



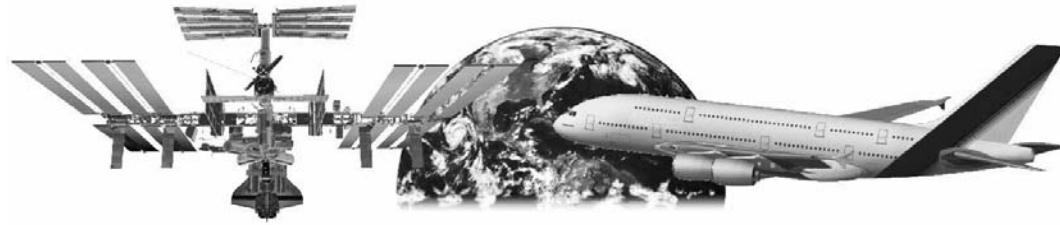
SIMPACK User Meeting 2004

Simulation of Ground Operations in Aircraft Design



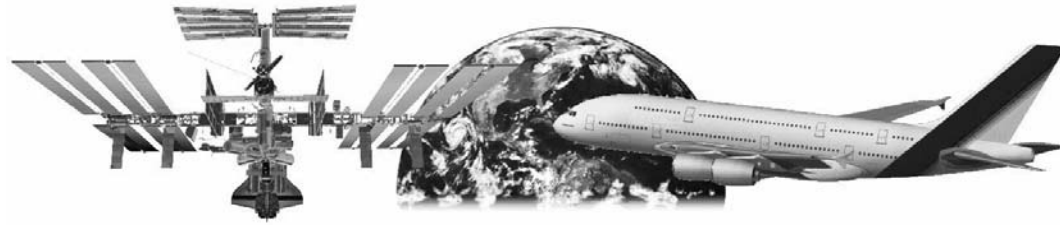
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Institute of Aeroelasticity



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- ▶ Motivation for a Closer Look on Aircraft Ground Dynamics
- ▶ Applications of Multibody Simulation in Aircraft Ground Dynamics
- ▶ Current Trends
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- ▶ Aeroelastic Preprocessing
- ▶ Example of a Landing Transport Aircraft
- ▶ Summary



