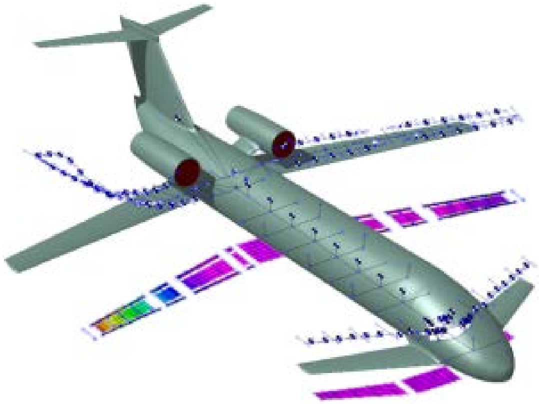
Sizing manoeuvres in NeoCASS/GUESS

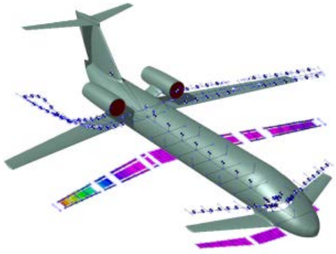


April 2020

Since NeoCASS 2.2.809
Since NeoRESP 1.0.104

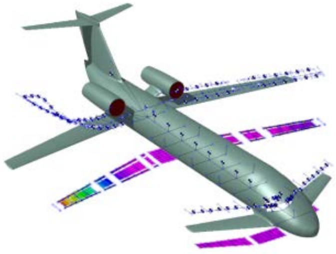
Introduction

- NeoCASS implements two approaches to define the maneuvers determining critical sizing loads used for the structural sizing: **user-defined** maneuvers and **automatic definition** on the base of the certification rules (EASA CS23 and CS25).
- The first approach is highly recommended for the initial check of the model and to verify that the sizing process ends up successfully
- The second approach allows for a more accurate definition of the most relevant set of maneuvers. However:
  - It does not include ALL the requested load conditions, but a limited even if significant subset
  - The load conditions are usually defined as function of speed and configuration for specific (usually extreme) values of the *V-n* diagram: the intermediate load conditions spanning the entire *V-n* diagram are not automatically defined



TRIM card

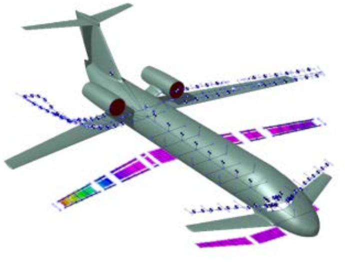
- Even in the case of using the complete set of load conditions they represent the frozen maneuvers only. The dynamic maneuvers have to be added.
- NeoCASS/GUESS can be used for the frozen maneuvers only, while NEoRESP can be used for the dynamic ones (typically Gust response)
- The description of each maneuver is defined through the TRIM card, saved in a user or automatic defined .inc text file.
- Any file can include different maneuvers: each TRIM card is defined with a different Identification Number ID
- The syntax of the TRIM card is very similar to one adopted in Nastran, with small differences



(NASTRAN) TRIM card syntax

1	2	3	4	5	6	7	8	9	10
TRIM	SID	MACH	Q	LABEL1	UX1	LABEL2	UX2	AEQR	
	LABEL3	UX3	-etc.-						

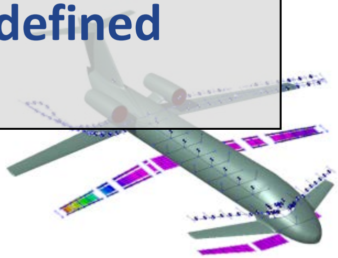
SID	Trim set identification number. (Integer > 0). See remarks 1 and 2.
MACH	Mach number. (Real $\geq$ 0.0 and $\neq$ 1.0)
Q	Dynamic pressure. (Real > 0.0)
LABELi	The label identifying aerodynamic trim variables defined on an AESTAT or AESURF entry. (Character)
UXi	The magnitude of the aerodynamic extra point degree-of-freedom. (Real)
AEQR	Flag to request a rigid trim analysis (Real $\geq$ 0.0 and $\leq$ 1.0; Default =1.0). A value of 0.0 provides a rigid trim analysis, see Remark 5.



TRIM Problem Definition

#	NAME	Description	Unit
1	AILERON	CONTROL SURFACE	RADIANS
2	ANGLEA	RIGID BODY	RADIANS
3	SIDES	RIGID BODY	RADIANS
4	ROLL	RIGID BODY	NONDIMEN. RATE
5	PITCH	RIGID BODY	NONDIMEN. RATE
6	YAW	RIGID BODY	NONDIMEN. RATE
7	ELEV	CONTROL SURFACE	RADIANS
8	RUDDER	CONTROL SURFACE	RADIANS
9	URDD1	RIGID BODY	LENGTH/S/S
10	URDD2	RIGID BODY	LENGTH/S/S
11	URDD3	RIGID BODY	LENGTH/S/S
12	URDD4	RIGID BODY	RADIANS/S/S
13	URDD5	RIGID BODY	RADIANS/S/S
14	URDD6	RIGID BODY	RADIANS/S/S

14 potential variables but 6 equations only! 8 variables must be defined using the TRIM card to define a consistent trim problem



