

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

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- Introduction
- Design considerations
- Safety considerations
- Models database creation
- Conclusions

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

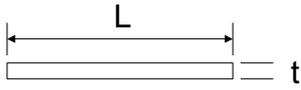
- 40% body weight saving for complete body and increase torsional stiffness .
- Meet world safety standards
- Ease of repair. Bolt-on front end for low speed damage repair
- Improved performance, economy, emissions
- Enhanced feature specification
- Improved interior/ luggage space.
- Durability to be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

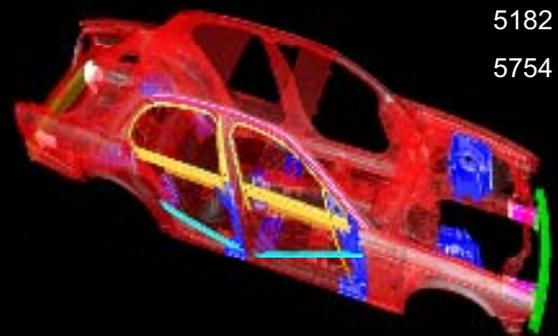
$$Gauge_{Al} = \sqrt[3]{3(Gauge_{St})^3}$$


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)

Body Construction



85% of body is sheet

6111 - Exterior panels

5182 - Inner panels

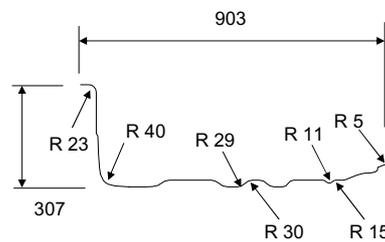
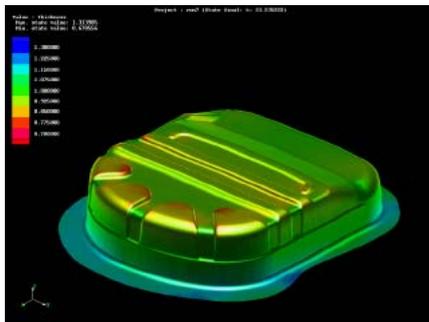
5754 - Structure panels

<p>Castings 5% of body</p> <ul style="list-style-type: none"> ■ Vacuum Die Cast ■ Green Sand Cast 	<p>Extrusions 10% of body</p> <ul style="list-style-type: none"> ■ 6082-T6 ■ 7108-T6 ■ 6060-T4 ■ 6063-T6
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Structural Panel Development

- Aluminium design & stamping guidelines used on all parts.

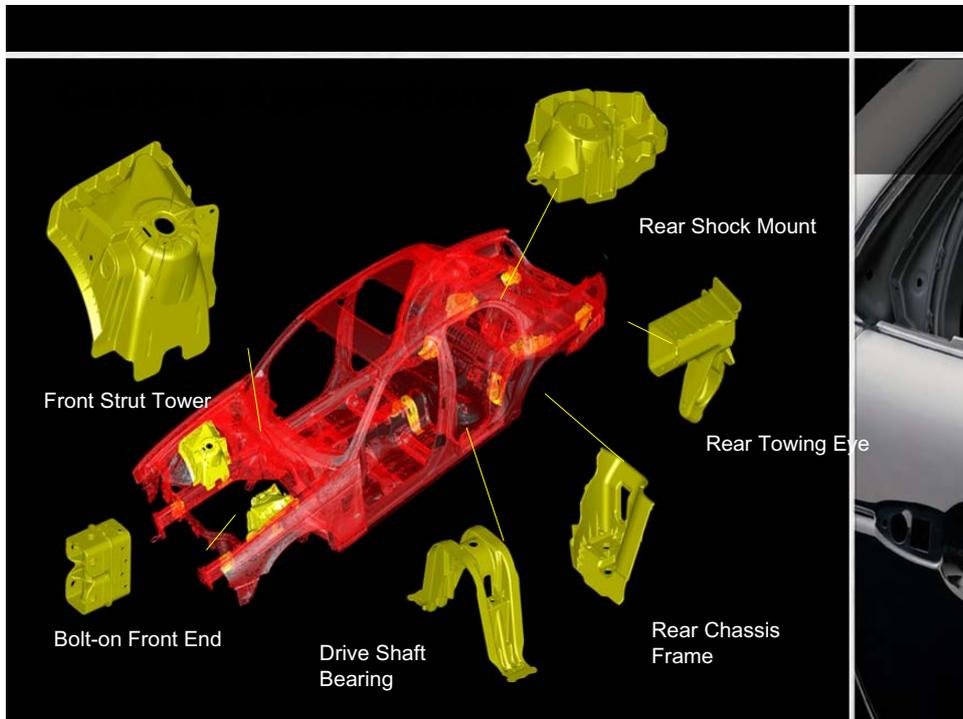
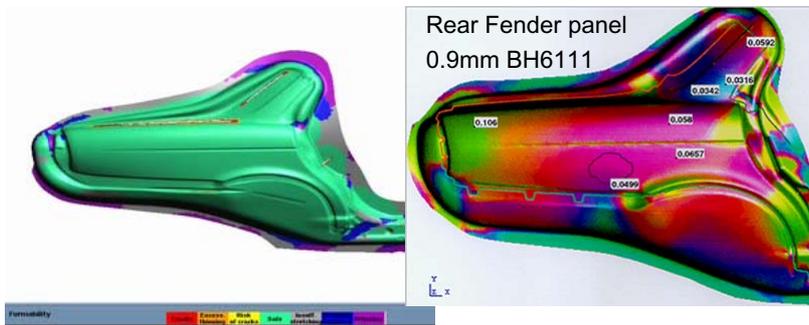


