N87-17824

Mathematical Modeling of SCOLE Configuration with Line-of-Sight Error as the Output

by

S. M. Joshi
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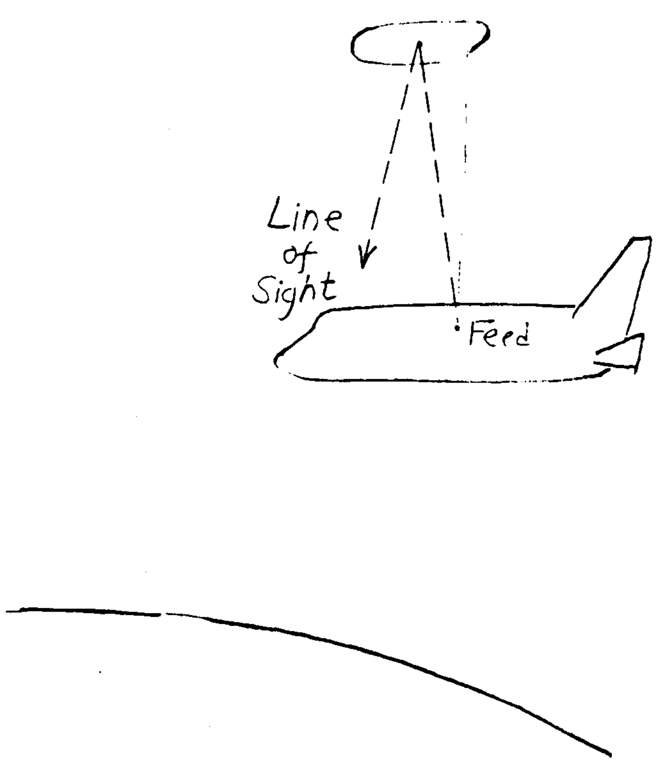


I-SCOLE Linear Model

3 - Rigid-body modes + 10 Flex. modes

(order = 26)

5 inputs $[\underbrace{M_x, M_y, M_z}, \underbrace{F_x, F_y}]$

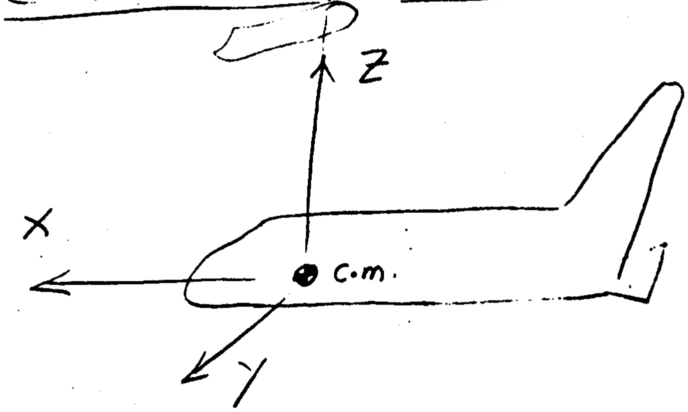
Moments applied at shuttle

Forces Applied at reflector ctr.

3 outputs $y = \Delta L.O.S.$

(3-dim. error in Line-of-sight vector)

