FOCUS5

An Integrated Wind Turbine Design Tool

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Sandia 2008 Blade Workshop

Tuesday May 13th, 2008

Knowledge Centre WMC
Wind turbine Materials and Constructions

Outline

- General Introduction
- Turbine Design
- Blade Design
- Future Development

Introduction

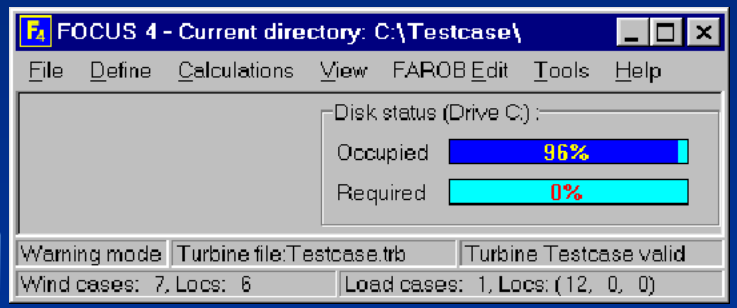
FOCUS, an integrated wind turbine design tool

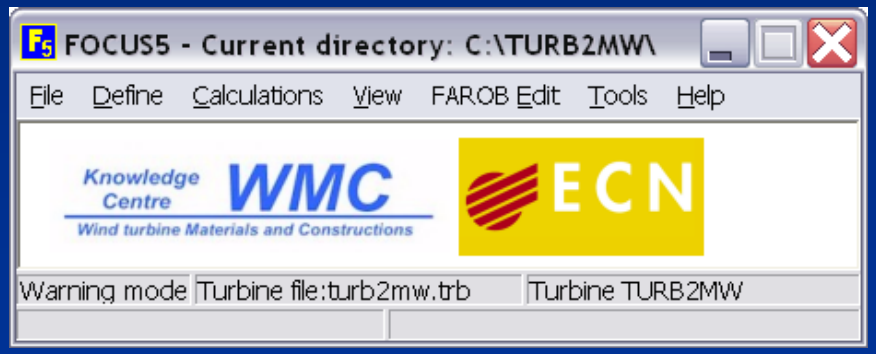
Novem project 224.720.9535: FOCUS version 4
Novem project 224.720.9635: Windows-95 interface for FOCUS4

FOCUS 5: Internal development

SenterNovem project: 2020-04-11-10-003: FOCUS 6 (2004-2008)

INNWIND - Innovation in Wind Energy (2006-2011)

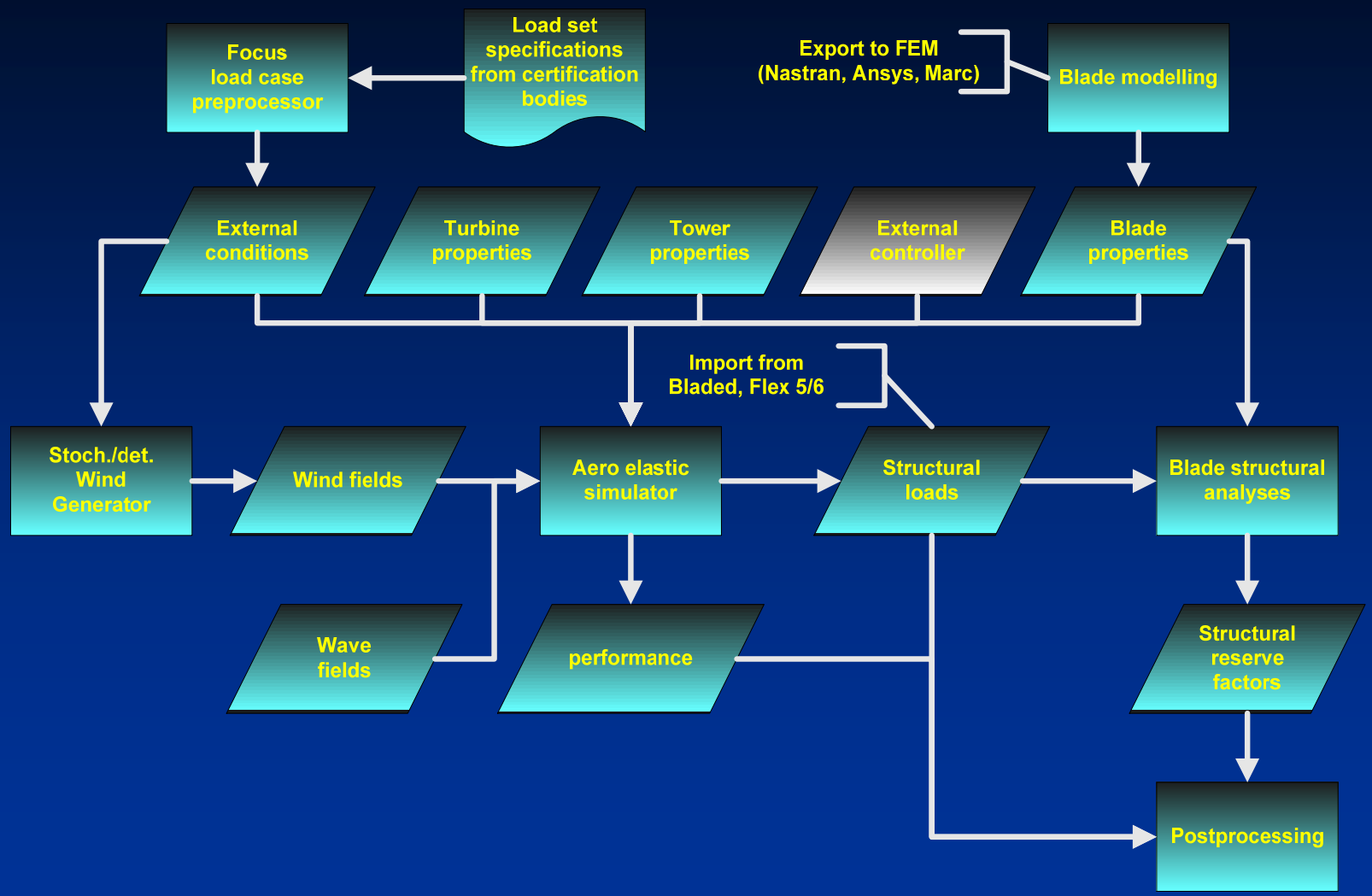




Main Features

- Wind turbine design
- Detailed blade design
- Load set calculation according to international standards (IEC, GL, DNV)
- Design load sets calculated and blade structural analyses results are accepted for certification
- Fatigue and strength analysis based on stress/strain time series
- World wide used by main players in industry
- Focus is also applied for many years in both national and international research projects
- Open architecture
- Support of external formats
- Graphical analysis of results
- Integrated help system

Focus flow chart



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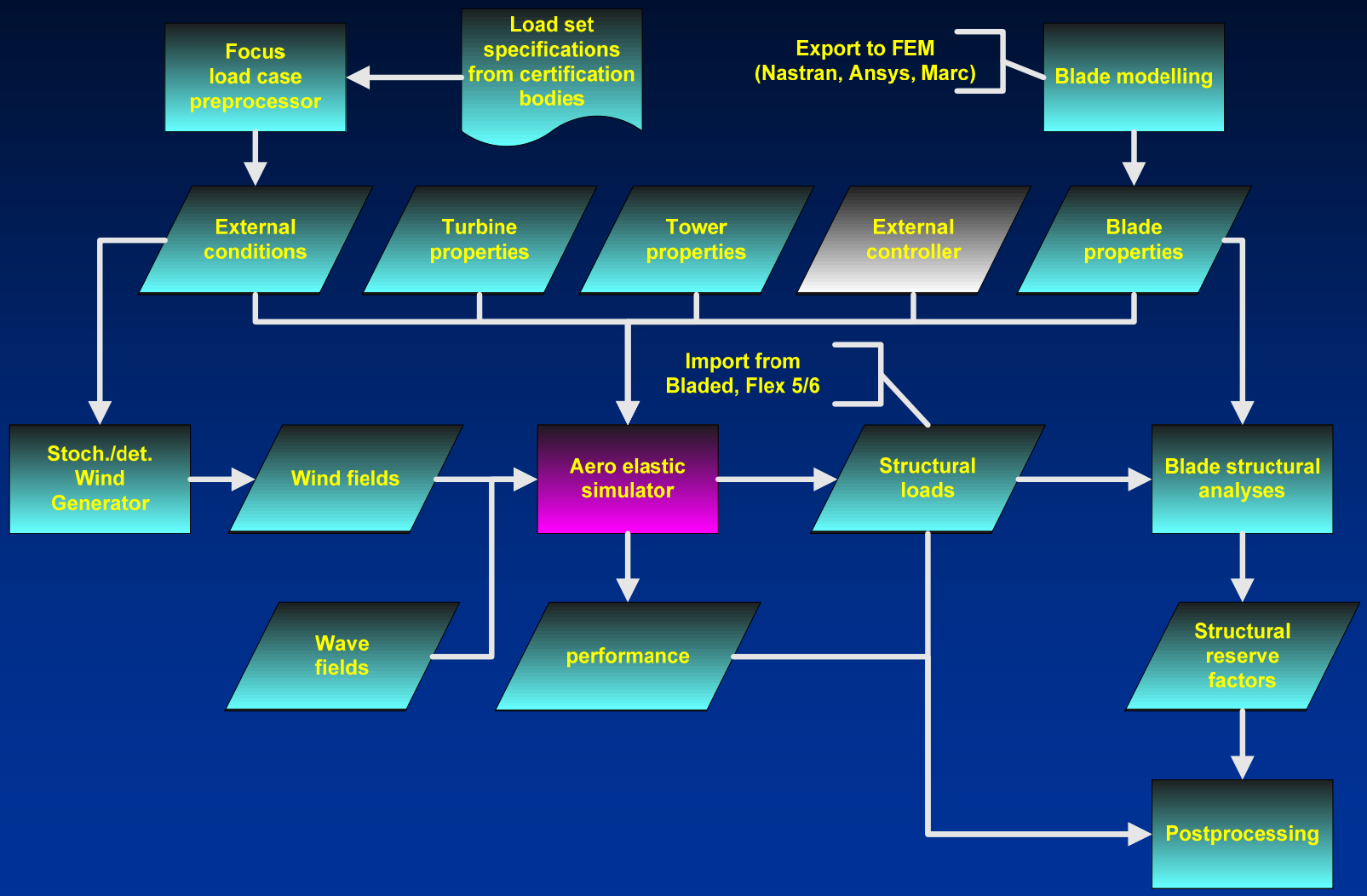
Wind turbine Materials and Constructions

Aero elastic simulator



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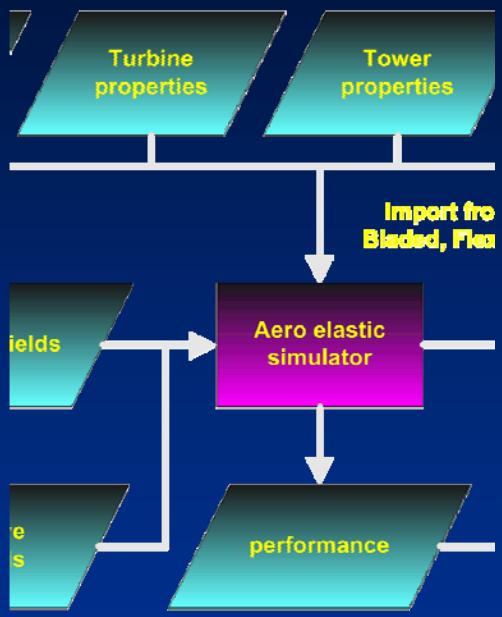
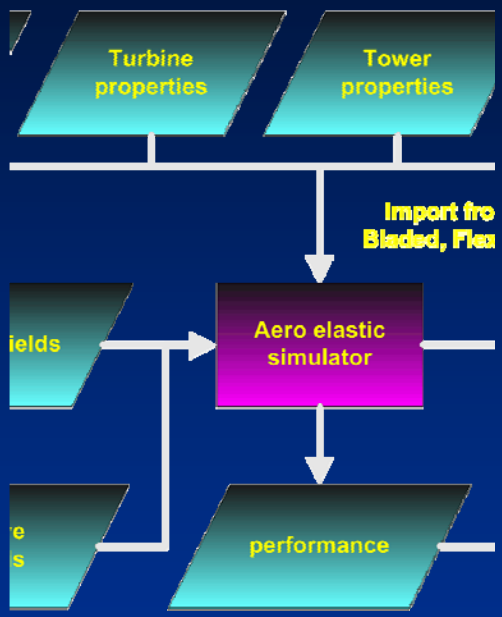
Aero Elastic Simulator (Phatas)



- *Simulation of non-linear structural and aerodynamic response of the complete wind turbine in time domain developed by ECN.*
- *The simulation includes full interaction between aerodynamic loads, structural deformations and controller response.*
- *Is suitable for pitch-to-vane controlled variable-speed turbines*
- *Accurate modal response model for tower and blades, including blade torsion*
- *Geometric non-linear model for blade bending*
- *Optional linkage of tower substructure exported from general purpose FEM package is possible*

