Appendix E Analysis Package User's Manual

E.1. Introduction

The package is intended to provide aircraft conceptual designers with tools to help automate the landing gear design process.

E.2. Package Organization

The package consists of four executable files, *config.for, limit.for, pave.for*, and *gearwei.for.* An input file with extension *.inp* is required for each program. Program *config.for* currently acts as the front-end of the package and accepts all the data that is input, even though some of the data may not be used by the program itself. Program *config.for* then creates input files for the other three programs. Data files *tire.dat* and *pavecoef.dat* are required to provide database for programs *config.for* and *pave.for*, respectively.

The first line in each input file is a blank card, to be used as a case title card. All the rest of the input is formatted. We suggest that the sample input files be used as templates. Typically, the character data is read in as alphanumeric format, the integer data is read in as 3(10x, i10), and real data is read in as 3(10x, f10.2). The fields that are skipped are intended for variable labels. Note that if the given aircraft does not exhibit a fuselage-mounted landing gear, zeros should be entered in place of those input variables that are related to the fuselage-mounted gear.

The codes produce minimal screen output, and do not write out anything until they enter subroutine output, at the end of the computation. *Config* does provide some write statements, to provide an indication of the progress during the calculation. If there are problems with input data sets it will be at least slightly difficult to troubleshoot. The input and output files names are hardwired, but could easily be changed to prompt the user for file names. The most painful input appears to be the stowage volume definition. This input

in *config* can be fictitious and the program will still execute. Note that three sets of stowage volumes are read in, whether a fuselage mounted main assembly is used or not. As mentioned above, zeros should be entered when a fuselage mounted gear is not present. If you don't input all three, the code will fail, giving an out of data error.

Process

Required aircraft/landing gear characteristics are arranged into card-style input file "config.inp" to be read in by program "config.for". Selected tire/wheel characteristics and landing gear model, as well as initial data are arranged to form "limit.inp", "pave.inp", and "gearwei.inp" to be read in by "limit.for", "pave.for", and "gearwei.for", respectively. Examination of the list of constraint violations as generated by "limit.for", *e.g.*, sideways turnover angle, takeoff rotation angle, turning radius, and stowage characteristics, and pavement thickness requirement and ACN as generated by "pave.for" will provide insight to what should be done to resolve these constraint violations. Some possible options include relocating the landing gear, extending the strut length, modifying the aircraft cg height off the ground, and an increase/decrease of clearance requirements. After all of the design constraints are satisfied through an iterative modification process, the finalized landing gear model is passed to "gearwei.for" for component/group weight estimation.

The following sections define the subroutines and calling tree for each program. The program input and output is also summarized. Details are contained in Chapter 9.

config.for

Subroutines

datain
brsize - brake sizing
select - tire/wheel selection
attach - landing gear attachment scheme
pivaxi - pivot axis alignment
cropro - cross-product
output

Subroutine calling sequence:

datain
brsize
select
attach
pivaxi
cropro
output

Outputs:

Brake dimension and weight
Tire/wheel design characteristics: dimensions and weight
Stroke length
Load-stroke curve
Mathematical landing gear model: axle, truck beam, piston, cylinder, trunnion, drag and side struts

limit.for

Subroutines

datain
layout - landing gear positioning constraints
runway - ground operation characteristics
stowag - stowage constraints
skewed - skewed pivot axis alignment
output

Subroutine calling sequence

datain
layout
stowag
    pivaxi
        skewed
        cropro
    retrac
    violat
output

Outputs

Takeoff/landing stability characteristics: pitch and roll angles
Ground stability characteristics: sideways turnover and tail-tipping
Ground clearance: nacelle-to-ground and wingtip-to-ground
Maneuverability characteristics: centerline-guidance tracking
    and minimum turning radius
Kinematics: pivot axis alignment, retraction angle, landing gear retracted position

pave.for

Subroutines

datain
offset - offset distance, analysis node to tire contact area
aceswl - equivalent single wheel load
rigith - rigid pavement thickness and ACN
flexth - flexible pavement thickness and ACN
output

Subroutine calling sequence

datain
offset
aceswl
rigith
flexth
output

Outputs

Flexible and rigid pavement thickness and corresponding ACN

gearwei.for

This program computes an estimate of the landing gear weight.

