OUTPUT IN PANDA2 THAT APPEARS IN THE *.OPM FILE WHEN THE PRINT INDEX, NPRINT IS SET EQUAL TO 2 IN THE *.OPT FILE (input for MAINSETUP). THIS LONG TABLE PROVIDES A GOOD SUMMARY OF WHAT HAPPENS DURING AN EXECUTION OF PANDA2 FOR ANALYSIS TYPE 2, THAT IS, FOR ITYPE = 2 IN THE FILE, *.OPT.

THIS TABLE PROVIDES A GOOD WAY FOR A PANDA2 USER TO LEARN WHAT PANDA2 DOES.

SOME OUTPUT FROM THE nasaortho.OPM FILE GENERATED WITH NPRINT = 2
(The "nasaortho" case is located in the directory, …panda2/case/nasaortho).
===
The following output is from the *.OPM file. This output is generated when the print index, NPRINT = 2, in the *.OPT file. Some sections have been omitted from this list to save space. The sections with data are from the case called "nasaortho": a uniformly axially compressed, imperfect, optimized cylindrical shell with internal rings and internal stringers, both with rectangular cross sections. The length of the cylindrical shell is 68.75 inches and the radius is 48 inches.

The optimized design is as follows:

```
 DIMENSIONS OF  CURRENT  DESIGN...
 VARIABLE   CURRENT
  NUMBER     VALUE            DEFINITION
    1    1.8617E+00        B(STR):stiffener spacing, b: STR seg=NA, layer=NA
    2    6.1973E-01       B2(STR):width of stringer base, b2 (must be > 0, see
    3    8.8811E-01        H(STR):height of stiffener (type H for sketch), h: S
    4    4.9565E-02    T(1 )(SKN):thickness for layer index no.(1 ): SKN seg=1
    5    8.0641E-02    T(2 )(STR):thickness for layer index no.(2 ): STR seg=3
    6    1.1458E+01        B(RNG):stiffener spacing, b: RNG seg=NA, layer=NA
    7    0.0000E+00       B2(RNG):width of ring base, b2 (zero is allowed): RNG
    8    1.7544E+00        H(RNG):height of stiffener (type H for sketch), h: R
    9    8.9081E-02    T(3 )(RNG):thickness for layer index no.(3 ): RNG seg=3
```

************ **MARCH, 2009 VERSION OF PANDA2** ************
******** BEGINNING OF THE **nasaortho.OPM** FILE *********

NOTE: The references called out in the following text are listed in the section following the headings, "PANDA2 REFERENCES", "ABOUT BOSOR4", and "ABOUT STAGS"

DESCRIPTION OF PANDA2

PANDA2 is a computer program for the minimum weight design of stiffened, composite, flat or cylindrical, perfect/imperfect panels and shells subjected to multiple sets of combined in-plane loads, normal pressure, and temperature. For most configurations the panels can be locally postbuckled. Previous work on PANDA2 is documented in [1]. PANDA2 incorporates the theories of earlier codes PANDA [2] and BOSOR4 [1B - 7B]. The optimizer used in PANDA2 is called ADS [20, 21]. Panels are optimized subject primarily to buckling and stress constraints.

PANDA2 Processors and Types of Analysis:

As described in [1],[16,17], the PANDA2 system consists of several processors, BEGIN, SETUP, DECIDE, MAINSETUP, PANDAOPT, CHOOSEPLOT, CHANGE, STAGSUNIT, PANEL, PANEL2, etc. The functions of these processors are as follows:

BEGIN	User establishes starting design, material properties, prebuckling and buckling boundary conditions.
SETUP	System sets up BOSOR4-type templates for stiffness and load-geometric matrices.
DECIDE	User chooses decision variables and bounds and sets up equality (linking) and inequality constraints.
MAINSETUP	User chooses analysis type, loading, solution strategies, imperfection amplitudes, factors of safety, etc.
PANDAOPT	Analysis type is performed (e.g. optimization).
CHOOSEPLOT	User chooses what to plot.
DIPLOT	The system obtains plots (postscript files).
CHANGE	User changes selected variables and constants.
AUTOCHANGE	A new starting design is automatically generated in a random manner.
SUPEROPT	An attempt is made to find a global optimum design.
PANEL	A BOSOR4 input file is generated for inter-ring buckling of panel skin and stringers, with stringers modelled as flexible shell branches.
PANEL2	A BOSOR4 input file is generated for inter-ring buckling of panel skin+smeared stringers with rings modelled as flexible shell branches.
STAGSMODEL	An input file for STAGS [1S - 4S] is generated (one finite element unit, only stringers are permitted).
STAGSUNIT	An input file for STAGS is generated (multiple shell units, both stringers and rings are permitted)
CLEANPAN	Delete all files except files containing the user-provided input data for BEGIN, DECIDE, MAINSETUP, CHANGE, PANEL, PANEL2, STAGSMODEL, STAGSUNIT, CHOOSEPLOT

PANDA2 can be run in five modes:

1. optimization
2. simple analysis of a fixed design
3. test simulation (monotonically increasing loading)
4. design sensitivity (margins computed for a user-selected range of one decision variable, all others held constant)
5. load-interaction curves (Nx,Ny) or (Nx,Nxy) or (Ny,Nxy)

Overview of models used in PANDA2

PANDA2 computes stress and buckling loads from several different models as follows:

1. Discretized single-module skin-stringer (Figs.20,22 of [1]) The cross section of a stringer and panel skin of width equal to the stringer spacing is discretized as shown in [1]. Variation of unknowns u,v,w in the axial direction is trigonometric with m axial halfwaves. This one-dimensional

discretization is analogous to that used in BOSOR4 [1B,3B] for shells of revolution.

(a) This model is for the axial length of shell between rings.
(b) This model can be used for local postbuckling analysis as shown in Figs. 23 of [1] and Fig. 10 of [11]. The local postbuckling theory [3] is an extension of that of Koiter described in Ref. [22].
(c) Buckling load factors can be checked by a BOSOR4 model [1B - 7B] generated by the PANDA2 processor, PANEL. (See Items 112c,d, 270, 319 in .../doc/panda2.news and Fig. 21 in [1] and Figs. 33 and 34 of [18]).

2. Discretized single-module "skin"-ring (Fig.30 of [6]): The cross section of a ring and panel skin with "smeared" stringers of axial length equal to the ring spacing is discretized. Variation of unknowns u,v,w, in the circumferential direction is trigonometric with n circumferential halfwaves. This one-dimensional discretization is the same as that used in BOSOR4 [1B,3B] for shells of revolution.

(a) This model involves discretized skin-with-smeared-stringers combined with discretized ring cross section.
(b) Buckling load factors can be checked by a BOSOR4 model [1B - 7B] generated by the PANDA2 processor, PANEL2. (See Item 463 in ...panda2/doc/panda2.news and Fig.33 of [6] and Figs. 35 and 36 of [18])
(c) This model is used to determine a knockdown factor that compensates for the inherent unconservativeness of models with "smeared" rings. (See Items 509, 511, 522, 532, 605, 617, 619, 632, 633, and 676 in the file, ...panda2/doc/panda2.news).

3. PANDA-type closed form buckling formulas [2] for shell skin and segments of stringers and segments of rings:

(a) This model involves an elaborate search over (m,n,s) space, in which m = number of axial halfwaves, n =number of circumferential halfwaves and s =slope of the buckling nodal lines (assumed straight)
(b) Either Donnell theory or Sanders theory or Marlowe theory is used for the shell analysis. (User chooses).
(c) This model is used to compute knockdown factors for stiffened or unstiffened cylindrical panels and shells with local, inter-ring, and general buckling modal imperfection shapes with user-specified amplitudes [4].
(d) This model is used to get a knockdown factor to compensate for the fact that the in-plane shear load Nxy equals zero in all BOSOR4-type (discretized) models
(e) This model is used for buckling of stiffener segments such as shown in Figs. 5 and 6 of [2].
(f) This model is used for the buckling of sandwich wall face sheets attached to an elastic foundation that represents the core of the sandwich wall [10].
(g) This model is used for many of the buckling modes that exist in panels with major stiffeners and substiffeners between the major stiffeners [16].

4. Sandwich wall failure modes unique to sandwich walls [10]:

(a) face sheet wrinkling
(b) face sheet dimpling
(c) core crimping
(d) stiffener-web-bending-induced face sheet pull-off
(e) stiffener-web-bending-induced core crushing
(f) amplification-of-initial-face-sheet-waviness-induced face sheet pull-off
(f) amplification-of-initial-face-sheet-waviness-induced core crushing
(g) hexagonal core face sheet pull-off
(h) transverse shear core failure
(i) core tension failure.

5. Models involving solution by double trigonometric series expansions [6]:
   (a) local buckling between adjacent major stiffeners
   (b) general buckling of a "patch" involving N x M major stiffener bays
   (c) inter-ring buckling of a "patch" involving N major stringer bays
   (d) local, "general", and inter-subring models in shells with substringers and subrings between major stiffners. The "general" buckling domain is a "patch" involving N x M substiffener bays lying between adjacent major stringers and major rings.

6. Optimum designs obtained by PANDA2 may be checked by running a general-purpose finite element program. The PANDA2 processor called STAGSUNIT generates input files, <casename>.inp and <casename>.bin for STAGS [1S - 4S]. STAGSUNIT [7] generates valid STAGS input files for any subdomain of a shell or panel, as seen in Refs. [7, 16, 17].

Stress and buckling margins and other facts about PANDA2

==

PART 1.1: stress constraints from discretized and non-discretized models.

PART 1.2: buckling constraints from discretized single module skin-stringer model (Example: Fig. 22 of [1]).

PART 1.3: buckling constraints from discretized single module skin-with-smeared-stringers/discretized ring model (Example: Fig. 30 of [6]).

PART 1.4: buckling constraints from PANDA-type models [2] and alternative models involving double trigonometric series expansions ("altsol" models, [6])

- **Part 1.4.1** Various types of buckling/models included in SUBROUTINE BUCPAN
- **Part 1.4.2** Special cases in SUBROUTINE BUCPAN
- **Part 1.4.3** Types of "knockdown" used in PANDA2
- **Part 1.4.4** Imperfections cause stress redistribution
- **Part 1.4.5** Buckling margins

PART 1.5: buckling constraints from PANDA-type models of buckling of stiffener segments (Fig. 5 of [2])

PART 1.6: Conservativeness of PANDA2 analyses

PART 1.7: How the effect of imperfections is handled in PANDA2

PART 1.1

PANDA2 computes the following types of margins relating to stress constraints:

```
------------------- typical margin names ---------------------
eff.stress:matl=1,STR,Dseg=5,node=11,layer=1,z=.281; MID.;FS=1
eff.stress:matl=1,RNG,Iseg=3,at:TIP,layer=1,z=0.363;-MID.;FS=1
fibertensn:matl=1,STR,Dseg=4,node=6,layer=1,z=-0.11; ENDS;FS=1
fibercompr:matl=1,SKN,Dseg=2,node=6,layer=2,z=0.11; ENDS;FS=1
transtensn:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.11; ENDS;FS=1
transcompr:matl=1,SKN,Dseg=2,node=6,layer=2,z=0.11; ENDS;FS=1
inplnshear:matl=1,STR,Dseg=3,node=1,layer=1,z=0.083; ENDS;FS=1
fibertensn:matl=1,STR,Iseg=4,allnode,layer=1,z=-.11;-ENDS;FS=1
fibercompr:matl=1,SKN,Iseg=1,at:n=11,layer=2,z=0.11;-ENDS;FS=1
transtensn:matl=1,SKN,Iseg=2,at:n=11,layer=1,z=-.11;-ENDS;FS=1
transcompr:matl=1,STR,Iseg=4,allnode,layer=1,z=0.11;-ENDS;FS=1
inplnshear:matl=1,STR,Iseg=3,at:TIP,layer=1,z=0.;-ENDS;FS=1
---------------------------------------------------------------
```

in which the following definitions apply:
"STR" = "stringer"; "RNG" = "ring"; "SKN" = "skin";
"MID" = midway between rings (midbay); "ENDS" = "at rings"
"TIP" = at the tip of a stiffener web
"Dseg" = segment numbering for discretized single module model
"Iseg" = segment numbering from "BEGIN" (See *.BEG file)
"z" = distance from reference surface (thickness coordinate)
"node" = nodal point in discretized single module model
"allnode" = "at all nodes" [IQUICK=1 (non-discretized) model]
"layer" = layer number in the segment wall
"FS" = factor of safety
"eff.stress" = von Mises effective stress
"fibertensn" = tensile stress in the direction of the fibers
"fibercompr" = compressive stress along the fibers
"transtensn" = tension stress normal to the fibers
"transcompr" = compressive stress normal to the fibers
"inplnshear" = in-plane shear stress

Stresses in the category denoted "Iseg"(non-discretized model) are computed in SUBROUTINE STRCON for both positive and negative amplitudes of buckling modal imperfection. Stresses in the category denoted "Dseg"(discretized model) are computed in SUBROUTINE STRTHK and include the effect of local postbuckling of the panel skin between adjacent stringers.

In computing the various stress constraints, SUB.STRCON/STRTHK include the effect of redistribution of stress resultants between panel skin and stiffener segments caused by bending of an initially imperfect shell subjected to its design load. For example, in one case (not this case), this prebuckling bending gives rise to additional compressive stress resultants as follows:

```
Additional resultants (Nx,Ny) in panel skin from
global and inter-ring bending of imperfect panel:
             Additional axial resultant, DNX = -1.4357E+03
             Additional  hoop resultant, DNY = -2.3231E+04
    Additional in-plane shear resultant, DNXY=  0.0000E+00

Additional axial resultants DNX along webs and flanges of
stringers from global and inter-ring bending of imperfect panel:
    Additional Nx in  base  of stringer, DNX = -1.4357E+03
    Additional Nx at webtip of stringer, DNX = -2.5133E+03
    Additional Nx in flange of stringer, DNX = -1.8180E+03

Additional axial resultants DNX along webs and flanges of
rings from global and inter-ring bending of imperfect panel:
    Additional Nx in  base  of   ring,   DNX = -2.5529E+04
    Additional Nx at webtip of   ring,   DNX = -9.7624E+04
    Additional Nx in flange of   ring,   DNX = -6.4280E+04
---------------------------------------------------------------
```

PART 1.2

Buckling load factors may be computed with use of the single discretized skin-stringer module model [1]. Examples of this model appear in Figs. 22, 46, 98, and 99 of Ref.[1]. This one-dimensionally-discretized model is analogous to the model used in BOSOR4 [1B,3B] for analysis of axisymmetric shells. This model is used only for inter-ring buckling phenomena (no rings!). The types of buckling margins obtained with this model are as follows:

```
------------------- typical margin names ---------------------
Local buckling from discrete model-1.,M=5 axial halfwaves;FS=1
long-wave local buckling, discrete model(m=1 axial halfwav);FS
Local buckling from Koiter theory,M=5 axial halfwaves;FS=1.0
Bending-torsion buckling; M=1  ;FS=1.0
(m=1 lateral-torsional buckling load factor)/(FS)-1;FS=1.0
local wide-column bucking, discrete model(m=1 axial halfwave)
stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
stringer popoff margin:(allowable/actual)-1, web 2  MID.;FS=1.
(Wide column panel buckling load factor)/(F.S.) - 1; FS=1.0
(Funny hat buckling load factor)/(F.S.) -1; FS=1.0
-.05+(eig(high-axial-m) -eig(low-axial-m))/eig(high-m);FS=1.0
---------------------------------------------------------------
```

A typical local buckling mode is shown in Fig.22a of [1].
A typical wide column panel buckling mode is in [1], Fig. 22c.
Stringer popoff is explained in the discussion associated with Figs. 5 - 8 of [1].
Bending-torsion buckling and lateral-torsional buckling modes are modes in which the tip of the stringer deforms more than the panel skin midway between adjacent stringers. Fig. 20b in [18] shows an example.
The "Funny hat" buckling mode applies only to hat-stiffened

panels and is discussed in Item 123(u) of ..doc/panda2.news.
The last margin listed above attempts to keep buckling modes with high numbers of axial halfwaves m non-critical compared to those with low numbers of axial halfwaves.

In computing the various buckling load factors, SUB. LOCAL includes the effect of redistribution of stress resultants between panel skin and stiffener segments caused by bending of an initially imperfect shell subjected to its design load. For example, see the list of DNX, DNY, DNXY printed above.

PART 1.3

Computations with "SKIN"-RING discrete single module model[6]: See Item No. 463 of the file, ../doc/panda2.news and Ref.[6]: Bushnell, D., et al, "Additional buckling solutions in PANDA2" AIAA Paper 99-1233, Proc. 40th AIAA Structures and Materials Conference, pp 302-345 (1999) [6]. See especially pp 318-323 and Figs. 30-33. Also, read ITEMs 509, 511, 522, 605 of the file, ..panda2/doc/panda2.news, about how PANDA2 develops a knockdown factor to compensate for the unconservativeness of buckling models in which the rings are smeared out.

This model is used only for ring-stiffened cylindrical shells. The model is analogous to the discretized single module skin-stringer model described previously. It is a discretized single module "skin"-ring model of axial length equal to the ring spacing. The cylindrical "skin" part extends from midbay to midbay, with symmetry conditions applied at top and bottom. "Skin" is in quotes because it consists of the actual skin of the cylindrical shell plus smeared stringers, if any. The ring cross section is discretized (branched shell model), with the plane of the ring web lying in the horizontal plane of symmetry of the entire discretized "skin"-ring module.

```
------------------- typical margin names ---------------------
The types of buckling margins obtained with this model are:
Inter-ring bucklng, discrete model, n=37 circ.halfwaves;FS=1.0
Ring sidesway buk., discrete model, n=4  circ.halfwaves;FS=1.0
Ring web buckling,  discrete model, n=?? circ.halfwaves;FS=1.0
Ring flange buckling,discrete model,n=54 circ.halfwaves;FS=1.0
Hi-n Inter-ring buc.,discrete model,n=?? circ.halfwaves;FS=1.0
Hi-n Ring sidesway,  discrete model,n=?? circ.halfwaves;FS=1.0
Hi-n Ring web buckl.,discrete model,n=27 circ.halfwaves;FS=1.0
Hi-n Ring flang buckl.discret model,n=67 circ.halfwaves;FS=1.0
Lo-n Inter-ring buc.,discrete model,n=?? circ.halfwaves;FS=1.0
Lo-n Ring sidesway, discrete model, n=7  circ.halfwaves;FS=1.0
Lo-n Ring web buck., discrete model,n=?? circ.halfwaves;FS=1.0
Lo-n Ring flng buck.,discrete model,n=?? circ.halfwaves;FS=1.0
---------------------------------------------------------------
```

In computing the various buckling load factors, SUB. STRUCT includes the effect of redistribution of stress resultants between panel skin and stiffener segments caused by bending of an initially imperfect shell subjected to its design load. For example, see the list of DNX, DNY, DNXY printed above

---

PART 1.4 Computations that occur in SUBROUTINE BUCPAN...

Buckling load factors are computed from PANDA-type theory [2] and possibly also from the "alternative" buckling theory where the buckling mode is expanded in a double-trigonometric series as described in Ref.[6]. Stiffener rolling, referred to below, is shown in Fig.6 (a-c) on p. 546 of [2]. If the panel is of sandwich wall construction, then Ref.[10] applies. If the panel has both stiffeners and substiffeners, then Ref. [16] applies. A very large eigenvalue, such as 1.E+17, indicates that buckling does not occur, probably because the loading is tensile and there is no shear (positive Nx, Ny; no Nxy), or that PANDA2 did not compute a particular buckling mode.

Part 1.4.1 Various types of buckling/models included in SUBROUTINE BUCPAN:

If the panel is stiffened by both rings and stringers, then the following computations are performed:

1. Local buckling of the panel skin between adjacent stringers and rings:

   (a) with the use of PANDA-type (closed form) theory [2]
   (b) with the use of double-trig. series expansions [6] over a "patch" which spans the stringer spacing and may be shorter than the ring spacing.

2. Inter-ring buckling of panel skin and possibly smeared stringers between adjacent rings:

   (a) with the use of PANDA-type (closed form) theory [2] (stringers smeared; rings replaced by simple support)
   (b) with the use of PANDA-type theory and for a panel of the same geometry except that it is flat (huge R)
   (c) with the use of double-trig. series expansions [6] over a "patch" that spans the ring spacing and that includes up to 6 stringer spacings with discrete stringers.

   NOTE: Results from 2(a,b) may be superseded by results from a discretized module model in which there is one ring attached to a length of cylindrical skin-with-smeared-stringers equal to the ring spacing, with symmetry boundary conditions applied to the top and bottom of the cylindrical part of the model. See Fig. 30 of Ref.[6]. If 2(a,b) have been superseded, a message such as the following will appear in the *.OPM file:

   "Simple-support inter-ring buckling with smeared stringers is not recorded as a margin because this type of buckling has been superseded by the results from the discretized inter-ring module model, for which inter-ring buckling

load factors have been computed in the range from n = 1
to n = 118 circumferential halfwaves.
The critical simple-support inter-ring buckling model has
34 circ. half waves, which lies within this range."

3. General buckling of panel skin with possibly smeared stringers and possibly smeared rings:

   (a) with the use of PANDA-type (closed form) theory [2] (stringers and rings both smeared)
   (b) with the use of double-trig. series expansions [6] over a "patch" that may include up to six stringer spacings and up to five ring spacings with discrete. stringers and discrete rings.

4. Inter-ring buckling with ring rolling, smeared stringers; PANDA-type theory [2] only.(May be superseded as with 2a,b)

5. Buckling between stringers with smeared rings including stringer rolling; PANDA-type theory only.

6. Low-axial-wave stringer rolling without skin participation; PANDA-type theory only.

7. High-axial-wave stringer rolling without skin participation; PANDA-type theory only.

8. Low-circumferential-wave ring rolling without skin participation; PANDA-type theory. (May be superseded as with 2a,b).

9. High-circumferential-wave ring rolling without skin participation. (May be superseded as with 2a,b).

10. Axisymmetric rolling of ring without participation of skin.

11. Stringer web buckling from PANDA-type theory only.

12. Ring web buckling from PANDA-type theory only.

13. For hat or truss-core stiffened configurations:
    (a) hat base or truss core lower skin buckling
    (b) hat crown or truss core upper skin buckling

Part 1.4.2 Special cases in SUBROUTINE BUCPAN:

Special behavioral constraints for sandwich wall construction if applicable [10]. For each panel module segment:

1. Local buckling of sandwich segment (from VINSON 1986)

2. For both upper and lower face sheets of sandwich wall:
(a) Face sheet wrinkling from BUSHNELL theory (PANDA-type with the sandwich core represented by an elastic foundation)
(b) Face sheet wrinkling from VINSON theory
(c) Face sheet wrinkling from HOFF theory (Plantema book)
(d) Face sheet dimpling (local buckling of face sheet

with wavelength equal to the honeycomb cell diameter).

3. Failure modes that involve the sandwich core and interaction of the core with face sheets:
(a) Core crimping (from VINSON)
(b) Stringer-web-bending-induced face sheet pull-off
(c) Stringer-web-bending-induced core crushing
(d) Ring-web-bending-induced face sheet pull-off
(e) Ring-web-bending-induced core crushing
(f) Amplification-of-initial-face-sheet-waviness induced face sheet pull-off
(g) Amplification-of-initial-face-sheet-waviness induced core crushing
(h) hexagonal-core face sheet pull-off, if applicable
(i) L-direction (x-z) transverse shear core failure
(j) W-direction (y-z) transverse shear core failure
(k) core tension failure.

Buckling modes involving substiffeners [16], if applicable:

1. For isogrid substiffening: buckling of triangular piece of subskin between adjacent substiffeners including rolling of the subisogrid members along the three edges [12, 16].

2. Buckling of subring as wide column with linearly varying width-wise web compression from subring tip to subring root

3. Local subskin buckling between adjacent substiffeners including substiffener rolling along the 4 edges of the domain (PANDA-type theory [2]). This calculation is analogous to that for local buckling; see 1(a) above.

4. Buckling of substringer simply supported along root, no participation of the panel skin (ENDBUK-like coding).

5. Buckling of subring simply supported along root, no participation of the panel skin (ENDBUK-like coding).

6. Buckling of "patch" with use of double-trigonometric series expansion [6] over domain including up to 6 substringer spacings and 6 subring spacings with discrete substringers and discrete subrings. (The margin contains the string "altsoln4"). This calculation is analogous to the model 3(b) for general instability listed above [6].

7. Buckling of "patch" with use of double-trigonometric series expansion [6] over domain between adjacent substringers and subrings, with rolling of substiffeners included along the four edges. (The margin contains the string "altsoln5"). This calculation is analogous to the model 1(b) for local buckling listed above.

8. buckling between subrings with smeared substringers, subring rolling included. This calculation is analogous to the models 2(a) and 4 for inter-ring buckling listed above [2].

9. Buckling of "patch" with use of double-trigonometric series

expansion [6] over domain between adjacent subrings, with rolling of subrings included. The domain includes up to six substringer spacings and the substringers are discrete. (The margin contains the string "altsol6"). This calculation is analogous to the model 2(c) for inter-ring buckling listed above [6].

10. Buckling between substringers with smeared subrings from PANDA-type theory [2]. Substringer rolling is included. This calculation is analogous to model 5 listed above [2].

11. Models involving rolling of substringers and subrings without participation of the panel skin [2]:
   (a) low-m rolling of substringer
   (b) high-m rolling of substringer
   (c) low-m rolling of subring
   (d) high-m rolling of subring
   (e) axisymmetric rolling of subring.
   These models are analagous to Models 6 - 10 listed above for stringer and ring rolling [2].

Part 1.4.3 Types of "knockdown" used in PANDA2

The Local, Inter-ring, and General buckling load factors are knocked down by the following factors:

(a) Imperfection sensitivity factor
(b) Inherent unconservativeness of smearing stringers
    (if there are smeared stringers in the model)
(c) Inherent unconservativeness of smearing rings
    (if there are smeared rings in the model)
(d) Transverse shear deformation (t.s.d.) effects
(e) Ratio of buckling loads from ARBOCZ/PANDA2 theories, if
    that ratio is less than 1.0.

Part 1.4.4 Imperfections cause stress redistribution:

In computing the various buckling load factors, SUB. GENSTB includes the effect of redistribution of stress resultants between panel skin and stiffener segments caused by bending of an initially imperfect shell subjected to its design load. For example, see the listing for DNX, DNY, DNXY at the end of PART 1.1.

Part 1.4.5 Buckling margins

Buckling load factors corresponding to buckling margins of the following types are computed in SUBROUTINE GENSTB (called by SUBROUTINE BUCPAN):

```
------------------- typical margin names ---------------------
buck.(SAND);simp-support local buck.; M=1;N=1;slope=0.09;FS=1.
```

```
buck.(SAND);simp-support smear rings; M=272;N=1;slope=0.;FS=1.
buck.(SAND);simp-support general buck;M=1;N=3;slope=3.4427;FS=
buck.(SAND);rolling with local buck.; M=1;N=1;slope=6.57;FS=1.
buck.(SAND);rolling with smear rings;M=110;N=1;slope=0.01;FS=1
buck.(SAND);rolling only of stringers;M=12;N=0;slope=0.;FS=1.6
buck.(SAND);hiwave roll. of stringers;M=92;N=0;slope=0.;FS=1.2
buck.(SAND); STRINGERS:  web buckling;M=7;N=1;slope=0.;FS=1.0
buck.(SAND);   RINGS:    web buckling;M=1;N=1;slope=0.186;FS=1
----------------------------------------------------------------
```

in which "SAND" = "Sanders shell theory", (M,N,slope)=buckling mode (axial halfwaves,circ.halfwaves,slope of nodal lines) and "FS" = "factor of safety".

If the user seeks additional buckling solutions [6], the following additional buckling margins are computed:

```
------------------- typical margin names ---------------------
buck.(SAND);simp-support local buck.; (0.95*altsol);FS=0.999
buck.(SAND);simp-support inter-ring;  (1.00*altsol);FS=0.999
buck.(SAND);simp-support general buck;(0.85*altsol);FS=0.999
---------------------------------------------------------------
```

in which the string "altsol" indicates that the margins were computed with use of double trigonometric series expansions.

In the presence of substiffeners [16] SUBROUTINE BUCPAN computes the following additional buckling margins:

```
------------------- typical margin names ---------------------
buck.(SAND);rolling with skin buckl.;M=1;N=1;slope=0.175;FS=1.
buckling:simp-support of substring.M=1;FS=1.
buckling:simp-support of subrings  N=1;FS=1.
buckling:simp-support altsoln4  intermajorpatch; FS=0.999
buckling:simp-support altsoln5  skin+edgsubroll; FS=0.999
buck.(SAND);rolling with smear substr;M=1;N=1;slope=14.3;FS=1.
buckling:simp-support altsoln6  inter-subring  ; FS=0.999
buck.(SAND);rolling with smear subrng;M=43;N=1;slope=0.02;FS=1
buck.(SAND);rolling only of substring;M=29;N=0;slope=0.;FS=1.6
buck.(SAND);hiwave roll. of substring;M=31;N=0;slope=0.;FS=1.6
buck.(SAND);rolling only of subrings; M=0;N=3;slope=0.;FS=1.6
----------------------------------------------------------------
```

If one or more of the panel module segments is of sandwich wall construction [10], SUBROUTINE GENSTB computes the following additional margins (also see below for yet more behavioral constraints relating to sandwich walls):

```
------------------- typical margin names ---------------------
localbuck (VINSON);strng Iseg1 ;MID; local buck.; M=5;FS=1.1
Face1 wavelength/celldiam;STR;Iseg=1 ;Matl=2 ;MIDLENGTH;FS=1.
Core crushing margin;STR;Iseg=1 ;Matl 2 ;MIDLENGTH;FS=1.
L-dir. sandwich core shear;STR;Iseg=1 ;Matl 2 ;MIDLENGTH;FS=1.
W-dir. sandwich core shear;STR;Iseg=1 ;Matl 2 ;MIDLENGTH;FS=1.
----------------------------------------------------------------
```

If the stiffeners form an isogrid pattern (ISOGRD=1)[12], then there are additional margins pertaining to the isogrid members

```
------------------- typical margin names ---------------------
buck.(SAND);rolling only of isogrid3 ;M=1;N=0;slope=0.;FS=1.6
buck.(SAND);hiwave roll. of isogrid3 ;M=5;N=0;slope=0.;FS=1.2
buck.(SAND); ISOGRID  :  web buckling;M=4;N=1;slope=0.;FS=1.0
--------------------------------------------------------------
```

in which "isogrid3" means "the 3rd set of isogrid members". (There are three sets of equally spaced isogrid members, the three sets forming equilateral triangles).

If the panel is a truss-core sandwich, Ref.[5], Fig.9, there are additional margins, as follows:

```
------------------- typical margin names ---------------------
buck.(DONL); STRINGERS:lower skin; M=69;N=1;slope=0.723;FS=1.0
buck.(DONL); STRINGERS:webbuckling;M=35;N=1;slope=-0.356;FS=1.
buck.(DONL); STRINGERS:upper skin; M=19;N=1;slope=0.2281;FS=1.
0.45*(Stringer spacing, b)/(Stringer base width, b2) - 1;FS=1.
(Str. base width, b2)/(0.2*(Str. spacing, b)) - 1; FS=1.0
--------------------------------------------------------------
```

in which "DONL" means "Donnell shell theory" and "webbuckling" indicates the most critical truss core web.

If the panel is hat-stiffened, Ref.[1], Figs.19,20, there are additional margins, as follows:

```
------------------- typical margin names ---------------------
buck.(DONL); STRINGERS: under hat; M=18;N=1;slope=0.01;FS=1.0
buck.(DONL); STRINGERS: crown of hat;M=23;N=1;slope=0.;FS=1.0
---------------------------------------------------------------
```

PART 1.5

Computations that occur in SUBROUTINE STFEIG...
The purpose of SUBROUTINE STFEIG is to compute buckling load factors for the various segments of the stiffeners. There is a double loop: outer loop over K = 1,2 (1=stringers; 2=rings); inner loop over I = ISTART,IEND, the segment number within the stiffener. The buckling modes are of the type shown in Fig.5 in Ref.[2]. Examples of corresponding buckling margins are:

```
------------------- typical margin names ---------------------
buckling margin stringer Iseg.3. Local halfwaves=7. MID.;FS=1.
buckling margin stringer Iseg.4. Local halfwaves=7. MID.;FS=1.
buckling stringer Isegs.3+4 together.M=7  ;C=0.; MID.;FS=1.4
buckling stringer Iseg 4 as beam on foundation.M=221;MID.;FS=3
buckling margin   ring   Iseg.3. Local halfwaves=1. MID.;FS=1.
buckling   ring   Iseg 4 as beam on foundation.M=114;MID.;FS=3
---------------------------------------------------------------
```

in which "Iseg" is the stiffener segment number used in the prompts to the user during the interactive BEGIN execution, "MID" = "midway between rings" and "FS" ="factor of safety".

In computing the stiffener buckling load factors, SUB. STFEIG includes the effect of redistribution of stress resultants between panel skin and stiffener segments caused by bending of an initially imperfect shell subjected to its design load. For example, see the listing for DNX, DNY, DNXY at the end of PART 1.1.

