DRAFT
General Mission Analysis Tool (GMAT)
Acceptance Test Plan

GMAT PC Build Date: February 11, 2007

GMAT Mac Build Date: December 10, 2007

GMAT Linux Build Date: December 10, 2007

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February 11, 2008

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Chapter 1

Acceptance Test Plan Overview

1.1 GMAT Introduction

The information presented in this Acceptance Test Plan document shows the current status of the General Mission Analysis Tool (GMAT). GMAT is a software system developed by NASA Goddard Space Flight Center (GSFC) in collaboration with the private sector. The GMAT development team continuously performs acceptance tests in order to verify that the software continues to operate properly after updates are made. The GMAT Development team consists of NASA/GSFC Code 583 software developers, NASA/GSFC Code 595 analysts, and contractors of varying professions.

GMAT was developed to provide a development approach that maintains involvement from the private sector and academia, encourages collaborative funding from multiple government agencies and the private sector, and promotes the transfer of technology from government funded research to the private sector.

GMAT contains many capabilities, such as integrated formation flying modeling and MATLAB compatibility. The propagation capabilities in GMAT allow for fully coupled dynamics modeling of multiple spacecraft, in any flight regime. Other capabilities in GMAT include: user definable coordinate systems, 3-D graphics in any coordinate system GMAT can calculate, 2-D plots, branch commands, solvers, optimizers, GMAT functions, planetary ephemeris sources including DE405, DE200, SLP and analytic models, script events, impulsive and finite maneuver models, and many more.

GMAT runs on Windows, Mac, and Linux platforms. Both the Graphical User Interface (GUI) and the GMAT engine were built and tested on all of the mentioned platforms. GMAT was designed for intuitive use from both the GUI and with an importable script language similar to that of MATLAB.

1.2 Testing Methodology

Purpose

GMAT needs to undergo a series of rigorous tests to validate the numerical implementations of its models and establish a set of acceptable performance times. The 595 analysts created the acceptance test plan to achieve this goal by comparing GMAT with flight-operational reference software packages and documenting the results. Results can be reproduced with the initial conditions and software setups presented in this document.

Reference software

For this comparative study to have merit, GMAT was tested against reliable, trustworthy, and flight operational programs, such as STK-HPOP,STK-Astrogator, Free-Flyer, Swingby, and previous GMAT Builds that were comparable to the aforementioned programs. To achieve accurate comparison results, each program was compared with equivalent, or close to equivalent, test case setups.

Testing Categories

The Acceptance Test Plan divides into the following testing categories: Propagation, Calculation Parameters [Central body(Cb) and Coordinate System(CS) dependent], Integrators, Libration Points, Stopping Conditions, Delta V, and Performance.

Scripts Used

MATLAB scripts were created to make comparisons between GMAT Builds and the reference software. The majority of the comparisons involved taking the difference of the data and extracting the maximum absolute difference observed over the propagation duration. Scripts were also created to compare performance times for individual GMAT test cases to the reference software. The scripts created are as followed: Comparison_Tool1_Tool2_PV.m, Comparison_Tool1_Tool2_CS.m, Comparison_Tool1_Tool2_Cb.m, Comparison_Integ.m, TimeComparo.m, BuildRun_Script_GMAT.m, Comparison_Tool1_Tool2_Libr.m, Comparison_StopCond, and STK_Repropagate.m.

The user of the semi-automated scripts provides input when requested, in order to perform the script's core functions. For example, a user that wants to see the position and velocity differences between STK and GMAT would select a few choices from a menu. Next, the script would generate the comparisons based on the report data available. The semi-automation scripts adhere to the naming conventions outlined in their relevant testing category chapter.

Most of the scripts generate output in at least one of the following formats: ASCII, LaTex, MATLAB .mat, or Excel .xls files. The report files are in an ASCII space delimited format and contain the different test case parameters outputted after propagation. The LaTex files contain the comparison data between two programs and provide an easy way to include that data into a PDF document. The .mat and .xls file are two other methods used to save the comparison data that proved useful from the software development team.

The details of each script and how to use them are outlined in the relevant Testing Category section and/or the Comparison Scripts Guide section, located in Appendix C.

1.2.1 Propagation

The propagation test cases account for various orbits about Earth, as well as other celestial bodies. The main propagation parameters to monitor for differences are the position and velocity vectors. The following script was generated to perform the comparisons for this category:
Comparison_Tool1_Tool2_CS.m

See the Propagators section (Chapter 2) for more detail and comparison results.

1.2.2 Calculation Parameters

The calculation parameter test cases verify the internal calculations used to output the various parameters presented in the list below. This section consists of two subsections: Coordinate System(CS) and Central Body(Cb) dependent parameters. The following scripts were generated to perform the comparisons for this testing category: Comparison_Tool1_Tool2_CS.m & Comparison_Tool1_Tool2_Cb.m

- Coordinate Systems
  - Earth Fixed
  - Earth Mean J2000 Equator (MJ2000Eq)
  - Earth Mean J2000 Ecliptic (MJ2000Ec)
  - Earth Mean of Date Equator (MODEq)
  - Earth Mean of Date Ecliptic (MODEc)
  - Earth True of Date Equator (TODEq)
  - Earth True of Date Ecliptic (TODEq)
  - Earth Geocentric Solar Ecliptic (GSE)
  - Earth Geocentric Solar Magnetic (GSM)
  - Mars Fixed
  - Mars MJ2000Eq
  - Mars MJ2000Ec
  - Mercury Fixed
  - Mercury MJ2000Eq
  - Mercury MJ2000Ec
  - Moon Fixed
  - Moon MJ2000Eq
  - Moon MJ2000Ec
  - Neptune Fixed
  - Neptune MJ2000Eq
  - Neptune MJ2000Ec
  - Pluto Fixed
  - Pluto MJ2000Eq
  - Pluto MJ2000Ec
  - Saturn Fixed
  - Saturn MJ2000Eq
  - Saturn MJ2000Ec
  - Uranus Fixed
  - Uranus MJ2000Eq
  - Uranus MJ2000Ec
  - Venus Fixed
  - Venus MJ2000Eq
  - Venus MJ2000Ec
- Coordinate System Parameters
  - Position (X,Y,Z)

  - Velocity(X,Y,Z)
  - Magnitude of Velocity
  - Right Ascension of Velocity
  - Specific Angular Momentum
  - Argument of Periapsis
  - Declination
  - Declination of Velocity
  - Inclination
  - Right Ascension
  - Right Ascension of Ascending Node

- Central Body Parameters
  - Altitude
  - Beta Angle
  - C3 Energy
  - Eccentricity
  - Latitude
  - Longitude
  - Specific Angular Momentum
  - Mean Anomaly
  - Mean Motion
  - Period
  - Apoapsis Radius
  - Perigee Radius
  - Position Magnitude
  - Semi-major Axis
  - True Anomaly
  - Semilatus Rectum
  - Apoapsis Velocity
  - Periapsis Velocity
  - Greenwich Hour Angle
  - Local Sidereal Time

See the Calculation Parameters Section (Chapter 3) for more detail and comparison results.

1.2.3 Integrators

The integrator test cases isolate the differences that would occur when changing the integrators for the same orbit. The following script was generated to perform the test case comparisons for this category:
Comparison_Integ.m

- RungaKutta(RKV) 8(9)
- DormandElMikkawyPrince(RKN) 6(8)

- RungeKuttaFehlberg(RKF) 5(6)
- PrinceDormand(PD) 4(5)
- PrinceDormand(PD) 7(8)
- BulirschStoer(BS)
- AdamsBashforthMoulton(ABM)

See the Integrators Section (Chapter 4) for more detail and comparison results.

1.2.4 Stopping Conditions

The stopping condition test cases determine how effective GMAT is at stopping satellite propagation on certain conditions. The following script was created to perform the test case comparisons for this category:
Comparison_StopCond.m

The stopping conditions tested are as followed:

- Epoch (A1 Modified Julian Date)
- Apoapsis
- Elapsed Days
- Mean Anomaly
- Periapsis
- Elapsed Seconds
- True Anomaly
- XY Plane Intersection
- XZ Plane Intersection
- YZ Plane Intersection

See the Stopping Conditions Section (Chapter 5) for more detail and comparison results.

1.2.5 Libration Point

The libration point test cases create data about the location of several libration points. Current and future satellite missions use libration points as part of their mission architecture. It is important to have accurate data for these libration points. The following script was created to perform the test case comparisons for this category:
Comparison_Tool1_Tool2_Libr.m

See the Libration Point Section (Chapter 6) for more detail and comparison results.

1.2.6 Delta V

The delta v test cases determine the effectiveness of the delta v capabilities built into GMAT. When thruster burns are added to the mission sequence it is important that they are added correctly. The following script was created to perform the test case comparisons for this category:
Comparison_DeltaV.m

See the Delta V Section (Chapter 7) for more detail and comparison results.

1.2.7 Performance

The performance test cases generate performance time data for later comparison between GMAT and the reference software packages. Numerical calculation accuracy is important, but the amount of computing time it takes for the software to run is equally as important. We extracted several test cases from previous sections and ran them on the reference software packages, in order to check to make sure GMAT can perform just as good or better.

See the Performance Section (Chapter 8) for more detail and comparison results.

1.2.8 Control Flow

The control flow tests generate report data that easily allows a Matlab script to produce a table of Pass and Fail cases.The following script was created to generate the Pass/Fail table for this category:
LoopTestSummary.m

See the Control Flow Section (Chapter 9) for more detail and results.

Chapter 2

Propagation

In order to validate the accuracy of GMAT's propagation, the fundamental unit-level components need to be combined and propagated on a system level. From a software development point of view, if the program under development is tested in a wide range of core applications, it is more likely that problems would be found before each new version is released to the public. This Acceptance Test Plan tests GMAT by comparing many possible scenarios users of GMAT would encounter to reference software packages. Although it is impossible to create all the possible scenarios each user would encounter in GMAT, this is a start to eliminate possible frustrations a user could experience if a component did not work correctly.

Propagation is one of the most important aspects of GMAT. Everything from outputting parameters to performing a thruster burns at the correct stopping condition depend on whether or not GMAT is able to propagate the satellite/object for a defined time period with acceptable accuracy.

Parts of the Initial Orbit State Conditions section are referenced from Emergent Space Technologies' Orbit Determination Toolbox (ODTBX) Spiral 1 DEMO document,[1] due to a similar objective of testing the numerical implementation of the programs base functions.

2.1 Initial Orbit State Conditions

2.1.1 Earth Based Test Cases

The initial orbit states for the Sun-Synchronous (SunSync), Geostationary (GEO), Molniya, International Space Station (ISS) and the Global Positioning Satellite (GPS) orbits were obtained from Emergent Space Technologies' ODTBX Spiral 1 Demo .[1] Emergent used STK-High Precision Orbit Propagator (STK-HPOP) models and two-Line Element (TLE) sets with an initial UTC orbit epoch of June 1st 2004, 12:00:00:00. The initial orbit states that were used for the test case orbits can be seen in Table 2.1, on Page 20. The perigee and apogee altitudes of the test case orbits can be seen in Table 2.2, on Page 20.

The propagation duration, report output step size, and integrator step sizes were varied for the different test cases. For the ISS, SunSync, GPS, Molynia, and GEO cases, the propagation length and report output step size were chosen based on a study performed by The Aerospace Corporation to validate STK-HPOP's.[2] The integrator time steps were chosen to allow for the most accurate comparison of the test case results. These time steps were based on Vallado's analysis of state vector propagation.[3]

Table 2.1: Satellite Initial Conditions

Category	Orbit Type	X(km)	Y(km)	Z(km)	Vx(km/s)	Vy(km/s)	Vz(km/s)
LEO	ISS	-4453.783586	-5038.203756	-426.384456	3.831888	-2.887221	-6.018232
LEO	Sun-Sync	-2290.301063	-6379.471940	0	-0.883923	0.317338	7.610832
MEO	GPS	5525.33668	-15871.18494	-20998.992446	2.750341	2.434198	-1.068884
HEO	Molniya	-1529.894287	-2672.877357	-6150.115340	8.717518	-4.989709	0
GEO	GEO	36607.358256	-20921.723703	0	1.525636	2.669451	0

Table 2.2: Apogee and Perigee Altitudes for Test Satellites

Orbit Type	Perigee Altitude(km)	Apogee Altitude(km)
ISS	358.168	380.387
Sun-Sync	400	400
GPS	19757.6	20603.8
Molniya	500	39850.5
GEO	35786	35786

The chosen parameters can be seen in Table 2.3, on Page 20.

Table 2.3: Integrator,Propagator, and Output Frequency

Orbit Type	Integrator Step Size(s)	Propagator Length(days)	Output Frequency(mins)
ISS	5	1	1
Sun-Sync	5	1	1
GPS	60	2	2
Molniya	5	3	5
GEO	60	7	10

Several test cases were created for each satellite orbit to verify GMAT's ability to perform accurately, while applying various forces. The forces used for Earth-based test cases were two-body, JGM2, EGM96, and JGM3 gravity models, third-body perturbation effects from other planets, the Jacchia-Roberts (JR) and the Mass Spectrometer and Incoherent Scatter Radar Exosphere (MSISE 1990 & 2000) Atmospheric Drag Model, and Solar Radiation Pressure (SRP). Each of the force models were run independently within GMAT to verify their individual accuracy, as well as a test case that includes an atmospheric drag model, the SRP model, a non-spherical gravity model, and third-body perturbations. These last test cases were performed to validate the capability of the GMAT to accurately propagate satellite orbits while multiple force models were applied.

The Degree and Order for Earth-based non-spherical gravity cases was set at a constant 20 by 20.

Refer to Appendix B.1 for an alternate listing of all Propagator initial orbit state conditions.

2.1.2 Non-Earth Based Test Cases

GMAT is designed for accuracy in non-Earth mission scenarios. Test cases for Mars, Mercury, the Moon, Neptune, Pluto, Saturn, Uranus, Venus, L2 orbits, and deep space orbits were created to test various forces,individually and jointly, affecting a spacecraft in an orbit. Many satellite parameters, such as Cd,Cr, satellite area, and satellite mass, were kept the same as the Earth test cases for simplicity and consistency. The initial Keplerian satellite state only varied in Semi-Major Axis and gravity field degree & order for the non-Earth test cases.

Refer to Table 2.4 for the initial Keplerian orbital elements and the Degree & Order used for the non-spherical gravity force cases. The integrator step size, propagation length, and output frequency for all the non-Earth cases are 5 seconds, 3 days, and 5 minutes, respectively. Table 2.4 excludes the deep space and L2 orbit test cases.

Table 2.4: Non-Earth Keplerian Orbital Elements

Orbit Type	SMA (km)	Ecc.	Inc. (deg)	AOP (deg)	RAAN (deg)	TA (deg)	Deg. x Ord. used
Mars	4603	0.2	45	45	90	45	20x20
Mercury	3640	0.2	45	45	90	45	4x0
Moon	2500	0.2	45	45	90	45	20x20
Neptune	34999	0.2	45	45	90	45	4x0
Pluto	1795	0.2	45	45	90	45	4x0
Saturn	80000	0.2	45	45	90	45	4x0
Uranus	45000	0.2	45	45	90	45	4x0
Venus	8125	0.2	45	45	90	45	20x20

SMA: Semi-Major Axis | Ecc.: Eccentricity | Inc.: Inclination | AOP: Argument of Perigee
RAAN: Right Ascension of Ascending Node | TA: True Anomaly

The DeepSpace, Earth Moon L2 (EML2), and Earth Sun L2 (ESL2) cases involve propagating about libration points and propagating deep space orbits. Table B.14, B.15, and B.16, in Appendix B, provide the initial states for the DeepSpace, EML2, and ESL2 test cases, respectively.

Refer to Appendix B.1 for a listing of all Propagator initial orbit state conditions.

2.2 Other Initial State Conditions

In order to reduce the complications of the comparisons, certain initial orbit parameters were kept constant throughout all of the cases. These parameters are Cd, Cr, Spacecraft Area, each programs integrator, and software settings affecting the results of various force models.

The GMAT integrator used for all the test cases was Runga Kutta 8(9), except for the STK-HPOP test cases, to avoid any additional differences that could occur from changing integrators. The Integrators Section compares the differences between the various integrators GMAT can use.

The parameters in Table 2.5 shows the differences between GMAT and the reference programs. The ideal situation would be for all the programs to match perfectly, but that is not realistic due to the different approaches each program takes to solve each problem.

Table 2.5: Universal Test Case Parameters

Parameter	GMAT	STK-HPOP	FF	STK-Astro
Cd	2.2	2.2	2.2	2.2
Cr	1.2	1.2	1.2	1.2
Area(m^2)	20	20	20	20
Satellite Mass(kg)	1000	1000	1000	1000
Integrator (excluding integrator test cases)	RK8(9)	RK7(8)	RK8(9)	RK8(9)
Integrator error tolerance	1e-013	1e-013	1e-013	1e-013
Integrator error control. Relative to	Step	Step?	?	Step
Drag: Altitude Calculation	Approximate	Approximate	Exact	?
Drag: Sun Position	True	True	True	True
SRP: Sun Position	True	True	True?	True
Solar Flux (W/m^2) at 1 AU	1359.38857	1359.38857	1358	1359.38857
Solid Tides	N/A	Disabled	N/A	N/A
Ocean Tides	N/A	Disabled	N/A	N/A
Daily F10.7: JR and MSISE models	150	150	N/A	150
Average F10.7	150	150	150	150
Geomagnetic Index(Kp): JR and MSISE only	3	3	N/A	3
Drag: Geomagnetic Flux Update	Constant	Constant	N/A	Constant
Boundary Mitigation	N/A	Disabled	N/A	N/A
Relativistic Accelerations	N/A	Disabled	N/A	N/A
Shadow Modeling	Dual Cone	Dual Cone	Dual Cone	?
IERS EOP format used:	Long term C04	Bulletin A	Bulletin A	Bulletin A
Polar Motion calculation:	Enabled	Enabled	Enabled	Enabled?
Nutation update interval: Earth (sec)	60	60	60	60
Planetary Ephemeris update interval (sec)	0	0?	0	0?

Exceptions to Table 2.5 are as followed:

- STK has trouble propagating the EML2 test case at an error tolerance of 1e-013 with a relative to step error control. The GMAT and STK cases were changed to both use relative to state error control

2.2.1 Earth Orientation Parameters(EOP) data

"International Earth Rotation Service (IERS) Bulletins A and B provide current information on the Earth's orientation in the IERS Reference System. This includes Universal Time, coordinates of the terrestrial pole, and celestial pole offsets. Bulletin A gives an advanced solution updated weekly by e-mail subscription or daily by anonymous ftp; the standard solution is given monthly in Bulletin B and updated every week in the (IERS) C04 solution."[6]

"Bulletin A is issued by the IERS Rapid Service/Prediction Centre at the U.S. Naval Observatory(USNO), Washington, DC and Bulletin B", as well as the C04 data, *"is issued by the IERS Earth Orientation Centre at the Paris Observatory."*[4]

"Bulletin A is intended for users who need accurate information before the Bulletin B finals series is available, i.e., those who reduce data in the very recent past (require rapid service) or those who operate in real-time (require predictions). Bulletin B is intended for standard use. For scientific and long-term analyses of the Earth's orientation, the long-term continuous series",[4] C04 (1962- present), can be used.

"EOP (IERS) C04 is regularly recomputed to take advantage on one hand of the improvement of the various individual contributions and in the other hand of the refinement of the analysis procedures. To date, it is twice-weekly updated."[5]

"The EOP (IERS) C04 is given at one-day intervals, it is free from the diurnal/subdiurnal terms due to the oceanic effects and can be interpolated linearly. The oscillations in UT and duration of the days due to zonal tides for periods under 35 days are present in full size in the series."[5]

GMAT retrieves long term earth orientation IERS EOP CO4 data, which includes UTC-UT1 data, from a file. This file includes smoothed values at 1-day intervals and data from 1962-present.

STK and FF retrieves its EOP data from the USNO series 7 / IERS Bulletin A.

The differences between the EOP data sets are displayed in Table 2.6. The Terrestrial Pole column refers to the accuracy of the pole position [x,y] and the UT1 column refers to the accuracy of the rotation angle about the pole UT1.

As shown in Table 2.6, there are differences between STK and GMAT, but the Terrestrial Pole data agrees to within the thousandth place of a milli-arcseconds and the UT1 data agrees to within the hundredth place of second.

Table 2.6: EOP Format Accuracy

EOP Format	Pole Position (mas)	UT1 (ms)
Bulletin A obs. 1-d (1)	0.10	0.02
Bulletin A pred. 1-d (2)	0.50	0.14
Bulletin A pred. 4-d (2)	1.60	0.52
Bulletin A pred. 10-d (2)	3.9	1.60
Bulletin A pred. 40-d (2)	11.2	7.70
Bulletin B obs. smooth 5-d (3)	0.15	0.02
Bulletin B obs. raw 5-d (3)	0.15	0.02
Bulletin B pred. 5-d (3)	1.6	0.60
Bulletin B pred. 10-d (3)	3.0	1.60
Bulletin B pred. 30-d (3)	10.0	4.0
Long-Term C04 ’62-’67	30.0	2.0
Long-Term C04 ’68-’71	20.0	1.5
Long-Term C04 ’72-’79	15.0	1.0
Long-Term C04 ’80-’83	2.0	0.4
Long-Term C04 ’84-’95	0.7	0.04
Long-Term C04 ’96-present	0.2	0.02

NOTES: (1) Based on data after 1997; applies only to latest epochs in each update.
(2) Based on data since 1995.
(3) Based on data since 1996.
The Terrestrial Pole and UT1 data is free from the diurnal/subdiurnal terms due to the oceanic effects and can be interpolated linearly. These terms can be added after interpolation.

2.2.2 Other Planetary Parameters

Gravitational Constant

All programs used for comparisons utilize the DE405 Planetary Gravitational Constants listed in Table 2.7, except when non-spherical gravity was used. When non-spherical gravity files are used they typically call the gravitational constants located in the file, unless the program creates an exception.

Table 2.7: Planetary Gravitational Constants(mu values)

Planet	mu (km^3/s^2)
Sun	132712440017.99
Mercury	22032.080486418
Venus	324858.59882646
Earth	398600.44150000
Moon	4902.8005821478
Mars	42828.314258067
Jupiter	126712767.85780
Saturn	37940626.061137
Uranus	5794549.0070719
Neptune	6836534.0638793
Pluto	981.60088770700

Flattening Coefficient

Whenever possible the flattening coefficients listed in Table 2.8 were used. Without the use of these values the planetary bodies could have wildly different shapes, which would result in large differences in parameters such as longitude, latitude, and altitude.

Table 2.8: Flattening Coefficient

Planet	Flattening Coefficient
Sun	0.00000000
Mercury	0.00000000
Venus	0.00000000
Earth	0.00335270
Moon	0.00000000
Mars	0.00647630
Jupiter	0.06487439
Saturn	0.09796243
Uranus	0.02292734
Neptune	0.01856029
Pluto	0.00000000

Equatorial Radius

The several celestial body equatorial radii used are listed in Table 2.9. Similar differences as the flattening coefficient occur when GMAT and the reference programs don't use the same values.

Table 2.9: Equatorial Radius

Planet	Radius (km)
Sun	695990.0
Mercury	2439.7
Venus	6051.90
Earth	6378.1363
Moon	1738.2
Mars	3397.0
Jupiter	71492.0
Saturn	60268.0
Uranus	25559.0
Neptune	25269.0
Pluto	1162.0

Leap Seconds

The amount of leap seconds, or ΔAT, has been used since 1972 in order to keep —UTC-UT1—$\leq$ 0.9sec. GMAT and the reference software packages use all the leap seconds up until 2004. In 2004 the amount of leap seconds in use were 32 seconds.

2.3 Naming Convention

This section describes the naming convention for propagator scripts and output reports. The naming convention consists of an ordered series of option strings, separated by underscores (_). Currently, options are allowed for the following fields, and will be present in the file name in order:

1. *tool* - The tool used to generate the test case
2. *traj* - The trajectory to use. This includes initial conditions, physical parameters, and time step
3. *pmg* - The point-mass gravity model to use
4. *nsg* - The non-spherical gravity model to use
5. *drag* - The atmospheric drag model to use
6. *other* - Any other forces to include, such as SRP, secondary body gravity, etc

The *tool* field should always be the first field. Future additional fields should be added to the end of the list of fields. If multiple *other* options are required, they should be added to the end of the file as required. For example, the file name will be *tool_traj_pmg_nsg_drag_other1_other2.report* (file extensions are described later.) Each field has a finite list of options, as follows (future options should be added to this list):

1. *tool*

STK	- Satellite Toolkit HPOP or Astrogator
FF	- FreeFlyer
GMAT	- General Mission Analysis Tool

2. *traj*

ISS	- LEO orbit
SunSync	- LEO orbit
GPS	- MEO orbit
GEO	- GEO orbit
Molniya	- HEO orbit
Mars1	- eccentric low orbit
Mercury1	- eccentric low orbit
Moon	- eccentric low orbit
Neptune1	- eccentric low orbit
Pluto1	- eccentric low orbit
Saturn1	- eccentric low orbit
Uranus1	- eccentric low orbit
Venus1	- eccentric low orbit
DeepSpace	deep space orbit
EML2	- Earth Moon L2 orbit
ESL2	- Earth Sun L2 orbit

NOTE: Some test cases contain *traj* variations. In these cases, *traj* precedes the modification. For example, if ISS trajectory is needed with no output, then *traj* can be ISSnoOut. The lack of a report file is shortened to noOut.

3. *pmg*

Earth	- Earth point mass gravity
Sun	- Sun point mass gravity
Luna	- Lunar point mass gravity
AllPlanets	- Sun, Mercury, Venus, Earth, Moon, Mars, Mercury, Jupiter, and Pluto point mass gravity included.

NOTE: When dealing with a combination of *pmg*'s the first point mass is the primary body and the following are third body point masses. For example, LunaSunEarth would be a Lunar primary body with the Earth and Sun as third body point masses. The *pmg*'s after the primary body are arranged based on the order from the sun, in order to reduce repeat filenames.

4. *nsg*

0	- no non-spherical gravity included
JGM2	- Earth JGM2 20x20 gravity
JGM3	- Earth JGM3 20x20 gravity
EGM96	- Earth EGM96 20x20 gravity
MARS50C	- Mars Mars50c 20x20 gravity
LP165P	- Moon LP165P 20x20 gravity

5. *drag*

0	- drag not included
HP	- Harris Priester
JRXX	- Jacchia-Roberts
MSISEXX	- NRL MSISE

NOTE: XX in the *drag* field refers to the year. For example, JR77 would be the Jacchia-Roberts 1977 model, and MSISE00 would be NRL MSISE 2000. Refer to Table 2.5 for the drag settings used.

6. *other*

0	- no other forces included
SRP	- Solar Radiation Pressure

NOTE: Any of the above options may be included as an *other* field. Refer to Table 2.5 for the SRP settings used.

2.3.1 Comparison Script Information

The script used to perform the position and velocity comparisons needed for the Propagator section is Comparison_Tool1_Tool2_PV.m. This script takes the normalized position and velocity vector difference between two programs.

Refer to Appendix C for more details about this script and others used in the Acceptance Test Plan document.

2.4 Test Case Results

The following results are for the Propagator section. The current GMAT Build is compared to STK and FreeFlyer for this section, with the maximum normalized position and velocity difference displayed in table format.

To determine if a propagator test case comparison value was acceptable, an acceptance matrix, presented in Table 2.10, was created. The values in Table 2.10 were obtained from the lower position difference bounds of David Vallados An Analysis of State Vector Propagation Using Differing Flight Dynamics Programs, presented at the 2005 American Astronomical Society (AAS)/AIAA Astrodynamics Specialist Conference. These lower bounds are difficult to meet in some orbits due to the wide range of orbits that are possible but they give a order of magnitude number to strive for. If a case has a combination of either Drag, Non-Spherical Gravity, Solar Radiation Pressure(SRP), or Point Mass gravity, the largest acceptable position difference is used.

The next step beyond this acceptance matrix is to compare GMAT's comparison data to differences seen in FF and STK comparisons, and peer reviews.

Table 2.10: Acceptance Matrix

Difference in	Acceptable Position Difference (m)
Non-Spherical Gravity	< 0.001
Point Mass Gravity	< 0.001
Solar Radiation Pressure	< 0.6
Drag	< 20

Table 2.11: WinGMAT/STK GEO Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.0002573600464	1.793782766e-008
EarthLuna-0-0-0	0.000319469177	2.245968491e-008
EarthSunLuna-EGM96-JR-SRP	0.000157111986	1.10145998e-008
EarthSunLuna-EGM96-MSISE90-SRP	0.0001571119996	1.101459883e-008
EarthSunLuna-JGM2-JR-SRP	0.0001132816464	7.86017199e-009
EarthSunLuna-JGM2-MSISE90-SRP	0.0001132816525	7.860172342e-009
EarthSunLuna-JGM3-JR-SRP	0.0002438654858	1.730861641e-008
EarthSunLuna-JGM3-MSISE90-SRP	0.0002438654861	1.730861648e-008
EarthSun-0-0-0	2.279168371e-005	1.61733327e-009
Earth-0-0-0	2.111395905e-005	1.406994785e-009
Earth-0-0-SRP	4.571760608e-005	2.615384024e-009
Earth-0-JR-0	2.111395905e-005	1.406994785e-009
Earth-0-MSISE90-0	2.111395905e-005	1.406994785e-009
Earth-EGM96-0-0	0.0001110202624	8.026471479e-009
Earth-EGM96full-0-0	0.0001110202624	8.026471479e-009
Earth-JGM2-0-0	2.954895496e-005	2.054073235e-009
Earth-JGM2full-0-0	2.954895496e-005	2.054073235e-009
Earth-JGM3-0-0	1.603674008e-005	1.085055615e-009
Earth-JGM3full-0-0	1.603674009e-005	1.085055615e-009

Table 2.12: WinGMAT/STK GPS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.857890303e-005	2.692489413e-009
EarthLuna-0-0-0	2.280562281e-005	3.313474128e-009
EarthSunLuna-EGM96-JR-SRP	0.04423319518	4.494744959e-006
EarthSunLuna-EGM96-MSISE90-SRP	0.04425083865	4.497443366e-006
EarthSunLuna-JGM2-JR-SRP	0.04423757254	4.4953771e-006
EarthSunLuna-JGM2-MSISE90-SRP	0.0442455997	4.496600974e-006
EarthSunLuna-JGM3-JR-SRP	0.04423934565	4.495691689e-006
EarthSunLuna-JGM3-MSISE90-SRP	0.04423592869	4.495186505e-006
EarthSun-0-0-0	1.81527305e-006	2.214883804e-010
Earth-0-0-0	2.704817671e-006	3.709235187e-010
Earth-0-0-SRP	0.04675382861	4.841397638e-006
Earth-0-JR-0	2.704817671e-006	3.709235187e-010
Earth-0-MSISE90-0	1.54909103e-005	2.225873381e-009
Earth-EGM96-0-0	3.230673797e-005	4.258922497e-009
Earth-EGM96full-0-0	3.230673797e-005	4.258922497e-009
Earth-JGM2-0-0	3.207859422e-005	4.296841145e-009
Earth-JGM2full-0-0	3.207859422e-005	4.296841145e-009
Earth-JGM3-0-0	3.197574489e-005	4.249781094e-009
Earth-JGM3full-0-0	3.197574489e-005	4.249781094e-009

Table 2.13: WinGMAT/STK ISS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.236533809e-005	1.385227256e-008
EarthLuna-0-0-0	2.656381117e-005	3.027412372e-008
EarthSunLuna-EGM96-JR-SRP	278.7566272	0.3182101779
EarthSunLuna-EGM96-MSISE90-SRP	56.2421725	0.06448778396
EarthSunLuna-JGM2-JR-SRP	265.0511827	0.3028951491
EarthSunLuna-JGM2-MSISE90-SRP	56.24215684	0.06448774979
EarthSunLuna-JGM3-JR-SRP	278.7568014	0.3182104054
EarthSunLuna-JGM3-MSISE90-SRP	56.24206048	0.06448766318
EarthSun-0-0-0	1.433764674e-005	1.600823115e-008
Earth-0-0-0	2.047203147e-005	2.325189569e-008
Earth-0-0-SRP	0.130272568	0.0001262632038
Earth-0-JR-0	251.765217	0.2867219205
Earth-0-MSISE90-0	54.12970949	0.06180127344
Earth-EGM96-0-0	0.0003663016096	4.164100958e-007
Earth-EGM96full-0-0	0.0003621628298	4.134604421e-007
Earth-JGM2-0-0	0.0002104591217	2.411864887e-007
Earth-JGM2full-0-0	0.0002185235364	2.48797737e-007
Earth-JGM3-0-0	0.0002166929687	2.47503413e-007
Earth-JGM3full-0-0	0.0002197092927	2.507716249e-007

Table 2.14: WinGMAT/STK Molniya Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.0001645654561	1.252146304e-007
EarthLuna-0-0-0	0.0001587779228	1.205681387e-007
EarthSunLuna-EGM96-JR-SRP	13.29848959	0.009564197805
EarthSunLuna-EGM96-MSISE90-SRP	7.084035367	0.004827064426
EarthSunLuna-JGM2-JR-SRP	13.29849439	0.009564215374
EarthSunLuna-JGM2-MSISE90-SRP	7.083986451	0.004827011437
EarthSunLuna-JGM3-JR-SRP	13.2985248	0.009564255446
EarthSunLuna-JGM3-MSISE90-SRP	7.08473615	0.004827602744
EarthSun-0-0-0	0.000348717827	2.914219951e-007
Earth-0-0-0	0.0002791429809	2.328580346e-007
Earth-0-0-SRP	0.6111776321	0.0005124550223
Earth-0-JR-0	15.70095053	0.01312840386
Earth-0-MSISE90-0	7.009963698	0.005861408
Earth-EGM96-0-0	0.001747777921	1.46609689e-006
Earth-EGM96full-0-0	0.001874691883	1.572010942e-006
Earth-JGM2-0-0	0.00156516582	1.313726266e-006
Earth-JGM2full-0-0	0.00153824279	1.291402628e-006
Earth-JGM3-0-0	0.001286385724	1.080852205e-006
Earth-JGM3full-0-0	0.001517774713	1.273995917e-006

Table 2.15: WinGMAT/STK SunSync Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	4.699222822e-005	5.325243128e-008
EarthLuna-0-0-0	1.738032476e-005	1.943482273e-008
EarthSunLuna-EGM96-JR-SRP	185.4905295	0.2108184432
EarthSunLuna-EGM96-MSISE90-SRP	45.11411956	0.05130834281
EarthSunLuna-JGM2-JR-SRP	185.4896262	0.2108173466
EarthSunLuna-JGM2-MSISE90-SRP	45.1146799	0.05130896317
EarthSunLuna-JGM3-JR-SRP	185.4905136	0.2108184389
EarthSunLuna-JGM3-MSISE90-SRP	45.11393481	0.0513081406
EarthSun-0-0-0	4.687777606e-006	5.019368405e-009
Earth-0-0-0	4.483249915e-005	5.068336761e-008
Earth-0-0-SRP	0.173198102	0.0001547951558
Earth-0-JR-0	172.0259163	0.1950745493
Earth-0-MSISE90-0	42.66516434	0.04839009285
Earth-EGM96-0-0	7.308356983e-005	8.466320674e-008
Earth-EGM96full-0-0	7.478889446e-005	8.088061938e-008
Earth-JGM2-0-0	8.928348594e-005	9.655246367e-008
Earth-JGM2full-0-0	6.955767447e-005	7.95181581e-008
Earth-JGM3-0-0	6.997911597e-005	7.571096195e-008
Earth-JGM3full-0-0	7.300904469e-005	7.891681204e-008

Table 2.16: WinGMAT/STK Mars1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.1994303898	0.0001681334573
Mars-0-0-0	0.1873874394	0.0001577557948
Mars-0-0-SRP	0.6688079458	0.0005576090938
Mars-MARS50C-0-0	0.4488316637	0.0003800813667
Mars-MARS50C-0-SRP	1.105089608	0.0009291075949

Table 2.17: WinGMAT/STK Mercury1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.1124163711	9.591759819e-005
Mercury-0-0-0	0.02585481636	2.218352736e-005
Mercury-0-0-SRP	0.07778801121	6.658571119e-005

Table 2.18: WinGMAT/STK Moon Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.0002227517348	1.414654829e-007
Luna-0-0-0	0.0001960891057	1.399292279e-007
Luna-0-0-SRP	5.486875354e-005	3.881689429e-008
Luna-LP165P-0-0	0.0002701673647	1.922174669e-007
Luna-LP165P-0-SRP	0.0002393214314	1.693094815e-007

Table 2.19: WinGMAT/STK Neptune1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.9974264518	0.0005074875215
Neptune-0-0-0	1.171036908	0.0005920828399
Neptune-0-0-SRP	0.9524248353	0.0004889922186

Table 2.20: WinGMAT/STK Pluto1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.8883195792	0.0004683900657
Pluto-0-0-0	0.2632397208	0.0001382385307
Pluto-0-0-SRP	0.7534556636	0.0003932303114

Table 2.21: WinGMAT/STK Saturn1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.1414864331	4.873107384e-005
Saturn-0-0-0	0.4497282767	0.0001561546333
Saturn-0-0-SRP	0.4994435851	0.0001686750308

Table 2.22: WinGMAT/STK Uranus1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.2465709269	7.912323063e-005
Uranus-0-0-0	1.320413817	0.0004243963023
Uranus-0-0-SRP	1.156382201	0.0002904419051

Table 2.23: WinGMAT/STK Venus1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.02561929021	2.548815625e-005
Venus-0-0-0	0.01793453836	1.768517227e-005
Venus-0-0-SRP	0.006332820969	6.249825126e-006
Venus-MGNP180U-0-0	0.007510965788	7.525754724e-006
Venus-MGNP180U-0-SRP	0.006805940089	6.750530974e-006

Table 2.24: WinGMAT/STK DeepSpace Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.02376142886	4.703584393e-009

Table 2.25: WinGMAT/STK EML2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	522765.3537	2.863727241
AllPlanets-0-0-SRP	304992.5809	1.654543949
EarthSunLuna-0-0-0	191050.7911	1.043593334
EarthSunLuna-JGM2-0-0	83171.00019	0.4533443656

Table 2.26: WinGMAT/STK ESL2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	29036.71985	0.01713684894
AllPlanets-0-0-SRP	162456.0169	0.1246828624

Table 2.27: FF/WinGMAT GEO Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.02466296086	2.348952999e-006
EarthLuna-0-0-0	0.02466037174	2.264158243e-006
EarthSun-0-0-0	4.79785384e-005	8.493947765e-007
Earth-0-0-0	5.214381207e-005	6.89627309e-007
Earth-0-0-SRP	2.899321865	0.0001245219489
Earth-JGM2-0-0	0.02515954067	2.313999898e-006

Table 2.28: FF/WinGMAT GPS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.001885974435	1.052020705e-006
EarthLuna-0-0-0	0.001874007099	9.43361654e-007
EarthSun-0-0-0	3.432176702e-006	8.317293859e-007
Earth-0-0-0	5.489921041e-006	7.9829921e-007
Earth-0-0-SRP	0.6535523199	6.830245231e-005
Earth-JGM2-0-0	0.01104317452	2.140216499e-006

Table 2.29: FF/WinGMAT ISS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	5.610904349e-006	8.224014796e-007
EarthLuna-0-0-0	1.133489824e-005	8.407000067e-007
EarthSun-0-0-0	9.638402495e-006	8.134703987e-007
Earth-0-0-0	2.358180759e-005	8.186468434e-007
Earth-0-0-SRP	0.03352070462	2.995220929e-005
Earth-JGM2-0-0	0.2076314901	0.0002404721693

Table 2.30: FF/WinGMAT Molniya Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.01444526657	1.203396044e-005
EarthLuna-0-0-0	0.01424235005	1.19546892e-005
EarthSun-0-0-0	0.0003311394147	8.232647373e-007
Earth-0-0-0	5.789754939e-005	8.078947532e-007
Earth-0-0-SRP	2.774957384	0.002291583263
Earth-JGM2-0-0	3.064693947	0.002562937467

Table 2.31: FF/WinGMAT SunSync Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.624452888e-005	8.363014362e-007
EarthLuna-0-0-0	3.641972152e-005	8.139327674e-007
EarthSun-0-0-0	1.62185169e-005	8.470799538e-007
Earth-0-0-0	8.93851495e-006	8.215195e-007
Earth-0-0-SRP	0.03205041923	2.81000432e-005
Earth-JGM2-0-0	0.09458368297	0.0001055216409

Table 2.32: FF/WinGMAT EML2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	732436.6987	4.007738969
AllPlanets-0-0-SRP	512825.9651	2.780610367
EarthSunLuna-0-0-0	400326.9215	2.185454594
EarthSunLuna-JGM2-0-0	292445.684	1.595241714

Table 2.33: FF/WinGMAT ESL2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	5690806.264	3.131093893
AllPlanets-0-0-SRP	6718791.552	5.235648755

2.5 Win/Mac GMAT Comparison

Table 2.34: WinGMAT/MacGMAT GEO Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	7.889320184e-006	4.981092583e-010
EarthLuna-0-0-0	3.862310091e-005	2.829034403e-009
EarthSunLuna-EGM96-JR-SRP	0.0001255674449	9.1445459e-009
EarthSunLuna-EGM96-MSISE90-SRP	0.0001255674449	9.144545899e-009
EarthSunLuna-JGM2-JR-SRP	7.353496438e-005	5.462181017e-009
EarthSunLuna-JGM2-MSISE90-SRP	7.353496437e-005	5.462181016e-009
EarthSunLuna-JGM3-JR-SRP	0.0001352482846	9.775905712e-009
EarthSunLuna-JGM3-MSISE90-SRP	0.0001352482846	9.775905715e-009
EarthSun-0-0-0	9.928130768e-005	7.154327853e-009
Earth-0-0-0	4.990522323e-005	3.634067315e-009
Earth-0-0-SRP	4.520549659e-005	3.269987835e-009
Earth-0-JR-0	4.990522323e-005	3.634067315e-009
Earth-0-MSISE90-0	4.990522323e-005	3.634067315e-009
Earth-EGM96-0-0	6.81671185e-005	4.950072943e-009
Earth-EGM96full-0-0	6.81671185e-005	4.950072943e-009
Earth-JGM2-0-0	1.538671514e-005	1.112479746e-009
Earth-JGM2full-0-0	1.538671514e-005	1.112479746e-009
Earth-JGM3-0-0	5.489787175e-006	4.047244602e-010
Earth-JGM3full-0-0	5.489787175e-006	4.047244602e-010

Table 2.35: WinGMAT/MacGMAT GPS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.524285564e-005	2.13023419e-009
EarthLuna-0-0-0	7.689731018e-006	1.062224728e-009
EarthSunLuna-EGM96-JR-SRP	1.627453194e-005	2.270918492e-009
EarthSunLuna-EGM96-MSISE90-SRP	9.265605105e-006	1.328441506e-009
EarthSunLuna-JGM2-JR-SRP	2.80275826e-006	3.762387107e-010
EarthSunLuna-JGM2-MSISE90-SRP	7.908282521e-006	1.128542622e-009
EarthSunLuna-JGM3-JR-SRP	6.035842385e-006	7.962769859e-010
EarthSunLuna-JGM3-MSISE90-SRP	6.490395836e-006	9.21768e-010
EarthSun-0-0-0	3.222076727e-006	4.833482138e-010
Earth-0-0-0	5.234750509e-006	7.706152625e-010
Earth-0-0-SRP	1.171446476e-006	1.822703558e-010
Earth-0-JR-0	5.234750509e-006	7.706152625e-010
Earth-0-MSISE90-0	2.782120359e-006	3.443304045e-010
Earth-EGM96-0-0	1.050744267e-005	1.447584802e-009
Earth-EGM96full-0-0	1.050744267e-005	1.447584802e-009
Earth-JGM2-0-0	2.283784887e-006	3.435638023e-010
Earth-JGM2full-0-0	2.283784887e-006	3.435638023e-010
Earth-JGM3-0-0	7.101270799e-006	1.060395602e-009
Earth-JGM3full-0-0	7.101270799e-006	1.060395602e-009

Table 2.36: WinGMAT/MacGMAT ISS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.767688707e-005	1.987826967e-008
EarthLuna-0-0-0	4.058801998e-005	4.617387375e-008
EarthSunLuna-EGM96-JR-SRP	2.350033054e-005	2.662367385e-008
EarthSunLuna-EGM96-MSISE90-SRP	0.0006669672891	7.368745763e-007
EarthSunLuna-JGM2-JR-SRP	1.840611847e-005	2.086797767e-008
EarthSunLuna-JGM2-MSISE90-SRP	0.0006391410111	7.093227198e-007
EarthSunLuna-JGM3-JR-SRP	4.906955953e-005	5.585723624e-008
EarthSunLuna-JGM3-MSISE90-SRP	0.0001694547514	1.723059642e-007
EarthSun-0-0-0	3.963497881e-006	4.502622513e-009
Earth-0-0-0	3.476512236e-005	3.980331596e-008
Earth-0-0-SRP	1.709387551e-005	1.961412784e-008
Earth-0-JR-0	1.516771704e-006	1.633830233e-009
Earth-0-MSISE90-0	0.0006871347746	7.902102731e-007
Earth-EGM96-0-0	1.608009486e-005	1.792593523e-008
Earth-EGM96full-0-0	1.796350308e-005	2.023666e-008
Earth-JGM2-0-0	8.522888644e-006	9.778070887e-009
Earth-JGM2full-0-0	7.900862621e-006	8.784310979e-009
Earth-JGM3-0-0	6.904868565e-006	7.605149901e-009
Earth-JGM3full-0-0	8.703769381e-006	9.962336035e-009

Table 2.37: WinGMAT/MacGMAT Molniya Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.0001161355335	9.734627028e-008
EarthLuna-0-0-0	0.0001765185068	1.474675389e-007
EarthSunLuna-EGM96-JR-SRP	9.149240024e-005	7.550332195e-008
EarthSunLuna-EGM96-MSISE90-SRP	0.000337018456	2.517462331e-007
EarthSunLuna-JGM2-JR-SRP	0.0001687015187	1.180293741e-007
EarthSunLuna-JGM2-MSISE90-SRP	0.0003458685231	2.567145268e-007
EarthSunLuna-JGM3-JR-SRP	2.89102084e-005	1.439959413e-008
EarthSunLuna-JGM3-MSISE90-SRP	0.0004306462955	3.433138109e-007
EarthSun-0-0-0	0.0004166915691	3.484312793e-007
Earth-0-0-0	0.0004592790738	3.839183118e-007
Earth-0-0-SRP	3.343036684e-005	2.780900576e-008
Earth-0-JR-0	0.0002482930089	2.078309993e-007
Earth-0-MSISE90-0	9.929293779e-005	8.265330135e-008
Earth-EGM96-0-0	4.303627343e-005	2.617173925e-008
Earth-EGM96full-0-0	0.0001105407449	9.218740603e-008
Earth-JGM2-0-0	0.0002507869521	1.785682667e-007
Earth-JGM2full-0-0	0.0002346500837	1.623140036e-007
Earth-JGM3-0-0	5.099576082e-005	4.255038887e-008
Earth-JGM3full-0-0	0.0001446553101	8.368203852e-008