Subroutines

datain	
exload	- applied load
noreac	- structural nodal actions
crosec	- cross-sectional area sizing
weiest	- weight estimation
cropro	- cross-product
cotran	- coordinate transformation
matinv	- matrix inverse
rowpiv	- row pivoting
ccross	- cylindrical cross section sizing
cirstr	- circular tube stresses
icross	- i-bar cross section sizing
select	- design cross section selection
output	

Subroutine calling sequence

```
datain
exload
    cropro
noreac
    cropro
crosec
    cotran
        matinv
            rowpiv
    ccross
        cirstr
    icross
    select
weiest
output
```

Outputs

Component dimensions
Component/group weight estimation

E.3. Program Input Variables

aircraft	Aircraft identification	
brake	Brake material	
	1	steel
	2	carbon
wheel	Wheel material	
	1	forged aluminum
	2	cast aluminum
	3	titanium
	4	steel
objec	Wheel selection criterion	
	1	minimum pressure
	2	minimum weight
	3	minimum size
metal	Landing gear structure material	
	1	4340 steel
	2	300M steel
mtow	MTOW, lb	
mldw	Maximum landing weight, lb	
fuel	Fuel weight, lb	
cmax	Maximum main assembly load, percent MTOW	
cmin	Minimum main assembly load, percent MTOW	
warea	Wing area, ft^2	
wspan	Wing span, in	
qswep	Quarter chord sweep, deg	
dihed	Dihedral, deg	

croot	Root chord, in
taper	Taper ratio
clmax	Clmax, landing
nms	Number of main struts
nmw	Number of main wheels
nnw	Number of nose wheels
wpsm	Number of wheels per strut, main assembly
wpsn	Number of wheels per strut, nose assembly
dyna	Landing gear load factor
alpha	Angle of attack, touchdown, deg
wbeta	Truck beam rotation angle, wing-mounted assembly, deg
fbeta	Truck beam rotation angle, fuselage-mounted assembly, deg
incl	Axle incline from the vertical, deg
scrap	Tail scrape angle, deg
dnace	Nacelle diameter, in
clear	Nacelle-to-ground clearance, in
cg(i)	Aircraft *cg* location, aircraft reference frame, in
wing(i)	Wing root leading edge location, aircraft reference frame, in i = 1, .., 3 (x, y, and z coordinate, airframe)
engi(i)	Inboard engine location, aircraft reference frame, in i = 1, .., 3 (x, y, and z coordinate, airframe)
tcon(i)	Tail bumper location, aircraft reference frame, in i = 1, .., 3 (x, y, and z coordinate, airframe)
gear(i,j)	Landing gear assembly location, aircraft reference frame, in in the order: main, nose, body
well(i,j,k)	Landing gear stowage volume, aircraft reference frame, in

in the order main, nose, body

The number at the end of the variable denotes the corners of the rectangular-shaped stowage volume:

