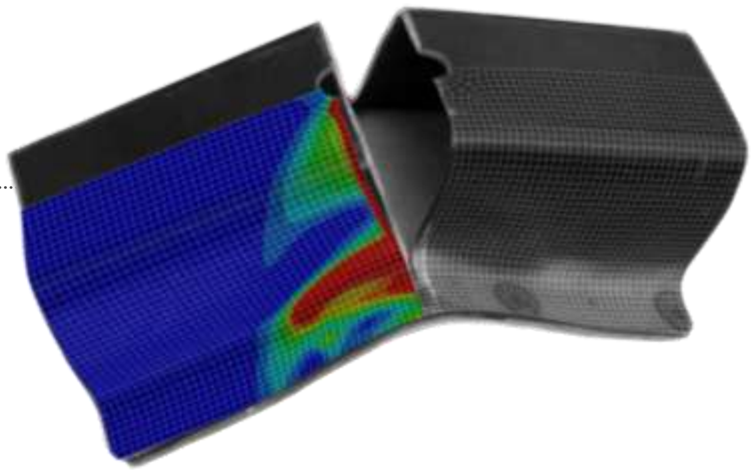
HyperWorks

FASTER REALISTIC CRASH SIMULATIONS

Radioss Version 11



Francis Arnaudeau

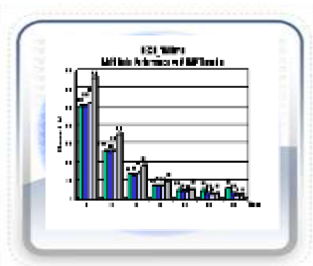
4th EHTC

Versailles, October 28th 2010

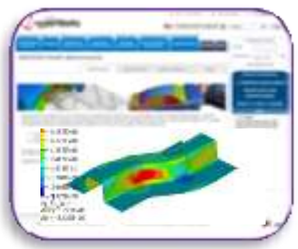
Version 2.0

HyperWorks

AGENDA

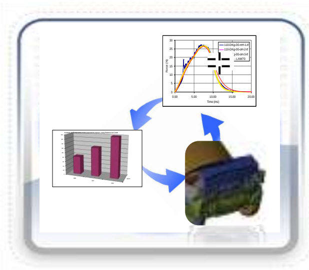


Hybrid MPP



CPU Reduction

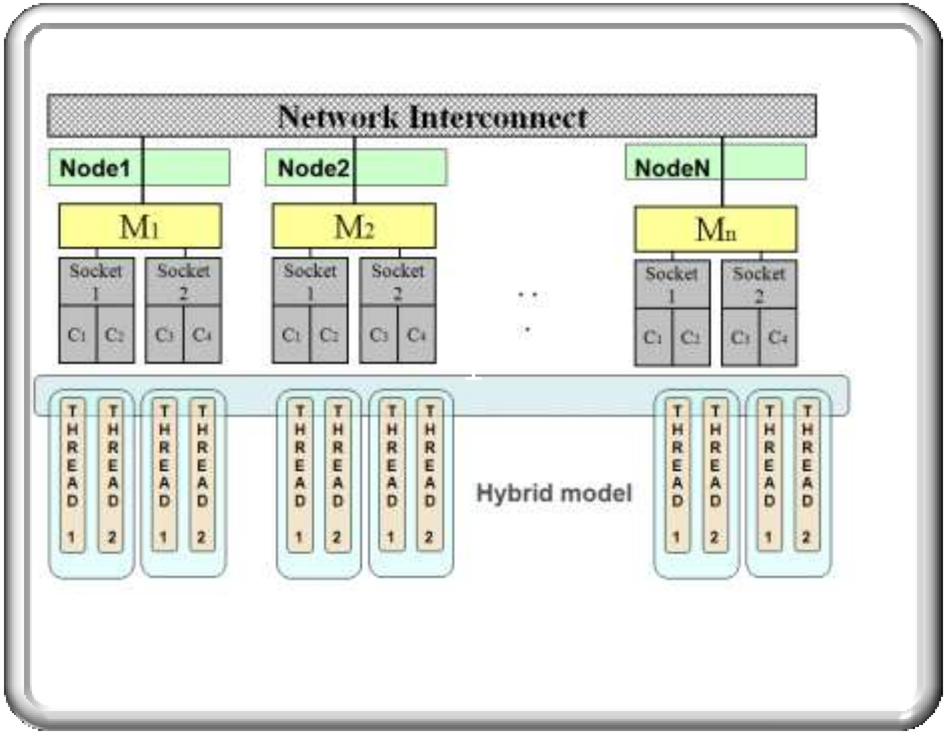
Full Car Crash



Conclusion

RADIOSS HYBRID MPP

- **Hybrid MPP version** will replace the previous SMP & SPMD ones.
  - Hybrid version combines the benefit of booth Radioss parallel versions inside an unique code with enhanced performance.
  - Hybrid version means high flexibility: adapt to customer's needs and hardware resources & their evolution.
  - Increased Scalability for high number of cores
  - Repeatability continues to be provided