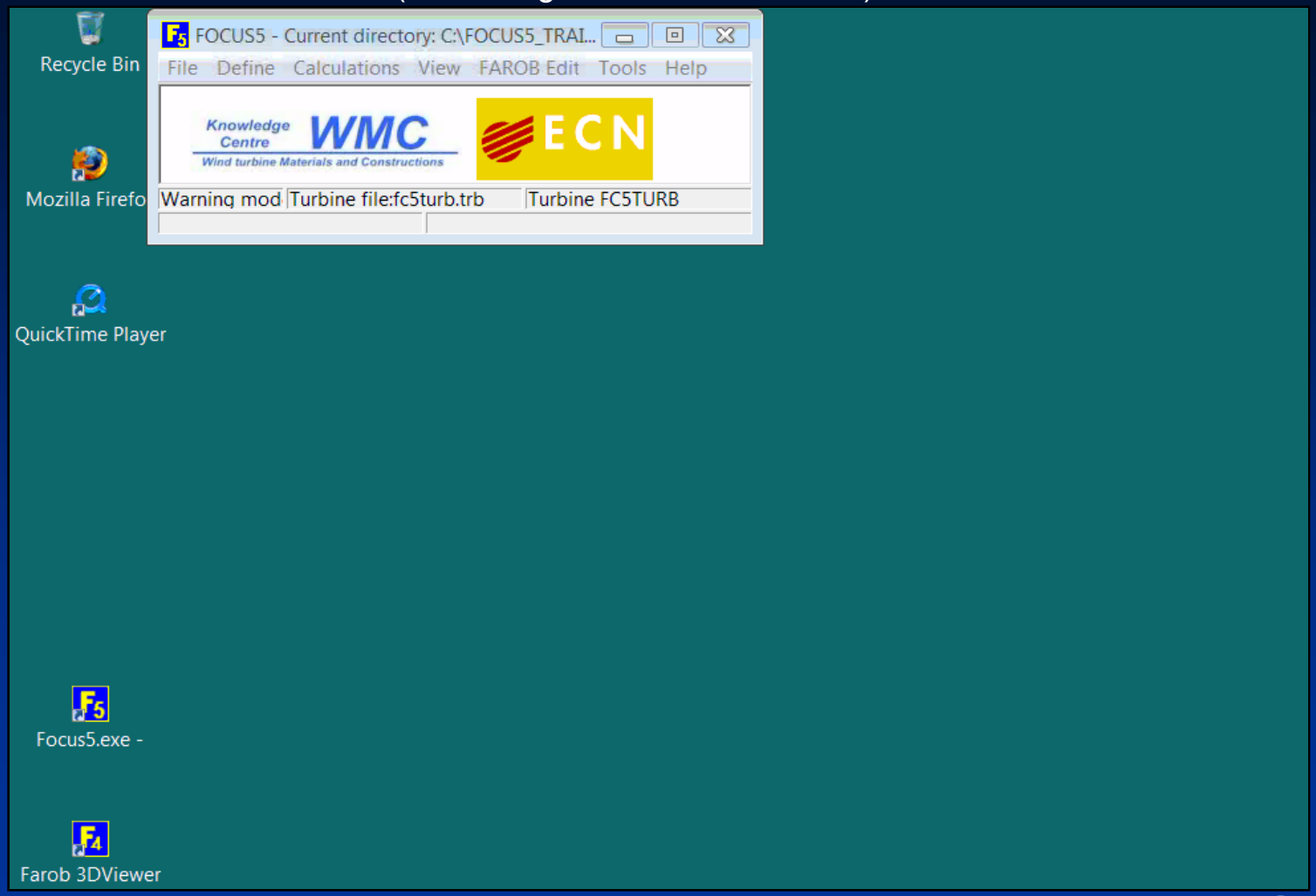
Aero Elastic Simulator (Phatas)



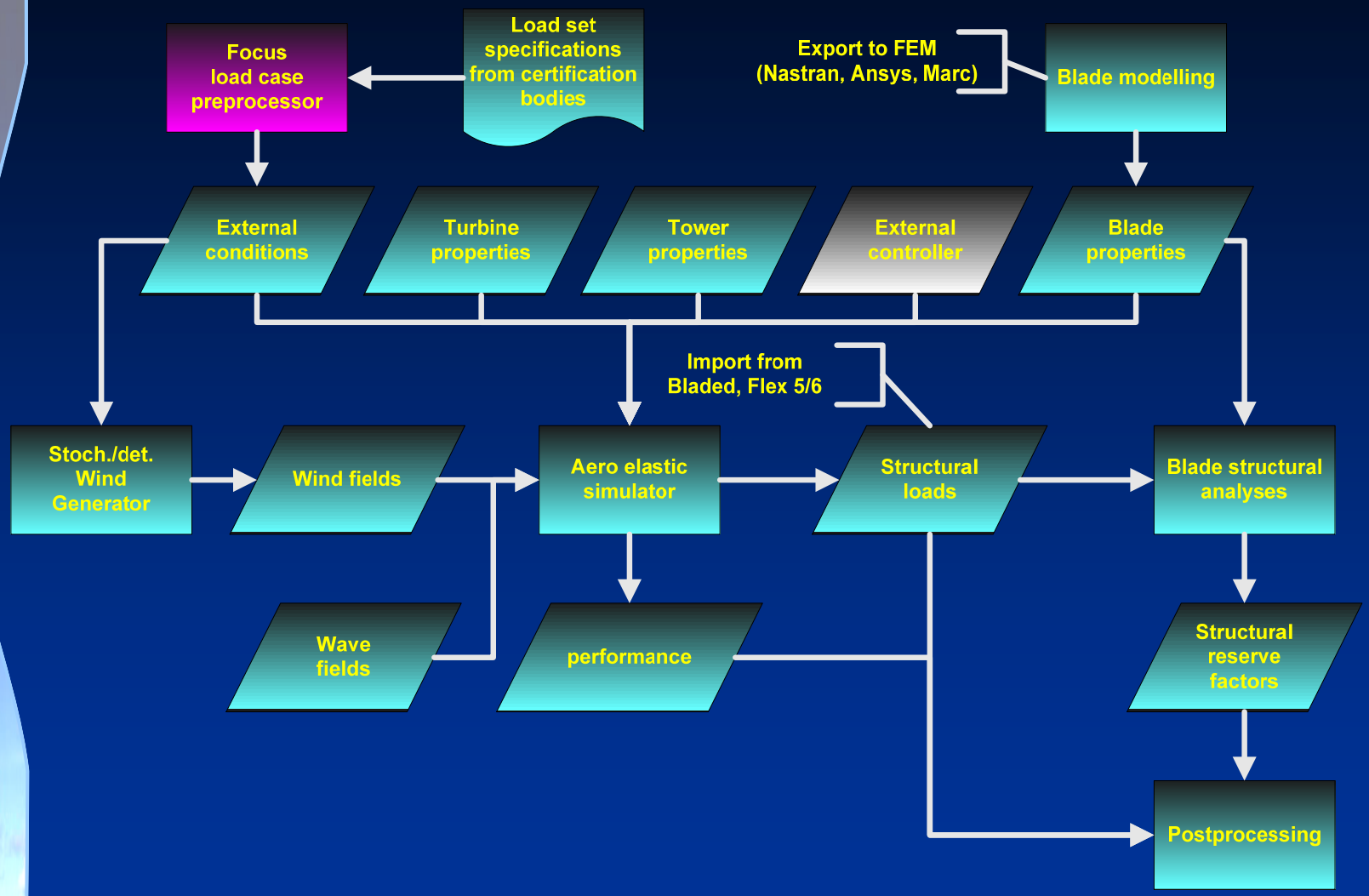
- *Analyses of the aerodynamic rotor characteristics*
- *Power curve calculations*
- *Built-in advanced PD controller, custom PD controllers can be linked*
- *Modeling of operational states of the turbine like starts and stops and emergency conditions*
- *Detailed modeling options of deterministic wind conditions*
- *Option to apply stochastic wave loading*

FOCUS GUI
Phatas

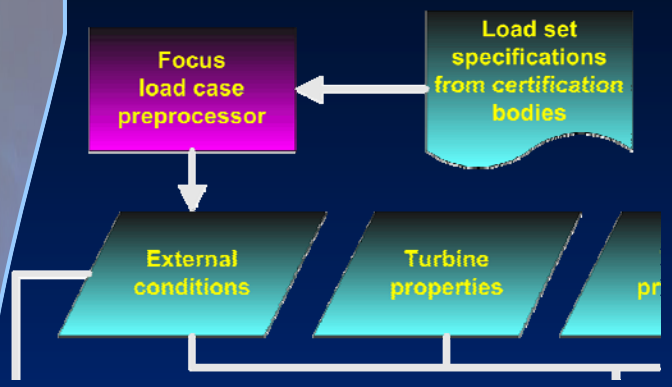
(Click image below to start video)



