APPENDIX C

MATLAB SOFTWARE USED TO COMPUTE PREDICTED RELATIVISTIC EFFECTS FOR A FLIGHT FROM RHODES AIRPORT TO UNIVERSITY AIRPORT

```
%
%  CALCREL:  Calculates the predicted relativistic effects in
%  the double differences for a flight from Rhodes airport to
%  University Airport on 10/7/96.
%

flysim;                  % See FLYSIM below
load sv3pos.dat;         % Load Satellite Positions
load sv9pos.dat;
load sv17pos.dat;
load sv23pos.dat;
load sv26pos.dat;
load sv28pos.dat;
time=sv17pos(:,1);       % Set up time vector
tinc=time(2)-time(1);    % Time increment, usually 1 second
sv3pos(:,1)=[ ];
sv9pos(:,1)=[ ];
sv17pos(:,1)=[ ];
sv23pos(:,1)=[ ];
sv26pos(:,1)=[ ];
sv28pos(:,1)=[ ];
user_ece=air_ece;
eceeci;                  % See ECEECI and EQ9 below
eq9;
terms3a=[term1_3 term2_3 term3];
airoff3=off3;
terms9a=[term1_9 term2_9 term3];
airoff9=off9;
terms17a=[term1_17 term2_17 term3];
airoff17=off17;
terms23a=[term1_23 term2_23 term3];
airoff23=off23;
terms26a=[term1_26 term2_26 term3];
airoff26=off26;
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terms28a=[term1_28 term2_28 term3];
airoff28=off28;
user_ece=gnd_ece;
eceeci;
eq9;
terms3g=[term1_3 term2_3 term3];
gndoff3=off3;
terms9g=[term1_9 term2_9 term3];
gndoff9=off9;
terms17g=[term1_17 term2_17 term3];
gndoff17=off17;
terms23g=[term1_23 term2_23 term3];
gndoff23=off23;
terms26g=[term1_26 term2_26 term3];
gndoff26=off26;
terms28g=[term1_28 term2_28 term3];
gndoff28=off28;

td=2:(max(size(user_ece))-1);
c=299792458;
it3=c*(gndoff3-airoff3);
it9=c*(gndoff9-airoff9);
it17=c*(gndoff17-airoff17);
it23=c*(gndoff23-airoff23);
it26=c*(gndoff26-airoff26);
it28=c*(gndoff28-airoff28);
axis([0 800 -0.6 0.6]);
plot(td,it17-it3,'-',td,it17-it9,'-',...
td,it17-it23,'-',td,it17-it26,'-',td,it17-it28,'-');
grid;
title('Expected Relativistic Effect in Double Differences (Rhodes to UNI)');
ylabel('Relativistic Effect (meters)')
xlabel('Time (seconds)');
text(220,-.27,'- SV17 is the Reference');
text(220,-0.47,'- NE Flight 55 m/s');
text(220,-0.37,'- Ground Station on Hangar Roof at UNI');
```

```
%
%   FLYSIM: Generates a simple aircraft flight path, level
%   flight from Rhodes airport near Jackson to UNI.  The velocity
%   is approximately constant at 55 m/s.  The result approximates
%   the expected clock errors due to relativity terms as outlined
%   by Deines ("Missing Relativity Terms in GPS"), Navigation:
%   Journal of the Institute of Navigation, Vol. 39, No. 1, Spring
%   1992.
%

time_start=1;
time_stop=719;
time_incr=1;
degrad = pi/180;
air_llh = [38.98390313608*degrad -82.57660988614*degrad 220.243];
% air initial position in LLH (rad,rad,m) at Rhodes Airport
% Here the height is not really used.  When the air positions are converted
% to LLH the height will be set to 500 meters.

% gnd initial position in LLH (rad,rad,m)
gnd_llh = [39.21074291944*degrad -82.22468458889*degrad 247.063];

vel_llh = [5.519974915e-6 8.530046207e-6 0]; % velocity in
%                                   llh (rad/s,rad/s,m/s)
%   This is about 55 m/s in a southwesterly heading

gnd_ece = llh2ec(gnd_llh);

% Here is where we make the height constant at 500 m in LLH coordinates
air_llh(3) = 500;
air_ece = llh2ec(air_llh);

index = 1;          % point at first position
first = 1;

for time = time_start:time_incr:time_stop
    air_llh(index+1,:)=air_llh(index,:)+time_incr*vel_llh;
    air_llh(index+1,3) = 500;
    air_ece(index+1,:)=llh2ec(air_llh(index+1,:));
    gnd_llh(index+1,:)=gnd_llh(index,:);
    gnd_ece(index+1,:)=llh2ec(gnd_llh(index+1,:));
  index = index + 1;
end
```

```
%
%  ECEECI:  Takes Earth Centered Earth Fixed (ECEF) satellite
%  positions and user position, then rotates back to the ECEF
%  coordinates at the first epoch.  The ECEF coordinates at the
%  first epoch represent a fixed, Earth Centered Intertial (ECI)
%  reference frame.  This software is set up for the six satellites
%  in view during a flight test from Rhodes Airport to University
%  Airport.
