Simulation of Ground Operations in Aircraft Design

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Deep-Drawn Sigh of an Expert…

"Landing gear is an invaluable aircraft system, albeit quite unpopular with most aircraft designers:

In extended position, it spoils the ***aerodynamic shape*** *of the aircraft. Retracted, it uses internal space which "could much better have been devoted to fuel or other useful things". Moreover, its dead weight impairs* ***flight performance****. Looking at landing gear from a structur point of view, it produces* ***large concentrated loads*** *and provides for a lot of difficulties by requiring voluminous landing gear bays and doors interrupting the smooth flow of* ***loads and stress****. There is also the possibility that the optimal position of the landing gear with regard to e.g. nosewheel liftoff differs from that required for a satisfactory* ***behaviour as a ground vehicle****, and both positions might be unfavourable with regard to* ***structural attachment****."*

A. Krauss

Motivation for Simulation of Aircraft Ground Dynamics

rigid body oscillations

structural strength

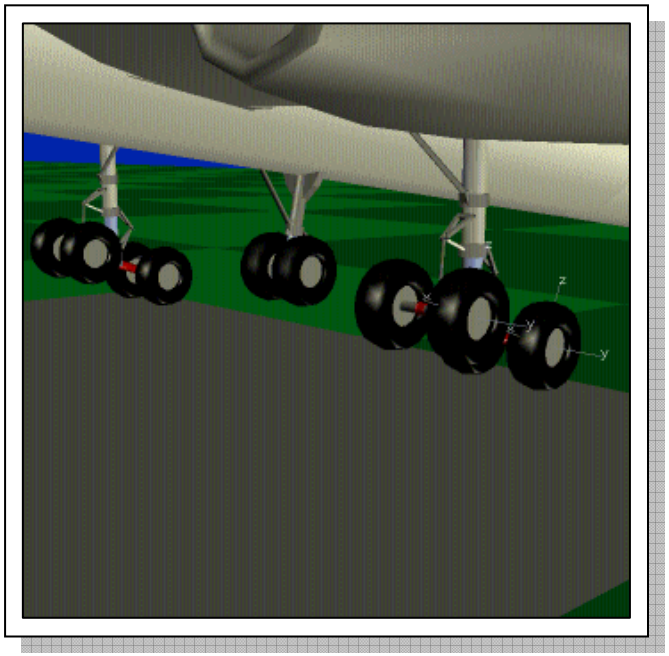
dynamic loads on LG

structural vibrations

landing gear vibrations

Applications of Multibody Simulation as a “Virtual Testbed”

- **Applications in aircraft ground dynamics**
  - landing impact: dynamic ground loads
  - landing impact: dynamic behaviour of overall system
  - ground run: resonance effects, vibrations
  - cornering: dynamic loads
  - brake-gear interaction
  - soft-soil operations
  - landing gear positioning, kinematics
  - evaluation of new concepts
  - etc…



Trends in Aircraft and Landing Gear Design

Enhancement of simulation capabilities, esp. in respect to:

- Aircraft tyre properties (high and low speed)
- Aerodynamic effects (steady and dynamic)

"For aerodynamic aspects of takeoff and landing flight dynamics, current analysis capabilities are not sufficient to detect and avoid undesirable dynamic characteristics. […]
It is important that sufficiently accurate techniques be applied to predict dynamic characteristics from the beginning of the design effort"

Committee on Aeronautical Technologies of the Aeronautics and Space Engineering Board, in: Aeronautical Technologies for the Twenty-First Century

Aerodynamics in Aircraft Ground Dynamics: Why…?

Problems of the standard approach of modelling and simulation

Modelling derives from FAR 25 certification requirements:

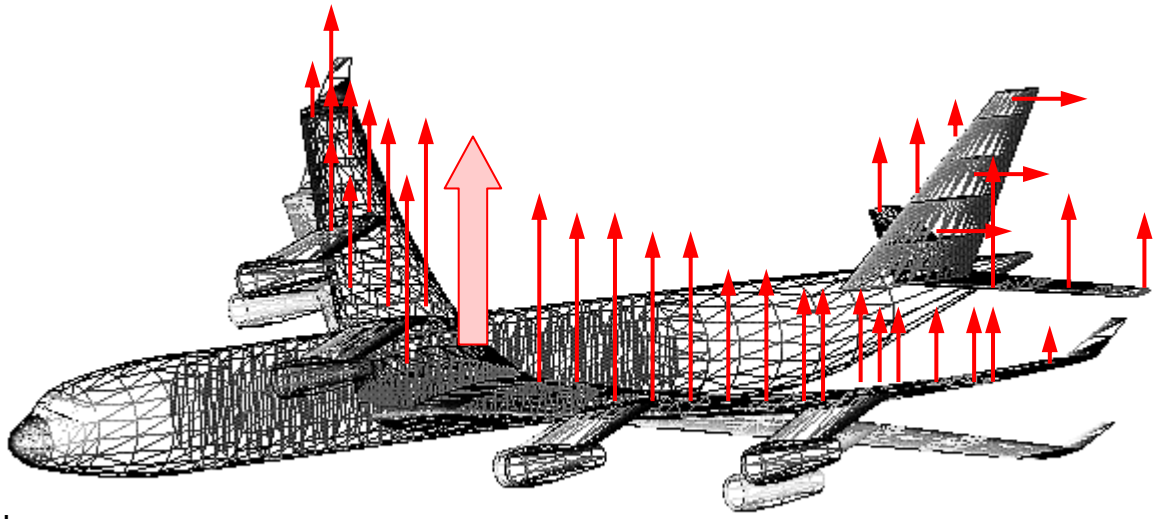
„lift = weight“ ⇨ NWW (Newton-was-wrong) approach

- Complex landing sequences are not realisticly modelled.
- Airframe deformation at impact starts from the undeformed 0g-state, not from the pre-stressed +1g-state.
- Wing deformation (bending, torsion) causes aerodynamic effects which influence dynamic behavior and loads.
- Pilot / FCS inputs cannot be modeled.
- Ground effect is being neglected.

Aerodynamics in Aircraft Ground Dynamics: How…?

Standard approach of MBS

- Force elements and sensor at marker frames of the flexible MBS body



…but:

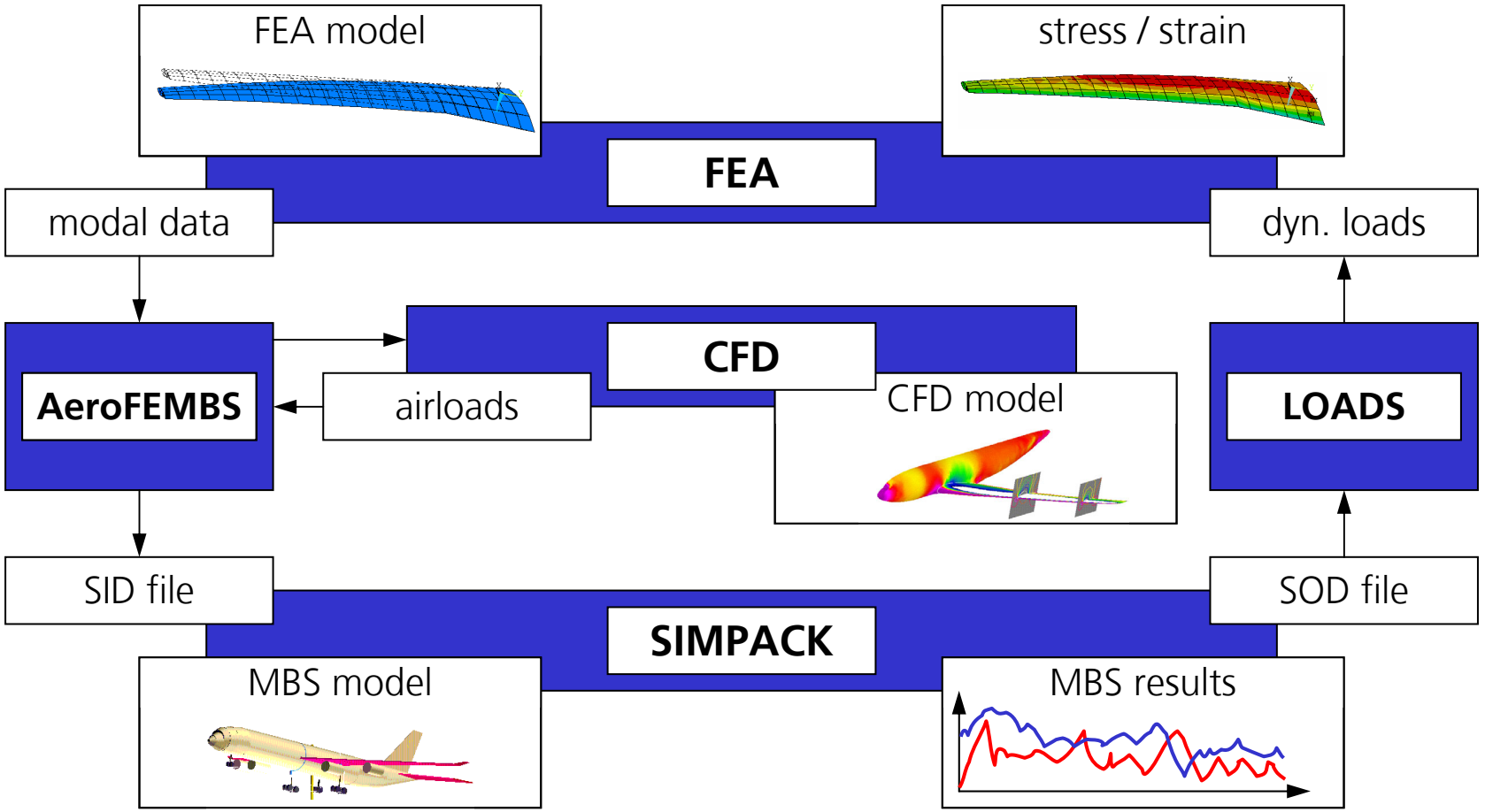
- CPU time „explodes“
- a lot of work to set up the model
- much more work to modify the model in trade-off studies or optimizations