Motivation for Simulation of Aircraft Ground Dynamics



rigid body oscillations



structural strength



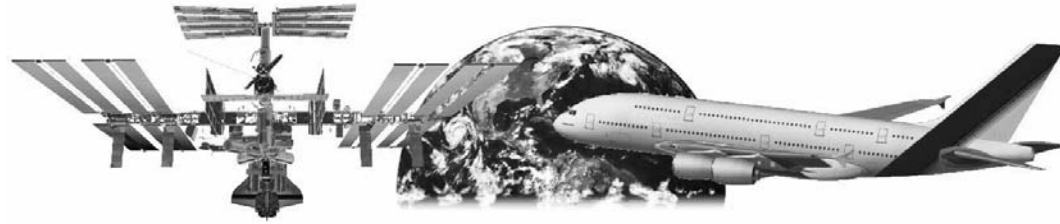
dynamic loads on LG



structural vibrations



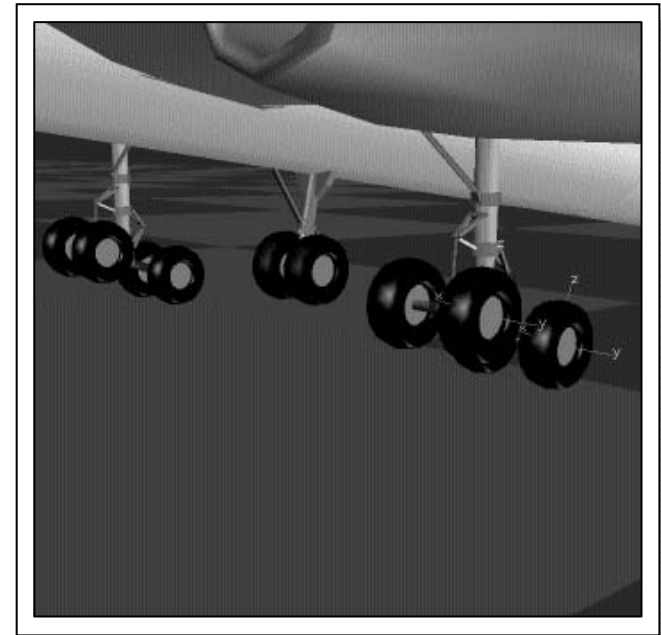
landing gear vibrations

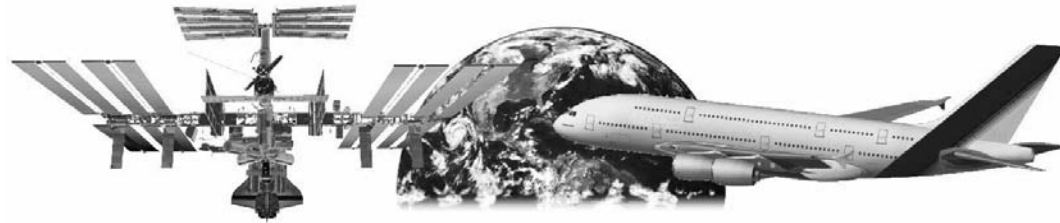


Applications of Multibody Simulation as a “Virtual Testbed”

► 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

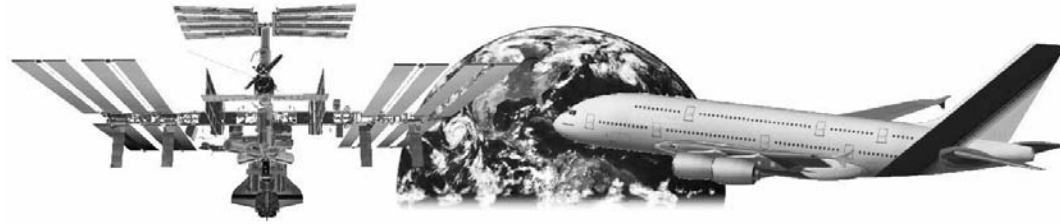
Enhancement of simulation capabilities, esp. in respect to:

- ▶ 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



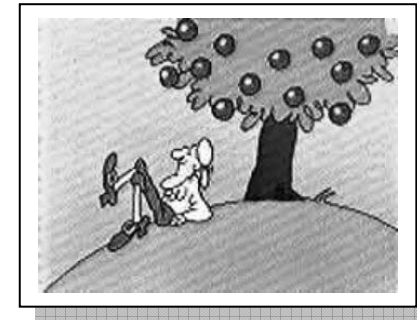
Aerodynamics in Aircraft Ground Dynamics: Why...?

Problems of the standard approach of modelling and simulation

Modelling derives from FAR 25 certification requirements:

„**lift = weight**“ \Rightarrow NWW (Newton-was-wrong) approach

- ▶ Complex landing sequences are not realistically 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.