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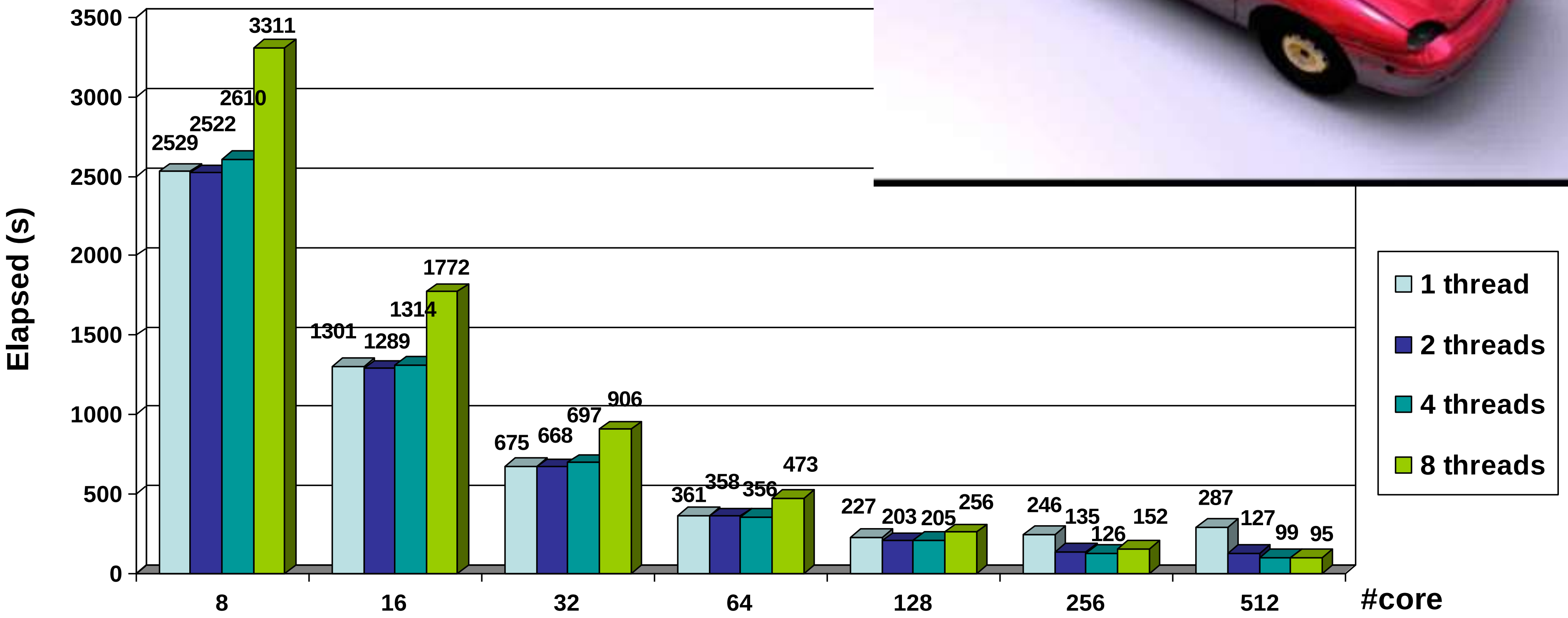
RADIOSS HYBRID MPP

Performance Results Nehalem
2.80 GHz Cluster
Neon 1 million elements
8 ms simulation



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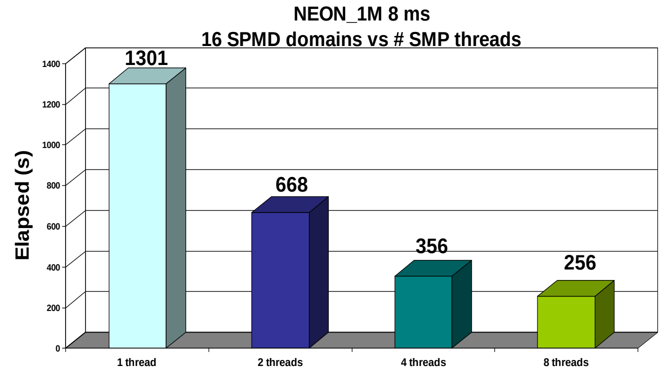
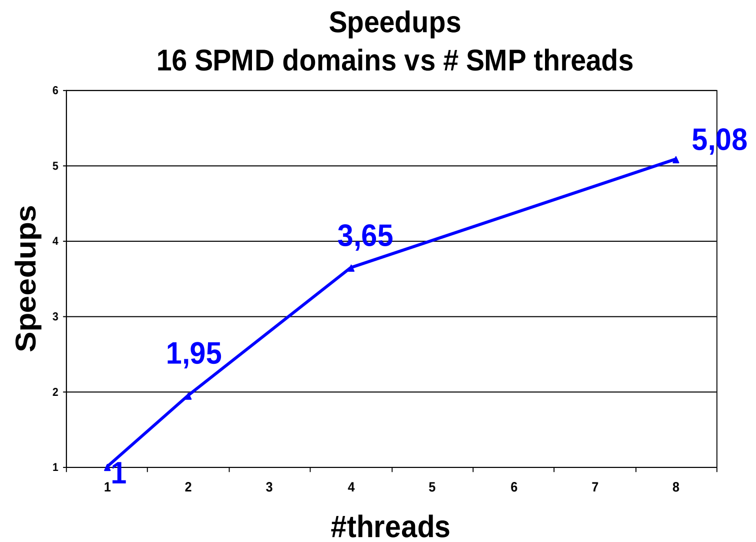
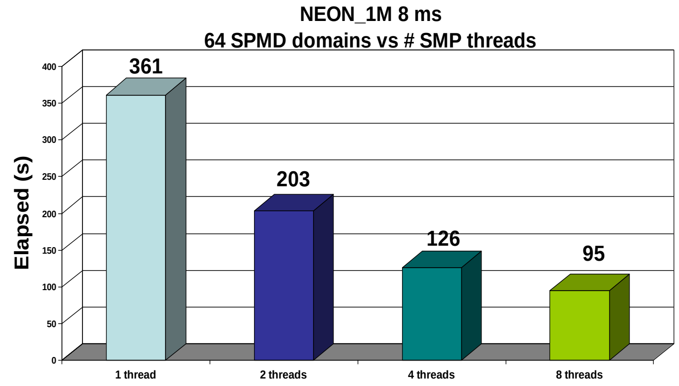
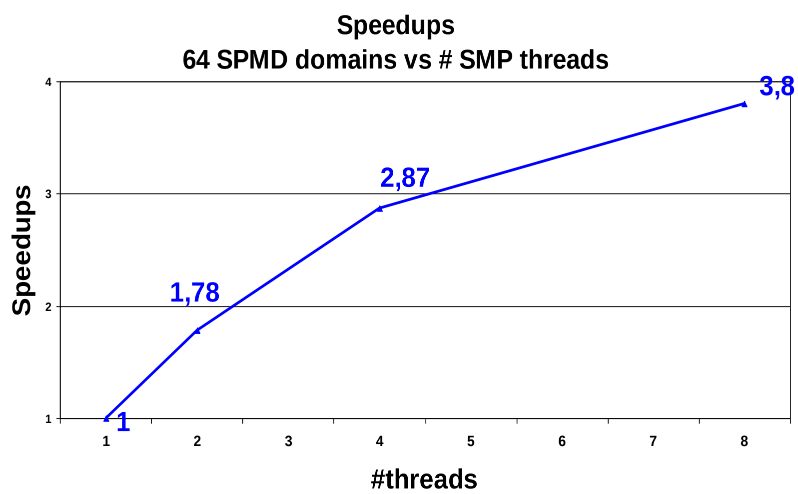
RADIOSS HYBRID MPP









