AIRBUS DEFENCE & SPACE AWACS PROTOTYPES: AWACS-DOME AEROELASTIC AND DYNAMIC LOADS CHALLENGES

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Abstract: This paper summarizes the aeroelastic activities performed by AIRBUS Defence & Space (AIRBUS-DS) for the preliminary design of the A330-AWACS (Airborne Warning and Control System), which is based on the AIRBUS A330-200 platform that is modified to include a dome-type radar on top of the fuselage. The A330-AWACS general design concept is detailed with emphasis on those features that impact on the Aeroelasticity or the Dynamic Loads of the basic aircraft. Flutter of the dome-struts structure is analyzed in three configurations: isolated clamped-to-floor, isolated clamped-to-fuselage, and dome-struts installed in the A330-200 (complete aircraft simulations). Ground and flight dynamic loads scenarios used for the preliminary design are also detailed. Improvements on both static and dynamic aeroelastic calculations by using CFD computations are briefly described. Finally, further developments and tasks are enumerated.

1 INTRODUCTION

Airbus Derivatives is a business line of AIRBUS-DS that is specialized in the conversion of existing AIRBUS aircrafts for including new capabilities: in-flight refueling, VIP, medical evacuation, and surveillance and control with a dome-struts system, the objective of this paper.

The installation of the dome-struts structure in the green aircraft presents different challenges:

- perform an optimum design to minimize the structural modifications
- reduce the penalty on aircraft handling qualities and performance
- adequate the total electric power to the AWACS mission and, of course,
- fulfil the Airworthiness Regulations concerning loads and aeroelastic instabilities.

This paper describes the most relevant preliminary analyses performed during the risk mitigation phase of the A330-AWACS. One of the main objectives of this mitigation phase was to detect as soon as possible any no-go condition for the design from the aeroelastic and dynamic loads standpoint. The inertia effect of the dome on the low-frequency A330 aircraft normal modes and the possible aerodynamic interference of the dome-struts with the aircraft aerodynamics were initially the main uncertainties.

AIRBUS-DS has previous experience on this type of major modifications because of the transformation of the C295 twin-engine turbo-propeller aircraft for including Airborne Early Warning (AEW) capabilities (C295-AEW). Lessons learned have been applied to the A330-AWACS design procedure. Next section shows the main activities carried out during the C295 AEW design.

2 DOME-INSTALLATION DEVELOPMENT PHASES: C295 AEW & A330-AWACS

Both C295-AEW and A330-AWACS are based on installing a dome-type radar on top of fuselages that were not initially designed to withstand the dome-struts heavy structure. In addition, the installation of the dome does modify the aerodynamics, handling qualities, and performance of the basic aircraft. AIRBUS-DS has successfully designed, manufactured, and tested (ground and flight) the C295-AEW (Figure 1). This version of the propeller-driven C295 aircraft was in fact developed in a record time of 1 year by completing the following activities:

1. Design stage, including risk mitigation, preliminary, and detailed design.
2. Aerodynamic analyses, including Wind Tunnel Tests for characterizing the flow and assessing the CFD calculations.
3. Ground tests, including a tap test to characterize the dome normal modes (Figure 1).
4. Flight tests, including the flight envelope expansion campaign (Figure 2).

Component	Mass [Kg]
Rotodome	956
RH Strut	129.5
LH Strut	129.5
Total mass	1215

Figure 1: Images of the C295-AEW tap ground test to characterize the Dome normal modes

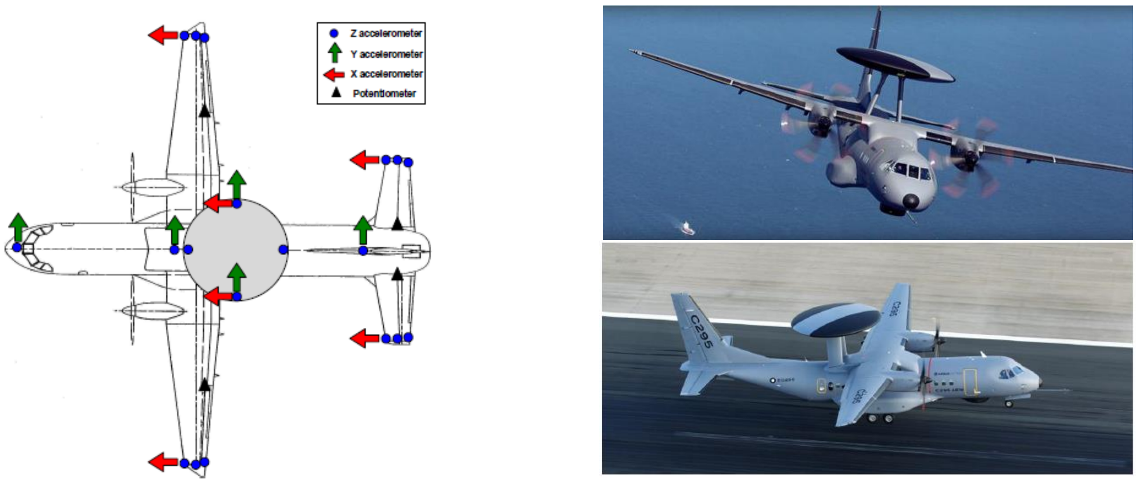


Figure 2: Left: Accelerometers installed in the C295-AEW for the flight vibration tests. Right: Images of the C295-AEW taken during the flight test campaign

The A330-AWACS design will take benefit of the lessons learned during the C295-AEW development, although the AWACS exhibits per se particular features that make it a challenging project from the aeroelastic standpoint: the weight of the dome is substantially larger than the one installed in the C295-AEW, the A330-200 fuselage normal modes frequencies could couple with dome-struts normal modes, and the aircraft EFCS shall be revisited to check possible aeroservoelastic instabilities. Nowadays AIRBUS-DS is fully involved in the A330-AWACS preliminary design and the risk mitigation activities that will be described in the next sections.

3 A330-AWACS GENERAL ARRANGEMENT

Figure 3 shows different aircrafts that are currently flying as AEW or AWACS. The A330-AWACS is intended to cover the large cargo segment and to perform not only the classical AWACS operation but also to be used as a multi-role platform with logistic, transport, or medevac support. The experience with previous AIRBUS Derivatives based on the A330-200 platform is crucial to offer these capabilities apart from the AWACS function.

