Date: 28 Sept 2001
Contract No. NAS8-00114

AVIONICS TETHER OPERATIONS CONTROL
FINAL REPORT

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Under:

NAS8-00114, Task Order 5
Purchase Order H-32835D

September 28, 2001

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1.0 INTRODUCTION

The activities described in this Final Report were authorized and performed under Purchase Order Number H32835D, issued as part of NASA contract number NAS8-00114. The period of performance of this PO was from March 1 to September 30, 2001. The primary work activity was the continued development and updating of the tether dynamic simulation tools GTOSS and TSSIM and use of these and other tools in the analysis of various tether dynamics problems. Several updated versions of GTOSS were delivered during the period of performance by the author of the simulation, Lang Associates' David Lang. These updates had mainly to do with updated documentation and an updated coordinate system definition to the J2000 standards. This Final Report is organized by the months in which the activities described were performed. The following sections review the Statement of Work (SOW) and activities performed to satisfy it.

2.0 STATEMENT OF WORK

TASK 1 *The contractor shall modify the existing tether dynamics computer simulation, GTOSS or TSSIM-R, to provide the capability to model the key dynamic/electrodynamic interactions driving the STEP class electrodynamic tether systems.*

TASK 2 *The contractor shall perform simulations that demonstrate control of various orbital maneuvers, including but not limited to altitude changes (boost and deboost), and inclination changes. The control strategies for affecting all the orbital elements will be examined.*

TASK 3 *The contractor shall develop criteria for defining acceptable envelopes of tether motion during the maneuvers described in 3.2 and shall develop and simulate tether control strategies that will keep tether motion within those bounds. The implications of the tether control strategies on the system (e.g. propulsion performance penalties, system requirements for the control architecture, etc.) shall be noted.*

TASK 4 *The contractor shall provide regular, informal, technical coordination and communication via telephone and email with the MSFC Study Managers on a biweekly or as-needed basis. The contractor shall participate in periodic technical meetings with other organizations working on related technical issues.*

3.0 WORK ACCOMPLISHED UNDER PO H-32835D

4.0 MARCH 2001 WORK ACTIVITIES

During the month of March, bd Systems performed tasks related to each of the SOW areas. The simulation tools were addressed by a review of GTOSS and a recommendation of modifications/additions to provide a single, comprehensive output data base file along with a map showing the location of each of the data items. We also discussed modifications needed for GTOSS to be consistent in its internal use of coordinate frames with the user's input date and time information. At that time, GTOSS only used date/time information in the ionosphere model.

bd Systems participated in the meeting of the NASA Tether Technology Working Group (TWG), March 4-5, 2001. At this meeting, we reviewed the status of existing tether tasks and helped develop the requirements for future tasks. Proposed new tasks and planning roadmaps were suggested and inputs prepared for FY02-07 PowerPoint Budgetary Planning Presentation charts.

bd Systems provided comments to NASA/MSFC on the proposed TMTC SOW for the next contractual period.

We participated in a review and demonstration of tether dynamics simulation software by TMTC subcontractor Bob Strunce. The review was accomplished in the form of a 1-day meeting/presentation at MSFC. Bob Strunce and Fran Maher demonstrated the latest version of their software/hardware system SDT/TOSS. Needed additions and modifications were discussed. Plans were made to re-convene in 2-3 weeks to discuss details of proposed upgrades to the SDT/TOSS software to make it a more standalone package, so that the user no longer would have to set up tether characteristics through a GTOSS input file.

5.0 APRIL ACTIVITIES

During the month of April, we continued to develop and update the tether simulations through our support to the implementation of new inertial reference frame options for GTOSS. We provided specifications and helped validate the resulting code. This modification makes GTOSS output satellite and tether positions with respect to familiar celestial references known as M50 and J2000. These are standard reference frames known and understood for calculation of launch and satellite trajectories. Also, added to GTOSS was logic to calculate the proper sun position consistent with these reference frames and proper earth rotations so that satellite earth fixed latitude and longitude data are appropriate for the simulated date, time and position. Much or our checking involved cross-referencing GTOSS and TSSIM outputs for sets of initial conditions. Updated versions of GTOSS were provided to NASA/MSFC TD55/Ken Welzyn as they were received.

Another enhancement to our simulation capabilities was the development of animations using the freeware program called BLENDER. This is available for download through the web site blender.nl. The SW provider is NAN located in the Netherlands. Our development has been to define an animation model consisting of 17 bodies including the 2 end bodies, 2 solar arrays, sun, earth, and 11 tether segments. In addition, we developed MATLAB m-files to convert simulation output data into the format that BLENDER accepts. We also wrote a script file for BLENDER which implements the animation and allows the user to animate either as a post process on line or to build a movie file in the JPEG or MPEG formats. The MATLAB m-files and blender script file are listed in Appendix A. This capability was demonstrated for MSFC, Ken Welzyn and Randy Baggett.

In addition to the above activities, we reviewed proposed TMTC statements of work and provided comments. Also, we reviewed TMTC reports from their completed work activities.

6.0 MAY ACTIVITIES

During the May 2001 reporting period, we provided continued assistance to David Lang Associates in updating the GTOSS tethered satellites dynamic simulation system. The implementation of the new version of GTOSS with updated M50 and J2000 astrodynamic coordinate references and the ionosphere model was completed. We played a major role in defining the changes and checking out the completed product. Two CD's with updated versions of the simulation were evaluated for PC readability and suggestions were developed for improvements to ease users labors involved in building executables for the PC version of the simulation code and the post processors. This is necessary to provide TMTC with the tether simulation capabilities required to assess Step-Airseds dynamics and controls issues.

As a part of the above activities, we developed automated software in Matlab to process the GTOSS delivery source files into the structure required to build the simulation and post-processors. This involves constructing source directories of modified source files, which have been edited to add the proper end of line character if absent and remove the comment characters, activating the appropriate source lines for each source file. The source files as delivered are set up to be compatible with many computer platforms using different fortran compilers which have different syntaxes for INCLUDE statements and some data I/O operations. The appropriate versions of these lines must be uncommented in order to be processed by the compiler, which in our PC case is Digital Visual Fortran Version 6.0. Also, different platforms use different syntaxes for end-of-line in text files and in some cases, the proper end-of-line characters for the PC platform must be added. The original deliveries were processed by hand thinking this would be a one time exercise. The PC fortran compiler editor makes this process simple but tedious. However, as the number of deliveries and updates have become more frequent, it is evident that automation is desirable and even necessary. In excess of 400 files are involved in this process.

A set of CAD 3D drawings were provided electronically by TMTC's subcontractor Double R Controls for review and evaluation of their present design for the S-A Tether Deployer. We reviewed the drawings and participated in a telecon on 5-10-01 with MSFC and TMTC/Double R Controls. Completed development of the animation models in the Blender format and developed interfaces for both GTOSS and TSSIMR simulation systems.

7.0 JUNE ACTIVITIES

During the month of June, we received another revision to the GTOSS tether simulation (version H9.0 6-11-01 revision). Since this process of distributing the code revisions is new, we wanted to confirm that the code delivery was complete and the build process did not yield any anomalies. As explained previously, building this new revision into an executable version of the GTOSS simulation system requires processing the source files using special auxiliary software we have written in Matlab. Copies are provided in Appendix B. We were successfully able to build the updated executable in time to have it available for the review of the Step-Airseds activity with the contractor, TMTC on 12-14 June. The first phase of this review was an update and demonstration of the SDT/TOSS software presented by Bob Strunce and Fran Maher of

TMTC. This software is TMTC's tether simulation and system modeling tool and incorporates GTOSS as the tether modeling component. Over the 2 days duration of the review several speakers from TMTC presented the remaining review material. This consisted of a complete overview of ongoing S-A activities at TMTC as well as a summary of TMTC's planned test activities.

At NASA's request, bd Systems broadened our tether involvement by providing assistance to a summer research project looking into the tether dynamics of the momentum transfer tether being performed by Dr. Stephen Canfield from the Tennessee Space Institute and two of his graduate students. We got them get up and running with the latest version of GTOSS and assisted them in setting up an input file representing an appropriate tether configuration. This input file, nominally called INGOSS is listed in Appendix C. We set up a two body, rotating system in a circular equatorial orbit with a 100 km length tether. The rotation rate was approximately 1 revolution per 300 seconds.

Finally, we demonstrated the animation capabilities of the Blender Software system to NASA with an animation of the Step-Airseds Configuration.

8.0 JULY ACTIVITIES

In July, John Glaese/bd Systems traveled to Salt Lake City to attend the 37th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, 8-11 July and participate in the meeting of the AIAA Space Tethers Technical Committee chaired by Andrew Santangelo. Sessions on each of the conference days were attended. The sessions of greatest interest were Electrodynamics and Tethers, Session 27 EP-4, Future Flight – 1, Session FPC-1, Breakthrough Propulsion Physics – 1, Session FPC-3, Future Flight – 2, Session FPC-5, Future STS-2, session FPC-7, Breakthrough Propulsion Physics – 3 and Session FPC-15, Future Flight – 5, Session FPC-16. There were 125 scheduled technical sessions spread over 3 days. In addition to the separate session devoted to tethers, there were 2 other sessions containing 1 or more papers concerning tether momentum transfer.

During the June Step-Airseds Project Review, TMTC requested a test case be provided to complete verification/validation of the SDT/TOSS dynamics simulation. A Proseds sample GTOSS ingoss file was selected and bd Systems agreed to help expedite the transfer process to TMTC. This file had to be modified slightly to account for the update of GTOSS from version H7.0 to H9.0 in the form and units of the electrodynamic and thermal parameters. These changes were made and the files transferred to TMTC. Appendix D lists this INGOSS file. Simulation runs using the sample INGOSS file were made by TMTC with SDT/TOSS. The results of these runs agreed well with runs made by bd Systems for both the Proseds sample case and a comparable case in which the Step-Airseds electrodynamic model had been configured to duplicate the Proseds dynamics. Results of both cases agreed well between TMTC's SDT/TOSS and bd Systems GTOSS results.

In July, bd Systems also provided guidance and support to Dr. Stephen Canfield and his student David Johnson along with John Westerhoff, a student from the University of Illinois, Champaign-Urbana, IL working with them. They are doing research in the dynamics of tether momentum transfer as part of the summer faculty program at MSFC. This support consisted of installing a copy of GTOSS for them and helping them set up a sample simulation input file for a representative momentum transfer tether configuration. Some problems were encountered achieving integration convergence for the momentum transfer configuration runs and this was partially solved but bd Systems is still investigating why this necessitates exceedingly small integration step sizes in GTOSS. Corresponding cases in TSSIM achieve comparable results with significantly larger steps and shorter run times.

9.0 AUGUST ACTIVITIES

During August, bd Systems continued to provide guidance and support to Dr. Stephen Canfield, David Johnson and John Westerhoff. They are performing research studies into the dynamics of momentum transfer, electrodynamic reboost tether systems. They reported on their progress over the summer session. Although, their summer sessions were completed and they returned to their respective campuses for the beginning of fall classes, they are continuing their research using the modeling tools provided by MSFC and bd Systems as well as those they developed independently. Our support during this period consisted primarily of providing modeling advice and assistance in the implementation of GTOSS in a PC environment. In addition, we observed an apparent anomaly in the GTOSS code whereby it seems to require exceedingly small integration step sizes to achieve convergence for the rotating tether systems of the momentum transfer tether configurations. This does not necessarily mean an error condition exists but may indicate certain calculations are performed out of order causing inefficiently leading to inefficient execution and unnecessarily long run times. I have referred this to the GTOSS author, Mr. David Lang. He is investigating this and as a related exercise, we are investigating addition of a variable step integration scheme with error checking and automatic step size control to GTOSS. As an example, GTOSS presently requires 0.5 microseconds to converge such that no significant change of rotational phase of the tether system is observed over a 2 orbit period, whereas, TSSIM using a 4 pass Runge-Kutta fixed step scheme achieves the same result using a step size of 1 second.

An additional activity performed in August was an investigation into the feasibility of the use of an electrodynamic tether as a source of reboost thrust to supplement or replace present propellant sources for maintaining the orbit of the International Space Station (ISS). As part of this activity, a brief search was made into micro-gravity requirements on ISS. The steady state g-level requirement within the micro gravity volume is 1 micro-g according to SSP 41000R, 15 March 2000, System Specification for the International Space Station, section 3.2.1.1.4.1. This would imply that 166 kg is the most an end mass could be for a 7 km long tether deployed from ISS without violating this requirement. Since upward deployment seems to be the most viable concept, we need a good estimate of how much power might be produced by an upper end mass within this mass limit. The 7 km tether length was an initial concept. With this, we can estimate how much drag compensation an ED tether would be able to provide and in turn how much benefit it would be to ISS. We also investigated an ED Tether Tug concept suggested by Ken Welzyn. The tug would be a separate system consisting of an upper body power supply, a lower body ballast mass connected by a conducting, ED tether. The tug would attach to ISS by a towing tether and would co-orbit with the ISS. It would provide its own electrical power and thrust. The towing forces would be along the towing tether and would counteract the drag without disturbing the micro-g environment. This concept seems to overcome concerns about disturbing the micro-g environment but many details still need to be worked such as how to stabilize the tug in a position in front of the ISS. This position is passively unstable and an active control appears required. To explore this concept further, we have built a GTOSS model of this system and made a few simulation runs.

