



Coupling MSC.Nastran with external aerodynamics for Static Aeroelastic Analysis

Method shown on the example of NEWPAN

**Michael Hermes
Johannes Wandinger**



- **Objective**
- **Dataflow and Software interaction**
- **Preprocessing**
 - **Aero import into MSC.Flightloads**
 - **Splining**
 - **Spline Verify**
 - **Aero and Aeroelastic Export to MSC.Nastran**
- **Static Aeroelastic Analysis**
 - **Basic Equations**
 - **Implementation**
 - **Convergence Acceleration Techniques**
 - **MSC.Nastran job setup**
- **Summary**

Agenda

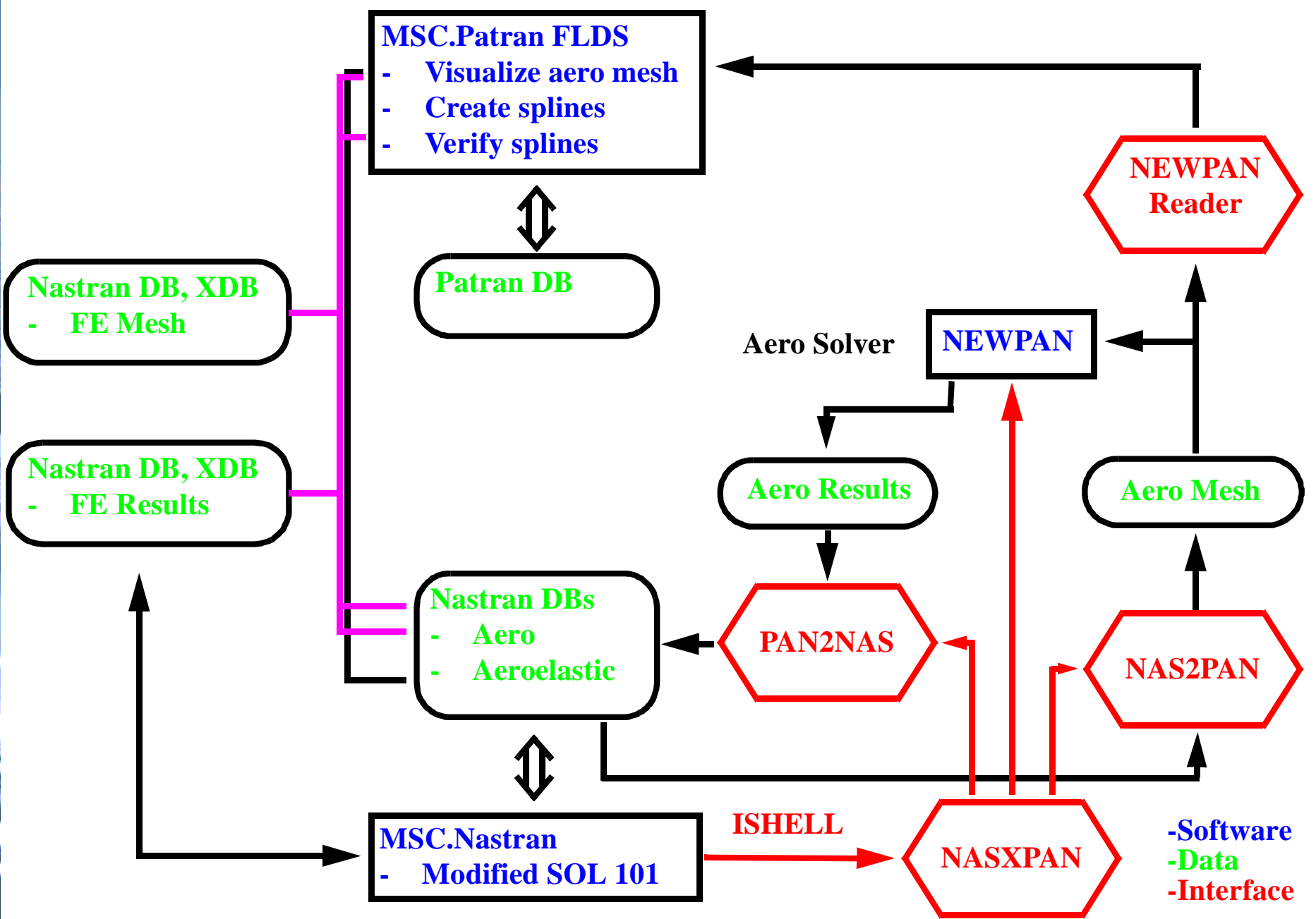


- **Compute the static deformation of a flexible structure due to**
 - Initial loads
 - Aerodynamic loads
- **Initial loads do not depend on the structural deformation**
- **Aerodynamic loads depend in a nonlinear way on the structural deformation**
- **The structure is assumed to satisfy the assumption of linear elasticity**

