

## Ground Cycle Load Profile

During ground cycling, the weight of the doors and cross winds result in moment loads reacted along the RGA driveline. This document calculates RGA driveline moments based on weight data provided in ICM T-243-DC-063006, Enclosure (1) Word Document "prelim\_door\_mass\_prop.doc" provided by Boeing on June, 30 2006.

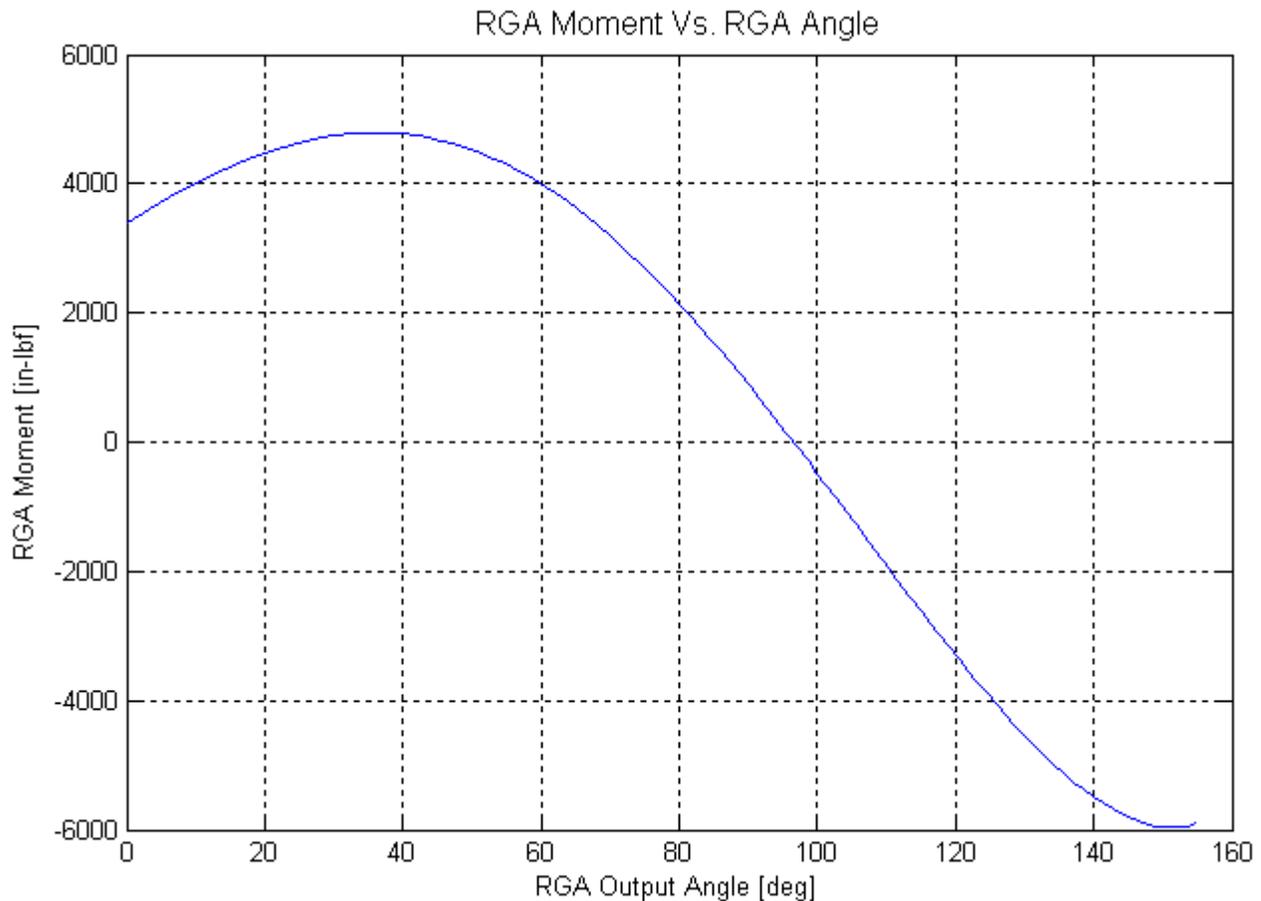
Cross wind loading is assumed to act on the projected area of one door with the Boeing recommended speed of 60 knots. It is assumed that the door facing the oncoming wind shields the other door from 100% of the wind load. In reality, some percentage of the wind hitting the other door would generate a door opening moment, partially cancelling the door closing moment.

Moment arms, angles and other geometric measurements were taken from Boeing's Catia weapons bay solid model layout provided on July 18, 2006.

### 1. *Moment About RGA Driveline Due to Door Weight*

The moment about the centerline of the rotary geared actuators (RGA) was determined based on the weight of the inner and outer door panels as shown in the figure on the next page. The moment due to the weight of the struts were assumed negligible. Goosenecks weight was assumed to be included in the Boeing provided weight and CG location of the outer door.