Coordinate System: D. Robertson's



Units : FPS System

85

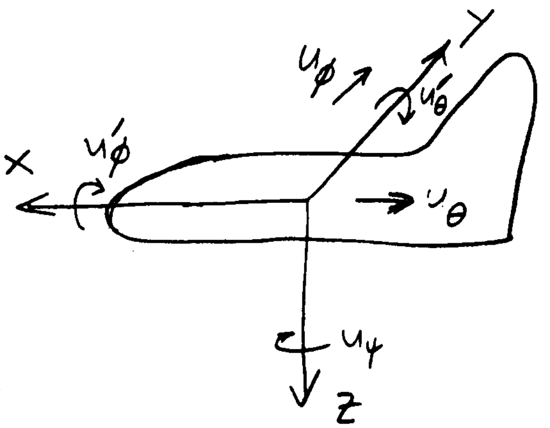
Expression for linearized LOS error

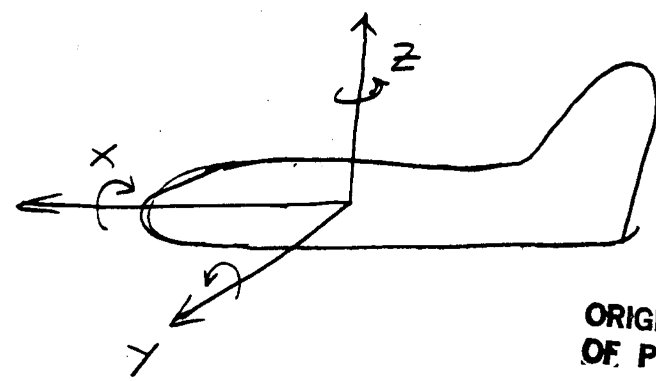
If everything is in Robertson's coordinate system the linearized LOS error is:

$$\Delta_{LOS} = \begin{vmatrix} -L\theta_s + r_y\psi_s + u_\theta(L) - u_\theta(0) + r_y u_\psi(L) - 2Lu'_\theta(L) \\ L\phi_s + r_x\psi_s + u_\phi(L) - u_\phi(0) + r_x u_\psi(L) - 2Lu'_\phi(L) \\ -r_x\theta_s - r_y\phi_s - r_x u'_\theta(L) + r_y u'_\phi(L) \end{vmatrix}$$

(Where ϕ_s, θ_s, ψ_s are the rigid-body angles) about x, y, z axes.

u_θ, u_ϕ, are elastic deflections, u'_ϕ, u'_θ, u_ψ are elastic angular deflections





Taylor's coordinate system

x-defl.	$-u_\theta$
y-defl.	u_ϕ
Angular defl. (about x)	u'_ϕ
Angular defl. (about y)	u'_θ
Angular defl. (about z)	u_ψ

Robertson's system

x-defl.	u_θ
y-defl.	u_ϕ
Angular defl. (about x-axis)	$-u'_\phi$
Angular defl. (about y-axis)	u'_θ
Angular defl. (about z-axis)	u_ψ

nominal Coordinates of refl. c.m. rel. to shuttle

$(r_x, r_y, -L)$ $\quad r_x = 18.75$, $r_y = -32.5$, $L = 130.$ $\quad (r_x, -r_y, L)$

S. M. Joshi
Nov. '86

LOAD MAP - CONTROL   CYBER LOADER 1.5-552   86/11/04. 16.00.26.   PAGE 01

1.411 CP SECONDS   52300B CM STORAGE USED   89 TABLE MOVES

A (26×26)

$$
x = \begin{array}{l} \left[\begin{array}{c} \phi_1 \\ \theta_1 \\ \psi_1 \\ \hline \dot\phi_1 \\ \dot\theta_1 \\ \dot\psi_1 \\ \hline q_1 \\ \dot q_1 \\ \hline q_2 \\ \dot q_2 \\ \vdots \\ q_{10} \\ \dot q_{10} \end{array}\right]_{26\times 1} \end{array}
\begin{array}{l} \left.\begin{array}{c} \\ \\ \\ \end{array}\right\} \text{rigid-body attitude} \\ \left.\begin{array}{c} \\ \\ \\ \end{array}\right\} \text{rigid-body rates} \\ \left.\begin{array}{c} \\ \\ \end{array}\right\} \text{Flex. Mode 1} \\ \\ \\ \vdots \\ \left.\begin{array}{c} \\ \\ \end{array}\right\} \text{Flex. Mode 10} \end{array}
$$

1st row	0.	0.	0.	.10000E+01	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
2nd row	0.	0.	0.	0.	.10000E+01	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
3rd row	0.	0.	0.	0.	0.	.10000E+01	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	.10000E+01	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	-.30520E+01	-.10482E-01	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	.10000E+01
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	-.38819E+01	-.11821E-01
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	.10000E+01	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	-.26094E+02	-.30650E-01	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	.10000E+01	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	-.55494E+02	-.44697E-01	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
Row 15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	.10000E+01	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				

Cont.