10.0 SEPTEMBER ACTIVITIES

In September, bd System continued the development of the ISS Tether Reboost system concept. And supported the Tether Reboost Task Team by providing sample run results in the form of plots and tables of data. Early in the month, it was observed that the objections to the upward deployed tether reboost system could be overcome by shortening the tether and lightening the mass of the upper end body high voltage power supply. Since the tether tow concept was still immature and the upward deployed system more like previously studied concepts, efforts were concentrated on this configuration. Bd Systems developed a GTOSS model of the concept and ran a few simulations of it to study potential performance and power consumption. A proposed feature that is unique is the use of twin tethers connecting the ISS and the upper spacecraft ED tether high voltage power supply (HVPS). The primary purpose of the two tethers is to improve the roll stability of the ISS and also lower the total Ohmic resistance of the tether conducting path between the HVPS and the ISS. Theoretically, electrodynamic (ED) thrust produced by a tether carrying a current is equal to the electrical power E I which equates to the mechanical power F*V. The thrust force in the direction of the velocity is E I divided by the orbital velocity magnitude V. Since the orbit is nearly circular, the velocity magnitude is virtually constant. Thus, one can maintain constant thrust if desired by maintaining constant electrical power E I. The previous is based on the use of an end body collector (EBC). An EBC model was previously developed for the Step-Airseds study. It was based on the bare wire collection model and was simply meant to serve as a place holder until a better model was found since no general shape EBC model exists. For the ISS reboost investigation, a spherical shape was proposed and a model exists for this, the Parker-Murphy (PM) model. To reduce drag, a mesh collector is proposed, although research is still required to model this effect. Dr. Nobie Stone provided this model for GTOSS and it has been implemented in place of the earlier model. The main difference between this model and the previous one is the presence of the thermal current. The thermal current provides the bulk of collection according to the PM model. Additional current is collected as positive bias voltage is increased by a rate proportional to the square root of the bias according to the PM model, but the rate of increase is much smaller than the bare wire collector model would predict. The reason for this lies in the large size of the EBC compared to the Debye Length which is the theoretical limiting dimension for bare wire diameter over which the orbital motion limit (OML) collection is expected to be achieved. The PM model as implemented in GTOSS is defined in Appendix E. The source file called TOSSH6.F was developed by bd Systems for GTOSS and also adapted to TSSIM. It modeled the dynamics of bare wire current collection in the earth's ionosphere. This file was modified during September with PM replacing the previous EBC model. Other modifications were made to improve the convergence properties of the iteration loop. The ISS reboost suggested configuration uses a 2 tether system. For simplicity in this initial study, the two 2.5 km tether system was replaced by one 5 km tether. Thus, only a single current and EBC needs to be modeled. The equivalence resulted from flowing one tether's worth of current over twice the distance which results in an equivalent amount of thrust. The HVPS power required differs in the two cases only by the power to drive the current of one tether across the EBC bias voltage. This is assumed to be small compared to HVPS voltage and is in the direction to make power slightly less for the two-tether system.

Finally, a few considerations are in order with respect to the formulation of a control law for this or any ED tether system. The area of optimal control appears to be a fruitful source of such control laws. The basic idea is to define an optimization integral sometimes called a cost or objective or penalty function. This integral is carried out over a desired sample period which may be anywhere from a few seconds to one or more orbits. This function is to be optimized using the procedures of the calculus of variations. The optimization is carried out while certain other integral values are constrained. For our problem, a suitable objective function is the integral of the Ohmic power ($I^2 R$) loss over the sample period. The integrals to be constrained are the integrals of the ED force and the velocity. This will result in a desired average ED force being attained and a desired end state being achieved over the sample period. This is analogous to the guidance problem for launch vehicles. It has also been applied successfully to the angular momentum management problem for control momentum gyros and reaction wheel control. This is the roadmap that we hope to follow for the next phase of activities.

APPENDIX A
LISTINGS OF ANIMATION SUPPORT SOFTWARE

BLENDER_TETHER_GTOSS.M

```
% This script builds the array out which is structured the way the blender
animation m-file for tethers
% is expecting.  Matches corresponding output for TSSIM.
% scale = 1;
% keyframe_const = 3.000000;

% body_title(1,1:7)  =  'body_1 ';
% body_title(2,1:7)  =  'body_2 ';
% body_title(3,1:7)  =  'body_3 ';
% body_title(4,1:7)  =  'body_4 ';
% body_title(5,1:7)  =  'body_5 ';
% body_title(6,1:7)  =  'body_6 ';
% body_title(7,1:7)  =  'body_7 ';
% body_title(8,1:7)  =  'body_8 ';
% body_title(9,1:7)  =  'body_9 ';
% body_title(10,1:7) = 'body_10';
% body_title(11,1:7) = 'body_11';
% body_title(12,1:7) = 'body_12';
% body_title(13,1:7) = 'body_13';
% body_title(14,1:7) = 'body_14';
% body_title(15,1:7) = 'Earth  ';
% body_title(16,1:7) = 'Sun    ';

% num_bodies = size(body_title);

len=length(time);

% string_in = ['load ',filename_in];
% eval(string_in);

rsa_ap_sa=[0;0; 0.5;0]; % attach pt vector expressed as quaternion in 1P
rsh_ap_sh=[0;0;-0.5;0]; % attach pt vector expressed as quaternion in 2P

tethxa=[zeros(1,len);tethx;sum(uxt.*ob2pos)]; % In tether frame
tethya=[zeros(1,len);tethy;sum(uyt.*ob2pos)];
tethza=[zeros(1,len);tethz;sum(uzt.*ob2pos)];

nnode=length(tethxa(:,1));JJ=(0:10)*(nnode-1)/10;
tethxp=[];tethyp=[];tethzp=[];

for j=0:10;fac=rem(JJ(j+1),1);I=floor(JJ(j+1));if j == 10 fac=1;I=nnode-2;end
   tethxp=[tethxp;(1-fac)*tethxa(I+1,:)+fac*tethxa(I+2,:)];
   tethyp=[tethyp;(1-fac)*tethya(I+1,:)+fac*tethya(I+2,:)];
   tethzp=[tethzp;(1-fac)*tethza(I+1,:)+fac*tethza(I+2,:)];
end

clear tethxa tethya tethza

uxtlp=[1 0 0;0 -1 0;0 0 -1]*uxtl; % Express in LVLHP (X forward, Z toward
zenith)
uytlp=[1 0 0;0 -1 0;0 0 -1]*uytl;
```

```
uztlp=[1 0 0;0 -1 0;0 0 -1]*uztl;
nodeposl=[];
for j=1:11;
   IN=[j j
j];nodeposl=[nodeposl;tethxp(IN,:).*uxtlp+tethyp(IN,:).*uytlp+tethzp(IN,:).*u
ztlp];
end

qlpi=[0 0 0 1;0 0 1 0;0 -1 0 0;-1 0 0 0]*qli;
pearth=-ob1pos;
ome=2*pi*(1+1/365.25)/86400;lat=-25.004;lon=-128.487;lon=0;
the=(ome*time-lon)/2;eclang = 23.5*pi/180;
q1=[[0;0;1]*sin(the);cos(the)];p1=[pearth;zeros(1,len)]; % Earth position
quaternion
q1=qp(qina(qlpi),q1);
p1=qp(qina(qlpi),qp(p1,qlpi));

q2=qp(qeul2(eaorp(1,:)),qp(qeul3(eaorp(3,:)),qeul1(eaorp(2,:)))); %Body 1
quaternion from LVLH
q2=[0 0 0 1;0 0 -1 0;0 1 0 0;-1 0 0 0]*q2; % Convert to body 1 quaternion
from LVLHP
q2= qp(q2,[ones(1,len);zeros(3,len)]); %Convert to body 1P quaternion from
LVLHP
q5i=qp(qeul2(eaiob2(1,:)),qp(qeul3(eaiob2(3,:)),qeul1(eaiob2(2,:))));
q5=qp(qina(qlpi),q5i); %Body 2 quaternion from LVLHP
q5=qp(q5,[ones(1,len);zeros(3,len)]); % Body 2P from LVLHP
q3=q2;q4=q2;% Solar array bodies fixed to upper body for now
%  Tether nodes in z-nadir pointing local vertical, node11 at origin

pnode1=[nodeposl(1:3,:);zeros(1,len)];
pnode2=[nodeposl(4:6,:);zeros(1,len)];
pnode3=[nodeposl(7:9,:);zeros(1,len)];
pnode4=[nodeposl(10:12,:);zeros(1,len)];
pnode5=[nodeposl(13:15,:);zeros(1,len)];
pnode6=[nodeposl(16:18,:);zeros(1,len)];
pnode7=[nodeposl(19:21,:);zeros(1,len)];
pnode8=[nodeposl(22:24,:);zeros(1,len)];
pnode9=[nodeposl(25:27,:);zeros(1,len)];
pnode10=[nodeposl(28:30,:);zeros(1,len)];
pnode11=[nodeposl(31:33,:);zeros(1,len)];

qux=[ones(1,len);zeros(3,len)];
quy=[zeros(1,len);ones(1,len);zeros(2,len)];
quz=[zeros(2,len);ones(1,len);zeros(1,len)];
ub1x=qp(q2,qp(qux,qina(q2)));
ub1y=qp(q2,qp(quy,qina(q2)));
ub1z=qp(q2,qp(quz,qina(q2)));

ub2x=qp(q5,qp(qux,qina(q5)));
ub2y=qp(q5,qp(quy,qina(q5)));
ub2z=qp(q5,qp(quz,qina(q5)));
p2=pnode1-(rsh_ap_sh(1)*ub1x+rsh_ap_sh(2)*ub1y+rsh_ap_sh(3)*ub1z);
p3=p2+0.5*ub1y;
p4=p2-0.5*ub1y;
p5=pnode11-(rsa_ap_sa(1)*ub2x+rsa_ap_sa(2)*ub2y+rsa_ap_sa(3)*ub2z);
p6=pnode1;
p7=pnode2;
```

```
p8=pnode3;
p9=pnode4;
p10=pnode5;
p11=pnode6;
p12=pnode7;
p13=pnode8;
p14=pnode9;
p15=pnode10;
p16=pnode11;

doy=183;eclang = 23.5*pi/180;tha = 2*pi*(doy - 80)/365.25;
usun=[1;0;0;0]*cos(tha)+((cos(eclang)*[0;1;0;0]+sin(eclang)*[0;0;1;0])*sin(th
a));
p17=1.496e11*usun*ones(1,len); % Sun body position data in inertial frame
p17=qp(qina(qlpi),qp(p17,qlpi));q17=qp(qina(qlpi),[0;0;0;1]*ones(1,len)); %
Transform to lpi

shift=-p2;
p1=p1+shift;
p2=p2+shift;
p3=p3+shift;
p4=p4+shift;
p5=p5+shift;
p6=p6+shift;
p7=p7+shift;
p8=p8+shift;
p9=p9+shift;
p10=p10+shift;
p11=p11+shift;
p12=p12+shift;
p13=p13+shift;
p14=p14+shift;
p15=p15+shift;
p16=p16+shift;
p17=p17+shift;

inv=diag([-1 -1 -1 1]); % Accounts for treetops opposite sense definition of
quaternions.
% Above inv required to make consistent with treetops animation conditioning
m-files.

q1 = inv*q1;
q2 = inv*q2;
q3 = inv*q3;
q4 = inv*q4;
q5 = inv*q5;
q6 = inv*[zeros(3,len);ones(1,len)];
q7 = inv*[zeros(3,len);ones(1,len)];
q8 = inv*[zeros(3,len);ones(1,len)];
q9 = inv*[zeros(3,len);ones(1,len)];
q10 = inv*[zeros(3,len);ones(1,len)];
q11 = inv*[zeros(3,len);ones(1,len)];
q12 = inv*[zeros(3,len);ones(1,len)];
q13 = inv*[zeros(3,len);ones(1,len)];
q14 = inv*[zeros(3,len);ones(1,len)];
q15 = inv*[zeros(3,len);ones(1,len)];
q16 = inv*[zeros(3,len);ones(1,len)];
```

```
q17 = inv*q17;
;

out=[time
   q1
   p1(1:3,:)
   q2
   p2(1:3,:)
   q3
   p3(1:3,:)
   q4
   p4(1:3,:)
   q5
   p5(1:3,:)
   q6
   p6(1:3,:)
   q7
   p7(1:3,:)
   q8
   p8(1:3,:)
   q9
   p9(1:3,:)
   q10
   p10(1:3,:)
   q11
   p11(1:3,:)
   q12
   p12(1:3,:)
   q13
   p13(1:3,:)
   q14
   p14(1:3,:)
   q15
   p15(1:3,:)
   q16
   p16(1:3,:)
   q17
   p17(1:3,:)];

clear q1 q2 q3 q4 q5i q5 q6 q7 q8 q9 q10 q11 q12 q13 q14 q15 q16 q17
clear p1 p2 p3 p4 p5 p6 p7 p8 p9 p10 p11 p12 p13 p14 p15 p16 p17
clear len pearth rsa_ap_sa rsh_ap_sh nnode tethxp tethyp tethzp
clear q1pi the ome JJ fac uxt1p uyt1p uzt1p shift inv ub1x ub1y ub1z
clear ub2x ub2y ub2z qux quy quz nodepos1 fac
clear pnode1 pnode2 pnode3 pnode4 pnode5 pnode6 pnode7 pnode8 pnode9 pnode10
pnode11
```