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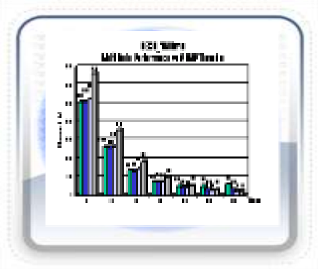
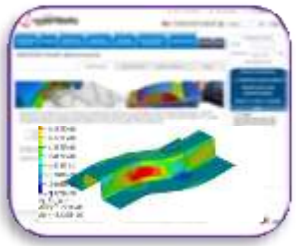


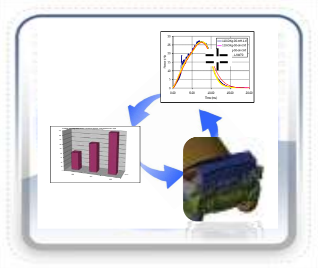
Hybrid

MPP



CPU Reduction

Full Car Crash



Conclusion

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CPU Reduction

- Time step issues
  - Time step is smaller than physics request
  - Time step is given by smallest element
    - A local mesh refinement will increase drastically the global simulation cost
  - Time step decreases during crash simulation
    - Element size issue

- Solutions to avoid time step decrease
  - Mass scaling
  - Element deletion
  - Small strain formulation
  - Flexible Body
  - XFEM
  - Cut methodology
  - **Multi-domain**

- Solutions to increase the time step
  - Implicit
  - Static & dynamic condensation
  - **Advanced mass scaling**

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Multi-Domain

Multi-Domain => Reduction of the CPU time without accuracy loss

- Objective
  - The basic idea is *to replace the global model by physically equivalent sub domains*, part separation will be based on the different time steps => ***significant reduction of the CPU time.***
- Motivation
  - Increased computation accuracy (prediction of rupture) requires mesh refinement for crash applications
- Validation examples:
  - Work initiated in collaboration with PSA in 2003

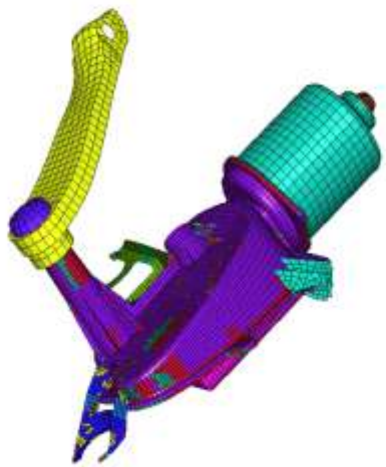
PSA PEUGEOT CITROËN
Direction Technique et Industrielle

  - "Multi-Domain Simulation Approach for Radioss – Efficient Coupling of Refined and Standard Meshes in Full Vehicle Crash Simulations" EHTC 2009 , *Aleksandar Bach[1], Marian Bulla[2], Bertrand Maurel[2]*

