AERIAL DELIVERY DYNAMIC MODEL VALIDATION BY FLIGHT TEST

Mercedes Oliver Herrero
Airbus Defence and Space. Military Transport Aircraft (ADS-MTA)
Structural Dynamics and Aeroelasticity
Avda. John Lennon s/n, Getafe (MADRID) 28906 Spain
mercedes.oliver-herrero@airbus.com
Alvaro Pérez de la Serna (ALTRAN), Antonio José Rodríguez Jiménez (ALTRAN), Félix Arévalo (ADS-MTA), Héctor Climent (ADS-MTA)

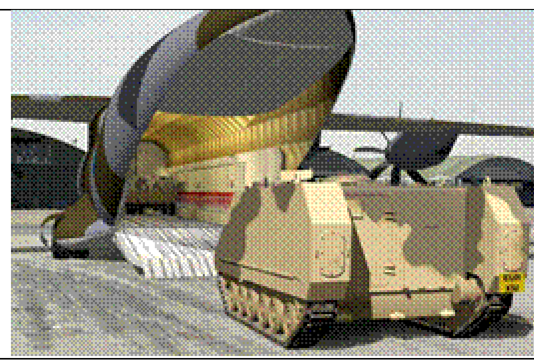
ABSTRACT

This paper presents the continuation of the works performed at Airbus DS Military Transport Aircraft Aeroelasticity and Structural Dynamics department in the last years ([1], [2] & [3]) and is devoted to present the A400M aerial delivery dynamic loads calculation methodology and validation by means of flight test. Some of the aerial delivery dynamic loads are among the A400M sizing critical load cases, therefore the validation of the aerial delivery loads model is a critical issue in the certification path. Dynamic loads analyses envisage two situations that are the most severe during the aerial delivery phases: The turbulence encounter during the payload units movement backwards inside the fuselage the aircraft dynamic response due to the ramp spring-back when the payload unit leaves the ramp. From the structural point of view, the non-linearities in the ramp-fuselage interfaces are one of the most relevant parameters of this study and for this reason, it has been used a non-linear approach.

The aerial delivery dynamic loads model will be validated by comparison of the analytical predictions with the flight test data from the A400M flight test campaign envisaged for the end of 2015.

1 INTRODUCTION

The missions that a military transport aircraft has to accomplish are the explanation of why these aircraft are as they are. One of the most recognizable features is the ramp located in the rear fuselage, which will give clearance to payload introduction/extraction.



This need for enhancing loading and unloading performance is particularly critical in one of the most typical mission of military transport aircrafts: aerial delivery. This mission can be accomplished in different ways:

— Airland. It is the most efficient and cost effective and permits delivery of larger loads with less risk of cargo loss or damage. It can be done from a stationary aircraft or combat offload from a moving aircraft

- Airdrop. It consists of the payload release while the aircraft is still on the air. Extraction process may imply single or multiple pallets delivery depending on the mission. There are different methods of extraction:
    - Parachute extraction. Payload is pulled out the aircraft through the ramp. It is used with low-velocity loads.
    - Gravity extraction. Requires the aircraft to fly in "nose-up" configuration, making containers roll or slide out of the aircraft through ramp. This method is feasible for both low & high velocity scenarios.

This study is devoted to "Airdrop" missions and the way to calculate dynamic loads associated to their occurrence. It is established in the regulation that they must be accounted for, and the better and more accurate loads calculations are, the lighter and more efficient aircraft structures will be. These loads result critical and sizing cases for the ramp, rear fuselage and ramp-fuselage interface.

2 STATEMENT OF THE PROBLEM

2.1 Ramp opening dynamic effects

One of the operations of a Military Transport Aircraft is the in-flight loads delivery. For this operation, the aircraft opens the ramp and door and then the load, pallets or platforms with vehicles, are extracted. There are two dynamic effects associated to the fact of opening the ramp:

- Rear fuselage torsional stiffness reduction.
- Open ramp dynamic response.

Rear fuselage torsional stiffness reduction

When the ramp is opened the fuselage closed section evolves to an open section thus changing its torsional stiffness and elastic axes position. The closed ramp fuselage and T-tail normal modes change in shape and frequency and new normal modes, ramp and door, appear. In the A400M, the HTP Roll reduces its frequency by a 13%

Open ramp dynamic response

As a separate structure joint to the fuselage (connected through the hinge, actuators and struts), ramp local modes are expected to arise and modify (increasing) the ramp response.

2.2 Certification requirements

The civil or military regulations followed by Airbus Group to certify its airplanes (CS-25, FAR-25, MIL-STD or DEF STAN) do not have any specific paragraph either for open ramp nor aerial delivery. For this reason an agreement is usually reached with the authorities to cover typically:

1. <u>Gust loads while the aircraft is flying with the ramp open</u>

Aircraft without payload on the ramp, maximum velocity for flying with open ramp, lower than Vc. The loads due to the response to a gust of 100% of intensity defined in CS 25.341 will contribute to the design loads of the ramp and rear fuselage.

2. <u>Gust loads during the extraction process</u>:

Transient movement of the payload from the cargo hold to the ramp. The time that the aircraft is flying is a small portion of the aircraft life, therefore it is accepted that the gust intensity is reduced to 50% of that defined in CS 25.341.

3. <u>Release Loads</u>:

The extraction process is quasi-stationary, but the release of the load is dynamic. The pallet arrives to the edge of the ramp, rotates and leaves the ramp. These movements are produced in a very short time, producing a dynamic response similar to the one produced by a step loading.

3 FLIGHT WITH OPEN RAMP + GUST LOADS

Before and after the pallets release, the aircraft will be flying with the ramp open. In this flight configuration the aircraft loads due to the response to the gust excitation have to be computed.
The portion of time while the pallet is moving through the cargo hold and ramp or rotating and sliding in the ramp has to be treated as a release event (and therefore described in §5) or a failure case.

