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Accuracy in orbital propagation: A comparison of predictive software models

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THESIS

ACCURACY IN ORBITAL PROPAGATION: A COMPARISON OF PREDICTIVE SOFTWARE MODELS

by

Christopher F. Wildt

June 2017

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ACCURACY IN ORBITAL PROPAGATION: A COMPARISON OF PREDICTIVE SOFTWARE MODELS

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ABSTRACT

Current analytical satellite vulnerability planning in the U.S. Space Surveillance System is reliant on two orbital propagators, PPT3 and SGP4, both of which have a foundation in similar theory. Since their first operational use, both propagators have incorporated updated theory and mathematical techniques to model additional forces in the space environment, causing their calculation methods to diverge over time. The aggregate effects of these diverging mathematical techniques cause calculation differences for perturbations of an orbit over time, resulting in differences in future predicted positions from PPT3 and SGP4, as well as differences in their accuracy. The atmospheric model within each propagator is determined to be the most effective component of each propagator to test, as the theoretical atmospheric drag calculation methods of PPT3 and SGP4 differ greatly. PPT3 and SGP4 both perform well within the expected accuracy limits inherent with analytical models, with neither propagator demonstrating an accuracy rate decay that was significantly better or worse than the other. Compared to ground truth observations, both propagators demonstrate decreased accuracy for satellites under greater effects from atmospheric drag, i.e., satellites that are closer to the Earth. Satellite vulnerability planning with these propagators should therefore utilize the most current TLE data available to avoid accuracy errors.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFSPC SMC	Air Force Space Command, Space and Missile Systems Center
CME	coronal mass ejection
COE	classic orbital elements
CTU	canonical time unit
FK4	Fundamental Katalog 4
GEO	geosynchronous orbit
GHA	Greenwich hour angle
GPS	Global Positioning System
GSD	ground sample distance
HEO	highly elliptical orbit
ICBM	intercontinental ballistic missiles
IMINT	imagery intelligence
ISS	International Space Station
J2000	Julian 2000
JFCC Space	Joint Functional Component Command for Space
LEO	low Earth orbit
MEO	medium Earth orbit
NAVSPASUR	Naval Space Surveillance System
NORAD	North American Aerospace Defense Command
NPS	Naval Postgraduate School
NSSCC	National Space Surveillance Control Center
NSWC	Naval Surface Warfare Center
PNT	position, navigation, and timing
PPT3	Position and Partials as functions of Time 3
RAAN	right ascension of the ascending node
SAR	synthetic aperture radar
SATVUL	satellite vulnerability planning
SGP4	Simplified General Perturbations 4
SIGINT	signals intelligence

SMA	semimajor axis
TLE	two line element
UTC	universal coordinated time
WGS72	World Geodetic Survey 72

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I. INTRODUCTION TO ASTRODYNAMICS

This chapter reviews mankind's historical scientific curiosity and progress in the area of astrodynamics, summarizing how we advanced from concerns in religion and agriculture to a scientific community capable of easily and accurately predicting orbits. General terms for describing orbits and orbital regimes are also reviewed in order to build a foundation for discussing perturbation of these terms by natural forces in later chapters.

A. THE HISTORY OF ASTRODYNAMICS

From ancient societies to the modern era, our fascination with the movement of celestial bodies has driven observers to quantify this motion with mathematics, ultimately refining our understanding and evolving in technical sophistication and accuracy over time.

1. Ancient Origin

Astrodynamics, "the study of the motion of man-made objects in space, subject to both natural and artificially induced forces," [1] has a history spanning thousands of years. Human understanding of orbital mechanics and astrodynamics originated in astrology and astronomy, as ancient cultures observed patterns in the sun and moon [2]. These early observers and philosophers sought to devise methods of recording time and explaining the nature of the universe around them. Though much of this early discovery was far from purely scientific, the methods and observations of the time would shape the science and mathematics still in use in modern orbital mechanics [3].

Astronomy and astrology began in Mesopotamia, where societies were concerned with the survival of their crops and a religious belief that celestial bodies would impact their fortunes and misfortunes [4]. Chaldean astronomers in Mesopotamia utilized observation of the lunar cycle and mathematics to determine an accurate lunar month. This lead to the creation of the first calendars in ancient society, allowing farmers to predict seasons and ensure that their crops were planted and harvested during the most advantageous times of the year. In addition, the Chaldeans are credited with determining the Saros cycle [4], which accurately predicts the recurrence of eclipses. The cultural and religious impact of eclipses in ancient civilization was enormous, which makes the ability to predict them incredibly significant [2].

Chaldean observations and charts heavily influenced Thales of Miletus (c. 640-546 B.C.), who gained early fame by predicting eclipses, and would go on to be one of the founders of Greek philosophy and astronomy [4]. He was the first Greek to teach that the Earth was both spherical and tilted on its axis, and is credited as the first person to determine the length of a year. This work would also influence Pythagoras (569-470 B.C.), who taught that the Earth rotates and revolves around the sun, and that comets also revolve around the sun [4].

The works of Euclid (c. 330-275 B.C.) and Hipparchus (c. 161-126 B.C.) led to the development of the conic sections and spherical trigonometry still used in calculating and describing orbits today [4]. Hipparchus also made observations that led to his theories about orbital motion, but the elliptical orbits he observed conflicted with religious beliefs at the time; the Greeks believed that the heavens were perfect and circles were perfect and therefore elliptical orbits should not exist in the heavens [2].

Unfortunately, the last word on orbital mechanics from antiquity came from Ptolemy (100-170 A.D.). Though he faithfully continued much of Hipparchus' work and is credited with observing the evection[1] of the moon by the sun throughout its orbit (given the time period, an incredible discovery about the effects of gravity from multiple bodies on an obit), his published works put the Earth at the center of the universe. After the fall of Rome, this view would go virtually unchallenged for over thirteen centuries [2].

[1] A term in orbital mechanics for the stretching of an orbit, causing it to become more elliptical.

2. The Renaissance

The rebirth of astronomy and start of astrodynamics came toward the end of the fifteenth century, when the Renaissance spread to Germany and allowed Nicholas Copernicus (1473-1543) to explore his own detailed observations of orbital motion [2]. Despite the accuracy of his sun-centric theory, as well as its satisfying explanation for the irregular motion of the outer planets of the solar system from Earth, Copernicus' controversial work would not be published until very near the time of his death. However, his theory would be essential to providing future astronomers with a simpler and more accurate model for celestial orbital mechanics [2].

The next great leap in astrodynamics resulted from Johann Kepler's (1571-1630) work for Emperor Rudolph II as his imperial mathematician [4]. Kepler was left with a tremendous amount of observational data after the death of his predecessor, Tycho Brahe (1546-1601). Though Brahe still held a geo-centric view of the solar system, his recorded data were so precise that Kepler was able to develop his three laws of planetary motion and finally give the world an accurate model of planetary motion:

1. The orbit of each planet is an ellipse with the Sun at one focus.
2. The line joining the planet to the Sun sweeps out equal areas in equal times.
3. The square of the period of a planet is proportional to the cube of its mean distance to the Sun. [2]

With Kepler's theories in place, Sir Isaac Newton (1642-1747) unlocked the mathematical mechanics of physical motion, and published three laws in *Principia Mathematica* in 1687:

1. Every body continues in its state of rest, or of uniform motion in a right [straight] line, unless it is compelled to change that state by forces impressed upon it.
2. The change of motion is proportional to the motive force impressed and is made in the direction of the right line in which that force is impressed.

3. To every action there is always opposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal and directed to contrary parts. [2]

Newton also revealed to the world why celestial bodies have orbital motion: gravitation. Newton's Law of Universal Gravitation, is expressed as

$$F_g = \frac{Gm_1m_2}{R^2}$$

where

F_G = the force due to gravity (in Newtons, N)
R = the distance between the two bodies (in meters, m)
m_1, m_2 = the mass of the two bodies (in kilograms, kg)
G = the universal gravitational constant $\left(\approx 6.67\times10^{-11}\, N\, m^2 / kg^2\right)$.

This gravitational force is what continually accelerates an orbiting body (a satellite) back toward the elliptical focus of its orbital path (the Earth), and prevents it from continuing in a straight line. The combination of Kepler's Laws and Newton's Laws forms the basis of the modern understanding of orbits and astrodynamics [5].

B. CHARACTERIZING ORBITS

This section introduces terms that describe physical characteristics of orbits, such as size, shape, and orientation. Additionally, common orbital regimes are introduced to give context to these terms, which are referred to later in this thesis.

1. Classic Orbital Elements

With a basic understanding of Newton's laws of mechanics and universal gravitation, as well as Kepler's laws of planetary motion, it is actually possible to begin predicting the orbital path of a satellite [5]. Given a satellite's position in time, the magnitude and direction of its velocity, and the gravitational parameter[2]

2 A simplification of Newton's law of universal gravitation. The gravitational parameter, μ, is the product of Newton's gravitational constant, G ($\approx 6.67 \times 10^{-11} Nm^2/kg^2$) and the mass of the much larger object or planet (Earth) that the satellite is orbiting.

of the central body of the orbit (Earth), a simple, two-dimensional path can be determined by disregarding all of the external forces that exist in space. Unfortunately, while this “restricted two-body problem” provides an accessible approach to modeling orbital mechanics, it is too simple a model to be accurate over time [5].

Earth’s shape, non-uniform distribution of mass, and atmosphere, as well as solar radiation pressure and the gravitation of the sun and the moon, all exert force on an orbiting spacecraft [5]. Recalling Newton’s laws of mechanics, these forces must be considered in any model of an orbit; otherwise, the accuracy of the model will deteriorate rapidly over time. Additionally, these forces are not uniform for any position in space; a set of terms, or elements, is therefore required in order to describe the orbital path and position of the satellite in three dimensions. These classic orbital elements (COEs) provide a clear description of the size, shape, and orientation of the orbit, as well as the satellite’s position within that orbit, so that a predictive model can account for the varying forces that act on a satellite as it moves through its orbital path.

a. Semimajor Axis

The first COE is the size of the orbit, known as its semimajor axis, or a (shown in Figure 1). In an elliptical orbit, this is half of the distance across the long axis of the ellipse. The semimajor axis can be calculated using observations of its closest point to Earth, perigee, and its furthest point from earth, apogee. Adding the Earth’s radius to the altitudes of these observed points gives a radius of perigee, R_p, and a radius of apogee, R_a. The semimajor axis is then calculated by taking the mean of these radii, or $a = \frac{R_a + R_p}{2}$. A circular orbit is a

The mass of the satellite is considered negligible, because the force on Earth’s center of gravity by a satellite in orbit, even a massive space station like the International Space Station (ISS), only amounts to $[(4.19 \times 10^5 kg)(6.67 \times 10^{-11} Nm^2/kg^2)]/(6.78 \times 10^6 m)^2 = 6.08 \times 10^{-19} N$, resulting in a center of gravity between the satellite and Earth of $4 \times 10^{-13} m$ from the Earth’s center of gravity. Thus $F_g = Gm_1m_2/R^2$ reduces to $F_g = Gm_{Earth}m_{Satellite}/R^2 \rightarrow F = ma \rightarrow a_g = (\mu \times m_{Satellite})/(R^2 \times m_{Satellite}) = \mu/R^2$ [38].

special case where R_p and R_a are equal, and are therefore both equal to the semimajor axis.

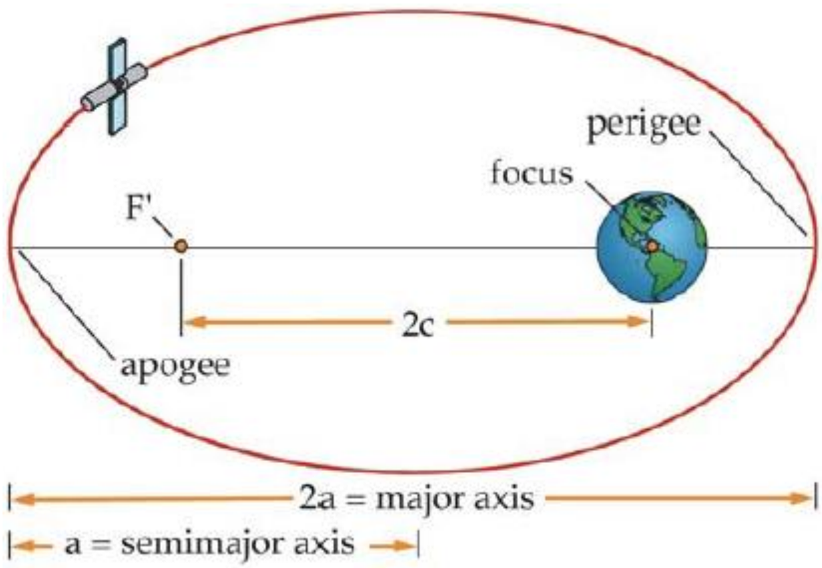


Figure 1. Illustration of the Semimajor Axis, *a*.
Source: [5].

b. Eccentricity

The second COE is the shape of the orbit, known as its *eccentricity*, or *e*. Eccentricity is the ratio of the distance between the foci of the ellipse and the total distance between R_p and R_a, or $e = \frac{R_a - R_p}{R_a + R_p}$. Put simply, this ratio expresses the shape of the orbit in terms of roundness. As the distance between the foci decreases to zero (F' and the focus in Figure 1), the ratio also decreases to zero, which results in a perfect circle. Another way to define this relationship for elliptical orbits is with $e = 1 - \frac{R_p}{a} = \frac{R_a}{a} - 1$, which highlights the special circular case: when $R_a = a = R_p$, then $\frac{R_p}{a} = \frac{R_a}{a} = 1$ and therefore, eccentricity is equal to zero for all circles [6]. The eccentricity for all ellipses then falls between zero and one.[3]

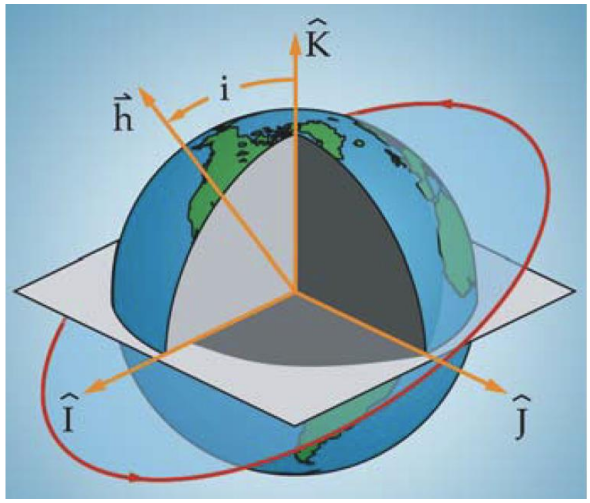
c. *Inclination*

The third COE relates to the orientation of the orbit, and is known as its *inclination*, or *i*. In three-dimensional space, inclination is the tilt of the orbital path relative to the Earth's equator (see Figure 2). This angular tilt is important because Earth's *oblateness*, the compression of its mass which results in the planet being wider along the equator, has varying gravitational effects on satellites according to their inclination. Orbits can be further classified as *equatorial* $(i = 0°)$, *polar* $(i = 90°)$, *prograde* $(0° \le i < 90°)$, or *retrograde* $(90° < i \le 180°)$ [4], depending on the inclination of the orbit [5].

[3] There are also specific orbits for which eccentricity is one (parabolic) and greater than one (hyperbolic), but these orbits define the closed orbit boundary and orbital velocity necessary to achieve escape velocity, respectively, and begin interplanetary travel. Interplanetary orbits are beyond the scope of this thesis.

[4] In a prograde orbit, the satellite revolves around the Earth in the same direction as the Earth's rotation. In a retrograde orbit, the satellite revolves around the Earth in the opposite direction of the Earth's rotation [5].

[5].



Inclination is the tilt of the orbital path relative to the Earth's equator. Though this illustration shows that angle relative to $\hat{K}$ (the z axis in three-dimensional space), this axis is orthogonal to $\hat{I}$ and $\hat{J}$ (the x and y axes, respectively), making the angle equal to one measured relative to the Earth's equator [5].

Figure 2. Illustration of Inclination, *i.*
Source: [5].

d. Right Ascension of the Ascending Node

The fourth COE also relates to the orientation of the orbit, and is known as the *right ascension of the ascending node* (RAAN), or Ω. Despite the complex name, RAAN is simply the "swivel" of the orbit's plane around Earth's polar axis, relative to a fixed direction with respect to distant stars. This is measured with an angle around the equator, $0° \le \Omega < 360°$, which begins at the *vernal equinox*[5] and is recorded at the point on the equator where the satellite transitions from the southern hemisphere to the northern hemisphere, as shown in Figure 3 [6].

[5] Also known as the first point of Ares, this is a reference line from the Earth to the Sun, which is drawn at the vernal equinox each year, for reference. It serves as a similar reference to the Prime Meridian on Earth, but does not change as the Earth rotates and orbits around the Sun [5].

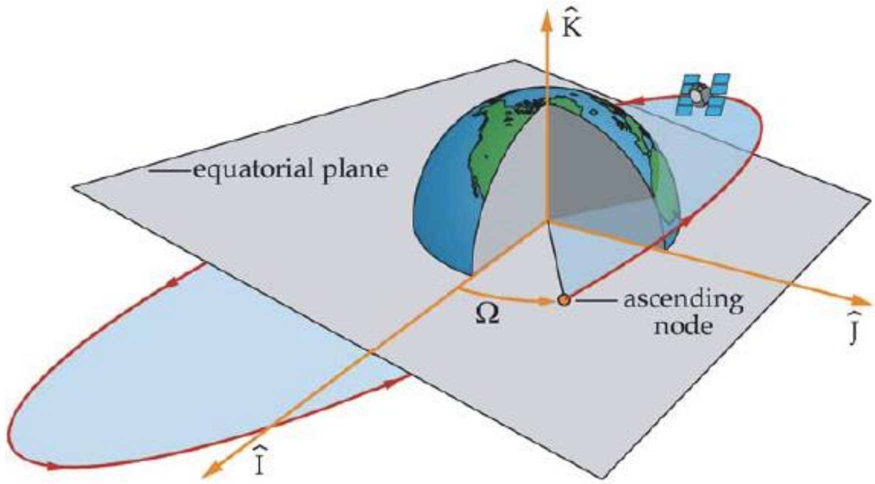


Figure 3. Illustration of Right Ascension of the Ascending Node, Ω. Source: [5].

e. Argument of Perigee

The fifth COE relates to the orientation of an orbit as well, but differs slightly. Known as the *argument of perigee*, or *ω*, this measurement describes another "swivel" of the orbit, but is oriented on the orbital plane itself, rather than the plane of the Earth's equator. As shown in Figure 4, this is measured with an angle around the orbital path, $0° \leq \omega < 360°$, beginning with the orbit's ascending node (from RAAN) and ending at perigee, the closest point of the orbital path to Earth. Put simply, an orbit which is closest to Earth at the instant it crosses the equator from the southern hemisphere has an argument of perigee of $0°$ [6]. In the case of a circular orbit, argument of perigee is assumed to be $0°$, in order to avoid complications [7].

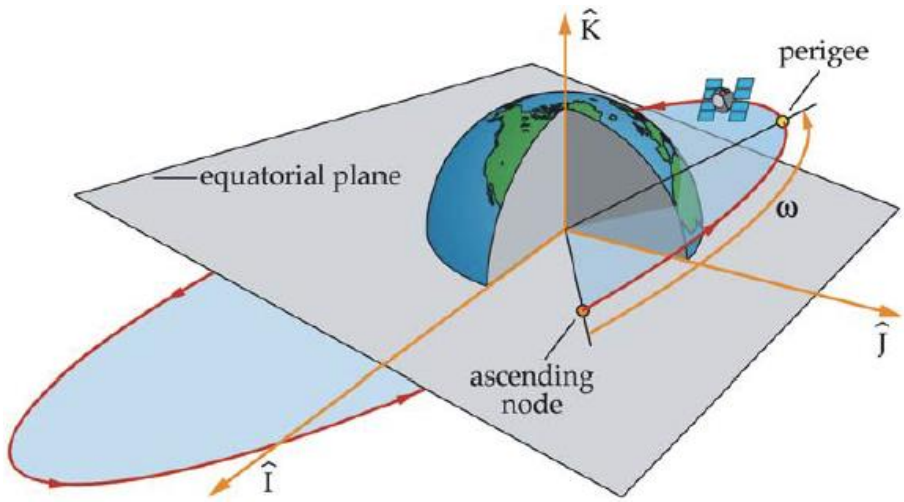


Figure 4. Illustration of Argument of Perigee, ω.
Source: [5].

f. True Anomaly

The sixth and final COE describes to the satellite's position within the orbit at a given time, and is known as the *true anomaly*, or v. As with argument of perigee, true anomaly is measured with an angle around the orbital path, $0° \leq v < 360°$, but it begins at the perigee of the orbit and ends at the current position of the satellite at the instant the measurement is taken, as shown in Figure 5 [6].

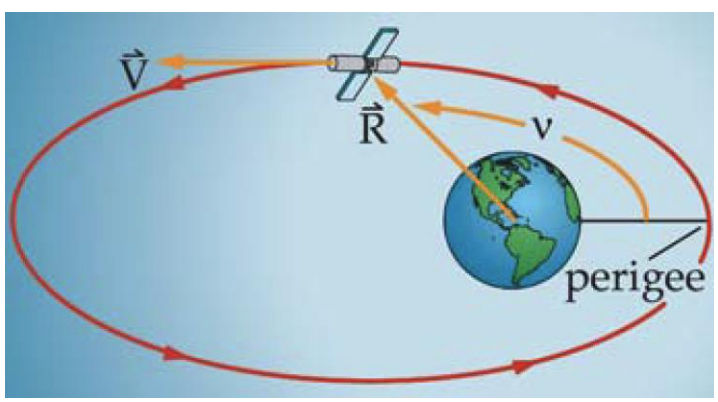


Figure 5. Illustration of True Anomaly, v.
Source: [5].

2. Common Orbital Regimes

Common orbits fall into generalized categories, based on altitude and shape, that allow them to be easily grouped and described. Each regime experiences varying magnitudes of the natural forces that occur in the space environment [8], and therefore contain unique challenges for mathematical modeling.

a. Low Earth Orbit

Low Earth orbit (LEO) is the lowest altitude common orbital regime. Satellites in LEO typically orbit the Earth between 160 to 2,000 kilometers altitude, achieving 10 to 15 revolutions per day [9]. Satellites at these lower altitudes have particular advantages for imaging missions: optical sensors benefit from decreased range to their targets, allowing for higher resolution imagery without overly large mirrors[6] and synthetic aperture radar (SAR) sensors benefit from decreased range to their targets, allowing greater power efficiency.[7] The predominant forces that must be accounted for when modeling satellites at lower altitudes are atmospheric drag and gravitational variation from the non-uniform mass distribution and shape of the Earth [6].