Table 2.38: WinGMAT/MacGMAT SunSync Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	6.500418074e-006	6.999302677e-009
EarthLuna-0-0-0	4.322773976e-005	4.846536744e-008
EarthSunLuna-EGM96-JR-SRP	1.07874072e-005	1.222942998e-008
EarthSunLuna-EGM96-MSISE90-SRP	0.0002907736973	3.198710152e-007
EarthSunLuna-JGM2-JR-SRP	5.336201438e-006	5.644390406e-009
EarthSunLuna-JGM2-MSISE90-SRP	8.135754448e-005	8.017598457e-008
EarthSunLuna-JGM3-JR-SRP	4.666661247e-005	5.293796337e-008
EarthSunLuna-JGM3-MSISE90-SRP	0.0003578443346	3.980896788e-007
EarthSun-0-0-0	1.500943262e-005	1.689722434e-008
Earth-0-0-0	2.653939383e-005	2.998036763e-008
Earth-0-0-SRP	3.969621364e-005	4.465304759e-008
Earth-0-JR-0	3.885692582e-005	4.338304594e-008
Earth-0-MSISE90-0	0.0001846260209	2.024641677e-007
Earth-EGM96-0-0	2.749076581e-006	2.902225971e-009
Earth-EGM96full-0-0	3.242311524e-006	3.49137102e-009
Earth-JGM2-0-0	1.047153324e-005	1.171331382e-008
Earth-JGM2full-0-0	1.439187158e-005	1.599554939e-008
Earth-JGM3-0-0	1.416756213e-005	1.591877652e-008
Earth-JGM3full-0-0	1.85849559e-005	2.086516383e-008

Table 2.39: WinGMAT/MacGMAT Mars1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.03972223921	3.343331462e-005
Mars-0-0-0	0.005311861757	4.268418571e-006
Mars-0-0-SRP	0.05222305978	4.393980991e-005
Mars-MARS50C-0-0	0.01297658486	1.093110803e-005
Mars-MARS50C-0-SRP	0.1117967472	9.414441698e-005

Table 2.40: WinGMAT/MacGMAT Mercury1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.004516330784	3.600005592e-006
Mercury-0-0-0	0.03778257814	3.190578299e-005
Mercury-0-0-SRP	0.02607980485	2.236210801e-005

Table 2.41: WinGMAT/MacGMAT Moon Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.0003918908681	2.810115186e-007
Luna-0-0-0	8.768096011e-005	6.221838761e-008
Luna-0-0-SRP	0.000593804859	4.250992344e-007
Luna-LP165P-0-0	0.0004664933125	3.338481962e-007
Luna-LP165P-0-SRP	0.0001597775244	1.143221729e-007

Table 2.42: WinGMAT/MacGMAT Neptune1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.455191523e-008	6.20685014e-010
Neptune-0-0-0	1.543463691e-008	1.126411949e-010
Neptune-0-0-SRP	1.458030924e-008	1.741877302e-010

Table 2.43: WinGMAT/MacGMAT Pluto1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.286219742e-009	3.384705673e-011
Pluto-0-0-0	1.286219742e-009	9.024959195e-012
Pluto-0-0-SRP	1.023181539e-009	1.649647961e-010

Table 2.44: WinGMAT/MacGMAT Saturn1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.626953583e-008	1.628929876e-010
Saturn-0-0-0	2.057951587e-008	1.669113889e-010
Saturn-0-0-SRP	2.057951587e-008	1.124589615e-010

Table 2.45: WinGMAT/MacGMAT Uranus1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.458030924e-008	2.642610672e-011
Uranus-0-0-0	1.455191523e-008	8.413351831e-011
Uranus-0-0-SRP	2.057951587e-008	6.76066571e-011

Table 2.46: WinGMAT/MacGMAT Venus1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.001945532067	1.947340584e-006
Venus-0-0-0	0.01882594263	1.859722326e-005
Venus-0-0-SRP	0.02322953755	2.299817313e-005
Venus-MGNP180U-0-0	0.03289233273	3.254048475e-005
Venus-MGNP180U-0-SRP	0.03086632412	3.063642165e-005

Table 2.47: WinGMAT/MacGMAT DeepSpace Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.004474133849	9.33402511e-010

Table 2.48: WinGMAT/MacGMAT EML2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	55804.23343	0.3054834604
AllPlanets-0-0-SRP	124016.2439	0.6662855702
EarthSunLuna-0-0-0	33336.13696	0.1885640618
EarthSunLuna-JGM2-0-0	214046.0535	1.167672328

Table 2.49: WinGMAT/MacGMAT ESL2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	380849.9527	0.2067925122
AllPlanets-0-0-SRP	234119.7653	0.1824594525

2.6 Win/Linux GMAT Comparison

Table 2.50: WinGMAT/LinuxGMAT GEO Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.818989404e-008	1.256073967e-012
EarthLuna-0-0-0	1.818989404e-008	1.256073967e-012
EarthSunLuna-EGM96-JR-SRP	1.818989404e-008	1.256073967e-012
EarthSunLuna-EGM96-MSISE90-SRP	1.818989404e-008	1.256073967e-012
EarthSunLuna-JGM2-JR-SRP	1.818989404e-008	1.256073967e-012
EarthSunLuna-JGM2-MSISE90-SRP	1.818989404e-008	1.256073967e-012
EarthSunLuna-JGM3-JR-SRP	1.818989404e-008	1.256073967e-012
EarthSunLuna-JGM3-MSISE90-SRP	1.818989404e-008	1.256073967e-012
EarthSun-0-0-0	1.818989404e-008	1.256073967e-012
Earth-0-0-0	1.818989404e-008	1.256073967e-012
Earth-0-0-SRP	1.626953583e-008	1.256073967e-012
Earth-0-JR-0	1.818989404e-008	1.256073967e-012
Earth-0-MSISE90-0	1.818989404e-008	1.256073967e-012
Earth-EGM96-0-0	1.818989404e-008	1.256073967e-012
Earth-EGM96full-0-0	1.818989404e-008	1.256073967e-012
Earth-JGM2-0-0	1.818989404e-008	8.950904183e-013
Earth-JGM2full-0-0	1.818989404e-008	8.950904183e-013
Earth-JGM3-0-0	1.466516141e-008	1.256073967e-012
Earth-JGM3full-0-0	1.466516141e-008	1.256073967e-012

Table 2.51: WinGMAT/LinuxGMAT GPS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.543463691e-008	1.256073967e-012
EarthLuna-0-0-0	1.164721514e-008	1.256073967e-012
EarthSunLuna-EGM96-JR-SRP	1.543463691e-008	1.256073967e-012
EarthSunLuna-EGM96-MSISE90-SRP	1.286219742e-008	1.25611709e-012
EarthSunLuna-JGM2-JR-SRP	1.311691913e-008	1.256073967e-012
EarthSunLuna-JGM2-MSISE90-SRP	1.311691913e-008	1.256073967e-012
EarthSunLuna-JGM3-JR-SRP	1.314841238e-008	1.538370149e-012
EarthSunLuna-JGM3-MSISE90-SRP	1.311691913e-008	1.256073967e-012
EarthSun-0-0-0	1.42067614e-008	1.256073967e-012
Earth-0-0-0	1.311691913e-008	1.256073967e-012
Earth-0-0-SRP	1.311691913e-008	1.256073967e-012
Earth-0-JR-0	1.311691913e-008	1.256073967e-012
Earth-0-MSISE90-0	1.42067614e-008	1.256073967e-012
Earth-EGM96-0-0	1.311691913e-008	1.256073967e-012
Earth-EGM96full-0-0	1.311691913e-008	1.256073967e-012
Earth-JGM2-0-0	1.311691913e-008	1.256073967e-012
Earth-JGM2full-0-0	1.311691913e-008	1.256073967e-012
Earth-JGM3-0-0	1.311691913e-008	1.256073967e-012
Earth-JGM3full-0-0	1.311691913e-008	1.256073967e-012

Table 2.52: WinGMAT/LinuxGMAT ISS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	2.087012916e-009	2.512147934e-012
EarthLuna-0-0-0	2.033691978e-009	2.512147934e-012
EarthSunLuna-EGM96-JR-SRP	2.033691978e-009	2.512147934e-012
EarthSunLuna-EGM96-MSISE90-SRP	0.0008470424638	9.587548246e-007
EarthSunLuna-JGM2-JR-SRP	2.572439484e-009	2.512147934e-012
EarthSunLuna-JGM2-MSISE90-SRP	0.0007669211768	8.667589808e-007
EarthSunLuna-JGM3-JR-SRP	2.572439484e-009	1.986027323e-012
EarthSunLuna-JGM3-MSISE90-SRP	0.0008251276656	9.357517454e-007
EarthSun-0-0-0	2.572439484e-009	2.512147934e-012
Earth-0-0-0	2.572439484e-009	1.986027323e-012
Earth-0-0-SRP	2.033691978e-009	2.512147934e-012
Earth-0-JR-0	2.033691978e-009	2.512147934e-012
Earth-0-MSISE90-0	0.0005086050402	5.7095113e-007
Earth-EGM96-0-0	2.033691978e-009	2.512147934e-012
Earth-EGM96full-0-0	2.033691978e-009	2.664535259e-012
Earth-JGM2-0-0	2.572439484e-009	2.512147934e-012
Earth-JGM2full-0-0	2.572439484e-009	2.512147934e-012
Earth-JGM3-0-0	2.033691978e-009	1.986027323e-012
Earth-JGM3full-0-0	2.033691978e-009	2.512147934e-012

Table 2.53: WinGMAT/LinuxGMAT Molniya Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.543463691e-008	1.776356839e-012
EarthLuna-0-0-0	1.818989404e-008	1.776356839e-012
EarthSunLuna-EGM96-JR-SRP	1.818989404e-008	1.986027323e-012
EarthSunLuna-EGM96-MSISE90-SRP	0.0002835450278	1.639475709e-007
EarthSunLuna-JGM2-JR-SRP	1.818989404e-008	1.776356839e-012
EarthSunLuna-JGM2-MSISE90-SRP	0.0003637177938	2.536251812e-007
EarthSunLuna-JGM3-JR-SRP	1.818989404e-008	1.986027323e-012
EarthSunLuna-JGM3-MSISE90-SRP	0.0001377244321	6.842684735e-008
EarthSun-0-0-0	1.455191523e-008	2.512147934e-012
Earth-0-0-0	1.818989404e-008	1.986027323e-012
Earth-0-0-SRP	1.455191523e-008	1.776356839e-012
Earth-0-JR-0	1.818989404e-008	2.512147934e-012
Earth-0-MSISE90-0	0.0005204508808	4.351107742e-007
Earth-EGM96-0-0	1.543463691e-008	1.986027323e-012
Earth-EGM96full-0-0	1.818989404e-008	2.512147934e-012
Earth-JGM2-0-0	1.626953583e-008	1.779822905e-012
Earth-JGM2full-0-0	1.818989404e-008	1.776356839e-012
Earth-JGM3-0-0	1.626953583e-008	2.512147934e-012
Earth-JGM3full-0-0	1.626953583e-008	1.986027323e-012

Table 2.54: WinGMAT/LinuxGMAT SunSync Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	2.033691978e-009	1.986027323e-012
EarthLuna-0-0-0	2.033691978e-009	2.512147934e-012
EarthSunLuna-EGM96-JR-SRP	2.033691978e-009	2.664535259e-012
EarthSunLuna-EGM96-MSISE90-SRP	0.0004937360699	5.662979365e-007
EarthSunLuna-JGM2-JR-SRP	2.033691978e-009	2.512147934e-012
EarthSunLuna-JGM2-MSISE90-SRP	0.0006551562744	7.5461681e-007
EarthSunLuna-JGM3-JR-SRP	2.033691978e-009	1.986027323e-012
EarthSunLuna-JGM3-MSISE90-SRP	0.0005964945835	6.857578925e-007
EarthSun-0-0-0	2.033691978e-009	1.986027323e-012
Earth-0-0-0	2.572439484e-009	1.986027323e-012
Earth-0-0-SRP	2.572439484e-009	2.512147934e-012
Earth-0-JR-0	2.033691978e-009	1.986027323e-012
Earth-0-MSISE90-0	0.0006288991645	7.221314608e-007
Earth-EGM96-0-0	2.033691978e-009	1.986027323e-012
Earth-EGM96full-0-0	2.036867143e-009	2.512147934e-012
Earth-JGM2-0-0	2.033691978e-009	1.986027323e-012
Earth-JGM2full-0-0	2.572439484e-009	1.986027323e-012
Earth-JGM3-0-0	2.033691978e-009	2.512147934e-012
Earth-JGM3full-0-0	2.572439484e-009	2.512147934e-012

Table 2.55: WinGMAT/LinuxGMAT Mars1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	2.033691978e-009	1.256073967e-012
Mars-0-0-0	1.818989404e-009	1.256073967e-012
Mars-0-0-SRP	1.818989404e-009	1.256073967e-012
Mars-MARS50C-0-0	1.818989404e-009	1.256073967e-012
Mars-MARS50C-0-SRP	1.822538655e-009	1.256073967e-012

Table 2.56: WinGMAT/LinuxGMAT Mercury1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.818989404e-009	1.256073967e-012
Mercury-0-0-0	1.286219742e-009	1.256073967e-012
Mercury-0-0-SRP	1.822538655e-009	1.26097096e-012

Table 2.57: WinGMAT/LinuxGMAT Moon Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.286219742e-009	8.950904183e-013
Luna-0-0-0	1.575291033e-009	8.950904183e-013
Luna-0-0-SRP	1.286219742e-009	8.881784197e-013
Luna-LP165P-0-0	0.0001310647334	9.401096987e-008
Luna-LP165P-0-SRP	0.0001872108595	1.337602461e-007

Table 2.58: WinGMAT/LinuxGMAT Neptune1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.455191523e-008	1.50728876e-011
Neptune-0-0-0	1.543463691e-008	1.080515682e-011
Neptune-0-0-SRP	1.458030924e-008	1.080515682e-011

Table 2.59: WinGMAT/LinuxGMAT Pluto1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.286219742e-009	1.570092459e-013
Pluto-0-0-0	1.286219742e-009	1.570092459e-013
Pluto-0-0-SRP	1.023181539e-009	1.570092459e-013

Table 2.60: WinGMAT/LinuxGMAT Saturn1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.626953583e-008	1.50728876e-011
Saturn-0-0-0	2.057951587e-008	1.280949134e-011
Saturn-0-0-SRP	2.057951587e-008	1.280949134e-011

Table 2.61: WinGMAT/LinuxGMAT Uranus1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.458030924e-008	1.065814104e-011
Uranus-0-0-0	1.455191523e-008	1.065814104e-011
Uranus-0-0-SRP	2.057951587e-008	1.065814104e-011

Table 2.62: WinGMAT/LinuxGMAT Venus1 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	2.572439484e-009	1.986027323e-012
Venus-0-0-0	2.572439484e-009	1.986027323e-012
Venus-0-0-SRP	2.033691978e-009	2.514600007e-012
Venus-MGNP180U-0-0	2.572439484e-009	2.512147934e-012
Venus-MGNP180U-0-SRP	2.572439484e-009	2.512147934e-012

Table 2.63: WinGMAT/LinuxGMAT DeepSpace Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.009386010342	1.886732646e-009

Table 2.64: WinGMAT/LinuxGMAT EML2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	135364.0795	0.7390519353
AllPlanets-0-0-SRP	269258.1081	1.459047458
EarthSunLuna-0-0-0	13791.8204	0.07140281919
EarthSunLuna-JGM2-0-0	104302.9029	0.5713126463

Table 2.65: WinGMAT/LinuxGMAT ESL2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	161033.6102	0.0878775284
AllPlanets-0-0-SRP	70022.39058	0.05565825527

2.7 FF/STK Comparison

Table 2.66: FF/STK GEO Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.02441863704	2.331183059e-006
EarthLuna-0-0-0	0.02435631273	2.242953735e-006
EarthSunLuna-JGM2-HP-SRP	2.852626845	0.0001210061727
EarthSun-0-0-0	4.231055926e-005	8.493736892e-007
Earth-0-0-0	6.836800608e-005	6.889863428e-007
Earth-0-0-SRP	2.899330477	0.0001245233005
Earth-0-HP-0	6.836800608e-005	6.889863428e-007
Earth-JGM2-0-0	0.02513336324	2.312005083e-006

Table 2.67: FF/STK GPS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.001903432726	1.053971199e-006
EarthLuna-0-0-0	0.001896072444	9.455916149e-007
EarthSunLuna-JGM2-HP-SRP	0.6785588953	6.968633698e-005
EarthSun-0-0-0	3.872950958e-006	8.316397374e-007
Earth-0-0-0	8.164858288e-006	7.983006024e-007
Earth-0-0-SRP	0.6692784196	6.82998214e-005
Earth-0-HP-0	8.164858288e-006	7.983006024e-007
Earth-JGM2-0-0	0.01104063243	2.139211093e-006

Table 2.68: FF/STK ISS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	1.17832665e-005	8.274218823e-007
EarthLuna-0-0-0	2.023778135e-005	8.422726373e-007
EarthSunLuna-JGM2-HP-SRP	3.468138188	0.003970584682
EarthSun-0-0-0	2.067991746e-005	8.1799381e-007
Earth-0-0-0	4.404163183e-005	8.186528591e-007
Earth-0-0-SRP	0.1637932094	0.0001561216566
Earth-0-HP-0	3.213782043	0.003648358681
Earth-JGM2-0-0	0.2076446785	0.0002404801574

Table 2.69: FF/STK Molniya Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	0.01457313187	1.215436806e-005
EarthLuna-0-0-0	0.01409431455	1.184376446e-005
EarthSunLuna-JGM2-HP-SRP	7.784661066	0.004770671087
EarthSun-0-0-0	0.0006798546862	1.003660696e-006
Earth-0-0-0	0.0003365057467	8.083469211e-007
Earth-0-0-SRP	2.16384821	0.001779529358
Earth-0-HP-0	15.27354394	0.01277094127
Earth-JGM2-0-0	3.063128789	0.002561623783

Table 2.70: FF/STK SunSync Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	3.408772257e-005	8.692082437e-007
EarthLuna-0-0-0	1.971678896e-005	8.200621923e-007
EarthSunLuna-JGM2-HP-SRP	0.7800584002	0.0008377097699
EarthSun-0-0-0	1.533280696e-005	8.472050762e-007
Earth-0-0-0	3.656123033e-005	8.215198955e-007
Earth-0-0-SRP	0.2052485046	0.0001828464597
Earth-0-HP-0	0.6524853805	0.0007361489035
Earth-JGM2-0-0	0.09463135069	0.0001055896904

Table 2.71: FF/STK EML2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	209675.0986	1.14402647
AllPlanets-0-0-SRP	207842.3945	1.126072479
EarthSunLuna-0-0-0	209277.3047	1.141861418
EarthSunLuna-JGM2-0-0	209283.0825	1.141942183

Table 2.72: FF/STK ESL2 Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
AllPlanets-0-0-0	5661795.485	3.114044517
AllPlanets-0-0-SRP	6881239.331	5.360316234

Chapter 3

Calculation Parameters

GMAT's Central Body (Cb) and Coordinate System (CS) dependent parameters were tested to verify that the internal calculations were correct. In order to minimize the effects of other forces/elements, the two-body cases from the Propagators section were used, with some modification, to test both the central body and coordinate system parameters. The only changes to the two body cases were in the report output intervals and report output parameters. Data was outputted in ten minute intervals. The ISS two-body case was used for the Earth case and each planets respective two-body case was used for the non-Earth cases.

3.1 Initial Orbit State Conditions

The ISS, GEO, Mars1, Mercury1, Moon, Neptune1, Pluto1, Saturn1, Uranus1 and Venus1 two-body case's initial orbit parameters were used from the Propagation section (Chapter 2) for the test cases in this section.

Refer to Appendix B.1 Tables B.1- B.13 for a listing of all Propagator initial orbit states used for the Calculation Parameter test cases.

3.2 Central Body Dependent Parameters

3.2.1 Naming Convention

This section describes the naming convention for central body dependent parameter scripts and output reports. The naming convention consists of a case sensitive ordered series of option strings, separated by underscores (_). Currently, options are allowed for the following fields, and will be present in the file name:

1. *tool* - The tool used to generate the test case.

2. *traj* - The trajectory to use. This includes initial conditions, physical parameters, and time step.

CbParams precedes the *tool* field and 2Body follows the *traj* field. The central body used can be determined based on the *traj* field. The final Cb file format is as followed:
CbParams_*tool*_*traj*_2Body.report

The *tool* field should always be the first option field. Each field has a finite list of options, as follows (future options should be added to this list):

1. *tool*
   STK - Satellite Toolkit HPOP or Astrogator
   FF - FreeFlyer
   GMAT - General Mission Analysis Tool

2. *traj*
   ISS - leo orbit
   Mars1 - eccentric low orbit
   Mercury1 - eccentric low orbit
   Moon - eccentric low orbit
   Pluto1 - eccentric low orbit
   Venus1 - eccentric low orbit

   NOTE: Some test cases contain *traj* variations. In this case *traj* precedes the modification. For example, if an ISS trajectory is needed with a different Cd, *traj* could be ISSdiffCd1.

3.2.2 Comparison Script Information

Comparison_Tool1_Tool2_Cb.m is the script used to perform the coordinate system comparisons needed for the Acceptance Test Plan. Many elements of this script were extracted from the Comparison_Tool1_Tool2_CS.m script.

Comparison_Tool1_Tool2_Cb.m was designed to allow the user to select two programs to compare to one another. The comparison involves taking the difference of the variables listed in the Acceptance Test Plan Overview Chapter->Testing Methodology->Calculation Parameters section.

Refer to Appendix C for more details on this script and others used in the Acceptance Test Plan document.

3.2.3 Test Case Results

The following results are for the Central Body-Calculation Parameter section. The current GMAT Build is compared to STK and FreeFlyer for this section.

FF-STK comparison results presented in Tables 3.11- 3.15 are used as a way to determine if the GMAT comparison values are acceptable. If GMAT comparison data is within the same order of magnitude as the FF-STK comparison data, that is acceptable. A more detailed acceptance metric/matrix will be developed at a later date.

Table 3.1: WinGMAT/STK Central Body Dependent Parameter Differences (1)

Test Case	Altitude (m)	Eccentricity	M. Anomaly (deg)	M. Motion (rad/sec)	Period (sec)
GEO-2Body	1.89175e-006	1.71688e-014	1.90373e-005	3.0114e-015	3.55067e-009
Hyperbolic-2Body	0.00422986	1.98064e-013	351.401	0.000223215	N/A
ISS-2Body	0.00543367	5.95719e-014	5.82162e-010	4.99015e-015	2.5193e-010
Mars1-2Body	0.0144309	9.74698e-011	7.84791e-007	1.62511e-013	2.29212e-006
Mercury1-2Body	0.00224375	2.36836e-011	1.7241e-007	5.54375e-014	7.66082e-007
Moon-2Body	2.60019e-005	1.24706e-013	2.88698e-009	3.85868e-016	7.42875e-009
Neptune1-2Body	0.129938	1.31684e-010	6.04911e-007	1.00481e-013	4.02816e-006
Pluto1-2Body	0.19231	1.83823e-009	2.95607e-005	3.82792e-012	0.000141823
Saturn1-2Body	0.752271	1.05362e-011	6.3449e-008	1.11997e-014	1.04643e-006
Uranus1-2Body	0.216614	5.31596e-011	6.35362e-007	8.48005e-014	8.31598e-006
Venus1-2Body	0.000632367	1.26323e-011	2.13253e-008	1.53591e-014	1.51652e-007

Table 3.2: WinGMAT/STK Central Body Dependent Parameter Differences (2)

Test Case	Semi-major Axis (m)	True Anomaly (deg)	Semilatus Rectum(m)
GEO-2Body	1.16415e-006	1.90373e-005	7.42148e-007
Hyperbolic-2Body	1.648e-006	7.53175e-012	1.32495e-005
ISS-2Body	2.06455e-007	5.78609e-010	1.71894e-007
Mars1-2Body	0.000741843	1.15747e-006	0.000794765
Mercury1-2Body	0.000199977	2.61636e-007	0.000175894
Moon-2Body	1.10276e-006	4.32073e-009	1.07548e-006
Neptune1-2Body	0.00597339	9.2047e-007	0.00497125
Pluto1-2Body	0.0111278	4.499e-005	0.0106515
Saturn1-2Body	0.00241793	9.55595e-008	0.00235179
Uranus1-2Body	0.0100126	9.19017e-007	0.00930848
Venus1-2Body	0.000101745	3.07957e-008	0.00013864

Table 3.3: WinGMAT/STK Central Body Dependent Parameter Differences (3)

Test Case	Apoapsis Rad. (m)	Periapsis Rad. (m)	Apo. Vel. (m/sec)	Per. Vel. (m/sec)
GEO-2Body	1.23691e-006	1.28057e-006	8.21565e-011	1.03029e-010
Hyperbolic-2Body	N/A	4.5402e-006	N/A	1.87583e-009
ISS-2Body	5.26597e-007	3.39242e-007	4.40536e-010	3.47278e-010
Mars1-2Body	0.000683647	0.000800039	2.75849e-007	4.86309e-007
Mercury1-2Body	0.000280259	0.000125894	7.84977e-008	7.33316e-008
Moon-2Body	1.18234e-006	1.12323e-006	2.56017e-010	5.06262e-010
Neptune1-2Body	0.0107941	0.00538058	2.2861e-006	2.18703e-006
Pluto1-2Body	0.0145814	0.00998796	2.30184e-006	3.55073e-006
Saturn1-2Body	0.002828	0.00203526	2.94648e-007	5.08262e-007
Uranus1-2Body	0.0133233	0.00759641	1.41239e-006	1.43534e-006
Venus1-2Body	0.000149412	0.000183741	6.66214e-008	1.50022e-007

Table 3.4: WinGMAT/STK Central Body Dependent Parameter Differences (4)

Test Case	C3-Energy (m^2/sec^2)	Latitude (deg)	Longitude (deg)	MHA (deg)	LST (deg)
GEO-2Body	2.6823e-007	3.24498e-008	3.14812e-007	0.00196854	0.00196864
Hyperbolic-2Body	1.64846e-006	5.65537e-008	1.35016e-007	0.00196849	0.00196858
ISS-2Body	1.74794e-006	1.07149e-007	1.3276e-007	0.00196849	0.0019686
Mars1-2Body	0.00149955	5.58338e-007	9.73051e-007	N/A	N/A
Mercury1-2Body	0.000332532	1.88133e-007	2.69651e-007	N/A	N/A
Moon-2Body	8.62199e-007	3.26031e-009	1.41482e-007	N/A	N/A
Neptune1-2Body	0.0333365	7.39515e-007	1.15656e-006	N/A	N/A
Pluto1-2Body	0.00339014	3.20069e-005	7.44124e-005	N/A	N/A
Saturn1-2Body	0.014334	1.24281e-006	5.18835e-007	N/A	N/A
Uranus1-2Body	0.028651	9.64237e-007	2.34538e-006	N/A	N/A
Venus1-2Body	0.000500677	2.22686e-008	3.82501e-008	N/A	N/A

Table 3.5: WinGMAT/STK Central Body Dependent Parameter Differences (5)

Test Case	Beta Angle (deg)	(RxV)-Mag (m^2/sec)	R-Mag (m)
GEO-2Body	45.7421	0.00180444	1.88447e-006
Hyperbolic-2Body	130.969	0.025655	1.35624e-005
ISS-2Body	98.3615	0.000749424	4.62933e-007
Mars1-2Body	70.1724	1.23719	0.0126011
Mercury1-2Body	173.794	0.220796	0.00224375
Moon-2Body	34.7765	0.00081809	2.6002e-005
Neptune1-2Body	122.85	35.4559	0.0763421
Pluto1-2Body	56.4158	4.01956	0.19231
Saturn1-2Body	99.1135	26.1241	0.0181717
Uranus1-2Body	150.273	53.902	0.101524
Venus1-2Body	31.881	0.447268	0.000632365

Table 3.6: FF/WinGMAT Central Body Dependent Parameter Differences (1)

Test Case	Altitude (m)	Eccentricity	M. Anomaly (deg)	M. Motion (rad/sec)	Period (sec)
GEO-2Body	8.20728e-006	1.93962e-010	6.42153e-006	5.69653e-016	7.75617e-009
ISS-2Body	0.433346	6.39335e-012	1.714e-009	4.2466e-015	7.69433e-010

Table 3.7: FF/WinGMAT Central Body Dependent Parameter Differences (2)

Test Case	Semi-major Axis (m)	True Anomaly (deg)	Semilatus Rectum(m)
GEO-2Body	2.23372e-006	6.4215e-006	2.4811e-006
ISS-2Body	4.09273e-007	1.86708e-009	1.7917e-007

Table 3.8: FF/WinGMAT Central Body Dependent Parameter Differences (3)

Test Case	Apoapsis Rad. (m)	Periapsis Rad. (m)	Apo. Vel. (m/sec)	Per. Vel. (m/sec)
GEO-2Body	2.72848e-006	3.00497e-006	2.39764e-008	2.39013e-008
ISS-2Body	3.98359e-007	6.89397e-007	2.91838e-008	2.88605e-008

Table 3.9: FF/WinGMAT Central Body Dependent Parameter Differences (4)

Test Case	C3-Energy (m^2/sec^2)	Latitude (deg)	Longitude (deg)	MHA (deg)	LST (deg)
GEO-2Body	0.00014728	5.40781e-008	0	0.00300898	0.00300919
ISS-2Body	0.000444231	6.02545e-006	5.81869e-007	0.00300898	0.00300919

Table 3.10: FF/WinGMAT Central Body Dependent Parameter Differences (5)

Test Case	Beta Angle (deg)	(RxV)-Mag (m^2/sec)	R-Mag (m)
GEO-2Body	45.7413	0.00429281	3.27418e-006
ISS-2Body	98.3649	0.00164437	1.18325e-006

Table 3.11: FF/STK Central Body Dependent Parameter Differences (1)

Test Case	Altitude (m)	Eccentricity	M. Anomaly (deg)	M. Motion (rad/sec)	Period (sec)
GEO-2Body	8.04721e-006	1.9396e-010	1.76421e-005	2.44679e-015	6.4756e-009
ISS-2Body	0.427915	6.34e-012	1.73014e-009	9.18666e-015	8.14907e-010

Table 3.12: FF/STK Central Body Dependent Parameter Differences (2)

Test Case	Semi-major Axis (m)	True Anomaly (deg)	Semilatus Rectum(m)
GEO-2Body	2.08092e-006	1.76414e-005	1.92085e-006
ISS-2Body	4.47471e-007	1.67717e-009	1.56433e-007

Table 3.13: FF/STK Central Body Dependent Parameter Differences (3)

Test Case	Apoapsis Rad. (m)	Periapsis Rad. (m)	Apo. Vel. (m/sec)	Per. Vel. (m/sec)
GEO-2Body	2.72848e-006	2.03727e-006	2.38942e-008	2.38796e-008
ISS-2Body	5.23869e-007	6.23913e-007	2.87432e-008	2.88605e-008

Table 3.14: FF/STK Central Body Dependent Parameter Differences (4)

Test Case	C3-Energy (m^2/sec^2)	Latitude (deg)	Longitude (deg)	MHA (deg)	LST (deg)
GEO-2Body	0.000147141	3.06691e-008	0	0.00497708	0.00497715
ISS-2Body	0.000442895	5.92635e-006	6.1431e-007	0.00497708	0.00497716

Table 3.15: FF/STK Central Body Dependent Parameter Differences (5)

Test Case	Beta Angle (deg)	(RxV)-Mag (m^2/sec)	R-Mag (m)
GEO-2Body	0.000773444	0.00355067	4.05998e-006
ISS-2Body	0.00344889	0.00178261	1.01772e-006

3.2.4 Win/Mac GMAT Comparison

Table 3.16: WinGMAT/MacGMAT Central Body Dependent Parameter Differences (1)

Test Case	Altitude (m)	Eccentricity	M. Anomaly (deg)	M. Motion (rad/sec)	Period (sec)
GEO-2Body	2.452e-006	1.74542e-014	8.52452e-006	6.93889e-018	8.22183e-009
Hyperbolic-2Body	5.23869e-007	9.99201e-015	0	1.0842e-018	N/A
ISS-2Body	4.58385e-007	3.9682e-014	1.38419e-009	8.39172e-017	4.02906e-010
Mars1-2Body	0.00342313	1.47847e-010	2.00985e-007	1.34903e-013	1.93017e-006
Mercury1-2Body	0.00505079	4.83717e-011	3.89952e-007	1.08871e-013	1.49741e-006
Moon-2Body	2.24818e-005	1.43691e-013	2.53274e-009	4.53522e-016	9.08949e-009
Neptune1-2Body	2.00089e-008	4.93383e-013	4.70095e-011	2.99186e-016	1.17889e-008
Pluto1-2Body	0.0110934	9.63307e-010	1.50655e-006	1.2462e-012	4.61344e-005
Saturn1-2Body	5.09317e-008	5.10703e-015	1.19371e-012	2.81893e-018	2.40107e-010
Uranus1-2Body	3.09228e-008	1.8624e-014	7.95808e-012	1.24141e-017	1.22236e-009
Venus1-2Body	0.00131446	1.40132e-011	4.55151e-008	2.2602e-014	2.34479e-007

Table 3.17: WinGMAT/MacGMAT Central Body Dependent Parameter Differences (2)

Test Case	Semi-major Axis (m)	True Anomaly (deg)	Semilatus Rectum(m)
GEO-2Body	2.67755e-006	8.52451e-006	2.67755e-006
Hyperbolic-2Body	6.91216e-008	5.11591e-013	3.27418e-007
ISS-2Body	3.29237e-007	1.38273e-009	3.28328e-007
Mars1-2Body	0.000624696	3.06826e-007	0.000545762
Mercury1-2Body	0.000390883	5.87062e-007	0.000336432
Moon-2Body	1.35014e-006	3.8051e-009	1.19917e-006
Neptune1-2Body	1.74914e-005	3.54987e-011	2.07729e-005
Pluto1-2Body	0.00361984	2.21937e-006	0.00371269
Saturn1-2Body	5.38421e-007	1.3074e-012	4.80213e-007
Uranus1-2Body	1.46974e-006	7.53175e-012	1.36788e-006
Venus1-2Body	0.000157314	6.88501e-008	0.000105473

Table 3.18: WinGMAT/MacGMAT Central Body Dependent Parameter Differences (3)

Test Case	Apoapsis Rad. (m)	Periapsis Rad. (m)	Apo. Vel. (m/sec)	Per. Vel. (m/sec)
GEO-2Body	2.78669e-006	2.91766e-006	1.22125e-010	1.15019e-010
Hyperbolic-2Body	N/A	1.89175e-007	N/A	7.81597e-011
ISS-2Body	3.21052e-007	5.7571e-007	2.98428e-010	4.69846e-010
Mars1-2Body	0.00139151	0.000626785	5.33045e-007	5.19715e-007
Mercury1-2Body	0.000578938	0.00021615	1.72014e-007	1.50894e-007
Moon-2Body	1.92404e-006	8.39918e-007	4.62075e-010	3.57048e-010
Neptune1-2Body	3.5041e-005	2.87691e-005	7.62945e-009	1.22924e-008
Pluto1-2Body	0.00374967	0.00349214	4.00636e-007	1.2944e-006
Saturn1-2Body	1.06229e-006	7.05768e-007	1.59872e-010	2.02505e-010
Uranus1-2Body	2.55386e-006	1.56433e-006	3.23297e-010	3.8014e-010
Venus1-2Body	0.000302634	6.57656e-005	1.25344e-007	5.78817e-008

Table 3.19: WinGMAT/MacGMAT Central Body Dependent Parameter Differences (4)

Test Case	C3-Energy (m^2/sec^2)	Latitude (deg)	Longitude (deg)	MHA (deg)	LST (deg)
GEO-2Body	6.00409e-007	5.68504e-014	3.10763e-010	1.16529e-010	3.10706e-010
Hyperbolic-2Body	7.10543e-008	6.03961e-014	2.24389e-010	1.16529e-010	2.24304e-010
ISS-2Body	2.8848e-006	5.10916e-011	2.10321e-010	1.16529e-010	2.10321e-010
Mars1-2Body	0.00126275	1.58843e-007	3.08052e-007	N/A	N/A
Mercury1-2Body	0.00064998	4.31925e-007	6.27266e-007	N/A	N/A
Moon-2Body	1.05893e-006	2.93206e-009	4.7355e-009	N/A	N/A
Neptune1-2Body	9.75149e-005	6.39488e-014	2.08502e-010	N/A	N/A
Pluto1-2Body	0.0011028	1.59299e-006	3.42747e-006	N/A	N/A
Saturn1-2Body	3.18323e-006	6.39488e-014	4.16918e-010	N/A	N/A
Uranus1-2Body	4.20641e-006	6.03961e-014	2.08502e-010	N/A	N/A
Venus1-2Body	0.000774136	5.2415e-008	8.42126e-008	N/A	N/A

Table 3.20: WinGMAT/MacGMAT Central Body Dependent Parameter Differences (5)

Test Case	Beta Angle (deg)	(RxV)-Mag (m^2/sec)	R-Mag (m)
GEO-2Body	1.42109e-014	0.00410364	2.43745e-006
Hyperbolic-2Body	7.10543e-014	0.000640284	4.07454e-007
ISS-2Body	5.96856e-013	0.00125874	4.65661e-007
Mars1-2Body	2.6164e-009	0.849539	0.0034188
Mercury1-2Body	1.88567e-009	0.422386	0.00505079
Moon-2Body	6.94911e-012	0.000856744	2.24832e-005
Neptune1-2Body	1.7053e-013	0.14808	1.45519e-008
Pluto1-2Body	2.51034e-008	1.40107	0.0110934
Saturn1-2Body	4.26326e-014	0.0060536	1.45519e-008
Uranus1-2Body	1.84741e-013	0.00791624	1.45519e-008
Venus1-2Body	1.98796e-010	0.34034	0.00131445

3.2.5 Win/Linux GMAT Comparison

Table 3.21: WinGMAT/LinuxGMAT Central Body Dependent Parameter Differences (1)

Test Case	Altitude (m)	Eccentricity	M. Anomaly (deg)	M. Motion (rad/sec)	Period (sec)
GEO-2Body	1.45519e-008	1.05879e-022	1.02318e-012	0	0
Hyperbolic-2Body	1.16415e-007	8.88178e-016	0	1.0842e-019	N/A
ISS-2Body	1.13687e-010	1.0842e-018	1.13687e-013	1.0842e-018	1.81899e-012
Mars1-2Body	9.09495e-010	1.11022e-016	1.50635e-012	1.0842e-019	0
Mercury1-2Body	9.09495e-010	1.11022e-016	1.13687e-013	1.0842e-019	0
Moon-2Body	1.13687e-009	1.11022e-016	4.83169e-013	1.0842e-019	1.09139e-011
Neptune1-2Body	1.09139e-008	1.11022e-016	3.41061e-013	1.0842e-019	1.09139e-011
Pluto1-2Body	1.13687e-010	1.11022e-016	1.3074e-012	1.0842e-019	1.09139e-011
Saturn1-2Body	1.45519e-008	1.11022e-016	1.98952e-013	1.0842e-019	1.09139e-011
Uranus1-2Body	1.09139e-008	1.11022e-016	1.10845e-012	1.0842e-019	1.09139e-011
Venus1-2Body	1.02318e-009	1.11022e-016	5.55099e-013	1.0842e-019	1.81899e-012

Table 3.22: WinGMAT/LinuxGMAT Central Body Dependent Parameter Differences (2)

Test Case	Semi-major Axis (m)	True Anomaly (deg)	Semilatus Rectum(m)
GEO-2Body	1.45519e-008	9.09495e-013	1.45519e-008
Hyperbolic-2Body	1.09139e-008	1.13687e-013	7.27596e-009
ISS-2Body	1.81899e-009	1.13687e-013	1.81899e-009
Mars1-2Body	1.81899e-009	9.9476e-013	1.81899e-009
Mercury1-2Body	9.09495e-010	1.13687e-013	9.09495e-010
Moon-2Body	9.09495e-010	3.97904e-013	9.09495e-010
Neptune1-2Body	1.45519e-008	3.97904e-013	1.45519e-008
Pluto1-2Body	9.09495e-010	7.95808e-013	9.09495e-010
Saturn1-2Body	0	1.98952e-013	0
Uranus1-2Body	1.45519e-008	7.10543e-013	1.45519e-008
Venus1-2Body	1.81899e-009	8.4982e-013	1.81899e-009

Table 3.23: WinGMAT/LinuxGMAT Central Body Dependent Parameter Differences (3)

Test Case	Apoapsis Rad. (m)	Periapsis Rad. (m)	Apo. Vel. (m/sec)	Per. Vel. (m/sec)
GEO-2Body	1.45519e-008	1.45519e-008	8.88178e-013	8.88178e-013
Hyperbolic-2Body	N/A	1.09139e-008	N/A	0
ISS-2Body	1.81899e-009	1.81899e-009	1.77636e-012	1.77636e-012
Mars1-2Body	1.81899e-009	9.09495e-010	8.88178e-013	8.88178e-013
Mercury1-2Body	1.81899e-009	9.09495e-010	8.88178e-013	8.88178e-013
Moon-2Body	9.09495e-010	9.09495e-010	8.88178e-013	8.88178e-013
Neptune1-2Body	1.45519e-008	1.09139e-008	1.06581e-011	1.06581e-011
Pluto1-2Body	9.09495e-010	9.09495e-010	0	0
Saturn1-2Body	0	1.45519e-008	1.06581e-011	1.06581e-011
Uranus1-2Body	1.45519e-008	1.45519e-008	0	1.06581e-011
Venus1-2Body	0	1.81899e-009	1.77636e-012	1.77636e-012

Table 3.24: WinGMAT/LinuxGMAT Central Body Dependent Parameter Differences (4)

Test Case	C3-Energy (m^2/sec^2)	Latitude (deg)	Longitude (deg)	MHA (deg)	LST (deg)
GEO-2Body	0	1.04083e-017	0	1.13687e-013	1.13687e-013
Hyperbolic-2Body	1.06581e-008	1.06581e-014	1.13687e-013	1.13687e-013	1.13687e-013
ISS-2Body	1.42109e-008	1.42109e-014	1.13687e-013	1.13687e-013	1.13687e-013
Mars1-2Body	0	1.06581e-014	1.13687e-013	N/A	N/A
Mercury1-2Body	1.77636e-009	1.42109e-014	1.13687e-013	N/A	N/A
Moon-2Body	8.88178e-010	6.03961e-014	1.13687e-013	N/A	N/A
Neptune1-2Body	1.13687e-007	1.42109e-014	1.13687e-013	N/A	N/A
Pluto1-2Body	0	1.42109e-014	1.13687e-013	N/A	N/A
Saturn1-2Body	1.13687e-007	1.42109e-014	1.13687e-013	N/A	N/A
Uranus1-2Body	1.13687e-007	1.42109e-014	1.13687e-013	N/A	N/A
Venus1-2Body	1.42109e-008	1.42109e-014	1.13687e-013	N/A	N/A

Table 3.25: WinGMAT/LinuxGMAT Central Body Dependent Parameter Differences (5)

Test Case	Beta Angle (deg)	(RxV)-Mag (m^2/sec)	R-Mag (m)
GEO-2Body	1.42109e-014	0.000101863	1.45519e-008
Hyperbolic-2Body	1.42109e-014	0	1.16415e-007
ISS-2Body	1.42109e-014	0	1.81899e-009
Mars1-2Body	1.42109e-014	1.09139e-005	1.81899e-009
Mercury1-2Body	2.84217e-014	0	1.81899e-009
Moon-2Body	1.42109e-014	9.09495e-007	9.09495e-010
Neptune1-2Body	1.42109e-014	0.000116415	1.45519e-008
Pluto1-2Body	1.42109e-014	9.09495e-007	9.09495e-010
Saturn1-2Body	1.42109e-014	0.000931323	1.45519e-008
Uranus1-2Body	1.42109e-014	0.000116415	1.45519e-008
Venus1-2Body	1.42109e-014	1.45519e-005	1.81899e-009

3.3 Coordinate System Dependent Parameters

3.3.1 Naming Convention

This section describes the naming convention for coordinate system dependent parameter scripts and output reports. The naming convention consists of a case sensitive ordered series of option strings, separated by underscores (_). Currently, options are allowed for the following fields, and will be present in the file name:

1. *tool* - The tool used to generate the test case
2. *traj* - The trajectory to use. This includes initial conditions, physical parameters, and time step
3. *CS* - The coordinate system to use. The celestial body to use is followed by the CS in the name

CSParams precedes the *tool* field and 2Body precedes the *CS* field. The final CS file format is as followed:
CSParams_*tool*_*traj*_2Body_*CS*.report

The *tool* field should always be the first option field. Each field has a finite list of options, as follows (future options should be added to this list):

1. *tool*

STK	- Satellite Toolkit HPOP or Astrogator
FF	- FreeFlyer
GMAT	- General Mission Analysis Tool

2. *traj*

ISS	- leo orbit
SunSync	- leo orbit
GPS	- meo orbit
GEO	- geo orbit
Molniya	- heo orbit
Mars1	- eccentric low orbit
Mercury1	- eccentric low orbit
Moon	- eccentric low orbit
Pluto1	- eccentric low orbit
Venus1	- eccentric low orbit

NOTE: Some test cases contain *traj* variations. In this case *traj* precedes the modification. For example, if ISS trajectory is needed with no output, then *traj* can be ISSnoOut. The lack of a report file is shortened to noOut.

3. *CS*

EarthFixed	EarthMJ2000Eq	EarthMJ2000Ec
EarthTODEq	EarthTODEc	EarthMODEq
EarthMODEc	EarthGSM	EarthGSE
MarsFixed	MarsMJ2000Eq	MarsMJ2000Ec
MercuryFixed	MercuryMJ2000Eq	MercuryMJ2000Ec
MoonFixed	MoonMJ2000Eq	MoonMJ2000Ec
NeptuneFixed	NeptuneMJ2000Eq	NeptuneMJ2000Ec
PlutoFixed	PlutoMJ2000Eq	PlutoMJ2000Ec
SaturnFixed	SaturnMJ2000Eq	SaturnMJ2000Ec
UranusFixed	UranusMJ2000Eq	UranusMJ2000Ec
VenusFixed	VenusMJ2000Eq	VenusMJ2000Ec

3.3.2 Comparison Script Information

The script used to perform the Coordinate System comparisons needed for the Acceptance Test Plan is Comparison_Tool1_Tool2_CS.m. Many elements of this script were extracted from the Comparison_Tool1_Tool2_PV.m script.

Comparison_Tool1_Tool2_CS.m was designed to allow the user to select two programs to compare to one another. The comparison involves taking the difference of the variables listed in the Acceptance Test Plan Overview Chapter->Testing Methodology->Calculation Parameters section.

Refer to Appendix C for more details of this script and others used in the Acceptance Test Plan document.

3.3.3 Test Case Results

The following results are for the Coordinate System-Calculation Parameter section. The current GMAT Build is compared to STK and FreeFlyer for this section.

FF-STK comparison results presented in Tables 3.36- 3.40 are used as a way to determine if the GMAT comparison values are acceptable. If GMAT comparison data is within the same order of magnitude as the FF-STK comparison data that is acceptable. A more detailed acceptance metric/matrix will be developed at a later date.