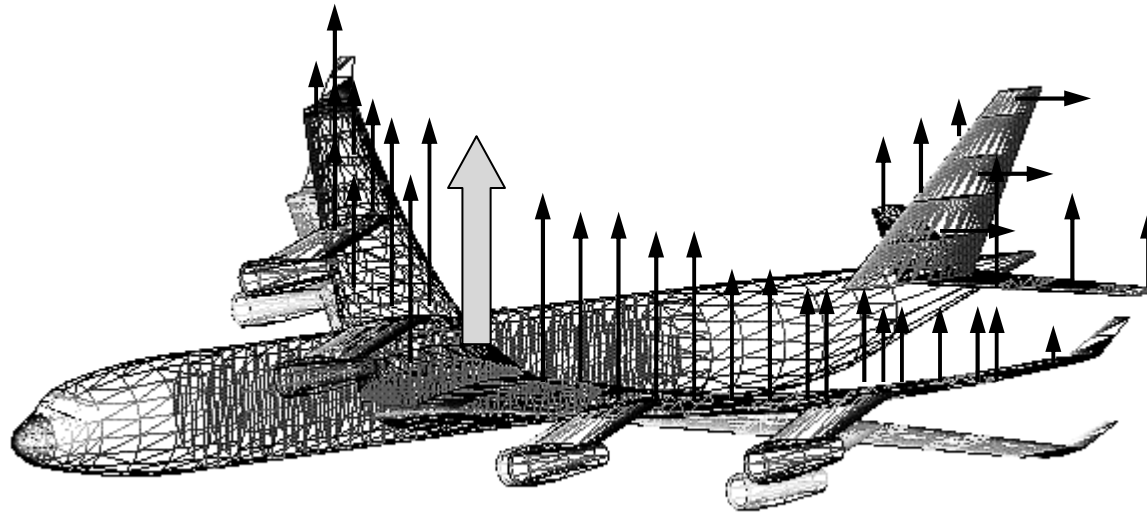




Aerodynamics in Aircraft Ground Dynamics: How...?

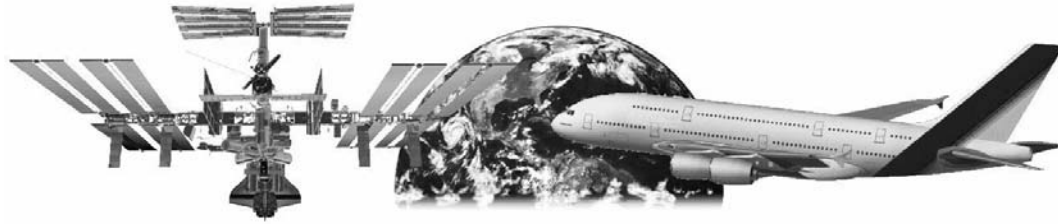
Standard approach of MBS

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



...but:

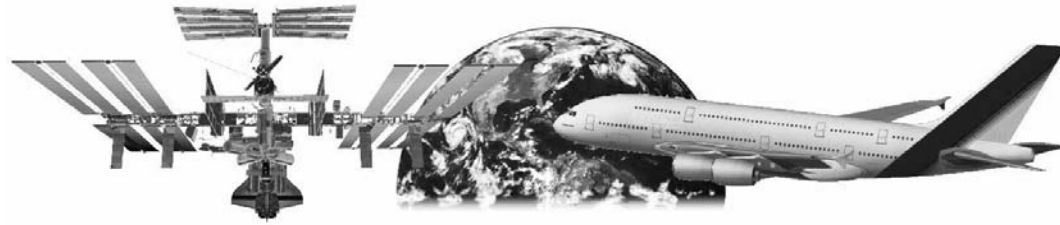
- ▶ CPU time „explodes“
- ▶ a lot of work to set up the model
- ▶ much more work to modify the model in trade-off studies or optimizations