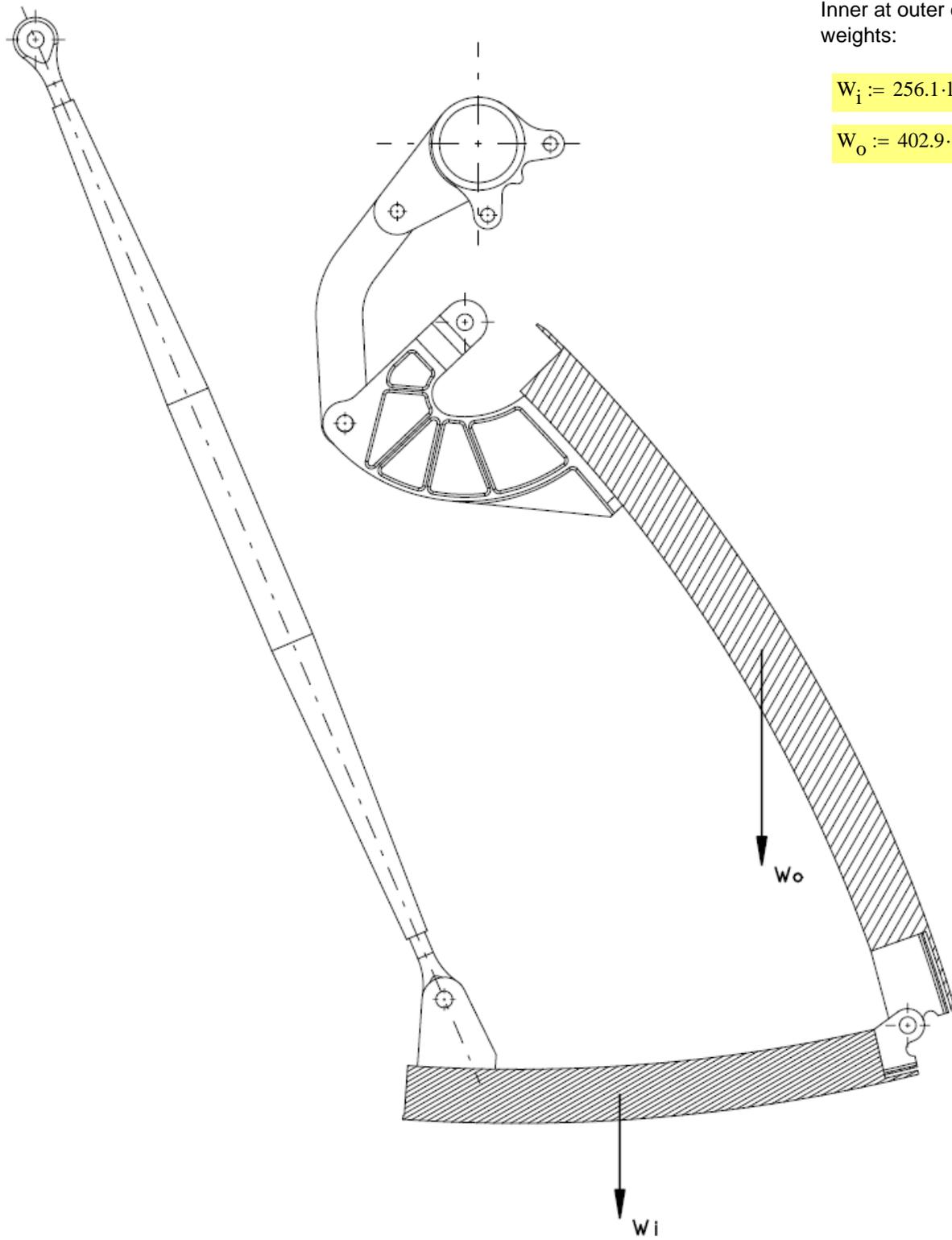
The moment loads (per door) due to door weight were computed for door positions from closed (0 degrees) to fully open (95 degrees) as shown in the figure below.



$M_{RGA\_max} := 4800 \cdot \text{in} \cdot \text{lbf}$  at 36.3 deg RGA output angle (15 deg door angle) (door opening load)

$M_{RGA\_min} := -6000 \cdot \text{in} \cdot \text{lbf}$  at 151.9 deg RGA output angle (93 deg door angle) (door closing load)

The following free body diagrams (FBD) in this section were used to compute RGA moment at the 93 degree door position.