The various buckling margins listed above are computed as follows:
(a) buckling of "interior" stiffener segments (stiffener segments attached to other structure along both long edges): SUBROUTINE WEBBUK, called by SUBROUTINE CRIPPL. Linear variation of axial compression from web root to web tip is accounted for. See Items 120d and 121 in ../doc/panda2.news.
(b) buckling of "end" stiffener segments (stiffener segments attached to other structure along only one long edge): SUBROUTINE ENDBUK, called by SUBROUTINE CRIPPL. See Item 121 in ../doc/panda2.news.
(c) buckling of web and outstanding flange together: SUBROUTINE CRIPP2. The axial load in the stiffener web in this calculation is the average of that at the web root and that at the web tip. See panda2.news Items 30 and 516
(d) buckling of outstanding flange as beam on an elastic foundation. The elastic foundation is the web. (Item 383)

In addition, for truss-core sandwich walls the wide column width-wise buckling of segments of the truss core and face sheets are computed. In the case of isogrid stiffening, the rolling of isogrid members assumed to be hinged along their roots is computed in SUBROUTINE EIGISO. See [12],Item no. 122.

If the stiffeners form an isogrid pattern [12] there exist buckling margins of the following type:

```
------------------- typical margin names ---------------------
buckling margin isogrd1  web. Local halfwaves=4  .MID.;FS=1.0
buckling margin isogrd2  web. Local halfwaves=4  .MID.;FS=1.0
buckling margin isogrd3  web. Local halfwaves=4  .MID.;FS=1.0
buckling margin isogrd3  flange. Local halfwaves=3.MID.;FS=1.0
buckling isogrd3  Isegs.3+4 together.M=4  ;C=0.;  MID.;FS=1.4
buckling isogrd3  stiff.no.J=3 ;panel MID.;M=1 ;FS=1.2
--------------------------------------------------------------
```

in which "isogrd1", "isogrd2", "isogrd3" mean "isogrid members 1, 2, 3, respectively. (There are three sets of equally spaced isogrid stiffeners that form equilateral triangles).

If the panel is truss-core sandwich, Ref.[5],Fig.9, there are additional margins, as follows:

```
------------------- typical margin names ---------------------
buckling marg. stringer Iseg.(width-wise wide col.)MID.;FS=1.0
buckling marg. stringer Iseg.(width-wise wide col.)MID.;FS=1.0
buckling marg. stringer Iseg.(width-wise wide col.)NOPO;FS=1.0
buckling marg. stringer Iseg.(width-wise wide col.)NOPO;FS=1.0
--------------------------------------------------------------
```

in which Iseg = segment numbering as in "BEGIN"; "MID." =

"midway between rings" (midbay); "NOPO" = "no postbuckling".

PART 1.6 Conservativeness of PANDA2 analyses

Designs generated by PANDA2 tend to be conservative because:

1. In several instances there is more than one model of a particular phenomenon. {Example: general buckling from PANDA-type (closed form) theory [2] and general buckling from double trigonometric series expansion [6].} PANDA2 retains the margins from both models so that the design that evolves during optimization cycles will be feasible with respect to both models.

2. For imperfect shells the imperfection sensitivity knockdown factors generated from the PANDA-type theory [4] are applied to the double-trigonometric series "patch" models [6] even if the "patch" models yield buckling modes that do not resemble the corresponding buckling modes (local, inter-ring, general) from PANDA-type (closed form) theory.

3. Knockdown factors are applied to the double-trig. series expansion models [6] to compensate for possible truncation error. For example, in the case of the general buckling "patch" model, a rather conservative knockdown factor 0.85 is applied to the buckling load factor (in addition to the knockdown factor for imperfection sensitivity) in order to compensate for truncation of the double trigonometric series expansion.

4. For imperfect cylindrical panels and shells subjected to pure axial compression or predominantly axial compression, [specifically: SQRT(Nx^2 + Nxy^2)/ABS(Ny) > 10], a factor of 4.0 is applied to the initial amplitude of the imperfection specified by the user. This is done because hyperbolic growth of the imperfection amplitude is assumed to hold [6] as the applied load approaches the design load. This assumption is only valid if the buckling eigenvalues are well separated, as is true for axially compressed columns or externally pressurized cylindrical shells. For axially compressed, very thin cylindrical shells there exists a cluster of eigenvalues in the neighborhood of the "classical" buckling load, with the result that the initial imperfection grows more slowly than hyperbolically for low loads and more steeply than hyperbolically for high loads. The factor of 4.0 compensates for the approximation, of hyperbolic growth of the buckling modal imperfection amplitude; most likely it compensates conservatively.

5. In panels and shells with both stringers and rings, the stringers and rings are allowed to deform "through eachother" where they intersect. That is, they do not support eachother in any way where they intersect.

6. The knockdown factor to compensate for the unconservative-ness of smearing rings is quite conservative, since it is computed with the use of a discretized "skin"-ring single

module model with symmetry conditions applied at top and bottom, which simulates an infinitely long cylindrical shell. (See leftmost image, bottom row in Fig. 30 of [6]).

The "smeared ring" knockdown factor is the ratio:

(buckling load factor from the discretized module model)/
(buckling load factor of a ring with the same cross-sect.)

computed for the critical number of circumferential waves determined from a PANDA-type model with smeared rings and an axial length equal to the user-specified length. The knockdown factor is less than 1.0 primarily because the cross section of the discretized module model can deform whereas the ring cross section is assumed not to deform.

7. The knockdown factor for transverse shear deformation (t.s.d.) is on the conservative side. (See Fig. 25 on p.527 of [1]).

8. The buckling load factor for the outstanding flanges of stringers and rings, computed in SUBROUTINE ENDBUK (called by SUB.CRIPPL, which is called by SUB.STFEIG) is conservative because it is based on the assumption that the flange is simply supported where it joins the web tip.

9. The buckling load factor for the web and outstanding flange of a stringer (or ring) (stiffener segment 3+4 buckling) is conservative because it is assumed that the web root is simply supported where it joins the panel skin.

10. The buckling load factor of an outstanding flange acting as a beam on an elastic foundation is conservative because of the factor of safety of 3.0 applied to that kind of failure.

11. The buckling load factor of a stringer and/or ring rolling without participation of the panel skin is conservative because of the factor of safety, F.S.=1.6, applied to that kind of failure. (For a picture of this kind of buckling see Fig. 6b, p. 546 of [2]).

12. The knockdown factor to compensate for the unconservativeness of smearing stringers is felt to be conservative.

13. For panels stiffened by stringers and/or rings with cross sections that have outstanding flanges (not blades), the buckling load factors computed with use of the double trigonometric series expansions [6] will usually be conservative because the edges of the "altsol patch" are assumed to be simply supported rather than supported by a stiffener.

14. The "knockdown" factor for imperfection sensitivity (see PART 1.7) is often made smaller by multiplication by a ratio, (ARBOCZ/PANDA2), which is either unity or less than unity. In the ratio, (ARBOCZ/PANDA2):
ARBOCZ = buckling load of perfect shell from ARBOCZ theory (see [5])

PANDA2 = buckling load of perfect shell from PANDA-type (closed form) theory (see [2]).

15. PANDA2 computes a "knockdown" factor for imperfection sensitivity by iteratively computing an effective circumferential radius of curvature as described below and in Ref. [17]. The effective radius of the imperfect shell is larger than the nominal radius of the perfect shell because it corresponds to the local circumferential radius of curvature at the point on the shell surface where there is a maximum inward lobe of the general buckling modal imperfection pattern. Although this maximum circumferential radius of curvature is local, varying along the circumference because of the waviness of the general buckling modal imperfection shape, in PANDA2 it is assumed that the maximum circumferential radius of curvature of the imperfect shell is UNIFORM over the entire circumference of the panel. This is almost certainly a conservative model. See below and Ref. [17] for a more complete discussion of how imperfection sensitivity is handled in PANDA2. It is emphasized here that the theory used in PANDA2 is NOT the very conservative asymptotic "classical" imperfection sensitivity theory by Koiter.

****
**** **2006: A NEW "CONSERVATIVENESS" INDEX, "ICONSV"** *****
****

In 2006 a new "conservativeness" index, ICONSV, was introduced as an input datum in the *.OPT file.
ICONSV= 1 generates the most conservative model.
ICONSV= 0 generates a model of intermediate conservativeness.
ICONSV=-1 generates the least conservative model.
Please see Section 9.0, Item No. 676 in [18] for details.

ICONSV = 1 (recommended model) means:
a. Include ARBOCZ theory when computing knockdown factors for local, inter-ring, general buckling.
b. Use more conservative knockdown factors for models in which the stringers are smeared.
c. Use computed knockdown factor for smearing rings
d. The Donnell shell theory is used in SUBROUTINE STRIMP, where imperfection sensitivity is being computed.

ICONSV = 0 (less conservative model) means:
a. Do NOT include ARBOCZ theory when computing knockdown factors for local, inter-ring, general buckling.
b. Use less conservative knockdown factors for models in which the stringers are smeared.
c. Use computed knockdown factor for smearing rings (Same as for ICONSV = 1).
d. The user-selected shell theory is used in SUBROUTINE STRIMP, where imperfection sensitivity is being computed.

ICONSV = -1 (still less conservative model) means:
a. Do NOT include ARBOCZ theory when computing knockdown factors for local, inter-ring, general buckling.

(Same as for ICONSV = 0)

b. Use less conservative knockdown factors for models in which the stringers are smeared.
   (Same as for ICONSV = 0)

c. Do NOT use computed knockdown factor for smearing rings (Knockdown factor for smearing rings = 1.0).

d. Set the knockdown factor for truncated double-trig series expansion (altsol) models to RFACT = 0.95.
   (RFACT=0.85 for "altsol" models in which there are smeared stiffeners if ICONSV = 0 or 1).

e. The user-selected shell theory is used in SUBROUTINE STRIMP, where imperfection sensitivity is being computed.

PART 1.7 How the effect of imperfections is handled in PANDA2:

PANDA2 can optimize imperfect stiffened panels and shells [4]. Imperfections are assumed to be in the shapes of the general, inter-ring, and local buckling modes obtained from the "PANDA-type" model [2]. This section of PANDA2 applies to stiffened panels with a general buckling modal imperfection, that is, an imperfection shape that is determined from a model in which the stiffeners are smeared out. A general buckling modal imperfection in a stiffened shell has two major effects:

1. The imperfect stiffened panel or shell bends as soon as any loading is applied. This bending causes significant redistribution of stresses between the panel skin and the various stiffener parts, thus affecting significantly many local and inter-ring buckling and stress constraints.

2. The "effective" curvature of an imperfect cylindrical panel or shell depends on the amplitude of the initial imperfection, on the circumferential wavelength of the critical buckling mode of the perfect and of the imperfect shell, and on the amount that the initial imperfection grows as the loading increases from zero to the design load. The "effective" circumferential radius of curvature of the imperfect and loaded shell is larger than its nominal radius of curvature because this radius corresponds to the maximum local radius of a typical inward circumferential lobe of the initial and subsequently load-amplified buckling modal imperfection.

In PANDA2 this larger local radius of curvature is assumed to be the governing radius in the buckling equations pertaining to the imperfect shell. For each type of buckling modal imperfection (general, inter-ring, local) PANDA2 computes a "knockdown" factor based on the ratio:
(buckling load factor: panel with its "effective" radius)/
(buckling load factor: panel with its nominal radius)

In the following "imperfection sensitivity" calculations PANDA2 does the following (using Donnell shell theory if

ICONSV = 1 and using the user-selected shell theory if ICONSV = 0 or ICONSV = -1):

1. Computes the buckling load factor for a PERFECT panel
   from PANDA-type theory [2].
2 Computes the buckling load factor for a PERFECT panel
   from ARBOCZ theory. Equations are from "The effect of
   initial imperfections on shell stability - an updated
   review" by Johann Arbocz, Faculty of Aerospace Engineering,
   Delft University of Technology, Report LR-695, Sept.1992.
   in particular, see Equation No. (3.61) in that report.
   This ARBOCZ theory is also described briefly in [5].

3. Computes the buckling load factor for an IMPERFECT panel
   from ARBOCZ theory.

4. Computes the buckling load factor for an IMPERFECT panel
   from PANDA-type theory [2]. This is done iteratively
   since the "effective" circumferential radius of curvature
   of the imperfect panel depends on the buckling load
   factor that is being computed.

5. Decides (partly depending on user-provided input) on
   whether to use the buckling mode for the PERFECT shell or
   the buckling mode of the IMPERFECT shell as the
   imperfection shape.

6. Computes the curvature changes and twist, Wxx, Wyy, Wxy,
   generated because of prebuckling bending of the imperfect
   shell as it is loaded by the design load.

7. Presents a summary of "knockdown" factors to be used in
   connection with local, inter-ring, and general buckling of
   the stiffened shell.

For more information on the behavior of imperfect stiffened shells, please see the following news items in the file, ..doc/panda2/news: 377, 456, 525, 553, 564, 594, and 596. Also, please read the papers [4], [5], and especially [17]. Study Sections 11 - 14 and Tables 9 and 10 of [17].

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```
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****************************************
ITERATION NO., LOAD SET NO., SUBCASE NO. =   0   1   1     PANEL MIDLENGTH
****************************************
ILOADS,ICASES,NWAVES(ILOADS,ICASES)=     1     1     0



************** NEXT LOAD SET *****************
************** NEXT LOAD SET *****************
************** NEXT LOAD SET *****************

*********** LOAD SET NO. 1  **************
ICASE =  1  (ICASE=1 MEANS PANEL MIDLENGTH)
```

```
           (ICASE=2 MEANS PANEL ENDS                      )

   APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
         Applied     axial       stress resultant, Nx= -2.2190E+03
         Applied circumferential stress resultant, Ny=  0.0000E+00
         Applied    in-plane     shear  resultant,Nxy=  1.1095E+01
         Applied     axial       moment resultant, Mx=  0.0000E+00
         Applied circumferential moment resultant, My=  0.0000E+00
         Applied pressure (positive for upward),   p =  0.0000E+00

   APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
         Applied     axial       stress resultant,Nx0=  0.0000E+00
         Applied circumferential stress resultant,Ny0=  0.0000E+00
         Applied    in-plane    shear  resultant,Nxy0=  0.0000E+00

 NOTE: "F.S." means "Factor of Safety";
 "DONL" means "Donnell shell theory used.";
 "SAND" means "Sanders shell theory used." panda2.news ITEM 128
 "Dseg" means "Segment numbering used in discretized model"
 "Iseg" means "Segment numbering used for input data." ITEM 272
 ****************************************
 ENTERING STRUCT. IMOD= 0
 ITERATION NO., LOAD SET NO., SUBCASE NO. =   0   1   1       CURRENT DESIGN
 ****************************************

 The numbers of the references [ ] given in the CHAPTER
 headings correspond to those listed at the end of the paper:
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007
```

Reference [1] from that April 2007 paper:

[1] Bushnell, D., et al, (A) "PANDA2 - Program for minimum weight design of stiffened, composite, locally buckled panels", Computers and Structures, Vol. 25 (1987) pp. 469-605. See also: (B) "Theoretical basis of the PANDA computer program for preliminary design of stiffened panels under combined in-plane loads", Computers and Structures, v. 27, No. 4, pp 541-563, 1987; (C) "Optimization of composite, stiffened, imperfect panels under combined loads for service in the postbuckling regime", Computer Methods in Applied Mechanics and Engineering, Vol. 103, pp 43-114, 1993; (D) "Recent enhancements to PANDA2" 37th AIAA Structures, Dynamics, and Materials (SDM) Conference, April 1996; (E) "Approximate method for the optimum design of ring and stringer stiffened cylindrical panels and shells with local, inter-ring, and general buckling modal imperfections", Computers and Structures, Vol. 59, No. 3, 489-527, 1996, with W. D. Bushnell; (F) "Optimum design via PANDA2 of composite sandwich panels with honeycomb or foam cores", AIAA Paper 97-1142, AIAA 38th SDM Conference, April 1997; (G) "Additional buckling solutions in PANDA2", AIAA 40th SDM Conference, p 302-345, April 1999, with H. Jiang and N. F. Knight, Jr.; (H) "Minimum-weight design of a stiffened panel via PANDA2 and evaluation of the optimized panel via STAGS", Computers and Structures, Vol. 50, 569-602 (1994); (I) "Optimization of perfect and imperfect ring and stringer stiffened cylindrical shells with PANDA2 and evaluation of the optimum designs with STAGS", AIAA Paper 2002-1408, pp 1562-1613, Proceedings of the 43rd AIAA SDM Meeting, April, 2002, with C. Rankin; (J) "Optimum design of stiffened panels with substiffeners, AIAA Paper 2005-1932, AIAA 46th SDM Conference, April 2005, with C. Rankin; (K) "Difficulties in optimization of imperfect stiffened cylindrical shells, AIAA Paper 2006-1943, AIAA 47th SDM Conference, April 2006, with C. Rankin; (L).../panda2/doc/panda2.news, a continually updated file distributed with PANDA2 that contains a log of all significant modifications to PANDA2 from 1987 on.

```
 The overall structure of PANDA2 and its use are described in
 the first PANDA2 paper, Ref.[1A], cited in the April 2007
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paper just identified. Ref.[1A] is the following paper:
Bushnell, D.,
"PANDA2 - Program for minimum weight design of stiffened,
composite, locally buckled panels", COMPUTERS AND STRUCTURES,
Vol. 25, No. 4, pp 469-605, 1987

Concepts such as "wide-column" buckling, "discretized module model", "stringer pop-off", "constitutive matrices" "reduction factor for transverse shear deformtion (t.s.d.)" "smeared stiffeners", "neutral surface", "overall and local static response to uniform pressure", "knockdown factors for anisotropy and in-plane shear loading", "crippling of stiffener parts", and "local postbuckling" are described there, with many early PANDA2 examples provided.

The string, "PANDA-type theory" often occurs. This refers to the theory presented in Ref. [1B] of the April 2007 citation listed first. Ref.[1B] contains the theory given in the paper:
Bushnell, D.,
"Theoretical basis of the PANDA computer program for
preliminary design of stiffened panels under combined in-
plane loads", COMPUTERS & STRUCTURES, v. 27, No. 4,
pp 541-563 (1987).

The theory used for local postbuckling behavior appears in Ref. [1C] of the April 2007 paper cited first (above).
Ref. [1C] is the following paper:
Bushnell, D.,
"Optimization of composite, stiffened, imperfect panels
under combined loads for service in the postbuckling
regime", Computer Methods in Applied Mechanics and
Engineering, Vol. 103 (1993) 43-114

The theory used for imperfection sensitivity appears in Refs. [1E] and [1D] of the first-cited paper above.
Refs. [1E] and [1D] are the following two papers:

Bushnell, D. and Bushnell, W. D.,
"Approximate method for the optimum design of ring and
stringer stiffened cylindrical panels and shells with
local, inter-ring, and general buckling modal imperfections"
Computers and Structures, Vol. 59, No. 3, pp 489-527 (1996)

Bushnell, D.,
"Recent enhancements to PANDA2" AIAA Paper 96-1337-CP,
Proc. of the AIAA 37th Structures, Structural Dynamics and
Materials Conference, pp 126-182, April, 1996.

The last paper cited also describes the "global" optimizer, "SUPEROPT", implementation of Sanders shell equations into PANDA2, implementation of the Arbocz theory for imperfection sensitivity, implementation of isogrid geometry, and implementation of various truss-core geometries, with examples.

The theories used in PANDA2 for the analysis of sandwich walls are given in Ref.[1F] of the first-cited paper above.
Ref. [1K] is the following paper:
Bushnell, D.,

"Optimum design via PANDA2 of composite sandwich panels with honeycomb or foam cores", AIAA Paper 97-1142, Proc. 38th AIAA Structures, Structural Dynamics and Materials Conference, pp 2163-2202, April, 1997

The "alternate" (double-trigonometric series expansion buckling theory) and the discretized "skin"-ring module model are described in Ref. [1G] of the first-cited paper. Ref. [1G] is the following paper:
Bushnell, D., Jiang, H., and Knight, N.F.,
"Additional buckling solutions in PANDA2", Proceedings of the 40th AIAA SDM Conference, AIAA Paper 99-1233, pp 302-345 April 1999

Details of the strategy used in PANDA2 for accounting for initial buckling modal imperfections are described and listed in a table in Ref. [1K]. Ref. [1K] is the following paper:
Bushnell, D. and Rankin, C.C.,
"Difficulties in optimization of imperfect stiffened cylindrical shells",
AIAA Paper 1943, 47th AIAA Structures, Structural Dynamics and Materials Meeting, Newport RI, April 2006

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************************************************************
ENTERING SUBROUTINE STRUCT
***************    TABLE OF CONTENTS   ********************
CHAPTER 1  Compute the 6 x 6 constitutive matrices [C] for
           individual model segments and various combinations
           thereof (skin with smeared stiffener sets [1A]).
CHAPTER 2  Do PANDA-type [1B] general buckling analysis to
           get Donnell factors for later use, if appropriate.
CHAPTER 3  Do various PANDA-type [1B] general buckling
           analyses needed for later computation of effective
           length of the panel. Compute the effective length.

CHAPTER NEW Compute wide-column buckling from discretized
           skin-stringer module model (Figs. 20b,c & 22b,c in
           [1A]) with only Nx (Ny=0, Nxy=0). The purpose is to
           obtain a knockdown factor, WIDKNK, for smearing
           the stringers in an inter-ring buckling mode
CHAPTER 4  Compute axisymmetric prebuckling "hungry-horse"
           state of the curved panel or cylindrical shell.
           (See Ref.[1E]).
CHAPTER 5  Get static response of panel to normal pressure
           [1A].
CHAPTER 6  Do PANDA-type [1B] general and inter-ring buckling
           analyses to permit later computation of
           amplification of panel bowing.
CHAPTER 7  Compute distribution of loads in panel module
           skin-stringer segments, neglecting redistribution
           due to initial buckling modal imperfections
           (See Section 10 of [1A]).
CHAPTER 8  Do PANDA-type local, inter-ring, general buckling
           analyses and PANDA-type stringer web and ring web
           buckling analyses to get knockdown factors to
           compensate for lack of in-plane shear Nxy loading
```

and anisotropy in discretized BOSOR4-type models. (See Section 11 of [1A] and Item No. 81 in [1L]).

CHAPTER 9 Do BOSOR4-type "skin"-ring buckling analyses to compute knockdown factor to compensate for inherent unconservativeness of models with smeared rings. (See Items 509, 511, 522, and 605 in [1L]; "skin"=skin+smeared stringers).

CHAPTER 10 Compute knockdown factors and prebuckling bending associated with initial general, inter-ring, local buckling modal imperfections. (See Ref.[1E]).

CHAPTER 10.1 Compute knockdown factor and prebuckling bending associated with general buckling modal initial imperfection. (See Sectons 13 and 14 and Tables 9 and 10 of [1K] for a detailed example)

CHAPTER 10.2 Compute knockdown factor and prebuckling bending associated with inter-ring buckling modal initial imperfection.

CHAPTER 10.3 Compute knockdown factor and prebuckling bending associated with local buckling modal initial imperfection.

CHAPTER 10.4 Present a summary of imperfection sensitivity results. (See Section 13 and Table 9 of [1K])

CHAPTER 11 Get change in stress resultants, Nx, Ny, Nxy in various segments of the skin-stringer module during prebuckling bending of the imperfect shell. Also, do PANDA-type [1B] local, inter-ring, general buckling analyses and PANDA-type stringer web and ring web buckling analyses to get knockdown factors to compensate for the lack of in-plane shear Nxy loading and anisotropy in discretized BOSOR4-type models. (See Section 11 in [1A])

CHAPTER 12 List prebuckled state of the initially imperfect and loaded and bent panel or shell. This section includes the redistribution of Nx, Ny, Nxy in the various segments of the stiffened shell structure.

CHAPTER 13 List prebuckling stress resultants, Nx, Ny, needed for the discretized single-module skin-stringer model used for local buckling and bending-torsion buckling (BOSOR4-type model: see Figs. 18, 20, 22, 97, and 98 of [1A], for examples).

CHAPTER 14 Compute local buckling from BOSOR4-type discretized skin-stringer single module model. See Section 12.2 in [1A].

CHAPTER 15 Compute bending-torsion (low-m) buckling from BOSOR4-type discretized skin-stringer single module model. See Section 12.2 in [1A].

CHAPTER 16 Compute post-local buckling from the Koiter theory given in Ref.[1C]. (Figs. 23, 24 in [1A] and Fig. 6 in [1C]).

CHAPTER 17 Compute stresses in layers and at various locations in skin-stringer module model, including local post-buckling, if any. Compute stringer popoff constraints [1A].SUBROUTINE STRTHK is used.

CHAPTER 18 Present summary of state of loaded imperfect panel and give effective stiffnesses of possibly locally postbuckled skin-stringer module. These effective stiffnesses (Table 12 of Ref. [18]) are used later for overall buckling and inter-ring buckling.

```
CHAPTER 19 Do wide-column inter-ring buckling analysis with
           possibly locally postbuckled skin-stringer module
           model. (See Fig. 20c of [1A]).
CHAPTER 20 Compute width-wise wide column buckling and
           lateral-torsional buckling load factors from the
           possibly locally postbuckled skin-stringer module
           model (inter-ring buckling modes).
           See panda2.news Item Numbers 379 and 381 in [1L].
CHAPTER 20b Compute high-m buckling of single discretized
           skin-stringer module (same model as used in
           CHAPTER 14 except explored in the range of high
           numbers of axial halfwaves). See panda2.news
           Item Numbers 682 and 754.
CHAPTER 20c Compute buckling of a single discretized
           skin-substringer module. See panda2.news Item 764.
           The axial length of the module is equal to the
           spacing of the subrings, and the width of the
           module is equal to the spacing of the substringers.
CHAPTER 21 Compute "skin"-ring buckling load factor for
           computing knockdown to compensate for inherent
           unconservativeness of smeared ring models.
           (See bottom row in Fig. 30 of Ref.[1G]. Also see
           panda2.news Items 509, 511, 522, 532, 605, 617
           619, 632, 633, 676.
CHAPTER 22 Compute "skin"-ring buckling load factors for:
           1. medium-n inter-ring buckling mode (See
              rightmost three mode shapes in top row of
              Fig. 30 of Ref.[1G]),
           2. high-n inter-ring buckling mode (See rightmost
              mode shape in middle row of Fig. 30, Ref.[1G]),
           3. low-n inter-ring buckling mode (See leftmost
              mode shape in top row of Fig. 30, Ref.[1G]).
CHAPTER 23 Compute stresses in layers and at various
           locations in modules for both positive and
           negative imperfection amplitudes from SUBROUTINE
           STRCON (local postbuckling neglected).
CHAPTER 24 Present short summary of redistribution of stress
           resultants, Nx, Ny, Nxy, caused by prebuckling
           bending of an initially imperfect shell.
           See Section 6.0 in [1K].
CHAPTER 25 Compute buckling load factors from PANDA-type
           theory for the various segments of a stringer and
           a ring. Typical buckling modes are displayed in
           Figs. 5 and 6 of Ref.[1B].
CHAPTER 26 Compute local, inter-ring, general buckling load
           factors from PANDA-type models [1B] and from
           "alternative" (double-trigonometric series
           expansion) models, Ref.[1G]. Also compute
           sandwich wall behavior [1F], if applicable.
           Also, compute buckling load factors appropriate
           when substiffeners are present.
CHAPTER 27 Compute the objective function (e.g. WEIGHT).
CHAPTER 28 Present design, loading, and margins for the
           current load set and subcase. (See Table 6 in [18],
           that is in:
           Bushnell, D.
           "Optimization of an axially compressed ring and stringer
           stiffened cylindrical shell with a general buckling modal
```

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            imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
            Honolulu, Hawaii, April 2007)
```

```
 Just before LTESTB: ITESTB,IABP,IABT,Pressure P=    0    1    0  0.0000E+00
 Just after  LTESTB: ITESTB,IABP,IABT,Pressure P=    0    1    0  0.0000E+00
 If ITESTB = 1 then PANDA2 computes some margins for
 Load Set B acting by itself. The purpose of this strategy is
 to make sure that Load Set B cannot cause buckling by itself.


 ********** IN SUBROUTINE STRUCT (after "2 CONTINUE)" *********
 Constraints higher than CONMAX are excluded: CONMAX =  1.0000E+07


 ***********************************************
 *****   DESIGN ITERATION NO.  0  ***********
 *****           LOAD SET NO.  1  ***********
 ***** STRESS AND BUCKLING STATE AT PANEL MIDLENGTH  ***
 ***** MATERIAL ITERATION NO.  0  ***********


 DIMENSIONS OF  CURRENT  DESIGN...
 VARIABLE   CURRENT
  NUMBER     VALUE            DEFINITION
    1    1.8617E+00        B(STR):stiffener spacing, b: STR seg=NA, layer=NA
    2    6.1973E-01       B2(STR):width of stringer base, b2 (must be > 0, see
    3    8.8811E-01        H(STR):height of stiffener (type H for sketch), h: S
    4    4.9565E-02    T(1 )(SKN):thickness for layer index no.(1 ): SKN seg=1
    5    8.0641E-02    T(2 )(STR):thickness for layer index no.(2 ): STR seg=3
    6    1.1458E+01        B(RNG):stiffener spacing, b: RNG seg=NA, layer=NA
    7    0.0000E+00       B2(RNG):width of ring base, b2 (zero is allowed): RNG
    8    1.7544E+00        H(RNG):height of stiffener (type H for sketch), h: R
    9    8.9081E-02    T(3 )(RNG):thickness for layer index no.(3 ): RNG seg=3

 Get new constitutive matrices, C(i,j), static response
 to uniform normal pressure, distributions of resultants
 Nx, Ny, Nxy, in the skin and stiffener parts for Load Set A,
 Load Set B, curing, and other thermal effects, and knockdown
 factors for buckling modal imperfections....
```

The following fairly long section is generated when NPRINT = 0
in the *.OPT file (where, in this example, "*" = "nasaortho").

```
 ***********************************************************
 CHAPTER 1  Compute the 6 x 6 constitutive matrices [C] for
            individual model segments and various combinations
            thereof (skin with smeared stiffener sets [1A]).
            See Section 8 in [1A], Eq.(8.1) on p.495 of [1A].

*** BEGIN SUBROUTINE GETCIJ (CONSTIT. LAW: SEGS AND SMEARED ***
 See Section 8, pp 494-503 of Reference [1A]. First the 6 x 6
 integrated constitutive coefficients Cij (Eq.8.1) and thermal
 loading are found for each segment in the skin-stringer module
 then for the skin-ring module, then for the skin with smeared
 stringers only, then for the skin with smeared rings only,
 and finally for the skin with both stringers and rings smeared.
```

```
**** END   SUBROUTINE GETCIJ (CONSTIT. LAW: SEGS AND SMEARED ***
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
CHAPTER 2  Do PANDA-type [1B] general buckling analysis to
           get Donnell factors for later use, if appropriate.

** BEGIN SUBROUTINE BUCPAN (GENERAL PANDA-TYPE BUCKL.) ***
PURPOSE IS TO GET DONNELL FACTORS FOR LATER USE IN SUB.DONELL.
*** END  SUBROUTINE BUCPAN (EIGENVALUES. PANDA-TYPE BUCKL.) ***
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
CHAPTER 3  Do various PANDA-type [1B] general buckling
           analyses needed for later computation of effective
           length of the panel. Compute the effective length.

User-specified axial length of the panel, AXIAL=  6.8750E+01
Computed factor to modify the length, AXIAL: LENMOD=  1.0000E+00
Axial length of "equivalent" simply-supported panel, LENMOD*AXIAL=  6.8750E+01

*************************************************************
CHAPTER NEW Compute wide-column buckling from discretized
           skin-stringer module model (Figs. 20b,c & 22b,c in
           [1A]) with only Nx (Ny=0, Nxy=0). The purpose is to
           obtain a knockdown factor, WIDKNK, for smearing
           the stringers in an inter-ring buckling mode
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

******* Begin the section where WIDKNK is computed *********
******* See ..panda2/doc/panda2.news Items 724 & 725.*******

 WIDE COLUMN PANEL BUCKLING LOAD FACTOR =   2.5571E+00
ISKINX = 0. MODE OF BUCKLING IS THE PANEL SKIN IF ISKINX = 1.
ITIPWX = 0. MODE OF BUCKLING IS STRINGER SIDESWAY IF ITIPWX=1
ICWBWX = 0. MODE OF BUCKLING IS THE STRINGER WEB IF ICWBWX=1
IFLGWX = 0. MODE OF BUCKLING IS STRINGER OUTSTANDING FLANGE IF IFLGWX=1
ICRWNX = 0. MODE OF BUCKLING IS THE CROWN OF THE HAT IF ICRWNX=1

Mode number  1 IS a wide column mode and is therefore acceptable.

SMEARED STRINGER KNOCKDOWN FROM SKIN-STRINGER DISCRETE MODEL
(See ..panda2/doc/panda2.news Items 724 and 725):
Buckling axial resultant Nx from simple Euler model,   EULER =  7.0914E+03
Buckling axial resultant Nx from discretized  model,   EIGWID=  5.6742E+03
Knockdown factor for cross section rigidity & t.s.d.,  WIDKNK=  8.0015E-01
Effective axial length of the wide column model,       AXLEFF=  1.1458E+01

Axial resultant, Nx, in each of the segments of the
discretized skin-stringer cross-section before any deformation
-1.2600E+03 -1.2600E+03 -2.0102E+03 -1.2600E+03
******* End of the section where WIDKNK is computed ********
******* See ..panda2/doc/panda2.news Items 724 & 725.*******

********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

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```

CHAPTER 4 Compute axisymmetric prebuckling "hungry-horse"
state of the curved panel or cylindrical shell.
(See Ref.[1E], especially Fig. 1 and pp.495-498).