Aerodynamics in Aircraft Ground Dynamics: What…?

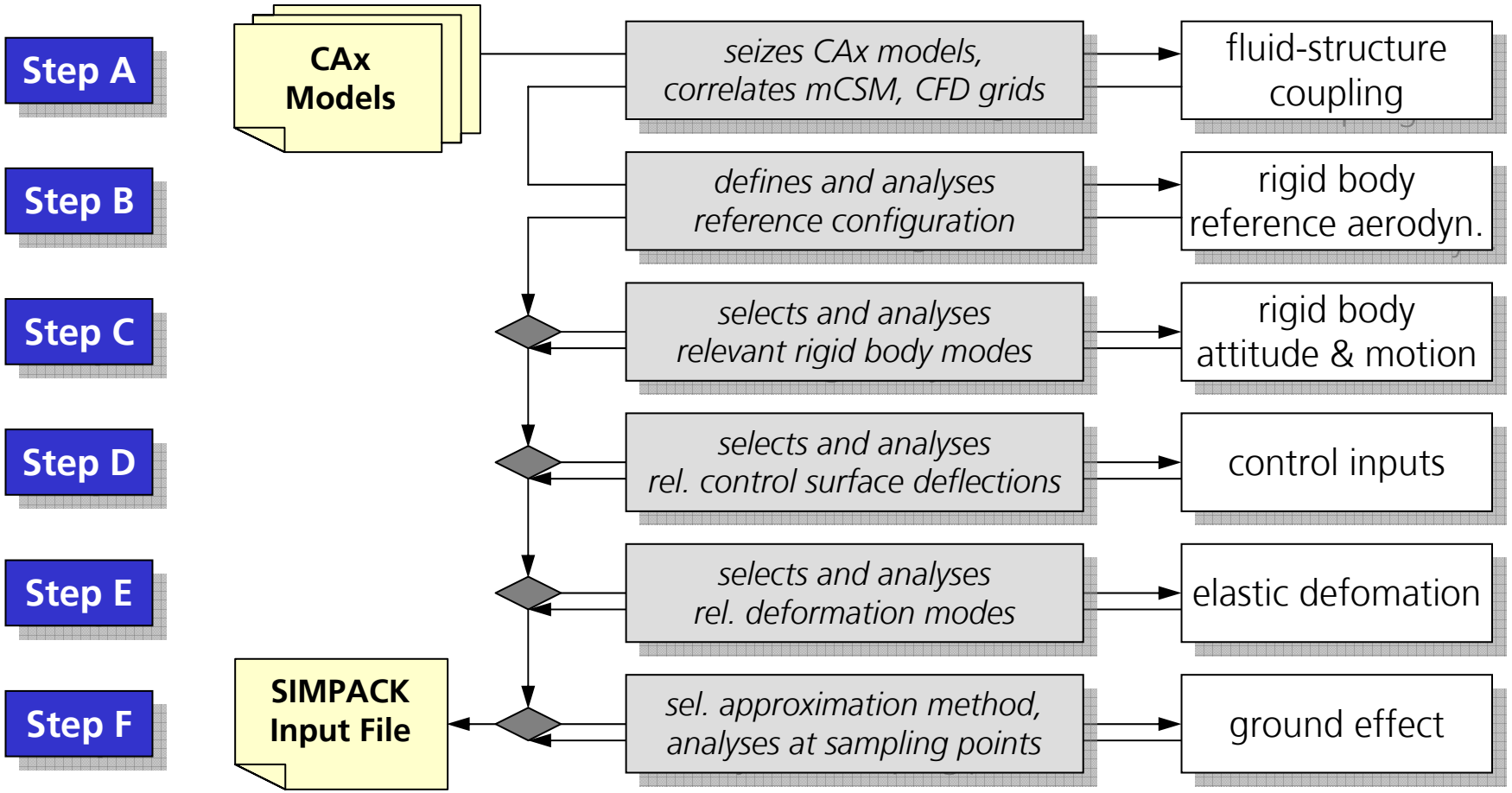
Requirements of „MBS Aerodynamics of the Flexible, Maneuvering A/C“