Northrop Grumman E-2 Hawkeye
(Grumman / Northrop Grumman)
1960-[today]
(Egypt, France, Japan, Mexico, Taiwan, and USA Air Forces)

Boeing E3 Sentry
1977-[today]:
(production ended 1992)
(USA, NATO, RAF, and RSAF Air Forces)

Boeing E-767 AWACS
1994-[today]
(Japan Air Force)

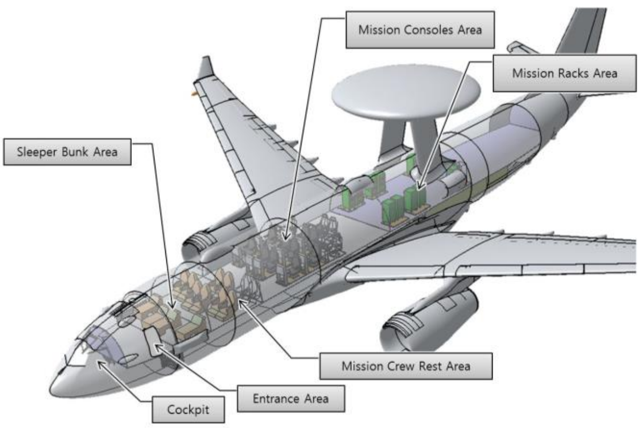
EMB-145 AEW&C
1999-[today]
(Air Forces of Brasil, Greece, and Mexico)

SAAB 340 AEW&C
1997-[today]
(Air Forces of Sweden, Thailand, and UAE)

Boeing 737 Wedgetail
2004-[today]
Royal Australian Air Force

Figure 3: Current aircraft fleet operating as AEW or AWACS

The A330-AWACS upper deck will accommodate the zones shown in Figure 4, i.e., cockpit, entrance area, crew rest area (also called sleeper bunk area), mission crew rest area, mission consoles area, and mission racks area. The location of the different zones is approximated.



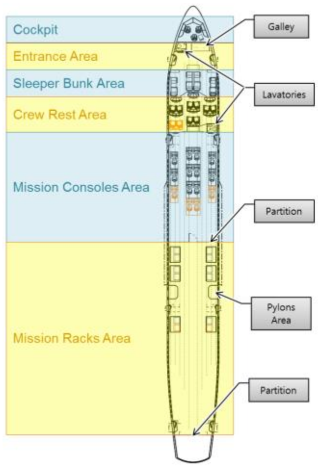


Figure 4: AWACS upper deck zones ([2])

The dome is an ellipsoidal surface with all the radar electronic devices inside, which are cooled by parallel lines inside the struts (Figure 5) supply and return coolant liquid at high flow rate.

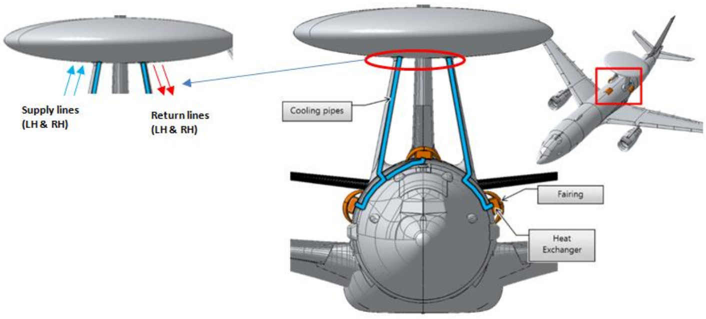


Figure 5: Liquid cooling system (LCS) interface

The A330-AWACS will be equipped with antennas and electronic support measure systems (ESM), all of them with a possible impact on mass and exterior aerodynamics that need to be assessed. Besides this, all these electronic devices will be qualified against standard vibrations, operational shocks, and emergency landing guidelines (mainly RTCA DO-160G and MIL STD 810).

Based on the previously detailed AWACS configuration, the following considerations are highlighted from the aeroelastic/dynamic loads standpoint:

- Fuselage antennas: not relevant neither for flutter or dynamic loads calculations.

- ESM antennas: these antennas could be placed at the wing using the same location as the air-to-air refueling pod of the A330-MRTT RAAF (tanker aircraft certified by AIRBUS-DS, Figure 6). Besides this, the total mass will be below the MRTT pod and the external shape of the radome will be also based on this pod. Both flutter and dynamic loads are therefore expected to be covered by the MRTT project.

- Mass variations on fuselage (specific racks, etc.) are show to have limited effect on the global A330-200 flutter behavior. However, dynamic loads shall be calculated to calculate shear force and bending moment along the fuselage.

Figure 6: A330-MRTT RAAF with the AAR pod hoses deployed

4 A330-AWACS RISK MITIGATION PHASE ACTIVITIES

The dome installation on the A330-200 will certainly impact on the structure, aerodynamics, and performance of the basic aircraft. AIRBUS-DS, in close cooperation with AIRBUS Commercial, has completed a risk mitigation phase covering disciplines as Aerodynamics, Performance, Weight and Balance, Maneuver Loads, Dynamic Loads, Aeroelasticity, and Structure (Stress Office).

The AIRBUS-DS Aerodynamic department has performed an extensive wind-tunnel test campaign together with CFD calculations (Figure 7) that have led to select the optimum shape of the struts-dome structure. The struts sweep angle, the dome shape, and the difference distances shown in Figure 8 have been selected to optimize the fluid flow around the dome-struts.

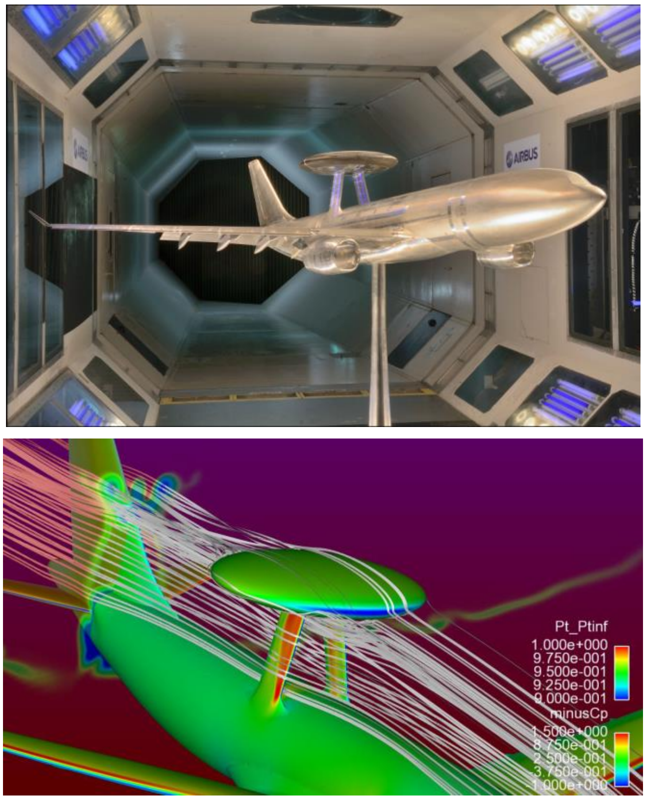


Figure 7: (Above) A330-AWACS wind-tunnel test mock up (Bottom) CFD calculations

Once the dome-struts configuration has been optimized from the aerodynamics standpoint, the AIRBUS-DS Stress Office has designed the structure that withstands preliminary loads scenarios, mainly load factors associated to emergency landing or maneuver conditions.

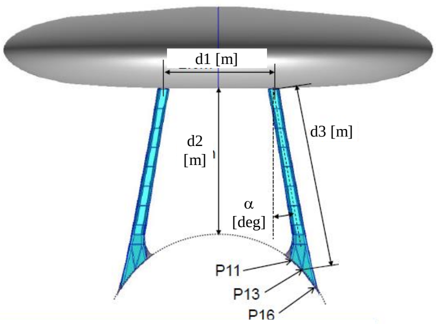


Figure 8: A330-AWACS spar-ribs internal structure

Concerning weight and balance, the A330-AWACS is targeted to maintain the same design weights and center of gravity of the basic aircraft A330-200 WV080 ([5]). For this purpose, extra ballast at the forward fuselage could be needed.