To calculate the total load due to the gust excitation, the incremental load due to the gust response is added to the 1g steady load. The DTG incremental loads correspond to 100% of CS-25.341 gust intensity. The procedure is exactly the same as the one followed for closed ramp.

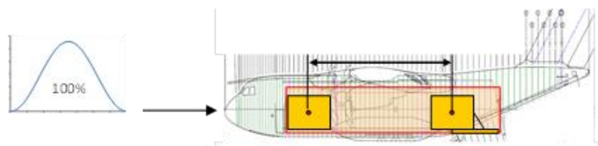


Figure 1: Gust intensity for DTG incremental load.

The A400M Manoeuvre Alleviation System integrated in the Flight Control System (FCS) is nonlinear and this nonlinearity has been included in the gust response calculation using DYNRESP©, see [4].
The differences of this analysis with respect to the same analysis with the ramp closed are:

- The flight velocity will be lower than Vc.
- The low speed that may be needed for the aerial delivery leads to the use of flaps.
- The torque capability of the open section will change, being very important in a T-tail aircraft.

Influence in loads:
Open ramp gust loads are more critical than closed ramp ones for the magnitudes shown in Figure 2 and Figure 3:

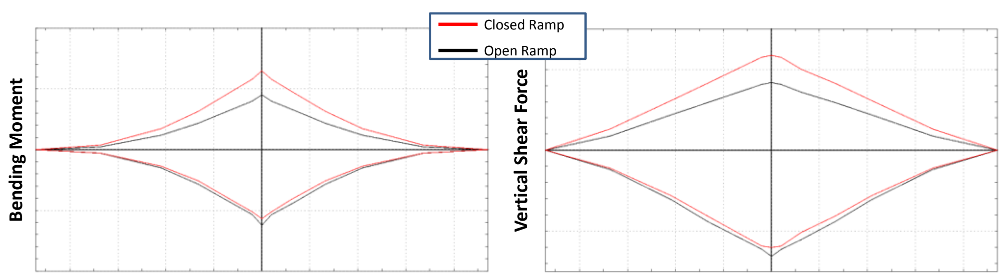


Figure 2: HTP bending moment and vertical shear force - open ramp vs. closed ramp

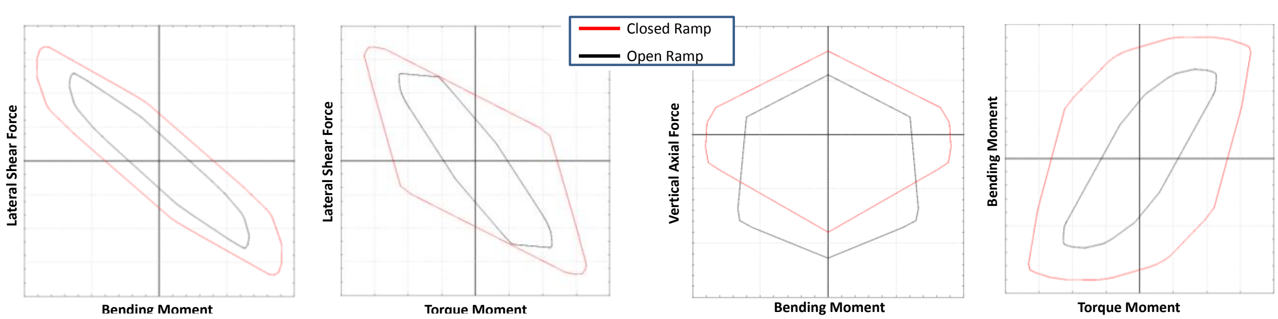


Figure 3: VTP root 2D envelopes - open ramp vs. closed ramp

4 "PSEUDO-1G" CONDITION

Dynamic loads are typically obtained by using Superposition Method which combines two loads contributions: 1g load (aircraft loads in steady condition) and incremental load (due to gust or release).
The aerial delivery is intrinsically a transient process. When a platform moves inside the fuselage, the centre of gravity moves rearward as well and the effect in the aircraft is a pitch-up movement.

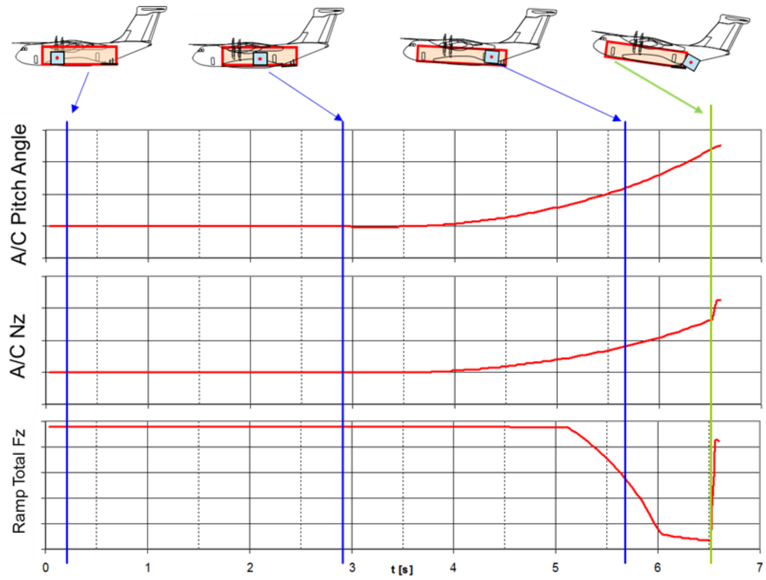


Figure 4: From top: sketch of aerial delivery; A/C pitch; Nz and ramp total Fz evolution

As a consequence there are no sets of steady 1g loads for a particular mass state and flight point but a time history of pseudo-1g loads for each combination of the cargo units extraction process.
Loads to be combined with dynamic incremental loads, as required in [5], are then obtained by freezing at certain time instant the 1g-loads time history. This instant represents the payload position that maximizes loads at the ramp itself and/or at fuselage-ramp interfaces (struts, hinges, actuators…); then a whole set of correlated static loads corresponding to that payload position is extracted for the whole aircraft representing the static load contribution to aerial delivery loads.
Extraction process may imply single or multiple pallets delivery depending on the mission. Figure 5 shows two examples of time instant selection, one for each type of delivery.