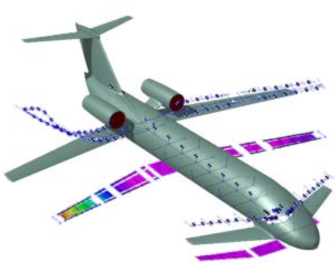
Symmetric models

- The aerodynamic solver developed enables to exploit geometry symmetry to reduce the algebraic system for Υ circulation to the minimum possible size. The general problem for the left L and right R side of the aircraft reads:

$$\begin{bmatrix} \mathbf{A}_{LL} & \mathbf{A}_{LR} \\ \mathbf{A}_{RL} & \mathbf{A}_{RR} \end{bmatrix} \begin{Bmatrix} \gamma_L \\ \gamma_R \end{Bmatrix} = \begin{Bmatrix} \alpha_L \\ \alpha_R \end{Bmatrix}$$

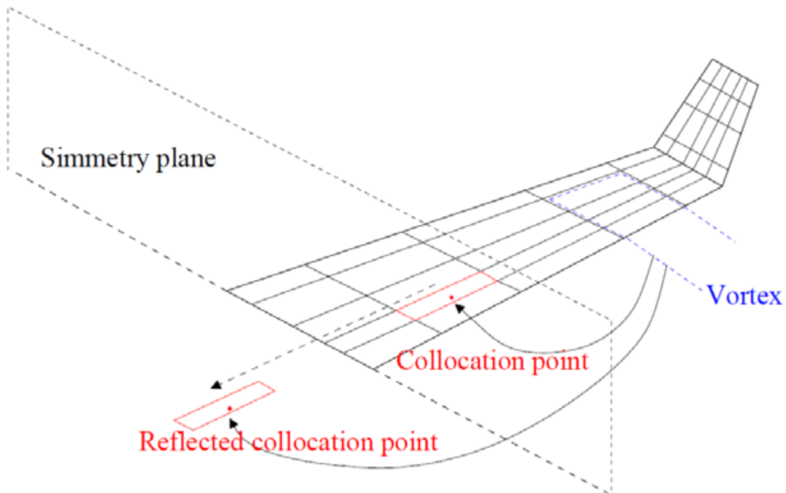
- where $\boldsymbol{A}_{ij}$ represents the induced velocity matrix due to horse-shoe vortices of the side *j* on the side *i*, α_i the downwash boundary condition on the side *i* and Υ_i the circulation on the panels of side *i*. Thus, if the problem has symmetry along the vertical plane, $\Upsilon_L = \Upsilon_R$ and only half of the model is required. For example if the right side of the model is used:

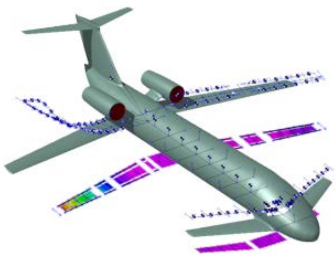
$$(\mathbf{A}_{RR} + \mathbf{A}_{LR})\,\gamma_R = \mathbf{A}_{F_V} = \alpha_R$$



Symmetric models (2)

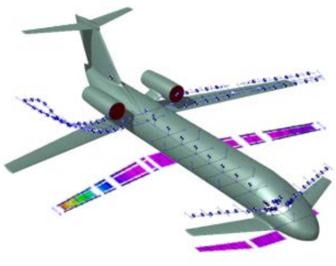
- By doing this way, the resulting algebraic system for the full model is governed by the matrix A_{F_V} which is characterized by half of the total panels which should be used.
- The following Figure shows how the symmetry condition works, by simply considering the influence of the modelled vortices on the mirrored collocation points. This term is exactly the same as considering the influence of the mirrored vortices on the modelled collocation points.