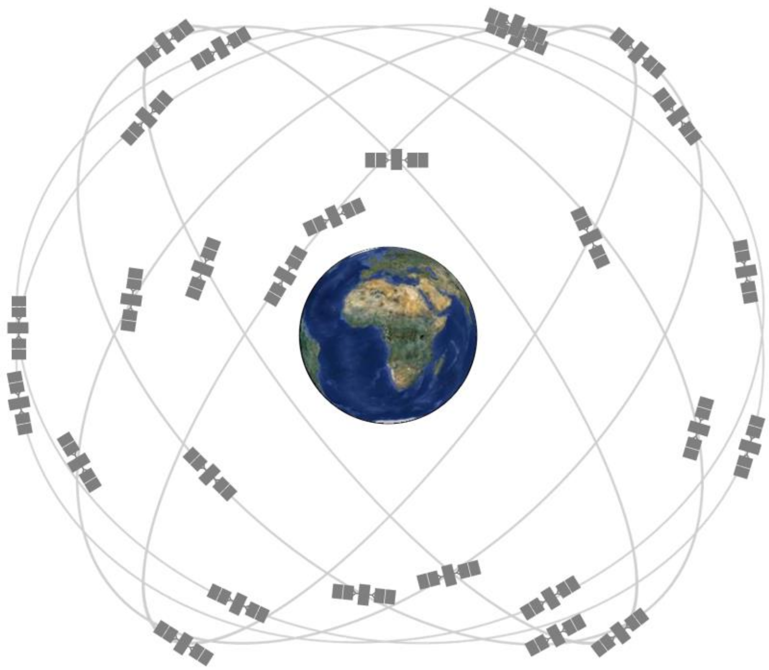
b. Medium Earth Orbit

Medium Earth orbit (MEO) is a higher altitude common orbital regime. Satellites orbit the Earth between 2,000 to 30,000 kilometers altitude, achieving 2

[6] Ground sample distance (GSD), or the ground distance between pixels in a remotely sensed image, is a measure of the capability of a space or airborne optic to resolve objects (a smaller GSD will resolve smaller objects on the ground, providing more detailed images) [37]. Driven by the Rayleigh criterion, GSD in the visible spectrum of light is calculated with $GSD = 1.22(\lambda/a)R$, where $\lambda = 5 \times 10^{-7} m$ is the midpoint for visible light, a is the diameter of the mirror in the optic in meters, and *R* is the range to the ground. The trade space is then mirror size or range to achieve a desired GSD, and range has a much larger practical impact on lowering GSD [37].

[7] A Radar's ability to detect a target depends on the returned power it receives from its illuminated target. This is calculated by $P_{Received} = P_{Transmitted} \times (1/4\pi R^2)^{\,2} \times G_{Antenna} \times A_{Antenna} \times \sigma$, where P is power, G is antenna gain, A is the area of the antenna, σ is the cross-sectional area of the target, and R is the range to the target. The $(1/R^2)^2 = 1/R^4$ term dominates this equation, and therefore determines the power requirement of the space or airborne radar [37].

to 10 revolutions per day [9]. Satellites in circular orbits in MEO are generally used for broadcasting position, navigation, and timing (PNT) signals (GPS, GLONASS, BeiDou, COMPASS, and Galileo all utilize MEO orbits [10]) because the altitude allows for constellation designs that keep at least 4 satellites in view of a location on the Earth at all times, as shown in Figure 6. The predominant forces that must be accounted for when modeling satellites at MEO are gravitation from the Moon and the Sun, solar radiation pressure, and gravitational variation from the mass and shape of the Earth [6].



GPS Satellites orbit at an altitude of 20,200 kilometers, which allows 4 satellites from the constellation to be in view of a location on Earth as each satellite continuously revolves around the Earth.

Figure 6. The GPS Constellation. Source: [11].

c. Geosynchronous Orbit

Geosynchronous orbit (GEO) is a much higher altitude common orbital regime. Satellites in GEO orbit the Earth at low inclinations and around 35,786 kilometers altitude, achieving 1 revolution per sidereal day.[8] Because of this, satellites in this orbital regime are able to match the angular velocity of the Earth's rotation, so they appear to "hover" over one location on the Earth. GEO orbits are primarily used for high throughput communications satellites and missile warning sensors because of the stability and Earth coverage available in the GEO belt [9]. The predominant forces that must be accounted for when modeling satellites at GEO are gravitation from the mass of the Earth, gravitation from the Moon and the Sun, and solar radiation pressure [6].

d. Highly Elliptical Orbit

Highly elliptical orbit (HEO) is both a high and low altitude orbital regime, passing through LEO, MEO, and GEO altitudes during each revolution of the Earth. Satellites in HEO generally orbit the Earth at 63.4 degrees inclination because this inclination nullifies the perturbation of the argument of perigee by the J2 effect of the Earth’s gravity, which will be discussed in Chapter II. These orbits are termed highly elliptical because their perigee altitudes fall between 500 to 1,000 kilometers and their apogee altitudes fall between 39,000 to 70,000 kilometers, resulting in eccentricity values between 0.741 and 0.825. These high inclination and apogee values allow satellites in HEO orbits to “dwell” over the Northern Hemisphere for 10 hours or more per orbit, providing communications and missile warning to the high latitudes that GEO orbits cannot cover [9]. The predominant forces that must be accounted for when modeling satellites in HEO orbits are atmospheric drag, gravitational variation from the mass and shape of the Earth, gravitation from the Moon and the Sun, and solar radiation pressure [6].

[8] A sidereal day is the length of time the Earth takes to complete one full rotation relative to the stars, which is actually 23 hours, 56 minutes, 4.1 seconds. A solar day is 24 hours because the Earth is revolving around the sun during that time, requiring another 4 minutes to complete a rotation relative to the sun [5].

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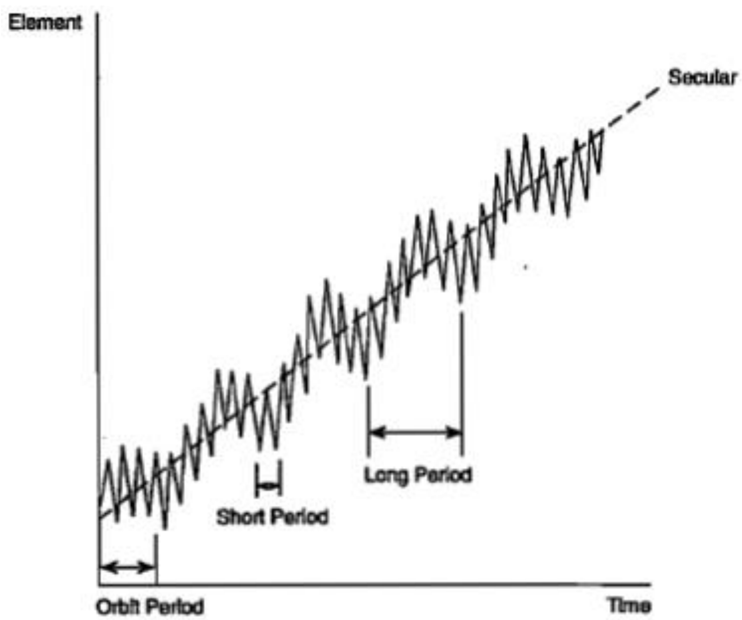
II. MODELING ORBITAL PERTURBATIONS

This chapter reviews the various forces acting on a satellite in orbit, and their perturbing effects on the orbital path of that satellite. In addition, general information on the mathematical methods for modelling these effects, as well as a description of the various types of propagators that employ these methods, is presented.

A. VARIATIONS OF ORBITAL ELEMENTS

Moving beyond the "restricted two-body problem" and toward modeling reality, Kepler's simplified methods for calculating orbital elements break down because of the additional forces acting on a satellite in orbit [5]. These *perturbations* result in *short period*, *long period* and *secular* variations of the orbital elements over time (examples of these are shown in Figure 7) [6]. The simplest of these are secular variations to the orbital elements, which represent a best fit linear approximation of accumulative short and long period effects over time. Though lower in accuracy over time, secular effects are much simpler to calculate, and provide a quick solution to an orbital prediction problem. In addition, perturbations can be calculated using *special perturbation* methods, which use the more complex equations of motion to numerically calculate variable forces acting on velocity and position of the satellite, or *general perturbation* methods, which apply effects to all the orbital elements over time and integrate these effects to generate a future predicted position and velocity [6]. This thesis focuses on orbital models that apply general perturbation methods to calculate secular variations of the orbital elements of a satellite in order to predict its position and velocity at a future time of interest.



Secular variations of orbital elements represent a linear approximation of the accumulated short and long term variations over time. Short period variations take place during a period less than the orbital period, whereas long period variations have a period greater than the orbital period.

Figure 7. Periodic and Secular Variations.
Source: [6].

B. GRAVITATIONAL VARIATIONS CAUSED BY THE NONSPHERICAL EARTH

Unfortunately for modeling purposes, the Earth is not the homogenous sphere that it appears in images from space; it is 22 kilometers wider at the equator than the poles, has a slight pear shape in the Southern Hemisphere, and is flatter at the poles [12] [6]. Because of this variation in shape and mass, the Earth is split into several independent components for modeling, each with a geopotential coefficient that modifies how the model calculates the forces acting on a satellite [13]. Examples of the most prominent of these coefficients are

$J_2 = 0.00108263$ [9]
$J_3 = -0.00000254$
$J_4 = -0.00000161$ [6].

[9] The J2 perturbation is by far the most impactful force; it is roughly 1000 times greater than the others [5].

The subscripted notation in each coefficient relates to the Legendre polynomial [14] that corresponds to the calculation of each variation in gravitational acceleration, which is found by taking the gradient of the geopotential function:

$$\Phi = \frac{\mu}{r}\left[1 - \sum_{n=2}^{\infty} J_n \left(R_{Earth} / r\right)^n P_n\left(\sin L\right)\right]$$

where

μ = Earth's gravitational constant (from Newton's formula)
R_{Earth} = the equatorial radius of the Earth
r = the orbital radius of the satellite
P_n = the Legendre polynomial corresponding with J_n
L = geocentric latitude [6].

The most prominent of these geopotential forces, known as the J2 effect from its coefficient, represents the pull of the Earth's equatorial bulge (shown in Figure 8). From Figure 8, it is obvious that the inclination of the satellite, in addition to the satellite's orbital radius, will greatly influence the J2 effect on orbital elements. The secular rates of change in degrees per day for RAAN and argument of perigee from the J2 effect are thusly calculated:

$$\dot{\Omega}_{J_2} = -1.5n \times J_2 \left(R_E / a\right)^2 \left(\cos i\right)\left(1 - e^2\right)^{-2}$$
$$\dot{\omega}_{J_2} = 0.75n \times J_2 \left(R_E / a\right)^2 \left(4 - 5\sin^2 i\right)\left(1 - e^2\right)^{-2}$$

where

R_E = the radius of the Earth in kilometers
n = the mean motion of the satellite in degrees/day
a, i, e = COEs in kilometers and degrees, respectively
$\dot{\Omega}$ and $\dot{\omega}$ are in degrees/day [6].

It is worth noting that the $\left(4 - 5\sin^2 i\right)$ term in the rate of change of argument of perigee reduces to 0 at 63.4 degrees, which is why satellites in HEO use this inclination; perigee will stay in the Southern Hemisphere without expending propellant to maintain the orbit. In addition, a special type of LEO orbit, known as *sun-synchronous*, uses the rate of change of RAAN equation to choose inclinations that match the Earth's rotation rate around the sun

$(360° / 365.25 = 0.9856° / day)$. These practical applications prove the effectiveness and accuracy of even the simple secular geopotential model.

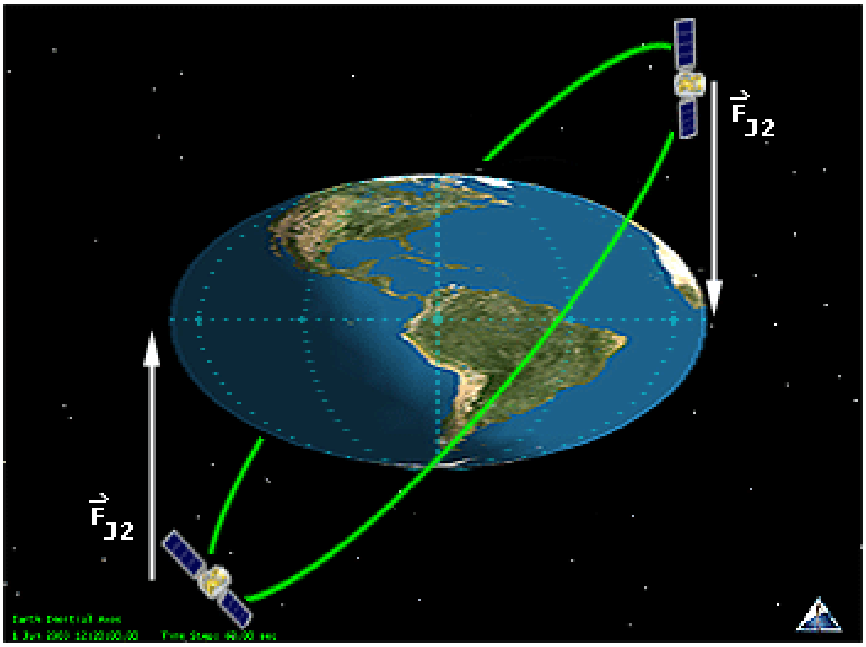


Figure 8. Exaggerated Illustration of the J2 Effect.
Source: [12].

C. THIRD BODY EFFECTS

The sun and moon also supply a gravitational force on satellites, which causes periodic and secular effects on the orbital elements of the satellite. Because they have predictable motion from a geocentric perspective, the position of the sun and moon relative to the Earth at the time of interest in a model is generally calculated at initialization of the model. For the models discussed in this thesis, this involves a start point for the sun and moon at an epoch date of 0.5 January 1900, which is then propagated to the epoch date of the satellite's last observation point based on the predictable motion of the sun and moon over time [15]. This supplies a relatively accurate basis from which to calculate the secular gravitation effects of the sun and moon on the orbital elements of a satellite.

D. SOLAR RADIATION PRESSURE

Solar radiation pressure is a small but constant acceleration applied to satellites above LEO whenever they are in view of the sun. The magnitude of this acceleration is given in meters per second squared, by the equation:

$$a_r \approx -4.5 \times 10^{-6} (1 + r) A / m$$

where

r = the reflection factor for the satellite surface (0 for absorption, 1 for complete reflection)
A = the cross sectional surface area of the satellite exposed to the sun
m = the mass of the satellite [6].

Because this is such a small force that only causes periodic variation in orbital elements, rather than secular variation, solar radiation pressure is not included in general perturbation models when calculating secular effects on a satellite's orbital elements [15]. However, it is important to note that this acceleration is still occurring in the space environment, especially above LEO altitudes [8].

E. ATMOSPHERIC DRAG

Atmospheric drag on LEO satellites is by far the most difficult force to accurately model, especially using general perturbation methods that only calculate secular effects. The concept is deceptively simple, and attempts to model atmospheric drag eventually derive from the formula for acceleration due to drag:

$$a_D = -\left(1/2\right) \rho \left(C_D A / \mathrm{m}\right) V^2$$

where

ρ = atmospheric density
C_D = drag coefficient of the satellite
A = the cross sectional area of the satellite
m = the mass of the satellite
V = the velocity of the satellite [6].

However, none of the above variables remain constant for an active satellite. Mass may remain relatively stable if the satellite doesn't maneuver during the period of interest, but the cross sectional area and drag coefficients of a satellite, relative to its velocity in the atmosphere, can vary tremendously as the satellite moves along its orbital path, as show in Figure 9 [6]. With the exception of a perfectly circular orbit, the velocity of a satellite will also vary in relation to its eccentricity, as described in Kepler's second law [2].

Satellite	Mass (kg)	Shape	Max. XA (m^2)	Min. XA (m^2)	Max. XA Drag Coef.	Min. XA Drag Coef.	Max. Ballistic Coef. (kg/m^2)	Min. Ballistic Coef. (kg/m^2)	Type of Mission
Oscar-1	5	box	0.075	0.0584	4	2	42.8	16.7	Comm.
Intercos.-16	550	cylind.	2.7	3.16	2.67	2.1	82.9	76.3	Scientific
Viking	277	octag.	2.25	0.833	4	2.6	126	30.8	Scientific
Explorer-11	37	octag.	0.18	0.07	2.83	2.6	203	72.8	Astronomy
Explorer-17	188.2	sphere	0.621	0.621	2	2	152	152	Scientific
Sp. Teles.	11,000	cylind.*	112	14.3	3.33	4	192	29.5	Astronomy
OSO-7	634	9-sided	1.05	0.5	3.67	2.9	437	165	Solar Physics
OSO-8	1,063	cylind.*	5.99	1.81	3.76	4	147	47.2	Solar Physics
Pegasus-3	10,500	cylind.*	264	14.5	3.3	4	181	12.1	Scientific
Landsat-1	891	cylind.*	10.4	1.81	3.4	4	123	25.2	Rem. Sens.
ERS-1	2,160	box*	45.1	4	4	4	135	12.0	Rem. Sens.
LDEF-1	9,695	12-face	39	14.3	2.67	4	169	93.1	Environment
HEAO-2	3,150	hexag.	13.9	4.52	2.83	4	174	80.1	Astronomy
Vanguard-2	9.39	sphere	0.2	0.2	2	2	23.5	23.5	Scientific
SkyLab	76,136	cylind.*	462	46.4	3.5	4	410	47.1	Scientific
Echo-1	75.3	sphere	731	731	2	2	0.515	0.515	Comm.
Extrema							437	0.515	

Values for the ballistic coefficient (mass divided by the product of cross sectional area and drag coefficient) can vary up to an order of magnitude, based on the satellite's shape and direction that the satellite is facing, relative to its velocity.

Figure 9. Example Ballistic Coefficient Variation for LEO Satellites. Source: [6].

The variation of satellite-specific elements in the drag equation pales in comparison to the remaining variable: atmospheric density. Atmospheric density is nearly impossible to model because the density and pressure of the atmosphere, like any fluid, increases and expands with temperature. The challenge for any attempt at modeling the atmosphere is that atmospheric temperature and density is heavily influenced by the unpredictable release of energy from the sun [16]. In addition, the atmosphere rotates with the Earth and follows the Earth's bulge at the equator, especially at lower altitudes, resulting in density variations at the equator and on the night side of Earth [17]. The motion of a LEO satellite complicates drag modeling further, because the orbital path traverses the night side of the Earth, causing drag variation from the effect of variation in day and night temperature on atmospheric density, as shown in Figure 10 [5].

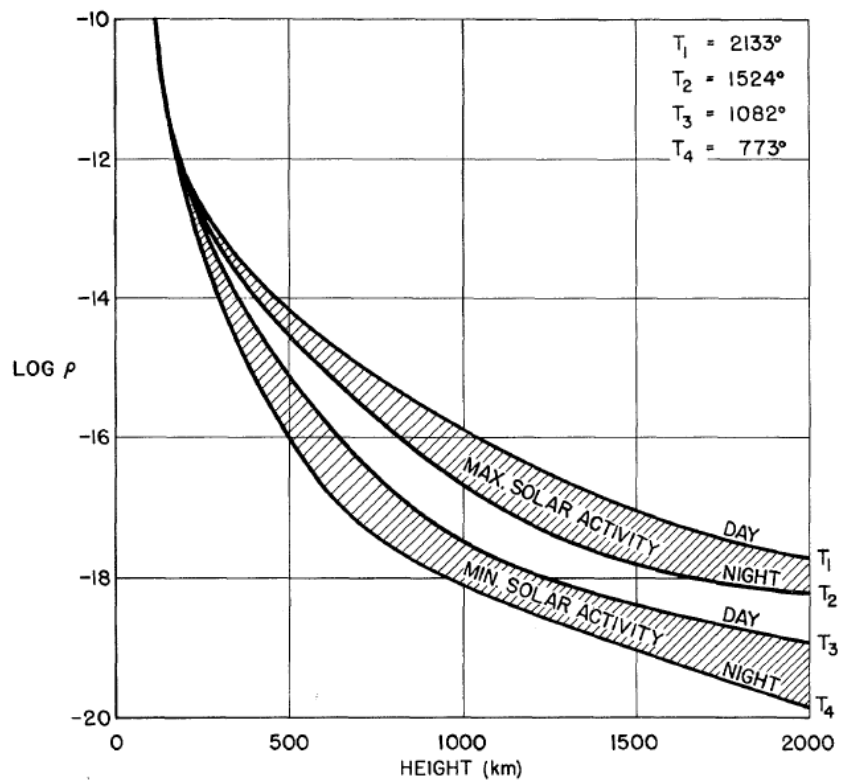
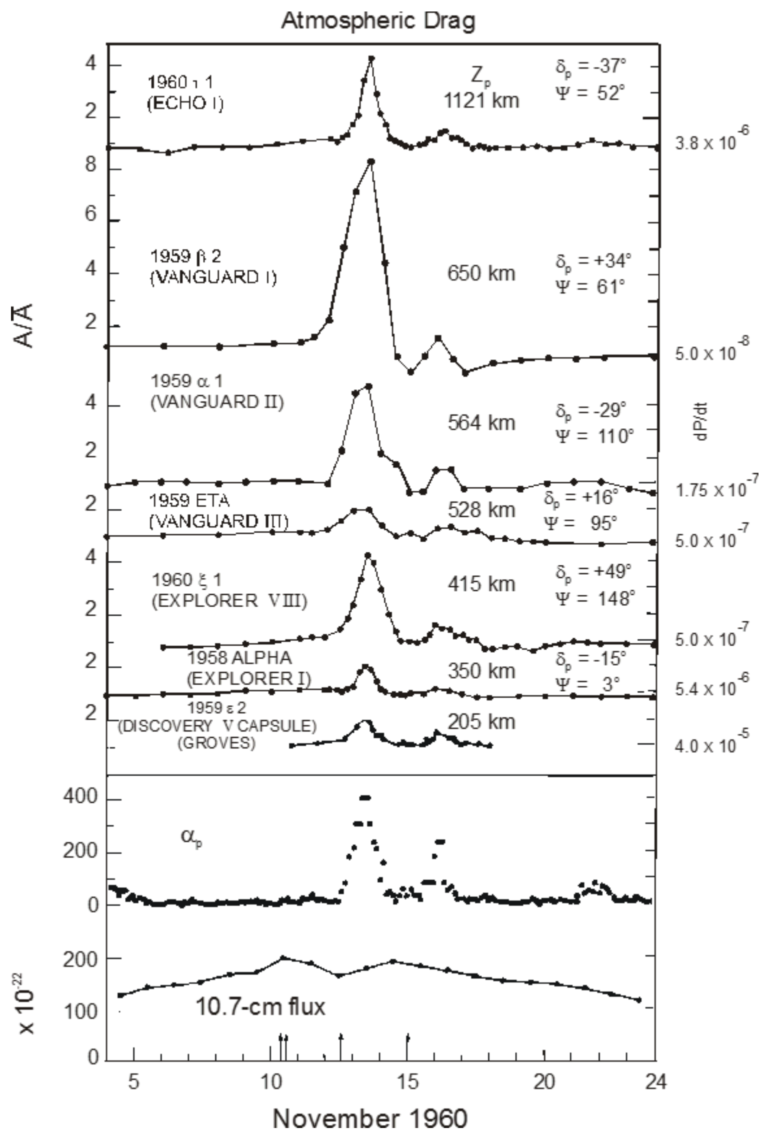


Figure 10. Day and Night Density Profiles in the Upper Atmosphere. Source: [16].