Structural Castings

- 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:-

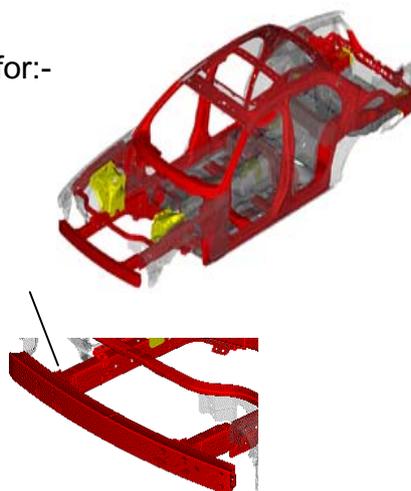
- Weight save & reduced part count
- Reduced tooling investment
- High strength applications
- Ability to form simple shapes/profiles

➤ 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

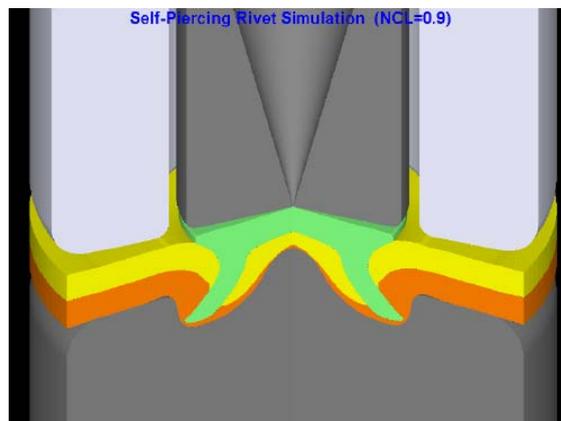
	Equivalent steel	XJ alu hybrid	Weight saved
Front Door	19Kg	10.48Kg	45%
Rear Door	15Kg	8.72Kg	42%

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

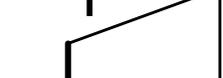


Adhesive Bonding

- 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

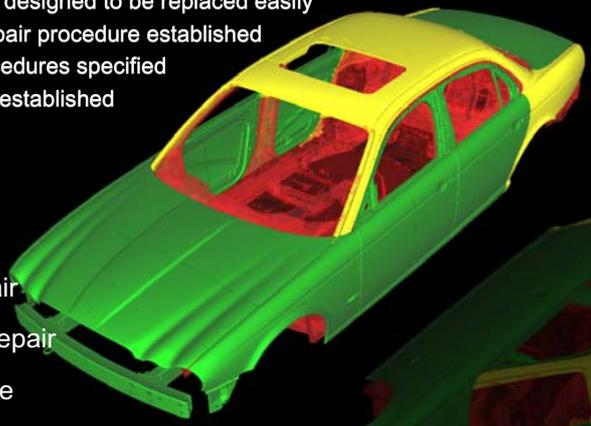
New XJ BIW information

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

Panel Repairability

- Worked with Insurance organisations to establish repair strategy
- All exterior panels designed to be replaced easily
- Rivet/adhesive repair procedure established
- Equipment & Procedures specified
- Repair guidelines established

Green – Bolt On Repair
Yellow – Unstitch & Repair
Red – Main Structure



New XJ Safety Philosophy

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

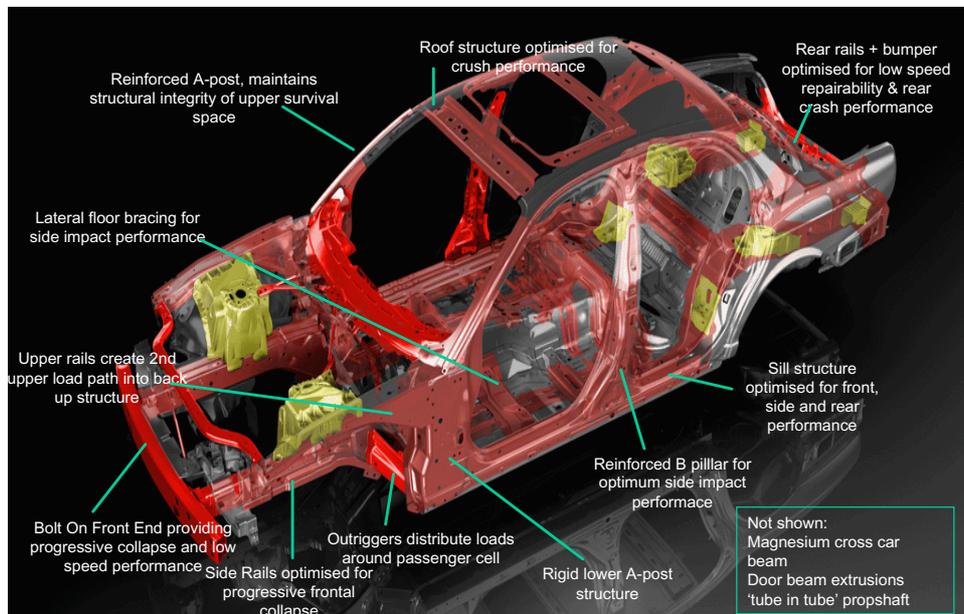
- **World safety standards Proven via:**
 - 1000+ CAE virtual crash tests using 175,000 hrs of computing power
 - 79 full vehicle crash tests