=> Aerodynamic configuration on deformed structure

=> Aerodynamic loads on structure due to deformation

Objective



Dataflow of Aeroelastic Analysis



- Use existing FE-model in MSC.Patran
- Import NEWPAN input file (aero mesh)
- Create splines between structural and aero mesh
- Verify the splines
- Export aero and aeroelastic data to MSC.Nastran databases
- Setup the job parameter for the aeroelastic analysis

Preprocessing



Grid ID List
13509

Panel ID List
13360

Existing Supergroups
AeroSG3D
Iann_wng

Select File...

Preview

Supergroup [Max 8 Chars]
Iann_wng

Aero Groups
Aero_Wing_Lower
Aero_Wing_Upper

Apply Cancel

Import into MSC.Flightloads

- Preview of selected NEWPAN file
- Creation of the supergroup and the aero groups
- Import of the aero grids and elements
- Creation of the wetted surfaces
- Sorting of the grids and elements into the aero groups

MSC.Flightloads was modified to allow the handling of 3D Supergroups!

Import of 3D aero



Action: ?

Object:

Method:

Spline Name

Structural Points

Nodes Groups

Select Nodes

Aero Boxes

Elements Surface

Select Elements

- **Standard FLDS functions are used for the splining**
- **Only TPS splines can be used with 3D aero**
- **Show functions can be used**

FLDS was modified to accept 3D aero for splining!

Splining



Aerodynamics Model
Name: lann_wng

Structural Model
Select Structural Model...
Name: Entire Model

Available Splines
spline_upper
spline_lower

Result: Modes ▾

Conditions
A1:Mode 1 : Freq. = 8.8038
A1:Mode 2 : Freq. = 16.972
A1:Mode 3 : Freq. = 30.331
A1:Mode 4 : Freq. = 37.778
A1:Mode 5 : Freq. = 47.962
A1:Mode 6 : Freq. = 52.783
A1:Mode 7 : Freq. = 100.13
A1:Mode 8 : Freq. = 104.96

Reset Graphics

Animation Style
 Wireframe
 Shaded

Apply Cancel

New tool to verify splines on 3D aero

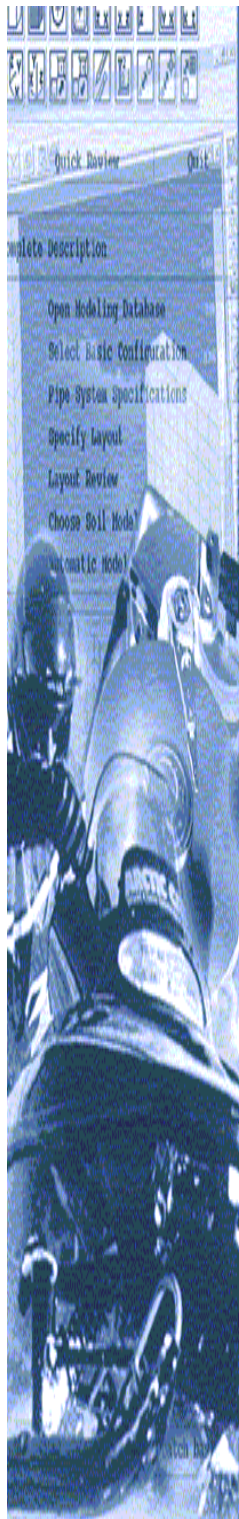
- Works on current Supergroup
- Exports the 3D aero and the selected splines to MSC.Nastran DBs
- Calculates spline matrices and aero grid displacements in a separate MSC.Nastran run

Differences to standard FLDS

- Direct creation of MSC.Nastran DBs
- Direct data transfer in between MSC.Patran and MSC.Nastran
- Merged result of structure and aero
- Animation of structure and aero

=> Fast way to find the interference of aero and structural mesh

Spline verification I



File Group Viewport Viewing Display Preferences Tools Insight Control Mike's PCL Utilities Form Builder Help

Geometry Results Insight XY Plot Flight Loads

fwing.db - default_viewport - FEM - Entity

MSC Patran 2000r2 07-May-01 10:54:07
Deform: SplVerify, C1:Mode 1 : Freq. = 1.5179, Eigenvector, Translational, (NON-LAYERED)

- If a structure group is posted aero and structure are animated
- Structure and aero have different colors

3D Aero Spline Verify

Aerodynamics Model
Name: fwing

Structural Model
Select Structural Model...

