
  - **Rear Impact**
  - **Low speed**
  - **Others**
- **By country**
  - **USA**
  - **Europe**
  - **Japan**
  - **Australia**
  - **Rest of the world**
- **By governing body**
  - **Legislative** (pass / fail)
  - **Consumer** (USNCAP, LINCAP, Euro NCAP, IIHS, Thatcham, GDV)
  - **Internal** (Corporate Acceptance Criteria)

One global safety standard

Crash Structure Simplified



New XJ Restraints System

- A.R.T.S. key elements
  - occupant weight & position sensing
  - dual stage driver & passenger airbags
  - multi-point distributed crash sensing
  - safety belts with pyrotechnic pre-tensioner for all occupant positions
  - fronts safety belts with limiting retractors
- Combined with
  - side curtain & front seat thorax airbags
  - "beltminder"
  - anti-whiplash front seats

Split Hopkinson Bar apparatus

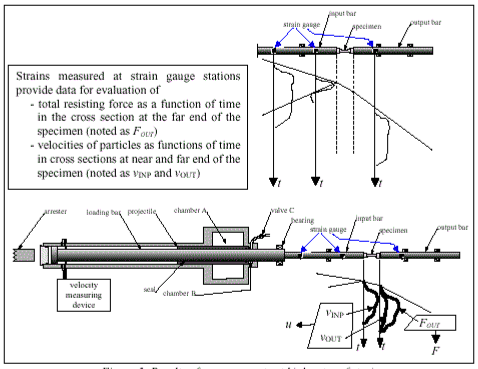


Figure 5: Results of measurements at high rates of strain

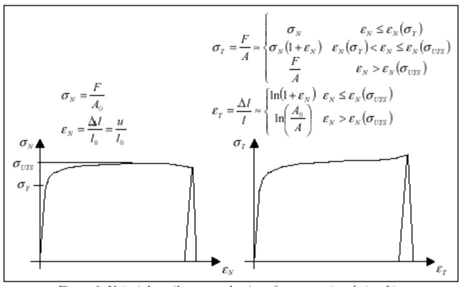
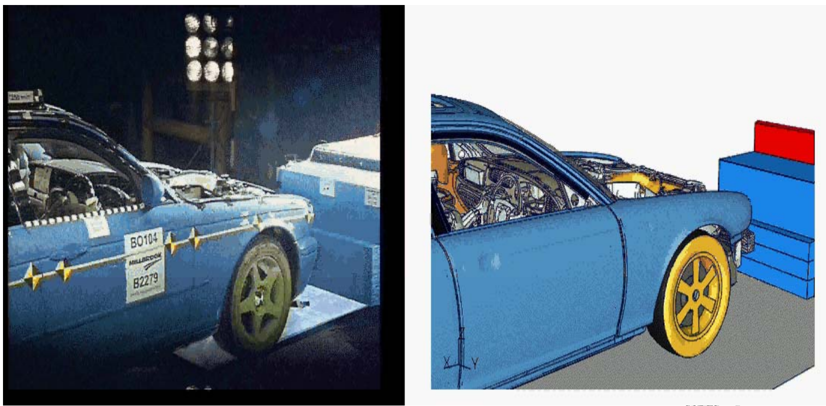


Figure 6: Uniaxial tensile test: evaluation of stress-strain relationship

High Speed Crash Performance



CAE accurately predicting and allowing virtual world optimisation of crash performance

High Speed Crash Performance

- Very stable structure delivering excellent occupant protection
  - minimal a pillar deformation (at roof)
  - good door aperture stability
    all doors openable after crash
  - controlled bulkhead intrusion providing a stable platform for the IP beam;
    - minimising steering column intrusion
    - providing stable deployment of front airbag restraint system
  - low toeboard intrusion to minimise lower leg injury
  - limited floorpan deformation in seat mounting area
- Delivering controlled occupant kinematics

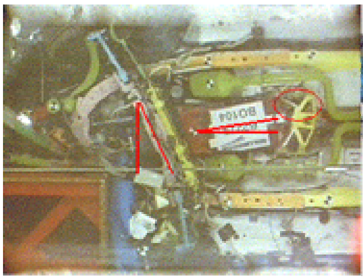
The New FMVSS208

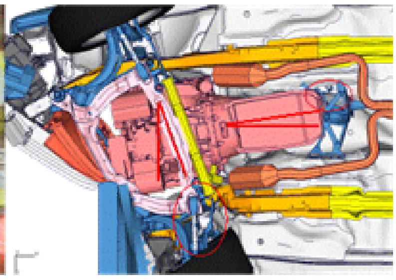
- Probably the most comprehensive measure to date for all round frontal crash performance, the new FMVSS208 is introduced 2003-06
- Test consists of 25-30 mph belted and unbelted tests into full frontal and angled barriers, plus verification of safe airbag deployment.
- The Jaguar XJ's crash architecture and ARTS equipment is expected to make this the first passenger car to meet this legislation

Front Impact

Euro NCAP – ODB 64 kph

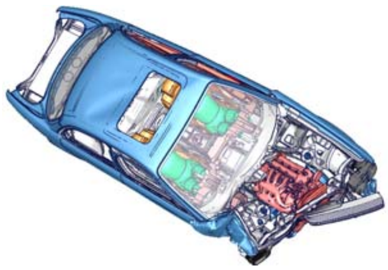
Vehicle Collapse Mechanisms Using Films and Photos, Post test and Strip Down