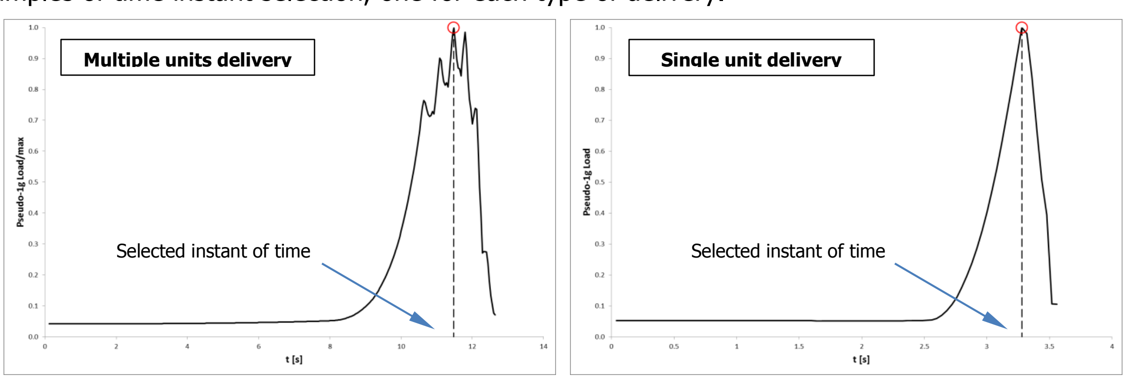


Figure 5: Example of pseudo-1g load

5 "AERIAL DELIVERY + GUST" LOADS

Aerial delivery is the operation in which a platform moves rearwards inside the fuselage and then released through the ramp opened.
As stated in §2, in the case of A400M an agreement is reached with the Airworthiness Authorities [5] as follows:
The airplane shall encounter discrete tuned gusts of:

- the specified intensities at VC in CS 25.341, before and after the cargo extraction process and
- intensities of 50% of those specified at VC in CS 25.341, during the cargo extraction process

Figure 6 illustrates the two scenarios foreseen, considering any position of the platform through the fuselage and any position on the ramp.

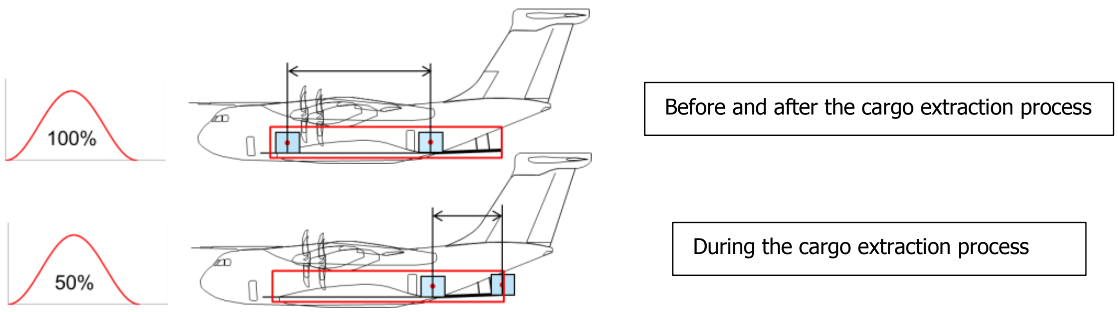


Figure 6. DTG analysis should cover any position of the platform during aerial delivery

As general procedure for dynamic loads analysis, the total load is a combination of the 1g steady load plus the incremental load that results from the dynamic response to the excitation. In the aerial delivery + gust analysis, the pseudo-1g (already described in §4) is used instead of 1g steady load.
The procedure used for selecting the cases to be run is as follows:

- For different flight points and payload types, the rear fuselage, ramp, hinge, actuators and struts forces and moments pseudo-1g time histories are provided by Static Loads department.
- The maximum positive and negative peak of each monitored magnitude is obtained. This defines the pseudo-1g that will be added to its correspondent incremental load. The case is identified by the source time history: load position, altitude, aircraft speed, aircraft attitude, instant time.
- The full set of aircraft correlated loads corresponding to this pseudo-1g is calculated for each of the load cases selected.
- The specific mass state for each of the load cases is created. As the pallets are moving along the fuselage, the specific x-position is needed in order to create the CONM2 entries.

Once identified the critical instant of time flight and mass position, the gust response is calculated for those conditions. Finally, total loads are calculated adding the pseudo-1g (acting as steady 1g) to the incremental load. The non-linear Flight Control System (FCS) is used with the Manoeuvre Loads Alleviation system as described in §3.
Aerial delivery gust loads are higher than pen ramp in the fuselage frames close to the ramp and in the ramp itself.

6 RELEASE LOADS

6.1 Release Loads Procedure Description

The final phase of the aerial delivery is the platform release. During this last phase, the total release loads is the sum of two parts:

- Pseudo 1g loads: the loads when the platform is in the ramp edge and the aircraft behaviour corresponds to the platform movement up to that point.
- The incremental dynamic part: when the platform rotates over the ramp edge and immediately abandons the ramp creating a transient excitation. During the subsequent non-linear response, the non-linearity of some components should be taken into account (e.g. strut, which only work under traction, but not under compression).