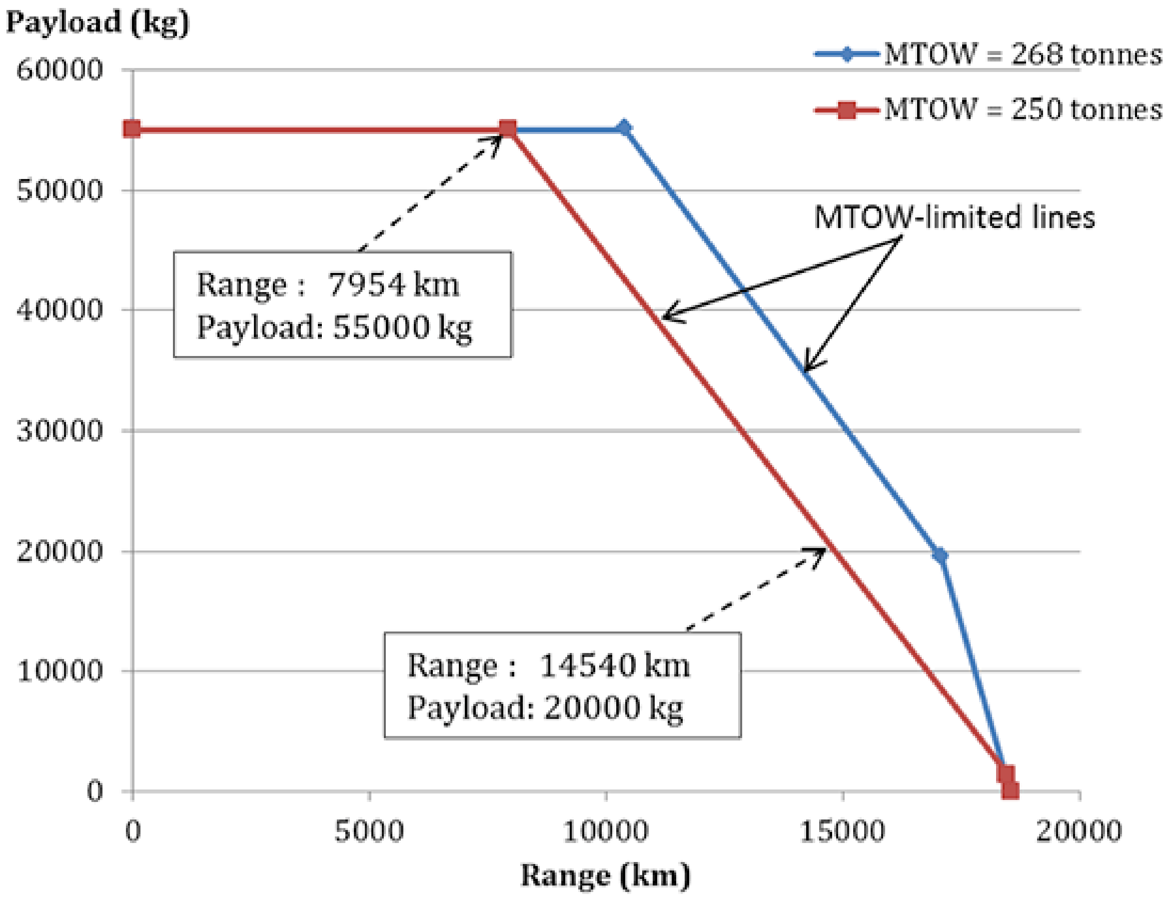


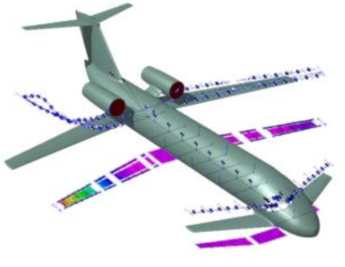
How many MASS configurations?

- Different mass configurations can be created before running GUESS through the dedicated GUI panel, by changing percentage and span-fuselage position of FUEL and PAX
- GUESS automatically generates as many text files named **`*_CONM_CONF*.inc`** as the number of mass configurations created
- But how many mass configurations have to be taken into account?
- **General rule**. For a complete sizing at least the following configurations have to be taken into account:
    - o OEM
    - o MTOW
    - o Max fuel (with corresponding pax)
    - o Min fuel (with corresponding pax)
    - o Max fuel with payload in ahead position
    - o Max fuel with payload in rear position

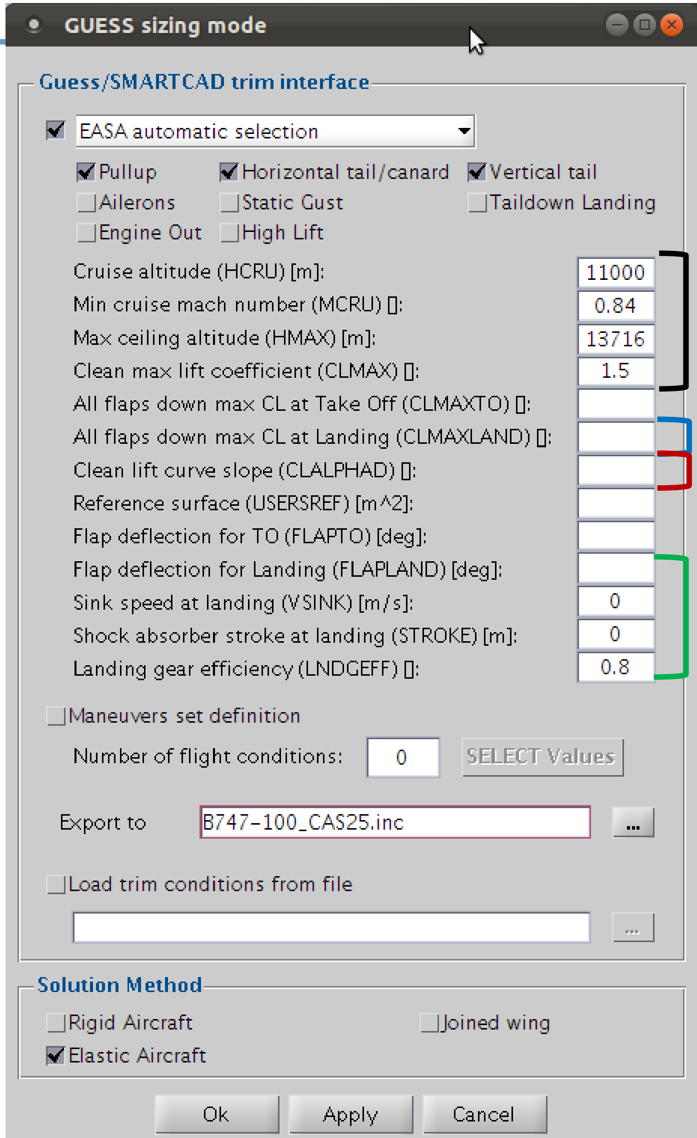


Example of Payload diagram





Optional vs compulsory parameters



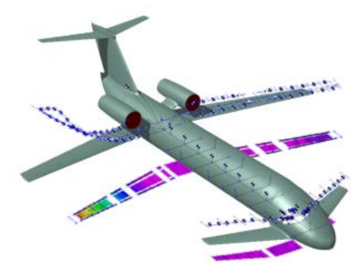
To compute V-n and Placard diagram

To size wing, fuselage and tail planes with balanced maneuvers

To size the high lift devices

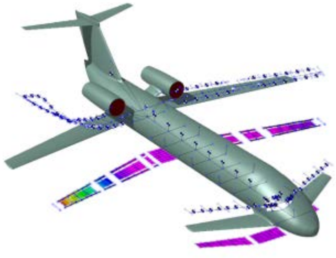
To define the gust (static) responses

To define the landing maneuvers



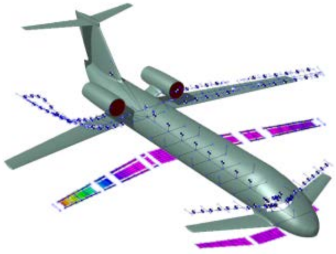
Sizing Maneuvers Available (EASA CS23/25)