Because the sun is a largely composed of plasma, it does not rotate the way the Earth does (as a solid body). Instead, the sun's equator rotates every 27 days, while the poles rotate about 30 percent slower. This differential rotation results in the twisting of magnetic field lines, which leads to the creation of volatile magnetic regions that generate sunspots, solar flares, and coronal mass ejections (CMEs). These events produce greatly increased releases of energy that directly influence the temperature, height, and density of the atmosphere over time. Even short bursts of energy can have tremendous impact on the atmospheric drag acting on LEO satellites, as seen in Figure 11 [8].



This chart presents data from November of 1960, highlighting the solar events and their corresponding orbital perturbations that took place during 12 through 17 November. The lower data represents measured changes in solar flux and the 3-hourly geomagnetic index, a_p. The plotted points represent the instantaneous accelerations of the satellites during these events, A, as compared to their mean acceleration data over time, $\bar{A}$.

Figure 11. Atmospheric Drag Increase from Intense Solar Events. Source: [16].

Fortunately, the sun is able to reset its magnetic field over time and goes through solar cycles of minimum and maximum activity about every 11 years, taking 22 years to completely reset [8]. These cycles are measured by the recording the number of sunspots present on the surface of the sun, which occur more frequently at solar maximum, as shown in Figure 13 [18].

Because drag is not a conservative force, it takes energy away from the LEO satellite under its effects. This results in an acceleration in the opposite direction of the satellite's velocity, which will lower the satellite's radius of apogee (consequently lowering its semimajor axis and eccentricity, which circularizes the orbit), and ultimately decay the orbit until reentry, as shown in Figure 12 [4]. Understanding the effect of solar energy on the atmosphere, specifically in relation to current and predicted future solar activity, is critical to modeling atmospheric density accurately [16].

Modelling atmospheric density without regard to the sun can have serious consequences. Based on solar minimum data in 1974, NASA estimated that an orbital altitude of 433 x 455 kilometers would keep Skylab in orbit through 1983 [19]. In Figure 13, the sun headed into a solar maximum leading up to 1980, which resulted in the decay and deorbit of Skylab in 1979, four years earlier than anticipated.

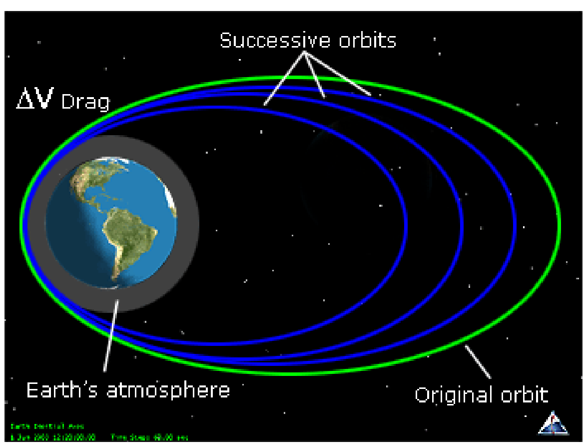
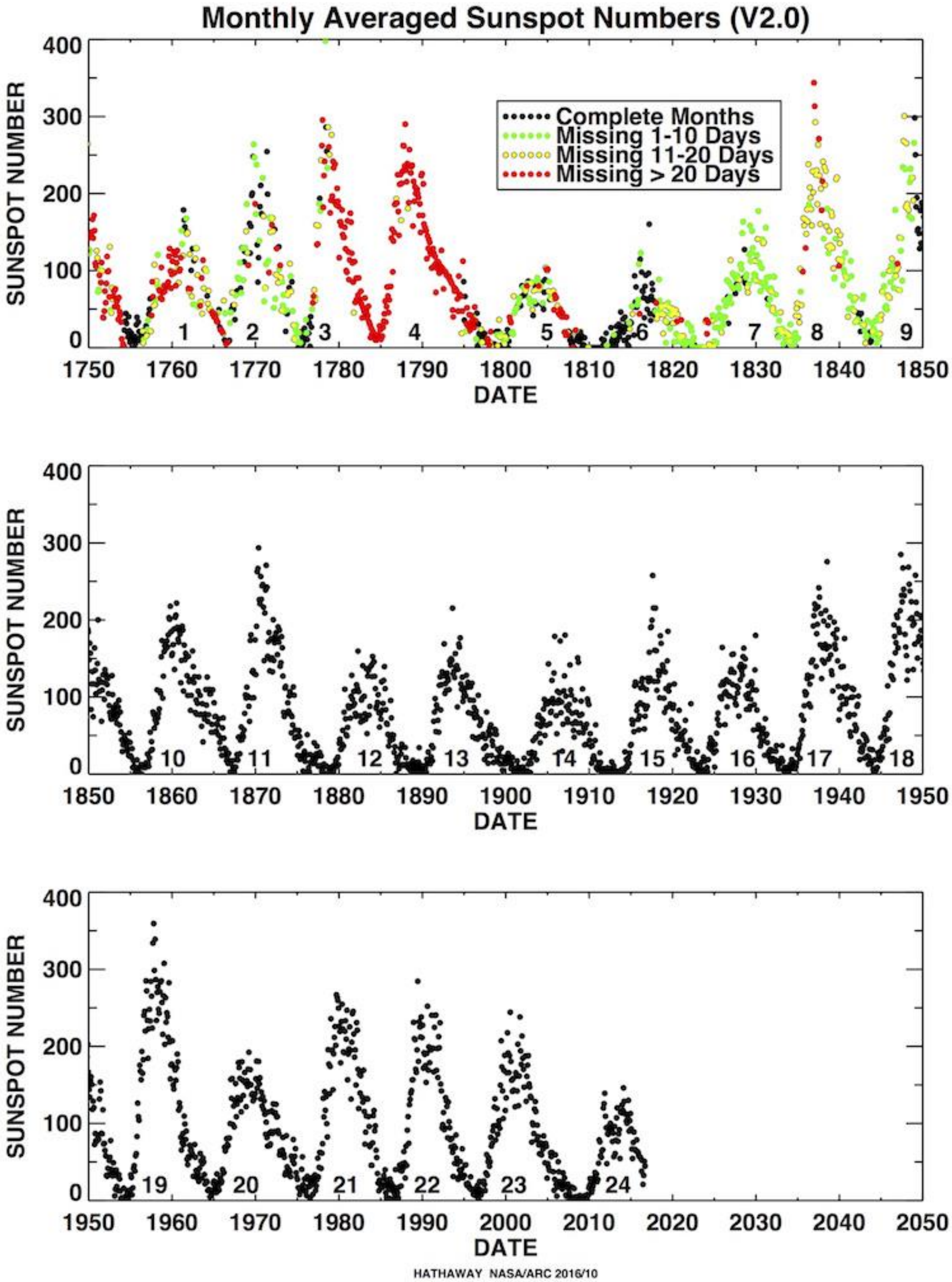


Figure 12. Illustration of the Effects of Drag on an Eccentric LEO Orbit. Source: [12].



The number of observable sunspots over time gives an approximate model for predicting solar activity during the solar cycle. The sun can still behave unpredictably however, as shown in the fluctuation of sunspot data over time.

Figure 13. Sunspot Numbers. Source: [18].

F. TYPES OF ORBITAL PROPAGATORS

Various types of propagators attempt to model the complex environment described in this chapter and predict future positions of a satellite based on their internal model and the input generated by a data set.

- Analytic. These propagators use general perturbation methods to approximate secular and some periodic effects, while ignoring more complex orbital perturbations that require numerical calculation. This results in a lower fidelity model for constellation design or planning, and can be run more quickly than the higher fidelity propagators due to the use of simpler formulas that require fewer computations.[10]

- Semi-Analytic. These propagators are a hybrid of analytic and numerical methods, incorporating higher fidelity techniques to solve for Newton's equations of motion. This results in a medium fidelity model that has greater accuracy than a purely analytic method.

- Numerical. These propagators incorporate all significant force models, applying full numerical methods to solving Newton's equations for force and motion at each appropriate time step and integrating all short period variations over time. This results in a high fidelity prediction that is much slower to calculate, but obtains a highly accurate prediction for operations and maneuvers in space. [20]

[10] SGP4 and PPT3 are both analytic propagators [15].

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III. PPT3 AND SGP4

This chapter reviews the history of current mathematical theory used in the U.S. Air Force and U.S. Navy space surveillance systems. Detailed descriptions of the differences between the propagators are also presented, as these differences will be tested and quantified empirically in Chapter IV.

A. INTRODUCTION

Orbital modelling, analysis, and prediction have been an immensely important endeavor for national defense and scientific study since the start of the space age. Triggered by the launch of Earth's first artificial satellite by the Soviet Union in 1957, the critical need for orbital propagators became immediately apparent to the United States military. Because of the tension from the rising threat of intercontinental ballistic missiles (ICBM) from the Soviet Union in the 1950s [21], the U.S. Air Force needed to be able to distinguish satellites passing through its missile warning sensors from ICBMs [15]. Seeing the potential for an adversary capability like Corona [37,Ch. 3], the U.S. Navy needed a means of predicting flyover by adversary reconnaissance satellites, so as to reduce their vulnerability to adversary imagery intelligence (IMINT) and signals intelligence (SIGINT) collection [15]. From these needs, the satellite catalog was created in order to retain and update orbital data on detectable debris and satellites. These data would later be used as inputs in the predictive models that are the subjects of this analysis.

The origin of formal satellite tracking and orbital prediction in the United States is Project SPACETRACK, an Air Force project which started in 1959 with the creation of the National Space Surveillance Control Center (NSSCC), becoming a formal project in 1960 [15] [22]. Utilizing data from a global network of optical and radar sensors, Project SPACETRACK collected orbital observations and began to catalog both current positions and orbital prediction data. One of the early discoveries of the project was a conclusion that "long-periodic variation with a eighty-day period in the perigee height for 1958 β2, Vanguard 1, was caused by north-south asymmetry in the potential, that is, zonal spherical harmonics of odd orders [23].” In essence, visual observations and sensor data about the orbital path of Vanguard 1, specifically variations in that path when compared to a simple orbit around a point mass, revealed gravitational variations around the earth. These variations, previously described in Chapter I, account for the largest gravitational perturbations on the orbital path of a satellite in LEO [12]. Such observations led to theoretical models for these effects, which would be incorporated into two operational models still in use today.

B. PPT3

In November 1959, Brouwer published the “Solution of the Problem of Artificial Satellite Theory Without Drag,” [13] which included a mathematical model for the perturbations of a satellite transiting near Earth orbit, and also included the effects of zonal harmonics J3, J4, and J5, in addition to the J2 perturbation [15]. Brouwer and Hori also published solutions in 1961 to include atmospheric considerations to Brouwer’s drag-free model, though he noted that his atmospheric model came with certain limitations [24]; for instance, the solution assumed a homogenous sphere, with “a static exponential representation for atmospheric density with a constant scale height [15],” rather than a rotating atmosphere with slightly increased density at the equator [17]. Because of the complexity of the atmospheric model and Brouwer’s original solution, the complete model was too large and computationally intensive to use on computers available at the time [15].

The most significant modification to Brouwer’s theory was developed in 1963 by Lydanne [25]. His contribution was a solution to eliminate issues with eccentricity and inclination as divisors in Brouwer’s formulas, which were based on Delaunay variables, reformulating them in terms of Poincaré variables [15]. This method eliminated mathematical singularities that arose with equatorial or circular orbits, in which divisors of eccentricity or inclination, respectively, would be equal to zero [26]. With incorporation of this improved method of handling variables, Brouwer's model was ready to be translated into software, and became known as Position and Partials as functions of Time (PPT).

The model was first programmed onto an IBM 7090 at the Naval Space Surveillance System (NAVSPASUR) in Dahlgren, VA in 1964, and included modified atmospheric drag equations, provided by Richard H. Smith, due to the computer's processing limitations with Brouwer and Hori's atmospheric model. Smith's model was adapted from work by King-Hele in 1964 that proposed representing the effects of atmospheric drag as a function of the mean motion of a satellite over time [15]. The resulting calculation of secular atmospheric perturbation on mean anomaly is represented by a cubic polynomial as a function of time:

$$M'' = M_0'' + n_0''(t - t_0) + \frac{\dot{n}_0''}{2}(t - t_0)^2 + \frac{\ddot{n}_0''}{6}(t - t_0)^3$$

where

M_0'' = the mean anomaly recorded at epoch
t_0 = the time recorded at epoch
t = the future time of interest
n_0'' = the mean motion recorded at epoch
$\frac{\dot{n}_0''}{2}$ = the first derivative of mean motion recorded at epoch
$\frac{\ddot{n}_0''}{6}$ = the second derivative of mean motion recorded at epoch [26].

Although this equation isn't as accurate as a complex atmospheric model, a cubic polynomial is a much simpler and faster process for a computer to run multiple times for thousands of satellites; especially considering the speed of a computer in 1964. The terms for this model are still produced today in the Two Line Element (TLE) format [27], though as Schumacher, et al note: "In practice, it turns out that the [second derivative of mean motion] is almost always small and poorly determined. Orbital analysts sometimes use it for special purposes, but for all cataloged orbits the cubic coefficient is set to zero a priori." [26]

Similar calculations are performed in PPT for the secular effects on mean semimajor axis and mean eccentricity. Kepler's third law is invoked to generate a simple formula for the rate of change of the semimajor axis:

$$\frac{d}{dt}\left(n''^2 a''^3\right) = 0 \rightarrow \dot{a}'' = -\frac{4}{3}\frac{a_0''}{n_0''}\left(\frac{\dot{n}''}{2}\right)$$

where a_0'' is the mean semimajor axis at epoch (calculated using TLE data at epoch) [26].

With the rate of change of the semimajor axis in hand, PPT then calculates the change of eccentricity as:

$$\dot{e}'' = e_0''\left(1 - e_0''^2\right)\frac{\dot{a}''}{a_0''}$$

where e_0'' is the eccentricity at epoch, given in the TLE data. Final calculations for semimajor axis and eccentricity for an orbital prediction at a future time of interest are then simply computed with:

$$a'' = a_0'' + \dot{a}''\left(t - t_0\right)$$
$$e'' = e_0'' + \dot{e}''\left(t - t_0\right)$$

resulting in an easily computable method for the technology available in 1964 to update the satellite catalog [26].

These simplified secular calculations for atmospheric drag, while efficient for updating thousands of objects in the satellite catalog, are still based on estimates of the rate of change of mean motion from sensor data. Essentially, inputting estimated data into a simple model for complex atmospheric effects results in orbital prediction errors that will grow as time increases away from epoch. Schumacher, et al define a "useful accuracy" fit span for PPT3 as "typically on the order of 10 to several tens of kilometers in vector components of position" and provide examples of expected fit spans from epoch in Tables 1 and 2 [26].

Table 1. Useful Accuracy Fit Span for Large Period Orbits. Adapted from [26].

Orbital Period (minutes)	Span (days from epoch)
> 800	30
600 to 800	15

Table 2. Useful Accuracy Fit Span for Orbits with Period Less than 600 Minutes. Adapted from [26].

Orbital Period Rate of Change (minutes/day)	Span (days from epoch)
< -0.0005	10
-0.001 to -0.0005	7
-0.01 to -0.001	5
> -0.01	3

The final update to PPT3, the inclusion of lunar and solar gravitation effects and deep space resonance effects of Earth tesseral harmonics, was implemented in 1997 [15]. The terms for these effects are used in the 1977 updates to the model developed for the U.S. Air Force, SGP4, which will be discussed in Section C of this chapter. The implementation is unique in PPT3 in that these effects are considered in all orbits, rather than solely for orbits with a period of 225 minutes or greater (as is the case in SGP4) [15] [26].

C. SGP4

Concurrent with the development efforts of the PPT3 system, the U.S. Air Force developed its own model for orbital propagation in the early 1960s [15]. Rather than concentrating solely on Brouwer's [13] work for the basis of their model, the Air Force incorporated the work of Kozai's "The Motion of a Close Earth Satellite," [28] also published in November 1959. The result of this development was the Simplified General Perturbations (SGP) model, by Hilton and Kuhlman [29], which became the primary model in use by the Air Force in 1964 [15].

Similar to PPT3, drag effects on orbital decay in the original SGP model were modeled as secular effects in the equation:

$$a = a_0 \left\{ \frac{n_0}{n_0 + 2\left(\frac{\dot{n}_0}{2}\right)(t - t_0) + 3\left(\frac{\ddot{n}_0}{6}\right)(t - t_0)^2} \right\}^{\frac{2}{3}}$$

where the mean motion (n) and its derivative terms are identically taken from observation data and a_0, the mean semimajor axis at epoch, is calculated with Kozai's non-Keplerian approach [15]. Unlike PPT3, fewer zonal harmonic terms were retained from Brouwer's original work, in order to ease the computational work required to predict future orbital position in SGP [26].

SGP was altered in the 1970s in several important ways. Lane and Cranford [30] made several modifications to Brouwer and Hori's [24] work on an atmospheric model to supplement Brouwer's original model [26]. These modifications were added to SGP in the form of power density functions, all of which were dependent upon a new constant, B^*,[11] which is "half the product of the estimated satellite ballistic coefficient and power-law reference density" [26]. The result is a much more complex model for orbital decay in SGP4 than the one seen in PPT3 and the original SGP, and is the reason why the B^* term is still included in TLE data [27]. The mathematical terms for this model are reproduced in Appendix B of this thesis.

The other major modification to SGP4 came from a desire to track highly-eccentric Molniya orbits and deep space orbits [26]. This required terms to account for the gravitational effects of the moon and sun, as well as geopotential

[11] In mathematical notation, $B^* = 1/2 \times C_D \times A/m$, where C_D is the drag coefficient of a satellite with mass *m* and cross sectional area *A* [36].

resonance effects, all of which were incorporated into the SGP4 model, though only for orbits with a period greater than 225 minutes [15].

D. DIFFERENCES IN SEMIMAJOR AXIS CALCULATION

Orbital element calculations can vary greatly between PPT3 and SGP4 [15]. The greatest difference is in the initial calculation of semimajor axis. Though both models utilize the same Fundamental Katalog 4 (FK4) and World Geodetic Survey 72 (WGS72) reference standards for Earth mass, radius, gravitational constant, and J_2 through J_4 constants, as well as the Julian 2000 (J2000) epoch for reference time synchronization, their varying methods produce different results in the calculated size of an orbit [15] [26].

SGP4 calculates Brouwer's definition of mean mean motion (n_0'') and mean semimajor axis (a_0'') [13] by converting the Kozai (Keplerian; calculated without oscillation effects) [28] mean motion in observation data (n_0, in revolutions per day). This is done with the calculation of several terms that simulate the oscillations of mean semimajor axis by the J_2 effect, in order to ultimately remove the effect of these oscillations before propagating:

$$a_1 = \left(\frac{k_e}{n_0}\right)^{\frac{2}{3}}$$

$$\delta_1 = \frac{3}{2}\frac{k_2}{a_1^2}\frac{\left(3\cos^2 i_0 - 1\right)}{\left(1-e_0^2\right)^{\frac{3}{2}}}$$

$$a_2 = a_1\left(1 - \frac{1}{3}\delta_1 - \delta_1^2 - \frac{134}{81}\delta_1^3\right)$$

$$\delta_0 = \frac{3}{2}\frac{k_2}{a_2^2}\frac{\left(3\cos^2 i_0 - 1\right)}{\left(1-e_0^2\right)^{\frac{3}{2}}}$$

$$n_0'' = \frac{n_0}{1+\delta_0}$$

$$a_0'' = \left(\frac{k_e}{n_0''} \right)^{\frac{2}{3}}$$

where

i_0 = inclination at epoch
e_0 = eccentricity at epoch
$k_2 = \frac{1}{2} J_2 a_E^2$, (Earth radii)²
$J_2 = 1.082616 \times 10^{-3}$
$k_e = \sqrt{GM} = 0.0743669161$, (Earth radii) $^{1.5} / \min$
G = universal gravitational constant
M = mass of the Earth
A_E = equatorial radius of the Earth. [15]

PPT3 follows a different convention for mean motion, which is incompatible with Kozai's definition used in SGP4, and is determined using additional processing at Naval Surface Warfare Center (NSWC) Dahlgren before it can be utilized in orbital calculation [15]. PPT3 then performs additional calculation to generate Brouwer's [13] mean semimajor axis by iterating the following sequence:

For i=1,5

$$\gamma_2' = k_2 / a_{i-1}^2 \eta^4$$

$$\gamma_4' = k_4 / a_{i-1}^4 \eta^8$$

$$\begin{aligned}\delta_s M = & (3/2)\gamma_2' \eta \left(-1 + 3\theta^2\right) \\ & + (3/32)\gamma_2'^2 \eta \left[-15 + 16\eta + 25\eta^2 + \left(30 - 96\eta - 90\eta^2\right)\theta^2 + \left(105 + 144\eta + 25\eta^2\right)\theta^4\right] \\ & + (15/16)\gamma_4' \eta e''^2 \left(3 - 30\theta^2 + 35\theta^4\right)\end{aligned}$$

$$a_i = \left[\left(1 + \delta_s M\right) / n_0''\right]^{\frac{2}{3}}$$

where

the initial input for semimajor axis, $a_0 = n_0''^{-\frac{2}{3}}$

$\eta = \sqrt{1 - e''^2}$

$\theta = \cos I''$

$k_2 = \frac{1}{2} J_2 R_\oplus^2 = 0.54130789 \times 10^{-3}$

$k_4 = -\frac{3}{8} J_4 R_\oplus^4 = 0.62098875 \times 10^{-6}$

$R_\oplus =$ radius of the Earth

e'' = mean eccentricity at epoch
I'' = mean inclination at epoch
n_0'' = processed mean motion at epoch. [15]

E. CONCLUSION

There are several differences in the computations included in the PPT3 and SGP4 models. As Schumacher and Glover [26] note, differences in mean element (such as mean semimajor axis) definition and calculation alone are enough to make elements determined in one model incompatible with the other model. Propagation values for position and velocity vectors will therefore vary between the two models, regardless of similarities in atmospheric modeling, third body effects, and Earth resonance values, because the initial elements that define the orbit are varied. These position and velocity variances are then amplified by the actual differences in the computation methods used in PPT3 and SGP4 to model the secular effects of atmospheric and gravitational phenomena. In practice, the errors in these models[12] cause NORAD to update TLE element set data frequently, in order to maintain accuracy for predictions. These errors are tested and analyzed in Chapter IV of this thesis.

[12] SGP4 is estimated to have an error of nearly 1km at epoch, growing between 1-3 kilometers per day from epoch [3]. PPT3's estimated errors are detailed in Tables 1 and 2.

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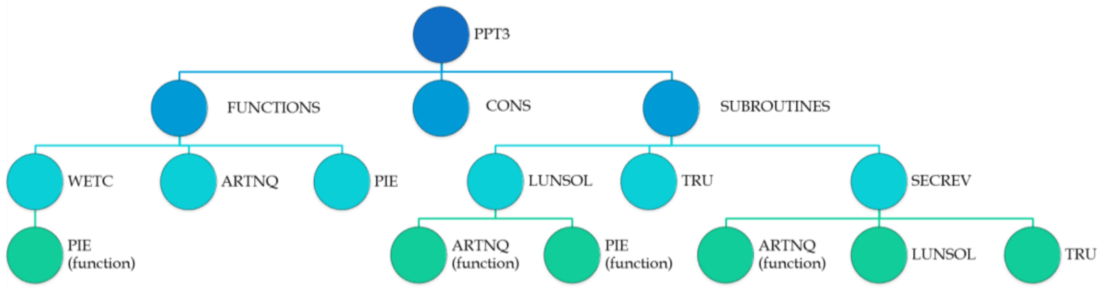
IV. ANALYSIS OF PPT3 AND SGP4

From technical literature about PPT3 and SGP4, Chapter III established that there are significant differences in the mathematical methods each propagator employs to model Earth's non-uniform distribution of mass and atmosphere. This chapter explores those differences numerically and analytically, in order to further understanding of the impact of these differences in orbital prediction. This analysis is then used to draw conclusions and determine operational impacts due to the utilization of each propagator in satellite vulnerability planning (SATVUL).