1 upper starboard corner, forward

2 upper port corner, forward

3 lower starboard corner, forward

4 upper port corner, forward

5 upper starboard corner, aft

6 upper port corner, aft

7 lower starboard corner, aft

8 upper port corner, aft

E.4. Sample Input Files

747conf.inp

```
c landing gear layout/configuration input file
  aircraft: b747
  brake =          1, wheel =          1, objec =          2
  metal =          1
  mtow =   738000.00, mldw =   564000.00, fuel =   316307.00
  cmax =        0.96, cmin =        0.88, warea =    5500.00
  wspan =    2348.00, qswep =      37.70, dihed =       7.00
  croot =     642.00, taper =       0.25, clmax =       2.55
  nms =         4.00, nmw =        16.00, nnw =         2.00
  wpsm =        4.00, wpsn =        2.00, dyna =        1.20
  alpha =       4.00, wbeta =      60.00, fbeta =       0.00
  incl =       10.00, scrap =      12.00, dnace =     110.00
  clear =      12.00
c component location
  xcg =      1260.00, ycg =         0.00, zcg =       -24.00
  xwing =     870.00, ywing =       0.00, zwing =     -88.00
  xengi =    1050.00, yengi =    -465.00, zengi =     -95.00
  xtcon =    2375.00, ytcon =       0.00, ztcon =       0.00
  xmain =    1254.00, ymain =    -216.00, zmain =     -62.00
  xnose =     290.00, ynose =       0.00, znose =    -106.00
  xbody =    1375.00, ybody =     -75.00, zbody =    -118.00
c wing-mounted main assembly stowage
  xm1 =      1164.00, ym1 =       -17.00, zm1 =       -38.00
  xm2 =      1164.00, ym2 =      -115.00, zm2 =       -38.00
  xm3 =      1164.00, ym3 =      -115.00, zm3 =      -136.00
  xm4 =      1164.00, ym4 =       -17.00, zm4 =      -136.00
  xm5 =      1260.00, ym5 =       -17.00, zm5 =       -38.00
  xm6 =      1260.00, ym6 =      -115.00, zm6 =       -38.00
  xm7 =      1260.00, ym7 =      -115.00, zm7 =      -136.00
  xm8 =      1260.00, ym8 =       -17.00, zm8 =      -136.00
c nose assembly stowage
  xn1 =       150.00, yn1 =        32.00, zn1 =       -38.00
  xn2 =       150.00, yn2 =       -32.00, zn2 =       -38.00
  xn3 =       150.00, yn3 =       -32.00, zn3 =       -88.00
  xn4 =       150.00, yn4 =        32.00, zn4 =       -88.00
  xn5 =       290.00, yn5 =        32.00, zn5 =       -38.00
  xn6 =       290.00, yn6 =       -32.00, zn6 =       -38.00
  xn7 =       290.00, yn7 =       -32.00, zn7 =      -112.00
  xn8 =       290.00, yn8 =        32.00, zn8 =      -112.00
c fuselage-mounted main assembly stowage
  xb1 =      1260.00, yb1 =        -8.00, zb1 =       -38.00
  xb2 =      1260.00, yb2 =      -115.00, zb2 =       -38.00
  xb3 =      1200.00, yb3 =      -115.00, zb3 =      -136.00
  xb4 =      1200.00, yb4 =        -8.00, zb4 =      -136.00
  xb5 =      1390.00, yb5 =        -8.00, zb5 =       -38.00
  xb6 =      1390.00, yb6 =      -115.00, zb6 =       -38.00
  xb7 =      1390.00, yb7 =      -115.00, zb7 =      -136.00
  xb8 =      1390.00, yb8 =        -8.00, zb8 =      -136.00
```

```
c landing gear layout/stowage constraints input file
  aircraft: b747
  cmax =        0.96, cmin =        0.88, hcg =       181.00
  wspan =    2348.00, qswep =      37.70, dihed =       7.00
  croot =     642.00, taper =       0.25
  nms =         4.00, wpsm =        4.00, wpsn =        2.00
  scrap =      12.00, dnace =     110.00, clear =      12.00
  wbeta =      60.00, fbeta =       0.00, incl =        6.00
  smain =      27.65, snose =      27.97, sfuse =      27.65
c component location
  xcg =      1260.00, ycg =         0.00, zcg =       -24.00
  xwing =     870.00, ywing =       0.00, zwing =     -88.00
  xengi =    1050.00, yengi =    -465.00, zengi =     -95.00
  xtcon =    2375.00, ytcon =       0.00, ztcon =       0.00
  xmain =    1253.50, ymain =    -215.00, zmain =     -64.00
  xnose =     290.00, ynose =       0.00, znose =    -106.00
  xfuse =    1375.00, yfuse =     -75.00, zfuse =    -118.00
c wing-mounted main assembly stowage
  xm1 =      1164.00, ym1 =       -17.00, zm1 =       -38.00
  xm2 =      1164.00, ym2 =      -132.00, zm2 =       -38.00
  xm3 =      1164.00, ym3 =      -132.00, zm3 =      -136.00
  xm4 =      1164.00, ym4 =       -17.00, zm4 =      -136.00
  xm5 =      1260.00, ym5 =       -17.00, zm5 =       -38.00
  xm6 =      1260.00, ym6 =      -132.00, zm6 =       -38.00
  xm7 =      1260.00, ym7 =      -132.00, zm7 =      -136.00
  xm8 =      1260.00, ym8 =       -17.00, zm8 =      -136.00
c nose assembly stowage
  xn1 =       150.00, yn1 =        32.00, zn1 =       -38.00
  xn2 =       150.00, yn2 =       -32.00, zn2 =       -38.00
  xn3 =       150.00, yn3 =       -32.00, zn3 =       -88.00
  xn4 =       150.00, yn4 =        32.00, zn4 =       -88.00
  xn5 =       290.00, yn5 =        32.00, zn5 =       -38.00
  xn6 =       290.00, yn6 =       -32.00, zn6 =       -38.00
  xn7 =       290.00, yn7 =       -32.00, zn7 =      -112.00
  xn8 =       290.00, yn8 =        32.00, zn8 =      -112.00
c fuselage-mounted main assembly stowage
  xf1 =      1260.00, yf1 =       -17.00, zf1 =       -30.00
  xf2 =      1260.00, yf2 =      -115.00, zf2 =       -30.00
  xf3 =      1200.00, yf3 =      -115.00, zf3 =      -136.00
  xf4 =      1200.00, yf4 =       -17.00, zf4 =      -136.00
  xf5 =      1390.00, yf5 =       -17.00, zf5 =       -30.00
  xf6 =      1390.00, yf6 =      -115.00, zf6 =       -30.00
  xf7 =      1390.00, yf7 =      -115.00, zf7 =      -136.00
  xf8 =      1390.00, yf8 =       -17.00, zf8 =      -136.00


c selected tire data
  criterion: minimum weight
    type            size  ply speed    load  infl   brake   wei  dia  wid
                               (mph)    (lb) (psi)    (lb)  (lb) (in) (in)
  wing             49x17 32.0 235.0 50400.0 210.0 75600.0 243.3 48.8 17.3
  nose             46x16 28.0 210.0 41800.0 210.0 62700.0 185.8 45.3 16.0
  fuselage         49x17 32.0 235.0 50400.0 210.0 75600.0 243.3 48.8 17.3


c selected wheel data
  material: aluminum, forging
```