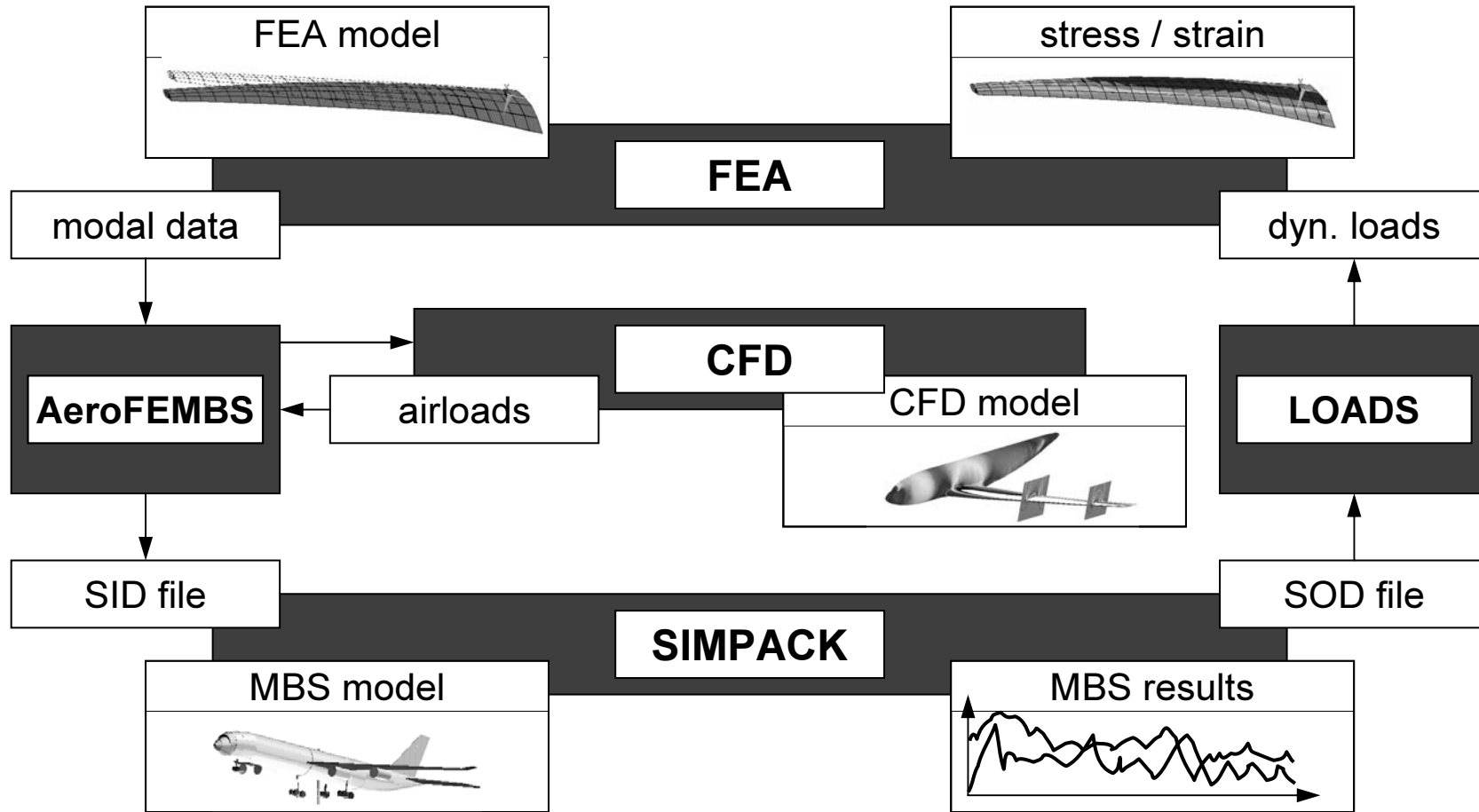
Aerodynamics in Aircraft Ground Dynamics: What...?

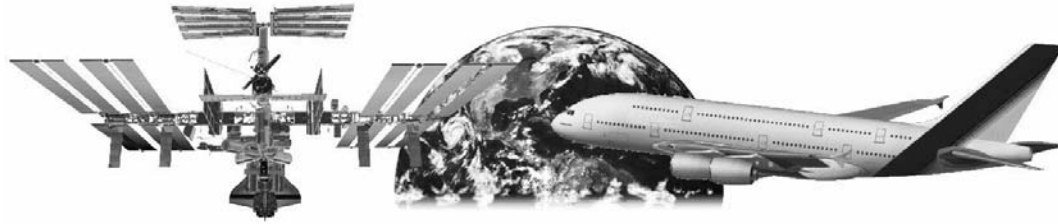
Requirements of „MBS Aerodynamics of the Flexible, Maneuvering A/C“