Load Case PreProcessor

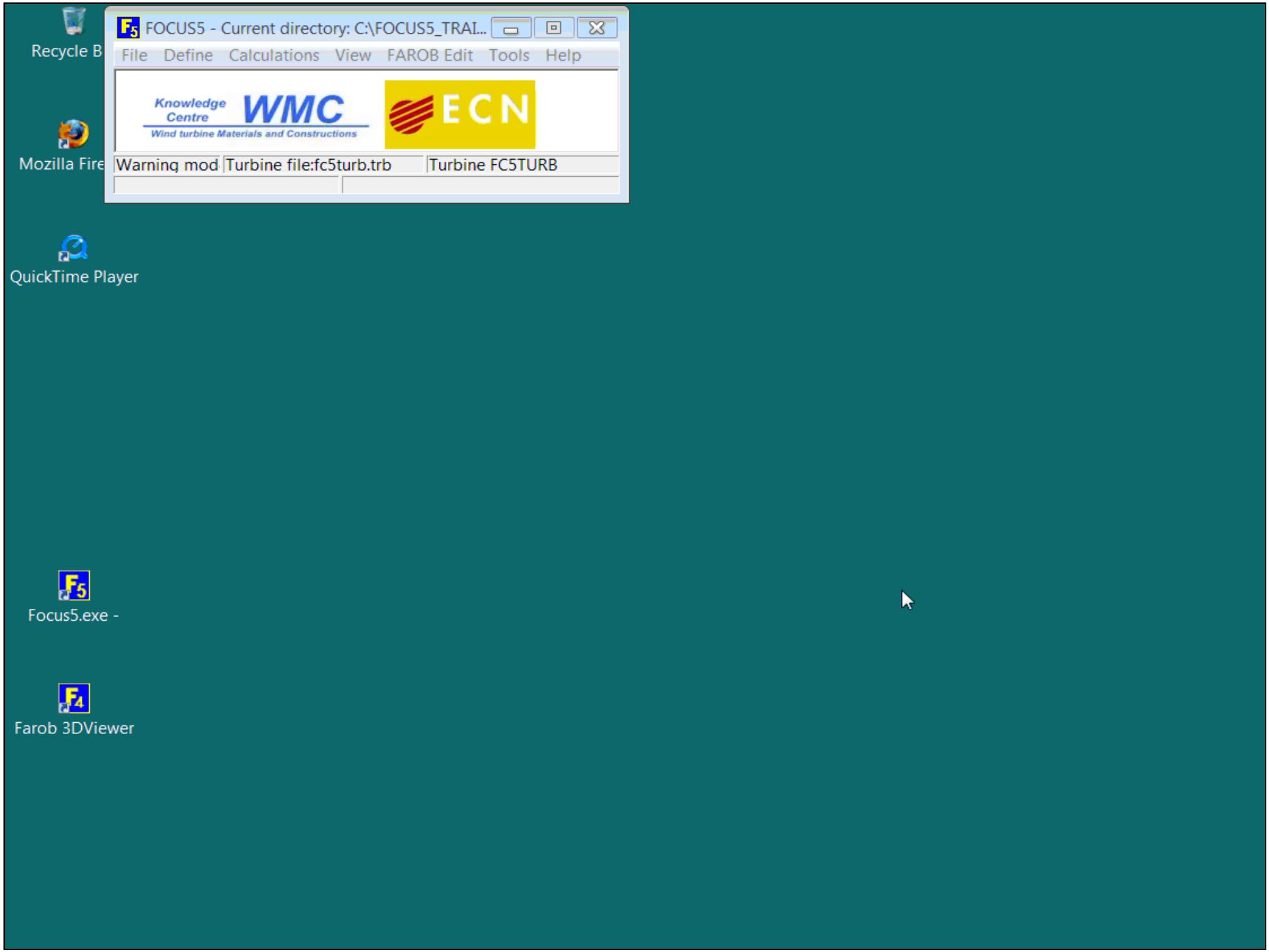


Load Case PreProcessor

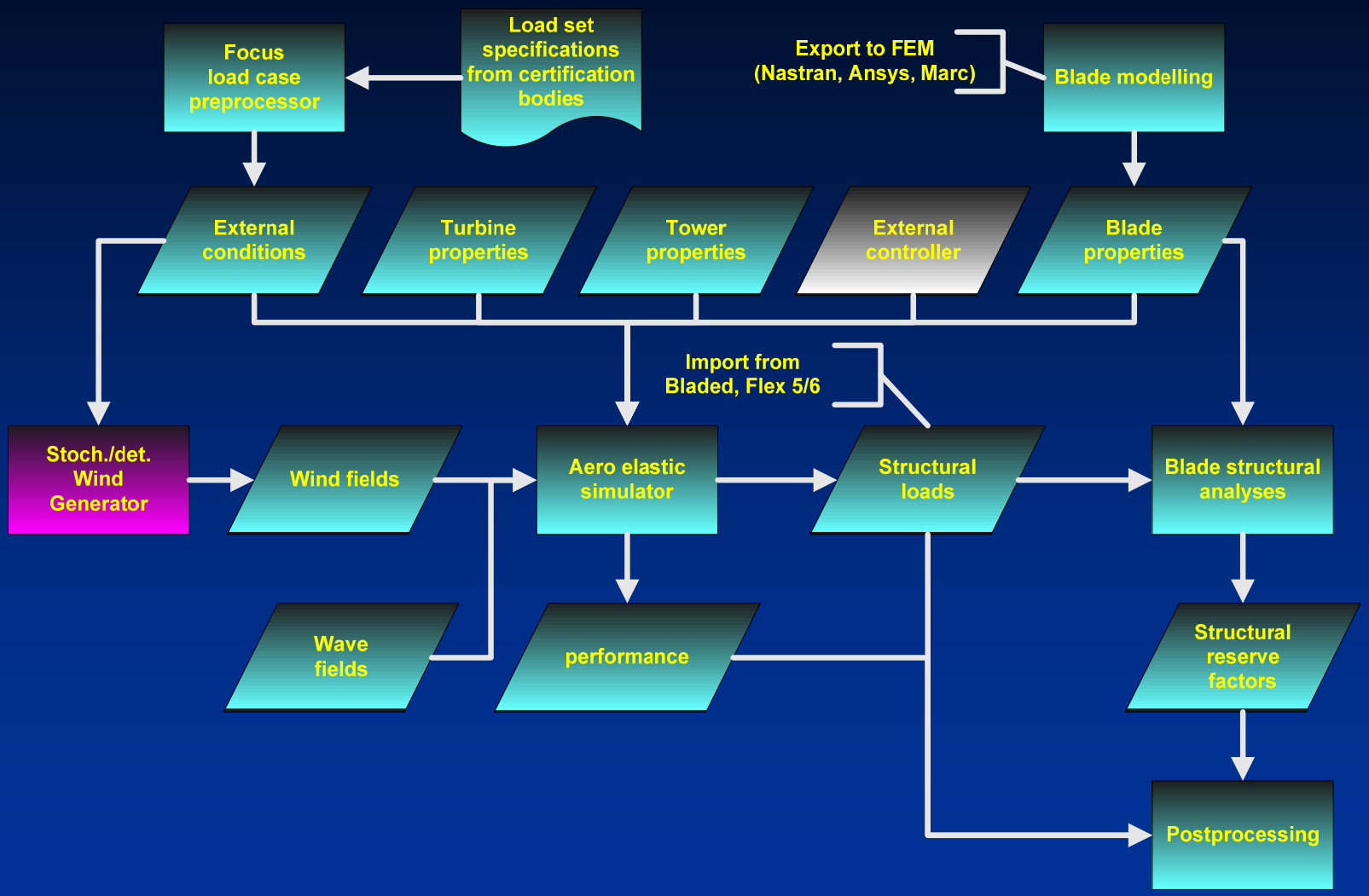


- *The LoadCase PREProcessor LCPREP is provided for automatic generation of load case input files following IEC-2 and GL or IEC-3.*

(Click image below to start video)



3D Wind Field Generator



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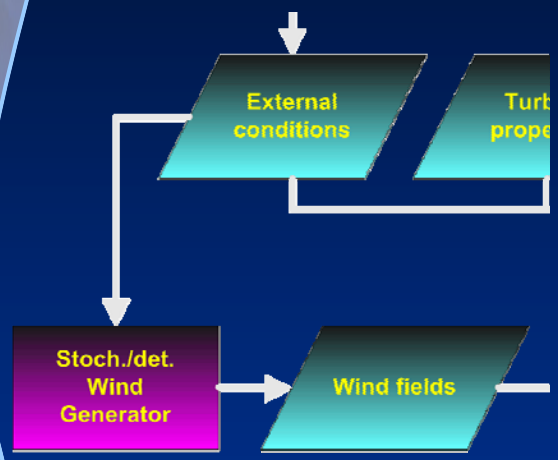
Wind Simulator (SWIFT)

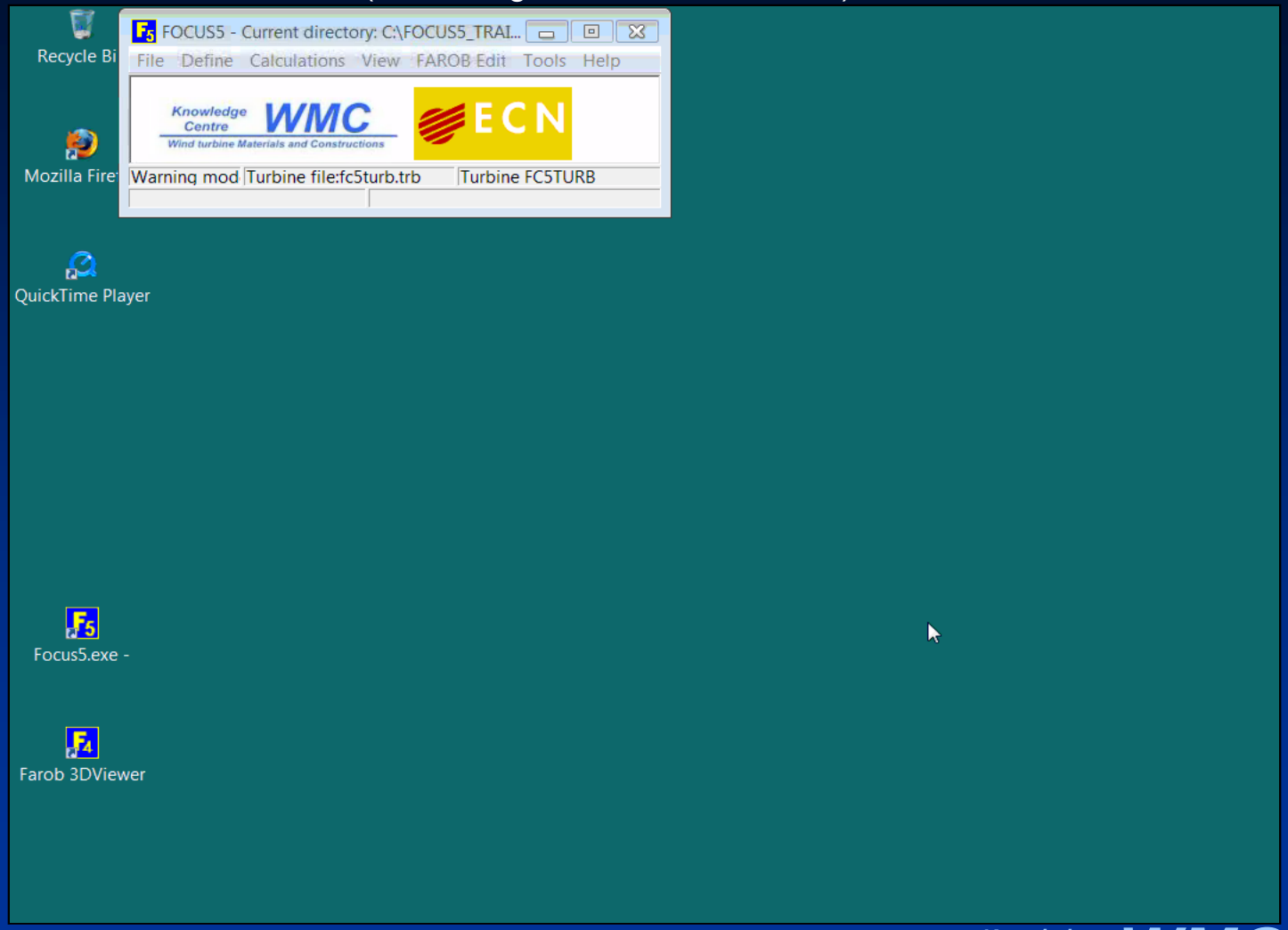
SWIFT Simulation of Wind Fields in Time



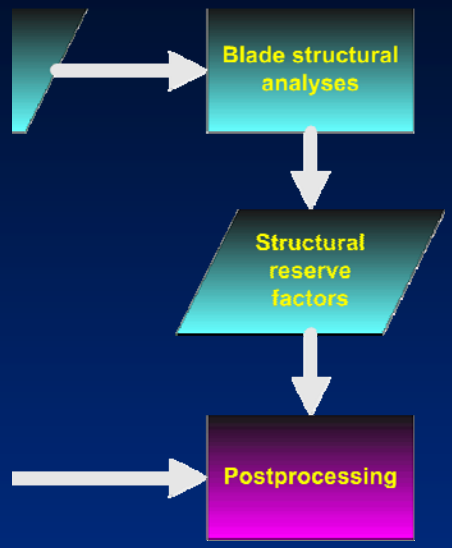
- *A full field of three-component turbulent wind is generated for variable speed wind turbines*
- *The discrete time history of the wind speed in wind direction are calculated at nodal points on the rotor plane.*
- *SWIFT is compatible with the commonly applied standards for wind turbine design: IEC, GL and DNV.*

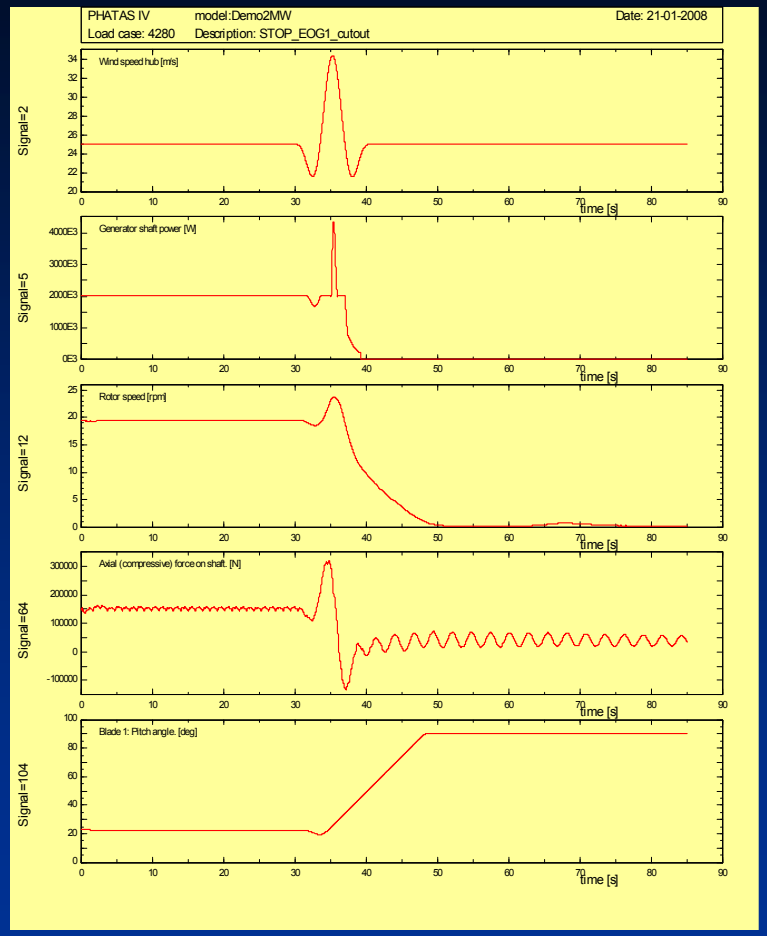
FOCUS GUI
3D wind definition (Swift)

(Click image below to start video)



Post-processing
Time series turbine simulation





V_{hub}

Generator shaft power

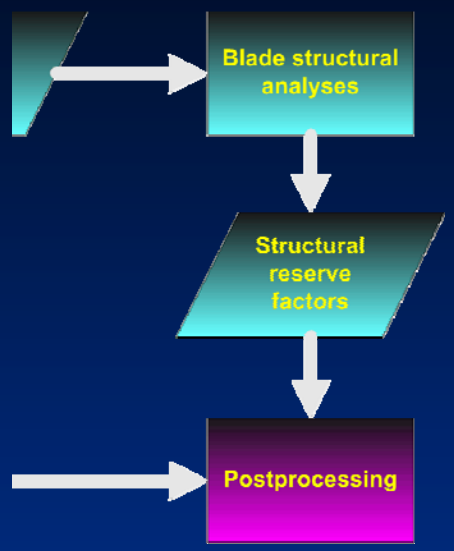
Rotor speed

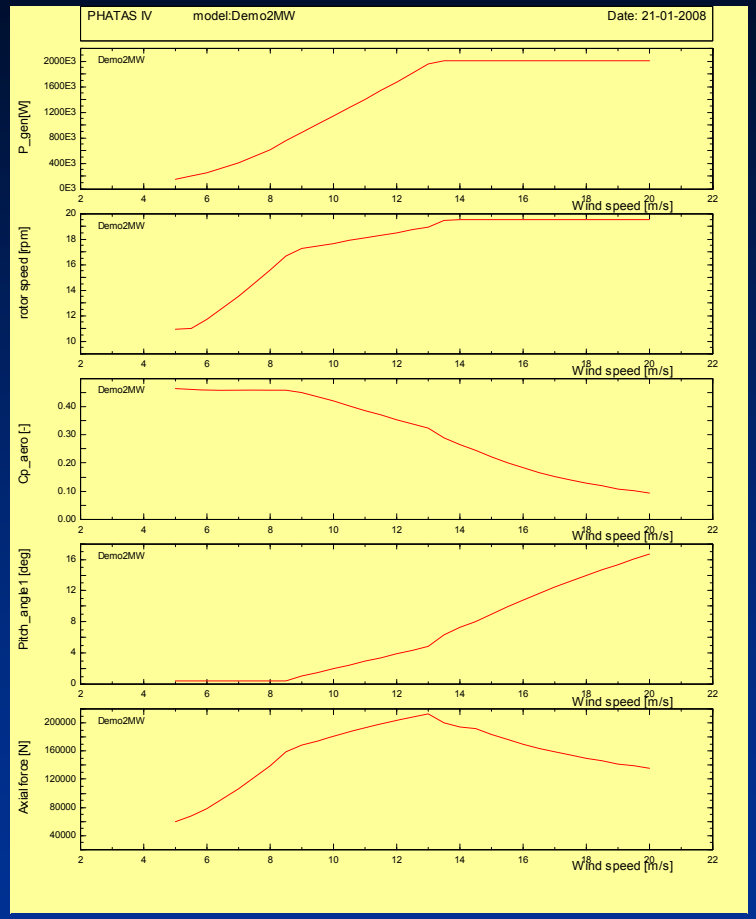
Axial force shaft

Pitch angle blade 1

Load case GL 4.2 Normal stop, Extreme Operating Gust (EOG) at V_{out}

Post-processing
Power curve





$P_{generator}$

Rotor speed

Cp_{aero}

Pitch angle

Axial Force

External links

- *External controller DLL can be linked to Phatas*
  - *Native Phatas API*
  - *Bladed API*