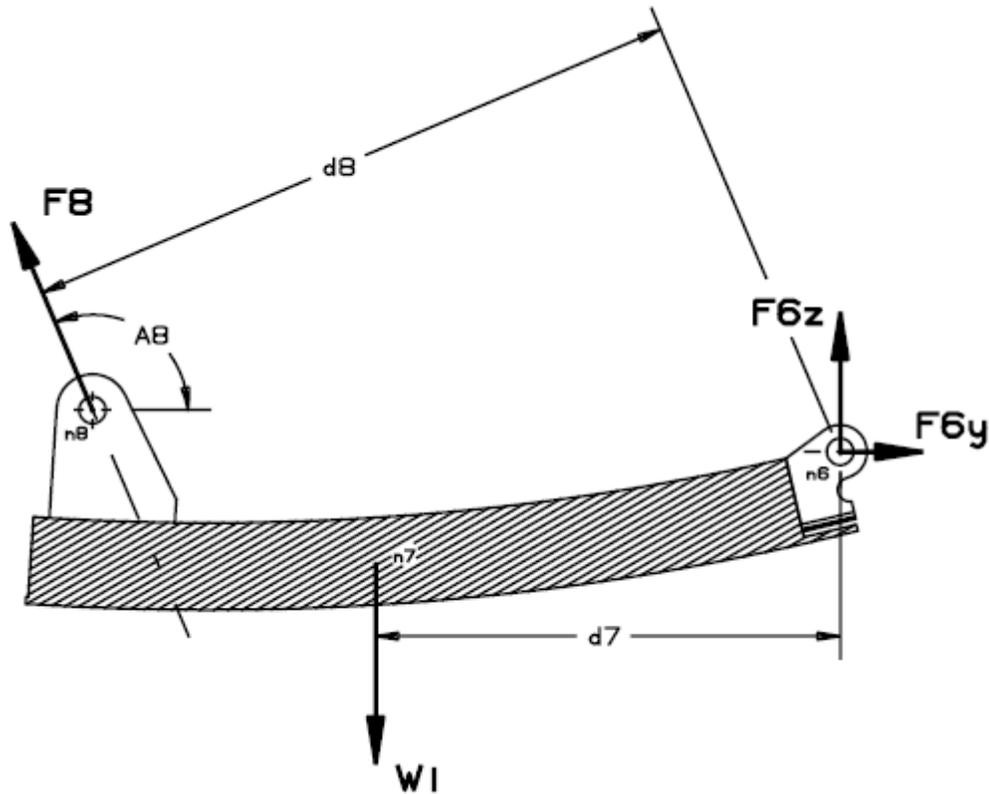
Inner at outer door panel weights:

$$W_i := 256.1 \cdot \text{lbf}$$

$$W_o := 402.9 \cdot \text{lbf}$$

### 1.1 Loads on Inner Door Panel

The loads acting on the inner door panel were found using the following FBD:



$$\sum M_6 = W_1 \cdot d_7 + F_8 \cdot d_8 = 0$$

$$W_1 = 256.1 \text{ lbf} \quad d_7 := 12.1821 \cdot \text{in} \quad d_8 := 12.7905 \cdot \text{in}$$