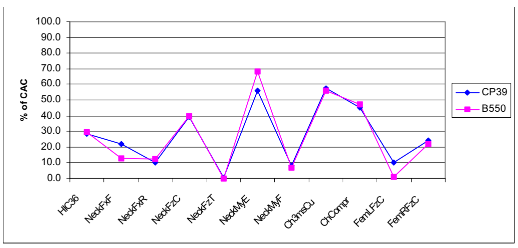




Front Impact

Euro NCAP – ODB 64 kph





EURO NCAP

New XJ Safety Performance

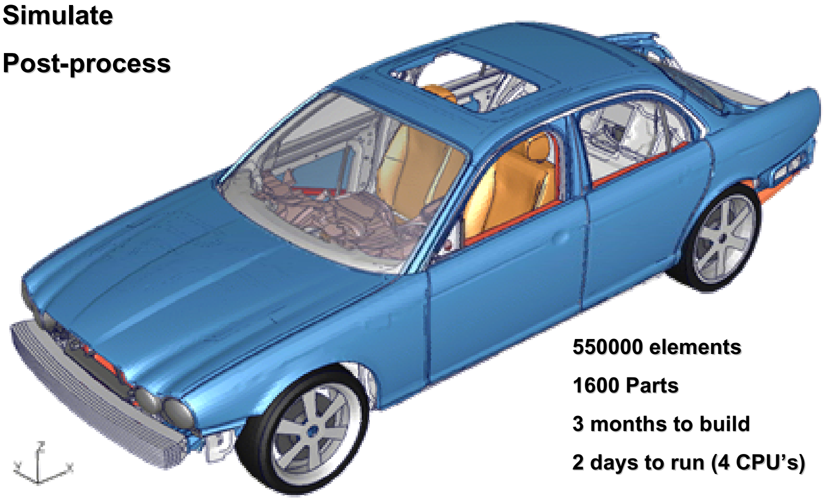
- New XJ has excelled in Jaguar's internal testing and makes significant strides in safety protection
- Strong aluminium body structure provide excellent occupant protection
- The vehicle includes a comprehensive array of safety technology including Jaguars sophisticated ARTS system
- Low speed performance has resulted in very competitive insurance group ratings ahead of key competitors
- Non derivatised safety features mean all customers benefit from a vehicle engineered to world safety standards

XJ common model

Pre-process

Simulate

Post-process



550000 elements

1600 Parts

3 months to build

2 days to run (4 CPU's)

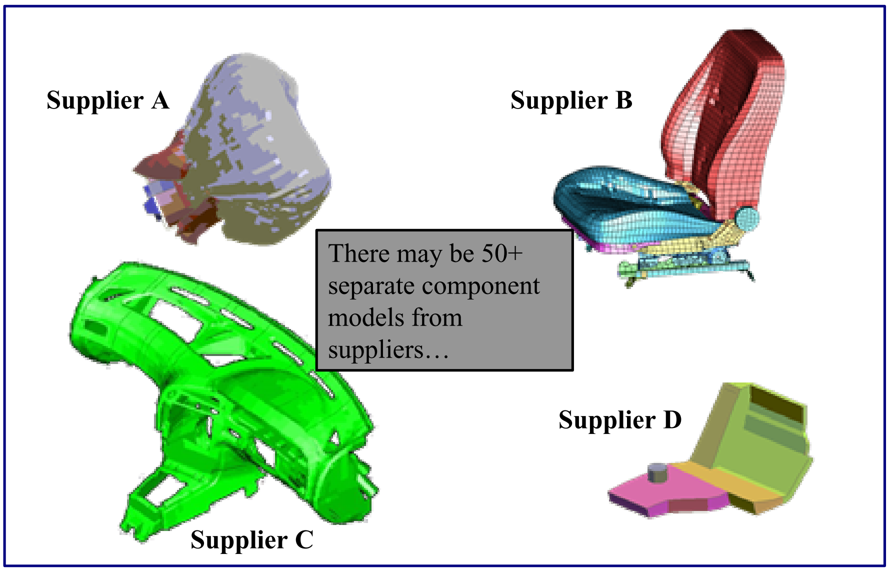
Current process

- The model building process is extensive. Engineers spend months building the models for just one vehicle configuration.
- Even with experienced engineers , it take a long time to debug complex models.
- New engineers take a long time to build crash models and even longer time to debug them.
- Storage space needed for every engineer to perform its own analysis.
- Connecting shared components isn’t easy because of design changes.
- Simulation is not as effective as it could be because models take too long to build.
- Quality, cost and stress.

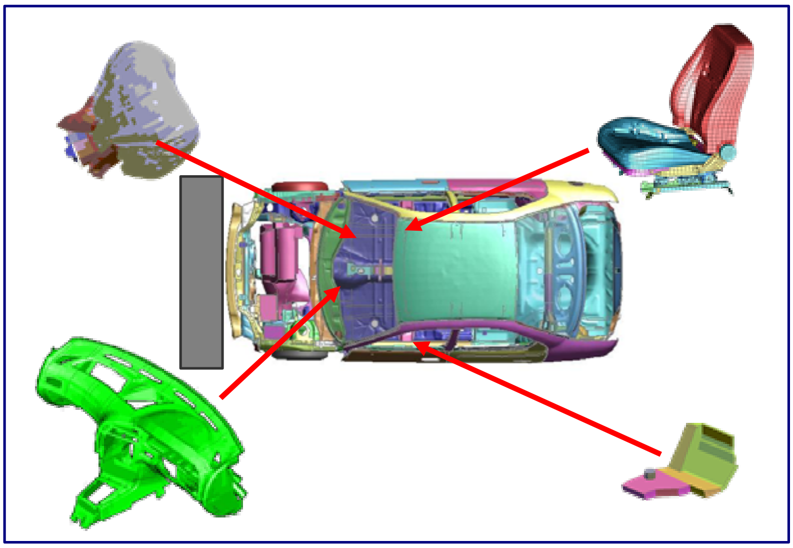
Why we need the new process ?

