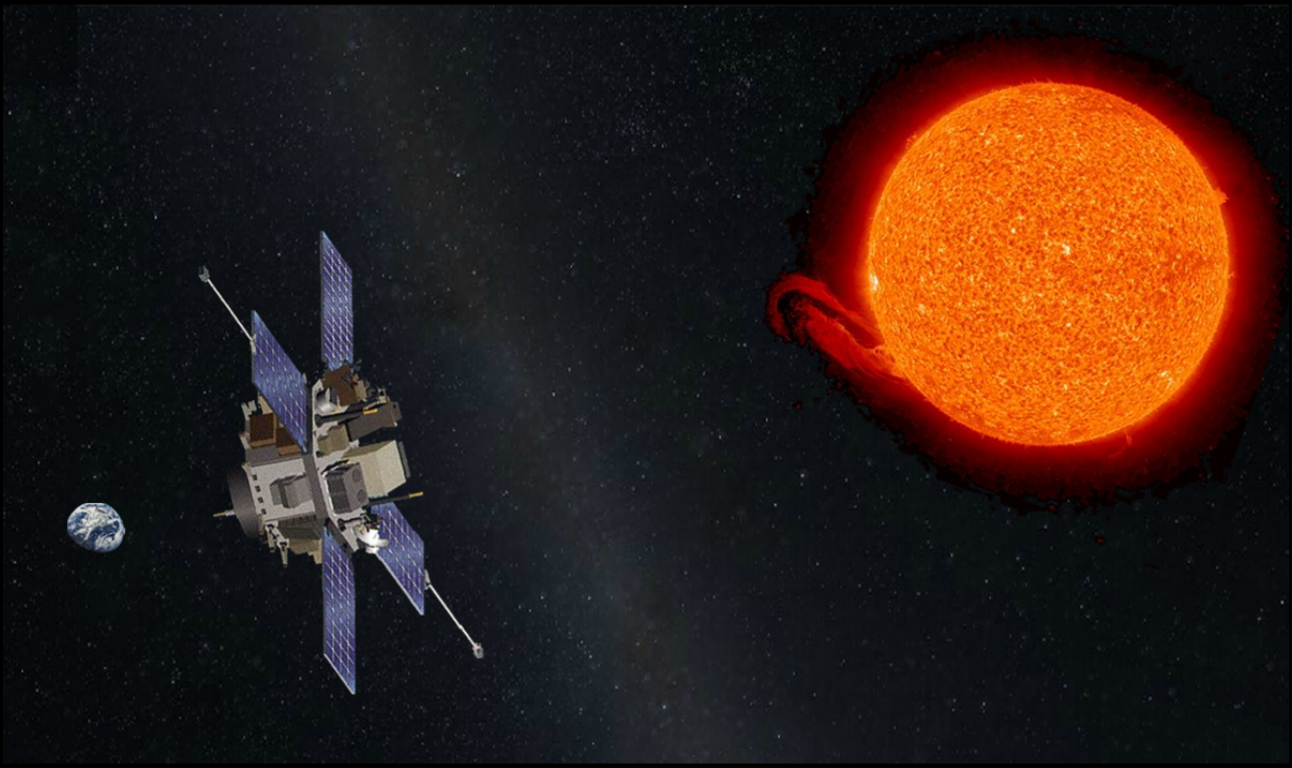
ADVANCED COMPOSITION EXPLORER (ACE)



Credit: Andrzej Mirecki

AA 403/603: Space Engineering System Assignment:02

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Introduction

NASA's Advanced Composition Explorer (ACE) spacecraft was designed to study spaceborne energetic particles. Specifically, the spacecraft was launched to investigate the matter ejected from the Sun to establish the commonality and interaction between the Sun, Earth and the Milky Way galaxy. When bursts of solar material – known as a coronal mass ejection or CME – erupts from the sun toward Earth and passes ACE, the instruments onboard the spacecraft observe the increase in particles and automatically transmit this information to publicly available websites within five minutes. This offers a crucial advance warning of some 20 to 60 minutes to those who need to protect their technology from the effects of space weather, such as satellite operators, airplane pilots and utility companies.