When the platform is on the ramp, the ramp frames support the weight of the platform until the platform centre of gravity reaches the ramp edge. Figure 7 shows the triangular distributed load on frames. This weight is not at 1g level flight but is computed at the load factor corresponding to the aerial delivery manoeuvre at that time.

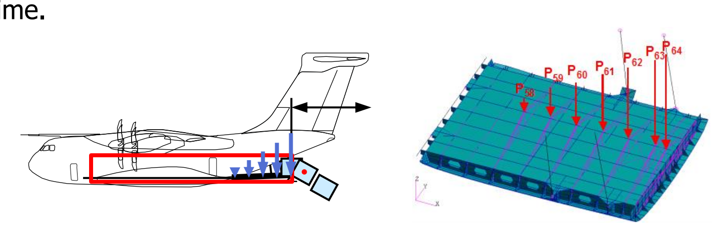


Figure 7 Sketch of aerial delivery.

The quasi-steady ramp Fz time history is used twofold, to fix the magnitude of the applied load at the critical instant of time, and to select the instant of time for the pseudo-1g loads.
Figure 8 shows the instant of time when the platform rotates producing the maximum load on the ramp (t_i) and when the platform leaves the ramp (t_f).

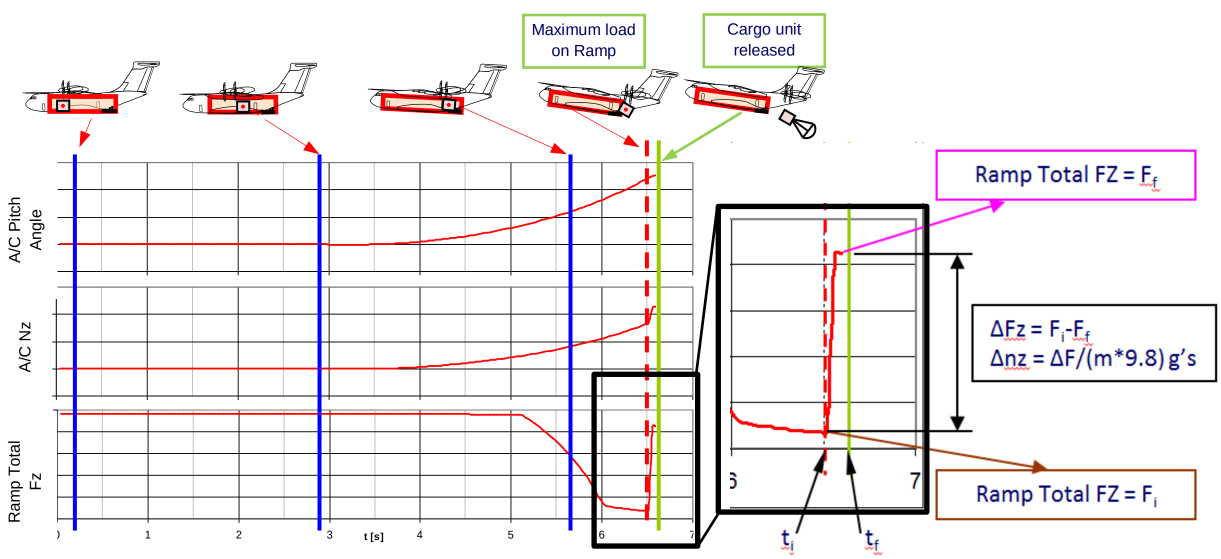


Figure 8 From top: sketch of aerial delivery; A/C pitch; A/C Nz and total ramp Fz evolution.

The applied load ΔFz magnitude is obtained by difference between the force at the ramp in t_f and t_i.
The working methodology is based in the simulation of the load that is going to be released as a force that "moves" along the ramp and suddenly disappears when the platforms leaves the ramp. The procedure follows the diagram in Figure 9.

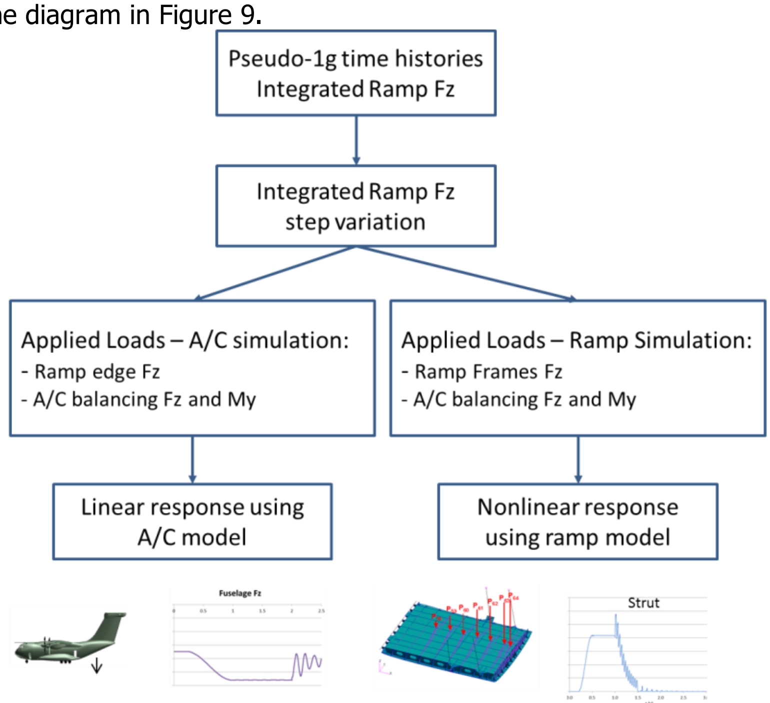


Figure 9 Release loads computation process

This procedure is as follows:

1. The vertical force at the ramp (F_z) is the criterion to select the most critical release loads.
2. From the different unit loads release F_z time histories, those which produce the maximum variation in F_z at the platform rotation moment are selected. As shown in Figure 8 above, this variation is obtained by difference between the maximum F_z and its value when the load unit has left the ramp.

