Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

TÜBİTAK (The Scientific and Technological Research Council of Turkey)
Project 107M103

Prof. Dr. Yavuz YAMAN
Prof. Dr. Serkan ÖZGEN
Assist. Prof. Dr. Melin ŞAHİN
Assist. Prof. Dr. Güçlü SEBER
Mr. Evren SAKARYA (MSc.)
Mr. Levent ÜNLÜSOY (MSc.)
Mr. E. Tolga İNSUYU (MSc.)

Department of Aerospace Engineering
Middle East Technical University

Starting Date: 01.10.2007, End Date: 31.03.2011

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

.The air vehicle was indigeneously designed in

METU, Aerospace Engineering Department

.The structural modelling and analysis were conducted by MSC®PATRAN/ NASTRAN Package programs.

.The aerodynamic analysis was conducted by ANSYS®/FLUENT Package program.

.The aeroelastic analysis was conducted by MSC®PATRAN/ FLDS Package programs.

.The Ground Vibration Tests of the wing was conducted in METU Aerospace Engineering for the verification of the design.

.The production of the Unmanned Aerial Vehicle was done by Turkish Aerospace Industries, TAI.

.The flight tests of the Unmanned Aerial Vehicle were conducted by TAI.

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

- Low speed, non-aerobatic airplane with a conventional configuration:
  - Rectangular, mid aspect ratio high wing,
  - Circular fuselage,
  - Conventional tail attached to the fuselage with a boom,
  - Conventional elevator and rudder, deflectable ailerons and flaps
  - Tricycle landing gear,
  - Metal structure, composite skin.
  - 6.5 hp gasoline engine.

Initial Design Specifications

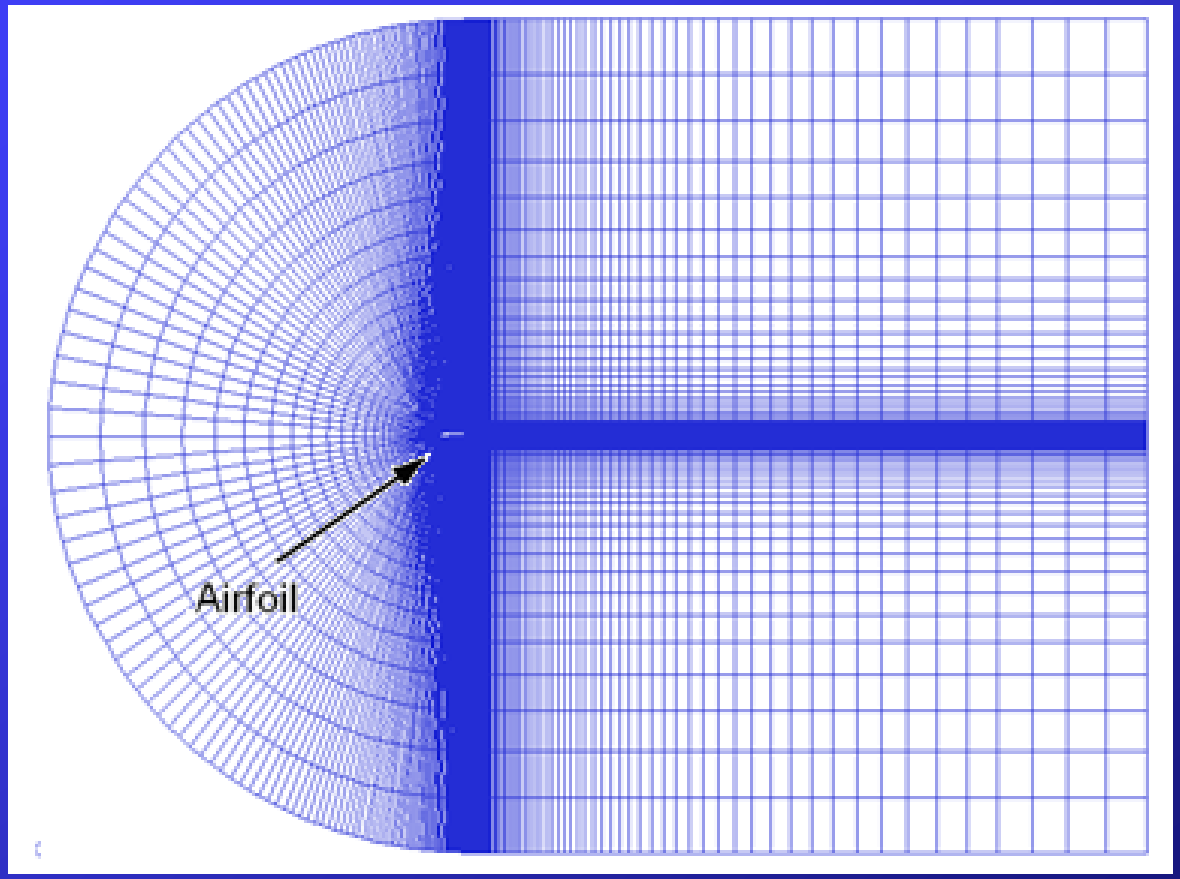
Specifications	Value
Take-off gross weight	37.8 kg
Empty weight	36.3 kg
Fuel weight	1.5 kg
Wing span	3 m
Wing chord	0.5 m
Total length (excluding propeller hub)	2 m
Height	1.0 m
Horizontal tail volume ratio	0.37

Performance Specifications

Specifications	Value
Maximum speed	**75 knots**
Cruise speed (@ 4000 ft)	**60 knots**
Stall speed	**40 knots**
Service ceiling	**5000 ft**
Endurance (@ 4000 ft)	**3 h**