ACE orbits a point between Earth and the sun called a Lagrange point,L1 about 870,000 miles (1.4 million kilometers) from Earth as shown in Figure 2 to conduct in situ measurements of particles originating from the solar corona, the interplanetary medium, the local interstellar medium and galactic matter.
Table 1 shows various details like launch data, launch vehicle, on board instruments etc[2],.

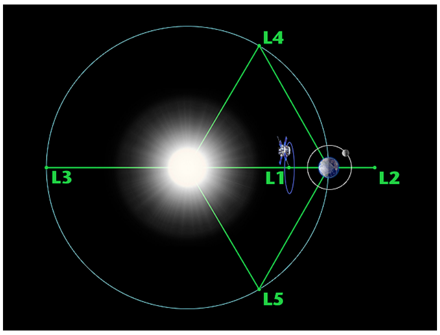

Figure 2: ACE Location[1]

Various Details of ACE Spacecraft	
Spacecraft	ACE
Launch Date and Time	Aug. 25, 1997 / 14:39 UT
Launch Vehicle	Delta 7920-8 (no. D247)
Launch Site	Cape Canaveral, Fla. / Launch Complex 17A
Misson Lifetime	$>$ 2years (goal of 5 years)
Current Status	Operational (24 years 11 months)
Mass Budget	1. Spacecraft and Instrument : 587 kg 2. Fuel : 189 kg 3. SLAM : 9 kg Net: 785 kg
Scientific Instruments	1. Solar Wind Ion Mass Spectrometer (SWIMS) and Solar Wind Ion Composition Spectrometer (SWICS) 2. Ultra-Low Energy Isotope Spectrometer (ULEIS) 3. Solar Energetic Particle Ionic Charge Analyzer (SEPICA) 4. Solar Isotope Spectrometer (SIS) 5. Cosmic Ray Isotope Spectrometer (CRIS) 6. Solar Wind Electron, Proton, and Alpha Monitor (SWEPAM) 7. Electron, Proton, and Alpha-Particle Monitor (EPAM) 8. Magnetometer (MAG) 9. Real Time Solar Wind Experiment (RTSW)