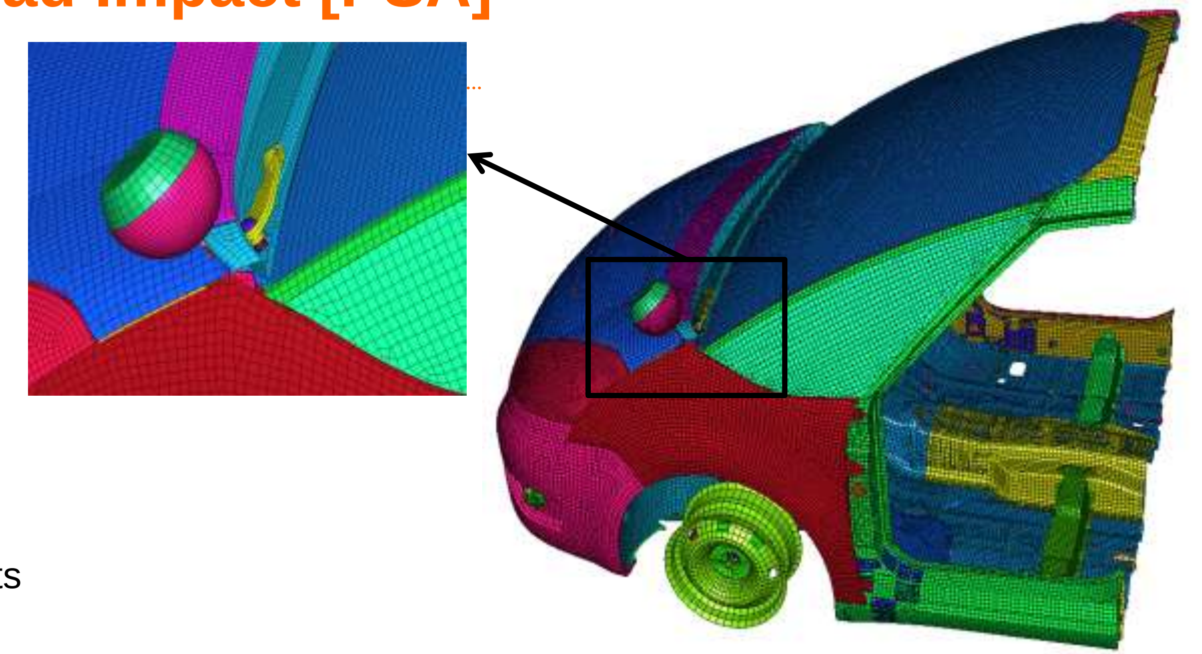
1) Ford Research & Advanced Engineering

2) Altair

Multi-Domain - Head Impact [PSA]



DOMAIN 1 : 13803 shell elements
time step : 0.3 µs



DOMAIN 2 : 303648 shell elements
time step : 0.8 µs

CPU's	1	16	32	64
Monodomain	63500 s	5420 s	3470 s	2790 s
Multidomain	27260 s	2584 s	1670 s	1390 s
Efficiency	2.30	2.09	2.08	2.01

Time step factor = (Δt domain 1) / (Δt domain 2) = 2.66

Monodomain = complete model with smaller time step

Efficiency = Elapsed Time Monodomain / Elapsed Time Multidomain

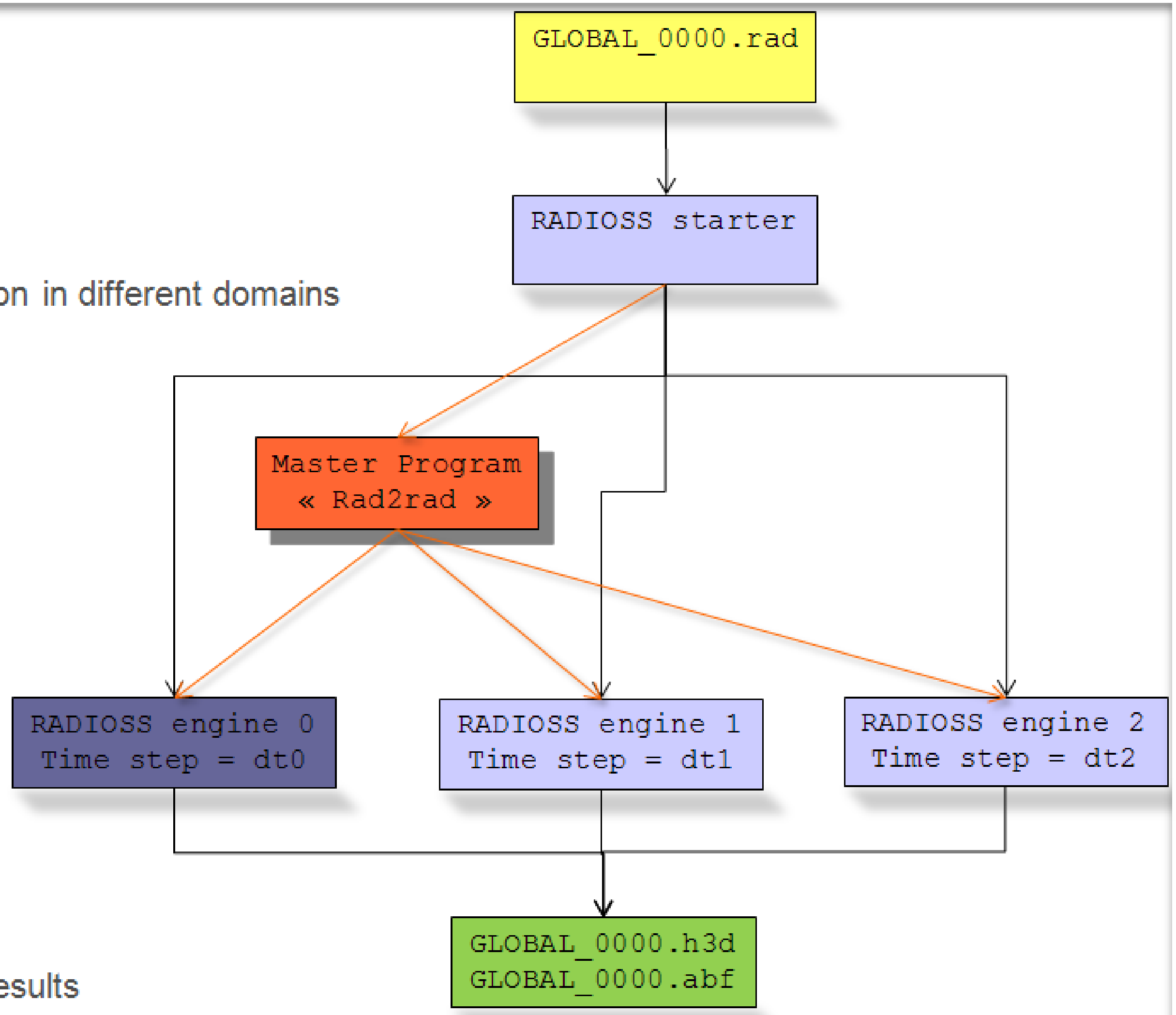
Multi-Domain - [FORD]

Das Bild kann zurzeit nicht angezeigt werden.