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

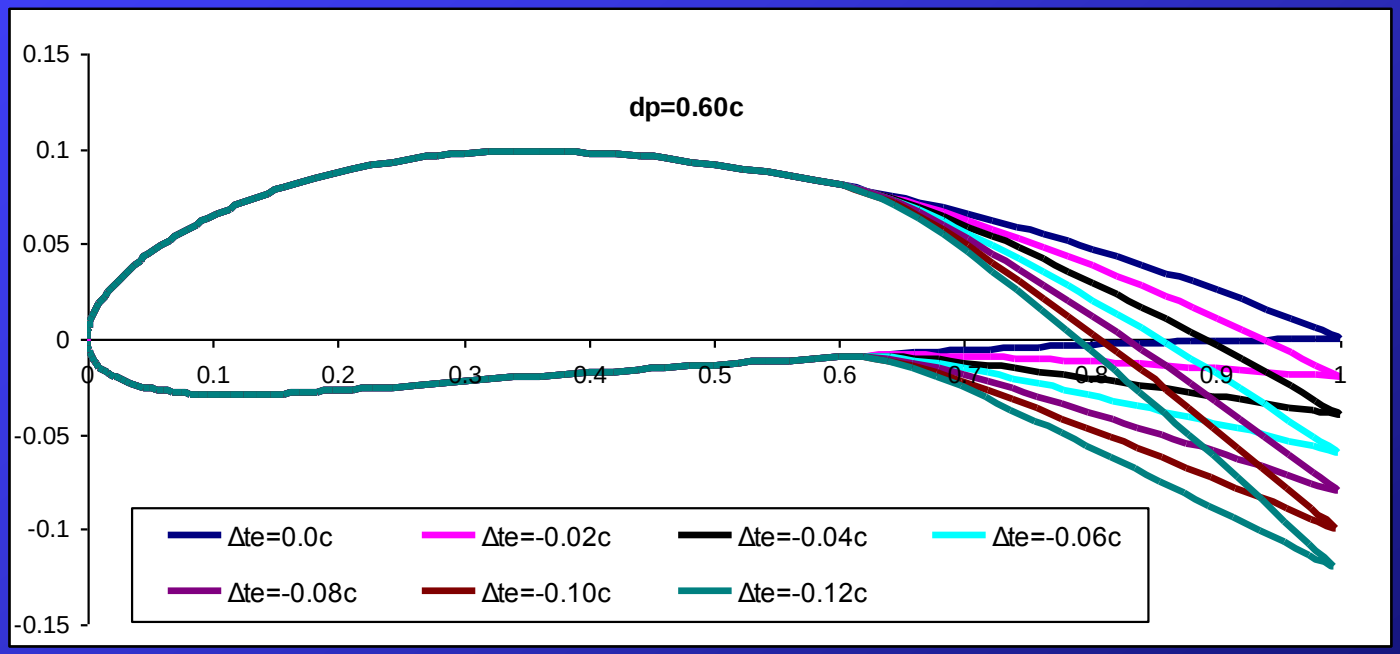
Aerodynamic Analysis



2D Analysis, NACA 4412 Airfoil and the Solution Domain

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Aerodynamic Analysis



2D Analysis, Cambered NACA4412 Airfoils, deflection from 0.6c

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

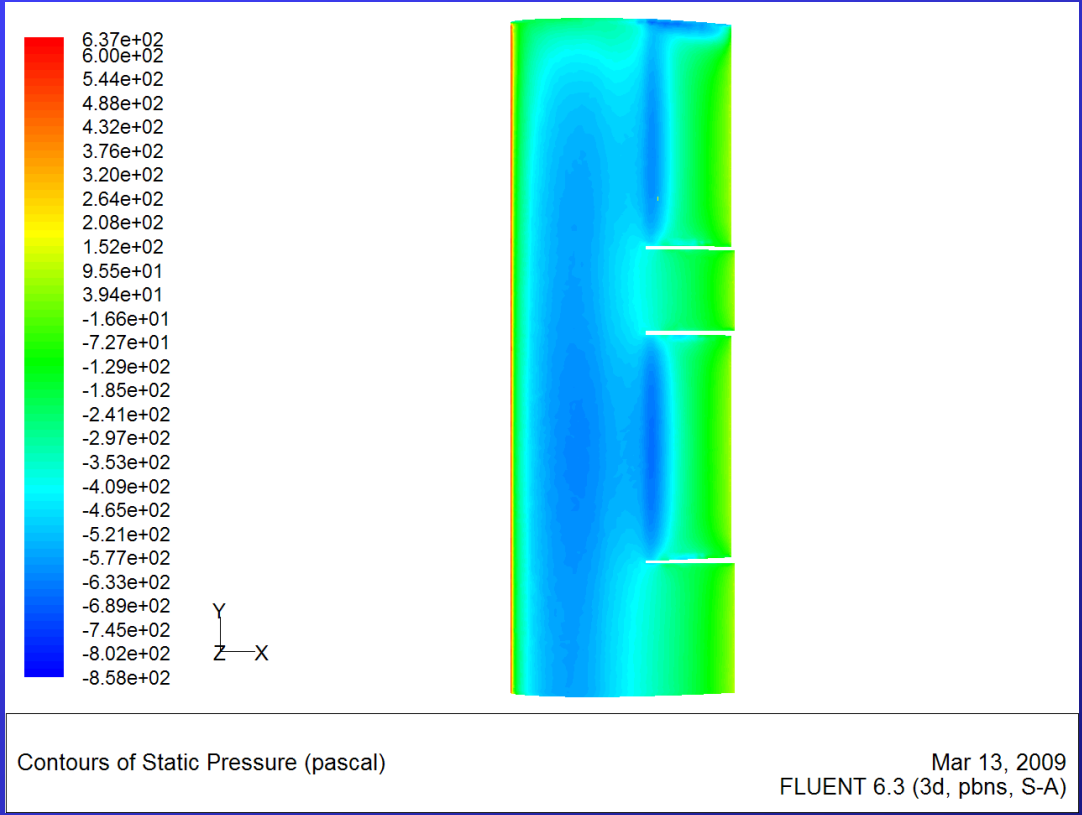
Aerodynamic Analysis

Δte	0.0c	-0.02c	-0.04c	-0.06c	-0.08c	-0.10c	-0.12c
C_l	0.4502	0.6904	0.9193	1.1344	1.3050	1.5574	1.6922
C_l [Raymer]	0.4000	0.6652	0.920	1.1696	1.4244	1.6688	1.9184
C_d	0.0111	0.0124	0.0142	0.0169	0.0210	0.0578	0.0714
C_m	0.2133	0.3039	0.3941	0.4813	0.5520	0.6798	0.7426
C_l / C_d	40.7201	55.6774	64.7394	67.1243	62.1429	26.9446	23.7009