```
***** BEGIN COMPUTATIONS FOR AXISYMMETRIC PREBUCKLING
***** STATE OF THE PANEL. (See pp 495-498 of journal
***** article, COMPUTERS & STRUCTURES vol 59, no.3, 1996
***** Computations carried out in SUBROUTINE SKIN.
***** Axisymmetric response of the curved panel to the loads in Load Set A *****

***** Axisymmetric response of the curved panel to the loads in Load Set B *****
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
```

CHAPTER 5 Get static response of panel to normal pressure
[1A], especially Section 9 and Section 20.5 and
Figs. 55 - 60 in [1A].

```
Begin static response of entire panel to normal pressure:
Axial length of panel, AXLEN=  6.8750E+01

** NOTE ** If the panel is curved it is treated as a complete
(360-degree) cylindrical shell. The axisymmetric
"hungry-horse" deformed state is computed for a single ring
spacing in Chapter 4. For curved panels, therefore, no
computations are performed for the entire panel here.
End of equilibrium calculations for entire panel
with smeared stiffeners under uniform normal pressure,
p =  4.6229E-05
***** NOTE ****** See Chapter 4 for static response of a
single "skin"-ring module of the curved panel, which is
modelled as a complete (360-degree) cylindrical shell there.
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
```

**** **CHAPTER 5b** ****:

```
Next, find bending of a single skin-stringer panel
module under uniform normal pressure, p=  4.6229E-05, See
Section 9 of Ref.[1A].The panel skin is assumed to be flat
Also see Fig. 56 on p. 555 of [1A] for an example.
 LABEL NO. IN STRUCT= 9100

***** BEGIN SUBROUTINE FORCES (MODULE PRESSURE RESPONSE) *****
Purpose is to obtain resultants in each segment of the skin-
stringer single module model for input to the nonlinear static
response of single skin-stringer module to normal pressure.
See Section 10, pp 506-509, of Reference [1A].
****** END SUBROUTINE FORCES (MODULE PRESSURE RESPONSE) *******

****** BEGIN SUBROUTINE BUCKLE (MODULE PRESSURE RESPONSE) *****
****** END SUBROUTINE BUCKLE (MODULE PRESSURE RESPONSE) *******

*** NOTE ****** NOTE ****** NOTE ****** NOTE ****** NOTE ***
Because the stringers are relatively weak, the local
amplitude of "pillowing" between stringers is being reduced
by the factor, PLOCF =   1.0000E+00. See news ITEM 117(g).
*** END NOTE ***** END NOTE ***** END NOTE ***** END NOTE ***
```

```
****** BEGIN SUBROUTINE BUCKLE (MODULE PRESSURE RESPONSE) *****
 See Fig. 56 in Ref.[1A] for the model and its behavior.
 ****** END SUBROUTINE BUCKLE (MODULE PRESSURE RESPONSE) *******

****** BEGIN SUBROUTINE MODE (MODULE PRESSURE RESPONSE) *****
 ****** END SUBROUTINE MODE (MODULE PRESSURE RESPONSE) *******

****** BEGIN SUBROUTINE OUTPRS (MODULE PRESSURE RESPONSE) *****
 ****** END SUBROUTINE OUTPRS (MODULE PRESSURE RESPONSE) *******
 End of nonlinear equilibrium calculations for
 panel module with uniform normal pressure, p=  4.6229E-05


 ************************************************************
 CHAPTER 5c (prebuckling bending between rings with beam
 model) is not executed because:
 (PEDG.OR.P.EQ.0.0.OR.ISKIPL.NE.0.OR.ISTIF(2).EQ.0
 .OR.ISOGRD.NE.0.OR.ISTIF(1).EQ.5.OR.AXIAL.LT.2.5*B(2))
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 ************************************************************
 CHAPTER 6  Do PANDA-type [1B] general and inter-ring buckling
            analyses to permit later computation of
            amplification of panel bowing.

**** BEGIN SUBROUTINE BUCPAN (PRELIM. PANDA-TYPE BUCKLING) ****
**** This execution of BUCPAN is used to find the general
**** buckling load factor that is used to compute the
**** amplification of bowing from all sources except pressure.

 GENERAL BUCKLING LOAD FACTOR USED FOR CALCULATION OF THE
 AMPLIFICATION OF BOWING FROM ALL SOURCES EXCEPT PRESSURE.
 EIGBOW(M,N)=  2.3269E+00(  3,  6)
 **** END SUBROUTINE BUCPAN (PRELIM. PANDA-TYPE BUCKLING) *******

*** BEGIN BUCPAN (INTER-RING BUCKLING, SMEARED STRINGERS) ***
*** This execution of BUCPAN is used to get amplification
*** factors for inter-ring axial bowing and inter-ring local
*** prebuckling deformations (pillowing).
 EIGPAN(M,N)=  2.1573E+00(  1,  8,  0.00E+00)
 AMPLIFICATION OF INTER-RING BOWING,       AMPLT3=  1.3526E+00
 AMPLIFICATION OF INTER-RING PREB.DEFORM., AMPLT4=  1.0697E+00
 *** END BUCPAN  (INTER-RING BUCKLING, SMEARED STRINGERS) ***
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 ************************************************************
 CHAPTER 7  Compute distribution of loads in panel module
            skin-stringer segments, neglecting redistribution
            due to initial buckling modal imperfections
            (See Section 10 of [1A]).

 *** BEGIN SUBROUTINE FORCES (LOAD DISTRIB. IN SEGMENTS) *****
 Resultants in each segment of the skin-stringer and skin-ring
 modules are computed. The effect of prebuckling bending due to
 initial buckling modal imperfections is ignored at this time,
 but will be accounted for later when buckling load factors and
 stresses are computed. See Section 10, pp 506-509 of Ref.[1A]
```

```
 **** END SUBROUTINE FORCES (LOAD DISTRIB. IN SEGMENTS) *******
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
 CHAPTER 8  Do PANDA-type local, inter-ring, general buckling
            analyses and PANDA-type stringer web and ring web
            buckling analyses to get knockdown factors to
            compensate for lack of in-plane shear Nxy loading
            and anisotropy in discretized BOSOR4-type models.
            (See Section 11 of [1A] and Item No. 81 in [1L]).

*** BEGIN SUBROUTINE BUCPAN (KNOCKDOWN PANDA-TYPE BUCKLING) ***
**** The purpose of the following BUCPAN execution is to find:
*** LOCAL BUCKLING (buckling of skin between stiffeners):
**** a.with in-plane shear Nxy and anisotropic effects included
**** b.without in-plane shear Nxy and anisotropic effects
*** INTER-RING BUCKLING (stringers smeared out):
**** a.with in-plane shear Nxy and anisotropic effects included
**** b.without in-plane shear Nxy and anisotropic effects
*** GENERAL INSTABILITY (rings and stringers smeared out):
**** a.with in-plane shear Nxy and anisotropic effects included
**** b.without in-plane shear Nxy and anisotropic effects
*** THE PURPOSE IS TO FIND KNOCKDOWN FACTORS TO COMPENSATE
*** FOR THE ABSENCE OF IN-PLANE SHEAR AND ANISOTROPY IN BOSOR4-
*** TYPE MODELS (DISCRETIZED MODULE MODELS).
**** See Section 11, p. 509, of Reference [1].
*** NOTE: This set of calculations does NOT include the effect
***       of initial geometric buckling modal imperfections.

 Entering ALTSOL: radius, axial, circ. dimensions =  4.8000E+01  1.1458E+01  1.8617E+00
 See ITEMs 438, 444  in the file ..panda2/doc/panda2.news .
 and AIAA paper 99-1233, Proc. 40th AIAA SDM Meeting, 1999
 pp 302-345, especially pp 304-316 and associated figures.
 *** BUCKLING BETW MAJOR STIFFENERS, SMEARED SUBSTIFFENERS ***
        Number of discrete stringers, rings: NUMSTR, NUMRNG=  0  0

 No alternative solution sought because user did not want one.
 (IALTSN was set equal to zero in MAINSETUP)

 Label No. in STRUCT= 9140: Modifiers for knockdowns
 generated from use of the alternative buckling soln.(if any)
  General Instability, FKNOCK(1), EIGRT9 =  1.0000E+00  1.0000E+00
  Local Buckling,      FKNOCK(2), EIGRT7 =  1.0000E+00  1.0000E+00
**** END SUBROUTINE BUCPAN (KNOCKDOWN PANDA-TYPE BUCKL.) ******
**** Knockdown factors to account for anisotropy and/or the
**** presence of in-plane shear, in order to compensate for the
**** neglect of these in the BOSOR4-type discretized models for
**** buckling.
***************************************************************


 Conservativeness indicator, ICONSV= 1 (See panda2.news Item No. 676)
 Initial imperfections for general, panel, local buckling=
 Total out-of-roundness + modal,    W0GLOB =  1.2500E-01
 Out-of-roundness,                    WG1  =  0.0000E+00
 General buckling modal,              WG2  =  1.2500E-01
 Inter-ring buckling modal,          W0PAN =  0.0000E+00
 Local buckling modal,               W0LOC =  1.0000E-07
```

```
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
```

CHAPTER 9 Do BOSOR4-type "skin"-ring buckling analyses to compute knockdown factor to compensate for inherent unconservativeness of models with smeared rings. (See Items 509, 511, 522, and 605 in [1L]; "skin"=skin+smeared stringers).

```
Mode number  1 is     a suitable ring mode.

Knockdown for smeared rings on cylindrical shell...
 Buckling load factor for n+dn = FNARCQ=  6.0206E+00
                              from discrete model =  4.1164E+01
 Buckling load factor for ring with bending stiffness EI:
                     pcrit=[(n+dn)**2-1]*EI/r**3/p=  4.3417E+01
 Knockdown factor, general buckling,   EIGR/EIGRNG=  9.4809E-01
END OF SECTION ON GENERATION OF KNOCKDOWN FACTOR FOR
COMPENSATING FOR THE UNCONSERVATIVENESS OF SMEARING RINGS
---------------------------------------------------------


Knockdown for smeared rings, RNGKNZ=  9.4809E-01(FNARCQ=  6.0206E+00)
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
```

CHAPTER 10 Compute knockdown factors and prebuckling bending associated with initial general, inter-ring, local buckling modal imperfections. (See Ref.[1E]. Also see Sections 13 and 14 and Tables 9 and 10 of Ref.[1K]).

```
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
```

CHAPTER 10.1 Compute knockdown factor and prebuckling bending associated with GENERAL buckling modal initial imperfection. (See Sectons 13 and 14 and Tables 9 and 10 of [1K] for a detailed example)

```
At 9150 in STRIMP, 7165 in BUCPAN, General instability, PERFECT shell:

Buckling load factors are computed from Donnell theory
EIGMNC=  2.67E+00  2.67E+00  2.67E+00  1.00E+17  1.00E+17  2.67E+00  1.00E+17
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=    3         3         3         0         0         3         0
NWAVEX=    6         6         6         0         0         6         0
TESTX =  5.86E-01  5.86E-01  5.86E-01  0.00E+00  0.00E+00  5.86E-01  0.00E+00

********* NOTE ********* NOTE ********** NOTE *********
Factor by which general buckling modal imperfection
amplitude will be changed for the purpose of computing
the effective radius of curvature of the initially
imperfect and loaded panel, AXLRED =  1.0000E+00
Axial length in this model of the panel, A =   6.8750E+01
Axial halfwaves in critical general mode, MBAR+DMWAVE=  3.3345E+00
******* END NOTE ****** END NOTE ****** END NOTE *********
```

```
GENERAL BUCKLING EIGENV. OF PERFECT PANEL, IMOD= 0
  EILC91(m,dm,n,dn,s)=  2.3568E+00(  3, 3.345E-01,  6,-3.874E-03, 0.000E+00)


************ ITERATION LOOP FOR IMPERFECT PANEL ***********
Begin iteration loop for general buckling of the imperfect
panel. The general imperfection is amplified by the factor
WYYAMP, which increases from iteration to iteration.

*************** ITERATION NUMBER  1 *****************
The radius of curvature is modified by initial imperfections:
Orig.radius  Mod.radius  CURCHG    WYYOUT    WYYPAN    WYYLOC
-4.800E+01 -7.680E+01  7.812E-03  0.000E+00  0.000E+00  0.000E+00
GENERAL BUCKLING EIGENV. OF IMPERFECT PANEL, IMOD= 0
  EILOC9(m,dm,n,dn,s)=  1.6750E+00(  3, 2.669E-01,  6,-2.773E-01, 0.000E+00)
IMPERFECTION AMPLITUDE FACTOR, WYYAMP=  4.0000E+00
EIGEFF =RNGKNZ*(FACIM1*EILOC9 +FACIM2*FMULT2*EILC91)/(FACIM1+FMULT2*FACIM2)=  1.8028E+00
in which FACIM1, FACIM2, and EILC91 are given by:
FACIM1=1./(EILOC9 - 1.) =  1.4814E+00
FACIM2=1./(EILC91 - 1.) =  7.3704E-01
EILC91                  =  2.3568E+00
FMULT2                  =  1.0000E+00
RNGKNZ                  =  9.4809E-01

*** NOTE: The number of circumfer. halfwaves in the general
          buckling mode of the PERFECT panel is greater
          than that for the IMPERFECT panel or ICONSV=-1  .
          Hence,the PERFECT panel mode is used for computation
          of deformations Wxx, Wyy, Wxy in SUBROUTINE CURIMP.
ICD91, ICD9  = indicators for coordinate direction
               in which panel is longest.
General buckling mode for the PERFECT panel (PANDA theory):
(m=  3, dm=  3.35E-01, n=  6, dn= -3.87E-03, slope=  0.00E+00, ICD91= 1)
General buckling mode for the IMPERFECT panel (PANDA theory):
(m=  3, dm=  2.67E-01, n=  6, dn= -2.77E-01, slope=  0.00E+00 ICD9= 1)
(0.1 radian)/(shell wall rotation), AMPTST =  5.2502E+00

QUANTITIES USED FOR OVERALL BENDING OF IMPERFECT PANEL
(used for generation of WXX9,WYY9,WXY9), IMOD= 0:
 Amplitude of overall ovalization,                WG1=  0.0000E+00
 Amplitude of general buckling modal imperf.,AMWIMP=  1.2500E-01
 Effective load factor for general buckling, EIGEFF=  1.8028E+00
 Number of  axial halfwaves in general mode,      m=    3
 Fractional axial halfwaves in general mode,     dm=  3.3453E-01
 Number of  circ. halfwaves in general mode,      n=    6
 Fractional circ. halfwaves in general mode,     dn= -3.8739E-03
 Slope of nodal lines in general bucklng mode,slope=  0.0000E+00
 Additional amplitude factor,                 FACIM3=  1.0000E+00
 Original imperfection is increased by 1/(EIGEFF-1)=  1.2456E+00

********* NOTE ********* NOTE ********** NOTE *********
Prebuckling bending and twist from general imperfection growth:
   Wxx9,Wyy9,Wxy9,ICD9= -3.6149E-03 -2.4296E-03 -2.9636E-03    1    CURRENT DESIGN
******************************************************
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
```
CHAPTER 10.2 Compute knockdown factor and prebuckling bending

```
             associated with INTER-RING buckling modal
             initial imperfection.
INTER-RING BUCKLING EIGENV. OF "PERFECT" PANEL, IMOD= 0
  EILC81(m,dm,n,dn,s)=  1.2214E+00(  1, 0.000E+00, 63,-2.826E-01, 0.000E+00)


************ ITERATION LOOP FOR IMPERFECT PANEL ***********
Begin iteration loop for inter-ring buckling of the imperfect
panel. The inter-ring imperfection is amplified by the factor
WYYAMP, which increases from iteration to iteration.

*************** ITERATION NUMBER  1 *****************
The radius of curvature is modified by initial imperfections:
Orig.radius  Mod.radius  WYYGEN    WYYOUT    CURCHG    WYYLOC
-4.800E+01 -7.674E+01  7.802E-03  0.000E+00  7.802E-03  0.000E+00
The radius of curvature is modified by initial imperfections:
Orig.radius  Mod.radius  WYYGEN    WYYOUT    CURCHG    WYYLOC
-4.800E+01 -7.674E+01  7.802E-03  0.000E+00  7.802E-03  0.000E+00
INTER-RING BUCKLING EIGENV. OF IMPERFECT PANEL, IMOD= 0
  EILOC8(m,dm,n,dn,s)=  1.2214E+00(  1, 0.000E+00, 63, 4.237E-01, 0.000E+00)
INTER-RING IMPERFECTION AMPLITUDE FACTOR, WYYAMP=  4.0000E+00
EIGEFF =FACIM1*EILOC8 +FACIM2*FMULT2*EILC81)/(FACIM1+FMULT2*FACIM2)=  1.2214E+00
in which FACIM1, FACIM2, and EILC81 are given by:
FACIM1=1./(EILOC8 - 1.) =  4.5171E+00
FACIM2=1./(EILC81 - 1.) =  4.5171E+00
EILC81                  =  1.2214E+00
FMULT2                  =  1.0000E+00

*** NOTE: The number of circ. halfwaves in the inter-ring
          buckling mode of the PERFECT panel is less than or
          equal to that for the IMPERFECT panel. Therefore,
          the IMPERFECT panel mode is used for computation
          of deformations Wxx, Wyy, Wxy in SUBROUTINE CURIMP.
ICD81, ICD8  = indicators for coordinate direction
               in which the inter-ring portion of the
               panel is longest.
Inter-ring buckling mode for the PERFECT panel (PANDA theory):
(m=  1, dm=  0.00E+00, n= 63, dn= -2.83E-01, slope=  0.00E+00, ICD81= 1)
Inter-ring buckling mode for IMPERFECT panel (PANDA theory):
(m=  1, dm=  0.00E+00, n= 63, dn=  4.24E-01, slope=  0.00E+00 ICD8= 1)

(0.1 radian)/(shell wall rotation), AMPTST =  7.5682E+08
QUANTITIES USED FOR INTER-RING BENDING OF IMPERFECT PANEL
(used for generation of WXX8,WYY8,WXY8), IMOD= 0:
 Amplitude of overall ovalization,              WG1=  0.0000E+00
 Amplitude of inter-ring buckling modal imp.,AMWIMP= -1.0000E-10
 Effective load factor for inter-ring buck., EIGEFF=  1.2214E+00
 Number of  axial halfwaves in inter-ring mode,   m=    1
 Fractional axial halfwaves in inter-ring mode,  dm=  0.0000E+00
 Number of  circ. halfwaves in inter-ring mode,   n=   63
 Fractional circ. halfwaves in inter-ring mode,  dn=  4.2369E-01
 Slope of nodal lines in inter-ring buck.mode,slope=  0.0000E+00
 Additional amplitude factor,                FACIM3=  1.0000E+00
 Original imperfection is increased by 1/(EIGEFF-1)=  4.5171E+00

********* NOTE ********* NOTE ********** NOTE *********
Prebuckling bending and twist from inter-ring imperfection growth:
   Wxx8,Wyy8,Wxy8,ICD8= -3.3956E-11 -7.8864E-10 -1.6364E-10    1
```

```
******************************************************
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
CHAPTER 10.3 Compute knockdown factor and prebuckling bending
             associated with LOCAL buckling modal initial
             imperfection.
LOCAL BUCKLING EIGENV. OF "PERFECT" PANEL, IMOD= 0
  EILC71(m,dm,n,dn,s)=  6.9581E-01(  5,-1.905E-01,  1, 0.000E+00, 0.000E+00)


************ ITERATION LOOP FOR IMPERFECT PANEL ***********
Begin iteration loop for local buckling of the imperfect
panel. The local imperfection is amplified by the factor
WYYAMP, which increases from iteration to iteration.

*************** ITERATION NUMBER  1 *****************
The radius of curvature is modified by initial imperfections:
Orig.radius  Mod.radius  WYYGEN    WYYOUT    WYYPAN    CURCHG
-4.800E+01 -7.675E+01  7.802E-03  0.000E+00  6.984E-10  7.804E-03
LOCAL BUCKLING EIGENV. OF IMPERFECT PANEL, IMOD= 0
  EILOC7(m,dm,n,dn,s)=  6.9037E-01(  5,-1.560E-01,  1, 0.000E+00, 0.000E+00)
LOCAL IMPERFECTION AMPLITUDE FACTOR, WYYAMP=  4.0000E+00
EIGEFF =(FACIM1*EILOC7 +FACIM2*FMULT2*EILC71)/(FACIM1+FMULT2*FACIM2)=  6.9309E-01
in which FACIM1, FACIM2, and EILC71 are given by:
FACIM1=1./(EILOC7 - 1.) =  1.0000E+02
FACIM2=1./(EILC71 - 1.) =  1.0000E+02
EILC71                  =  6.9581E-01
FMULT2                  =  1.0000E+00

*** NOTE: The number of circ. halfwaves in the local
          buckling mode of the PERFECT panel is less than or
          equal to that for the IMPERFECT panel. Therefore,
          the IMPERFECT panel mode is used for computation
          of deformations Wxx, Wyy, Wxy in SUBROUTINE CURIMP.
ICD71, ICD7  = indicators for coordinate direction
               in which the "local" portion of the
               panel is longest.
Local buckling mode for the PERFECT panel (PANDA theory):
(m=  5, dm= -1.90E-01, n=  1, dn=  0.00E+00, slope=  0.00E+00, ICD71= 1)
Inter-ring buckling mode for IMPERFECT panel (PANDA theory):
(m=  5, dm= -1.56E-01, n=  1, dn=  0.00E+00, slope=  0.00E+00 ICD7= 1)
(0.1 radian)/(shell wall rotation), AMPTST =  5.9259E+05
QUANTITIES USED FOR LOCAL BENDING OF IMPERFECT PANEL
(used for generation of WXX7,WYY7,WXY7), IMOD= 0:
 Amplitude of overall ovalization,             WG1=  0.0000E+00
 Amplitude of  local  buckling modal imperf.,AMWIMP=  1.0000E-07
 Effective load factor for  local  buckling, EIGEFF=  6.9309E-01
 Number of  axial halfwaves in  local  mode,      m=    5
 Fractional axial halfwaves in  local  mode,     dm= -1.5604E-01
 Number of  circ. halfwaves in  local  mode,      n=    1
 Fractional circ. halfwaves in  local  mode,     dn=  0.0000E+00
 Slope of nodal lines in local buckling mode, slope=  0.0000E+00
 Additional amplitude factor,                FACIM3=  1.4428E+00
 Original imperfection is increased by 1/(EIGEFF-1)=  3.2582E+00

********* NOTE ********* NOTE ********** NOTE *********
Prebuckling bending and twist from local imperfection growth:
```

```
 Wxx7(1),Wyy7(1),Wxy7(1),ICD7=  7.6347E-07  1.2326E-06  0.0000E+00    1
*******************************************************
```

```
===========================================================
BUCKLING LOAD FACTORS AND IMPERFECTION SENSITIVITY SUMMARY
-----------------------------------------------------------
                         LOCAL     INTER-RING      GENERAL
                       BUCKLING     BUCKLING      BUCKLING
RATIOS OF BUCKLING LOADS FROM ARBOCZ THEORY TO THOSE FROM
PANDA2 THEORY FOR THE PERFECT STRUCTURE:
   (ARBOCZ/PANDA2):   1.0000E+00   9.7837E-01   1.0000E+00
-----------------------------------------------------------
KNOCKDOWN FACTORS FOR IMPERFECTIONS DERIVED FROM
PANDA2 THEORY VS THOSE FROM ARBOCZ 1992 UPDATE OF KOITERs
1963 SPECIAL THEORY:
FROM PANDA2 THEORY:   9.9218E-01   1.0000E+00   7.1074E-01
FROM ARBOCZ THEORY:   9.9706E-01   1.0000E+00   6.8873E-01
THE GOVERNING KNOCKDOWN FACTOR FOR EACH TYPE OF BUCKLING
(LOCAL, INTER-RING, GENERAL) IS SET EQUAL TO THE MINIMUM
KNOCKDOWN FACTOR FOR THAT TYPE OF BUCKLING, REDUCED
FURTHER BY THE RATIO (ARBOCZ/PANDA2) FOR THE PERFECT PANEL
IF THE RATIO (ARBOCZ/PANDA2) IS LESS THAN UNITY:
The ARBOCZ theory is used only if ICONSV=1. ICONSV= 1

USED NOW IN PANDA2:   9.9218E-01   9.7837E-01   6.8873E-01

FACTOR APPLIED TO   6.8873E-01 FOR ALTERNATIVE SOLUTION FOR
GENERAL    BUCKLING WITH DISCRETE STIFFENERS, FKNMLT=  1.0000E+00
FACTOR APPLIED TO   9.7837E-01 FOR ALTERNATIVE SOLUTION FOR
INTER-RING BUCKLING WITH DISCRETE STIFFENERS, FKNMLS=  1.0000E+00

***NOTE*** IF THERE IS INTERNAL PRESSURE THESE KNOCKDOWN
           FACTORS MAY BE CHANGED AS NOTED BELOW.
===========================================================
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
```

```
**************************************************************
CHAPTER 11 Get change in stress resultants, Nx, Ny, Nxy in
           various segments of the skin-stringer module
           during prebuckling bending of the imperfect shell.
           Also, do PANDA-type [1B] local, inter-ring, gen-
           eral buckling analyses and PANDA-type stringer web
           and ring web buckling analyses to get knockdown
           factors to compensate for the lack of in-plane
           shear Nxy loading and anisotropy in discretized
           BOSOR4-type models. (See Section 11 in [1A])

In-plane shear and anisotropy are not directly accounted for
in any of the BOSOR4-type of discretized models. In order to
compensate for this error, knockdown factors are established
as given below for various types of buckling. These knockdowns
account for:
 1. the effect of in-plane shear, and
 2. anisotropy [e.g. C(4,6), C(5,6)] in the panel skin.
Knockdown factors from PANDA-type analysis are as follows:
   Knockdown factor for general instability=   1.0000E+00
   Knockdown factor for local instability=     1.0000E+00
```

```
   Knockdown factor (under hat crippling)=     1.0000E+00
   Knockdown factor for inter-ring buckling=   1.0000E+00
   Knockdown factor for stringer web bucklng=  1.0000E+00
   Knockdown factor for   ring   web bucklng=  1.0000E+00
```

Please note that the purpose of these knockdown factors is NOT to compensate for initial imperfections. You can account for initial imperfections by assigning amplitudes of local, inter-ring, and general imperfections in the forms of the local, inter-ring and general buckling modes. And/or you can use appropriate factors of safety (different for different buckling modes) to compensate for initial imperfections.

********* DESIGN PERTURBATION INDEX, IMOD= 0 *********

****

CHAPTER 12 Obtain prebuckled state of the initially imperfect and loaded and bent panel or shell. This section includes the redistribution of Nx, Ny, Nxy in the various segments of the stiffened shell structure.

********* DESIGN PERTURBATION INDEX, IMOD= 0 *********

****

CHAPTER 13 Get prebuckling stress resultants, Nx, Ny, needed for the discretized single-module skin-stringer model used for local buckling and bending-torsion buckling (BOSOR4-type model: see Figs. 18, 20, 22, 97, and 98 of [1A], for examples of the discretized single skin-stringer BOSOR4-type module model.).

Effective circumferential radius of curvature, RADNEW= -7.6747E+01

```
      Internal Stringer

     MODULE WITH RECTANGULAR STIFFENER...

                               !   ^
         Segment No. 3 -----> !   !
                               !   !
             Seg. No. 2-.     !   h
                         .    !   !
     Segment No. 1-.       .  !   !          .-Seg. No. 4
                   .        . !   V         .(same as Seg. 1)
       -------------==================================-----------
                    !<------ b2 ------->!
       !<--- Module width  =  stiffener spacing, b --->!


   EXPLODED VIEW, SHOWING LAYERS and (SEGMENT, NODE) NUMBERS

                            (3,11)
                               !
          Layer No. 1 -----> ! <---------- Layer No. k
                               !
       Layer No. 1-.          !
                   .           !
   Layer No. 1-.       .       !              .-Layer No. 1
           .          .        !               .
          .            .   (3,1)               .
```

```
   --------------    =====================    --------------
  (1,1)   .   (1,11)(2,1)   . (2,6)    (2,11)(4,1)  .    (4,11)
           .                 .                        .
            .                 .                        .
             Layer No. m       Layer No. n    Layer No. m
```

```
==============================================
BEGIN: PREBUCKLING STRESS RESULTANTS USED IN THE
DISCRETIZED SINGLE MODULE MODEL WITH IQUICK = 0...
----------------------------------------------------------
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 1 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -1.2470E+03 -7.6529E+01  1.1095E+01
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 2 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -8.6452E+02  1.6275E+02  1.1095E+01
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 3 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -1.3716E+03  3.2032E-31  5.4240E-08
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00

PREBUCKLING AXIAL RESULTANTS IN STRINGER WEB: SEGMENT NO.  3
 "Eigenvalue" axial resultant, Nx(var)=
-1.3716E+03 -1.6731E+03 -1.9745E+03 -2.2760E+03 -2.5774E+03 -2.8789E+03
-3.1803E+03 -3.4818E+03 -3.7832E+03 -4.0847E+03 -4.3861E+03
 "  fixed   " axial resultant, Nx(fix)=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 4 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -1.2470E+03 -7.6529E+01  1.1095E+01
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
-------------------------------------------------
END:  PREBUCKLING STRESS RESULTANTS USED IN THE
DISCRETIZED SINGLE MODULE MODEL WITH IQUICK = 0...
==========================================================
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
```

CHAPTER 14 Compute local buckling from BOSOR4-type discretized skin-stringer single module model. See Section 12.2 (upper table on p. 511) and Figs. 46c and 98b in [1A], for examples.

```
**** BEGIN SUBROUTINE LOCAL (INITIAL LOCAL BUCKLING SEARCH) ****

 Value of dm used in SUBROUTINE ARRAYS=  3.3046E-01
 IMOD= 0; Eigenvalue passed to STRUCT=  1.0437E+00
 Knockdown for transverse shear deformation=  9.9252E-01
 Buckling load factor from SUB. LOCAL, EIGITR(1)=  1.0437E+00
 Number of axial halfwaves between rings, N=    4
 ****  END  SUBROUTINE LOCAL (INITIAL LOCAL BUCKLING SEARCH) ****
  **** END OF LOCAL BUCKLING EIGENVALUE CALC.****

**** BEGIN SUBROUTINE MODE (LOCAL BUCKLING MODE SHAPE) ****
 **** END SUBROUTINE MODE (LOCAL BUCKLING MODE SHAPE) ******
```

```
  *******************************************
  **** LOCAL MODE HAS STRINGER SIDESWAY ****
  *******************************************
 Margin=  4.9801E-02  Local buckling from discrete model-1.,M=4   axial halfwaves;FS=0.999
 Margin=  4.4709E-02  Bending-torsion buckling; M=4  ;FS=0.999
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
```
CHAPTER 15 Compute bending-torsion (low-m) buckling from BOSOR4-type discretized skin-stringer single module model. See Section 12.2 (lower table on p. 511) in [1A], for example.

```
**** BEGIN SUBROUTINE LOCAL (LOW-M LOCAL BUCKLING SEARCH) ****
 Buckling load factor from SUB. LOCAL, EIGITR(4)=  1.0487E+00
 Number of axial halfwaves between rings, NLOW=    4
 **** END SUBROUTINE LOCAL (LOW-M LOCAL BUCKLING SEARCH) ******
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
```
CHAPTER 16 Compute post-local buckling from the Koiter theory given in Ref.[1C]. See Figs. 23, 24, and Figs. 47-49 in [1A], Fig. 6 in [1C], and Fig. 4 in
Bushnell, D.
"Optimization of an axially compressed ring and stringer stiffened cylindrical shell with a general buckling modal imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting, Honolulu, Hawaii, April 2007

```
*** BEGIN CALCULATIONS RELATING TO THE KOITER THEORY ***
*** See Ref.[3]: Bushnell, D., "Optimization of composite,
*** stiffened, imperfect panels under combined loads for
*** service in the posbuckling regime", CMAME, vol.103,
*** pp 43-114 (1993)
** BEGIN SUBROUTINE INTMOD (INTEGRALS OF PRODUCTS OF MODES) **
 SUB.INTMOD computes the quantities given on pp 58 and 59 of
 the paper just cited.
 **** END SUBROUTINE INTMOD (INTEGRALS OF PRODUCTS OF MODES) ****
  BEFORE POSSIBLE CHANGE: INITIAL LOCAL IMPERFECTION W0=  1.00000001E-07
  AFTER POSSIBLE CHANGE: INITIAL LOCAL IMPERFECTION W0=  1.00000001E-07

***** BEGIN SUBROUTINE KOIT2 (KOITER THEORY POSTBUCKLING) ****

 ******** ENTERING KOITER BRANCH, SUBROUTINE KOIT2 *********
 This subroutine is an implementation of the theory described
 in the PANDA2 paper by David Bushnell:
     "Optimization of composite, stiffened, imperfect panels
      under combined loads for service in the postbuckling
      regime", Computer Methods in Applied Mechanics and
      Engineering, Vol. 103 (1993) 43-114 (volume in honor of
      Besselings 65th birthday).

 LOCAL BIFURCATION BUCKLING LOAD FACTOR ESTIMATES
 AND AMPLITUDE Wo OF LOCAL IMPERFECTION, Wo*(buckling mode)
 Critical number of axial half-waves                =  4
 Slope of buckling nodal lines from Koiter Theory, m=  5.03E-03
 Knockdown factor for C44, C45, C55 for transv.shear=  9.93E-01
 Local buckling load Factor from Koiter-type Theory =  1.04E+00
```

```
Load Factor from BOSOR4-type panel module model    =  1.04E+00
BOSOR4-type load factor without knockdowns for
  effects of anisotropy [e.g. C(4,6)] of the skin,
  transverse shear def., or in-plane shear loading =  1.05E+00
Amplitude Wo of local imperfection                 =  1.0000E-07

Even if the load factor from Koiter-type theory is greater
than unity, the panel is in a "post-locally-buckled" state
because there is always a finite local imperfection in the
panel skin and stringer that grows under the applied loads.