A. PPT3 CODE

In cooperation with the Naval Postgraduate School (NPS), Air Force Space Command, Space and Missile Systems Center (AFSPC SMC) personnel, who took control of NAVSPASUR and its systems in 2004 [31], shared several PPT3 subroutines and functions, written in the FORTRAN language. However, the FORTRAN code that was shared, while sufficient to analyze and visualize many of the mathematical methods described in technical literature on PPT3 in code, lacked the initialization code and libraries to run as a fully functioning propagator. Because of this, a full, empirical analysis of PPT3 accuracy is not possible in this thesis. Instead, a detailed analysis of the FORTAN code and its underlying algorithms was conducted, and functions within the code, shown in Figure 14, were utilized to generate secular perturbation rates for comparison against similar rates generated in SGP4.



Subroutines LUNSOL, TRU, and SECREV calculate lunar and solar gravity, the true anomaly of the satellite, and the secular perturbation rates of change of orbital elements over time, respectively. Functions WETC, ARTNQ, and PIE calculate the Greenwich hour angle (GHA) for Earth reference at a time of interest, the four quadrant angle (in radians) of an angle of interest, and the modulus value of an angle (in radians) between zero and 2π, respectively. The CONS subroutine loads WGS-72, J2000, and FK4 constants into memory.

Figure 14. Structure of the PPT3 FORTRAN code Provided by AFSPC.

1. PPT3 Initialization Methodology

A key component of initializing a propagator for practical use is initialization code, which reads input, prepares variables for use in the other subroutines of the program, and calibrates the model [3]. These initialization functions, while not directly involved in the mathematical processing of the main program, reduce input burden on the user and ensure that initial input variables are conditioned and converted to proper units, which in turn results in successful operation of the propagator [3]. The initialization code for PPT3 was not included in the functions and subroutines transferred to NPS by AFSPC.

In Chapter III, it was established that PPT3 has several special definitions for orbital elements that differentiate it from SGP4. Mean motion (which directly determines semimajor axis) is a particular case, as noted by Schumacher and Glover:

> A special feature of [PPT3] is that the [mean motion] is defined differently from Brouwer's quantity of the same name. Brouwer defined mean motion in terms of mean semimajor axis by essentially the Keplerian formula. However, for [PPT3] it was decided for computational reasons to define the mean motion as the entire coefficient of time in the linear term in perturbed mean

anomaly. That is, the [PPT3] mean motion includes the zonal secular perturbation rate of mean anomaly that Brouwer derived. As a result, the expression for [PPT3] mean motion explicitly contains perturbation parameters and functions of the other mean elements, similarly to the definition adopted by Kozai in a theory contemporary with Brouwer's. [26]

The procedures for converting the traditional definition of mean motion from a TLE, in revolutions per day, to this special definition of mean motion for PPT3 use, are not present in the functions and subroutines of Figure 14, and must reside in the initialization code for PPT3. However, the main PPT3 subroutine begins with several error checks, including a check for orbits below 100 kilometers (above the surface of the Earth) by checking for mean motion greater than 16.66 [32]. A mean motion of 16.66, if taken to be in units of revolutions per day, equates to a 100 kilometer orbit by converting to radians per second and using Kepler's third law to generate the semimajor axis:

$n_0 = 16.66$ (mean motion input)
$R_\oplus$ = 6378.135 (radius of Earth in kilometers)
μ =398600.8 (universal gravitational constant multiplied by the mass of Earth)
$a_0 = R_\oplus[\mu / ((\mathrm{n}_0)2\pi / 86400)^2]^{(1/3)} = 6475.679 km$ (semimajor axis in kilometers)
$r = a_0 - R_\oplus = 97.544 km$ (orbital height above the surface of the Earth). [3]

This result is interesting because it indicates that PPT3 begins computation with a mean motion in revolutions per day (the standard TLE format). In addition, the 97.544 kilometer orbital height equates to a ratio of $r / (R_\oplus + 100 km) = 0.9996$, which is comparable with the mean mean semimajor axis to Keplerian semimajor axis ratio results from SGP4 in the SGP4 ratio column of Table 3. This indicates that an oscillated mean semimajor axis from SGP4 could possibly be used to initialize PPT3 and calculate the semimajor axis of an orbit. The mathematical theory from PPT3's LUNSOL, CONS, and SECREV subroutines, as well as the PIE and ARTNQ functions, were translated into Excel in order to test this mean motion input for further use within PPT3. The results of this test, along with results using SGP4's method from Chapter III, are presented in Table 3.

Table 3. Results from Initial SGP4 and PPT3 Semimajor Axis Calculation.

Satellite	TLE Mean Motion (Revolutions / Day)	Keplerian Semimajor Axis	SGP4 Mean Semimajor Axis	SGP4 Ratio (SGP4/Kepler)	PPT3 Mean Semimajor Axis	PPT3 Ratio (PPT3/Kepler)
ISS	15.54145775	6782.775923	6779.699346	**0.999546413**	8487.741165	**1.251366883**
41026	15.30257756	6853.181677	6850.124887	**0.99955396**	13578.08546	**1.981281995**
40362	15.26683402	6863.874201	6860.825427	**0.999555823**	13522.1806	**1.970050762**
41907	15.20966091	6881.06431	6878.033641	**0.999559564**	13393.88167	**1.946484013**
41908	15.18599199	6888.212348	6885.182832	**0.999560188**	13379.54027	**1.942382086**
41038	14.80361417	7006.322646	7003.357849	**0.99957684**	12740.41414	**1.818416706**
40894	14.763699	7018.945169	7015.990005	**0.999578973**	12637.68647	**1.800510784**
41898	14.5633613	7083.168207	7080.247803	**0.999587698**	12202.27351	**1.722714067**
40340	13.4516106	7468.254572	7467.078973	**0.999842587**	6910.662124	**0.925338318**
40338	13.45160331	7468.25727	7467.081622	**0.999842581**	6910.648219	**0.925336122**
40339	13.45160236	7468.257622	7467.081862	**0.999842566**	6910.614008	**0.925331497**
39239	13.45159969	7468.25861	7467.081851	**0.999842432**	6909.451255	**0.925175682**
39241	13.45159731	7468.259491	7467.08263	**0.999842418**	6909.406691	**0.925169606**
39240	13.45159361	7468.260861	7467.084052	**0.999842425**	6909.438812	**0.925173737**
36287	1.002685	42165.66551	42166.70889	**1.000024745**	44152.03305	**1.047108649**
25354	1.00271315	42164.87634	42165.92017	**1.000024756**	44152.06963	**1.047129115**

All semimajor axis values are presented in kilometers. The ratios of the calculated "mean mean" value (with oscillations removed) from each propagator to the Keplerian value for semimajor axis are bolded to highlight their differences.

Because there are no changes to mean motion, eccentricity, or inclination (all of which are used to calculate initial semimajor axis and remove gravitational oscillations) between their initial calls in PPT3 and the SECREV subroutine [32], it is evident from these results that without the initialization code for PPT3 input, the calculation of mean semimajor axis in PPT3 with direct elements from TLE data contains too much accuracy error to carry forward into the calculation of secular rates of change and future predicted position. Because of this, the SGP4 calculation of mean semimajor axis was used for PPT3 secular rate calculation, in lieu of the PPT3 mean semimajor axis, due to its inclusion of terms to remove semimajor axis oscillations by the J2 effect. This value will be different from what a properly initialized PPT3 propagator would calculate, but is much closer than what PPT3 generates with an unprocessed mean motion taken directly from a TLE.

Further indications that additional subroutines are required to properly operate PPT3 include the appearance of uninitialized variables for the semimajor axis and the cosine of inclination in the initial error checks of PPT3 [32]. These variables depend on orbital properties that must be calculated from input, and cannot simply appear without initial processing. In addition, a missing subroutine for calculating the Greenwich hour angle at the J2000 epoch is referred to in the CONS subroutine, though as the constant for this angle is provided, the subroutine is not necessary for PPT3 use.

2. PPT3 MATLAB Conversion

In order to analyze partial PPT3 code for comparison with SGP4, all of the FORTRAN subroutines provided by AFSPC were translated into the MATLAB script language. From observation during the process, it was noted that MATLAB syntax is close enough to FORTRAN that the translation process was relatively straightforward for the 4,197 lines of PPT3 FORTRAN code. Particular attention had to be paid to input and output arguments in PPT3 functions, as the FORTRAN code would include both types of variables in the definition line, whereas MATLAB requires that input and output variables be split for the function definition, and defined again as an array or structure with multiple fields during the function call (especially if multiple output variables are produced by the function) [33]. PPT3 subroutines were much simpler to translate because they could be written as MATLAB scripts, which can share, define, call, and update global variables in memory [33].

Because of the missing initialization code for PPT3, additional MATLAB code was written in order to read elements from TLE files published on the Joint Functional Component Command for Space's (JFCC Space) space-track.org website [27], and convert those elements into conditioned variables for propagation. Borrowing from Mahooti's MATLAB scripts for reading similar TLE files [34] and Sohrabinia's function for converting Julian dates into recognizable MATLAB date input [35], this script enables the same TLE inputs to be used with both the PPT3 and SGP4 propagators. Elements from TLE input are converted from standard TLE units to canonical units, which PPT3 utilizes for calculation, utilizing the conversion methods contained in the error checks of the PPT3 subroutine, along with constants contained in the CONS subroutine. Copies of all MATLAB scripts, with exception of direct PPT3 translation (which is under export control, but can be accessed at NPS), can be found in Appendix A of this thesis.

The full MATLAB version of the PPT3 propagator is still in development at NPS because its final position and velocity outputs have not been debugged for use. However, enough of the SECREV PPT3 subroutine was successfully translated to allow calculation of secular rates of change for prediction. In particular, the calculations for secular atmospheric effects (described in Chapter III) function properly when used in conjunction with the SGP4 theory for calculation of semimajor axis and direct input from a TLE file.

B. SGP4 CODE

Multiple public versions of SGP4 are available for use in orbital prediction and analysis. For this thesis, a PYTHON version of SGP4, adapted from Vallado's C++ source code from "Revisiting Spacetrack Report #3" [3], along with a simplified MATLAB version of SGP4 [34], were used to produce orbital prediction data and secular terms for comparison with PPT3. Vallado's code, in particular, is "highly compatible with recent versions" of the SGP4 code in use by the Air Force [3]. The MATLAB code was tested against the PYTHON version of Vallado's code for this thesis, and found to have a mean computation error within 3 millimeters of the PYTHON version; well within the 1-3 kilometer produced by SGP4 theory itself [3].

C. COMPARISON

It was established in Chapter III that SGP4 and PPT3 both use Brouwer methods for calculating the secular effects of Earth's oblateness and resonance effects [15], [26]. Both propagators also contain the same terms for calculating the secular effects of lunar and solar gravity, though SGP4 does not implement these for orbits with a period less than 225 minutes [15].[13] The remaining differences between SGP4 and PPT3 mathematical theory lie in the calculation of orbital elements and secular atmospheric effects, which were detailed in Chapter III. Because the version of PPT3 provided to NPS is incomplete, it is not possible to accurately perform the orbital element calculation in full (particularly semimajor axis). However, thanks to the simplicity of the PPT3 atmospheric model, and using the assumption that an SGP4-determined semimajor axis will be similar in mathematical value to a properly calculated PPT3 semimajor axis, it is possible to generate secular terms for orbital decay using the model in PPT3.

1. Method

Since atmospheric models were determined to be most useful component of each propagator to test, TLE data from 24 LEO satellites were collected for use in SGP4 and PPT3 testing. These data are available in Appendix C. Each propagator was set to predict orbital decay on semimajor axis over a 24 hour period, and then the rates of change for each were collected as data points for comparison. Because the SGP4 propagator is able to run through to a final state vector, data from SGP4's position and velocity vectors were also collected to help practically quantify the effects each prediction difference would have; e.g. a 0.04 kilometer difference in decay prediction results in a 0.06 second difference in orbital period, which in turn—for a satellite travelling at 7.6 kilometers per second—is a difference of 456.0 meters. Finally, TLE data from observations on the same satellites were collected for semimajor axis at epoch and 24 hours later, in order to serve as a comparison to "ground truth" data.

[13] During PPT3 data analysis for this thesis, it was observed that these lunar and solar effects generally produced terms on the order of 1.0×10^{-10} radians per canonical time unit (806.814 seconds) at LEO altitudes. This is not a significant difference in terms of what SGP4 produced without them, especially when compared to the secular effects of Earth gravity and atmosphere.

2. Results

The comparison of each propagator's prediction of orbital decay over 24 hours is presented in Table 4. It is interesting to note the effect of TLE input, which is generated from sensor data, on the models. For instance, several of the satellites have the SGP4 drag term, B*, set to 0 in the TLE. This implies the simulated orbit will not decay. Because orbital decay due to atmospheric drag causes an actual LEO satellite's semimajor axis to circularize and decrease in size [5], its velocity will increase. Thus, the satellite will be overhead sooner than expected such a model is not recalibrated over time.

The comparison of each propagator's prediction of orbital decay over 24 hours to 24 hour observation data is presented in Table 5. Descriptive statistics for this data are presented in Table 6. It is important to note that satellite observation data for satellite number 41908 are not included in the statistics below 1,000 kilometers, because the percent error of both propagators was 19 standard deviations away from the mean. This appears to be due to a problem with the observation data, such as a maneuver, reconfiguration of solar panels, or an error in mean motion calculation, as can be seen from the differences (shown in Appendix C) in mean motion of the satellite over several observations.

Table 4. PPT3 and SGP4 Semimajor Axis Orbital Decay Comparison

Satellite Number	Altitude km	Mean Motion Derivative	Bstar	-km/day SGP4	-km/day PPT3	SGP4 Period Difference (s)	PPT3 Period Difference (s)	Sat V km/s
41908	507.0478	-0.00000073	00000+0	0	0.047257903	0	0.058537407	7.5874
41026	471.9899	0.00001658	59137-4	0.010321	1.059736025	0.012752026	1.309278963	7.6301
40362	482.6904	0.00001519	60624-4	0.00952	0.974685333	0.011771683	1.205144809	7.6244
40701	482.8359	0.00001714	68158-4	0.010682	1.099868012	0.013208416	1.359934525	7.6206
41907	499.8986	-0.00000076	00000+0	0	0.049072437	0	0.060753464	7.5961
36596	576.5534	0.00000991	93467-4	0.00648	0.65784708	0.008067262	0.818946558	7.5622
28413	582.0234	0.00000607	62078-4	0.004129	0.403731111	0.005142713	0.502802611	7.5544
28414	582.6534	0.00000685	69761-4	0.004608	0.455713952	0.00573935	0.567566139	7.5574
39358	610.0742	0.00000134	18851-4	0.001021	0.09001817	0.001273776	0.11233466	7.5531
41038	625.2229	0.00000027	10290-4	4.95E-04	0.018238184	0.000617781	0.022784343	7.5279
40894	637.855	-0.00000053	00000+0	0	0.035962421	0	0.044967101	7.5096
39210	664.76	0.0000001	10014-4	3.66E-04	0.006850566	0.000458566	0.008582306	7.5097
41898	702.1128	0.00000114	35964-4	0.001035	0.079135428	0.001299882	0.099402205	7.5137
36413	1088.941	-0.00000053	54043-4	2.78E-04	0.042007925	0.000358374	0.054188603	7.1511
36415	1088.942	-0.00000035	79135-4	4.08E-04	0.027741088	0.000525748	0.035784951	7.1501
40340	1088.944	-0.0000009	00000+0	0	0.071334273	0	0.092018388	7.2677
40338	1088.947	-0.0000009	00000+0	0	0.071334337	0	0.092018486	7.2676
39239	1088.947	-0.0000009	00000+0	0	0.071334358	0	0.092018515	7.2286
40339	1088.947	-0.0000009	00000+0	0	0.071334344	0	0.092018497	7.2676
39241	1088.948	-0.0000009	00000+0	0	0.071334378	0	0.092018546	7.228
39240	1088.949	-0.0000009	00000+0	0	0.071334412	0	0.092018598	7.2286
39013	1088.954	-0.00000048	68362-4	3.16E-04	0.038045046	0.000407473	0.049076689	7.2168
39012	1088.954	-0.00000033	92085-4	4.25E-04	0.026155975	0.000548854	0.033740246	7.217
39011	1088.955	-0.0000015	95769-4	4.43E-04	0.118890809	0.000570932	0.153364302	7.2169

Table 4 presents prediction data for orbital decay of the semimajor axis of a satellite from both the SGP4 and PPT3 propagators. The secular rate is linear, increasing every day from epoch. Satellite velocity is presented at the 24 hour prediction time to quantify how much further ahead each propagator predicts the orbit will be, based on velocity multiplied by the period difference in time. Only atmospheric effects are included. This is merely a direct comparison of the magnitude of each propagator's atmospheric calculations, given TLE input. The accuracy of each, compared to ground truth, is presented in Table 5.

Table 5. Comparison of Prediction Data to Observation Data

Satellite	TLE 24 hours later		SGP4 SMA	PPT3 SMA	% error	% error
Number	**N0**	**SMA**	**Delta (km)**	**Delta (km)**	**SGP4**	**PPT3**
41908	15.13129	6904.804	19.62130683	19.66856473	0.284169	0.284853
41026	15.30261	6853.172	3.057446164	4.10686104	0.044614	0.059926
40362	15.26686	6863.865	3.049316855	4.014481935	0.044426	0.058487
40701	15.26639	6864.008	3.048126703	4.137312629	0.044407	0.060275
41907	15.19837	6884.471	6.437129819	6.486202256	0.093502	0.094215
36596	14.95911	6957.686	3.004398107	3.655765032	0.043181	0.052543
28413	14.94151	6963.147	2.993036556	3.392638326	0.042984	0.048723
28414	14.93952	6963.766	2.982484197	3.433589947	0.042829	0.049307
39358	14.85319	6990.723	2.515014503	2.60401195	0.035976	0.03725
41038	14.80362	7006.321	2.964003654	2.981747323	0.042305	0.042558
40894	14.7637	7018.944	2.954199961	2.990162382	0.042089	0.042601
39210	14.67926	7045.837	2.941972258	2.948456788	0.041755	0.041847
41898	14.56336	7083.167	2.920264738	2.998365316	0.041228	0.042331
36413	13.45162	7468.251	1.175034839	1.216764947	0.015734	0.016293
36415	13.45162	7468.253	1.176532842	1.203866362	0.015754	0.01612
40340	13.45161	7468.254	1.175288266	1.246622539	0.015737	0.016692
40338	13.4516	7468.257	1.175359626	1.246693963	0.015738	0.016693
39239	13.4516	7468.258	1.176533551	1.247867909	0.015754	0.016709
40339	13.4516	7468.257	1.175444671	1.246779015	0.015739	0.016694
39241	13.4516	7468.259	1.176605776	1.247940154	0.015755	0.01671
39240	13.45159	7468.261	1.176630563	1.247964974	0.015755	0.01671
39013	13.45159	7468.261	1.172929911	1.210659078	0.015706	0.016211
39012	13.45159	7468.262	1.172617674	1.198348168	0.015701	0.016046
39011	13.45159	7468.261	1.1721699	1.290618114	0.015695	0.017281

Table 5 presents the predicted decayed semimajor axis at t=24 hours past epoch, compared with observation data from the TLE recorded at or near 24 hours after the epoch data. The mean motion (N0) and semimajor axis (SMA) of the observation data for each satellite are presented in the "TLE 24 hours later" column, followed by the difference in calculated semimajor axis (24 hours past epoch) from each propagator, and finally the percent error of each propagator, calculated with the difference in kilometers divided by the observed semimajor axis. Each propagator is performing within the expected margin of error (1-3 kilometers per day) described in Chapter III of this thesis.

Table 6. Atmospheric Model Accuracy Performance

SGP4 Accuracy Below 1000km			*PPT3 Accuracy Below 1000km*	
Mean	0.046608		Mean	0.052505
Standard Error	0.004314		Standard Error	0.004406
Median	0.042906		Median	0.049015
Mode	#N/A		Mode	#N/A
Standard Deviation	0.014943		Standard Deviation	0.015262
Sample Variance	0.000223		Sample Variance	0.000233
Kurtosis	11.2983		Kurtosis	5.061988
Skewness	3.312156		Skewness	2.018941
Range	0.057526		Range	0.056965
Minimum	0.035976		Minimum	0.03725
Maximum	0.093502		Maximum	0.094215
Sum	0.559295		Sum	0.630063
Count	12		Count	12

SGP4 Accuracy Above 1000km			*PPT3 Accuracy Above 1000km*	
Mean	0.015733		Mean	0.01656
Standard Error	6.79E-06		Standard Error	0.000108
Median	0.015738		Median	0.016693
Mode	#N/A		Mode	#N/A
Standard Deviation	2.25E-05		Standard Deviation	0.00036
Sample Variance	5.08E-10		Sample Variance	1.29E-07
Kurtosis	-0.93917		Kurtosis	0.230177
Skewness	-0.77907		Skewness	0.288931
Range	5.97E-05		Range	0.001235
Minimum	0.015695		Minimum	0.016046
Maximum	0.015755		Maximum	0.017281
Sum	0.173068		Sum	0.182159
Count	11		Count	11

Table 6 presents statistics, derived from data in Table 5, on the accuracy performance of each propagator, weighed against observation data. The means are representative of percent difference (of calculated semimajor axis, in kilometers) between the predicted decayed semimajor axis 24 hours after epoch and the final observed semimajor axis after 24 hours. These percentage differences are all absolute values, though in all calculations the predicted semimajor axis was smaller than the observed semimajor axis.

D. CONCLUSION

Both propagators perform atmospheric decay prediction at an accuracy rate that falls within the expected values described by Schumacher [26] and Vallado [3], i.e. between 1-3 kilometers of error per day, and neither propagator is significantly more accurate than the other. Because of similarities in the secular theories for Earth gravity and resonance in each propagator, it can be assumed that the differences in the calculation of secular effects from those forces will be much smaller than the effects from atmosphere. Neither propagator appears to have an accuracy rate growth that is significantly better or worse than the other, but it is important to note that the differences presented in this data are based on the assumption of accurate TLE input data from observation. Therefore, it is equally important to know the accuracy and timeliness of any observation data entered into one of the models for SATVUL planning. Unexpected values in TLE input should be investigated before propagating the orbit, and the epoch time of the TLE should be taken into consideration before using the TLE to propagate; i.e. using a two week old TLE for initial calculation will introduce greater accumulated error than a one day old TLE.

The accuracy performance of each atmospheric model increases as semimajor axis, along with altitude above the Earth, increases. This is to be expected, as the drag values from observation data that drive each atmospheric model should eventually become indistinguishable from zero at a high enough altitude, reflecting the physical reality of the upper limits of Earth’s atmosphere [8]. Thus, it can be assumed that outside the effects of atmosphere, where the secular effects of lunar and solar gravity are more prevalent and both propagators utilize identical mathematical theory in modeling, the accuracy differences between SGP4 and PPT3 will continue to decrease. This assumption is reflected in the fit span in Tables 1 and 2, from Schumacher and Glover [26].