- MANOEUVRING BALANCED CONDITIONS
- HIGH LIFT DEVICES
- HORIZONTAL TAIL SURFACES
- YAW MANOEUVRE CONDITIONS
- ROLLING CONDITIONS
- GUST CONDITIONS
- TAIL DOWN LANDING
- ENGINE OUT CONDITIONS



Legenda

- GREEN: CS25 requirement correctly implemented
- BLUE: CS23 requirement correctly implemented
- RED: CS25 requirement NOT correctly implemented and approximated with the corresponding CS23 requirement
- **TEXT bold blue**, values in the TRIM card specific for the maneuver

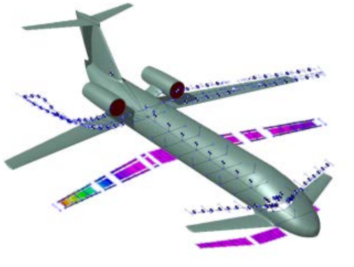


MANOEUVRING BALANCED CONDITIONS

CS 25.331 b / CS 23.333

"Manoeuvring balanced conditions. Assuming the aeroplane to be in equilibrium with zero pitching acceleration, the manoeuvring conditions A through I on the manoeuvring envelope in CS 25.333 (b) must be investigated."

"Compliance with the strength requirements of this subpart must be shown at any combination of airspeed and load factor on and within the boundaries of a flight envelope (similar to the one in sub-paragraph (d)) that represents the envelope of the flight loading conditions specified by the manoeuvring and gust criteria of sub-paragraphs (b) and (c) respectively."



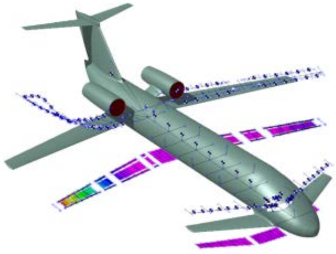
Nastran like TRIM card

TRIM	Ntrim	1	Mach	Altitude	SIDES	0,0	ROLL	0,0
	PITCH	**p**	YAW	0,0	URDD2	0,0	THRUST	0,0
	URDD4	0,0	URDD5	0,0	URDD6	0,0	CLIMB	0,0
	BANK	0,0	HEAD	0,0	**URDD3**	**Zacc**		

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: Flap deflection = 0°) .

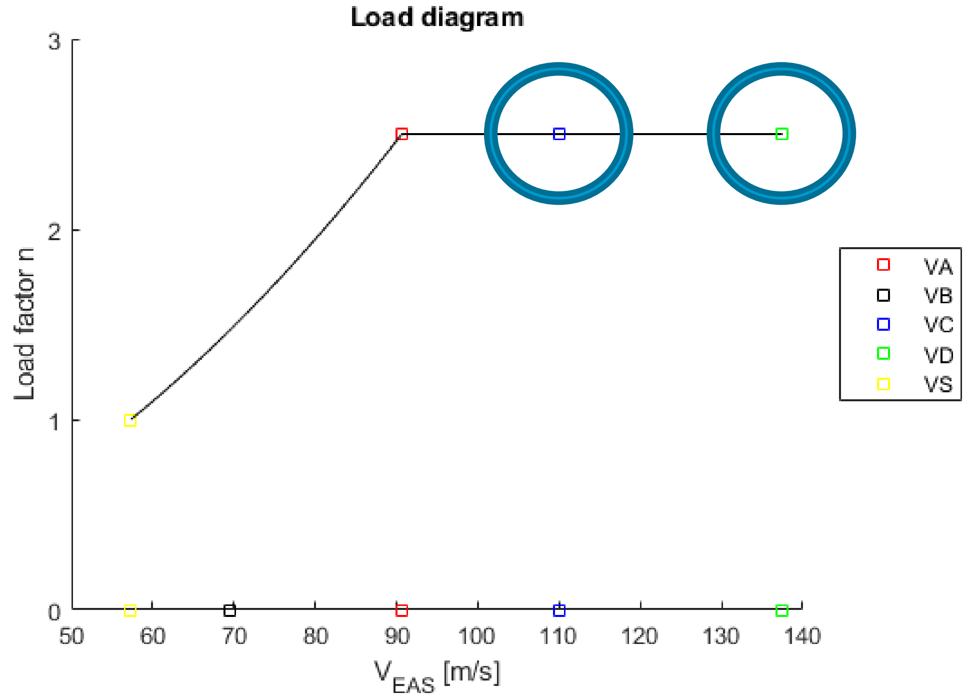
$$Zacc = Max\ load\ factor\ *\ 9{,}81\ \mathrm{m}/s^2$$