Margin=  3.8676E-02  Bending-torsion buckling: Koiter theory,M=4   axial halfwav;FS=0.999

LOCAL DEFORMATION CHARACTERISTICS:
Average axial strain(not including thermal),EXAVE = -1.5931E-03
Initial local imperfection amplitude,          Wo=  1.0000E-07
Slope of local buckling nodal lines in skin     M =  5.2161E-03
Parameter "a" in the expression f*(phi +a*phi**3) =  0.0000E+00
Amplitude  f  in the expression f*(phi +a*phi**3) =  1.3169E-04
Normal displacement amplitude between stringers W =  7.4700E-05
Number of axial halfwaves at local bifurcation    =     4
Number of axial halfwaves in postbuckled regime   =  4.0000E+00
Convergence characteristic,              NOCONV   =  4


RESULTS FOR  4.0000E+00 AXIAL WAVES...
LOCAL DEFORMATION PARAMETERS:
   SLOPE, a, f       =  5.2161E-03  0.0000E+00  1.3169E-04
APPLIED STRESS RESULTANTS (Load set A):
   Nx, Ny, Nxy       = -2.2190E+03  5.0436E+00  1.1095E+01
APPLIED STRESS RESULTANTS (Load set B):
  Nxo, Nyo, Nxyo     =  0.0000E+00  0.0000E+00  0.0000E+00
STRAIN AND STRESS FROM APPLIED LOADS:
AVERAGE STRAIN COMPONENTS:
  EPS1, EPS2, EPS12  = -1.5931E-03  8.2783E-04  5.2909E-05
AVERAGE RESULTANTS IN SKIN:
N1SKIN,N2SKIN,N12SKIN= -8.0571E+02  2.0963E+02  1.1095E+01
NOTE: N1SKIN includes average of Nx in skin and stringer base.


TANGENT STIFFNESS AFTER SYMMETRIZATION
AVERAGE SKIN TANGENT STIFFNESS MATRIX
(Segments 1 and 2 averaged),    CTAN...
 5.9907E+05  1.7968E+05  3.2679E-02
 1.7968E+05  5.9909E+05  3.0990E-02
 3.2679E-02  3.0990E-02  2.0970E+05

(APPLIED LOAD)/(BUCKLING LOAD)=  9.6373E-01

NORMALIZED AVERAGE SKIN TANGENT STIFFNESS MATRIX
(CTAN(i,i)/CX(i,i,1), i=1,2,3) =   9.9988E-01  9.9992E-01  1.0000E+00
TANGENT POISSON RATIO
CTAN(1,2)/CTAN(1,1) =   2.9994E-01
NORMALIZED AVERAGE (N1skin,N12skn) COUPLING
CTAN(1,3)/CX(1,1,1) =   5.4544E-08
NORMALIZED AVERAGE (N2skin,N12skn) COUPLING
CTAN(2,3)/CX(2,2,1) =   5.1725E-08
***** END SUBROUTINE KOIT2 (KOITER THEORY POSTBUCKLING) ******
```

```
 ********** END OF NONLINEAR EQUILIBRIUM CALCS.************
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
```
CHAPTER 17 Compute stresses in layers and at various locations in skin-stringer module model, including local post-buckling, if any. Compute stringer popoff constraints (Figs. 5 - 7 in [1A]). Local post-buckling such as that shown in Figs. 48 & 49 of [1A] is included. Therefore, SUBROUTINE STRTHK is used.

```
***** BEGIN SUBROUTINE STRTHK (POSTBUCKLING STRESSES) ******
 Margin=  2.5390E+00  eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.0248; MID.;FS=1.
 Margin=  7.6889E+06  stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 Margin=  2.7258E-01  eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0403; MID.;FS=1.
 ***** END SUBROUTINE STRTHK (POSTBUCKLING STRESSES) ********

***** BEGIN SUBROUTINE STRCON (STRESSES IN RINGS) ******
 ***** END   SUBROUTINE STRCON (STRESSES IN RINGS) ******
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
```
CHAPTER 18 Present summary of state of loaded imperfect panel and give effective stiffnesses of possibly locally postbuckled skin-stringer module. These effective stiffnesses are used later for overall buckling and inter-ring buckling. See Table 12 in the paper
Bushnell, D.
"Optimization of an axially compressed ring and stringer stiffened cylindrical shell with a general buckling modal imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting, Honolulu, Hawaii, April 2007

```
 PANEL OVERALL & LOCAL IMPERFECTIONS AND DEFORMATION
 General out-of-roundness of cylindrical panel,WIMPG1 =  0.0000E+00
 General initial buckling modal imperfection amplitude=  1.2500E-01
 General modified imperfection amplitude, Wimp(global)=  1.2500E-01
 Local   initial imperfection amplitude, Wimp(local)  =  1.0000E-07
 Panel (inter-ring) initial imp. amplt., Wimp(panel)  =  1.0000E-10
 Bowing due to temperature effects,     W(residual)   =  0.0000E+00
 Overall (inter-ring in cyl) bowing from pressure ,Wp =  9.0976E-04
 Inter-ring bowing (flat panel) from pressure, WPRESR =  0.0000E+00
 Maximum local "pillowing" between stringers,  WLPRES =  4.3324E-04
 Inter-ring bowing due to postbucking effects, WDELKP =  0.0000E+00
 Amplitude factor for bowing except from press,AMPLIT =  1.7536E+00
 Amplitude factor for bowing due to pressure,  AMPLT2 =  1.0522E+00
 Amplitude factor for inter-ring bowing,       AMPLT3 =  1.3526E+00
 Eccentricity of application of axial loads,     ECC  =  0.0000E+00

*** BEGIN SUBROUTINE DEFCIJ (POST-LOCALLY BUCKLED CS(I,J)) ****
 Effective stiffnesses of undeformed and of
 locally deformed module segments:
                                                         Undeformed   Deformed
     Effective axial stiffness of panel SKIN + BASE =  5.9914E+05  5.9910E+05
     Effective hoop  stiffness of panel SKIN + BASE =  5.9914E+05  5.9909E+05
     Effective (1,2) stiffness of panel SKIN + BASE =  1.7974E+05  1.7970E+05
     Effective axial stiffness of stringer   WEB    =  9.7478E+05  9.7472E+05
```

```
    Effective axial stiffness of stringer   FLANGE =  0.0000E+00  0.0000E+00
    Effective shear stiffness of panel SKIN + BASE =  2.0970E+05  2.0970E+05
    Effective shear stiffness of stringer   WEB    =  3.4117E+05  3.4117E+05
    Effective shear stiffness of stringer   FLANGE =  0.0000E+00  0.0000E+00

Integrated stringer stiffnesses...
    Effective axial stiffness of stringer,   STIFL =  4.2314E+05
    Effective first moment, Int[STIF*zdz],   STIFM =  1.9838E+05
    Effective second moment,Int[STIF*z**2dz],STIFMM=  1.2082E+05

Constitutive law, CS(i,j), for locally deformed
panel with smeared stringers and rings.....
      1.0222E+06  1.7970E+05  0.0000E+00  1.9838E+05  0.0000E+00  0.0000E+00
      1.7970E+05  7.4912E+05  0.0000E+00  0.0000E+00  1.3533E+05  0.0000E+00
      0.0000E+00  0.0000E+00  2.0970E+05  0.0000E+00  0.0000E+00  0.0000E+00
      1.9838E+05  0.0000E+00  0.0000E+00  1.2094E+05  3.6797E+01  0.0000E+00
      0.0000E+00  1.3533E+05  0.0000E+00  3.6797E+01  1.6067E+05  0.0000E+00
      0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.6929E+02

Constitutive law, C(i,j), for locally deformed
panel between rings with smeared stringers.....
      1.0222E+06  1.7970E+05  0.0000E+00  1.9838E+05  0.0000E+00  0.0000E+00
      1.7970E+05  5.9909E+05  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
      0.0000E+00  0.0000E+00  2.0970E+05  0.0000E+00  0.0000E+00  0.0000E+00
      1.9838E+05  0.0000E+00  0.0000E+00  1.2094E+05  3.6797E+01  0.0000E+00
      0.0000E+00  0.0000E+00  0.0000E+00  3.6797E+01  1.2266E+02  0.0000E+00
      0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.3113E+02
*** END   SUBROUTINE DEFCIJ (POST-LOCALLY BUCKLED CS(I,J)) ****
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
```

CHAPTER 19 Do wide-column inter-ring buckling analysis with possibly locally postbuckled skin-stringer module model. (See Figs. 20c, 22c, 46d, and 67 of [1A], for examples.).

```
*** BEGIN SUBROUTINE BUCKLE (WIDE-COLUMN BUCKLING - MODULE) ****
*** END SUBROUTINE BUCKLE (WIDE-COLUMN BUCKLING - MODULE) ****

*** BEGIN SUBROUTINE MODE (WIDE-COLUMN BUCKLING MODE SHAPE) ****
 *** END SUBROUTINE MODE (WIDE-COLUMN BUCKLING MODE SHAPE) ****

  WIDE COLUMN PANEL BUCKLING LOAD FACTOR =          2.5957E+00
 ISKIN = 0. WIDE COLUMN BUCKLING IS IGNORED IF ISKIN = 1.
 IWIDE = 0. WIDE COLUMN BUCKLING IS IGNORED IF IWIDE = 0.
 ITIP  = 0. MODE OF BUCKLING IS STRINGER SIDESWAY IF ITIP=1
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
```

CHAPTER 20 Compute width-wise wide column buckling and lateral-torsional buckling load factors from the possibly locally postbuckled skin-stringer module model (inter-ring buckling modes). See panda2.news Item Numbers 379 and 381 in [1L].

```
Number of axial halfwaves=  1; Buckling load factor=  1.2469E+01
Number of axial halfwaves=  2; Buckling load factor=  2.1572E+00
```

```
 Number of axial halfwaves=  3; Buckling load factor=  1.3395E+00
 Number of axial halfwaves=  4; Buckling load factor=  1.1746E+00
 Number of axial halfwaves=  5; Buckling load factor=  1.1692E+00
 Margin=  1.7574E-01  (m=4   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
```

CHAPTER 21 Compute "skin"-ring buckling load factor for computing knockdown to compensate for inherent unconservativeness of smeared ring models. (See bottom row in Fig. 30 of Ref.[1G]. Also see panda2.news Items 509, 511, 522, 532, 605, 617 619, 632, 633, 676.

```
*** Infinite cyl, external lateral pressure) **
 Uniform external lateral pressure,      PRESS=  1.0000E+00
 Buck. circ. halfwaves from PANDA-type, NGENQQ=  6

 ** BEGIN SUB. BUCKLE ("SKIN"-RING n=   6 GENERAL BUCKLNG MODEL) **
 **  END  SUB. BUCKLE ("SKIN"-RING n=   6 GENERAL BUCKLNG MODEL) **

 ** BEGIN SUB. MODE ("SKIN"-RING n=   6 GENERAL BUCKLNG MODE) **
 **** END  SUB. MODE ("SKIN"-RING n=   6 GENERAL BUCKLNG MODE) **
 Mode shape properties for n=  6 circ. halfwaves:
 Normal displacement midway between rings,   WFIRST=  1.0000E+00
 Normal displacement midway between rings,    WLAST=  1.0000E+00
 Normal displacement in skin at web root,     WMIDQ=  9.9785E-01
 Normal displacement in ring at flange tip,    WFLG=  1.0000E+00
 Normal displacement, ring flange at web tip, WFLGW=  1.0000E+00
 Normalized difference,     ABS(WFLG-WFLGW)/WFLGMAX=  0.0000E+00
 Possible candidate for knockdown factor,     WFLGK=  1.0000E+00

 Mode number  1 is     a suitable ring mode.
 Buckling load factor BEFORE knockdown for smeared stringers=  4.1163E+01
 In this n=   6 general buckling analysis there is no knockdown
 for smeared stringers.
 NOTE: The buckling load factor,  4.1163E+01, will not be
 further reduced by the "shear/anisotropy" factor.

 Knockdown for smeared rings on cylindrical shell...
  Buckling load factor for n+dn = FNARCQ=  6.0206E+00
                              from discrete model =  4.1163E+01
  Buckling load factor for ring with bending stiffness EI:
                     pcrit=[(n+dn)**2-1]*EI/r**3/p=  4.3417E+01
  Knockdown factor, general buckling,   EIGR/EIGRNG=  9.4810E-01

 Knockdown for smeared rings, RNGKNK=  9.4810E-01(FNARCQ=  6.0206E+00)
 END OF SECTION ON GENERATION OF KNOCKDOWN FACTOR FOR
 COMPENSATING FOR THE UNCONSERVATIVENESS OF SMEARING RINGS
 ---------------------------------------------------------

 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
```

CHAPTER 22 Compute "skin"-ring buckling load factors for:
1. medium-n inter-ring buckling mode (See rightmost three mode shapes in top row of

```
              Fig. 30 of Ref.[1G]),
           2. high-n inter-ring buckling mode (See rightmost
              mode shape in middle row of Fig. 30, Ref.[1G]),
           3. low-n inter-ring buckling mode (See leftmost
              mode shape in top row of Fig. 30, Ref.[1G]).

***** BEGIN SUBROUTINE STRCON (GET DELFCR,DELWBR) *****
 DELFCR =changes in resultants, dNx,dNy,dNxy, in skin-ring
         module caused by growth of the initial imperfections.
 DELWBR =change in axial resultant dNx in the ring web at the
         ring web root and ring web tip.
 ******* END SUBROUTINE STRCON (GET DELFCR,DELWBR) ******

*** BEGIN "SKIN"-RING BUCKLING, DISCRETE MODEL) **
 *** BEGIN SUB. LOCAL ("SKIN"-RING BUCKLING, DISCRETE MODEL) **
 Buckling load factor from SUB. LOCAL, EIGITR(16)=  1.1879E+00
 Number of axial halfwaves between rings, NSTART=   49
 *** END   SUB. LOCAL ("SKIN"-RING BUCKLING, DISCRETE MODEL) **

 **** BEGIN SUB. MODE ("SKIN"-RING MODULE BUCKLING MODE) ****
  **** END   SUB. MODE ("SKIN"-RING MODULE BUCKLING MODE) ****

 ******* NOTE ********** NOTE ******** NOTE *********
 Discretized "skin"-ring module buckling mode involves
 significant sidesway of the ring web.
 ***** END NOTE ****** END NOTE ***** END NOTE *********
 Margin=  1.6338E-01  Ring sidesway buk., discrete model, n=49  circ.halfwaves;FS=0.999

 Next, explore "skin"-ring module buckling from n=  73 to  219 circ. waves.
 Minimum buckling load factor found so far, EIGBEF=  1.1879E+00
 Corresponding critical number of circ. waves, n=  49
 n circ. waves   Buckling Load Factor

 No critical (minimum) eigenvalue detected in high-n range.
 Therefore, no "hi-n" buckling margin for the discretized
 "skin"-ring single module will be recorded.
 Maximum number of circ. waves, NMAXRG=  231
 Minimum eigenvalue in N-range, EIGMNH=  1.4817E+00

 Next, explore "skin"-ring module buckling from n=   1 to   44 circ. waves.
 n circ. waves   Buckling Load Factor

 No critical (minimum) eigenvalue detected in low-n range.
 Therefore, no "lo-n" buckling margin for the discretized
 "skin"-ring single module will be recorded.
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
```

CHAPTER 23 Compute stresses in layers and at various locations in modules for both positive and negative imperfection amplitudes from SUBROUTINE STRCON (local postbuckling neglected). See [1L] (panda2.news) Items 36b,d,w, 41b, and Section E of Table 122.6 in Item 122.

```
***** BEGIN SUBROUTINE STRCON (IQUICK = 1 TYPE STRESSES) ******
 Margin=  1.1436E+00  eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=-0.0248;-MID.;FS=1.
```

```
 Margin=  2.8699E-01  eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
 Margin=  4.3989E-01  eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
 ***** END   SUBROUTINE STRCON (IQUICK = 1 TYPE STRESSES) ******
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
 CHAPTER 24 Present short summary of redistribution of stress
            resultants, Nx, Ny, Nxy, caused by prebuckling
            bending of an initially imperfect shell.
            See Section 6.0 in [1K], for example.

 Additional resultants (Nx,Ny) in panel skin from
 global and inter-ring bending of imperfect panel:
            Additional axial resultant, dNx = -3.8247E+02
            Additional  hoop resultant, dNy = -2.3929E+02
   Additional in-plane shear resultant, dNxy=  0.0000E+00

 Additional axial resultants dNx along webs and flanges of
 stringers from global and inter-ring bending of imperfect panel:
     Additional Nx in  base  of stringer, dNx = -3.8248E+02
     Additional Nx at webtip of stringer, dNx = -2.3049E+03
     Additional Nx in flange of stringer, dNx =  0.0000E+00

 Additional axial resultants dNx along webs and flanges of
 rings from global and inter-ring bending of imperfect panel:
     Additional Nx in  base  of   ring,   dNx = -2.6296E+02
     Additional Nx at webtip of   ring,   dNx = -3.8057E+03
     Additional Nx in flange of   ring,   dNx =  0.0000E+00
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
 CHAPTER 25 Compute buckling load factors from PANDA-type
            theory for the various segments of a stringer and
            a ring. Typical buckling modes are displayed in
            Figs. 5 and 6 of Ref.[1B].

***** BEGIN SUBROUTINE STFEIG (BUCKLING IN STIFFENERS) ******
 Margin=  1.4450E-02  buckling margin stringer Iseg.3 . Local halfwaves=5  .MID.;FS=1.
 ***** END   SUBROUTINE STFEIG (BUCKLING IN STIFFENERS) ******

***** BEGIN SUBROUTINE STFEIG (NO POSTBUCKLING EFFECT) ******
 Margin= -8.1967E-03  buckling margin stringer Iseg.3 . Local halfwaves=5  .NOPO;FS=1.
 ******* END SUBROUTINE STFEIG (NO POSTBUCKLING EFFECT) ******
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
 CHAPTER 26 Compute local, inter-ring, general buckling load
            factors from PANDA-type models [1B] and from
            "alternative" (double-trigonometric series
            expansion) models, Ref.[1G]. Also compute
            sandwich wall behavior [1F], if applicable.
            Also, compute buckling load factors appropriate
            when substiffeners are present.

*** BEGIN SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS) ****

 Sanders theory is used for these buckling calculations in this case.
 Local buckling load factors & mode shapes before any knockdown factors applied:
```

```
EIGMNC=  5.46E+00  1.00E+17  2.22E+00  1.00E+17  2.22E+00  2.22E+00  1.00E+17
SLOPEX=  2.00E-02  0.00E+00  1.00E-02  0.00E+00  0.00E+00  1.00E-02  0.00E+00
MWAVEX=    4         0         8         0         8         8         0
NWAVEX=    1         0         1         0         1         1         0
NOTE: The buckling nodal line slopes, SLOPEX, are as
defined in Fig. 9a or Fig. 9b of the 1987 "Theoretical
basis of the PANDA...",if NWAVEX > 0; that is, there
has not yet been any inversion of SLOPEX when 9b holds.

LOCAL BUCKLING FROM PANDA-TYPE THEORY [1B] AFTER KNOCKDOWN FOR t.s.d.:
EIGLOC =   2.1997E+00(m=   8,n=   1)

INTER-RING BUCKLING load factors and (axial, circumfer.) halfwaves:
Sanders theory is used for these buckling calculations in this case.
INTER-RING BUCKLING FROM PANDA-TYPE THEORY [1B]
   AFTER KNOCKDOWN FOR t.s.d. AND FOR SMEARED STRINGERS:
EIGSS =   2.4864E+00(m=   1,n=  13)
Inter-ring eigenvalue with panel as flat:
EIGSS2=   2.2203E+00(m=   1,n=   4)

Simple-support inter-ring buckling with smeared stringers
is not recorded as a margin because this type of buckling
has been superseded by the results from the discretized
inter-ring module model, for which inter-ring buckling
load factors have been computed in the range from n =     1
to n =   231 circumferential halfwaves.
The critical simple-support inter-ring buckling model has   13
circ. half waves, which lies within this range.

Entering ALTSOL: radius, axial, circ. dimensions =  4.8000E+01  1.1458E+01  1.1170E+01
See ITEMs 438, 444  in the file ..panda2/doc/panda2.news .
and AIAA paper 99-1233, Proc. 40th AIAA SDM Meeting, 1999
pp 302-345, especially pp 304-316 and associated figures.
***INTER-RING BUCKLING, N-STRINGER-BAY PATCH, SMEARED SUBSTF **
        Number of discrete stringers, rings: NUMSTR, NUMRNG=  7  2

No alternative solution sought because user did not want one.
(IALTSN was set equal to zero in MAINSETUP)

Sanders theory is used for these buckling calculations in this case.
General buckling load factors & mode shapes before any knockdown factors applied:
EIGMNC=  2.62E+00  2.62E+00  2.62E+00  1.00E+17  1.00E+17  2.62E+00  6.21E+00
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=    3         3         3         0         0         3         4
NWAVEX=    6         6         6         0         0         6         0
NOTE: The buckling nodal line slopes, SLOPEX, are as
defined in Fig. 9a or Fig. 9b of the 1987 "Theoretical
basis of the PANDA...",if NWAVEX > 0; that is, there
has not yet been any inversion of SLOPEX when 9b holds.

Entering ALTSOL: radius, axial, circ. dimensions =  4.8000E+01  5.7292E+01  1.1170E+01
See ITEMs 438, 444  in the file ..panda2/doc/panda2.news .
and AIAA paper 99-1233, Proc. 40th AIAA SDM Meeting, 1999
pp 302-345, especially pp 304-316 and associated figures.
*** GENERAL BUCKLING, N x M BAY PATCH, SMEARED SUBSTIFFRS ***
        Number of discrete stringers, rings: NUMSTR, NUMRNG=  7  6

No alternative solution sought because user did not want one.
```

```
(IALTSN was set equal to zero in MAINSETUP)
General buckling loads AFTER knockdown for t.s.d.
Number of circumferential halfwaves in buckling pattern=  6.0000E+00
Buckling load factor BEFORE knockdown for smeared stringers=  2.4811E+00
Buckling load factor AFTER  knockdown for smeared stringers=  2.3268E+00

General buckling load factor before and after knockdown:
EIGGEN(before modification by 5 factors below)     =  2.3268E+00
Knockdown factor from modal imperfection(s)        =  6.8873E-01
Knockdown factor for smearing rings on cyl. shell  =  9.4810E-01
Knockup factor to avoid twice accounting for t.s.d.=  1.0000E+00
1st modifying factor, FKNMOD=1 or 1/(EIG9X*FMDKD9) =  1.0000E+00
2nd modifying factor, EIGMR9=1 or EIGGNX/EIGGEN    =  1.0000E+00
After knockdn,EIGGEN*FKNOCK(9)*(RNGKNK/SHRFCT)*FKNMOD*EIGMR9=  1.5193E+00
in which
EIG9X  = lambda(ARBOCZ)/lambda(original PANDA-type theory)=  1.0000E+00
      lambda(ARBOCZ)=perfect panel buckling from ARBOCZ theory
      lambda(PANDA) =perfect panel buckling from PANDA  theory
FMDKD9 = 1 or 0.9/EIG9X =  1.0000E+00
EIGGNX = eigenvalue for perfect panel from alternate solution
Margin=  5.2086E-01  buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999

Smeared stringer with rolling before and after knockdown:
EIGRSS(before knockdown by 2 factors below)        =  2.4620E+00
Knockdown factor from inter-ring modal imperfection=  9.7837E-01
Modifying factor, FKNMOD=1 or 1/(EIG8X*FMDKD8)     =  1.0000E+00
After knockdown, EIGRSS*FKNOCK(8)*FKNMOD           =  2.4088E+00
in which
EIG8X  = lambda(ARBOCZ)/lambda(original PANDA-type theory)=  9.7837E-01
      lambda(ARBOCZ)=perfect panel buckling from ARBOCZ theory
      lambda(PANDA) =perfect panel buckling from PANDA  theory
FMDKD8 = 1 or 0.9/EIG8X =  1.0000E+00

Inter-ring buckling with smeared stringers and ring rolling
is not recorded as a margin because this type of buckling
has been superseded by the results from the discretized
inter-ring module model, for which inter-ring buckling
load factors have been computed in the range from n =     1
to n =   231 circumferential halfwaves.
The critical inter-ring-buckling-with-ring-rolling model has   14
circ. half waves, which lies within this range.
Margin=  1.6084E+01  buck.(SAND);rolling with smear rings; M=172;N=1;slope=0.;FS=0.999
Margin=  6.7862E-01  buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4

Stringer rolling from PANDA-type theory [1B]:
PANDA-type buckling load factor, EIGRLL(2)(m,n,slope)=  2.3501E+00(  45,0,0)

Ring rolling without participation of the panel skin
is not recorded as a margin because this type of buckling
has been superseded by the results from the discretized
"skin"-ring module model, for which buckling load factors
have been computed in the range from n =     1 to n =   231 circ. halfwaves.
The critical ring-rolling-without-participation-of-the-panel-skin model has   50
circ. half waves, which lies within this range.
Margin=  1.5261E+01  buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4

Axisymmetric ring rolling from PANDA-type theory [1B]:
PANDA-type buckling load factor, EIGRLL(4)(m,n,slope)=  2.2766E+01(0,   0,0)
```

```
 ****  END SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS) ****
 *** END   SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS) ****
 Margin=  6.2670E+02  (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
 CHAPTER 27 Compute the objective function (e.g. WEIGHT).

 Objective (weight of PANDA2 model of panel), OBJ =  1.0014E+02
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 *************************************************************
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 1:
 LOADING: Nx, Ny, Nxy, Mx, My =  -2.22E+03 -2.22E-03  1.11E+01  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00  4.62E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  1.0376E+00 (flat skin)
  Local buckling load factor from BOSOR4 theory =  1.0437E+00 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE                 DEFINITION
 1  4.98E-02 Local buckling from discrete model-1.,M=4   axial halfwaves;FS=0.99
 2  4.47E-02 Bending-torsion buckling; M=4  ;FS=0.999
 3  3.87E-02 Bending-torsion buckling: Koiter theory,M=4   axial halfwav;FS=0.99
 4  2.54E+00 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=-0.0248; MID.;FS=1.
 5  7.69E+06 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6  2.73E-01 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0403; MID.;FS=1.
 7  1.76E-01 (m=4   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
 8  1.63E-01 Ring sidesway buk., discrete model, n=49  circ.halfwaves;FS=0.999
 9  1.14E+00 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=-0.0248;-MID.;FS=1.
10  2.87E-01 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11  4.40E-01 eff.stress:matl=3,RNG,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
12  1.45E-02 buckling margin stringer Iseg.3 . Local halfwaves=5  .MID.;FS=1.
13 -8.20E-03 buckling margin stringer Iseg.3 . Local halfwaves=5  .NOPO;FS=1.
14  5.21E-01 buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999
15  1.61E+01 buck.(SAND);rolling with smear rings; M=172;N=1;slope=0.;FS=0.999
16  6.79E-01 buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4
17  1.53E+01 buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
18  6.27E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
------------------------------------------------------------------------------
```

Next, we go back and give some more details printed in selected CHAPTERS when the print index, NPRINT, is set equal to 2 in the *.OPT file.

DETAILS FROM CHAPTER 4 (printed in *.OPM when NPRINT = 2)

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************************************************************
************************************************************
************************************************************
************          CHAPTER 4             ****************
************************************************************
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********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

***********************************************************
```

CHAPTER 4 Compute axisymmetric prebuckling "hungry-horse" state of the curved panel or cylindrical shell. (See Ref.[1E], especially Fig. 1 and pp.495-498).

```
***** BEGIN COMPUTATIONS FOR AXISYMMETRIC PREBUCKLING
***** STATE OF THE PANEL. (See pp 495-498 of journal
***** article, COMPUTERS & STRUCTURES vol 59, no.3, 1996
***** Computations carried out in SUBROUTINE SKIN.
***** Axisymmetric response of the curved panel to the loads in Load Set A *****
Entering SUB. SKIN (get prebuckling behavior), IMOD= 0
 Normal pressure,                     P= -4.6229E-05
 Axial resultant,                    Nx= -2.2190E+03
 Hoop  resultant,                    Ny= -2.2190E-03
 Average hoop strain,               E0Y=  5.4370E-04
 Average hoop thermal strain, ETHERM(2)=  0.0000E+00
 Value of computation control,   WCALCS=  0.0000E+00
 Prebuckling b.c. indicator,     IBPRE =  0
 Ring stiffener indicator,     ISTIF(2)=  3
 Average Nyo, membrane theory,  FNYAVE = -8.1575E+01
 Average normal displacement,   WDPAVE =  2.6098E-02

PREBUCKLING STATE IN CYLINDRICAL PANEL. X=0 CORRESPONDS TO MIDBAY
      AXIAL       NORMAL    MERIDIONAL    AXIAL       HOOP
   COORDINATE  DISPLACEMENT CURVATURE   RESULTANT   RESULTANT
I       X           WDISP      WXXDSP       FNXX       FNYY
 1  0.0000E+00  2.6623E-02 -1.1065E-04 -2.2190E+03 -7.1498E+01
 2  2.2917E-01  2.6621E-02 -1.1012E-04 -2.2190E+03 -7.1551E+01
 3  4.5833E-01  2.6612E-02 -1.0854E-04 -2.2190E+03 -7.1709E+01
 4  6.8750E-01  2.6598E-02 -1.0591E-04 -2.2190E+03 -7.1971E+01
 5  9.1667E-01  2.6578E-02 -1.0221E-04 -2.2190E+03 -7.2335E+01
 6  1.1458E+00  2.6552E-02 -9.7466E-05 -2.2190E+03 -7.2800E+01
 7  1.3750E+00  2.6522E-02 -9.1658E-05 -2.2190E+03 -7.3362E+01
 8  1.6042E+00  2.6487E-02 -8.4790E-05 -2.2190E+03 -7.4018E+01
 9  1.8333E+00  2.6447E-02 -7.6860E-05 -2.2190E+03 -7.4764E+01
10  2.0625E+00  2.6403E-02 -6.7864E-05 -2.2190E+03 -7.5594E+01
11  2.2917E+00  2.6356E-02 -5.7800E-05 -2.2190E+03 -7.6504E+01
12  2.5208E+00  2.6306E-02 -4.6666E-05 -2.2190E+03 -7.7487E+01
13  2.7500E+00  2.6253E-02 -3.4460E-05 -2.2190E+03 -7.8536E+01
14  2.9792E+00  2.6198E-02 -2.1179E-05 -2.2190E+03 -7.9645E+01
15  3.2083E+00  2.6143E-02 -6.8208E-06 -2.2190E+03 -8.0803E+01
16  3.4375E+00  2.6087E-02  8.6160E-06 -2.2190E+03 -8.2004E+01
17  3.6667E+00  2.6031E-02  2.5133E-05 -2.2190E+03 -8.3237E+01
18  3.8958E+00  2.5977E-02  4.2730E-05 -2.2190E+03 -8.4492E+01
19  4.1250E+00  2.5925E-02  6.1408E-05 -2.2190E+03 -8.5758E+01
20  4.3542E+00  2.5876E-02  8.1165E-05 -2.2190E+03 -8.7023E+01
21  4.5833E+00  2.5832E-02  1.0200E-04 -2.2190E+03 -8.8276E+01
22  4.8125E+00  2.5793E-02  1.2391E-04 -2.2190E+03 -8.9503E+01
```

```
23  5.0417E+00  2.5760E-02  1.4689E-04 -2.2190E+03 -9.0690E+01
24  5.2708E+00  2.5735E-02  1.7093E-04 -2.2190E+03 -9.1823E+01
25  5.5000E+00  2.5719E-02  1.9603E-04 -2.2190E+03 -9.2886E+01
26  5.7292E+00  2.5714E-02  2.2217E-04 -2.2190E+03 -9.3864E+01

Average Ny over x-integration interval (XL=  5.7292E+00): Ny(ave)= -8.0467E+01
Average normal displacement over x-integration interval=  2.6198E-02
Average axial curvature change over x-integration int. =  2.2301E-06
 Value of computation control,   WCALCS=  0.0000E+00
 Hoop resultant in web of ring,            FCEWEB =  5.3470E+02
 Hoop resultant in flange of ring,         FCEFLG =  0.0000E+00
 Hoop strain in web and flange of ring,    EPSRNG =  5.3570E-04
 Hoop resultant at each node in ring web, (FCXWEB(i),i=1,11)=
 5.2493E+02  5.2686E+02  5.2880E+02  5.3075E+02  5.3272E+02  5.3470E+02
 5.3670E+02  5.3871E+02  5.4074E+02  5.4279E+02  5.4484E+02
 Meridional resultant at each node in ring web, (FCYWEB(i),i=1,11)=
 1.9543E+01  1.7589E+01  1.5635E+01  1.3680E+01  1.1726E+01  9.7717E+00
 7.8173E+00  5.8630E+00  3.9087E+00  1.9543E+00  0.0000E+00

PREBUCKLING DEFORMATION OF CYLINDRICAL SHELL BETWEEN RINGS:
 Subcase number                              ICASE =    1
 Radius of cylindrical shell                     R = -4.8000E+01
 Ring spacing,                                B(2) =  1.1458E+01
 Axial resultant,                   Nx(Loadset A) = -2.2190E+03
 Hoop  resultant,                   Ny(Loadset A) = -2.2190E-03
 Normal displacement at midbay,               WMID =  2.6623E-02
 Normal displacement at rings,               WRING =  2.5714E-02
 Average normal displacement, Wave =-EPSILON(y)*R =  2.6098E-02
 Meridional curvature change at midbay,    WXXMID = -1.1065E-04
 Meridional curvature change at rings,     WXXRNG =  2.2217E-04
 Axial boundary layer length,                  BLL =  2.1441E+01
 Hoop stiffness EA of ring,              EA(ring) =  1.7191E+06
 Applied normal pressure,             P(Loadset A) =  4.6229E-05
 Shear in web of stringer,                 SHEARX =  0.0000E+00
 Correction to hoop resultant,             DFNYP0 =  5.0458E+00
 Transverse resultant in isogrid web,      POPISO =  0.0000E+00

***** Axisymmetric response of the curved panel to the loads in Load Set B *****
Entering SUB. SKIN (get prebuckling behavior), IMOD= 0
 Normal pressure,                    P=  0.0000E+00
 Axial resultant,                   Nx=  0.0000E+00
 Hoop  resultant,                   Ny=  0.0000E+00
 Average hoop strain,              E0Y=  0.0000E+00
 Average hoop thermal strain, ETHERM(2)=  0.0000E+00
 Value of computation control,   WCALCS=  0.0000E+00
 Prebuckling b.c. indicator,     IBPRE =  0
 Ring stiffener indicator,     ISTIF(2)=  3
 Average Nyo, membrane theory,  FNYAVE =  0.0000E+00
 Average normal displacement,   WDPAVE =  0.0000E+00

OVERALL AVERAGE HOOP STRAIN, E0Y = 0.
NO CALCULATION OF WMID,WRING,WXXMID,WXXRNG
WMID,WRING,WXXMID,WXXRNG=  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 Value of computation control,   WCALCS=  1.0000E+00
 Hoop resultant in web of ring,            FCEWEB =  0.0000E+00
 Hoop resultant in flange of ring,         FCEFLG =  0.0000E+00
 Hoop strain in web and flange of ring,    EPSRNG =  0.0000E+00
 Hoop resultant at each node in ring web, (FCXWEB(i),i=1,11)=
```

```
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  Meridional resultant at each node in ring web, (FCYWEB(i),i=1,11)=
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00

 PREBUCKLING DEFORMATION OF CYLINDRICAL SHELL BETWEEN RINGS:
  Subcase number                              ICASE =    1
  Radius of cylindrical shell                     R = -4.8000E+01
  Ring spacing,                                B(2) =  1.1458E+01
  Axial resultant,                    Nx(Loadset B) =  0.0000E+00
  Hoop  resultant,                    Ny(Loadset B) =  0.0000E+00
  Normal displacement at midbay,               WMID =  0.0000E+00
  Normal displacement at rings,               WRING =  0.0000E+00
  Average normal displacement, Wave =-EPSILON(y)*R =  0.0000E+00
  Meridional curvature change at midbay,     WXXMID =  0.0000E+00
  Meridional curvature change at rings,      WXXRNG =  0.0000E+00
  Axial boundary layer length,                  BLL =  2.1441E+01
  Hoop stiffness EA of ring,               EA(ring) =  1.7191E+06
  Applied normal pressure,             P(Loadset B) =  0.0000E+00
  Shear in web of stringer,                  SHEARX =  0.0000E+00
  Correction to hoop resultant,              DFNYP0 =  0.0000E+00
  Transverse resultant in isogrid web,       POPISO =  0.0000E+00
```

END OF DETAILS FROM CHAPTER 4 (printed in *.OPM when NPRINT = 2)
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DETAILS FROM CHAPTERS 11 - 16 (printed in *.OPM when NPRINT = 2)
(The beginning part of CHAPTER 11 and The end part of CHAPTER 16
are omitted to save space).