- ▶ 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

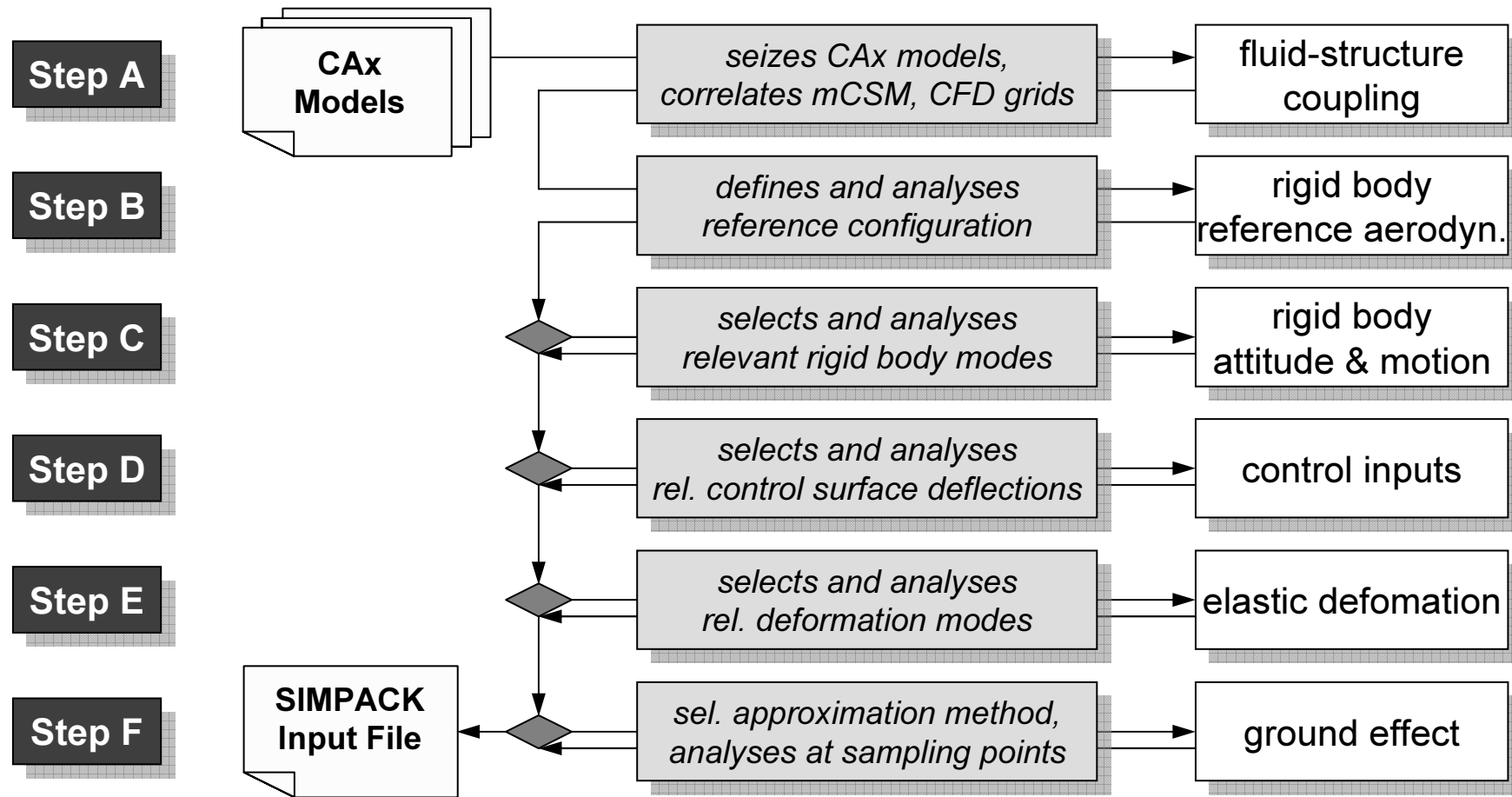


Integrated Design Process of Aircraft Ground Dynamics





Aeroelastic Preprocessing

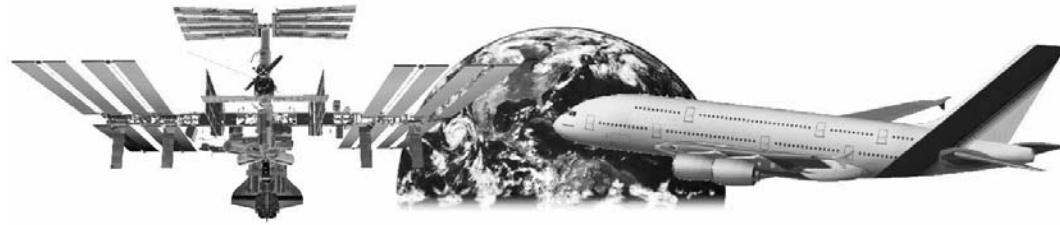