type	size	dia (in)	wid (in)	hub (in)	wei (lb)
wing	49x17	13.3	20.0	10.0	86.2
nose	46x16	13.3	20.0	10.0	105.3
fuselage	49x17	13.3	20.0	10.0	86.2

c mathmatical model

wing

component	x0 (in)	y0 (in)	z0 (in)	x1 (in)	y1 (in)	z1 (in)
tire	0.00	0.00	0.00	0.00	13.25	-20.20
axle	0.00	22.00	0.00	0.00	-22.00	0.00
truck beam	-29.00	0.00	0.00	29.00	0.00	0.00
piston	0.00	0.00	0.00	0.00	0.00	-50.00
cylinder	0.00	0.00	0.00	0.00	0.00	-112.00
drag strut	0.00	0.00	0.00	-42.00	-4.00	-101.00
side strut	0.00	0.00	0.00	0.00	-84.00	-88.00
forward trunnion	0.00	0.00	0.00	36.00	12.00	0.00
aft trunnion	0.00	0.00	0.00	12.00	12.00	0.00

nose

component	x0 (in)	y0 (in)	z0 (in)	x1 (in)	y1 (in)	z1 (in)
tire	0.00	0.00	0.00	0.00	13.25	-20.20
axle	0.00	18.00	0.00	0.00	-18.00	0.00
truck beam	0.00	0.00	0.00	0.00	0.00	0.00
piston	0.00	0.00	0.00	0.00	0.00	-34.00
cylinder	0.00	0.00	0.00	0.00	0.00	-75.60
drag strut	0.00	0.00	0.00	-32.40	0.00	-88.00
side strut	0.00	0.00	0.00	0.00	18.00	-32.40
forward trunnion	0.00	0.00	0.00	0.00	-18.00	0.00
aft trunnion	0.00	0.00	0.00	0.00	18.00	0.00