Figure 9 shows (blue trajectory) the evolution of the AWACS weight as fuel tanks (outer, inner, center, and trim tanks) are filled, starting from an the initial Operating Weight Empty (OWE).

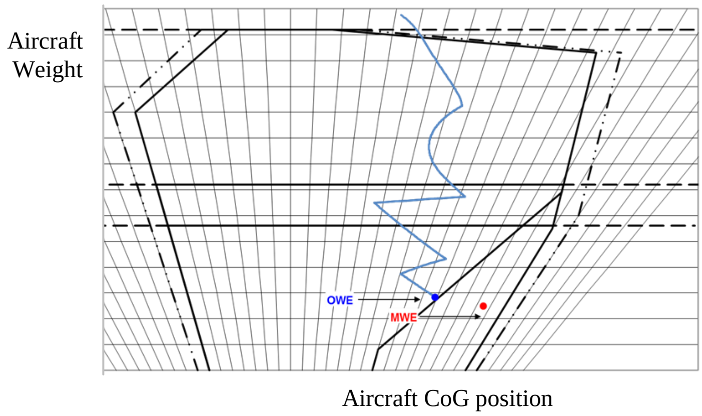


Figure 9: Aircraft weight vs. CoG position, showing the OEW and how it evolves as fuel is included.

The AIRBUS-DS Aeroelasticity and Structural Department has been involved in the project since the beginning, supplying clearance to the different dome-struts geometries and performing more extensive analyses in the final concept. Next sections detail all the flutter and dynamic loads calculations performed.

5 A330-AWACS AEROELASTIC MODEL

The A330-AWACS aeroelastic model has been built by including the dome-struts stiffness, inertia (lumped-mass model), and aerodynamics (Doublet-Lattice) into the A330-200 aeroelastic model.

Both complete and condensed MSC.NASTRAN FE model of the AWACS have been used for different purposes. The complete FE model has been used for assessing the fuselage static local deformation when applying unitary external loads at the dome CoG, information that has been used for including flexible effects on the static loads model. The condensed model (Guyan’s reduction) of Figure 10 has been used for both aeroelastic and dynamic loads calculations.

Figure 10: A330-AWACS condensed dynamic model

Figure 11 shows a comparison between the A330-AWACS (y-axis) and the A330-200 basic aircraft (x-axis) in terms of non-dimensional normal modes frequencies. If a blue point lies in the bisector (red line) then both AWACS and basic aircraft share the same frequency for that particular normal mode. It is seen that the low-frequency modes of the basic aircraft are slightly affected by the dome presence, and that the dome-struts structure has three normal modes in the low-frequency range: dome-struts lateral bending, dome z-axis (vertical) rotation, and dome fore-aft pitch.

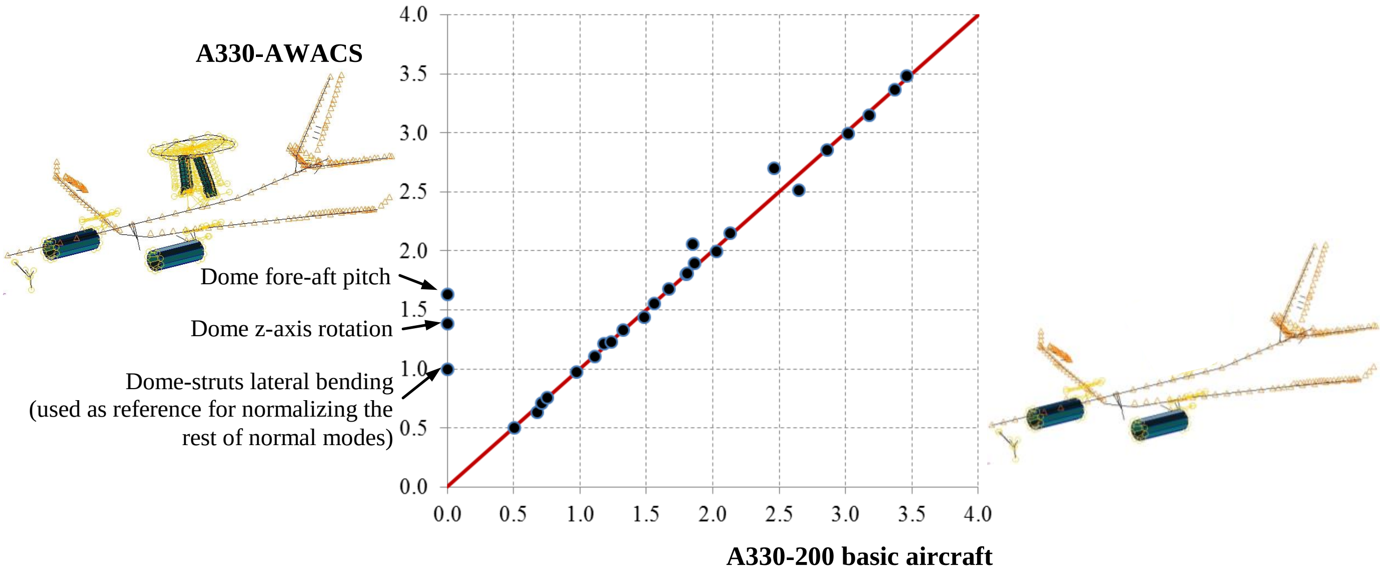


Figure 11: A330-AWACS vs. A330-200 basic aircraft normal modes frequencies. Frequencies in Hz are normalized with the dome-struts lateral bending (see 1.0 in y-axis)

The three dome-struts normal modes are shown in Figure 12. The yellow contour corresponds to the non-deformed dome-struts, while the black lines define the deformed structure.

Figure 13 and Figure 14 show the A330-AWACS Doublet-Lattice Method (DLM) unsteady aerodynamic model for flutter analyses, which is based on the basic aircraft DLM model plus additional lifting surfaces to consider the struts and the dome. The dome itself is simulated by two cruciform-shaped panels, the horizontal one with the dimensions of the dome projected in xy-plane, and the vertical one with the dome dimensions projected in the yz-plane. These panels associated to the dome will be tuned to CFD, wind-tunnel tests or flight tests as the Doublet-Lattice is not able to capture all geometrical (thickness) or flow (transonic) effects. The struts unsteady aerodynamics is captured with two vertical lifting panels with the appropriate dihedral angle. In addition, the dome-fuselage interference is simulated with a semi-arc rounded panel that is not linked to the structure.