Name: Entire Model

Available Splines

- mplane_top
- mplane_bot
- flap_top
- flap_bot

Result: Modes

Conditions

- SC1:MODAL, A2:Mode 1 : Fr
- SC1:MODAL, A2:Mode 2 : Fr
- SC1:MODAL, A2:Mode 3 : Fr
- SC1:MODAL, A2:Mode 4 : Fr
- SC1:MODAL, A2:Mode 5 : Fr

Reset Graphics

Animation Style

- Wireframe
- Shaded

Apply Cancel

Spline verification II



Aeroelastic Model
Aero: lann_wng
Structure: Entire Model

Reference Data

Reference Span (Full)	2.0
Reference Chord	0.2515
Reference Area	0.503
Reference Length	0.361

Structure Database...
Aero Database...
Aeroelastic Database...

Used Databases:
lann_modal.DBALL
lann_aero.DBALL
lann_aeroelas.DBALL

Apply Cancel

- **Export of aero and splines to MSC.Nastran DBs**
- **The aerodynamic model is frozen after this export**
- **Aerodynamic and aeroelastic data is stored in separate DBs**
- **A structural DB is needed to calculate the spline matrices**
- **The spline matrices can be accessed by DMAP**
- **Grid uniqueness in splines is assured**
- **The aerodynamic and aeroelastic DBs are later used for MSC.Nastran runs (Sol 144, 145 and 146)**

Aero Export to MSC.Nastran



- **Solution of the structural and aerodynamic problem at the same time**
- **Computation of the aero parameters on the deformed structure**
- **Deformation of the structure at Real Life Loads**
- **MSC.Nastran drives the aero solver**
- **No alternating job runs => Fast closed loop solution**

Static Aeroelastic Analysis



- **The equation of equilibrium reads**

$$\mathbf{Ku} = \mathbf{P}_0 + \mathbf{P}(\mathbf{u})$$

Elastic Force Initial Loads Aerodynamic Loads

- **This equation can be solved iteratively according to**

$$\mathbf{Ku}_{n+1} = \mathbf{P}_0 + \mathbf{P}(\mathbf{u}_n)$$

- **It can be shown that the iteration converges provided there exists a solution (Fixed point theorem of Banach)**

Basic Equations



Actions in the iteration steps

- **The actual deformed configuration is transferred from MSC.Nastran to the aerodynamic solver (New input file)**
- **The aerodynamic solver computes the aerodynamic pressures on the deformed configuration**
- **The aerodynamic pressures are translated into aerodynamic forces and transferred to MSC.Nastran (New load)**
- **MSC.Nastran computes the new deformed configuration**

One script controls the activities outside of MSC.Nastran including the run of the aero solver

Implementation



Convergence can be accelerated

- **either by relaxation**
- **or by load prediction**

Acceleration Techniques



- **The new configuration is computed from**

$$\mathbf{Ku}_{n+1} = \mathbf{P}_0 + \beta \mathbf{P}(\mathbf{u}_n) + (1 - \beta) \mathbf{Ku}_n$$

- **Underrelaxation: Use $\beta < 1$ if the aerodynamic loads are decreased by the elastic deformation**
- **Overrelaxation: Use $\beta > 1$ if the aerodynamic loads are increased by the elastic deformation**

Relaxation



- The most time consuming step during one iteration cycle is the computation of the aerodynamic loads
- To minimize the number of computations, an approximate model is used to predict the aerodynamic loads.
- The new configuration is computed from

$$K\mathbf{u}_{n+1} = \mathbf{P}_0 + \bar{\mathbf{P}}_{n+1}$$

where $\bar{\mathbf{P}}_{n+1}$ is the load predicted from $\mathbf{P}_{n-1} = \mathbf{P}(\mathbf{u}_{n-1})$ and $\mathbf{P}_n = \mathbf{P}(\mathbf{u}_n)$