Example: Landing of a Large Transport Aircraft

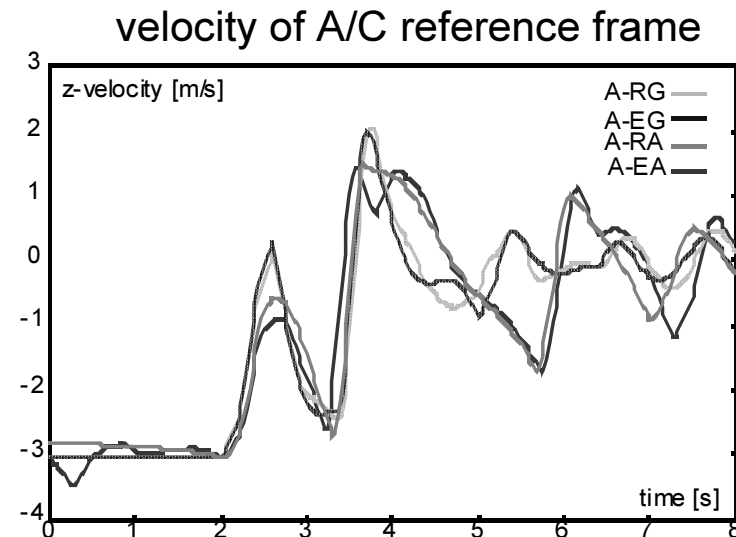
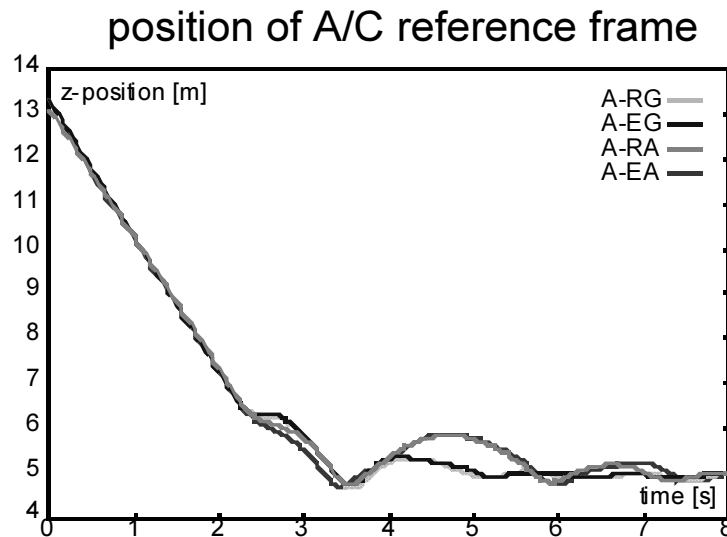
- ▶ **Model:** large transport aircraft (basing on A340-300)
- ▶ **Scenario:** hard touch-down, low wing