- Car 1,200,000 FE model with a refined frontal beam (24,000 FE 2%)
- Time step ratio: $(\Delta t_{D1} / \Delta t_{D2}) = 2.8$
- Elapsed time ratio Mono-domain / Multi-domain = **3.9** with 16 CPU’s

Multi-Domain - Improvements- Radioss V11

- Single input
  - Automatic decomposition in different domains



- Single output
  - Easier to analyze the results

Advanced Mass Scaling

Theoretical background

- L. Olovsson, K. Simonsson and M. Unosson. Selective mass scaling for explicit finite element analyses. *Int. J. Numer. Meth. Engng 2005*

- Modified (non diagonal) mass matrix $\boldsymbol{M} = [m] + \boldsymbol{A}$
  - $\boldsymbol{A}$ is assembled from elementary matrices

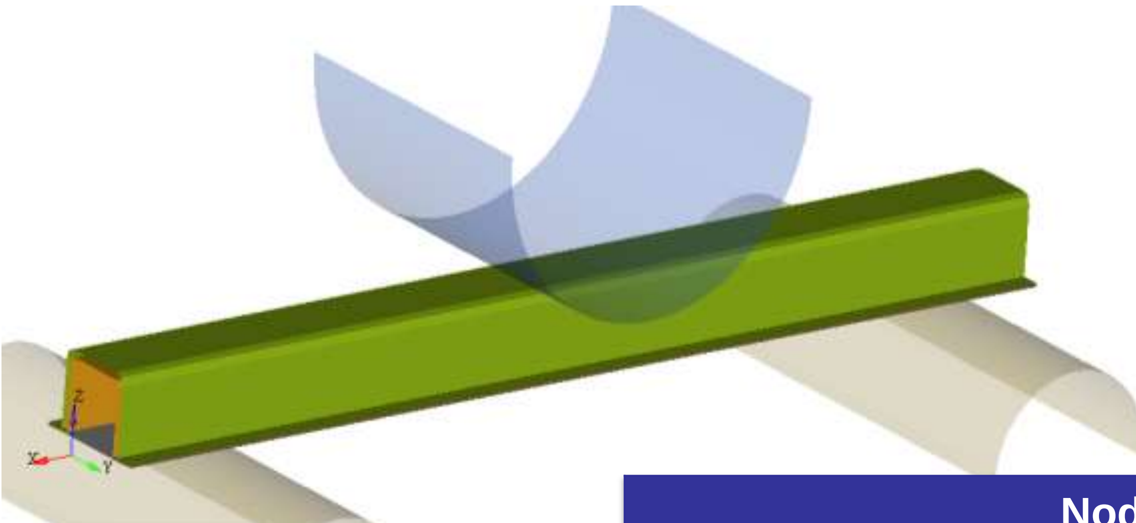
$$A^e = \frac{\mu_e}{12}\begin{bmatrix} 3 & -1 & -1 & -1 \\ -1 & 3 & -1 & -1 \\ -1 & -1 & 3 & -1 \\ -1 & -1 & -1 & 3 \end{bmatrix}$$ for 4 node shells

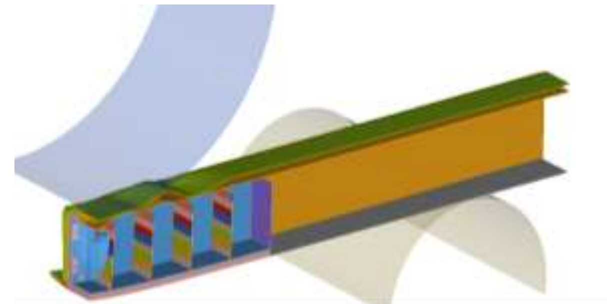
  - Allows to increase the time step
    - Given some time step, non diagonal mass is added
  - There is no change in inertia effects on translational global acceleration
  - Low frequencies are less affected than high frequencies

- Solution of $\boldsymbol{M}\ddot{u} = F$ is approximated using a conjugate gradient iterative method up to some tolerance

Advanced Mass Scaling

AMS for quasi-static analysis





3 points bending test

	Noda Cst	AMS
Time step (ms)	0.45	4
Energy error	1.15%	0
Number of cycles	224 450	25 340
Cpu time (s)	3 988	710
Efficiency	-	5.6

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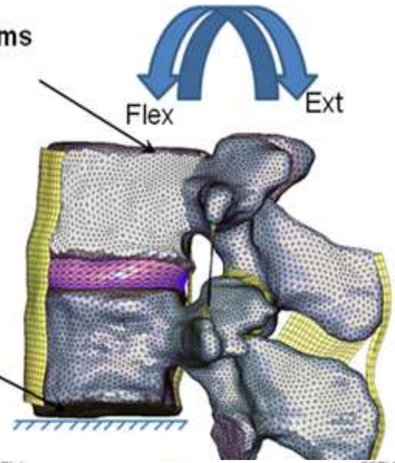
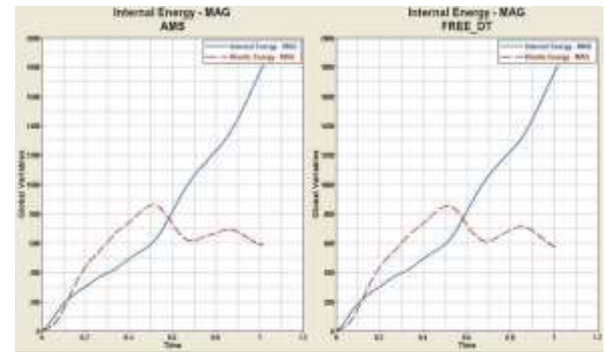
Advanced Mass Scaling