2D Analysis, Calculated Aerodynamic Coefficients for Camber deflection from 0.6c

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

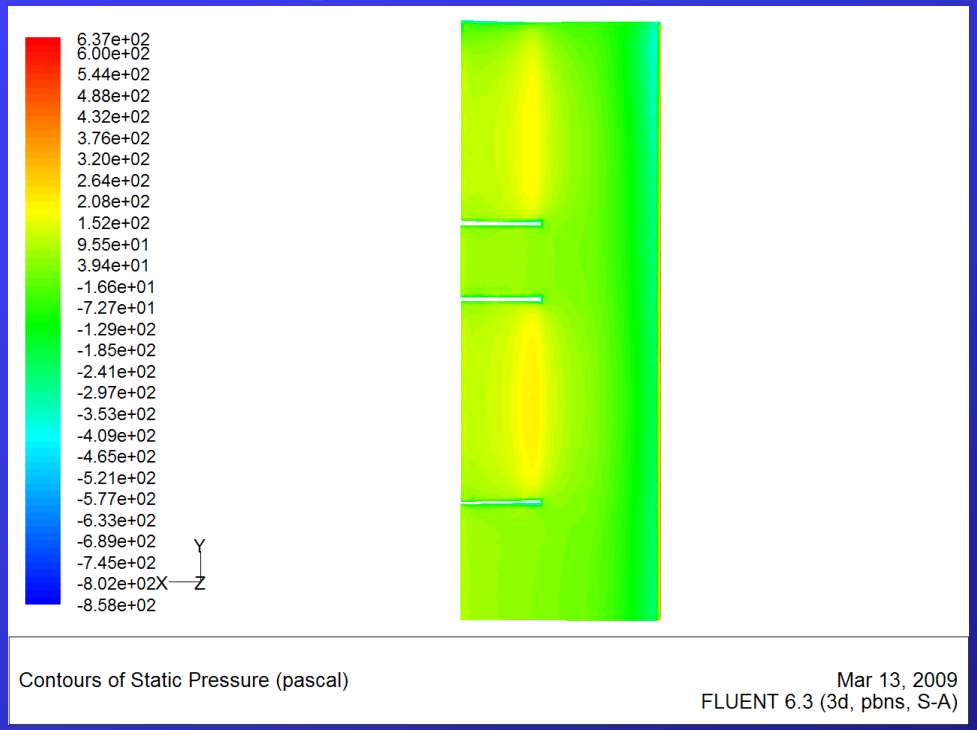
Aerodynamic Analysis



3D Analysis, Upper Surface Static Pressure Contours, deflection from 0.6c

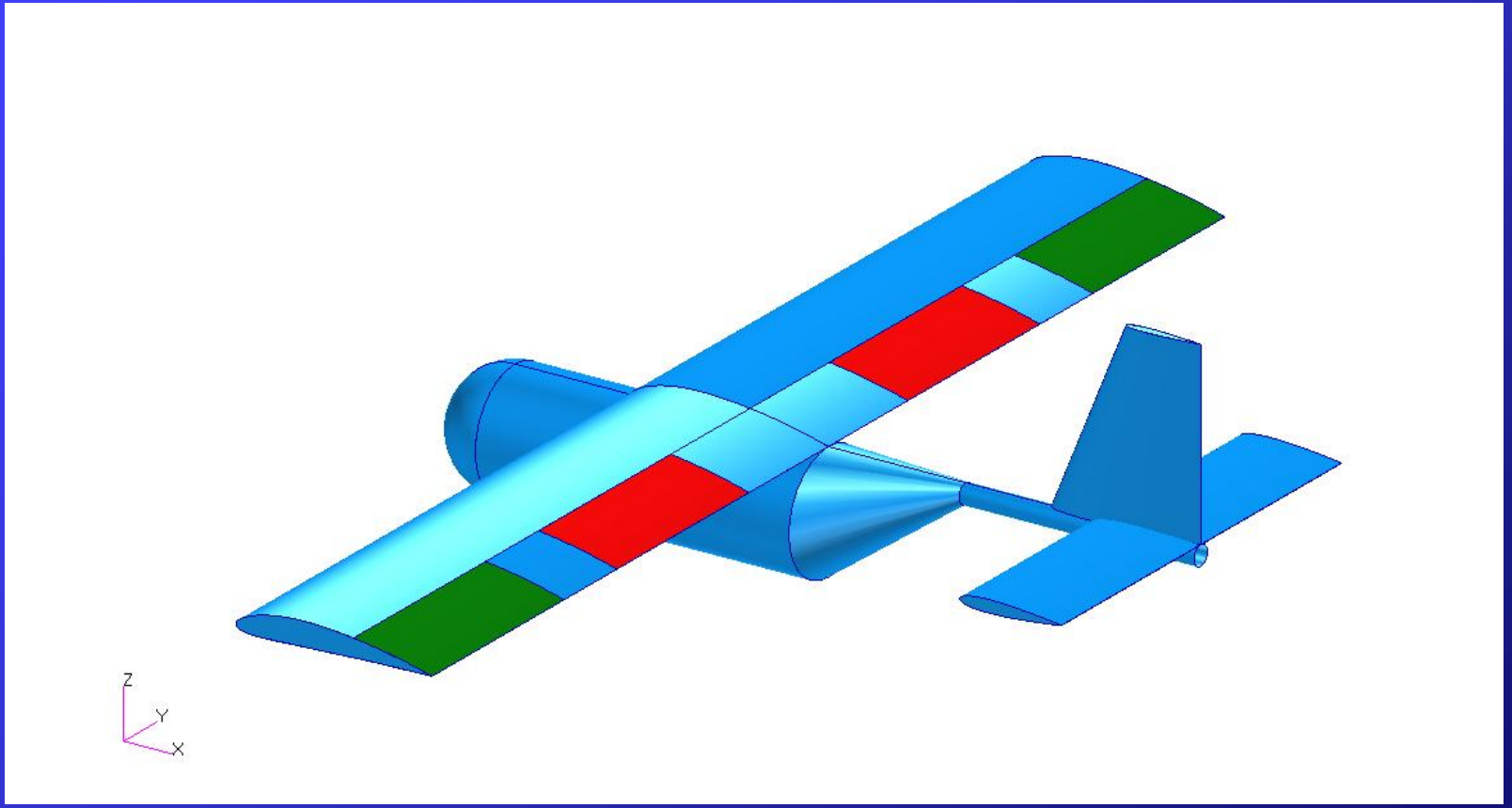
Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Aerodynamic Analysis