V. CONCLUSION AND FUTURE WORK

Building on the conclusions from Chapter IV, as well as previous literature and empirical study of SGP4 and PPT3, this chapter summarizes the analysis and findings of this thesis. In addition, the analysis and conclusions of previous chapters are put into a practical context for tactical and operational planning of satellite vulnerability windows, including general recommendations for their use and recommendations for planning buffers around those same vulnerability windows.

A. RESEARCH SUMMARY

Despite the unavailability of a fully functional copy of the PPT3 code for this thesis, several conclusions can still be drawn from previous studies of PPT3 and SGP4; especially previous empirical tests of SGP4's accuracy over time. In addition, performance data in this thesis from each propagator's atmospheric model helps inform conclusions about the most impactful difference in the two propagators: the methods each employs to attempt to model Earth's complex atmosphere.

Along with the mathematical differences for calculating secular effects, it is important to note that both propagators are also heavily dependent on their input for predictive accuracy. There are several examples of TLE inputs in Appendix C which have a mean motion derivative for PPT3 atmospheric decay calculation, but have a 00000+0 B* term for SGP4 atmospheric decay calculation. This will cause PPT3 to predict cumulatively shorter orbits, while SGP4 will maintain the exact same orbital period over time. The physical world that these propagators are attempting to model is somewhere in between, emphasizing the importance of recalibrating each model as frequently as possible (updated observations of active satellites are available at least daily).

The atmospheric model accuracy results in this thesis, along with previous empirical studies on the performance of SGP4 [3], and the fit spans for PPT3 provided in Tables 1 and 2 [26], show relatively similar performance of both propagators over time; i.e. a cumulative error rate of 1-3 kilometers per day from epoch. Hoots notes in Spacetrack Report #3 that the effect of error in mean motion input at epoch will generate cumulative position errors at a rate of:

$$\Delta r = \Delta \mathrm{n} \times (t - t_0) \times (6378.135)$$

where
Δr = position error (in kilometers)
$\Delta \mathrm{n}$ = mean motion error (in radians)
$(t - t_0)$ = time difference since epoch [36].

This essentially means that accuracy errors in initial input can have a large impact on the future predicted position of the satellite. With an expected TLE accuracy error of 1 kilometer at epoch [3], the findings in this thesis correlate well with this previous work. As noted in Chapter II of this thesis, errors of this size are inherent in the use of any analytical propagator that solely calculates the linear secular perturbations on an orbit over time.

For the application of SGP4 and PPT3 in catalog maintenance and general planning, the empirical propagation errors are acceptable in the context of the accuracy required to successfully perform these functions. As an example, a 2 kilometer error in a typical circular LEO orbit represents just over a quarter of a second in travel time for the satellite at a velocity of 7.5 km/s (2.0km/7.5km/s=0.27 s). Given that this same orbit should have an altitude of 700km from the surface of the Earth, this error also represents arctangent(2.0km/700.0km) = 0.16 degrees difference in the angular error of the satellite as observed by someone on the surface of the Earth. As Vallado notes in “Revisiting Spacetrack Report #3,” analytical propagators are valuable, despite their decrease in accuracy from numerical propagators, when applied to:

- Rapid searches for satellite visibility for ground stations, and generation of communication schedules.
- Programmed tracking of medium beamwidth antennas (or initial acquisition for narrow beamwidth auto-track systems) using limited CPU power embedded devices.

- Investigations into initial orbit design based on low-precision requirements, such as general sensor and/or ground station visibility statistics.
- Rapid assessment of close conjunctions can be made computationally efficient by pre-processing with analytical techniques, and then applying numerical techniques only to those cases that appear to warrant additional consideration. [3]

B. SATELLITE VULNERABILITY PLANNING

For a ship or unit that wants to avoid detection, it is assumed that procedures for stowing sensitive equipment, turning off radiating signals, or concealing local presence will not be on the order of less than a second. It is likely that such procedures will be on the order of minutes, with time buffers built into any satellite vulnerability planning scenario to allow for variation and ensure that satellite detection is avoided. Both SGP4 and PPT3 are therefore capable of propagating orbits with sufficient accuracy to be used in tactical and operational planning, within the useful fit spans detailed in Tables 1 and 2.

While the cumulative errors of both propagators will build up over time from epoch, knowledge of the size of the orbit, the accuracy of the input, and the performance of the model will allow planners to choose to extend propagation for planning up to several days from epoch, or to choose to recalibrate more frequently and plan satellite vulnerability windows that are much closer to epoch. The most accurate employment of these models will require frequently recalibrating with new observation data, which is available at least daily from JFCC Space for active satellites (as shown in the data sets in Appendix C). When less accuracy is required or availability of observation data is limited, additional time buffers on the order of minutes will allow ships and ground units to extend planning of satellite vulnerability windows for additional time past epoch. The size of these time buffers will depend on the altitude of the satellite of interest, as the accuracy of each propagator increases with greater altitude.

C. FUTURE WORK

This thesis discovered and analyzed the theoretical differences between the SGP4 and PPT3 orbital propagator models. Data from the models were used to compare accuracy between the propagators, and describe differences in how each accumulates error and propagates that error forward. However, due to the incomplete software package provided to study PPT3, the study and analysis were limited to the atmospheric decay modelling by each propagator. Though atmospheric modelling presents the greatest theoretical difference between PPT3 and SGP4, it is still only one component in a system that will carry its errors forward into other areas. Due to the complex nature of its initial semimajor axis calculator, numerous assumptions had to be made in order to calibrate PPT3 to predict atmospheric decay. The consequence of these assumptions is a level of uncertainty about PPT3's performance within the study, as it may be more or less accurate when used as a whole system and properly calibrated.

Further research with these propagators will most certainly require continued engagement with AFSPC, in order to acquire the complete set of PPT3 code, as well as guidance on properly calibrating and initializing the model. It would be useful to encapsulate the functions and subroutines in PPT3 together with the needed initialization code in a software wrapper that takes a TLE and a time as input and produces predicted satellite position at the given time as output. This would make PPT3 very much easier to use.

With the complete model in hand, PPT3 software could efficiently be called to predict future positional data for hundreds of variations on satellite orbits, including user-defined orbital elements designed to create singularities within each propagator and reveal where they break down mathematically.

Additional work with the partial MATLAB translation of PPT3, along with the available MATLAB versions of SGP4, would also provide more insight into the functions of the propagator as a whole. MATLAB was found to be both accessible and straightforward for writing scripts and functions for this thesis, and allowed easy retrieval of comparison variables from memory during propagation.

Any model is only as reliable as the data it is based on. The analysis of sample TLEs in Chapter IV found instances where the model elements derived from the observation data had unexpected characteristics. Closer analysis and validation of the model calibration procedures used to fit TLEs to data from satellite position observations may provide additional insights into factors affecting prediction accuracy that may be relevant to satellite vulnerability planning.

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APPENDIX A. MATLAB CODE

A. MATLAB TLE READER FOR PPT3 INPUT

```
%-------------------------------------------------------------------
%------------------------------- TLE  ------------------------------
%-------------------------------------------------------------------

% Classification: Unclassified
%
% Naval Postgraduate School
% Christopher Wildt
% Created: 26 May 2017
% Version: 1.0

% Code elements borrowed from:
% 'test_sgp4.m' version 1.0 by Meysam Mahooti, uploaded 22 Mar 2017
% from: https://www.mathworks.com/matlabcentral/fileexchange/62013-sgp4
%
% 'jl2normaldate' version 1.1 by M Sohrabinia, uploaded 6 Jun 2012
% from: https://www.mathworks.com/matlabcentral/fileexchange/36901-
convert-julian-date-to-normal-date

% TLE Inputs for PPT3
% TLE file name
fname = '*.tle';

% Open the TLE file and read TLE elements
fid = fopen(fname, 'r');

% 19-32 04236.56031392  Element Set Epoch (UTC)
% 3-7   25544   Satellite Catalog Number
% 9-16  51.6335 Orbit Inclination (degrees)
% 18-25 344.7760    Right Ascension of Ascending Node (degrees)
% 27-33 0007976 Eccentricity (decimal point assumed)
% 35-42 126.2523    Argument of Perigee (degrees)
% 44-51 325.9359    Mean Anomaly (degrees)
% 53-63 15.70406856 Mean Motion (revolutions/day)
% 64-68 32890   Revolution Number at Epoch

while (1)
    % read first line
    tline = fgetl(fid);
    if ~ischar(tline)
        break
    end
    Cnum = tline(3:7);              % Catalog Number (NORAD)
    SC   = tline(8);                % Security Classification
    ID   = tline(10:17);            % Identification Number
    epoch = str2num(tline(19:32));   % Epoch
    TD1   = str2num(tline(34:43));   % first time derivative
    TD2   = str2num(tline(45:50));   % 2nd Time Derivative
```

```
    ExTD2 = tline(51:52);            % Exponent of 2nd Time Derivative
    BStar = str2num(tline(54:59));   % Bstar/drag Term
    ExBStar = str2num(tline(60:61)); % Exponent of Bstar/drag Term
    BStar = BStar*1e-5*10^ExBStar;
    Etype = tline(63);               % Ephemeris Type
    Enum  = str2num(tline(65:end));  % Element Number

    % read second line
    tline = fgetl(fid);
    if ~ischar(tline)
        break
    end
    i = str2num(tline(9:16));        % Orbit Inclination (degrees)
    raan = str2num(tline(18:25));    % Right Ascension of Ascending
Node (degrees)
    e = str2num(strcat('0.',tline(27:33)));     % Eccentricity
    omega = str2num(tline(35:42));   % Argument of Perigee (degrees)
    M = str2num(tline(44:51));       % Mean Anomaly (degrees)
    no = str2num(tline(53:63));      % Mean Motion
    rNo = str2num(tline(64:68));     % Revolution Number at Epoch
end
fclose(fid);

    N0 = no;
    NODOT = TD1;
    NODOT2 = TD2;
    ECC = e;
    I_DEG = i;
    AGRPER_D = omega;
    RTASC_DEG = raan;
    EPOCH = mjuliandate(jl2normaldate(2000000+epoch,'dd-mmm-yyyy
HH:MM:SS'));
    MNANOM_D = M;
%
% RADIAN and CTU Conversion
%
    MNMOT = (CTUDAY/(2*PI))*N0;
    DECAY1 = (CTUDAY^2/(2*PI))*NODOT;
    DECAY2 = (CTUDAY^3/(2*PI))*NODOT2;
    I = I_DEG/DEGRAD;
    COSI = cos(I);
    ARGPER = AGRPER_D/DEGRAD;
    RTASC = RTASC_DEG/DEGRAD;
    XMA = MNANOM_D/DEGRAD;
    MNANOM = XMA;
```

B. MATLAB JULIAN DATE CONVERTER

```
function [normalDate status] = jl2normaldate(jl_dates,dateFormat)
% Function Description:
% This function accepts Julian Date vector (jl_dates, numerical type),
and
% writes the output in a character vector (normalDate). The output
% character date format can be defined in the second input variable
% (dateFormat), or the default 'dd-mmm-yyyy HH:MM:SS' string date
format
% will be used.
% Julian Date input format: yyyyddd, e.g, 01 Jan 2009 = 2009001 or
% 31 Dec 2009 = 2009365. Normal date output format can be 'dd-mmm-yyyy'
% (e.g., 31-Dec-2009).
%
%   The function is suitable to convert Julian Date with the above
format
% to normal date. It is useful for processing of remote sensing
datasets
% available in HDF-EOS format, such as MODIS LST or AMSR datasets,
where
% Julian Date is part of each HDF_EOS file-name. To extract date of
% observation in these dataset, Julian Date part can be extracted from
the
% file name (e.g., in MODIS LST L3 datasets JL-Date is given in 10th
till
% 16th characters in the file name). Using this function, these dates
can
% be converted to normal date.
%
% --Inputs:
%   jl_dates: one or a vector of numerical Julian dates (7 digits:
0000000)
%   dateFormat: format of the output string date (optional)
% --Outputs:
%   normalDate: a character vector of output date(s)
%   status: a string character giving information about possible
warnings
%   which will be generated if the input jl_dates vector does not
follow
%   required conditions.
%-----------------------------------------------------------------------
----
% First Version: 01 Nov 2011 (V01)
% Updated: Jun 06 2012
% Email: sohrabinia.m@gmail.com
%-----------------------------------------------------------------------
----

if nargin <1
    disp('Error! at least one argument must be provided');
    return;
elseif nargin <2
    dateFormat='dd-mmm-yyyy HH:MM:SS';
end
```

```
tst1=jl_dates(1)/1000000;
tst2=jl_dates(1)/10000000;
if tst1<1 || tst1>9 || floor(tst2)>0
    fprintf(['Warning! input Julian dates should be numeric formatted
'...
        'yyyyddd,\n where yyyy is year and ddd is days out of 365 (or
'...
        '366 for leap years)\n']);
    status='returned with warnings';
else
    status='Returned with no warning';
end


years  = floor(jl_dates/1000);
days   = jl_dates-years*1000;
months =
['Jan';'Feb';'Mar';'Apr';'May';'Jun';'Jul';'Aug';'Sep';'Oct';...
    'Nov';'Dec'];
% work out dates:
normalDate = cell(length(days),1);
yr1=0;
j=1;
for i=1:length(years)
    diff=years(i)-yr1;
    if diff>0
        yrEnd(j)=i-1; %first element will be the end of non-exsitant
year
        yr1=yr1+diff;
        yrs(j)=yr1;
        j=j+1;
    end
end
yrEnd(j)=i;     %last element will be the end of last year in data
for jj=1:length(yrs)
    ly = leapyear(yrs(jj)); %check if the year is a leap year (yes:1,
no:0)
    if ly == 0
        dMonths = [31;28;31;30;31;30;31;31;30;31;30;31]; %days of
months
                   % in normal years
    else
        dMonths = [31;29;31;30;31;30;31;31;30;31;30;31]; %days of
months
                   % in leap-years
    end
    for j = (yrEnd(jj)+1):yrEnd(jj+1) %start from beg of the yr go to
end
                   % of that yr
        i = 1;
        while days(j) > dMonths(i)
            days(j) = days(j)-dMonths(i);
            i = i+1;
        end
```

```
        mnth           = months(i,1:end);    %this is the month of the
                          % original Julian day
        dy             = num2str(days(j));   %actual day after
subtracting
                          % cumulative days of earlier months
        normalDate{j}= strcat(dy,'-',mnth,'-',num2str(yrs(jj))); %write
                         % string dates in cell-array
    end
end
normalDate = datestr(datenum(normalDate),dateFormat);
end %end of function
```

C. MATLAB SGP4

```
% 'test_sgp4.m' version 1.0 by Meysam Mahooti, uploaded 22 Mar 2017
% available at:
https://www.mathworks.com/matlabcentral/fileexchange/62013-sgp4

clc
clear
format long g

ge = 398600.8; % Earth gravitational constant
TWOPI = 2*pi;
MINUTES_PER_DAY = 1440.;
MINUTES_PER_DAY_SQUARED = (MINUTES_PER_DAY * MINUTES_PER_DAY);
MINUTES_PER_DAY_CUBED = (MINUTES_PER_DAY * MINUTES_PER_DAY_SQUARED);

% TLE file name
fname = 'tle.txt';

% Open the TLE file and read TLE elements
fid = fopen(fname, 'r');

% 19-32     04236.56031392    Element Set Epoch (UTC)
% 3-7 25544 Satellite Catalog Number
% 9-16      51.6335     Orbit Inclination (degrees)
% 18-25     344.7760    Right Ascension of Ascending Node (degrees)
% 27-33     0007976     Eccentricity (decimal point assumed)
% 35-42     126.2523    Argument of Perigee (degrees)
% 44-51     325.9359    Mean Anomaly (degrees)
% 53-63     15.70406856 Mean Motion (revolutions/day)
% 64-68     32890 Revolution Number at Epoch

while (1)
    % read first line
    tline = fgetl(fid);
    if ~ischar(tline)
        break
    end
    Cnum = tline(3:7);                            %    Catalog    Number
(NORAD)
    SC   = tline(8);                                    %       Security
Classification
    ID   = tline(10:17);                              %   Identification
Number
    epoch = str2num(tline(19:32));             % Epoch
    TD1   = str2num(tline(34:43));             % first time derivative
    TD2   = str2num(tline(45:50));             % 2nd Time Derivative
    ExTD2 = tline(51:52);                        % Exponent of 2nd Time
Derivative
    BStar = str2num(tline(54:59));             % Bstar/drag Term
    ExBStar  =  str2num(tline(60:61));                 %  Exponent  of
Bstar/drag Term
    BStar = BStar*1e-5*10^ExBStar;
    Etype = tline(63);                         % Ephemeris Type
    Enum  = str2num(tline(65:end));            % Element Number
```

```
    % read second line
    tline = fgetl(fid);
    if ~ischar(tline)
        break
    end
    i = str2num(tline(9:16));                        % Orbit Inclination
(degrees)
    raan = str2num(tline(18:25));                    % Right Ascension of
Ascending Node (degrees)
    e = str2num(strcat('0.',tline(27:33)));     % Eccentricity
    omega = str2num(tline(35:42));                  % Argument of Perigee
(degrees)
    M = str2num(tline(44:51));                               % Mean Anomaly
(degrees)
    no = str2num(tline(53:63));                 % Mean Motion
    a = ( ge/(no*2*pi/86400)^2 )^(1/3);         % semi major axis (m)
    rNo = str2num(tline(64:68));                  % Revolution Number at
Epoch
end
fclose(fid);

satdata.epoch = epoch;
satdata.norad_number = Cnum;
satdata.bulletin_number = ID;
satdata.classification = SC; % almost always 'U'
satdata.revolution_number = rNo;
satdata.ephemeris_type = Etype;
satdata.xmo = M * (pi/180);
satdata.xnodeo = raan * (pi/180);
satdata.omegao = omega * (pi/180);
satdata.xincl = i * (pi/180);
satdata.eo = e;
satdata.xno = no * TWOPI / MINUTES_PER_DAY;
satdata.xndt2o = TD1 * 1e-8 * TWOPI / MINUTES_PER_DAY_SQUARED;
satdata.xndd6o = TD2 * TWOPI / MINUTES_PER_DAY_CUBED;
satdata.bstar = BStar;

tsince = 1440;

[pos, vel] = sgp4(tsince, satdata);
fprintf('     TSINCE               X                  Y                  Z
[km]\n');
fprintf(' %9.1f%22.8f%18.8f%18.8f \n',tsince,pos(1),pos(2),pos(3));
fprintf('                        XDOT              YDOT              ZDOT
[km/s]\n');
fprintf('  %28.8f%18.8f%18.8f \n\n',vel(1),vel(2),vel(3));
```

```
%-------------------------------------------------------------------
%------------------------------ sgp4 -------------------------------
%-------------------------------------------------------------------
function [pos, vel] = sgp4(tsince, satdata)

ae = 1.0;
tothrd = (2.0/3.0);
XJ3 = -2.53881e-6;
e6a = 1.0E-6;
xkmper = 6378.135;
ge = 398600.8; % Earth gravitational constant
CK2 = (1.0826158e-3 / 2.0);
CK4 = (-3.0 * -1.65597e-6 / 8.0);

% Constants
s = ae + 78 / xkmper;
qo = ae + 120 / xkmper;
xke = sqrt((3600.0 * ge) / (xkmper^3));
qoms2t = ((qo - s)^2)^2;
temp2 = xke / (satdata.xno);
a1 = temp2^tothrd;
cosio = cos (satdata.xincl);
theta2 = (cosio^2);
x3thm1 = 3.0 * theta2 - 1.0;
eosq = (satdata.eo^2);
betao2 = 1.0 - eosq;
betao = sqrt(betao2);
del1 = 1.5 * CK2 * x3thm1 / ((a1^2) * betao * betao2);
ao = a1 * ( 1.0 - del1*((1.0/3.0) + del1 * (1.0 + (134.0/81.0) *
del1)));
delo = 1.5 * CK2 * x3thm1 / ((ao^2) * betao * betao2);
xnodp = (satdata.xno)/(1.0 + delo);
aodp = ao/(1.0 - delo);
% Initialization
% For perigee less than 220 kilometers, the isimp flag is set and
% the equations are truncated to linear variation in sqrt a and
% quadratic variation in mean anomaly.  Also, the c3 term, the
% delta omega term, and the delta m term are dropped.
isimp = 0;
if ((aodp * (1.0 - satdata.eo)/ ae) < (220.0/xkmper + ae))
    isimp = 1;
end
% For perigee below 156 km, the values of s and qoms2t are altered.
s4 = s;
qoms24 = qoms2t;
perige = (aodp * (1.0 - satdata.eo) - ae) * xkmper;
if (perige < 156)
    s4 = perige - 78.0;
    if (perige <= 98)
        s4 = 20.0;
    end
    qoms24 = (((120.0 - s4) * ae / xkmper)^4.0);
    s4 = s4 / xkmper + ae;
end
pinvsq = 1.0 / ( (aodp^2) * (betao2^2) );
```

```
tsi = 1.0 / (aodp - s4);
eta = aodp * (satdata.eo) * tsi;
etasq = (eta^2);
eeta = (satdata.eo) * eta;
psisq = abs( 1.0 - etasq);
coef = qoms24 * (tsi^4.0);
coef1 = coef / (psisq^3.5);
c2 = coef1 * xnodp * (aodp * (1.0 + 1.5 * etasq + eeta * (4.0 + etasq))
+ 0.75 * CK2 * tsi / psisq * x3thm1 * (8.0 + 3.0 * etasq * (8.0 +
etasq)));
c1 = (satdata.bstar) * c2;
sinio = sin(satdata.xincl);
a3ovk2 = -XJ3 / CK2 * (ae^3.0);
c3 = coef * tsi * a3ovk2 * xnodp * ae * sinio / (satdata.eo);
x1mth2 = 1.0 - theta2;
c4 = 2.0 * xnodp * coef1 * aodp * betao2 * ( eta * (2.0 + 0.5 * etasq)
+ (satdata.eo) * (0.5 + 2.0 * etasq) - 2.0 * CK2 * tsi / (aodp * psisq)
* ( -3.0 * x3thm1 * ( 1.0 - 2.0 * eeta + etasq * (1.5 - 0.5*eeta)) +
0.75 * x1mth2 * (2.0 * etasq - eeta * (1.0 + etasq)) * cos(2.0 *
(satdata.omegao))));
c5 = 2.0 * coef1 * aodp * betao2 * (1.0 + 2.75 * (etasq + eeta) + eeta
* etasq);
theta4 = (theta2^2);
temp1 = 3.0 * CK2 * pinvsq * xnodp;
temp2 = temp1 * CK2 * pinvsq;
temp3 = 1.25 * CK4 * pinvsq * pinvsq * xnodp;
xmdot = xnodp + 0.5 * temp1 * betao * x3thm1 + 0.0625 * temp2 * betao *
(13.0 - 78.0 * theta2 + 137.0 * theta4);
x1m5th = 1.0 - 5.0 * theta2;
omgdot = -0.5 * temp1 * x1m5th + 0.0625 * temp2 * (7.0 - 114.0 * theta2
+ 395.0 * theta4) + temp3 * (3.0 - 36.0 * theta2 + 49.0 * theta4);
xhdot1 = -temp1 * cosio;
xnodot = xhdot1 + (0.5 * temp2 * (4.0 - 19.0 * theta2) + 2.0 * temp3 *
(3.0 - 7.0 * theta2)) * cosio;
omgcof = (satdata.bstar) * c3 * cos(satdata.omegao);
xmcof = -(2.0/3.0) * coef * (satdata.bstar) * ae / eeta;
xnodcf = 3.5 * betao2 * xhdot1 * c1;
t2cof = 1.5 * c1;
xlcof = 0.125 * a3ovk2 * sinio * (3.0 + 5.0 * cosio) / (1.0 + cosio);
aycof = 0.25 * a3ovk2 * sinio;
delmo = ((1.0 + eta * cos(satdata.xmo))^3);
sinmo = sin(satdata.xmo);
x7thm1 = 7.0 * theta2 - 1.0;
if (isimp==0)
    c1sq = (c1^2);
    d2 = 4.0 * aodp * tsi * c1sq;
    temp = d2 * tsi * c1 / 3.0;
    d3 = (17.0 * aodp + s4)*temp;
    d4 = 0.5 * temp * aodp * tsi * (221.0 * aodp + 31.0 * s4) * c1;
    t3cof = d2 + 2.0*c1sq;
    t4cof = 0.25 * (3.0 * d3 + c1 * (12.0 * d2 + 10.0 * c1sq));
    t5cof = 0.2 * (3.0 * d4 + 12.0 * c1 * d3 + 6.0 * d2 * d2 + 15.0 *
c1sq * (2.0 * d2 + c1sq));
end
% Update for secular gravity and atmospheric drag.
```

```
xmdf = satdata.xmo + xmdot * tsince;
omgadf = satdata.omegao + omgdot * tsince;
xnoddf = satdata.xnodeo + xnodot * tsince;
omega = omgadf;
xmp = xmdf;
tsq = (tsince^2);
xnode = xnoddf + xnodcf * tsq;
tempa = 1.0 - c1 * tsince;
tempe = (satdata.bstar) * c4 * tsince;
templ = t2cof * tsq;
if (isimp == 0)
    delomg = omgcof * tsince;
    delm = xmcof*(((1.0 + eta * cos(xmdf))^ 3.0) - delmo);
    temp = delomg + delm;
    xmp = xmdf + temp;
    omega = omgadf - temp;
    tcube = tsq * tsince;
    tfour = tsince * tcube;
    tempa = tempa - d2 * tsq - d3 * tcube - d4 * tfour;
    tempe = tempe + (satdata.bstar) * c5 * (sin(xmp) - sinmo);
    templ = templ + t3cof * tcube + tfour * (t4cof + tsince * t5cof);
end
a = aodp * (tempa^2);
e = (satdata.eo) - tempe;
xl = xmp + omega + xnode + xnodp*templ;
beta = sqrt(1.0 - (e^2));
xn = xke / (a^1.5);
% Long period periodics
axn = e * cos(omega);
temp = 1.0 / (a * (beta^2));
xll = temp * xlcof * axn;
aynl = temp * aycof;
xlt = xl + xll;
ayn = e * sin(omega) + aynl;
% Solve Kepler's Equation
capu = fmod2p(xlt - xnode);
temp2 = capu;
i=1;
while(1)
    sinepw = sin(temp2);
    cosepw = cos(temp2);
    temp3 = axn * sinepw;
    temp4 = ayn * cosepw;
    temp5 = axn * cosepw;
    temp6 = ayn * sinepw;
    epw  =  (capu  -  temp4  +  temp3  -  temp2)  /  (1.0  -  temp5  -  temp6)  +
temp2;
    temp7 = temp2;
    temp2 = epw;
    i = i+1;
      if ((i>10) || (abs(epw - temp7) <= e6a))
            break
      end
end
```

```
% Short period preliminary quantities
ecose = temp5 + temp6;
esine = temp3 - temp4;
elsq = (axn^2) + (ayn^2);
temp = 1.0 - elsq;
pl = a * temp;
r = a * (1.0 - ecose);
temp1 = 1.0 / r;
rdot = xke * sqrt(a) * esine * temp1;
rfdot = xke * sqrt(pl) * temp1;
temp2 = a * temp1;
betal = sqrt(temp);
temp3 = 1.0 / (1.0 + betal);
cosu = temp2 * (cosepw - axn + ayn * esine * temp3);
sinu = temp2 * (sinepw - ayn - axn * esine * temp3);
u = actan(sinu, cosu);
sin2u = 2.0 * sinu * cosu;
cos2u = 2.0 * (cosu^2) - 1.0;
temp = 1.0 / pl;
temp1 = CK2 * temp;
temp2 = temp1 * temp;
% Update for short periodics
rk = r * (1.0 - 1.5 * temp2 * betal * x3thm1) + 0.5 * temp1 * x1mth2 *
cos2u;
uk = u - 0.25 * temp2 * x7thm1 * sin2u;
xnodek = xnode + 1.5 * temp2 * cosio * sin2u;
xinck = (satdata.xincl) + 1.5 * temp2 * cosio * sinio * cos2u;
rdotk = rdot - xn * temp1 * x1mth2 * sin2u;
rfdotk = rfdot + xn * temp1 * (x1mth2 * cos2u + 1.5 * x3thm1);
% Orientation vectors
MV.v(1) = -sin(xnodek) * cos(xinck);
MV.v(2) = cos(xnodek) * cos(xinck);
MV.v(3) = sin(xinck);

NV.v(1) = cos(xnodek);
NV.v(2) = sin(xnodek);
NV.v(3) = 0;

for i=1:3
      UV.v(i) = MV.v(i) * sin(uk) + NV.v(i) * cos(uk);
      VV.v(i) = MV.v(i) * cos(uk) - NV.v(i) * sin(uk);
end

% position + velocity
for i=1:3
      pos.v(i) = rk * UV.v(i);
      vel.v(i) = rdotk * UV.v(i) + rfdotk * VV.v(i);
end

[pos, vel] = Convert_Sat_State(pos, vel);
```

```
%------------------------------------------------------------------
%------------------------------ modulus ---------------------------
%------------------------------------------------------------------
function modu = modulus(arg1, arg2)

modu = arg1 - floor(arg1/arg2) * arg2;

if (modu >= 0)
    return
else
    modu = modu + arg2;
    return
end


%------------------------------------------------------------------
%------------------------------- fmod2p ---------------------------
%------------------------------------------------------------------
function x = fmod2p(x)

x = modulus(x,2*pi);


%------------------------------------------------------------------
%------------------------- Convert_Sat_State ----------------------
%------------------------------------------------------------------
function [p, v] = Convert_Sat_State(pos, vel)

xkmper = 6378.135;

p = zeros(3,1);
v = zeros(3,1);

for i=1:3
    p(i) = pos.v(i) * xkmper;
    v(i) = vel.v(i) * xkmper / 60;
end


%------------------------------------------------------------------
%------------------------------ Magnitude -------------------------
%------------------------------------------------------------------
function t = actan(y, x)

t = atan2(y,x);
if (t < 0)
    t = t + 2*pi;
end
```