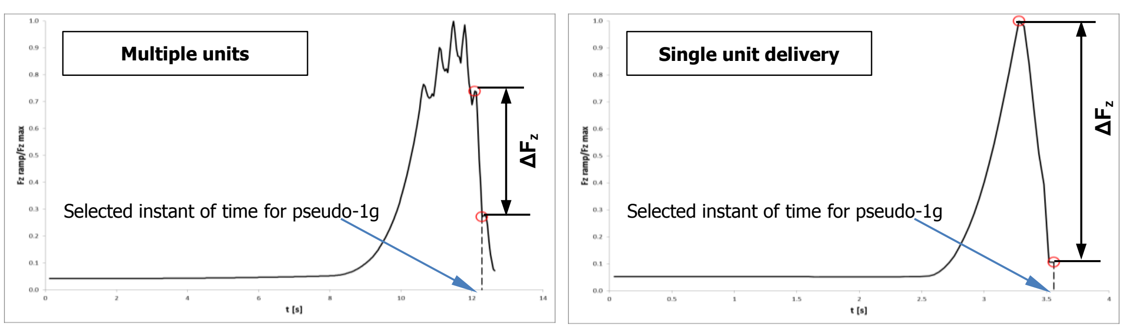


Figure 10 Selection of delta Total Ramp Fz

3. The aircraft global loads are not affected by local non-linear effects and a linear approach can be used to obtain rear fuselage and ramp loads due to release (§6.2). Instead, the strut is strongly non-linear (works only under traction, but not under compression) and this affects to actuator compression loads (§6.3).

6.2 Linear Release Analysis

For the linear release analysis, a vertical transient simplified load applied in the ramp edge simulates the effect of the platform over the ramp, when the platform mass reaches the ramp edge and it rotates and slides around this point. For this purpose, a full A/C condensed dynamic model is used.
The applied force at the ramp edge is shown in Figure 11. The load during (a) and (b) interval times are considered quasi-steady processes.

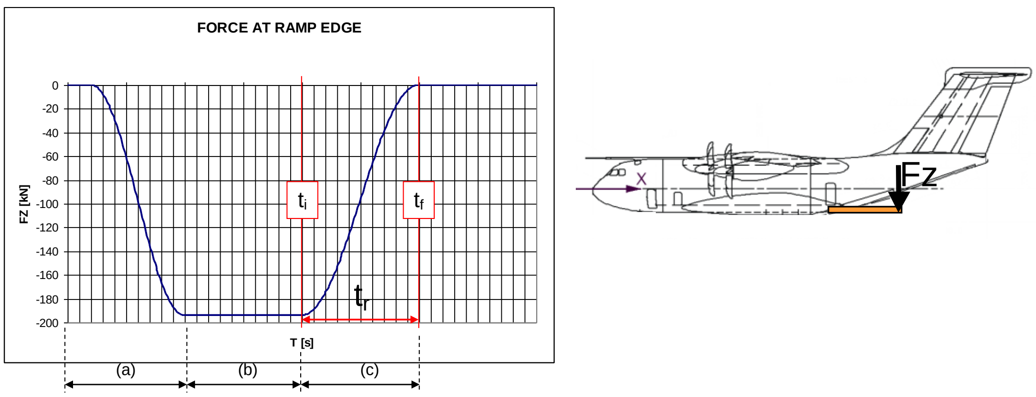


Figure 11: Force applied at ramp edge for release analysis and application point

Where:

(a): (1-cos) smooth shape to introduce the quasi-steady loads corresponding to the initial conditions.
(b): Initial conditions.
(c): Release event. (1-cos) assumed shape.
t_i: Time instant when the centre of gravity of the platform reaches the ramp edge.
t_f: Time instant when the platform leaves the ramp.
t_r: Platform rotation and sliding time.

During the release process, this load is balanced with a force and a moment in the wing-fuselage joint in order to ensure the equilibrium of forces in the aircraft.
Sensitivity analyses to the aircraft balancing and to the platform rotation and sliding time, tr, have been performed.
Aircraft balance: Four equilibrium conditions are considered.

1. Balance force is smoothly applied and then suddenly removed in a t_r = 0.001 sec.
2. Balance force is smoothly applied and smoothly removed in a tr = 1sec.
3. Balance force is smoothly applied and kept constant.
4. Balance force is zero.

Condition 2 has been selected, attending to the aircraft displacement and centre of gravity acceleration.
Platform release time: Five release time intervals, from 0.0001s to 1s are considered. The analysis time step is varied coherently. The selected time interval for the release analysis is 0.001s, which does not improve the results with respect to 0.0001s.
From MSC-NASTRAN SOL 112 analysis, linear modal transient response, fuselage, ramp and ramp and hinge total loads are obtained. Actuator linear loads are also obtained for comparison with the isolated ramp actuator non-linear loads.

6.3 Non-linear Release Analysis

For the non-linear release analysis, the vertical transient load is applied in the ramp frames, and for this purpose a detailed model of the clamped ramp with actuators and struts is used.
In the detailed ramp Finite Element model, same as in the A/C, the actuator and strut are modelled as NASTRAN CROD elements with constant stiffness. For the non-linear release analysis the strut non-linearity is modelled by substituting the strut element (CROD) by an equivalent non-linear force in two steps (see Figure 12 and Figure 13).
In a first step the strut element is replaced by equivalent linear forces for the process checking:

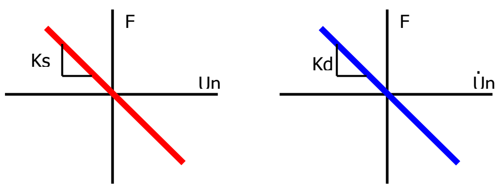


Figure 12: Equivalent linear forces for strut

In the second step the non-linear forces replace the struts: traction force is the same as the linear one and compression force is set to zero.