Table 1: Details of ACE Spacecraft

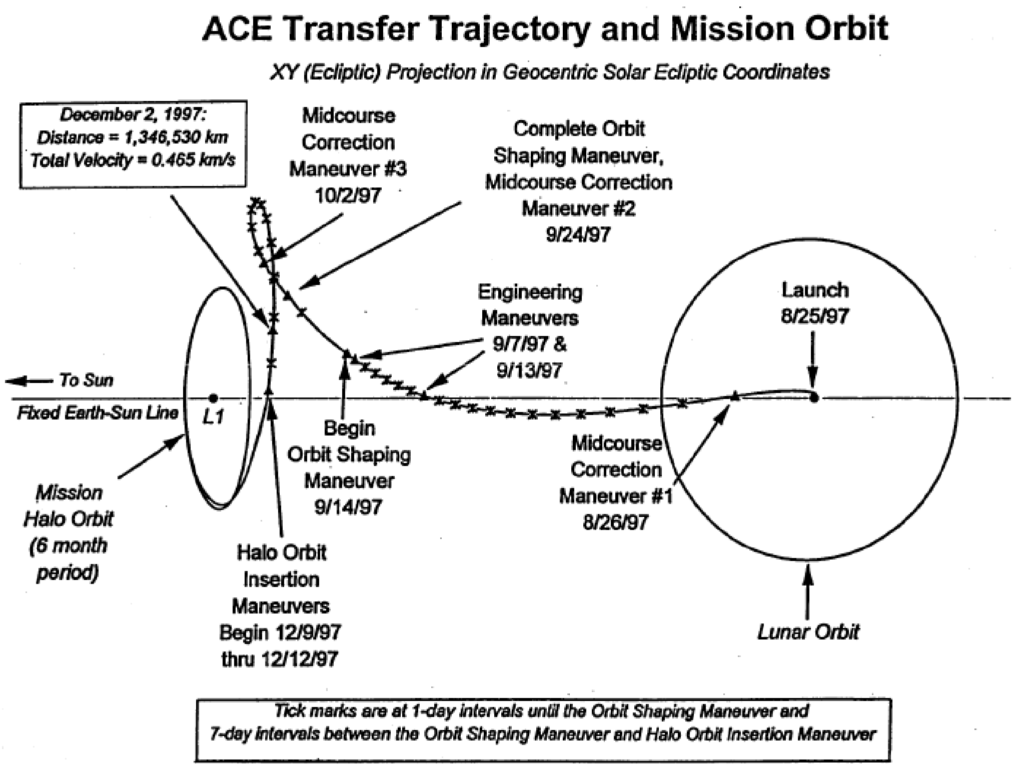

Figure 3: ACE Transfer Trajectory

Figure 3 shows the path/trajectory of ACE spacecraft. It is clearly shown that the spacecraft is orbiting about L1.

ACE Scientific Goals

The prime objective of ACE is to measure and compare the composition of several samples of matter, including the solar corona, the solar wind, and other interplanetary particle populations, the local interstellar medium (ISM), and galactic matter. The observations from ACE instruments allow the investigation of a wide range of fundamental problems in the following major areas[3],[4]:

1. **The Elemental and Isotopic Composition of Matter**
   A major objective is the accurate and comprehensive determination of the elemental and isotopic composition of the various samples of "source material" from which nuclei are accelerated. Thus, ACE measurements:

   - Generate a set of solar isotopic abundances based on direct sampling of solar material.
   - Determine the coronal elemental and isotopic composition with greatly improved accuracy.
   - These are almost symmetric about the equator in both the Northern and Southern hemispheres.
   - Establish the pattern of isotopic differences between galactic cosmic ray and solar system matter.
   - Measure the elemental and isotopic abundances of interstellar and interplanetary "pick-up ions".

- Determine the isotopic composition of the "anomalous cosmic ray" component thought to represent a sample of the very local interstellar medium.

2. **Origin of the Elements and Subsequent Evolutionary Processing**
   Isotopic "anomalies" in meteorites indicate that the solar system was not homogeneous when formed, while other data suggest that the solar composition continues to evolve. Similarly, the galaxy is neither uniform in space nor constant in time due to continuous stellar nucleosynthesis. ACE measurements:

   - Search for additional differences between the isotopic composition of solar and meteoritic material.
   - Determine the contributions of solar-wind and solar flare nuclei to lunar and meteoritic material, and to planetary atmospheres and magnetospheres.
   - Determine the dominant nucleosynthesic processes that contribute to cosmic ray source material.
   - Determine whether cosmic rays are a sample of freshly sythesized material (e.g., from supernovae), or of the contemporary interstellar medium.
   - Search for isotopic patterns in solar and galactic material as a test of galactic evolution models.

3. **Formation of the Solar Corona and Acceleration of the Solar Wind**
   Solar energetic particles, solar wind, and spectroscopic observations show that the elemental composition of the corona is differentiated from that of the photosphere, although the processes by which this occurs, and by which the solar wind is subsequently accelerated, are poorly understood. The detailed composition and charge-state data provided by ACE:

   - Isolate the dominant coronal formation processes by comparing a broad range of coronal and photospheric abundances.
   - Study plasma conditions at the source of the solar wind and the solar energetic particles by measuring and comparing the charge states of these two populations.
   - Study solar wind acceleration processes and any charge or mass-dependent fractionation in various types of solar wind flows.

4. **Particle Acceleration and Transport in Nature**
   Particle acceleration is ubiquitous in nature and is one of the fundamental problems of space plasma astrophysics. The unique data set that will be obtained by ACE measurements:

   - Make direct measurements of charge and/or mass-dependent fractionation during solar flare and interplanetary acceleration.
   - Constrain solar flare and interplanetary acceleration models with charge, mass, and spectral data spanning up to five decades in energy.
   - Test theoretical models for 3He-rich flares and solar gamma ray events.
   - Measure cosmic ray acceleration and propagation time scales using radioactive "clocks".

Data Analysis

ACE spacecraft one year data from Jan 01, 2000 to Jan 05, 2001, available at OMNIWeb Plus is used in this analysis. The orbital location in GSE coordinate system are plotted in 2d & 3d and various major orbital parameters are extracted. The time series of magnetic field is also plotted and compared with the plots available on the website.

Orbital Plots

X, Y & Z orbital location are plotted as shown in figure.