APPENDIX B. SGP4 ATMOSPHERIC MODELING THEORY

The following excerpt on atmospheric modeling theory is from the work of Hoots, Schumacher, and Glover [15, pp. 180-181]:

> Atmospheric drag modeling [in SGP4] is based on a power-law density function given by:
>
> $$\rho = \rho_0 (q_0 - s)^4 / (r - s)^4$$
>
> where r is the radial distance of the satellite from the center of the Earth with q_0 and s being altitude parameters of the power-law density function. The parameter q_0 is a constant equal to 120 km plus one Earth radius, whereas s is determined based of epoch perigee height above a spherical Earth. If perigee height is greater than or equal 156 km, the value of s is fixed to be 78 km plus one Earth radius. For altitudes greater than or equal to 98 km but less than 156 km, s is defined to be perigee height minus 78 km plus one Earth radius. For altitudes below 98 km, s is 20 km plus one Earth radius. In the following equations, the parameters q_0 and s should be in units of Earth radii:

$$\theta = \cos i_0 \qquad \xi = \frac{1}{a_0 - s}$$

$$\beta_0 = \left(1 - e_0^2\right)^{\frac{1}{2}} \qquad \eta - a_0 e_0 \xi$$

$$C_2 = (q_0 - s)^4 \xi^4 n_0 (1 - \eta^2)^{-\frac{7}{2}} \left[\begin{array}{l} a_0 \left(1 + \frac{3}{2}\eta^2 + 4e_0\eta + e_0\eta^3\right) \\ + \frac{3}{2}\frac{k_2\xi}{\left(1-\eta^2\right)}\left(-\frac{1}{2} + \frac{3}{2}\theta^2\right)\left(8 + 24\eta^2 + 3\eta^4\right) \end{array} \right]$$

$$C_1 = B^* C_2 \qquad C_3 = \frac{(q_0 - s)^4 \xi^5 A_{3,0} n_0 a_E \sin i_0}{k_2 e_0}$$

$$C_4 = 2n_0 (q_0 - s)^4 \xi^4 a_0 \beta_0^2 \left(1-\eta^2\right)^{-\frac{7}{2}} \left\{ \begin{aligned} &\left[2\eta\left(1+e_0\eta\right) + \frac{1}{2}e_0 + \frac{1}{2}\eta^3 \right] \\ &\frac{-2k_2\xi}{a_0\left(1-\eta^2\right)} \left[\begin{aligned} &3\left(1-3\theta^2\right)\left(1+\frac{3}{2}\eta^2 - 2e_0\eta - \frac{1}{2}e_0\eta^3\right) \\ &+\frac{3}{4}\left(1-\theta^2\right)\left(2\eta^2 - e_0\eta - e_0\eta^3\right)\cos 2\omega_0 \end{aligned} \right] \end{aligned} \right\}$$

$$C_5 = 2(q_0 - s)^4 \xi^4 a_0 \beta_0^2 \left(1-\eta^2\right)^{-\frac{7}{2}} \left[1 + \frac{11}{4}\eta\left(\eta + e_0\right) + e_0\eta^3 \right]$$

$$D_2 = 4a_0\xi C_1^2 \qquad D_3 = \frac{4}{3}a_0\xi^2\left(17a_0 + s\right)C_1^3$$

$$D_4 = \frac{2}{3}a_0^2\xi^3\left(221a_0 + 31s\right)C_1^4$$

where

$k_2 = \frac{1}{2}J_2 a_E^2$, (Earth radii) ^{2}

$J_2 = 1.082616\times 10^{-3}$

$k_e = \sqrt{GM} = 0.0743669161$ (Earth radii) $^{1.5}/\min$

G = universal gravitational constant

M = mass of the Earth

a_E = equatorial radius of the Earth

$J_3 = -0.253881\times 10^{-5}$

$A_{3,0} = -J_3 a_E^3$

Then the secular update for remaining atmospheric drag effects is given as:

$$e = e_0 - B^*C_4(t-t_0) - B^*C_5(\sin M - \sin M_0)$$

$$a = (k_e/n)^{\frac{2}{3}}\left[1 - C_1(t-t_0) - \mathrm{D}_2(t-t_0)^2 - D_3(t-t_0)^3 - D_4(t-t_0)^4\right]^2$$

$$IL = M + \omega + \Omega + n_0 \left[\begin{array}{l} \frac{3}{2} C_1 (t - t_0)^2 + \left(D_2 + 2C_1^2 \right)(t - t_0)^3 \\ + \frac{1}{4}(3D_3 + 12C_1 D_2 + 10C_1^3)(t - t_0)^4 \\ + \frac{1}{5}(3D_4 + 12C_1 D_3 + 6D_2^2 + 30C_1^2 D_2 + 15C_1^4)(t - t_0)^5 \end{array} \right]$$

where $(t - t_0)$ is time since epoch in minutes

t_0 = epoch time

n_0 = mean motion, revolutions/day

e_0 = eccentricity

ω = argument of perigee, deg
Ω = right ascension of ascending node, deg
M = mean anomaly, deg
$B*$ = atmospheric drag coefficient, 1/Earth radii

Note that when epoch perigee height is less than 220 km or for deep space satellites, the equations for *a* and *I L* are truncated after the linear and quadratic terms, respectively, and the term involving C_5 is dropped. [15]

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APPENDIX C. TLE DATA

All satellite data sourced from JFCC Space at [https://www.space-track.org.](https://www.space-track.org) Data is read in the format shown in Figure 15.

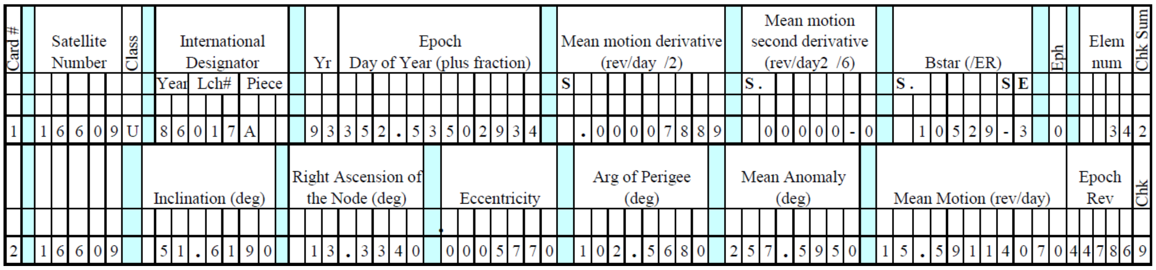

Figure 15. Two-line Element Set Format. Source: [3].

A. SATELLITE 41908

```
1 41908U 16083B   17001.15422700 -.00000073  00000-0  00000+0 0  9990
2 41908  97.5690  78.7679 0029278 328.7989 106.3171 15.18599199   622
1 41908U 16083B   17001.21953318 -.00000068  00000-0  00000+0 0  9995
2 41908  97.5596  78.8377 0015115 288.5184 142.8120 15.15655625   632
1 41908U 16083B   17001.22311200 -.00000068  00000-0  00000+0 0  9994
2 41908  97.5762  78.8526 0015188 298.2479 152.5766 15.15116796   633
1 41908U 16083B   17001.50458333 -.00000068  00000-0  00000+0 0  9994
2 41908  97.5689  79.1213 0017092 304.8809 239.9906 15.14906068   673
1 41908U 16083B   17001.63290328 -.00000066  00000-0  00000+0 0  9994
2 41908  97.5726  79.2360 0011903 295.3267 228.0372 15.13112223   695
1 41908U 16083B   17001.82293381 -.00000066  00000-0  00000+0 0  9997
2 41908  97.5634  79.4342 0013019 277.3232 200.5641 15.13111689   720
1 41908U 16083B   17002.20237858 -.00000066  00000-0  00000+0 0  9997
2 41908  97.5655  79.8079 0012790 275.4699 108.0535 15.13128847   789
1 41908U 16083B   17002.49697917 -.00000066  00000-0  00000+0 0  9994
2 41908  97.5659  80.1020 0012771 274.7105 272.5704 15.13131089   829
1 41908U 16083B   17002.81878933 -.00000066  00000-0  00000+0 0  9999
2 41908  97.5656  80.4210 0012780 273.3952 225.7614 15.13130138   874
1 41908U 16083B   17003.20555135 -.00000066  00000-0  00000+0 0  9999
2 41908  97.5650  80.8056 0012798 270.3196 174.3080 15.13130849   938
1 41908U 16083B   17003.54148895 -.00000066  00000-0  00000+0 0  9997
2 41908  97.5654  81.1385 0012769 269.4287 203.9842 15.13130931   981
1 41908U 16083B   17003.87198693 -.00000066  00000-0  00000+0 0  9994
2 41908  97.5654  81.4665 0012766 268.4412 204.1452 15.13130993  1036
1 41908U 16083B   17004.07141501 -.00000066  00000-0  00000+0 0  9993
2 41908  97.5653  81.6643 0012829 266.9848 211.2526 15.13130654  1067
1 41908U 16083B   17004.53379771 -.00000066  00000-0  00000+0 0  9996
2 41908  97.5654  82.1227 0012891 266.5839 208.7860 15.13131250  1130
1 41908U 16083B   17004.79947209 -.00000066  00000-0  00000+0 0  9991
2 41908  97.5654  82.3870 0012940 264.5434 217.1131 15.13131120  1175
1 41908U 16083B   17004.92529909 -.00000066 +00000-0 +00000-0 0  9990
2 41908 097.5655 082.5112 0012924 264.9711 181.6633 15.13131063001191
1 41908U 16083B   17005.18859666 -.00000066  00000-0  00000+0 0  9994
2 41908  97.5657  82.7727 0012949 263.1659 176.8179 15.13131215  1231
```

```
1 41908U 16083B   17005.51493238 -.00000066  00000-0  00000+0 0  9990
2 41908  97.5658  83.0961 0012933 263.0361 153.4614 15.13131279  1288
1 41908U 16083B   17005.85513072 -.00000066  00000-0  00000+0 0  9996
2 41908  97.5658  83.4336 0012918 261.7135 206.7655 15.13131308  1331
1 41908U 16083B   17005.93568412 -.00000066  00000-0  00000+0 0  9993
2 41908  97.5657  83.5140 0012925 260.3926 286.6075 15.13131332  1346
1 41908U 16083B   17006.04478453 -.00000066  00000-0  00000+0 0  9991
2 41908  97.5658  83.6225 0012868 260.0470 160.8784 15.13131461  1364
1 41908U 16083B   17006.11713950 -.00000066  00000-0  00000+0 0  9993
2 41908  97.5662  83.6938 0013121 259.0373 195.7827 15.13132518  1373
1 41908U 16083B   17006.13483154 -.00000066  00000-0  00000+0 0  9995
2 41908  97.5660  83.7114 0012980 259.6195 291.5095 15.13131730  1375
1 41908U 16083B   17006.18261344 -.00000066  00000-0  00000+0 0  9995
2 41908  97.5659  83.7589 0012991 259.5296 191.7163 15.13131786  1381
1 41908U 16083B   17006.46693287 -.00000066  00000-0  00000+0 0  9991
2 41908  97.5655  84.0395 0013007 258.9111 300.1209 15.13131868  1427
1 41908U 16083B   17006.65490316 -.00000066  00000-0  00000+0 0  9990
2 41908  97.5655  84.2260 0012984 258.2951 244.0159 15.13131937  1458
1 41908U 16083B   17006.78792949 -.00000066 +00000-0 +00000-0 0  9992
2 41908 097.5653 084.3579 0012982 257.9049 248.5789 15.13131972001471
1 41908U 16083B   17006.98252578 -.00000066  00000-0  00000+0 0  9992
2 41908  97.5655  84.5511 0012972 257.3093 228.5246 15.13132065  1507
1 41908U 16083B   17007.17488892 -.00000066  00000-0  00000+0 0  9994
2 41908  97.5656  84.7421 0013025 256.4713 196.5575 15.13132243  1539
1 41908U 16083B   17007.50956297 -.00000066  00000-0  00000+0 0  9990
2 41908  97.5658  85.0744 0012984 254.9395 220.0015 15.13132430  1580
1 41908U 16083B   17007.83943007 -.00000066  00000-0  00000+0 0  9991
2 41908  97.5661  85.4018 0012938 253.4307 217.2566 15.13132842  1630
1 41908U 16083B   17008.03417198 -.00000066 +00000-0 +00000-0 0  9992
2 41908 097.5661 085.5951 0012938 252.7601 198.0695 15.13132842001668
1 41908U 16083B   17008.16509782 -.00000066  00000-0  00000+0 0  9996
2 41908  97.5662  85.7250 0013042 252.3724 191.2013 15.13133281  1681
1 41908U 16083B   17008.51483796 -.00000066  00000-0  00000+0 0  9991
2 41908  97.5663  86.0723 0013038 250.9635 296.5432 15.13133720  1739
1 41908U 16083B   17008.83110913 -.00000066  00000-0  00000+0 0  9994
2 41908  97.5665  86.3871 0012990 249.4209 219.8137 15.13133715  1783
1 41908U 16083B   17009.15701933 -.00000066  00000-0  00000+0 0  9998
2 41908  97.5663  86.7104 0013286 248.0738 195.4142 15.13140410  1836
1 41908U 16083B   17009.50739583 -.00000066  00000-0  00000+0 0  9999
2 41908  97.5670  87.0578 0013247 247.4351 303.4176 15.13135481  1889
1 41908U 16083B   17009.82333101 -.00000066  00000-0  00000+0 0  9990
2 41908  97.5667  87.3710 0013204 246.1506 224.6089 15.13135858  1938
1 41908U 16083B   17010.21387821 -.00000066  00000-0  00000+0 0  9993
2 41908  97.5663  87.7584 0013314 244.8733 191.9837 15.13137182  1991
1 41908U 16083B   17010.48784579 -.00000066  00000-0  00000+0 0  9993
2 41908  97.5665  88.0306 0013652 243.3131 244.9995 15.13138348  2035
1 41908U 16083B   17010.87769866 -.00000066  00000-0  00000+0 0  9998
2 41908  97.5664  88.4174 0013608 241.5760 209.0453 15.13138783  2090
1 41908U 16083B   17011.20187723 -.00000066  00000-0  00000+0 0  9992
2 41908  97.5664  88.7386 0013326 241.2313 174.1820 15.13139887  2148
1 41908U 16083B   17011.49144676 -.00000066  00000-0  00000+0 0  9993
2 41908  97.5664  89.0259 0013370 239.7841 312.0097 15.13140210  2183
1 41908U 16083B   17011.87346801 -.00000066  00000-0  00000+0 0  9999
2 41908  97.5660  89.4046 0013325 238.2394 233.2302 15.13140494  2248
1 41908U 16083B   17012.08822656 -.00000066  00000-0  00000+0 0  9990
2 41908  97.5663  89.6204 0013175 235.4898 325.1333 15.13144973  2274
1 41908U 16083B   17012.19914778 -.00000066  00000-0  00000+0 0  9999
2 41908  97.5660  89.7280 0013391 237.1198 207.3162 15.13141239  2293
1 41908U 16083B   17012.39405272 -.00000066  00000-0  00000+0 0  9995
2 41908  97.5659  89.9219 0013503 236.1011 189.3762 15.13141500  2323
1 41908U 16083B   17012.64654633 -.00001275  00000-0  00000+0 0  9993
2 41908  97.5655  90.1716 0015482 231.4068 128.6941 15.13148414  2363
1 41908U 16083B   17012.73091870 -.00000066  00000-0  00000+0 0  9998
```

```
2 41908  97.5658  90.2561 0013383 234.8698 224.4649 15.13141811  2374
1 41908U 16083B   17012.86563941 -.00000066 +00000-0 +00000-0 0  9996
2 41908 097.5659 090.3899 0013357 234.4589 238.2788 15.13141923002399
1 41908U 16083B   17013.19103715 -.00000066  00000-0  00000+0 0  9991
2 41908  97.5657  90.7125 0013459 233.3300 210.8375 15.13142388  2445
1 41908U 16083B   17013.52908255 -.00000066  00000-0  00000+0 0  9990
2 41908  97.5659  91.0485 0013476 231.3851 253.0619 15.13142580  2497
1 41908U 16083B   17013.91901852 -.00000066  00000-0  00000+0 0  9999
2 41908  97.5658  91.4352 0013454 230.2495 216.9607 15.13142785  2550
1 41908U 16083B   17014.07257082 -.00000066 +00000-0 +00000-0 0  9997
2 41908 097.5654 091.5885 0013214 229.8657 333.2720 15.13143675002576
1 41908U 16083B   17014.24937110 -.00000066  00000-0  00000+0 0  9992
2 41908  97.5656  91.7638 0013337 229.4383 216.1821 15.13143919  2600
1 41908U 16083B   17014.52118938 -.00000066  00000-0  00000+0 0  9992
2 41908  97.5657  92.0335 0013350 227.9330 257.4352 15.13144170  2640
1 41908U 16083B   17014.85373050 -.00000066  00000-0  00000+0 0  9996
2 41908  97.5659  92.3641 0013320 226.4895 269.1944 15.13144437  2690
```