No more Bad supplier models !!!!

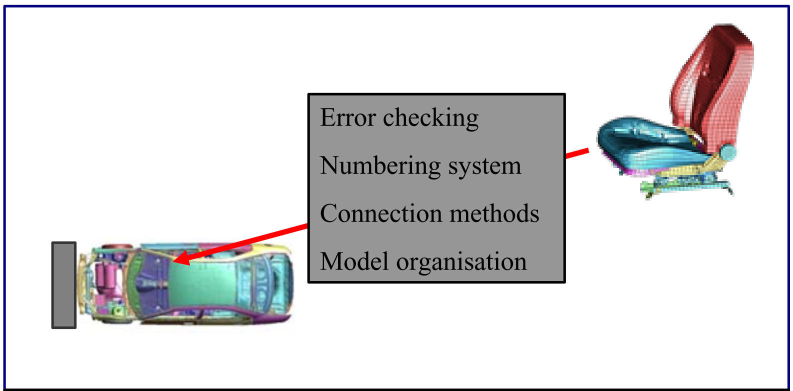
Component models from suppliers...



... must be integrated into crash models



Integration needs work from Team C

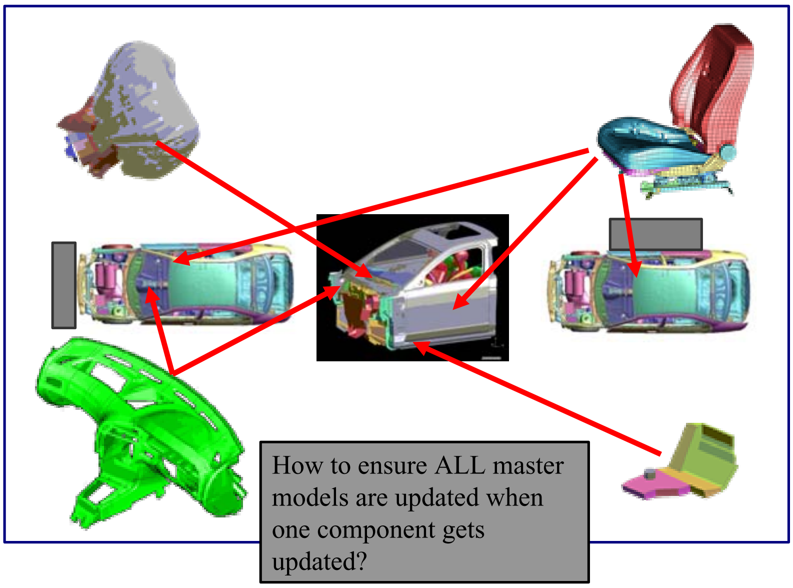


Chance of errors…

Repeat the work for each new release of component model…

Some of these issues also arise with Jaguar-generated component models

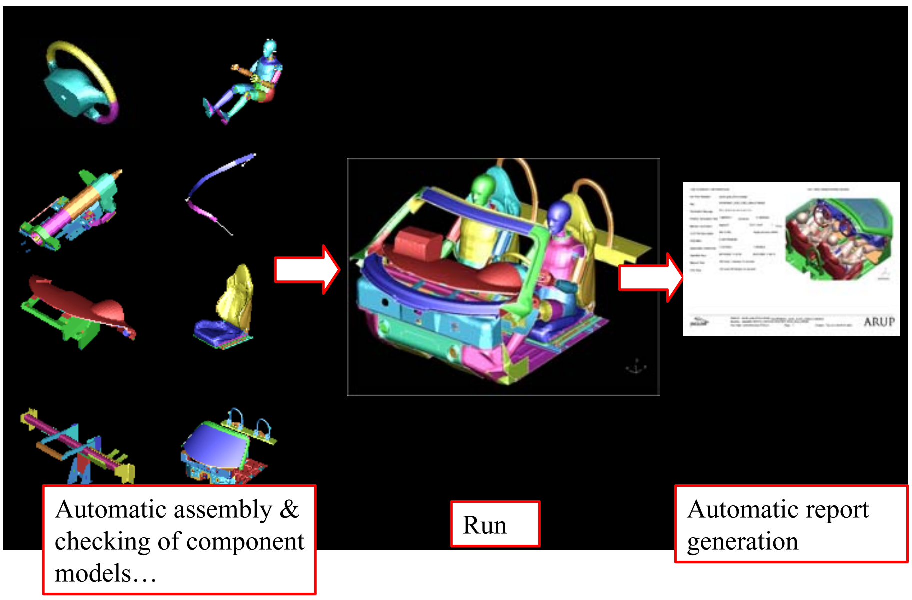
Some components go into several models



Problems of Model Organisation:

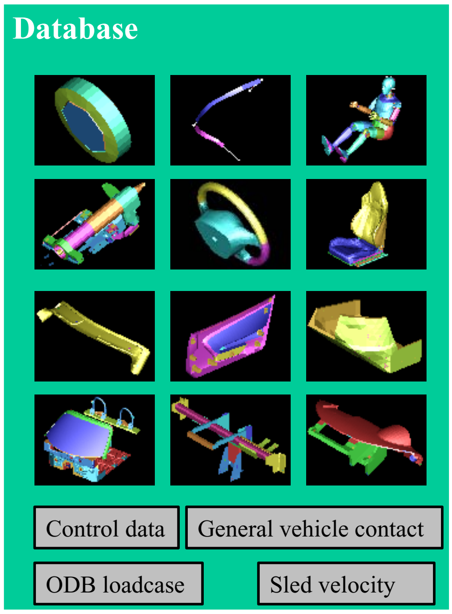
- How to achieve reliable system when so many separate components are provided by different suppliers?
- How do we ensure that all the correct component models are chosen for each crash load case?
- How do we ensure that the most recent frozen version of a given component is used in every crash load case?