BLENDER_TETHER_TSSIMR5.M

```
function out=blender_tether_tssim5(data)

% body_title(1,1:7) =  'Earth  ';
% body_title(2,1:7) =  'body_2 ';
% body_title(3,1:7) =  'body_3 ';
% body_title(4,1:7) =  'body_4 ';
% body_title(5,1:7) =  'body_5 ';
% body_title(6,1:7) =  'body_6 ';
```

```
% body_title(7,1:7) =  'body_7 ';
% body_title(8,1:7) =  'body_8 ';
% body_title(9,1:7) =  'body_9 ';
% body_title(10,1:7) = 'body_10';
% body_title(11,1:7) = 'body_11';
% body_title(12,1:7) = 'body_12';
% body_title(13,1:7) = 'body_13';
% body_title(14,1:7) = 'body_14';
% body_title(15,1:7) = 'body_15';
% body_title(16,1:7) = 'body_16';
% body_title(17,1:7) = 'Sun    ';
% num_bodies = size(body_title);
% string_in = ['load ',filename_in];
% eval(string_in);
% Changing quaternions to pitch, yaw and roll angles.
qli=data(24:27,:); qlpi=qli;%LVLH quaternion
q2=qp(qina(qli),data(46:49,:));% Upper (shuttle) body quaternion from LVLH
q3=q2;q4=q2;% Solar array bodies fixed to upper body for now
q5=qp(qina(qli),data(39:42,:)); % Lower (subsatellite) body quaternion from
LVLH
%  Tether nodes in z-nadir pointing local vertical, node11 at origin
len=length(data(1,:));

   rsa_ap_sa=[0;0;0.5;0]; % quaternion
   rsh_ap_sh=[0;0;-0.5;0];% quaternion
   rotx=[1 0 0;0 -1 0;0 0 -1];% Transforms nodes to zenith pointing local
vertical
   time=data(1,:);
   node1=76:78;
   node2=node1+3;
   node3=node2+3;
   node4=node3+3;
   node5=node4+3;
   node6=node5+3;
   node7=node6+3;
   node8=node7+3;
   node9=node8+3;
   node10=node9+3;
   node11=node10+3;
   node12=node11+3;
% rotx transforms to zenith pointing local vertical
pnode1=1000*rotx*data(node1,:);pnode1 =[pnode1;zeros(1,len)];
pnode2=1000*rotx*data(node2,:);pnode2 =[pnode2;zeros(1,len)];
pnode3=1000*rotx*data(node3,:); pnode3 =[pnode3;zeros(1,len)];
pnode4=1000*rotx*data(node4,:);  pnode4 =[pnode4;zeros(1,len)];
pnode5=1000*rotx*data(node5,:);  pnode5 =[pnode5;zeros(1,len)];
pnode6=1000*rotx*data(node6,:);  pnode6 =[pnode6;zeros(1,len)];
pnode7=1000*rotx*data(node7,:);  pnode7 =[pnode7;zeros(1,len)];
pnode8=1000*rotx*data(node8,:);  pnode8 =[pnode8;zeros(1,len)];
pnode9=1000*rotx*data(node9,:);  pnode9 =[pnode9;zeros(1,len)];
pnode10=1000*rotx*data(node10,:); pnode10=[pnode10;zeros(1,len)];
pnode11=1000*rotx*data(node11,:); pnode11=[pnode11;zeros(1,len)];
pnode12=1000*rotx*data(node12,:); pnode12=[pnode12;zeros(1,len)];
pearth=-1000*data(69:71,:);
ome=2*pi*(1+1/365.25)/86400;the0=0;
the=(the0+ome*data(1,:))/2;
```

```
q1=[[0;0;1]*sin(the);cos(the)];p1=[pearth;zeros(1,len)]; % Earth position
quaternion
q1=qp(qina(qli),q1);
p1=qp(qina(qli),qp(p1,qli));

qux=[ones(1,len);zeros(3,len)];                 % X axis unit vector represented
as quaternion
quy=[zeros(1,len);ones(1,len);zeros(2,len)]; % Y axis unit vector represented
as quaternion
quz=[zeros(2,len);ones(1,len);zeros(1,len)]; % Z axis unit vector represented
as quaternion


ub1x=qp(q2,qp(qux,qina(q2))); % Upper body fixed axes
ub1y=qp(q2,qp(quy,qina(q2)));
ub1z=qp(q2,qp(quz,qina(q2)));

ub2x=qp(q5,qp(qux,qina(q5))); % Lower body fixed axes
ub2y=qp(q5,qp(quy,qina(q5)));
ub2z=qp(q5,qp(quz,qina(q5)));


doy=183;eclang = 23.5*pi/180;tha = 2*pi*(doy - 80)/365.25;
usun=[1;0;0;0]*cos(tha)+((cos(eclang)*[0;1;0;0]+sin(eclang)*[0;0;1;0])*sin(th
a));
p17=1.496e11*usun*ones(1,len); % Sun body position data in inertial frame
p17=qp(qina(qlpi),qp(p17,qlpi));q17=[0;0;0;1]*ones(1,len);q17=qp(qlpi,q17);

p2=pnode1-rsh_ap_sh(1)*ub1x-rsh_ap_sh(2)*ub1y-rsh_ap_sh(3)*ub1z;
p3=p2 + ub1y;
p4=p2 - ub1y;
p5=pnode12-rsa_ap_sa(1)*ub2x-rsa_ap_sa(2)*ub2y-rsa_ap_sa(3)*ub2z;

% The following logic interpolates between 12 TSSIM nodes to produce the
% 11 nodes used in the animation.

x=0;
p6= (1-x)*pnode1 +x*pnode2;
x=.1;
p7= (1-x)*pnode2 +x*pnode3;
x=.2;
p8= (1-x)*pnode3 +x*pnode4;
x=.3;
p9= (1-x)*pnode4 +x*pnode5;
x=.4;
p10=(1-x)*pnode5 +x*pnode6;
x=.5;
p11=(1-x)*pnode6 +x*pnode7;
x=.6;
p12=(1-x)*pnode7 +x*pnode8;
x=.7;
p13=(1-x)*pnode8 +x*pnode9;
x=.8;
p14=(1-x)*pnode9 +x*pnode10;
x=.9;
p15=(1-x)*pnode10+x*pnode11;
x=1;
```

```
p16=(1-x)*pnode11+x*pnode12;

shift=-p2;
p1=p1+shift;
p2=p2+shift;
p3=p3+shift;
p4=p4+shift;
p5=p5+shift;
p6=p6+shift;
p7=p7+shift;
p8=p8+shift;
p9=p9+shift;
p10=p10+shift;
p11=p11+shift;
p12=p12+shift;
p13=p13+shift;
p14=p14+shift;
p15=p15+shift;
p16=p16+shift;
p17=p17+shift;

inv=diag([-1 -1 -1 1]);

q1 = inv*q1;
q2 = inv*q2;
q3 = inv*q3;
q4 = inv*q4;
q5 = inv*q5;
q6 = inv*[zeros(3,len);ones(1,len)];
q7 = inv*[zeros(3,len);ones(1,len)];
q8 = inv*[zeros(3,len);ones(1,len)];
q9 = inv*[zeros(3,len);ones(1,len)];
q10 = inv*[zeros(3,len);ones(1,len)];
q11 = inv*[zeros(3,len);ones(1,len)];
q12 = inv*[zeros(3,len);ones(1,len)];
q13 = inv*[zeros(3,len);ones(1,len)];
q14 = inv*[zeros(3,len);ones(1,len)];
q15 = inv*[zeros(3,len);ones(1,len)];
q16 = inv*[zeros(3,len);ones(1,len)];
q17 = inv*q17;

out=[time
   q1
   p1(1:3,:)
   q2
   p2(1:3,:)
   q3
   p3(1:3,:)
   q4
   p4(1:3,:)
   q5
   p5(1:3,:)
   q6
   p6(1:3,:)
   q7
   p7(1:3,:)
   q8
```

```
p8(1:3,:)
q9
p9(1:3,:)
q10
p10(1:3,:)
q11
p11(1:3,:)
q12
p12(1:3,:)
q13
p13(1:3,:)
q14
p14(1:3,:)
q15
p15(1:3,:)
q16
p16(1:3,:)
q17
p17(1:3,:)];
```

PYR_Q.M

```
function pyr=pyr_q(q)
% Calculate pitch-yaw-roll euler sequence from quaternion
% function pyr=pyrq(q)

a13=2*(q(1,:).*q(3,:)-q(2,:).*q(4,:));
a11=q(1,:).^2-q(2,:).^2-q(3,:).^2+q(4,:).^2;
a22=-q(1,:).^2+q(2,:).^2-q(3,:).^2+q(4,:).^2;
a12=2*(q(1,:).*q(2,:)+q(3,:).*q(4,:));
a32=2*(q(3,:).*q(2,:)-q(1,:).*q(4,:));
pyr=180/pi*[atan2(-a13,a11);asin(a12);atan2(-a32,a22)];
```

QINA.M

```
function r=qina(q)
r=-q;
r(4,:)=q(4,:);

function r=qp(a,b)
av=a(1:3,:);
bv=b(1:3,:);
x=ones(3,1)*a(4,:);
y=ones(3,1)*b(4,:);
r=cross(av,bv)+(bv.*x)+(av.*y);
r(4,:)=[-1 -1 -1 1]*(a.*b);
```

BLENDER SCRIPT FILE

This script file is not viewable as a text file. It is only viewable from BLENDER.

APPENDIX B
MATLAB FILES FOR AUTOMATING THE CONVERSION OF GENERIC GTOSS DELIVERY SOURCE FILES INTO PC FORMATTED SOURCE FILES

BUILD_GTOSS_SOURCE.M

```
%script to build gtossrc
% copies source files from GTOSS original file structure as copied from the
zip files on theGTOSS CD
% to the distination directories

src='c:\users\john\gtoss_h9_6-11-01\"Source Code
vH9"';dstg='c:\users\john\gtoss_h9_6-11-01\gtossrc';
dci='c:\users\john\gtoss_h9_6-11-01\incs';dstc='c:\users\john\gtoss_h9_6-11-
01\ctossrc';
dstcg='c:\users\john\gtoss_h9_6-11-01\shared';

%build gtossrc
txt=['!copy ' src '\a_goss\g_general\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_goss\g_exec\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_goss\g_init\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_toss\t_exec\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_toss\t_general\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_toss\t_ggic\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_toss\t_init\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_toss\t_late_start\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_toss\t_scenario\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_toss\t_tss_deploy\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_foss\f_general\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_foss\f_init\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_foss\f_thermal\*.f ' dstg];eval(txt);
txt=['!copy ' src '\a_boss\b_general\*.f ' dstg];eval(txt);

%build incs
txt=['!copy ' src '\a_goss\*.i ' dci];eval(txt);
txt=['!copy ' src '\a_toss\*.i ' dci];eval(txt);
txt=['!copy ' src '\a_foss\*.i ' dci];eval(txt);
txt=['!copy ' src '\a_boss\*.i ' dci];eval(txt);
txt=['!copy ' src '\a_ross\*.i ' dci];eval(txt);
txt=['!copy ' src '\a_envr\*.i ' dci];eval(txt);

%build ctossrc
txt=['!copy ' src '\a_coss\c_exec\*.f ' dstc];eval(txt);
txt=['!copy ' src '\a_coss\c_shape_fmts\*.f ' dstc];eval(txt);
txt=['!copy ' src '\a_coss\c_time_fmts\*.f ' dstc];eval(txt);
txt=['!copy ' src '\a_coss\*.i ' dci];eval(txt);

%build shared
txt=['!copy ' src '\a_ross\r_ascii\*.f ' dstcg];eval(txt);
txt=['!copy ' src '\a_ross\r_aux\*.f ' dstcg];eval(txt);
txt=['!copy ' src '\a_ross\r_basic\*.f ' dstcg];eval(txt);
txt=['!copy ' src '\a_ross\r_exec\*.f ' dstcg];eval(txt);
txt=['!copy ' src '\a_ross\r_init\*.f ' dstcg];eval(txt);
txt=['!copy ' src '\a_ross\r_wild\*.f ' dstcg];eval(txt);
txt=['!copy ' src '\a_envr\*.f ' dstcg];eval(txt);
```

```
txt=['!copy ' src '\a_util\*.f ' dstcg];eval(txt);
```