$$F_8 := \frac{W_1 \cdot d_7}{d_8} \quad F_8 = 243.9 \text{ lbf}$$

$$\sum F_{6y} = F_8 \cdot \cos(A_8) + F_{6y} = 0$$

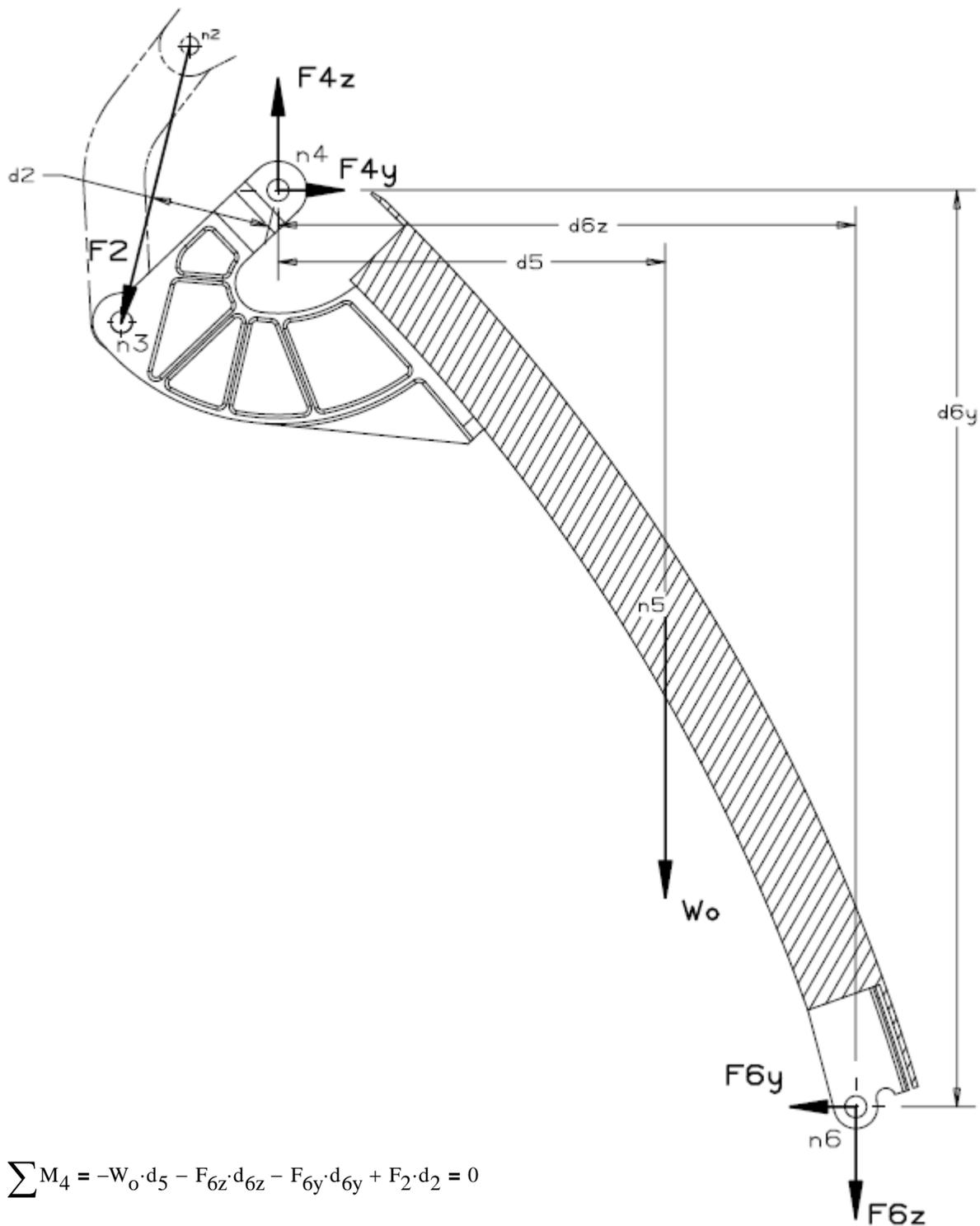
$$A_8 := 121.8843 \cdot \text{deg}$$

$$F_{6y} := -F_8 \cdot \cos(A_8) \quad F_{6y} = 128.8 \text{ lbf}$$

$$\sum F_{6z} = F_8 \cdot \sin(A_8) - W_1 + F_{6z} = 0$$

$$F_{6z} := W_1 - F_8 \cdot \sin(A_8) \quad F_{6z} = 49 \text{ lbf}$$

## 1.2 Loads on Outer Door Panel

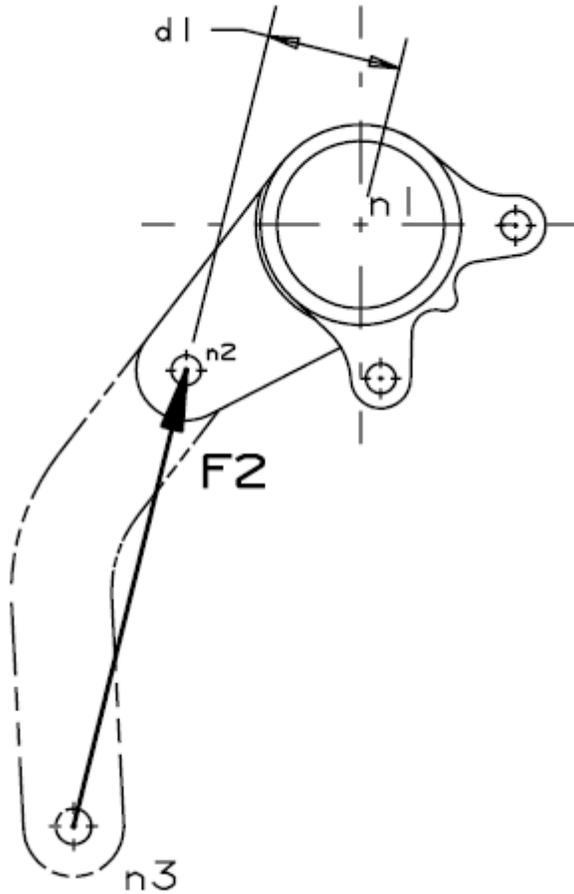


$$\sum M_4 = -W_o \cdot d_5 - F_{6z} \cdot d_{6z} - F_{6y} \cdot d_{6y} + F_2 \cdot d_2 = 0$$

$$d_5 := 11.0601\text{-in} \quad d_{6z} := 22.3179\text{-in} \quad d_{6y} := 29.9888\text{-in} \quad d_2 := 3.6854\text{-in}$$

$$F_2 := \frac{W_o \cdot d_5 + F_{6z} \cdot d_{6z} + F_{6y} \cdot d_{6y}}{d_2} \quad F_2 = 2554\text{ lbf}$$