Target process.. So what does this all mean

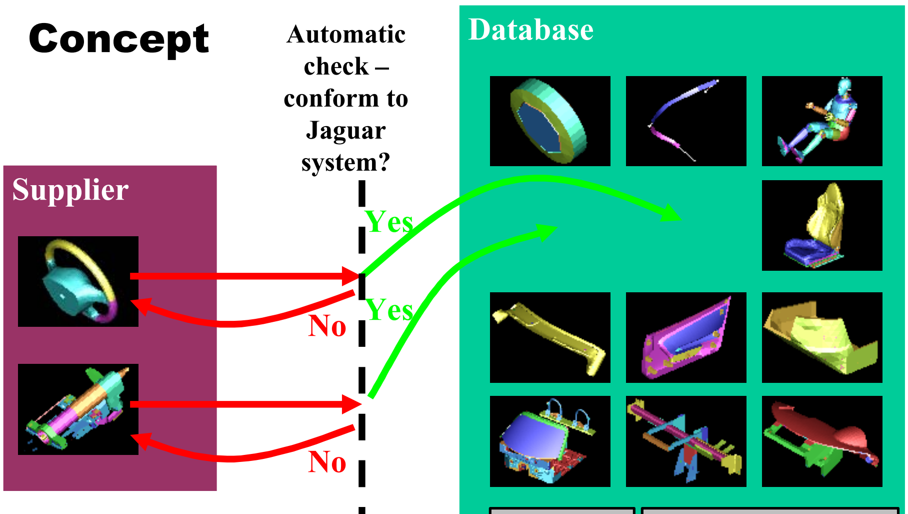


Concept

- Database of “ingredients”: components and other model data
- Entry to database controlled by nominated Jaguar person
- Software can check the models prior to entry to database for conformity to Jaguar system
- Database will contain only checked, error-free models and data

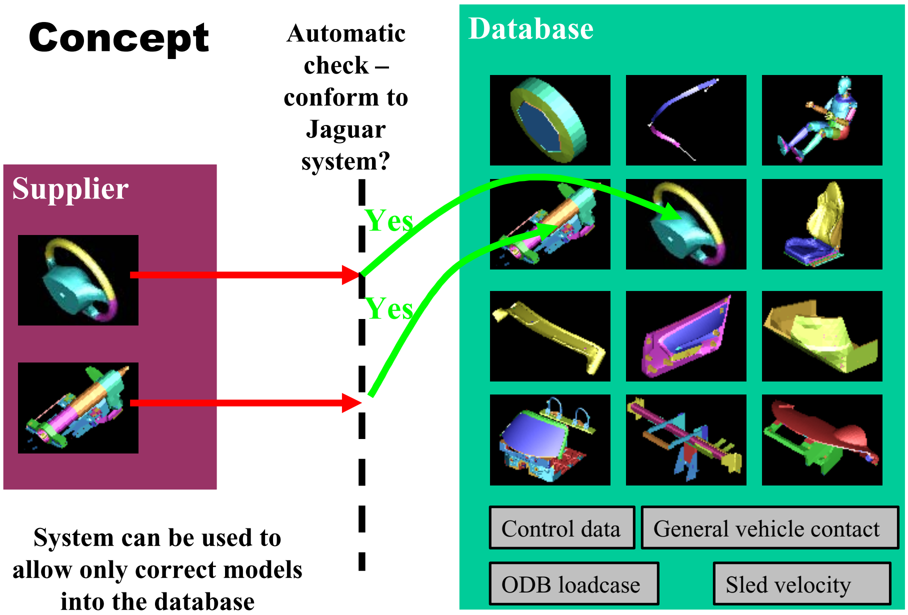


Concept



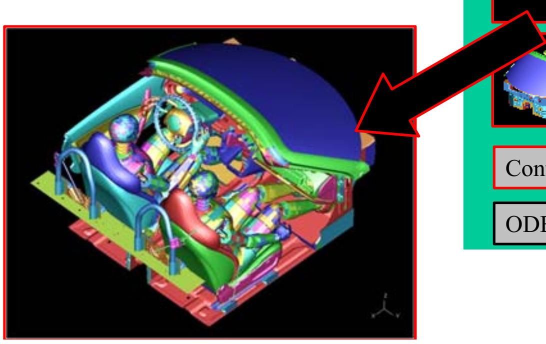
System can be used to allow only correct models into the database