FOCUS5
Blade design

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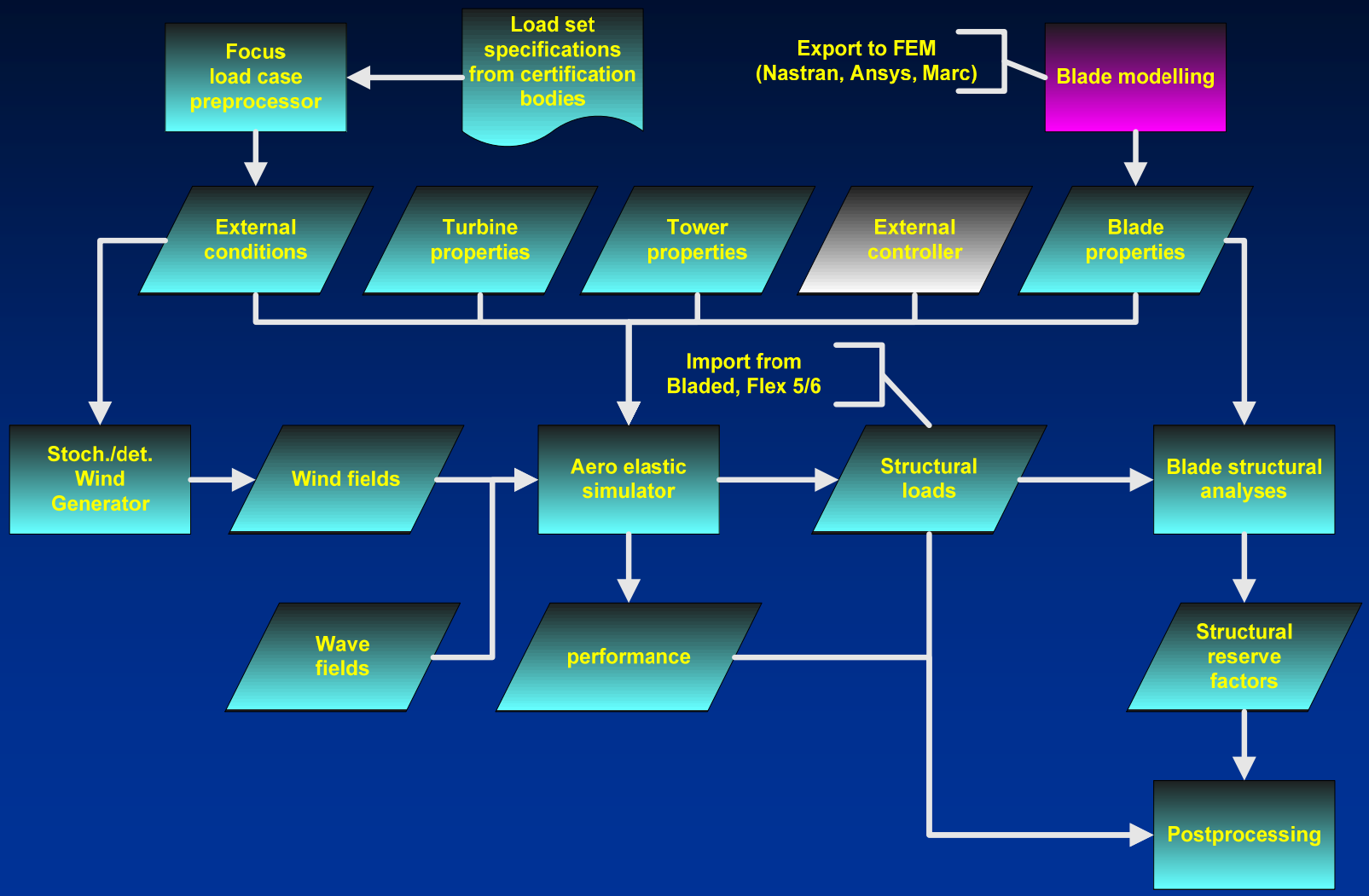
Blade modelling



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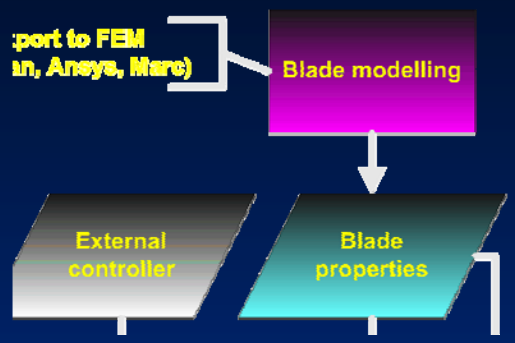
FOCUS blade design



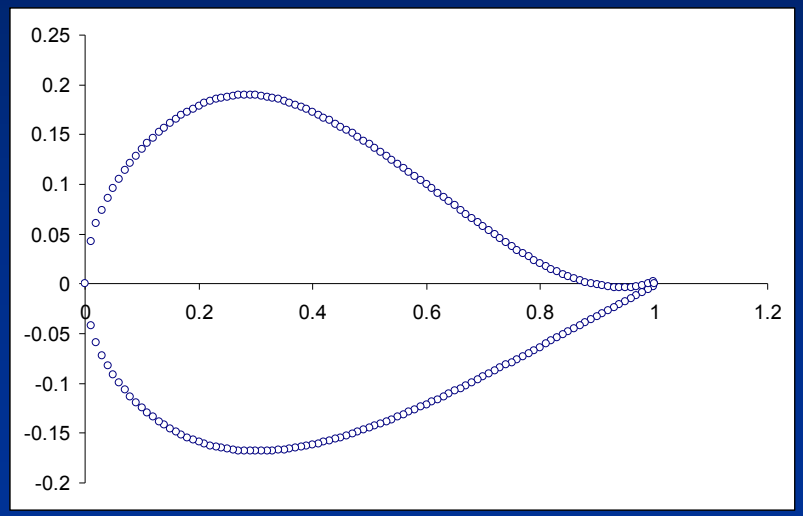
1. Define the profiles of the blade
2. Define position of profiles in the blade
3. Define lines through the profiles
4. Define materials
5. From lines and radii + materials: define sections (sheets of material)
6. Select load cases
7. Run

Profile definition

Blade modelling

1. Define the profiles of the blade
2. Define position of profiles
3. Define lines through the profiles
4. Define materials
5. Define sections

- *Normalized shape*
- *# of points constant for the whole blade*
- *Closed profiles*

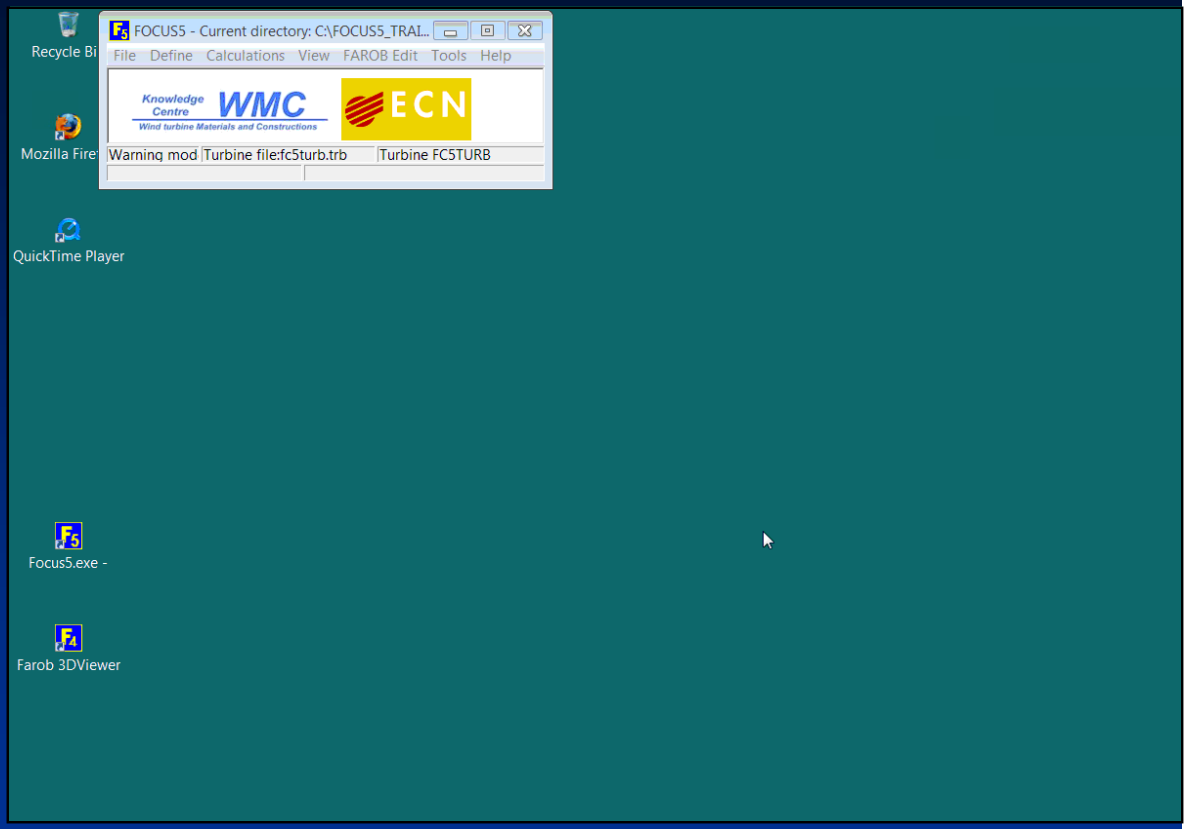


FOCUS shape tool

Blade modelling

1. Define the profiles of the blade
2. Define position of profiles
3. Define lines through the profiles
4. Define materials
5. Define sections

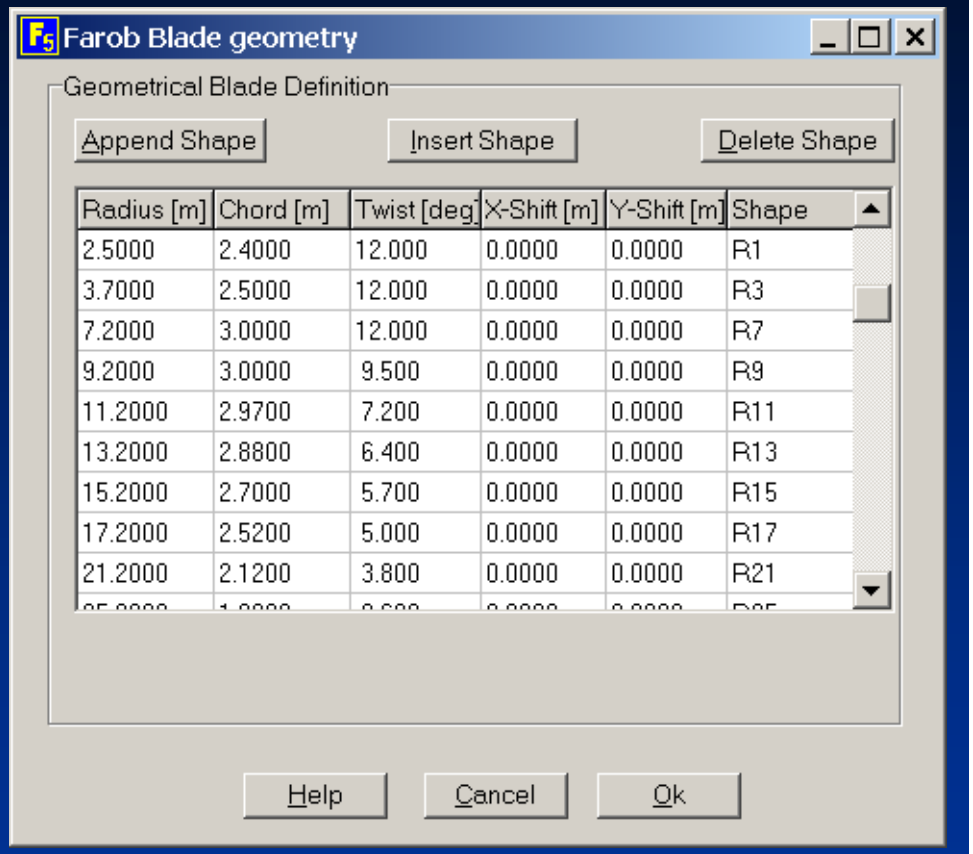
(Click image below to start video)