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

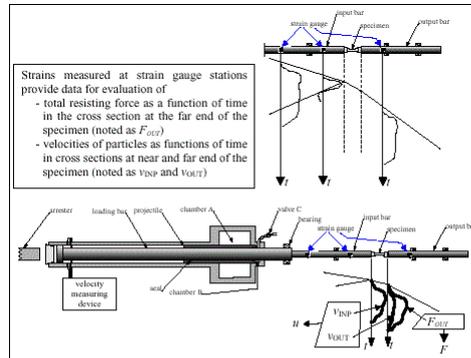


Figure 5: Results of measurements at high rates of strain

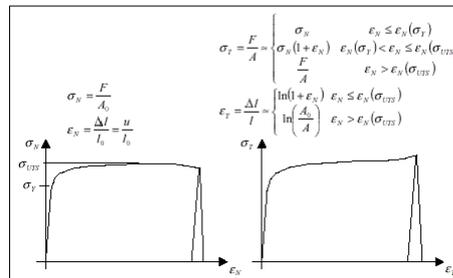
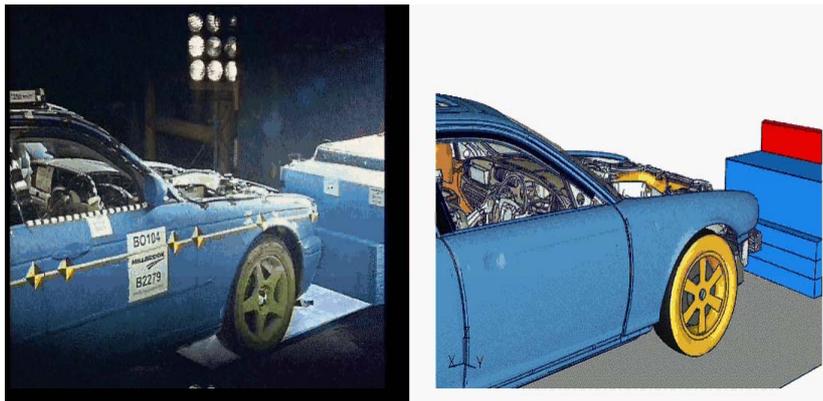