--

FROM CHAPTER 11, printed to the *.OPM file if NPRINT = 2

```
 In discretized local buckling model the panel skin is being
 modelled as flat if IICURV=0; as curved if IICURV=1: IICURV= 0
 Radius of curvature used in SUBROUTINE LOCAL, RMAX =  1.6573E+06
 LOADING IN THE PANEL SKIN BEFORE ADJUSTMENTS:
 PREBUCKLING TOTAL RESULTANTS, Nx, Ny, Nxy = -1.2470E+03 -7.6529E+01  1.1095E+01
 PREBUCKLING FIXED RESULTANTS, Nxo,Nyo,Nxyo=  0.0000E+00  0.0000E+00  0.0000E+00
 Axial halfwaves in skin buckling mode (PANDA), MLOC71=    5
 Axial length used for "hungry-horse" analysis, RNGSPA=  1.1458E+01
 Number of nodal points used in "hungry-horse" analysis= 26

***** BEGIN SUBROUTINE STRCON (GET DELFCX,DELCUR,DELWBX) *****
 DELFCX =changes in resultants, dNx,dNy,dNxy, in skin-stringer
         module caused by growth of the initial imperfections.
 DELCUR =changes in curvature and twist in the panel skin.
 DELWBX =change in axial resultant dNx at web root and web tip.
 ******* END SUBROUTINE STRCON (GET DELFCX,DELCUR,DELWBX) ******



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************          CHAPTER 12            *****************
***************************************************************
***************************************************************
***************************************************************
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

**************************************************************
CHAPTER 12 Obtain prebuckled state of the initially imperfect
           and loaded and bent panel or shell. This section
           includes the redistribution of Nx, Ny, Nxy in the
           various segments of the stiffened shell structure.

********** BEGIN OUTPUT FOR STATE CHANGE ***********
CHANGES IN STATE OF THE PANEL DUE TO GROWTH OF INITIAL
IMPERFECTIONS AS THE LOADING IS APPLIED. THESE CHANGES AFFECT
THE BUCKLING LOAD FACTORS AND STRESSES IN THE VARIOUS SEGMENTS
OF THE SKIN-STRINGER AND SKIN-RING PANEL MODULES.....

**** NOTE ********* NOTE ********* NOTE ********* NOTE ****
This is Segment 1 (Panel skin between adjacent stringers)
Because of "effective width" considerations, the incremental
AXIAL tension in the panel skin, which is generated by
prebuckling bending of the imperfect panel, is being reset to
zero for the buckling computations (ONLY in Segs.1 and NSEG).
This is done because in the real world the incremental axial
tension in the panel skin decays from its computed value at
the hoop coordinate corresponding to the stringer station to
nearly zero midway between adjacent stringers. Therefore, it
is conservative to neglect the effect of this axial tension
on the local buckling load factor computed from the discrete
skin-stringer module. Axial tension is retained in Segment 2.
 Axial tension before the reset to zero, dNx(1)=  3.8249E+02
 Axial tension after  the reset to zero, dNx(1)= 0.0

**** NOTE ********* NOTE ********* NOTE ********* NOTE ****
This is Segment 1 (Panel skin between adjacent stringers)
Because of "effective width" considerations, the incremental
CIRCUMFERENTIAL tension in the panel skin, generated by
prebuckling bending of the imperfect panel, is being reset to
zero for the buckling computations (ONLY in Segs.1 and NSEG).
This is done because in the "real world" the incremental hoop
tension in the panel skin decays from its computed value at
the axial coordinate corresponding to the ring station
to nearly zero midway between adjacent rings. Therefore, it
is conservative to neglect the effect of this hoop tension
on the local buckling load factor computed from the discrete
skin-stringer module. Hoop tension is retained in Segment 2.
 Hoop tension before the reset to zero, dNy(1)=  2.3928E+02
 Hoop tension after  the reset to zero, dNy(1)= 0.0

CHANGES IN CURVATURE AND TWIST, CHANGES IN RESULTANTS USED
IN THE IQUICK = 0 (DISCRETIZED MODULE) TYPE OF ANALYSIS.
THE FOLLOWING RESULT FROM GROWTH OF INITIAL IMPERFECTIONS
DURING LOADING. THEY DEPEND ON THE SIGNS OF THE
IMPERFECTION AMPLITUDES....
Curvature changes and twist: axial, hoop, twist:
 DELCUR(1), DELCUR(2), DELCUR(3)=     -3.6149E-03 -2.4296E-03 -2.9636E-03
Change in axial resultant Nx in: skin, stringer base, flange:
```

```
 DELFCX(1,1),DELFCX(1,2),DELFCX(1,4)=  0.0000E+00  3.8249E+02  0.0000E+00
Change in circ. resultant Ny in: skin, stringer base, flange:
 DELFCX(2,1),DELFCX(2,2),DELFCX(2,4)=  0.0000E+00  2.3928E+02  0.0000E+00
Change in in-plane shear Nxy in: skin, stringer base, flange:
 DELFCX(3,1),DELFCX(3,2),DELFCX(3,4)=  0.0000E+00  0.0000E+00  0.0000E+00
Change in axial resultant Nx in web at: web root,    web tip:
 DELWBX(1), DELWBX(2)=                 6.2230E+02 -2.3050E+03
Change in in-plane shear Nxy in stringer web:
               DELWEB(1)    =  8.5650E+01

FOR PANELS THAT ARE NOT ISOGRID NOR TRUSS-CORE...
CHANGES IN RESULTANTS USED IN THE IQUICK = 1 (CLOSED FORM)
TYPE OF ANALYSIS. THE VALUES ARE INDEPENDENT OF THE SIGNS
OF THE IMPERFECTIONS BECAUSE THE IQUICK = 1 MODE OF
ANALYSIS USES THE MOST COMPRESSIVE VALUES FOR EITHER
POSITIVE OR NEGATIVE IMPERFECTION AMPLITUDES...
Change in axial resultant Nx in: skin and stringer base:
 DELSKN(1,1,1),DELSKN(1,2,1)= -3.8249E+02 -3.8249E+02
Change in circ. resultant Ny in: skin and stringer base:
 DELSKN(2,1,1),DELSKN(2,2,1)= -2.3928E+02 -2.3928E+02
Change in in-plane shear Nxy in: skin and stringer base:
 DELSKN(3,1,1),DELSKN(3,2,1)=  0.0000E+00  0.0000E+00
Change in axial resultant Nx at the tip of the stringer web:
              DELFCE(JWEB,1)= -2.3050E+03
Change in axial resultant Nx in the outstndg stringer flange:
             DELFCE(JWEBP,1)=  0.0000E+00
Change in in-plane shear Nxy in stringer web:
               DELWEB(1)    =  8.5650E+01

ADDITIONAL CIRCUMFERENTIAL CHANGE IN CURVATURE
FROM GROWTH OF INTER-RING BUCKLING MODAL IMPERFECTION,
TO BE USED IN THE COMPUTATION OF STRESSES IN THE PANEL SKIN
IN SUBROUTINE STRTHK DURING AN IQUICK=0 ANALYSIS: DELCRC=  0.0000E+00




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**************************************************************
************          CHAPTER 13            *****************
**************************************************************
**************************************************************
**************************************************************
********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

*************************************************************
```

CHAPTER 13 Get prebuckling stress resultants, Nx, Ny, needed for the discretized single-module skin-stringer model used for local buckling and bending-torsion buckling (BOSOR4-type model: see Figs. 18, 20, 22, 97, and 98 of [1A], for examples of the discretized single skin-stringer BOSOR4-type module model.).

```
Effective circumferential radius of curvature, RADNEW= -7.6747E+01
      Internal Stringer
```

```
     MODULE WITH RECTANGULAR STIFFENER...

                              !   ^
          Segment No. 3 -----> !   !
                              !   !
              Seg. No. 2-.     !   h
                        .     !   !
     Segment No. 1-.       .   !   !          .-Seg. No. 4
                .         .  !   V         .(same as Seg. 1)
       --------------=================================-----------
                  !<------ b2 ------->!
       !<--- Module width  =  stiffener spacing, b --->!


   EXPLODED VIEW, SHOWING LAYERS and (SEGMENT, NODE) NUMBERS

                            (3,11)
                              !
            Layer No. 1 -----> ! <---------- Layer No. k
                              !
         Layer No. 1-.         !
                      .       !
   Layer No. 1-.       .       !              .-Layer No. 1
             .         .      !               .
            .           .   (3,1)              .
   --------------    =====================    --------------
 (1,1)   .   (1,11)(2,1)   . (2,6)    (2,11)(4,1)  .    (4,11)
          .                 .                       .
           .                 .                       .
            Layer No. m       Layer No. n    Layer No. m
```

```
==============================================
BEGIN: PREBUCKLING STRESS RESULTANTS USED IN THE
DISCRETIZED SINGLE MODULE MODEL WITH IQUICK = 0...
----------------------------------------------------------
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 1 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -1.2470E+03 -7.6529E+01  1.1095E+01
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 2 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -8.6452E+02  1.6275E+02  1.1095E+01
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 3 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -1.3716E+03  3.2032E-31  5.4240E-08
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00

AXIAL CURVATURE CHANGES FROM SOURCES OTHER THAN
INITIAL IMPERFECTIONS (FROM EPSLOD(4) AND ETHERM(4))...
 "Eigenvalue" axial curvature change
      CURVAR = EPSLOD(4) - FFIABT*ETHERM(4) = -1.1065E-04
 "Fixed" axial curvature change
      CURFIX = EPSLDF(4)                    =  0.0000E+00

PREBUCKLING AXIAL RESULTANTS IN STRINGER WEB: SEGMENT NO.  3
 "Eigenvalue" axial resultant, Nx(var)=
```

```
 -1.3716E+03 -1.6731E+03 -1.9745E+03 -2.2760E+03 -2.5774E+03 -2.8789E+03
 -3.1803E+03 -3.4818E+03 -3.7832E+03 -4.0847E+03 -4.3861E+03
  "  fixed   " axial resultant, Nx(fix)=
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
 IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 4 .....
  "Total." loads, Nx(var),Ny(var),Nxy(var)= -1.2470E+03 -7.6529E+01  1.1095E+01
  "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
 -------------------------------------------------
 END:  PREBUCKLING STRESS RESULTANTS USED IN THE
 DISCRETIZED SINGLE MODULE MODEL WITH IQUICK = 0...
 ==========================================================
 ********** END OF OUTPUT FOR STATE CHANGE ************
 New C(i,j) and Nx, Ny, Nxy have now been calculated for  design iter. no.  0, load set no.  1,
matl iter. no.  0




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 ************          CHAPTER 14           *****************
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 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

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CHAPTER 14

```
 CHAPTER 14 Compute local buckling from BOSOR4-type
            discretized skin-stringer single module model.
            See Section 12.2 (upper table on p. 511) and
            Figs. 46c and 98b in [1A], for examples.

 EXPLANATION OF FOLLOWING CALCULATIONS (LOAD SET NO. 1):
     Eigenvalues corresponding to local buckling of the skin
     obtained from the BOSOR4-discretized panel module model
     are calculated for a range of axial wavenumbers. All four
     edges of the panel are assumed to be simply supported,
     even if you indicated "clamped" in your input, and the in-
     plane loading is assumed to be uniform (N1, N2, N12), even
     if you provided for axial load Nx varying in the L2 (cir-
     cumferential) direction.


 Local buckling load factors from discretized model of a single panel module for
 design iteration no.  0, load set no. 1,  material iteration no.  0. These load factors
 include the knockdown factor,  1.0000E+00 that accounts for the
 effect of in-plane shear loading and anisotropy [e.g. C(4,6)]
 in the panel skin.  Resultants are uniform and given by:
   LOAD SET A: axial, Nx = -2.22E+03; circ., Ny = -2.22E-03; in-plane shear, Nxy =  1.11E+01
(Not from normal pressure)
   LOAD SET B: axial, Nxo=  0.00E+00; circ., Nyo=  0.00E+00; in-plane shear, Nxyo=  0.00E+00
(Not from normal pressure)
   LOAD SET A: Uniform normal pressure, P =   4.6229E-05
```

```
      Resultants from global (smeared stiffener) model: Nx(p)=  0.00E+00,  Ny(p)=  0.00E+00,
Nxy(p)= 0.0
      Resultants from local (discrete stiffener) model: Nx(p)= -9.99E-05,  Ny(p)=  9.92E-07,
Nxy(p)= 0.0 :

**** BEGIN SUBROUTINE LOCAL (INITIAL LOCAL BUCKLING SEARCH) ****
  LABEL NO. IN STRUCT= 9310
 Before CALL LOCAL: N =     0

 BUCKLING LOAD FACTORS FROM BOSOR4-TYPE DISCRETIZED MODEL...
          (skin-stringer discretized module of local buckling)
  AXIAL     BUCKLING        KNOCKDOWN FOR    KNOCKDOWN FOR      BUCKLING
  HALF-    LOAD FACTOR     TRANSVERSE SHEAR  IN-PLANE SHEAR    LOAD FACTOR
  WAVES  BEFORE KNOCKDOWN    DEFORMATION     LOADING AND/OR  AFTER KNOCKDOWN
                                               ANISOTROPY
    M        EIGOLD             KSTAR            KNOCK     EIGOLD*KSTAR*KNOCK
    8      1.34641E+00       1.00000E+00      1.00000E+00     1.34641E+00
    9      1.48412E+00       1.00000E+00      1.00000E+00     1.48412E+00
    7      1.22600E+00       1.00000E+00      1.00000E+00     1.22600E+00
    6      1.12932E+00       1.00000E+00      1.00000E+00     1.12932E+00
    5      1.06604E+00       1.00000E+00      1.00000E+00     1.06604E+00
    4      1.05666E+00       1.00000E+00      1.00000E+00     1.05666E+00
    3      1.16184E+00       1.00000E+00      1.00000E+00     1.16184E+00
 Buckling load factor before t.s.d.=  1.0567E+00 After t.s.d.=  1.0488E+00
    4      1.05666E+00       9.92516E-01      1.00000E+00     1.04875E+00

 In the iterative refinement section: No.of axial halfwaves, m=     4
 dm =  0.0000E+00, Eigenvalue (without knockdowns)=  1.0567E+00

 In the iterative refinement section: No.of axial halfwaves, m=     4
 dm =  5.0000E-01, Eigenvalue (without knockdowns)=  1.0524E+00

 In the iterative refinement section: No.of axial halfwaves, m=     4
 dm = -5.0000E-01, Eigenvalue (without knockdowns)=  1.0874E+00

 In the iterative refinement section: No.of axial halfwaves, m=     4
 dm =  3.3046E-01, Eigenvalue (without knockdowns)=  1.0515E+00

 Value of dm used in SUBROUTINE ARRAYS=  3.3046E-01
 IMOD= 0; Eigenvalue passed to STRUCT=  1.0437E+00
 Knockdown for transverse shear deformation=  9.9252E-01
 Buckling load factor from SUB. LOCAL, EIGITR(1)=  1.0437E+00
 Number of axial halfwaves between rings, N=    4
 ****  END  SUBROUTINE LOCAL (INITIAL LOCAL BUCKLING SEARCH) ****
  **** END OF LOCAL BUCKLING EIGENVALUE CALC.****

**** BEGIN SUBROUTINE MODE (LOCAL BUCKLING MODE SHAPE) ****

 WIDTH-WISE WIDE COLUMN BUCKLING LOAD FACTOR =
 pi**2*EI/[abs(local hoop load)*WIDTH**2]=  4.5641E+00
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    1    1  3.0005E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    1    2  4.8817E-02
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    2    1  5.2057E-02
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    2    2  5.2058E-02
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    3    1  9.3767E-02
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    3    2  1.0034E-01
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    4    1  4.8817E-02
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    4    2  3.0005E-03
```

Internal Stringer

```
 MODULE WITH RECTANGULAR STIFFENER...

                           !   ^
      Segment No. 3 -----> !   !
                           !   !
          Seg. No. 2-.     !   h
                      .    !   !
 Segment No. 1-.       .   !   !          .-Seg. No. 4
             .          .  !   V         .(same as Seg. 1)
   ---------------------=====================---------------------
                !<------ b2 ------->!
   !<--- Module width  =  stiffener spacing, b --->!
```

```
EXPLODED VIEW, SHOWING LAYERS and (SEGMENT, NODE) NUMBERS

                        (3,11)
                           !
        Layer No. 1 -----> ! <---------- Layer No. k
                           !
     Layer No. 1-.         !
                 .         !
Layer No. 1-.      .       !              .-Layer No. 1
          .          .     !             .
         .             .  (3,1)           .
--------------    ====================    --------------
(1,1)   .   (1,11)(2,1)   . (2,6)    (2,11)(4,1)  .    (4,11)
         .                 .                       .
          .                 .                       .
        Layer No. m       Layer No. n    Layer No. m
```

NORMAL MODAL DISPLACEMENTS IN THE PANEL MODULE SHOWN ABOVE
SKIN-STRINGER PANEL MODULE HAS 4 SEGMENTS
NUMBER OF HALF-WAVES IN THE AXIAL DIRECTION, M= 4

MODAL DISPLACEMENTS FOR SEGMENT NO. 1

NODE	Z	W	WD	WDD	U	V	WDDD
1	0.00E+00	5.67E-01	0.00E+00	-1.57E+00	0.00E+00	-6.25E-04	3.77E-01
2	0.00E+00	5.64E-01	-9.64E-02	-1.55E+00	-1.02E-04	-6.24E-04	3.77E-01
3	0.00E+00	5.55E-01	-1.92E-01	-1.53E+00	-2.04E-04	-6.17E-04	3.77E-01
4	0.00E+00	5.40E-01	-2.85E-01	-1.49E+00	-3.06E-04	-6.06E-04	6.23E-01
5	0.00E+00	5.20E-01	-3.76E-01	-1.43E+00	-4.08E-04	-5.91E-04	8.63E-01
6	0.00E+00	4.94E-01	-4.63E-01	-1.36E+00	-5.10E-04	-5.70E-04	1.09E+00
7	0.00E+00	4.62E-01	-5.45E-01	-1.28E+00	-6.12E-04	-5.45E-04	1.31E+00
8	0.00E+00	4.26E-01	-6.22E-01	-1.19E+00	-7.14E-04	-5.14E-04	1.51E+00
9	0.00E+00	3.85E-01	-6.92E-01	-1.08E+00	-8.15E-04	-4.77E-04	1.70E+00
10	0.00E+00	3.40E-01	-7.56E-01	-9.68E-01	-9.16E-04	-4.33E-04	1.87E+00
11	0.00E+00	2.91E-01	-8.13E-01	-8.52E-01	-1.02E-03	-3.83E-04	1.87E+00

MODAL DISPLACEMENTS FOR SEGMENT NO. 2

NODE	Z	W	WD	WDD	U	V	WDDD
1	0.00E+00	2.91E-01	-8.13E-01	-8.37E-01	-1.02E-03	-3.83E-04	2.80E-01
2	0.00E+00	2.39E-01	-8.65E-01	-8.20E-01	-1.12E-03	-3.25E-04	2.80E-01
3	0.00E+00	1.84E-01	-9.16E-01	-8.02E-01	-1.21E-03	-2.58E-04	2.80E-01
4	0.00E+00	1.26E-01	-9.65E-01	-7.92E-01	-1.31E-03	-1.82E-04	1.66E-01
5	0.00E+00	6.44E-02	-1.01E+00	-7.90E-01	-1.41E-03	-9.50E-05	2.50E-02

```
  6  0.00E+00 -1.59E-07 -1.04E+00 -2.31E-05 -1.46E-03  3.15E-08  1.28E+01
  7  0.00E+00 -6.44E-02 -1.01E+00  7.90E-01 -1.41E-03  9.50E-05  1.28E+01
  8  0.00E+00 -1.26E-01 -9.65E-01  7.92E-01 -1.31E-03  1.82E-04  2.52E-02
  9  0.00E+00 -1.84E-01 -9.16E-01  8.02E-01 -1.21E-03  2.58E-04  1.67E-01
 10  0.00E+00 -2.39E-01 -8.65E-01  8.20E-01 -1.12E-03  3.25E-04  2.80E-01
 11  0.00E+00 -2.91E-01 -8.13E-01  8.37E-01 -1.02E-03  3.83E-04  2.80E-01

                 MODAL DISPLACEMENTS FOR SEGMENT NO. 3
  1 -2.48E-02 -2.72E-02 -1.04E+00 -2.89E-01  1.59E-07  2.68E-08  8.01E-01
  2 -1.14E-01 -1.21E-01 -1.07E+00 -2.18E-01  1.58E-07  1.65E-08  8.01E-01
  3 -2.02E-01 -2.16E-01 -1.08E+00 -1.47E-01  1.57E-07  6.76E-09  8.01E-01
  4 -2.91E-01 -3.13E-01 -1.09E+00 -8.50E-02  1.55E-07 -2.55E-09  6.96E-01
  5 -3.80E-01 -4.10E-01 -1.10E+00 -3.60E-02  1.54E-07 -1.17E-08  5.51E-01
  6 -4.69E-01 -5.08E-01 -1.10E+00 -4.91E-03  1.53E-07 -2.09E-08  3.50E-01
  7 -5.58E-01 -6.06E-01 -1.10E+00  1.58E-03  1.51E-07 -3.05E-08  7.31E-02
  8 -6.46E-01 -7.03E-01 -1.10E+00 -2.51E-02  1.50E-07 -4.09E-08 -3.01E-01
  9 -7.35E-01 -8.01E-01 -1.11E+00 -9.58E-02  1.48E-07 -5.21E-08 -7.96E-01
 10 -8.24E-01 -9.00E-01 -1.12E+00 -2.23E-01  1.46E-07 -6.47E-08 -1.44E+00
 11 -9.13E-01 -1.00E+00 -1.14E+00 -3.51E-01  1.44E-07 -7.84E-08 -1.44E+00

                 MODAL DISPLACEMENTS FOR SEGMENT NO. 4
  1  0.00E+00 -2.91E-01 -8.13E-01  8.52E-01 -1.02E-03  3.83E-04  1.87E+00
  2  0.00E+00 -3.40E-01 -7.56E-01  9.68E-01 -9.16E-04  4.33E-04  1.87E+00
  3  0.00E+00 -3.85E-01 -6.92E-01  1.08E+00 -8.15E-04  4.77E-04  1.87E+00
  4  0.00E+00 -4.26E-01 -6.22E-01  1.19E+00 -7.14E-04  5.14E-04  1.70E+00
  5  0.00E+00 -4.62E-01 -5.45E-01  1.28E+00 -6.12E-04  5.45E-04  1.51E+00
  6  0.00E+00 -4.94E-01 -4.63E-01  1.36E+00 -5.10E-04  5.70E-04  1.31E+00
  7  0.00E+00 -5.20E-01 -3.76E-01  1.43E+00 -4.08E-04  5.91E-04  1.09E+00
  8  0.00E+00 -5.40E-01 -2.85E-01  1.49E+00 -3.06E-04  6.06E-04  8.63E-01
  9  0.00E+00 -5.55E-01 -1.92E-01  1.53E+00 -2.04E-04  6.17E-04  6.23E-01
 10  0.00E+00 -5.64E-01 -9.64E-02  1.55E+00 -1.02E-04  6.24E-04  3.77E-01
 11  0.00E+00 -5.67E-01  0.00E+00  1.57E+00  0.00E+00  6.25E-04  3.77E-01
 **** END SUBROUTINE MODE (LOCAL BUCKLING MODE SHAPE) ******
 EILOCL,EIGLCS(1),FKNOCS,EIGRAT=
  6.8737E-01  1.0437E+00  1.0000E+00  6.5861E-01
  *******************************************
  **** LOCAL MODE HAS STRINGER SIDESWAY ****
  *******************************************
  **** END OF LOCAL BUCKLING EIGENVECTOR CALC.****
 IPANDA= 0
 Margin=  4.9801E-02  Local buckling from discrete model-1.,M=4   axial halfwaves;FS=0.999
 Margin=  4.4709E-02  Bending-torsion buckling; M=4  ;FS=0.999
 ******** THE FOLLOWING BENDING-TORSION MARGIN JUST COMPUTED:
Bending-torsion buckling; M=4  ;FS=0.999
 ******** CONSTRAINT NO.  2; LOAD SET NO. 1; SUBCASE NO. 1



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 ************          CHAPTER 15           *****************
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 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
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 CHAPTER 15 Compute bending-torsion (low-m) buckling from
            BOSOR4-type discretized skin-stringer single
            module model. See Section 12.2 (lower table on
            p. 511) in [1A], for example.

**** BEGIN SUBROUTINE LOCAL (LOW-M LOCAL BUCKLING SEARCH) ****
  LABEL NO. IN STRUCT= 9340

 BUCKLING LOAD FACTORS FROM BOSOR4-TYPE DISCRETIZED MODEL...
         (skin-stringer discretized module of local buckling)
  AXIAL     BUCKLING        KNOCKDOWN FOR    KNOCKDOWN FOR      BUCKLING
  HALF-    LOAD FACTOR     TRANSVERSE SHEAR  IN-PLANE SHEAR    LOAD FACTOR
  WAVES  BEFORE KNOCKDOWN    DEFORMATION     LOADING AND/OR  AFTER KNOCKDOWN
                                               ANISOTROPY
    M        EIGOLD            KSTAR             KNOCK     EIGOLD*KSTAR*KNOCK
    1      6.82750E+00      1.00000E+00      1.00000E+00     6.82750E+00
    2      1.66409E+00      1.00000E+00      1.00000E+00     1.66409E+00
    3      1.16183E+00      1.00000E+00      1.00000E+00     1.16183E+00
    4      1.05665E+00      1.00000E+00      1.00000E+00     1.05665E+00
 Buckling load factor before t.s.d.=  1.0566E+00 After t.s.d.=  1.0487E+00
    4      1.05665E+00      9.92516E-01      1.00000E+00     1.04874E+00
 Buckling load factor from SUB. LOCAL, EIGITR(4)=  1.0487E+00
 Number of axial halfwaves between rings, NLOW=    4
 **** END SUBROUTINE LOCAL (LOW-M LOCAL BUCKLING SEARCH) ******
  **** END OF LOW-AXIAL-WAVENUMBER CHECK FOR ****
  ***************  LOCAL BUCKLING  **************



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 ************         CHAPTER 16          *****************
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 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

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 CHAPTER 16 Compute post-local buckling from the Koiter
            theory given in Ref.[1C]. See Figs. 23, 24, and
            Figs. 47-49 in [1A], Fig. 6 in [1C], and Fig. 4 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007

*** BEGIN CALCULATIONS RELATING TO THE KOITER THEORY ***
*** See Ref.[3]: Bushnell, D., "Optimization of composite,
*** stiffened, imperfect panels under combined loads for
*** service in the posbuckling regime", CMAME, vol.103,
*** pp 43-114 (1993)
** BEGIN SUBROUTINE INTMOD (INTEGRALS OF PRODUCTS OF MODES) **
 SUB.INTMOD computes the quantities given on pp 58 and 59 of
 the paper just cited.
```

```
       INTEGRATED MODAL PRODUCTS A(I,ISEG)
 FORMULA SEGMENT 1   SEGMENT 2   SEGMENT 3   SEGMENT 4   SEGMENT 5   SEGMENT 6
   NO.
     1  1.5329E-01  1.0049E-02  1.6135E-01  0.0000E+00  0.0000E+00  0.0000E+00
     2  3.8961E-02  5.2397E-04  9.6338E-02  0.0000E+00  0.0000E+00  0.0000E+00
     3  1.0561E-02  3.2239E-05  6.8606E-02  0.0000E+00  0.0000E+00  0.0000E+00
     4  1.6952E-01  2.9456E-01  5.7247E-01  0.0000E+00  0.0000E+00  0.0000E+00
     5  2.8583E-02  7.8026E-03  1.9905E-01  0.0000E+00  0.0000E+00  0.0000E+00
     6  5.4404E-03  3.8720E-04  1.2013E-01  0.0000E+00  0.0000E+00  0.0000E+00
     7 -4.2453E-01 -4.0458E-02  2.7024E-02  0.0000E+00  0.0000E+00  0.0000E+00
     8  2.9811E-03  2.1634E-06  5.3288E-02  0.0000E+00  0.0000E+00  0.0000E+00
     9  8.6394E-04  1.5390E-07  4.3629E-02  0.0000E+00  0.0000E+00  0.0000E+00
    10  2.5489E-04  1.1445E-08  3.7034E-02  0.0000E+00  0.0000E+00  0.0000E+00
    11  5.2902E-01  3.3827E-01  6.2552E-01  0.0000E+00  0.0000E+00  0.0000E+00
    12  7.6356E-01  1.3829E-02 -1.5281E-01  0.0000E+00  0.0000E+00  0.0000E+00
    13  5.4587E-01  3.1360E-03  7.4834E-01  0.0000E+00  0.0000E+00  0.0000E+00
    14  1.7456E-01  1.5247E-04 -3.2134E-01  0.0000E+00  0.0000E+00  0.0000E+00
    15  2.1047E-02  1.6670E-05  5.2812E-01  0.0000E+00  0.0000E+00  0.0000E+00
    16 -1.0760E-01 -1.8252E-03  1.8390E-02  0.0000E+00  0.0000E+00  0.0000E+00
    17 -2.9119E-02 -1.0563E-04  1.5268E-02  0.0000E+00  0.0000E+00  0.0000E+00
    18  1.1758E+00  1.8716E-01  1.0996E-02  0.0000E+00  0.0000E+00  0.0000E+00
    19  8.2314E-01 -3.5170E-01  4.3276E-01  0.0000E+00  0.0000E+00  0.0000E+00
    20  5.5082E-01  1.7468E-01  9.7216E+00  0.0000E+00  0.0000E+00  0.0000E+00
    21  1.5329E-01  1.0050E-02  1.6135E-01  0.0000E+00  0.0000E+00  0.0000E+00
    22  2.2724E-08  9.0726E-09  1.3324E-15  0.0000E+00  0.0000E+00  0.0000E+00
    23  2.0408E-07  1.8882E-08  6.4954E-16  0.0000E+00  0.0000E+00  0.0000E+00
    24  0.0000E+00  0.0000E+00 -1.1074E-01  0.0000E+00  0.0000E+00  0.0000E+00
    25  3.8961E-02  5.2400E-04  9.6338E-02  0.0000E+00  0.0000E+00  0.0000E+00
    26  3.6194E-01  3.5173E-04  5.9539E-02  0.0000E+00  0.0000E+00  0.0000E+00
    27  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
    28  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
    29  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
    30  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 **** END SUBROUTINE INTMOD (INTEGRALS OF PRODUCTS OF MODES) ****

 EXPLANATION OF FOLLOWING CALCULATIONS (LOAD SET NO. 1):
  Corresponding to M=  4 waves from the local buckling
  analysis above, the distributions of Nx, Ny, and Nxy
  in the locally imperfect and additionally deformed panel are
  next calculated.  The maximum stress components in the
  deformed skin as well as in the stiffener segments are also
  computed. In addition, the tangent membrane stiffness CTAN
  in the locally deformed skin is calculated.  CTAN is needed
  for subsequent calculation of the load factor corres-
  ponding to wide column panel buckling (buckling between
  rings) and general instability.