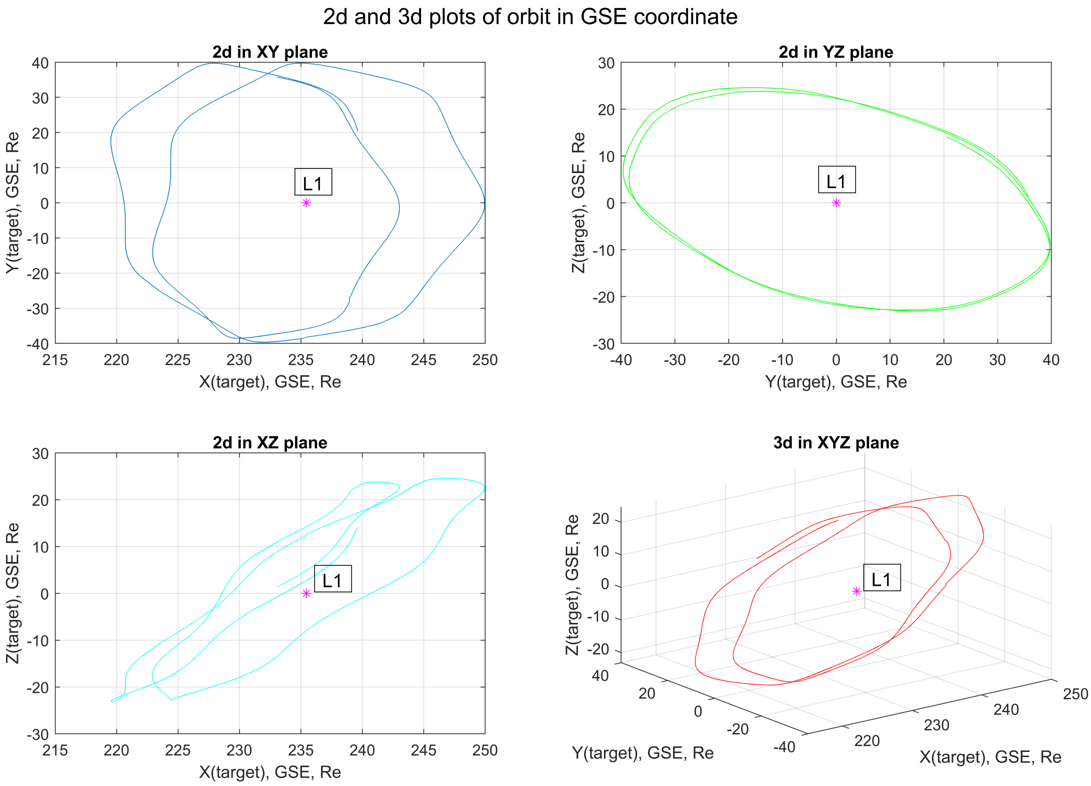

Figure 4: Orbital plots in 2d and 3d

The major orbital parameters extracted are:

- Perigee distance, r_p = 22.549293 Re or 1.436615×10^5 km
- Apogee distance, r_a = 41.932171 Re or 2.671499×10^5 km
- Semi major axis, a = 32.240732 Re or 2.054057×10^5 km
- Semi minor axis, b = 30.749647 Re or 1.959060×10^5 km
- Eccentricity, e = 0.300596

Magnetic Field Time Series Plots

The time series of magnetic field is plotted as shown in Figure 5. It is exactly matching with the plot generated from the website as shown in Figure 6.