ORIGINAL PAGE IS OF POOR QUALITY

$A_{26\times 26}$ (Contd. from previous page)

Row 16

```
0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           -.16650E+03  -.77420E-01  0.           0.           0.           0.
0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           .10000E+01   0.           0.
0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           -.69557E+03  -.17956E+00  0.           0.
0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           .10000E+01
0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           -.12011E+04  -.20794E+00
0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           .10000E+01   0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
-.59545E+04  -.46299E+00  0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           .10000E+01   0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           -.65599E+04  -.48596E+00  0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           .10000E+01
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           0.           0.           0.           0.           0.           0.
0.           0.           0.           0.           -.22136E+05  -.89270E+00
```

26th row

B (26×5)

0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
.88486E-06	-.10610E-08	.14337E-07	-.59958E-06	-.11476E-03
-.10610E-08	.14272E-06	-.10662E-08	.18588E-04	.11794E-06
.14337E-07	-.10662E-08	.14681E-06	-.46726E-05	.77638E-06
0.	0.	0.	0.	0.
-.14847E-03	-.67762E-03	.48084E-04	.19876E+01	-.62670E-01
0.	0.	0.	0.	0.
.51993E-02	-.45857E-04	-.26141E-04	.14599E+00	.26186E+01
0.	0.	0.	0.	0.
-.32276E-03	-.73050E-04	-.30638E-04	.10032E+01	-.56127E+00
0.	0.	0.	0.	0.
.71189E-03	-.54339E-04	.35965E-07	.27669E+00	.48924E+00
0.	0.	0.	0.	0.
-.18890E-03	-.43101E-04	.21280E-06	-.91695E-01	.51600E-01
0.	0.	0.	0.	0.
.12068E-03	-.93335E-05	.51659E-09	-.15570E+00	-.26696E+00
0.	0.	0.	0.	0.
-.62175E-04	-.14263E-04	.11394E-06	-.37195E+00	.21550E+00
0.	0.	0.	0.	0.
.45351E-04	-.35004E-05	-.33958E-10	.10385E+00	.17885E+00
0.	0.	0.	0.	0.
-.25440E-04	-.58583E-05	-.19414E-07	.31226E+00	-.18050E+00
0.	0.	0.	0.	0.
.23310E-04	-.17963E-05	.56658E-11	-.76610E-01	-.13216E+00

$$U = \begin{bmatrix} M_x \\ M_y \\ M_z \\ F_x \\ F_y \end{bmatrix}_{5\times 1}$$

M_x, M_y, M_z: Applied moments at shuttle.

F_x, F_y: Appl. forces at reflector.

C (3×26)

$y = [\Delta L.O.S.]_{3\times 1}$

Row 1	0.	-.13000E+03	-.32200E+02	0.	0.	0.	-.34352E+00	0.	-.81771E-01	0.
	-.46647E+00	0.	.57773E+00	0.	.13541E+01	0.	-.88903E-01	0.	-.55986E+00	0.
	.36432E-01	0.	.21907E+00	0.	-.20755E-01	0.				
Row 2	.13000E+03	0.	.18750E+02	0.	0.	0.	-.93653E-02	0.	.86560E+00	0.
	-.25707E+00	0.	-.88594E+00	0.	.79047E+00	0.	.10136E+00	0.	-.30605E+00	0.
	-.28930E-01	0.	.11102E+00	0.	.11240E-01	0.				
Row 3	.32200E+02	-.18750E+02	0.	0.	0.	0.	-.38918E-01	0.	.76339E-01	0.
	-.65548E-01	0.	-.75790E-01	0.	.19557E+00	0.	.10363E-01	0.	-.78259E-01	0.
	-.37941E-02	0.	.29526E-01	0.	.19829E-02	0.				

II - SCOLE - Flexible linear model

(10 Flex. modes only)

8 inputs
14 outputs } as described

Coordinate System: D. Robertson's

FPS units.

Note: For control of LOS using ΔLOS measurements, the previous model which includes rigid + 10 flex. modes should be adequate. The following model is provided for those wishing to use additional inputs or outputs. This can be accomplished by selecting appropriate elements of "B" and "C" matrices. Note that the following model contains only flex. modes since its purpose is to supplement the previous (rigid + elastic) model.