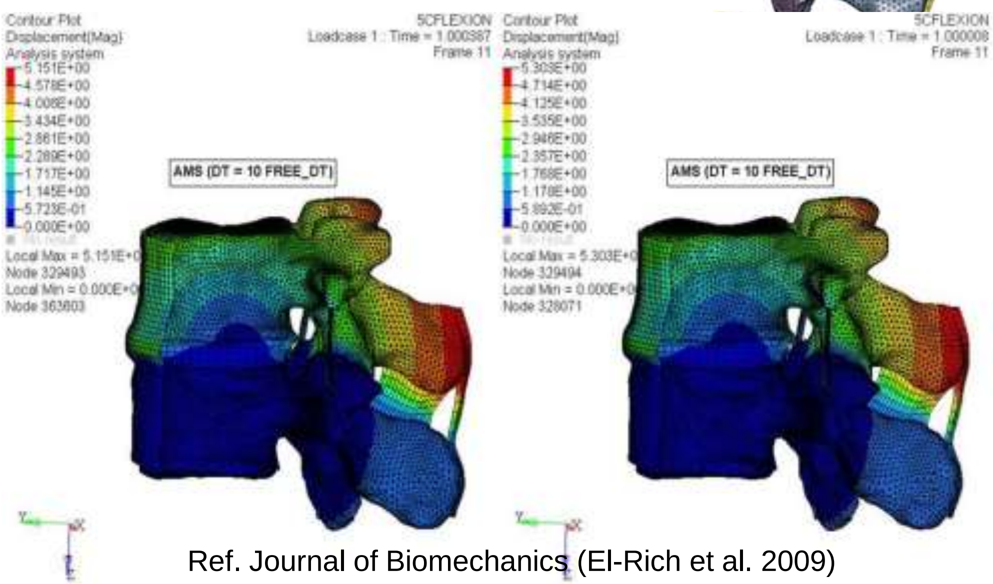
Biomechanics applications

5° of Flexion / Extension @ high rate of 5°/ms

The L3 lower endplate was fixed







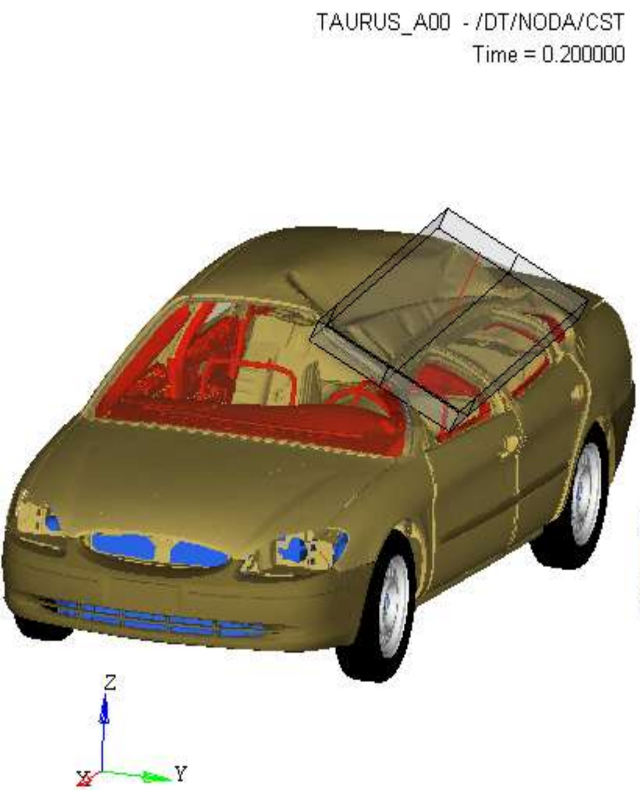
Ref. Journal of Biomechanics (El-Rich et al. 2009)

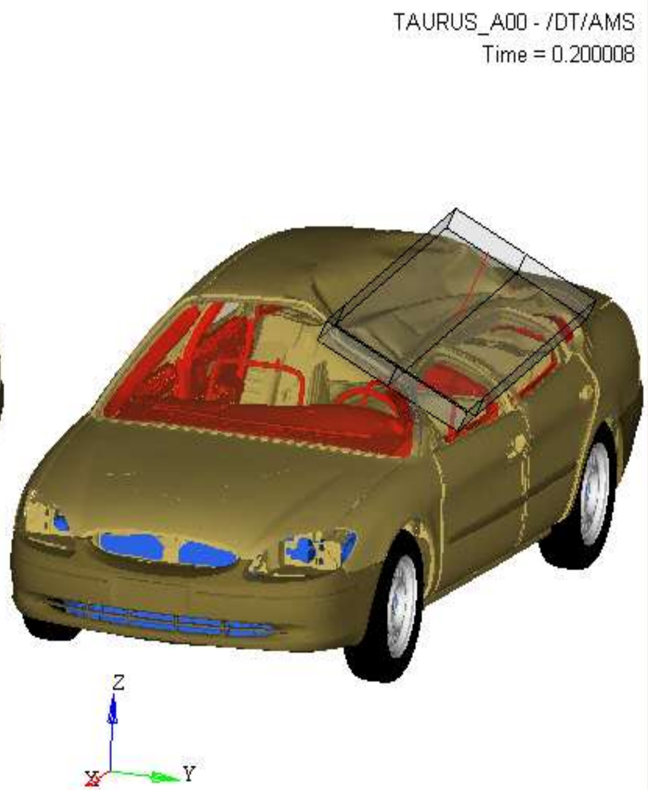
	Default Time Step	AMS
Time step (ms)	0.1	1
Time step ratio versus basis		10
Elapsed time (s)	21 280	2 571
Efficiency		8.28