EXECUTE.M

```
% Script to strip GTOSS source files for PC compilation

%dir = a_coss\c_shape_fmts

%list='YFM141.F YFM144.F YFM150.F YFM153.F YPHDSB.F YPLNSB.F YPSHSB.F
YFM142.F YFM145.F YFM151.F YPHDBB.F YPLNBB.F YPSHBB.F '
%list = [list 'YFM140.F YFM143.F YFM149.F YFM152.F YPHDBO.F YPLNBO.F YPSHBO.F
'];

%dir = a_coss\c_time_fmts

%list='YFM007.F YFM015.F YFM023.F YFM031.F YFM039.F YFM047.F YFM055.F
YFM008.F YFM016.F YFM024.F YFM032.F YFM040.F YFM048.F YPDFBB.F ';
%list=[list 'YFM001.F YFM009.F YFM017.F YFM025.F YFM033.F YFM041.F YFM049.F
YPDFBC.F '];
%list=[list 'YFM002.F YFM010.F YFM018.F YFM026.F YFM034.F YFM042.F YFM050.F
YPDFDP.F '];
%list=[list 'YFM003.F YFM011.F YFM019.F YFM027.F YFM035.F YFM043.F YFM051.F
YPDFTT.F '];
%list=[list 'YFM004.F YFM012.F YFM020.F YFM028.F YFM036.F YFM044.F YFM052.F
'];
%list=[list 'YFM005.F YFM013.F YFM021.F YFM029.F YFM037.F YFM045.F YFM053.F
'];
%list=[list 'YFM006.F YFM014.F YFM022.F YFM030.F YFM038.F YFM046.F YFM054.F
'];

%a_doss\d_exec

%list='CRTDIS.F DTOSS.F  INPUL.F  XFMT.F  XPRINT.F CRTPUL.F DTOSUB.F INPULI.F
XPLASO.F';
%list=[list 'XUNIT.F CLEANO.F DECIDE.F INCHEK.F XFEED.F  XPLINO.F '];

%dir = a_doss_\d_fmts

%list='YFM006.F YFM013.F YFM023.F YFM042.F YFM049.F YFM056.F YPDFEL.F ';
%list=[list 'YFM007.F YFM014.F YFM024.F YFM043.F YFM050.F YFM057.F YPDFTT.F
'];
%list=[list 'YFM001.F YFM008.F YFM015.F YFM025.F YFM044.F YFM051.F YFM058.F
'];
%list=[list 'YFM002.F YFM009.F YFM016.F YFM026.F YFM045.F YFM052.F YFM059.F
'];
%list=[list 'YFM003.F YFM010.F YFM017.F YFM039.F YFM046.F YFM053.F YFM060.F
'];
%list=[list 'YFM004.F YFM011.F YFM018.F YFM040.F YFM047.F YFM054.F YPDFBB.F
'];
%list=[list 'YFM005.F YFM012.F YFM019.F YFM041.F YFM048.F YFM055.F YPDFDP.F
'];

%dir=a_envr

%list='ATMOS.F  EFTEI.F  GAUSSG.F J20FRM.F M50FRM.F SUNPOS.F IRIT13.F ';
%list=[list 'ATMOS2.F EITEF.F  GEOD.F  JACHIA.F MONDAY.F WINDS.F  '];
```

```
%list=[list 'ATM62.F  ATMOS3.F GAUSS.F  GRAV.F   JULIAN.F MONSEC.F CIRA86.F
'];
%list=[list 'ATM76.F  GAUSS2.F GRAV4.F  M50EF.F  PLASMA.F IRIF13.F '];
%list=[list 'ATMO3V.F GAUSSD.F INTERP.F M50EFV.F SOLEPH.F IRIS13.F '];

%dir=a_foss\f_general

%list='TISSTW.F TNSBIT.F TNSCUP.F TNSHOK.F TNSPVS.F TNSTHR.F TOSSFM.F ';
%list=[list 'TISUTL.F TNSBRK.F TNSELC.F TNSHST.F TNSPVT.F TNSVEL.F '];
%list=[list 'TISFRM.F TNSAD1.F TNSBTH.F TNSFOR.F TNSMKS.F TNSSEG.F TNSXET.F
'];
%list=[list 'TISLDW.F TNSARO.F TNSBTI.F TNSFSI.F TNSPRG.F TNSSGT.F TNSYET.F
'];

%dir=a_foss\f_init

%list='TISSV.F  TNSBMV.F TNSKPV.F TISZZ.F  TNSHIC.F TNSWAV.F ';

%dir=a_foss\f_thermal

%list='QDALBN.F QDEBBN.F QDSOLN.F TNSQD.F  TNSQDS.F ';

%dir=a_goss\g_general

%list='ADAM1D.F APSPUT.F DERMAS.F DRAGO.F  GGTORK.F PGCALC.F RPAFOR.F
RPATTC.F ';
%list=[list 'APSGET.F DERIV.F  DERROT.F EVLVIR.F NEWRPS.F PLNFIX.F RPAMOM.F
'];

%dir=a_goss\g_general

%list='COMLAT.F CRTHD.F  GTOSS.F  INPUT.F  LOOKLN.F  COMSNP.F CRTRUN.F
GTOSUB.F INTEST.F OUTPUT.F '
%list=[list 'COMGRB.F CRTDOT.F DECIDE.F HOSSTG.F LOOKHD.F POPREF.F '];

%dir=a_goss\g_init

%list='INITIA.F INITSS.F INIVIR.F INTROT.F INTTRN.F ';

%dir=a_ross\r_ascii

%list='POPIDB.F POPIDO.F POPIDS.F POPIDT.F '

%dir=a_ross\a_aux

%list='POPAXB.F POPAXJ.F PULAXA.F PULAXG.F PULAXT.F ';
%list=[list 'POPAXF.F POPAXK.F PULAXB.F PULAXJ.F ']
%list=[list 'POPAXA.F POPAXG.F POPAXT.F PULAXF.F PULAXK.F '];

%dir=a_ross\r_basic

%list='POPBSA.F POPBST.F PULBSB.F POPBSB.F PULBSA.F PULBST.F ';

%dir=a_ross\r_exec

%list='FIXPTH.F MACPTH.F POPDBO.F PULCLO.F PULOPN.F RDBOPN.F ';
%list=[list 'GETPTH.F NEWNAM.F POPID.F  PULDB.F  RDBCLO.F '];
```

```
%list=[list 'GTROOT.F POPDB.F  POPIDX.F PULNAM.F RDBNME.F '];
%dir=a_ross\r_init

%list='RDBIC.F  RDBSET.F RDBZZ.F';

%dir=a_ross\r_wild

%list='POPBSF.F POPBSK.F POPJ1.F  PULBSG.F PULF1.F  PULK1.F';
%list=[list 'POPBSG.F POPF1.F  POPK1.F  PULBSJ.F PULG1.F ' ];
%list=[list 'POPBSJ.F POPG1.F  PULBSF.F PULBSK.F PULJ1.F ' ];

%dir=a_soss\s_analytic

%list='OBJEUL.F POPMAG.F POPSOL.F SCLGEN.F SUPEUL.F ';
%list=[list 'OFBBS.F  POPSCL.F POPTET.F SCLUSR.F '];
%list=[list 'FINDCN.F POPFOS.F POPSOB.F SCALIT.F SOBDEF.F '];

%dir=a_soss\s_disp_list

%list='YCHSTL.F YFSORG.F YOBFIL.F YOFFIL.F YTTLIN.F YVVPEN.F YXXPEN.F ';
%list=[list 'YCHSTR.F YFSPEN.F YOBORG.F YOFPEN.F YTTPEN.F YVVROT.F YXXROT.F
'];
%list=[list 'YCHFIL.F YCHTXT.F YMNORG.F YOBPEN.F YOFSCL.F YTTSTR.F YVVSCL.F
YXXSCL.F '];
%list=[list 'YCHFNT.F YDRAW.F  YMNROT.F YOBROT.F YPPPEN.F YVVFIL.F YXXFIL.F
'];
%list=[list 'YCHREC.F YFSLIN.F YMNSCL.F YOBSCL.F YPPPNT.F YVVORG.F YXXORG.F
'];

%dir=a_soss\s_exec

list='CRTDIS.F INCHEK.F INPUL.F  STOSS.F  SUPOPN.F CRTPUL.F INIPEN.F SHOWID.F
STOSUB.F XCOLOR.F ';
list=[list 'CLEANO.F DECIDE.F INIPPS.F SHOWTX.F SUPINT.F XSUPER.F '];

%dir=a_toss\t_exec

%list='TOSBD.F  TOSBJ.F  TOSDIC.F TOSLIN.F TOSQF.F  TOSQL.F ';
%list=[list 'TOSBF.F  TOSBL.F  TOSIN.F  TOSQD.F  TOSQJ.F  TOSRIN.F '];

%dir=a_toss\t_general

%list='TOSCAL.F TOSCNA.F TOSEXE.F TOSLDW.F TOSROT.F TOSRR4.F TOSSTW.F ';
%list=[list 'TOSCN.F  TOSCND.F TOSGET.F TOSMS.F  TOSRR1.F TOSSA.F  TOSTEN.F
'];
%list=[list 'TOSAE.F  TOSCN2.F TOSCNF.F TOSGR.F  TOSMS2.F TOSRR2.F TOSSET.F
TOSTHR.F '];
%list=[list 'TOSATT.F TOSCN3.F TOSCNL.F TOSHOW.F TOSPUT.F TOSRR3.F TOSSRP.F
'];

%dir=a_toss\t_ggic

%list='TOZCON.F TOZDIF.F TOZGGV.F TOZTTS.F TOZDBB.F TOZGGT.F TOZTTN.F ';

%dirf=a_toss\t_init

%list='TOSBV.F  TOSBVA.F TOSBVT.F TOSQV.F  TOSZZ.F ';
```

```
%dir=a_toss\t_late_start

%list='XGAPS.F  XGRABI.F XGRABS.F XSNAP.F  XSNAPL.F  XGRAB.F  XGRABL.F
XSAPS.F  XSNAPI.F XSNAPS.F ';

%dir=t_scenario

list='CMODE1.F CMODE4.F TOSSF2.F TOSSF5.F TOSSF8.F TOSSFU.F TOSSH3.F TOSSH6.F
';
list=[list 'CMODE2.F CURCAL.F TOSSF3.F TOSSF6.F TOSSF9.F TOSSH1.F TOSSH4.F
TOSSHU.F '];
list=[list 'CMODE3.F TOSSF1.F TOSSF4.F TOSSF7.F TOSSFQ.F TOSSH2.F TOSSH5.F
'];

%dir=t_tss_deploy

%list='FOFT.F   MMF.F    MMGSED.F MMGSEL.F MMI.F    MMO.F    RESUME.F ';
%list=[list 'MMD.F MMGSE.F  MMGSEF.F MMGSEV.F MML.F    MMV.F    TERP.F'];

%dir=a_uoss\u_exec

%list='CLEANO.F DECIDE.F ICEXP.F  INCHEU.F UTOSS.F  XPOPEX.F XUNIT.F ';
%list=[list 'CRTDIS.F EXPCLO.F ICIMP.F  INPULU.F UTOSUB.F XPORTO.F '];
%list=[list 'ALLCLO.F CRTPUL.F EXPOPN.F IMPOPN.F SNAPEV.F XFCHUZ.F XPULEX.F
'];

%dir=a_uoss\u_fmt

%list='Y04BSB.F Y04POP.F YFMT02.F YFMT06.F YFMT50.F YFMT54.F ';
%list=[list 'Y04BSG.F Y04RPS.F YFMT03.F YFMT07.F YFMT51.F YFMT55.F '];
%list=[list 'GETTPT.F Y04BSM.F Y04TET.F YFMT04.F YFMT08.F YFMT52.F '];
%list=[list 'Y04APS.F Y04BST.F YFMT01.F YFMT05.F YFMT09.F YFMT53.F '];

%dir=a_util

%list='DMOUSE.F MATDIF.F MATSNV.F RIBXYZ.F TOPOGR.F VECMAT.F XYZRIB.F ';
%list=[list 'DOT.F    MATEUL.F MATSUM.F SHOERR.F TR3SOL.F VECMOV.F '];
%list=[list 'ADAM.F   EULICS.F MATFIX.F MATVEC.F SLINT.F  TR4SOL.F VECNRM.F
'];
%list=[list 'CROSS.F  EULINT.F MATMOV.F NCROSS.F TCROSS.F TR5SOL.F VECSCL.F
'];
%list=[list 'DAYNIT.F EULMAT.F MATMUL.F NEWPAG.F TDOT.F   VECDIF.F VECSUM.F
'];
%list=[list 'DLINT.F  LIBXYZ.F MATSCL.F ORBFRM.F TOPOGA.F VECMAG.F XYZLIB.F
'];

%dir=a_voss\v_exec

%list='ALLCLO.F CRTPUL.F INCHEV.F INPULV.F VTOSS.F  XFCHUZ.F ';
%list=[list 'CRTDIS.F DECIDE.F INFOPN.F REPOPN.F VTOSUB.F '];

%dir=a_voss\v_fmts

%list='YFMT01.F YFMT02.F YFMT03.F YFMT04.F YFMT50.F ';

%dir=a_boss\b_general
```

```
%list='BOMDAT.F BOMDER.F BOMLOD.F BOMTIP.F BOOMID.F ';

%dir=gtossrc

listg='ADAM.F   EULINT.F MATMOV.F POPBSJ.F QDEBBN.F TNSHST.F TOSIN.F
TOSSTW.F ';
listg=[listg 'ADAM1D.F EULMAT.F MATMUL.F POPBSK.F QDSOLN.F TNSKPV.F TOSLDW.F
TOSTEN.F '];
listg=[listg 'APSGET.F EVLVIR.F MATSCL.F POPBST.F RDBCLO.F TNSMKS.F TOSLIN.F
TOSTHR.F '];
listg=[listg 'APSPUT.F FIXPTH.F MATSNV.F POPDB.F  RDBIC.F  TNSPRG.F TOSMS.F
TOSZZ.F  '];
listg=[listg 'ATM62.F  FOFT.F   MATSUM.F POPDBO.F RDBNME.F TNSPVS.F TOSMS2.F
TOZCON.F '];
listg=[listg 'ATM76.F  GAUSS.F  MATVEC.F POPF1.F  RDBOPN.F TNSPVT.F TOSPUT.F
TOZDBB.F '];
listg=[listg 'ATMO3V.F GAUSS2.F MMD.F    POPG1.F  RDBSET.F TNSQD.F  TOSQD.F
TOZDIF.F '];
listg=[listg 'ATMOS.F  GAUSSD.F MMF.F    POPID.F  RDBZZ.F  TNSQDS.F TOSQF.F
TOZGGT.F '];
listg=[listg 'ATMOS2.F GAUSSG.F MMGSE.F  POPIDB.F RESUME.F TNSSEG.F TOSQJ.F
TOZGGV.F '];
listg=[listg 'ATMOS3.F GEOD.F   MMGSED.F POPIDO.F RIBXYZ.F TNSSGT.F TOSQL.F
TOZTTN.F '];
listg=[listg 'BOMDAT.F GETPTH.F MMGSEF.F POPIDS.F RPAFOR.F TNSTHR.F TOSQV.F
TOZTTS.F '];
listg=[listg 'BOMDER.F GGTORK.F MMGSEL.F POPIDT.F RPAMOM.F TNSVEL.F TOSRIN.F
TR3SOL.F '];
listg=[listg 'BOMLOD.F GRAV.F   MMGSEV.F POPIDX.F RPATTC.F TNSWAV.F TOSROT.F
TR4SOL.F '];
listg=[listg 'BOMTIP.F GRAV4.F  MMI.F    POPJ1.F  SHOERR.F TNSXET.F TOSRR1.F
TR5SOL.F '];
listg=[listg 'BOOMID.F GTOSS.F  MML.F    POPK1.F  SLINT.F  TNSYET.F TOSRR2.F
VECDIF.F '];
listg=[listg 'CMODE1.F GTOSUB.F MMO.F    POPREF.F SOLEPH.F TOPOGA.F TOSRR3.F
VECMAG.F '];
listg=[listg 'CMODE2.F GTROOT.F MMV.F    PULAXA.F SUNPOS.F TOPOGR.F TOSRR4.F
VECMAT.F '];
listg=[listg 'CMODE3.F HOSSTG.F MONDAY.F PULAXB.F TCROSS.F TOSAE.F  TOSSA.F
VECMOV.F '];
listg=[listg 'CMODE4.F INITIA.F MONSEC.F PULAXF.F TDOT.F   TOSATT.F TOSSET.F
VECNRM.F '];
listg=[listg 'COMGRB.F INITSS.F NCROSS.F PULAXG.F TERP.F   TOSBD.F  TOSSF1.F
VECSCL.F '];
listg=[listg 'COMLAT.F INIVIR.F NEWNAM.F PULAXJ.F TISFRM.F TOSBF.F  TOSSF2.F
VECSUM.F '];
listg=[listg 'COMSNP.F INPUT.F  NEWPAG.F PULAXK.F TISLDW.F TOSBJ.F  TOSSF3.F
WINDS.F  '];
listg=[listg 'CROSS.F  INTERP.F NEWRPS.F PULAXT.F TISSTW.F TOSBL.F  TOSSF4.F
XGAPS.F  '];
listg=[listg 'CRTDOT.F INTEST.F ORBFRM.F PULBSA.F TISSV.F  TOSBV.F  TOSSF5.F
XGRAB.F  '];
listg=[listg 'CRTHD.F  INTROT.F OUTPUT.F PULBSB.F TISUTL.F TOSBVA.F TOSSF6.F