SCOLE-Flexible model (10 modes)

S. Joshi
5/22/85

(The state, input, output variables are defined in the SCOLE w/s presentation (Dec '84))

NO. OF MODES= 10N= 20 M= 8 L= 14
A MATRIX (20×20)

$$X = \begin{bmatrix} q_1 \\ \dot{q}_1 \\ q_2 \\ \dot{q}_2 \\ \vdots \\ q_{10} \\ \dot{q}_{10} \end{bmatrix}_{20\times 1}$$

0.	.10000E+01	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-.30520E+01	-.10482E-01	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	.10000E+01	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	-.38819E+01	-.11821E-01	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	.10000E+01	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	-.26094E+02	-.30650E-01	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	.10000E+01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	-.55494E+02	-.44697E-01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	.10000E+01
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	-.16650E+03	-.77420E-01

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	.10000E+01	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-.89557E+03	-.17956E+00	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	.10000E+01	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	-.12011E+04	-.20794E+00	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	.10000E+01	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	-.59545E+04	-.46299E+00	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	.10000E+01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	-.65599E+04	-.48596E+00	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	.10000E+01
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	-.22136E+05	-.89270E+00

$$\underset{8\times 1}{U} = [\underbrace{M_x, M_y, M_z}_{\text{Moments appld. at shuttle}}, \underbrace{F_x, F_y}_{}, \underbrace{M_{rx}, M_{ry}, M_{rz}}_{\text{Moments appld. at reflector}}]^T$$

Forces applied at reflector c.m.

B MATRIX (20 × 8)

0.	0.	0.	0.	0.	0.	0.	0.
-.14847E-03	-.67762E-03	.48084E-04	.19876E+01	-.62670E-01	-.35536E-03	.22331E-01	-.33316E-02
0.	0.	0.	0.	0.	0.	0.	0.
.51993E-02	-.45857E-04	-.26141E-04	.14599E+00	.20186E+01	-.26714E-01	.32714E-02	.23108E-02
0.	0.	0.	0.	0.	0.	0.	0.
-.32276E-03	-.73050E-04	-.30038E-04	.10032E+01	-.58127E+00	.10762E-01	.18102E-01	.18013E-01
0.	0.	0.	0.	0.	0.	0.	0.
.71189E-03	-.54339E-04	.35905E-07	.27669E+00	.40924E+00	.37542E-01	-.22172E-01	-.45803E-04
0.	0.	0.	0.	0.	0.	0.	0.
-.18890E-03	-.43101E-04	.21280E-06	-.91695E-01	.51600E-01	-.31739E-01	-.54643E-01	-.81304E-03
0.	0.	0.	0.	0.	0.	0.	0.
.12068E-03	-.93335E-05	.51659E-09	-.13570E+00	-.26696E+00	-.51053E-02	.29835E-02	-.10460E-04
0.	0.	0.	0.	0.	0.	0.	0.
-.62175E-04	-.14263E-04	.11394E-06	-.37195E+00	.21550E+00	.12693E-01	.21880E-01	-.30748E-02
0.	0.	0.	0.	0.	0.	0.	0.
.45351E-04	-.35004E-05	-.33958E-10	.10365E+00	.17685E+00	.18544E-02	-.10671E-02	.61097E-05
0.	0.	0.	0.	0.	0.	0.	0.
-.25440E-04	-.58583E-05	-.19414E-07	.31226E+00	-.18050E+00	-.47872E-02	-.82578E-02	.25549E-02
0.	0.	0.	0.	0.	0.	0.	0.
.23310E-04	-.17963E-05	.56858E-11	-.76610E-01	-.13216E+00	-.95988E-03	.54178E-03	-.17527E-05

(Flexible part only) $\rightarrow \underset{20\times 1}{y} = [\underbrace{\phi_0, \theta_0, \psi_0}_{\text{Attd. at shuttle}}, \dot{\phi}_0, \dot{\psi}_0, \dot{\theta}_0, \underbrace{\xi_x, \xi_y}_{\text{Deflection of beam tip rel. to base}}, \underbrace{\phi_r, \theta_r, \psi_r}_{\text{Attitude at reflector}}, \dot{\phi}_r, \dot{\theta}_r, \dot{\psi}_r]^T$