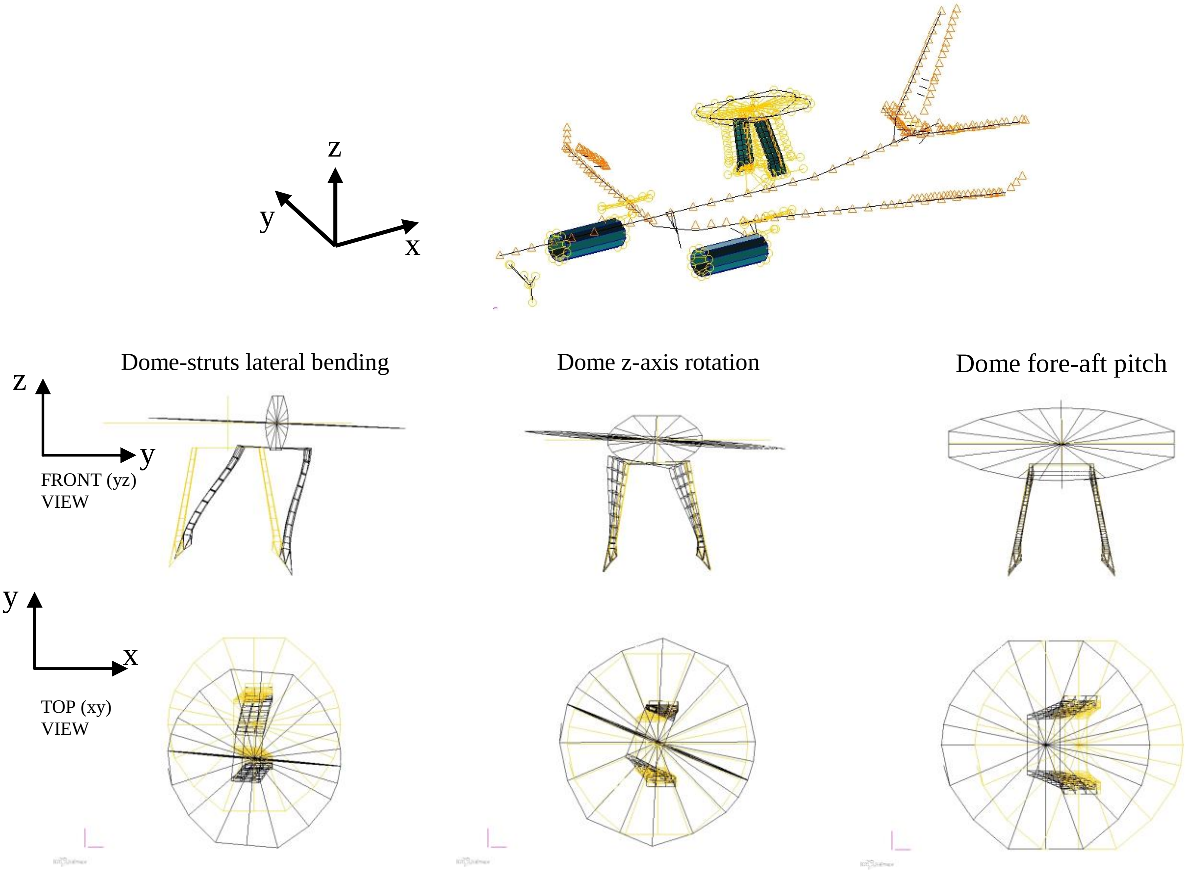


Figure 12: Main low-frequency normal modes of the dome-struts structure

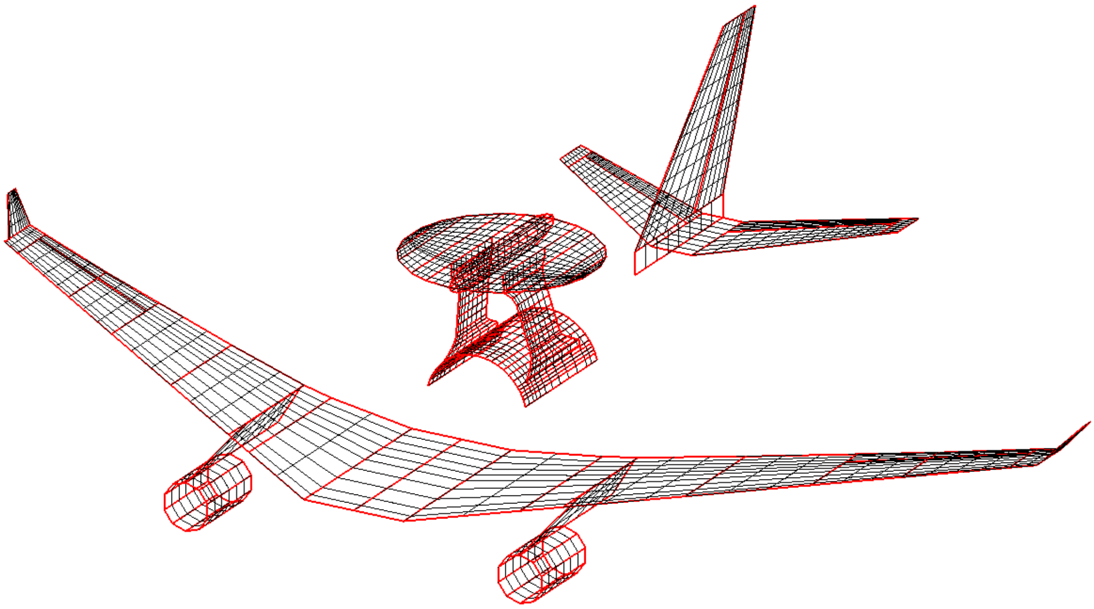


Figure 13: Isometric view of the A330-AWACS Doublet-Lattice unsteady aerodynamic model

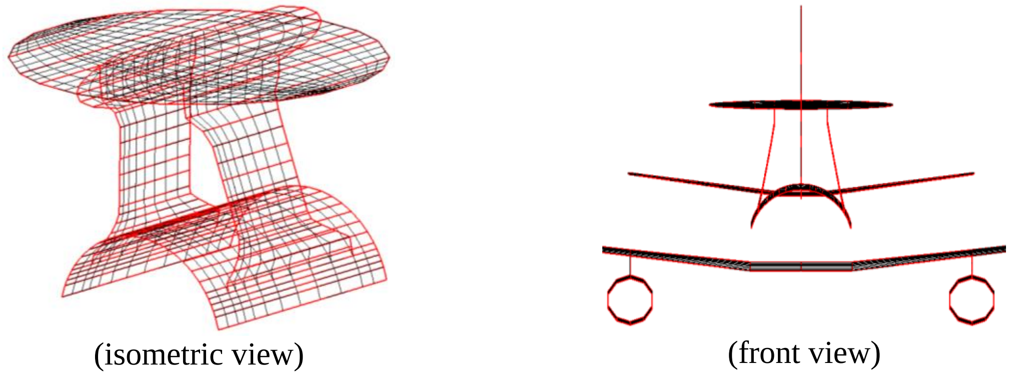


Figure 14: A330-AWACS Doublet-Lattice unsteady aerodynamic model

6 ISOLATED DOME FLUTTER CALCULATIONS

Figure 15 shows flutter calculations (matched pk-method) for the isolated dome in two configurations:

- Clamped-to-floor configuration, with both struts bases rigidly joined to a virtual "floor" (see points A1 and B1 in Figure 15).
- Clamped-to-fuselage configuration, with the struts bases flexibly joined to the virtual "floor" thru the points A2, B2, and C2 with local stiffness' adjusted to reproduce the effect of the fuselage flexibility on the dome normal modes.