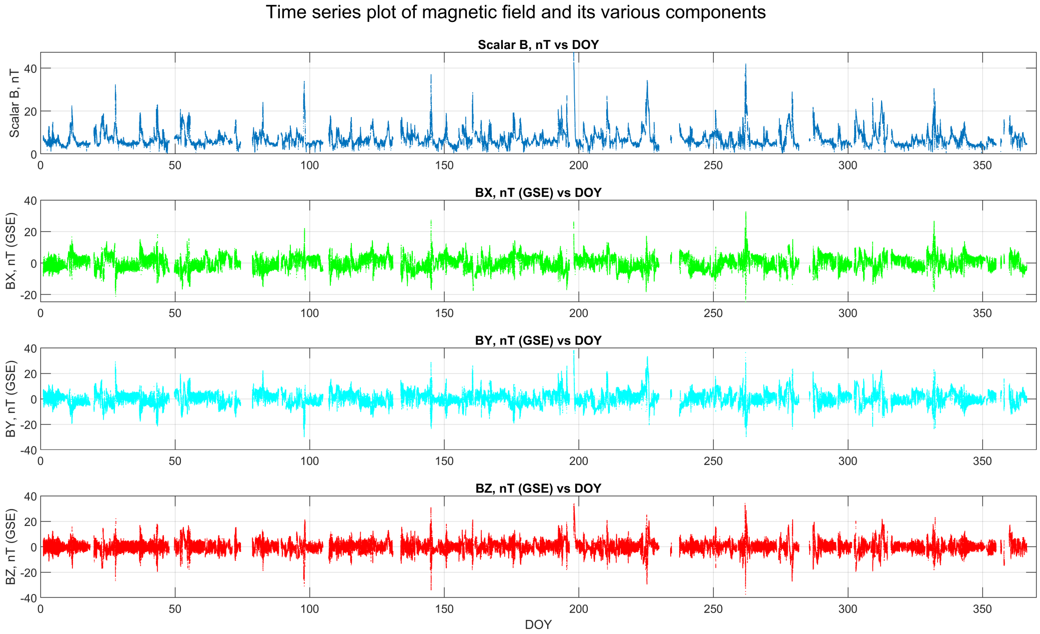

Figure 5: magnetic field time series plot

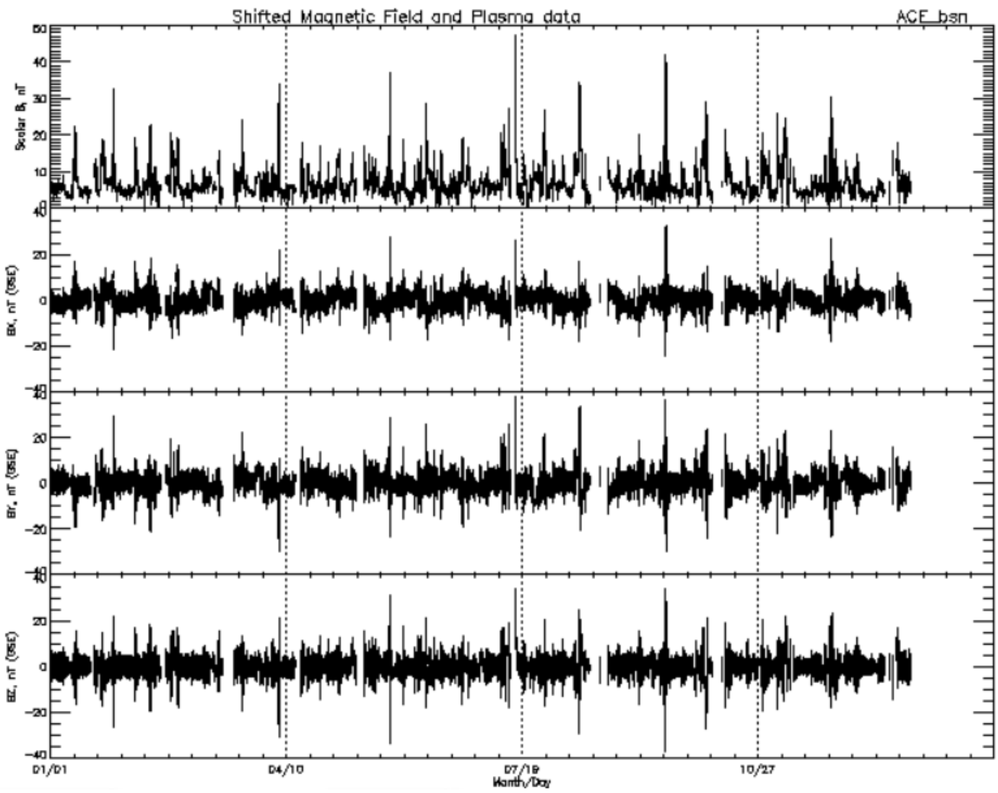

Figure 6: magnetic field time series plot[5]

Appendix: Matlab Code

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%% AA403/407 Space Engeineering system: Assignment 02

%% Code to create plots and finding orbital parameters
%Importing data from excel file, eliminating the NaN(9999.99) values and
%creating new excel file.