B. SATELLITE 41907

```
1 41907U 16083A   17001.20413519 -.00000076  00000-0  00000+0 0  9996
2 41907  97.6150  78.8495 0037571 334.5503  48.9970 15.20966091   622
1 41907U 16083A   17001.27535863 -.00000075  00000-0  00000+0 0  9999
2 41907  97.6092  78.9209 0031683 333.5727  79.2805 15.19856146   638
1 41907U 16083A   17001.50000000 -.00000075  00000-0  00000+0 0  9995
2 41907  97.6161  79.1539 0033747 331.2242 229.9302 15.19839207   662
1 41907U 16083A   17001.75436635 -.00000075  00000-0  00000+0 0  9999
2 41907  97.6149  79.4090 0033727 330.4608 181.5520 15.19837505   707
1 41907U 16083A   17001.94535821 -.00000075 +00000-0 +00000-0 0  9998
2 41907 097.6146 079.6008 0033601 329.8120 146.5298 15.19835844000737
1 41907U 16083A   17002.12538148 -.00000075  00000-0  00000+0 0  9993
2 41907  97.6148  79.7834 0033516 329.0388  51.6628 15.19837361   762
1 41907U 16083A   17002.40882990 -.00000075  00000-0  00000+0 0  9991
2 41907  97.6143  80.0691 0033515 327.8651 162.7227 15.19839679   809
1 41907U 16083A   17002.74269997 -.00000075  00000-0  00000+0 0  9994
2 41907  97.6138  80.4054 0033514 326.7787 189.3944 15.19840191   854
1 41907U 16083A   17002.93146192 -.00000075 +00000-0 +00000-0 0  9997
2 41907 097.6137 080.5959 0033571 326.1842 142.1272 15.19839849000889
1 41907U 16083A   17003.12398388 -.00000075  00000-0  00000+0 0  9994
2 41907  97.6135  80.7893 0033369 325.1588 115.8590 15.19840727   918
1 41907U 16083A   17003.45592671 -.00000075  00000-0  00000+0 0  9991
2 41907  97.6135  81.1242 0033379 323.9766 132.0896 15.19841043   963
1 41907U 16083A   17003.78837041 -.00000075  00000-0  00000+0 0  9990
2 41907  97.6128  81.4587 0033366 322.8840 150.9692 15.19841289  1019
1 41907U 16083A   17003.92075443 -.00000075 +00000-0 +00000-0 0  9997
2 41907 097.6127 081.5925 0033376 322.4272 155.2948 15.19841208001036
1 41907U 16083A   17004.11193137 -.00000075  00000-0  00000+0 0  9999
2 41907  97.6127  81.7851 0033377 321.6196 121.4512 15.19841552  1060
1 41907U 16083A   17004.38420403 -.00000075  00000-0  00000+0 0  9997
2 41907  97.6127  82.0598 0033353 320.5999 171.2470 15.19841768  1105
1 41907U 16083A   17004.77585404 -.00000075  00000-0  00000+0 0  9993
2 41907  97.6126  82.4549 0033355 319.2764 154.0963 15.19841989  1168
1 41907U 16083A   17004.95299769 -.00000075 +00000-0 +00000-0 0  9990
2 41907 097.6126 082.6335 0033374 318.6578 043.3293 15.19842128001195
1 41907U 16083A   17005.10291388 -.00000075  00000-0  00000+0 0  9996
2 41907  97.6129  82.7849 0033406 318.1199 143.6056 15.19842488  1212
1 41907U 16083A   17005.43701583 -.00000075  00000-0  00000+0 0  9995
2 41907  97.6131  83.1219 0033435 316.9564 171.6272 15.19842815  1265
1 41907U 16083A   17005.76014834 -.00000075  00000-0  00000+0 0  9997
2 41907  97.6132  83.4481 0033366 315.8250 139.6387 15.19843218  1318
1 41907U 16083A   17005.95807793 -.00000075 +00000-0 +00000-0 0  9993
2 41907 097.6131 083.6477 0033358 315.1971 142.5408 15.19843510001343
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1 41907U 16083A   17006.21757007 -.00000075  00000-0  00000+0 0  9994
2 41907  97.6131  83.9091 0033015 314.0631 122.5816 15.19844349  1385
1 41907U 16083A   17006.48995934 -.00000075  00000-0  00000+0 0  9996
2 41907  97.6138  84.1844 0032966 313.0860 172.9761 15.19844531  1424
1 41907U 16083A   17006.69208747 -.00000075  00000-0  00000+0 0  9998
2 41907  97.6136  84.3880 0032993 312.4878 198.8068 15.19844805  1450
1 41907U 16083A   17007.01621850 -.00000075  00000-0  00000+0 0  9999
2 41907  97.6138  84.7153 0033055 311.4980 172.1379 15.19845159  1501
1 41907U 16083A   17007.07896828 -.00000071  00000-0  00000+0 0  9990
2 41907  97.6118  84.7831 0022596 286.0610 180.0441 15.17185064  1516
1 41907U 16083A   17007.20766406 -.00000070  00000-0  00000+0 0  9992
2 41907  97.6116  84.9041 0019650 289.0375 159.1473 15.16359784  1532
1 41907U 16083A   17007.20766406 -.00000070  00000-0  00000+0 0  9992
2 41907  97.6116  84.9041 0019650 289.0375 159.1473 15.16359784  1532
1 41907U 16083A   17007.41146866 -.00000067  00000-0  00000+0 0  9993
2 41907  97.6152  85.1059 0014051 252.6236 225.1855 15.13182933  1564
1 41907U 16083A   17007.41146866 -.00000067  00000-0  00000+0 0  9993
2 41907  97.6152  85.1059 0014051 252.6236 225.1855 15.13182932  1563
1 41907U 16083A   17007.54200159 -.00000067  00000-0  00000+0 0  9993
2 41907  97.6177  85.2386 0013939 251.9577 216.4682 15.13171821  1586
1 41907U 16083A   17007.61229884 -.00000067  00000-0  00000+0 0  9997
2 41907  97.6179  85.3091 0013932 251.5775 239.5451 15.13171645  1596
1 41907U 16083A   17007.68362377 -.00000067  00000-0  00000+0 0  9999
2 41907  97.6160  85.3803 0013853 250.8834 268.5254 15.13166663  1606
1 41907U 16083A   17007.87208478 -.00000067  00000-0  00000+0 0  9991
2 41907  97.6147  85.5684 0013529 249.8825 215.4888 15.13158432  1630
1 41907U 16083A   17008.00770924 -.00000067 +00000-0 +00000-0 0  9998
2 41907 097.6156 085.7042 0013902 248.5419 235.1720 15.13164229001657
1 41907U 16083A   17008.20025454 -.00000067  00000-0  00000+0 0  9990
2 41907  97.6148  85.8979 0014360 246.5887 205.3450 15.13168282  1689
1 41907U 16083A   17008.45301619 -.00000067  00000-0  00000+0 0  9997
2 41907  97.6156  86.1510 0014231 246.7615 141.1949 15.13168208  1724
1 41907U 16083A   17008.53870578 -.00000067  00000-0  00000+0 0  9991
2 41907  97.6167  86.2377 0014128 246.4059 248.0429 15.13168737  1730
1 41907U 16083A   17008.60727819 -.00000067  00000-0  00000+0 0  9998
2 41907  97.6170  86.3066 0014070 245.8961 261.8601 15.13169113  1746
1 41907U 16083A   17008.73093133 -.00000067  00000-0  00000+0 0  9997
2 41907  97.6161  86.4295 0014117 245.2588 215.6594 15.13168386  1763
1 41907U 16083A   17008.86448569 -.00000067  00000-0  00000+0 0  9998
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1 41907U 16083A   17009.19006294 -.00000067  00000-0  00000+0 0  9990
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1 41907U 16083A   17009.47502315 -.00000067  00000-0  00000+0 0  9996
2 41907  97.6170  87.1723 0014191 242.9472 308.7808 15.13168542  1873
1 41907U 16083A   17009.85359519 -.00000067  00000-0  00000+0 0  9994
2 41907  97.6169  87.5504 0014193 241.6063 211.0539 15.13168374  1933
1 41907U 16083A   17010.18327072 -.00000067  00000-0  00000+0 0  9991
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1 41907U 16083A   17010.52088760 -.00000067  00000-0  00000+0 0  9997
2 41907  97.6168  88.2167 0014244 239.2123 246.1678 15.13168815  2037
1 41907U 16083A   17010.66020081 -.00000067  00000-0  00000+0 0  9994
2 41907  97.6166  88.3564 0014216 238.7060 285.0908 15.13168880  2052
1 41907U 16083A   17010.71396997 -.00000067  00000-0  00000+0 0  9992
2 41907  97.6165  88.4099 0014228 238.4939 218.0206 15.13168901  2062
1 41907U 16083A   17010.84845916 -.00000067  00000-0  00000+0 0  9996
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1 41907U 16083A   17011.17452527 -.00000067  00000-0  00000+0 0  9995
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1 41907U 16083A   17011.37083631 -.00000067  00000-0  00000+0 0  9993
2 41907  97.6165  89.0652 0014316 236.1338 196.3436 15.13169330  2161
1 41907U 16083A   17011.46094907 -.00000067  00000-0  00000+0 0  9991
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1 41907U 16083A   17011.52505787 -.00000067  00000-0  00000+0 0  9991
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2 41907  97.6170  89.2204 0014330 235.1551 316.9072 15.13169968  2189
1 41907U 16083A   17011.71879484 -.00000067  00000-0  00000+0 0  9990
2 41907  97.6169  89.4139 0014276 235.0849 291.6756 15.13170097  2211
1 41907U 16083A   17011.84081413 -.00000067  00000-0  00000+0 0  9991
2 41907  97.6167  89.5351 0014260 234.5137 236.5178 15.13170209  2236
1 41907U 16083A   17012.16642814 -.00000067  00000-0  00000+0 0  9995
2 41907  97.6167  89.8600 0014316 233.2452 210.4219 15.13170391  2288
1 41907U 16083A   17012.42649454 -.00000067  00000-0  00000+0 0  9991
2 41907  97.6180  90.1217 0014667 231.2549 188.2371 15.13182492  2327
1 41907U 16083A   17012.70982348 -.00000067  00000-0  00000+0 0  9994
2 41907  97.6169  90.4032 0014368 231.6778 290.2213 15.13170713  2364
1 41907U 16083A   17012.90319574 -.00000067 +00000-0 +00000-0 0  9992
2 41907 097.6168 090.5963 0014375 231.1605 263.4537 15.13170887002395
1 41907U 16083A   17012.96576539 -.00000067  00000-0  00000+0 0  9993
2 41907  97.6172  90.6602 0014458 230.7797 244.4652 15.13171114  2403
1 41907U 16083A   17013.22462719 -.00000067  00000-0  00000+0 0  9997
2 41907  97.6168  90.9176 0014359 230.4308 214.0571 15.13171755  2440
1 41907U 16083A   17013.56025250 -.00000067  00000-0  00000+0 0  9999
2 41907  97.6170  91.2528 0014308 229.0416 242.5774 15.13171361  2495
1 41907U 16083A   17013.89291506 -.00000067  00000-0  00000+0 0  9994
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1 41907U 16083A   17013.95437189 -.00000067  00000-0  00000+0 0  9990
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2 41907  97.6169  91.7179 0014205 228.0395 255.3897 15.13173026  2567
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C. SATELLITE 41898

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2 41898  98.1534 305.9751 0020945 189.1268 170.9541 14.56336110  1555
1 41898U 16081A   17001.77676687  .00000104  00000-0  33662-4 0  9998
2 41898  98.1534 306.3109 0020977 188.0792 172.0084 14.56336261  1600
1 41898U 16081A   17002.12029817  .00000122  00000-0  37722-4 0  9996
2 41898  98.1535 306.6468 0020970 187.0045 173.0869 14.56336492  1658
1 41898U 16081A   17002.46382902  .00000126  00000-0  38506-4 0  9995
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1 41898U 16081A   17002.80736071  .00000127  00000-0  38831-4 0  9995
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1 41898U 16081A   17003.08218538  .00000145  00000-0  42922-4 0  9995
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1 41898U 16081A   17003.42571652  .00000141  00000-0  41919-4 0  9993
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1 41898U 16081A   17003.76924821  .00000136  00000-0  40757-4 0  9993
2 41898  98.1539 308.2594 0021180 182.0092 178.1030 14.56337186  1894
1 41898U 16081A   17004.11277940  .00000150  00000-0  43962-4 0  9993
2 41898  98.1542 308.5955 0021189 180.9074 179.2090 14.56337387  1945
1 41898U 16081A   17004.45631066  .00000116  00000-0  36378-4 0  9998
2 41898  98.1540 308.9315 0021211 179.8114 180.3082 14.56337250  1993
1 41898U 16081A   17004.79984230  .00000113  00000-0  35735-4 0  9992
2 41898  98.1539 309.2674 0021228 178.7532 181.3730 14.56337351  2043
1 41898U 16081A   17005.07466718  .00000108  00000-0  34610-4 0  9995
2 41898  98.1540 309.5362 0021255 177.8726 182.2568 14.56337406  2081
1 41898U 16081A   17005.41819825  .00000115  00000-0  36083-4 0  9998
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1 41898U 16081A   17006.44879173  .00000111  00000-0  35105-4 0  9994
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1 41898U 16081A   17010.77728119  .00000146  00000-0  43046-4 0  9999
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1 41898U 16081A   17011.12081189  .00000140  00000-0  41679-4 0  9992
2 41898  98.1541 315.4478 0021548 159.0407 201.1679 14.56339754  2968
1 41898U 16081A   17011.46434238  .00000139  00000-0  41552-4 0  9994
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1 41898U 16081A   17012.42622819  .00000137  00000-0  40997-4 0  9995
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1 41898U 16081A   17013.11328933  .00000141  00000-0  42003-4 0  9997
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1 41898U 16081A   17014.14388115  .00000111  00000-0  35192-4 0  9997
2 41898  98.1546 318.4042 0021720 149.6253 210.6209 14.56340468  3407
1 41898U 16081A   17014.55611774  .00000107  00000-0  34214-4 0  9991
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1 41898U 16081A   17014.89964822  .00000101  00000-0  32937-4 0  9997
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2 41898  98.1544 319.1433 0021807 147.3475 212.9080 14.56340587  3510
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D. SATELLITE 41038

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1 41038U 15069A   17001.51384927  .00000030  00000-0  10688-4 0  9995
2 41038  97.8804 346.5309 0001923  65.7270 294.4138 14.80361495 59428
1 41038U 15069A   17001.85181067  .00000039  00000-0  11841-4 0  9993
2 41038  97.8804 346.8628 0001909  64.4560 295.6859 14.80361643 59470
1 41038U 15069A   17002.18977152  .00000047  00000-0  12896-4 0  9998
2 41038  97.8806 347.1948 0001896  63.5992 296.5420 14.80361825 59527
1 41038U 15069A   17002.52773256  .00000045  00000-0  12615-4 0  9992
2 41038  97.8806 347.5268 0001896  63.5833 296.5572 14.80361876 59579
1 41038U 15069A   17002.86569378  .00000049  00000-0  13169-4 0  9996
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1 41038U 15069A   17003.20365488  .00000043  00000-0  12324-4 0  9997
2 41038  97.8807 348.1904 0001892  63.3351 296.8058 14.80362015 59672
1 41038U 15069A   17003.54161588  .00000036  00000-0  11419-4 0  9995
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1 41038U 15069A   17005.90734493 -.00000000  00000-0  67092-5 0  9999
2 41038  97.8815 350.8455 0001851  60.3556 299.7850 14.80361884 60072
1 41038U 15069A   17006.17771366  .00000015  00000-0  87265-5 0  9998
2 41038  97.8815 351.1111 0001852  61.1184 299.0229 14.80362089 60118
1 41038U 15069A   17006.51567433  .00000022  00000-0  96800-5 0  9997
2 41038  97.8816 351.4431 0001866  60.8393 299.3000 14.80362198 60166
1 41038U 15069A   17006.71845111 +.00000031 +00000-0 +10811-4 0  9998
2 41038 097.8816 351.6422 0001859 060.9442 299.1958 14.80362284060195
1 41038U 15069A   17006.92122772  .00000034  00000-0  11189-4 0  9994
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1 41038U 15069A   17007.12400421  .00000039  00000-0  11840-4 0  9996
2 41038  97.8818 352.0405 0001842  60.2069 299.9334 14.80362465 60257
1 41038U 15069A   17007.46196505  .00000043  00000-0  12401-4 0  9997
2 41038  97.8818 352.3724 0001836  60.9927 299.1481 14.80362618 60308
1 41038U 15069A   17007.79992598  .00000052  00000-0  13500-4 0  9990
2 41038  97.8819 352.7042 0001808  62.1725 297.9685 14.80362744 60352
1 41038U 15069A   17007.93511009 +.00000047 +00000-0 +12924-4 0  9993
2 41038 097.8819 352.8370 0001812 061.1609 298.9787 14.80362759060374
1 41038U 15069A   17008.13788665  .00000047  00000-0  12862-4 0  9991
2 41038  97.8819 353.0361 0001806  60.8967 299.2429 14.80362807 60408
1 41038U 15069A   17008.47584747  .00000044  00000-0  12563-4 0  9998
2 41038  97.8820 353.3681 0001798  60.9883 299.1514 14.80362889 60455
1 41038U 15069A   17008.81380859  .00000038  00000-0  11738-4 0  9990
2 41038  97.8820 353.7001 0001773  62.1686 297.9713 14.80362856 60500
1 41038U 15069A   17009.15176940  .00000032  00000-0  10982-4 0  9996
2 41038  97.8819 354.0319 0001778  61.1267 299.0122 14.80362881 60553
1 41038U 15069A   17009.42213816  .00000028  00000-0  10426-4 0  9998
2 41038  97.8820 354.2975 0001780  61.0448 299.0942 14.80362895 60597
1 41038U 15069A   17009.76009948  .00000025  00000-0  10052-4 0  9996
2 41038  97.8820 354.6294 0001792  61.6436 298.4958 14.80362834 60640
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1 41038U 15069A   17010.09806033  .00000027  00000-0  10222-4 0  9995
2 41038  97.8820 354.9612 0001789  60.4451 299.6940 14.80362923 60695
1 41038U 15069A   17010.43602124  .00000044  00000-0  12487-4 0  9992
2 41038  97.8820 355.2932 0001694  62.9609 297.1812 14.80363205 60742
1 41038U 15069A   17010.77398161  .00000055  00000-0  13943-4 0  9992
2 41038  97.8820 355.6252 0001698  65.6311 294.5087 14.80363315 60797
1 41038U 15069A   17011.11194209  .00000062  00000-0  14890-4 0  9998
2 41038  97.8820 355.9571 0001679  64.5427 295.5959 14.80363475 60841
1 41038U 15069A   17011.44990289  .00000068  00000-0  15644-4 0  9990
2 41038  97.8821 356.2892 0001697  64.5287 295.6101 14.80363602 60893
1 41038U 15069A   17011.78786373  .00000076  00000-0  16641-4 0  9991
2 41038  97.8820 356.6211 0001703  64.4264 295.7125 14.80363710 60946
1 41038U 15069A   17012.12582446  .00000076  00000-0  16709-4 0  9990
2 41038  97.8819 356.9531 0001693  63.5083 296.6308 14.80363829 60998
1 41038U 15069A   17012.46378507  .00000076  00000-0  16700-4 0  9999
2 41038  97.8819 357.2849 0001706  63.7163 296.4225 14.80363930 61046
1 41038U 15069A   17012.80174590  .00000072  00000-0  16148-4 0  9995
2 41038  97.8820 357.6168 0001702  63.6974 296.4412 14.80363934 61098
1 41038U 15069A   17013.13970660  .00000066  00000-0  15332-4 0  9991
2 41038  97.8818 357.9488 0001695  62.5657 297.5727 14.80363986 61144
1 41038U 15069A   17013.47766733  .00000057  00000-0  14154-4 0  9993
2 41038  97.8818 358.2806 0001689  61.8886 298.2495 14.80363990 61191
1 41038U 15069A   17013.81562841  .00000038  00000-0  11759-4 0  9992
2 41038  97.8819 358.6126 0001689  61.7829 298.3551 14.80363830 61240
1 41038U 15069A   17013.95081276 +.00000033 +00000-0 +11073-4 0  9999
2 41038 097.8819 358.7453 0001688 061.3740 298.7642 14.80363821061268
1 41038U 15069A   17014.15358921  .00000027  00000-0  10244-4 0  9998
2 41038  97.8819 358.9444 0001699  60.5225 299.6153 14.80363804 61292
1 41038U 15069A   17014.42395789  .00000013  00000-0  84387-5 0  9996
2 41038  97.8819 359.2098 0001689  59.7149 300.4226 14.80363730 61330
1 41038U 15069A   17014.76191900 -.00000001  00000-0  65524-5 0  9992
2 41038  97.8819 359.5417 0001685  59.5145 300.6224 14.80363553 61386
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E. SATELLITE 41026

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1 41026U 15064A   17001.23569260  .00001658  00000-0  59137-4 0  9990
2 41026  97.2946 131.8413 0008965 185.9269 265.7644 15.30257756 64220
1 41026U 15064A   17001.55721243  .00001645  00000-0  58717-4 0  9995
2 41026  97.2946 132.1571 0008994 184.8458 236.9320 15.30258890 64275
1 41026U 15064A   17001.89381742  .00001647  00000-0  58780-4 0  9990
2 41026  97.2947 132.4880 0009023 183.6279 291.2871 15.30260123 64327
1 41026U 15064A   17002.22117284  .00001607  00000-0  57393-4 0  9991
2 41026  97.2948 132.8094 0009074 182.4364 294.6932 15.30260993 64372
1 41026U 15064A   17002.55058582  .00001638  00000-0  58454-4 0  9995
2 41026  97.2947 133.1330 0009185 181.3090 309.3680 15.30262426 64428
1 41026U 15064A   17002.87467609  .00001678  00000-0  59820-4 0  9996
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1 41026U 15064A   17003.21880359  .00001674  00000-0  59663-4 0  9997
2 41026  97.2948 133.7895 0009237 178.8824  30.5951 15.30265023 64526
1 41026U 15064A   17003.53133443  .00001715  00000-0  61077-4 0  9995
2 41026  97.2947 134.0966 0009269 178.0367 312.0490 15.30266462 64576
1 41026U 15064A   17003.86306243  .00001758  00000-0  62551-4 0  9996
2 41026  97.2948 134.4225 0009256 176.9135 339.4686 15.30267917 64627
1 41026U 15064A   17004.24351354  .00001807  00000-0  64207-4 0  9997
2 41026  97.2949 134.7964 0009402 175.1353 275.7870 15.30269588 64686
1 41026U 15064A   17004.56496009  .00001852  00000-0  65732-4 0  9993
2 41026  97.2948 135.1119 0009498 174.0890 246.5322 15.30271182 64738
1 41026U 15064A   17004.90183734  .00001930  00000-0  68406-4 0  9997
2 41026  97.2948 135.4429 0009456 172.8716 302.4014 15.30272984 64788
1 41026U 15064A   17005.22491546  .00001929  00000-0  68348-4 0  9999
2 41026  97.2948 135.7603 0009546 171.8157 282.1390 15.30274184 64834
1 41026U 15064A   17005.55820051  .00001948  00000-0  68990-4 0  9996
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1 41026U 15064A   17005.87978054  .00001991  00000-0  70455-4 0  9995
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1 41026U 15064A   17006.21033747  .00001956  00000-0  69281-4 0  9991
2 41026  97.2946 136.7283 0009589 168.3553 310.7766 15.30278390 64989
1 41026U 15064A   17006.53933112  .00001976  00000-0  69951-4 0  9997
2 41026  97.2945 137.0514 0009601 167.3021 323.0871 15.30279903 65035
1 41026U 15064A   17006.73675513 +.00001973 +00000-0 +69853-4 0  9995
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1 41026U 15064A   17006.93489031  .00002008  00000-0  71050-4 0  9997
2 41026  97.2946 137.4402 0009615 165.8891 342.2323 15.30281729 65099
1 41026U 15064A   17007.12620547  .00001981  00000-0  70106-4 0  9998
2 41026  97.2947 137.6280 0009609 165.1900 316.2072 15.30282322 65129
1 41026U 15064A   17007.44646471  .00002035  00000-0  71952-4 0  9998
2 41026  97.2945 137.9428 0009662 164.3140 280.2607 15.30284118 65174
1 41026U 15064A   17007.78284317  .00002073  00000-0  73243-4 0  9999
2 41026  97.2946 138.2732 0009680 163.0486 333.4476 15.30285831 65220
1 41026U 15064A   17007.97312572 +.00002101 +00000-0 +74196-4 0  9995
2 41026 097.2945 138.4601 0009675 162.3767 301.7137 15.30286728065255
1 41026U 15064A   17008.10568381  .00002059  00000-0  72759-4 0  9997
2 41026  97.2945 138.5902 0009672 161.9191 311.9640 15.30286970 65276
1 41026U 15064A   17008.48897317  .00002085  00000-0  73656-4 0  9998
2 41026  97.2945 138.9666 0009714 160.6177 263.4576 15.30288855 65334
1 41026U 15064A   17008.82658946  .00002116  00000-0  74684-4 0  9996
2 41026  97.2946 139.2985 0009729 159.3217 323.4952 15.30290538 65380
1 41026U 15064A   17009.15403071  .00002044  00000-0  72252-4 0  9999
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1 41026U 15064A   17009.47009315  .00002044  00000-0  72251-4 0  9996
2 41026  97.2942 139.9305 0009785 157.2536 268.3627 15.30292755 65482
1 41026U 15064A   17009.81410094  .00002044  00000-0  72234-4 0  9995
2 41026  97.2946 140.2690 0009766 155.9515   3.5978 15.30294182 65539
1 41026U 15064A   17010.13475899  .00001927  00000-0  68252-4 0  9990
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1 41026U 15064A   17010.44636214  .00001921  00000-0  68021-4 0  9992
2 41026  97.2944 140.8902 0009868 153.7388 246.7219 15.30295921 65638
1 41026U 15064A   17010.78978817  .00001895  00000-0  67133-4 0  9990
2 41026  97.2946 141.2277 0009904 152.5968 338.5974 15.30297090 65684
1 41026U 15064A   17011.11120135  .00001801  00000-0  63942-4 0  9991
2 41026  97.2943 141.5440 0009912 151.3614 309.3718 15.30297588 65730
1 41026U 15064A   17011.49689003  .00001795  00000-0  63741-4 0  9995
2 41026  97.2943 141.9229 0010038 150.2166 273.9330 15.30299103 65797
1 41026U 15064A   17011.76607653  .00001786  00000-0  63418-4 0  9997
2 41026  97.2945 142.1877 0010062 149.3137 316.8474 15.30300083 65836
1 41026U 15064A   17012.16170345  .00001686  00000-0  60003-4 0  9991
2 41026  97.2946 142.5764 0010126 148.0294 336.2604 15.30300778 65895
1 41026U 15064A   17012.47325478  .00001668  00000-0  59388-4 0  9998
2 41026  97.2944 142.8824 0010151 147.0293 252.5139 15.30301796 65949
1 41026U 15064A   17012.82083558  .00001650  00000-0  58767-4 0  9998
2 41026  97.2948 143.2243 0010152 145.8284   7.3302 15.30302897 65996
1 41026U 15064A   17013.14276883  .00001557  00000-0  55605-4 0  9993
2 41026  97.2947 143.5409 0010221 144.8880 340.6809 15.30303306 66048
1 41026U 15064A   17013.45424228  .00001579  00000-0  56334-4 0  9999
2 41026  97.2947 143.8468 0010235 144.0457 256.3521 15.30304525 66096
1 41026U 15064A   17013.80249501  .00001536  00000-0  54872-4 0  9995
2 41026  97.2950 144.1893 0010179 142.8906  14.8227 15.30305292 66146
1 41026U 15064A   17013.99010443 +.00001512 +00000-0 +54051-4 0  9999
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1 41026U 15064A   17014.12288458  .00001425  00000-0  51094-4 0  9995
2 41026  97.2951 144.5040 0010259 141.6000 340.0270 15.30305505 66190
1 41026U 15064A   17014.44306322  .00001435  00000-0  51448-4 0  9995
2 41026  97.2952 144.8186 0010277 140.6379 303.7468 15.30306593 66242
1 41026U 15064A   17014.77991942  .00001428  00000-0  51200-4 0  9997
2 41026  97.2953 145.1496 0010294 139.5492 359.4127 15.30307581 66296
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F. SATELLITE 40894

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1 40894U 15047A   17001.17355007 -.00000053  00000-0  00000+0 0  9997
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1 40894U 15047A   17001.51242473 -.00000053  00000-0  00000+0 0  9997
2 40894  97.9776  87.9904 0034071 156.8639 203.4116 14.76369956 70136
1 40894U 15047A   17001.85129958 -.00000053  00000-0  00000+0 0  9996
2 40894  97.9776  88.3252 0034092 155.7524 204.5300 14.76370012 70188
1 40894U 15047A   17001.91907458 -.00000053 +00000-0 +00000-0 0  9993
2 40894 097.9776 088.3921 0034101 155.5392 204.7448 14.76370030070199
1 40894U 15047A   17002.19017431 -.00000053  00000-0  00000+0 0  9996
2 40894  97.9775  88.6598 0034238 154.7914 205.5009 14.76370204 70233
1 40894U 15047A   17002.52904851 -.00000053  00000-0  00000+0 0  9994
2 40894  97.9777  88.9948 0034281 153.7262 206.5705 14.76370276 70288
1 40894U 15047A   17002.80014815 -.00000053  00000-0  00000+0 0  9997
2 40894  97.9777  89.2624 0034303 152.8480 207.4533 14.76370320 70324
1 40894U 15047A   17002.93569811 -.00000053 +00000-0 +00000-0 0  9993
2 40894 097.9777 089.3963 0034312 152.4434 207.8611 14.76370348070349
1 40894U 15047A   17003.20679781 -.00000053  00000-0  00000+0 0  9991
2 40894  97.9776  89.6639 0034250 151.5077 208.8012 14.76370415 70380
1 40894U 15047A   17003.54567241 -.00000053  00000-0  00000+0 0  9995
2 40894  97.9776  89.9985 0034288 150.4618 209.8542 14.76370500 70437
1 40894U 15047A   17003.88454706 -.00000053  00000-0  00000+0 0  9993
2 40894  97.9774  90.3332 0034361 149.3684 210.9548 14.76370576 70486
1 40894U 15047A   17004.22342146 -.00000053  00000-0  00000+0 0  9996
2 40894  97.9772  90.6679 0034346 148.3209 212.0080 14.76370681 70533
1 40894U 15047A   17004.56229619 -.00000053  00000-0  00000+0 0  9992
2 40894  97.9774  91.0028 0034367 147.1903 213.1458 14.76370739 70589
1 40894U 15047A   17004.83339574 -.00000053  00000-0  00000+0 0  9994
2 40894  97.9772  91.2703 0034415 146.3810 213.9603 14.76370811 70627
1 40894U 15047A   17004.90117050 -.00000053 +00000-0 +00000-0 0  9996
2 40894 097.9772 091.3373 0034414 146.1630 214.1786 14.76370818070631
1 40894U 15047A   17005.17227013 -.00000052  00000-0  00000+0 0  9995
2 40894  97.9771  91.6050 0034394 145.2955 215.0514 14.76370906 70673
1 40894U 15047A   17005.51114457 -.00000052  00000-0  00000+0 0  9990
2 40894  97.9771  91.9397 0034413 144.2576 216.0955 14.76370975 70722
1 40894U 15047A   17005.85001913 -.00000052  00000-0  00000+0 0  9999
2 40894  97.9770  92.2742 0034434 143.1878 217.1716 14.76371020 70779
1 40894U 15047A   17005.91779388 -.00000052 +00000-0 +00000-0 0  9995
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1 40894U 15047A   17006.52776751 -.00000052  00000-0  00000+0 0  9993
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1 40894U 15047A   17006.79886707 -.00000052 +00000-0 +00000-0 0  9996
2 40894 097.9770 093.2115 0034532 140.2308 220.1446 14.76371227070918
1 40894U 15047A   17007.00219175 -.00000052  00000-0  00000+0 0  9999
2 40894  97.9770  93.4120 0034512 139.5267 220.8524 14.76371282 70947
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2 40894  97.9770  93.8808 0034596 138.1054 222.2820 14.76371409 71010
1 40894U 15047A   17007.81548971 -.00000052  00000-0  00000+0 0  9997
2 40894  97.9769  94.2154 0034623 137.0152 223.3773 14.76371454 71069
1 40894U 15047A   17008.08658911 -.00000052 +00000-0 +00000-0 0  9994
2 40894 097.9768 094.4833 0034545 136.0526 224.3447 14.76371578071102
1 40894U 15047A   17008.15436388 -.00000052  00000-0  00000+0 0  9993
2 40894  97.9767  94.5503 0034703 135.9838 224.4167 14.76371633 71119
1 40894U 15047A   17008.49323756 -.00000052  00000-0  00000+0 0  9994
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1 40894U 15047A   17008.89988631 -.00000052 +00000-0 +00000-0 0  9998
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1 40894U 15047A   17009.17098562 -.00000052  00000-0  00000+0 0  9994
2 40894  97.9766  95.5544 0034761 132.8042 227.6108 14.76371928 71264
1 40894U 15047A   17009.50985959 -.00000052  00000-0  00000+0 0  9996
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1 40894U 15047A   17009.84873362 -.00000052  00000-0  00000+0 0  9997
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1 40894U 15047A   17009.91650843 -.00000052 +00000-0 +00000-0 0  9993
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1 40894U 15047A   17010.79758065 -.00000052  00000-0  00000+0 0  9995
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1 40894U 15047A   17010.86535546 -.00000052 +00000-0 +00000-0 0  9991
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1 40894U 15047A   17011.47532832 -.00000052  00000-0  00000+0 0  9993
2 40894  97.9766  97.8303 0034814 125.4996 234.9472 14.76372363 71604
1 40894U 15047A   17011.81420222 -.00000052  00000-0  00000+0 0  9990
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1 40894U 15047A   17011.88197698 -.00000052 +00000-0 +00000-0 0  9996
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1 40894U 15047A   17012.15307603 -.00000052  00000-0  00000+0 0  9995
2 40894  97.9763  98.4997 0034807 123.2559 237.1998 14.76372493 71703
1 40894U 15047A   17012.42417493 -.00000052  00000-0  00000+0 0  9994
2 40894  97.9762  98.7672 0034825 122.4642 237.9946 14.76372548 71745
1 40894U 15047A   17012.83082342 -.00000052  00000-0  00000+0 0  9990
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1 40894U 15047A   17012.89859815 -.00000052 +00000-0 +00000-0 0  9994
2 40894 097.9762 099.2360 0034865 120.9841 239.4802 14.76372611071810
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1 40894U 15047A   17013.50857048 -.00000052  00000-0  00000+0 0  9998
2 40894  97.9763  99.8386 0034907 119.1983 241.2735 14.76372781 71903
1 40894U 15047A   17013.84744410 -.00000052  00000-0  00000+0 0  9993
2 40894  97.9763 100.1734 0034929 118.1092 242.3657 14.76372805 71957
1 40894U 15047A   17013.98299363 -.00000052 +00000-0 +00000-0 0  9991
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1 40894U 15047A   17014.18631784 -.00000052  00000-0  00000+0 0  9990
2 40894  97.9762 100.5077 0035010 117.2162 243.2648 14.76372893 72004
1 40894U 15047A   17014.52519090 -.00000052  00000-0  00000+0 0  9993
2 40894  97.9760 100.8421 0034998 116.2043 244.2777 14.76372964 72057
1 40894U 15047A   17014.79628971 -.00000052  00000-0  00000+0 0  9991
2 40894  97.9761 101.1098 0034992 115.3483 245.1357 14.76372964 72092
1 40894U 15047A   17014.93183919 -.00000052 +00000-0 +00000-0 0  9996
2 40894 097.9761 101.2437 0034999 114.9184 245.5671 14.76372979072112
```