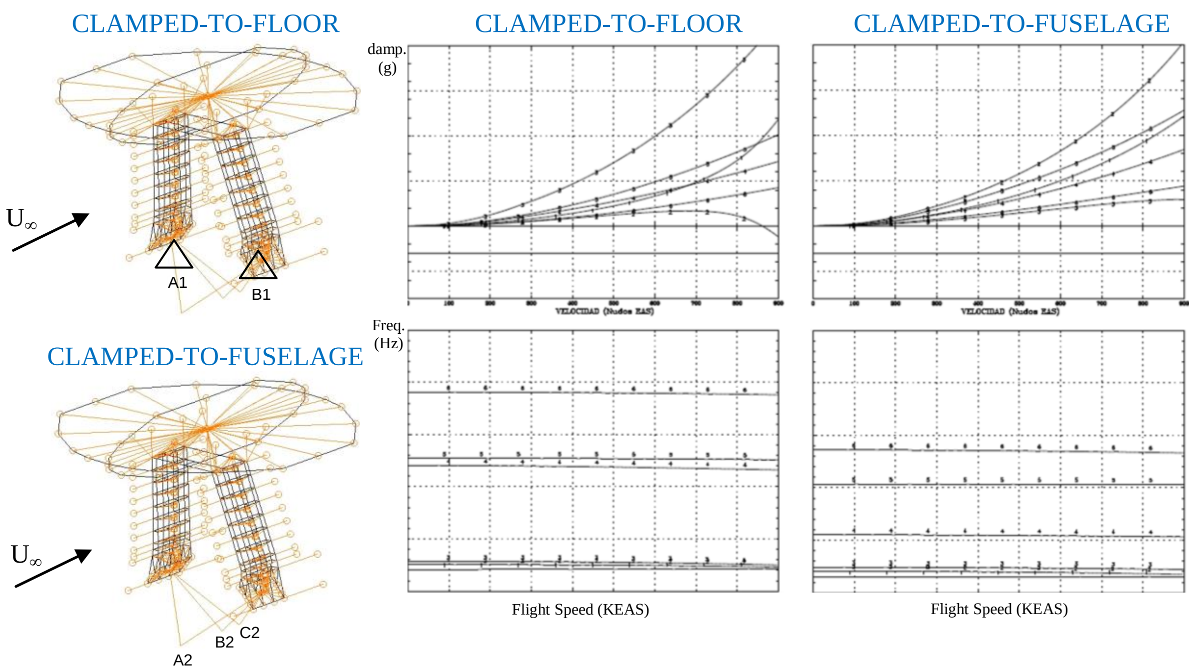
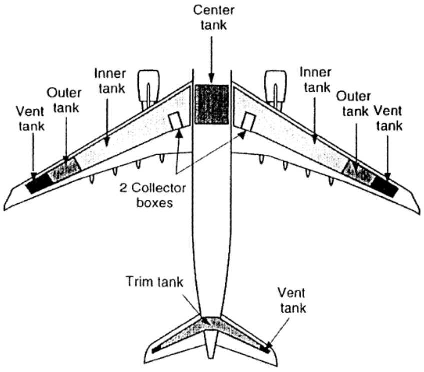


Figure 15: A330-AWACS Doublet-Lattice unsteady aerodynamic model

The isolated clamped-to-floor dome/struts sub-structure exhibits a flutter mechanism (coupling lateral bending with z-axis dome rotation) although well outside the A330-AWACS envisaged flight envelope. The isolated clamped-to-fuselage configuration (simulating the fuselage local stiffness) decouples the dome/struts normal modes and the flutter mechanism disappears.

7 A330-AWACS FLUTTER CALCULATIONS

Flutter calculations at aircraft level have been performed on 32 mass configurations (Figure 16) that widely cover the operational usage. Vg-plots, as shown in Figure 17 for basic aircraft (left) and A330-AWACS (right), have been compared to assess the effect of the dome-struts installation.



	OUTER TANK	INNER TANK	CENTER TANK	TRIM TANK	PAYLOAD	
PERCENTAGE	0% 100%	0% 100%	0% 100%	0% 100%	EMPTY FULL	
NUMBER OF CASES	2	2	2	2	2	2^5=32 MASS STATES

Figure 16: A330-AWACS mass states configurations in terms of tanks fuel distribution (0% or 100%) and payload (empty or full)

The main conclusion from the flutter analyses is that the installed-in-aircraft dome-struts do not exhibit specific own flutter mechanisms, and the A330-AWACS flutter mechanisms are those of the basic aircraft potentially modified by the dome-struts presence (mainly dome inertia). Figure 17 right shows a mild flutter mechanism that appears on the A330-AWACS but is in fact a low-damped mode that appeared in the basic aircraft.

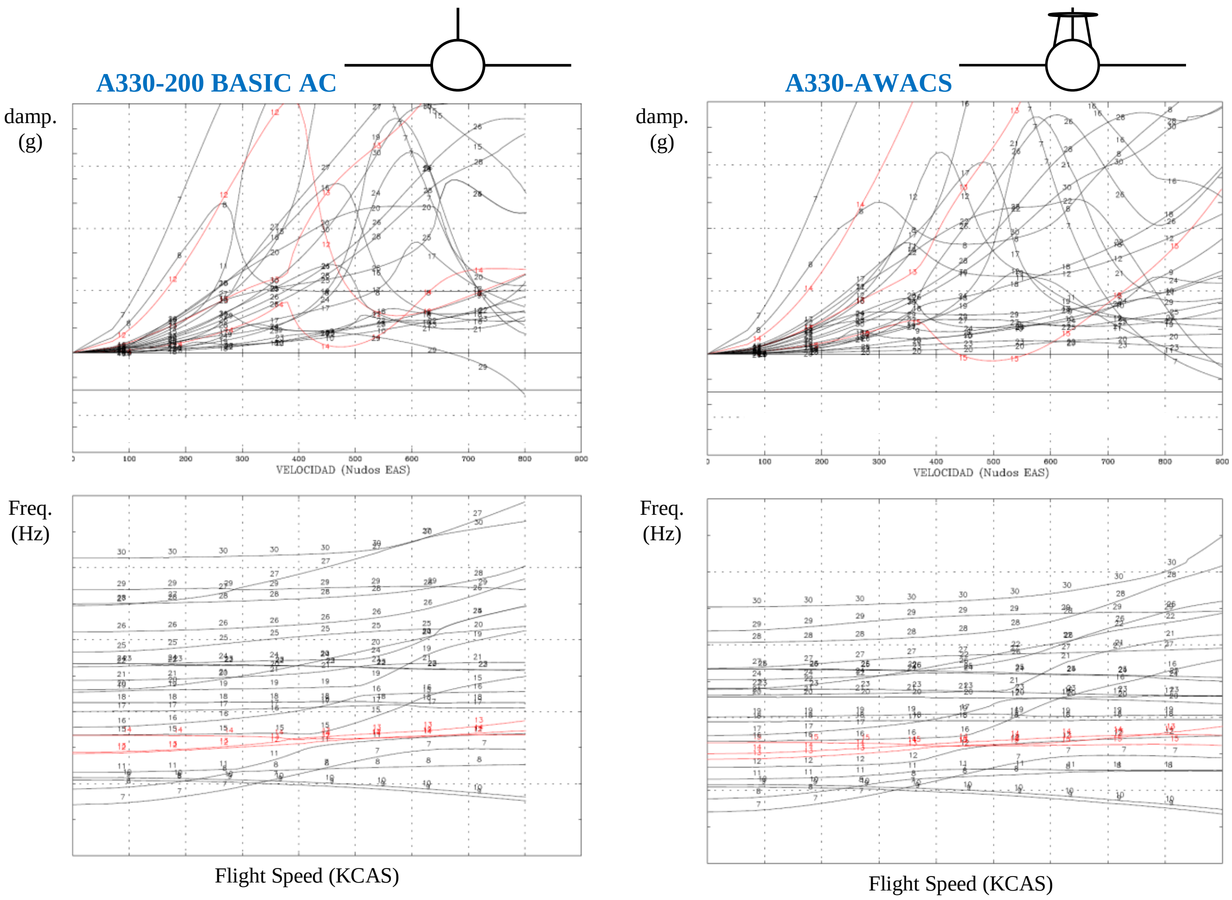


Figure 17: Left: Vg-plot (pk-method) of the A330-200 basic aircraft for the mass state with outer tank empty, inner tank full, center tank empty, trim tank full, and maximum payload. Right: A330-AWACS results for the same mass state.