Use of profile files in blade definition

Blade modelling

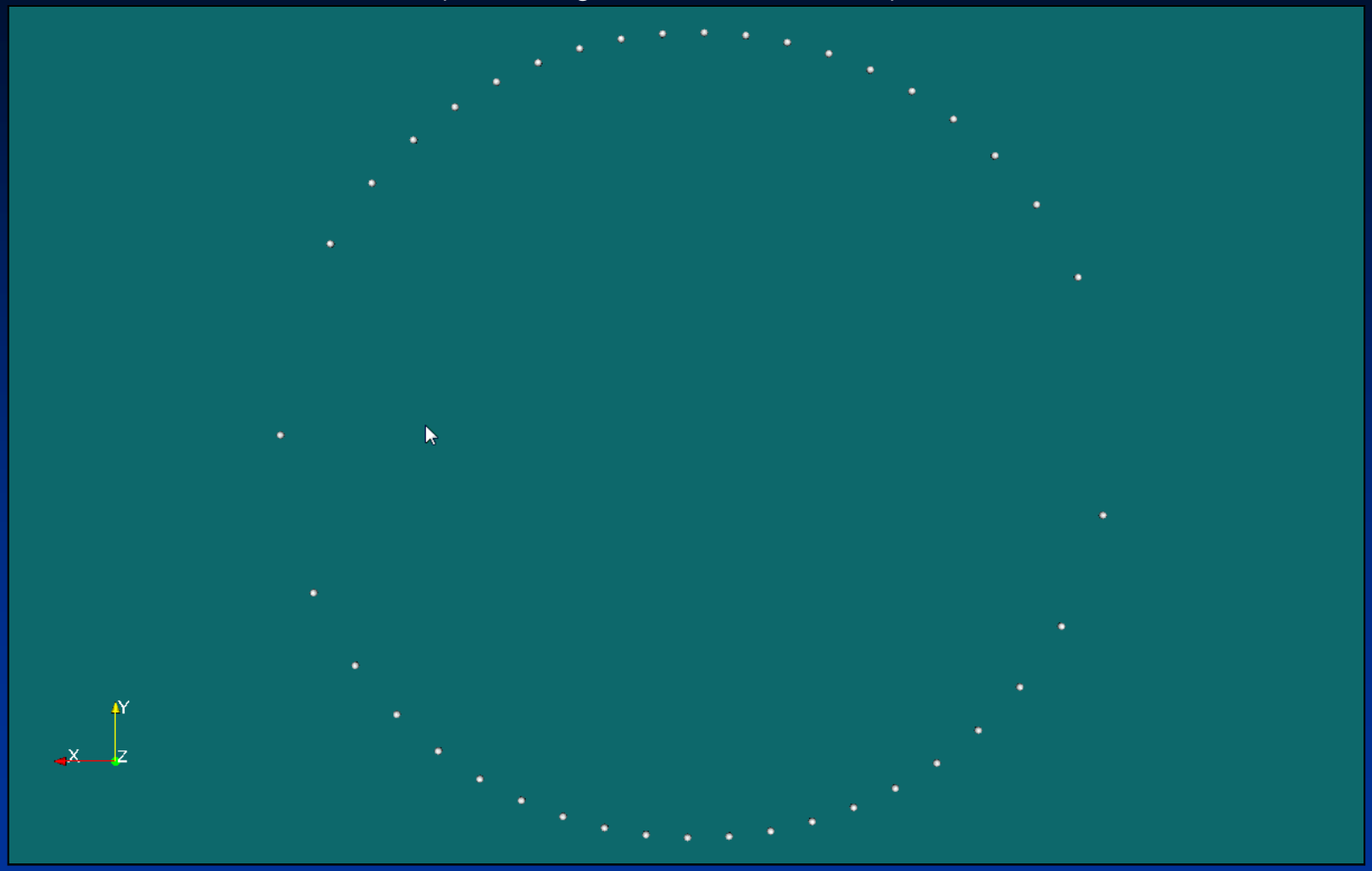
1. Define the profiles of the blade
2. **Define position of profiles**
3. Define lines through the profiles
4. Define materials
5. Define sections



Radius [m]	Chord [m]	Twist [deg]	X-Shift [m]	Y-Shift [m]	Shape
2.5000	2.4000	12.000	0.0000	0.0000	R1
3.7000	2.5000	12.000	0.0000	0.0000	R3
7.2000	3.0000	12.000	0.0000	0.0000	R7
9.2000	3.0000	9.500	0.0000	0.0000	R9
11.2000	2.9700	7.200	0.0000	0.0000	R11
13.2000	2.8800	6.400	0.0000	0.0000	R13
15.2000	2.7000	5.700	0.0000	0.0000	R15
17.2000	2.5200	5.000	0.0000	0.0000	R17
21.2000	2.1200	3.800	0.0000	0.0000	R21

From profiles to blade shape

(Click image below to start video)

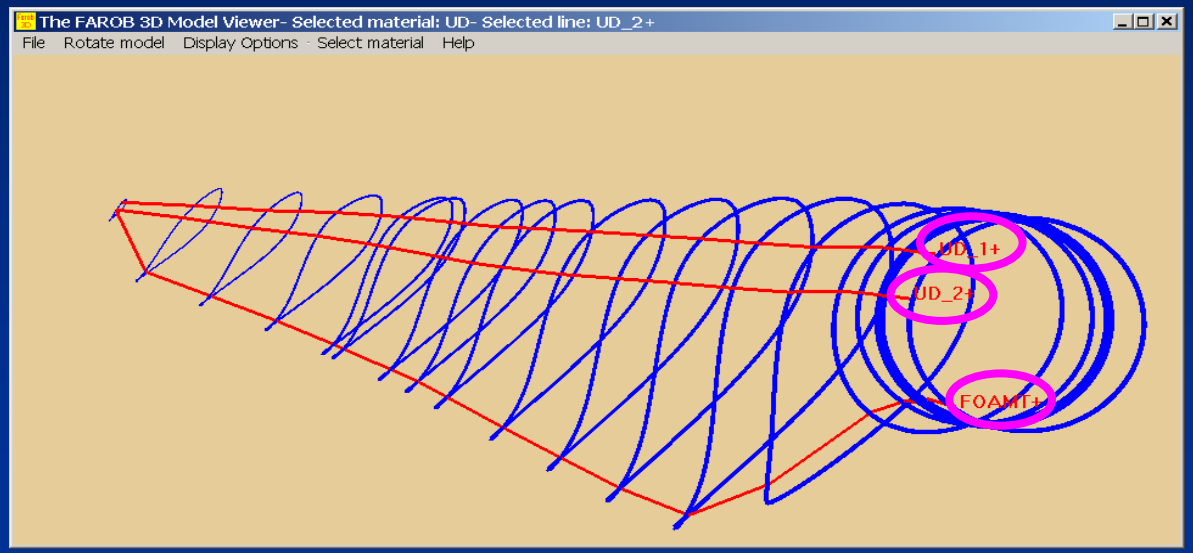


Lines definition

Blade modelling

1. Define the profiles of the blade
2. Define position of profiles
3. **Define lines through the profiles**
4. Define materials
5. Define sections

- Lines are defined as ≥ 2 points :
  - Radius
  - % chord
  - Offset mm //chord
  - Offset along //profile
  - Offset ⊥ chord



Define material properties

Blade modelling

1. Define the profiles of the blade
2. Define position of profiles
3. Define lines through the profiles
4. **Define materials**
5. Define sections

- **Define materials by:**
- **Type**
  - Isotropic
  - Orthotropic
  - Core
- **Partial material factors according to GL**
- **Additional material properties can be set for export to FEM**
- **Material dependent S-N line data (like slope)**
  - For fatigue analysis

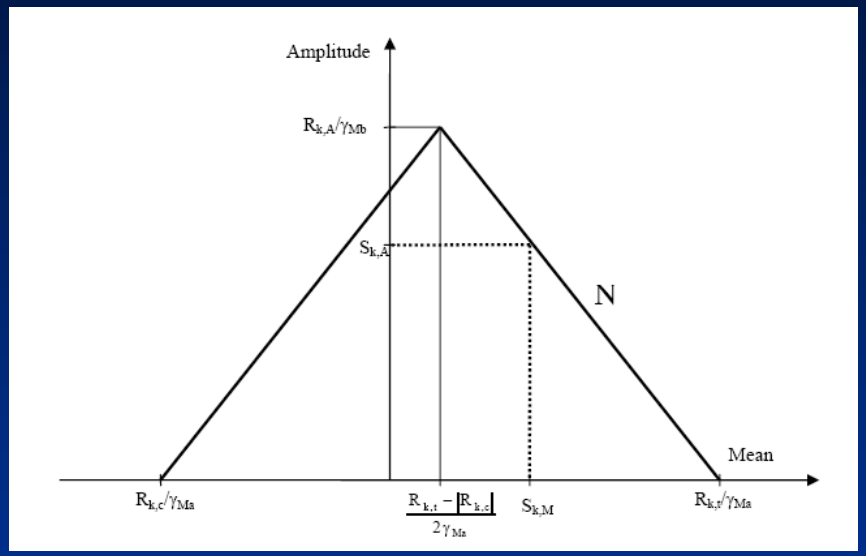
Define fatigue formulation

Blade modelling

1. Define the profiles of the blade
2. Define position of profiles
3. Define lines through the profiles
4. **Define materials**
5. Define sections

Goodman & S-N lines defined by user defined equations

$$N = \left[\frac{R_{k,t} + |R_{k,c}| - |2 \cdot \gamma_{Ma} \cdot S_{k,M} - R_{k,t} + |R_{k,c}||}{2 \cdot (\gamma_{Mb}/C_{1b}) \cdot S_{k,A}} \right]^m$$



GRP Goodman diagram according to GL2003

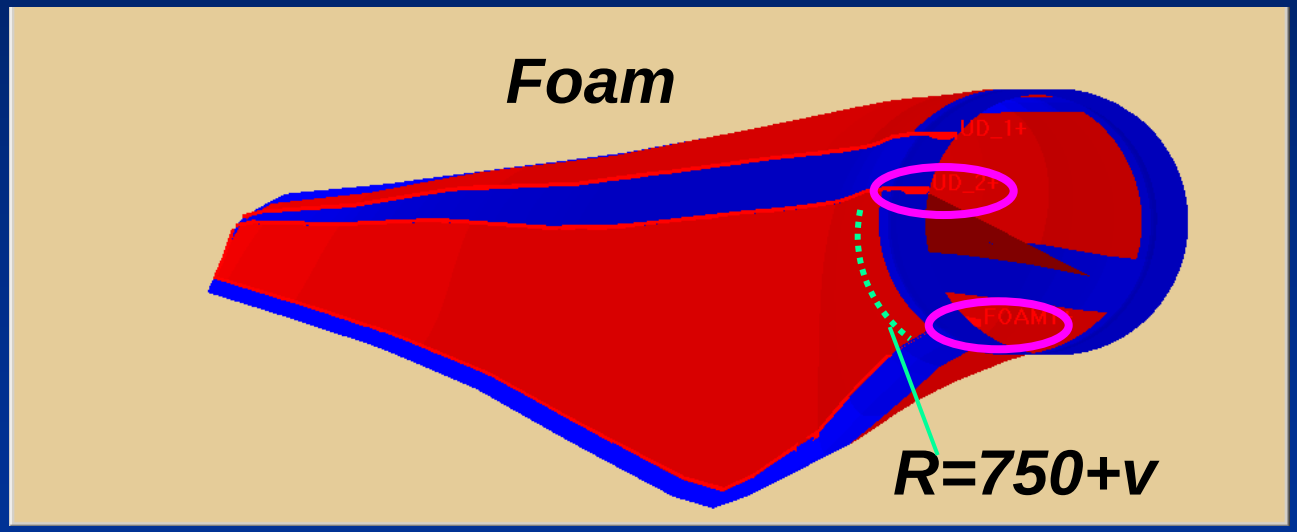
```
# Goodman diagram according to GL 2003
DEF S-N LINE        GL2003
LINE  :             ((UTS+ABS(UCS)-ABS(2*GMa*Smean-UTS+ABS(UCS)))/(2*GMb*Samp))^SLOPE
END DEF S-N LINE
```

Define Sections

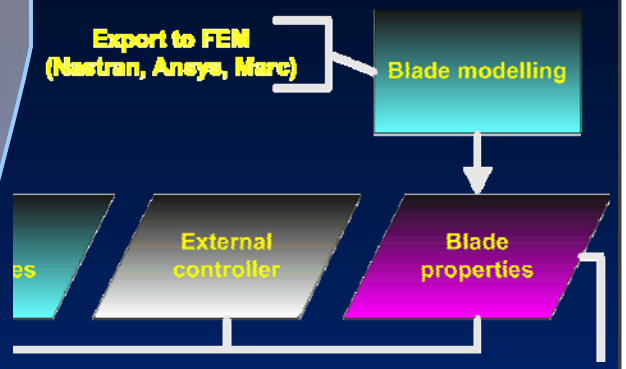
Blade modelling

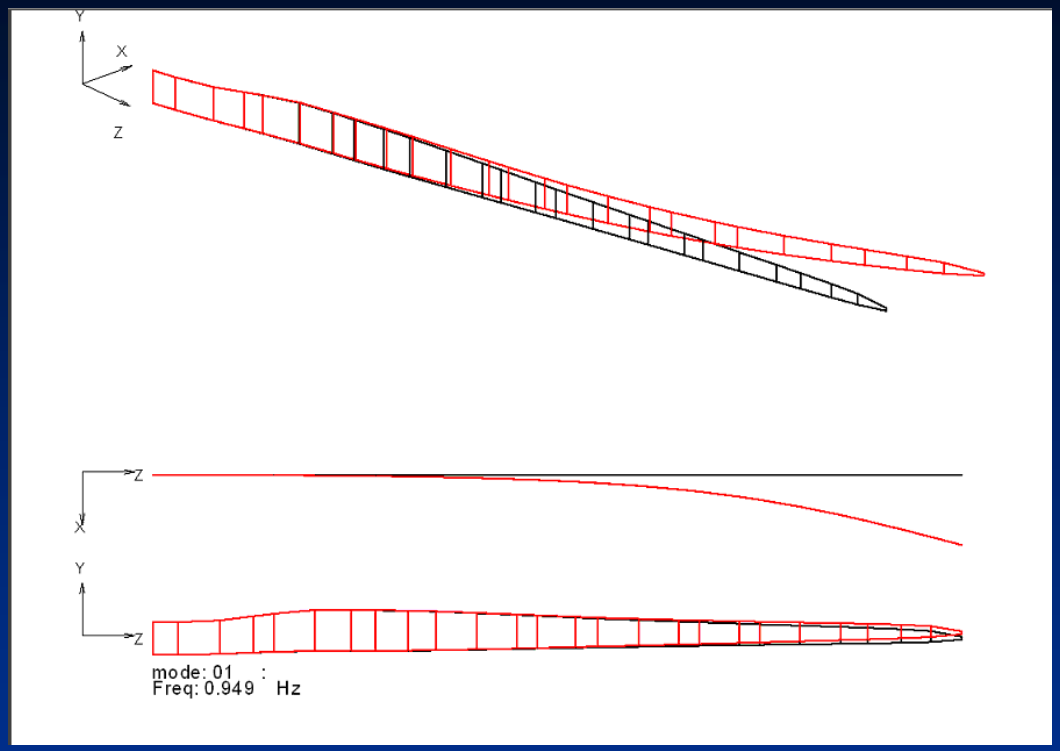
1. Define the profiles of the blade
2. Define position of profiles
3. Define lines through the profiles
4. Define materials
5. Define sections