XGRABI.F '];
listg=[listg 'CRTRUN.F INTTRN.F PGCALC.F PULBSF.F TISZZ.F  TOSBVT.F TOSSF7.F
XGRABL.F '];
```

```
listg=[listg 'CURCAL.F J20FRM.F PLASMA.F PULBSG.F TNSAD1.F TOSCAL.F TOSSF8.F
XGRABS.F '];
listg=[listg 'DAYNIT.F JACHIA.F PLNFIX.F PULBSJ.F TNSARO.F TOSCN.F  TOSSF9.F
XSAPS.F  '];
listg=[listg 'DECIDE.F JULIAN.F POPAXA.F PULBSK.F TNSBIT.F TOSCN2.F TOSSFM.F
XSNAP.F  '];
listg=[listg 'DERIV.F  LIBXYZ.F POPAXB.F PULBST.F TNSBMV.F TOSCN3.F TOSSFQ.F
XSNAPI.F '];
listg=[listg 'DERMAS.F LOOKHD.F POPAXF.F PULCLO.F TNSBRK.F TOSCNA.F TOSSFU.F
XSNAPL.F '];
listg=[listg 'DERROT.F LOOKLN.F POPAXG.F PULDB.F  TNSBTH.F TOSCND.F TOSSH1.F
XSNAPS.F '];
listg=[listg 'DLINT.F  M50EF.F  POPAXJ.F PULF1.F  TNSBTI.F TOSCNF.F TOSSH2.F
XYZLIB.F '];
listg=[listg 'DMOUSE.F M50EFV.F POPAXK.F PULG1.F  TNSCUP.F TOSCNL.F TOSSH3.F
XYZRIB.F '];
listg=[listg 'DOT.F    M50FRM.F POPAXT.F PULJ1.F  TNSELC.F TOSDIC.F TOSSH4.F
cira86.f '];
listg=[listg 'DRAGO.F  MACPTH.F POPBSA.F PULK1.F  TNSFOR.F TOSEXE.F TOSSH5.F
irif13.f '];
listg=[listg 'EFTEI.F  MATDIF.F POPBSB.F PULNAM.F TNSFSI.F TOSGET.F TOSSH6.F
iris13.f '];
listg=[listg 'EITEF.F  MATEUL.F POPBSF.F PULOPN.F TNSHIC.F TOSGR.F  TOSSHU.F
irit13.f '];
listg=[listg 'EULICS.F MATFIX.F POPBSG.F QDALBN.F TNSHOK.F TOSHOW.F TOSSRP.F
'];

%revised list of files in gtossrc
listg='COMSNP.F  INITIA.F  MMI.F     TERP.F    TNSFOR.F  TNSWAV.F  TOSCNA.F
TOSQF.F   TOSSF5.F  TOSSTW.F  XSAPS.F ';
listg=[listg 'CRTDOT.F  INITSS.F  MML.F     TISFRM.F  TNSFSI.F  TNSXET.F
TOSCND.F  TOSQJ.F   TOSSF6.F  TOSTEN.F  XSNAP.F '];
listg=[listg 'ADAM1D.F  CRTHD.F   INIVIR.F  MMO.F     TISLDW.F  TNSHIC.F
TNSYET.F  TOSCNF.F  TOSQL.F   TOSSF7.F  TOSTHR.F  XSNAPI.F '];
listg=[listg 'APSGET.F  CRTRUN.F  INPUT.F   MMV.F     TISSTW.F  TNSHOK.F
TOSAE.F   TOSCNL.F  TOSQV.F   TOSSF8.F  TOSZZ.F   XSNAPL.F '];
listg=[listg 'APSPUT.F  CURCAL.F  INTEST.F  NEWRPS.F  TISSV.F   TNSHST.F
TOSATT.F  TOSDIC.F  TOSRIN.F  TOSSF9.F  TOZCON.F  XSNAPS.F '];
listg=[listg 'BOMDAT.F  DECIDE.F  INTROT.F  OUTPUT.F  TISUTL.F  TNSKPV.F
TOSBD.F   TOSEXE.F  TOSROT.F  TOSSFM.F  TOZDBB.F '];
listg=[listg 'BOMDER.F  DERIV.F   INTTRN.F  PGCALC.F  TISZZ.F   TNSMKS.F
TOSBF.F   TOSGET.F  TOSRR1.F  TOSSFQ.F  TOZDIF.F '];
listg=[listg 'BOMLOD.F  DERMAS.F  LOOKHD.F  PLNFIX.F  TNSAD1.F  TNSPRG.F
TOSBJ.F   TOSGR.F   TOSRR2.F  TOSSFU.F  TOZGGT.F '];
listg=[listg 'BOMTIP.F  DERROT.F  LOOKLN.F  POPREF.F  TNSARO.F  TNSPVS.F
TOSBL.F   TOSHOW.F  TOSRR3.F  TOSSH1.F  TOZGGV.F '];
listg=[listg 'BOOMID.F  DRAGO.F   MMD.F     QDALBN.F  TNSBIT.F  TNSPVT.F
TOSBV.F   TOSIN.F   TOSRR4.F  TOSSH2.F  TOZTTN.F '];
listg=[listg 'CMODE1.F  EVLVIR.F  MMF.F     QDEBBN.F  TNSBMV.F  TNSQD.F
TOSBVA.F  TOSLDW.F  TOSSA.F   TOSSH3.F  TOZTTS.F '];
listg=[listg 'CMODE2.F  FOFT.F    MMGSE.F   QDSOLN.F  TNSBRK.F  TNSQDS.F
TOSBVT.F  TOSLIN.F  TOSSET.F  TOSSH4.F  XGAPS.F '];
listg=[listg 'CMODE3.F  GGTORK.F  MMGSED.F  RESUME.F  TNSBTH.F  TNSSEG.F
TOSCAL.F  TOSMS.F   TOSSF1.F  TOSSH5.F  XGRAB.F '];
listg=[listg 'CMODE4.F  GTOSS.F   MMGSEF.F  RPAFOR.F  TNSBTI.F  TNSSGT.F
TOSCN.F   TOSMS2.F  TOSSF2.F  TOSSH6.F  XGRABI.F '];
```

```
listg=[listg 'COMGRB.F  GTOSUB.F  MMGSEL.F  RPAMOM.F  TNSCUP.F  TNSTHR.F
TOSCN2.F  TOSPUT.F  TOSSF3.F  TOSSHU.F  XGRABL.F '];
listg=[listg 'COMLAT.F  HOSSTG.F  MMGSEV.F  RPATTC.F  TNSELC.F  TNSVEL.F
TOSCN3.F  TOSQD.F   TOSSF4.F  TOSSRP.F  XGRABS.F '];

%dir=incs

listi='COM_BOOM.i COM_COSS.i COM_ROSS.i EQU_FOSS.i EQU_OBJ.i  EQU_TOSS.i
COM_FOSS.i COM_RPS.i  EQU_HOST.i EQU_OBJI.i ';
listi=[listi 'COM_ALL.i  COM_HOST.i COM_TOSS.i EQU_MMDS.i EQU_OBS2.i CATMO3.i
CM50EF.i'];

%files in ctossrc

listc='EFTEI.F   JULIAN.F  ORBFRM.F  POPID.F   PULBSK.f  SLINT.F   WINSET.f
YFM014.f  YFM034.f  YFM054.f  YPLNBB.f ';
listc=[listc 'EITEF.F   LIBXYZ.F  PLASMA.F  POPIDB.F  PULBST.f  SOLEPH.F
XFMT.f    YFM015.f  YFM035.f  YFM055.f  YPLNBO.f '];
listc=[listc 'ADAM.F    EULICS.F  M50EF.F   POPAXA.F  POPIDO.F  PULCLO.f
SUNPOS.F  XROWPO.f  YFM016.f  YFM036.f  YFM140.f  YPLNSB.f  '];
listc=[listc 'ATM62.F   EULINT.F  M50EFV.F  POPAXB.F  POPIDS.F  PULDB.f
TCROSS.F  XUNITS.f  YFM017.f  YFM037.f  YFM141.f  YPSHBB.f  '];
listc=[listc 'ATM76.F   EULMAT.F  M50FRM.F  POPAXF.F  POPIDT.F  PULF1.f
TDOT.F    XWINDO.f  YFM018.f  YFM038.f  YFM142.f  YPSHBO.f  '];
listc=[listc 'ATMO3V.F  FIXPTH.F  MACPTH.F  POPAXG.F  POPIDX.F  PULG1.f
TOPOGA.F  XYZLIB.F  YFM019.f  YFM039.f  YFM143.f  YPSHSB.f  '];
listc=[listc 'ATMOS.F   GAUSS.F   MATDIF.F  POPAXJ.F  POPJ1.F   PULJ1.f
TOPOGR.F  XYZRIB.F  YFM020.f  YFM040.f  YFM144.f  cira86.f  '];
listc=[listc 'ATMOS2.F  GAUSS2.F  MATEUL.F  POPAXK.F  POPK1.F   PULK1.f
TR3SOL.F  YFM001.f  YFM021.f  YFM041.f  YFM145.f  irif13.f  '];
listc=[listc 'ATMOS3.F  GAUSSD.F  MATFIX.F  POPAXT.F  PULAXA.f  PULNAM.f
TR4SOL.F  YFM002.f  YFM022.f  YFM042.f  YFM149.f  iris13.f  '];
listc=[listc 'CLEANO.f  GAUSSG.F  MATMOV.F  POPBSA.F  PULAXB.f  PULOPN.f
TR5SOL.F  YFM003.f  YFM023.f  YFM043.f  YFM150.f  irit13.f  '];
listc=[listc 'CROSS.F   GEOD.F    MATMUL.F  POPBSB.F  PULAXF.f  RDBCLO.F
VECDIF.F  YFM004.f  YFM024.f  YFM044.f  YFM151.f  '];
listc=[listc 'CRTDIS.f  GETPTH.F  MATSCL.F  POPBSF.F  PULAXG.f  RDBIC.F
VECMAG.F  YFM005.f  YFM025.f  YFM045.f  YFM152.f  '];
listc=[listc 'CRTPUL.f  GRAV.F    MATSNV.F  POPBSG.F  PULAXJ.f  RDBNME.F
VECMAT.F  YFM006.f  YFM026.f  YFM046.f  YFM153.f  '];
listc=[listc 'CTOSS.f   GRAV4.F   MATSUM.F  POPBSJ.F  PULAXK.f  RDBOPN.F
VECMOV.F  YFM007.f  YFM027.f  YFM047.f  YPDFBB.f  '];
listc=[listc 'CTOSUB.f  GTROOT.F  MATVEC.F  POPBSK.F  PULAXT.f  RDBSET.F
VECNRM.F  YFM008.f  YFM028.f  YFM048.f  YPDFBC.f  '];
listc=[listc 'DAYNIT.F  INCHEK.f  MONDAY.F  POPBST.F  PULBSA.f  RDBZZ.F
VECSCL.F  YFM009.f  YFM029.f  YFM049.f  YPDFDP.f  '];
listc=[listc 'DECIDE.f  INPUL.f   MONSEC.F  POPDB.F   PULBSB.f  RIBXYZ.F
VECSUM.F  YFM010.f  YFM030.f  YFM050.f  YPDFTT.f  '];
listc=[listc 'DLINT.F   INTERP.F  NCROSS.F  POPDBO.F  PULBSF.f  SHAPEV.f
WINCLO.f  YFM011.f  YFM031.f  YFM051.f  YPHDBB.f  '];
listc=[listc 'DMOUSE.F  J20FRM.F  NEWNAM.F  POPF1.F   PULBSG.f  SHOERR.F
WINDS.F   YFM012.f  YFM032.f  YFM052.f  YPHDBO.f  '];
listc=[listc 'DOT.F     JACHIA.F  NEWPAG.F  POPG1.F   PULBSJ.f  SHPSAV.f
WINOPN.f  YFM013.f  YFM033.f  YFM053.f  YPHDSB.f  '];

%Revised list of files in ctossrc
```

```
listc='INPUL.F   XWINDO.F  YFM009.F  YFM018.F  YFM027.F  YFM036.F  YFM045.F
YFM054.F  YFM150.F  YPHDBO.F ';
listc=[listc 'SHAPEV.F  YFM001.F  YFM010.F  YFM019.F  YFM028.F  YFM037.F
YFM046.F  YFM055.F  YFM151.F  YPHDSB.F '];
listc=[listc 'CLEANO.F  SHPSAV.F  YFM002.F  YFM011.F  YFM020.F  YFM029.F
YFM038.F  YFM047.F  YFM140.F  YFM152.F  YPLNBB.F '];
listc=[listc 'CRTDIS.F  WINCLO.F  YFM003.F  YFM012.F  YFM021.F  YFM030.F
YFM039.F  YFM048.F  YFM141.F  YFM153.F  YPLNBO.F '];
listc=[listc 'CRTPUL.F  WINOPN.F  YFM004.F  YFM013.F  YFM022.F  YFM031.F
YFM040.F  YFM049.F  YFM142.F  YPDFBB.F  YPLNSB.F '];
listc=[listc 'CTOSS.F   WINSET.F  YFM005.F  YFM014.F  YFM023.F  YFM032.F
YFM041.F  YFM050.F  YFM143.F  YPDFBC.F  YPSHBB.F '];
listc=[listc 'CTOSUB.F  XFMT.F    YFM006.F  YFM015.F  YFM024.F  YFM033.F
YFM042.F  YFM051.F  YFM144.F  YPDFDP.F  YPSHBO.F '];
listc=[listc 'DECIDE.F  XROWPO.F  YFM007.F  YFM016.F  YFM025.F  YFM034.F
YFM043.F  YFM052.F  YFM145.F  YPDFTT.F  YPSHSB.F '];
listc=[listc 'INCHEK.F  XUNITS.F  YFM008.F  YFM017.F  YFM026.F  YFM035.F
YFM044.F  YFM053.F  YFM149.F  YPHDBB.F '];

% list of files in shared

lists='DMOUSE.F  GEOD.F    M50FRM.F  NCROSS.F  POPBSA.F  POPIDB.F  PULAXK.F
PULG1.F   SHOERR.F  VECMAG.F  irit13.f ';
lists=[lists 'DOT.F     GETPTH.F  MATDIF.F  NEWNAM.F  POPBSB.F  POPIDO.F
PULAXT.F  PULJ1.F   SLINT.F   VECMAT.F '];
lists=[lists 'ADAM.F    EFTEI.F   GRAV.F    MATEUL.F  NEWPAG.F  POPBSF.F
POPIDS.F  PULBSA.F  PULK1.F   SOLEPH.F  VECMOV.F '];
lists=[lists 'ATM62.F   EITEF.F   GRAV4.F   MATFIX.F  ORBFRM.F  POPBSG.F
POPIDT.F  PULBSB.F  PULNAM.F  SUNPOS.F  VECNRM.F '];
lists=[lists 'ATM76.F   EULICS.F  GTROOT.F  MATMOV.F  PLASMA.F  POPBSJ.F
POPIDX.F  PULBSF.F  PULOPN.F  TCROSS.F  VECSCL.F '];
lists=[lists 'ATMO3V.F  EULINT.F  INTERP.F  MATMUL.F  POPAXA.F  POPBSK.F
POPJ1.F   PULBSG.F  RDBCLO.F  TDOT.F    VECSUM.F '];
lists=[lists 'ATMOS.F   EULMAT.F  J20FRM.F  MATSCL.F  POPAXB.F  POPBST.F
POPK1.F   PULBSJ.F  RDBIC.F   TOPOGA.F  WINDS.F '];
lists=[lists 'ATMOS2.F  FIXPTH.F  JACHIA.F  MATSNV.F  POPAXF.F  POPDB.F
PULAXA.F  PULBSK.F  RDBNME.F  TOPOGR.F  XYZLIB.F '];
lists=[lists 'ATMOS3.F  GAUSS.F   JULIAN.F  MATSUM.F  POPAXG.F  POPDBO.F
PULAXB.F  PULBST.F  RDBOPN.F  TR3SOL.F  XYZRIB.F '];
lists=[lists 'CROSS.F   GAUSS2.F  LIBXYZ.F  MATVEC.F  POPAXJ.F  POPF1.F
PULAXF.F  PULCLO.F  RDBSET.F  TR4SOL.F  cira86.f '];
lists=[lists 'DAYNIT.F  GAUSSD.F  M50EF.F   MONDAY.F  POPAXK.F  POPG1.F
PULAXG.F  PULDB.F   RDBZZ.F   TR5SOL.F  irif13.f '];
lists=[lists 'DLINT.F   GAUSSG.F  M50EFV.F  MONSEC.F  POPAXT.F  POPID.F
PULAXJ.F  PULF1.F   RIBXYZ.F  VECDIF.F  iris13.f '];

cd c:\users\john\gtoss_h9_6-11-01\gtossrc
process(listg);
!del *.f
!ren *.f_out *.f
!ren decide.f decideg.f
cd ..\incs
process(listi);
!del *.inc
!del *.i
!ren *.i_out *.inc
cd ..\ctossrc
```

```
process(listc);
!del *.f
!ren *.f_out *.f
!ren decide.f decidec.f
cd ..\shared
process(lists);
!del *.f
!ren *.f_out *.f
!copy ..\gtossrc\tosldw.f .
!del ..\gtossrc\tosldw.f
!copy ..\gtossrc\tosstw.f .
!del ..\gtossrc\tosstw.f
!copy ..\gtossrc\tisldw.f .
!del ..\gtossrc\tisldw.f
!copy ..\gtossrc\tisstw.f .
!del ..\gtossrc\tisstw.f
!copy puldb.f ..\ctossrc
!del puldb.f
!del macpth.f
```