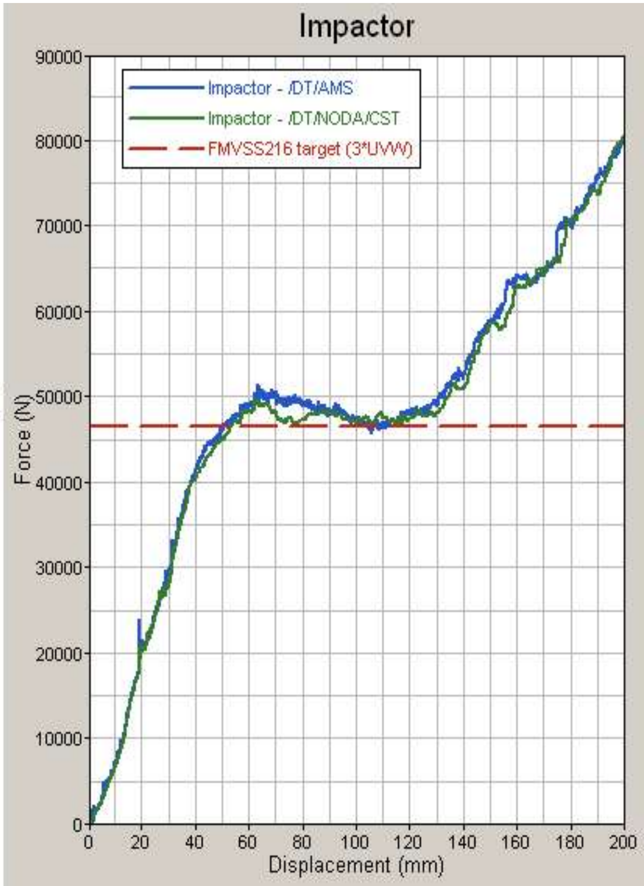
Advanced Mass Scaling

ROOF CRUSH - FORD TAURUS

- Same deformation and crush force







Advanced Mass Scaling

ROOF CRUSH - FORD TAURUS

- Small difference in the buckling mode

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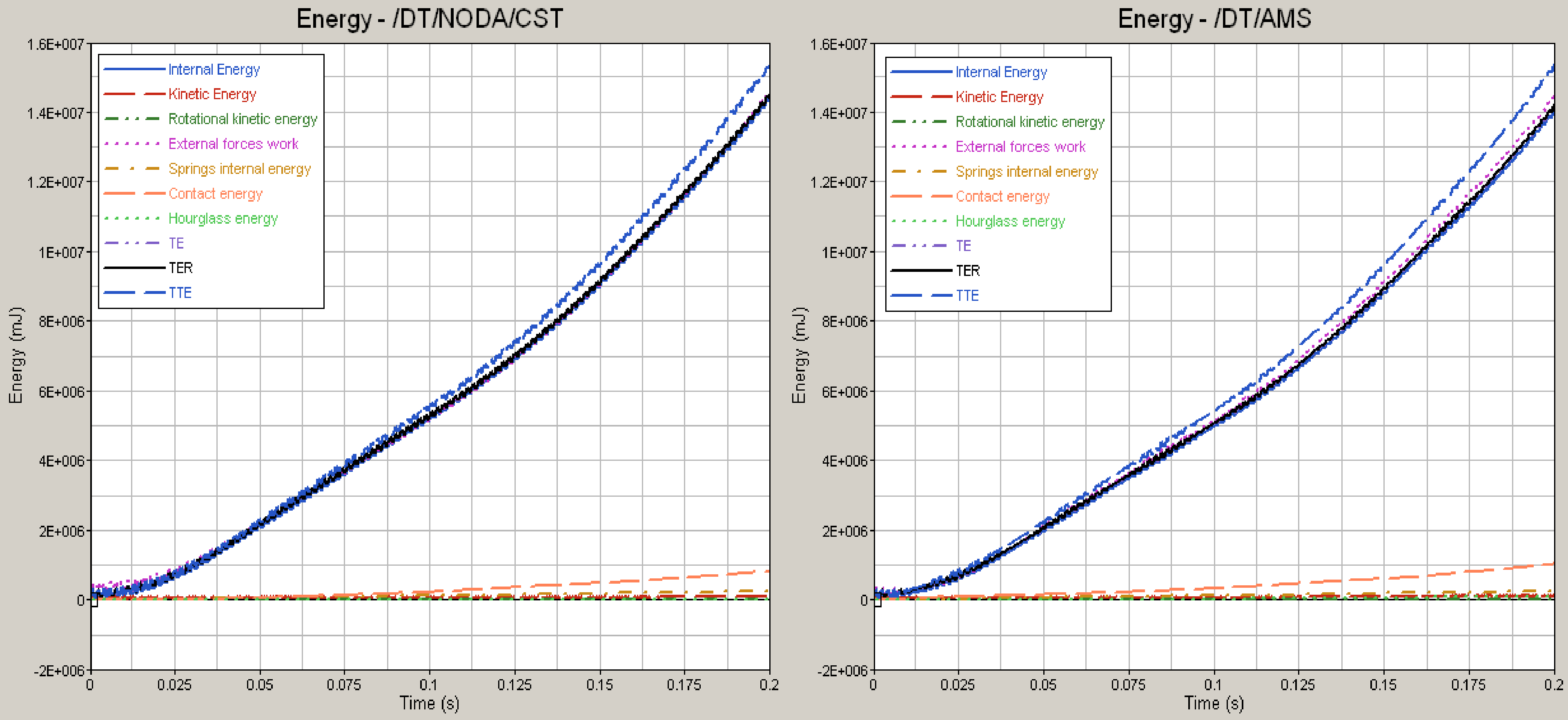
Advanced Mass Scaling

ROOF CRUSH - FORD TAURUS

- Same absorbed energy



Advanced Mass Scaling

ROOF CRUSH - FORD TAURUS

- CPU time
  - With AMS and single precision version the computation time is almost **8 times** faster with the same result.