Table 3.26: WinGMAT/STK Coordinate System Dependent Parameter Differences (Position)

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)
GEO-2Body-EarthFixed	0.2281413654	0.04023080692	0.02037045935
GEO-2Body-EarthMJ2000Ec	2.294098067e-005	0.00032580283	0.0007504095265
GEO-2Body-EarthMJ2000Eq	2.294098067e-005	2.433989721e-005	4.46e-009
GEO-2Body-EarthMODEc	0.001272894679	0.001382489927	8.563802112e-006
GEO-2Body-EarthMODEq	0.001272895247	0.001271334213	0.000543207701
GEO-2Body-EarthMOEEc	2.295053037e-005	2.237175067e-005	9.603354556e-006
GEO-2Body-EarthMOEEq	2.295053037e-005	2.433989721e-005	4.162467864e-009
GEO-2Body-EarthTODEc	0.006357750408	0.006834059604	0.0006267036952
GEO-2Body-EarthTODEq	0.006357749726	0.006271528946	0.003423117541
GEO-2Body-EarthTOEEc	0.005487542296	0.005975813906	9.603354556e-006
GEO-2Body-EarthTOEEq	0.005487542239	0.005486127634	0.002404046552
Hyperbolic-2Body-EarthFixed	0.348804344	0.5436688334	0.1095402695
Hyperbolic-2Body-EarthMJ2000Ec	1.6822014e-005	0.001917796908	0.004851564881
Hyperbolic-2Body-EarthMJ2000Eq	1.6822014e-005	1.979060471e-006	2.124579623e-006
Hyperbolic-2Body-EarthMODEc	0.008121191058	0.01077665365	7.392372936e-006
Hyperbolic-2Body-EarthMODEq	0.008121191058	0.0098834862	0.004294328392
Hyperbolic-2Body-EarthMOEEc	1.693842933e-005	2.211891115e-006	2.153683454e-006
Hyperbolic-2Body-EarthMOEEq	1.693842933e-005	1.979060471e-006	2.066371962e-006
Hyperbolic-2Body-EarthTODEc	0.01367426012	0.01960279769	0.003635126632
Hyperbolic-2Body-EarthTODEq	0.01367420191	0.02924879664	0.005363341188
Hyperbolic-2Body-EarthTOEEc	0.03536941949	0.04713787348	2.153683454e-006
Hyperbolic-2Body-EarthTOEEq	0.03536941949	0.04508509301	0.01691197394
ISS-2Body-EarthFixed	0.01006907041	0.01444909003	0.002770384526
ISS-2Body-EarthGSE	5.300529438e-005	3.603599907e-005	7.66544872e-006
ISS-2Body-EarthGSM	4.9540688e-005	0.003799988463	0.00293166886
ISS-2Body-EarthMJ2000Ec	1.033299668e-005	8.047527444e-005	0.0001261635134
ISS-2Body-EarthMJ2000Eq	1.033299668e-005	9.667246559e-006	9.215000318e-006
ISS-2Body-EarthMODEc	0.000210427288	0.0001799346592	7.613095931e-006
ISS-2Body-EarthMODEq	0.0002104279702	0.0001652065293	7.136577551e-005
ISS-2Body-EarthMOEEc	1.033140506e-005	1.099556357e-005	7.695803106e-006
ISS-2Body-EarthMOEEq	1.033140506e-005	9.666564438e-006	9.215000318e-006
ISS-2Body-EarthTODEc	0.0003583738817	0.0002511692401	0.0001079586127
ISS-2Body-EarthTODEq	0.0003583736543	0.0003260520316	0.0003840964382
ISS-2Body-EarthTOEEc	0.0009193927326	0.0007893422662	7.69603048e-006
ISS-2Body-EarthTOEEq	0.0009193925052	0.0006983391359	0.0002934716576
Mars1-2Body-MarsFixed	0.05898887696	0.05711927406	0.03425882358
Mars1-2Body-MarsMJ2000Ec	0.04854124924	0.06378650704	0.05515928102
Mars1-2Body-MarsMJ2000Eq	0.04854124947	0.06874534654	0.04854127501
Mercury1-2Body-MercuryFixed	0.009607810114	0.01088151507	0.009587843124
Mercury1-2Body-MercuryMJ2000Ec	0.008947269691	0.01142762343	0.01022404834
Mercury1-2Body-MercuryMJ2000Eq	0.008947269691	0.01220655815	0.008947248972
Moon-2Body-MoonFixed	0.006440109019	0.006437562433	0.0001137458128
Moon-2Body-MoonMJ2000Ec	0.0001012271014	0.0001030929297	7.894885101e-005
Moon-2Body-MoonMJ2000Eq	0.0001012270729	0.0001460622414	0.0001010863286
Neptune1-2Body-NeptuneFixed	0.4543228424	0.474102093	0.2913599029
Neptune1-2Body-NeptuneMJ2000Ec	0.2946186363	0.379445413	0.3350099975
Neptune1-2Body-NeptuneMJ2000Eq	0.2946186363	0.4144292316	0.30129434
Pluto1-2Body-PlutoFixed	0.6182226091	1.111364997	0.7629325749
Pluto1-2Body-PlutoMJ2000Ec	0.7527405821	0.9494719067	0.8475838174
Pluto1-2Body-PlutoMJ2000Eq	0.7527405819	1.085654527	0.7521445426
Saturn1-2Body-SaturnFixed	0.6340523651	0.6134889563	0.06666205172
Saturn1-2Body-SaturnMJ2000Ec	0.07298453147	0.09547611444	0.08217663634
Saturn1-2Body-SaturnMJ2000Eq	0.07298453147	0.1048656477	0.0737594446
Uranus1-2Body-UranusFixed	0.4395935848	0.5642743054	0.5180439475
Uranus1-2Body-UranusMJ2000Ec	0.385162361	0.5115039512	0.433244951
Uranus1-2Body-UranusMJ2000Eq	0.3851623601	0.5548048448	0.3789037312
Venus1-2Body-VenusFixed	0.003286658284	0.002153384223	0.002565443879
Venus1-2Body-VenusMJ2000Ec	0.002135182285	0.003261576126	0.002492622912

Table 3.27: WinGMAT/STK Coordinate System Dependent Parameter Differences (Velocity)

Test Case	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
GEO-2Body-EarthFixed	1.014408074e-005	1.788716823e-006	2.603041318e-007
GEO-2Body-EarthMJ2000Ec	1.658007065e-009	2.383426789e-008	5.472688969e-008
GEO-2Body-EarthMJ2000Eq	1.658007065e-009	1.708189146e-009	0
GEO-2Body-EarthMODEc	9.276047985e-008	1.009415607e-007	6.031009026e-010
GEO-2Body-EarthMODEq	9.276047985e-008	9.284496089e-008	3.961584403e-008
GEO-2Body-EarthMOEEc	1.658895243e-009	1.566302643e-009	6.827038934e-010
GEO-2Body-EarthMOEEq	1.658895243e-009	1.70885528e-009	3.03533858e-013
GEO-2Body-EarthTODEc	4.572472123e-007	5.051409152e-007	4.601985459e-008
GEO-2Body-EarthTODEq	4.572472123e-007	4.636103862e-007	2.603101342e-007
GEO-2Body-EarthTOEEc	4.000988846e-007	4.359142977e-007	6.827038934e-010
GEO-2Body-EarthTOEEq	4.000988846e-007	4.002142819e-007	1.75307769e-007
Hyperbolic-2Body-EarthFixed	3.961041983e-005	4.825957234e-005	7.70518005e-006
Hyperbolic-2Body-EarthMJ2000Ec	1.829647545e-010	2.841105129e-008	7.195000151e-008
Hyperbolic-2Body-EarthMJ2000Eq	1.900701818e-010	7.416289804e-011	7.505107646e-011
Hyperbolic-2Body-EarthMODEc	1.202220545e-007	3.21276783e-007	2.733924198e-010
Hyperbolic-2Body-EarthMODEq	1.202220545e-007	2.946597966e-007	1.280426876e-007
Hyperbolic-2Body-EarthMOEEc	1.829647545e-010	8.482103908e-011	5.306866058e-011
Hyperbolic-2Body-EarthMOEEq	1.829647545e-010	7.283063042e-011	7.416289804e-011
Hyperbolic-2Body-EarthTODEc	1.646727199e-007	2.454381143e-007	6.046185774e-008
Hyperbolic-2Body-EarthTODEq	1.646727199e-007	3.61354946e-007	2.50673704e-007
Hyperbolic-2Body-EarthTOEEc	5.242357659e-007	1.403959171e-006	5.306866058e-011
Hyperbolic-2Body-EarthTOEEq	5.242357659e-007	1.28404859e-006	5.625165889e-007
ISS-2Body-EarthFixed	1.122181903e-005	1.427654617e-005	3.056610076e-006
ISS-2Body-EarthGSE	3.752820277e-008	6.98910979e-008	8.158362874e-009
ISS-2Body-EarthGSM	3.523581427e-008	4.26608171e-006	3.338248789e-006
ISS-2Body-EarthMJ2000Ec	1.084418666e-008	9.146905455e-008	1.441839981e-007
ISS-2Body-EarthMJ2000Eq	1.084418666e-008	1.137612227e-008	1.016586815e-008
ISS-2Body-EarthMODEc	2.404640931e-007	2.0532398e-007	8.086198378e-009
ISS-2Body-EarthMODEq	2.404640931e-007	1.883493361e-007	8.178480115e-008
ISS-2Body-EarthMOEEc	1.084238255e-008	1.291988738e-008	8.192335699e-009
ISS-2Body-EarthMOEEq	1.084238255e-008	1.137490102e-008	1.016536855e-008
ISS-2Body-EarthTODEc	4.073232862e-007	2.878270955e-007	1.22599042e-007
ISS-2Body-EarthTODEq	4.073232862e-007	3.764446532e-007	4.359921313e-007
ISS-2Body-EarthTOEEc	1.051030152e-006	8.982550259e-007	8.192335699e-009
ISS-2Body-EarthTOEEq	1.051030152e-006	7.945391012e-007	3.338689325e-007
Mars1-2Body-MarsFixed	4.119460101e-005	5.040193685e-005	2.244996011e-005
Mars1-2Body-MarsMJ2000Ec	3.9224898e-005	5.612389309e-005	3.773446111e-005
Mars1-2Body-MarsMJ2000Eq	3.9224898e-005	5.5061041e-005	3.923428094e-005
Mercury1-2Body-MercuryFixed	8.297573739e-006	1.056043131e-005	6.28309893e-006
Mercury1-2Body-MercuryMJ2000Ec	7.406872116e-006	1.084578205e-005	6.911486272e-006
Mercury1-2Body-MercuryMJ2000Eq	7.406872116e-006	1.046935982e-005	7.379157396e-006
Moon-2Body-MoonFixed	3.128622111e-006	3.435717294e-006	6.516048812e-008
Moon-2Body-MoonMJ2000Ec	6.996597746e-008	7.435752014e-008	3.883038335e-008
Moon-2Body-MoonMJ2000Eq	6.996597746e-008	9.943851298e-008	6.991998647e-008
Neptune1-2Body-NeptuneFixed	0.002311382259	0.00232459858	0.0001281027884
Neptune1-2Body-NeptuneMJ2000Ec	0.0001425149572	0.0002082204933	0.0001364492723
Neptune1-2Body-NeptuneMJ2000Eq	0.0001425149572	0.0002067147653	0.0001464608648
Pluto1-2Body-PlutoFixed	0.0003613682175	0.0004667307785	0.0004682860251
Pluto1-2Body-PlutoMJ2000Ec	0.0003872987759	0.0005522331561	0.000344448214
Pluto1-2Body-PlutoMJ2000Eq	0.0003872987759	0.0005410307473	0.0003868007483
Saturn1-2Body-SaturnFixed	0.0001164046752	0.0001207579849	2.354126405e-005
Saturn1-2Body-SaturnMJ2000Ec	2.488907747e-005	3.488300981e-005	2.320261316e-005
Saturn1-2Body-SaturnMJ2000Eq	2.488907747e-005	3.502235213e-005	2.510042485e-005
Uranus1-2Body-UranusFixed	0.0001044264559	0.0001481343457	0.000160607621
Uranus1-2Body-UranusMJ2000Ec	0.0001229694768	0.000170892658	0.0001139574768
Uranus1-2Body-UranusMJ2000Eq	0.0001229694768	0.0001702024259	0.000120316952
Venus1-2Body-VenusFixed	3.298453583e-006	1.926899973e-006	2.241729913e-006
Venus1-2Body-VenusMJ2000Ec	2.213821571e-006	3.107874846e-006	2.148337952e-006

Table 3.28: WinGMAT/STK Coordinate System Dependent Parameter Differences (Specific Angular Momentum)

Test Case	X-(H) (m^2/sec)	Y-(H) (m^2/sec)	Z-(H) (m^2/sec)
GEO-2Body-EarthFixed	10.77395299	2.103745961	434.3113619
GEO-2Body-EarthMJ2000Ec	1.13710075e-005	2.306616807	1.000254997
GEO-2Body-EarthMJ2000Eq	0	0	0.001542503014
GEO-2Body-EarthMODEc	1.670207936	0.001840817276	0.001789885573
GEO-2Body-EarthMODEq	1.670203311	0.001656591829	0.002357410267
GEO-2Body-EarthMOEEc	2.159488468e-005	0.0008076312952	0.001688022166
GEO-2Body-EarthMOEEq	1.279825357e-005	2.844632424e-021	0.001542503014
GEO-2Body-EarthTODEc	8.532207623	1.939180947	0.8412171155
GEO-2Body-EarthTODEq	8.532204795	9.575566487	0.004365574569
GEO-2Body-EarthTOEEc	7.285380082	0.001295120455	0.001702574082
GEO-2Body-EarthTOEEq	7.285369859	1.252006488	0.001396983862
Hyperbolic-2Body-EarthFixed	12999.11691	5061.392323	11584.83326
Hyperbolic-2Body-EarthMJ2000Ec	0.0002509729892	1.80931238	0.7227790775
Hyperbolic-2Body-EarthMJ2000Eq	0.000197488248	0.01781154424	0.01760781743
Hyperbolic-2Body-EarthMODEc	1.183687445	0.007588823792	0.02351589501
Hyperbolic-2Body-EarthMODEq	1.183715035	0.01674925443	0.01817534212
Hyperbolic-2Body-EarthMOEEc	0.00026047443	0.008927599993	0.0233121682
Hyperbolic-2Body-EarthMOEEq	0.000217340812	0.01784064807	0.01766602509
Hyperbolic-2Body-EarthTODEc	2.066649429	1.515742042	0.6023328751
Hyperbolic-2Body-EarthTODEq	2.066692929	5.087713362	5.08732046
Hyperbolic-2Body-EarthTOEEc	5.182947816	0.00926957	0.02366141416
Hyperbolic-2Body-EarthTOEEq	5.182958375	0.6900227163	0.6991467671
ISS-2Body-EarthFixed	89.91428695	67.10288835	31.77833423
ISS-2Body-EarthGSE	0.2475189831	0.02900196705	0.0004220055416
ISS-2Body-EarthGSM	3.261639904	22.63644274	29.37960016
ISS-2Body-EarthMJ2000Ec	0.0007530616131	0.7919024938	0.2579763532
ISS-2Body-EarthMJ2000Eq	0.0007603375707	0.0005566107575	0.000301952241
ISS-2Body-EarthMODEc	0.4284956958	0.9411342035	0.001266016625
ISS-2Body-EarthMODEq	0.4284956958	0.8629867807	0.3752065822
ISS-2Body-EarthMOEEc	0.0007530616131	0.0002983142622	0.0004874891602
ISS-2Body-EarthMOEEq	0.0007603375707	0.0005566107575	0.000301952241
ISS-2Body-EarthTODEc	0.7472881407	2.260314432	0.2173910616
ISS-2Body-EarthTODEq	0.7472772268	3.630950232	2.533914085
ISS-2Body-EarthTOEEc	1.879539923	4.109922884	0.0004874891602
ISS-2Body-EarthTOEEq	1.879554475	4.081139195	1.909433195
Mars1-2Body-MarsFixed	23.98886318	22.21717	10.38143819
Mars1-2Body-MarsMJ2000Ec	0.9952709661	0.5993915693	0.5886722647
Mars1-2Body-MarsMJ2000Eq	0.9952691471	0.2261380806	0.7740909496
Mercury1-2Body-MercuryFixed	0.327698217	0.4808271115	0.2502738425
Mercury1-2Body-MercuryMJ2000Ec	0.1878624971	0.2510159902	0.2059750841
Mercury1-2Body-MercuryMJ2000Eq	0.1878634066	0.1111429479	0.2888264135
Moon-2Body-MoonFixed	5.5748352	5.283694918	0.002652541298
Moon-2Body-MoonMJ2000Ec	0.001063199306	0.04336504844	0.0190548235
Moon-2Body-MoonMJ2000Eq	0.001064108801	0.0002578476294	0.00038107828
Neptune1-2Body-NeptuneFixed	42849.13634	43033.72977	96195.52572
Neptune1-2Body-NeptuneMJ2000Ec	29.59038829	77.10719365	79.3626532
Neptune1-2Body-NeptuneMJ2000Eq	29.59038829	84.00197472	57.43693328
Pluto1-2Body-PlutoFixed	12.66916559	15.03451797	18.39295624
Pluto1-2Body-PlutoMJ2000Ec	2.923446004	0.8473472235	3.204913128
Pluto1-2Body-PlutoMJ2000Eq	2.923445891	0.8302175236	3.147571306
Saturn1-2Body-SaturnFixed	7341.511315	7984.995318	864.7177019
Saturn1-2Body-SaturnMJ2000Ec	13.2243149	25.11031926	27.86074765
Saturn1-2Body-SaturnMJ2000Eq	13.22408207	16.91115992	24.03883263
Uranus1-2Body-UranusFixed	2955.545322	3574.169823	2353.711105
Uranus1-2Body-UranusMJ2000Ec	5.186127964	39.40385068	90.66710481
Uranus1-2Body-UranusMJ2000Eq	5.186419003	61.77691968	77.83877663
Venus1-2Body-VenusFixed	0.7762544101	0.3817622201	0.2173546818

Table 3.29: WinGMAT/STK Coordinate System Dependent Parameter Differences (Velocity Vector-based)

Test Case	Mag-Vel (m/s)	Right Asc. of Vel. (deg)	Dec. of Vel. (deg)
GEO-2Body-EarthFixed	3.278583187e-006	1.162789617	0.178531639
GEO-2Body-EarthMJ2000Ec	1.07913678e-010	2.742908123e-010	1.110862513e-009
GEO-2Body-EarthMJ2000Eq	1.07913678e-010	3.426237072e-011	0
GEO-2Body-EarthMODEc	1.070254996e-010	1.887912049e-009	1.108624303e-011
GEO-2Body-EarthMODEq	1.070254996e-010	1.733170052e-009	7.381565394e-010
GEO-2Body-EarthMOEEc	1.07913678e-010	3.628031209e-011	1.261213356e-011
GEO-2Body-EarthMOEEq	1.07913678e-010	3.427658157e-011	5.656303434e-015
GEO-2Body-EarthTODEc	1.070254996e-010	9.472358897e-009	9.347012053e-010
GEO-2Body-EarthTODEq	1.070254996e-010	8.702897958e-009	4.850753133e-009
GEO-2Body-EarthTOEEc	1.07913678e-010	8.130868423e-009	1.261213356e-011
GEO-2Body-EarthTOEEq	1.07913678e-010	7.460869256e-009	3.266776493e-009
Hyperbolic-2Body-EarthFixed	4.71472088e-005	2.061432909e-007	5.501368605e-008
Hyperbolic-2Body-EarthMJ2000Ec	1.616484724e-010	2.155502443e-010	7.097700205e-010
Hyperbolic-2Body-EarthMJ2000Eq	1.616484724e-010	1.421085472e-012	9.201528428e-013
Hyperbolic-2Body-EarthMODEc	1.616484724e-010	1.854090215e-009	1.578293052e-012
Hyperbolic-2Body-EarthMODEq	1.616484724e-010	1.910734682e-009	7.375620115e-010
Hyperbolic-2Body-EarthMOEEc	1.616484724e-010	1.591615728e-012	2.415845302e-013
Hyperbolic-2Body-EarthMOEEq	1.616484724e-010	1.449507181e-012	9.166001291e-013
Hyperbolic-2Body-EarthTODEc	1.616484724e-010	3.401112281e-009	5.87760951e-010
Hyperbolic-2Body-EarthTODEq	1.616484724e-010	5.039368034e-009	1.719470788e-009
Hyperbolic-2Body-EarthTOEEc	1.616484724e-010	8.096151305e-009	2.415845302e-013
Hyperbolic-2Body-EarthTOEEq	1.616484724e-010	8.594184919e-009	3.265999027e-009
ISS-2Body-EarthFixed	1.000267424e-006	1.289333902e-007	3.871187459e-008
ISS-2Body-EarthGSE	4.574118861e-010	5.30000932e-010	6.077804926e-011
ISS-2Body-EarthGSM	3.126210402e-008	2.998996962e-008	3.987213404e-008
ISS-2Body-EarthMJ2000Ec	4.636291351e-010	8.293685738e-010	1.106641889e-009
ISS-2Body-EarthMJ2000Eq	4.636291351e-010	1.526245796e-010	7.80993048e-011
ISS-2Body-EarthMODEc	4.627409567e-010	1.852910714e-009	6.026290578e-011
ISS-2Body-EarthMODEq	4.52970994e-010	2.479552563e-009	7.349498787e-010
ISS-2Body-EarthMOEEc	4.636291351e-010	1.305977548e-010	6.103206829e-011
ISS-2Body-EarthMOEEq	4.627409567e-010	1.526245796e-010	7.80993048e-011
ISS-2Body-EarthTODEc	4.627409567e-010	3.180247177e-009	9.443787974e-010
ISS-2Body-EarthTODEq	4.627409567e-010	4.238856377e-009	4.168732914e-009
ISS-2Body-EarthTOEEc	4.627409567e-010	8.094446002e-009	6.103206829e-011
ISS-2Body-EarthTOEEq	4.627409567e-010	1.066266009e-008	3.259224002e-009
Mars1-2Body-MarsFixed	9.592806993e-006	9.947378707e-007	3.948958787e-007
Mars1-2Body-MarsMJ2000Ec	8.899687209e-006	1.432667602e-006	6.136789708e-007
Mars1-2Body-MarsMJ2000Eq	8.899676995e-006	1.215923845e-006	6.201466789e-007
Mercury1-2Body-MercuryFixed	1.59941127e-006	3.112265077e-007	1.274611101e-007
Mercury1-2Body-MercuryMJ2000Ec	1.597606047e-006	3.378602003e-007	1.397476694e-007
Mercury1-2Body-MercuryMJ2000Eq	1.597606047e-006	2.85895851e-007	1.4250252e-007
Moon-2Body-MoonFixed	1.504485425e-008	1.412774111e-007	2.357179341e-009
Moon-2Body-MoonMJ2000Ec	1.500399804e-008	4.380240171e-009	1.342904454e-009
Moon-2Body-MoonMJ2000Eq	1.500399804e-008	4.660591912e-009	2.414738631e-009
Neptune1-2Body-NeptuneFixed	0.001546170623	1.309179918e-005	1.351642366e-005
Neptune1-2Body-NeptuneMJ2000Ec	3.205422061e-005	1.140866715e-006	4.847768089e-007
Neptune1-2Body-NeptuneMJ2000Eq	3.205422949e-005	9.779481331e-007	4.998895804e-007
Pluto1-2Body-PlutoFixed	8.217843617e-005	4.784315172e-005	2.956015004e-005
Pluto1-2Body-PlutoMJ2000Ec	8.345292613e-005	5.652545477e-005	2.377500014e-005
Pluto1-2Body-PlutoMJ2000Eq	8.345292613e-005	4.844967677e-005	2.512714485e-005
Saturn1-2Body-SaturnFixed	8.716019906e-006	4.920609911e-007	9.227543885e-008
Saturn1-2Body-SaturnMJ2000Ec	5.18404164e-006	1.242314625e-007	5.306250017e-008
Saturn1-2Body-SaturnMJ2000Eq	5.18404164e-006	1.061025898e-007	5.502680978e-008
Uranus1-2Body-UranusFixed	3.448082886e-005	7.157807744e-006	7.584381549e-007
Uranus1-2Body-UranusMJ2000Ec	2.627271023e-005	1.159199428e-006	5.016063795e-007
Uranus1-2Body-UranusMJ2000Eq	2.627271023e-005	9.843604971e-007	5.082584709e-007
Venus1-2Body-VenusFixed	5.125109226e-007	3.693500616e-008	1.783747905e-008
Venus1-2Body-VenusMJ2000Ec	5.126095104e-007	3.734896836e-008	1.708282227e-008

Table 3.30: WinGMAT/STK Coordinate System Dependent Parameter Differences (Angle-based)

Test Case	Arg. of Per. (deg)	Decl. (deg)	Inc. (deg)	RA (deg)	RAAN (deg)
GEO-2Body-EarthFixed	3.357e-005	2.768e-008	0.2044	3.148e-007	9.529e-005
GEO-2Body-EarthMJ2000Ec	1.354e-005	1.111e-009	1.111e-009	2.715e-010	0
GEO-2Body-EarthMJ2000Eq	1.309e-005	0	1e-014	3.513e-011	0
GEO-2Body-EarthMODEc	1.381e-005	1.148e-011	3.233e-013	1.886e-009	1.864e-009
GEO-2Body-EarthMODEq	1.322e-005	7.381e-010	7.548e-010	1.734e-009	8.657e-010
GEO-2Body-EarthMOEEc	1.354e-005	1.291e-011	3.126e-013	3.401e-011	0
GEO-2Body-EarthMOEEq	1.343e-005	5.656e-015	0	3.513e-011	0
GEO-2Body-EarthTODEc	1.367e-005	9.281e-010	9.348e-010	9.5e-009	9.482e-009
GEO-2Body-EarthTODEq	1.095e-005	4.652e-009	3.537e-009	8.705e-009	1.046e-005
GEO-2Body-EarthTOEEc	1.354e-005	1.291e-011	3.126e-013	8.129e-009	8.107e-009
GEO-2Body-EarthTOEEq	8.314e-005	3.267e-009	1.764e-009	7.462e-009	6.978e-005
Hyperbolic-2Body-EarthFixed	3.504e-007	1.754e-008	2.357e-007	1.35e-007	1.528e-007
Hyperbolic-2Body-EarthMJ2000Ec	7.617e-012	1.096e-009	1.111e-009	2.172e-010	1.4e-013
Hyperbolic-2Body-EarthMJ2000Eq	7.844e-012	8.207e-013	4.334e-013	1.251e-012	2.5e-013
Hyperbolic-2Body-EarthMODEc	1.18e-011	1.561e-012	3.411e-013	1.854e-009	1.858e-009
Hyperbolic-2Body-EarthMODEq	1.052e-009	7.379e-010	5.755e-013	2.405e-009	9.755e-010
Hyperbolic-2Body-EarthMOEEc	7.518e-012	2.984e-013	3.517e-013	1.393e-012	1.4e-013
Hyperbolic-2Body-EarthMOEEq	7.674e-012	8.313e-013	1.421e-013	1.251e-012	0
Hyperbolic-2Body-EarthTODEc	9.422e-012	9.216e-010	9.348e-010	3.396e-009	3.235e-009
Hyperbolic-2Body-EarthTODEq	1.824e-009	3.924e-009	4.129e-009	4.887e-009	1.696e-009
Hyperbolic-2Body-EarthTOEEc	7.631e-012	2.984e-013	3.375e-013	8.096e-009	8.107e-009
Hyperbolic-2Body-EarthTOEEq	4.561e-009	3.265e-009	5.531e-010	1.062e-008	4.29e-009
ISS-2Body-EarthFixed	3.206e-008	3.275e-008	3.965e-008	1.328e-007	1.38e-007
ISS-2Body-EarthGSE	7.436e-010	6.5e-011	5.4e-013	5.681e-010	4.462e-010
ISS-2Body-EarthGSM	2.426e-006	3.92e-008	4.043e-008	2.862e-008	7.132e-009
ISS-2Body-EarthMJ2000Ec	2.188e-009	1.109e-009	4.623e-010	8.22e-010	1.29e-009
ISS-2Body-EarthMJ2000Eq	5.568e-010	7.966e-011	5.471e-013	1.525e-010	5.4e-013
ISS-2Body-EarthMODEc	5.555e-010	6.455e-011	1.592e-012	1.853e-009	1.852e-009
ISS-2Body-EarthMODEq	1.215e-009	7.378e-010	5.283e-010	2.49e-009	1.291e-009
ISS-2Body-EarthMOEEc	5.49e-010	6.525e-011	4.05e-013	1.269e-010	7.105e-013
ISS-2Body-EarthMOEEq	5.525e-010	7.966e-011	5.471e-013	1.525e-010	5.542e-013
ISS-2Body-EarthTODEc	1.658e-009	9.461e-010	3.891e-010	3.178e-009	4.239e-009
ISS-2Body-EarthTODEq	3.32e-009	4.163e-009	3.569e-009	4.248e-009	4.395e-009
ISS-2Body-EarthTOEEc	5.487e-010	6.526e-011	4.05e-013	8.095e-009	8.095e-009
ISS-2Body-EarthTOEEq	2.92e-009	3.264e-009	2.689e-009	1.063e-008	5.96e-009
Mars1-2Body-MarsFixed	2.247e-006	5.221e-007	5.014e-008	9.731e-007	2.604e-007
Mars1-2Body-MarsMJ2000Ec	4.431e-008	8.568e-007	2.152e-009	1.285e-006	1.562e-009
Mars1-2Body-MarsMJ2000Eq	4.543e-008	7.205e-007	2.049e-009	1.377e-006	1.332e-009
Mercury1-2Body-MercuryFixed	7.263e-009	1.881e-007	1.462e-009	2.697e-007	5.066e-009
Mercury1-2Body-MercuryMJ2000Ec	8.609e-009	1.99e-007	1.004e-009	3.065e-007	2.237e-009
Mercury1-2Body-MercuryMJ2000Eq	7.477e-009	1.735e-007	1.664e-009	3.307e-007	1.026e-009
Moon-2Body-MoonFixed	1.68e-010	3.26e-009	5.607e-011	1.415e-007	1.412e-007
Moon-2Body-MoonMJ2000Ec	1.394e-009	2.259e-009	4.114e-010	4.055e-009	8.905e-010
Moon-2Body-MoonMJ2000Eq	3.644e-011	2.817e-009	1.148e-011	5.613e-009	6.096e-012
Neptune1-2Body-NeptuneFixed	4.002e-005	5.911e-007	1.341e-005	1.157e-006	7.627e-006
Neptune1-2Body-NeptuneMJ2000Ec	2.001e-008	6.812e-007	1.011e-008	1.058e-006	1.042e-008
Neptune1-2Body-NeptuneMJ2000Eq	2.142e-008	6.033e-007	6.69e-009	1.147e-006	1.42e-008
Pluto1-2Body-PlutoFixed	5.512e-006	3.201e-005	7.484e-007	7.441e-005	8.117e-007
Pluto1-2Body-PlutoMJ2000Ec	5.338e-007	3.39e-005	4.962e-008	5.105e-005	3.472e-008
Pluto1-2Body-PlutoMJ2000Eq	5.077e-007	2.963e-005	3.899e-008	5.878e-005	5.172e-008
Saturn1-2Body-SaturnFixed	1.508e-007	5.809e-008	5.751e-008	5.188e-007	4.571e-007
Saturn1-2Body-SaturnMJ2000Ec	3.259e-009	7.328e-008	6.576e-010	1.179e-007	9.333e-010
Saturn1-2Body-SaturnMJ2000Eq	4.55e-009	6.548e-008	5.383e-010	1.273e-007	8.028e-010
Uranus1-2Body-UranusFixed	4.529e-006	8.4e-007	3.03e-007	2.345e-006	4.615e-007
Uranus1-2Body-UranusMJ2000Ec	1.129e-008	6.9e-007	8.766e-009	1.112e-006	5.248e-009
Uranus1-2Body-UranusMJ2000Eq	1.392e-008	6.011e-007	6.433e-009	1.201e-006	1e-008
Venus1-2Body-VenusFixed	1.012e-009	2.227e-008	1.379e-010	3.825e-008	1.158e-009
Venus1-2Body-VenusMJ2000Ec	2.027e-009	2.162e-008	4.209e-010	3.816e-008	8.709e-010

Table 3.31: FF/WinGMAT Coordinate System Dependent Parameter Differences (Position)

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)
ISS-2Body-EarthMJ2000Eq	2.54757424e-005	2.516884479e-005	2.321598913e-005

Table 3.32: FF/WinGMAT Coordinate System Dependent Parameter Differences (Velocity)

Test Case	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
ISS-2Body-EarthMJ2000Eq	4.993130354e-007	5.00476105e-007	4.961786537e-007

Table 3.33: FF/WinGMAT Coordinate System Dependent Parameter Differences (Specific Angular Momentum)

Test Case	X-(H) (m^2/sec)	Y-(H) (m^2/sec)	Z-(H) (m^2/sec)
ISS-2Body-EarthMJ2000Eq	0.0005493347999	0.001349690137	0.001567968866

Table 3.34: FF/WinGMAT Coordinate System Dependent Parameter Differences (Velocity Vector-based)

Test Case	Mag-Vel (m/s)	Right Asc. of Vel. (deg)	Dec. of Vel. (deg)
ISS-2Body-EarthMJ2000Eq	4.860067904e-007	296.2928006	67.36750845

Table 3.35: FF/WinGMAT Coordinate System Dependent Parameter Differences (Angle-based)

Test Case	Arg. of Per. (deg)	Decl. (deg)	Inc. (deg)	RA (deg)	RAAN (deg)
ISS-2Body-EarthMJ2000Eq	1.681e-009	5.884e-010	4.684e-010	7.628e-010	2.418e-010

Table 3.36: FF/STK Coordinate System Dependent Parameter Differences (Position)

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)
ISS-2Body-EarthMJ2000Eq	3.580873909e-005	3.470813681e-005	3.243098945e-005

Table 3.37: FF/STK Coordinate System Dependent Parameter Differences (Velocity)

Test Case	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
ISS-2Body-EarthMJ2000Eq	5.092002375e-007	5.105600387e-007	5.025699856e-007

Table 3.38: FF/STK Coordinate System Dependent Parameter Differences (Specific Angular Momentum)

Test Case	X-(H) (m^2/sec)	Y-(H) (m^2/sec)	Z-(H) (m^2/sec)
ISS-2Body-EarthMJ2000Eq	0.0005711626727	0.001346052159	0.00146246748

Table 3.39: FF/STK Coordinate System Dependent Parameter Differences (Velocity Vector-based)

Test Case	Mag-Vel (m/s)	Right Asc. of Vel. (deg)	Dec. of Vel. (deg)
ISS-2Body-EarthMJ2000Eq	4.857803049e-007	296.2928006	67.36750845

Table 3.40: FF/STK Coordinate System Dependent Parameter Differences (Angle-based)

Test Case	Arg. of Per. (deg)	Decl. (deg)	Inc. (deg)	RA (deg)	RAAN (deg)
ISS-2Body-EarthMJ2000Eq	1.347e-009	6.518e-010	4.685e-010	8.637e-010	2.414e-010

3.3.4 Win/Mac GMAT Comparison

Table 3.41: WinGMAT/MacGMAT Coordinate System Dependent Parameter Differences (Position)

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)
GEO-2Body-EarthFixed	0.0001842481652	3.285822459e-005	8.177306055e-009
GEO-2Body-EarthMJ2000Ec	1.167290975e-005	1.199748567e-005	5.201599151e-006
GEO-2Body-EarthMJ2000Eq	1.167290975e-005	1.307660114e-005	0
GEO-2Body-EarthMODEc	1.167200026e-005	1.199771305e-005	5.201400199e-006
GEO-2Body-EarthMODEq	1.167200026e-005	1.30769422e-005	5.027978034e-009
GEO-2Body-EarthMOEEc	1.167381924e-005	1.199748567e-005	5.201599151e-006
GEO-2Body-EarthMOEEq	1.167381924e-005	1.307660114e-005	1.15236801e-021
GEO-2Body-EarthTODEc	1.167200026e-005	1.199788358e-005	5.201400199e-006
GEO-2Body-EarthTODEq	1.167200026e-005	1.307682851e-005	8.173711707e-009
GEO-2Body-EarthTOEEc	1.167427399e-005	1.199748567e-005	5.201599151e-006
GEO-2Body-EarthTOEEq	1.167427399e-005	1.307671482e-005	2.659095166e-009
Hyperbolic-2Body-EarthFixed	0.0008837669156	0.001192296622	1.164153218e-007
Hyperbolic-2Body-EarthMJ2000Ec	3.492459655e-007	1.164153218e-007	8.731149137e-008
Hyperbolic-2Body-EarthMJ2000Eq	3.492459655e-007	1.164153218e-007	1.164153218e-007
Hyperbolic-2Body-EarthMODEc	3.492459655e-007	1.164153218e-007	1.018634066e-007
Hyperbolic-2Body-EarthMODEq	3.492459655e-007	1.164153218e-007	1.164153218e-007
Hyperbolic-2Body-EarthMOEEc	3.492459655e-007	1.164153218e-007	7.275957614e-008
Hyperbolic-2Body-EarthMOEEq	3.492459655e-007	1.164153218e-007	1.164153218e-007
Hyperbolic-2Body-EarthTODEc	4.074536264e-007	1.164153218e-007	1.018634066e-007
Hyperbolic-2Body-EarthTODEq	4.074536264e-007	1.164153218e-007	1.164153218e-007
Hyperbolic-2Body-EarthTOEEc	3.492459655e-007	1.164153218e-007	7.275957614e-008
Hyperbolic-2Body-EarthTOEEq	3.492459655e-007	1.164153218e-007	1.164153218e-007
ISS-2Body-EarthFixed	2.39901965e-005	3.032710083e-005	1.251714821e-005
ISS-2Body-EarthGSE	7.217067832e-006	5.829974725e-006	4.693333722e-006
ISS-2Body-EarthGSM	1.589199883e-005	1.367493496e-005	9.297707493e-006
ISS-2Body-EarthMJ2000Ec	6.370953543e-006	7.136122804e-006	4.692878974e-006
ISS-2Body-EarthMJ2000Eq	6.370953543e-006	6.066102287e-006	5.955598681e-006
ISS-2Body-EarthMODEc	6.370100891e-006	7.13589543e-006	4.693220035e-006
ISS-2Body-EarthMODEq	6.370100891e-006	6.06996764e-006	5.953893378e-006
ISS-2Body-EarthMOEEc	6.371124073e-006	7.136122804e-006	4.692537914e-006
ISS-2Body-EarthMOEEq	6.371124073e-006	6.065874913e-006	5.955598681e-006
ISS-2Body-EarthTODEc	6.370214578e-006	7.13589543e-006	4.693220035e-006
ISS-2Body-EarthTODEq	6.370214578e-006	6.069058145e-006	5.954348126e-006
ISS-2Body-EarthTOEEc	6.371124073e-006	7.136122804e-006	4.692537914e-006
ISS-2Body-EarthTOEEq	6.371124073e-006	6.065192792e-006	5.955371307e-006
Mars1-2Body-MarsFixed	0.01889046771	0.0188483892	0.0101035551
Mars1-2Body-MarsMJ2000Ec	0.01384317869	0.01948085998	0.01588558911
Mars1-2Body-MarsMJ2000Eq	0.01384317869	0.020802021	0.01400709147
Mercury1-2Body-MercuryFixed	0.02247740872	0.02563626177	0.02199024959
Mercury1-2Body-MercuryMJ2000Ec	0.020712614	0.0263996169	0.02335545349
Mercury1-2Body-MercuryMJ2000Eq	0.020712614	0.02828240395	0.02072751528
Moon-2Body-MoonFixed	0.0001181998073	8.823919018e-005	0.0001023369123
Moon-2Body-MoonMJ2000Ec	8.999450074e-005	0.0001172169846	0.0001019149067
Moon-2Body-MoonMJ2000Eq	8.999450074e-005	0.0001284061	9.025099246e-005
Neptune1-2Body-NeptuneFixed	0.000139336862	0.0001421121851	1.818989404e-008
Neptune1-2Body-NeptuneMJ2000Ec	1.091393642e-008	1.455191523e-008	1.091393642e-008
Neptune1-2Body-NeptuneMJ2000Eq	1.091393642e-008	1.455191523e-008	1.091393642e-008
Pluto1-2Body-PlutoFixed	0.02447438351	0.05146786219	0.03691279483
Pluto1-2Body-PlutoMJ2000Ec	0.0331401825	0.0482615705	0.03949610559
Pluto1-2Body-PlutoMJ2000Eq	0.0331401825	0.05435943603	0.03361701965
Saturn1-2Body-SaturnFixed	0.0006473801477	0.0005969686754	1.455191523e-008
Saturn1-2Body-SaturnMJ2000Ec	1.455191523e-008	1.455191523e-008	1.455191523e-008
Saturn1-2Body-SaturnMJ2000Eq	1.455191523e-008	1.455191523e-008	1.455191523e-008
Uranus1-2Body-UranusFixed	0.0001626394805	0.0001651487764	2.182787284e-008
Uranus1-2Body-UranusMJ2000Ec	1.455191523e-008	1.455191523e-008	1.455191523e-008
Uranus1-2Body-UranusMJ2000Eq	1.455191523e-008	1.455191523e-008	1.455191523e-008
Venus1-2Body-VenusFixed	0.00709690994	0.005248550565	0.005916503937
Venus1-2Body-VenusMJ2000Ec	0.005392357707	0.007055124229	0.006031767612

Table 3.42: WinGMAT/MacGMAT Coordinate System Dependent Parameter Differences (Velocity)

Test Case	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
GEO-2Body-EarthFixed	1.909583602e-010	1.048050535e-010	6.29813042e-013
GEO-2Body-EarthMJ2000Ec	8.857428679e-010	8.001099783e-010	3.468336729e-010
GEO-2Body-EarthMJ2000Eq	8.857428679e-010	8.719136524e-010	0
GEO-2Body-EarthMODEc	8.85735929e-010	7.99998956e-010	3.468336729e-010
GEO-2Body-EarthMODEq	8.85735929e-010	8.719136524e-010	3.816391647e-013
GEO-2Body-EarthMOEEc	8.857428679e-010	7.99998956e-010	3.468197951e-010
GEO-2Body-EarthMOEEq	8.857428679e-010	8.718858968e-010	8.744261208e-026
GEO-2Body-EarthTODEc	8.857498068e-010	7.99998956e-010	3.468336729e-010
GEO-2Body-EarthTODEq	8.857498068e-010	8.719136524e-010	6.299214622e-013
GEO-2Body-EarthTOEEc	8.857428679e-010	7.99998956e-010	3.468197951e-010
GEO-2Body-EarthTOEEq	8.857428679e-010	8.719136524e-010	1.940721889e-013
Hyperbolic-2Body-EarthFixed	9.596945461e-008	5.1627147e-008	2.220446049e-012
Hyperbolic-2Body-EarthMJ2000Ec	5.329070518e-012	1.33226763e-012	1.110223025e-012
Hyperbolic-2Body-EarthMJ2000Eq	5.329070518e-012	1.33226763e-012	1.33226763e-012
Hyperbolic-2Body-EarthMODEc	5.329070518e-012	1.33226763e-012	1.998401444e-012
Hyperbolic-2Body-EarthMODEq	5.329070518e-012	1.33226763e-012	2.220446049e-012
Hyperbolic-2Body-EarthMOEEc	4.440892099e-012	2.220446049e-012	1.110223025e-012
Hyperbolic-2Body-EarthMOEEq	4.440892099e-012	1.33226763e-012	1.33226763e-012
Hyperbolic-2Body-EarthTODEc	4.440892099e-012	2.220446049e-012	1.998401444e-012
Hyperbolic-2Body-EarthTODEq	4.440892099e-012	2.220446049e-012	2.220446049e-012
Hyperbolic-2Body-EarthTOEEc	5.329070518e-012	1.33226763e-012	1.110223025e-012
Hyperbolic-2Body-EarthTOEEq	5.329070518e-012	1.33226763e-012	1.33226763e-012
ISS-2Body-EarthFixed	2.755173867e-008	2.405187161e-008	1.391098348e-008
ISS-2Body-EarthGSE	8.265110818e-009	6.57274235e-009	5.144329407e-009
ISS-2Body-EarthGSM	1.852806797e-008	1.512762138e-008	9.931833134e-009
ISS-2Body-EarthMJ2000Ec	6.995792834e-009	8.162914789e-009	5.144218385e-009
ISS-2Body-EarthMJ2000Eq	6.995792834e-009	6.909979533e-009	6.708356093e-009
ISS-2Body-EarthMODEc	6.994210766e-009	8.163247855e-009	5.144329407e-009
ISS-2Body-EarthMODEq	6.994210766e-009	6.913029177e-009	6.706690758e-009
ISS-2Body-EarthMOEEc	6.995792834e-009	8.162692744e-009	5.143885318e-009
ISS-2Body-EarthMOEEq	6.995792834e-009	6.909979533e-009	6.708356093e-009
ISS-2Body-EarthTODEc	6.994294033e-009	8.162803766e-009	5.144329407e-009
ISS-2Body-EarthTODEq	6.994294033e-009	6.912781111e-009	6.706801781e-009
ISS-2Body-EarthTOEEc	6.995889978e-009	8.162248655e-009	5.143885318e-009
ISS-2Body-EarthTOEEq	6.995889978e-009	6.909500749e-009	6.708245071e-009
Mars1-2Body-MarsFixed	1.65924548e-005	1.533683858e-005	6.959634646e-006
Mars1-2Body-MarsMJ2000Ec	1.200730537e-005	1.675083128e-005	1.136635897e-005
Mars1-2Body-MarsMJ2000Eq	1.200730537e-005	1.665495386e-005	1.200201838e-005
Mercury1-2Body-MercuryFixed	1.854803089e-005	2.453733106e-005	1.46014203e-005
Mercury1-2Body-MercuryMJ2000Ec	1.714795417e-005	2.490750972e-005	1.591344523e-005
Mercury1-2Body-MercuryMJ2000Eq	1.714795417e-005	2.425520762e-005	1.714533227e-005
Moon-2Body-MoonFixed	8.846923194e-008	5.997391472e-008	5.85231863e-008
Moon-2Body-MoonMJ2000Ec	6.150671639e-008	8.812783836e-008	5.794542624e-008
Moon-2Body-MoonMJ2000Eq	6.150671639e-008	8.844119881e-008	6.176040235e-008
Neptune1-2Body-NeptuneFixed	4.272804333e-008	4.349276495e-008	2.337685601e-009
Neptune1-2Body-NeptuneMJ2000Ec	1.761257806e-009	2.033040403e-009	2.637001728e-009
Neptune1-2Body-NeptuneMJ2000Eq	1.761257806e-009	2.881250794e-009	1.721289777e-009
Pluto1-2Body-PlutoFixed	1.731889131e-005	2.236791574e-005	2.158779519e-005
Pluto1-2Body-PlutoMJ2000Ec	1.866654031e-005	2.554708012e-005	1.668872029e-005
Pluto1-2Body-PlutoMJ2000Eq	1.866654031e-005	2.480730821e-005	1.907892511e-005
Saturn1-2Body-SaturnFixed	1.174538244e-007	1.154329965e-007	2.131628207e-011
Saturn1-2Body-SaturnMJ2000Ec	3.552713679e-011	6.039613254e-011	4.97379915e-011
Saturn1-2Body-SaturnMJ2000Eq	3.552713679e-011	7.105427358e-011	2.842170943e-011
Uranus1-2Body-UranusFixed	3.869882192e-008	3.740296961e-008	1.643130076e-010
Uranus1-2Body-UranusMJ2000Ec	6.75015599e-011	1.740829703e-010	5.151434834e-011
Uranus1-2Body-UranusMJ2000Eq	6.75015599e-011	1.767475055e-010	3.286954042e-011
Venus1-2Body-VenusFixed	7.910974986e-006	4.326484948e-006	4.740029036e-006
Venus1-2Body-VenusMJ2000Ec	5.252162039e-006	7.2970468e-006	4.826740119e-006

Table 3.43: WinGMAT/MacGMAT Coordinate System Dependent Parameter Differences (Specific Angular Momentum)