fuselage

component	x0 (in)	y0 (in)	z0 (in)	x1 (in)	y1 (in)	z1 (in)
tire	0.00	0.00	0.00	0.00	13.25	-20.20
axle	0.00	22.00	0.00	0.00	-22.00	0.00
truck beam	-29.00	0.00	0.00	29.00	0.00	0.00
piston	0.00	0.00	0.00	0.00	0.00	-50.00
cylinder	0.00	0.00	0.00	0.00	0.00	-60.00
drag strut	0.00	0.00	0.00	92.00	-56.00	-40.00
side strut	0.00	0.00	0.00	0.00	-48.00	-36.00
forward trunnion	0.00	0.00	0.00	0.00	56.00	0.00
aft trunnion	0.00	0.00	0.00	0.00	-8.00	0.00

```
c aircraft flotation input file
  aircraft: b747
  mtow =   738000.00, mldw =   564000.00
  cmax =        0.96
  nmw =        16.00, wpsm =        4.00


c selected tire data
  criterion: minimum weight
    type            size  ply speed    load  infl   brake   wei  dia  wid
                               (mph)    (lb) (psi)    (lb)  (lb) (in) (in)
  wing             49x17 32.0 235.0 50400.0 210.0 75600.0 243.3 48.8 17.3
  nose             46x16 28.0 210.0 41800.0 210.0 62700.0 185.8 45.3 16.0
  fuselage         49x17 32.0 235.0 50400.0 210.0 75600.0 243.3 48.8 17.3


c selected wheel data
  material: aluminum, forging
    type            size  dia  wid  hub   wei
                         (in) (in) (in)  (lb)
  wing             49x17 13.3 20.0 10.0  86.2
  nose             46x16 13.3 20.0 10.0 105.3
  fuselage         49x17 13.3 20.0 10.0  86.2


c mathmatical model
  wing
  component                 x0      y0      z0      x1      y1      z1
                           (in)    (in)    (in)    (in)    (in)    (in)
  tire                     0.00    0.00    0.00    0.00   13.25  -20.20
  axle                     0.00   22.00    0.00    0.00  -22.00    0.00
  truck beam             -29.00    0.00    0.00   29.00    0.00    0.00
  piston                   0.00    0.00    0.00    0.00    0.00  -50.00
  cylinder                 0.00    0.00    0.00    0.00    0.00 -112.00
  drag strut               0.00    0.00    0.00   42.00    4.00 -101.00
  side strut               0.00    0.00    0.00    0.00  -84.00  -88.00
  forward trunnion         0.00    0.00    0.00   16.00    4.00    0.00
  aft trunnion            16.00    4.00    0.00   56.00   18.00    0.00

  nose
  component                 x0      y0      z0      x1      y1      z1
                           (in)    (in)    (in)    (in)    (in)    (in)
  tire                     0.00    0.00    0.00    0.00   13.25  -20.20
  axle                     0.00   17.00    0.00    0.00  -17.00    0.00
  truck beam               0.00    0.00    0.00    0.00    0.00    0.00
  piston                   0.00    0.00    0.00    0.00    0.00  -34.00
  cylinder                 0.00    0.00    0.00    0.00    0.00  -78.00
  drag strut               0.00    0.00    0.00   41.00    0.00  -82.00
  side strut               0.00    0.00    0.00    0.00   19.00   38.00
  forward trunnion         0.00   24.00    0.00    0.00    0.00    0.00
  aft trunnion             0.00    0.00    0.00    0.00  -24.00    0.00

  fuselage
  component                 x0      y0      z0      x1      y1      z1
                           (in)    (in)    (in)    (in)    (in)    (in)
  tire                     0.00    0.00    0.00    0.00   13.25  -20.20
  axle                     0.00   22.00    0.00    0.00  -22.00    0.00
```