PARSER.M

```
function [part1,listout]=parser(listin)
% This function parses a list of *.f source files to pass to another function
which reads each function and strips out the sequence
% C@DOS so that it can be used to build the latest version of GTOSS more
easily.

ln=length(listin);
reading=1;istart=1;iend=2;
while reading==1 & iend<ln;
   if listin(iend-1:iend) == '.F' | listin(iend-1:iend) == '.f' |
listin(iend-1:iend) == '.I' | listin(iend-1:iend) == '.i'
      reading=0;
   else
      iend=iend+1;
   end
end

istart=iend-2;
if istart<1 istart=1; end
while listin(istart) ~=' ' & istart>1
   istart=istart-1;
end
if listin(istart) ==' '; istart=istart+1;end
part1=listin(istart:iend);
if iend<ln
   listout=listin(iend+1:ln);
else
   listout='';
end
```

PROCESS.M

```
function process(list)

listin=list;
while length(listin)>3
   [part1 listout]=parser(listin);
   out=gtoss_source_proc(part1);
   listin=listout;
end
```

GTOSS_SOURCE_PROC.M

```
function [line]=gtoss_source_proc(name);
%Function to read gtoss source files and uncomment PC lines
%function [textout]=gtoss_source_proc(name);

% read source files for GTOSS, uncomment DOS lines, Dr. up end-of-line
problem write to output file

noerr = 1;
fid=fopen(name);fid2=fopen([name '_out'],'w');

while noerr == 1
   line=fgets(fid);
   if line(1) == -1 noerr = 0;
   else
      len=length(line);
      if len >=11
         if line(1:11)=='C@DOS      ' line=[char(9) line(12:len)]; end;
      end
      len=length(line);
      if len >=5
         if line(1:5)=='C@DOS' line=line(6:len); end;
      end
      len=length(line);
      if line(len)==char(13);
%  Adds a linefeed character, if absent, to account for MAC-to-PC conversion.
         line=[line char(10)];
      end
      fprintf(fid2,'%s', line);
   end
end
ex=fclose(fid);ex=fclose(fid2);
```