- Give radii and lines for each sheet of material
- Sequence: start from the mold, as in the production



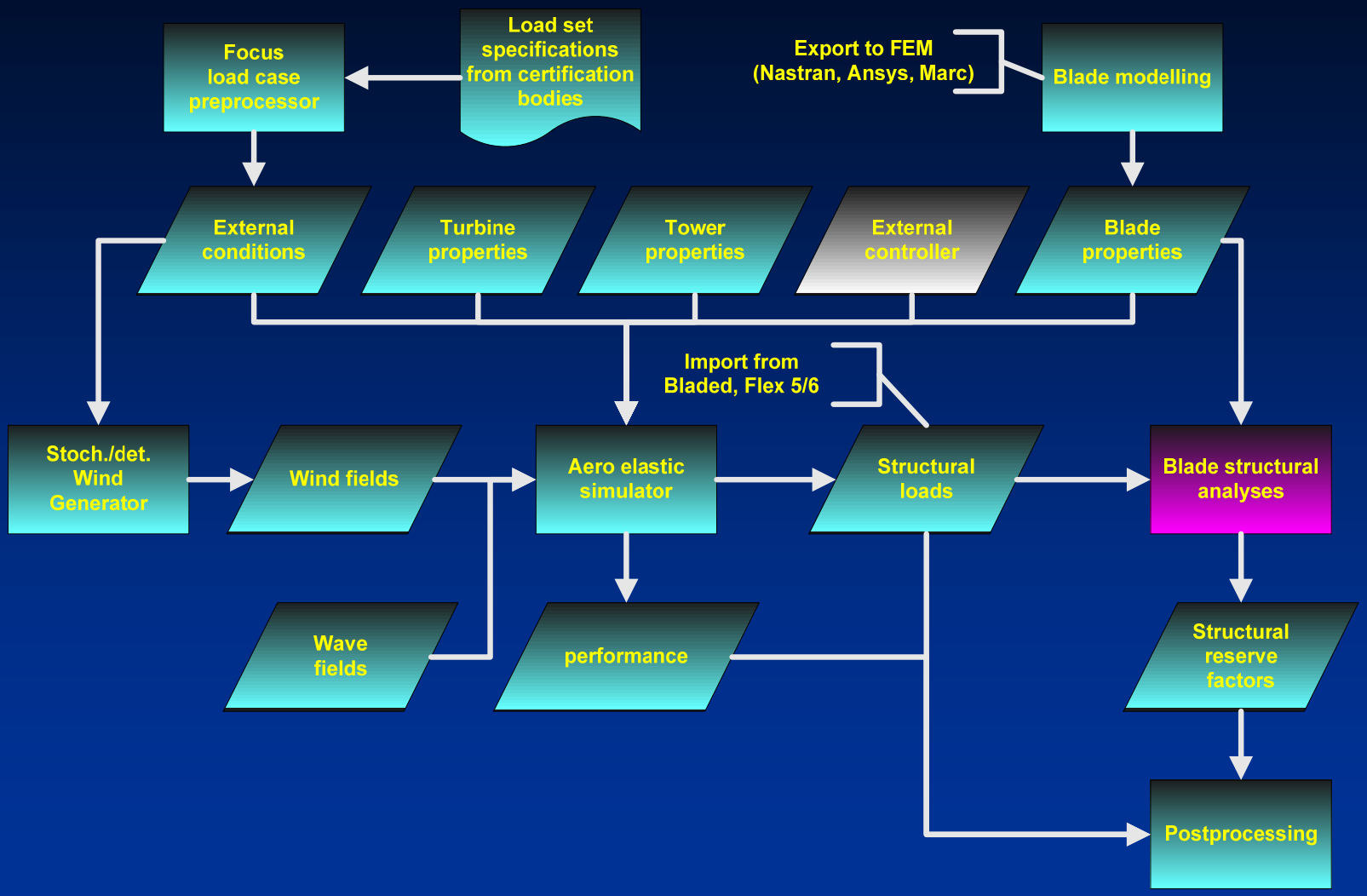
Blade Eigen frequencies/modes





- Coupled eigen frequencies/modes calculated by Focus

Blade Structural analyses



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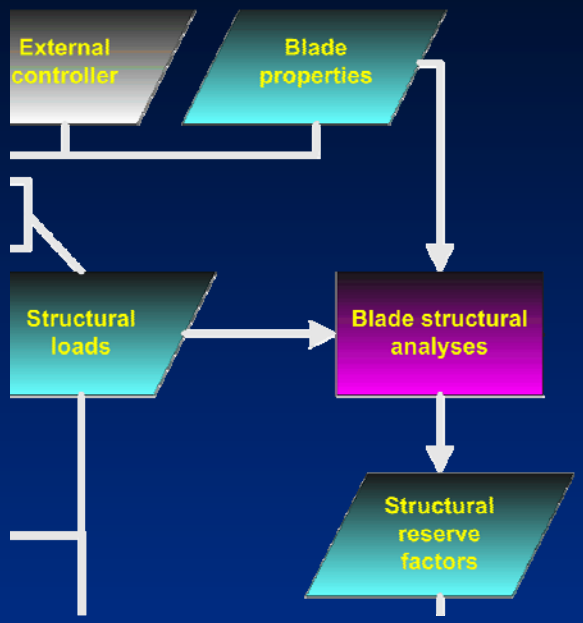
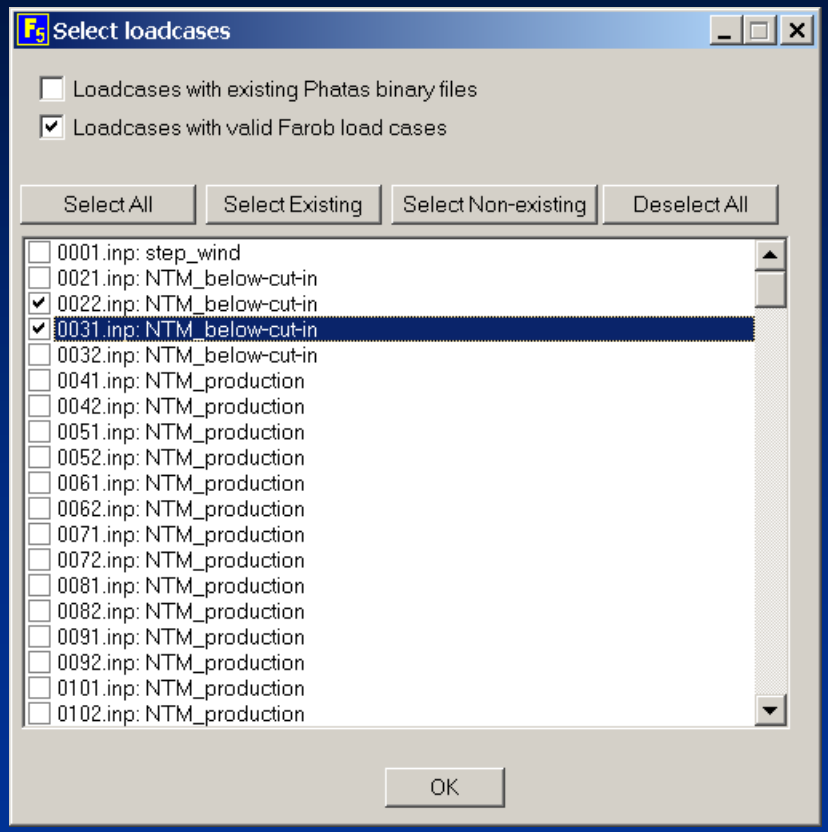
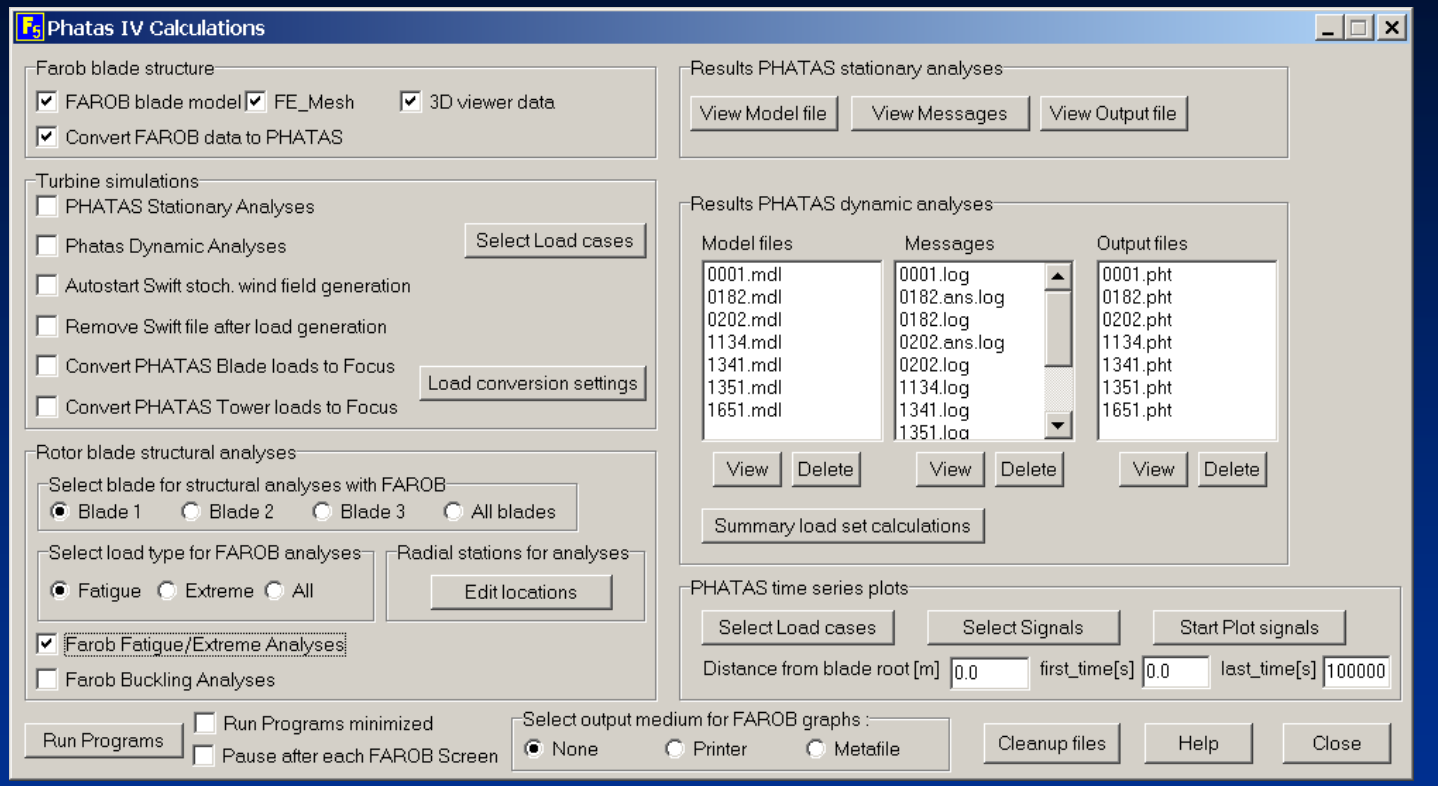
Load case selection

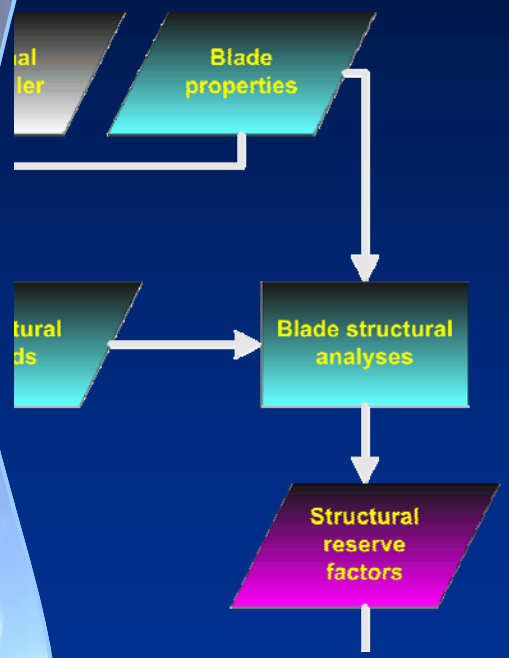




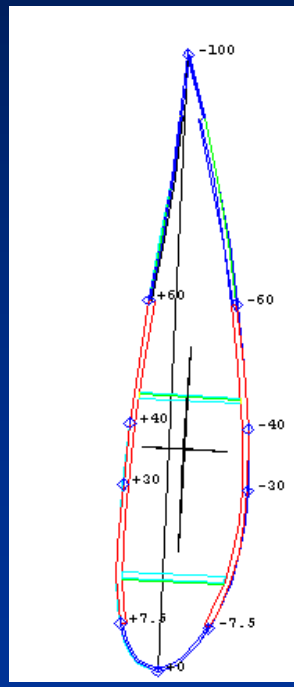
Run Blade design analysis



Blade structural analyses
Fatigue Results



- Fatigue damage (life based)
- Fatigue reserve factor (strength based)
- Stress spectra