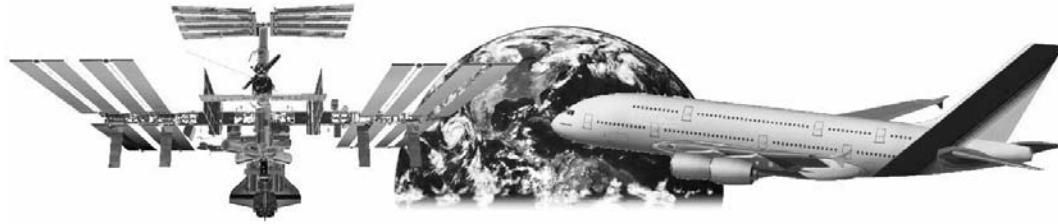




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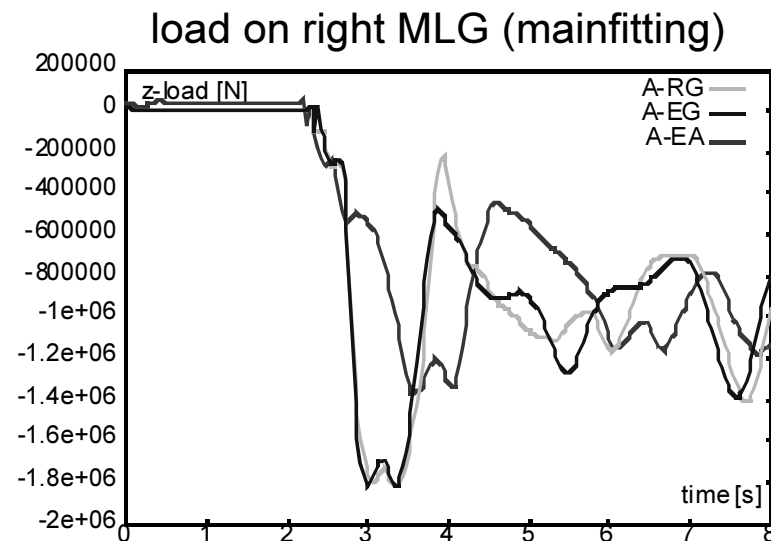
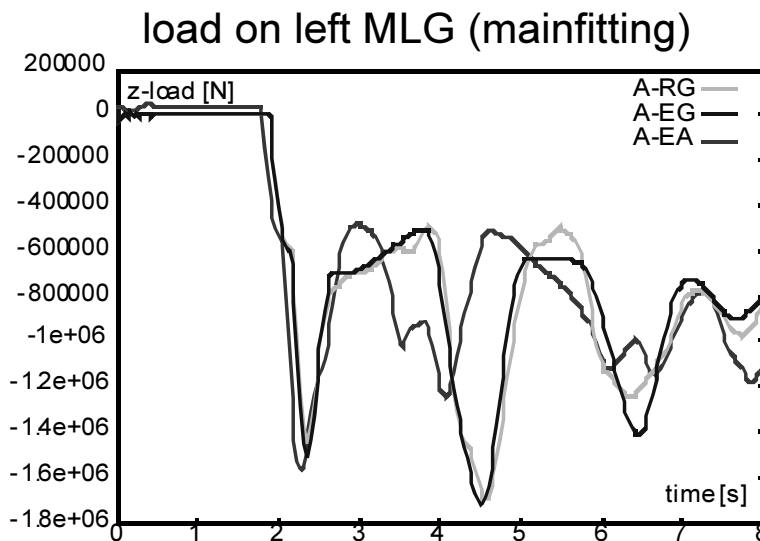
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Example: Landing of a Large Transport Aircraft