8 A330-AWACS DYNAMIC LOADS

The AWACS preliminary design dynamic loads activities have considered the following scenarios:

- Emergency landing conditions

  CS 25.561 states that fuselage mounted engines or APUs shall be restrained under all loads up to the inertia forces of Figure 18 acting separately relative to the surrounding structure. The AWACS Dome is designed to withstand these loads.

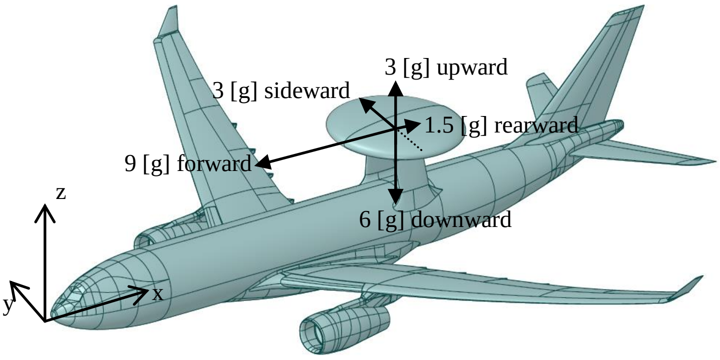


Figure 18: Emergency landing inertia loads that have been locally applied at the dome CoG as a design case for dimensioning the dome struts

  Other ground loading conditions as dynamic landing and taxiing will be considered for further stages of the design. At this preliminary stage, the severe scenario of emergency landing is taken as reference.

- Low-speed dynamic braking

  AIRBUS Commercial has performed simulations ([1]) for assessing the AWACS configuration from ground loads standpoint. The analysis was focused on low speed braking and 0.5 [g] turn maneuvers, with emphasis on capturing the effect of a different z-axis CoG and inertia moment Iyy (see Figure 19) of the AWACS when compared with the basic aircraft.

  For the low-speed dynamic braking, the aircraft is braked with the brake torque of Figure 19 applied on each wheel. Results of vertical force Fz at the nose landing gear (Figure 19, right) show exceedances of around 10% with respect to the same loading condition calculated on the basic aircraft.

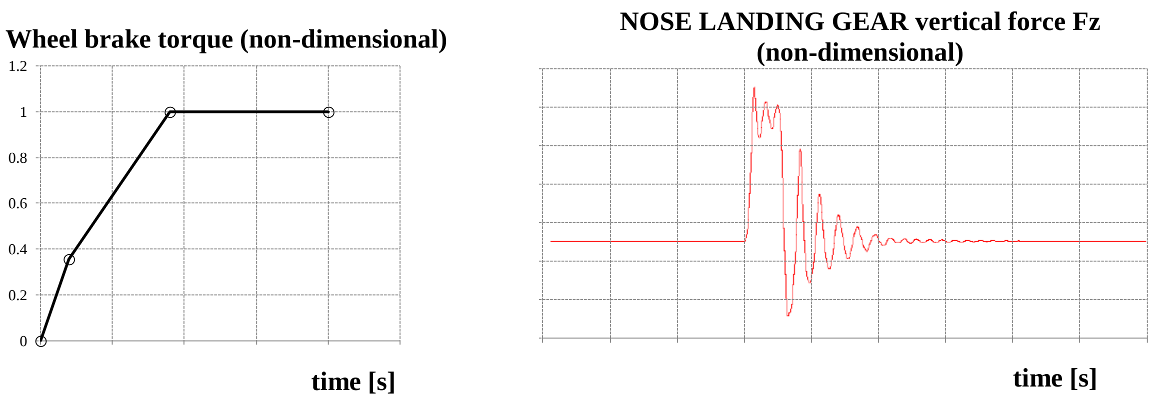


Figure 19: Left: non-dimensional brake torque applied on each wheel. Right: non-dimensonal vertical force Fz at the A330 nose landing gear.

The 0.5g turn maneuver consists in a bookcase scenario with 0.5g lateral load factor turn. This calculation does not consider either aerodynamics or engine thrust. Results on AWACS platform reveal exceedances w.r.t. the basic aircraft of around 3-4 % in both lateral and vertical forces at the main landing gear.

- Discrete tuned gusts and continuous turbulence

  Fuselage aerodynamics shall be included in the Doublet-Lattice unsteady aerodynamic model to reproduce adequately the aircraft gust response. The fuselage effect is simulated thru a cruciform shape composed of a horizontal panel to capture the lift and a vertical panel to simulate the lateral aerodynamic forces. Both panels need to be adjusted to CFD, wind tunnel tests, or flight tests as the pure Doublet-lattice usually over-predicts the aerodynamic pressure of body-like shapes.

  Preliminary calculations will be focused on assessing the lateral load factor at the dome driven by lateral gust encountering scenarios. More specifically, the transfer function between the fuselage lateral acceleration (measured at x-axis location of a strut-to-AC forward fitting) and the dome CoG lateral acceleration shall be calculated to estimate the amplification factor associated to the struts flexible structure.

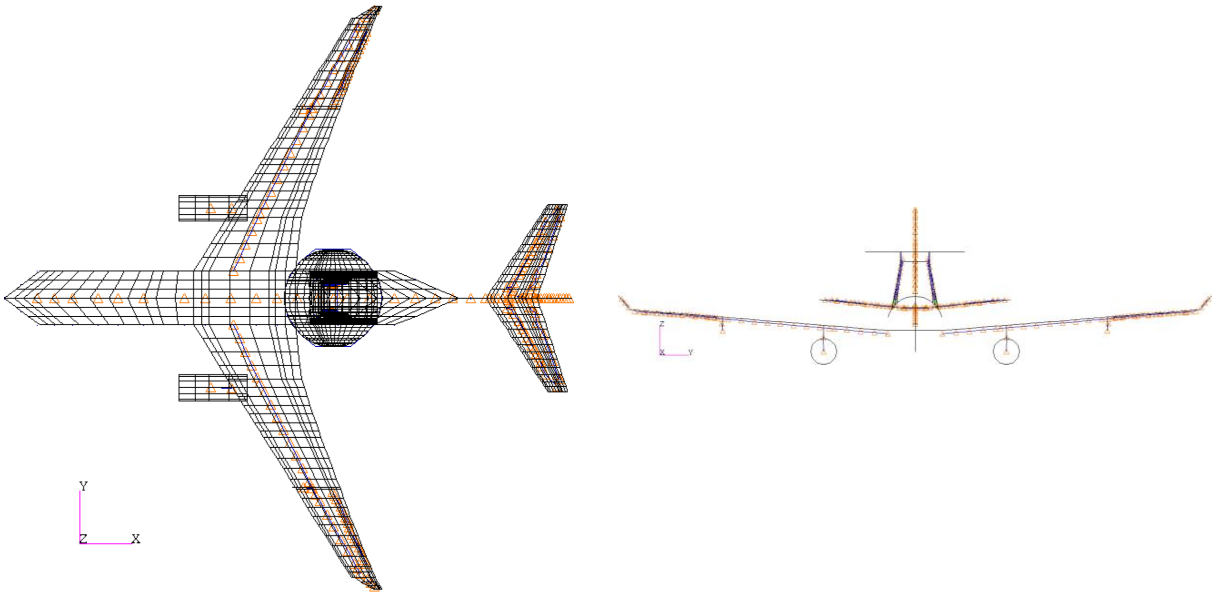


Figure 20: Several views of the Doublet-Lattice Method used for gust/turbulence dynamic loads calculations