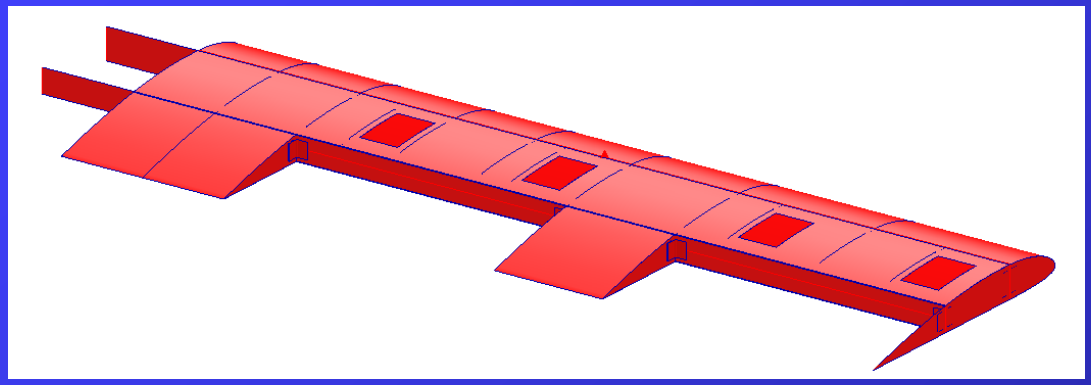
3D Analysis, Lower Surface Static Pressure Contours, deflection from 0.6c

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

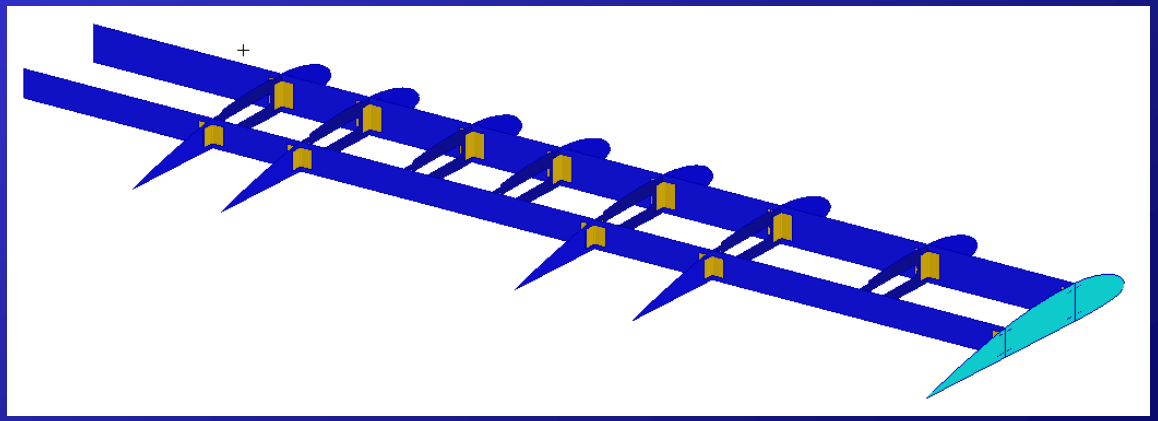


Tactical Unmanned Aerial Vehicle (TUAV)

Structural Models



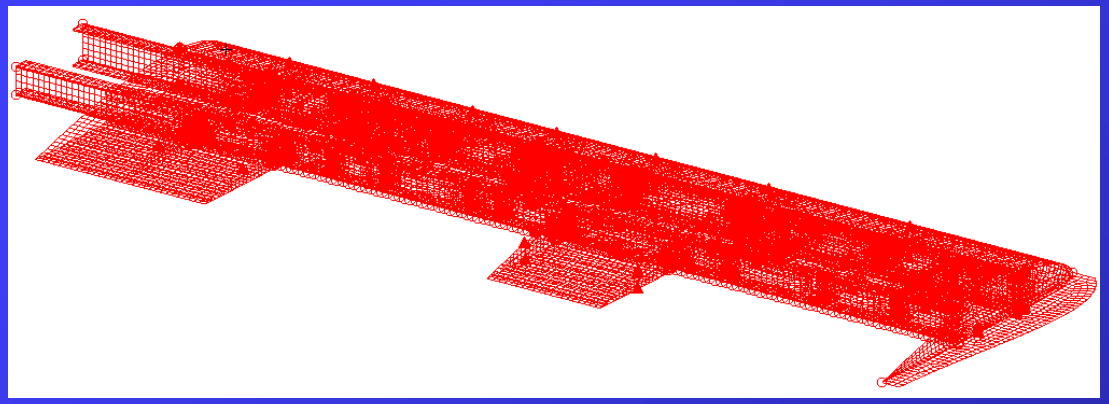
Isometric view of the external geometry of the right wing



Isometric view of the internal structure of the right wing

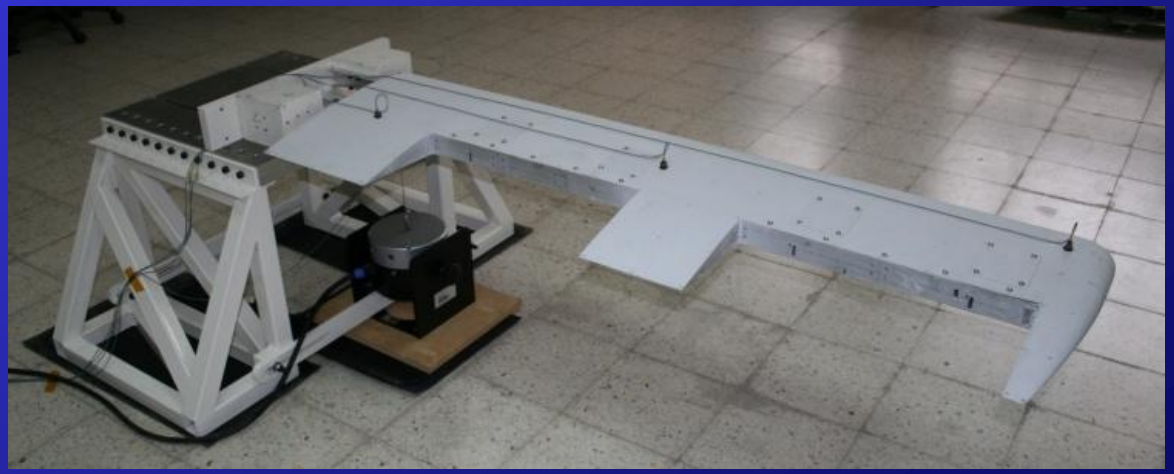
Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Structural Models