%
sv3eci=zeros(sv3pos);
sv9eci=zeros(sv9pos);
sv17eci=zeros(sv17pos);
sv23eci=zeros(sv23pos);
sv26eci=zeros(sv26pos);
sv28eci=zeros(sv28pos);
user_eci=zeros(user_ece);
omega_e=7.292115147e-5;
for i=1:max(size(user_ece)),
  theta=omega_e*(time(i)-time(1));
  trans=[cos(theta) -sin(theta) 0;sin(theta) cos(theta) 0;0 0 1];
  sv3eci(i,:)=(trans*sv3pos(i,:)')';
  sv9eci(i,:)=(trans*sv9pos(i,:)')';
  sv17eci(i,:)=(trans*sv17pos(i,:)')';
  sv23eci(i,:)=(trans*sv23pos(i,:)')';
  sv26eci(i,:)=(trans*sv26pos(i,:)')';
  sv28eci(i,:)=(trans*sv28pos(i,:)')';
  user_eci(i,:)=(trans*user_ece(i,:)')';
end;
```

```
%
%  EQ9:  Calculates the terms under the second integral in Eq. 9
%  of "Missing Relativity Terms in GPS" by Deines.  This is the
%  same integral that appears in Eq. 7.15.  This software is set
%  up for the six satellites in view during a flight test from
%  Rhodes Airport to University Airport on 10/7/96.
%
%note: tinc must exist!
% here we set tinc=1 second
tinc=time(2)-time(1);
c=299792458;
c2=c*c;
v_user=(1/tinc)*diff(user_eci);
a_user=(1/tinc)*diff(v_user);
v_sv3=(1/tinc)*diff(sv3eci);
v_sv9=(1/tinc)*diff(sv9eci);
v_sv17=(1/tinc)*diff(sv17eci);
v_sv23=(1/tinc)*diff(sv23eci);
v_sv26=(1/tinc)*diff(sv26eci);
v_sv28=(1/tinc)*diff(sv28eci);
total=max(size(user_eci))-2;
term1_3=zeros(total,1);
term2_3=zeros(total,1);
drift3=zeros(total,1);
off3=zeros(total,1);
term1_9=zeros(total,1);
term2_9=zeros(total,1);
drift9=zeros(total,1);
off9=zeros(total,1);
term1_17=zeros(total,1);
term2_17=zeros(total,1);
drift17=zeros(total,1);
off17=zeros(total,1);
term1_23=zeros(total,1);
term2_23=zeros(total,1);
drift23=zeros(total,1);
off23=zeros(total,1);
term1_26=zeros(total,1);
term2_26=zeros(total,1);
drift26=zeros(total,1);
off26=zeros(total,1);
term1_28=zeros(total,1);
term2_28=zeros(total,1);
```

```
drift28=zeros(total,1);
off28=zeros(total,1);
term3=zeros(total,1);   % Term 3 depends only on receiver velocity
for i=1:total,
   rho3=sv3eci(i+2,:)-user_eci(i+2,:);
   rho9=sv9eci(i+2,:)-user_eci(i+2,:);
   rho17=sv17eci(i+2,:)-user_eci(i+2,:);
   rho23=sv23eci(i+2,:)-user_eci(i+2,:);
   rho26=sv26eci(i+2,:)-user_eci(i+2,:);
   rho28=sv28eci(i+2,:)-user_eci(i+2,:);
   term1_3(i)=a_user(i,:)*rho3';
   term1_9(i)=a_user(i,:)*rho9';
   term1_17(i)=a_user(i,:)*rho17';
   term1_23(i)=a_user(i,:)*rho23';
   term1_26(i)=a_user(i,:)*rho26';
   term1_28(i)=a_user(i,:)*rho28';
   bigv=v_user(i+1,:);
   litv3=v_sv3(i+1,:);
   litv9=v_sv9(i+1,:);
   litv17=v_sv17(i+1,:);
   litv23=v_sv23(i+1,:);
   litv26=v_sv26(i+1,:);
   litv28=v_sv28(i+1,:);
   term2_3(i)=bigv*litv3';
   term2_9(i)=bigv*litv9';
   term2_17(i)=bigv*litv17';
   term2_23(i)=bigv*litv23';
   term2_26(i)=bigv*litv26';
   term2_28(i)=bigv*litv28';
   term3(i)=-0.5*bigv*bigv';
      drift3(i)=term1_3(i)+term2_3(i)+term3(i);
      drift9(i)=term1_9(i)+term2_9(i)+term3(i);
      drift17(i)=term1_17(i)+term2_17(i)+term3(i);
      drift23(i)=term1_23(i)+term2_23(i)+term3(i);
      drift26(i)=term1_26(i)+term2_26(i)+term3(i);
      drift28(i)=term1_28(i)+term2_28(i)+term3(i);
   off3(i)=sum(tinc*drift3(1:i));
   off9(i)=sum(tinc*drift9(1:i));
   off17(i)=sum(tinc*drift17(1:i));
   off23(i)=sum(tinc*drift23(1:i));
   off26(i)=sum(tinc*drift26(1:i));
   off28(i)=sum(tinc*drift28(1:i));
end;
```

```
drift3=(1/c2)*drift3;
off3=(1/c2)*off3;
drift9=(1/c2)*drift9;
off9=(1/c2)*off9;
drift17=(1/c2)*drift17;
off17=(1/c2)*off17;
drift23=(1/c2)*drift23;
off23=(1/c2)*off23;
drift26=(1/c2)*drift26;
off26=(1/c2)*off26;
drift28=(1/c2)*drift28;
off28=(1/c2)*off28;
```