APPENDIX C
MOMENTUM TRANSFER TETHER SPINNING SYSTEM INPUT FILE

INGOSS

```
$MX_001
  Momentum Xsfer Tether.  10,000 - 1000 kg system masses, 100 km tether.
  Rotating configuration to study dynamics of tether system spin.

   1  0.100          DELTAT: REF PT
   2  10800.         TMAX
   3  250.000        N, THE RDB SOLN OUTPUT INTERVAL = N * DELTAT
   4  0.0            START RDB OUTPUT AT THIS TIME
  16  1.000          RUN NUMBER
  17  4.0            CRT OUTPUT EVERY M RDB INTERVALS
  94  -1.0           -1 SUPPRESSES DOT OUTPUTS TO CRT

C LATE START SNAPSHOTS
398  1.0           TAKE LATE START SNAPSHOTS
387  250.0         TIME FOR FIRST SNAPSHOT DUMP
388  500.0         TIME FOR 2ND SNAPSHOT DUMP
389  750.0         Time for 3rd snapshot dump
390  1250000.
c391  2000000.

C REFERENCE DATE CORRESPONDING TO ZERO SIMULATION RUN TIME
287  2003.         YEAR
288    10.         MONTH
289    10.         DAY
290    18.         HOUR
291     0.         MINUTE
292     0.         SECOND


C QUICK LOOK PAGE FORMAT CONTROL
117  1.            SELECT QUICK LOOK PAGE FORMAT
381  2.0           CHOOSE TOSS OBJ FOR QUICK LOOK (IF APPROP)
382  1.              "     "
421  1.0           CHOOSE TOSS TETHER FOR QUICK LOOK (IF APPROP)
422  2.              "     "
435  1.0           CHOOSE FINITE SOLN FOR QUICK LOOK (IF APPROP)
442  2.            BEAD NUMBER TO DISPLAY FOR QUICK LOOK (IF APPROP)
443  3.              "    "
444  5.              "    "

C GTOSS EXECUTION CONTROL DATA
111  1.            = 1. TO INHIBIT ROTATIONAL DYNAMICS (PARTICLE OPT)
112  3.            EULER ANGLE TYPE OF REF PT (Pitch,roll,yaw)
113  2.            NUMBER OF LAST TOSS OBJECT BEING SIMULATED
114  1.            NUMBER OF ATTACH PTS ON THE REF POINT

C PLANETARY ENVIRONMENT SIMULATION FIDELITY LEVEL(GLOBAL TO TOSS)
481  0.            ACCEL OF GRAVITY (0.0 =SPHERICAL; 1.0 =OBLATE EARTH)
482  1.            ATMOSPHERIC DENSITY MODEL (0.0 =EARTH ARDC 1976)
483  5.            MAGNETIC FIELD (0.0 =EARTH TILTED/SHIFTED DIPOLE)
484  0.            PLANET GLOBE SHAPE (0.0 =SPHERICAL EARTH)
```

```
485  0.              WINDS MODEL (0.0 =ROTATING EARTH, NO PERTURBS)
486  2.              INERTIAL FRAME (0.0 =FOR INITIALLY-EARTH-ALIGNED)
487  3.              Global Euler Angles (RP & TOSS Obj)- Pitch, Roll, Yaw

563  1.0             Time between ATMOS evals
564  1.0             Time between MAGNETIC evals
565  1.0             Time between WIND evals
566  1.0             Time between PLASMA evals

C BASIC REF PT GEOMETRY
 20    685.2         REF PT MASS (SLUGS) = 10,000 kg (includes tether)
 21    000.0         IXX: REF PT (SLUG-FT**2)
 22    000.0         IYY
 23    000.0         IZZ

 24  0.0             XCG: REF PT CENTER OF MASS LOC (FT)
 25  0.0             YCG
 26  0.0             ZCG
 27  0.0             IXY: REF PT INERTIA PRODS (SLUG-FT**2)
 28  0.0             IXZ
 29  0.0             IYZ

C REF PT TRANSLATION STATE INITIALIZATION
100  1.0             TRNS IC OPT: =0. TOPO;=1. INERTIAL;=2 circ

C FOR TRANSLATION IC OPTION = 1.0
 81    22238074.15      XIO REF PT POSITION (FT) [INER FRAME]
 82           0.0       YIO  "        "
 83           0.0       ZIO  "        "
 84           0.0       XIDO REF PT RATE (FT/SEC) [INER FRAME]
 85       24288.02      YIDO  "      "
 86           0.0       ZIDO  "      "

C FOR TRANSLATION IC OPTION = 0.0
101  1312000.         REF PT  ALT (FT) = 400 km (perigee)
102        0.0        REF PT  TOPO LONGITUDE (DEG)
103        0.0        REF PT  TOPO LATITUDE (DEG)
 80       36.0        Azimuth (inclination)

C ATTACH PT COORDS (ONLY 1 USED FOR PARTICLE REF PT)
134        0.00       PXBT1: REF PT (FT) X COORD OF ATTACH PT 1
142        0.00       PYBT1: REF PT (FT) Y COORD OF ATTACH PT 1
150        0.00       PZBT1: REF PT (FT) Z COORD OF ATTACH PT 1

C SIMPLE REF POINT AERO DRAG OPT DATA
455  1.                =1. TO ACTIVATE SIMPLE DRAG OPTION ON REF PT
456  0.0               AERO REFERENCE AREA FOR REF PT OBJECT (FT**2)
457  2.2               SIMPLE DRAG COEFFICIENT (NON-DIMENS)

C---------------------------------------------------
C ACTIVATE ATTITUDE CONTROL ALGORITHMS ON HOST OBJECT
C---------------------------------------------------
C (NOTE SPECIFYING GREATER THAN 2. RESULTS IN ADDITIONAL OPTIONS)
C      OPT 1 & 2 PERFORMS AN ATTITUDE HOLD ON INITIAL RP ATTITUDE

807  0.              0.=OFF, 1.=WR/T ORB FRM, 2.=WR/T INER FRM, 3.=ETC
```

```
  0  0.0             END OF GTOSS AND REF POINT DATA

C********************************************
C BEGIN READ IN OF TOSS GENERAL INTEGER DATA
C********************************************

 =====> GENERAL <======= READ-IN LTOSQ ARRAY HERE - INTEGER CONSTANTS

C GENERAL DATA APPLYING TO ALL OF TOSS
C-------------------------------------
  23      1 NOMOM, MASTER TOSS PARTICLE OPT (=1 INHIBITS ROT DYN CALC)
 125      0 MASEUL, SELECT MASTER EULER ANGLE TYPE FOR ALL TOSS OBJECTS
 127      1 Down-zero Libration Def.

C DATA APPLYING TO ALL TOSS TETHERS
C----------------------------------
  24      1 NTETH, THE TOTAL NUMBER OF TOSS TETHERS (FINITE+MASSLESS)

C DEFINITION OF TOSS TETHER CONNECTIVITY
  25      1 OBJ # TO WHICH "X" END ATTACHES-TOSS TETHER #1

  50      1 ATT PT #, FOR "X" END OF TOSS TETHER #1

  75      2 OBJ TO WHICH "Y" END ATTACHES-TOSS TETHER #1

 100      1 ATT PT #, FOR "Y" END OF TOSS TETHER #1

C WHERE APPLICABLE, DEFINE TYPE OF DISTRIBUTED FORCES ON TOSS TETHERS
 194      0 LOPG, EVAL OPTION FOR GRAV FORCES, FOR ALL TOSS TETHERS
 195      0 LOPA,  "     "     "  AERO FORCES,  "  ALL TOSS TETHERS

C SPECIFY TOSS TETHER BREAKAGE MODE (ALSO SEE BEAD-SEG. BREAK FEATURE)
C (SEE REF MAN FOR DEFINITION OF POSSIBLE CRITERIA)
 309      0 SPECIFY BREAK MODE ASSOCIATED WITH TOSS TETHER #1

C-------------------------------------------------
C THERMAL SIMULATION CONTROL FOR ALL TOSS TETHERS
C-------------------------------------------------
 177      0 DIRECT SOLAR RADIATION HEATING          (=1 ACTIVATES)
 178      0 PLANET ALBEDO HEATING
 179      0 PLANET BLACK BODY RADIATION HEATING
 180      0 AERODYNAMIC HEATING
 181      1 ELECTRICAL RESISTIVE HEATING
 182      0 HEAT RADIATION FROM A TETHER
 183      0 HEAT CONDUCTION ALONG A TETHER
 184      0 THERMAL EXPANSION CHANGES TETHER LENGTH


C DATA APPLYING TO ALL FINITE SOLUTIONS
C--------------------------------------
 129      1 NFINIT, LARGEST FINITE SOLN # ALLOWED TO BE ACTIVE

 130      1 ASSIGN A FINITE SOLN # TO TOSS TETHER #1

 198      1 SPECIFY SOLUTION TYPE (0=MODAL, >0=BEAD MODEL) SOLN #1

 185      0 COORDINATE STATE IC OPTION FOR SOLN #1
```

```
C DATA ASSOCIATED SPECIFICALLY W/ BEAD MODEL FINITE SOLNS
C---------------------------------------------------------
 207     9 NUMBER OF BEADS ASSIGNED TO FINITE SOLN #1


   0     0           END OF DATA

   --------------------- READ-IN JTOSQ ARRAY HERE - INTEGER VARIABLES
   0     0           END OF DATA


C*****************************************
C BEGIN READ IN OF TOSS GENERAL REAL DATA
C*****************************************
   --------------------- READ-IN FTOSQ ARRAY HERE - REAL CONSTANTS
  10          0.000  TOSS MASTER INTEGRATION INTERVAL <--------<<<<<<

C TOSS TETHER INITIAL LENGTHS
  50       328084.0   UN-STRETCHED LENGTH (FT) - TOSS TETHER #1

C MASSLESS TETHER DATA (USED ONLY IF NO FINITE SOLN IS ASSIGNED)
C (BASED ON INITIAL LENGTHS, IE. ITEMS 50,..., ABOVE)
  25            0.2  SPRING RATE (LB/FT) - MASSLESS TOSS TETHER #1

  75            0.05 DAMPING CONST (LB/FPS) - MASSLESS TOSS TETHER #1

C TOSS TETHER BREAKAGE CRITERIA LEVEL (SEE ALSO BEAD-SEG BREAKAGE)
 310     0.0         BREAKAGE CRITERIA LEVEL FOR - TOSS TETHER #1

C FINITE SOLN TETHER PROPERTIES (ALL FINITE SOLNS)
1223       5.611      LINEAL DENSITY (LBM/KFT) FINITE SOLN #1

1248     1.8032E6     YOUNG'S MODULUS (PSI)

1273     1.000        ELASTIC DIAMETER (IN)

1298     0.800        0.3968        BETA DAMPING FACTOR (SEC)

1323     0.000        (EST) AERODYNAMIC DIA (IN)

C DATA SPECIFIC TO BEAD MODEL FINITE SOLNS
 163     0.0          TIME FOR 1ST BREAK IN BEAD SOLN #1

 172     0.0          TIME FOR 2ND BREAK

C THERMAL PROPERTIES FOR FINITE TETHERS
C---------------------------------------
1506       293.0    PROPERTIES BASELINE TEMP (K)     TOSS TETHER #1
1398       0.0      THERMAL HEAT CONDUCTIVITY / UNIT AREA
1407       0.0      THERMAL LINEAR EXPANSION COEFF (/K)
1416       0.9      ABSORPTIVITY
1425       0.8      EMISSIVITY
1434       900.     SPECIFIC HEAT/UNIT MASS (J/KG-K) (ALUM)
1443       0.0      SLOPE OF SPECIFIC HEAT
1470     2.6548E-8  CONDUCTOR RESISTIVITY/UNIT LENGTH (OHM-M)
```

```
1479     0.000        SLOPE OF RESISTIVITY WRT TEMP (K)
1515     1.00E00      CONDUCTING X-SECTION AREA (M^2)
1524     0.000        PLASMA CONTACT CIRCUMFERENCE (M)

C VALUE TO INITIALIZE AMPERAGE IN TOSS TETHERS (EASY CONST CURRENT OPT)
 181        0.0000      INITIAL CONSTANT CURRENT (AMPS) TOSS TETHER #1

C MULTIPLIER USED BY TOSS TETHER FOR ANY ASSIGNED POWER GEN SCENARIO
 335        0.0         PWR MULTIPLIER (DEFAULTS TO 1.0) - TOSS TETHER #1

C FIXED SUN ANGLE OPTION, ETC
C---------------------------
 222           180.00     SUN LONG. (DEG) WR/T GREENWICH-EQUATOR (INER)
 223             0.00     SUN LATITUDE "
 224          1367.00     SOLAR CONSTANT (W/M**2)
 225             0.40      EARTH ALBEDO (PERCENT OF REFLECTED VS INCIDENT)

   0             0.0       END DATA

   --------------------- READ-IN DTOSQ ARRAY HERE - REAL VARIABLES
   0               0.0        END DATA

C*****************************************
C BEGIN READ IN DATA FOR EACH TOSS OBJECT
C*****************************************

C-----------------------------------------------
C TOSS OBJECT 2 DATA (INTEGER FOLLOWED BY REAL)
C-----------------------------------------------
======> OBJECT 2 <====== READ-IN LTOS2 ARRAY HERE - INTEGER CONSTANTS
  18       1 # OF ATTACH POINTS ON THIS OBJECT
  19       1 AERO, ACTIVATES AERO CALC OPTIONS IF .GT. 0
  20       0 Attitude Control Option for TOSS object 2
  21       1 ICTRN, SELECTS TRANS STATE IC OPTION

C ATTITUDE: EULER ANG WR/T 1=TOPO, 2=RP-ORB, 3=ARB, 4=OBJ-ORB, 5=INER
  22       0 ATTITUDE STATE IC OPTION
  24       1 Inhibit Rotational Dynamics for this object
  25       0 OBJECT SPECIFIC EULER ANGLE TYPE FOR INPUT

C INTEGERS APPLYING TO OBJECT ATTITUDE CONTROL OPTION = 5
  41       0 ATT HOLD TYPE (1 = WR/T ORB FRM,  2 = WR/T INER FRAME)

   0      0             END OF DATA

   --------------------- READ-IN JTOS2 ARRAY HERE - INTEGER VARIABLES
   0      0             END OF  DATA
   --------------------- READ-IN FTOS2 ARRAY HERE - REAL CONSTANTS
   3             68.519  END MASS (upper end mass) (SLUGS)
   4             00.00   INITIAL IXX FOR THIS OBJECT  (SLUG-FT**2)
   5             00.00    "     IYY          "     "
   6             00.00    "     IZZ          "     "

  10              0.0     INITIAL X CG POS WITHIN OBJECT 2 (FT)
  11              0.0     INITIAL Y CG POS WITHIN OBJECT 2 (FT)
  12              0.0     INITIAL Z CG POS WITHIN OBJECT 2 (FT)
```

```
  13           0.0   X COORD FOR ATTACH PT # 1 ON THIS OBJECT (FT)
  21           0.0   Y COORD FOR ATTACH PT # 1 ON THIS OBJECT
  29           0.0   Z COORD FOR ATTACH PT # 1 ON THIS OBJECT

C OBJECT TRANSLATION STATE INITIALIZATION FOR ALL IC OPTIONS ~=5
  40            0.0  INITIAL POSITION X COORD (OF OBJECT WR/T RP) (FT)
  41            0.0     "       "      Y   "          "      "
  42      -329684.0     "       "      Z   "          "      "
  43            0.0 INITIAL RATE X COORD (OF OBJECT WR/T RP) (FPS)
  44         7242.3     "     "   Y   "          "     "
  45            0.0     "     "   Z   "          "     "
  46            0.0 BODY-X ANG VEL,
  47            0.0 BODY-Y ANG VEL,
  48            0.0 BODY-Z ANG VEL,
  49            0.0 EULER PITCH ANGLE OF OBJECT (DEG),
  50            0.0 EULER ROLL ANGLE
  51            0.0 EULER YAW ANGLE

C DATA FOR SIMPLE AERO DRAG ON OBJECT
 102           0.0  AERO REF AREA (FT)
 103           2.2  SIMPLE DRAG COEFF FOR OBJECT

C OBJECT TRANSLATION STATE INITIALIZATION FOR  IC OPTION  = 5
 170            0.0 Initial IP Libration
 171            0.0 Initial OP Libration
 172            0.0
 173            0.0
 174       328084.0 Initial Range (ft)
 175            0.0 Range Rate

   0           0.0       END DATA

   --------------------- READ-IN DTOS2 ARRAY HERE - REAL VARIABLES
   0            0.0       END DATA


 >>>>>>>>>>>>>>>>>>>>>>>>End of GTOSS Run Definition Data
 >>>>>>>>>>>>>>>>>>>>>>>>Terminate Program

 -1
```