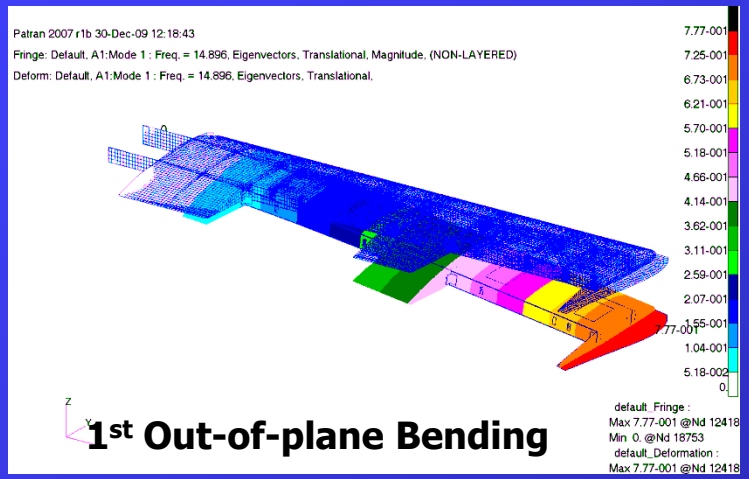
Generated mesh for the finite element analysis

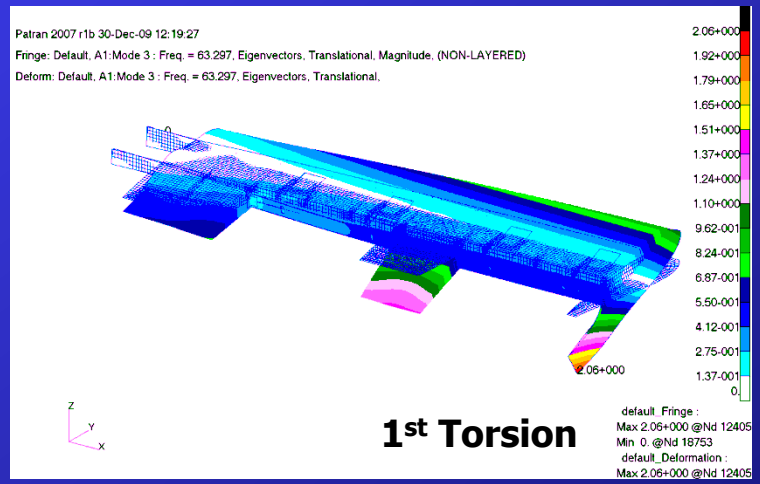
Ground vibration tests of the wing

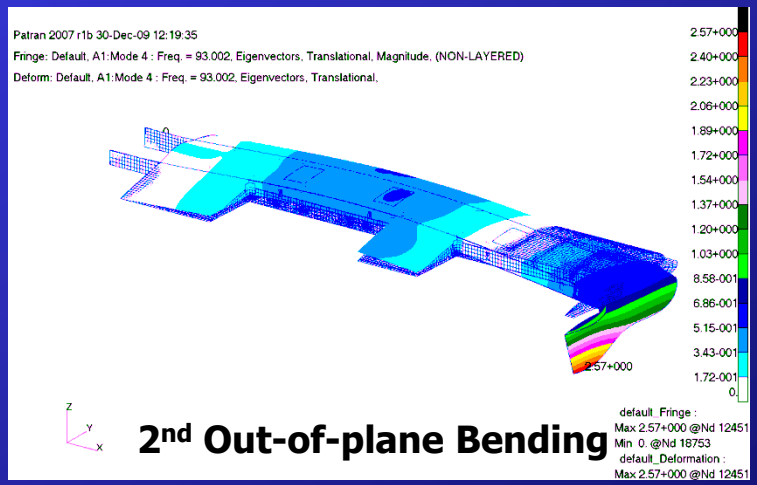


Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

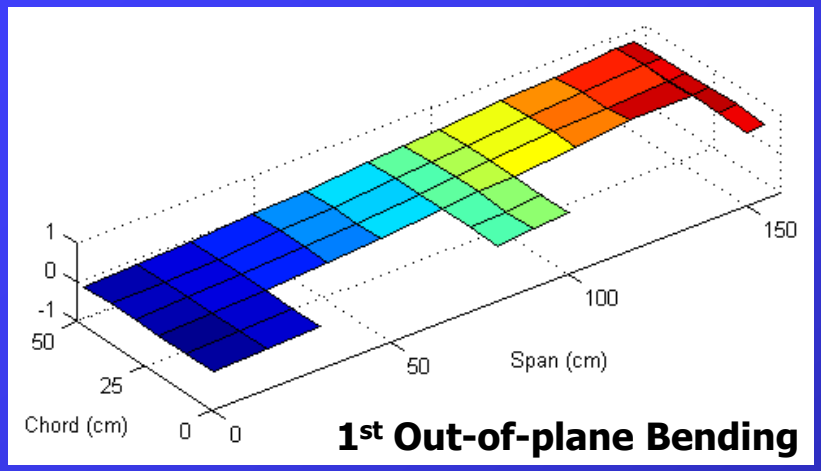
Finite Element Analysis: Mode Shapes



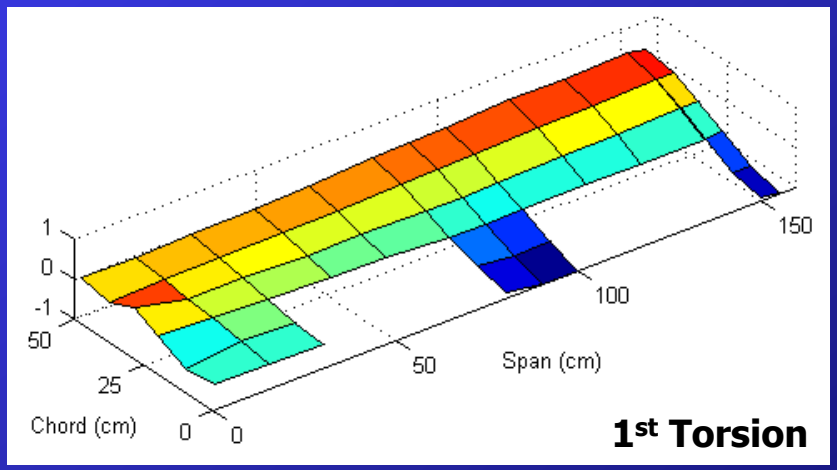




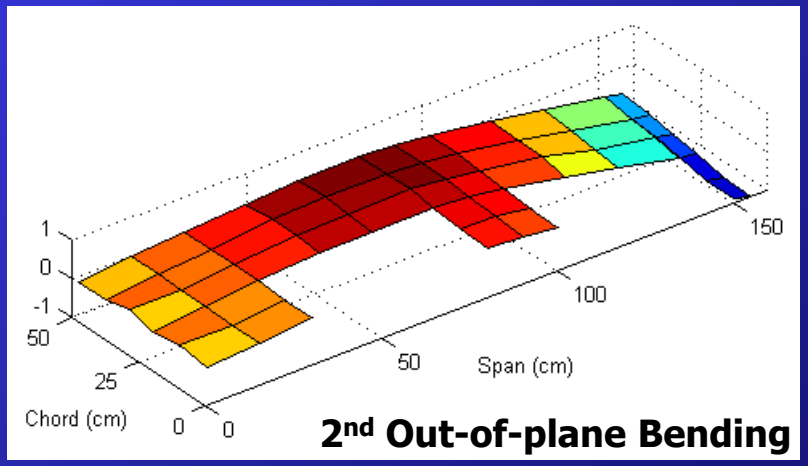
Experimental Modal Testing: Mode Shapes



1st Out-of-plane Bending



1st Torsion



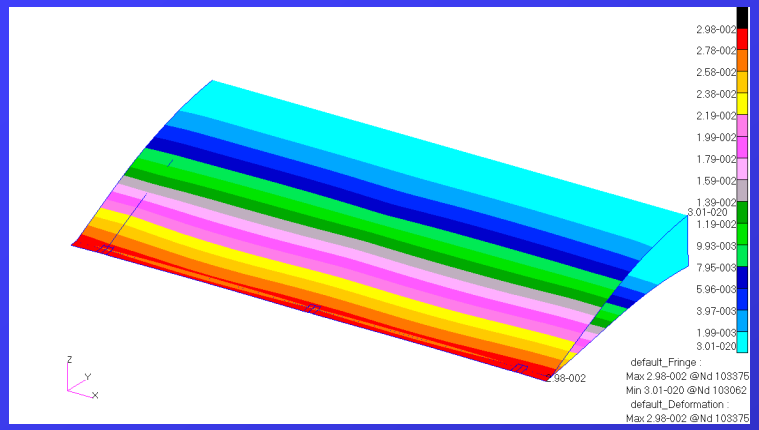