- Quick and simple modeling:
  - „computer-aided“ model set-up
  - use of existing disciplinary modeling
- Easy to modify if design changes
- Efficient computation of the job
- Adequate representation of high-lift aerodynamics
- Pilot controlled 3D-maneuvers
- Aerodynamic effects of structural deformation:
  - state-dependent
  - velocity-dependent

Integrated Design Process of Aircraft Ground Dynamics

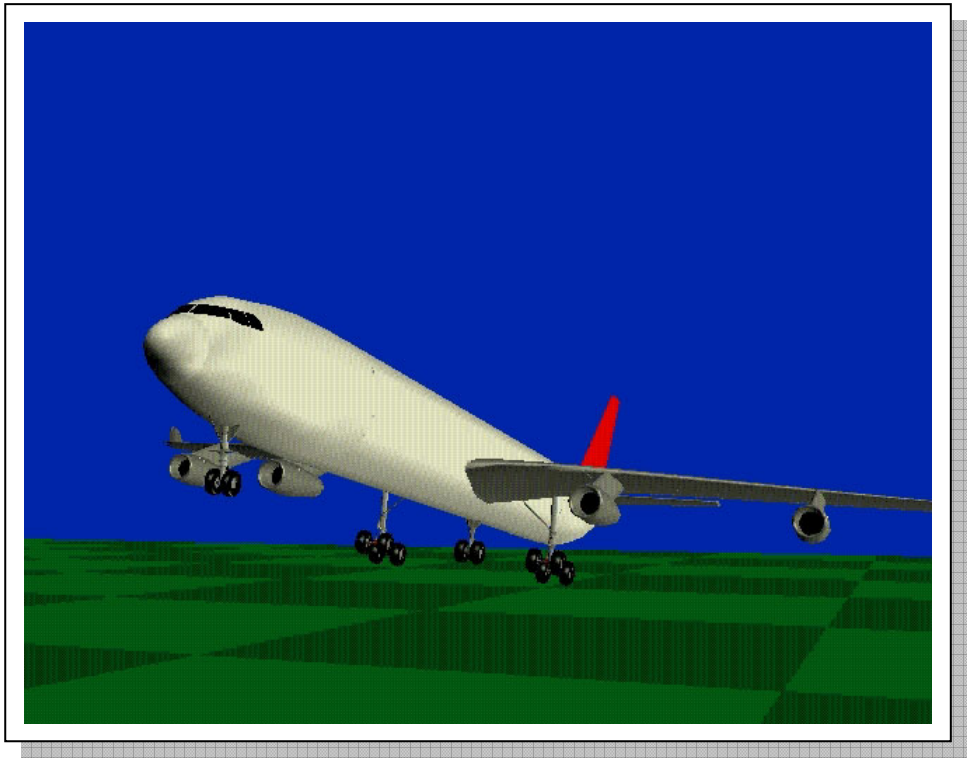


Aeroelastic Preprocessing



Example: Landing of a Large Transport Aircraft

- Model: large transport aircraft (basing on A340-300)
- Scenario: hard touch-down, low wing