Figure 6: Uniaxial tensile test: evaluation of stress-strain relationship

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

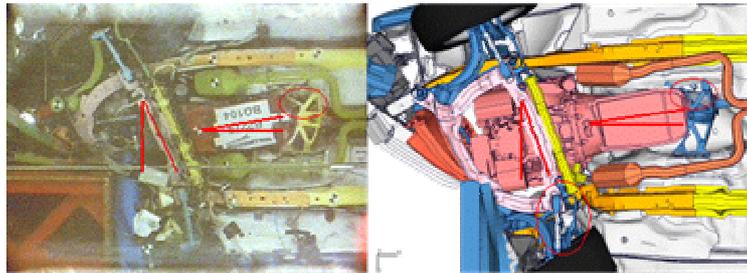
The New FMVSS208

- 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

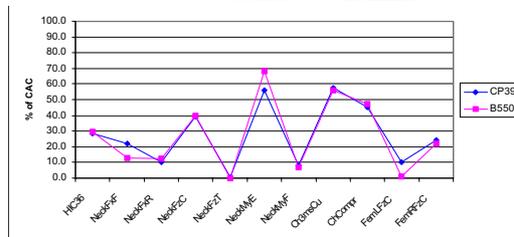
Euro NCAP – ODB 64 kph

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



Front Impact

Euro NCAP – ODB 64 kph



New XJ Safety Performance

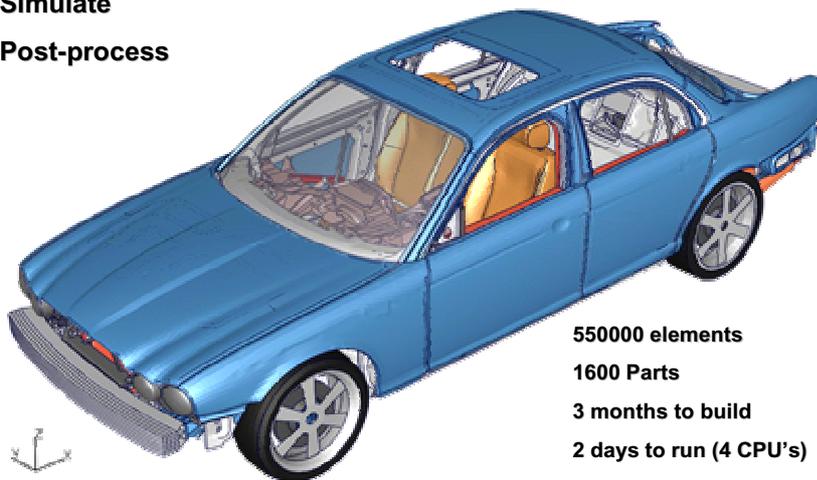
- New XJ has excelled in Jaguar's internal testing and makes significant strides in safety protection
- Strong aluminium body structure provide excellent occupant protection
- The vehicle includes a comprehensive array of safety technology including Jaguars sophisticated ARTS system
- Low speed performance 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)

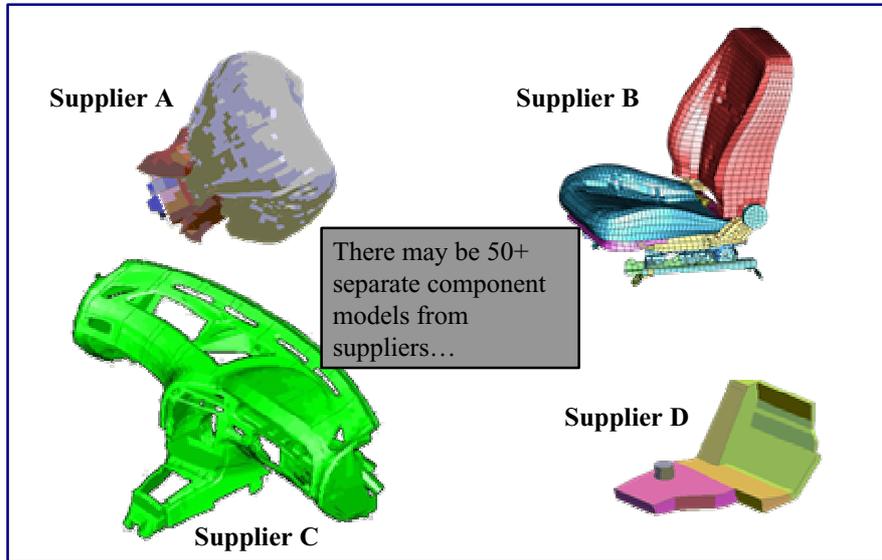
Current process

- 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.

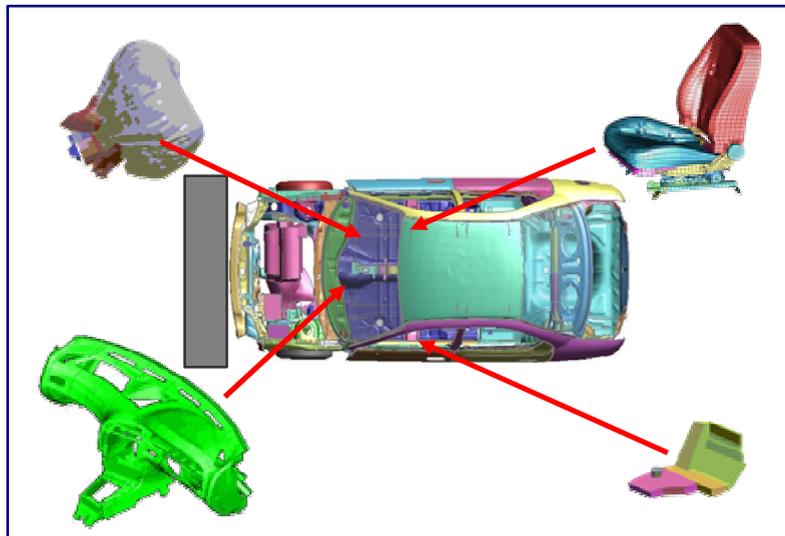
Why we need the new process ?

No more Bad supplier models !!!!

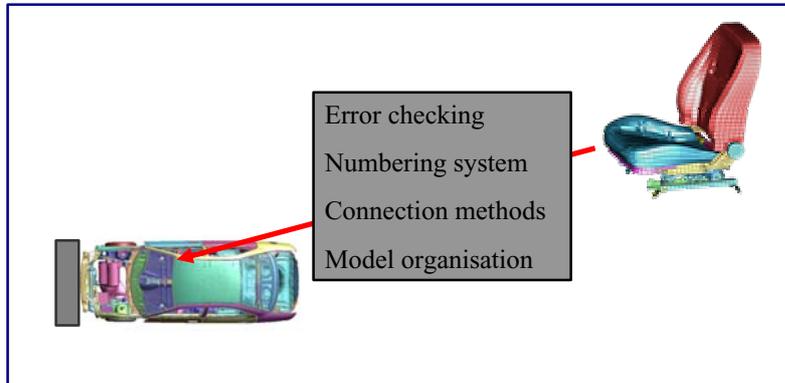
Component models from suppliers...