- Empennage buffeting

  Further calculations/tests shall include the effect of the dome-struts wake (buffet) on the aircraft empennage. Buffet analyses were also performed for the certification of the A330-MRTT tanker whose vertical tailplane (VTP) is subjected to the wake of the receiver aircraft during the refueling operation (Figure 21). Flight tests were used to characterize the buffeting (vibration) of the VTP, the aeroelastic model was used to obtain the transfer functions and, with these two inputs, the power spectral density (PSD) of the external turbulence (buffet excitation) was inferred. Knowing the PSD of the buffet excitation, the rest of magnitudes (VTP root bending moment, accelerations, etc.) were obtained thru the corresponding transfer functions. It was concluded that the buffet loads were negligible even from fatigue standpoint.

Figure 21: A330-MRTT being refueled by the A310-Demo (prototype to test the Aerial Refuelling Boom System)

Figure 22 shows the CFD computations as part of the mitigation risk analyses for assessing the A330-AWACS empennage buffeting. Although absolute values of the pressure coefficient will be refined with WTT or flight tests, these theoretical computations serve to detect the critical zones that are expected to be more affected by the dome wake.

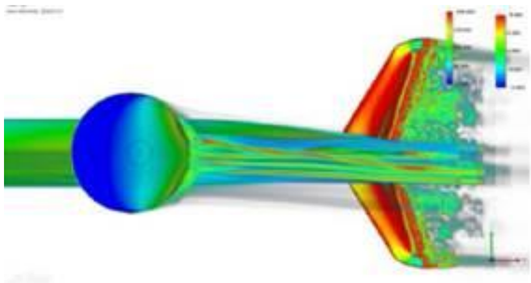


Figure 22: Preliminary CFD computations for assessing the buffeting of the A330 empennage

The Certification Loads Loop shall include all the previous calculations in the A330-AWACS aeroelastic model. However, preliminary loads will take benefit of the extensive database and the experience on the AIRBUS Derivatives A330-MRTT RAAF (A330-200 equipped with Aerial Refuelling Boom System and Outer Aerial Refuelling Wing Pods) and A330-FSTA (Fuselage Refueling Unit FRU and AAR Pods) to reduce the time to deliver the design loads. In particular, it is envisaged the use of data-analytics (on the MRTT and FSTA databases) with surrogate models to:

- Obtain preliminary aircraft 1g-loads, to superimpose the dome-struts loads in static loading scenarios (flexibility effects on the maneuver static loads model, static Aeroelasticity, etc.)

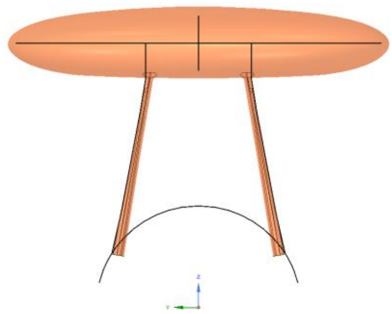
- Obtain a reduced set of critical cases (flight point, mass states, CoG, etc.) of the MRTT/FSTA calculations associated to gust, turbulence or dynamic landing which will be re-calculated with the dome-struts installed. In this way, the design loads could be delivered in a short time and the rest of less-critical conditions could be postponed to the final certification phase.

Besides this, the complexity of the dome-struts geometry leads to consider the usage of CFD-based computations to correct the DLM-based unsteady pressure coefficient. Next section details the procedure that is envisaged to be used in the A330-AWACS design for improving the unsteady aerodynamics.

9 DOUBLET-LATTICE CORRECTIONS BASED ON TRANSONIC CFD CALCULATIONS

The linear potential approach of the Doublet-lattice (DLM) has inherent limitations and CFD computations, wind-tunnel tests, or flight tests are to be used as shape-related or transonic effects appear as relevant. AIRBUS-DS is applying a classical methodology of substituting rows/columns the DLM Q_{hh} matrices by calculating them with CFD. In particular, for this preliminary phase of the AWACS, AIRBUS-DS is testing the CFD FLUENT that is embedded into the ANSYS Workbench.

Concerning shape-related effects, the simplified representation of the lenticular-shaped dome with a DLM lifting panel (Figure 23) leads to underestimate both thickness and curvature effects on the steady pressure distribution.



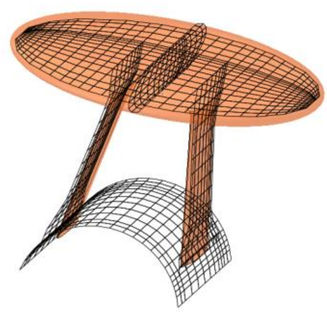
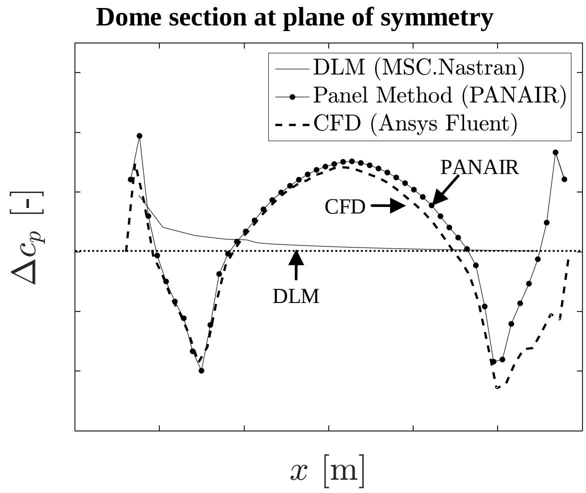


Figure 23: External geometry of the dome and struts (orange shaded contour) superimposed on the DLM lifting panels (black lines).

Figure 24 shows a comparison between CFD and DLM of the isolated dome (no struts) lifting pressure ΔCp distribution at the symmetry plane (y=0) and the 45% semi-span section of the dome. Reference conditions are Mach 0.20 and angle of attack 0.5 degrees. The dome section has a particular shape of the lower surface that optimizes the shock wave formation at high Mach number; for this reason, the DLM-predicted lifting pressure trend is quite different to the CFD-predicted one (Figure 24). For reference, the PANAIR panel method ([6]) has been also included for validation of the CFD-ANSYS results of the isolated Dome configuration.