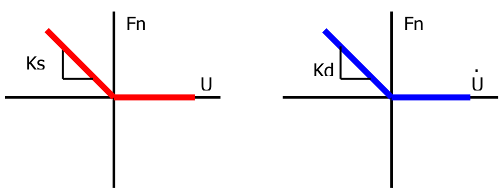


Figure 13: Equivalent non-linear forces for strut

When the platform moves rearward, once its centre of gravity lies outside the ramp, there is a rotation of the platform that separates it from the ramp except in the last frame. Therefore there is a sudden increase of the load at the last frame while the load vanishes at the rest of ramp frames (modelled with a 1-cos shape). This phenomenon is depicted in Figure 14 (time histories of the transient loads in all frames). The final rotation and sliding phase produces a load on the last frame which mathematical development is shown in §6.4.

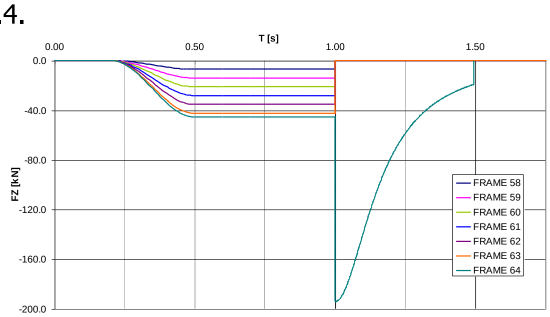


Figure 14: Loads applied in the ramp frames

From MSC-NASTRAN SOL 129 analysis, non-linear transient response, actuator and strut loads are obtained. Comparison between actuator and strut maximum loads in traction obtained with the aircraft model and linear approach and the ones obtained with the ramp isolated model and non-linear approach show good agreement.

6.4 Platform rotation and sliding governing equations

Figure 15 shows the platform while being dropped from the aircraft, detailing the acting forces and the relevant variables that define the platform position.

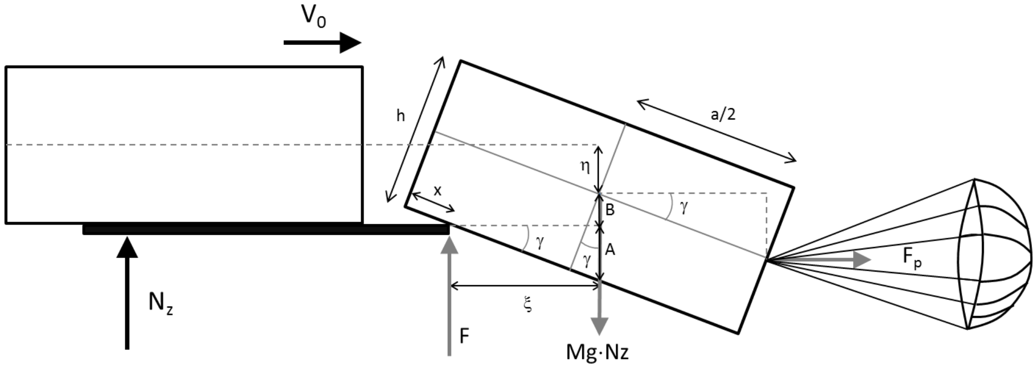


Figure 15: Platform being dropped from the aircraft

a	Platform length	F_p	Parachute force (taken as 40% of the platform weight)
F	Ramp force	x	Platform length remaining inside the aircraft while being dropped
H	Platform height	η	Platform vertical incremental displacement (positive upwards)
M	Platform mass	ξ	Platform horizontal displacement (relative to the aircraft ramp corner)
N_z	Aircraft local load factor	γ	Platform rotation angle
V_0	Platform initial velocity	g	Gravity (9.81 m/s^2)

Following equations describe the platform motion:

1. The horizontal displacement ξ is calculated by stating the x-axis forces equilibrium as

$$M\ddot{\xi} = F_p \text{ with } \xi(0) = 0 \text{ and } \dot{\xi}(0) = V_0 \quad (1)$$

which is easily integrated to obtain the time-evolution of the horizontal displacement ξ(t)

$$\xi(t) = \frac{F_p}{2M}t^2 + V_0 t \quad (2)$$

2. The boundary condition of pivoting around the corner of the aircraft ramp is stated as follows. As shown in Figure 15, the following geometrical relation applies if the platform pivots around the ramp corner

$$(A + B)\cos\gamma = \frac{h}{2} \rightarrow A\cos\gamma + B\cos\gamma = \frac{h}{2} \quad (3)$$

By considering the relations $\tan\gamma = \frac{A}{\xi}$ and $B = \eta + \frac{h}{2}$, the previous equation is written as

$$\xi\sin\gamma + (\eta + \frac{h}{2})\cos\gamma = \frac{h}{2} \quad (4)$$

which is two-times derived with respect to the time to obtain

$$\frac{d}{dt}: \dot{\xi}\sin\gamma + \xi\dot{\gamma}\cos\gamma + \dot{\eta}\cos\gamma - (\eta + \frac{h}{2})\dot{\gamma}\sin\gamma = 0 \quad (5)$$

$$\frac{d^2}{dt^2}: \left[\xi\cos\gamma - \left(\eta + \frac{h}{2}\right)\sin\gamma\right]\ddot{\gamma} + \cos\gamma\ddot{\eta} = 2\dot{\gamma}\dot{\eta}\sin\gamma + \left(\eta + \frac{h}{2}\right)\dot{\gamma}^2\cos\gamma$$

$$-\ddot{\xi}\sin\gamma - 2\dot{\xi}\dot{\gamma}\cos\gamma + \xi\dot{\gamma}^2\sin\gamma \quad (6)$$

3. z-axis forces equilibrium:

$$F - MgN_z = M\ddot{\eta} \rightarrow F = M(gN_z + \ddot{\eta}) \tag{7}$$

4. γ-rotation dynamic equation:

$$I\ddot{\gamma} = F\xi - \frac{a}{2}\sin\gamma F_p = M\xi(gN_z + \ddot{\eta}) - \frac{a}{2}\sin\gamma F_p \rightarrow I\ddot{\gamma} - M\xi\ddot{\eta} = M\xi gN_z - \frac{a}{2}\sin\gamma F_p \tag{8}$$

where the expression for the ramp force F obtained from (7) has been substituted.