... must be integrated into crash models



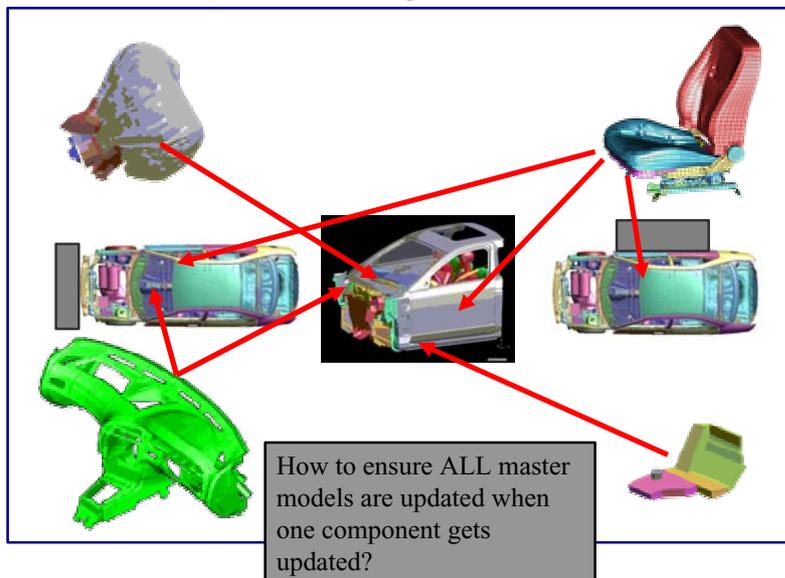
Integration needs work from Team C



Error checking
 Numbering system
 Connection methods
 Model organisation

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

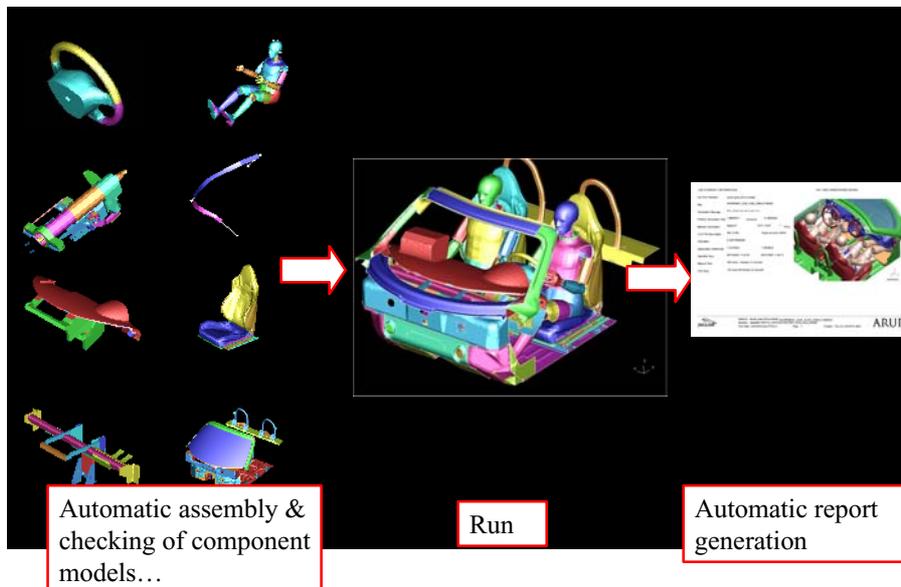


How to ensure ALL master models are updated when one component gets updated?