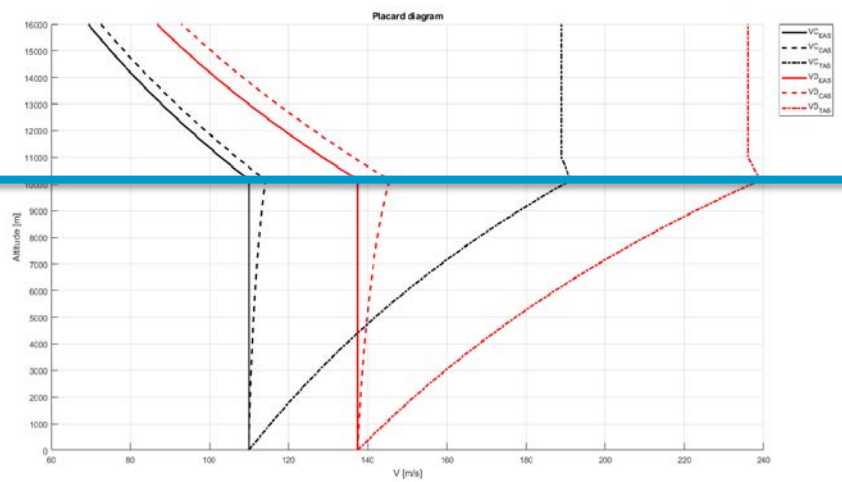
$$p = \frac{9{,}81(Nmax - 1)\ c_{ref}}{2{v_{ref}}^2}$$



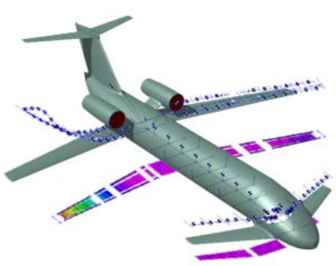
4 loading conditions

Mach number	Altitude
MD	0 m
MD	HD
MC	0 m
MC	HC





HC ~ HD



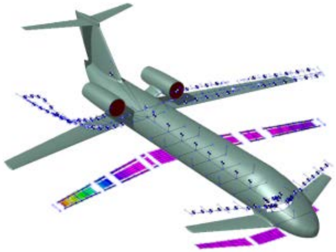
HIGH LIFT DEVICES

CS 25.345 / CS 23.345

“(a) If flaps or similar high lift devices are to be used for take-off, approach or landing, the aeroplane, with the flaps fully extended at VF, is assumed to be subjected to symmetrical manoeuvres and gusts within the range determined by

(1) Manoeuvring to a positive limit load factor of 2·0; and

(2) Positive and negative gusts of 7.62 m/sec (25 ft/sec) EAS acting normal to the flight path in level flight.”



Nastran like TRIM card (1)

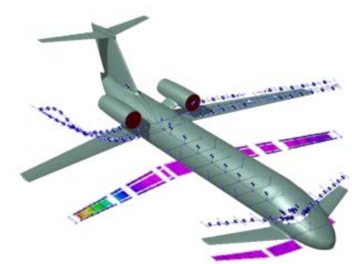
TRIM	Ntrim	1	Mach	Altitude	SIDES	0,0	ROLL	0,0
	PITCH	0,0	YAW	0,0	URDD2	0,0	THRUST	0,0
	URDD4	0,0	URDD5	0,0	URDD6	0,0	CLIMB	0,0
	BANK	0,0	HEAD	0,0	**URDD3**	**Zacc**	**FLAP**	**Landing deflection**

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: no other deflections imposed) .

$$\text{Zacc} = 2 * \ 9{,}81\ \text{m/s}^2$$

$$\text{Altitude} = 0\ \text{m}$$

Mach corresponding to VF



Nastran like TRIM card (2)

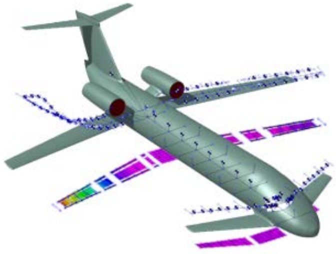
TRIM	Ntrim	1	Mach	Altitude	SIDES	0,0	ROLL	0,0
	PITCH	0,0	YAW	0,0	URDD2	0,0	THRUST	0,0
	URDD4	0,0	URDD5	0,0	URDD6	0,0	CLIMB	0,0
	BANK	0,0	HEAD	0,0	**URDD3**	**Zacc**	**VGUST**	**7,62**
	FLAP	**Landing deflection**						

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: no other deflections imposed) .

$$\mathrm{Zacc} = 2 * 9{,}81\ \mathrm{m/s^2}$$

$$\text{Altitude} = 0\ \text{m}$$

Mach corresponding to VF



HORIZONTAL TAIL SURFACES

CS 25

CS 25 requires horizontal tail surfaces conditions to be taken into account with dynamic analyses (CS 25.331 (c)). CS 23 simplified formulations are used for CS 25, too.

CS 23.423

"(b) A sudden aft movement of the pitching control at speeds above VA, followed by a forward movement of the pitching control resulting in the following combinations of normal and angular acceleration:

Nose-up pitching:

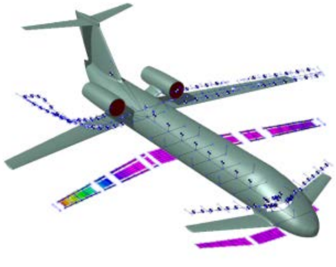
Angular: + 39 V nm (nm 1.5)

Normal: 1g

Nose-down pitching:

Angular: − 39 V nm (nm 1.5)

Normal: Nmax"

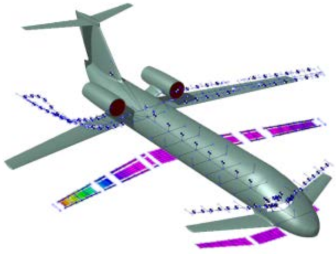


Nastran like TRIM card

TRIM	Ntrim	1	Mach	Altitude	SIDES	0,0	ROLL	0,0
	PITCH	0,0	YAW	0,0	URDD2	0,0	THRUST	0,0
	URDD4	0,0	BANK	0,0	URDD6	0,0	CLIMB	0,0
	HEAD	0,0	**URDD3**	**Zacc**	**URDD5**	**Pacc**		

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: Flap deflection = 0°) .