Concept



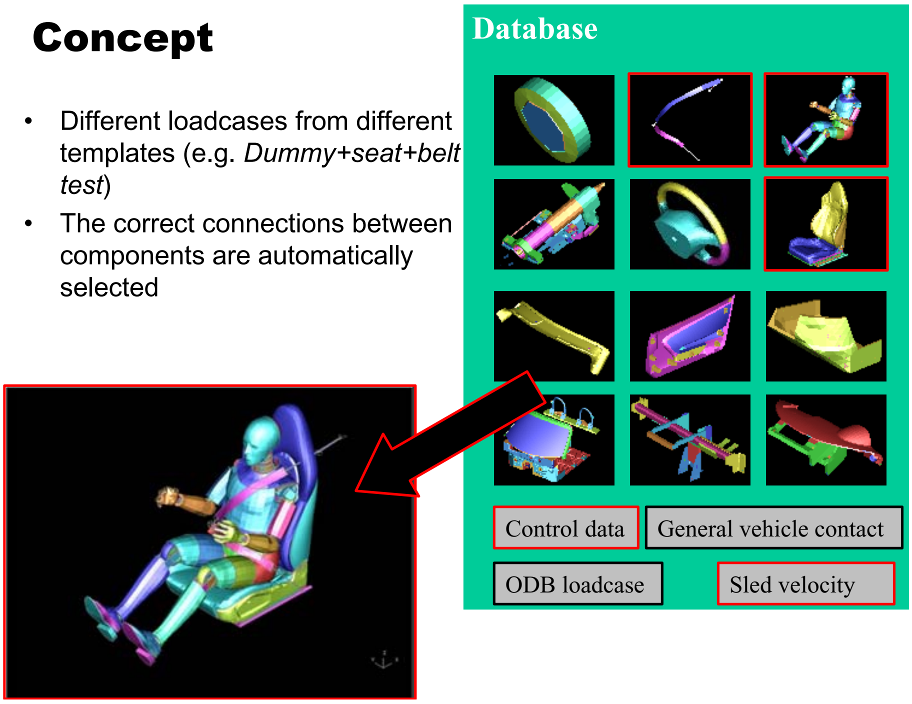
Concept

- Combination of components and other data automatically picked from database using a pre-defined TEMPLATE (e.g. *LHD Cockpit ODB with Intrusion*)

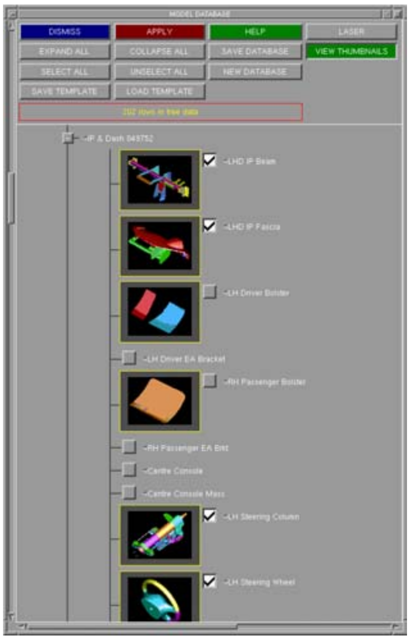


Concept

- Different loadcases from different templates (e.g. *Dummy+seat+belt test*)
- The correct connections between components are automatically selected



Example – selecting components from the database

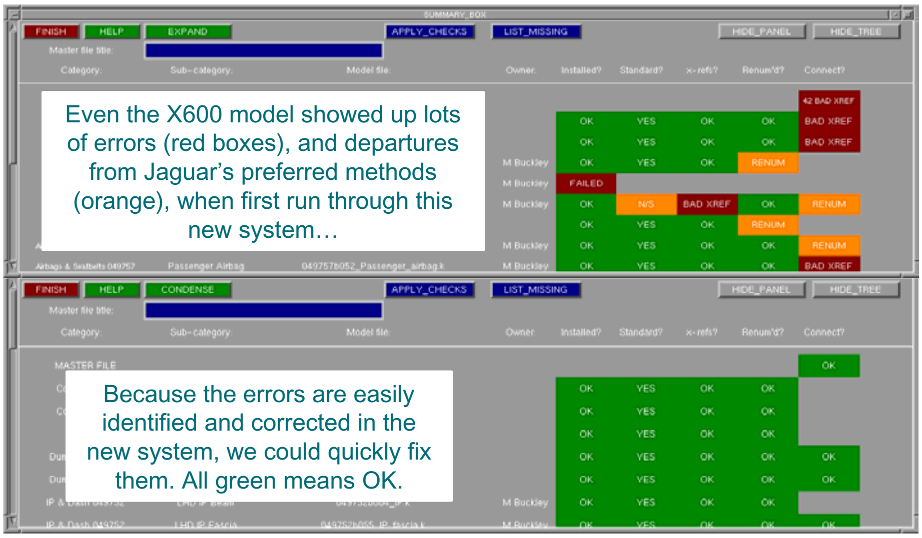


Component models in database are presented graphically, in a hierarchical tree structure.

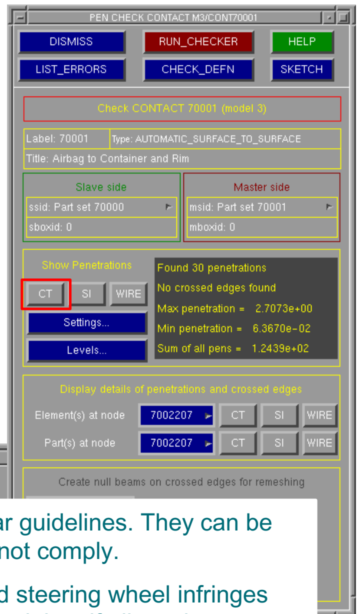
Users can click to select each component…