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

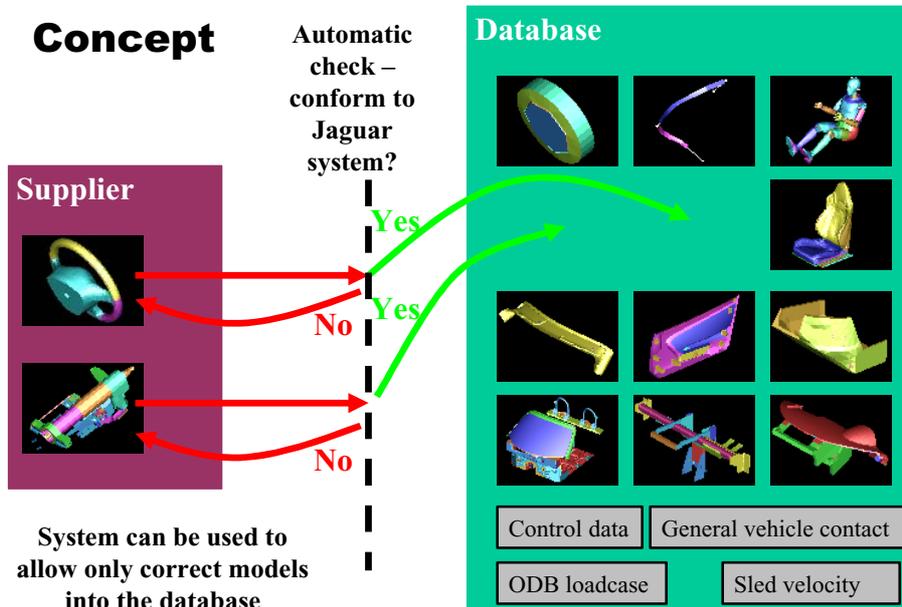


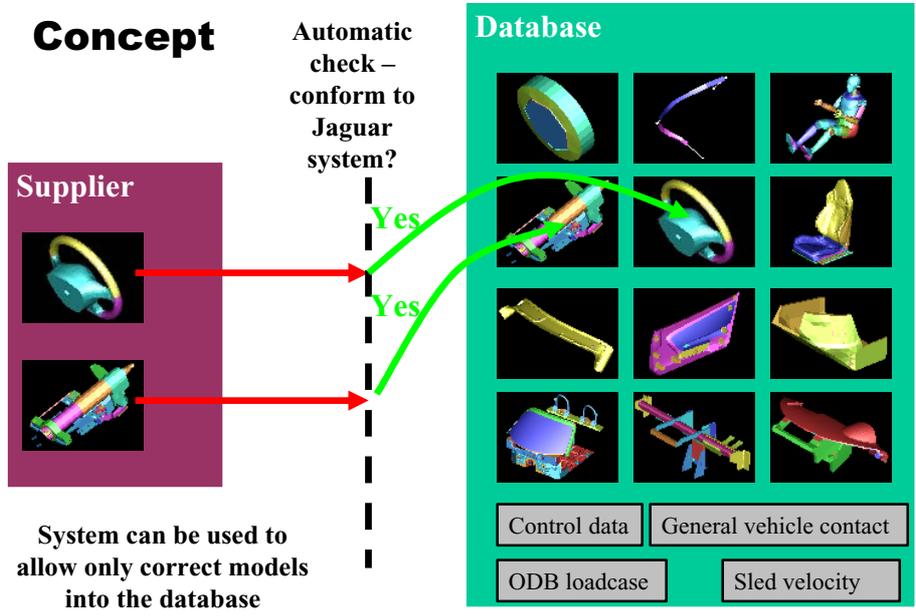
Concept

- 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



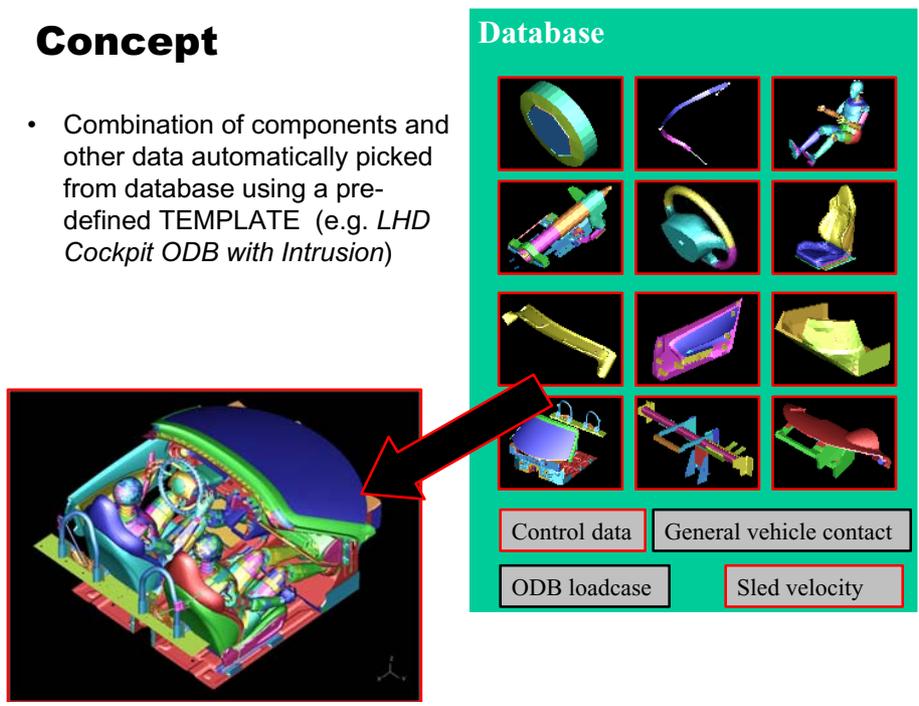
Concept





Concept

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

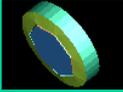
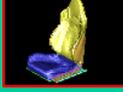
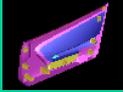
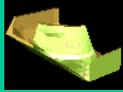
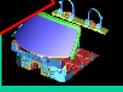


Concept

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



Database

Control data

General vehicle contact

ODB loadcase

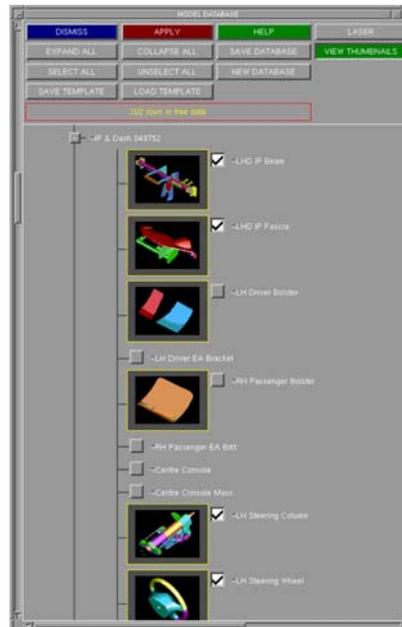
Sled velocity

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

Even the X600 model showed up lots of errors (red boxes), and departures from Jaguar's preferred methods (orange), when first run through this new system...