### 1.3 Resultant Moment about RGA Driveline



$$\sum M_{RGA} = F_2 \cdot d_1$$

$$d_1 := 2.3348 \cdot \text{in}$$

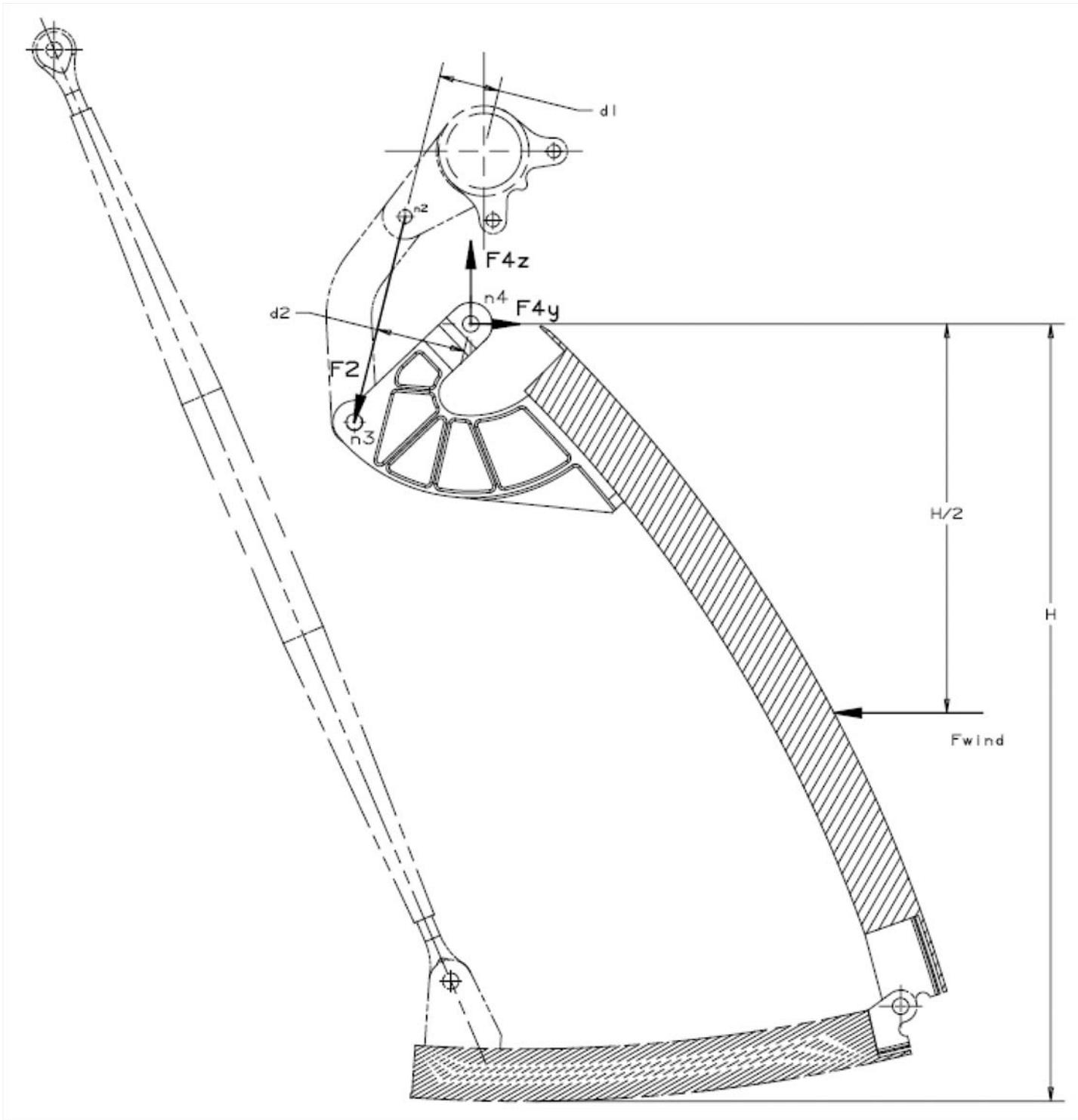
$$M_{RGA} := F_2 \cdot d_1$$

$$M_{RGA} = 5963 \text{ in} \cdot \text{lbf}$$

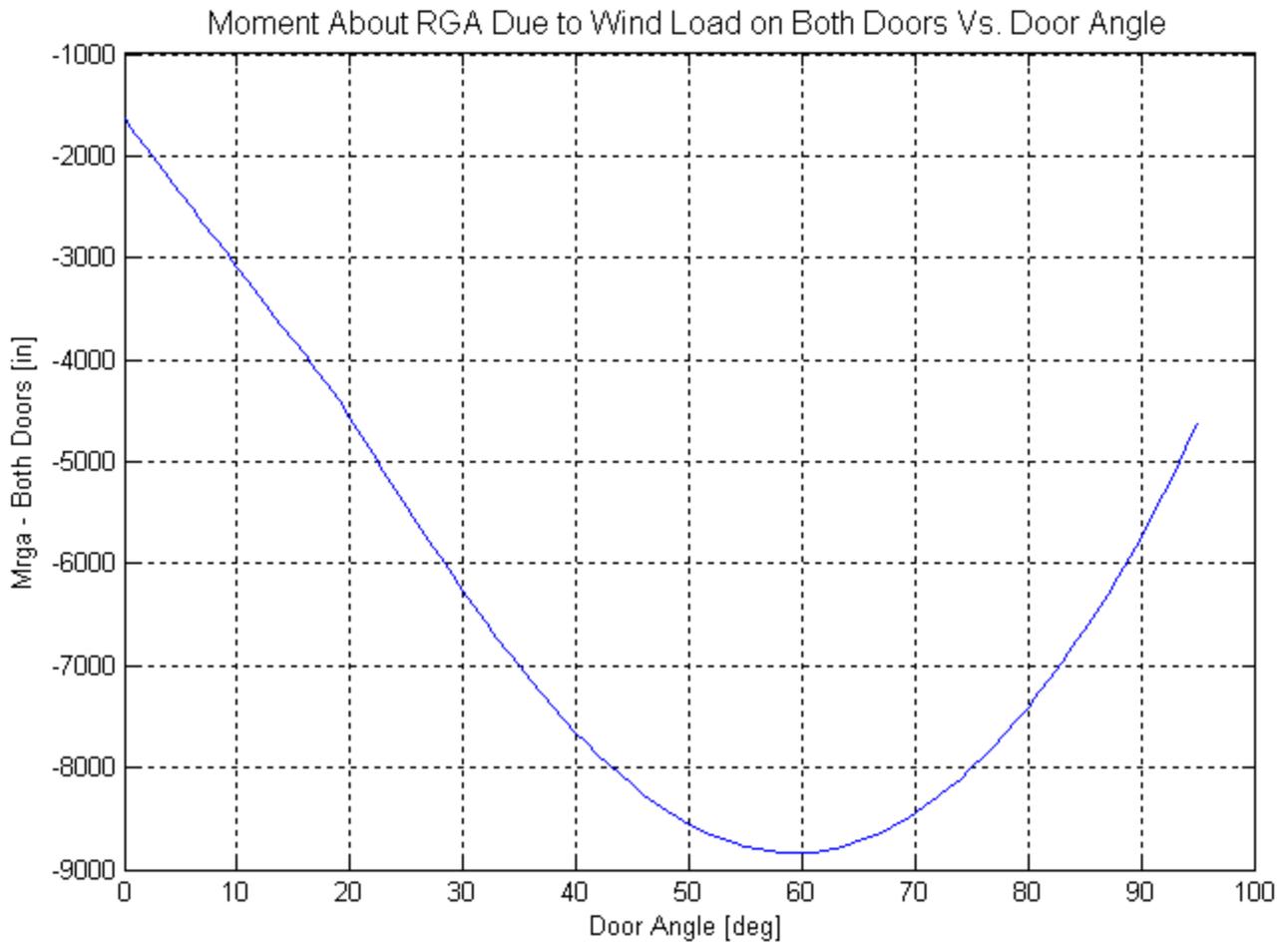
The net moment acting on the line of RGA outputs due to door weight is 6,000 in-lbf per side.

## 2. Moment About RGA Driveline Due to Cross Wind Loading

Cross wind loading is assumed to act normal to the doors and the center of pressure is assumed to act at the mid point of the projected height between the door hingeline and lowest point of the doors. All the load is assumed to be reacted through the RGA driveline.