The equations (6) and (8) can be written in matrix form as

$$\begin{bmatrix} I & -M\xi \\ \xi\cos\gamma - (\eta + \frac{h}{2})\sin\gamma & \cos\gamma \end{bmatrix} \begin{Bmatrix} \ddot{\gamma} \\ \ddot{\eta} \end{Bmatrix} = \begin{Bmatrix} M\xi gN_z - \frac{a}{2}\sin\gamma F_p \\ 2\dot{\gamma}\dot{\eta}\sin\gamma + (\eta + \frac{h}{2})\dot{\gamma}^2\cos\gamma - \ddot{\xi}\sin\gamma - 2\dot{\xi}\dot{\gamma}\cos\gamma + \xi\dot{\gamma}^2\sin\gamma \end{Bmatrix} \tag{9}$$

or in condensed form

$$[L_1]\begin{Bmatrix} \ddot{\gamma} \\ \ddot{\eta} \end{Bmatrix} = \{L_2\} \tag{10}$$

This second-order matrix equation is changed to a first-order non-linear differential form by introducing the state-space variable {y}, defined as

$$\{y\} = \begin{Bmatrix} \gamma \\ \eta \\ \dot{\gamma} \\ \dot{\eta} \end{Bmatrix} \tag{11}$$

in such a way that equation (9) is split into two matrix-form differential equations

$$\frac{d}{dt}\begin{Bmatrix} y(1) \\ y(2) \end{Bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}\{y\} \tag{12}$$

$$\frac{d}{dt}\begin{Bmatrix} y(3) \\ y(4) \end{Bmatrix} = [L_1]^{-1}[L_2] \tag{13}$$

That combined lead to the first-order non-linear differential equation that is solved to obtain the motion of the platform

$$\frac{d}{dt}\begin{Bmatrix} \gamma \\ \eta \\ \dot{\gamma} \\ \dot{\eta} \end{Bmatrix} = f(t, \xi, \dot{\xi}, \ddot{\xi}, \gamma, \eta, \dot{\gamma}, \dot{\eta}) \tag{14}$$

$$\xi(0) = 0 \text{ and } \dot{\xi}(0) = V_0 \tag{15}$$

$$\eta(0) = \dot{\eta}(0) = 0 \tag{16}$$

Equations (14) to (16) are solved using the MATLAB R2012b commercial software.

6.5 Comparison between linear and non-linear response

The non-linear release methodology has been checked in several steps. With the detailed ramp Finite Element model clamped at the hinge fittings and at the actuator and strut fuselage ends, the process has been as follows:

- Transient linear response using a linear solution (SOL112).
- Transient linear response using a non-linear solution (SOL129). The strut is modelled with the original linear CROD element.
- Transient linear response using a non-linear solution (SOL129) and a linear force replacing the original linear CROD strut element.
- Transient non-linear response using a non-linear solution (SOL129) and a non-linear force replacing the original linear CROD strut element.

The first three steps provide equal results, thus guaranteeing the procedure robustness. The actuator and strut non-linear loads, as expected, are similar to the linear loads while in traction and only different while the actuators are in compression.