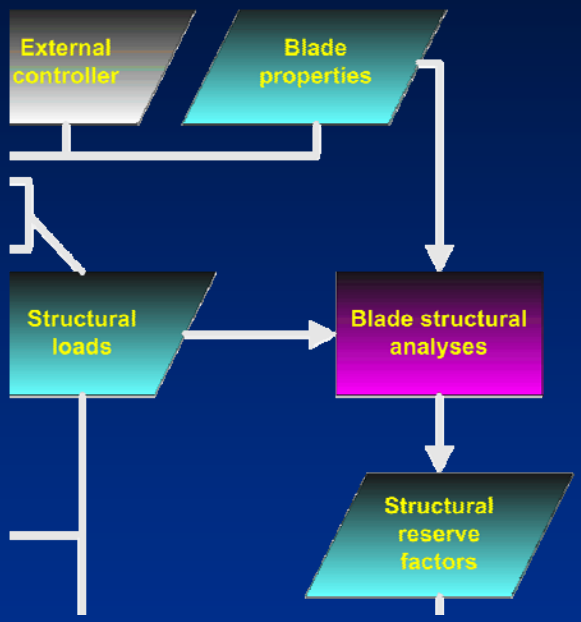


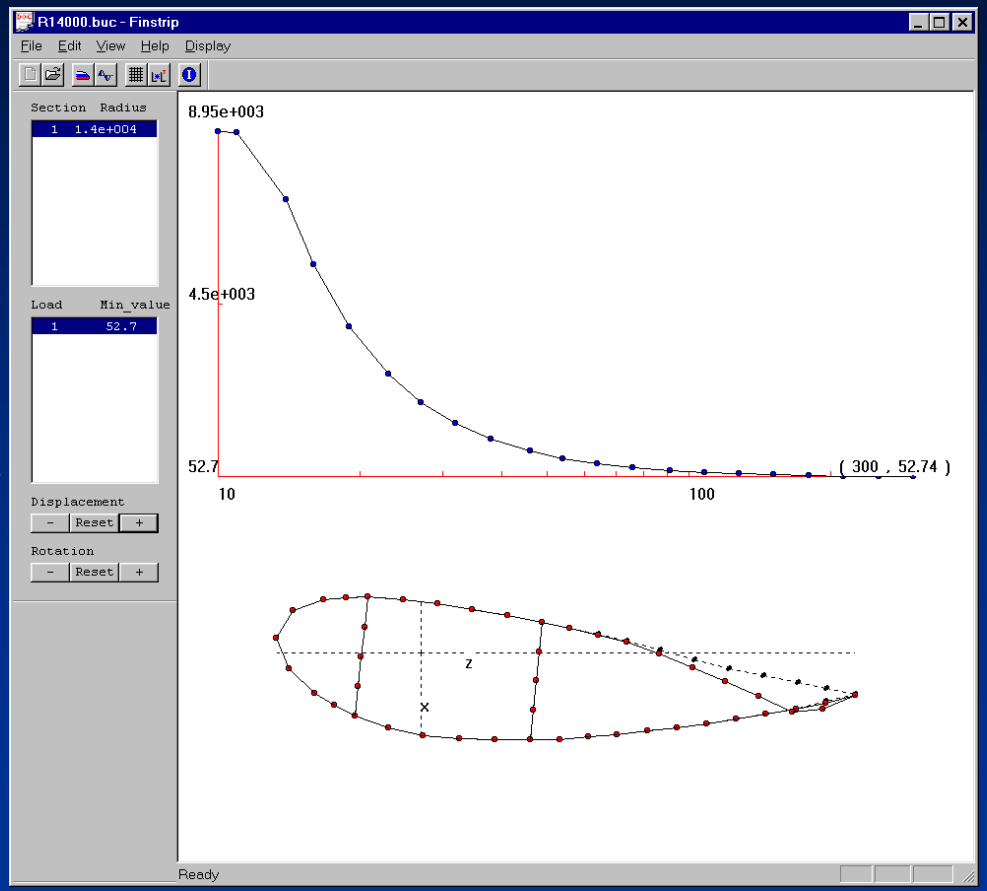
LOC. PR. COORD. FATIGUE RESULTS

NR	X1	Y1	K	1 K	D
-100	-54	1034	42	75	0.00
-60	115	387	48	75	0.00
-60	115	387	178	275	0.00
-40	163	62	264	275	0.59
-30	173	-100	286	275	1.60
-7.5	94	-466	48	75	0.00
-7.5	94	-466	181	275	0.00
+0	-33	-590	23	75	0.00
+7.5	-138	-469	55	75	0.02
+7.5	-138	-469	159	275	0.00
+30	-154	-104	180	275	0.00
+40	-146	58	175	275	0.00
+60	-118	384	55	75	0.01
+60	-118	384	157	275	0.00

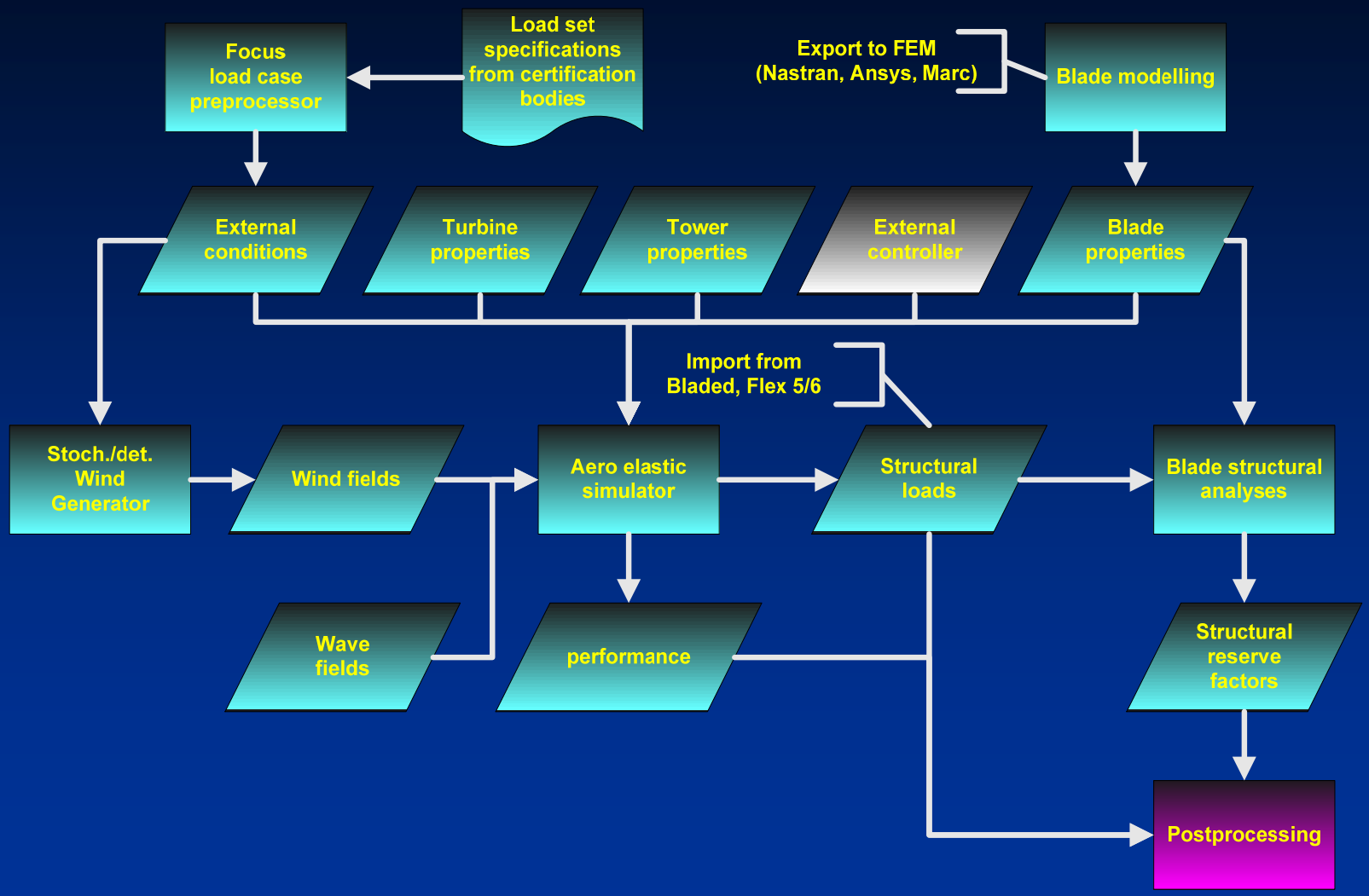
Blade Buckling/FINSTRIP

Cross section based buckling analyses





Post Processing



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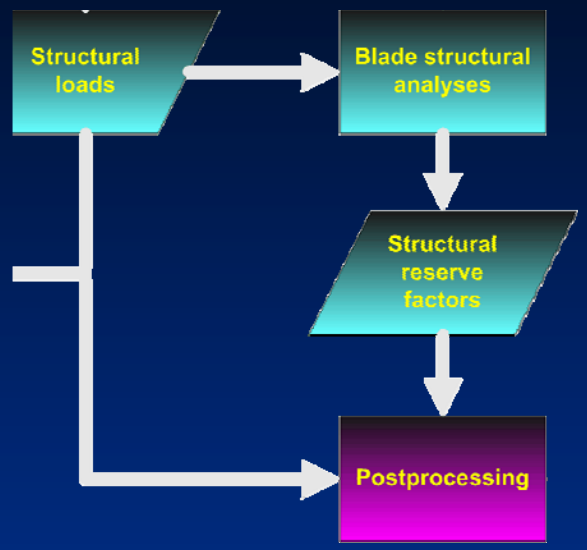
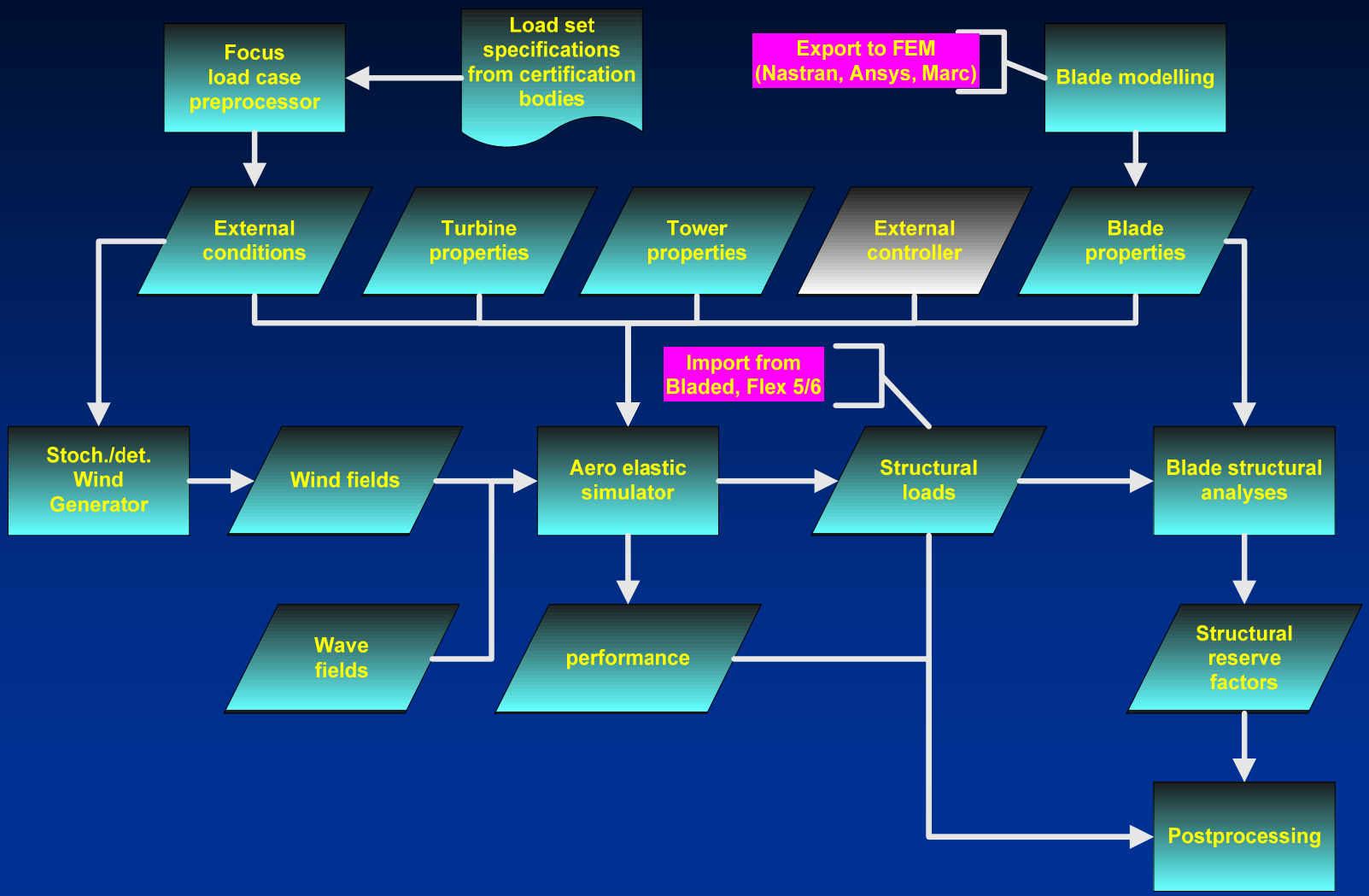
Post-processing features



- *Plot the structural data of the blade*
- *Plot load-time sequences, load spectra and spectral density plots*
- *Plot the PHATAS simulation variables*
- *Plot stress-spectra*
- *View the FAROB model with the 3D-Viewer*