	Double precision	Single precision	Single precision
	/DT/NODA/CST	/DT/NODA/CST	/DT/AMS
Time step target (ms)	0.5	0.5	10
Nb cycles	402044	403187	20146
Elapsed time (h)	33.4	19.6	4.2
ratio		-41%	-87%
Total CPU time (h)	739.6	434.3	93.7
ratio		-41%	-87%
Nb CPU	16	16	16
Radioss version	11main	11main	11main

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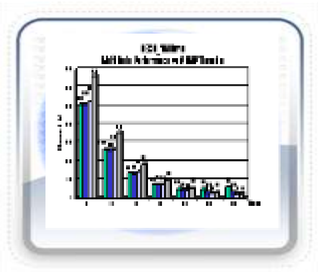
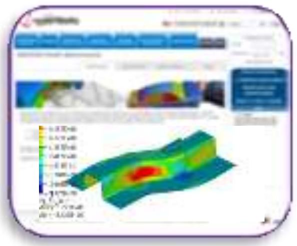
AGENDA



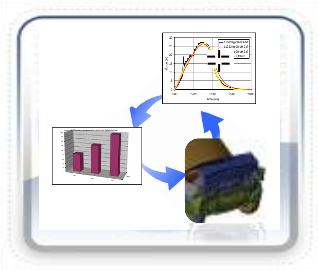
Hybrid

MPP



CPU Reduction

Full Car Crash



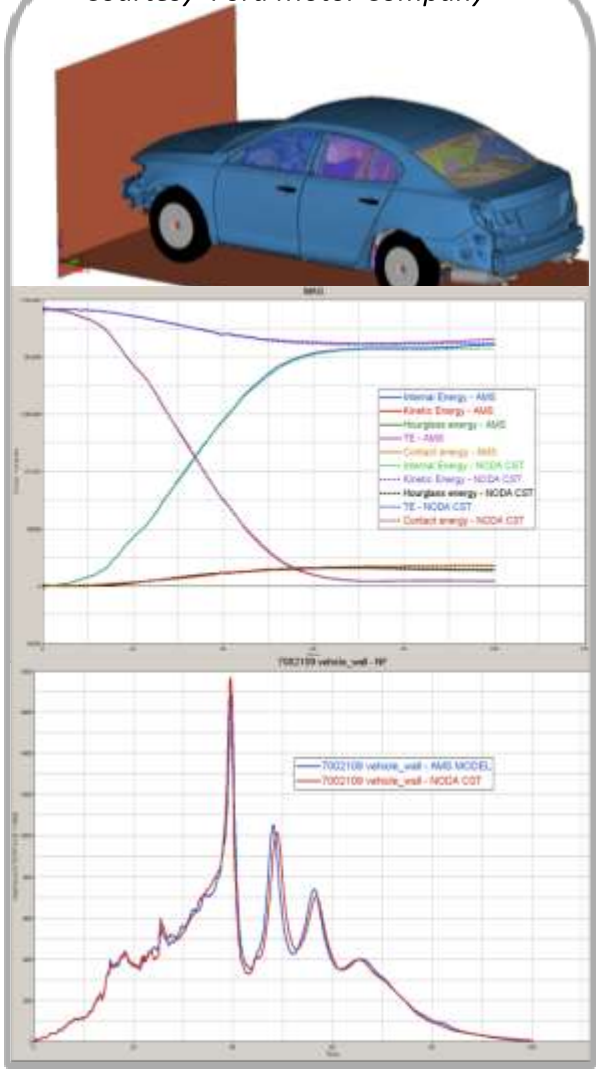
Conclusion

RADIOSS Advanced Mass Scaling - Full Car Crash

FORD TAURUS	NODA CST	NODA AMS	NODA AMS	ELEM AMS
Time step (ms) Scale factor	0.5 0.67	2.0 0.67	5 0.67	5 0.67
Tolerance for AMS		1e-4	1e-4	1e-4
Energy error	-10.0%	-11.9%	-9.7%	-9.8%
Number of cycles (80ms)	160 855	45 091	28 924	18037
Elapsed time (s)*	18 396	13 055	9 129	6 517
Mean time step	0.5	1.77	2.75	4.43
Efficiency	1	1.41	2.01	2.82
Cost of AMS as % of total		49.5%	53%	48%

* RADIOSS SPMD 24 processors

Courtesy Ford Motor Company



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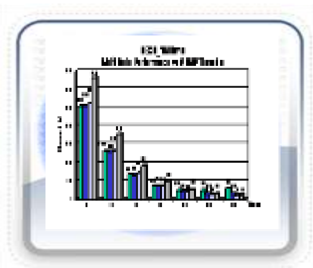
RADIOSS Advanced Mass Scaling - Full Car Crash

- *Version 11 β Hybrid MPP (2010)*
- *Intel Xeon X5560 @ 2.80 GHz*
- *About 20 iterations of conjugate gradient at each cycle (Tolerance = 10^{-3})*

Altair NEON 1Million elements (80ms)	CST Double precision	AMS Single precision
	64 SPMD x 8 SMP 512 cores	128 SPMD x 8 SMP 1024 cores
Objective time step (ms)	0.5	10
Mean time step (ms)	0.5	7
Nb of cycles	162 343	14 514
Elapsed Time	17.5' (1050 s)	5' (294 s)
Efficiency versus Basis		3.5
Amount of time spent in AMS		68%

AGENDA



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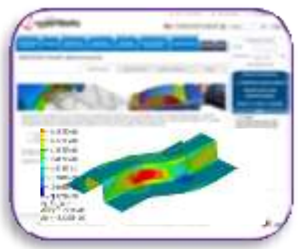
MPP



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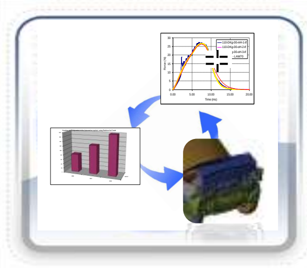

Conclusion

Conclusions

- Advanced solutions are now available in RADIOSS to reduce the simulation CPU time:
  - AMS
  - Multidomain

- With RADIOSS Hybrid Massively parallel computation it is now possible to use 500 to 1000 cores with typical industrial crash model

- This will enable to run a full car crash simulation in some minutes instead of some hours and open the door for new way of performing crash analysis:
  - scattering analysis
  - sensitivity analysis
  - crash optimization