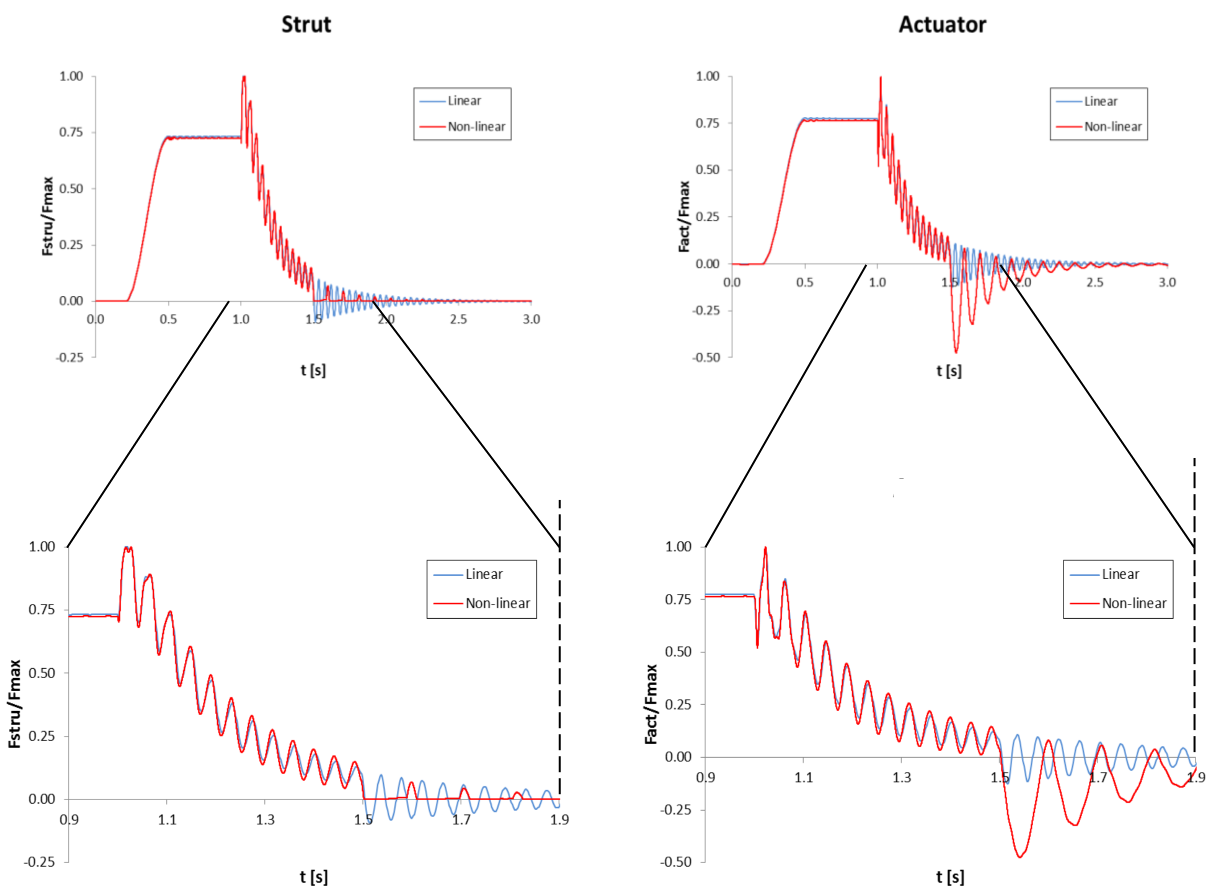


Figure 16: Comparison between linear and nonlinear analysis

7 FLIGHT TEST

7.1 Flight test instrumentation

A flight testing campaign is scheduled after this paper writing. This means that unfortunately its results will not be available for being presented.
Flight testing involves the aerial delivery of cargo from the rear of the aircraft, where the cargo traverses over the cargo ramp floor. For this aerial delivery to occur the cargo ramp must be fully open and the cargo door must be in its up-latched position.
The primary objective of these tests is to check the load assumptions associated with an aerial delivery event. In addition, the cargo extraction speed and its effect on the local aircraft g-level are to be investigated, where the time required for a payload to traverse the cargo ramp is of specific interest.
For load measurement, strains from the gauges will be used. From these strains it is anticipated that the aerial delivery loads can be deduced using the associated strain/load calibration information, where such calibration has been performed prior to flight test. The main areas of interest for load measurement are the interfaces between the cargo ramp and the rear fuselage to which the cargo ramp is attached and supported:

- Ramp hinges, struts and actuators
- Payload mass, CG and speed along the ramp and its effect of on the local aircraft g-level.

Flight testing will include gravity drops and parachute extraction.

7.2 Flight test clearance

Dedicated clearance analyses will be performed prior to the test campaign, devoted to prevent any load exceedance due to the progressively increasing weight of each platform extraction. The analysis will consist of simulating realistic deliveries at typical flight points with increasing platform weights, thus providing the expected evolution with platform weight of the parameters to be measured.
Those analyses will allow giving a general clearance to the heaviest platform to be extracted, 16 tonnes, and also to track the measured data and compare it with the analytical predictions.

8 CONCLUSIONS AND FUTURE WORK

The A400M methodology for aerial delivery dynamic loads has been presented. This methodology has been used for the preliminary A400M certification analyses, which will be completed with the loads model validation. For this purpose dedicated flight test with progressively increasing weight platform extraction are foreseen, which will be monitored and compared with dedicated clearance analyses.
Following steps will be focused on the dynamic loads model validation, based on simulation results comparison with flight test data. Dedicated analyses to reproduce flight conditions, payload distribution and release conditions of flight test will be carried out and compared with flight test results, in the same way as it was done in [1].

9 REFERENCES

[1] Pastor, G., Pérez-Galán, J.L., Climent, H., Rodriguez-Jimenez, A.J., Pérez de la Serna, A. and Veguillas, S. "A400M Tests used for Dynamic Loads Model Validation," Proceedings of the International Forum of Aeroelasticity and Structural Dynamics *IFASD* 2011. Paris, 27-30 June 2011.

[2] Climent, H., Maderuelo, C., Oliver, M., Claverías, S and Martinez-Lopez, P. "Military Transport Aircraft Dynamic Loads," Proceedings of the International Forum of Aeroelasticity and Structural Dynamics *IFASD* 2011. Paris, 27-30 June 2011.

[3] Pérez de la Serna, A., Rodriguez Jimenez, A.J., Oliver, M. and Climent, H. "Aerial Delivery Dynamic Loads". Proceedings of the International Forum of Aeroelasticity and Structural Dynamics *IFASD* 2015. Saint Petersburg, Russia, 28 June -2 July 2015.

[4] Karpel, M., Shousterman, A., Climent, H. and Perez de la Serna, A. "Dynamic Aeroservoelastic Response with Nonlinear Structural Elements". *IFASD* 2011. Paris, 27-30 June 2011.

[5] *EASA* A400M Military Certification Review Item C-16, "Aerial Delivery Load Conditions". 28 October 2004.

[6] Llamazares, J. and Climent, H. "A400M LAP11B: Open Ramp and Aerial Delivery Discrete Tuned Gust Loads". *Airbus DS* Report NT-A4-AA0-08021. 19 December 2008.

[7] Climent, H., Maderuelo, Anguita, L., Rodriguez-Jimenez, A.J., Perez de la Serna, A., Shousterman, A. and Karpel, M. "Dynamic Loads Analysis for the A400M Transport with Nonlinear Control System". *IFASD* 2011. Paris, 27-30 June 2011.