2nd Out-of-plane Bending

Comparison of Resonance Frequencies

Mode Shape	FEA Frequency [Hz]	Experimental Frequency [Hz]	Percentage Difference wrt Experimental Value
1. Out-of-plane bending	14.90	14.75	~ 1.02
1. Torsion	63.30	66.75	~ - 5.17
2. Out-of-plane bending	93.00	93.00	~ 0.00

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Unconventional Control Surface: Camber Change Case

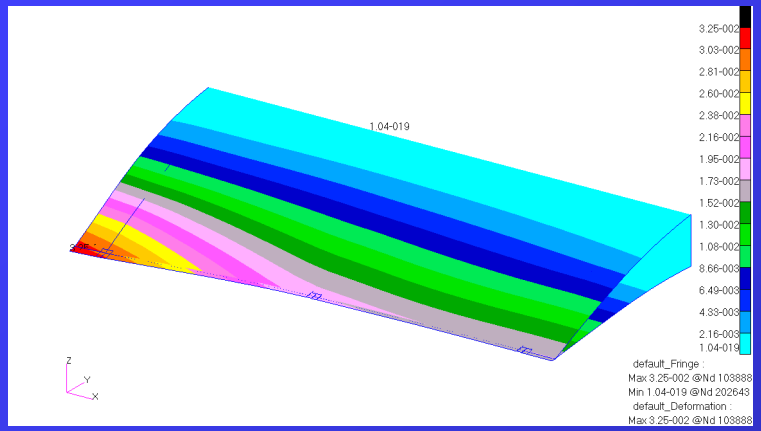


Finite element analysis

Testing

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Unconventional Control Surface: Twist Change Case