  BEFORE POSSIBLE CHANGE: INITIAL LOCAL IMPERFECTION W0=  1.00000001E-07
  AFTER POSSIBLE CHANGE: INITIAL LOCAL IMPERFECTION W0=  1.00000001E-07
  IF W0 WAS CHANGED, SEE PANDA2.NEWS ITEM 141 FOR WHY IT WAS

***** BEGIN SUBROUTINE KOIT2 (KOITER THEORY POSTBUCKLING) ****

 ******** ENTERING KOITER BRANCH, SUBROUTINE KOIT2 *********
 This subroutine is an implementation of the theory described
 in the PANDA2 paper by David Bushnell:
     "Optimization of composite, stiffened, imperfect panels
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     under combined loads for service in the postbuckling
     regime", Computer Methods in Applied Mechanics and
     Engineering, Vol. 103 (1993) 43-114 (volume in honor of
     Besselings 65th birthday).

NOTE: Computations herein do not include the effect of
      "hungry-horse" adjustments to the hoop resultant in the
      panel skin: FNYADJ=  0.0000E+00 for Load Set A and
                  FNYAD0=  0.0000E+00 for Load Set B.
      unless a negative eigenvalue is computed in SUBROUTINE
      EIGKOI.

BIFURCATION BUCKLING EIGENVALUE FROM KOITER-TYPE THEORY
 AXIAL    ITER.    SLOPE      DSLOPE      EIGKOI
 WAVES     NO.       m          dm
   4         1  5.0272E-03  4.0272E-03  1.0376E+00
   4         2  5.0272E-03 -5.4400E-08  1.0376E+00
   4         3  5.0272E-03  6.5126E-10  1.0376E+00

LOCAL BIFURCATION BUCKLING LOAD FACTOR ESTIMATES
AND AMPLITUDE Wo OF LOCAL IMPERFECTION, Wo*(buckling mode)
Critical number of axial half-waves                =  4
Slope of buckling nodal lines from Koiter Theory, m=  5.03E-03
Knockdown factor for C44, C45, C55 for transv.shear=  9.93E-01
Local buckling load Factor from Koiter-type Theory =  1.04E+00
Load Factor from BOSOR4-type panel module model    =  1.04E+00
BOSOR4-type load factor without knockdowns for
  effects of anisotropy [e.g. C(4,6)] of the skin,
  transverse shear def., or in-plane shear loading =  1.05E+00
Amplitude Wo of local imperfection                 =  1.0000E-07

Even if the load factor from Koiter-type theory is greater
than unity, the panel is in a "post-locally-buckled" state
because there is always a finite local imperfection in the
panel skin and stringer that grows under the applied loads.

The load factor computed from Koiter theory may not agree well
with that computed from the BOSOR4-type module model. Some
reasons for the discrepancy are:
       1. there are significant non-zero coupling terms
             C13, C16, C23, C26, C34, C35, C46, C56
          in the constitutive matrix Cij,
       2. significant in-plane shear loads exist,
       3. there is a significant effect of transverse
          shear deformation,
       4. the stringer web deforms significantly in the
          local buckling mode,
       5. there is significant hoop compression.
       6. the temperature varies significantly in a seg-
          ment where the material props. are temp.-dependent,
       7. the critical number of axial half-waves is one,
       8. the configuration is TRUSS-CORE SANDWICH.
       9. any segment laminate is unbalanced.
      10. the user selected "N" for the MAINSETUP prompt:
Do you want "flat skin" discretized module for local buckling?
      11. there is significant prebuckling axial bending,
          especially in panels with rectangular stringers.
      12. "hungry-horse" skin hoop resultant adjustments are
```

```
          ignored: for Load Set A: FNYADJ=  0.0000E+00
                   for Load Set B: FNYAD0=  0.0000E+00
Margin=  3.8676E-02  Bending-torsion buckling: Koiter theory,M=4   axial halfwav;FS=0.999
ENTERING "NEWTON", LABEL=8004; IMOD= 0

NONLINEAR POST-LOCAL BUCKLING BEHAVIOR WITH
INITIAL LOCAL IMPERFECTION INCLUDED (Wo =  1.0000E-07):
Starting iterations with fixed slope, m =  5.0272E-03

SUBROUTINE NEWTON CALLED FROM KOIT2 AT LABEL= 8004
NEWTON ITERATIONS BEGIN; SLOPE=  5.0272E-03; a=  0.0000E+00; f=  0.0000E+00
Imperfection, Wo=  4.9565E-06; Load Perturbation=  0.0000E+00
 ITER   SLOPE       DSLOPE        a           da          f           df
   1  5.0272E-03  0.0000E+00  0.0000E+00  0.0000E+00  1.3169E-04  1.3169E-04
   2  5.0272E-03  0.0000E+00  0.0000E+00  0.0000E+00  1.3169E-04 -6.7843E-09
   3  5.0272E-03  0.0000E+00  0.0000E+00  0.0000E+00  1.3169E-04 -3.0908E-12
 CONVERGENCE OBTAINED WITH m = m0 AND
 FLATTENING PARAMETER a = 0.
 FREE DSLOPE NOW, AND TRY AGAIN.
   1  5.2161E-03  1.8892E-04  0.0000E+00  0.0000E+00  1.3169E-04 -3.0848E-12
   2  5.2161E-03 -1.1595E-11  0.0000E+00  0.0000E+00  1.3169E-04 -3.8701E-12
   3  5.2161E-03 -1.1595E-11  0.0000E+00  0.0000E+00  1.3169E-04 -3.8701E-12
LABEL= 8004 CONVERGENCE OF LOCAL STATE SUCCESSFUL! IMOD= 0
SOLUTION FROM "NEWTON", F,AL,M=  1.3169E-04  0.0000E+00  5.2161E-03
LEAVING "NEWTON", LABEL=8004; IMOD,NOCONV= 0 4
SOLN FROM "NEWTON": F,AL,M;  N=  1.3169E-04  0.0000E+00  5.2161E-03  3.0069E-01

LOCAL DEFORMATION CHARACTERISTICS:
Average axial strain(not including thermal),EXAVE = -1.5931E-03
Initial local imperfection amplitude,           Wo=  1.0000E-07
Slope of local buckling nodal lines in skin     M =  5.2161E-03
Parameter "a" in the expression f*(phi +a*phi**3) =  0.0000E+00
Amplitude  f  in the expression f*(phi +a*phi**3) =  1.3169E-04
Normal displacement amplitude between stringers W =  7.4700E-05
Number of axial halfwaves at local bifurcation    =     4
Number of axial halfwaves in postbuckled regime   =  4.0000E+00
Convergence characteristic,               NOCONV  =  4


RESULTS FOR  4.0000E+00 AXIAL WAVES...
LOCAL DEFORMATION PARAMETERS:
   SLOPE, a, f       =  5.2161E-03  0.0000E+00  1.3169E-04
APPLIED STRESS RESULTANTS (Load set A):
   Nx, Ny, Nxy       = -2.2190E+03  5.0436E+00  1.1095E+01
APPLIED STRESS RESULTANTS (Load set B):
  Nxo, Nyo, Nxyo     =  0.0000E+00  0.0000E+00  0.0000E+00
STRAIN AND STRESS FROM APPLIED LOADS:
AVERAGE STRAIN COMPONENTS:
  EPS1, EPS2, EPS12  = -1.5931E-03  8.2783E-04  5.2909E-05
AVERAGE RESULTANTS IN SKIN:
N1SKIN,N2SKIN,N12SKIN= -8.0571E+02  2.0963E+02  1.1095E+01
NOTE: N1SKIN includes average of Nx in skin and stringer base.

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 PERTURB THE APPLIED AXIAL LOAD, Nx...
ENTERING "NEWTON", LABEL=8250; IMOD= 0

SUBROUTINE NEWTON CALLED FROM KOIT2 AT LABEL= 8250
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NEWTON ITERATIONS BEGIN; SLOPE=  5.2161E-03; a=  0.0000E+00; f=  1.3169E-04
Imperfection, Wo=  4.9565E-06; Load Perturbation=  4.4381E+01
 ITER   SLOPE       DSLOPE        a           da         f           df
   1  4.9920E-03 -2.2414E-04  0.0000E+00  0.0000E+00  2.0971E-04  7.8022E-05
   2  5.0755E-03  8.3533E-05  0.0000E+00  0.0000E+00  2.0970E-04 -1.2386E-08
   3  5.0755E-03  5.0527E-09  0.0000E+00  0.0000E+00  2.0970E-04 -8.1589E-11
LABEL= 8250 CONVERGENCE OF LOCAL STATE SUCCESSFUL! IMOD= 0
SOLUTION FROM "NEWTON", F,AL,M=  2.0970E-04  0.0000E+00  5.0755E-03
LEAVING "NEWTON", LABEL=8250; IMOD,NOCONV= 0 4
SOLN FROM "NEWTON": F,AL,M;  N=  2.0970E-04  0.0000E+00  5.0755E-03  3.0069E-01
 --------------------------------------------
 PERTURB THE APPLIED HOOP LOAD, Ny...
ENTERING "NEWTON", LABEL=8260; IMOD= 0

SUBROUTINE NEWTON CALLED FROM KOIT2 AT LABEL= 8260
NEWTON ITERATIONS BEGIN; SLOPE=  5.2161E-03; a=  0.0000E+00; f=  1.3169E-04
Imperfection, Wo=  4.9565E-06; Load Perturbation=  3.2523E+01
 ITER   SLOPE       DSLOPE        a           da         f           df
   1  5.1181E-03 -9.8046E-05  0.0000E+00  0.0000E+00  1.9800E-04  6.6312E-05
   2  5.1510E-03  3.2920E-05  0.0000E+00  0.0000E+00  1.9799E-04 -8.3973E-09
   3  5.1510E-03  1.0547E-09  0.0000E+00  0.0000E+00  1.9799E-04  3.5460E-11
LABEL= 8260 CONVERGENCE OF LOCAL STATE SUCCESSFUL! IMOD= 0
SOLUTION FROM "NEWTON", F,AL,M=  1.9799E-04  0.0000E+00  5.1510E-03
LEAVING "NEWTON", LABEL=8260; IMOD,NOCONV= 0 4
SOLN FROM "NEWTON": F,AL,M;  N=  1.9799E-04  0.0000E+00  5.1510E-03  3.0069E-01
 --------------------------------------------
 PERTURB THE APPLIED IN-PLANE SHEAR LOAD, Nxy...
ENTERING "NEWTON", LABEL=8270; IMOD= 0

SUBROUTINE NEWTON CALLED FROM KOIT2 AT LABEL= 8270
NEWTON ITERATIONS BEGIN; SLOPE=  5.2161E-03; a=  0.0000E+00; f=  1.3169E-04
Imperfection, Wo=  4.9565E-06; Load Perturbation=  9.1035E+00
 ITER   SLOPE       DSLOPE        a           da         f           df
   1  9.4995E-03  4.2834E-03  0.0000E+00  0.0000E+00  1.3182E-04  1.3064E-07
   2  9.4954E-03 -4.1387E-06  0.0000E+00  0.0000E+00  1.3179E-04 -3.1262E-08
   3  9.4954E-03 -2.0706E-09  0.0000E+00  0.0000E+00  1.3179E-04  8.8505E-11
LABEL= 8270 CONVERGENCE OF LOCAL STATE SUCCESSFUL! IMOD= 0
SOLUTION FROM "NEWTON", F,AL,M=  1.3179E-04  0.0000E+00  9.4954E-03
LEAVING "NEWTON", LABEL=8270; IMOD,NOCONV= 0 4
SOLN FROM "NEWTON": F,AL,M;  N=  1.3179E-04  0.0000E+00  9.4954E-03  3.0069E-01
 --------------------------------------------

 3X3 MATRICES FOR STRAIN AND FORCE CHANGE...
      EMAT, THE STRAIN-CHANGE MATRIX       NMAT, THE FORCE-CHANGE MATRIX
      d(EPS1)    d(EPS2)    d(EPS12)     d(N1skin)  d(N2skin)   d(N12skn)
 dNx -4.533E-05  1.087E-05  1.091E-11   -2.520E+01 -1.631E+00  0.000E+00
 dNy  7.967E-06 -4.533E-05  1.091E-11   -3.371E+00 -2.572E+01  0.000E+00
dNxy  0.000E+00  0.000E+00  4.341E-05    0.000E+00  0.000E+00  9.104E+00

TANGENT STIFFNESS BEFORE SYMMETRIZATION
AVERAGE SKIN TANGENT STIFFNESS MATRIX
(Segments 1 and 2 averaged),    CTAN...
 5.9907E+05  1.7968E+05  0.0000E+00
 1.7968E+05  5.9909E+05  0.0000E+00
 6.5358E-02  6.1980E-02  2.0970E+05

TANGENT STIFFNESS AFTER SYMMETRIZATION
AVERAGE SKIN TANGENT STIFFNESS MATRIX
```

```
 (Segments 1 and 2 averaged),    CTAN...
  5.9907E+05  1.7968E+05  3.2679E-02
  1.7968E+05  5.9909E+05  3.0990E-02
  3.2679E-02  3.0990E-02  2.0970E+05

 (APPLIED LOAD)/(BUCKLING LOAD)=  9.6373E-01

 NORMALIZED AVERAGE SKIN TANGENT STIFFNESS MATRIX
 (CTAN(i,i)/CX(i,i,1), i=1,2,3) =   9.9988E-01  9.9992E-01  1.0000E+00
 TANGENT POISSON RATIO
 CTAN(1,2)/CTAN(1,1) =   2.9994E-01
 NORMALIZED AVERAGE (N1skin,N12skn) COUPLING
 CTAN(1,3)/CX(1,1,1) =   5.4544E-08
 NORMALIZED AVERAGE (N2skin,N12skn) COUPLING
 CTAN(2,3)/CX(2,2,1) =   5.1725E-08

  Average tangent stiffnesses of the panel skin
 have been calculated by integration of the local tangent
 stiffnesses, C11TAN, C12TAN, C22TAN, and C33TAN with
 Simpsons rule integration:
 Average axial tangent stiffness,         CTAN(1,1) =  5.9910E+05
 Average (1,2) tangent stiffness,         CTAN(1,2) =  1.7970E+05
 Average hoop  tangent stiffness,         CTAN(2,2) =  5.9909E+05
 Average shear tangent stiffness,         CTAN(3,3) =  2.0970E+05
 These tangent stiffness components affect wide column,
 general instability, and panel instability load factors.
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End of Details from CHAPTER 16

DETAILS FROM CHAPTERS 18 and 19 (printed in *.OPM when NPRINT = 2)

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 ************          CHAPTER 18            *****************
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 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

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CHAPTER 18 Present summary of state of loaded imperfect panel and give effective stiffnesses of possibly locally postbuckled skin-stringer module. These effective stiffnesses are used later for overall buckling and inter-ring buckling. See Table 12 in the paper

Bushnell, D.
"Optimization of an axially compressed ring and stringer stiffened cylindrical shell with a general buckling modal imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting, Honolulu, Hawaii, April 2007

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 PANEL OVERALL & LOCAL IMPERFECTIONS AND DEFORMATION
 General out-of-roundness of cylindrical panel,WIMPG1 =  0.0000E+00
 General initial buckling modal imperfection amplitude=  1.2500E-01
 General modified imperfection amplitude, Wimp(global)=  1.2500E-01
 Local   initial imperfection amplitude, Wimp(local)  =  1.0000E-07
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```
 Panel (inter-ring) initial imp. amplt., Wimp(panel)  =  1.0000E-10
 Bowing due to temperature effects,     W(residual)   =  0.0000E+00
 Overall (inter-ring in cyl) bowing from pressure ,Wp =  9.0976E-04
 Inter-ring bowing (flat panel) from pressure, WPRESR =  0.0000E+00
 Maximum local "pillowing" between stringers,  WLPRES =  4.3324E-04
 Inter-ring bowing due to postbucking effects, WDELKP =  0.0000E+00
 Amplitude factor for bowing except from press,AMPLIT =  1.7536E+00
 Amplitude factor for bowing due to pressure,  AMPLT2 =  1.0522E+00
 Amplitude factor for inter-ring bowing,       AMPLT3 =  1.3526E+00
 Eccentricity of application of axial loads,     ECC  =  0.0000E+00

*** BEGIN SUBROUTINE DEFCIJ (POST-LOCALLY BUCKLED CS(I,J)) ****
 IN SUB.CSTIF; STRINGERS; ISMEAR=3; ZSTART,TBASE,UNBAL=  2.4782E-02  4.9565E-02  0.0000E+00
 IN SUB.CSTIF;   RINGS;   ISMEAR=3; ZSTART,TBASE,UNBAL=  2.4782E-02  4.9565E-02  0.0000E+00
 Effective stiffnesses of undeformed and of
 locally deformed module segments:
                                                          Undeformed   Deformed
     Effective axial stiffness of panel SKIN + BASE =  5.9914E+05  5.9910E+05
     Effective hoop  stiffness of panel SKIN + BASE =  5.9914E+05  5.9909E+05
     Effective (1,2) stiffness of panel SKIN + BASE =  1.7974E+05  1.7970E+05
     Effective axial stiffness of stringer   WEB    =  9.7478E+05  9.7472E+05
     Effective axial stiffness of stringer   FLANGE =  0.0000E+00  0.0000E+00
     Effective shear stiffness of panel SKIN + BASE =  2.0970E+05  2.0970E+05
     Effective shear stiffness of stringer   WEB    =  3.4117E+05  3.4117E+05
     Effective shear stiffness of stringer   FLANGE =  0.0000E+00  0.0000E+00

 Integrated stringer stiffnesses...
     Effective axial stiffness of stringer,   STIFL =  4.2314E+05
     Effective first moment, Int[STIF*zdz],   STIFM =  1.9838E+05
     Effective second moment,Int[STIF*z**2dz],STIFMM=  1.2082E+05

 Constitutive law, CS(i,j), for locally deformed
 panel with smeared stringers and rings.....
       1.0222E+06  1.7970E+05  0.0000E+00  1.9838E+05  0.0000E+00  0.0000E+00
       1.7970E+05  7.4912E+05  0.0000E+00  0.0000E+00  1.3533E+05  0.0000E+00
       0.0000E+00  0.0000E+00  2.0970E+05  0.0000E+00  0.0000E+00  0.0000E+00
       1.9838E+05  0.0000E+00  0.0000E+00  1.2094E+05  3.6797E+01  0.0000E+00
       0.0000E+00  1.3533E+05  0.0000E+00  3.6797E+01  1.6067E+05  0.0000E+00
       0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.6929E+02

 Constitutive law, C(i,j), for locally deformed
 panel between rings with smeared stringers.....
       1.0222E+06  1.7970E+05  0.0000E+00  1.9838E+05  0.0000E+00  0.0000E+00
       1.7970E+05  5.9909E+05  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
       0.0000E+00  0.0000E+00  2.0970E+05  0.0000E+00  0.0000E+00  0.0000E+00
       1.9838E+05  0.0000E+00  0.0000E+00  1.2094E+05  3.6797E+01  0.0000E+00
       0.0000E+00  0.0000E+00  0.0000E+00  3.6797E+01  1.2266E+02  0.0000E+00
       0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.3113E+02
 *** END   SUBROUTINE DEFCIJ (POST-LOCALLY BUCKLED CS(I,J)) ****
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 EXPLANATION OF FOLLOWING CALCULATION (LOAD SET NO. 1):
     Next, the load factor for wide column panel buckling is
     computed from the discretized panel module model. The
     analysis takes into account local deformation of the
     skin between stringers and local deformation of the
     stringers.
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```
    Clamping of the L2 edges (edges that lie in the plane of
    the screen and parallel to it) is accounted for by doing
    the wide column calculation for a panel that is shorter in
    the axial direction by a factor, LENMOD =  1.0000E+00 than the
    axial dimension that you gave in your input.



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 ************          CHAPTER 19           ****************
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 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

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CHAPTER 19
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            Do wide-column inter-ring buckling analysis with
            possibly locally postbuckled skin-stringer module
            model. (See Figs. 20c, 22c, 46d, and 67 of [1A],
            for examples.).

*** BEGIN SUBROUTINE BUCKLE (WIDE-COLUMN BUCKLING - MODULE) ****
  LABEL NO. IN STRUCT= 9450
 Skin stiffnesses, CX(1,1,1),CX(1,2,1),CX(2,2,1),CX(3,3,1)=
  5.9909E+05  1.7969E+05  5.9909E+05  2.0970E+05
*** END SUBROUTINE BUCKLE (WIDE-COLUMN BUCKLING - MODULE) ****

*** BEGIN SUBROUTINE MODE (WIDE-COLUMN BUCKLING MODE SHAPE) ****
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF= 1 1  3.8445E-04
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF= 1 2  3.6186E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF= 2 1  3.3854E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF= 2 2  3.3853E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF= 3 1  1.7577E-17
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF= 3 2  1.9576E-17
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF= 4 1  3.6185E-03
 Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF= 4 2  3.8445E-04

 NUMBER OF AXIAL HALFWAVES =       1
 AMPLITUDE OF BUCKLING MODE AT STRINGER BASE, WSTR  =  9.6285E-01
 AMPLITUDE OF BUCKLING MODE BETWEEN STRINGERS,WSKIN =  1.0000E+00
 RATIO OF BUCKLING MODAL DISPLACEMENTS,  WSTR/WSKIN =  9.6285E-01
 AMPLIT.OF BUCKLING MODE AT STRINGER WEB TIP, WTIP  =  2.4217E-16
 AMPLIT.OF BUCKLING MODE AT STRINGER MIDWEB,  WMID  =  1.4487E-16
 *** END SUBROUTINE MODE (WIDE-COLUMN BUCKLING MODE SHAPE) ****

 Wide column buckling factor from discretized model of a single panel module for
 design iteration no.  0, load set no. 1,  material iteration no.  0. This load factor in-
 cludes the knockdown factor,  1.0000E+00 that accounts for the
 effect of in-plane shear loading and anisotropy [e.g. C(4,6)]
 in the panel skin.  The axial length of the wide column is
  1.1458E+01.  Resultants are uniform and given by:
   LOAD SET A: axial, Nx = -2.22E+03; circ., Ny = -2.22E-03; in-plane shear, Nxy =  1.11E+01
   LOAD SET B: axial, Nxo=  0.00E+00; circ., Nyo=  0.00E+00; in-plane shear, Nxyo=  0.00E+00
(Not from normal pressure)
   LOAD SET A: Uniform normal pressure, P =   4.6229E-05
```

```
      Resultants from global (smeared stiffener) model: Nx(p)=  0.00E+00,  Ny(p)=  0.00E+00,
Nxy(p)= 0.0
      Resultants from local (discrete stiffener) model: Nx(p)= -9.99E-05,  Ny(p)=  9.92E-07,
Nxy(p)= 0.0 :

  WIDE COLUMN PANEL BUCKLING LOAD FACTOR =          2.5957E+00
 ISKIN = 0. WIDE COLUMN BUCKLING IS IGNORED IF ISKIN = 1.
 IWIDE = 0. WIDE COLUMN BUCKLING IS IGNORED IF IWIDE = 0.
 ITIP  = 0. MODE OF BUCKLING IS STRINGER SIDESWAY IF ITIP=1
  *** END OF WIDE COLUMN BUCKLING CALCULATIONS ***
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********
```
End of details from Chapters 18 and 19

DETAILS FROM CHAPTER 22 (printed in *.OPM when NPRINT = 2)

```
 ***************************************************************
 ***************************************************************
 ***************************************************************
 ************          CHAPTER 22           *****************
 ***************************************************************
 ***************************************************************
 ***************************************************************
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 **************************************************************
```
CHAPTER 22 Compute "skin"-ring buckling load factors for:
```
           1. medium-n inter-ring buckling mode (See
              rightmost three mode shapes in top row of
              Fig. 30 of Ref.[1G]),
           2. high-n inter-ring buckling mode (See rightmost
              mode shape in middle row of Fig. 30, Ref.[1G]),
           3. low-n inter-ring buckling mode (See leftmost
              mode shape in top row of Fig. 30, Ref.[1G]).

*** BEGIN "SKIN"-RING BUCKLING, DISCRETE MODULE MODEL) **

***** BEGIN SUBROUTINE STRCON (GET DELFCR,DELWBR) *****
 DELFCR =changes in resultants, dNx,dNy,dNxy, in skin-ring
         module caused by growth of the initial imperfections.
 DELWBR =change in axial resultant dNx in the ring web at the
         ring web root and ring web tip.
 ******* END SUBROUTINE STRCON (GET DELFCR,DELWBR) ******

 **** NOTE ********* NOTE ********* NOTE ********* NOTE ****
 Because of "effective width" considerations, the incremental
 CIRCUMFERENTIAL tension in the panel skin, generated by
 prebuckling bending of the imperfect panel, is being reset to
 zero for the buckling computations (ONLY in Segs.1 and NSEG).
 This is done because in the "real world" the incremental hoop
 tension in the panel skin decays from its computed value at
 the axial coordinate corresponding to the ring station
 to nearly zero midway between adjacent rings. Therefore, it
 is conservative to neglect the effect of this hoop tension
 on the local buckling load factor computed from the discrete
 "skin"-ring module. Hoop tension is retained in Segment 2.
```

```
  Hoop tension before the reset to zero, dNy(1)=  2.3929E+02
  Hoop tension after  the reset to zero, dNy(1)= 0.0

 CHANGES IN RESULTANTS USED IN THE BUCKLING ANALYSIS
 OF THE "SKIN"-RING DISCRETIZED MODULE.
 THE FOLLOWING RESULT FROM GROWTH OF INITIAL IMPERFECTIONS
 DURING LOADING. THEY DEPEND ON THE SIGNS OF THE
 IMPERFECTION AMPLITUDES....
 Change in hoop resultant Ny in: skin, ring base, flange:
  DELFCR(1,1),DELFCR(1,2),DELFCR(1,4)=  0.0000E+00  2.3930E+02  0.0000E+00
 Change in axial resultant Ny in: Seg. 1, ring base, flange:
  DELFCR(2,1),DELFCR(2,2),DELFCR(2,4)=  0.0000E+00  0.0000E+00  0.0000E+00
 Change in in-plane shear Nxy in: Seg. 1, ring base, flange:
  DELFCR(3,1),DELFCR(3,2),DELFCR(3,4)=  0.0000E+00  0.0000E+00  0.0000E+00
 Change in resultant Ny in ring web at: web root,   web tip:
  DELWBR(1), DELWBR(2)=                 4.3008E+02 -3.8057E+03

*** BEGIN "SKIN"-RING BUCKLING, DISCRETE MODEL) **
  LABEL NO. IN STRUCT= 9485
 *** BEGIN SUB. LOCAL ("SKIN"-RING BUCKLING, DISCRETE MODEL) **

 Constitutive law, C(i,j), for locally deformed
 panel between rings with smeared stringers.....
       1.0222E+06  1.7970E+05  0.0000E+00  1.9838E+05  0.0000E+00  0.0000E+00
       1.7970E+05  5.9909E+05  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
       0.0000E+00  0.0000E+00  2.0970E+05  0.0000E+00  0.0000E+00  0.0000E+00
       1.9838E+05  0.0000E+00  0.0000E+00  1.2094E+05  3.6797E+01  0.0000E+00
       0.0000E+00  0.0000E+00  0.0000E+00  3.6797E+01  1.2266E+02  0.0000E+00
       0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.3113E+02

 **** PREBUCKLING LOADS IN "SKIN"-RING DISCRETIZED MODULE ****
 ---------------------------------------------------------------
 Circ. waves, Discretized seg., Seg. type, N,ISEG,JSEG=    63     1     1
 Integrated constitutive diagonal, (C(i,i),i=1,6), Seg. 1
  1.0222E+06  5.9909E+05  2.0970E+05  1.2094E+05  1.2266E+02  1.3113E+02
 Total axial nodal point resultants, (Nx+Nxo)=
 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03
 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03
 Total circ. nodal point resultants, (Ny+Nyo)=
 -7.1498E+01 -7.1689E+01 -7.2244E+01 -7.3151E+01 -7.4391E+01 -7.5935E+01
 -7.7749E+01 -7.9789E+01 -8.2004E+01 -8.4335E+01 -8.6707E+01
 Fixed axial nodal point resultants, Nxo=
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 Fixed circ. nodal point resultants, Nyo=
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 ---------------------------------------------------------------
 Circ. waves, Discretized seg., Seg. type, N,ISEG,JSEG=    63     2     1
 Integrated constitutive diagonal, (C(i,i),i=1,6), Seg. 2
  1.0222E+06  5.9909E+05  2.0970E+05  1.2094E+05  1.2266E+02  1.3113E+02
 Total axial nodal point resultants, (Nx+Nxo)=
 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03
 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03
 Total circ. nodal point resultants, (Ny+Nyo)=
 -8.6707E+01 -8.8276E+01 -8.9800E+01 -9.1256E+01 -9.2620E+01 -9.3864E+01
 -9.2620E+01 -9.1256E+01 -8.9800E+01 -8.8276E+01 -8.6707E+01
 Fixed axial nodal point resultants, Nxo=
```

```
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
Fixed circ. nodal point resultants, Nyo=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
-------------------------------------------------------------
Circ. waves, Discretized seg., Seg. type, N,ISEG,JSEG=    63     3     3
Integrated constitutive diagonal, (C(i,i),i=1,6), Seg. 3
 1.0768E+06  1.0768E+06  3.7688E+05  7.1207E+02  7.1207E+02  2.4923E+02
Eigenvalue hoop resultants in ring web from bending:
 resultant at web root, DLWBR1=  4.3008E+02; at tip, DLWBR2= -3.8057E+03
Fixed hoop resultants in ring web:
 resultant at web root, WBROTF=  0.0000E+00; at tip, WBTIPF=  0.0000E+00
Total meridional nodal point resultants, (Nx+Nxo)=
 1.9543E+01  1.7589E+01  1.5635E+01  1.3680E+01  1.1726E+01  9.7717E+00
 7.8173E+00  5.8630E+00  3.9087E+00  1.9543E+00  0.0000E+00
Total circ. nodal point resultants, (Ny+Nyo)=
 9.5501E+02  5.3335E+02  1.1171E+02 -3.0991E+02 -7.3152E+02 -1.1531E+03
-1.5747E+03 -1.9963E+03 -2.4178E+03 -2.8394E+03 -3.2609E+03
Fixed meridional nodal point resultants, Nxo=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
Fixed circ. nodal point resultants, Nyo=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
-------------------------------------------------------------
Circ. waves, Discretized seg., Seg. type, N,ISEG,JSEG=    63     4     1
Integrated constitutive diagonal, (C(i,i),i=1,6), Seg. 4
 1.0222E+06  5.9909E+05  2.0970E+05  1.2094E+05  1.2266E+02  1.3113E+02
Total axial nodal point resultants, (Nx+Nxo)=
-2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03
-2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03 -2.2190E+03
Total circ. nodal point resultants, (Ny+Nyo)=
-8.6707E+01 -8.4335E+01 -8.2004E+01 -7.9789E+01 -7.7749E+01 -7.5935E+01
-7.4391E+01 -7.3151E+01 -7.2244E+01 -7.1689E+01 -7.1498E+01
Fixed axial nodal point resultants, Nxo=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
Fixed circ. nodal point resultants, Nyo=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
=============================================================

BUCKLING LOAD FACTORS FROM BOSOR4-TYPE DISCRETIZED MODEL...
          (skin-smeared-stringer-ring discretized module)
 HOOP      BUCKLING        KNOCKDOWN FOR    KNOCKDOWN FOR      BUCKLING
 HALF-    LOAD FACTOR     TRANSVERSE SHEAR  IN-PLANE SHEAR    LOAD FACTOR
 WAVES  BEFORE KNOCKDOWN    DEFORMATION     LOADING AND/OR  AFTER KNOCKDOWN
                                              ANISOTROPY
   n        EIGOLD             KSTAR            KNOCK     EIGOLD*KSTAR*KNOCK
  63      1.28211E+00       1.00000E+00      9.99999E-01     1.28211E+00
  68      1.34031E+00       1.00000E+00      9.99999E-01     1.34031E+00
  58      1.23831E+00       1.00000E+00      9.99999E-01     1.23831E+00
  53      1.21185E+00       1.00000E+00      9.99999E-01     1.21185E+00
  49      1.20610E+00       1.00000E+00      9.99999E-01     1.20610E+00
  45      1.21766E+00       1.00000E+00      9.99999E-01     1.21766E+00
Buckling load factor before t.s.d.=  1.2061E+00 After t.s.d.=  1.1879E+00
  49      1.20610E+00       9.84916E-01      9.99999E-01     1.18790E+00
```

```
Buckling load factor from SUB. LOCAL, EIGITR(16)=  1.1879E+00
Number of axial halfwaves between rings, NSTART=   49
*** END   SUB. LOCAL ("SKIN"-RING BUCKLING, DISCRETE MODEL) **

**** BEGIN SUB. MODE ("SKIN"-RING MODULE BUCKLING MODE) ****
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    1    1  4.9953E-04
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    1    2  9.1687E-03
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    2    1  6.6054E-03
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    2    2  6.6054E-03
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    3    1  2.5286E-02
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    3    2  1.3365E-01
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    4    1  9.1687E-03
Check for FICTITIOUS buckling mode(WDIFF>0.8): ISEG,IEND,WDIFF=    4    2  4.9953E-04
AMPLIT.OF BUCKLING MODE MIDWAY BETWEEN RINGS, WMID =  8.5807E-02
AMPLIT.OF BUCKLING MODE AT   RING   WEB TIP,  WTIP =  1.0000E+00
AMPLIT.OF BUCKLING MODE AT   RING   MIDWEB,  WCRIP =  3.6907E-01
AMPLIT.OF BUCKLING MODE AT  RING FLANGE TIP,, WFLG =  0.0000E+00
      Internal Ring

     MODULE WITH RECTANGULAR STIFFENER...