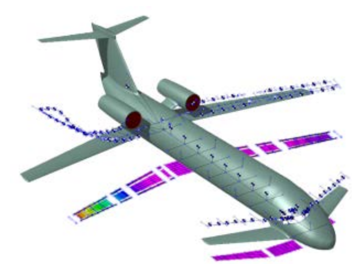
Altitude = 0 m



6 loading conditions

Speed	Normal acceleration	Angular acceleration
VA	9,81	+Pacc
VA	9,81*Nmax	-Pacc
VC	9,81	+Pacc
VC	9,81*Nmax	-Pacc
VD	9,81	+Pacc
VD	9,81*Nmax	-Pacc

$$\mathrm{Pacc} = \frac{39}{V}\mathrm{Nmax}(\mathrm{Nmax} - 1{,}5)$$

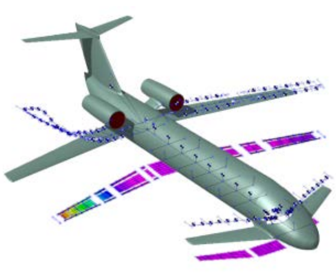


YAW MANOEUVRE CONDITIONS

CS 25.351/CS 23.351

“The aeroplane must be designed for loads resulting from the yaw manoeuvre conditions specified in sub-paragraphs (a) through (d) of this paragraph at speeds from VMC to VD. Unbalanced aerodynamic moments about the centre of gravity must be reacted in a rational or conservative manner considering the aeroplane inertia forces. In computing the tail loads the yawing velocity may be assumed to be zero. ”

“The aeroplane must be designed for yawing loads on the vertical surfaces resulting from the loads specified in CS 23.441 to 23.445. ”

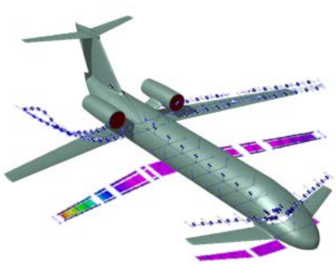


YAW MANOEUVRE CONDITIONS

CS 25.351 (a)/CS 23.441(a)(1)

"With the aeroplane in unaccelerated flight at zero yaw, it is assumed that the cockpit rudder control is suddenly displaced to achieve the resulting rudder deflection, as limited by: (1) the control system or control surface stops; or (2) a limit pilot force of 1335 N (300 lbf) from VMC to VA and 890 N (200 lbf) from VC/MC to VD/MD, with a linear variation between VA and VC/MC. "

"With the aeroplane in unaccelerated flight at zero yaw, it is assumed that the rudder control is suddenly displaced to the maximum deflection, as limited by the control stops or by limit pilot forces."

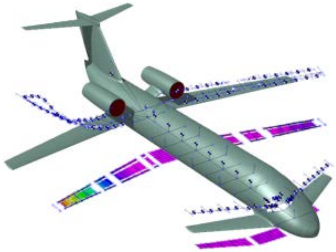


Nastran like TRIM card

TRIM	Ntrim	1	Mach	Altitude	HEAD	0,0	ROLL	0,0
	PITCH	0,0	YAW	0,0	SIDES	0,0	THRUST	0,0
	BANK	0,0	CLIMB	0,0	URDD5	0,0	**URDD3**	**Zacc**
	RUDDER	**Max Def**						

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: Flap deflection = 0°) .

Altitude = 0 m

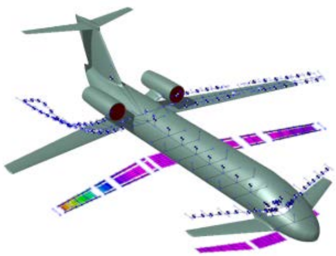


YAW MANOEUVRE CONDITIONS

CS 25.351 (b)/CS 23.441(a)(2)

"With the cockpit rudder control deflected so as always to maintain the maximum rudder deflection available within the limitations specified in sub-paragraph (a) of this paragraph, it is assumed that the aeroplane yaws to the overswing sideslip angle. "

"With the rudder deflected as specified in sub-paragraph (1), it is assumed that the aeroplane yaws to the overswing sideslip angle. In lieu of a rational analysis, an overswing angle equal to 1·5 times the static sideslip angle of sub-paragraph (3) may be assumed. "



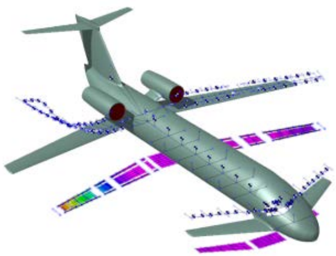
Nastran like TRIM card

TRIM	Ntrim	1	Mach	Altitude	HEAD	0,0	ROLL	0,0
	PITCH	0,0	YAW	0,0	**SIDES**	**Beta**	THRUST	0,0
	BANK	0,0	CLIMB	0,0	URDD5	0,0	**URDD3**	**Zacc**
	RUDDER	**Max Def**						

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: Flap deflection = 0°) .