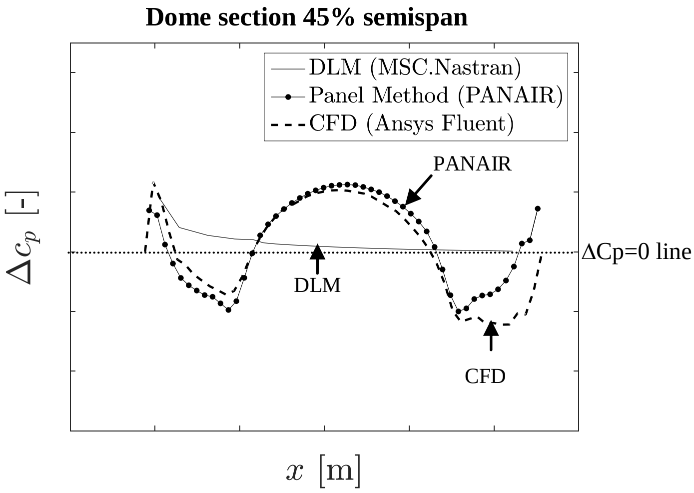


Figure 24: ΔCp distribution on isolated dome configuration (no struts). Left: Dome ΔCp distribution at the y=0 symmetry plane. Right: ΔCp distribution at the 45% semispan. Mach number is 0.20 and AoA is 0.5 [deg].

The lift coefficient C_L has been calculated as function of the angle of attack with both DLM and CFD methods at Mach 0.20. As expected, DLM over-predicts the value of the lift coefficient slope $C_{L\alpha}$.

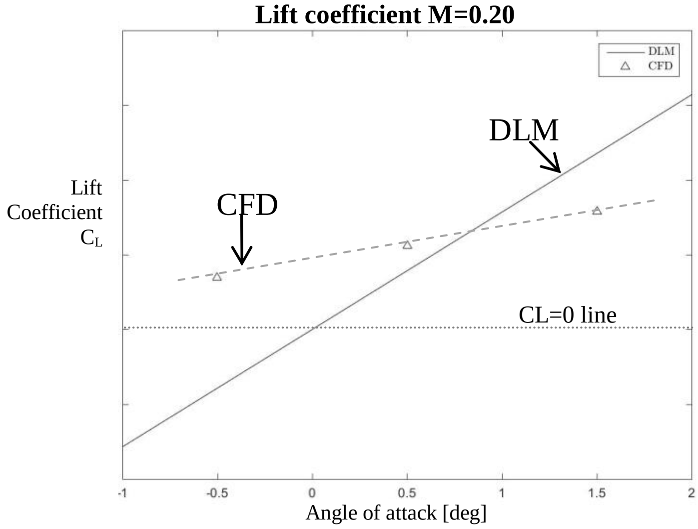


Figure 25: Lift coefficient C_L as function of angle of attack (degrees) for Mach number 0.20

Previous steady state calculations are used for assessing the static Aeroelasticity (mainly flexibility effects on static loads) and serve as starting point for the subsequent unsteady CFD computations. Although preliminary factor corrections could be obtained from steady calculations by adjusting lift and moment aerodynamic coefficients, a more accurate procedure based on time-domain unsteady CFD calculations will be used for this project. The procedure for improving the definition of the unsteady aerodynamic matrices Q_{hh} includes the following steps:

1. Run an MSC.NASTRAN SOL103 to obtain a normal mode "j" in the a-set structural FEM grids.
2. Import the normal mode shape "j" in the ANSYS structural module.
3. Run a time-domain 1-way CFD coupling simulation moving the external aerodynamic surface with the deformations dictated by the structural mode "j".
4. Calculate the time-history of the term Q_{ij} according to the following expression of the generalized aerodynamic matrices (MSC.NASTRAN formulation):

$$Q_{ij}(t) = \iint C_{pj}(\bar{r},t) \cdot u_i(\bar{r}) \cdot dS$$

where $C_{pj}(\bar{r},t)$ is the pressure coefficient at the location $\bar{r}$ and time t associated to the mode "j", and $u_i(\bar{r})$ is the modal displacement of mode "i" (maximum deformation) at location $\bar{r}$.

Previous procedure is in the definition phase, although preliminary validation has been done for the well-documented Goland wing and the A330-MRTT. The final setup is envisaged for end of this year and will be operative in the AIRBUS-DS Structural Dynamics and Aeroelasticity Department software workbench (ODYN) for 2018.

10 CONCLUSIONS AND FURTHER ACTIVITIES

Previous sections have shown the preliminary aeroelastic computations on the A330-AWACS that have supported the design of the main radar (dome-struts installed in the fuselage). No flutter instabilities have been found inside the flight envelope, and the dome-struts installation has a limited effect on the Aeroelasticity of the green aircraft. Some loads scenarios have been also used for assessing the struts design (emergency landing, dynamic braking, etc.). Although previous analyses are valid for a risk mitigation phase, following points shall be included for supporting a more detailed design:

- Improvement of the struts-to-aircraft fittings on the dynamic FE model by using information from the detailed FE model of the Stress Office. Previous preliminary calculations have covered uncertainties with sensitivity analyses but, mainly for loads calculations, these fittings shall be more accurately defined.
- Flutter analyses with transonic corrections in both aircraft and dome-struts. In this sense, the experience on previous projects (A330-MRTT) will be useful as these high-speed corrections were also needed.
- A complete dynamic loads loop: vertical/lateral discrete tuned gusts, vertical/lateral continuous turbulence, dynamic landing, and taxiing. AIRBUS-DS in cooperation with AIRBUS Commercial will perform all the analyses needed for the aircraft certification.
- Ground vibration test on the ready-for-flight aircraft for characterizing the dome-struts normal modes, the local flexibility of the struts-to-aircraft, and the struts-to-dome fittings. AIRBUS-DS did perform the GVT on the A330-MRTT and the AIRBUS-DS Structural Test Department has enough experience, resources, and hardware/software to perform the GVT on the A330-AWACS.
- Finally, the mandatory Flight Vibration Tests (FVTs) on the prototype. AIRBUS-DS has well-proven experience on numerous FVTs with real-tracking software (jFlutter) that allows supplying clearance in seconds at each flight test point. This FVTs tests will be used also for characterizing the possible buffeting on the A330 empennage induced by the dome-struts wake.

11 REFERENCES

[1] AIRBUS-OPS. AWACS Ground Loads assessment with OSMA. LR00FM1506876-1.0. Date: 16-Dec-2015.

[2] AIRBUS-DS. Response to the RFP of the DRDO-Centre of Airborne Systems of the MOD Government of India for the selling of A330 aircraft platform for AWACS. PR 91.01_2014 (Issue 1). Date: 31-Jul-2014.

[3] AIRBUS-DS. A330 AWACS Workshare (Airframe / Stress / F&DT). TAE-OF-PR-150003-A. Date: 29-Jan-2015.

[4] AIRBUS-DS. TLARD for A330-200 DRDO AWACS Blue A/C. TAE-FI-NT-150001. Date: 15-Jul-2015.

[5] AIRBUS-DS. Data Basis for Design for A330 DRDO AWACS Blue A/C. TAE-FI-NT-150002. Date: 7-Sep-2016.

[6] NASA Contractor Report 3250, Derbyshire, T. and Sidwell, K.W. PAN AIR Summary Document, (Version 1.0), 1982.

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