                               !   ^
          Segment No. 3 -----> !   !
                               !   !
              Seg. No. 2-.     !   h
                          .    !   !
     Segment No. 1-.       .   !   !          .-Seg. No. 4
                  .         .  !   V         .(same as Seg. 1)
       --------------=====================---------------
                     !<------ b2 ------->!
       !<--- Module width  =  stiffener spacing, b --->!


   EXPLODED VIEW, SHOWING LAYERS and (SEGMENT, NODE) NUMBERS

                             (3,11)
                               !
            Layer No. 1 -----> ! <---------- Layer No. k
                               !
         Layer No. 1-.         !
                      .        !
   Layer No. 1-.       .       !               .-Layer No. 1
              .         .      !                .
             .           .   (3,1)               .
   --------------    =====================    --------------
 (1,1)   .   (1,11)(2,1)   . (2,6)    (2,11)(4,1)  .    (4,11)
          .                 .                       .
           .                 .                       .
            Layer No. m       Layer No. n    Layer No. m


    NORMAL MODAL DISPLACEMENTS IN THE PANEL MODULE SHOWN ABOVE
           "SKIN"-RING PANEL MODULE HAS 4 SEGMENTS
        NUMBER OF HALF-WAVES IN THE CIRC. DIRECTION, n= 49
NODE   Z         W         WD       WDD        U         V         WDDD

                MODAL DISPLACEMENTS FOR SEGMENT NO. 1
 1  0.00E+00  8.58E-02  0.00E+00 -5.42E-03  0.00E+00  1.82E-03  4.18E-05
```

```
  2  0.00E+00  8.53E-02 -2.32E-03 -5.41E-03  7.07E-05  1.81E-03  4.18E-05
  3  0.00E+00  8.38E-02 -4.64E-03 -5.39E-03  1.42E-04  1.78E-03  4.18E-05
  4  0.00E+00  8.13E-02 -6.95E-03 -5.36E-03  2.12E-04  1.73E-03  6.92E-05
  5  0.00E+00  7.78E-02 -9.25E-03 -5.32E-03  2.83E-04  1.66E-03  9.80E-05
  6  0.00E+00  7.34E-02 -1.15E-02 -5.26E-03  3.53E-04  1.57E-03  1.28E-04
  7  0.00E+00  6.79E-02 -1.38E-02 -5.19E-03  4.23E-04  1.45E-03  1.58E-04
  8  0.00E+00  6.15E-02 -1.60E-02 -5.11E-03  4.93E-04  1.32E-03  1.91E-04
  9  0.00E+00  5.42E-02 -1.82E-02 -5.02E-03  5.61E-04  1.17E-03  2.25E-04
 10  0.00E+00  4.59E-02 -2.03E-02 -4.90E-03  6.29E-04  1.00E-03  2.60E-04
 11  0.00E+00  3.68E-02 -2.24E-02 -4.79E-03  6.96E-04  8.07E-04  2.60E-04

                MODAL DISPLACEMENTS FOR SEGMENT NO. 2
  1  0.00E+00  3.68E-02 -2.24E-02 -4.78E-03  6.96E-04  8.07E-04  3.68E-04
  2  0.00E+00  3.02E-02 -2.37E-02 -4.68E-03  7.37E-04  6.67E-04  3.68E-04
  3  0.00E+00  2.32E-02 -2.51E-02 -4.57E-03  7.77E-04  5.17E-04  3.68E-04
  4  0.00E+00  1.58E-02 -2.63E-02 -4.46E-03  8.15E-04  3.56E-04  4.03E-04
  5  0.00E+00  8.09E-03 -2.76E-02 -4.33E-03  8.50E-04  1.83E-04  4.43E-04
  6  0.00E+00 -1.17E-17 -2.82E-02  2.85E-16  8.67E-04  0.00E+00  1.51E-02
  7  0.00E+00 -8.09E-03 -2.76E-02  4.33E-03  8.50E-04 -1.83E-04  1.51E-02
  8  0.00E+00 -1.58E-02 -2.63E-02  4.46E-03  8.15E-04 -3.56E-04  4.43E-04
  9  0.00E+00 -2.32E-02 -2.51E-02  4.57E-03  7.77E-04 -5.17E-04  4.03E-04
 10  0.00E+00 -3.02E-02 -2.37E-02  4.68E-03  7.37E-04 -6.67E-04  3.68E-04
 11  0.00E+00 -3.68E-02 -2.24E-02  4.78E-03  6.96E-04 -8.07E-04  3.68E-04

                MODAL DISPLACEMENTS FOR SEGMENT NO. 3
  1 -2.48E-02  1.67E-04 -2.82E-02 -1.25E+00  7.31E-18 -2.03E-19  1.39E+00
  2 -2.00E-01 -2.51E-02 -2.33E-01 -1.01E+00  6.89E-18 -5.49E-19  1.39E+00
  3 -3.76E-01 -8.15E-02 -3.89E-01 -7.67E-01  6.51E-18 -8.09E-19  1.39E+00
  4 -5.51E-01 -1.62E-01 -5.06E-01 -5.69E-01  6.17E-18 -1.00E-18  1.13E+00
  5 -7.27E-01 -2.59E-01 -5.92E-01 -4.06E-01  5.87E-18 -1.17E-18  9.30E-01
  6 -9.02E-01 -3.69E-01 -6.51E-01 -2.71E-01  5.62E-18 -1.34E-18  7.69E-01
  7 -1.08E+00 -4.87E-01 -6.89E-01 -1.65E-01  5.42E-18 -1.55E-18  6.04E-01
  8 -1.25E+00 -6.11E-01 -7.12E-01 -9.67E-02  5.24E-18 -1.84E-18  3.91E-01
  9 -1.43E+00 -7.37E-01 -7.28E-01 -8.27E-02  5.09E-18 -2.23E-18  7.96E-02
 10 -1.60E+00 -8.66E-01 -7.49E-01 -1.51E-01  4.93E-18 -2.77E-18 -3.91E-01
 11 -1.78E+00 -1.00E+00 -7.82E-01 -2.20E-01  4.76E-18 -3.45E-18 -3.91E-01

                MODAL DISPLACEMENTS FOR SEGMENT NO. 4
  1  0.00E+00 -3.68E-02 -2.24E-02  4.79E-03  6.96E-04 -8.07E-04  2.60E-04
  2  0.00E+00 -4.59E-02 -2.03E-02  4.90E-03  6.29E-04 -1.00E-03  2.60E-04
  3  0.00E+00 -5.42E-02 -1.82E-02  5.02E-03  5.61E-04 -1.17E-03  2.60E-04
  4  0.00E+00 -6.15E-02 -1.60E-02  5.11E-03  4.93E-04 -1.32E-03  2.25E-04
  5  0.00E+00 -6.79E-02 -1.38E-02  5.19E-03  4.23E-04 -1.45E-03  1.91E-04
  6  0.00E+00 -7.34E-02 -1.15E-02  5.26E-03  3.53E-04 -1.57E-03  1.58E-04
  7  0.00E+00 -7.78E-02 -9.25E-03  5.32E-03  2.83E-04 -1.66E-03  1.28E-04
  8  0.00E+00 -8.13E-02 -6.95E-03  5.36E-03  2.12E-04 -1.73E-03  9.80E-05
  9  0.00E+00 -8.38E-02 -4.64E-03  5.39E-03  1.42E-04 -1.78E-03  6.92E-05
 10  0.00E+00 -8.53E-02 -2.32E-03  5.41E-03  7.07E-05 -1.81E-03  4.18E-05
 11  0.00E+00 -8.58E-02  0.00E+00  5.42E-03  0.00E+00 -1.82E-03  4.18E-05
  **** END   SUB. MODE ("SKIN"-RING MODULE BUCKLING MODE) ****

******* NOTE ********** NOTE ******** NOTE *********
Discretized "skin"-ring module buckling mode involves
significant sidesway of the ring web.
***** END NOTE ****** END NOTE ***** END NOTE *********
Knockdown factors, EIGKNS(1),FKNSRG(1),FKNOCK(8)=  1.0000E+00  1.0000E+00  9.7837E-01
Margin=  1.6338E-01  Ring sidesway buk., discrete model, n=49  circ.halfwaves;FS=0.999
```

(many lines omitted to save space)

DETAILS FROM CHAPTERS 24 - 27 (printed in *.OPM when NPRINT = 2)

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 ***************************************************************
 ***************************************************************
 ***************************************************************
 ************          CHAPTER 24            *****************
 ***************************************************************
 ***************************************************************
 ***************************************************************
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 **************************************************************
 CHAPTER 24 Present short summary of redistribution of stress
            resultants, Nx, Ny, Nxy, caused by prebuckling
            bending of an initially imperfect shell.
            See Section 6.0 in [1K], for example.

 Additional resultants (Nx,Ny) in panel skin from
 global and inter-ring bending of imperfect panel:
            Additional axial resultant, dNx = -3.8247E+02
            Additional  hoop resultant, dNy = -2.3929E+02
   Additional in-plane shear resultant, dNxy=  0.0000E+00

 Additional axial resultants dNx along webs and flanges of
 stringers from global and inter-ring bending of imperfect panel:
     Additional Nx in  base  of stringer, dNx = -3.8248E+02
     Additional Nx at webtip of stringer, dNx = -2.3049E+03
     Additional Nx in flange of stringer, dNx =  0.0000E+00

 Additional axial resultants dNx along webs and flanges of
 rings from global and inter-ring bending of imperfect panel:
     Additional Nx in  base  of   ring,   dNx = -2.6296E+02
     Additional Nx at webtip of   ring,   dNx = -3.8057E+03
     Additional Nx in flange of   ring,   dNx =  0.0000E+00
  LABEL NO. IN STRUCT= 9560



 ***************************************************************
 ***************************************************************
 ***************************************************************
 ************          CHAPTER 25            *****************
 ***************************************************************
 ***************************************************************
 ***************************************************************
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 **************************************************************
 CHAPTER 25 Compute buckling load factors from PANDA-type
            theory for the various segments of a stringer and
            a ring. Typical buckling modes are displayed in
```

```
           Figs. 5 and 6 of Ref.[1B].


***** BEGIN SUBROUTINE STFEIG (BUCKLING IN STIFFENERS) ******
 ENTERING STFEIG: MIDEND=    1
 IMOD= 0, Wavenumbers: MSKIN=    5, NSKIN=    1




 STRINGER:

 ***  BUCKLING (short wavelength buckling) of parts of the panel module cross section
perpendicular to generator ***
 NOTE: The segment numbering scheme used here corresponds to
       that used when the user provides input data.  It may
       differ from that used for the discretized module model.
       Please see ITEM 272 in the file panda2/doc/panda2.news.
 STIFFENER   MODULE    PRELOAD     RESULTANT   BUCKLING       BUCKLING     NO. OF BUCKLING
COMMENT
   TYPE     SEGMENT   RESULTANT    FROM LOAD  LOAD FACTOR    LOAD FACTOR      HALFWAVES
                     (LOAD SET B)    SET A  (no transverse (with transverse   BETWEEN
                      (average)     (ave.)   shear deform.) shear deform.)   STIFFENERS
 Prebuck.resultant along stringer axis at root and tip of web:
   At root of web: -1.4951E+03;   At tip of web: -4.4301E+03
 Knockdown factor to account for in-plane shearing of web and
   any anisotropic properties of the web, FKNOCK(5)=  1.0000E+00

 Entering CRIPPL:
 Eigenvalue preload at web root and tip= -1.4951E+03 -4.4301E+03
 Fixed      preload at web root and tip=  0.0000E+00  0.0000E+00
 M = SQRT(SQRT((EFOUND+C(5,5)*FACT**2)/C(4,4)))*A0/3.1415927=     5
 IN SUB. ENDBUK: EIG=  1.0296E+00
 In CRIPPL, before SHRRED: LAMBDA,SHRLOD,T,GT(1),GT(2)=
  1.0296E+00 -4.1150E+03  8.0641E-02  4.2308E+06  4.2308E+06
 ISEG,ISRIDY,NMINSR,NWAVE,NMAXSR,FKNOCK=    3    1    3    5    9  1.0000E+00
 NOTE: If FKNOCK is less than 0.99 the stringer web buckling
       WILL be recorded as a margin even if the critical number
       of axial halfwaves lies within the range, NMINSR - NMAXSR
 Margin=  1.4450E-02  buckling margin stringer Iseg.3 . Local halfwaves=5  .MID.;FS=1.
  stringer     3     0.0000E+00  -4.1150E+03   1.0296E+00    1.0145E+00         5




 RING:

 ***  BUCKLING (short wavelength buckling) of parts of the panel module cross section
parallel    to generator ***
 NOTE: The segment numbering scheme used here corresponds to
       that used when the user provides input data.  It may
       differ from that used for the discretized module model.
       Please see ITEM 272 in the file panda2/doc/panda2.news.
 STIFFENER   MODULE    PRELOAD     RESULTANT   BUCKLING       BUCKLING     NO. OF BUCKLING
COMMENT
   TYPE     SEGMENT   RESULTANT    FROM LOAD  LOAD FACTOR    LOAD FACTOR      HALFWAVES
                     (LOAD SET B)    SET A  (no transverse (with transverse   BETWEEN
                      (average)     (ave.)   shear deform.) shear deform.)   STIFFENERS
 Prebuck.resultant along   ring   axis at root and tip of web:
   At root of web:  5.2493E+02;   At tip of web: -3.2808E+03
```

```
 Knockdown factor to account for in-plane shearing of web and
   any anisotropic properties of the web, FKNOCK(6)=  1.0000E+00

 Entering CRIPPL:
 Eigenvalue preload at web root and tip=  5.2493E+02 -3.2808E+03
 Fixed      preload at web root and tip=  0.0000E+00  0.0000E+00
 M = SQRT(SQRT((EFOUND+C(5,5)*FACT**2)/C(4,4)))*A0/3.1415927=     1
 IN SUB. ENDBUK: EIG=  1.2877E+00
 In CRIPPL, before SHRRED: LAMBDA,SHRLOD,T,GT(1),GT(2)=
  1.2877E+00 -2.1391E+03  8.9081E-02  4.2308E+06  4.2308E+06
 ISEG,IRNIDY,NMINRG,NWAVE,NMAXRG,FKNOCK=    3    1    1    1  231  1.0000E+00
 NOTE: If FKNOCK is less than 0.99 the ring web buckling
       WILL be recorded as a margin even if the critical number
       of circ. halfwaves lies within the range, NMINRG - NMAXRG

 Ring Seg. 3 buckling (no participation of the panel skin)
 is not recorded as a margin because this type of buckling
 has been superseded by the results from the discretized
 "skin"-ring module model, for which buckling load factors
 have been computed in the range from n =     1 to n =   231 circ. halfwaves.
 The critical ring web (Seg.3) buckling mode from STFEIG has    1
 circ. half waves, which lies within this range.
    ring       3     0.0000E+00  -2.1391E+03   1.2877E+00    1.2765E+00         1
 ***** END   SUBROUTINE STFEIG (BUCKLING IN STIFFENERS) ******
  LABEL NO. IN STRUCT= 9565
```

******* BEGIN SUBROUTINE STFEIG (NO POSTBUCKLING EFFECT) ********

```
 ENTERING STFEIG: MIDEND=    1
 IMOD= 0, Wavenumbers: MSKIN=    5, NSKIN=    1
```

STRINGER:

```
 ***  BUCKLING (short wavelength buckling) of parts of the panel module cross section
perpendicular to generator ***
 NOTE: The segment numbering scheme used here corresponds to
       that used when the user provides input data.  It may
       differ from that used for the discretized module model.
       Please see ITEM 272 in the file panda2/doc/panda2.news.
 STIFFENER   MODULE    PRELOAD     RESULTANT   BUCKLING       BUCKLING     NO. OF BUCKLING
COMMENT
   TYPE     SEGMENT   RESULTANT    FROM LOAD  LOAD FACTOR    LOAD FACTOR      HALFWAVES
                     (LOAD SET B)    SET A  (no transverse (with transverse   BETWEEN
                      (average)     (ave.)   shear deform.) shear deform.)   STIFFENERS
 Prebuck.resultant along stringer axis at root and tip of web:
   At root of web: -1.9939E+03;   At tip of web: -4.3860E+03
 Knockdown factor to account for in-plane shearing of web and
   any anisotropic properties of the web, FKNOCK(5)=  1.0000E+00

 Entering CRIPPL:
 Eigenvalue preload at web root and tip= -1.9939E+03 -4.3860E+03
 Fixed      preload at web root and tip=  0.0000E+00  0.0000E+00
 M = SQRT(SQRT((EFOUND+C(5,5)*FACT**2)/C(4,4)))*A0/3.1415927=     5
 IN SUB. ENDBUK: EIG=  1.0047E+00
 In CRIPPL, before SHRRED: LAMBDA,SHRLOD,T,GT(1),GT(2)=
```

```
 1.0047E+00 -3.6684E+03  8.0641E-02  4.2308E+06  4.2308E+06
ISEG,ISRIDY,NMINSR,NWAVE,NMAXSR,FKNOCK=    3    1    3    5    9  1.0000E+00
NOTE: If FKNOCK is less than 0.99 the stringer web buckling
      WILL be recorded as a margin even if the critical number
      of axial halfwaves lies within the range, NMINSR - NMAXSR
Margin= -8.1967E-03  buckling margin stringer Iseg.3 . Local halfwaves=5  .NOPO;FS=1.
 stringer     3     0.0000E+00  -3.6684E+03   1.0047E+00    9.9180E-01         5
```

RING:

```
*** BUCKLING (short wavelength buckling) of parts of the panel module cross section
parallel    to generator ***
NOTE: The segment numbering scheme used here corresponds to
      that used when the user provides input data.  It may
      differ from that used for the discretized module model.
      Please see ITEM 272 in the file panda2/doc/panda2.news.
STIFFENER   MODULE    PRELOAD     RESULTANT   BUCKLING       BUCKLING     NO. OF BUCKLING
COMMENT
  TYPE     SEGMENT   RESULTANT    FROM LOAD  LOAD FACTOR    LOAD FACTOR      HALFWAVES
                    (LOAD SET B)    SET A  (no transverse (with transverse   BETWEEN
                     (average)     (ave.)   shear deform.) shear deform.)   STIFFENERS
Prebuck.resultant along   ring   axis at root and tip of web:
  At root of web:  5.2493E+02;   At tip of web: -3.2808E+03
Knockdown factor to account for in-plane shearing of web and
  any anisotropic properties of the web, FKNOCK(6)=  1.0000E+00

Entering CRIPPL:
Eigenvalue preload at web root and tip=  5.2493E+02 -3.2808E+03
Fixed      preload at web root and tip=  0.0000E+00  0.0000E+00
M = SQRT(SQRT((EFOUND+C(5,5)*FACT**2)/C(4,4)))*A0/3.1415927=     1
IN SUB. ENDBUK: EIG=  1.2877E+00
In CRIPPL, before SHRRED: LAMBDA,SHRLOD,T,GT(1),GT(2)=
 1.2877E+00 -2.1391E+03  8.9081E-02  4.2308E+06  4.2308E+06
ISEG,IRNIDY,NMINRG,NWAVE,NMAXRG,FKNOCK=    3    1    1    1  231  1.0000E+00
NOTE: If FKNOCK is less than 0.99 the ring web buckling
      WILL be recorded as a margin even if the critical number
      of circ. halfwaves lies within the range, NMINRG - NMAXRG

Ring Seg. 3 buckling (no participation of the panel skin)
is not recorded as a margin because this type of buckling
has been superseded by the results from the discretized
"skin"-ring module model, for which buckling load factors
have been computed in the range from n =     1 to n =   231 circ. halfwaves.
The critical ring web (Seg.3) buckling mode from STFEIG has    1
circ. half waves, which lies within this range.
   ring       3     0.0000E+00  -2.1391E+03   1.2877E+00    1.2765E+00         1
******* END SUBROUTINE STFEIG (NO POSTBUCKLING EFFECT) ******
 *** END OF STIFFENER SEGMENT BUCKLING (if any) ****

 LABEL NO. IN STRUCT= 9570

Buckling load factors from PANDA-type models for
design iteration no.  0,  load set no. 1,  material iteration no.  0.
These load factors include the effect of in-plane shear loading.  M = axial half-waves; N =
circ. half-waves.
Loading is uniform, with resultants given by:
```

```
   LOAD SET A: axial, Nx = -2.22E+03; circ., Ny = -2.22E-03; in-plane shear, Nxy =  1.11E+01
   LOAD SET B: axial, Nxo=  0.00E+00; circ., Nyo=  0.00E+00; in-plane shear, Nxyo=  0.00E+00
(Not from normal pressure)
   LOAD SET A: Uniform normal pressure, P =   4.6229E-05
      Resultants from global (smeared stiffener) model: Nx(p)=  0.00E+00,  Ny(p)=  0.00E+00,
Nxy(p)= 0.0
      Resultants from local (discrete stiffener) model: Nx(p)= -9.99E-05,  Ny(p)=  9.92E-07,
Nxy(p)= 0.0 :
 BEHAVIORAL  EIGENVALUE      MODEL DESCRIPTION AND BUCKLING MODE
 CONSTRAINT (load factor)




 ***************************************************************
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 ***************************************************************
 ************          CHAPTER 26           *****************
 ***************************************************************
 ***************************************************************
 ***************************************************************
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 **************************************************************
```

CHAPTER 26 Compute local, inter-ring, general buckling load factors from PANDA-type models [1B] and from "alternative" (double-trigonometric series expansion) models, Ref.[1G]. Also compute sandwich wall behavior [1F], if applicable. Also, compute buckling load factors appropriate when substiffeners are present.

*** **BEGIN SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS Ref. 1B)** ****

```
 Number of constraints, NCONST=       0

  LABEL NO. IN STRUCT= 9260
 ******* ENTERING BUCPAN FROM STRUCT OR STRIMP:
 ILABEL,IPRELM,IGENRL,IGENX,   EIGMAX=
  9260     0     0     0  1.0000E+07
```

Local buckling, C11= 5.9909E+05, radius, R= -4.8000E+01

```
 C(i,j) for skin with smeared substringers and subrings.
  Reference surface is at the reference surface of the skin.
  5.9909E+05  1.7969E+05  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  1.7969E+05  5.9909E+05  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  0.0000E+00  0.0000E+00  2.0970E+05  0.0000E+00  0.0000E+00  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00  1.2266E+02  3.6797E+01  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00  3.6797E+01  1.2266E+02  0.0000E+00
  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  4.2930E+01
 ******** ENTERING GENSTB: PANDA-type buckling model ********
 PANDA-type buckling theory is described in the journal paper:
 D. Bushnell, "Theoretical basis of the PANDA computer program"
 Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987
 Also see Items 415 and 443 in ...panda2/doc/panda2.news.
 ILABEL = unique "CALL GENSTB" within SUBROUTINE BUCPAN
 ILABLY = label number near where SUBROUTINE BUCPAN is called.
```

```
  ILABEL, ILABLY, IDESGN,  ISAND,   INDX,   ITHRU,  IROLL    IFFLAT =
   7010    9260       0       1       1       1       0       0
 Radius  R,   Axial length, A,   Width  B
-4.800000E+01  1.145833E+01  1.861685E+00
Initial imperfections for general, panel, local buckling=
Total out-of-roundness + modal,    W0GLOB =  1.2500E-01
Out-of-roundness,                    WG1  =  0.0000E+00
General buckling modal,              WG2  =  1.2500E-01
Inter-ring buckling modal,          W0PAN =  1.0000E-10
Local buckling modal,               W0LOC =  1.0000E-07
***** Sanders theory is used in this section (ISAND=1)
Load Set A: Nx,  Ny,  Nxy= -8.0571E+02  2.0963E+02  1.1095E+01
Load Set B: Nxo, Nyo, Nxyo=  0.0000E+00  0.0000E+00  0.0000E+00
Membrane stiffnesses ((C(i,j),j=1,3),i=1,3)=
 5.9909E+05  1.7969E+05  0.0000E+00
 1.7969E+05  5.9909E+05  0.0000E+00
 0.0000E+00  0.0000E+00  2.0970E+05
     R/B,      C44MLT,      C44N,      C55N,      FFLAT=
 2.5783E+01  1.0354E+00  2.0474E-04  2.0474E-04  0.0000E+00
Test for direction panel is long: TEST=(A/B)*SQRT(C55N/(C44N*C44MLT))=6.05E+00
If TEST > 0.99 then d = 0;  c = SLOPE (panel is long in x-direction, Fig.(9a).
If TEST < 0.99 then d = SLOPE; c = 0. (panel is long in y-direction, Fig.(9b).
See Eq.(51) and Fig. 9 of "Theoretical basis..." paper (1987).
***(low-n)***
(high-m) mode:ICHEK ISAND  m    n      s      EIGENVALUE  TEST
                0     0    8    1  1.000E-02  2.222E+00  6.049E+00
Ratio needed in ARBOCZ: EIGTST/EIGTS2= EIGRAT=  1.0000E+00

EIGMNC=  5.46E+00  1.00E+17  2.22E+00  1.00E+17  2.22E+00  2.22E+00  1.00E+17
SLOPEX=  2.00E-02  0.00E+00  1.00E-02  0.00E+00  0.00E+00  1.00E-02  0.00E+00
MWAVEX=    4         0         8         0         8         8         0
NWAVEX=    1         0         1         0         1         1         0
TESTX =  6.05E+00  0.00E+00  6.05E+00  0.00E+00  6.05E+00  6.05E+00  0.00E+00
Before refinement (before CALL EIG), EIGVAL,CSLOPE=  2.2222E+00  1.0000E-02
 After refinement ( after CALL EIG), EIGVAL,CSLOPE=  2.2222E+00  1.0000E-02
Teff(1),Teff(2),G13,G23=  4.9565E-02  4.9565E-02  4.2308E+06  4.2308E+06

If EIGVAL and EIGVLX are different:
EIGVAL = eigenvalue with fractional wavenumbers and "fractional" slope
EIGVLX = original eigenvalue: no "fractional" refinement
EIGVAL,EIGVLX before knockdown for t.s.d.=  2.2222E+00  2.2222E+00
Buckling load factor before t.s.d.=  2.2222E+00 After t.s.d.=  2.1997E+00
EIGVAL,EIGVLX after  knockdown for t.s.d.=  2.1997E+00  2.1997E+00
EIGRAT = EIGTST/EIGTS2 =   1.0000E+00

Sanders theory is used for these buckling calculations in this case.
Local buckling load factors & mode shapes before any knockdown factors applied:
EIGMNC=  5.46E+00  1.00E+17  2.22E+00  1.00E+17  2.22E+00  2.22E+00  1.00E+17
SLOPEX=  2.00E-02  0.00E+00  1.00E-02  0.00E+00  0.00E+00  1.00E-02  0.00E+00
MWAVEX=    4         0         8         0         8         8         0
NWAVEX=    1         0         1         0         1         1         0
NOTE: The buckling nodal line slopes, SLOPEX, are as
defined in Fig. 9a or Fig. 9b of the 1987 "Theoretical
basis of the PANDA...",if NWAVEX > 0; that is, there
has not yet been any inversion of SLOPEX when 9b holds.

LOCAL BUCKLING FROM PANDA-TYPE THEORY [1B] AFTER KNOCKDOWN FOR t.s.d.:
EIGLOC =   2.1997E+00(m=   8,n=   1)
```

```
IPRELM=    0  ILOWSS(IPRELM+1,20)=    0
```