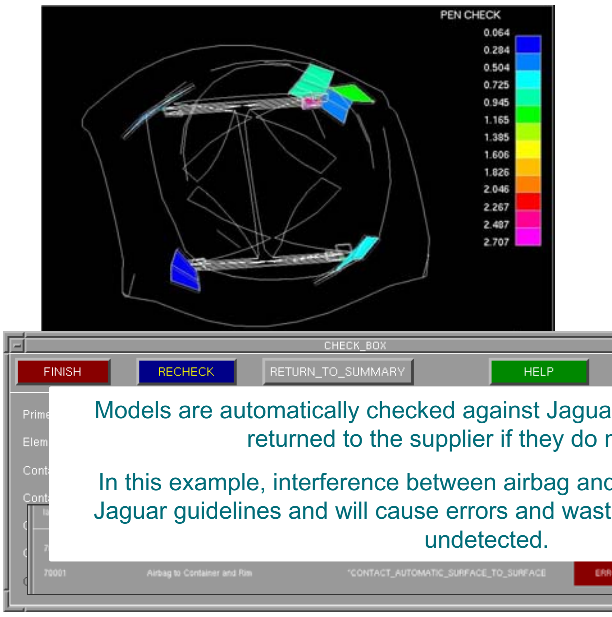
…or use a ready-made template containing the correct pattern of ticks for each loadcase