External links



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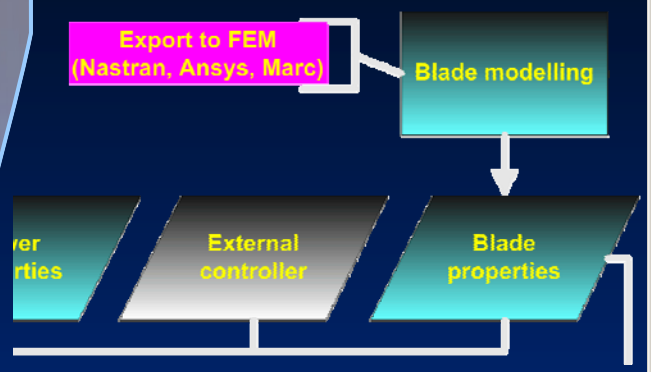
Wind turbine Materials and Constructions

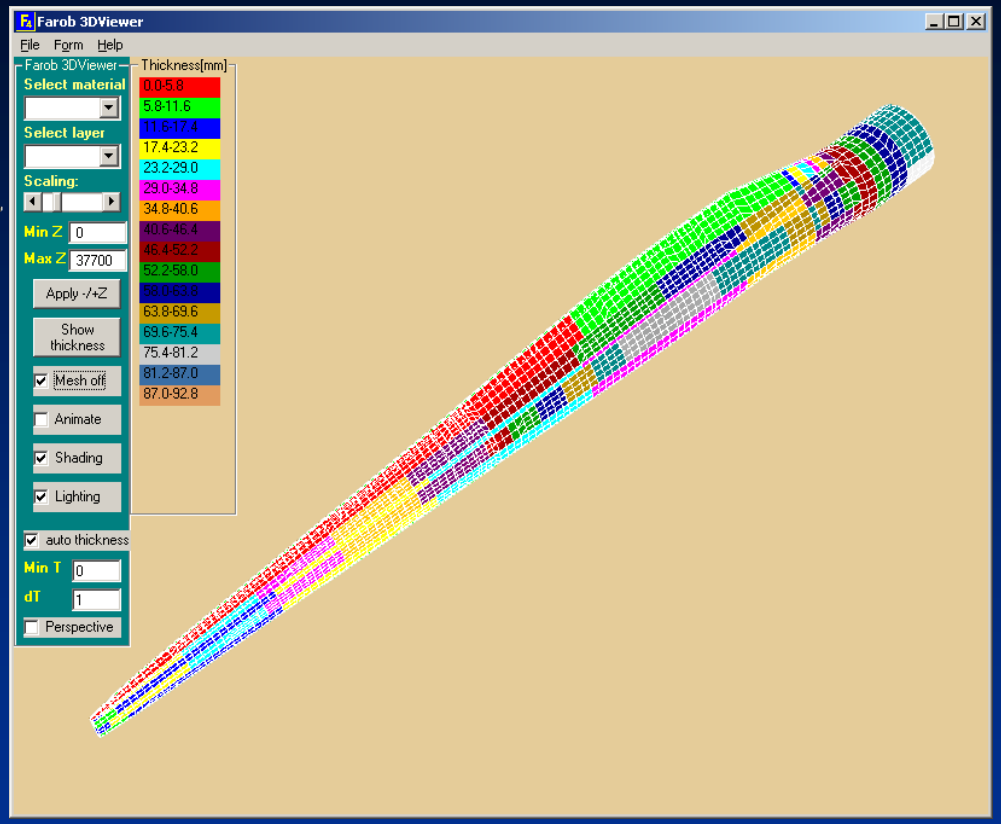
External links

- *FOCUS Load file format is standardized and made public for external program use.*
- *Load files can be exported to ASCII*
- *Load file import from Flex5/6 and Bladed*
- *FOCUS can convert the blade model into FE mesh*

MSC.MARC MSC.Nastran ANSYS

Focus generated FE mesh



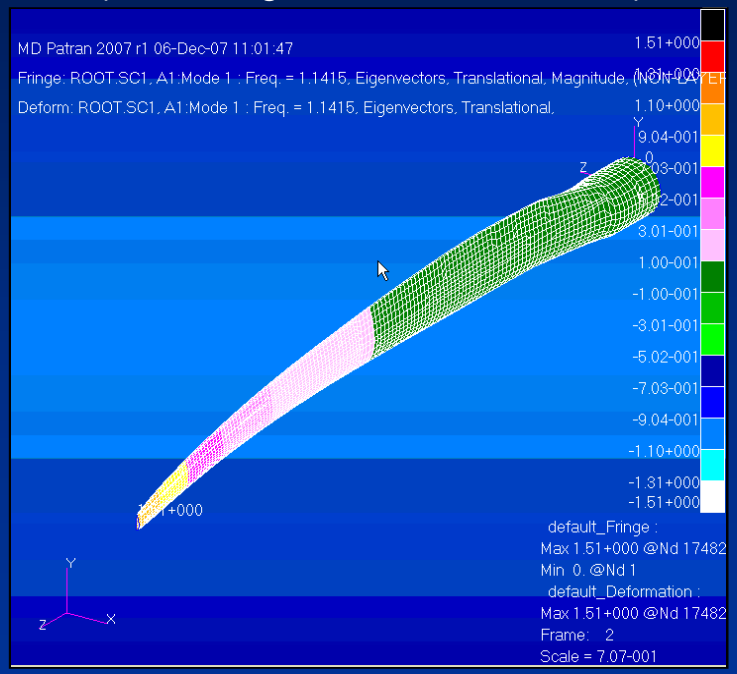


- MSC.MARC, MSC.Nastran and ANSYS
- Thick shell elements
  - Geometry
  - Materials
  - Full ply lay-up

Sample Nastran analyses

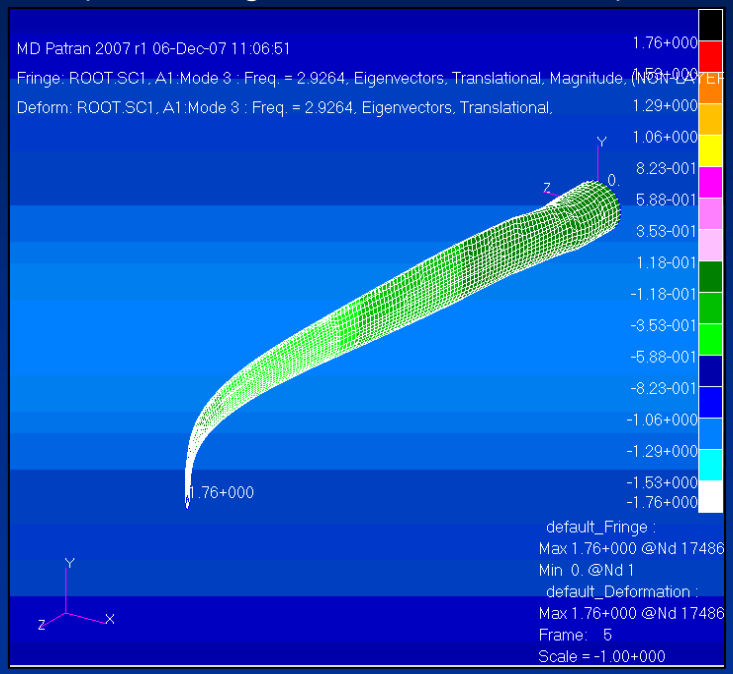
Nastran modal analyses with Focus generated FE mesh

(Click image below to start video)



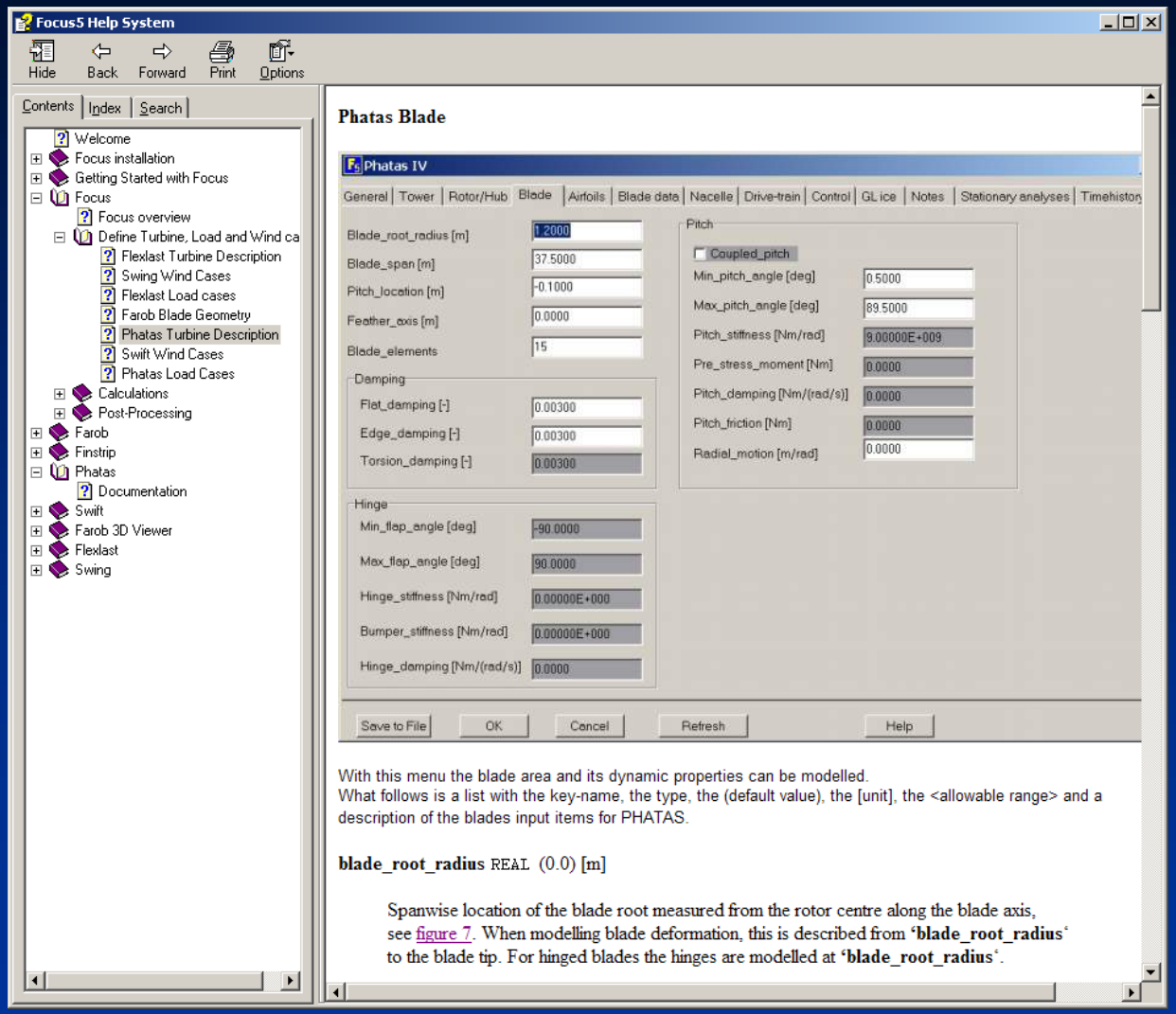
First flap mode

(Click image below to start video)

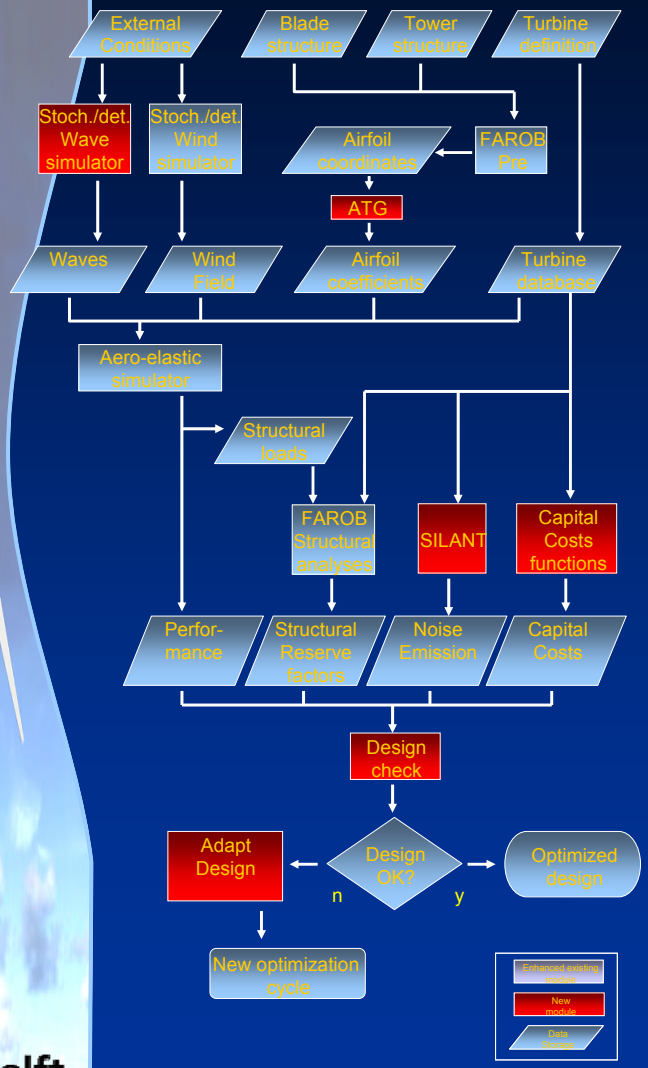


Second flap mode

FOCUS GUI Help system



New developments FOCUS6/INNWIND



- ***2004-2011: SenterNovem projects***
- ***New user interface with a database back-end***
- ***Linear and non-linear wave generator for offshore***
- ***Aerodynamics table generator***
- ***Internal finite element solver for rotor blade calculations***
- ***Generic cost module for capital turbine costs***
- ***Turbine optimization tool***
- ***SILANT, turbine noise emission tool***
- ***Structural analyses support structures (offshore applications)***
- ***Improvement of the PHATAS tower model PHATAS***
- ***Option to perform load set calculations on a grid of computers to reduce turnaround time significantly.***

Thanks!