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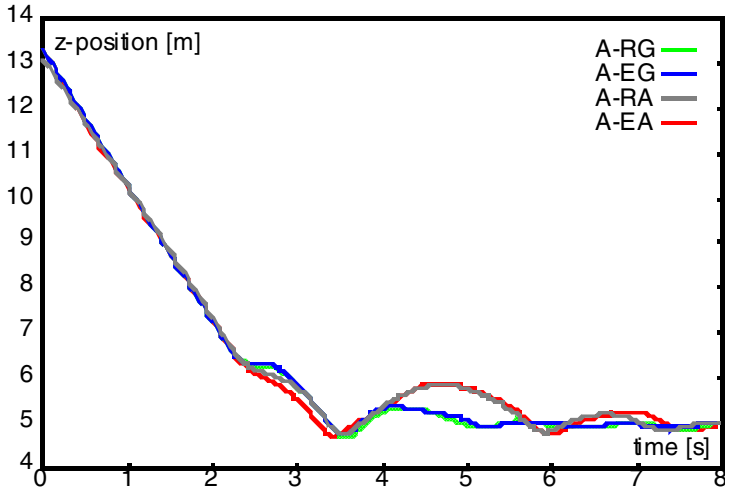
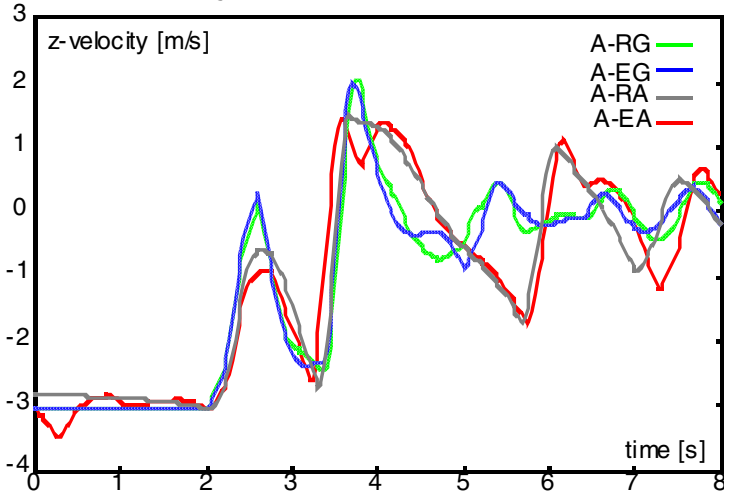
position of A/C reference frame



velocity of A/C reference frame



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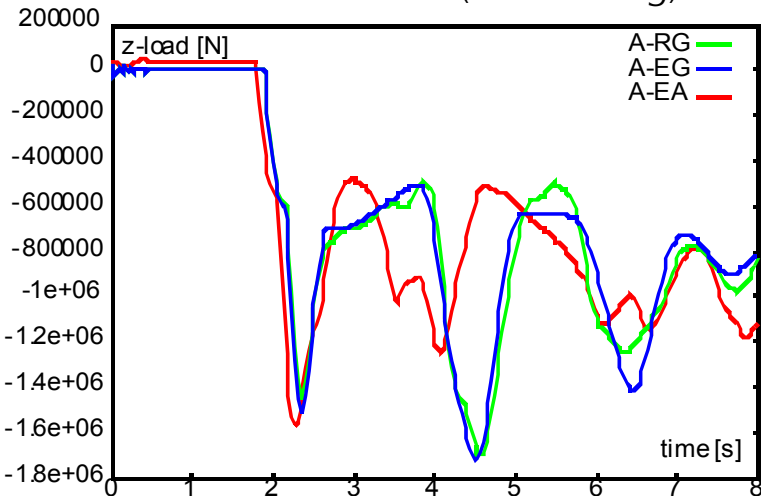
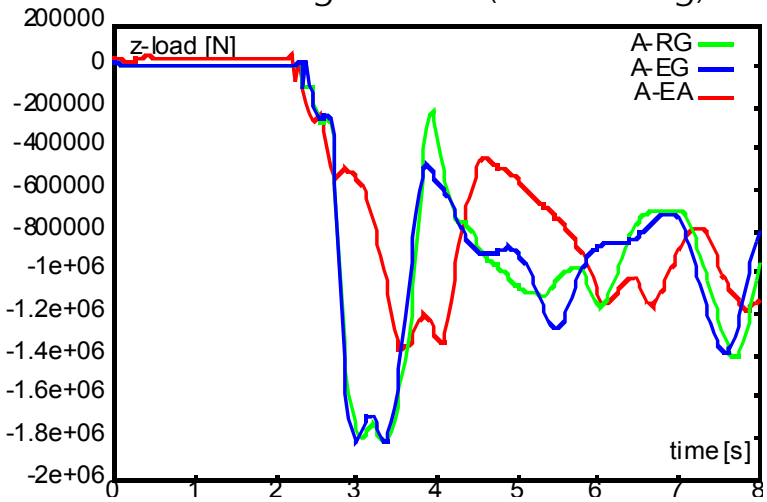
load on left MLG (mainfitting)