Test Case	X-(H) (m^2/sec)	Y-(H) (m^2/sec)	Z-(H) (m^2/sec)
GEO-2Body-EarthFixed	3.896616363e-005	0.0002159961099	0.00803578162
GEO-2Body-EarthMJ2000Ec	1.003716411e-005	0.0005893525667	0.001411535777
GEO-2Body-EarthMJ2000Eq	0	0	0.001411535777
GEO-2Body-EarthMODEc	1.380584536e-005	0.0006111804396	0.001396983862
GEO-2Body-EarthMODEq	6.323830348e-007	1.447106324e-008	0.001498847269
GEO-2Body-EarthMOEEc	1.02179897e-005	0.0005966285244	0.001396983862
GEO-2Body-EarthMOEEq	1.486340163e-019	2.762164459e-021	0.001411535777
GEO-2Body-EarthTODEc	1.321609489e-005	0.0005966285244	0.001396983862
GEO-2Body-EarthTODEq	6.394884622e-007	2.097522156e-005	0.001498847269
GEO-2Body-EarthTOEEc	1.725020127e-005	0.0005893525667	0.001396983862
GEO-2Body-EarthTOEEq	4.218847494e-008	7.14317494e-006	0.001498847269
Hyperbolic-2Body-EarthFixed	12.21429557	16.07602462	0.01862645149
Hyperbolic-2Body-EarthMJ2000Ec	0.0001451052704	0.0002546585165	0.0003929017112
Hyperbolic-2Body-EarthMJ2000Eq	8.698973375e-005	0.0003346940503	0.0002182787284
Hyperbolic-2Body-EarthMODEc	0.000164668279	0.0002983142622	0.0004802132025
Hyperbolic-2Body-EarthMODEq	0.0001312869813	0.0004074536264	0.0003055902198
Hyperbolic-2Body-EarthMOEEc	0.0001579081028	0.0002546585165	0.0003929017112
Hyperbolic-2Body-EarthMOEEq	9.90183124e-005	0.0003055902198	0.0002328306437
Hyperbolic-2Body-EarthTODEc	0.0001351310175	0.0003055902198	0.0004365574569
Hyperbolic-2Body-EarthTODEq	0.0001949373996	0.0004365574569	0.0004220055416
Hyperbolic-2Body-EarthTOEEc	0.0001569260277	0.0002401066013	0.0005675246939
Hyperbolic-2Body-EarthTOEEq	0.0002851092695	0.0004802132025	0.0004511093721
ISS-2Body-EarthFixed	0.1522203092	0.1153202902	0.005118636182
ISS-2Body-EarthGSE	0.0006320988177	0.0007676135283	0.001055013854
ISS-2Body-EarthGSM	0.002212800609	0.01764419721	0.02349042916
ISS-2Body-EarthMJ2000Ec	0.0007821654435	0.0007894414011	0.001033185981
ISS-2Body-EarthMJ2000Eq	0.0007821654435	0.001149601303	0.0006511982065
ISS-2Body-EarthMODEc	0.0007785274647	0.0007894414011	0.001055013854
ISS-2Body-EarthMODEq	0.0007785274647	0.001142325345	0.00064028427
ISS-2Body-EarthMOEEc	0.0007821654435	0.0008003553376	0.001047737896
ISS-2Body-EarthMOEEq	0.0007821654435	0.001142325345	0.0006511982065
ISS-2Body-EarthTODEc	0.0007821654435	0.0007894414011	0.001055013854
ISS-2Body-EarthTODEq	0.0007821654435	0.001138687367	0.0006511982065
ISS-2Body-EarthTOEEc	0.0007894414011	0.0007894414011	0.001047737896
ISS-2Body-EarthTOEEq	0.0007785274647	0.001149601303	0.0006693881005
Mars1-2Body-MarsFixed	3.465424925	3.332335609	3.114930223
Mars1-2Body-MarsMJ2000Ec	0.3840796126	0.6094032869	0.784824806
Mars1-2Body-MarsMJ2000Eq	0.3840814315	0.5609703017	0.9097748261
Mercury1-2Body-MercuryFixed	0.3643126547	0.2606343514	0.3183149602
Mercury1-2Body-MercuryMJ2000Ec	0.3474442565	0.2259671419	0.2800552465
Mercury1-2Body-MercuryMJ2000Eq	0.3474442565	0.1747036688	0.3285458661
Moon-2Body-MoonFixed	0.000881982487	0.0009599716577	0.0007757989806
Moon-2Body-MoonMJ2000Ec	0.0008471943147	0.0005061338015	0.0002769411367
Moon-2Body-MoonMJ2000Eq	0.0008471943147	0.0004473084551	0.0004151843314
Neptune1-2Body-NeptuneFixed	1.165190042	1.052001608	0.1091102604
Neptune1-2Body-NeptuneMJ2000Ec	0.1045991667	0.04150206223	0.09627547115
Neptune1-2Body-NeptuneMJ2000Eq	0.1045991667	0.0009723253477	0.1047737896
Pluto1-2Body-PlutoFixed	1.363703973	1.145837388	1.336115361
Pluto1-2Body-PlutoMJ2000Ec	1.259122314	0.8433575545	0.5252992423
Pluto1-2Body-PlutoMJ2000Eq	1.2591222	0.5801695134	0.7820016208
Saturn1-2Body-SaturnFixed	7.802096661	7.727998309	0.004423782229
Saturn1-2Body-SaturnMJ2000Ec	0.004190951586	0.001455191523	0.004190951586
Saturn1-2Body-SaturnMJ2000Eq	0.004190951586	0.001082360576	0.004190951586
Uranus1-2Body-UranusFixed	1.692169462	1.658292604	0.003681634553
Uranus1-2Body-UranusMJ2000Ec	0.005529727787	0.00320142135	0.004714820534
Uranus1-2Body-UranusMJ2000Eq	0.005587935448	0.001361763341	0.00570435077
Venus1-2Body-VenusFixed	0.1877981504	0.235006155	0.2762390068

Table 3.44: WinGMAT/MacGMAT Coordinate System Dependent Parameter Differences (Velocity Vector-based)

Test Case	Mag-Vel (m/s)	Right Asc. of Vel. (deg)	Dec. of Vel. (deg)
GEO-2Body-EarthFixed	2.259566986e-011	1.8981672e-005	1.296584657e-006
GEO-2Body-EarthMJ2000Ec	9.90318938e-011	1.799094207e-011	6.445399769e-012
GEO-2Body-EarthMJ2000Eq	9.90318938e-011	1.661248916e-011	0
GEO-2Body-EarthMODEc	9.90318938e-011	1.799094207e-011	6.445177725e-012
GEO-2Body-EarthMODEq	9.90318938e-011	1.659827831e-011	7.11149889e-015
GEO-2Body-EarthMOEEc	9.90318938e-011	1.799094207e-011	6.445510792e-012
GEO-2Body-EarthMOEEq	9.90318938e-011	1.661248916e-011	1.6293922e-027
GEO-2Body-EarthTODEc	9.992007222e-011	1.799094207e-011	6.445399769e-012
GEO-2Body-EarthTODEq	9.90318938e-011	1.661248916e-011	1.174581266e-014
GEO-2Body-EarthTOEEc	9.858780459e-011	1.799094207e-011	6.445510792e-012
GEO-2Body-EarthTOEEq	9.90318938e-011	1.651301318e-011	3.609959554e-015
Hyperbolic-2Body-EarthFixed	3.197442311e-011	2.243467634e-010	2.131628207e-014
Hyperbolic-2Body-EarthMJ2000Ec	3.552713679e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthMJ2000Eq	3.552713679e-012	1.136868377e-013	3.197442311e-014
Hyperbolic-2Body-EarthMODEc	4.440892099e-012	1.136868377e-013	1.953992523e-014
Hyperbolic-2Body-EarthMODEq	4.440892099e-012	1.136868377e-013	3.197442311e-014
Hyperbolic-2Body-EarthMOEEc	4.440892099e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthMOEEq	4.440892099e-012	1.136868377e-013	2.842170943e-014
Hyperbolic-2Body-EarthTODEc	4.440892099e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthTODEq	4.440892099e-012	1.136868377e-013	2.842170943e-014
Hyperbolic-2Body-EarthTOEEc	4.440892099e-012	1.136868377e-013	1.953992523e-014
Hyperbolic-2Body-EarthTOEEq	4.440892099e-012	1.136868377e-013	2.842170943e-014
ISS-2Body-EarthFixed	3.392841563e-010	4.350155791e-010	1.116795545e-010
ISS-2Body-EarthGSE	4.076738946e-010	7.855760487e-011	3.865352483e-011
ISS-2Body-EarthGSM	2.98427949e-010	1.684554718e-010	7.426859128e-011
ISS-2Body-EarthMJ2000Ec	4.085620731e-010	7.858602658e-011	3.864730758e-011
ISS-2Body-EarthMJ2000Eq	4.067857162e-010	9.879386198e-011	5.010614146e-011
ISS-2Body-EarthMODEc	4.067857162e-010	7.850076145e-011	3.864730758e-011
ISS-2Body-EarthMODEq	4.076738946e-010	9.879386198e-011	5.009281878e-011
ISS-2Body-EarthMOEEc	4.067857162e-010	7.861444828e-011	3.864464304e-011
ISS-2Body-EarthMOEEq	4.067857162e-010	9.879386198e-011	5.010614146e-011
ISS-2Body-EarthTODEc	4.058975378e-010	7.861444828e-011	3.864730758e-011
ISS-2Body-EarthTODEq	4.067857162e-010	9.879386198e-011	5.009415105e-011
ISS-2Body-EarthTOEEc	4.085620731e-010	7.861444828e-011	3.864553122e-011
ISS-2Body-EarthTOEEq	4.067857162e-010	9.882228369e-011	5.010303283e-011
Mars1-2Body-MarsFixed	2.56695909e-006	3.176321002e-007	1.198383277e-007
Mars1-2Body-MarsMJ2000Ec	2.3802742e-006	4.106476013e-007	1.879441101e-007
Mars1-2Body-MarsMJ2000Eq	2.3802742e-006	3.544875824e-007	1.887221774e-007
Mercury1-2Body-MercuryFixed	3.661154935e-006	7.217152387e-007	2.972837123e-007
Mercury1-2Body-MercuryMJ2000Ec	3.65724917e-006	7.752641977e-007	3.230690897e-007
Mercury1-2Body-MercuryMJ2000Eq	3.65724917e-006	6.616439805e-007	3.315035197e-007
Moon-2Body-MoonFixed	1.3161916e-008	4.923492725e-009	2.117699793e-009
Moon-2Body-MoonMJ2000Ec	1.312683295e-008	4.903711215e-009	2.089478812e-009
Moon-2Body-MoonMJ2000Eq	1.312683295e-008	4.149796951e-009	2.132098054e-009
Neptune1-2Body-NeptuneFixed	3.32711636e-009	2.27714736e-010	1.292577156e-011
Neptune1-2Body-NeptuneMJ2000Ec	3.531397397e-009	1.518785098e-011	1.053734877e-011
Neptune1-2Body-NeptuneMJ2000Eq	3.531397397e-009	1.961986129e-011	7.87991894e-012
Pluto1-2Body-PlutoFixed	4.408564513e-006	1.837341372e-006	1.37896188e-006
Pluto1-2Body-PlutoMJ2000Ec	4.473986848e-006	2.589462298e-006	1.17972953e-006
Pluto1-2Body-PlutoMJ2000Eq	4.473986848e-006	2.159538809e-006	1.245299624e-006
Saturn1-2Body-SaturnFixed	6.039613254e-011	4.178986046e-010	3.339550858e-013
Saturn1-2Body-SaturnMJ2000Ec	6.039613254e-011	2.611244554e-013	1.136868377e-013
Saturn1-2Body-SaturnMJ2000Eq	7.105427358e-011	2.486899575e-013	8.881784197e-014
Uranus1-2Body-UranusFixed	1.509903313e-010	2.093898388e-010	1.229238933e-012
Uranus1-2Body-UranusMJ2000Ec	1.705302566e-010	1.687538997e-012	5.897504707e-013
Uranus1-2Body-UranusMJ2000Eq	1.705302566e-010	1.440625397e-012	4.831690603e-013
Venus1-2Body-VenusFixed	1.088321433e-006	8.689147535e-008	3.770613866e-008

Table 3.45: WinGMAT/MacGMAT Coordinate System Dependent Parameter Differences (Angle-based)

Test Case	Arg. of Per. (deg)	Decl. (deg)	Inc. (deg)	RA (deg)	RAAN (deg)
GEO-2Body-EarthFixed	5.547e-009	1.111e-014	1.578e-006	2.543e-010	7.04e-010
GEO-2Body-EarthMJ2000Ec	8.149e-006	7.069e-012	3.908e-014	1.751e-011	0
GEO-2Body-EarthMJ2000Eq	8.149e-006	0	0	1.788e-011	0
GEO-2Body-EarthMODEc	8.39e-006	7.069e-012	3.908e-014	1.751e-011	1.188e-011
GEO-2Body-EarthMODEq	8.354e-006	6.855e-015	2.963e-011	1.782e-011	1.137e-013
GEO-2Body-EarthMOEEc	8.151e-006	7.069e-012	3.197e-014	1.751e-011	0
GEO-2Body-EarthMOEEq	8.151e-006	1.571e-027	0	1.782e-011	0
GEO-2Body-EarthTODEc	8.15e-006	7.069e-012	3.908e-014	1.751e-011	1.251e-011
GEO-2Body-EarthTODEq	8.029e-006	1.11e-014	3.12e-011	1.791e-011	2.268e-011
GEO-2Body-EarthTOEEc	8.309e-006	7.069e-012	3.197e-014	1.751e-011	9.419e-011
GEO-2Body-EarthTOEEq	8.029e-006	3.597e-015	0	1.782e-011	5.599e-011
Hyperbolic-2Body-EarthFixed	1.99e-013	3.197e-014	1.137e-013	2.243e-010	2.244e-010
Hyperbolic-2Body-EarthMJ2000Ec	4.263e-013	1.954e-014	1.599e-013	1.137e-013	0
Hyperbolic-2Body-EarthMJ2000Eq	3.553e-013	3.197e-014	8.527e-014	1.137e-013	0
Hyperbolic-2Body-EarthMODEc	3.979e-013	1.954e-014	1.315e-013	1.137e-013	1.184e-011
Hyperbolic-2Body-EarthMODEq	3.695e-013	3.908e-014	1.208e-013	1.137e-013	2.278e-011
Hyperbolic-2Body-EarthMOEEc	4.263e-013	1.954e-014	1.208e-013	1.137e-013	0
Hyperbolic-2Body-EarthMOEEq	3.553e-013	3.197e-014	1.066e-013	1.137e-013	0
Hyperbolic-2Body-EarthTODEc	4.405e-013	1.954e-014	1.208e-013	1.137e-013	1.251e-011
Hyperbolic-2Body-EarthTODEq	3.979e-013	3.197e-014	1.279e-013	1.137e-013	2.407e-011
Hyperbolic-2Body-EarthTOEEc	4.405e-013	1.954e-014	1.386e-013	1.137e-013	0
Hyperbolic-2Body-EarthTOEEq	4.263e-013	3.197e-014	1.705e-013	1.137e-013	0
ISS-2Body-EarthFixed	1.567e-010	1.078e-010	6.999e-012	3.318e-010	2.318e-010
ISS-2Body-EarthGSE	1.648e-009	4.005e-011	7.105e-013	7.881e-011	9.663e-013
ISS-2Body-EarthGSM	6.747e-009	7.885e-011	3.228e-011	1.605e-010	5.969e-012
ISS-2Body-EarthMJ2000Ec	1.418e-009	4.004e-011	6.892e-013	7.884e-011	9.805e-013
ISS-2Body-EarthMJ2000Eq	1.419e-009	5.081e-011	5.613e-013	1.026e-010	7.461e-013
ISS-2Body-EarthMODEc	1.419e-009	4.005e-011	6.892e-013	7.878e-011	9.663e-013
ISS-2Body-EarthMODEq	1.422e-009	5.079e-011	5.684e-013	1.026e-010	7.603e-013
ISS-2Body-EarthMOEEc	1.419e-009	4.004e-011	7.034e-013	7.878e-011	9.805e-013
ISS-2Body-EarthMOEEq	1.418e-009	5.081e-011	5.755e-013	1.026e-010	7.603e-013
ISS-2Body-EarthTODEc	1.428e-009	4.005e-011	7.105e-013	7.878e-011	9.805e-013
ISS-2Body-EarthTODEq	1.428e-009	5.079e-011	5.898e-013	1.026e-010	7.674e-013
ISS-2Body-EarthTOEEc	1.419e-009	4.004e-011	7.105e-013	7.884e-011	9.948e-013
ISS-2Body-EarthTOEEq	1.424e-009	5.08e-011	5.684e-013	1.027e-010	7.603e-013
Mars1-2Body-MarsFixed	6.651e-007	1.57e-007	1.706e-008	3.081e-007	3.345e-008
Mars1-2Body-MarsMJ2000Ec	4.123e-008	2.503e-007	1.833e-009	4.191e-007	3.198e-009
Mars1-2Body-MarsMJ2000Eq	4.11e-008	2.15e-007	2.508e-009	4.378e-007	3.304e-009
Mercury1-2Body-MercuryFixed	2.398e-008	4.319e-007	1.82e-009	6.273e-007	2.7e-009
Mercury1-2Body-MercuryMJ2000Ec	2.128e-008	4.547e-007	1.452e-009	7.112e-007	1.856e-009
Mercury1-2Body-MercuryMJ2000Eq	2.162e-008	3.982e-007	1.935e-009	7.662e-007	1.613e-009
Moon-2Body-MoonFixed	8.67e-011	2.932e-009	1.787e-011	4.735e-009	1.469e-011
Moon-2Body-MoonMJ2000Ec	4.79e-011	2.914e-009	9.791e-012	4.655e-009	4.306e-012
Moon-2Body-MoonMJ2000Eq	5.156e-011	2.513e-009	8.278e-012	4.934e-009	1.057e-011
Neptune1-2Body-NeptuneFixed	1.117e-010	2.132e-014	7.788e-012	2.085e-010	2.09e-010
Neptune1-2Body-NeptuneMJ2000Ec	3.546e-011	1.421e-014	1.208e-013	1.137e-013	1.99e-013
Neptune1-2Body-NeptuneMJ2000Eq	3.543e-011	1.421e-014	1.421e-013	1.137e-013	1.705e-013
Pluto1-2Body-PlutoFixed	3.573e-007	1.593e-006	4.45e-008	3.427e-006	5.587e-008
Pluto1-2Body-PlutoMJ2000Ec	2.584e-007	1.608e-006	2.63e-008	2.252e-006	2.507e-008
Pluto1-2Body-PlutoMJ2000Eq	2.522e-007	1.372e-006	1.672e-008	2.939e-006	3.615e-008
Saturn1-2Body-SaturnFixed	1.823e-011	2.132e-014	2.7e-013	4.169e-010	4.17e-010
Saturn1-2Body-SaturnMJ2000Ec	1.339e-012	1.421e-014	4.974e-014	1.137e-013	9.948e-014
Saturn1-2Body-SaturnMJ2000Eq	1.251e-012	1.421e-014	4.974e-014	1.137e-013	5.684e-014
Uranus1-2Body-UranusFixed	2.359e-011	2.132e-014	5.826e-013	2.085e-010	2.086e-010
Uranus1-2Body-UranusMJ2000Ec	7.58e-012	1.421e-014	1.563e-013	1.137e-013	2.984e-013
Uranus1-2Body-UranusMJ2000Eq	7.461e-012	1.421e-014	1.705e-013	1.137e-013	2.274e-013
Venus1-2Body-VenusFixed	2.72e-009	5.242e-008	1.107e-010	8.421e-008	3.777e-010
Venus1-2Body-VenusMJ2000Ec	2.669e-009	5.342e-008	1.041e-010	8.603e-008	2.702e-010

3.3.5 Win/Linux GMAT Comparison

Table 3.46: WinGMAT/LinuxGMAT Coordinate System Dependent Parameter Differences (Position)

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)
GEO-2Body-EarthFixed	1.818989404e-009	1.455191523e-008	1.065814104e-011
GEO-2Body-EarthMJ2000Ec	1.455191523e-008	1.455191523e-008	1.091393642e-008
GEO-2Body-EarthMJ2000Eq	1.455191523e-008	1.455191523e-008	0
GEO-2Body-EarthMODEc	1.455191523e-008	1.455191523e-008	1.091393642e-008
GEO-2Body-EarthMODEq	1.455191523e-008	1.455191523e-008	1.065814104e-011
GEO-2Body-EarthMOEEc	1.455191523e-008	1.455191523e-008	1.091393642e-008
GEO-2Body-EarthMOEEq	1.455191523e-008	1.455191523e-008	1.615587134e-024
GEO-2Body-EarthTODEc	1.455191523e-008	1.455191523e-008	1.091393642e-008
GEO-2Body-EarthTODEq	1.455191523e-008	1.455191523e-008	1.065814104e-011
GEO-2Body-EarthTOEEc	1.455191523e-008	1.455191523e-008	1.091393642e-008
GEO-2Body-EarthTOEEq	1.455191523e-008	1.455191523e-008	8.881784197e-013
Hyperbolic-2Body-EarthFixed	1.164153218e-007	1.164153218e-007	1.018634066e-007
Hyperbolic-2Body-EarthMJ2000Ec	1.164153218e-007	1.164153218e-007	1.455191523e-008
Hyperbolic-2Body-EarthMJ2000Eq	1.164153218e-007	1.164153218e-007	1.164153218e-007
Hyperbolic-2Body-EarthMODEc	1.164153218e-007	1.164153218e-007	1.455191523e-008
Hyperbolic-2Body-EarthMODEq	1.164153218e-007	1.164153218e-007	1.164153218e-007
Hyperbolic-2Body-EarthMOEEc	1.164153218e-007	1.164153218e-007	1.455191523e-008
Hyperbolic-2Body-EarthMOEEq	1.164153218e-007	1.164153218e-007	1.164153218e-007
Hyperbolic-2Body-EarthTODEc	1.164153218e-007	1.164153218e-007	1.455191523e-008
Hyperbolic-2Body-EarthTODEq	1.164153218e-007	1.455191523e-008	1.164153218e-007
Hyperbolic-2Body-EarthTOEEc	1.164153218e-007	1.164153218e-007	1.455191523e-008
Hyperbolic-2Body-EarthTOEEq	1.164153218e-007	1.164153218e-007	1.164153218e-007
ISS-2Body-EarthFixed	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthGSE	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthGSM	1.818989404e-009	9.094947018e-010	1.818989404e-009
ISS-2Body-EarthMJ2000Ec	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthMJ2000Eq	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthMODEc	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthMODEq	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthMOEEc	1.818989404e-009	1.818989404e-009	9.094947018e-010
ISS-2Body-EarthMOEEq	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthTODEc	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthTODEq	1.818989404e-009	1.818989404e-009	1.818989404e-009
ISS-2Body-EarthTOEEc	1.818989404e-009	1.818989404e-009	9.094947018e-010
ISS-2Body-EarthTOEEq	1.818989404e-009	1.818989404e-009	1.818989404e-009
Mars1-2Body-MarsFixed	1.818989404e-009	1.818989404e-009	9.094947018e-010
Mars1-2Body-MarsMJ2000Ec	9.094947018e-010	1.818989404e-009	9.094947018e-010
Mars1-2Body-MarsMJ2000Eq	9.094947018e-010	1.818989404e-009	9.094947018e-010
Mercury1-2Body-MercuryFixed	9.094947018e-010	9.094947018e-010	9.094947018e-010
Mercury1-2Body-MercuryMJ2000Ec	9.094947018e-010	9.094947018e-010	9.094947018e-010
Mercury1-2Body-MercuryMJ2000Eq	9.094947018e-010	1.818989404e-009	9.094947018e-010
Moon-2Body-MoonFixed	1.136868377e-009	1.364242053e-009	1.023181539e-009
Moon-2Body-MoonMJ2000Ec	9.094947018e-010	1.023181539e-009	9.094947018e-010
Moon-2Body-MoonMJ2000Eq	9.094947018e-010	9.094947018e-010	9.094947018e-010
Neptune1-2Body-NeptuneFixed	1.455191523e-008	1.455191523e-008	1.091393642e-008
Neptune1-2Body-NeptuneMJ2000Ec	1.091393642e-008	1.455191523e-008	1.091393642e-008
Neptune1-2Body-NeptuneMJ2000Eq	1.091393642e-008	1.455191523e-008	1.091393642e-008
Pluto1-2Body-PlutoFixed	9.094947018e-010	9.094947018e-010	1.023181539e-009
Pluto1-2Body-PlutoMJ2000Ec	1.023181539e-009	9.094947018e-010	1.023181539e-009
Pluto1-2Body-PlutoMJ2000Eq	1.023181539e-009	9.094947018e-010	1.023181539e-009
Saturn1-2Body-SaturnFixed	1.455191523e-008	1.455191523e-008	1.455191523e-008
Saturn1-2Body-SaturnMJ2000Ec	1.455191523e-008	1.455191523e-008	1.455191523e-008
Saturn1-2Body-SaturnMJ2000Eq	1.455191523e-008	1.455191523e-008	1.455191523e-008
Uranus1-2Body-UranusFixed	1.455191523e-008	1.455191523e-008	1.455191523e-008
Uranus1-2Body-UranusMJ2000Ec	1.455191523e-008	1.455191523e-008	1.455191523e-008
Uranus1-2Body-UranusMJ2000Eq	1.455191523e-008	1.455191523e-008	1.455191523e-008
Venus1-2Body-VenusFixed	1.818989404e-009	1.818989404e-009	1.818989404e-009
Venus1-2Body-VenusMJ2000Ec	1.818989404e-009	1.818989404e-009	1.818989404e-009

Table 3.47: WinGMAT/LinuxGMAT Coordinate System Dependent Parameter Differences (Velocity)

Test Case	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
GEO-2Body-EarthFixed	1.058791184e-018	1.058791184e-019	1.084202172e-015
GEO-2Body-EarthMJ2000Ec	8.881784197e-013	8.881784197e-013	8.881784197e-013
GEO-2Body-EarthMJ2000Eq	8.881784197e-013	8.881784197e-013	0
GEO-2Body-EarthMODEc	8.881784197e-013	8.881784197e-013	8.881784197e-013
GEO-2Body-EarthMODEq	8.881784197e-013	8.881784197e-013	1.084202172e-015
GEO-2Body-EarthMOEEc	8.881784197e-013	8.881784197e-013	8.881784197e-013
GEO-2Body-EarthMOEEq	8.881784197e-013	8.881784197e-013	9.860761315e-029
GEO-2Body-EarthTODEc	8.881784197e-013	8.881784197e-013	8.881784197e-013
GEO-2Body-EarthTODEq	8.881784197e-013	8.881784197e-013	1.084202172e-015
GEO-2Body-EarthTOEEc	8.881784197e-013	8.881784197e-013	8.881784197e-013
GEO-2Body-EarthTOEEq	8.881784197e-013	8.881784197e-013	1.084202172e-016
Hyperbolic-2Body-EarthFixed	1.776356839e-012	7.105427358e-012	8.881784197e-013
Hyperbolic-2Body-EarthMJ2000Ec	1.776356839e-012	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthMJ2000Eq	1.776356839e-012	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthMODEc	1.776356839e-012	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthMODEq	1.776356839e-012	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthMOEEc	1.776356839e-012	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthMOEEq	1.776356839e-012	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthTODEc	1.776356839e-012	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthTODEq	1.776356839e-012	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthTOEEc	8.881784197e-013	8.881784197e-013	8.881784197e-013
Hyperbolic-2Body-EarthTOEEq	8.881784197e-013	8.881784197e-013	8.881784197e-013
ISS-2Body-EarthFixed	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthGSE	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthGSM	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthMJ2000Ec	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthMJ2000Eq	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthMODEc	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthMODEq	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthMOEEc	1.776356839e-012	1.776356839e-012	8.881784197e-013
ISS-2Body-EarthMOEEq	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthTODEc	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthTODEq	1.776356839e-012	1.776356839e-012	1.776356839e-012
ISS-2Body-EarthTOEEc	1.776356839e-012	1.776356839e-012	8.881784197e-013
ISS-2Body-EarthTOEEq	1.776356839e-012	1.776356839e-012	1.776356839e-012
Mars1-2Body-MarsFixed	1.110223025e-012	1.33226763e-012	8.881784197e-013
Mars1-2Body-MarsMJ2000Ec	8.881784197e-013	8.881784197e-013	8.881784197e-013
Mars1-2Body-MarsMJ2000Eq	8.881784197e-013	8.881784197e-013	8.881784197e-013
Mercury1-2Body-MercuryFixed	8.881784197e-013	8.881784197e-013	8.881784197e-013
Mercury1-2Body-MercuryMJ2000Ec	8.881784197e-013	8.881784197e-013	8.881784197e-013
Mercury1-2Body-MercuryMJ2000Eq	8.881784197e-013	8.881784197e-013	8.881784197e-013
Moon-2Body-MoonFixed	8.881784197e-013	1.110223025e-012	8.881784197e-013
Moon-2Body-MoonMJ2000Ec	8.881784197e-013	8.881784197e-013	8.881784197e-013
Moon-2Body-MoonMJ2000Eq	8.881784197e-013	8.881784197e-013	8.881784197e-013
Neptune1-2Body-NeptuneFixed	1.065814104e-011	1.065814104e-011	1.065814104e-011
Neptune1-2Body-NeptuneMJ2000Ec	1.065814104e-011	1.065814104e-011	1.065814104e-011
Neptune1-2Body-NeptuneMJ2000Eq	1.065814104e-011	1.065814104e-011	1.065814104e-011
Pluto1-2Body-PlutoFixed	1.110223025e-013	1.110223025e-013	1.110223025e-013
Pluto1-2Body-PlutoMJ2000Ec	1.110223025e-013	1.110223025e-013	1.110223025e-013
Pluto1-2Body-PlutoMJ2000Eq	1.110223025e-013	1.110223025e-013	1.110223025e-013
Saturn1-2Body-SaturnFixed	1.065814104e-011	1.065814104e-011	1.065814104e-011
Saturn1-2Body-SaturnMJ2000Ec	1.065814104e-011	1.065814104e-011	1.065814104e-011
Saturn1-2Body-SaturnMJ2000Eq	1.065814104e-011	1.065814104e-011	1.065814104e-011
Uranus1-2Body-UranusFixed	1.065814104e-011	1.065814104e-011	1.065814104e-011
Uranus1-2Body-UranusMJ2000Ec	1.776356839e-012	1.065814104e-011	1.065814104e-011
Uranus1-2Body-UranusMJ2000Eq	1.776356839e-012	1.065814104e-011	1.776356839e-012
Venus1-2Body-VenusFixed	1.776356839e-012	1.776356839e-012	1.776356839e-012
Venus1-2Body-VenusMJ2000Ec	1.776356839e-012	1.776356839e-012	1.776356839e-012

Table 3.48: WinGMAT/LinuxGMAT Coordinate System Dependent Parameter Differences (Specific Angular Momentum)

Test Case	X-(H) (m^2/sec)	Y-(H) (m^2/sec)	Z-(H) (m^2/sec)
GEO-2Body-EarthFixed	1.421085472e-008	1.776356839e-009	1.387778781e-011
GEO-2Body-EarthMJ2000Ec	8.077935669e-022	1.455191523e-005	0.0001018634066
GEO-2Body-EarthMJ2000Eq	0	0	0.0001018634066
GEO-2Body-EarthMODEc	1.421085472e-008	1.455191523e-005	0.0001018634066
GEO-2Body-EarthMODEq	1.421085472e-008	1.040834086e-011	0.0001018634066
GEO-2Body-EarthMOEEc	9.693522803e-021	1.455191523e-005	0.0001018634066
GEO-2Body-EarthMOEEq	9.693522803e-021	0	0.0001018634066
GEO-2Body-EarthTODEc	1.421085472e-008	1.455191523e-005	0.0001018634066
GEO-2Body-EarthTODEq	1.421085472e-008	1.776356839e-009	0.0001018634066
GEO-2Body-EarthTOEEc	0	1.455191523e-005	0.0001018634066
GEO-2Body-EarthTOEEq	8.881784197e-010	8.881784197e-010	0.0001018634066
Hyperbolic-2Body-EarthFixed	0.001862645149	0.0009313225746	0.0111758709
Hyperbolic-2Body-EarthMJ2000Ec	9.693522803e-021	1.455191523e-005	0
Hyperbolic-2Body-EarthMJ2000Eq	8.077935669e-022	0	0
Hyperbolic-2Body-EarthMODEc	1.421085472e-008	1.455191523e-005	0
Hyperbolic-2Body-EarthMODEq	1.421085472e-008	0	0
Hyperbolic-2Body-EarthMOEEc	8.077935669e-022	1.455191523e-005	0
Hyperbolic-2Body-EarthMOEEq	8.077935669e-022	0	0
Hyperbolic-2Body-EarthTODEc	1.421085472e-008	1.455191523e-005	0
Hyperbolic-2Body-EarthTODEq	1.421085472e-008	0	0
Hyperbolic-2Body-EarthTOEEc	0	1.455191523e-005	0
Hyperbolic-2Body-EarthTOEEq	0	0	0
ISS-2Body-EarthFixed	1.455191523e-005	1.455191523e-005	7.275957614e-006
ISS-2Body-EarthGSE	9.094947018e-007	7.275957614e-006	1.455191523e-005
ISS-2Body-EarthGSM	9.094947018e-007	1.455191523e-005	1.455191523e-005
ISS-2Body-EarthMJ2000Ec	1.091393642e-005	0	1.455191523e-005
ISS-2Body-EarthMJ2000Eq	1.091393642e-005	0	0
ISS-2Body-EarthMODEc	1.091393642e-005	1.091393642e-005	1.455191523e-005
ISS-2Body-EarthMODEq	1.091393642e-005	1.091393642e-005	1.091393642e-005
ISS-2Body-EarthMOEEc	1.091393642e-005	1.091393642e-005	0
ISS-2Body-EarthMOEEq	1.091393642e-005	0	0
ISS-2Body-EarthTODEc	1.091393642e-005	1.091393642e-005	1.455191523e-005
ISS-2Body-EarthTODEq	7.275957614e-006	1.091393642e-005	7.275957614e-006
ISS-2Body-EarthTOEEc	7.275957614e-006	1.091393642e-005	0
ISS-2Body-EarthTOEEq	7.275957614e-006	1.091393642e-005	7.275957614e-006
Mars1-2Body-MarsFixed	1.818989404e-006	2.728484105e-006	1.091393642e-005
Mars1-2Body-MarsMJ2000Ec	0	9.094947018e-007	0
Mars1-2Body-MarsMJ2000Eq	0	1.058791184e-016	0
Mercury1-2Body-MercuryFixed	1.818989404e-006	1.818989404e-006	1.818989404e-006
Mercury1-2Body-MercuryMJ2000Ec	1.818989404e-006	9.094947018e-007	1.818989404e-006
Mercury1-2Body-MercuryMJ2000Eq	1.818989404e-006	1.32348898e-017	1.818989404e-006
Moon-2Body-MoonFixed	1.364242053e-006	1.136868377e-006	1.364242053e-006
Moon-2Body-MoonMJ2000Ec	9.094947018e-007	0	9.094947018e-007
Moon-2Body-MoonMJ2000Eq	9.094947018e-007	1.033975766e-019	9.094947018e-007
Neptune1-2Body-NeptuneFixed	0.0001164153218	0.0001164153218	0.0001164153218
Neptune1-2Body-NeptuneMJ2000Ec	0.0001164153218	0.0001164153218	0.0001164153218
Neptune1-2Body-NeptuneMJ2000Eq	0.0001164153218	1.355252716e-014	0.0001164153218
Pluto1-2Body-PlutoFixed	1.023181539e-006	1.023181539e-006	1.136868377e-007
Pluto1-2Body-PlutoMJ2000Ec	0	1.136868377e-007	0
Pluto1-2Body-PlutoMJ2000Eq	0	8.470329473e-016	0
Saturn1-2Body-SaturnFixed	0.0002328306437	0.0009313225746	0.0005384208634
Saturn1-2Body-SaturnMJ2000Ec	0.0009313225746	0.0001164153218	0.0009313225746
Saturn1-2Body-SaturnMJ2000Eq	0.0009313225746	1.016439537e-014	0.0009313225746
Uranus1-2Body-UranusFixed	0.0001164153218	0.0001164153218	0.0001164153218
Uranus1-2Body-UranusMJ2000Ec	0.0001164153218	0.0001164153218	0.0001164153218
Uranus1-2Body-UranusMJ2000Eq	0.0001164153218	1.355252716e-014	0.0001164153218
Venus1-2Body-VenusFixed	9.094947018e-007	1.455191523e-005	1.455191523e-005

Table 3.49: WinGMAT/LinuxGMAT Coordinate System Dependent Parameter Differences (Velocity Vector-based)

Test Case	Mag-Vel (m/s)	Right Asc. of Vel. (deg)	Dec. of Vel. (deg)
GEO-2Body-EarthFixed	1.084202172e-015	1.136868377e-013	0
GEO-2Body-EarthMJ2000Ec	8.881784197e-013	1.136868377e-013	1.065814104e-014
GEO-2Body-EarthMJ2000Eq	8.881784197e-013	1.136868377e-013	0
GEO-2Body-EarthMODEc	8.881784197e-013	1.136868377e-013	1.065814104e-014
GEO-2Body-EarthMODEq	8.881784197e-013	1.136868377e-013	1.040834086e-017
GEO-2Body-EarthMOEEc	8.881784197e-013	1.136868377e-013	1.065814104e-014
GEO-2Body-EarthMOEEq	8.881784197e-013	1.136868377e-013	1.57772181e-030
GEO-2Body-EarthTODEc	8.881784197e-013	1.136868377e-013	1.065814104e-014
GEO-2Body-EarthTODEq	8.881784197e-013	1.136868377e-013	1.040834086e-017
GEO-2Body-EarthTOEEc	8.881784197e-013	1.136868377e-013	1.065814104e-014
GEO-2Body-EarthTOEEq	8.881784197e-013	1.136868377e-013	1.084202172e-018
Hyperbolic-2Body-EarthFixed	1.065814104e-011	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthMJ2000Ec	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthMJ2000Eq	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthMODEc	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthMODEq	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthMOEEc	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthMOEEq	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthTODEc	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthTODEq	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthTOEEc	1.776356839e-012	1.136868377e-013	1.065814104e-014
Hyperbolic-2Body-EarthTOEEq	1.776356839e-012	1.136868377e-013	1.065814104e-014
ISS-2Body-EarthFixed	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthGSE	1.776356839e-012	1.065814104e-014	1.421085472e-014
ISS-2Body-EarthGSM	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthMJ2000Ec	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthMJ2000Eq	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthMODEc	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthMODEq	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthMOEEc	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthMOEEq	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthTODEc	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthTODEq	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthTOEEc	1.776356839e-012	1.136868377e-013	1.421085472e-014
ISS-2Body-EarthTOEEq	1.776356839e-012	1.136868377e-013	1.421085472e-014
Mars1-2Body-MarsFixed	1.33226763e-012	1.136868377e-013	1.065814104e-014
Mars1-2Body-MarsMJ2000Ec	8.881784197e-013	1.136868377e-013	1.421085472e-014
Mars1-2Body-MarsMJ2000Eq	8.881784197e-013	1.136868377e-013	1.421085472e-014
Mercury1-2Body-MercuryFixed	8.881784197e-013	1.136868377e-013	1.421085472e-014
Mercury1-2Body-MercuryMJ2000Ec	8.881784197e-013	1.136868377e-013	1.421085472e-014
Mercury1-2Body-MercuryMJ2000Eq	8.881784197e-013	1.136868377e-013	1.421085472e-014
Moon-2Body-MoonFixed	1.110223025e-012	1.136868377e-013	1.421085472e-014
Moon-2Body-MoonMJ2000Ec	8.881784197e-013	1.136868377e-013	1.421085472e-014
Moon-2Body-MoonMJ2000Eq	8.881784197e-013	1.136868377e-013	1.421085472e-014
Neptune1-2Body-NeptuneFixed	1.065814104e-011	1.136868377e-013	2.131628207e-014
Neptune1-2Body-NeptuneMJ2000Ec	1.065814104e-011	1.136868377e-013	1.421085472e-014
Neptune1-2Body-NeptuneMJ2000Eq	1.065814104e-011	1.136868377e-013	1.421085472e-014
Pluto1-2Body-PlutoFixed	1.110223025e-013	1.136868377e-013	1.421085472e-014
Pluto1-2Body-PlutoMJ2000Ec	0	1.136868377e-013	1.421085472e-014
Pluto1-2Body-PlutoMJ2000Eq	0	1.136868377e-013	1.421085472e-014
Saturn1-2Body-SaturnFixed	1.065814104e-011	3.552713679e-013	2.131628207e-014
Saturn1-2Body-SaturnMJ2000Ec	1.065814104e-011	1.136868377e-013	1.421085472e-014
Saturn1-2Body-SaturnMJ2000Eq	1.065814104e-011	1.136868377e-013	1.421085472e-014
Uranus1-2Body-UranusFixed	1.065814104e-011	1.136868377e-013	2.131628207e-014
Uranus1-2Body-UranusMJ2000Ec	1.065814104e-011	1.136868377e-013	1.421085472e-014
Uranus1-2Body-UranusMJ2000Eq	1.065814104e-011	1.136868377e-013	1.421085472e-014
Venus1-2Body-VenusFixed	1.776356839e-012	1.136868377e-013	1.421085472e-014

Table 3.50: WinGMAT/LinuxGMAT Coordinate System Dependent Parameter Differences (Angle-based)

Test Case	Arg. of Per. (deg)	Decl. (deg)	Inc. (deg)	RA (deg)	RAAN (deg)
GEO-2Body-EarthFixed	1.302e-011	1.041e-017	0	1.137e-013	1.137e-013
GEO-2Body-EarthMJ2000Ec	1.137e-013	1.066e-014	7.105e-015	1.137e-013	0
GEO-2Body-EarthMJ2000Eq	1.137e-013	0	0	1.137e-013	0
GEO-2Body-EarthMODEc	1.137e-013	1.066e-014	1.066e-014	1.137e-013	1.506e-012
GEO-2Body-EarthMODEq	1.137e-013	1.041e-017	3.7e-012	1.137e-013	1.137e-013
GEO-2Body-EarthMOEEc	1.137e-013	1.066e-014	1.066e-014	1.137e-013	0
GEO-2Body-EarthMOEEq	9.948e-014	1.578e-030	0	1.137e-013	0
GEO-2Body-EarthTODEc	1.137e-013	1.066e-014	1.066e-014	1.137e-013	1.62e-012
GEO-2Body-EarthTODEq	1.137e-013	1.041e-017	3.894e-012	1.137e-013	1.137e-013
GEO-2Body-EarthTOEEc	1.137e-013	1.066e-014	1.066e-014	1.137e-013	2.217e-012
GEO-2Body-EarthTOEEq	1.137e-013	1.084e-018	4.179e-013	1.137e-013	0
Hyperbolic-2Body-EarthFixed	1.137e-013	1.421e-014	1.137e-013	1.137e-013	1.137e-013
Hyperbolic-2Body-EarthMJ2000Ec	0	1.066e-014	1.066e-014	1.137e-013	0
Hyperbolic-2Body-EarthMJ2000Eq	0	1.066e-014	0	1.137e-013	0
Hyperbolic-2Body-EarthMODEc	0	1.066e-014	1.066e-014	1.137e-013	1.466e-012
Hyperbolic-2Body-EarthMODEq	0	1.066e-014	1.421e-014	1.137e-013	2.843e-012
Hyperbolic-2Body-EarthMOEEc	0	1.066e-014	1.066e-014	1.137e-013	0
Hyperbolic-2Body-EarthMOEEq	0	1.066e-014	0	1.137e-013	0
Hyperbolic-2Body-EarthTODEc	0	1.066e-014	1.066e-014	1.137e-013	1.555e-012
Hyperbolic-2Body-EarthTODEq	0	1.066e-014	1.421e-014	1.137e-013	3.004e-012
Hyperbolic-2Body-EarthTOEEc	0	1.066e-014	1.066e-014	1.137e-013	2.16e-012
Hyperbolic-2Body-EarthTOEEq	0	1.066e-014	1.421e-014	1.137e-013	3.411e-013
ISS-2Body-EarthFixed	1.851e-013	1.421e-014	1.421e-014	1.137e-013	2.842e-013
ISS-2Body-EarthGSE	1.137e-013	1.066e-014	1.421e-014	1.137e-013	1.137e-013
ISS-2Body-EarthGSM	1.137e-013	1.421e-014	1.421e-014	1.137e-013	1.137e-013
ISS-2Body-EarthMJ2000Ec	9.948e-014	1.421e-014	1.421e-014	1.137e-013	1.421e-014
ISS-2Body-EarthMJ2000Eq	1.137e-013	1.421e-014	1.421e-014	1.137e-013	1.421e-014
ISS-2Body-EarthMODEc	9.948e-014	1.421e-014	1.421e-014	1.137e-013	1.421e-014
ISS-2Body-EarthMODEq	1.137e-013	1.421e-014	1.421e-014	1.137e-013	1.421e-014
ISS-2Body-EarthMOEEc	1.137e-013	1.421e-014	1.421e-014	1.137e-013	1.421e-014
ISS-2Body-EarthMOEEq	1.137e-013	1.421e-014	1.421e-014	1.137e-013	1.421e-014
ISS-2Body-EarthTODEc	1.137e-013	1.421e-014	1.421e-014	1.137e-013	1.421e-014
ISS-2Body-EarthTODEq	1.137e-013	1.421e-014	1.421e-014	9.948e-014	1.421e-014
ISS-2Body-EarthTOEEc	1.137e-013	1.421e-014	1.421e-014	1.137e-013	1.421e-014
ISS-2Body-EarthTOEEq	1.137e-013	1.421e-014	1.421e-014	1.137e-013	1.421e-014
Mars1-2Body-MarsFixed	2.476e-013	1.066e-014	2.132e-014	1.137e-013	1.137e-013
Mars1-2Body-MarsMJ2000Ec	1.066e-014	1.421e-014	1.421e-014	1.137e-013	9.948e-014
Mars1-2Body-MarsMJ2000Eq	1.421e-014	1.421e-014	1.421e-014	1.137e-013	0
Mercury1-2Body-MercuryFixed	2.22e-014	1.421e-014	1.421e-014	1.137e-013	1.137e-013
Mercury1-2Body-MercuryMJ2000Ec	1.066e-014	1.421e-014	1.421e-014	1.137e-013	1.137e-013
Mercury1-2Body-MercuryMJ2000Eq	1.421e-014	1.421e-014	1.421e-014	1.137e-013	0
Moon-2Body-MoonFixed	1.599e-013	1.421e-014	2.132e-014	1.137e-013	3.553e-014
Moon-2Body-MoonMJ2000Ec	1.066e-014	1.421e-014	1.421e-014	1.137e-013	1.137e-013
Moon-2Body-MoonMJ2000Eq	1.421e-014	1.421e-014	1.421e-014	1.137e-013	0
Neptune1-2Body-NeptuneFixed	1.08e-012	1.421e-014	2.132e-014	1.137e-013	1.705e-013
Neptune1-2Body-NeptuneMJ2000Ec	1.066e-014	1.421e-014	1.421e-014	1.137e-013	1.137e-013
Neptune1-2Body-NeptuneMJ2000Eq	1.421e-014	1.421e-014	1.421e-014	1.137e-013	0
Pluto1-2Body-PlutoFixed	2.274e-013	1.421e-014	1.421e-014	1.137e-013	2.842e-013
Pluto1-2Body-PlutoMJ2000Ec	1.066e-014	1.421e-014	1.421e-014	1.137e-013	9.948e-014
Pluto1-2Body-PlutoMJ2000Eq	1.421e-014	1.421e-014	1.421e-014	1.137e-013	0
Saturn1-2Body-SaturnFixed	1.024e-012	1.421e-014	2.842e-014	1.137e-013	1.99e-013
Saturn1-2Body-SaturnMJ2000Ec	1.066e-014	1.421e-014	1.421e-014	1.137e-013	9.948e-014
Saturn1-2Body-SaturnMJ2000Eq	1.421e-014	1.421e-014	1.421e-014	1.137e-013	0
Uranus1-2Body-UranusFixed	3.979e-013	1.421e-014	9.948e-014	1.137e-013	1.137e-013
Uranus1-2Body-UranusMJ2000Ec	1.066e-014	1.421e-014	1.421e-014	1.137e-013	1.137e-013
Uranus1-2Body-UranusMJ2000Eq	1.421e-014	1.421e-014	1.421e-014	1.137e-013	0
Venus1-2Body-VenusFixed	1.066e-014	1.421e-014	1.421e-014	1.137e-013	3.695e-012
Venus1-2Body-VenusMJ2000Ec	1.066e-014	1.421e-014	1.421e-014	1.137e-013	9.948e-014

Chapter 4

Integrators

GMAT's integrators were tested on a system level in order to verify that all the integrators were working correctly. In order to minimize the effects of other forces/elements, the two-body cases from the Propagators section were used, with some modification, for testing the integrators. The report output interval and integrators were the only parameter changed when using the Propagator two body test cases. Data was outputted in ten minute intervals.