C Matrix (14×20)

1	-.14188E-04	0.	.49685E-03	0.	-.30843E-04	0.	.68028E-04	0.	-.18051E-04	0.
	.11532E-04	0.	-.59415E-05	0.	.43338E-05	0.	-.24310E-05	0.	.22275E-05	0.
2	-.64753E-04	0.	-.43821E-05	0.	-.69806E-03	0.	-.51927E-05	0.	-.41188E-05	0.
	-.89191E-06	0.	-.13630E-05	0.	-.33450E-06	0.	-.55982E-06	0.	-.17165E-06	0.
3	.13978E-04	0.	-.75992E-05	0.	-.87321E-05	0.	.10438E-07	0.	.61862E-07	0.
	.15017E-09	0.	.33122E-07	0.	-.98715E-11	0.	-.56438E-08	0.	.16528E-11	0.
4	0.	-.14188E-04	0.	.49685E-03	0.	-.30843E-04	0.	.68028E-04	0.	-.18051E-04
	0.	.11532E-04	0.	-.59415E-05	0.	.43338E-05	0.	-.24310E-05	0.	.22275E-05
5	0.	-.64753E-04	0.	-.43821E-05	0.	-.69806E-05	0.	-.51927E-05	0.	-.41188E-05
	0.	-.89191E-06	0.	-.13630E-05	0.	-.33450E-06	0.	-.55982E-06	0.	-.17165E-06
6	0.	.13978E-04	0.	-.75992E-05	0.	-.87321E-05	0.	.10438E-07	0.	.61862E-07
	0.	.15017E-09	0.	.33122E-07	0.	-.98715E-11	0.	-.56438E-08	0.	.16528E-11
7	.18013E+00	0.	.21140E-01	0.	.15169E+00	0.	.26425E-01	0.	-.11169E-01	0.
	-.14875E-01	0.	-.45033E-01	0.	.99586E-02	0.	.37812E-01	0.	-.73107E-02	0.
8	-.55188E-04	0.	.18927E+00	0.	-.87665E-01	0.	.47052E-01	0.	.63186E-02	0.
	-.25430E-01	0.	.26068E-01	0.	.17121E-01	0.	-.21848E-01	0.	-.12599E-01	0.
9	-.33959E-04	0.	-.25528E-02	0.	.10284E-02	0.	.35875E-02	0.	-.30330E-02	0.
	-.48786E-03	0.	.12129E-02	0.	.17720E-03	0.	-.45746E-03	0.	-.91726E-04	0.
10	.21340E-02	0.	.31262E-03	0.	.17298E-02	0.	-.21108E-02	0.	-.52217E-02	0.
	.28510E-03	0.	.20908E-02	0.	-.10197E-03	0.	-.78912E-03	0.	.51772E-04	0.
11	-.96830E-03	0.	.67175E-03	0.	.52363E-02	0.	-.13315E-04	0.	-.23535E-03	0.
	-.30409E-05	0.	-.89385E-03	0.	.11947E-05	0.	.74270E-03	0.	-.50950E-06	0.
12	0.	-.33959E-04	0.	-.25528E-02	0.	.10284E-02	0.	.35875E-02	0.	-.30330E-02
	0.	-.48786E-03	0.	.12129E-02	0.	.17720E-03	0.	-.45746E-03	0.	-.91726E-04
13	0.	.21340E-02	0.	.31262E-03	0.	.17298E-02	0.	-.21108E-02	0.	-.52217E-02
	0.	.28510E-03	0.	.20908E-02	0.	-.10197E-03	0.	-.78912E-03	0.	.51772E-04
14	0.	-.96830E-03	0.	.67175E-03	0.	.52363E-02	0.	-.13315E-04	0.	-.23535E-03
	0.	-.30409E-05	0.	-.89385E-03	0.	.11947E-05	0.	.74270E-03	0.	-.50950E-06

Note: y contains flexible part only. Rigid-body components may be added to get the complete output.