Altitude = 0 m

Beta = 1,5 *15°

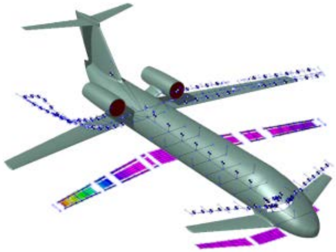


YAW MANOEUVRE CONDITIONS

CS 25.351 (d)/CS 23.441(a)(3)

"With the aeroplane yawed to the static equilibrium sideslip angle of sub-paragraph (c) of this paragraph, it is assumed that the cockpit rudder control is suddenly returned to neutral. "

"A yaw angle of 15° with the rudder control maintained in the neutral position (except as limited by pilot strength). "



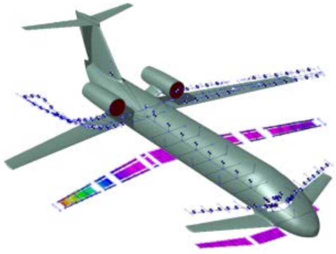
Nastran like TRIM card

TRIM	Ntrim	1	Mach	Altitude	HEAD	0,0	ROLL	0,0
	PITCH	0,0	YAW	0,0	**SIDES**	**Beta**	THRUST	0,0
	BANK	0,0	CLIMB	0,0	URDD5	0,0	**URDD3**	**Zacc**
	RUDDER	0,0						

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: Flap deflection = 0°) .

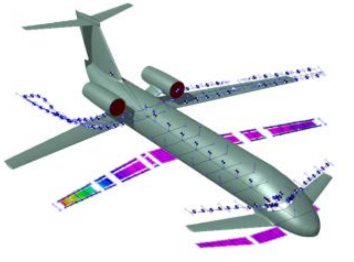
Altitude = 0 m

Beta = 15°



12 loading conditions

Regulation	Sides	Rudder	Speed
(a)	0°	+ Max def	VA
(a)	0°	- Max def	VA
(a)	0°	+ Max def	VS
(a)	0°	- Max def	VS
(b)	1,5*15°	+ Max def	VA
(b)	-1,5*15°	- Max def	VA
(b)	1,5*15°	+ Max def	VS
(b)	-1,5*15°	- Max def	VS
(d)	15°	0°	VA
(d)	-15°	0°	VA
(d)	15°	0°	VS
(d)	-15°	0°	VS

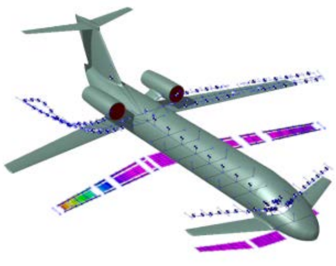


ROLLING CONDITIONS

CS 25.349/CS 23.349

“For the angular acceleration conditions, zero rolling velocity may be assumed in the absence of a rational time history investigation of the manoeuvre. (2) At VA, a sudden deflection of the aileron to the stop is assumed. ”

“Sudden maximum displacement of the aileron control at VA. Suitable allowance may be made for control system deflections. ”



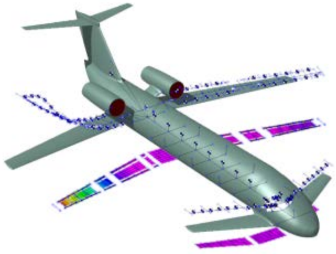
Nastran like TRIM card

TRIM	Ntrim	1	Mach	Altitude	HEAD	0,0	ROLL	0,0
	PITCH	**p**	YAW	0,0	SIDES	0,0	THRUST	0,0
	BANK	0,0	CLIMB	0,0	URDD5	0,0	**URDD3**	**Zacc**
	AILERON	**Max def**						

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: Flap deflection = 0°) .

Altitude = 0 m

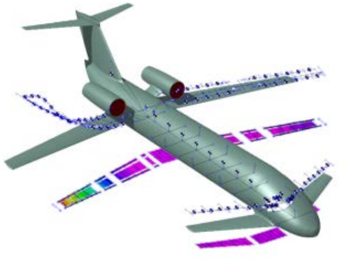
$$p = \frac{9{,}81(Nmax - 1)\, c_{ref}}{2{v_{ref}}^2}$$



4 loading conditions

Speed	Aileron	Load Factor
VA	+ Max def	1
VA	- Max def	2/3 Nmax
VA	+ Max def	1
VA	- Max def	2/3 Nmax

Zacc = Load Factor * 9,81 m/s^2



GUST CONDITIONS

CS 25

CS 23.333(c)

CS 25 requires gust conditions to be taken into account with dynamic analyses (CS 25.341). CS 23 simplified formulations are used for CS 25, too.

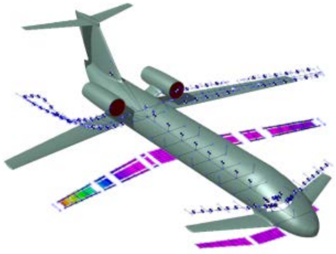
(c) In the absence of a more rational analysis the gust load factors must be computed as follows:

$$n = 1 \pm \frac{k_g \rho_o U_{de} V_a}{2(W/S)}$$

where –

$$k_g = \frac{0.88 \mu_g}{5.3 + \mu_g} \quad \text{= gust alleviation factor;}$$

$$\mu_g = \frac{2(W/S)}{\underline{\rho} \bar{C} a g} \quad = \text{ aeroplane mass ratio;}$$

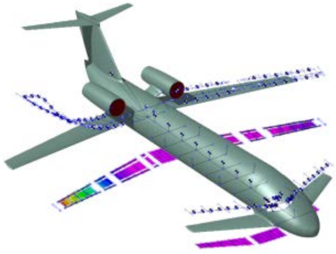


Nastran like TRIM card

TRIM	Ntrim	1	Mach	Altitude	SIDES	0,0	ROLL	0,0
	PITCH	0,0	YAW	0,0	URDD2	0,0	THRUST	0,0
	URDD4	0,0	URDD5	0,0	URDD6	0,0	CLIMB	0,0
	BANK	0,0	HEAD	0,0	**URDD3**	**Zacc**	**VGUST**	**gust**

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: Flap deflection = 0°) .