truck beam	-29.00	0.00	0.00	29.00	0.00	0.00
piston	0.00	0.00	0.00	0.00	0.00	-50.00
cylinder	0.00	0.00	0.00	0.00	0.00	-64.00
drag strut	0.00	0.00	0.00	84.00	-56.00	-40.00
side strut	0.00	0.00	0.00	0.00	-48.00	-36.00
forward trunnion	0.00	0.00	0.00	0.00	-62.00	0.00
aft trunnion	0.00	-62.00	0.00	0.00	-72.00	0.00

```
c landing gear weight estimation input file
  aircraft: b747
  metal =          1
  mtow =   738000.00, mldw =   564000.00
  cmax =        0.96, cmin =        0.88, hcg =       181.00
  nms =         4.00, nmw =        16.00, nnw =         2.00
  wpsm =        4.00, wpsn =        2.00, alpha =       4.00
  dyna =        1.20, inpr =     1500.00, bwei =      262.11
  smain =      26.65, snose =      26.97, sfuse =      26.65
c component location
  xmain =    1254.00, ymain =    -216.00, zmain =     -62.00
  xnose =     290.00, ynose =       0.00, znose =    -106.00
  xfuse =    1375.00, yfuse =     -75.00, zfuse =    -118.00


c selected tire data
  criterion: minimum weight
    type            size  ply speed    load  infl   brake   wei  dia  wid
                               (mph)    (lb) (psi)    (lb)  (lb) (in) (in)
  wing             49x17 32.0 235.0 50400.0 210.0 75600.0 243.3 48.8 17.3
  nose             46x16 28.0 210.0 41800.0 210.0 62700.0 185.8 45.3 16.0
  fuselage         49x17 32.0 235.0 50400.0 210.0 75600.0 243.3 48.8 17.3


c selected wheel data
  material: aluminum, forging
    type            size  dia  wid  hub   wei
                         (in) (in) (in)  (lb)
  wing             49x17 13.3 20.0 10.0  86.2
  nose             46x16 13.3 20.0 10.0 105.3
  fuselage         49x17 13.3 20.0 10.0  86.2


c mathmatical model
  wing
  component                 x0      y0      z0      x1      y1      z1
                           (in)    (in)    (in)    (in)    (in)    (in)
  tire                     0.00    0.00    0.00    0.00   13.25  -20.20
  axle                     0.00   22.00    0.00    0.00  -22.00    0.00
  truck beam             -29.00    0.00    0.00   29.00    0.00    0.00
  piston                   0.00    0.00    0.00    0.00    0.00  -50.00
  cylinder                 0.00    0.00    0.00    0.00    0.00 -112.00
  drag strut               0.00    0.00    0.00   42.00    4.00 -101.00
  side strut               0.00    0.00    0.00    0.00  -84.00  -88.00
  forward trunnion         0.00    0.00    0.00   16.00    4.00    0.00
  aft trunnion            16.00    4.00    0.00   56.00   18.00    0.00

  nose
  component                 x0      y0      z0      x1      y1      z1
                           (in)    (in)    (in)    (in)    (in)    (in)
  tire                     0.00    0.00    0.00    0.00   13.25  -20.20
  axle                     0.00   17.00    0.00    0.00  -17.00    0.00
  truck beam               0.00    0.00    0.00    0.00    0.00    0.00
  piston                   0.00    0.00    0.00    0.00    0.00  -34.00
  cylinder                 0.00    0.00    0.00    0.00    0.00  -78.00
  drag strut               0.00    0.00    0.00   41.00    0.00  -82.00
  side strut               0.00    0.00    0.00    0.00   19.00   38.00
```

forward trunnion	0.00	24.00	0.00	0.00	0.00	0.00
aft trunnion	0.00	0.00	0.00	0.00	-24.00	0.00

fuselage component	x0 (in)	y0 (in)	z0 (in)	x1 (in)	y1 (in)	z1 (in)
tire	0.00	0.00	0.00	0.00	13.25	-20.20
axle	0.00	22.00	0.00	0.00	-22.00	0.00
truck beam	-29.00	0.00	0.00	29.00	0.00	0.00
piston	0.00	0.00	0.00	0.00	0.00	-50.00
cylinder	0.00	0.00	0.00	0.00	0.00	-64.00
drag strut	0.00	0.00	0.00	84.00	-56.00	-40.00
side strut	0.00	0.00	0.00	0.00	-48.00	-36.00
forward trunnion	0.00	0.00	0.00	0.00	-62.00	0.00
aft trunnion	0.00	-62.00	0.00	0.00	-72.00	0.00