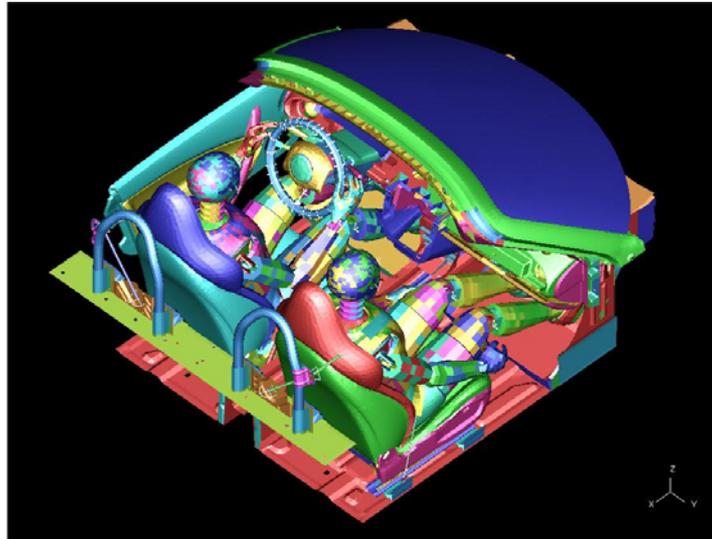
Because the errors are easily identified and corrected in the new system, we could quickly fix them. All green means OK.

Investigating errors – contact penetrations

Models are automatically checked against Jaguar guidelines. They can be returned to the supplier if they do not comply.

In this example, interference between airbag and steering wheel infringes Jaguar guidelines and will cause errors and wasted time if allowed to pass undetected.

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



Installing a component model

All these items can be edited at any time using this method

locate thumbnail (optional)

Connection files can be added here...

Rigid body connection definitions

Numbering scheme (optional)