Load Prediction



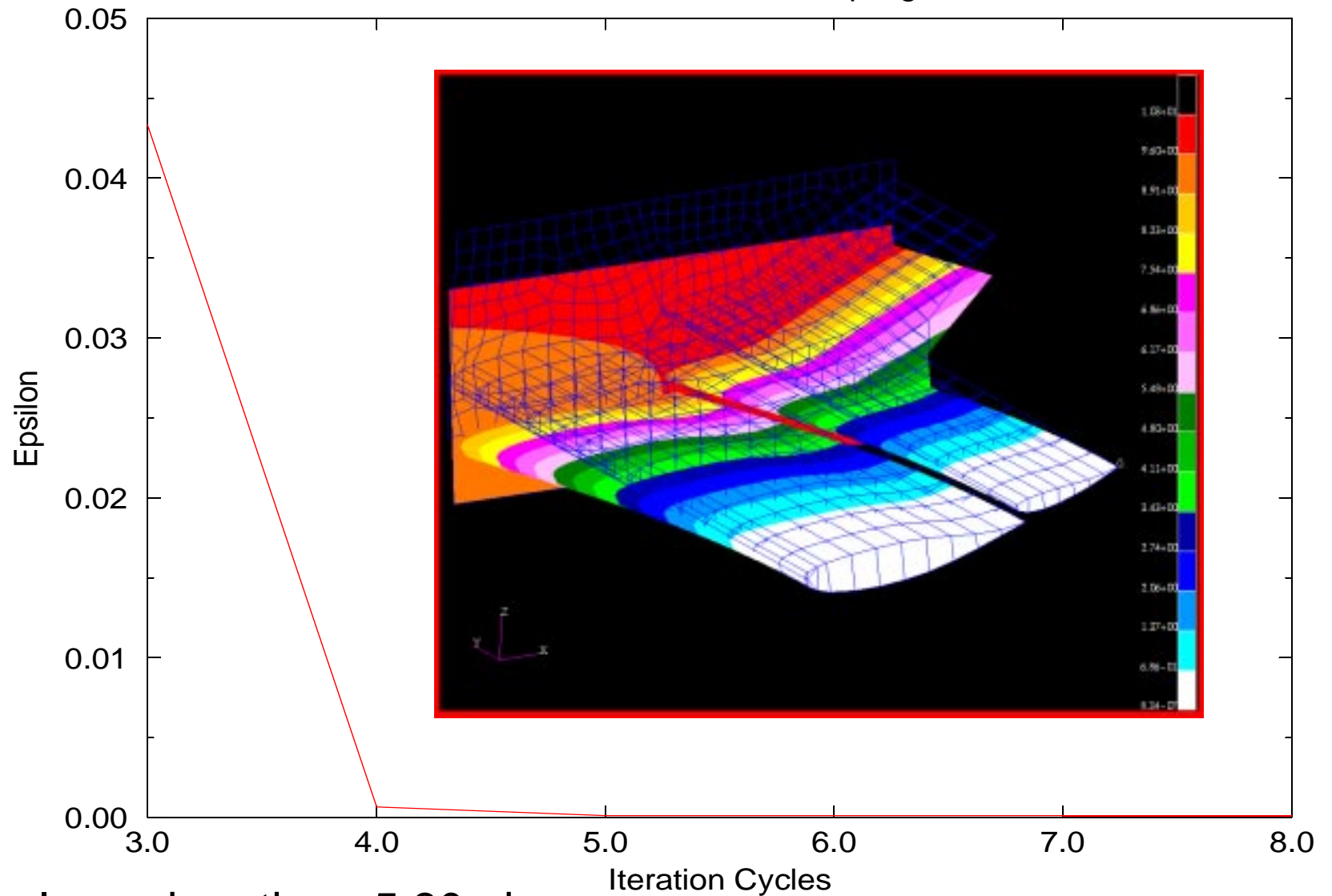
- **Dblocate of the aero and aeroelastic DB provides MSC.Nastran with the aerodynamic mesh and the splines**
- **Use of the “aestatrs” DMAP in a SOL 101 run**
- **Defining of the “aestatrs” solution parameters**

MSC.Nastran job setup



Formula 1 Front Wing

NEWPAN-Nastran coupling



Total elapsed runtime: 5:30min

Example: Formula 1 Front Wing



- **The coupling of NEWPAN and MSC.Nastran is a gapless solution**
- **Since MSC.Nastran controls the analysis no job offset time is wasted for assembling the stiffness matrix and no external convergence control is needed**
- **Given a MSC.Nastran deck and a NEWPAN input file exists both the structural and aerodynamic analyst can handle a coupled job independently**
- **Deformed midplane of wings can be used to design new cross sections with NEWPAN (Pressure distribution to airfoil)**

Summary



Modifications in the MSC.Patran environment

- **Input file reader for CFD Code**

Modifications in the MSC.Nastran environment

- **New job control script (NASXPAN)**
- **New input file reader for CFD Code**
- **New result file reader for CFD Code**
- **New input file writer for CFD Code**
- **CFD Code specials e.c. symmetry control**

MSC has the experience!

- **Interface to Euler Code**
- **Interface to A502**
- **Interface to NEWPAN**
- **Interface to MATLAB**

Integration of other CFD Codes