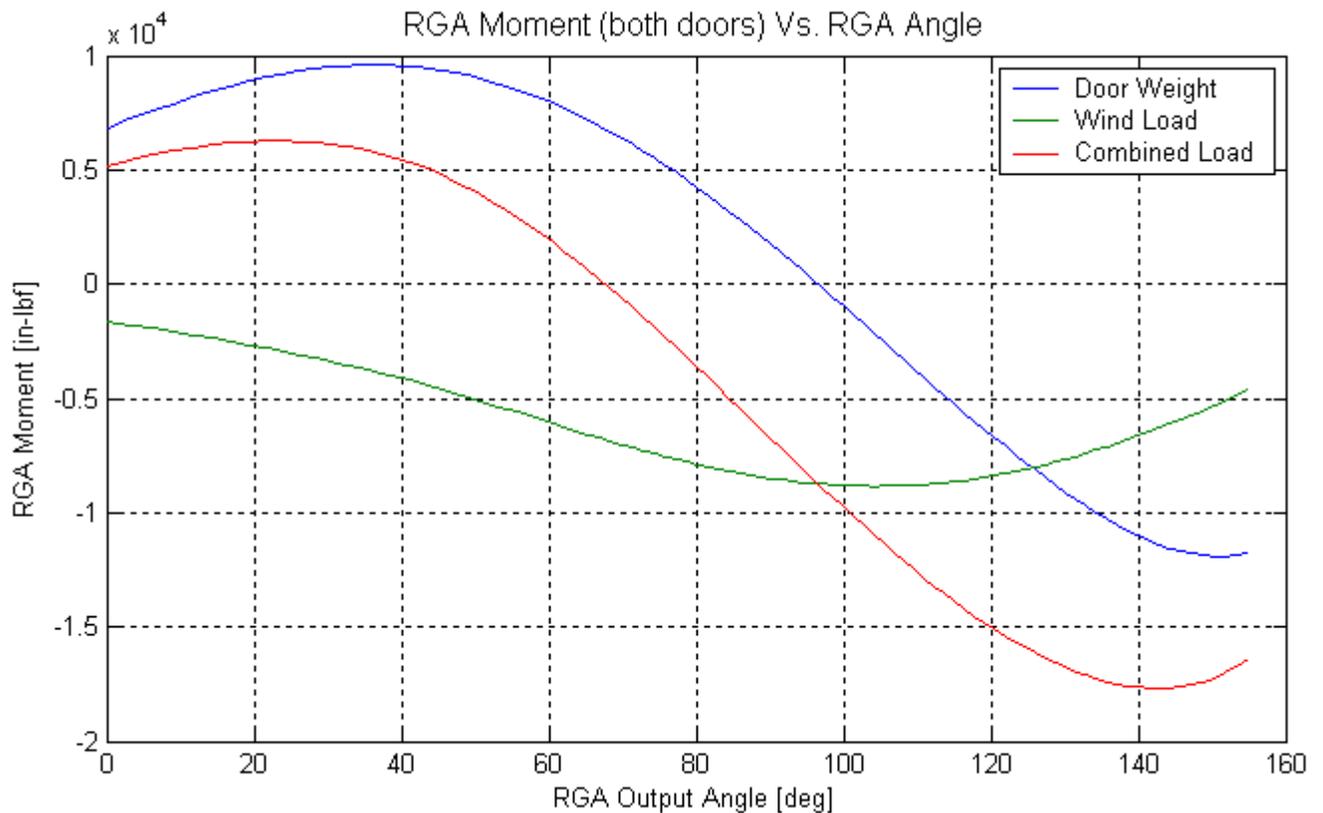
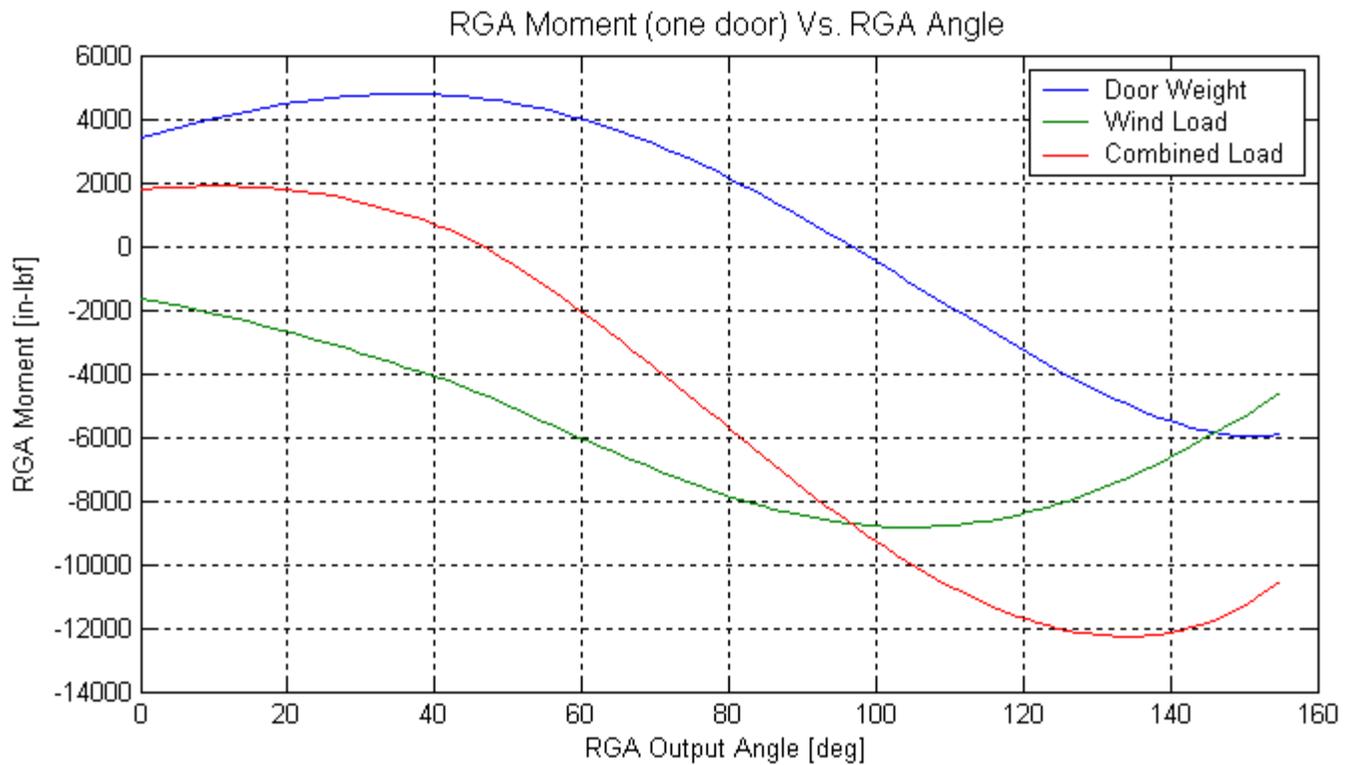
The following plots show the results as a function of door angle.