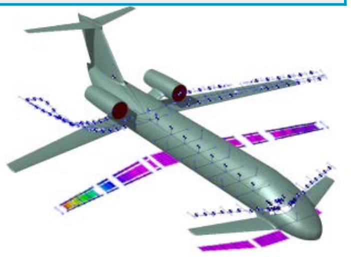
$$Zacc = 9{,}81\ m/s^2$$



6/9 loading conditions

CS 25		
Speed	Gust	Altitude
VC	17,08 m/s	0 m
VC	13,42 m/s	4575 m
VC	7,93 m/s	15250 m
VD	8,54 m/s	0 m
VD	6,71 m/s	4575 m
VD	3,97 m/s	15250 m

CS 23		
Speed	Gust	Altitude
VB	20,13 m/s	0 m
VB	20,13 m/s	4575 m
VB	11,59 m/s	15250 m
VC	17,08 m/s	0 m
VC	17,08 m/s	4575 m
VC	7,93 m/s	15250 m
VD	8,54 m/s	0 m
VD	8,54 m/s	4575 m
VD	3,97 m/s	15250 m

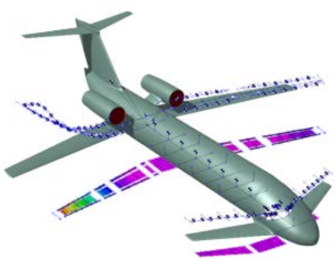


TAIL DOWN LANDING

CS 25.481/ CS 23.481

“In the tail-down attitude, the aeroplane is assumed to contact the ground at forward velocity components, ranging from VL1 to VL2 , parallel to the ground under the conditions prescribed in CS 25.473”

“For a tail down landing, the aeroplane is assumed to be in the following attitudes: (1) For aeroplanes with tail wheels, an attitude in which the main and tail wheels contact the ground simultaneously. (2) For aeroplanes with nose wheels, a stalling attitude, or the maximum angle allowing ground clearance by each part of the aeroplane, whichever is less. ”



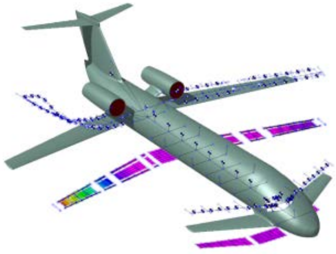
Nastran like TRIM card

TRIM	Ntrim	1	Mach	Altitude	SIDES	0,0	ROLL	0,0
	PITCH	0,0	YAW	0,0	URDD2	0,0	THRUST	0,0
	URDD4	0,0	URDD5	0,0	URDD6	0,0	CLIMB	0,0
	BANK	0,0	HEAD	0,0	**URDD3**	**Zacc**	**VSINK**	**Vsink**
	STROKE	**Stroke**	**LNDGEFF**	**Eff**				

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: no other deflections imposed) .

$$Zacc = 9{,}81\cos\left(\frac{Vsink}{Vland}\right) m/s^2$$

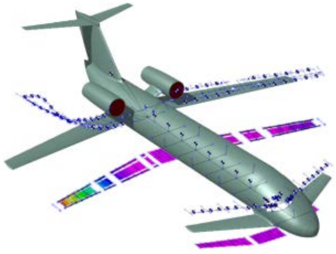
Altitude = 0 m



2/1 loading condition(s)

CS 25	
Speed	Vsink
Vland	3,05 m/s
Vland	1,83 m/s

CS 23	
Speed	Vsink
Vland	0,92 m/s

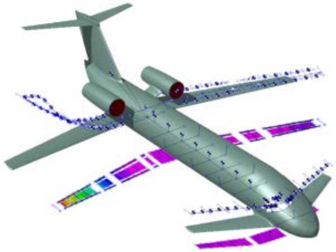


ENGINE OUT CONDITIONS

CS 25.121/CS 23.67

“The aeroplane must be designed for the unsymmetrical loads resulting from the failure of the critical engine. ”

“Turbopropeller aeroplanes must be designed for the unsymmetrical loads resulting from the failure of the critical engine including the following conditions in combination with a single malfunction of the propeller drag limiting system, considering the probable pilot corrective action on the flight controls. ”



Nastran like TRIM card

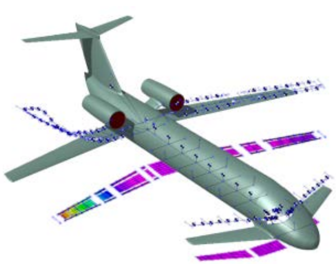
TRIM	Ntrim	1	Mach	Altitude	ROLL	0,0	THRUST	0,0
	PITCH	0,0	YAW	0,0	URDD2	0,0	CLIMB	0,0
	URDD4	0,0	URDD5	0,0	URDD6	0,0	BANK	0,0
	HEAD	0,0	URDD3	**Zacc**	**FLAP**	**Takeoff**		

+ control surfaces deflections imposed by the user, depending on aircraft configuration (Default: no other deflections imposed) .

+ MOMENT coming from max critical engine power not balanced by the other one (failure condition).

$$Zacc = 9{,}81\cos(\text{atan}(ClimbGrad))\, m/s^2$$

Altitude = 0 m



0/1/2 loading condition(s)

	2 engines	3 engines	4 engines
CS 23	1 engine failure	-	-
CS 25	1 engine failure	1 engine failure	2 engines failure