% P = readtable('data4.xlsx')
% P(P.X == 9999.99,:) = [];
% P(P.Y == 9999.99,:) = [];
% P(P.Z == 9999.99,:) = [];
% P(P.B == 9999.99,:) = [];
% P(P.BX == 9999.99,:) = [];
% P(P.BY == 9999.99,:) = [];
% P(P.BZ == 9999.99,:) = [];
% writetable(P,'data4_new.xlsx')

%loading new excel file and import data as .mat file. Load .mat file
%created and reading different variables.
load data4.mat
X = data4.X;
Y = data4.Y;
Z= data4.Z;
B=data4.B;
BX=data4.BX;
BY=data4.BY;
BZ=data4.BZ;
DOY=data4.DOY;

% Plotting B and its different component as time series
figure(1);
subplot(4,1,1),plot(DOY,B); ylabel('Scalar B, nT');xlim([0 370]); grid on; title('Scalar B, nT vs DOY'); hold on
subplot(4,1,2),plot(DOY,BX,'g');ylabel('BX, nT (GSE)');xlim([0 370]);grid on; title('BX, nT (GSE) vs DOY');
subplot(4,1,3),plot(DOY,BY,'c'); ylabel('BY, nT (GSE)');xlim([0 370]);grid on; title('BY, nT (GSE) vs DOY');
subplot(4,1,4),plot(DOY,BZ,'r');ylabel('BZ, nT (GSE)');xlim([0 370]) ; hold off; title('BZ, nT (GSE) vs DOY');
sgtitle('Time series plot of magnetic field and its various components');
xlabel('DOY');
grid on;

% Ploting orbit in various 2d planes and in 3d
figure(2);
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```
subplot(2,2,1),plot(X,Y); hold on ;plot(235.44,0,'m*'); hold off; xlabel('X(target), GSE, Re');ylabel('Y(target), GSE, Re');grid on ; title('2d in XY plane');hold on
subplot(2,2,2),plot(Y,Z,'g');hold on ;plot(0,0,'m*'); hold off; xlabel('Y(target), GSE, Re');ylabel('Z(target), GSE, Re');grid on; title('2d in YZ plane');
subplot(2,2,3),plot(X,Z,'c');hold on ;plot(235.44,0,'m*'); hold off; xlabel('X(target), GSE, Re'); ylabel('Z(target), GSE, Re');grid on; title('2d in XZ plane');
subplot(2,2,4),plot3(X,Y,Z,'r'); hold on ;plot3(235.44,0,0,'m*'); hold off; xlabel('X(target), GSE, Re');ylabel('Y(target), GSE, Re'); zlabel('Z(target), GSE, Re') ; title('3d in XYZ plane'); hold off
sgtitle('2d and 3d plots of orbit in GSE coordinate');
grid on;

% Finding Major Orbital paramaters
R=sqrt((X-235.44).^2+Y.^2+Z.^2)';      %Spacecraft distance from Earth
 rp=min(R);      %Perigee distance
 ra=max(R);      %Apogee distance
 a=(rp+ra)/2;    % Semi major axis
 b=sqrt(ra*rp); % Semi minor axis
 e=(ra-rp)/(ra+rp);  %Eccentricity
 disp('Major orbital Parameters are:')
 fprintf('Perigee distance, rp = %f Re or %i km\n',rp,rp* 6371);
 fprintf('Apogee distance, ra = %f Re or %i km\n',ra,ra*6371);
 fprintf('Semi major axis, a = %f Re or %i km\n',a,a*6371);
 fprintf('Semi minor axis, b = %f Re or %i km\n',b,b*6371);
 fprintf('Eccentricity, e = %f\n',e);

%% Results
% Major orbital Parameters are:
% Perigee distance, rp = 22.549293 Re or 1.436615e+05 km
% Apogee distance, ra = 41.932171 Re or 2.671499e+05 km
% Semi major axis, a = 32.240732 Re or 2.054057e+05 km
% Semi minor axis, b = 30.749647 Re or 1.959060e+05 km
% Eccentricity, e = 0.300596
```