APPENDIX D

MSFC PROVIDED PROSEDS SAMPLE CASE GTOSS INPUT FILE

INGOSS

```
$MX_001
   Momentum Transfer Tether Dynamics.  10,000 - 1000 kg system masses, 100 km
tether.
   Rotating configuration to study dynamics of tether system spin.

  1  0.100            DELTAT: REF PT
  2  10800.           TMAX
  3  250.000          N, THE RDB SOLN OUTPUT INTERVAL = N * DELTAT
  4  0.0              START RDB OUTPUT AT THIS TIME
 16  1.000            RUN NUMBER
 17  4.0              CRT OUTPUT EVERY M RDB INTERVALS
 94  -1.0             -1 SUPPRESSES DOT OUTPUTS TO CRT

C LATE START SNAPSHOTS
398  1.0             TAKE LATE START SNAPSHOTS
387  250.0           TIME FOR FIRST SNAPSHOT DUMP
388  500.0           TIME FOR 2ND SNAPSHOT DUMP
389  750.0           Time for 3rd snapshot dump
390  1250000.
c391  2000000.

C REFERENCE DATE CORRESPONDING TO ZERO SIMULATION RUN TIME
287  2003.           YEAR
288    10.           MONTH
289    10.           DAY
290    18.           HOUR
291     0.           MINUTE
292     0.           SECOND


C QUICK LOOK PAGE FORMAT CONTROL
117  1.              SELECT QUICK LOOK PAGE FORMAT
381  2.0             CHOOSE TOSS OBJ FOR QUICK LOOK (IF APPROP)
382  1.                "     "
421  1.0             CHOOSE TOSS TETHER FOR QUICK LOOK (IF APPROP)
422  2.                 "     "
435  1.0             CHOOSE FINITE SOLN FOR QUICK LOOK (IF APPROP)
442  2.              BEAD NUMBER TO DISPLAY FOR QUICK LOOK (IF APPROP)
443  3.                "    "
444  5.                "    "

C GTOSS EXECUTION CONTROL DATA
111  1.              = 1. TO INHIBIT ROTATIONAL DYNAMICS (IE. PARTICLE OPT)
112  3.              EULER ANGLE TYPE PERTAINING TO REF PT (Pitch,roll,yaw)
113  2.              NUMBER OF LAST TOSS OBJECT BEING SIMULATED
114  1.              NUMBER OF ATTACH PTS ON THE REF POINT

C PLANETARY ENVIRONMENT SIMULATION FIDELITY LEVEL (WILL BE GLOBAL TO TOSS)
481  0.              ACCEL OF GRAVITY (0.0 =SPHERICAL; 1.0 =OBLATE EARTH)
482  1.              ATMOSPHERIC DENSITY MODEL (0.0 =EARTH ARDC 1976)
483  5.              MAGNETIC FIELD (0.0 =EARTH TILTED/SHIFTED DIPOLE)
```

```
484  0.             PLANET GLOBE SHAPE (0.0 =SPHERICAL EARTH)
485  0.             ATMOSPHERIC WINDS MODEL (0.0 =ROTATING EARTH, NO PERTURBS)
486  2.             INERTIAL FRAME MODEL (0.0 =FOR INITIALLY-EARTH-ALIGNED)
487  3.             Global Euler Angle Type (RP and TOSS Objects)- Pitch,
Roll, Yaw

563  1.0           Time between ATMOS evals
564  1.0           Time between MAGNETIC evals
565  1.0           Time between WIND evals
566  1.0           Time between PLASMA evals

C BASIC REF PT GEOMETRY
 20    685.2        REFERENCE PT MASS (SLUGS) = 10,000 kg (includes tether
mass)
 21    000.0        IXX: REF PT (SLUG-FT**2)
 22    000.0        IYY
 23    000.0        IZZ

 24  0.0            XCG: REF PT CENTER OF MASS LOC (FT)
 25  0.0            YCG
 26  0.0            ZCG
 27  0.0            IXY: REF PT INERTIA PRODS (SLUG-FT**2)
 28  0.0            IXZ
 29  0.0            IYZ

C REF PT TRANSLATION STATE INITIALIZATION
100  1.0            TRNS IC OPT: =0. FOR TOPO;=1. FOR INERTIAL;=2 for circ

C FOR TRANSLATION IC OPTION = 1.0
 81    22238074.15    XIO REF PT POSITION (FT) [INER FRAME]
 82           0.0     YIO  "          "
 83           0.0     ZIO  "          "
 84           0.0     XIDO REF PT RATE (FT/SEC) [INER FRAME]
 85      24288.02     YIDO  "        "
 86           0.0     ZIDO  "        "

C FOR TRANSLATION IC OPTION = 0.0
101  1312000.       REF PT  ALT (FT) = 400 km (perigee)
102        0.0      REF PT  TOPO LONGITUDE (DEG)
103        0.0      REF PT  TOPO LATITUDE (DEG)
 80       36.0      Azimuth (inclination)

C ATTACH PT COORDS (ONLY 1 USED FOR PARTICLE REF PT)
134        0.00     PXBT1: REF PT (FT) X COORD OF ATTACH PT 1
142        0.00     PYBT1: REF PT (FT) Y COORD OF ATTACH PT 1
150        0.00     PZBT1: REF PT (FT) Z COORD OF ATTACH PT 1

C SIMPLE REF POINT AERO DRAG OPT DATA
455  1.              =1. TO ACTIVATE SIMPLE DRAG OPTION ON REF PT
456  0.0             AERO REFERENCE AREA FOR REF PT OBJECT (FT**2)
457  2.2             SIMPLE DRAG COEFFICIENT (NON-DIMENS)

C----------------------------------------------------
C ACTIVATE ATTITUDE CONTROL ALGORITHMS ON HOST OBJECT
C----------------------------------------------------
C (NOTE SPECIFYING GREATER THAN 2. RESULTS IN ADDITIONAL OPTIONS)
C      OPT 1 & 2 PERFORMS AN ATTITUDE HOLD ON INITIAL RP ATTITUDE
```

```
807  0.             0.=OFF, 1.=WR/T ORB FRM, 2.=WR/T INER FRM, 3.=ETC

  0  0.0              END OF GTOSS AND REF POINT DATA

C********************************************
C BEGIN READ IN OF TOSS GENERAL INTEGER DATA
C********************************************

 =====> GENERAL <======= READ-IN LTOSQ ARRAY HERE - INTEGER CONSTANTS

C GENERAL DATA APPLYING TO ALL OF TOSS
C-----------------------------------
  23      1 NOMOM, MASTER TOSS PARTICLE OPT (=1 INHIBITS ROT DYN CALC)
 125      0 MASEUL, SELECT MASTER EULER ANGLE TYPE FOR ALL TOSS OBJECTS
 127      1 Down-zero Libration Def.

C DATA APPLYING TO ALL TOSS TETHERS
C---------------------------------
  24      1 NTETH, THE TOTAL NUMBER OF TOSS TETHERS (FINITE+MASSLESS)

C DEFINITION OF TOSS TETHER CONNECTIVITY
  25      1 OBJ # TO WHICH "X" END ATTACHES-TOSS TETHER #1

  50      1 ATT PT #, FOR "X" END OF TOSS TETHER #1

  75      2 OBJ TO WHICH "Y" END ATTACHES-TOSS TETHER #1

 100      1 ATT PT #, FOR "Y" END OF TOSS TETHER #1

C WHERE APPLICABLE, DEFINE TYPE OF DISTRIBUTED FORCES ON TOSS TETHERS
 194      0 LOPG, EVAL OPTION FOR GRAV FORCES, FOR ALL TOSS TETHERS
 195      0 LOPA,  "     "     " AERO FORCES,  " ALL TOSS TETHERS

C SPECIFY TOSS TETHER BREAKAGE MODE (ALSO SEE BEAD-SEGMENT BREAK FEATURE)
C (SEE REF MAN FOR DEFINITION OF POSSIBLE CRITERIA)
 309      0 SPECIFY BREAK MODE ASSOCIATED WITH TOSS TETHER #1

C--------------------------------------------------
C THERMAL SIMULATION CONTROL FOR ALL TOSS TETHERS
C--------------------------------------------------
 177      0 DIRECT SOLAR RADIATION HEATING          (=1 ACTIVATES)
 178      0 PLANET ALBEDO HEATING
 179      0 PLANET BLACK BODY RADIATION HEATING
 180      0 AERODYNAMIC HEATING
 181      1 ELECTRICAL RESISTIVE HEATING
 182      0 HEAT RADIATION FROM A TETHER
 183      0 HEAT CONDUCTION ALONG A TETHER
 184      0 THERMAL EXPANSION CHANGES TETHER LENGTH


C DATA APPLYING TO ALL FINITE SOLUTIONS
C-------------------------------------
 129      1 NFINIT, LARGEST FINITE SOLN # ALLOWED TO BE ACTIVE

 130      1 ASSIGN A FINITE SOLN # TO TOSS TETHER #1
```

```
 198      1 SPECIFY SOLUTION TYPE (0=MODAL, >0=BEAD MODEL) SOLN #1

 185      0 COORDINATE STATE IC OPTION FOR SOLN #1


C DATA ASSOCIATED SPECIFICALLY W/ BEAD MODEL FINITE SOLNS
C---------------------------------------------------------
 207      9 NUMBER OF BEADS ASSIGNED TO FINITE SOLN #1


   0      0            END OF DATA

   --------------------- READ-IN JTOSQ ARRAY HERE - INTEGER VARIABLES
   0      0            END OF DATA


C*****************************************
C BEGIN READ IN OF TOSS GENERAL REAL DATA
C*****************************************
   --------------------- READ-IN FTOSQ ARRAY HERE - REAL CONSTANTS
  10          0.000   TOSS MASTER INTEGRATION INTERVAL <--------<<<<<<

C TOSS TETHER INITIAL LENGTHS
  50       328084.0   UN-STRETCHED LENGTH (FT) - TOSS TETHER #1

C MASSLESS TETHER DATA (USED ONLY IF NO FINITE SOLN IS ASSIGNED)
C (BASED ON INITIAL LENGTHS, IE. ITEMS 50,..., ABOVE)
  25            0.2   SPRING RATE (LB/FT) - MASSLESS TOSS TETHER #1

  75            0.05  DAMPING CONST (LB/FPS) - MASSLESS TOSS TETHER #1

C DEFINE TOSS TETHER BREAKAGE CRITERIA LEVEL (SEE ALSO BEAD-SEG BREAKAGE)
 310      0.0         BREAKAGE CRITERIA LEVEL FOR - TOSS TETHER #1

C FINITE SOLN TETHER PROPERTIES (ALL FINITE SOLNS)
1223       5.611       LINEAL DENSITY (LBM/KFT) FINITE SOLN #1

1248     1.8032E6      YOUNG'S MODULUS (PSI)

1273     1.000         ELASTIC DIAMETER (IN)

1298     0.800         0.3968         BETA DAMPING FACTOR (SEC)

1323     0.000         (EST) AERODYNAMIC DIA (IN)

C DATA SPECIFIC TO BEAD MODEL FINITE SOLNS
 163     0.0           TIME FOR 1ST BREAK IN BEAD SOLN #1

 172     0.0           TIME FOR 2ND BREAK

C THERMAL PROPERTIES FOR FINITE TETHERS
C-------------------------------------
1506       293.0     PROPERTIES BASELINE TEMP (K)      TOSS TETHER #1
1398       0.0       THERMAL HEAT CONDUCTIVITY / UNIT AREA
1407       0.0       THERMAL LINEAR EXPANSION COEFF (/K)
1416       0.9       ABSORPTIVITY
1425       0.8       EMISSIVITY
```

```
1434      900.       SPECIFIC HEAT/UNIT MASS (J/KG-K) (ALUM)
1443      0.0        SLOPE OF SPECIFIC HEAT
1470    2.6548E-8    CONDUCTOR RESISTIVITY/UNIT LENGTH (OHM-M)
1479    0.000        SLOPE OF RESISTIVITY WRT TEMP (K)
1515    1.00E00      CONDUCTING X-SECTION AREA (M^2)
1524    0.000        PLASMA CONTACT CIRCUMFERENCE (M)

C VALUE TO INITIALIZE AMPERAGE IN TOSS TETHERS (EASY CONST CURRENT OPT)
 181        0.0000       INITIAL CONSTANT CURRENT (AMPS) TOSS TETHER #1

C MULTIPLIER USED BY TOSS TETHER FOR ANY ASSIGNED POWER GEN SCENARIO
 335      0.0          PWR MULTIPLIER (DEFAULTS TO 1.0) - TOSS TETHER #1

C FIXED SUN ANGLE OPTION, ETC
C----------------------------
 222          180.00      SUN LONGITUDE (DEG) WR/T GREENWICH-EQUATOR (INER)
 223            0.00      SUN LATITUDE "
 224         1367.00      SOLAR CONSTANT (W/M**2)
 225            0.40       EARTH ALBEDO (PERCENT OF REFLECTED VS INCIDENT)

   0            0.0        END DATA

   --------------------- READ-IN DTOSQ ARRAY HERE - REAL VARIABLES
   0              0.0        END DATA

C*****************************************
C BEGIN READ IN DATA FOR EACH TOSS OBJECT
C*****************************************

C---------------------------------------------
C TOSS OBJECT 2 DATA (INTEGER FOLLOWED BY REAL)
C---------------------------------------------
======> OBJECT 2 <====== READ-IN LTOS2 ARRAY HERE - INTEGER CONSTANTS
  18      1 # OF ATTACH POINTS ON THIS OBJECT
  19      1 AERO, ACTIVATES AERO CALC OPTIONS IF .GT. 0
  20      0 Attitude Control Option for TOSS object 2
  21      1 ICTRN, SELECTS TRANS STATE IC OPTION

C ATTITUDE: EULER ANG WR/T 1=TOPO, 2=RP-ORB, 3=ARB, 4=OBJ-ORB, 5=INER
  22      0 ATTITUDE STATE IC OPTION
  24      1 Inhibit Rotational Dynamics for this object
  25      0 OBJECT SPECIFIC EULER ANGLE TYPE FOR INPUT

C INTEGERS APPLYING TO OBJECT ATTITUDE CONTROL OPTION = 5
  41      0 ATT HOLD TYPE (1 = WR/T ORB FRM,  2 = WR/T INER FRAME)

   0      0             END OF DATA

   --------------------- READ-IN JTOS2 ARRAY HERE - INTEGER VARIABLES
   0      0             END OF  DATA
   --------------------- READ-IN FTOS2 ARRAY HERE - REAL CONSTANTS
   3            68.519  END MASS (upper end mass) (SLUGS)
   4            00.00   INITIAL IXX FOR THIS OBJECT  (SLUG-FT**2)
   5            00.00    "    IYY           "    "
   6            00.00    "    IZZ           "    "

  10             0.0     INITIAL X CG POS WITHIN OBJECT 2 (FT)
```

```
 11             0.0     INITIAL Y CG POS WITHIN OBJECT 2 (FT)
 12             0.0     INITIAL Z CG POS WITHIN OBJECT 2 (FT)

 13             0.0   X COORD FOR ATTACH PT # 1 ON THIS OBJECT (FT)
 21             0.0   Y COORD FOR ATTACH PT # 1 ON THIS OBJECT
 29             0.0   Z COORD FOR ATTACH PT # 1 ON THIS OBJECT

C OBJECT TRANSLATION STATE INITIALIZATION FOR ALL IC OPTIONS ~=5
 40              0.0  INITIAL POSITION X COORD (OF OBJECT WR/T RP) (FT)
 41              0.0    "       "     Y   "          "      "
 42        -329684.0    "       "     Z   "          "      "
 43              0.0 INITIAL RATE X COORD (OF OBJECT WR/T RP) (FPS)
 44           7242.3    "    "  Y   "           "     "
 45              0.0    "    "  Z   "           "     "
 46              0.0 BODY-X ANG VEL,
 47              0.0 BODY-Y ANG VEL,
 48              0.0 BODY-Z ANG VEL,
 49              0.0 EULER PITCH ANGLE OF OBJECT (DEG),
 50              0.0 EULER ROLL ANGLE
 51              0.0 EULER YAW ANGLE

C DATA FOR SIMPLE AERO DRAG ON OBJECT
102             0.0  AERO REF AREA (FT)
103             2.2  SIMPLE DRAG COEFF FOR OBJECT

C OBJECT TRANSLATION STATE INITIALIZATION FOR  IC OPTION  = 5
170              0.0 Initial IP Libration
171              0.0 Initial OP Libration
172              0.0
173              0.0
174         328084.0 Initial Range (ft)
175              0.0 Range Rate

  0             0.0       END DATA

  --------------------- READ-IN DTOS2 ARRAY HERE - REAL VARIABLES
  0              0.0       END DATA


 >>>>>>>>>>>>>>>>>>>>>>>>End of GTOSS Run Definition Data
 >>>>>>>>>>>>>>>>>>>>>>>>Terminate Program

 -1
```

APPENDIX E
PARKER-MURPHY MODEL FOR SPHERICAL END BODY CURRENT COLLECTION AS IMPLEMENTED IN GTOSS

The basic assumptions are that the electron density (n_e), temperature (T_e), and the magnetic field vector (**B**) are provided by GTOSS. The EBC bias potential (ϕ_s) is defined by any of several alternate assumptions: 1. Constant ϕ_s; 2. Constant HVPS power; and 3. Constant HVPS voltage. The thermal current is assumed to result from the thermal motion of the electrons. The assumed average speed of the electrons is given by

$$V_e = \sqrt{\frac{2kT_e}{m_e}}$$

This average electron speed defines the electron current density or flux. This flux over the available area of the end body collector results in the thermal current I_0. Thus, for an electron charge e, an electron density ne and an effective collecting area A, the thermal current is

$$I_o = n_e e V_e A$$

The collection area A is $A = 2\pi R^2$. This is twice the cross section of the sphere and is based on the assumption that electrons are constrained to spiral around the magnetic field lines. Thus, electrons only strike the collecting surface along the + or – directions of the field. When a positive bias potential exists between EBC and the surrounding plasma, the collected electron current is increased. For a positive ϕ_s, the resulting current is

$$I = \alpha I_o \left(1 + \sqrt{\frac{4\phi_s}{\phi_o}}\right); \text{ where } \phi_o = \frac{eB^2R^2}{2m_e}.$$

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE September 28, 2001	3. REPORT TYPE AND DATES COVERED Final, 1 March 2001 – 30 September 2001

4. TITLE AND SUBTITLE Avionics Tether Operations Control	5. FUNDING NUMBERS NAS8-00114, H-32835D
6. AUTHORS John R. Glaese	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) bd Systems, Inc. Control Dynamics Division 600 Boulevard South, Suite 304 Huntsville, AL 35802	8. PERFORMING ORGANIZATION REPORT NUMBER TCD20010175A
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This final report documents and summarizes work performed under the PO # noted in item 5.

14. SUBJECT TERMS	15. NUMBER OF PAGES
Tether, current collection, simulation, dynamics, electrodynamic tethers, bare wire current collection, end body current collection, plasma contactor, skip rope observer	43
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	