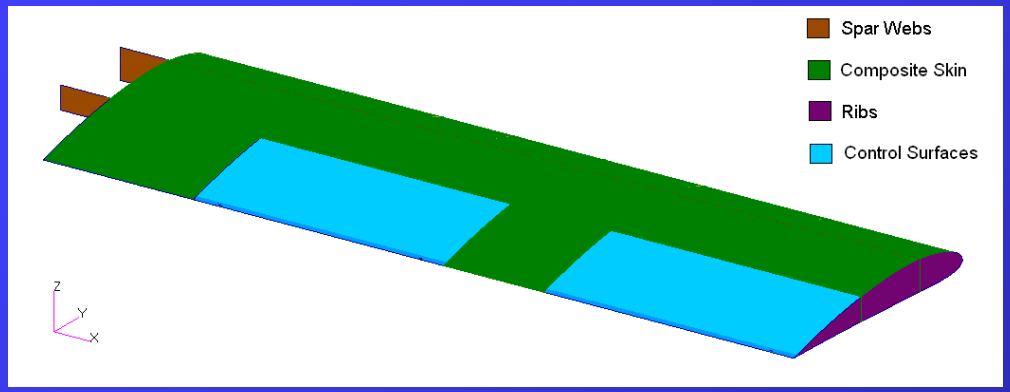


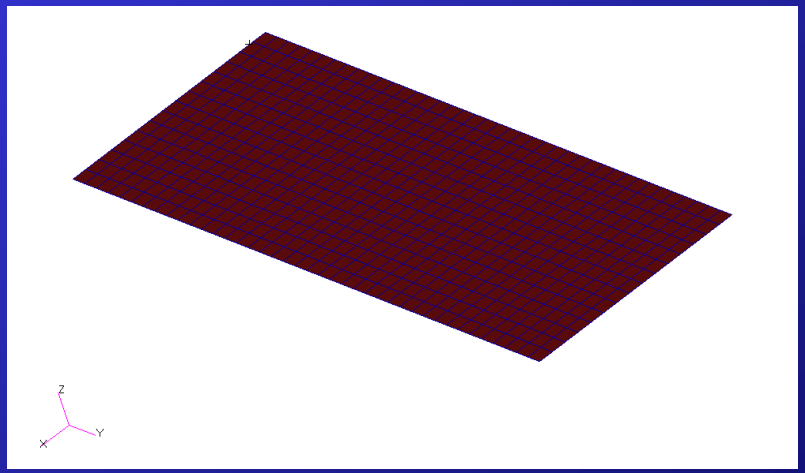
Finite element analysis

Testing

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

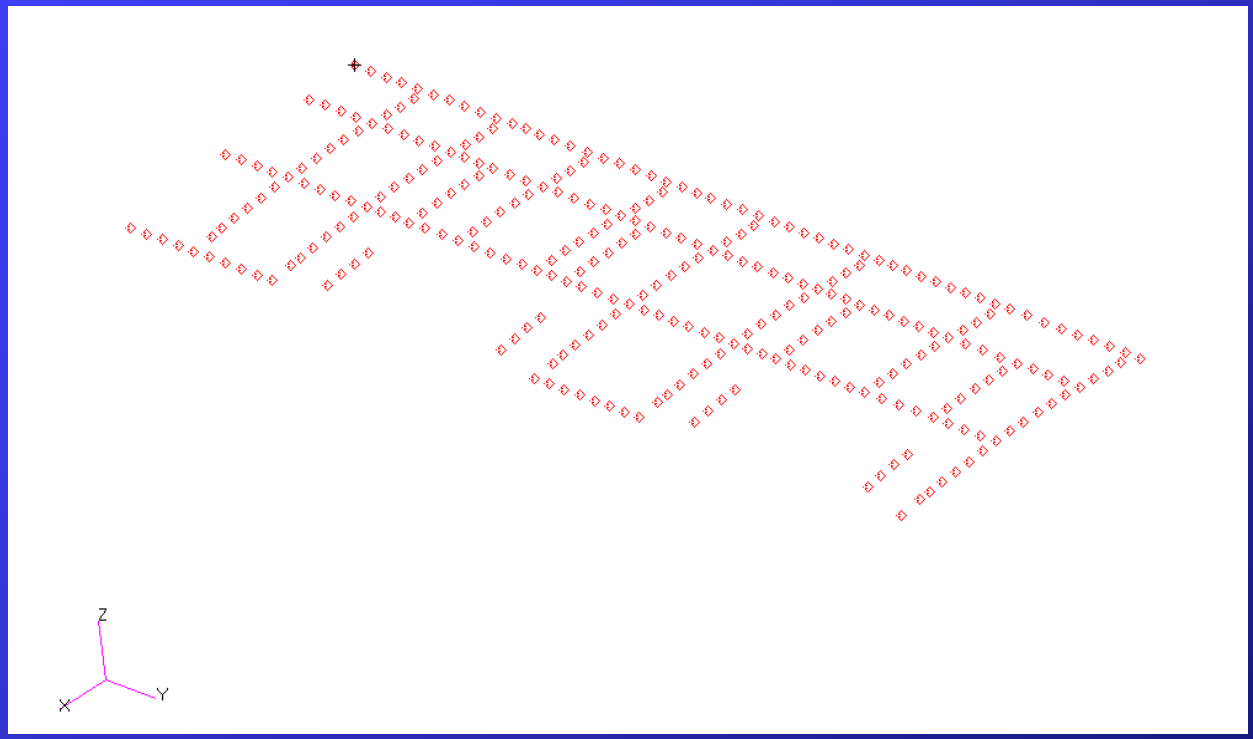
Aeroelastic Analysis





Aeroelastic Model and the Lifting Surface Used in the Aeroelastic Analyses

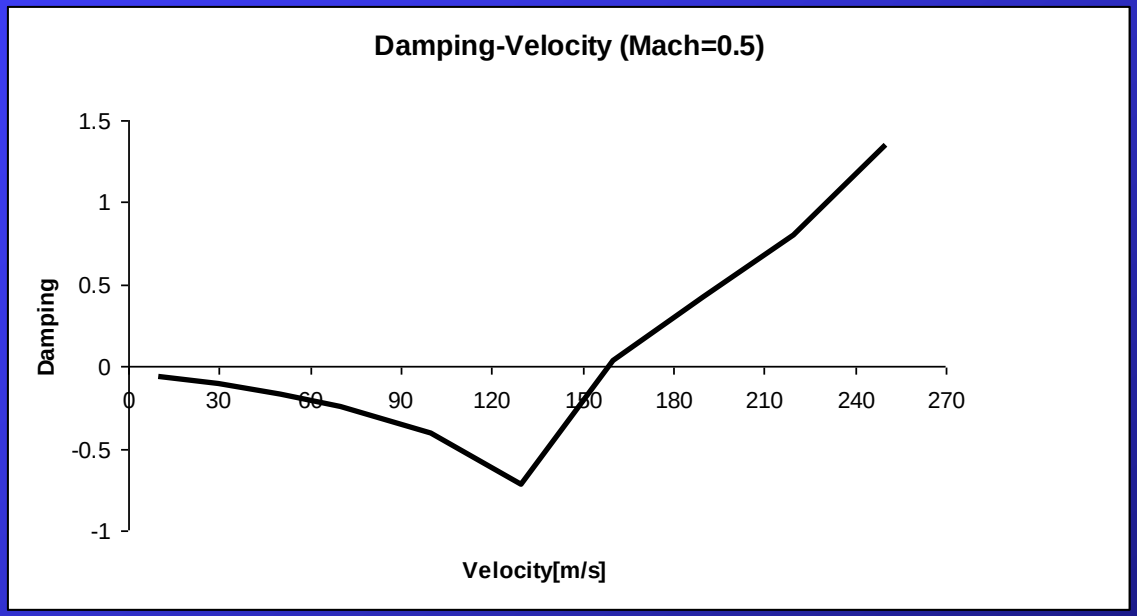
Aeroelastic Analysis



Grid Points Used to Generate Splines for Aeroelastic Analysis

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Aeroelastic Analysis



Possibility of flutter around 160 m/s,

outside the operational range,

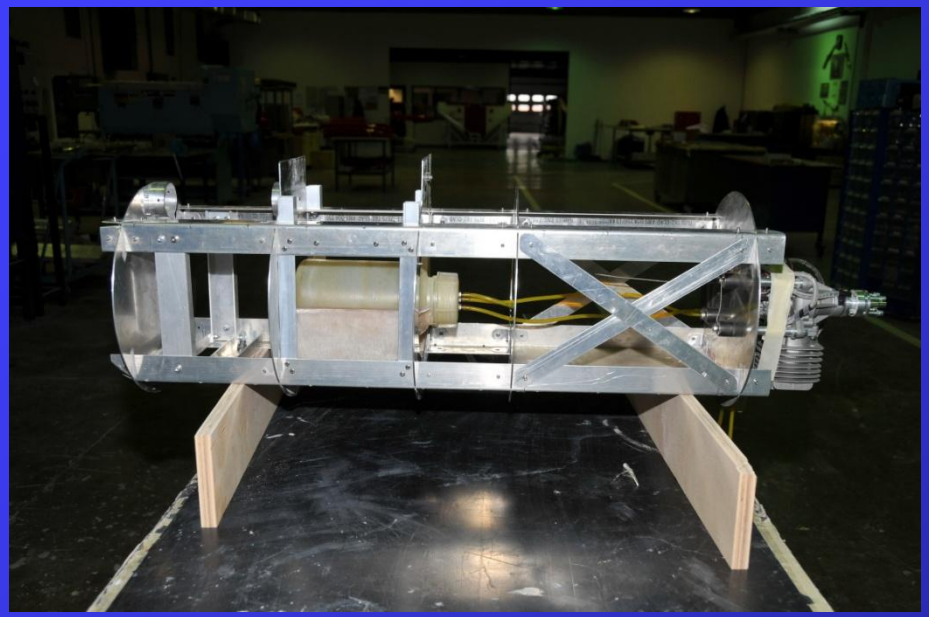
SAFE !!

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Production Stages

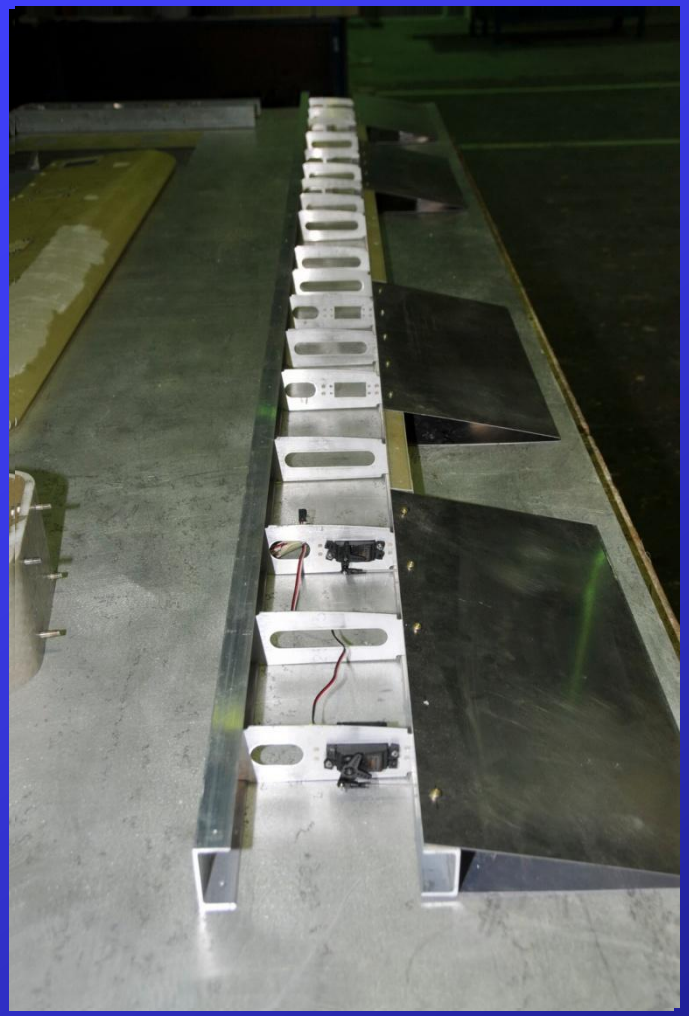
Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Production Stages



Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Production Stages



Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Production Stages

Production Stages

08 March 2010

Flight Tests

17 March 2010

Aircraft

Taxi Test

Flight Tests

17 March 2010

Thanks for their efforts

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Flight Tests

05 May 2010

Taxi and Jump Tests

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Flight Tests

05 May 2010

Taxi and Jump Tests

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Flight Tests

05 May 2010

Thanks for their efforts

Flight Tests

26 May 2010

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Flight Tests