4.1 Initial Orbit Conditions

The ISS and GEO two-body case's initial orbit parameters were used from the Propagation section (Chapter 2) for the test cases in this section.

Refer to Appendix B.1 Tables B.1- B.13 for a listing of all Propagation initial orbit states used for the Integrator test cases.

4.2 Naming Convention

This section describes the naming convention for integrator scripts and output reports. The naming convention consists of an ordered series of option strings, separated by underscores (_). Currently, options are allowed for the following fields, and will be present in the file name in order:

1. *tool* - The tool used to generate the test case
2. *traj* - The trajectory to use. This includes initial conditions, physical parameters, and time step
3. *integ* - The integrator to use

The word Integrator precedes the *tool* field and 2Body follows the *integ* field. The final integrator file format is as followed:
Integrator_*tool*_*traj*_*integ*_2Body.report

The *tool* field should always be the first option field. Future additional fields should be added to the end of the list of fields. Each field has a finite list of options, as follows (future options should be added to this list):

1. *tool*

STK	- Satellite Toolkit HPOP or Astrogator
FF	- FreeFlyer
GMAT	- General Mission Analysis Tool

2. *traj*

ISS	- leo orbit
GEO	- geo orbit

   NOTE: Some test cases contain *traj* variations. In this case *traj* precedes the modification. For example, if an ISS trajectory is needed with a different Cd, *traj* could be ISSdiffCd1.

3. *integ*

RKV89	- RungaKutta 8(9)
RKN68	- DormandElMikkawyPrince 6(8)
RKF56	- RungeKuttaFehlberg 5(6)
PD45	- PrinceDormand 4(5)
PD78	- PrinceDormand 7(8)
BS	- BulirschStoer
ABM	- AdamsBashforthMoulton

4.3 Comparison Script Information

Comparison_Integ.m is the script used to perform the integrator comparisons needed for the Integrators section of the Acceptance Test Plan. This script was designed to allow the user to select a GMAT Build or the exact analytic solution to compare to one another.

Refer to Appendix C for more details about this script and others used in the Acceptance Test Plan document.

4.4 Test Case Results

The following results are for the Integrator section. The GMAT Integrator results are being compared to an exact analytical two-body solution. We'd like the comparison data to be as close to zero as possible. A detailed acceptance metric/matrix will be developed at a later date.

Table 4.1: Exact/WinGMAT GEO Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
ABM-2Body	0.0001127712184	8.178707643e-009
BS-2Body	6.290317204e-005	4.535189696e-009
PD45-2Body	3.297921562e-005	2.320908148e-009
PD78-2Body	1.822370346e-005	1.253046654e-009
RKF56-2Body	3.459697578e-005	2.564071918e-009
RKN68-2Body	1.793126562e-005	1.297793489e-009
RKV89-2Body	0.0001127712184	8.178707643e-009

Table 4.2: Exact/WinGMAT ISS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
ABM-2Body	1.052211123e-005	1.172665432e-008
BS-2Body	1.691079091e-005	1.926879767e-008
PD45-2Body	3.080434654e-005	3.521816658e-008
PD78-2Body	2.772621462e-005	3.15224572e-008
RKF56-2Body	3.336029534e-005	3.80119779e-008
RKN68-2Body	3.617025125e-006	3.875411333e-009
RKV89-2Body	1.052211123e-005	1.172665432e-008

4.4.1 Win/Mac GMAT Comparison

Table 4.3: WinGMAT/MacGMAT GEO Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
ABM-2Body	4.990522323e-005	3.634067315e-009
BS-2Body	4.499516895e-005	3.048485196e-009
PD45-2Body	3.360510852e-005	2.346776158e-009
PD78-2Body	1.721559725e-005	1.110205705e-009
RKF56-2Body	4.772019229e-005	3.510581894e-009
RKN68-2Body	6.394945484e-005	4.727059048e-009
RKV89-2Body	4.990522323e-005	3.634067315e-009

Table 4.4: WinGMAT/MacGMAT ISS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
ABM-2Body	3.476512236e-005	3.980331596e-008
BS-2Body	3.902337183e-005	4.465750423e-008
PD45-2Body	1.214759222e-005	1.361758077e-008
PD78-2Body	1.808533949e-005	2.043945469e-008
RKF56-2Body	2.234706582e-005	2.518943482e-008
RKN68-2Body	4.459241486e-006	4.808133777e-009
RKV89-2Body	3.476512236e-005	3.980331596e-008

4.4.2 Win/Linux GMAT Comparison

Table 4.5: WinGMAT/LinuxGMAT GEO Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
ABM-2Body	1.818989404e-008	1.256073967e-012
BS-2Body	1.626953583e-008	1.256073967e-012
PD45-2Body	1.818989404e-008	1.256073967e-012
PD78-2Body	1.626953583e-008	8.950904183e-013
RKF56-2Body	1.466516141e-008	1.256073967e-012
RKN68-2Body	1.818989404e-008	1.256073967e-012
RKV89-2Body	1.818989404e-008	1.256073967e-012

Table 4.6: WinGMAT/LinuxGMAT ISS Test Case Comparison

Test Case	Position Difference(m)	Velocity Difference(m/s)
ABM-2Body	2.572439484e-009	1.986027323e-012
BS-2Body	2.033691978e-009	2.512147934e-012
PD45-2Body	2.572439484e-009	2.512147934e-012
PD78-2Body	2.572439484e-009	2.512147934e-012
RKF56-2Body	2.572439484e-009	2.512147934e-012
RKN68-2Body	2.033691978e-009	2.512147934e-012
RKV89-2Body	2.572439484e-009	1.986027323e-012

Chapter 5

Stopping Conditions

GMAT's Stopping Conditions were tested on a system level in order to determine if it stops correctly on user selected conditions. Refer to Table 5.1 for a list of the stopping conditions tested and the units used for the output of data.

Table 5.1: Stopping Conditions

Stopping Condition	Stopping Value	Unit Used
Epoch (A1 Modified Julian Date)	23158.042037434974	Days
Apoapsis	180	TA in degrees
Elapsed Days	6 Hours	Days
Elapsed Days (Multiple Satellites)	5 Hours	Days
Mean Anomaly	45, 90, & 180	MA in degrees
Periapsis	0	TA in degrees
Elapsed Seconds	3600	Seconds
True Anomaly	45, 90, & 180	TA in degrees
XY Plane Intersection	Z=0	Km
XZ Plane Intersection	Y=0	Km
YZ Plane Intersection	X=0	Km

5.1 Initial Orbit Conditions

For a listing of the initial conditions used to produce the data for the Stopping Conditions Section, refer to Table 5.2 for the Earth based non-hyperbolic point mass test cases, Table 5.3 for the Earth based non-hyperbolic all forces test cases, and Table 5.4 for the Earth based hyperbolic point mass test cases.

Table 5.2: Initial Orbit Parameters (EarthPM & EarthMJ2000EqPM)

Initial State Parameter	Parameter Value (unit)
Coordinate System (CS)	Earth Mean J2000 Equator
X	-8043.9600382977915 (km)
Y	-1564.9950345568864 (km)
Z	3750.9601677510364 (km)
VX	0.99861303787927636 (km)
VY	-6.8834168529193462 (km)
VZ	-0.46566090709653452 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag Area	15 (m^2)
Drag Model	None
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	RungaKutta 8(9)
Integrator Init. StepSize	60 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	2700 (sec)
Report Precision	16 significant figures
Report StepSize	Only initial state
Report CS/Cb	Same as initial state CS

Table 5.3: Initial Orbit Parameters (EarthAll & EarthMJ2000EqAll)

Initial State Parameter	Parameter Value (unit)
Coordinate System (CS)	Earth Mean J2000 Equator
X	-8043.9600382977915 (km)
Y	-1564.9950345568864 (km)
Z	3750.9601677510364 (km)
VX	0.99861303787927636 (km)
VY	-6.8834168529193462 (km)
VZ	-0.46566090709653452 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag Area	15 (m^2)
Drag Model	Jacchia Roberts
Drag F107/F107A	150/150
Drag Kp	3
NSG Model	JGM2
Degree x Order	4x4
SRP Area	1 (m^2)
SRP	On
Integrator Type	RungaKutta 8(9)
Integrator Init. StepSize	60 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	2700 (sec)
Report Precision	16 significant figures
Report StepSize	Only initial state
Report CS/Cb	Same as initial state CS

Table 5.4: Initial Orbit Parameters (EarthPMhyper & EarthMJ2000EqPMhyper)

Initial State Parameter	Parameter Value (unit)
Coordinate System (CS)	Earth Mean J2000 Equator
X	12371.791482634855 (km)
Y	5050.7627227610719 (km)
Z	5050.762722761071 (km)
VX	-7.9859921512608487 (km)
VY	2.44520073255755 (km)
VZ	2.4452007325575495 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag Area	15 (m^2)
Drag Model	None
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	RungaKutta 8(9)
Integrator Init. StepSize	60 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	2700 (sec)
Report Precision	16 significant figures
Report StepSize	Only initial state
Report CS/Cb	Same as initial state CS

Table 5.5: Initial Orbit Parameters (MoonPM)

Initial State Parameter	Parameter Value (unit)
Coordinate System (CS)	Earth Mean J2000 Equator
X	-1486.792117191545200 (km)
Y	0.0 (km)
Z	1486.792117191543000 (km)
VX	-0.142927729144255 (km)
VY	-1.631407624437537 (km)
VZ	0.142927729144255 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag Area	15 (m^2)
Drag Model	None
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	RungaKutta 8(9)
Integrator Init. StepSize	60 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	2700 (sec)
Report Precision	16 significant figures
Report StepSize	Only initial state
Report CS/Cb	Same as initial state CS

Table 5.6: Initial Orbit Parameters (MarsPM)

Initial State Parameter	Parameter Value (unit)
Coordinate System (CS)	Earth Mean J2000 Equator
X	-2737.481646173082000 (km)
Y	0.0 (km)
Z	2737.481646173082000 (km)
VX	-0.311321695052649 (km)
VY	-3.553492313930950 (km)
VZ	0.311321695052650 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag Area	15 (m^2)
Drag Model	None
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	RungaKutta 8(9)
Integrator Init. StepSize	60 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	2700 (sec)
Report Precision	16 significant figures
Report StepSize	Only initial state
Report CS/Cb	Same as initial state CS

5.2 Naming Convention

This section describes the naming convention for stopping condition scripts and output reports generated for use in GMAT's Acceptance Test Plan. The naming convention consists of an ordered series of option strings, separated by underscores (_). Currently, options are allowed for the following fields, and will be present in the file name in order:

1. *tool* - The tool used to generate the test cases.
2. *Cb* - The Central Body used for the stopping condition, including the force model setup.
3. *stopCond* - The stopping condition used for the test case.

The word StopCond precedes the *tool* field. The final stopping condition file format is as followed:
StopCond_*tool*_*Cb*_*stopCond*.report

The *tool* field should always be the first option field. Future additional fields should be added to the end of the list of fields. Each field has a finite list of options, as follows (future options should be added to this list):

1. *tool*

STK	- Satellite Toolkit HPOP or Astrogator
FF	- FreeFlyer
GMAT	- General Mission Analysis Tool

2. *Cb*

EarthPM	- Earth central body with point mass force model
EarthMJ2000EqPM	- Same as EarthPM and plane intersection calculations based on EarthMJ2000Eq
EarthAll	- Earth central body with all force model types turned on
EarthMJ2000EqAll	- Same as EarthAll and plane intersection calculations based on EarthMJ2000Eq
Earth#MultiSatsPM	- Same as EarthPM and the test case involves # satellites
MarsPM	- Mars central body with point mass force model
MoonPM	- Moon central body with point mass force model

3. *stopCond*

A1ModJulian	- A1 Modified Julian Date
Apoapsis	- Apoapsis of orbit based on TA
Days	- Elapsed Days
MA###	- ### degree Mean Anomaly
Periapsis	- Periapsis of orbit based on TA
Seconds	- Elapsed Seconds
TA###	- ### degree True Anomaly
XYplane	- XY Plane Intersection
XZplane	- XZ Plane Intersection
YZplane	- YZ Plane Intersection

5.3 Comparison Script Information

Comparison_StopCond.m is the script used to perform the comparisons needed for the Stopping Condition chapter of the Acceptance Test Plan. This script was designed to allow the user to select a GMAT Build and/or the exact solution to compare to one another.

Refer to Appendix C for more details on this script and others used in the Acceptance Test Plan document.

5.4 Test Case Results

The following results are for the Stopping Condition section. The GMAT Stopping Condition results are being compared to the exact desired stopping condition. We'd like the comparison data to be as close to zero as possible. A detailed acceptance metric/matrix will be developed at a later date.

Refer to Table 5.1 to determine the units used in the Difference(s) column of the Stopping Condition comparison results.

Table 5.7: Exact/WinGMAT EarthPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	3.637978807e-012
Apoapsis	1.207418308e-006
Days	3.637978807e-012
EA180	0
EA45	1.122458571e-009
EA90	5.233573575e-010
MA180	0
MA90	5.793253877e-009
Periapsis	0
Secs	2.09548034e-007
TA180	0
TA90	2.69331224e-009

Table 5.8: Exact/WinGMAT EarthAll StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	7.275957614e-012
Apoapsis	0
Days	0
EA180	0
EA45	8.15098673e-008
EA90	3.780471047e-009
MA180	0
MA90	5.370637268e-009
Periapsis	0
Secs	4.190951586e-007
TA180	0
TA90	2.783139053e-009

Table 5.9: Exact/WinGMAT EarthPMhyper StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	3.637978807e-012
Days	0
HA45	5.94486238e-009
HA90	6.062620628e-009
MA45	4.032202128e-009
MA90	7.014335779e-010
Periapsis	0
Secs	2.09548034e-007
TA45	1.530788296e-008
TA90	3.041570551e-008

Table 5.10: Exact/WinGMAT MoonPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	3.637978807e-012
Apoapsis	1.207418308e-006
Days	3.637978807e-012
EA180	1.478779296e-006
EA90	3.193633802e-009
MA180	1.774535207e-006
MA90	8.953790598e-009
Periapsis	0
Secs	2.09548034e-007
TA180	1.207418308e-006
TA90	9.594344874e-009

Table 5.11: Exact/WinGMAT MarsPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	3.637978807e-012
Apoapsis	0
Days	0
EA180	0
EA90	2.220498629e-008
MA180	0
MA90	1.276124806e-008
Periapsis	0
Secs	2.09548034e-007
TA180	0
TA90	1.505739533e-008

Table 5.12: Exact/WinGMAT EarthMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	1.967496619e-007
XZplane	1.187821727e-006
YZplane	4.2192789e-007

Table 5.13: Exact/WinGMAT EarthMJ2000EqAll StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	7.834555777e-007
XZplane	1.198100772e-006
YZplane	2.851115597e-007

Table 5.14: Exact/WinGMAT EarthMJ2000EqPMhyper StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	9.138221522e-007
XZplane	9.138204291e-007
YZplane	3.637831914e-006

Table 5.15: Exact/WinGMAT MoonMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	1.752778189e-007
XZplane	0
YZplane	1.752923708e-007

Table 5.16: Exact/WinGMAT MarsMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	2.384185791e-007
XZplane	0
YZplane	2.235174179e-007

Table 5.17: Exact/WinGMAT Earth3MultiSatsPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
Days	7.276e-012 7.276e-012 7.276e-012

5.4.1 Win/Mac GMAT Comparison

Table 5.18: WinGMAT/MacGMAT EarthPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	1.091393642e-011
Apoapsis	1.207418308e-006
Days	3.637978807e-012
EA180	0
EA45	1.249863146e-008
EA90	1.641892311e-008
MA180	0
MA90	1.010349138e-009
Periapsis	0
Secs	3.143209142e-007
TA180	0
TA90	1.477332034e-008

Table 5.19: WinGMAT/MacGMAT EarthAll StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	1.091393642e-011
Apoapsis	0
Days	1.091399193e-011
EA180	0
EA45	2.758255135e-008
EA90	6.509765171e-009
MA180	0
MA90	1.209116363e-009
Periapsis	0
Secs	6.286431926e-007
TA180	0
TA90	2.392090437e-008

Table 5.20: WinGMAT/MacGMAT EarthPMhyper StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	1.091393642e-011
Days	0
HA45	3.278302074e-010
HA90	5.154717542e-009
MA45	4.688160971e-009
MA90	1.775092073e-009
Periapsis	8.537736463e-007
Secs	6.286431926e-007
TA45	7.957417836e-009
TA90	9.00868713e-010

Table 5.21: WinGMAT/MacGMAT MoonPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	0
Apoapsis	1.207418308e-006
Days	3.637978807e-012
EA180	1.478779296e-006
EA90	1.050977971e-008
MA180	1.774535207e-006
MA90	3.044107189e-010
Periapsis	0
Secs	3.143218237e-007
TA180	1.207418308e-006
TA90	1.47603032e-008

Table 5.22: WinGMAT/MacGMAT MarsPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	0
Apoapsis	0
Days	7.276013125e-012
EA180	0
EA90	1.924313153e-008
MA180	0
MA90	2.515002961e-008
Periapsis	0
Secs	0
TA180	0
TA90	7.037499472e-010

Table 5.23: WinGMAT/MacGMAT EarthMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	1.078823641e-006
XZplane	1.354494348e-006
YZplane	2.313548366e-006

Table 5.24: WinGMAT/MacGMAT EarthMJ2000EqAll StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	7.639199145e-007
XZplane	2.233082799e-006
YZplane	1.636945122e-006

Table 5.25: WinGMAT/MacGMAT EarthMJ2000EqPMhyper StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	2.779416424e-007
XZplane	2.779415402e-007
YZplane	7.390968164e-006

Table 5.26: WinGMAT/MacGMAT MoonMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	4.745961633e-007
XZplane	0
YZplane	4.745961633e-007

Table 5.27: WinGMAT/MacGMAT MarsMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	2.980232239e-007
XZplane	0
YZplane	2.980232239e-007

Table 5.28: WinGMAT/MacGMAT Earth3MultiSatsPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
Days	0 0 0

5.4.2 Win/Linux GMAT Comparison

Table 5.29: WinGMAT/LinuxGMAT EarthPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	0
Apoapsis	0
Days	0
EA180	0
EA45	1.421085472e-014
EA90	0
MA180	0
MA90	0
Periapsis	0
Secs	0
TA180	0
TA90	0

Table 5.30: WinGMAT/LinuxGMAT EarthAll StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	1.091393642e-011
Apoapsis	0
Days	0
EA180	0
EA45	4.691976585e-009
EA90	3.45775959e-008
MA180	0
MA90	1.808709271e-008
Periapsis	0
Secs	3.143213689e-007
TA180	0
TA90	5.133045988e-009

Table 5.31: WinGMAT/LinuxGMAT EarthPMhyper StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	0
Days	0
HA45	0
HA90	0
MA45	0
MA90	0
Periapsis	0
Secs	0
TA45	0
TA90	0

Table 5.32: WinGMAT/LinuxGMAT MoonPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	0
Apoapsis	0
Days	0
EA180	0
EA90	0
MA180	0
MA90	0
Periapsis	0
Secs	0
TA180	0
TA90	0

Table 5.33: WinGMAT/LinuxGMAT MarsPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
A1ModJulian	0
Apoapsis	0
Days	0
EA180	0
EA90	0
MA180	0
MA90	0
Periapsis	0
Secs	0
TA180	0
TA90	0

Table 5.34: WinGMAT/LinuxGMAT EarthMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	0
XZplane	0
YZplane	0

Table 5.35: WinGMAT/LinuxGMAT EarthMJ2000EqAll StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	4.666101248e-007
XZplane	8.586826219e-007
YZplane	9.998882629e-007

Table 5.36: WinGMAT/LinuxGMAT EarthMJ2000EqPMhyper StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	0
XZplane	0
YZplane	0

Table 5.37: WinGMAT/LinuxGMAT MoonMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	0
XZplane	0
YZplane	0

Table 5.38: WinGMAT/LinuxGMAT MarsMJ2000EqPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
XYplane	0
XZplane	0
YZplane	0

Table 5.39: WinGMAT/LinuxGMAT Earth3MultiSatsPM StopCond Test Case Comparison

Stopping Condition	Difference(s)
Days	0 0 0

Chapter 6

Libration Points

The libration point tests are designed to verify the location of various libration points. In each software tool used the location of the libration point is defined by the tool and then converted to a MJ2000Eq representation for comparison purposes.

6.1 Initial Orbit Conditions

Table 6.1: Initial Orbit Parameters (Sun-Earth(SE) Libration Points)

Initial State Parameter	Parameter Value (unit)
Coordinate System (CS)	Sun-Earth L#* MJ2000Eq
X	0 (km)
Y	0 (km)
Z	0 (km)
VX	0 (km)
VY	0 (km)
VZ	0 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag Area	15 (m^2)
Drag Model	None
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	N/A
Integrator Init. StepSize	N/A
Integrator Accuracy	N/A
Integrator Max. StepSize	N/A
Report Precision	16 significant figures
Report StepSize	Only initial state
Report CS/Cb	Earth MJ2000Eq

NOTES: (*) All five libration points are defined in the test script.

Table 6.2: Initial Orbit Parameters (Sun-Earth-Moon(SEM) Libration Points)

Initial State Parameter	Parameter Value (unit)
Coordinate System (CS)	Sun-Earth-Moon L#* MJ2000Eq
X	0 (km)
Y	0 (km)
Z	0 (km)
VX	0 (km)
VY	0 (km)
VZ	0 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag Area	15 (m^2)
Drag Model	None
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	N/A
Integrator Init. StepSize	N/A
Integrator Accuracy	N/A
Integrator Max. StepSize	N/A
Report Precision	16 significant figures
Report StepSize	Only initial state
Report CS/Cb	Earth MJ2000Eq

NOTES: (*) All five libration points are defined in the test script.

6.2 Naming Convention

This section describes the naming convention for libration point scripts and output reports generated for use in GMAT's Acceptance Test Plan. The naming convention consists of an ordered series of option strings, separated by underscores (_). Currently, options are allowed for the following fields, and will be present in the file name in order:

1. *tool* - The tool used to generate the trajectory.
2. *libType* - The type of libration point used for the test case.
3. *libPoint* - The libration point used for the test case.

The word LibrationTest precedes the *tool* field. The final stopping condition file format is as followed: LibrationTest_*tool*_*libType*_*libPoint*.report

The *tool* field should always be the first option field. Future additional fields should be added to the end of the list of fields. Each field has a finite list of options, as follows (future options should be added to this list):

1. *tool*
   - STK - Satellite Toolkit HPOP or Astrogator
   - FF - FreeFlyer
   - GMAT - General Mission Analysis Tool
   - OD - Orbital Determination Toolbox
2. *libType*
   - SEML - Sun Earth Moon
   - SEL - Sun Earth
3. *libPoint* # - The libration Point number

6.3 Comparison Script Information

Comparison_Tool1_Tool2_Libr.m is the script used to perform the comparisons needed for the Libration Points chapter of the Acceptance Test Plan. This script was designed to allow the user to select two tools from a list for comparison. The Tools available are presented in this chapter's Naming Convention section.

Refer to Appendix C for more details on this script and others used in the Acceptance Test Plan document.

6.4 Test Case Results

The following results are for the Libration Points section. The current GMAT Build is compared to STK for the Libration Points section. We'd like the comparison data to be as close to zero as possible. A detailed acceptance metric/matrix will be developed at a later date.

Table 6.3: WinGMAT/STK SEM LibrationTest Test Case Comparison

Libration Point	Position Difference(m)	Velocity Difference(m/s)
1	3.608874977e-006	4.996003611e-013
2	7.275957614e-006	6.439293543e-012
3	2.980232239e-005	7.105427358e-012
4	0	18.76805413
5	2.980232239e-005	-1.37023761

Table 6.4: WinGMAT/STK SE LibrationTest Test Case Comparison

Libration Point	Position Difference(m)	Velocity Difference(m/s)
1	3.608874977e-006	4.996003611e-013
2	7.275957614e-006	6.439293543e-012
3	2.980232239e-005	7.105427358e-012
4	0	18.76805413
5	2.980232239e-005	-1.37023761

6.4.1 Win/Mac GMAT Comparison

Table 6.5: WinGMAT/MacGMAT SEM LibrationTest Test Case Comparison

Libration Point	Position Difference(m)	Velocity Difference(m/s)
1	0	1.040834086e-014
2	0	8.743006319e-013
3	0	0
4	0	0
5	0	0

Table 6.6: WinGMAT/MacGMAT SE LibrationTest Test Case Comparison

Libration Point	Position Difference(m)	Velocity Difference(m/s)
1	0	1.040834086e-014
2	0	8.743006319e-013
3	0	0
4	0	0
5	0	0

6.4.2 Win/Linux GMAT Comparison

Table 6.7: WinGMAT/LinuxGMAT SEM LibrationTest Test Case Comparison

Libration Point	Position Difference(m)	Velocity Difference(m/s)
1	0	1.040834086e-014
2	0	0
3	0	0
4	0	0
5	0	0

Table 6.8: WinGMAT/LinuxGMAT SE LibrationTest Test Case Comparison

Libration Point	Position Difference(m)	Velocity Difference(m/s)
1	0	1.040834086e-014
2	0	0
3	0	0
4	0	0
5	0	0

Chapter 7

Delta V

Once an initial state was created for these Delta V test cases, a set amount of Delta V was applied. For the impulsive burn test cases delta V values of 0.1, 0.1, and 0.1 were applied in the X,Y, and Z axes respectively for either the Cartesian or VNB axes. Each test case generate a report that contains the Cartesian elements of the state before and after the impulsive burn.

7.1 Initial Orbit Conditions

Initial conditions for the impulsive burn delta V test cases are presented in Tables 7.1- 7.4.

Table 7.1: Initial Orbit Parameters (Earth Impulsive Burns)

Initial State Parameter	Parameter Value (unit)
Start & Stop Time	01 Jan 2000 11:59:28.000 (UTCG)
Central Body	Earth
Coordinate System	Earth Mean J2000 Equator
X	7378.0 (km)
Y	0.0 (km)
Z	0.0 (km)
VX	0.0 (km)
VY	5.1973811193846027 (km)
VZ	5.1973811193846018 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag	15 (m^2)
Drag Model	None
PMG Bodies	Only Central Body
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	RungaKutta 8(9)
Integrator Init.	60 (sec)
Integrator Max. StepSize	2700 (sec)
Integrator Accuracy	1e-13
Report Precision	16 significant figures
Report CS/Cb	Same as initial state CS

Table 7.2: Initial Orbit Parameters (Mars Impulsive Burns)

Initial State Parameter	Parameter Value (unit)
Start & Stop Time	01 Jan 2000 11:59:28.000 (UTCG)
Central Body	Mars
Coordinate System	Mars Mean J2000 Equator
X	4500.0 (km)
Y	0.0 (km)
Z	0.0 (km)
VX	0.0 (km)
VY	2.1814448386859766 (km)
VZ	2.1814448386859713 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag	15 (m^2)
Drag Model	None
PMG Bodies	Only Central Body
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	RungaKutta 8(9)
Integrator Init.	60 (sec)
Integrator Max. StepSize	2700 (sec)
Integrator Accuracy	1e-13
Report Precision	16 significant figures
Report CS/Cb	Same as initial state CS

Table 7.3: Initial Orbit Parameters (Moon Impulsive Burns)

Initial State Parameter	Parameter Value (unit)
Start & Stop Time	01 Jan 2000 11:59:28.000 (UTCG)
Central Body	Moon
Coordinate System	Moon Mean J2000 Equator
X	2050.0 (km)
Y	0.0 (km)
Z	0.0 (km)
VX	0.0 (km)
VY	1.093528701 (km)
VZ	1.093528701 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag	15 (m^2)
Drag Model	None
PMG Bodies	Only Central Body
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	RungaKutta 8(9)
Integrator Init.	60 (sec)
Integrator Max. StepSize	2700 (sec)
Integrator Accuracy	1e-13
Report Precision	16 significant figures
Report CS/Cb	Same as initial state CS

Table 7.4: Initial Orbit Parameters (Sun Impulsive Burns)

Initial State Parameter	Parameter Value (unit)
Start & Stop Time	01 Jan 2000 11:59:28.000 (UTCG)
Central Body	Sun
Coordinate System	Sun Mean J2000 Equator
X	1000000.0 (km)
Y	0.0 (km)
Z	0.0 (km)
VX	0.0 (km)
VY	257.597010870 (km)
VZ	257.597010870 (km)
Mass (No Fuel)	850 (kg)
Cd	2.2
Cr	1.8
Drag	15 (m^2)
Drag Model	None
PMG Bodies	Only Central Body
NSG Model	None
SRP Area	1 (m^2)
SRP	Off
Integrator Type	RungaKutta 8(9)
Integrator Init.	60 (sec)
Integrator Max. StepSize	2700 (sec)
Integrator Accuracy	1e-13
Report Precision	16 significant figures
Report CS/Cb	Same as initial state CS

7.2 Naming Convention

This section describes the naming convention for Delta V scripts and output reports generated for use in GMAT's Acceptance Test Plan. The naming convention consists of an ordered series of option strings, separated by underscores (_). Currently, options are allowed for the following fields, and will be present in the file name in order:

1. *tool* - The tool used to generate the trajectory.
2. *deltaVbody* - The type of Delta V applied and the central body the test case uses.
3. *axes* - Axes type used for burn maneuver.

The word DeltaV precedes the *tool* field. The final stopping condition file format is as followed:
DeltaV_*tool*_*deltaVbody*_*axes*.report

The *tool* field should always be the first option field. Future additional fields should be added to the end of the list of fields. Each field has a finite list of options, as follows (future options should be added to this list):

1. *tool*

STK	- Satellite Toolkit HPOP or Astrogator
FF	- FreeFlyer
GMAT	- General Mission Analysis Tool
OD	- Orbital Determination Toolbox

2. *deltaVbody*

IEarth	- Earth centered impulsive burn
IMars	- Mars centered impulsive burn
IMoon	- Moon centered impulsive burn
ISun	- Sun centered impulsive burn

3. *axes*

VNB	- Velocity, Velocity Normal, Velocity BiNormal axes
Cartesian	- Typical X,Y,Z,Vx,Vy,Vz axes

7.3 Comparison Script Information

Comparison_DeltaV.m is the script used to perform the comparisons needed for the Delta V chapter of the Acceptance Test Plan. This script was designed to allow the user to select a GMAT Build and/or the exact solution to compare to one another.

Refer to Appendix C for more details on this script and others used in the Acceptance Test Plan document.

7.4 Test Case Results

The following results are for the Delta V section. The GMAT Delta V results are being compared to the exact desired Delta V values. We'd like the comparison data to be as close to zero as possible. A detailed acceptance metric/matrix will be developed at a later date.

Table 7.5: Exact/WinGMAT IEarth Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	8.881784197e-013	8.881784197e-013
VNB	0	0	0	0	2.664535259e-012	8.881784197e-013

Table 7.6: Exact/WinGMAT IMars Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	1.387778781e-012	8.881784197e-013	0
VNB	0	0	0	1.387778781e-012	3.108624469e-012	8.881784197e-013

Table 7.7: Exact/WinGMAT IMoon Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	2.775557562e-014	0	0
VNB	0	0	0	2.775557562e-014	0	0

Table 7.8: Exact/WinGMAT ISun Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	1.387778781e-012	0	0
VNB	0	0	0	0	0	0

7.4.1 Win/Mac GMAT Comparison

Table 7.9: WinGMAT/MacGMAT IEarth Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	0	0
VNB	0	0	0	0	0	0

Table 7.10: WinGMAT/MacGMAT IMars Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	0	0
VNB	0	0	0	0	0	0

Table 7.11: WinGMAT/MacGMAT IMoon Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	0	0
VNB	0	0	0	0	0	0

Table 7.12: WinGMAT/MacGMAT ISun Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	0	0
VNB	0	0	0	0	0	0

7.4.2 Win/Linux GMAT Comparison

Table 7.13: WinGMAT/LinuxGMAT IEarth Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	0	0
VNB	0	0	0	0	0	0

Table 7.14: WinGMAT/LinuxGMAT IMars Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	0	0
VNB	0	0	0	0	0	0

Table 7.15: WinGMAT/LinuxGMAT IMoon Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	0	0
VNB	0	0	0	0	0	0

Table 7.16: WinGMAT/LinuxGMAT ISun Test Case Comparison

Test Case	X-Pos (m)	Y-Pos (m)	Z-Pos (m)	X-Vel (m/s)	Y-Vel (m/s)	Z-Vel (m/s)
Cartesian	0	0	0	0	0	0
VNB	0	0	0	0	0	0

Chapter 8

Performance

One of the many goals of GMAT is to perform at satisfactory speed when running a script. By running similar scripts in GMAT and reference software, time performance comparisons could be made. We generated several test cases centered around the Earth and a minimal set of test cases about a few non-Earth bodies. Many of the test cases were extracted from the previous Chapters and used in these tests.

The performance tests cases were created from the propagator test cases with some slight variations. We were interested in test cases focused on only point mass bodies, non-spherical gravity present, solar radiation pressure turned on, or drag effects. Isolation of the mentioned perturbation forces allows us to see how long each process take for GMAT to complete. The deepspace, non-earth, and libration point test cases only focused on point mass bodies.

Propagation duration times for the GEO, GPS, LEO, Molniya, and SunSync cases were increased to obtain a more accurate measurement of the time between GMAT and the reference software packages. This could have been done for the other test cases but the amount time needed to modify the automation scripts was not worth the extra data. The reason extra code would have been needed was to account for the differences in propagation modules for STK. STK-HPOP is used for the GEO, GPS, LEO, Molniya, and Sunsyc test cases and STK-Astrogator is used for the others.

8.1 Test Machine Specifications

All tests presented in this Acceptance Test Plan document were performed on a desktop machine with the following specifications:

Computer Type - PC
OS - Microsoft Windows XP
RAM - 2.0 GB
Processor - Intel(R) Pentium(R) 4 CPU 3.40GHz
Architecture - 32-bit
Manufacturer - Dell
STK Version - STK 6.2.0
FF Version - FF 5.6.5.35

8.2 Initial Orbit Conditions

All of the initial orbit parameters for the test cases in this section were obtained from the Propagation section (Chapter 2) test cases. One of the differences is the propagation duration is extended to 30 days, excluding the DeepSpace, ESL2, and EML2 cases. Another difference is the use of NSG, PMG, Drag, and SRP. Refer to the Performance naming conventions section (Section 8.3) for the types of settings used.

Refer to Appendix B.1 Tables B.1- B.13 for a listing of all Propagator initial orbit states used for the Performance test cases.

8.3 Naming Convention

This section describes the naming convention for Performance scripts and output reports generated for use in GMAT's Acceptance Test Plan. The naming convention consists of an ordered series of option strings, separated by underscores (_). Currently, options are allowed for the following fields, and will be present in the file name in order:

1. *tool* - Tool used to generate the trajectory.
2. *traj* - Type of trajectory.
3. *forces* - Forces applied.
4. *output* - Flag noting if there is output.

The word Performance precedes the *tool* field. The final stopping condition file format is as followed:
Performance_*tool*_*traj*_*forces*_*output*.report or
Performance_*tool*_*traj*PM_*forces*_*output*.report

The *tool* field should always be the first option field. Future additional fields should be added to the end of the list of fields. Each field has a finite list of options, as follows (future options should be added to this list):

1. *tool*

STK	- Satellite Toolkit HPOP or Astrogator
FF	- FreeFlyer
GMAT	- General Mission Analysis Tool
OD	- Orbital Determination Toolbox

2. *traj*

Deepspace	- deep space orbit
EML2	- Earth Moon L2 orbit
GEO	- GEO orbit
GPS	- MEO orbit
ISS	- LEO orbit
Mars1	- eccentric low orbit
Molniya	- HEO orbit
Moon	- eccentric low orbit
SunSync	- LEO orbit

NOTE: Some test cases contain *traj* variations. In this case *traj* precedes the modification. For example, an ISS trajectory is used and the point mass code is used in GMAT instead of JGM2 0x0. In this case the *traj* is ISSPM.

3. *forces*

AllPlanets	- Sun, Mercury, Venus, Earth, Moon, Mars, Mercury, Jupiter, and Pluto point mass gravity included.
1PM	- Central body is the only point mass included.
Drag	- JR is used for Earth cases.
NSG	- JGM2 20x20 is used.
SRP	- SRP is turned on

8.4 Comparison Script Information

TimeComparo.m is the script used to perform the comparison data needed for the Performance chapter of the Acceptance Test Plan. This script was designed to allow the user to select from a list of dates and then generates output that includes all available performance results from GMAT, STK, and FF. The dates represent the times when all of the performance test cases were run from the BuildRun_Script_GMAT.m script.

STK_Repropagate.m is the script that generates the performance times for STK. The data generated is then exported into an excel document for use with the TimeComparo.m script.

Refer to Appendix C for more details of this script and others used in the Acceptance Test Plan document.

8.5 Test Results

We strive to make GMAT perform just as good or better than the reference software packages. For the test cases with performance numbers that are not nearly equivalent or better, work is being done to improve GMAT's performance without affecting its numerical accuracy.

The main performance output parameters of interest are the time taken to run the script, the amount of integration step taken during that run, and the time per integration step. The results in this section are outputted in seconds. Tables 8.1- 8.6 contain these performance parameters by tool.

Tables 8.7- 8.12 contain a percentage difference between GMAT and the other reference software used. The data indicates GMAT's performance data was divided into the reference softwares same performance data to obtain a percentage. A value of 100% indicates both tools were the same, greater than 100% indicates GMAT performed worse, and less than 100% indicates GMAT performed better.

Table 8.1: Performance Test Case Comparisons

Test Case	GMAT TimeToRun(sec)	STK TimeToRun(sec)	FF TimeToRun(sec)
DeepSpacePM-AllPlanets-noOutput.m	NaN	NaN	NaN
DeepSpacePM-AllPlanets-output.m	NaN	NaN	NaN
DeepSpace-AllPlanets-noOutput.m	NaN	NaN	NaN
DeepSpace-AllPlanets-output.m	NaN	NaN	NaN
EML2PM-AllPlanets-noOutput.m	NaN	NaN	NaN
EML2PM-AllPlanets-output.m	NaN	NaN	NaN
EML2-AllPlanets-noOutput.m	NaN	NaN	NaN
EML2-AllPlanets-output.m	NaN	NaN	NaN
GEOPM-1PM-noOutput.m	2.365369677	0.9100139264	NaN
GEOPM-1PM-output.m	3.624228889	2.025697121	NaN
GEOPM-AllPlanets-noOutput.m	9.262963421	4.056012761	NaN
GEOPM-AllPlanets-output.m	10.63963856	5.203490891	NaN
GEOPM-SRP-noOutput.m	3.221224485	1.527696956	NaN
GEOPM-SRP-output.m	4.613150554	2.711619773	NaN
GEO-1PM-noOutput.m	5.080978504	0.9100139264	NaN
GEO-1PM-output.m	9.065021783	2.025697121	NaN
GEO-AllPlanets-noOutput.m	12.82652415	4.056012761	NaN
GEO-AllPlanets-output.m	14.62352863	5.203490891	NaN
GEO-Drag-noOutput.m	9.083949943	1.076942908	NaN
GEO-Drag-output.m	9.863043934	2.161930469	NaN
GEO-NSG-noOutput.m	9.079661186	3.27783425	NaN
GEO-NSG-output.m	9.063319947	4.456671393	NaN
GEO-SRP-noOutput.m	9.086620394	1.527696956	NaN
GEO-SRP-output.m	9.037045099	2.711619773	NaN
GPSPM-1PM-noOutput.m	2.324964709	0.9494172025	NaN
GPSPM-1PM-output.m	3.695722836	2.657454174	NaN
GPSPM-AllPlanets-noOutput.m	9.27329574	4.106867269	NaN
GPSPM-AllPlanets-output.m	10.67132599	5.382557951	NaN
GPSPM-SRP-noOutput.m	4.068783658	1.55785984	NaN
GPSPM-SRP-output.m	5.080100348	2.793106498	NaN
GPS-1PM-noOutput.m	5.085208763	0.9494172025	NaN
GPS-1PM-output.m	9.064168882	2.657454174	NaN
GPS-AllPlanets-noOutput.m	12.82362876	4.106867269	NaN
GPS-AllPlanets-output.m	14.21737953	5.382557951	NaN
GPS-Drag-noOutput.m	9.078539423	1.11248804	NaN
GPS-Drag-output.m	9.829883966	2.366961555	NaN
GPS-NSG-noOutput.m	6.989305121	3.277017722	NaN
GPS-NSG-output.m	9.049662625	4.556902511	NaN
GPS-SRP-noOutput.m	9.063283294	1.55785984	NaN
GPS-SRP-output.m	10.14604839	2.793106498	NaN
ISSPM-1PM-noOutput.m	3.371743671	3.532383306	NaN
ISSPM-1PM-output.m	9.505570289	8.654091176	NaN
ISSPM-AllPlanets-noOutput.m	34.23165034	17.8158481	NaN
ISSPM-AllPlanets-output.m	40.2429021	23.11573611	NaN
ISSPM-SRP-noOutput.m	14.61508594	6.507057014	NaN

Table 8.2: Performance Test Case Comparisons

Test Case	GMAT TimeToRun(sec)	STK TimeToRun(sec)	FF TimeToRun(sec)
ISSPM-SRP-output.m	25.07031637	11.69117678	NaN
ISS-1PM-noOutput.m	9.069769649	3.532383306	NaN
ISS-1PM-output.m	14.29912081	8.654091176	NaN
ISS-AllPlanets-noOutput.m	39.95640016	17.8158481	NaN
ISS-AllPlanets-output.m	46.03288368	23.11573611	NaN
ISS-Drag-noOutput.m	25.20274035	6.702129963	NaN
ISS-Drag-output.m	31.62018206	11.94099205	NaN
ISS-NSG-noOutput.m	18.25562254	14.51133002	NaN
ISS-NSG-output.m	26.18732275	19.74322161	NaN
ISS-SRP-noOutput.m	27.42110369	6.507057014	NaN
ISS-SRP-output.m	37.81563076	11.69117678	NaN
Mars1PM-1PM-noOutput.m	NaN	NaN	NaN
Mars1PM-1PM-output.m	NaN	NaN	NaN
Mars1PM-AllPlanets-noOutput.m	NaN	NaN	NaN
Mars1PM-AllPlanets-output.m	NaN	NaN	NaN
Mars1-1PM-noOutput.m	NaN	NaN	NaN
Mars1-1PM-output.m	NaN	NaN	NaN
Mars1-AllPlanets-noOutput.m	NaN	NaN	NaN
Mars1-AllPlanets-output.m	NaN	NaN	NaN
MolniyaPM-1PM-noOutput.m	2.520149293	1.138387756	NaN
MolniyaPM-1PM-output.m	4.727116994	2.810948095	NaN
MolniyaPM-AllPlanets-noOutput.m	13.49447664	5.357828495	NaN
MolniyaPM-AllPlanets-output.m	15.48603786	7.016379791	NaN
MolniyaPM-SRP-noOutput.m	4.93236051	2.014259857	NaN
MolniyaPM-SRP-output.m	9.064659894	3.669778142	NaN
Molniya-1PM-noOutput.m	5.931093645	1.138387756	NaN
Molniya-1PM-output.m	9.067935171	2.810948095	NaN
Molniya-AllPlanets-noOutput.m	17.02801742	5.357828495	NaN
Molniya-AllPlanets-output.m	18.94455575	7.016379791	NaN
Molniya-Drag-noOutput.m	11.14562516	1.48759834	NaN
Molniya-Drag-output.m	12.81850503	3.148300748	NaN
Molniya-NSG-noOutput.m	9.06083695	4.249729672	NaN
Molniya-NSG-output.m	9.881694573	5.892727931	NaN
Molniya-SRP-noOutput.m	9.723377636	2.014259857	NaN
Molniya-SRP-output.m	11.63239417	3.669778142	NaN
MoonPM-1PM-noOutput.m	NaN	NaN	NaN
MoonPM-1PM-output.m	NaN	NaN	NaN
Moon-1PM-noOutput.m	NaN	NaN	NaN
Moon-1PM-output.m	NaN	NaN	NaN
SunSyncPM-1PM-noOutput.m	3.357036607	3.408378327	NaN
SunSyncPM-1PM-output.m	9.442151447	8.631484337	NaN
SunSyncPM-AllPlanets-noOutput.m	33.3628759	17.53388808	NaN
SunSyncPM-AllPlanets-output.m	39.61642969	22.77039115	NaN
SunSyncPM-SRP-noOutput.m	14.48378093	6.372961703	NaN
SunSyncPM-SRP-output.m	25.21344992	11.62540558	NaN

Table 8.3: Performance Test Case Comparisons

Test Case	GMAT TimeToRun(sec)	STK TimeToRun(sec)	FF TimeToRun(sec)
SunSync-1PM-noOutput.m	9.077130362	3.408378327	NaN
SunSync-1PM-output.m	14.25260635	8.631484337	NaN
SunSync-AllPlanets-noOutput.m	39.61202214	17.53388808	NaN
SunSync-AllPlanets-output.m	45.78612287	22.77039115	NaN
SunSync-Drag-noOutput.m	24.86261533	6.570531171	NaN
SunSync-Drag-output.m	31.29207997	11.86876567	NaN
SunSync-NSG-noOutput.m	18.61135222	14.13227078	NaN
SunSync-NSG-output.m	27.37641393	19.3581896	NaN
SunSync-SRP-noOutput.m	26.72110975	6.372961703	NaN
SunSync-SRP-output.m	37.03988272	11.62540558	NaN

Table 8.4: Performance Test Case Comparisons

Test Case	GMAT 10000xTime/Step	STK 10000xTime/Step	FF 10000xTime/Step
DeepSpacePM-AllPlanets-noOutput.m	NaN	NaN	NaN
DeepSpacePM-AllPlanets-output.m	NaN	NaN	NaN
DeepSpace-AllPlanets-noOutput.m	NaN	NaN	NaN
DeepSpace-AllPlanets-output.m	NaN	NaN	NaN
EML2PM-AllPlanets-noOutput.m	NaN	NaN	NaN
EML2PM-AllPlanets-output.m	NaN	NaN	NaN
EML2-AllPlanets-noOutput.m	NaN	NaN	NaN
EML2-AllPlanets-output.m	NaN	NaN	NaN
GEOPM-1PM-noOutput.m	2.736746126	1.052891272	NaN
GEOPM-1PM-output.m	4.193253372	2.343743053	NaN
GEOPM-AllPlanets-noOutput.m	10.71730119	4.69282976	NaN
GEOPM-AllPlanets-output.m	12.31012213	6.020468461	NaN
GEOPM-SRP-noOutput.m	3.726974992	1.767554039	NaN
GEOPM-SRP-output.m	5.337441344	3.13735945	NaN
GEO-1PM-noOutput.m	5.878720935	1.052891272	NaN
GEO-1PM-output.m	10.4882816	2.343743053	NaN
GEO-AllPlanets-noOutput.m	14.84036116	4.69282976	NaN
GEO-AllPlanets-output.m	16.91950553	6.020468461	NaN
GEO-Drag-noOutput.m	10.51018158	1.24602905	NaN
GEO-Drag-output.m	11.41159775	2.501365809	NaN
GEO-NSG-noOutput.m	10.50521947	3.79247281	NaN
GEO-NSG-output.m	10.48631256	5.156394068	NaN
GEO-SRP-noOutput.m	10.51327131	1.767554039	NaN
GEO-SRP-output.m	10.45591241	3.13735945	NaN
GPSPM-1PM-noOutput.m	2.68999735	1.098481086	NaN
GPSPM-1PM-output.m	4.275972274	3.074689545	NaN
GPSPM-AllPlanets-noOutput.m	10.72925574	4.751668714	NaN
GPSPM-AllPlanets-output.m	12.34678467	6.227650065	NaN
GPSPM-SRP-noOutput.m	3.450168454	1.801410545	NaN
GPSPM-SRP-output.m	4.307725217	3.229771621	NaN
GPS-1PM-noOutput.m	5.883615368	1.098481086	NaN
GPS-1PM-output.m	10.48729478	3.074689545	NaN
GPS-AllPlanets-noOutput.m	14.83701117	4.751668714	NaN
GPS-AllPlanets-output.m	16.44958872	6.227650065	NaN
GPS-Drag-noOutput.m	10.50392158	1.287154969	NaN
GPS-Drag-output.m	11.37323148	2.738587938	NaN
GPS-NSG-noOutput.m	8.085730126	3.791528082	NaN
GPS-NSG-output.m	10.46929966	5.27236204	NaN
GPS-SRP-noOutput.m	7.738459097	1.801410545	NaN
GPS-SRP-output.m	8.662951156	3.229771621	NaN
ISSPM-1PM-noOutput.m	0.8663044812	0.9223173727	NaN
ISSPM-1PM-output.m	2.442272883	2.25961283	NaN
ISSPM-AllPlanets-noOutput.m	8.795162081	4.651536018	NaN
ISSPM-AllPlanets-output.m	10.33963724	6.035282657	NaN
ISSPM-SRP-noOutput.m	2.173053102	1.699636154	NaN