inter-ring buckling: smeared stringers, C11= 1.0222E+06, radius, **R= -4.8000E+01**

```
******** ENTERING GENSTB: PANDA-type buckling model ********
PANDA-type buckling theory is described in the journal paper:
D. Bushnell, "Theoretical basis of the PANDA computer program"
Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987
Also see Items 415 and 443 in ...panda2/doc/panda2.news.
ILABEL = unique "CALL GENSTB" within SUBROUTINE BUCPAN
ILABLY = label number near where SUBROUTINE BUCPAN is called.
  ILABEL, ILABLY, IDESGN,  ISAND,   INDX,   ITHRU,  IROLL    IFFLAT =
   7120    9260       0       1       3       1       0       0
 Radius  R,   Axial length, A,   Width  B
-4.800000E+01  1.145833E+01  1.507960E+02
Initial imperfections for general, panel, local buckling=
Total out-of-roundness + modal,    W0GLOB =  1.2500E-01
Out-of-roundness,                   WG1  =  0.0000E+00
General buckling modal,             WG2  =  1.2500E-01
Inter-ring buckling modal,         W0PAN =  1.0000E-10
Local buckling modal,              W0LOC =  1.0000E-07
***** Sanders theory is used in this section (ISAND=1)
Load Set A: Nx,  Ny,  Nxy= -2.2190E+03  2.0963E+02  1.1095E+01
Load Set B: Nxo, Nyo, Nxyo=  0.0000E+00  0.0000E+00  0.0000E+00
Membrane stiffnesses ((C(i,j),j=1,3),i=1,3)=
 1.0222E+06  1.7970E+05  0.0000E+00
 1.7970E+05  5.9909E+05  0.0000E+00
 0.0000E+00  0.0000E+00  2.0970E+05
     R/B,      C44MLT,      C44N,      C55N,      FFLAT=
 3.1831E-01  1.0000E+00  8.0648E-02  1.1999E-04  0.0000E+00
Test for direction panel is long: TEST=(A/B)*SQRT(C55N/(C44N*C44MLT))=2.93E-03
If TEST > 0.99 then d = 0;  c = SLOPE (panel is long in x-direction, Fig.(9a).
If TEST < 0.99 then d = SLOPE; c = 0. (panel is long in y-direction, Fig.(9b).
See Eq.(51) and Fig. 9 of "Theoretical basis..." paper (1987).
***(low-n)***
(high-m) mode:ICHEK ISAND  m    n      s      EIGENVALUE  TEST
                0     1    1   13  0.000E+00  3.107E+00  2.931E-03
Ratio needed in ARBOCZ: EIGTST/EIGTS2= EIGRAT=  1.0000E+00

EIGMNC=  3.11E+00  1.21E+01  3.11E+00  1.00E+17  1.00E+17  3.11E+00  5.66E+00
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=    1         2         1         0         0         1         1
NWAVEX=   13         3        13         0         0        13         0
TESTX =  2.93E-03  2.93E-03  2.93E-03  0.00E+00  0.00E+00  2.93E-03  1.00E+01
Before refinement (before CALL EIG), EIGVAL,CSLOPE=  3.1074E+00  0.0000E+00
 After refinement ( after CALL EIG), EIGVAL,CSLOPE=  3.1074E+00  0.0000E+00
Teff(1),Teff(2),G13,G23=  9.3767E-01  4.9565E-02  3.8604E+05  4.2308E+06

If EIGVAL and EIGVLX are different:
EIGVAL = eigenvalue with fractional wavenumbers and "fractional" slope
EIGVLX = original eigenvalue: no "fractional" refinement
EIGVAL,EIGVLX before knockdown for t.s.d.=  3.1074E+00  3.1074E+00
Buckling load factor before t.s.d.=  3.1074E+00 After t.s.d.=  2.9894E+00
EIGVAL,EIGVLX after  knockdown for t.s.d.=  2.9894E+00  2.9894E+00
EIGRAT = EIGTST/EIGTS2 =   1.0000E+00
BEFORE KNOCKDOWN: EIGVLX=  2.9894E+00
Number of circumferential halfwaves in buckling pattern=  1.3000E+01
Buckling load factor BEFORE knockdown for smeared stringers=  2.9894E+00
Buckling load factor AFTER  knockdown for smeared stringers=  2.4864E+00
```

```
AFTER KNOCKDOWN: EIGVLX=  2.4864E+00

inter-ring buckling: smeared stringers, C11=  1.0222E+06, radius, R=  1.5123E+06
******** ENTERING GENSTB: PANDA-type buckling model ********
PANDA-type buckling theory is described in the journal paper:
D. Bushnell, "Theoretical basis of the PANDA computer program"
Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987
Also see Items 415 and 443 in ...panda2/doc/panda2.news.
ILABEL = unique "CALL GENSTB" within SUBROUTINE BUCPAN
ILABLY = label number near where SUBROUTINE BUCPAN is called.
  ILABEL, ILABLY, IDESGN,  ISAND,   INDX,   ITHRU,  IROLL    IFFLAT =
   7140    9260       0       1       3       1       0       1
 Radius  R,   Axial length, A,   Width  B
 1.512307E+06  1.145833E+01  1.507960E+02
Initial imperfections for general, panel, local buckling=
Total out-of-roundness + modal,    W0GLOB =  1.2500E-01
Out-of-roundness,                   WG1  =  0.0000E+00
General buckling modal,             WG2  =  1.2500E-01
Inter-ring buckling modal,         W0PAN =  1.0000E-10
Local buckling modal,              W0LOC =  1.0000E-07
***** NOTE: Panel is modelled as if it were flat. *****
***** Sanders theory is used in this section (ISAND=1)
Load Set A: Nx,  Ny,  Nxy= -2.2190E+03  2.0963E+02  1.1095E+01
Load Set B: Nxo, Nyo, Nxyo=  0.0000E+00  0.0000E+00  0.0000E+00
Membrane stiffnesses ((C(i,j),j=1,3),i=1,3)=
 1.0222E+06  1.7970E+05  0.0000E+00
 1.7970E+05  5.9909E+05  0.0000E+00
 0.0000E+00  0.0000E+00  2.0970E+05
     R/B,      C44MLT,      C44N,      C55N,      FFLAT=
 1.0000E+04  1.0000E+00  8.0648E-02  1.1999E-04  1.0000E+00
Test for direction panel is long: TEST=(A/B)*SQRT(C55N/(C44N*C44MLT))=2.93E-03
If TEST > 0.99 then d = 0;  c = SLOPE (panel is long in x-direction, Fig.(9a).
If TEST < 0.99 then d = SLOPE; c = 0. (panel is long in y-direction, Fig.(9b).
See Eq.(51) and Fig. 9 of "Theoretical basis..." paper (1987).
***(low-n)***
(high-m) mode:ICHEK ISAND  m    n      s      EIGENVALUE  TEST
                0     0    1    4  0.000E+00  2.775E+00  2.931E-03
Ratio needed in ARBOCZ: EIGTST/EIGTS2= EIGRAT=  1.0000E+00

EIGMNC=  2.77E+00  1.12E+01  2.77E+00  1.00E+17  1.00E+17  2.79E+00  1.00E+17
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=    1         2         1         0         0         1         0
NWAVEX=    4         2         4         0         0         1         0
TESTX =  2.93E-03  2.93E-03  2.93E-03  0.00E+00  0.00E+00  2.93E-03  0.00E+00
Before refinement (before CALL EIG), EIGVAL,CSLOPE=  2.7748E+00  0.0000E+00
 After refinement ( after CALL EIG), EIGVAL,CSLOPE=  2.7748E+00  0.0000E+00
Teff(1),Teff(2),G13,G23=  9.3767E-01  4.9565E-02  3.8604E+05  4.2308E+06

If EIGVAL and EIGVLX are different:
EIGVAL = eigenvalue with fractional wavenumbers and "fractional" slope
EIGVLX = original eigenvalue: no "fractional" refinement
EIGVAL,EIGVLX before knockdown for t.s.d.=  2.7748E+00  2.7748E+00
Buckling load factor before t.s.d.=  2.7748E+00 After t.s.d.=  2.6804E+00
EIGVAL,EIGVLX after  knockdown for t.s.d.=  2.6804E+00  2.6804E+00
EIGRAT = EIGTST/EIGTS2 =   1.0000E+00
BEFORE KNOCKDOWN: EIGVLX=  2.6804E+00
Number of circumferential halfwaves in buckling pattern=  4.0000E+00
Buckling load factor BEFORE knockdown for smeared stringers=  2.6804E+00
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```
Buckling load factor AFTER  knockdown for smeared stringers=  2.2203E+00
 AFTER KNOCKDOWN: EIGVLX=  2.2203E+00

INTER-RING BUCKLING load factors and (axial, circumfer.) halfwaves:
Sanders theory is used for these buckling calculations in this case.
INTER-RING BUCKLING FROM PANDA-TYPE THEORY [1B]
   AFTER KNOCKDOWN FOR t.s.d. AND FOR SMEARED STRINGERS:
EIGSS =   2.4864E+00(m=   1,n=  13)
Inter-ring eigenvalue with panel as flat:
EIGSS2=   2.2203E+00(m=   1,n=   4)

Smeared stringer buck. load factor before and after knockdown:
EIGSS(before knockdown by 2 factors below)         =  2.4864E+00
Knockdown factor from inter-ring modal imperfection=  9.7837E-01
Modifying factor, FKNMOD=1 or 1/(EIG8X*FMDKD8)     =  1.0000E+00
After knockdown, EIGSS*FKNOCK(8)*FKNMOD            =  2.4326E+00
in which
EIG8X  = lambda(ARBOCZ)/lambda(original PANDA-type theory)=  9.7837E-01
      lambda(ARBOCZ)=perfect panel buckling from ARBOCZ theory
      lambda(PANDA) =perfect panel buckling from PANDA  theory
FMDKD8 = 1 or 0.9/EIG8X =  1.0000E+00

Simple-support inter-ring buckling with smeared stringers
is not recorded as a margin because this type of buckling
has been superseded by the results from the discretized
inter-ring module model, for which inter-ring buckling
load factors have been computed in the range from n =     1
to n =   231 circumferential halfwaves.
The critical simple-support inter-ring buckling model has   13
circ. half waves, which lies within this range.
Discrete stringers: EAS,EIXS,EIYS,GJSS,ECCS,SPSTRS,YLONGS=
 7.878E+05  5.178E+04  4.691E+02  1.642E+02 -4.688E-01  1.862E+00  1.117E+01
Preload in web: HH(1),RESLTS(1)-RPRES(1),RPRES(1),FNXSTR(1),FX0STR(1),ZNXSTR(1)=
 8.8811E-01 -3.6684E+03  0.0000E+00 -3.2579E+03  0.0000E+00 -4.6884E-01
Preload in flng: WW(1),RESLTS(2)-RPRES(2),RPRES(2),FNXSTR(2),FX0STR(2),ZNXSTR(2)=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -9.1289E-01
Discrete rings:     EAR,EIXR,EIYR,GJRR,ECCR,SPRNG,XLONG=
 1.719E+06  4.409E+05  1.249E+03  4.372E+02 -9.020E-01  1.146E+01  0.000E+00
Preload in web: HH(2),RESLTR(1)-RPRER(1),RPRER(1),FNXRNG(1),FX0RNG(1),ZNXRNG(1)=
 1.7544E+00 -2.1391E+03  0.0000E+00 -3.7528E+03  0.0000E+00 -9.0198E-01
Preload in flng: WW(2),RESLTR(2)-RPRER(2),RPRER(2),FNXRNG(2),FX0RNG(2),ZNXRNG(2)=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -1.7792E+00
FNXSSA,FNYSSA,FNXYSS,FNXSPR,FNYSPR=
-8.0571E+02  2.0963E+02  1.1095E+01  0.0000E+00  0.0000E+00

Entering ALTSOL: radius, axial, circ. dimensions =  4.8000E+01  1.1458E+01  1.1170E+01
See ITEMs 438, 444  in the file ..panda2/doc/panda2.news .
and AIAA paper 99-1233, Proc. 40th AIAA SDM Meeting, 1999
pp 302-345, especially pp 304-316 and associated figures.
***INTER-RING BUCKLING, N-STRINGER-BAY PATCH, SMEARED SUBSTF **
        Number of discrete stringers, rings: NUMSTR, NUMRNG=  7  2
Membrane stiffnesses, C11,C12,C22,C33=
 5.9909E+05  1.7969E+05  5.9909E+05  2.0970E+05

No alternative solution sought because user did not want one.
(IALTSN was set equal to zero in MAINSETUP)

general buckling: smeared stiffeners, C11=  1.0222E+06, radius, R= -4.8000E+01
```

```
Now start the various buckling analyses.

Buckling load factors are computed from Sanders theory
******** ENTERING GENSTB: PANDA-type buckling model ********
PANDA-type buckling theory is described in the journal paper:
D. Bushnell, "Theoretical basis of the PANDA computer program"
Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987
Also see Items 415 and 443 in ...panda2/doc/panda2.news.
ILABEL = unique "CALL GENSTB" within SUBROUTINE BUCPAN
ILABLY = label number near where SUBROUTINE BUCPAN is called.
  ILABEL, ILABLY, IDESGN,  ISAND,   INDX,   ITHRU,  IROLL    IFFLAT =
   7185    9260       0       1       2       1       0       0
 Radius  R,   Axial length, A,   Width  B
-4.800000E+01  6.875000E+01  1.507960E+02
Initial imperfections for general, panel, local buckling=
Total out-of-roundness + modal,    W0GLOB =  1.2500E-01
Out-of-roundness,                    WG1  =  0.0000E+00
General buckling modal,              WG2  =  1.2500E-01
Inter-ring buckling modal,          W0PAN =  1.0000E-10
Local buckling modal,               W0LOC =  1.0000E-07
***** Sanders theory is used in this section (ISAND=1)
Load Set A: Nx,  Ny,  Nxy= -2.2190E+03 -2.2190E-03  1.1095E+01
Load Set B: Nxo, Nyo, Nxyo=  0.0000E+00  0.0000E+00  0.0000E+00
Membrane stiffnesses ((C(i,j),j=1,3),i=1,3)=
 1.0222E+06  1.7970E+05  0.0000E+00
 1.7970E+05  7.4912E+05  0.0000E+00
 0.0000E+00  0.0000E+00  2.0970E+05
     R/B,      C44MLT,      C44N,      C55N,      FFLAT=
 3.1831E-01  1.0000E+00  8.0648E-02  1.3326E-01  0.0000E+00
Test for direction panel is long: TEST=(A/B)*SQRT(C55N/(C44N*C44MLT))=5.86E-01
If TEST > 0.99 then d = 0;  c = SLOPE (panel is long in x-direction, Fig.(9a).
If TEST < 0.99 then d = SLOPE; c = 0. (panel is long in y-direction, Fig.(9b).
See Eq.(51) and Fig. 9 of "Theoretical basis..." paper (1987).

The following section is entered only if TEST < 1.0 and the
number of axial halfwaves is at least 3. (TEST < 1.0 means
that the buckling mode from PANDA-type theory is of the
type shown in Fig.9(b),p.554 of the "Theoretical basis..."
paper. TEST > 1.0 means that Fig.9(a) applies.)
In this section a ratio, EIGRAT = EIGTST/EIGTS2, is
obtained in which EIGTST = eigenvalue with TEST > 1.0 and
                  EIGTS2 = eigenvalue with TEST < 1.0.
The ratio EIGRAT is always 1.0 unless EIGTST < EIGTS2.
High m range: New value of "TEST" is assigned: TEST =   1.1000E+00
***(low-n)***
(high-m) mode:ICHEK ISAND  m    n      s      EIGENVALUE  TEST
                0     1    3    6  0.000E+00  2.623E+00  1.100E+00
Ratio needed in ARBOCZ: EIGTST/EIGTS2= EIGRAT=  1.0000E+00

EIGMNC=  2.62E+00  2.62E+00  2.62E+00  1.00E+17  1.00E+17  2.62E+00  6.21E+00
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=    3         3         3         0         0         3         4
NWAVEX=    6         6         6         0         0         6         0
TESTX =  5.86E-01  5.86E-01  1.10E+00  0.00E+00  0.00E+00  5.86E-01  1.00E+01
Before refinement (before CALL EIG), EIGVAL,CSLOPE=  2.6232E+00  0.0000E+00
 After refinement ( after CALL EIG), EIGVAL,CSLOPE=  2.6232E+00  0.0000E+00
Teff(1),Teff(2),G13,G23=  9.3767E-01  1.8040E+00  3.8604E+05  6.7627E+04
```

```
If EIGVAL and EIGVLX are different:
EIGVAL = eigenvalue with fractional wavenumbers and "fractional" slope
EIGVLX = original eigenvalue: no "fractional" refinement
EIGVAL,EIGVLX before knockdown for t.s.d.=  2.6232E+00  2.6232E+00

(lines skipped to save space)

Buckling load factor before t.s.d.=  2.6232E+00 After t.s.d.=  2.4811E+00
EIGVAL,EIGVLX after  knockdown for t.s.d.=  2.4811E+00  2.4811E+00
EIGRAT = EIGTST/EIGTS2 =   1.0000E+00

Sanders theory is used for these buckling calculations in this case.
General buckling load factors & mode shapes before any knockdown factors applied:
EIGMNC=  2.62E+00  2.62E+00  2.62E+00  1.00E+17  1.00E+17  2.62E+00  6.21E+00
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=    3         3         3         0         0         3         4
NWAVEX=    6         6         6         0         0         6         0
NOTE: The buckling nodal line slopes, SLOPEX, are as
defined in Fig. 9a or Fig. 9b of the 1987 "Theoretical
basis of the PANDA...",if NWAVEX > 0; that is, there
has not yet been any inversion of SLOPEX when 9b holds.
Discrete stringers: EAS,EIXS,EIYS,GJSS,ECCS,SPSTR,YLONG=
 7.878E+05  5.178E+04  4.691E+02  1.642E+02 -4.688E-01  1.862E+00  1.117E+01
Preload in web: HH(1),RESLTS(1)-RPRES(1),RPRES(1),FNXSTR(1),FX0STR(1),ZNXSTR(1)=
 8.8811E-01 -3.6684E+03  0.0000E+00 -3.2579E+03  0.0000E+00 -4.6884E-01
Preload in flng: WW(1),RESLTS(2)-RPRES(2),RPRES(2),FNXSTR(2),FX0STR(2),ZNXSTR(2)=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -9.1289E-01
Discrete rings:     EAR,EIXR,EIYR,GJRR,ECCR,SPRNG,XLONG=
 1.719E+06  4.409E+05  1.249E+03  4.372E+02 -9.020E-01  1.146E+01  5.729E+01
Preload in web: HH(2),RESLTR(1)-RPRER(1),RPRER(1),FNXRNG(1),FX0RNG(1),ZNXRNG(1)=
 1.7544E+00 -2.1391E+03  0.0000E+00 -3.7528E+03  0.0000E+00 -9.0198E-01
Preload in flng: WW(2),RESLTR(2)-RPRER(2),RPRER(2),FNXRNG(2),FX0RNG(2),ZNXRNG(2)=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00 -1.7792E+00
FNXGEN,FNYGEN,FNXYGN,FNXGPR,FNYGPR=
-8.0571E+02  2.0963E+02  1.1095E+01  0.0000E+00  0.0000E+00

Entering ALTSOL: radius, axial, circ. dimensions =  4.8000E+01  5.7292E+01  1.1170E+01
See ITEMs 438, 444  in the file ..panda2/doc/panda2.news .
and AIAA paper 99-1233, Proc. 40th AIAA SDM Meeting, 1999
pp 302-345, especially pp 304-316 and associated figures.
*** GENERAL BUCKLING, N x M BAY PATCH, SMEARED SUBSTIFFRS ***
        Number of discrete stringers, rings: NUMSTR, NUMRNG=  7  6
Membrane stiffnesses, C11,C12,C22,C33=
 5.9909E+05  1.7969E+05  5.9909E+05  2.0970E+05

No alternative solution sought because user did not want one.
(IALTSN was set equal to zero in MAINSETUP)
General buckling loads AFTER knockdown for t.s.d.
Number of circumferential halfwaves in buckling pattern=  6.0000E+00
Buckling load factor BEFORE knockdown for smeared stringers=  2.4811E+00
Buckling load factor AFTER  knockdown for smeared stringers=  2.3268E+00
MGEN,NGENF,IWAVE,NGENNW=         3         6         6         6

General buckling load factor before and after knockdown:
EIGGEN(before modification by 5 factors below)     =  2.3268E+00
Knockdown factor from modal imperfection(s)        =  6.8873E-01
Knockdown factor for smearing rings on cyl. shell  =  9.4810E-01
```

```
Knockup factor to avoid twice accounting for t.s.d.=  1.0000E+00
1st modifying factor, FKNMOD=1 or 1/(EIG9X*FMDKD9) =  1.0000E+00
2nd modifying factor, EIGMR9=1 or EIGGNX/EIGGEN    =  1.0000E+00
After knockdn,EIGGEN*FKNOCK(9)*(RNGKNK/SHRFCT)*FKNMOD*EIGMR9=  1.5193E+00
in which
EIG9X  = lambda(ARBOCZ)/lambda(original PANDA-type theory)=  1.0000E+00
      lambda(ARBOCZ)=perfect panel buckling from ARBOCZ theory
      lambda(PANDA) =perfect panel buckling from PANDA  theory
FMDKD9 = 1 or 0.9/EIG9X =  1.0000E+00
EIGGNX = eigenvalue for perfect panel from alternate solution
    14      1.51934E+00   buckling load factor simp-support general buck;M=3;N=6;slope=0.
Margin=  5.2086E-01  buck.(SAND);simp-support general buck;M=3;N=6;slope=0.;FS=0.999

                          Stringers              Rings
Segment 1 prestress: RESLTS(1)  RPRES(1)  RESLTR(1)  RPRER(1)=
                  -3.6684E+03  0.0000E+00 -2.1391E+03  0.0000E+00
Segment 2 prestress: RESLTS(2)  RPRES(2)  RESLTR(2)  RPRER(2)=
                   0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00

Enter SUBROUTINE ROLL. Label in STRUCT                 =  9260
NRS   = 1 for stringers, 2 for rings; NRS              =     1
FL = stiffener spacing; FL                             =  1.8617E+00
NPART = number of stiffener segments; NPART            =     1
IEND  = 0=no edges are free; 1=one edge is free; IEND  =     1     0     0
ANGL = 0 deg.or 180 deg.for web, 90 deg.for flange;ANGL=  0.0000E+00  0.0000E+00  0.0000E+00
C1    = axial stiffness/length of stiffener segment; C1=  9.7472E+05  0.0000E+00  0.0000E+00
AL    = height of stiffener segment; AL                =  8.8811E-01  0.0000E+00  0.0000E+00
NSEG  = number of stiffener segments attached  web,NSEG=     0     0     0
RESULT= axial resultant in stiff.seg, Load Set A;RESULT= -3.6684E+03  0.0000E+00  0.0000E+00
RPRE  = axial resultant in stiff.seg. Load Seg B, RPRE =  0.0000E+00  0.0000E+00  0.0000E+00
ISTIF = type of stiffener: for example, 3=blade; ISTIF =     3

Enter SUBROUTINE ROLL. Label in STRUCT                 =  9260
NRS   = 1 for stringers, 2 for rings; NRS              =     2
FL = stiffener spacing; FL                             =  1.1458E+01
NPART = number of stiffener segments; NPART            =     1
IEND  = 0=no edges are free; 1=one edge is free; IEND  =     1     0     0
ANGL = 0 deg.or 180 deg.for web, 90 deg.for flange;ANGL=  0.0000E+00  0.0000E+00  0.0000E+00
C1    = axial stiffness/length of stiffener segment; C1=  1.0768E+06  0.0000E+00  0.0000E+00
AL    = height of stiffener segment; AL                =  1.7544E+00  0.0000E+00  0.0000E+00
NSEG  = number of stiffener segments attached  web,NSEG=     0     0     0
RESULT= axial resultant in stiff.seg, Load Set A;RESULT= -2.1391E+03  0.0000E+00  0.0000E+00
RPRE  = axial resultant in stiff.seg. Load Seg B, RPRE =  0.0000E+00  0.0000E+00  0.0000E+00
ISTIF = type of stiffener: for example, 3=blade; ISTIF =     3
```

Inter-ring buckling/rolling:smeared stringers,C11= 1.0222E+06, radius, **R= -4.8000E+01**

```
******** ENTERING GENSTB: PANDA-type buckling model ********
PANDA-type buckling theory is described in the journal paper:
D. Bushnell, "Theoretical basis of the PANDA computer program"
Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987
Also see Items 415 and 443 in ...panda2/doc/panda2.news.
ILABEL = unique "CALL GENSTB" within SUBROUTINE BUCPAN
ILABLY = label number near where SUBROUTINE BUCPAN is called.
  ILABEL, ILABLY, IDESGN,  ISAND,   INDX,   ITHRU,  IROLL    IFFLAT =
   7255    9260       0       1       3       1       1       0
 Radius  R,   Axial length, A,   Width  B
-4.800000E+01  1.145833E+01  1.507960E+02
Initial imperfections for general, panel, local buckling=
```

```
Total out-of-roundness + modal,    W0GLOB =  1.2500E-01
Out-of-roundness,                    WG1  =  0.0000E+00
General buckling modal,              WG2  =  1.2500E-01
Inter-ring buckling modal,         W0PAN =  1.0000E-10
Local buckling modal,              W0LOC =  1.0000E-07
***** Sanders theory is used in this section (ISAND=1)
Load Set A: Nx,  Ny,  Nxy= -2.2190E+03  2.0963E+02  1.1095E+01
Load Set B: Nxo, Nyo, Nxyo=  0.0000E+00  0.0000E+00  0.0000E+00
Membrane stiffnesses ((C(i,j),j=1,3),i=1,3)=
 1.0222E+06  1.7970E+05  0.0000E+00
 1.7970E+05  5.9909E+05  0.0000E+00
 0.0000E+00  0.0000E+00  2.0970E+05
     R/B,      C44MLT,      C44N,      C55N,      FFLAT=
 3.1831E-01  1.0000E+00  8.0648E-02  1.1999E-04  0.0000E+00
Test for direction panel is long: TEST=(A/B)*SQRT(C55N/(C44N*C44MLT))=2.93E-03
If TEST > 0.99 then d = 0;  c = SLOPE (panel is long in x-direction, Fig.(9a).
If TEST < 0.99 then d = SLOPE; c = 0. (panel is long in y-direction, Fig.(9b).
See Eq.(51) and Fig. 9 of "Theoretical basis..." paper (1987).
***(low-n)***
(high-m) mode:ICHEK ISAND  m    n      s      EIGENVALUE  TEST
                0     1    1   14  0.000E+00  3.077E+00  2.931E-03
Ratio needed in ARBOCZ: EIGTST/EIGTS2= EIGRAT=  1.0000E+00

EIGMNC=  3.08E+00  1.21E+01  3.08E+00  1.00E+17  1.00E+17  3.08E+00  5.66E+00
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=    1         2         1         0         0         1         1
NWAVEX=   14         3        14         0         0        14         0
TESTX =  2.93E-03  2.93E-03  2.93E-03  0.00E+00  0.00E+00  2.93E-03  1.00E+01
Before refinement (before CALL EIG), EIGVAL,CSLOPE=  3.0770E+00  0.0000E+00
 After refinement ( after CALL EIG), EIGVAL,CSLOPE=  3.0770E+00  0.0000E+00
Teff(1),Teff(2),G13,G23=  9.3767E-01  4.9565E-02  3.8604E+05  4.2308E+06

If EIGVAL and EIGVLX are different:
EIGVAL = eigenvalue with fractional wavenumbers and "fractional" slope
EIGVLX = original eigenvalue: no "fractional" refinement
EIGVAL,EIGVLX before knockdown for t.s.d.=  3.0770E+00  3.0770E+00
Buckling load factor before t.s.d.=  3.0770E+00 After t.s.d.=  2.9613E+00
EIGVAL,EIGVLX after  knockdown for t.s.d.=  2.9613E+00  2.9613E+00
EIGRAT = EIGTST/EIGTS2 =   1.0000E+00
Number of circumferential halfwaves in buckling pattern=  1.4000E+01
Buckling load factor BEFORE knockdown for smeared stringers=  2.9613E+00
Buckling load factor AFTER  knockdown for smeared stringers=  2.4620E+00

Smeared stringer with rolling before and after knockdown:
EIGRSS(before knockdown by 2 factors below)        =  2.4620E+00
Knockdown factor from inter-ring modal imperfection=  9.7837E-01
Modifying factor, FKNMOD=1 or 1/(EIG8X*FMDKD8)     =  1.0000E+00
After knockdown, EIGRSS*FKNOCK(8)*FKNMOD           =  2.4088E+00
in which
EIG8X  = lambda(ARBOCZ)/lambda(original PANDA-type theory)=  9.7837E-01
      lambda(ARBOCZ)=perfect panel buckling from ARBOCZ theory
      lambda(PANDA) =perfect panel buckling from PANDA  theory
FMDKD8 = 1 or 0.9/EIG8X =  1.0000E+00
```

Inter-ring buckling with smeared stringers and ring rolling
is not recorded as a margin because this type of buckling
has been superseded by the results from the discretized
inter-ring module model, for which inter-ring buckling

```
load factors have been computed in the range from n =     1
to n =   231 circumferential halfwaves.
The critical inter-ring-buckling-with-ring-rolling model has   14
circ. half waves, which lies within this range.
```

Buckling w/rolling between stringers with smeared rings, C11= 5.9914E+05

```
******** ENTERING GENSTB: PANDA-type buckling model ********
PANDA-type buckling theory is described in the journal paper:
D. Bushnell, "Theoretical basis of the PANDA computer program"
Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987
Also see Items 415 and 443 in ...panda2/doc/panda2.news.
ILABEL = unique "CALL GENSTB" within SUBROUTINE BUCPAN
ILABLY = label number near where SUBROUTINE BUCPAN is called.
  ILABEL, ILABLY, IDESGN,  ISAND,   INDX,   ITHRU,  IROLL    IFFLAT =
   7275    9260       0       1       4       1       1       0
 Radius  R,   Axial length, A,   Width  B
-4.800000E+01  6.875000E+01  1.861685E+00
Initial imperfections for general, panel, local buckling=
Total out-of-roundness + modal,    W0GLOB =  1.2500E-01
Out-of-roundness,                    WG1  =  0.0000E+00
General buckling modal,              WG2  =  1.2500E-01
Inter-ring buckling modal,          W0PAN =  1.0000E-10
Local buckling modal,               W0LOC =  1.0000E-07
***** Sanders theory is used in this section (ISAND=1)
Load Set A: Nx,  Ny,  Nxy= -8.0571E+02 -2.2190E-03  1.1095E+01
Load Set B: Nxo, Nyo, Nxyo=  0.0000E+00  0.0000E+00  0.0000E+00
Membrane stiffnesses ((C(i,j),j=1,3),i=1,3)=
 5.9914E+05  1.7974E+05  0.0000E+00
 1.7974E+05  7.4917E+05  0.0000E+00
 0.0000E+00  0.0000E+00  2.0970E+05
     R/B,      C44MLT,      C44N,      C55N,      FFLAT=
 2.5783E+01  1.0354E+00  2.0472E-04  2.2736E-01  0.0000E+00
Test for direction panel is long: TEST=(A/B)*SQRT(C55N/(C44N*C44MLT))=1.21E+03
If TEST > 0.99 then d = 0;  c = SLOPE (panel is long in x-direction, Fig.(9a).
If TEST < 0.99 then d = SLOPE; c = 0. (panel is long in y-direction, Fig.(9b).
See Eq.(51) and Fig. 9 of "Theoretical basis..." paper (1987).
***(low-n)***
(high-m) mode:ICHEK ISAND  m    n      s      EIGENVALUE  TEST
                0     0  171    1  0.000E+00  1.974E+01  1.209E+03
Ratio needed in ARBOCZ: EIGTST/EIGTS2= EIGRAT=  1.0000E+00

In GENSTB:
The eigenvalue corresponding to m=MMXCHK= 20 axial
halfwaves and n=  1 circ. halfwaves is critical and is
at the upper end of the final search for missed eigenvalues.
Therefore, we must continue the search over m >  20
EIGMNC=  3.03E+01  1.00E+17  1.97E+01  1.00E+17  1.97E+01  2.00E+01  1.00E+17
SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
MWAVEX=  103         0       172         0       172       160         0
NWAVEX=    1         0         1         0         1         1         0
TESTX =  1.21E+03  0.00E+00  1.21E+03  0.00E+00  1.21E+03  1.21E+03  0.00E+00
Before refinement (before CALL EIG), EIGVAL,CSLOPE=  1.9737E+01  0.0000E+00
 After refinement ( after CALL EIG), EIGVAL,CSLOPE=  1.9737E+01  0.0000E+00
Teff(1),Teff(2),G13,G23=  4.9565E-02  1.8040E+00  4.2308E+06  6.7627E+04

If EIGVAL and EIGVLX are different:
EIGVAL = eigenvalue with fractional wavenumbers and "fractional" slope
EIGVLX = original eigenvalue: no "fractional" refinement
```

```
EIGVAL,EIGVLX before knockdown for t.s.d.=  1.9737E+01  1.9737E+01
Buckling load factor before t.s.d.=  1.9737E+01 After t.s.d.=  1.7067E+01
EIGVAL,EIGVLX after  knockdown for t.s.d.=  1.7067E+01  1.7067E+01
EIGRAT = EIGTST/EIGTS2 =   1.0000E+00
    15      1.70674E+01   buckling load factor rolling with smear rings; M=172;N=1;slope=0.
Margin=  1.6084E+01  buck.(SAND);rolling with smear rings; M=172;N=1;slope=0.;FS=0.999

STRINGER ROLLING, LOAD SET A+B Nx: WEB, FLANGE= -3.6684E+03  0.0000E+00
STRINGER ROLLING, LOAD SET B   Nx: WEB, FLANGE=  0.0000E+00  0.0000E+00
```

Lo-axial wave stringer rolling without skin participation

```
In SUBROUTINE MINVAL: Eigenvalue before t.s.d.=  2.4236E+00
                      Eigenvalue after  t.s.d.=  2.3501E+00
Prebuckling resultant, RESLTS(1)= -3.6684E+03
Buckling load factor, EIGRLL(2)=  2.3501E+00
Number of halfwaves over the axial distance, ABIG=  6.8750E+01; KWAVES(1,2)=   45
STRINGER ROLLING: KWAVES(1,2),DOCSTR(1),FSROLS(1)=   45  7.0319E-01  1.4000E+00
    16      2.35007E+00   buckling load factor rolling only of stringers;M=45;N=0;slope=0.
Margin=  6.7862E-01  buck.(SAND);rolling only of stringers;M=45;N=0;slope=0.;FS=1.4

Stringer rolling from PANDA-type theory [1B]:
PANDA-type buckling load factor, EIGRLL(2)(m,n,slope)=  2.3501E+00(  45,0,0)
```

high-axial wave stringer rolling without skin participation

```
In SUBROUTINE MINVAL: Eigenvalue before t.s.d.=  2.4285E+00
                      Eigenvalue after  t.s.d.=  2.3547E+00
Prebuckling resultant, RESLTS(1)= -3.6684E+03
Buckling load factor, EROLHS=  2.3547E+00
Number of halfwaves over the axial distance, ABIG=  6.8750E+01; MROLST=   44

  RING   ROLLING, LOAD SET A+B Nx: WEB, FLANGE= -2.1391E+03  0.0000E+00
  RING   ROLLING, LOAD SET B   Nx: WEB, FLANGE=  0.0000E+00  0.0000E+00
```

Lo-circ. wave ring rolling without skin participation

```
In SUBROUTINE MINVAL: Eigenvalue before t.s.d.=  1.4466E+00
                      Eigenvalue after  t.s.d.=  1.4325E+00
Prebuckling resultant, RESLTR(1)= -2.1391E+03
Buckling load factor, EIGRLL(3)=  1.4325E+00
Number of halfwaves over the circ. distance, BBIG=  1.5080E+02; KWAVES(2,3)=   50
  RING   ROLLING: KWAVES(2,3),DOCRNG(1),FSROLR(1)=   50  7.0927E-01  1.4000E+00

Ring rolling without participation of the panel skin
is not recorded as a margin because this type of buckling
has been superseded by the results from the discretized
"skin"-ring module model, for which buckling load factors
have been computed in the range from n =     1 to n =   231 circ. halfwaves.
The critical ring-rolling-without-participation-of-the-panel-skin model has   50
circ. half waves, which lies within this range.
```

High-circ. wave ring rolling without skin participation

```
 In SUBROUTINE MINVAL: Eigenvalue before t.s.d.=  1.4480E+00
                       Eigenvalue after  t.s.d.=  1.4338E+00
 Prebuckling resultant, RESLTR(1)= -2.1391E+03
 Buckling load factor, EROLHR=  1.4338E+00
 Number of halfwaves over the circ. distance, BBIG=  1.5080E+02; NROLRG=   49

 Axisymmetric ring rolling without skin participation
 Prebuckling resultant, RESLTR(1)= -2.1391E+03
 Buckling load factor,  EIGRLL(4))=  2.2766E+01
     17      2.27655E+01   buckling load factor rolling only axisym.rings;M=0;N=0;slope=0.
 Margin=  1.5261E+01  buck.(SAND);rolling only axisym.rings;M=0;N=0;slope=0.;FS=1.4
```

Axisymmetric ring rolling from PANDA-type theory [1B]:

```
 PANDA-type buckling load factor, EIGRLL(4)(m,n,slope)=  2.2766E+01(0,   0,0)
 ******* LEAVING SUBROUTINE BUCPAN: UNPERTURBED DESIGN ********
 ****  END SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS) ****
 *** END   SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS) ****
  **** END OF PANDA-TYPE (CLOSED FORM) *****
  *** CALCS. FOR A VARIETY OF BUCKLING MODES ***
  LABEL NO. IN STRUCT= 9580
 Margin=  6.2670E+02  (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ******* THE MAXIMUM AVERAGE AXIAL STRAIN MARGIN WAS COMPUTED:
(Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ******* CONSTRAINT NO. 18; LOAD SET NO. 1; SUBCASE NO. 1
  AFTER VARCON: IMOD,INUMTT,ICONST= 0 42 18



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 ***************************************************************
 ************          CHAPTER 27            *****************
 ***************************************************************
 ***************************************************************
 ***************************************************************
 ********* DESIGN PERTURBATION INDEX, IMOD=  0 *********

 **************************************************************
```

CHAPTER 27 Compute the objective function (e.g. WEIGHT).

```
****** BEGIN SUBROUTINE OBJECT (OBJECTIVE FUNCTION) ******

 Objective (weight of PANDA2 model of panel), OBJ =  1.0014E+02
****** END   SUBROUTINE OBJECT (OBJECTIVE FUNCTION) ******
===================================================================
```