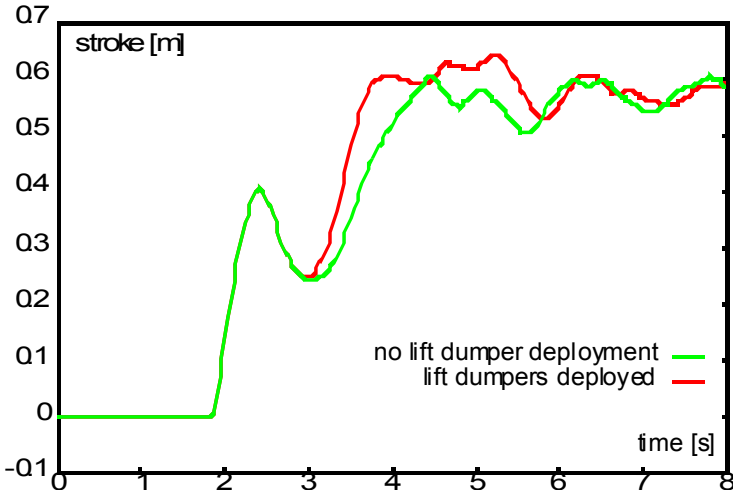
load on right MLG (mainfitting)



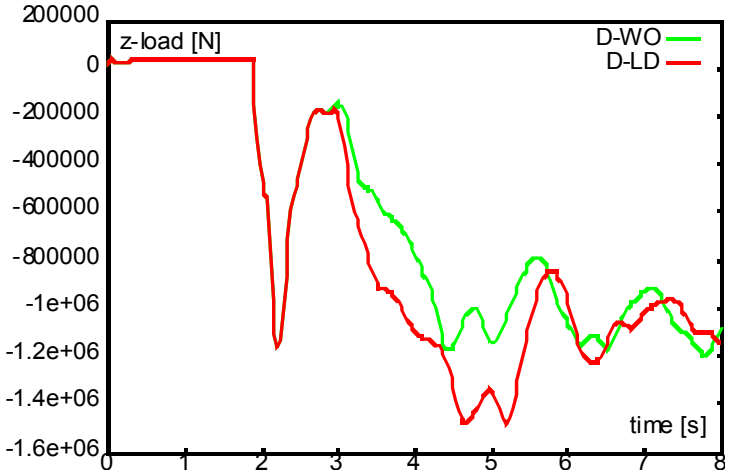
Example: Landing of a Large Transport Aircraft

- **Model: large transport aircraft (basing on A340-300)**
- **Scenario: lift dumper deployment at rebound**

stroke of left MLG



load on left MLG



Computational Advantage of Aeroelastic Preprocessing

SIMPACK-Simulation of Aircraft Landing Sequence							
Scenario		CPU Time			CPU Time Penalty		
		NWW	FEL	APP	NWW	FEL	APP
A	FAR 25.481 (high AoA)	111.8 s	526.4 s	141.2 s	100%	369%	26%
B	FAR 25.479 (3-point)	81.8 s	447.0 s	116.0 s	100%	446%	42%
C	Left wing low (5.7°)	117.3 s	625.8 s	175.4 s	100%	434%	49%
D	Lift dumpers deployed	-	599.5 s	214.0 s	-	-	-

Summary

- ☑ New approach for aerodynamic effects has been applied in SIMPACK.
- ☑ Aerodynamic forces are causing appropriate structural deformation.
- ☑ Aerodynamic effects of deforming airframe are accounted for.
- ☑ Approach fits well into existing design process.
- ☑ Setting-up of SIMPACK model is fast and simple.
- ☑ CPU time of SIMPACK analysis is significantly reduced.

  and

- ☑ Aerodynamic effects have a big impact on dynamic behavior of the aircraft.