Table 8.5: Performance Test Case Comparisons

Test Case	GMAT 10000xTime/Step	STK 10000xTime/Step	FF 10000xTime/Step
ISSPM-SRP-output.m	3.727595511	3.05372255	NaN
ISS-1PM-noOutput.m	2.330302317	0.9223173727	NaN
ISS-1PM-output.m	3.673883202	2.25961283	NaN
ISS-AllPlanets-noOutput.m	10.26602609	4.651536018	NaN
ISS-AllPlanets-output.m	11.82726129	6.035282657	NaN
ISS-Drag-noOutput.m	6.416339609	1.741039086	NaN
ISS-Drag-output.m	8.05014946	3.101959229	NaN
ISS-NSG-noOutput.m	3.455671717	3.778008335	NaN
ISS-NSG-output.m	4.957091456	5.140125387	NaN
ISS-SRP-noOutput.m	4.07785136	1.699636154	NaN
ISS-SRP-output.m	5.623643858	3.05372255	NaN
Mars1PM-1PM-noOutput.m	NaN	NaN	NaN
Mars1PM-1PM-output.m	NaN	NaN	NaN
Mars1PM-AllPlanets-noOutput.m	NaN	NaN	NaN
Mars1PM-AllPlanets-output.m	NaN	NaN	NaN
Mars1-1PM-noOutput.m	NaN	NaN	NaN
Mars1-1PM-output.m	NaN	NaN	NaN
Mars1-AllPlanets-noOutput.m	NaN	NaN	NaN
Mars1-AllPlanets-output.m	NaN	NaN	NaN
MolniyaPM-1PM-noOutput.m	1.809412186	0.9989362548	NaN
MolniyaPM-1PM-output.m	3.393966825	2.46660942	NaN
MolniyaPM-AllPlanets-noOutput.m	9.698488317	4.708523152	NaN
MolniyaPM-AllPlanets-output.m	11.12982454	6.166077679	NaN
MolniyaPM-SRP-noOutput.m	2.835504748	1.767514792	NaN
MolniyaPM-SRP-output.m	5.211072086	3.22023354	NaN
Molniya-1PM-noOutput.m	4.258395782	0.9989362548	NaN
Molniya-1PM-output.m	6.510579531	2.46660942	NaN
Molniya-AllPlanets-noOutput.m	12.23804615	4.708523152	NaN
Molniya-AllPlanets-output.m	13.61546338	6.166077679	NaN
Molniya-Drag-noOutput.m	7.904138115	1.305483405	NaN
Molniya-Drag-output.m	9.090493606	2.762879112	NaN
Molniya-NSG-noOutput.m	6.50081572	3.759824535	NaN
Molniya-NSG-output.m	7.089750734	5.213419385	NaN
Molniya-SRP-noOutput.m	5.574052761	1.767514792	NaN
Molniya-SRP-output.m	6.668421333	3.22023354	NaN
MoonPM-1PM-noOutput.m	NaN	NaN	NaN
MoonPM-1PM-output.m	NaN	NaN	NaN
Moon-1PM-noOutput.m	NaN	NaN	NaN
Moon-1PM-output.m	NaN	NaN	NaN
SunSyncPM-1PM-noOutput.m	0.8684386917	0.8905438109	NaN
SunSyncPM-1PM-output.m	2.442609542	2.25524112	NaN
SunSyncPM-AllPlanets-noOutput.m	8.630934134	4.581268277	NaN
SunSyncPM-AllPlanets-output.m	10.24872065	5.949465982	NaN
SunSyncPM-SRP-noOutput.m	2.172100138	1.665132522	NaN
SunSyncPM-SRP-output.m	3.781204529	3.037495251	NaN

Table 8.6: Performance Test Case Comparisons

Test Case	GMAT 10000xTime/Step	STK 10000xTime/Step	FF 10000xTime/Step
SunSync-1PM-noOutput.m	2.348181488	0.8905438109	NaN
SunSync-1PM-output.m	3.687035997	2.25524112	NaN
SunSync-AllPlanets-noOutput.m	10.24758043	4.581268277	NaN
SunSync-AllPlanets-output.m	11.84481254	5.949465982	NaN
SunSync-Drag-noOutput.m	6.382393873	1.712145917	NaN
SunSync-Drag-output.m	8.032878955	3.092757366	NaN
SunSync-NSG-noOutput.m	3.417686247	3.701970079	NaN
SunSync-NSG-output.m	5.027253917	5.070907558	NaN
SunSync-SRP-noOutput.m	4.003942303	1.665132522	NaN
SunSync-SRP-output.m	5.550127024	3.037495251	NaN

Table 8.7: GMAT/STK Performance Test Case Comparisons

Test Case	% Time to Run	% Int. Steps	% Time Per Step
DeepSpacePM-AllPlanets-noOutput.m	NaN	NaN	NaN
DeepSpacePM-AllPlanets-output.m	NaN	NaN	NaN
DeepSpace-AllPlanets-noOutput.m	NaN	NaN	NaN
DeepSpace-AllPlanets-output.m	NaN	NaN	NaN
EML2PM-AllPlanets-noOutput.m	NaN	NaN	NaN
EML2PM-AllPlanets-output.m	NaN	NaN	NaN
EML2-AllPlanets-noOutput.m	NaN	NaN	NaN
EML2-AllPlanets-output.m	NaN	NaN	NaN
GEOPM-1PM-noOutput.m	259.9267559	100	259.9267559
GEOPM-1PM-output.m	178.9126742	100	178.9126742
GEOPM-AllPlanets-noOutput.m	228.3760917	100	228.3760917
GEOPM-AllPlanets-output.m	204.4711672	100	204.4711672
GEOPM-SRP-noOutput.m	210.8549391	100	210.8549391
GEOPM-SRP-output.m	170.1252735	100	170.1252735
GEO-1PM-noOutput.m	558.3407415	100	558.3407415
GEO-1PM-output.m	447.5013412	100	447.5013412
GEO-AllPlanets-noOutput.m	316.2348076	100	316.2348076
GEO-AllPlanets-output.m	281.0330399	100	281.0330399
GEO-Drag-noOutput.m	843.4941054	100	843.4941054
GEO-Drag-output.m	456.2146691	100	456.2146691
GEO-NSG-noOutput.m	277.0018401	100	277.0018401
GEO-NSG-output.m	203.3652282	100	203.3652282
GEO-SRP-noOutput.m	594.7920731	100	594.7920731
GEO-SRP-output.m	333.271102	100	333.271102
GPSPM-1PM-noOutput.m	244.8833561	100	244.8833561
GPSPM-1PM-output.m	139.0700496	100	139.0700496
GPSPM-AllPlanets-noOutput.m	225.799743	100	225.799743
GPSPM-AllPlanets-output.m	198.2575216	100	198.2575216
GPSPM-SRP-noOutput.m	261.1777744	136.36679	191.5259386
GPSPM-SRP-output.m	181.8799373	136.36679	133.3755362
GPS-1PM-noOutput.m	535.6137164	100	535.6137164
GPS-1PM-output.m	341.0846731	100	341.0846731
GPS-AllPlanets-noOutput.m	312.2484345	100	312.2484345
GPS-AllPlanets-output.m	264.1379741	100	264.1379741
GPS-Drag-noOutput.m	816.0572608	100	816.0572608
GPS-Drag-output.m	415.2954637	100	415.2954637
GPS-NSG-noOutput.m	213.2824939	100.0115701	213.2578198
GPS-NSG-output.m	198.5924123	100.0115701	198.5694377
GPS-SRP-noOutput.m	581.777838	135.4301573	429.5777615
GPS-SRP-output.m	363.2531878	135.4301573	268.2217869
ISSPM-1PM-noOutput.m	95.45237251	101.6240633	93.92693956
ISSPM-1PM-output.m	109.8390356	101.6240633	108.0836881
ISSPM-AllPlanets-noOutput.m	192.1415705	101.6187567	189.0808122
ISSPM-AllPlanets-output.m	174.0931023	101.6187567	171.3198507
ISSPM-SRP-noOutput.m	224.6036251	175.6719342	127.8540173

Table 8.8: GMAT/STK Performance Test Case Comparisons

Test Case	% Time to Run	% Int. Steps	% Time Per Step
ISSPM-SRP-output.m	214.4379204	175.6719342	122.0672621
ISS-1PM-noOutput.m	256.7606306	101.6240633	252.6573158
ISS-1PM-output.m	165.2296067	101.6240633	162.5890575
ISS-AllPlanets-noOutput.m	224.274477	101.6187567	220.701851
ISS-AllPlanets-output.m	199.1408946	101.6187567	195.9686391
ISS-Drag-noOutput.m	376.0407585	102.0366281	368.5350696
ISS-Drag-output.m	264.8036438	102.0366281	259.5182227
ISS-NSG-noOutput.m	125.8025455	137.5370997	91.4680808
ISS-NSG-output.m	132.6395624	137.5370997	96.43911546
ISS-SRP-noOutput.m	421.4056159	175.6405903	239.9249599
ISS-SRP-output.m	323.4544431	175.6405903	184.1570007
Mars1PM-1PM-noOutput.m	NaN	NaN	NaN
Mars1PM-1PM-output.m	NaN	NaN	NaN
Mars1PM-AllPlanets-noOutput.m	NaN	NaN	NaN
Mars1PM-AllPlanets-output.m	NaN	NaN	NaN
Mars1-1PM-noOutput.m	NaN	NaN	NaN
Mars1-1PM-output.m	NaN	NaN	NaN
Mars1-AllPlanets-noOutput.m	NaN	NaN	NaN
Mars1-AllPlanets-output.m	NaN	NaN	NaN
MolniyaPM-1PM-noOutput.m	221.3788122	122.2183222	181.1338989
MolniyaPM-1PM-output.m	168.1680641	122.2183222	137.596443
MolniyaPM-AllPlanets-noOutput.m	251.8646623	122.2778803	205.9772885
MolniyaPM-AllPlanets-output.m	220.7126513	122.2778803	180.5008811
MolniyaPM-SRP-noOutput.m	244.8721049	152.6412776	160.4232542
MolniyaPM-SRP-output.m	247.0083897	152.6412776	161.8228002
Molniya-1PM-noOutput.m	521.0082077	122.2183222	426.2930453
Molniya-1PM-output.m	322.593476	122.2183222	263.9485391
Molniya-AllPlanets-noOutput.m	317.8156492	122.2778803	259.9126256
Molniya-AllPlanets-output.m	270.0047077	122.2778803	220.8123882
Molniya-Drag-noOutput.m	749.2361921	123.7472576	605.4568051
Molniya-Drag-output.m	407.1563062	123.7472576	329.0224884
Molniya-NSG-noOutput.m	213.2097251	123.3123949	172.9021038
Molniya-NSG-output.m	167.6930394	123.3123949	135.9904165
Molniya-SRP-noOutput.m	482.7270723	153.0712531	315.3610247
Molniya-SRP-output.m	316.9781312	153.0712531	207.0788112
MoonPM-1PM-noOutput.m	NaN	NaN	NaN
MoonPM-1PM-output.m	NaN	NaN	NaN
Moon-1PM-noOutput.m	NaN	NaN	NaN
Moon-1PM-output.m	NaN	NaN	NaN
SunSyncPM-1PM-noOutput.m	98.49366133	101.0007055	97.51779543
SunSyncPM-1PM-output.m	109.391978	101.0007055	108.3081326
SunSyncPM-AllPlanets-noOutput.m	190.2765419	100.9980927	188.3961735
SunSyncPM-AllPlanets-output.m	173.9822097	100.9980927	172.2628667
SunSyncPM-SRP-noOutput.m	227.269229	174.2246492	130.4460821
SunSyncPM-SRP-output.m	216.8823252	174.2246492	124.4842943

Table 8.9: GMAT/STK Performance Test Case Comparisons

Test Case	% Time to Run	% Int. Steps	% Time Per Step
SunSync-1PM-noOutput.m	266.3181575	101.0007055	263.6795023
SunSync-1PM-output.m	165.1234689	101.0007055	163.4874411
SunSync-AllPlanets-noOutput.m	225.9169328	100.9980927	223.6843557
SunSync-AllPlanets-output.m	201.0774543	100.9980927	199.0903482
SunSync-Drag-noOutput.m	378.3958205	101.5087555	372.7716084
SunSync-Drag-output.m	263.6506681	101.5087555	259.7319481
SunSync-NSG-noOutput.m	131.6939968	142.6483301	92.32074203
SunSync-NSG-output.m	141.4203213	142.6483301	99.13913554
SunSync-SRP-noOutput.m	419.2887231	174.3709665	240.4578764
SunSync-SRP-output.m	318.6115313	174.3709665	182.7205169

Table 8.10: GMAT/FF Performance Test Case Comparisons

Test Case	% Time to Run	% Int. Steps	% Time Per Step
DeepSpacePM-AllPlanets-noOutput.m	NaN	NaN	NaN
DeepSpacePM-AllPlanets-output.m	NaN	NaN	NaN
DeepSpace-AllPlanets-noOutput.m	NaN	NaN	NaN
DeepSpace-AllPlanets-output.m	NaN	NaN	NaN
EML2PM-AllPlanets-noOutput.m	NaN	NaN	NaN
EML2PM-AllPlanets-output.m	NaN	NaN	NaN
EML2-AllPlanets-noOutput.m	NaN	NaN	NaN
EML2-AllPlanets-output.m	NaN	NaN	NaN
GEOPM-1PM-noOutput.m	NaN	NaN	NaN
GEOPM-1PM-output.m	NaN	NaN	NaN
GEOPM-AllPlanets-noOutput.m	NaN	NaN	NaN
GEOPM-AllPlanets-output.m	NaN	NaN	NaN
GEOPM-SRP-noOutput.m	NaN	NaN	NaN
GEOPM-SRP-output.m	NaN	NaN	NaN
GEO-1PM-noOutput.m	NaN	NaN	NaN
GEO-1PM-output.m	NaN	NaN	NaN
GEO-AllPlanets-noOutput.m	NaN	NaN	NaN
GEO-AllPlanets-output.m	NaN	NaN	NaN
GEO-Drag-noOutput.m	NaN	NaN	NaN
GEO-Drag-output.m	NaN	NaN	NaN
GEO-NSG-noOutput.m	NaN	NaN	NaN
GEO-NSG-output.m	NaN	NaN	NaN
GEO-SRP-noOutput.m	NaN	NaN	NaN
GEO-SRP-output.m	NaN	NaN	NaN
GPSPM-1PM-noOutput.m	NaN	NaN	NaN
GPSPM-1PM-output.m	NaN	NaN	NaN
GPSPM-AllPlanets-noOutput.m	NaN	NaN	NaN
GPSPM-AllPlanets-output.m	NaN	NaN	NaN
GPSPM-SRP-noOutput.m	NaN	NaN	NaN
GPSPM-SRP-output.m	NaN	NaN	NaN
GPS-1PM-noOutput.m	NaN	NaN	NaN
GPS-1PM-output.m	NaN	NaN	NaN
GPS-AllPlanets-noOutput.m	NaN	NaN	NaN
GPS-AllPlanets-output.m	NaN	NaN	NaN
GPS-Drag-noOutput.m	NaN	NaN	NaN
GPS-Drag-output.m	NaN	NaN	NaN
GPS-NSG-noOutput.m	NaN	NaN	NaN
GPS-NSG-output.m	NaN	NaN	NaN
GPS-SRP-noOutput.m	NaN	NaN	NaN
GPS-SRP-output.m	NaN	NaN	NaN
ISSPM-1PM-noOutput.m	NaN	NaN	NaN
ISSPM-1PM-output.m	NaN	NaN	NaN
ISSPM-AllPlanets-noOutput.m	NaN	NaN	NaN
ISSPM-AllPlanets-output.m	NaN	NaN	NaN
ISSPM-SRP-noOutput.m	NaN	NaN	NaN

Table 8.11: GMAT/FF Performance Test Case Comparisons

Test Case	% Time to Run	% Int. Steps	% Time Per Step
ISSPM-SRP-output.m	NaN	NaN	NaN
ISS-1PM-noOutput.m	NaN	NaN	NaN
ISS-1PM-output.m	NaN	NaN	NaN
ISS-AllPlanets-noOutput.m	NaN	NaN	NaN
ISS-AllPlanets-output.m	NaN	NaN	NaN
ISS-Drag-noOutput.m	NaN	NaN	NaN
ISS-Drag-output.m	NaN	NaN	NaN
ISS-NSG-noOutput.m	NaN	NaN	NaN
ISS-NSG-output.m	NaN	NaN	NaN
ISS-SRP-noOutput.m	NaN	NaN	NaN
ISS-SRP-output.m	NaN	NaN	NaN
Mars1PM-1PM-noOutput.m	NaN	NaN	NaN
Mars1PM-1PM-output.m	NaN	NaN	NaN
Mars1PM-AllPlanets-noOutput.m	NaN	NaN	NaN
Mars1PM-AllPlanets-output.m	NaN	NaN	NaN
Mars1-1PM-noOutput.m	NaN	NaN	NaN
Mars1-1PM-output.m	NaN	NaN	NaN
Mars1-AllPlanets-noOutput.m	NaN	NaN	NaN
Mars1-AllPlanets-output.m	NaN	NaN	NaN
MolniyaPM-1PM-noOutput.m	NaN	NaN	NaN
MolniyaPM-1PM-output.m	NaN	NaN	NaN
MolniyaPM-AllPlanets-noOutput.m	NaN	NaN	NaN
MolniyaPM-AllPlanets-output.m	NaN	NaN	NaN
MolniyaPM-SRP-noOutput.m	NaN	NaN	NaN
MolniyaPM-SRP-output.m	NaN	NaN	NaN
Molniya-1PM-noOutput.m	NaN	NaN	NaN
Molniya-1PM-output.m	NaN	NaN	NaN
Molniya-AllPlanets-noOutput.m	NaN	NaN	NaN
Molniya-AllPlanets-output.m	NaN	NaN	NaN
Molniya-Drag-noOutput.m	NaN	NaN	NaN
Molniya-Drag-output.m	NaN	NaN	NaN
Molniya-NSG-noOutput.m	NaN	NaN	NaN
Molniya-NSG-output.m	NaN	NaN	NaN
Molniya-SRP-noOutput.m	NaN	NaN	NaN
Molniya-SRP-output.m	NaN	NaN	NaN
MoonPM-1PM-noOutput.m	NaN	NaN	NaN
MoonPM-1PM-output.m	NaN	NaN	NaN
Moon-1PM-noOutput.m	NaN	NaN	NaN
Moon-1PM-output.m	NaN	NaN	NaN
SunSyncPM-1PM-noOutput.m	NaN	NaN	NaN
SunSyncPM-1PM-output.m	NaN	NaN	NaN
SunSyncPM-AllPlanets-noOutput.m	NaN	NaN	NaN
SunSyncPM-AllPlanets-output.m	NaN	NaN	NaN
SunSyncPM-SRP-noOutput.m	NaN	NaN	NaN
SunSyncPM-SRP-output.m	NaN	NaN	NaN

Table 8.12: GMAT/FF Performance Test Case Comparisons

Test Case	% Time to Run	% Int. Steps	% Time Per Step
SunSync-1PM-noOutput.m	NaN	NaN	NaN
SunSync-1PM-output.m	NaN	NaN	NaN
SunSync-AllPlanets-noOutput.m	NaN	NaN	NaN
SunSync-AllPlanets-output.m	NaN	NaN	NaN
SunSync-Drag-noOutput.m	NaN	NaN	NaN
SunSync-Drag-output.m	NaN	NaN	NaN
SunSync-NSG-noOutput.m	NaN	NaN	NaN
SunSync-NSG-output.m	NaN	NaN	NaN
SunSync-SRP-noOutput.m	NaN	NaN	NaN
SunSync-SRP-output.m	NaN	NaN	NaN

Chapter 9

ControlFlow

The Control Flow tests were designed to verify that the control flow commands (If, While, and For) function as expected. There are scripts that test the control flow commands by themselves, nested, and using different user defined parameters, such as arrays, numbers, variables, and spacecraft parameters. Each test script was designed to store flags that contained details of the command execution for each test case and reported to a text file.

Due to the layout of the report, a Matlab script can easily create a pass and fail table based on the values of the flag variables. In the report output the main columns to pay attention to are the ranOK and ansFlag columns. The ansFlag variable tells us if there was an incorrect control flow execution (ansFlag=-99), correct control flow execution (ansFlag=1), or the control flow didn't get executed (ansFlag=1). The ranOK variable tells us if each test case inside the test script ran correctly (ranOK = 1) or not (ranOK = 0). The only scripts that do not generate the ranOK column are the IfLoopTest##_##, IfLoopTest##, and IfIfLoopTest##_##.m, because the ansFlag column is sufficient.

9.1 Test Case Results

The results in Table 9.1 display the Pass and Fail outcome of each Control Flow test script.

Table 9.1: Loop Test Case Results

TestName	Pass/Fail	Failed/TotalTests
For	Pass	0/15
ForFor	Pass	0/9
ForIf41-14	Pass	0/20
ForIf42-24	Pass	0/21
ForIf43-34	Pass	0/20
ForIf51-15	Pass	0/16
ForIf52-25	Pass	0/20
ForIf53-35	Pass	0/20
ForWhile42	Pass	0/8
If11	Pass	0/9
If12-21	Pass	0/18
If22	Pass	0/9
If32-23	Pass	0/18
If33	Pass	0/9
If42-24	Pass	0/16
If44	Pass	0/8
If52-25	Pass	0/16
If55	Pass	0/8
IfFor	Pass	0/9
IfIf41-14	Pass	0/16
IfIf42-24	Pass	0/16
IfIf43-34	Pass	0/20
IfIf51-15	Pass	0/16
IfIf52-25	Pass	0/16
IfIf53-35	Pass	0/16
IfWhile	Pass	0/8
While42-24	Pass	0/16
While43-34	Pass	0/16
While52-25	Pass	0/16
While53-35	Pass	0/16
WhileFor	Pass	0/9
WhileIf41-14	Pass	0/16
WhileIf42-24	Pass	0/16
WhileIf43-34	Pass	0/16
WhileIf51-15	Pass	0/17
WhileIf52-25	Pass	0/16
WhileIf53-35	Pass	0/16
WhileTarget	Pass	0/1
WhileWhile42-24	Pass	0/16

Part I

GUI and Script Tests

Chapter 10

Test Procedures

10.1 Spacecraft Orbit Tab

Name	STC-3 Conversion to Keplerian-type Elements Disallowed when Celestial Body Not at Origin
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to a Keplerian state when the coordinate system does not have a celestial body (i.e. mu value) at the origin.
PreConditions	BS-2
Steps	1. Load BS-2. 2. Open the dialog box for DefaultSC. 3. Change the StateType to Keplerian. 4. Click on the down arrow on the Coordinate System drop-down menu and inspect the available Coordinate Systems. 5. Change the StateType to Modified Keplerian. 6. Click on the down arrow on the Coordinate System drop-down menu and inspect the available Coordinate Systems. 7. Change the StateType to Equinoctial. 8. Click on the down arrow on the Coordinate System drop-down menu and inspect the available Coordinate Systems.
Expected Results	The only coordinate systems available in the inspection steps above should be EarthMJ2000Eq, EarthMJ2000Ec, and Earth Fixed. Coordinate Systems CS_ESL2 and CS_SSBary are NOT available because these orbit state representations are only valid for coordinate systems with a central body at the origin.

Table 10.1: STC-3 Conversion to Keplerian-type Elements Disallowed when Celestial Body Not at Origin.

Name	STC-4 Conversion to Disallowed Coordinate System from Keplerian-type Elements
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to a new coordinate system that does not have a celestial body at the center.
PreConditions	BS-2
Data	1. Load BS-2. 2. Open the dialog box for DefaultSC. 3. Change the Coordinate System to CS_ESL2. 4. Click on the down arrow on the State Type drop-down menu and inspect the available State Types. 5. Change the Coordinate System to CS_SSBary. 6. Click on the down arrow on the State Type drop-down menu and inspect the available State Types.
Expected Results	The only State Types available are Cartesian, SphericalRADEC, and SphericalAZFPA. State Types Keplerian, Modified Keplerian, and Equinoctial are NOT available because these orbit state representations are only valid for coordinate systems with a central body at the origin.

Table 10.2: STC-4 Conversion to Disallowed Coordinate System from Keplerian-type Elements

Name	STC-5 GUI Epoch and State Independence for Time Dependent Coordinate System
Requirements	FR-1.3
Summary	This test is to verify that changing the epoch of the spacecraft, does not effect the orbit state, even when the coordinate system is, for example, a libration point coordinate system that has a time varying origin and axis system.
PreConditions	BS-2
Steps	1. Load BS-2 2. Open the dialog box for DefaultSC 3. Change the CoordinateSystem to CS_ESL2 4. Change the Epoch Format to UTCGregorian 5. Change the Epoch value to 01 Jan 2010 12:00:00.000 6. Hit Ok to close the dialog box 7. Reopen the dialog box for DefaultSC.
Expected Results	The data in the GUI should agree with the data below to at least 12 significant figures. • DefaultSC.X = 273083.6097699367 ; • DefaultSC.Y = -1332500.504835084; • DefaultSC.Z = -576402.9744365886 ; • DefaultSC.VX = 0.2990482122160891; • DefaultSC.VY = 7.400368588891073; • DefaultSC.VZ = 1.021835464804587 ;

Table 10.3: STC-5 GUI Epoch and State Independence for Time Dependent Coordinate System

Name	STC-6 Orbit GUI Behavior for Singular Conic Section
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations with a cartesian state that results in a singular conic section.
PreConditions	BS-2 and TD-4
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Enter the Cartesian state data from TD-5. 4. Hit Apply. 5. Change the State Type to Keplerian and verify the following error message is thrown: "GMAT does not support parabolic orbits in conversion from Cartesian to Keplerian state". 6. Change the State Type to Modified Keplerian and verify the following error message is thrown: "GMAT does not support parabolic orbits in conversion from Cartesian to Keplerian state". 7. Change the state to SphericalRADEC and verify the numeric data with TD-5. 8. Change the state to SphericalAZEL and verify the numeric data with TD-5. 9. Change the State Type to Equinoctial and verify the following error message is thrown: "GMAT does not support parabolic orbits in conversion from Cartesian to Equinoctial state".
Expected Results	The only State Types available are Cartesian, SphericalRADEC, and SphericalAZFPA. State Types Keplerian, Modified Keplerian, and Equinoctial are NOT available because they are undefined.

Table 10.4: STC-6 Orbit GUI Behavior for Disallowed Conversions

Name	STC-7 Orbit GUI Behavior for Circular, Equatorial Orbit
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1 and TD-5
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Enter the Cartesian state data from TD-5. 4. Hit Apply. 5. Change the state to Keplerian and verify the numeric data with TD-5. 6. Change the state to Modified Keplerian and verify the numeric data with TD-5. 7. Change the state to SphericalRADEC and verify the numeric data with TD-5. 8. Change the state to SphericalAZEL and verify the numeric data with TD-5. 9. Change the state to Equinoctial and verify the numeric data with TD-5.
Expected Results	The truth data is contained in TD-5.

Table 10.5: STC-7 Orbit GUI Behavior for Circular, Equatorial Orbit

Name	STC-8 Orbit GUI Behavior for Circular, Inclined Orbit
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1 and TD-6
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Enter the Cartesian state data from TD-6. 4. Hit Apply. 5. Change the state to Keplerian and verify the numeric data with TD-6. 6. Change the state to Modified Keplerian and verify the numeric data with TD-6. 7. Change the state to SphericalRADEC and verify the numeric data with TD-6. 8. Change the state to SphericalAZEL and verify the numeric data with TD-6. 9. Change the state to Equinoctial and verify the numeric data with TD-6.
Expected Results	The truth data is contained in TD-6.

Table 10.6: STC-8 Orbit GUI Behavior for Circular, Inclined Orbit

Name	STC-9 Orbit GUI Behavior for orbit with zero velocity
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Enter the following Cartesian State data: (a) X = 7000 (b) Y = 7000 (c) Z = 7000 (d) VX = 0; (e) VY = 0; (f) VZ = 0; 4. Hit Apply. 5. Change the state to Keplerian and verify that the following error message is returned: The orbit is a singular conic section and the Keplerian elements are undefined. 6. Change the state to Modified Keplerian and verify that the following error message is returned: The orbit is a singular conic section and the Modified Keplerian elements are undefined. 7. Change the state to SphericalRADEC and verify that the following error message is returned: The orbit is a singular conic section and the SphericalRADEC elements are undefined. 8. Change the state to SphericalAZEL and verify that the following error message is returned: The orbit is a singular conic section and the SphericalAZEL elements are undefined. 9. Change the state to Equinoctial and verify that the following error message is returned: The orbit is a singular conic section and the Equinoctial elements are undefined.
Expected Results	The truth data is described above.

Table 10.7: STC-9 Orbit GUI Behavior for orbit with zero velocity

Name	STC-10 Orbit GUI Behavior for orbit with zero position
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Enter the following Cartesian State data: (a) X = 0.0 (b) Y = 0.0 (c) Z = 0.0 (d) VX = 7.0; (e) VY = 7.0; (f) VZ = 7.0; 4. Hit Apply. 5. Change the state to Keplerian and verify that the following error message is returned: The orbit is a singular conic section and the Keplerian elements are undefined. 6. Change the state to Modified Keplerian and verify that the following error message is returned: The orbit is a singular conic section and the Modified Keplerian elements are undefined. 7. Change the state to SphericalRADEC and verify that the following error message is returned: The orbit is a singular conic section and the SphericalRADEC elements are undefined. 8. Change the state to SphericalAZEL and verify that the following error message is returned: The orbit is a singular conic section and the SphericalAZEL elements are undefined. 9. Change the state to Equinoctial and verify that the following error message is returned: The orbit is a singular conic section and the Equinoctial elements are undefined.
Expected Results	The truth data is described above.

Table 10.8: STC-10 Orbit GUI Behavior for orbit with zero position

Name	STC-11 Orbit GUI Behavior for orbit with zero state
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Enter the following Cartesian State data: (a) X = 0.0 (b) Y = 0.0 (c) Z = 0.0 (d) VX = 0.0; (e) VY = 0.0; (f) VZ = 0.0; 4. Hit Apply. 5. Change the state to Keplerian and verify that the following error message is returned: The orbit is a singular conic section and the Keplerian elements are undefined. 6. Change the state to Modified Keplerian and verify that the following error message is returned: The orbit is a singular conic section and the Modified Keplerian elements are undefined. 7. Change the state to SphericalRADEC and verify that the following error message is returned: The orbit is a singular conic section and the SphericalRADEC elements are undefined. 8. Change the state to SphericalAZEL and verify that the following error message is returned: The orbit is a singular conic section and the SphericalAZEL elements are undefined. 9. Change the state to Equinoctial and verify that the following error message is returned: The orbit is a singular conic section and the Equinoctial elements are undefined.
Expected Results	The truth data is described above.

Table 10.9: STC-11 Orbit GUI Behavior for orbit with zero state

Name	STC-12 Orbit GUI behavior when performing Modulo on Keplerian Angular Elements
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Change the State Type to Keplerian 4. Change INC to 370.0 degrees. 5. Change RAAN to 380.0 degrees. 6. Change AOP to 390.0 degrees. 7. Change TA t0 400.0 degrees. 8. Change the State Type to Cartesian. 9. Change the State Type to Keplerian.
Expected Results	INC = 10.0 degrees, RAAN = 20 degrees, AOP = 30.0 degrees, and TA = 40.0 degrees. (All values match to 14 sig. figs.)

Table 10.10: STC-12 Orbit GUI behavior when performing Modulo on Keplerian Angular Elements

Name	STC-13 Orbit GUI behavior when performing Modulo on Modified Keplerian Angular Elements
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Change the State Type to Modified Keplerian 4. Change INC to 370.0 degrees. 5. Change RAAN to 380.0 degrees. 6. Change AOP to 390.0 degrees. 7. Change TA t0 400.0 degrees. 8. Change the State Type to Cartesian. 9. Change the State Type to Keplerian.
Expected Results	INC = 10.0 degrees, RAAN = 20 degrees, AOP = 30.0 degrees, and TA = 40.0 degrees. (All values match to 14 sig. figs.)

Table 10.11: STC-13 Orbit GUI behavior when performing Modulo on Modified Keplerian Angular Elements

Name	STC-14 Orbit GUI behavior when performing Modulo on SphericalRADEC Angular Elements
Requirements	FR-1.3
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Change the State Type to Spherical 4. Change RA to 370.0 degrees. 5. Change DEC to 380.0 degrees. 6. Change RAV to 390.0 degrees. 7. Change DECV t0 400.0 degrees. 8. Change the State Type to Cartesian. 9. Change the State Type to Keplerian.
Expected Results	RA = 10.0 degrees, DEC = 20 degrees, RAV = 30.0 degrees, and DECV = 40.0 degrees. (All values match to 14 sig. figs.)

Table 10.12: STC-14 Orbit GUI behavior when performing Modulo on SphericalRADEC Angular Elements

Name	STC-18 Orbit GUI behavior when Orbit is near parabolic
Requirements	FR-1.1
Summary	SMA is undefined for parabolic orbits. This test check behavior as orbit approaches parabolic from ECC ¡ 1 side for Keplerian state type.
PreConditions	BS-1
Steps	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Change the State Type to Keplerian 4. Change ECC to 0.99999999 5. Hit Apply.
Expected Results	The following error message should be displayed: The value of ”0.99999999” for field ”ECC” is not an allowed value. The allowed values are: [0.0 leq Real Number $\leq$ 0.9999999, or Real Number $\geq$ 1.0000001].)

Table 10.13: STC-18 Orbit GUI behavior when performing Modulo on Equinoctial Angular Elements

Name	STC-19 Orbit GUI conversion for near singular Cartesian state
Requirements	FR-1.3
PreConditions	BS-1
Steps	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Set the Cartesian state to the following values (a) X = 6999.998216286026 (b) Y = 0 (c) Z = -5.002359263770285 (d) VX = 10.63431352889248 (e) VY = 0 (f) VZ = -0.003772975815698364 4. Hit Apply. 5. Change state type to Keplerian and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the Cartesian state to the Keplerian elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 6. Change state type to Modified Keplerian and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the Cartesian state to the Modified Keplerian elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 7. Change state type to Equinoctial and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the Cartesian state to the Equinoctial elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 8. Change the following states. (a) X = 1e-10 (b) Y = 1e-10 (c) Z = 1e-10 9. Hit Apply 10. Repeat steps 5, 6, and 7. 11. Change state type to SphericalRADec and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialRADEC state to the Cartesian State so conversion was aborted. The Right Ascension and Declination of position are undefined.” 12. Change state type to SphericalAZFPA and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialAZFPA state to the Cartesian State so conversion was aborted. The Right Ascension and Declination of position are undefined.” 13. Change the following states: (a) X = 6999.998216286026 (b) Y = 0 (c) Z = -5.002359263770285 (d) VX = 1e-10 (e) VY = 1e-10 (f) VZ = 1e-10 14. Hit Apply 15. Repeat steps 5, 6, and 7. 16. Change state type to SphericalRADec and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the Cartesian state to the SphericalRADEC so conversion was aborted. The Right Ascension and Declination of velocity are undefined.” 17. Change state type to SphericalAZFPA and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialAZFPA state to the Cartesian State so conversion was aborted. The Right Ascension and Declination of velocity are undefined.”
Expected Results	Test results are described above.

Table 10.14: STC-19 Orbit GUI conversion for near singular Cartesian state

Name	STC-20 Orbit GUI conversion for near singular SphericalAZEl state
Requirements	FR-1.3
PreConditions	BS-1
Steps	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Change the state type to SphercialAZFPA 4. Set the SphercialAZFPA state to the following values (a) RMAG = 7000.00000 (b) RA = 0 (c) DEC = -0.04094487109516581 (d) VMAG = 10.63431419820442 (e) AZI = 0 (f) FPA = 0.02061675296478873 5. Hit Apply. 6. Change state type to Keplerian and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialAZFPA state to the Keplerian elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 7. Change state type to Modified Keplerian and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialAZFPA state to the Modified Keplerian elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 8. Change state type to Equinoctial and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialAZFPA state to the Equinoctial elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 9. Change RMAG to 0.00001 and click apply. 10. Repeat steps 5, 6, and 7. 11. Change RMAG to 70000. 12. Change VMAG to 1e-14. 13. Repeat steps 5, 6, and 7. 14. Change state type to SphericalRADEC and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialAZFPA state to the SphericalRADEC state so conversion was aborted. The Right Ascension and Declination of velocity are undefined.”
Expected Results	Test results are described above.

Table 10.15: STC-20 Orbit GUI conversion for near singular SphericalAZEl state

Name	STC-20 Orbit GUI conversion for near singular SphericalRADEC state
Requirements	FR-1.3
PreConditions	BS-1
Steps	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Change the state type to SphercialRADEC. 4. Set the SphercialRADec state to the following values: (a) RMAG = 7000.00000 (b) RA = 0 (c) DEC = -0.04094487109516581 (d) VMAG = 10.63431419820442 (e) RAV = 0 (f) DECV = -0.0203281181043372 5. Hit Apply. 6. Change state type to Keplerian and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialRADEC state to the Keplerian elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 7. Change state type to Modified Keplerian and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialRADEC state to the Modified Keplerian elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 8. Change state type to Equinoctial and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialRADEC state to the Equinoctial elements so conversion was aborted. The radius of periapsis must be greater than 1 meter.” 9. Change RMAG to 0.00001 and click apply. 10. Repeat steps 5, 6, and 7. 11. Change RMAG to 70000. 12. Change VMAG to 1e-14. 13. Repeat steps 5, 6, and 7. 14. Change state type to SphericalRADEC and ensure that the following error is thrown: “Warning: A nearly singular conic section was encountered while converting from the SphercialRADEC state to the SphericalAZEL state so conversion was aborted. The Azimuth and Flight Path Angle are undefined.”
Expected Results	Test results are described above.

Table 10.16: STC-21 Orbit GUI conversion for near singular SphericalRADEC state

Name	STC-27 Performing Modulo on Keplerian Elements for Circular, Equatorial orbit
Requirements	FR-1.1
Summary	This case tests GUI behavior when attempting to convert to element representations when the cartesian state results in a circular, equatorial orbit.
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Change the State Type to Keplerian 4. Change ECC to 0.0. 5. Change INC to 0.0 degrees. 6. Change RAAN to 380.0 degrees. 7. Change AOP to 390.0 degrees. 8. Change TA to 430.0 degrees. 9. Hit Apply.
Expected Results	RAAN = 0.0 degrees, AOP = 0.0 degrees, and TA = 120.0 degrees. (All values match to 14 sig. figs.)

Table 10.17: STC-27 Performing Modulo on Keplerian Elements for Circular, Equatorial orbit

Name	STC-28 Performing Modulo on Keplerian Elements for Circular, Inclined Orbit
Requirements	FR-1.1
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Change the State Type to Keplerian 4. Change ECC to 0.0. 5. Change INC to 45 degrees. 6. Change RAAN to 380.0 degrees. 7. Change AOP to 390.0 degrees. 8. Change TA to 430.0 degrees. 9. Hit Apply.
Expected Results	RAAN = 20.0 degrees, AOP = 0.0 degrees, and TA = 70.0 degrees. (All values match to 14 sig. figs.)

Table 10.18: STC-28 Performing Modulo on Keplerian Elements for Circular, Equatorial orbit

<table>
<tr><th>Name</th><th>STC-23 Epoch conversion in the spacecraft orbit dialog box</th></tr>
<tr><td>Requirements</td><td>FRR-2.3</td></tr>
<tr><td>Summary</td><td>This test case represents $n(n-1)$ tests where n is the number of epoch formats supported as input types in GMAT. Each test case is designated a unique number. For example, STC-23.32 test GUI conversion from A1Gregorian to TAIModJulian. The procedures described below must be performed for each test case in the table below.</td></tr>
<tr><td>PreConditions</td><td>To run this test you need to load BS-1 and have data defined in TD-2 available.</td></tr>
<tr><td>Steps</td><td>

Select subtest number. (STC-23.32, for example)
Create a new spacecraft.
Change the Epoch Format to the format defined in the first column of the row containing the test case ID. (A1Gregorian, for STC-23.32)
Enter the epoch in the Define Format from TD-2.
Change the Epoch Format to the format defined in the first row of the column containing the test case Id. (TAIModJulian for STC-23.32)
Verify that the new epoch exactly matches the value for that format given in TD-2.

<table>
<tr><th></th><th>UTCGregorian</th><th>UTCModJulian</th><th>TAIGregorian</th><th>TAIModJulian</th><th>A1Gregorian</th><th>A1ModJulian</th><th>TTGregorian</th><th>TTModJulian</th></tr>
<tr><td>UTCGregorian</td><td>N/A</td><td>23.1</td><td>23.2</td><td>23.3</td><td>23.4</td><td>23.5</td><td>23.6</td><td>23.7</td></tr>
<tr><td>UTCModJulian</td><td>23.8</td><td>N/A</td><td>23.9</td><td>23.10</td><td>23.11</td><td>23.12</td><td>23.13</td><td>23.14</td></tr>
<tr><td>TAIGregorian</td><td>23.15</td><td>23.16</td><td>N/A</td><td>23.17</td><td>23.18</td><td>23.19</td><td>23.20</td><td>23.21</td></tr>
<tr><td>TAIModJulian</td><td>23.22</td><td>23.23</td><td>23.24</td><td>N/A</td><td>23.25</td><td>23.26</td><td>23.27</td><td>23.28</td></tr>
<tr><td>A1Gregorian</td><td>23.29</td><td>23.30</td><td>23.31</td><td>23.32</td><td>N/A</td><td>23.33</td><td>23.34</td><td>23.35</td></tr>
<tr><td>A1ModJulian</td><td>23.36</td><td>23.37</td><td>23.38</td><td>23.39</td><td>23.40</td><td>N/A</td><td>23.41</td><td>23.42</td></tr>
<tr><td>TTGregorian</td><td>23.43</td><td>23.44</td><td>23.44</td><td>23.45</td><td>23.46</td><td>23.47</td><td>N/A</td><td>23.48</td></tr>
<tr><td>TTModJulian</td><td>23.49</td><td>23.50</td><td>23.51</td><td>23.52</td><td>23.53</td><td>23.54</td><td>23.55</td><td>N/A</td></tr>
</table>
</td></tr>
<tr><td>Expected Results</td><td>The expected numeric results are described above and in TD-2.</td></tr>
</table>

Table 10.19: STC-23 Epoch conversion in the spacecraft orbit dialog box

<table>
<tr><th>Name</th><th>STC-24 State conversion in the spacecraft orbit dialog box</th></tr>
<tr><td>Requirements</td><td>FRR-2.3</td></tr>
<tr><td>Summary</td><td>This test case represents $n(n-1)$ tests where n is the number of state representations supported as input types in GMAT. Each test case is designated a unique number. For example, STC-24.17 tests GUI conversion from SphericalRADEC to Keplerian elements. The procedures described below must be performed for each test case in the table below.</td></tr>
<tr><td>PreConditions</td><td>To run this test you need to load BS-1 and have data defined in TD-1 available.</td></tr>
<tr><td>Steps</td><td>

Select subtest number. (STC-24.17, for example)
Create a new spacecraft.
Change the Epoch Format to the format defined in the first column of the row containing the test case ID. (SphericalRADEC, for STC-24.17)
Enter the epoch in the Define Format from TD-1.
Change the Epoch Format to the format defined in the first row of the column containing the test case Id. (Keplerian for STC-24.17)
Verify that the new state matches the value for that format given in TD-1 to 14 significant figures.

<table>
<tr><th></th><th>Cartesian</th><th>Keplerian</th><th>Mod. Keplerian</th><th>SphericalRADEC</th><th>SphericalAZFPA</th><th>Equinoctial</th></tr>
<tr><td>Cartesian</td><td>N/A</td><td>24.1</td><td>24.2</td><td>24.3</td><td>24.4</td><td>24.5</td></tr>
<tr><td>Keplerian</td><td>24.6</td><td>N/A</td><td>24.7</td><td>24.8</td><td>24.9</td><td>24.10</td></tr>
<tr><td>TAIGregorian</td><td>25.11</td><td>24.12</td><td>N/A</td><td>24.13</td><td>24.14</td><td>24.15</td></tr>
<tr><td>SphericalRADEC</td><td>24.16</td><td>24.17</td><td>24.18</td><td>N/A</td><td>24.19</td><td>24.20</td></tr>
<tr><td>SphericalAZFPA</td><td>24.21</td><td>24.22</td><td>24.23</td><td>24.24</td><td>N/A</td><td>24.25</td></tr>
<tr><td>Equinoctial</td><td>24.26</td><td>24.27</td><td>24.28</td><td>24.29</td><td>24.30</td><td>N/A</td></tr>
</table>
</td></tr>
<tr><td>Expected Results</td><td>The expected numeric results are described above and in TD-1.</td></tr>
</table>

Table 10.20: STC-24 State Representation conversion in the spacecraft orbit dialog box

<table>
<tr><th>Name</th><th>STC-25 Epoch conversion in the spacecraft orbit dialog box</th></tr>
<tr><td>Requirements</td><td>FRR-2.3</td></tr>
<tr><td>Summary</td><td>This test case represents $n(n-1)$ tests where n is the number of epoch formats supported as input types in GMAT. Each test case is designated a unique number. For example, STC-25.32 test GUI conversion from A1Gregorian to TAIModJulian. The procedures described below must be performed for each test case in the table below.</td></tr>
<tr><td>PreConditions</td><td>To run this test you need to load BS-1 and have data defined in TD-2 available.</td></tr>
<tr><td>Steps</td><td>

Select subtest number. (STC-25.32, for example)
Create a new spacecraft.
Change the Epoch Format to the format defined in the first column of the row containing the test case ID. (A1Gregorian, for STC-25.32)
Enter the epoch in the Define Format from TD-2.
Change the Epoch Format to the format defined in the first row of the column containing the test case Id. (TAIModJulian for STC-25.32)
Verify that the new epoch exactly matches the value for that format given in TD-2.