26 May 2010

Thanks for their efforts

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Flight Tests

03 February 2011

Flight Tests

03 February 2011

Unmanned Aerial Vehicle with Overwing Camera

Flight Tests

03 February 2011

Flight from Overwing Camera

Flight Tests

03 February 2011

Flight from Overwing Camera

Flight Tests

03 February 2011

Flight from Overwing Camera

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Flight Tests

03 February 2011

Thanks for their efforts

Aeroservoelastic Analysis of the Effects of Camber and Twist on Tactical UAV Mission-adaptive Wings

Published Work

- MSc. Theses:

✓ "Aero-Structural Design And Analysis of an Unmanned Aerial Vehicle and its Mission Adaptive Wing" by E. Tolga İnsuyu – METU – 2010.

✓ "Structural Design And Analysis of The Mission Adaptive Wings of an Unmanned Aerial Vehicle" by Levent Ünlüsoy – METU – 2010.

✓ "Structural Design And Evaluation of an Adaptive Camber Wing" by Evren Sakarya – METU – 2010.

- International Journal Articles: 1
- International Conference Papers: 3
- National Conference Papers: 8

Contact Details:

Prof. Dr. Yavuz YAMAN
http://ae.metu.edu.tr/~yyaman/
yyaman@metu.edu.tr

Assist. Prof. Dr. Melin ŞAHİN
http://ae.metu.edu.tr/~melin/
msahin@metu.edu.tr

Prof. Dr. Serkan ÖZGEN
sozgen@ae.metu.edu.tr

Assist. Prof. Dr. Güçlü SEBER
gseber@ae.metu.edu.tr

Department of Aerospace Engineering
Middle East Technical University
06800, Ankara – TURKEY