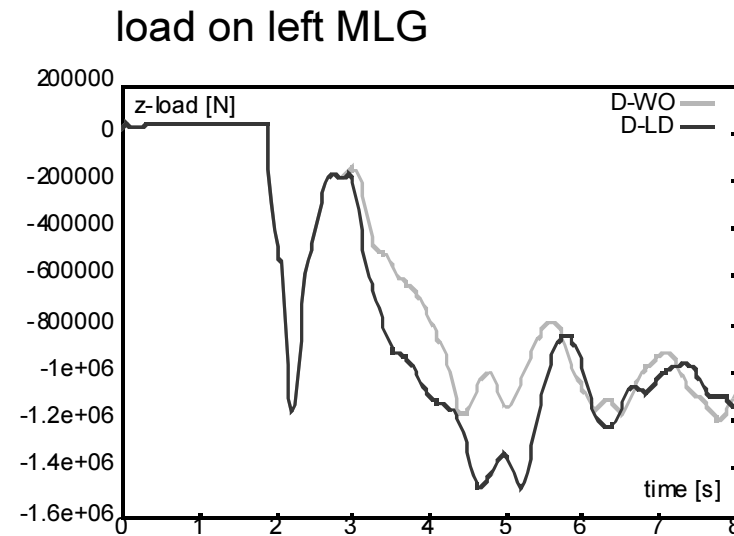
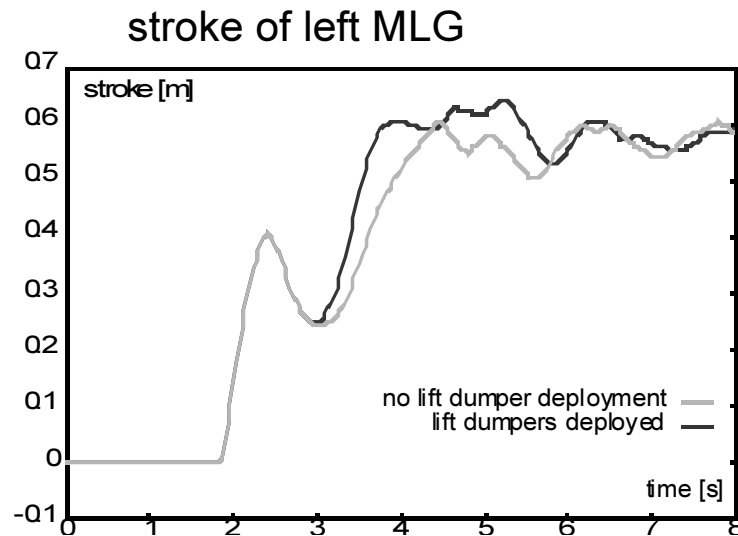
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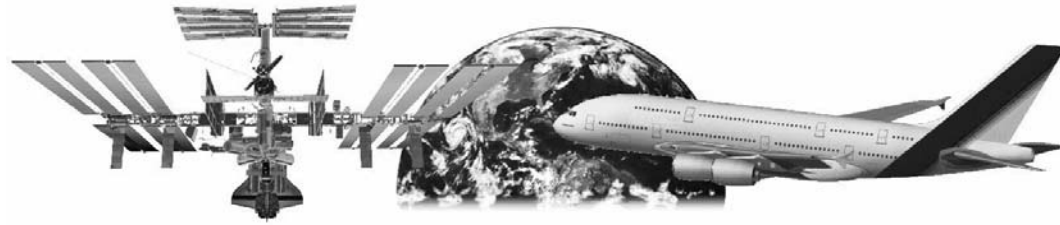




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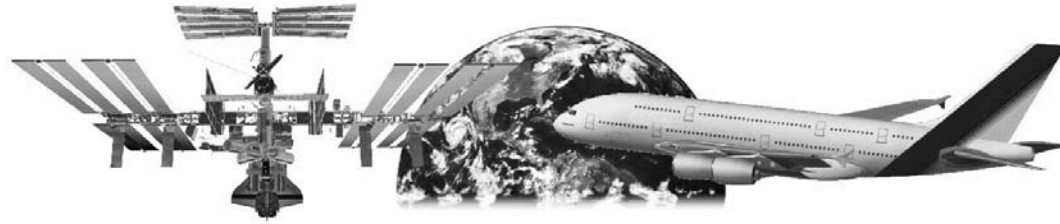
- ▶ **Model:** large transport aircraft (basing on A340-300)
- ▶ **Scenario:** lift dumper deployment at rebound





Computational Advantage of Aeroelastic Preprocessing

SIMPACK-Simulation of Aircraft Landing Sequence							
Scenario		CPU Time			CPU Time Penalty		
		0g-state (NWW)	Force Elements	Aeroelast. Pre-Proc.	0g-state (NWW)	Force Elements	Aeroelast. Pre-Proc.
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

- ✓ Thorough investigation of aircraft ground dynamics is important in aircraft design.
- ✓ Multibody simulation is a valuable software tool throughout the development process... from conceptual design to certification.
- ✓ SIMPACK can be efficiently employed in aircraft design – in its standard version, and even more so in customised „derivatives“.
- ✓ Analysis results indicate that aerodynamic effects play an important role in aircraft ground dynamics.
- ✓ Simulation of the elastic, free-flying, manoeuvring aircraft can be fast, straightforward and easy-to-perform in an integrated design process.
- ✓ Comprehensive simulation of a new design entails acceptable penalties, especially when compared to the potential gain.