<table>
<tr><th></th><th>EarthMJ2000Eq</th><th>EarthMJ2000Ec</th><th>EarthFixed</th><th>LunaFixed</th><th>EarthMoonRot</th><th>SunMJ2000Ec</th><th>CS_ESL2</th><th>CSSSBary</th><th>PhobosFixed</th></tr>
<tr><td>EarthMJ2000Eq</td><td>N/A</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td></td></tr>
<tr><td>EarthMJ2000Ec</td><td>8</td><td>N/A</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td></td></tr>
<tr><td>EarthFixed</td><td>15</td><td>16</td><td>N/A</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td></td></tr>
<tr><td>LunaFixed</td><td>22</td><td>23</td><td>24</td><td>N/A</td><td>25</td><td>26</td><td>27</td><td>28</td><td></td></tr>
<tr><td>EarthMoonRot</td><td>29</td><td>30</td><td>31</td><td>32</td><td>N/A</td><td>33</td><td>34</td><td>35</td><td></td></tr>
<tr><td>SunMJ2000Ec</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>N/A</td><td>41</td><td>42</td><td></td></tr>
<tr><td>CS_ESL2</td><td>43</td><td>44</td><td>44</td><td>45</td><td>46</td><td>47</td><td>N/A</td><td>48</td><td></td></tr>
<tr><td>CS_SSBary</td><td>49</td><td>50</td><td>51</td><td>52</td><td>53</td><td>54</td><td>55</td><td>N/A</td><td></td></tr>
<tr><td>PhobosFixed</td><td>49</td><td>50</td><td>51</td><td>52</td><td>53</td><td>54</td><td>55</td><td>N/A</td><td></td></tr>
</table>
</td></tr>
<tr><td>Expected Results</td><td>The expected numeric results are described above and in TD-2.</td></tr>
</table>

Table 10.21: STC-25 Coordiate system conversion in the spacecraft orbit dialog box

10.2 Spacecraft Attitude Tab

<table>
<tr><th>Name</th><th>STC-26 Attitude conversion in the spacecraft attitude dialog box</th></tr>
<tr><td>Requirements</td><td>FRR-3.3</td></tr>
<tr><td>Summary</td><td>This test case represents $n(n-1)$ tests where n is the number of attitude representations supported as input types in GMAT. Each test case is designated a unique number. For example, STC-26.32 tests conversion from a 231 to a 232 Euler angle sequence. The procedures described below must be performed for each test case in the table below.</td></tr>
<tr><td>PreConditions</td><td>To run this test you need to load BS-1 and have data defined in TD-8 available.</td></tr>
<tr><td>Steps</td><td>
1. Select subtest number. (STC-26.32, for example)
2. Create a new spacecraft.
3. Open the dialog box for the new spacecraft.
4. Click on the Attitude tab.
5. Change the AttitudeStateType to the format defined in the first column of the row containing the test case ID. (Euler Angles, for STC-26.32)
6. If the AttitudeStateType is EulerAngles, change the EulerAngleSequence to the sequence defined in the first column of the row containing the test case ID. (231, for STC-26.32)
7. Enter the attitude state for the test ID using the data from TD-8.
8. Hit Apply.
9. Change the AttitudeStateType to the format defined in the first row of the column containing the test case Id. (Euler Angles, for STC-26.32)
10. If the AttitudeStateType is EulerAngles, Change the EulerAngleSequence to the format defined in the first row of the column containing the test case Id. (232, for STC-26.32)
11. Verify that the new epoch exactly matches the value for that format given in TD-8.
12. Compare the new Euler Angles to those in TD-8 for the new attitude representation. The values should agree to at least 13 significant figures.
<table>
<tr><th></th><th>q</th><th>123</th><th>231</th><th>312</th><th>132</th><th>321</th><th>213</th><th>121</th><th>232</th><th>313</th><th>131</th><th>323</th><th>212</th></tr>
<tr><td>q</td><td>X</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr>
<tr><td>123</td><td>13</td><td>X</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td></tr>
<tr><td>231</td><td>25</td><td>26</td><td>X</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td></tr>
<tr><td>312</td><td>37</td><td>38</td><td>39</td><td>X</td><td>40</td><td>41</td><td>42</td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td></tr>
<tr><td>132</td><td>49</td><td>50</td><td>51</td><td>52</td><td>X</td><td>53</td><td>54</td><td>55</td><td>56</td><td>57</td><td>58</td><td>59</td><td>60</td></tr>
<tr><td>321</td><td>61</td><td>62</td><td>63</td><td>64</td><td>65</td><td>X</td><td>66</td><td>67</td><td>68</td><td>69</td><td>70</td><td>71</td><td>72</td></tr>
<tr><td>213</td><td>73</td><td>74</td><td>75</td><td>76</td><td>77</td><td>78</td><td>X</td><td>79</td><td>80</td><td>81</td><td>82</td><td>83</td><td>84</td></tr>
<tr><td>121</td><td>85</td><td>86</td><td>87</td><td>88</td><td>89</td><td>90</td><td>91</td><td>X</td><td>92</td><td>93</td><td>94</td><td>95</td><td>96</td></tr>
<tr><td>232</td><td>97</td><td>98</td><td>99</td><td>100</td><td>101</td><td>102</td><td>103</td><td>104</td><td>X</td><td>105</td><td>106</td><td>107</td><td>108</td></tr>
<tr><td>313</td><td>109</td><td>110</td><td>111</td><td>112</td><td>113</td><td>114</td><td>115</td><td>116</td><td>X</td><td>117</td><td>118</td><td>119</td><td>120</td></tr>
<tr><td>131</td><td>121</td><td>122</td><td>123</td><td>124</td><td>125</td><td>126</td><td>127</td><td>128</td><td>129</td><td>X</td><td>130</td><td>131</td><td>132</td></tr>
<tr><td>323</td><td>133</td><td>134</td><td>135</td><td>136</td><td>137</td><td>138</td><td>139</td><td>140</td><td>141</td><td>142</td><td>143</td><td>X</td><td>144</td></tr>
<tr><td>212</td><td>145</td><td>146</td><td>146</td><td>148</td><td></td><td>149</td><td>150</td><td>151</td><td>152</td><td>153</td><td>154</td><td>155</td><td>X</td></tr>
</table>
</td></tr>
<tr><td>Expected Results</td><td>The expected numeric results are described above and in TD-8.</td></tr>
</table>

Table 10.22: STC-26 Attitude conversion in the spacecraft attitude dialog box

Name	Attitude GUI behavior when entering zero quaternion
Requirements	FR-3.1
PreConditions	BS-1
Data	1. Load BS-1. 2. Open the dialog box for DefaultSC. 3. Click on the attitude tab. 4. Set all values of the quaternion to zero. 5. Click Ok.
Expected Results	The following warning is displayed: The magnitude of a quaternion must be greater than 1e-10.

Table 10.23: STC-17 Attitude GUI behavior when entering zero quaternion

10.3 Differential Corrector

Name	TC-1 Differential Corrector Dialog Box Range Tests - Disallowed Values
Requirements	FR-19
Summary	This case verifies the Differential Corrector dialog box rejects disallowed data.
PreConditions	BS-1
Data	1. Load BS-1. 2. In the solvers folder in the mission tree, right-click on the Boundary Value Solvers folder and add a Differential Corrector. 3. Open the dialog box for the new Differential Corrector. 4. In the Max Iterations field, enter -2, and hit Apply. Ensure the following error message is provided: The value of "-2" for field "Maximum Iterations" is not an allowed value. The allowed values are: [Integer Number > 0]. 5. In the Max Iterations field, enter DNE, and hit Apply. Ensure the following error message is provided: The value of "DNE" for field "Maximum Iterations" is not an allowed value. The allowed values are: [Integer Number > 0]. 6. In the Max Iterations field, enter 23.6, and hit Apply. Ensure the following error message is provided: The value of "23.6" for field "Maximum Iterations" is not an allowed value. The allowed values are: [Integer Number > 0].
Expected Results	Test results are described above.

Table 10.24: TC-1 Differential Corrector Dialog Box Range Tests - Disallowed Values

Name	TC-2 Differential Corrector Dialog Box Range Tests- Allowed Values
Requirements	FR-19
Summary	This case verifies the Differential Corrector accepts allowed data.
PreConditions	BS-1
Data	1. Load BS-1. 2. In the solvers folder in the mission tree, right-click on the Boundary Value Solvers folder and add a Differential Corrector. 3. Open the dialog box for the new Differential Corrector. 4. Set the Max Iterations to 56. 5. In the ReportFile field type `.\output\DCReport.txt` 6. Uncheck the ShowProgress box. 7. Set the DerivativeMethod drop-down menu to CentralDifference. 8. Set the ReportStyle drop-down menu to Verbose. 9. Click the Apply button. 10. Click the Show Script button.

Expected Results	`Create DifferentialCorrector DC1;`
	`GMAT DC1.ShowProgress = false;`
	`GMAT DC1.ReportStyle = 'Verbose';`
	`GMAT DC1.ReportFile = '.\output\DCData.txt';`
	`GMAT DC1.MaximumIterations = 56;`
	`GMAT DC1.DerivativeMethod = CentralDifference;`

Table 10.25: TC-2 Differential Corrector Dialog Box Range Tests- Allowed Values

Chapter 11

Test Data

Name	TD-1 Equivalent State Representations in EarthMJ2000Eq
Description	This table contains equivalent states in all GMAT state representations that have a central body at the origin.
Source	This is data comes from GMAT and allows testing consistency between state conversions. We have numerical tests that verify that GMAT is correctly performing conversions correctly via the script when compared to truth data from STK. The data below is to ensure that the GUI state conversions agree with conversions in the script. (The test data assumes $\mu = 398600.4415$)
Data	1. Cartesian State (a) X = -2011.554639349956 (b) Y = 7587.193672855249 (c) Z = 1362.382029017782 (d) VX = -7.694247416401868 (e) VY = -0.9065479140190984 (f) VZ = 0.4284953758282981 2. Keplerian State (a) SMA = 10000 (b) ECC = 0.25 (c) INC = 10.0 (d) RAAN = 25.0 (e) AOP = 35.0 (f) TA = 45.0 (g) MA = 27.24378911263291; (h) EA = 35.57751520702131; 3. Modified Keplerian (a) RadPer = 7500 (b) RadApo = 12500 (c) INC = 10.0 (d) RAAN = 25.0 (e) AOP = 35.0 (f) TA = 45.0 4. Spherical RADec (a) RMAG = 7966.67714229061 (b) RA = 104.8489182889519 (c) DEC = 9.846551939834079 (d) VMAG = 7.759309293508375 (e) AZI = 88.24621654190652 (f) FPA = 81.45684518510772 5. Spherical RADec (a) RMAG = 7966.67714229061 (b) RA = 104.8489182889519 (c) DEC = 9.846551939834079 (d) VMAG = 7.759309293508375 (e) AZI = -173.2803040524276 (f) FPA = 3.165677683357204 6. Equinoctial (a) SMA = 10000 (b) h = 0.2165063509461095 (c) k = 0.125 (d) p = 0.03697430690134294 (e) q = 0.07929165703097431 (f) MLONG = 87.2437891126329

Table 11.1: TD-1 Equivalent State Representations

Name	TD-2 Equivalent Epoch Representations
Description	This table contains equivalent epoch representations in all formats and systems supported as input types.
Source	Need to verify source.
Data	1. 04 Jul 2004 12:34:56.789 UTC 2. 23191.0242683912 UTC 3. 04 Jul 2004 12:35:28.789 TAI 4. 23191.02463876157 TAI 5. 04 Jul 2004 12:35:28.823 A1 6. 23191.02463915951 A1 7. 04 Jul 2004 12:36:00.973 TT 8. 23191.0250112616 TT

Table 11.2: TD-2 Equivalent Epoch Representations

Name	TD-3 Equivalent States in Different Coordinate Systems
Description	This table contains equivalent states in various coordinate systems. The epoch is 04 Feb 2001 11:59:28.000 UTC.
Source	This is data comes from GMAT and allows testing consistency between state conversions. We have numerical tests that verify that GMAT is correctly performing conversions correctly via the script when compared to truth data from STK. The data below is to ensure that the GUI state conversions agree with conversions in the script.
Data	1. EarthMJ2000Eq (a) 5071.298226925739 (b) 7611.115643763225 (c) 3591.57811088299 (d) -5.443963856628132 (e) 2.768170139549618 (f) 1.993434604659487 2. EarthMJ2000Eq (a) 5071.298226925739 (b) 8411.709801736053 (c) 267.6805571735547 (d) -5.443963856628132 (e) 3.332689195355913 (f) 0.7278256465019841 3. EarthFixed System —- (a) -1863.0575794316 (b) 8953.983671172193 (c) 3591.903847242492 (d) -5.139752276668541 (e) -1.799622038729856 (f) 1.992983974458626 4. LunaFixed System —- (a) 356291.5164882602 (b) -33974.36961780395 (c) 16667.54936624816 (d) -3.267914664134139 (e) -5.374404304814976 (f) 0.7247736501205496 5. EarthMoonRot System (a) 8968.872502970022 (b) -3907.723350348471 (c) 914.1141166948707 (d) 2.581713440043834 (e) 5.842794343296872 (f) 0.3253861743578399 6. SunMJ2000Ec System (a) 125912803.1220472 (b) 163450023.4650465 (c) 66337826.42493016 (d) -33.57498440092737 (e) 0.0008503562866066794 (f) 1.493151380860197 7. CS_ESL2 System (a) -560121.5615799141 (b) 284125.8138175178 (c) 13140.72166463266 (d) 5.466911578720965 (e) 0.7694483179080936 (f) 0.6355953786263187 8. CS_SSBary System (a) 147428584.0468952 (b) -9578.340467568873 (c) 266.8937442606475 (d) 6.68279484246637 (e) 1.370672075811688 (f) 0.726953785084683

Name	TD-4 Equivalent State Representations for a Singular Conic Section
Description	This table contains equivalent states in all GMAT state representations that have a central body at the origin.
Source	STK. The data below is to ensure that the GUI state conversions agree with conversions in the script. (The test data assumes $\mu = 398600.4415$)
Data	1. Cartesian State (a) X = 7000 (b) Y = 7000 (c) Z = 7000 (d) VX = -4.04145188432738 (e) VY = -4.04145188432738 (f) VZ = -4.04145188432738 2. Keplerian State: Undefined (e = 1); 3. Modified Keplerian: Undefined (e = 1); 4. Spherical RADec (a) RMAG = 12124.355652982142 (b) RA = 45 (c) DEC = 35.2643896827546470 (d) VMAG = 6.999999999999998 (e) AZI = 0 (f) FPA = 180 5. Spherical RADec (a) RMAG = 12124.355652982142 (b) RA = 45 (c) DEC = 35.2643896827546470 (d) VMAG = 6.999999999999998 (e) DECV = 225 (f) RAV = 35.264389682754661 6. Equinoctial: Undefined (e = 1);

Table 11.4: TD-4 Equivalent State Representations for a Singular Conic Section

Name	TD-5 Equivalent State Representations for a Circular, Equatorial Orbit
Description	This table contains equivalent states in all GMAT state representations that have a central body at the origin.
Source	Hand calculations based on Math spec for all except Equinoctial which is from STK. (The test data assumes $\mu = 398600.4415$)
Data	1. Cartesian State (a) X = 4949.747468305833 (b) Y = 4949.747468305833 (c) Z = 0.0 (d) VX = -5.335865450622125 (e) VY = 5.335865450622125 (f) VZ = 0 2. Keplerian State (a) SMA = 7000 (b) ECC = 0.0 (c) INC = 0.0 (d) RAAN = 0.0 (e) AOP = 0.0 (f) TA = 45.0 3. Modified Keplerian (a) RadPer = 7000 (b) RadApo = 7000 (c) INC = 0.0 (d) RAAN = 0.0 (e) AOP = 0.0 (f) TA = 45.0 4. Spherical RADec (a) RMAG = 7000 (b) RA = 45.0 (c) DEC = 0.0 (d) VMAG = 7.5460532872678359 (e) RAV = 135.00000000000000 (f) DECV= 0.0 5. Spherical RADec (a) RMAG = 7000 (b) RA = 45.0 (c) DEC = 0.0 (d) VMAG = 7.5460532872678359 (e) AZI = 90 (f) FPA = 90 6. Equinoctial (a) SMA = 7000 (b) h = 0.0 (c) k = 0.0 (d) p = 0.0 (e) q = 0.0 (f) MLONG = 45.0

Table 11.5: TD-5 Equivalent State Representations for a Circular, Equatorial Orbit

Name	TD-6 Equivalent State Representations for a Circular, Inclined (retrograde) Orbit
Description	This table contains equivalent states in all GMAT state representations that have a central body at the origin.
Source	Hand calculations based on Math spec for all except Equinoctial which is from STK. (The test data assumes $\mu = 398600.4415$)
Data	1. Cartesian State (a) X = -5975.5752861126311 (b) Y = 480.14719831222595 (c) Z = -3416.4248371584213 (d) VX = 3.8002690670377621 (e) VY = 0.9160734111800478 (f) VZ = -6.5182010133917370 2. Keplerian State (a) SMA = 6900 (b) ECC = 0.0 (c) INC = 98 (d) RAAN = 0.0 (e) AOP = 0.0 (f) TA = 210.0 3. Modified Keplerian (a) RadPer = 6900 (b) RadApo = 6900 (c) INC = 98 (d) RAAN = 0.0 (e) AOP = 0.0 (f) TA = 210.0 4. Spherical RADec (a) RMAG = 6900 (b) RA = 175.4060606593105 (c) DEC = -29.67858910292156 (d) VMAG = 7.6005381340755180 (e) RAV = 13.55286811093926 (f) DECV= -59.04786932043024 5. Spherical RADec (a) RMAG = 6900 (b) RA = 175.4060606593105 (c) DEC = -29.67858910292156 (d) VMAG = 7.6005381340755180 (e) AZI = 189.2177489242794 (f) FPA = 90 6. Equinoctial (a) SMA = 6900 (b) h = 0.0 (c) k = 0.0 (d) p = 0.0 (e) q = 1.1503684072210094 (f) MLONG = 210.0

Table 11.6: TD-6 Equivalent State Representations for a Circular, Inclined (retrograde) Orbit

<table>
<tr><th>Name</th><th>Equivalent Attitude Representations</th></tr>
<tr><td>Description</td><td>This table contains equivalent states in various coordinate systems. The epoch is 04 Feb 2001 11:59:28.000 UTC.</td></tr>
<tr><td>Source</td><td>This is data comes from GMAT and allows testing consistency between state conversions. We have numerical tests that verify that GMAT is correctly performing conversions correctly via the script when compared to truth data from STK. The data below is to ensure that the GUI state conversions agree with conversions in the script.</td></tr>
<tr><td>Data</td><td>

Quaternion

0.05431254465935684
0.1536190745285137
0.6870053865727263
0.7081489435519108

Euler Angles
<table>
<tr><th>Sequence</th><th>θ_1 (deg.)</th><th>θ_2 (deg.)</th><th>θ_3 (deg.)</th></tr>
<tr><td>123</td><td>-8.063660107792256</td><td>16.98949666527142</td><td>89.46981218935655</td></tr>
<tr><td>231</td><td>86.45739059790678</td><td>81.76589766113709</td><td>-69.50363702414091</td></tr>
<tr><td>312</td><td>86.99826598215141</td><td>16.73807760458099</td><td>8.584547140308942</td></tr>
<tr><td>132</td><td>80.12240308416057</td><td>73.0024763951768</td><td>88.26525116243468</td></tr>
<tr><td>321</td><td>89.48768989493576</td><td>8.21825906808993</td><td>16.91694843278077</td></tr>
<tr><td>213</td><td>17.14924429081384</td><td>-7.709559339371771</td><td>87.09931277680732</td></tr>
<tr><td>121</td><td>81.78141688239583</td><td>89.49295108504926</td><td>-73.00981782084581</td></tr>
<tr><td>232</td><td>16.7597858904212</td><td>87.12555469792072</td><td>7.719330705131926</td></tr>
<tr><td>313</td><td>114.6605285775403</td><td>18.75489666719195</td><td>-26.39703015347826</td></tr>
<tr><td>131</td><td>-8.218583117604172</td><td>89.49295108504926</td><td>16.99018217915419</td></tr>
<tr><td>323</td><td>24.66052857754036</td><td>18.75489666719195</td><td>63.60296984652174</td></tr>
<tr><td>212</td><td>-73.2402141095788</td><td>87.12555469792072</td><td>97.71933070513192</td></tr>
</table>

Direction Cosine Matrix
<table>
<tr><td>0.008849557522123823</td><td>0.9896911631236142</td><td>-0.1429443491946786</td></tr>
<tr><td>-0.9563173917401783</td><td>0.05014749262536867</td><td>0.2879970056070911</td></tr>
<tr><td>0.2921963921524783</td><td>0.134151521118533</td><td>0.9469026548672567</td></tr>
</table>

</td></tr>
</table>

Table 11.7: TD-8 Equivalent Attitude Representations

Chapter 12

Base States

Name	BS-1 The Default Mission
Summary	This base state configures GMAT to the default mission.
Description	See BS-1.script

Table 12.1: Spacecraft GUI State Conversion Test

Chapter 13

GUI

13.1 Individual GUI panels

(identify the most common user usage) [INSERT info for section]

13.1.1 S/C => Orbit — Resources Tab

[INSERT info for section]

13.1.2 S/C => Attitude — Resources Tab

[INSERT info for section]

13.1.3 S/C => Ballistic/Mass — Resources Tab

[INSERT info for section]

13.1.4 S/C => Sensors — Resources Tab

[INSERT info for section]

13.1.5 S/C => Tanks — Resources Tab

[INSERT info for section]

13.1.6 S/C => Actuators — Resources Tab

[INSERT info for section]

13.1.7 Fuel Tank — Resources Tab

[INSERT info for section]

13.1.8 Thruster — Resources Tab

[INSERT info for section]

13.1.9 Formation — Resources Tab

[INSERT info for section]

13.1.10 Finite Burn — Resources Tab

[INSERT info for section]

13.1.11 Impulsive Burn — Resources Tab

[INSERT info for section]

13.1.12 Propagator — Resources Tab

[INSERT info for section]

13.1.13 Solar System — Resources Tab

[INSERT info for section]

13.1.14 Barycenter — Resources Tab

[INSERT info for section]

13.1.15 Libration Point — Resources Tab

[INSERT info for section]

13.1.16 Celestial Bodies/Planets — Resources Tab

[INSERT info for section]

13.1.17 Differential Corrector — Resources Tab

[INSERT info for section]

13.1.18 OpenGL — Resources Tab

[INSERT info for section]

13.1.19 ReportFile — Resources Tab

[INSERT info for section]

13.1.20 XYPlot — Resources Tab

[INSERT info for section]

13.1.21 Variable/Array — Resources Tab

[INSERT info for section]

13.1.22 Coordinate System — Resources Tab

[INSERT info for section]

13.1.23 Function — Resources Tab

[INSERT info for section]

13.1.24 Propagate — Mission Tab

[INSERT info for section]

13.1.25 Target — Mission Tab

[INSERT info for section]

13.1.26 Maneuver — Mission Tab

[INSERT info for section]

13.1.27 Vary — Mission Tab

[INSERT info for section]

13.1.28 Achieve — Mission Tab

[INSERT info for section]

13.1.29 CallFunction — Mission Tab

[INSERT info for section]

13.1.30 ScriptEvent — Mission Tab

[INSERT info for section]

13.1.31 If — Mission Tab

[INSERT info for section]

13.1.32 For — Mission Tab

[INSERT info for section]

13.1.33 While — Mission Tab

[INSERT info for section]

13.2 Saving

[INSERT info for section]

13.3 Script Event

[INSERT info for section]

13.4 Buttons

[INSERT info for section]

13.4.1 Stop

[INSERT info for section]

13.4.2 Pause

[INSERT info for section]

13.4.3 Play

[INSERT info for section]

13.4.4 Show Script

[INSERT info for section]

13.4.5 Command Summary

[INSERT info for section]

13.4.6 Open

[INSERT info for section]

13.4.7 Other

(Print, default mission, close all, close child)

[INSERT info for section]

Chapter 14

Script

Chapter 15

Script-to-GUI template

A select group of tests recreated in the GUI from a script mission are created to help avoid situations where the script can perform actions that the GUI can not. The results of these Script-to-GUI tests are documented by a tester using the Script2GUI_GMAT_template.doc.

Using the available template, a tester needs to go through each panel of the GUI interface to duplicate the data seen in the script. The tester needs to have a general understanding of how the GMAT system works in order to get around some issues that may occur. The tester records successful panel completions, as well as any bugs generated. The template gives examples on how the data should be entered.

Part II

Appendix

Appendix A

Acronyms

Cb	- Central Body
Cd	- Drag coefficient
COTS	- Commercial Off The Shelf software
Cr	- Coefficient of reflexivity
CS	- Coordinate System
EGM	- Earth Gravity Model
EOP	- Earth Orientation Parameters
FDAB	- Flight Dynamics Analysis Branch
FF	- Free Flyer
GEO	- Geosynchronous Orbit
GMAT	- General Mission Analysis Tool
GPS	- Global Positioning Satellite
HEO	- Highly Elliptical Orbit
HPOP	- High Precision Orbit Propagator
IAU	- International Astronomical Union
IERS	- International Earth Rotation and Reference Systems Service
ISS	- International Space Station
JGM	- Joint Gravity Model
JR	- Jacchia Roberts
GMAT	- General Mission Analysis Tool
LEO	- Low Earth Orbit
LOD	- Length of Day
MEO	- Medium Earth Orbit
mas	- milliarcseconds
MSISE	- Mass Spectrometer and Incoherent Scatter Radar Exosphere
NSG	- Non-Spherical Gravity
PIP	- Professional Intern Program
PMG	- Point Mass Gravity
SRP	- Solar Radiation Pressure
STK	- Satellite Tool Kit
TAI	- International Atomic Time
TLE	- Two Line Element
USNO	- U.S. Naval Observatory
UT	- Universal time
UTC	- Coordinated Universal Time

Appendix B

Initial Conditions

The text and tables in this appendix allow someone to have an easier time duplicating the test case setups described in the previous chapters. The same information was presented in the previous chapters but this appendix has the information arranged different for ease of duplication reasons.

B.1 Propagator Test Cases

Table B.1: Initial Orbit Parameters (ISS)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	2 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Earth Mean J2000 Equator
X	-4453.783586 (km)
Y	-5038.203756 (km)
Z	-426.384456 (km)
VX	3.831888 (km)
VY	-2.887221 (km)
VZ	-6.018232 (km)
Mass (No Fuel)	1000 (kg) (some exceptions)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	60 (sec)
Report CS/Cb	Same as initial state CS

Table B.2: Initial Orbit Parameters (Sun-Sync)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	2 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Earth Mean J2000 Equator
X	-2290.301063 (km)
Y	-6379.471940 (km)
Z	0.0 (km)
VX	-0.883923 (km)
VY	0.317338 (km)
VZ	7.610832 (km)
Mass (No Fuel)	1000 (kg) (some exceptions)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	60 (sec)
Report CS/Cb	Same as initial state CS

Table B.3: Initial Orbit Parameters (GPS)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	3 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Earth Mean J2000 Equator
X	5525.33668 (km)
Y	-15871.18494 (km)
Z	-20998.992446 (km)
VX	2.750341 (km)
VY	2.434198 (km)
VZ	-1.068884 (km)
Mass (No Fuel)	1000 (kg) (some exceptions)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	60 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	60 (sec)
Report Precision	16 significant figures
Report StepSize	120 (sec)
Report CS/Cb	Same as initial state CS

Table B.4: Initial Orbit Parameters (Molniya)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Earth Mean J2000 Equator
X	-1529.894287 (km)
Y	-2672.877357 (km)
Z	-6150.115340 (km)
VX	8.717518 (km)
VY	-4.989709 (km)
VZ	0.0 (km)
Mass (No Fuel)	1000 (kg) (some exceptions)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.5: Initial Orbit Parameters (GEO)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	8 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Earth Mean J2000 Equator
X	36607.358256 (km)
Y	-20921.723703 (km)
Z	0.0 (km)
VX	1.525636 (km)
VY	2.669451 (km)
VZ	0.0 (km)
Mass (No Fuel)	1000 (kg) (some exceptions)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	60 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	60 (sec)
Report Precision	16 significant figures
Report StepSize	600 (sec)
Report CS/Cb	Same as initial state CS

Table B.6: Initial Orbit Parameters (Mars)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Mars Mean J2000 Equator
X	-2737.481646173082000 (km)
Y	0.0 (km)
Z	2737.481646173082000 (km)
VX	-0.311321695052649 (km)
VY	-3.553492313930950 (km)
VZ	0.311321695052650 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.7: Initial Orbit Parameters (Mercury)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Mercury Mean J2000 Equator
X	-2164.769322630887000 (km)
Y	0.0 (km)
Z	2164.769322630886100 (km)
VX	-0.251096955137200 (km)
VY	-2.866074270797602 (km)
VZ	0.251096955137201 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.8: Initial Orbit Parameters (Moon)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Moon Mean J2000 Equator
X	-1486.792117191545200 (km)
Y	0.0 (km)
Z	1486.792117191543000 (km)
VX	-0.142927729144255 (km)
VY	-1.631407624437537 (km)
VZ	0.142927729144255 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.9: Initial Orbit Parameters (Neptune)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Neptune Mean J2000 Equator
X	-20815.089640681723000 (km)
Y	0.0 (km)
Z	20815.089640681723000 (km)
VX	-1.426423063858300 (km)
VY	-16.281497481173282 (km)
VZ	1.426423063858303 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.10: Initial Orbit Parameters (Pluto)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Pluto Mean J2000 Equator
X	-1067.516740143530600 (km)
Y	0.0 (km)
Z	1067.516740143529700 (km)
VX	-0.075474392886505 (km)
VY	-0.861480838897026 (km)
VZ	0.075474392886505 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.11: Initial Orbit Parameters (Saturn)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Saturn Mean J2000 Equator
X	-47577.347750129338000 (km)
Y	0.0 (km)
Z	47577.347750129360000 (km)
VX	-2.222652848522210 (km)
VY	-25.369834288049386 (km)
VZ	2.222652848522210 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.12: Initial Orbit Parameters (Uranus)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Uranus Mean J2000 Equator
X	-26762.258109447845000 (km)
Y	0.0 (km)
Z	26762.258109447823000 (km)
VX	-1.158158360792704 (km)
VY	-13.219466869135891 (km)
VZ	1.158158360792704 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.13: Initial Orbit Parameters (Venus)

Initial State Parameter	Parameter Value (unit)
Start Time	1 Jun 2004 12:00:00.000 (UTCG)
Stop Time	4 Jun 2004 12:00:00.000 (UTCG)
Coordinate System	Venus Mean J2000 Equator
X	-4832.074380872521000 (km)
Y	0.0 (km)
Z	4832.074380872517400 (km)
VX	-0.645356787452373 (km)
VY	-7.366240195908405 (km)
VZ	0.645356787452373 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	300 (sec)
Report CS/Cb	Same as initial state CS

Table B.14: Initial Orbit Parameters (DeepSpace)

Initial State Parameter	Parameter Value (unit)
Start Time	01 Jan 2000 12:00:00.000 (UTCG)
Stop Time	01 Jan 2001 12:00:00.000 (UTCG)
Central Body	Sun
Coordinate System	Sun Mean J2000 Ecliptic
X	30043412.094803076000000 (km)
Y	143707423.481292670000000 (km)
Z	2198384.040184043300000 (km)
VX	-29.715920923036403 (km)
VY	6.056690472247896 (km)
VZ	0.123271169290614 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Variable
Integrator Init. StepSize	30000 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	30000 (sec)
Report Precision	16 significant figures
Report StepSize	86400 (sec)
Report CS/Cb	Same as initial state CS

Table B.15: Initial Orbit Parameters (EML2)

Initial State Parameter	Parameter Value (unit)
Start Time	23 Jan 2010 00:00:03.999 (UTCG)
Stop Time	6 Feb 2010 00:00:03.999 (UTCG)
Coordinate System	Earth Mean J2000 Equator
X	406326.22661300009 (km)
Y	177458.38761599999 (km)
Z	145838.58078999998 (km)
VX	-0.517274673822 (km)
VY	0.774650366561 (km)
VZ	0.331416602654 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Variable
Integrator Init. StepSize	1200 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	1200 (sec)
Report Precision	16 significant figures
Report StepSize	2400 (sec)
Report CS/Cb	Same as initial state CS

Table B.16: Initial Orbit Parameters (ESL2)

Initial State Parameter	Parameter Value (unit)
Start Time	5 Feb 2006 17:05:48.772 (UTCG)
Stop Time	4 Aug 2006 17:05:48.772 (UTCG)
Coordinate System	Earth Mean J2000 Equator
X	1010800.968074728 (km)
Y	-910963.5377102628 (km)
Z	-295145.6311353027 (km)
VX	0.2642852647102676 (km)
VY	0.286744175490658 (km)
VZ	0.07338744995264675 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	Case dependent
NSG Model	Case dependent
SRP Area	20 (m^2)
SRP	Case dependent
Integration Method	Tool/Program Dependent
Integrator StepSize control	Variable
Integrator Init. StepSize	15000 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	15000 (sec)
Report Precision	16 significant figures
Report StepSize	43200 (sec)
Report CS/Cb	Same as initial state CS

B.2 Calculation Parameter Test Cases

The Cb and CS initial orbit state conditions for the ISS, GEO, Mars1, Mercury1, Moon, Neptune1, Pluto1, Saturn1, Uranus1 and Venus1 test cases are the same as the vales presented in Tables B.1, B.5, B.6- B.13. The only exception is that the Report StepSize is 600 seconds.

Table B.17: Initial Orbit Parameters (Hyperbolic)

Initial State Parameter	Parameter Value (unit)
Coordinate System	Earth Mean J2000 Equator
Start Time	01 Jun 2004 12:00:00.000 (UTCG)
Stop Time	02 Jun 2004 12:00:00.000 (UTCG)
X	12371.791482634855 (km)
Y	5050.7627227610719 (km)
Z	5050.762722761071 (km)
VX	-7.9859921512608487 (km)
VY	2.44520073255755 (km)
VZ	2.4452007325575495 (km)
Mass (No Fuel)	1000 (kg)
Cd	2.2
Cr	1.2
Drag Area	20 (m^2)
Drag Model	None
NSG Model	None
SRP Area	20 (m^2)
SRP	None
Integration Method	Tool/Program Dependent
Integrator StepSize control	Fixed
Integrator Init. StepSize	5 (sec)
Integrator Accuracy	1e-13
Integrator Max. StepSize	5 (sec)
Report Precision	16 significant figures
Report StepSize	600 (sec)
Report CS/Cb	Case Dependent

B.3 Integrator Test Cases

The integrator initial orbit state conditions for the ISS and GEO test cases are the same as the vales presented in Tables B.1 and B.5. The only exception is that each test case uses one of the following Integration Methods: ABM, BS, PD45, PD78, RKF56, RKN68, and RKV89.

B.4 Stopping Condition Test Cases

Refer to Tables 5.2- 5.6 in Chapter 5 for initial orbit state values for the Stopping Condition test cases.

B.5 Libration Point Test Cases

Refer to Tables 6.1- 6.2 in Chapter 6 for initial orbit state values for the Stopping Condition test cases.

B.6 DeltaV Test Cases

Refer to Tables 7.1- 7.4 in Chapter 7 for initial orbit state values for the Performance test cases.

B.7 Performance

Refer to Tables **??**- **??** in Chapter 8 for initial orbit state values for the Performance test cases.

Appendix C

Comparison Scripts Guide

Using specific naming conventions, outlined in this acceptance test plan, and a folder architecture, highlighted below for the test cases, several semi-automated scripts were generated to compare all of the GMAT test case results with other tools. Most of these scripts have the ability to also compare results of older versions of GMAT.

C.1 Folder Architecture

The folder architecture for the files needed for the comparison scripts is presented below:

- GMAT_RegSetup/
  - output/AcceptTest/CompareResults/
    - [Tool1]_[Tool2]
  - input/AcceptTest/
  - output/AcceptTest/[Tool]_reports/
  - output/AcceptTest/Good_reports/
    - FF
    - STK
- GMATDocuments/
  - AcceptTest

C.2 Install Instructions

1. Copy the GMAT_RegSetup and GMATDocuments folders to the same location on your hard drive.
2. Check to make sure the folders listed in Section C.1
3. Make sure the GMAT executable folder has a Matlab folder with the latest GMAT commands and keywords
4. Open Matlab
5. Set the path in Matlab to include the GMAT matlab folder

6. Open GMAT and start the Matlab server
7. Make sure Excel is closed
8. Set current directory to the main GMAT_results/GMAT_scripts folder and then type BuildCompare_GMATteam in the command window or
9. Open one of the following files and run (F5 in Windows):
   Click ok to change the current Matlab directory if prompted
   (a) BuildRun_Script_GMAT.m
   (b) Comparison_Tool1_Tool2_PV.m
   (c) Comparison_Tool1_Tool2_CS.m
   (d) Comparison_Tool1_Tool2_Cb.m
   (e) Comparison_Tool1_Tool2_Libr.m
   (f) Comparison_Integ.m
   (g) Comparison_DeltaV.m
   (h) Comparison_StopCond.m
   (i) TimeComparo.m
   (j) LoopTestSummary.m

C.3 Warnings/Script Hints

- The following scripts were not designed for the user to hit one button, run multiple calculations, and output data without user interaction. User interaction is necessary in all of these scripts.
- The [ ] notation indicates multiple words can be used. For example,[Tool] means replace the bracketed expression with words such as FF,STK, and GMAT.
- As of November 2005, the Excel data created by the comparison scripts will be saved in one file name [Tool1]_[Tool2]_Results_[DD-MMM-YYYY].xls in their respective [Tool1]_[Tool2] folder in the CompareResults folder.
- Be careful adding MATLAB .m files that contain the text GMAT in their file name. These scripts use the text GMAT as an indicator to know if the file is a GMAT compatible script.
- The adherence to the naming conventions are very strict in these scripts. Make sure when adding reports, scripts, or folders to use case sensitive filenames that agree with the naming conventions at all times.
- Several output formats are overwritten when running each script. The Excel documents are saved with the current date as part of the filename. If the filename exists it will be replaced. The same overwriting process occurs with the Matlab .mat files.
- In order to compare old GMAT Builds to one another, a new folder must be created with the date of the GMAT Build. For example, the [Month] [Day] build performed well so after running the scripts that generate all the comparison data for the [Month] [Day] Build, a new folder must be created. The folder can be named YYMMDDGMAT_reports with the appropriate GMAT Build Year Month and Date replacing YYMMDD. Now simply copy the contents of GMAT_reports into YYMMDDGMAT_reports and the data can be used to compare future build of GMAT to one another.
- All the .mat files, except for the TimeComparo files, are formatted in a similar way. They contain the following variables mat_Tool11, mat_Tool21, mat_header, maxDiffs, and diffMat_Tool1_Tool2 or normMat_Tool1_Tool2.

  The mat_header variable contains what parameters each column represents for the other variables The mat_Tool11 and mat_Tool21 variables contain the report file data minus any headers. Tool1 is the alphabetical first tool selected and Tool2 is the other tool selected

- Common mistakes made with these scripts:
  - Adding report files and not following the naming convention (i.e. FF_ISS_Earth_0_0_0 was misnamed as FF_ISS_Earth_0_0).
  - Outputting other tools and not following the proper ordering of parameters for comparison
  - Report files were outputted in the wrong time interval increment
  - Report files were outputted without enough numerical precision. GMAT outputs data at a fixed width of 12 numerical characters (default). Other programs should be the same or better.

C.4 BuildRun_Script_GMAT.m script

Win compatible / Mac & Linux ?

C.4.1 Purpose

This script was designed to send multiple GMAT scripts from Matlab to GMAT to be built and ran. In early versions of GMAT, there was no capability to run multiple scripts, but since current versions of GMAT contain this capability this script is not as vital in the Acceptance test plan.

Its secondary purpose is to record the individual time elapsed to run each test case and output the results to a .mat file for later use.

C.4.2 Inputs

- All .m files located in the GMAT_RegSetup/input/AcceptTest/ folder that follow the GMAT comparison naming convention described in Sections 2.3, 3.2.1, 3.3.1, and 4.2

C.4.3 Outputs

- When choosing to build multiple scripts and the all command is used a mat file is created, which keeps a log of the time it takes to run each case. The script also displays the case name and the time it takes for GMAT to run the file in Matlab's command window.
- Any other output data is dependent on the GMAT script.

C.4.4 Script Algorithm

C.5 Comparison_Tool1_Tool2_PV.m

Win/Mac/Linux compatible

C.5.1 Purpose

This script is used to perform the position and velocity comparisons needed for the Propagator Section (2) of the Acceptance Test Plan. This script takes the normalized position and velocity vector differences between the two selected programs.

C.5.2 Inputs

- Folder to search for files: [$RootFolder$]/[Tool]_reports.
  (Refer to Section 2.3 for the naming convention of these report files.)
- The report files must be formatted the same way. The first column is time (Mod. Julian Date), second-fourth columns are the position vector components (x, y, z), and fifth-seventh columns are the velocity vector components (Vx, Vy, Vz). The data must be separated by spaces.
- Currently the location of the report's first row of numerical data is coded into the script. FreeFlyer is the fourth row, STK is the seventh row, GMAT is the first row, OD toolbox is the first row, and any other tools added will automatically search the first row.

C.5.3 Outputs

- Comparison data is displayed in MATLAB's command window for all test cases.
- Excel documents with comparison data and pass/fail information.
- MATLAB .mat files with comparison data.
- Latex documents with comparison data.

C.5.4 Script Algorithm

- Display welcome message
- Display menu for Tool1 options based on [Tool]_reports folder
- Wait for user to choose tool from menu
  Implement error system for incorrect choice
- Display menu for Tool2 options based on [Tool]_reports folder
- Wait for user to choose tool from menu
  Implement error system for incorrect choice
- Alphabetize Tool1 and Tool2 for naming purposes and rename if necessary
- Store the row location of the first instance of numerical data for both Tools' report files
- Initialize variables and folder locations
- Display a menu of Tool1 ∗.report files
  Generate error report if no ∗.report files are located in [Tool1]_report folder
- Wait for user to choose report comparison option
  Implement error system for incorrect choice
  Open Excel Connection if compare all choice selected
- Display filename, position difference, and velocity difference header
- Begin Loop. Loop once for single comparison and several times for comparing all files.
  - Check the Tool2 folder for the same report
    Display error message if no report found

  - Continue if match found or exit loop if no match found
  - Read both output files and save the data to different matrices
  - Check to see if the row sizes are the same in both matrices
    Display error if row sizes do not match
  - Take difference of both Tools report data
  - Normalize the results based on position and velocity
  - Determine the maximum normalized position and velocity difference
  - Store propagation duration of the test cases in a variable
  - Add acceptable differences values for Excel output
  - Save comparison data to .mat file
    * If compare all reports chosen, format data for output to Latex
    * Use BasicLatexTable script to save data to LaTex file
    * Save comparison results, acceptance errors, and duration to Excel
  - Close Excel connection if open.

- End Loop. Allow user to rerun script

C.6 Comparison_Tool1_Tool2_CS.m

Win/Mac/Linux compatible

C.6.1 Purpose

This script is used to perform the coordinate system dependent comparisons needed for the Calculation Parameters Section (3) of the Acceptance Test Plan. The comparison involves taking the maximum absolute value of the differences of the variables listed in the Inputs section of this help guide.

C.6.2 Inputs

- Folder to search for files: [$RootFolder$]/[Tool]_reports.
  (Refer to Section 3.3.1 for the naming convention of these report files.)
- The report files must be formatted the same way. Time, [$X, Y, andZ$] Position(km), [$X, Y, andZ$] Velocity(km/sec), Mag. of Velocity(km/sec), Right Ascension of Velocity(deg), [$X, Y, andZ$] RxV-Specific Angular Momentum(km^2/sec), Arg. of Perigee(deg), Declination(deg), Declination of Velocity(deg), Inclination(deg), Right Ascension(deg), Right Ascension of Ascending Node(deg)
- Currently the location of the reports first row of numerical data is coded into the script. FreeFlyer is the fourth row, STK is the seventh row, GMAT is the second row, OD toolbox is the first row, and any other tools added will automatically search the first row.

C.6.3 Outputs

- Excel documents with comparison data
- MATLAB .mat files with comparison data
- Latex documents with comparison data

C.6.4 Script Algorithm

- Display welcome message
- Display menu for Tool1 options based on [Tool]_reports folder
- Wait for user to choose tool from menu
  Implement error system for incorrect choice
- Display menu for Tool2 options based on [Tool]_reports folder
- Wait for user to choose tool from menu
  Implement error system for incorrect choice
- Alphabetize Tool1 and Tool2 for naming purposes and rename if necessary
- Store the row location of the first instance of numerical data for both Tools' report files
- Initialize variables and folder locations
- Display a menu of Tool1 ∗.report files
  Generate error report if no ∗.report files are located in [Tool1]_report folder
- Wait for user to choose report comparison option
  Implement error system for incorrect choice
  Open Excel Connection if compare all choice selected
- Display filename, position difference, and velocity difference header
- Begin Loop. Loop once for single comparison and several times for comparing all files.
  - Check the Tool2 folder for the same report
    Display error message if no report found
  - Continue if match found or exit loop if no match found
  - Read both output files and save the data to different matrices
  - Check to see if the row sizes are the same in both matrices
    Display error if row sizes do not match
  - Take difference of both Tools report data
  - Determine the maximum difference for each coordinate system dependent parameter
  - Store propagation duration of the test cases in a variable
  - Save comparison data to .mat file
    - If compare all reports chosen, format data for output to Latex
    - Use BasicLatexTable script to save data to LaTex file
    - Save comparison results, acceptance errors, and duration to Excel
  - Close Excel connection if open.
- End Loop. Allow user to rerun script

C.7 Comparison_Tool1_Tool2_Cb.m

Win/Mac/Linux compatible

C.7.1 Purpose

This script is used to perform the central body dependent comparisons needed for the Calculation Parameters Section (3) of the Acceptance Test Plan. The comparison involves taking the maximum absolute value of the differences of the variables listed in the Inputs section of this help guide.

C.7.2 Inputs

- Folder to search for files: [$RootFolder$]/[$Tool$]_reports.
  (Refer to Section 3.2.1 for the naming convention of these report files.)

- The report files must be formatted the same way. Time, Altitude (km), Beta Angle (deg), C3_Energy (km^2/sec^2), Eccentricity, Latitude (deg), Longitude (deg), (RxV)_Mag (km^2/sec), Mean Anomaly (deg), Mean Motion (rad/sec), Period (sec), Apoapsis Radius (km), Perigee Radius (km), R_Mag (km), Semi-major Axis (km), True Anomaly (deg), Semilatus Rectum(km), Apoapsis Velocity (km/sec), Periapsis Velocity (km/sec), Greenwich Hour Angle(deg), Local Sidereal Time

- Due to the inability of FF and STK tools to output all the parameters listed in the previous bullet, exceptions for FF and STK are built into the code.

  STK: Semilatus Rectum, Apoapsis Velocity, Perigee Velocity, Greenwich Hour Angle, and Local Sidereal Time can not be outputted in the same report file. Out of the aforementioned parameters Greenwich Hour Angle is the only parameter that can be outputted in a separate file. All the other parameters are calculated in MATLAB based on the results STK could generate.

  FF: (RxV)_Mag and R_Mag could not be outputted easily. Instead the [XYZ] components were outputted and the script computes the magnitude of the vectors. Apoapsis Velocity, Periapsis Velocity, and Local Sidereal Time are all created in this script based on available parameters.

  Modifications to the code will need to be made to add a new tool that cannot output all of the central body parameters that GMAT does.

- Currently the location of the reports first row of numerical data is coded into the script. FreeFlyer is the fourth row, STK is the seventh row, GMAT is the second row, OD toolbox is the first row, and any other tools added will automatically search the first row.