The maximum moment load on the RGA driveline due to wind loading occurs at a door angle of 59 degrees.

$C_D := 1.2$		Estimated drag coefficient for a flat plat.
$\rho := 1.20 \cdot \frac{\text{kg}}{\text{m}^3}$	$\rho = 0.075 \frac{\text{lb}}{\text{ft}^3}$	Density of air
$V := 60 \cdot \text{knot}$	$V = 69 \text{ mph}$	Velocity of wind
$H := 39.5976 \cdot \text{in}$	$L := 155.5 \cdot \text{in}$	Height and Length of projected area of doors in open position
$A := H \cdot L$	$A = 42.76 \text{ ft}^2$	Projected area
$K_1 := C_D \cdot \frac{1}{2} \cdot \rho \cdot V^2 \cdot L$	$K_1 = 15.471 \frac{\text{lbf}}{\text{in}}$	Force per unit height of projected area
$F_{\text{wind1}} := K_1 \cdot H$	$F_{\text{wind1}} = 613 \text{ lbf}$	Conservative calculation of ground cycle loads due to wind assumed to act horizontally at the geometric center of one door.
$F_{\text{wind}} := 1.00 \cdot F_{\text{wind1}}$	$F_{\text{wind}} = 613 \text{ lbf}$	Assumed total force acting on both doors
$\sum M_4 = (F_2 \cdot d_2 - F_{\text{wind}} \cdot d_{\text{wind}} = 0)$		Summation of moments about door hingeline
$d_{\text{wind}} := \frac{H}{2}$	$d_{\text{wind}} = 19.799 \text{ in}$	Approximate distance from door hingeline to center of pressure
$d_2 := 6.2846 \cdot \text{in}$		
$F_2 := F_{\text{wind}} \cdot \frac{d_{\text{wind}}}{d_2}$	$F_2 = 1930 \text{ lbf}$	
$d_1 := 4.579 \cdot \text{in}$		
$M_{\text{RGA\_wind}} := F_2 \cdot d_1$	$M_{\text{RGA\_wind}} = 8837 \text{ in} \cdot \text{lbf}$	Maximum closing moment acting on one door at 59 deg (assumed zero moment on other door)

### 3. Total Moment About RGA Driveline Due to Weight and Wind Loading



### 3.1 Peak Loads per Door

Maximum Door Opening Moment about RGA Driveline: 4,800 in-lbf (36.3 deg RGA angle)

Maximum Door Closing Moment about RGA Driveline: 12,300 in-lbf (134.3 deg RGA angle)

### 3.2 Peak Loads for Both Doors

Maximum Door Opening Moment about RGA Driveline: 9,600 in-lbf (36.3 deg RGA angle)

Maximum Door Closing Moment about RGA Driveline: 17,700 in-lbf (142.8 deg RGA angle)

## 4. Manual Drive Torque

$GR := 131.82 \cdot \frac{16}{9} \cdot 16.783$        $GR = 3933.04$       Overall ratio from RGA to manual drive

$\eta := 0.85 \cdot 0.82 \cdot 0.96 \cdot 0.70$        $\eta = 0.468$       Overall room temp efficiency for Flex Shaft, HPDU, AGB, RGA respectively.

### 4.1 Door Weight and Wind Loads

$T_{TOL} := \frac{17700}{\eta \cdot GR} \cdot \text{in} \cdot \text{lbf}$        $T_{TOL} = 9.6 \text{ in} \cdot \text{lbf}$       Maximum operating torque tending to tighten outer layer (TOL) of flex shaft.

$T_{LOL} := \frac{9600}{\eta \cdot GR} \cdot \text{in} \cdot \text{lbf}$        $T_{LOL} = 5.2 \text{ in} \cdot \text{lbf}$       Maximum operating torque tending to loosen outer layer (LOL) of flex shaft.

### 4.2 Door Preload

$M_{RGAp} := 2 \cdot 58600 \cdot \text{in} \cdot \text{lbf}$        $M_{RGAp} = 117200 \text{ in} \cdot \text{lbf}$       Preload on both doors at RGA output (ref. Boeing document, *Post IDR Prepreload Action Item 32 and 64 8-16-06.doc*)

$T_{TOLp} := \frac{M_{RGAp}}{\eta \cdot GR}$        $T_{TOLp} = 64 \text{ in} \cdot \text{lbf}$