Benefits of new process

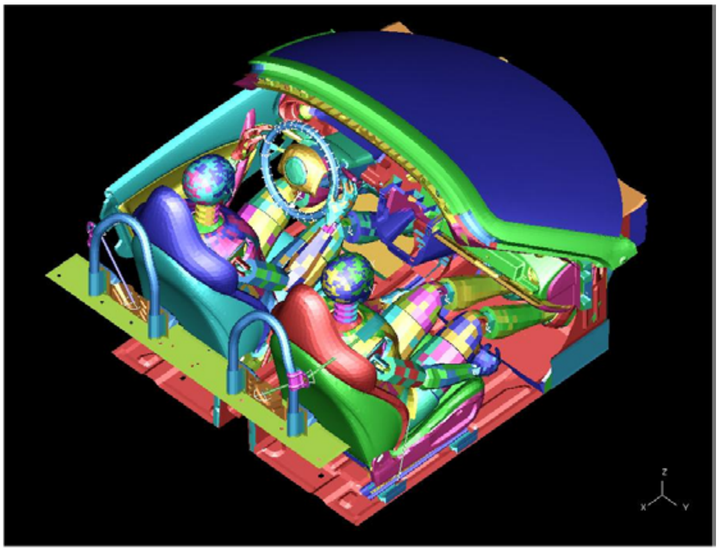


Investigating errors – contact penetrations

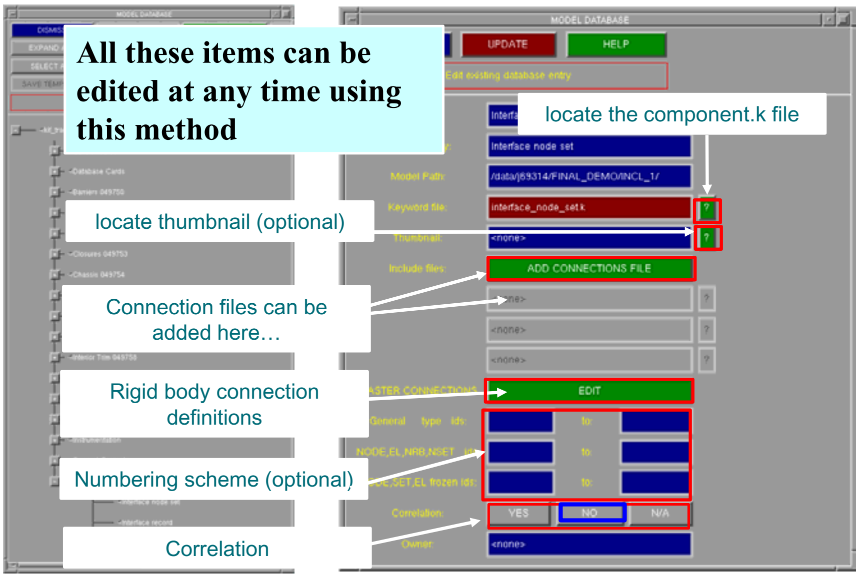




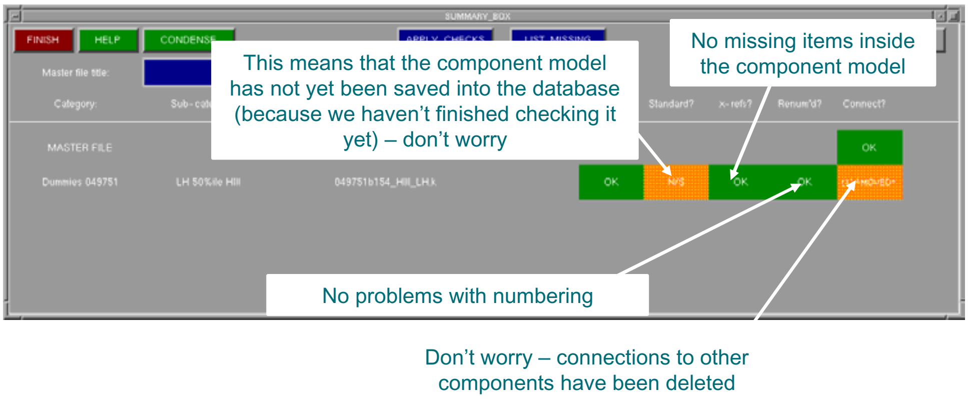
Result: ready-to-run, error-free model



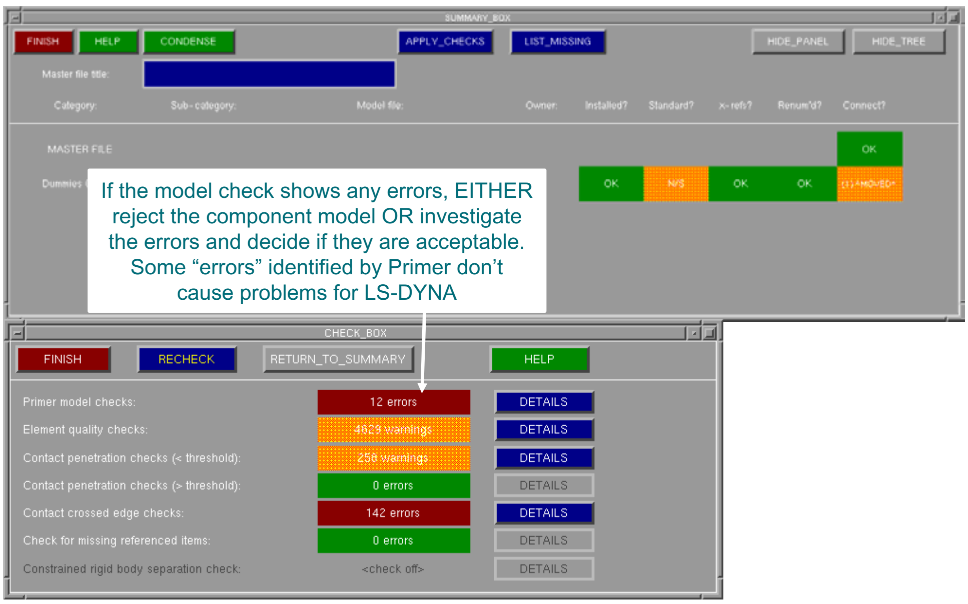
Installing a component model



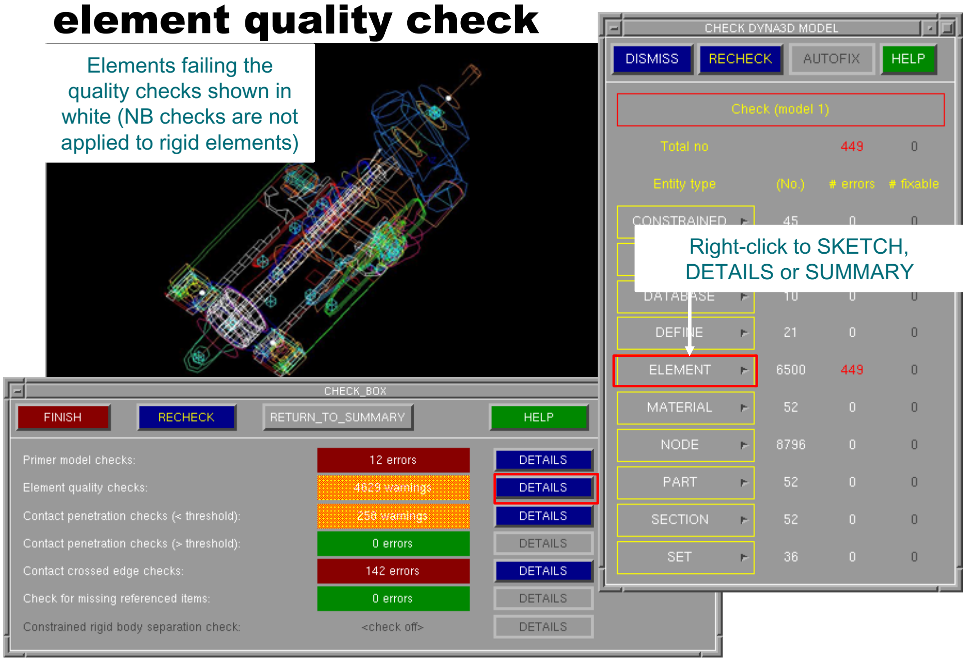
Checking the component models



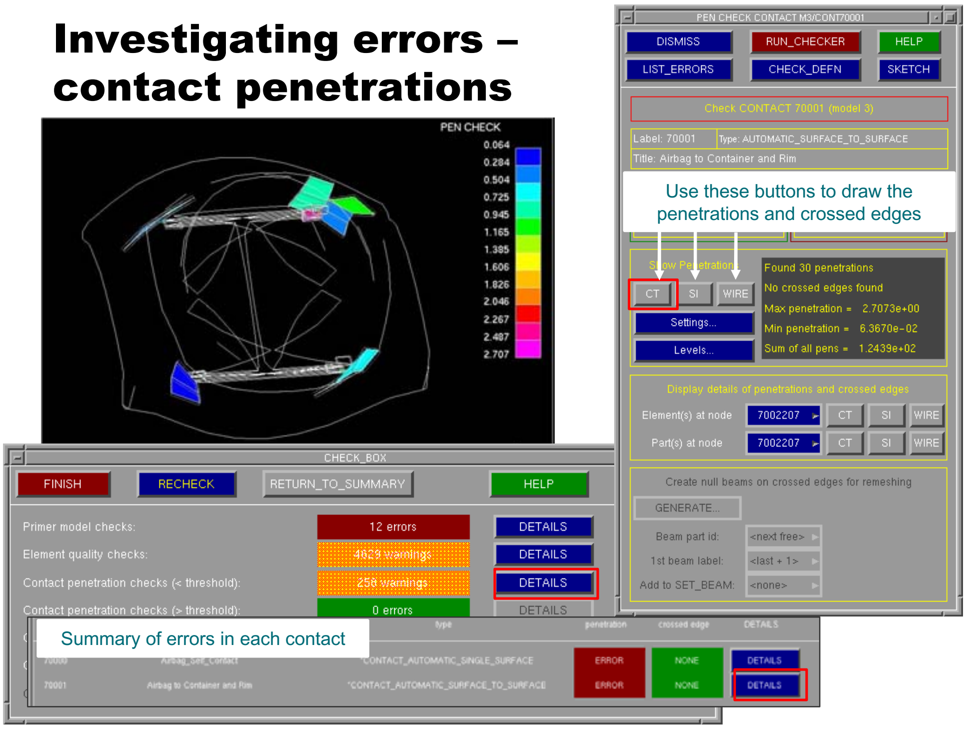
Checking the component models



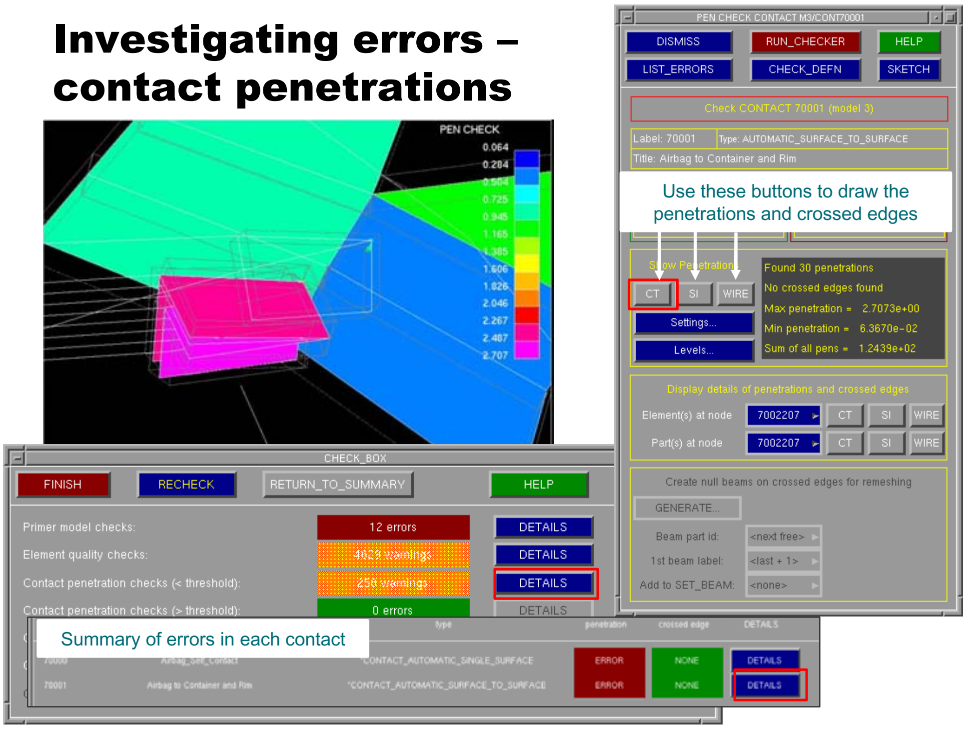
Investigating errors – element quality check



Investigating errors – contact penetrations



Investigating errors – contact penetrations



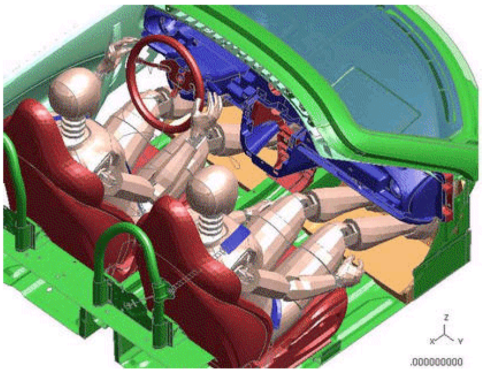
Automatic post-processing

- Report generated automatically from LS-DYNA results
- Same report template easily applied to different models
- All Euro-NCAP injury measures are calculated
- Writes report in web-ready or printable format
- Next slides show example pages

JOB SUMMARY INFORMATION

Job Root Filename	tayeb_arup_03A_noLbag2		
Title	052455B001_ODB_SLED_DEBUG:290502		
Termination Message	N o r m a l t e r m i n a t i o n		
Problem Termination Time	1.4000E-01	should be	0.1400E+00
Machine Information	atgdec01	OSF1 V4.0F	1 CPUs