Correlation

locate the component.k file

UPDATE HELP

Model Path: /data/99314/FINAL_DEMO/INCL_T/

interface_node_sst

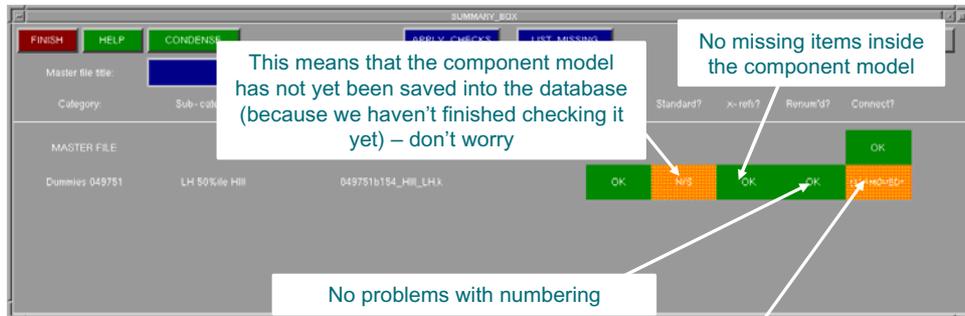
interface_node_sst.k

ADD CONNECTIONS FILE

EDIT

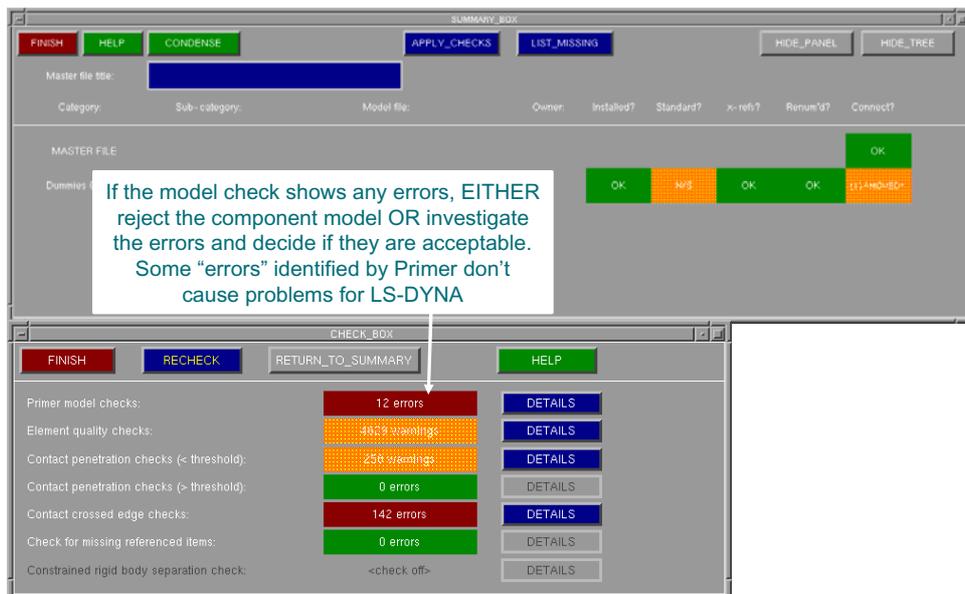
YES NO N/A

Checking the component models



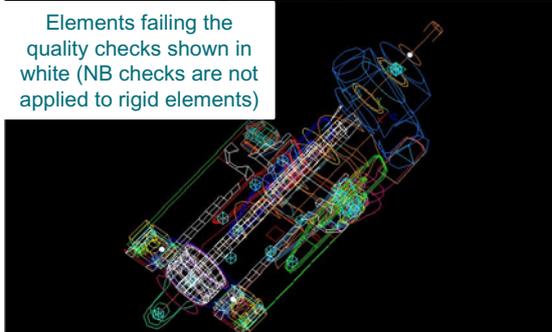
Don't worry – connections to other components have been deleted

Checking the component models



Investigating errors – element quality check

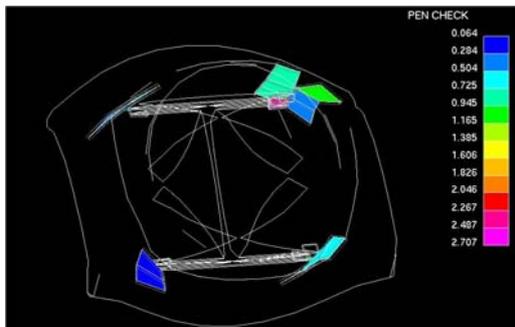
Elements failing the quality checks shown in white (NB checks are not applied to rigid elements)



Entity type	(No.)	* errors	# fixable
CONSTRAINED	45	0	0
DATABASE	10	0	0
DEFINE	21	0	0
ELEMENT	6500	449	0
MATERIAL	52	0	0
NODE	6736	0	0
PART	52	0	0
SECTION	52	0	0
SET	36	0	0

Check Category	Count	Status
Primer model checks:	12 errors	Red
Element quality checks:	4629 warnings	Yellow
Contact penetration checks (<= threshold):	258 warnings	Yellow
Contact penetration checks (> threshold):	0 errors	Green
Contact crossed edge checks:	142 errors	Red
Check for missing referenced items:	0 errors	Green
Constrained rigid body separation check:	<check off>	Grey

Investigating errors – contact penetrations



Found 30 penetrations
No crossed edges found
Max penetration = 2.7073e+00
Min penetration = 6.3670e-02
Sum of all pens = 1.2439e+02

Display details of penetrations and crossed edges

Element(s) at node: 7002207 CT SI WIRE
Part(s) at node: 7002207 CT SI WIRE

Create null beams on crossed edges for remeshing
GENERATE...
Beam part id: <next free>
1st beam label: <last + 1>
Add to SET_BEAM: <none>

Check Category	Count	Status
Primer model checks:	12 errors	Red
Element quality checks:	4629 warnings	Yellow
Contact penetration checks (<= threshold):	258 warnings	Yellow
Contact penetration checks (> threshold):	0 errors	Green
Contact crossed edge checks:	142 errors	Red
Check for missing referenced items:	0 errors	Green
Constrained rigid body separation check:	<check off>	Grey

Label	Type	penetration	crossed edge
70001	*CONTACT_AUTOMATIC_SINGLE_SURFACE	ERROR	NONE
70001	*CONTACT_AUTOMATIC_SURFACE_TO_SURFACE	ERROR	NONE

Investigating errors – contact penetrations

Summary of errors in each contact

Contact ID	Type	penetration	crossed edge	DETAILS
70000	Airbag_wire_Constact	CONTACT_AUTOMATIC_SINGLE_SURFACE	NONE	DETAILS
70001	Airbag to Container and Rim	*CONTACT_AUTOMATIC_SURFACE_TO_SURFACE	NONE	DETAILS

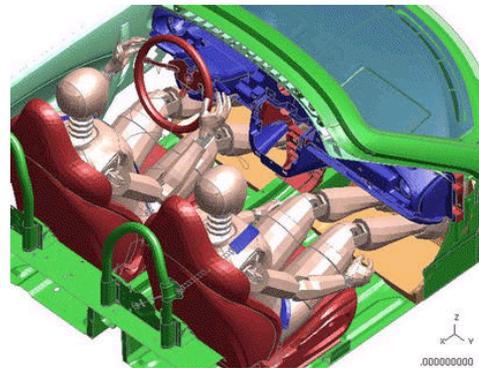
Automatic post-processing

- 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	0624658001_ODB_SLED_DEBUG:290602		
Termination Message	Normal termination		
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	0.29517809E+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



Analysis : tayeb_arup_03A_noLbag2 0624658001_ODB_SLED_DEBUG:290602
 Baseline : /data/099314/POST_PROCESSING/TEST_RUN_Z/cut_070200
 Test Data : /u/mid/brookes/TOOLS/ Page : 1 Created : Tue Jul 2 09:05:03 2002



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.