C.7.3 Outputs

- Excel documents with comparison data
- MATLAB .mat files with comparison data
- Latex documents with comparison data

C.7.4 Script Algorithm

- Display welcome message
- Display menu for Tool1 options based on [Tool]_reports folder
- Wait for user to choose tool from menu

  Implement error system for incorrect choice

- Display menu for Tool2 options based on [Tool]_reports folder
- Wait for user to choose tool from menu

  Implement error system for incorrect choice
- Alphabetize Tool1 and Tool2 for naming purposes and rename if necessary
- Store the row location of the first instance of numerical data for both Tools' report files
- Initialize variables and folder locations
- Display a menu of Tool1 ∗.report files

  Generate error report if no ∗.report files are located in [Tool1]_report folder
- Wait for user to choose report comparison option

  Implement error system for incorrect choice

  Open Excel Connection if compare all choice selected
- Display filename, position difference, and velocity difference header
- Begin Loop. Loop once for single comparison and several times for comparing all files.
  - Check the Tool2 folder for the same report

    Display error message if no report found
  - Continue if match found or exit loop if no match found
  - Read both output files and save the data to different matrices
  - Check to see if the row sizes are the same in both matrices

    Display error if row sizes do not match
  - Take difference of both Tools report data
  - Code in exceptions for STK, FF, and any other tools that don't output all the desired GMAT central body dependent parameters
  - Determine the maximum difference for each central body dependent parameter
  - Store propagation duration of the test cases in a variable
  - Save comparison data to .mat file
    - If compare all reports chosen, format data for output to Latex
    - Use BasicLatexTable script to save data to LaTex file
    - Save comparison results, acceptance errors, and duration to Excel
  - Close Excel connection if open.
- End Loop. Allow user to rerun script

C.8 Comparison_Tool1_Tool2_Libr.m

Win/Mac/Linux compatible

C.8.1 Purpose

This script is used to perform the position and velocity comparisons needed for the Libration Points Section (6) of the Acceptance Test Plan. This script takes the normalized position and velocity vector differences between the two selected programs.

C.8.2 Inputs

- Folder to search for files: [Root Folder]/[Tool]_reports.
(Refer to Section 6.2 for the naming convention of these report files.)
- The report files must be formatted the same way. The first column is time (Mod. Julian Date), second-fourth columns are the position vector components (x, y, z), and fifth-seventh columns are the velocity vector components (Vx, Vy, Vz). The data must be separated by spaces.
- Currently the location of the report's first row of numerical data is coded into the script. FreeFlyer is the fourth row, STK is the seventh row, GMAT is the first row, OD toolbox is the first row, and any other tools added will automatically search the first row.

C.8.3 Outputs

- Comparison data is displayed in MATLAB's command window for all test cases.
- Excel documents with comparison data and pass/fail information.
- MATLAB .mat files with comparison data.
- Latex documents with comparison data.

C.8.4 Script Algorithm

[INSERT script Algorithm]

C.9 Comparison_Integ.m

Win/Mac/Linux compatible

C.9.1 Purpose

This script is used to perform the integrator comparisons needed for the Integrator Section (4) of the Acceptance Test Plan. The comparison involves taking the difference of the position and velocity vector and then normalizing these two vectors to get the position and velocity difference. This script behaves similar to the Comparison_Tool1_Tool2_PV.m script but the components being varied are the integrators for two body test cases.

C.9.2 Inputs

- Folder to search for files: $[RootFolder]/[Tool]$_reports.
- Naming convention: Integrator_$[Tool]$_$[Trajectory]$_$[IntegratorType]$_2Body.report
- The report files must be formatted the same way. The first column is time, second-fourth columns are the position vector (x,y,z), and fifth-seventh columns are the velocity vector (x,y,z). The data must be separated by spaces.
- Currently the location of the reports' first row of numerical data is coded into the script. FreeFlyer is the fourth row, STK is the seventh row, GMAT is the second row, OD toolbox is the first row, and any other tools added will automatically search the first row.

C.9.3 Outputs

- Excel documents with comparison data into the following folder:
  [$RootFolder$]/CompareResults/[$Tool1$]_[$Tool2$]
- MATLAB .mat files with comparison data into the following folder:
  [$RootFolder$]/CompareResults/[$Tool1$]_[$Tool2$]
- Latex documents with comparison data into the following folder:
  [$RootFolder$]/Latex_Docs

C.9.4 Script Algorithm

- Display welcome message
- Display menu for Tool1 options based on [Tool]_reports folder (Can only be Exact or GMAT folders)
- Wait for user to choose tool from menu
  Implement error system for incorrect choice
- Display menu for Tool2 options based on [Tool]_reports folder (Can only be Exact or GMAT folders)
- Wait for user to choose tool from menu
  Implement error system for incorrect choice
- Alphabetize Tool1 and Tool2 for naming purposes and rename if necessary
- Store the row location of the first instance of numerical data for both Tools' report files
- Initialize variables and folder locations
- Display a menu of Tool1 ∗.report files
  Generate error report if no ∗.report files are located in [Tool1]_report folder
- Wait for user to choose report comparison option
  Implement error system for incorrect choice
  Open Excel Connection if compare all choice selected
- Display filename, position difference, and velocity difference header
- Begin Loop. Loop once for single comparison and several times for comparing all files.
  - Check the Tool2 folder for the same report
    Display error message if no report found
  - Continue if match found or exit loop if no match found
  - Read both output files and save the data to different matrices
  - Check to see if the row sizes are the same in both matrices
    Display error if row sizes do not match
  - Take difference of both Tools report data
  - Normalize the results based on position and velocity
  - Determine the maximum normalized position and velocity difference
  - Store propagation duration of the test cases in a variable
  - Save comparison data to .mat file
    - If compare all reports chosen, format data for output to Latex
    - Use BasicLatexTable script to save data to LaTex file
    - Save comparison results, acceptance errors, and duration to Excel
  - Close Excel connection if open.
- End Loop. Allow user to rerun script

C.10 Comparison_DeltaV.m

Win/Mac/Linux compatible

C.10.1 Purpose

C.10.2 Inputs

C.10.3 Outputs

C.10.4 Script Algorithm

C.11 Comparison_StopCond.m

Win/Mac/Linux compatible

C.11.1 Purpose

C.11.2 Inputs

C.11.3 Outputs

C.11.4 Script Algorithm

C.12 STK_Repropagate.m

Win compatible

C.12.1 Purpose

The STK_Repropagate script was designed to reduce the time it took to generate STK report files, after modifications to the STK scenario were made, and obtain more accurate STK run times. Through STK's connect module Matlab connect with STK and propagates satellites, generates reports, and outputs run times.

C.12.2 Inputs

- STK scenario folders that follow the GMAT Acceptance Test Plan naming convention, in the following folder: [*RootFolder*]/TruthFiles/STK

C.12.3 Outputs

- STK report file saved into [$RootFolder$]/STK_reports.
- Matlab .mat file with the time taken to propagate each satellite.

C.12.4 Script Algorithm

C.13 TimeComparo.m

Win/Mac/Linux compatible

C.13.1 Purpose

When running the BuildRun_Script_GMAT.m script there is an all option after selecting the build & run multiple cases choice. By using this all option, the GMAT performance times for all the test cases are saved to a .mat file. This script uses those saved performance times and, based on a pre-selected amount of test cases, creates a new excel file that contains GMAT, FF, and STK performance times for those pre-selected cases.

C.13.2 Inputs

- Template file containing pre-selected cases: [$RootFolder$]/NonGMATrunTimes.xls
- Folder to search for files: [$RootFolder$]/CompareResults
- Naming convention:
  [$Date$]/_Time2RunAll.mat

C.13.3 Outputs

- Excel document with comparison data

C.13.4 Script Algorithm

Appendix D

STK Setup

The STK setups were very crucial in determining a preliminary standard to compare GMAT to. In the initial stages of the Acceptance Test Plan STK scenarios were obtained from Emergent Space, as mentioned in Section 2.1. These Earth based cases were created in STK-HPOP and modified to provide a setup that was as equivalent to GMAT as was possible. Non-Earth test cases could not be created with STK-HPOP, so STK-Astrogator was used. In order to use STK-Astrogator several Astrogator elements needed to be created. Section D.4 details all the elements needed for the non-Earth STK test cases.

D.1 Support Files Needed

All alterations to STK scenarios were performed with STK 6.1 on the desktop machine described in the Performance Section (Section 8.1).

In order to duplicate data generated by STK for this Acceptance Test Plan, the same files presented in Table D.1 are needed.

Table D.1: STK support files

Filename(s)	File('s) and/or Folder('s) Location	Information in Section
EOP.dat	[STK Root Directory]\DynamicEarthData	2.2.1
EOP.dat.all	[STK Root Directory]\DynamicEarthData	2.2.1
All planetary cb files	[STK Root Directory]\STKData\CentralBodies	2.2.2
Non-spherical grav (nsg) files	[STK Root Directory]\STKData\CentralBodies	2.3
Report Styles	[STK individual user folder]\Config\Styles	D.5
Non-Earth Astrogator Elements	[STK Root Directory]\STKData\Astrogator	D.4
Leap Seconds File	[STK Root Directory]\STKData\Astro	2.2.2

D.2 STK modules used

Refer to Appendix B for a easy initial orbit state format to use as input into STK. Table D.2 displays the STK module to use in order to duplicate the results seen in theis Acceptance Test Plan document.

Table D.2: STK modules used

Test Cases	Test Group(s)	STK-type
ISS, GEO, SunSync, Molniya, GPS, Hyperbolic	Propagator, Cb, CS	STK-HPOP
DeepSpace, EML2, ESL2, All non-Earth cases	Propagator	STK-Astrogator
ISS, GEO	Integrator	STK-2Body

D.3 Scenario Setup

The following are guidelines we followed when creating STK Scenarios, excluding HPOP or Astrogator specific guidelines:

- Initial Scenario Epoch is the same as the satellite epoch
- Make sure all support files (Table D.1) are present and match the information in this document.
- *.cb planetary files need to contain the values in Tables 2.5, 2.7, and 2.9
- Remember the Modified Julian Date used in GMAT and STK are different.
  (i.e. UTC_GMAT_ModJulian = UTC_STK_ModJulian + 29999.5)

D.3.1 HPOP

- Planetary information should be taken from the JPL DE file
- Satellite properties must be consistent with table the values in Table 2.5

[INSERT Screen captures of HPOP]

D.3.2 STK

- All Astrogator support files (Table D.1) are essential in reproducing the values in this document.
- Make sure the maximum propagation is greater than the test case propagation duration or turn off the feature in STK.

[INSERT Screen captures of Astrogator]

D.4 Astrogator Elements

For the non-Earth cases a large number of Astrogator elements were created in order to compare STK to GMAT's results.

D.4.1 Calculation Objects: Cartesian Elements

Vx_EarthMJ2000Ec
Vx_EarthMODEc
Vx_EarthMODEq
Vx_EarthMOEEc
Vx_EarthMOEEq
Vx_EarthTODEc
Vx_EarthTODEq
Vx_EarthTOEEc
Vx_EarthTOEEq
Vy_EarthMJ2000Ec
Vy_EarthMODEc
Vy_EarthMODEq
Vy_EarthMOEEc
Vy_EarthMOEEq
Vy_EarthTODEc
Vy_EarthTODEq
Vy_EarthTOEEc
Vy_EarthTOEEq
Vz_EarthMJ2000Ec
Vz_EarthMODEc
Vz_EarthMODEq
Vz_EarthMOEEc
Vz_EarthMOEEq
Vz_EarthTODEc
Vz_EarthTODEq
Vz_EarthTOEEc
Vz_EarthTOEEq
Vx_Mars_Centered_Mean_J2000_Earth_Ec
Vx_Mars_Centered_Mean_J2000_Earth_Eq
Vy_Mars_Centered_Mean_J2000_Earth_Ec
Vy_Mars_Centered_Mean_J2000_Earth_Eq
Vz_Mars_Centered_Mean_J2000_Earth_Ec
Vz_Mars_Centered_Mean_J2000_Earth_Eq
Vx_MarsFixed
Vy_MarsFixed
Vz_MarsFixed
Vx_Mercury_Centered_Mean_J2000_Earth_Ec
Vx_Mercury_Centered_Mean_J2000_Earth_Eq
Vy_Mercury_Centered_Mean_J2000_Earth_Ec
Vy_Mercury_Centered_Mean_J2000_Earth_Eq
Vz_Mercury_Centered_Mean_J2000_Earth_Ec
Vz_Mercury_Centered_Mean_J2000_Earth_Eq
Vx_MercuryFixed
Vy_MercuryFixed
Vz_MercuryFixed
Vx_Neptune_Centered_Mean_J2000_Earth_Ec
Vx_Neptune_Centered_Mean_J2000_Earth_Eq
Vy_Neptune_Centered_Mean_J2000_Earth_Ec
Vy_Neptune_Centered_Mean_J2000_Earth_Eq
Vz_Neptune_Centered_Mean_J2000_Earth_Ec
Vz_Neptune_Centered_Mean_J2000_Earth_Eq
Vx_NeptuneFixed
Vy_NeptuneFixed
Vz_NeptuneFixed
Vx_Pluto_Centered_Mean_J2000_Earth_Ec
Vx_Pluto_Centered_Mean_J2000_Earth_Eq
Vy_Pluto_Centered_Mean_J2000_Earth_Ec
Vy_Pluto_Centered_Mean_J2000_Earth_Eq
Vz_Pluto_Centered_Mean_J2000_Earth_Ec
Vz_Pluto_Centered_Mean_J2000_Earth_Eq
Vx_PlutoFixed
Vy_PlutoFixed
Vz_PlutoFixed
Vx_Saturn_Centered_Mean_J2000_Earth_Ec
Vx_Saturn_Centered_Mean_J2000_Earth_Eq
Vy_Saturn_Centered_Mean_J2000_Earth_Ec
Vy_Saturn_Centered_Mean_J2000_Earth_Eq
Vz_Saturn_Centered_Mean_J2000_Earth_Ec
Vz_Saturn_Centered_Mean_J2000_Earth_Eq
Vx_SaturnFixed
Vy_SaturnFixed
Vz_SaturnFixed
Vx_Sun_Centered_Mean_J2000_Earth_Ec
Vx_Sun_Centered_Mean_J2000_Earth_Eq
Vy_Sun_Centered_Mean_J2000_Earth_Ec
Vy_Sun_Centered_Mean_J2000_Earth_Eq
Vz_Sun_Centered_Mean_J2000_Earth_Ec
Vz_Sun_Centered_Mean_J2000_Earth_Eq
Vx_SunFixed
Vy_SunFixed
Vz_SunFixed
Vx_Uranus_Centered_Mean_J2000_Earth_Ec
Vx_Uranus_Centered_Mean_J2000_Earth_Eq
Vy_Uranus_Centered_Mean_J2000_Earth_Ec
Vy_Uranus_Centered_Mean_J2000_Earth_Eq
Vz_Uranus_Centered_Mean_J2000_Earth_Ec
Vz_Uranus_Centered_Mean_J2000_Earth_Eq
Vx_UranusFixed
Vy_UranusFixed
Vz_UranusFixed

Vx_Moon_Centered_Mean_J2000_Earth_Ec
Vx_Moon_Centered_Mean_J2000_Earth_Eq
Vy_Moon_Centered_Mean_J2000_Earth_Ec
Vy_Moon_Centered_Mean_J2000_Earth_Eq
Vz_Moon_Centered_Mean_J2000_Earth_Ec
Vz_Moon_Centered_Mean_J2000_Earth_Eq
Vx_MoonFixed
Vy_MoonFixed
Vz_MoonFixed
X_EarthGSE
Y_EarthGSE
Z_EarthGSE
Vx_EarthGSE
Vy_EarthGSE
Vz_EarthGSE
Vx_Venus_Centered_Mean_J2000_Earth_Ec
Vx_Venus_Centered_Mean_J2000_Earth_Eq
Vy_Venus_Centered_Mean_J2000_Earth_Ec
Vy_Venus_Centered_Mean_J2000_Earth_Eq
Vz_Venus_Centered_Mean_J2000_Earth_Ec
Vz_Venus_Centered_Mean_J2000_Earth_Eq
Vx_VenusFixed
Vy_VenusFixed
Vz_VenusFixed
X_EarthGSM
Y_EarthGSM
Z_EarthGSM
Vx_EarthGSM
Vy_EarthGSM
Vz_EarthGSM

D.4.2 Calculation Objects: Geodetic Elements

Altitude_Mars
Latitude_Mars
Longitude_Mars
Altitude_Mercury
Latitude_Mercury
Longitude_Mercury
Altitude_Moon
Latitude_Moon
Longitude_Moon
Altitude_Neptune
Latitude_Neptune
Longitude_Neptune
Altitude_Pluto
Latitude_Pluto
Longitude_Pluto
Altitude_Saturn
Latitude_Saturn
Longitude_Saturn
Altitude_Uranus
Latitude_Uranus
Longitude_Uranus
Altitude_Venus
Latitude_Venus
Longitude_Venus

D.4.3 Calculation Objects: Keplerian Elements

Argument_of_Periapsis_(fixed)
Argument_of_Periapsis_(MJ2000Ec)
Argument_of_Periapsis_(MODEc)
Argument_of_Periapsis_(MOEEc)
Argument_of_Periapsis_(MOEEq)
Argument_of_Periapsis_(TODEc)
Argument_of_Periapsis_(TOEEc)
Argument_of_Periapsis_(TOEEq)
Argument_of_Periapsis_(EarthGSE)
Argument_of_Periapsis_(EarthGSM)
Argument_of_Periapsis_(MarsFixed)
Argument_of_Periapsis_(MarsMJ2000Ec)
Argument_of_Periapsis_Mars_(MJ2000Eq)
Argument_of_Periapsis_(MercuryFixed)
Argument_of_Periapsis_(MercuryMJ2000Ec)
Argument_of_Periapsis_Mercury_(MJ2000Eq)
Argument_of_Periapsis_(MoonFixed)
Argument_of_Periapsis_(MoonMJ2000Ec)
Argument_of_Periapsis_Moon_(MJ2000Eq)
Argument_of_Periapsis_(NeptuneFixed)
Argument_of_Periapsis_(NeptuneMJ2000Ec)
Argument_of_Periapsis_Neptune_(MJ2000Eq)
Argument_of_Periapsis_(PlutoFixed)
Argument_of_Periapsis_(PlutoMJ2000Ec)
Argument_of_Periapsis_Pluto_(MJ2000Eq)
Argument_of_Periapsis_(SaturnFixed)
Argument_of_Periapsis_(SaturnMJ2000Ec)
Argument_of_Periapsis_Saturn_(MJ2000Eq)
Argument_of_Periapsis_(UranusFixed)
Argument_of_Periapsis_(UranusMJ2000Ec)
Argument_of_Periapsis_Uranus_(MJ2000Eq)
Argument_of_Periapsis_(VenusFixed)
Argument_of_Periapsis_(VenusMJ2000Ec)
Argument_of_Periapsis_Venus_(MJ2000Eq)
Eccentricity_Mars
Eccentricity_Mercury
Eccentricity_Moon
Eccentricity_Neptune
Eccentricity_Pluto
Eccentricity_Saturn
Eccentricity_Uranus
Eccentricity_Venus

Inclination_(fixed)
Inclination_(MJ2000Ec)
Inclination_(MODEc)
Inclination_(MOEEc)
Inclination_(MOEEq)
Inclination_(TODEc)
Inclination_(TOEEc)
Inclination_(TOEEq)
Inclination_(EarthGSE)
Inclination_(EarthGSM)
Inclination_(MarsFixed)
Inclination_(MarsMJ2000Ec)
Inclination_Mars_(MJ2000Eq)
Inclination_(MercuryFixed)
Inclination_(MercuryMJ2000Ec)
Inclination_Mercury_(MJ2000Eq)
Inclination_(MoonFixed)
Inclination_(MoonMJ2000Ec)
Inclination_Moon_(MJ2000Eq)
Inclination_(NeptuneFixed)
Inclination_(NeptuneMJ2000Ec)
Inclination_Neptune_(MJ2000Eq)
Inclination_(PlutoFixed)
Inclination_(PlutoMJ2000Ec)
Inclination_Pluto_(MJ2000Eq)
Inclination_(SaturnFixed)
Inclination_(SaturnMJ2000Ec)
Inclination_Saturn_(MJ2000Eq)
Inclination_(UranusFixed)
Inclination_(UranusMJ2000Ec)
Inclination
Inclination_(VenusFixed)
Inclination_(VenusMJ2000Ec)
Inclination_Venus_(MJ2000Eq)
Mean_Motion_Mars
Mean_Motion_Mercury
Mean_Motion_Moon
Mean_Motion_Neptune
Mean_Motion_Pluto
Mean_Motion_Saturn
Mean_Motion_Uranus
Mean_Motion_Venus

Orbit_Period_Mars
Orbit_Period_Mercury
Orbit_Period_Moon
Orbit_Period_Neptune
Orbit_Period_Pluto
Orbit_Period_Saturn
Orbit_Period_Uranus
Orbit_Period_Venus
RAAN_(fixed)
RAAN_(MJ2000Ec)
RAAN_(MODEc)
RAAN_(MOEEc)
RAAN_(MOEEq)
RAAN_(TODEc)
RAAN_(TOEEc)
RAAN_(TOEEq)
RAAN_(MarsFixed)
RAAN_(MarsMJ2000Ec)
RAAN_Mars_(MJ2000Eq)
RAAN_(MercuryFixed)
RAAN_(MercuryMJ2000Ec)
RAAN_Mercury_(MJ2000Eq)
RAAN_(MoonFixed)
RAAN_(MoonMJ2000Ec)
RAAN_Moon_(MJ2000Eq)
RAAN_(NeptuneFixed)
RAAN_(NeptuneMJ2000Ec)
RAAN_Neptune_(MJ2000Eq)
RAAN_(PlutoFixed)
RAAN_(PlutoMJ2000Ec)
RAAN_Pluto_(MJ2000Eq)
RAAN_(SaturnFixed)
RAAN_(SaturnMJ2000Ec)
RAAN_Saturn_(MJ2000Eq)
RAAN_(UranusFixed)
RAAN_(UranusMJ2000Ec)
RAAN_Uranus_(MJ2000Eq)
RAAN_(VenusFixed)
RAAN_(VenusMJ2000Ec)
RAAN_Venus_(MJ2000Eq)
Radius_Of_Apoapsis_Mars
Radius_Of_Apoapsis_Mercury
Radius_Of_Apoapsis_Moon
Radius_Of_Apoapsis_Neptune
Radius_Of_Apoapsis_Pluto
Radius_Of_Apoapsis_Saturn
Radius_Of_Apoapsis_Uranus
Radius_Of_Apoapsis_Venus
Radius_Of_Periapsis_Mars
Radius_Of_Periapsis_Mercury
Radius_Of_Periapsis_Moon
Radius_Of_Periapsis_Neptune
Radius_Of_Periapsis_Pluto
Radius_Of_Periapsis_Saturn
Radius_Of_Periapsis_Uranus
Radius_Of_Periapsis_Venus
Semimajor_Axis_Mars
Semimajor_Axis_Mercury
Semimajor_Axis_Moon
Semimajor_Axis_Neptune
Semimajor_Axis_Pluto
Semimajor_Axis_Saturn
Semimajor_Axis_Uranus
Semimajor_Axis_Venus
True_Anomaly_Mars
True_Anomaly_Mercury
True_Anomaly_Moon
True_Anomaly_Neptune
True_Anomaly_Pluto
True_Anomaly_Saturn
True_Anomaly_Uranus
True_Anomaly_Venus
RAAN_(EarthGSE)
RAAN_(EarthGSM)

D.4.4 Calculation Objects: Other Orbit Elements

Beta_Angle_Mars
Beta_Angle_Mercury
Beta_Angle_Moon
Beta_Angle_Neptune
Beta_Angle_Pluto
Beta_Angle_Saturn
Beta_Angle_Uranus
Beta_Angle_Venus

D.4.5 Calculation Objects: Target Vector Elements

C3_Energy_Mars
C3_Energy_Mercury
C3_Energy_Moon
C3_Energy_Neptune
C3_Energy_Pluto
C3_Energy_Saturn
C3_Energy_Uranus
C3_Energy_Venus

D.4.6 Calculation Objects: Spherical Elements

Declination_(EarthGSE)
Declination_(EarthGSM)
Declination_(MJ2000Ec)
Declination_(MODEc)
Declination_(MOEEc)
Declination_(MOEEq)
Declination_(MarsFixed)
Declination_(MarsMJ2000Ec)
Declination_(MercuryFixed)
Declination_(MercuryMJ2000Ec)
Declination_(MoonFixed)
Declination_(MoonMJ2000Ec)
Declination_(NeptuneFixed)
Declination_(NeptuneMJ2000Ec)
Declination_(PlutoFixed)
Declination_(PlutoMJ2000Ec)
Declination_(SaturnMJ2000Ec)
Declination_(SaturnsFixed)
Declination_(TODEc)
Declination_(TOEEc)
Right_Asc_(MercuryMJ2000Ec)
Right_Asc_(MoonFixed)
Right_Asc_(MoonMJ2000Ec)
Right_Asc_(NeptuneFixed)
Right_Asc_(NeptuneMJ2000Ec)
Right_Asc_(PlutoFixed)
Right_Asc_(PlutoMJ2000Ec)
Right_Asc_(SaturnFixed)
Right_Asc_(SaturnMJ2000Ec)
Right_Asc_(TODEc)
Right_Asc_(TOEEc)
Right_Asc_(TOEEq)
Right_Asc_(UranusFixed)
Right_Asc_(UranusMJ2000Ec)
Right_Asc_(VenusFixed)
Right_Asc_(VenusMJ2000Ec)
Right_Asc_Mars_(MJ2000Eq)
Right_Asc_Mercury_(MJ2000Eq)
Right_Asc_Moon_(MJ2000Eq)
Right_Asc_Neptune_(MJ2000Eq)

Declination_(TOEEq)
Declination_(UranusFixed)
Declination_(UranusMJ2000Ec)
Declination_(VenusFixed)
Declination_(VenusMJ2000Ec)
Declination_Mars_(MJ2000Eq)
Declination_Mercury_(MJ2000Eq)
Declination_Moon_(MJ2000Eq)
Declination_Neptune_(MJ2000Eq)
Declination_Pluto_(MJ2000Eq)
Declination_Saturn_(MJ2000Eq)
Declination_Uranus_(MJ2000Eq)
Declination_Venus_(MJ2000Eq)
R_Mag_(MarsFixed)
R_Mag_(MercuryFixed)
R_Mag_(MoonFixed)
R_Mag_(NeptuneFixed)
R_Mag_(PlutoFixed)
R_Mag_(SaturnFixed)
R_Mag_(UranusFixed)
R_Mag_(VenusFixed)
R_Mag_Mars
R_Mag_Mercury
R_Mag_Moon
R_Mag_Neptune
R_Mag_Pluto
R_Mag_Saturn
R_Mag_Uranus
R_Mag_Venus
R_Mag_(EarthGSE)
R_Mag_(EarthGSM)
Right_Asc_(MJ2000Ec)
Right_Asc_(MODEc)
Right_Asc_(MOEEc)
Right_Asc_(MOEEq)
Right_Asc_(MarsFixed)
Right_Asc_(MarsMJ2000Ec)
Right_Asc_(MercuryFixed)
Right_Asc_(EarthGSM)
Right_Asc_Pluto_(MJ2000Eq)
Right_Asc_Saturn_(MJ2000Eq)
Right_Asc_Uranus_(MJ2000Eq)
Right_Asc_Venus_(MJ2000Eq)
V_Mag_(MJ2000Ec)
V_Mag_(MODEc)
V_Mag_(MOEEc)
V_Mag_(MOEEq)
V_Mag_(MarsFixed)
V_Mag_(MarsMJ2000Ec)
V_Mag_(MercuryFixed)
V_Mag_(MercuryMJ2000Ec)
V_Mag_(MoonFixed)
V_Mag_(MoonMJ2000Ec)
V_Mag_(NeptuneFixed)
V_Mag_(NeptuneMJ2000Ec)
V_Mag_(PlutoFixed)
V_Mag_(PlutoMJ2000Ec)
V_Mag_(SaturnMJ2000Ec)
V_Mag_(SaturnsFixed)
V_Mag_(TODEc)
V_Mag_(TOEEc)
V_Mag_(TOEEq)
V_Mag_(UranusFixed)
V_Mag_(UranusMJ2000Ec)
V_Mag_(VenusFixed)
V_Mag_(VenusMJ2000Ec)
V_Mag_Mars_(MJ2000Eq)
V_Mag_Mercury_(MJ2000Eq)
V_Mag_(EarthGSE)
V_Mag_(EarthGSM)
V_Mag_Moon_(MJ2000Eq)
V_Mag_Neptune_(MJ2000Eq)
V_Mag_Pluto_(MJ2000Eq)
V_Mag_Saturn_(MJ2000Eq)
V_Mag_Uranus_(MJ2000Eq)
V_Mag_Venus_(MJ2000Eq)
Right_Asc_(EarthGSE)

D.4.7 Calculation Objects: Vector Elements

(RxV)_Mag
(RxV)_Mag_(MarsFixed)
(RxV)_Mag_(MarsMJ2000)
(RxV)_Mag_(MarsMJ2000Ec)
(RxV)_Mag_(MercuryFixed)
(RxV)_Mag_(MercuryMJ2000)
(RxV)_Mag_(MercuryMJ2000Ec)
(RxV)_Mag_(MoonFixed)
(RxV)_Mag_(MoonMJ2000)
(RxV)_Mag_(MoonMJ2000Ec)
(RxV)_Mag_(NeptuneFixed)
(RxV)_Mag_(NeptuneMJ2000)
(RxV)_Mag_(NeptuneMJ2000Ec)
(RxV)_Mag_(PlutoFixed)
(RxV)_Mag_(PlutoMJ2000)
(RxV)_Mag_(PlutoMJ2000Ec)
(RxV)_Mag_(SaturnFixed)
(RxV)_Mag_(SaturnMJ2000)
(RxV)_Mag_(SaturnMJ2000Ec)
(RxV)_Mag_(UranusFixed)
(RxV)_Mag_(UranusMJ2000)
(RxV)_Mag_(UranussMJ2000Ec)
(RxV)_Mag_(VenusFixed)
(RxV)_Mag_(VenusMJ2000)
(RxV)_Mag_(VenusMJ2000Ec)
(RxV)_X
(RxV)_X_(Fixed)
(RxV)_X_(MJ2000Ec)
(RxV)_X_(MODEc)
(RxV)_X_(MODEq)
(RxV)_X_(MOEEq)
(RxV)_X_(MarsFixed)
(RxV)_X_(MarsMJ2000Ec)
(RxV)_X_(MarsMJ2000Eq)
(RxV)_X_(MercuryFixed)
(RxV)_X_(MercuryMJ2000Ec)
(RxV)_X_(MercuryMJ2000Eq)
(RxV)_X_(MoonFixed)
(RxV)_X_(MoonMJ2000Ec)
(RxV)_X_(MoonMJ2000Eq)
(RxV)_X_(NeptuneFixed)
(RxV)_X_(NeptuneMJ2000Ec)
(RxV)_X_(NeptuneMJ2000Eq)
(RxV)_X_(PlutoFixed)
(RxV)_X_(PlutoMJ2000Ec)
(RxV)_X_(PlutoMJ2000Eq)
(RxV)_X_(SaturnFixed)
(RxV)_X_(SaturnMJ2000Ec)
(RxV)_X_(SaturnMJ2000Eq)
(RxV)_X_(EarthGSE)
(RxV)_Y_(EarthGSE)
(RxV)_Z_(EarthGSE)
EarthGSM_Position_X
(RxV)_Z_(MOEEq)
(RxV)_Z_(MarsFixed)
(RxV)_Z_(MarsMJ2000Ec)
(RxV)_Z_(MarsMJ2000Eq)
(RxV)_Z_(MercuryFixed)
(RxV)_Z_(MercuryMJ2000Ec)
(RxV)_Z_(MercuryMJ2000Eq)
(RxV)_Z_(MoonFixed)
(RxV)_Z_(MoonMJ2000Ec)
(RxV)_Z_(MoonMJ2000Eq)
(RxV)_Z_(NeptuneFixed)
(RxV)_Z_(NeptuneMJ2000Ec)
(RxV)_Z_(NeptuneMJ2000Eq)
(RxV)_Z_(PlutoFixed)
(RxV)_Z_(PlutoMJ2000Ec)
(RxV)_Z_(PlutoMJ2000Eq)
(RxV)_Z_(SaturnFixed)
(RxV)_Z_(SaturnMJ2000Ec)
(RxV)_Z_(SaturnMJ2000Eq)
(RxV)_Z_(TODEc)
(RxV)_Z_(TODEq)
(RxV)_Z_(TOEEc)
(RxV)_Z_(TOEEq)
(RxV)_Z_(UranusFixed)
(RxV)_Z_(UranusMJ2000Ec)
(RxV)_Z_(UranusMJ2000Eq)
(RxV)_Z_(VenusFixed)
(RxV)_Z_(VenusMJ2000Ec)
(RxV)_Z_(VenusMJ2000Eq)
(RxV)_X_(MOEEc)
Vector_Dec_(Fixed)
Vector_Dec_(MJ2000Ec)
Vector_Dec_(MODEc)
Vector_Dec_(MODEq)
Vector_Dec_(MOEEc)
Vector_Dec_(MOEEq)
Vector_Dec_(MarsFixed)
Vector_Dec_(MarsMJ2000Ec)
Vector_Dec_(MarsMJ2000Eq)
Vector_Dec_(MercuryFixed)
Vector_Dec_(MercuryMJ2000Ec)
Vector_Dec_(MercuryMJ2000Eq)
Vector_Dec_(MoonFixed)
Vector_Dec_(MoonMJ2000Ec)
Vector_Dec_(MoonMJ2000Eq)
Vector_Dec_(NeptuneFixed)
Vector_Dec_(NeptuneMJ2000Ec)
Vector_Dec_(NeptuneMJ2000Eq)
(RxV)_Z_(MOEEc)
(RxV)_X_(EarthGSM)
(RxV)_Y_(EarthGSM)
(RxV)_Z_(EarthGSM)
EarthGSM_Velocity_X

EarthGSM_Position_Y
EarthGSM_Position_Z
Vector_Dec_(EarthGSE)
Vector_RA_(EarthGSE)
Vector_Dec_(PlutoFixed)
Vector_Dec_(PlutoMJ2000Ec)
Vector_Dec_(PlutoMJ2000Eq)
Vector_Dec_(SaturnFixed)
Vector_Dec_(SaturnMJ2000Ec)
Vector_Dec_(SaturnMJ2000Eq)
Vector_Dec_(TODEc)
Vector_Dec_(TODEq)
Vector_Dec_(TOEEc)
Vector_Dec_(TOEEq)
Vector_Dec_(UranusFixed)
Vector_Dec_(UranusMJ2000Ec)
Vector_Dec_(UranusMJ2000Eq)
Vector_Dec_(VenusFixed)
Vector_Dec_(VenusMJ2000Ec)
Vector_Dec_(VenusMJ2000Eq)
Vector_RA_(Fixed)
Vector_RA_(MJ2000Ec)
Vector_RA_(MODEc)
Vector_RA_(MODEq)
Vector_RA_(MOEEc)
Vector_RA_(MOEEq)
Vector_RA_(MarsFixed)
Vector_RA_(MarsMJ2000Ec)
Vector_RA_(MarsMJ2000Eq)
Vector_RA_(MercuryFixed)
Vector_RA_(MercuryMJ2000Ec)
Vector_RA_(MercuryMJ2000Eq)
Vector_RA_(MoonFixed)
Vector_RA_(MoonMJ2000Ec)
Vector_RA_(MoonMJ2000Eq)
Vector_RA_(NeptuneFixed)
Vector_RA_(NeptuneMJ2000Ec)
Vector_RA_(NeptuneMJ2000Eq)
Vector_RA_(PlutoFixed)
Vector_RA_(PlutoMJ2000Ec)
Vector_RA_(PlutoMJ2000Eq)
Vector_RA_(SaturnFixed)
Vector_RA_(SaturnMJ2000Ec)
Vector_RA_(SaturnMJ2000Eq)
Vector_RA_(TODEc)
Vector_RA_(TODEq)
Vector_RA_(TOEEc)
Vector_RA_(TOEEq)
Vector_RA_(UranusFixed)
Vector_RA_(UranusMJ2000Ec)
Vector_RA_(UranusMJ2000Eq)
Vector_RA_(VenusFixed)
Vector_RA_(VenusMJ2000Ec)
Vector_RA_(VenusMJ2000Eq)
EarthGSM_Velocity_Y
EarthGSM_Velocity_Z
Vector_Dec_(EarthGSM)
Vector_RA_(EarthGSM)
(RxV)_X_(TODEc)
(RxV)_X_(TODEq)
(RxV)_X_(TOEEc)
(RxV)_X_(TOEEq)
(RxV)_X_(UranusFixed)
(RxV)_X_(UranusMJ2000Ec)
(RxV)_X_(UranusMJ2000Eq)
(RxV)_X_(VenusFixed)
(RxV)_X_(VenusMJ2000Ec)
(RxV)_X_(VenusMJ2000Eq)
(RxV)_Y
(RxV)_Y_(Fixed)
(RxV)_Y_(MJ2000Ec)
(RxV)_Y_(MODEc)
(RxV)_Y_(MODEq)
(RxV)_Y_(MOEEc)
(RxV)_Y_(MOEEq)
(RxV)_Y_(MarsFixed)
(RxV)_Y_(MarsMJ2000Ec)
(RxV)_Y_(MarsMJ2000Eq)
(RxV)_Y_(MercuryFixed)
(RxV)_Y_(MercuryMJ2000Ec)
(RxV)_Y_(MercuryMJ2000Eq)
(RxV)_Y_(MoonFixed)
(RxV)_Y_(MoonMJ2000Ec)
(RxV)_Y_(MoonMJ2000Eq)
(RxV)_Y_(NeptuneFixed)
(RxV)_Y_(NeptuneMJ2000Ec)
(RxV)_Y_(NeptuneMJ2000Eq)
(RxV)_Y_(PlutoFixed)
(RxV)_Y_(PlutoMJ2000Ec)
(RxV)_Y_(PlutoMJ2000Eq)
(RxV)_Y_(SaturnFixed)
(RxV)_Y_(SaturnMJ2000Ec)
(RxV)_Y_(SaturnMJ2000Eq)
(RxV)_Y_(TODEc)
(RxV)_Y_(TODEq)
(RxV)_Y_(TOEEc)
(RxV)_Y_(TOEEq)
(RxV)_Y_(UranusMJ2000Ec)
(RxV)_Y_(UranusMJ2000Eq)
(RxV)_Y_(UranussFixed)
(RxV)_Y_(VenusFixed)
(RxV)_Y_(VenusMJ2000Ec)
(RxV)_Y_(VenusMJ2000Eq)
(RxV)_Z
(RxV)_Z_(Fixed)
(RxV)_Z_(MJ2000Ec)
(RxV)_Z_(MODEc)
(RxV)_Z_(MODEq)

D.4.8 Coordinate Systems: Central Body Inertial Elements

Mars_Centered_Mean_J2000
Mercury_Centered_Mean_J2000
Moon_Centered_Mean_J2000
Neptune_Centered_Mean_J2000
Pluto_Centered_Mean_J2000
Saturn_Centered_Mean_J2000
Uranus_Centered_Mean_J2000
Venus_Centered_Mean_J2000
Sune_Centered_MJ2000Ec
Mars_Centered_MJ2000Ec
Mercury_Centered_MJ2000Ec
Moon_Centered_MJ2000Ec
Neptune_Centered_MJ2000Ec
Pluto_Centered_MJ2000Ec
Saturn_Centered_MJ2000Ec
Uranus_Centered_MJ2000Ec
Venus_Centered_MJ2000Ec

D.4.9 Propagators Elements

Moon_LP165P
CisLunar
EarthMoon_L2_AllPlanets
EarthMoon_L2_AllPlanets_and_SRP
EarthMoon_L2_ESM
EarthMoon_L2_ESM_JGM
EarthMoon_L2_ESM_LP165P
EarthSun_L2_AllPlanets
EarthSun_L2_AllPlanets_and_SRP
Earth_J2
Earth_Point_Mass
Heliocentric
Lunar
Mars_2-Body
Mars_AllPlanets
Mars_MARS50C
Mars_MARS50C_and_SRP
Mars_SRP
Mercury_2-Body
Mercury_AllPlanets
Mercury_SRP
Moon_2-Body
Moon_LP165P_and_SRP
Moon_SRP
Neptune_2-Body
Neptune_AllPlanets
Neptune_SRP
Pluto_2-Body
Pluto_AllPlanets
Pluto_SRP
Saturn_2-Body
Saturn_AllPlanets
Saturn_SRP
Sun_AllPlanets
Sun_AllPlanets_and_SRP
Uranus_2-Body
Uranus_AllPlanets
Uranus_SRP
Venus_2-Body
Venus_AllPlanets
Venus_MGNP180U
Venus_MGNP180U_and_SRP
Venus_SRP
Moon_AllPlanets

D.4.10 Axes Elements

Earth_GSE Earth_GSM

D.4.11 Coordinate System Elements

Earth_GSE Earth_GSM

D.4.12 Vectors Elements

Cross_Product_(RxV)
Cross_Product_(RxV)_(fixed)
Cross_Product_(RxV)_(MarsFixed)
Cross_Product_(RxV)_(MarsMJ2000)
Cross_Product_(RxV)_(MarsMJ2000Ec)
Cross_Product_(RxV)_(MercuryFixed)
Cross_Product_(RxV)_(MercuryMJ2000)
Cross_Product_(RxV)_(MercuryMJ2000Ec)
Cross_Product_(RxV)_(MoonFixed)
Cross_Product_(RxV)_(MoonMJ2000)
Cross_Product_(RxV)_(MoonMJ2000Ec)
Cross_Product_(RxV)_(NeptuneFixed)
Cross_Product_(RxV)_(NeptuneMJ2000)
Cross_Product_(RxV)_(NeptuneMJ2000Ec)
Cross_Product_(YofGSM)
EarthSun_J2K_Velocity
DiPole_Vector_GSM
Cross_Product_(RxV)_(PlutoFixed)
Cross_Product_(RxV)_(PlutoMJ2000)
Cross_Product_(RxV)_(PlutoMJ2000Ec)
Cross_Product_(RxV)_(SaturnFixed)
Cross_Product_(RxV)_(SaturnMJ2000)
Cross_Product_(RxV)_(SaturnMJ2000Ec)
Cross_Product_(RxV)_(UranusFixed)
Cross_Product_(RxV)_(UranusMJ2000)
Cross_Product_(RxV)_(UranusMJ2000Ec)
Cross_Product_(RxV)_(VenusFixed)
Cross_Product_(RxV)_(VenusMJ2000)
Cross_Product_(RxV)_(VenusMJ2000Ec)
Cross_Product_(RxV)_(EarthGSE)
Cross_Product_(RxV)_(EarthGSM)
Cross_Product_(ZofGSE)
EarthSun_Vector

D.4.13 Vectors: Vehicle Local Elements

Position_(MarsFixed)
Position_(MarsMJ2000Ec)
Position_(MercuryFixed)
Position_(MercuryMJ2000Ec)
Position_(MoonFixed)
Position_(MoonMJ2000Ec)
Position_(NeptuneFixed)
Position_(NeptuneMJ2000Ec)
Position_(PlutoFixed)
Position_(PlutoMJ2000Ec)
Position_(SaturnFixed)
Position_(SaturnMJ2000Ec)
Position_(UranusFixed)
Position_(UranusMJ2000Ec)
Position_(VenusFixed)
Position_(VenusMJ2000Ec)
Position_Mars_(MJ2000)
Position_Mercury_(MJ2000)
Position_Moon_(MJ2000)
Position_Neptune_(MJ2000)
Position_Saturn_(MJ2000)
Position_Uranus_(MJ2000)
Position_Venus_(MJ2000)
Position_(EarthGSE)
Position_(EarthGSM)
Velocity_(MarsFixed)
Velocity_(MarsMJ2000Ec)
Velocity_(MercuryFixed)
Velocity_(MercuryMJ2000Ec)
Velocity_(MoonFixed)
Velocity_(MoonMJ2000Ec)
Velocity_(NeptuneFixed)
Velocity_(NeptuneMJ2000Ec)
Velocity_(PlutoFixed)
Velocity_(PlutoMJ2000Ec)
Velocity_(SaturnFixed)
Velocity_(SaturnMJ2000Ec)
Velocity_(UranusFixed)
Velocity_(UranusMJ2000Ec)
Velocity_(VenusFixed)
Velocity_(VenusMJ2000Ec)
Velocity_Mars_(MJ2000)
Velocity_Mercury_(MJ2000)
Velocity_Moon_(MJ2000)
Velocity_Neptune_(MJ2000)
Velocity_Saturn_(MJ2000)
Velocity_Uranus_(MJ2000)
Velocity_Venus_(MJ2000)
Velocity_(EarthGSE)
Velocity_(EarthGSM)

D.5 Report Styles

Classical_Orbit_Elements
Earth_MJ2000_Position_Velocity
GMAT_Apoapsis_Periapsis
GMAT_CSParameters_Fixed
GMAT_CSParameters_MJ2000Ec
GMAT_CSParameters_MJ2000Eq
GMAT_CSParameters_MODEc
GMAT_CSParameters_MODEq
GMAT_CbParameters
GMAT_CbParameters_Mars
GMAT_CSParameters_MOEEq
GMAT_CSParameters_MarsFixed
GMAT_CSParameters_Mars_MJ2000Ec
GMAT_CSParameters_Mars_MJ2000Eq
GMAT_CSParameters_MercuryFixed
GMAT_CSParameters_Mercury_MJ2000Ec
GMAT_CSParameters_Mercury_MJ2000Eq
GMAT_CSParameters_MoonFixed
GMAT_CSParameters_Moon_MJ2000Ec
GMAT_CSParameters_Moon_MJ2000Eq
GMAT_CSParameters_NeptuneFixed
GMAT_CSParameters_Neptune_MJ2000Ec
GMAT_CSParameters_Neptune_MJ2000Eq
Pluto_MJ2000_Position_Velocity
Saturn_MJ2000_Position_Velocity
Sun_MJ2000Ec_Position_Velocity
Sun_MJ2000_Position_Velocity
Uranus_MJ2000_Position_Velocity
Venus_MJ2000_Position_Velocity
Greenwich_Hour_Angle
GMAT_CSParameters_TODEq
GMAT_CSParameters_TOEEc
GMAT_CSParameters_TOEEq
GMAT_CSParameters_UranusFixed
GMAT_CSParameters_Uranus_MJ2000Ec
GMAT_CSParameters_Uranus_MJ2000Eq
GMAT_CSParameters_VenusFixed
GMAT_CSParameters_Venus_MJ2000Ec
GMAT_CSParameters_Venus_MJ2000Eq
GMAT_CSParameters_MOEEc
GMAT_CbParameters_Mercury
GMAT_CbParameters_Moon
GMAT_CbParameters_Neptune
GMAT_CbParameters_Pluto
GMAT_CbParameters_Saturn
GMAT_CbParameters_Uranus
GMAT_CbParameters_Venus
J2000_ECI_Position_Velocity
Mars_MJ2000_Position_Velocity
Mercury_MJ2000_Position_Velocity
Moon_MJ2000_Position_Velocity
Neptune_MJ2000_Position_Velocity
GMAT_CSParameters_PlutoFixed
GMAT_CSParameters_Pluto_MJ2000Ec
GMAT_CSParameters_Pluto_MJ2000Eq
GMAT_CSParameters_SaturnFixed
GMAT_CSParameters_Saturn_MJ2000Ec
GMAT_CSParameters_Saturn_MJ2000Eq
GMAT_CSParameters_TODEc

D.6 Scripts Used

The main script used with STK is the STK_Repropagate.m Matlab script. STK_Repropagate.m connects to STK, propagates satellites in the scenario, generates reports, and outputs performance run times. The STK_Repropagate script was designed to reduce the time it took to generate STK report files, after modifications to the STK scenario were made, and obtain accurate STK run times.

Refer to Appendix C for more details of this script and others used in the Acceptance Test Plan document.

Appendix E

FF Setup

[INSERT explanation of how the FF scenarios were setup]

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