LS-DYNA Executable	960 (1106)	Single precision (I4R4)	
Total Mass	0.29517609E+00		
Added Mass Initial/Final	1.3273E-02	1.3664E-02	
Start/End Time	06/14/2002 11:38:59	06/21/2002 11:40:12	
Elapsed Time	168 hours 1 minutes 13 seconds		
CPU Time	132 hours 50 minutes 22 seconds		

ISO VIEW UNDEFORMED MODEL



Data for traceability (e.g. version of LS-DYNA, any errors reported during the run) are taken from the output files

JAGUAR

Analysis : tayeb_arup_03A_noLbag2 052455B001_ODB_SLED_DEBUG:290502
Baseline : /data/j69314/POST_PROCESSING/TEST_RUN_2/cut_070200
Test Data: /u/mid/rbrookes/TOOLS/ Page : 1 Created : Tue Jul 2 09:05:03 2002

ARUP

Conclusions

- *We chose the lightweight vehicle architecture for the New XJ not because it was new, but because it would help us deliver significant benefits for our customers*
- *Ls_Dyna was effectively used for the the new XJ car from concept to production.*
- *Opportunities was identified for further LS_DYNA development to models complexities such as:*
  - *Structure: casting, rivets, adhesive , material failures*
  - *Restraints: airbags, seatbelts, Composite materials.*
- *More automation is needed in producing high standards models so that engineer could concentrate in helping design than debugging models.*