G. SATELLITE 40701

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1 40701U 15030A   17001.21698698  .00001714  00000-0  68158-4 0  9994
2 40701  97.3507 120.9543 0002015 243.6441 209.1434 15.26634588 84666
1 40701U 15030A   17001.55129318  .00001697  00000-0  67498-4 0  9995
2 40701  97.3508 121.2835 0002047 241.7287 247.1868 15.26635775 84715
1 40701U 15030A   17001.88340674  .00001690  00000-0  67245-4 0  9994
2 40701  97.3507 121.6102 0002077 239.4733 273.5287 15.26636978 84767
1 40701U 15030A   17002.25320802  .00001734  00000-0  68920-4 0  9997
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2 40701  97.3510 121.9746 0002204 230.3308 153.7577 15.26638637 84820
1 40701U 15030A   17002.53446223  .00001731  00000-0  68784-4 0  9999
2 40701  97.3509 122.2516 0002223 230.1994 258.6404 15.26639707 84864
1 40701U 15030A   17002.86730517  .00001750  00000-0  69531-4 0  9999
2 40701  97.3508 122.5791 0002216 228.3187 288.6192 15.26641126 84917
1 40701U 15030A   17003.24708260  .00001816  00000-0  72026-4 0  9998
2 40701  97.3510 122.9531 0002225 226.8723 215.9471 15.26642922 84979
1 40701U 15030A   17003.56977029  .00001840  00000-0  72934-4 0  9999
2 40701  97.3509 123.2709 0002246 226.1607 188.9838 15.26644372 85029
1 40701U 15030A   17003.90839811  .00001863  00000-0  73830-4 0  9994
2 40701  97.3508 123.6043 0002231 224.8639 250.1563 15.26645853 85074
1 40701U 15030A   17004.23127731  .00001909  00000-0  75588-4 0  9995
2 40701  97.3508 123.9220 0002247 223.9175 224.4814 15.26647309 85123
1 40701U 15030A   17004.55325321  .00001946  00000-0  77003-4 0  9990
2 40701  97.3507 124.2389 0002303 222.8922 193.9276 15.26648873 85177
1 40701U 15030A   17004.89163600  .00001931  00000-0  76414-4 0  9996
2 40701  97.3507 124.5720 0002316 221.6235 253.7298 15.26650111 85220
1 40701U 15030A   17005.21522042  .00001965  00000-0  77713-4 0  9992
2 40701  97.3508 124.8905 0002336 219.7273 232.8841 15.26651602 85274
1 40701U 15030A   17005.54952297  .00002015  00000-0  79616-4 0  9998
2 40701  97.3508 125.2197 0002372 217.6528 271.0881 15.26653321 85327
1 40701U 15030A   17005.87129368  .00002023  00000-0  79915-4 0  9990
2 40701  97.3507 125.5365 0002385 216.7981 239.2428 15.26654773 85373
1 40701U 15030A   17006.25135556  .00002036  00000-0  80387-4 0  9998
2 40701  97.3507 125.9107 0002379 214.7299 168.7720 15.26656418 85430
1 40701U 15030A   17006.53271832  .00002032  00000-0  80244-4 0  9995
2 40701  97.3507 126.1877 0002407 213.5578 275.3100 15.26657648 85473
1 40701U 15030A   17006.72996383 +.00002048 +00000-0 +80841-4 0  9991
2 40701 097.3506 126.3819 0002406 212.6528 279.5740 15.2665864108550 8
1 40701U 15030A   17006.97993141  .00002036  00000-0  80402-4 0  9997
2 40701  97.3506 126.6278 0002426 211.5521 213.6059 15.26659657 85547
1 40701U 15030A   17007.12204951  .00002069  00000-0  81637-4 0  9996
2 40701  97.3506 126.7679 0002399 210.6801 275.0537 15.26660456 85567
1 40701U 15030A   17007.43865627  .00002088  00000-0  82363-4 0  9991
2 40701  97.3504 127.0797 0002420 209.7257 214.9547 15.26662039 85617
1 40701U 15030A   17007.78281527  .00002123  00000-0  83686-4 0  9999
2 40701  97.3503 127.4186 0002432 207.8258 307.1322 15.26663782 85662
1 40701U 15030A   17007.96992352 +.00002103 +00000-0 +82920-4 0  9992
2 40701 097.3503 127.6028 0002436 207.3571 255.2828 15.2666439908569 8
1 40701U 15030A   17008.16493010  .00002135  00000-0  84140-4 0  9993
2 40701  97.3503 127.7947 0002415 206.7132 246.9920 15.26665410 85721
1 40701U 15030A   17008.48815140  .00002172  00000-0  85549-4 0  9995
2 40701  97.3502 128.1126 0002433 206.0660 222.9216 15.26667137 85778
1 40701U 15030A   17008.82453961  .00002168  00000-0  85415-4 0  9999
2 40701  97.3503 128.4438 0002444 204.8142 271.7745 15.26668611 85824
1 40701U 15030A   17009.15346244  .00002143  00000-0  84449-4 0  9990
2 40701  97.3503 128.7676 0002448 203.7341 279.4512 15.26669740 85870
1 40701U 15030A   17009.47072942  .00002186  00000-0  86089-4 0  9995
2 40701  97.3502 129.0794 0002580 201.2512 224.5197 15.26671549 85920
1 40701U 15030A   17009.81540550  .00002174  00000-0  85626-4 0  9991
2 40701  97.3503 129.4187 0002610 199.8276 319.0706 15.26673012 85972
1 40701U 15030A   17010.13659814  .00002109  00000-0  83140-4 0  9999
2 40701  97.3504 129.7349 0002663 197.6606 285.3815 15.26673881 86024
1 40701U 15030A   17010.39196534  .00002086  00000-0  82269-4 0  9997
2 40701  97.3503 129.9863 0002704 196.7208 248.9231 15.26674858 86066
1 40701U 15030A   17010.79856000  .00002034  00000-0  80286-4 0  9992
2 40701  97.3505 130.3867 0002710 194.9310 323.9314 15.26676288 86121
1 40701U 15030A   17011.11547258  .00001962  00000-0  77541-4 0  9990
2 40701  97.3505 130.6986 0002729 192.5475 266.9530 15.26676956 86175
1 40701U 15030A   17011.43275188  .00001909  00000-0  75505-4 0  9994
2 40701  97.3505 131.0112 0002758 190.9890 211.1683 15.26677942 86229
1 40701U 15030A   17011.78201447  .00001851  00000-0  73305-4 0  9991
2 40701  97.3507 131.3555 0002752 190.0186 330.4631 15.26678869 86270
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1 40701U 15030A   17012.10336981  .00001809  00000-0  71690-4 0  9998
2 40701  97.3508 131.6719 0002782 188.3343 297.1923 15.26679720 86320
1 40701U 15030A   17012.48634412  .00001801  00000-0  71400-4 0  9990
2 40701  97.3508 132.0490 0002796 186.6537 242.3644 15.26681130 86388
1 40701U 15030A   17012.83187668  .00001738  00000-0  68997-4 0  9991
2 40701  97.3508 132.3892 0002795 185.8323 341.0269 15.26681964 86431
1 40701U 15030A   17013.15150527  .00001641  00000-0  65295-4 0  9992
2 40701  97.3511 132.7040 0002821 184.5166 297.9039 15.26682283 86489
1 40701U 15030A   17013.40701311  .00001621  00000-0  64523-4 0  9994
2 40701  97.3511 132.9556 0002878 183.9389 261.8644 15.26683074 86521
1 40701U 15030A   17013.81354911  .00001588  00000-0  63271-4 0  9990
2 40701  97.3512 133.3557 0002891 182.5010 336.2107 15.26684249 86581
1 40701U 15030A   17013.93595042 +.00001533 +00000-0 +61144-4 0  9992
2 40701 097.3512 133.4763 0002885 182.1780 288.8242 15.26684276086609
1 40701U 15030A   17014.13479257  .00001519  00000-0  60641-4 0  9999
2 40701  97.3512 133.6721 0002915 181.5442 301.6035 15.26684790 86635
1 40701U 15030A   17014.38923591  .00001503  00000-0  60024-4 0  9999
2 40701  97.3513 133.9227 0002989 180.7072 259.9790 15.26685532 86673
1 40701U 15030A   17014.79666229  .00001478  00000-0  59070-4 0  9996
2 40701  97.3515 134.3239 0003067 178.2445 340.2455 15.26686696 86738
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H. SATELLITE 40362

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1 40362U 14088A   17001.20473813  .00001519  00000-0  60624-4 0  9991
2 40362  97.3712  82.5163 0006556 133.2086 311.2287 15.26683402112281
1 40362U 14088A   17001.53971113  .00001479  00000-0  59110-4 0  9996
2 40362  97.3711  82.8473 0006552 131.6015 352.6830 15.26684235112331
1 40362U 14088A   17001.86928862  .00001449  00000-0  57944-4 0  9995
2 40362  97.3708  83.1723 0006581 130.7197   3.7779 15.26685011112386
1 40362U 14088A   17002.18780596  .00001503  00000-0  60024-4 0  9995
2 40362  97.3707  83.4867 0006593 130.0972 313.8699 15.26686397112434
1 40362U 14088A   17002.52389378  .00001494  00000-0  59675-4 0  9995
2 40362  97.3708  83.8185 0006593 128.8250   1.1174 15.26687426112480
1 40362U 14088A   17002.91275115  .00001504  00000-0  60055-4 0  9997
2 40362  97.3707  84.2023 0006615 127.4475 338.3106 15.26688707112544
1 40362U 14088A   17003.23513382  .00001619  00000-0  64411-4 0  9991
2 40362  97.3708  84.5206 0006775 127.5072 308.9601 15.26690638112596
1 40362U 14088A   17003.50504738  .00001638  00000-0  65152-4 0  9990
2 40362  97.3708  84.7870 0006761 126.5269 352.4555 15.26691703112638
1 40362U 14088A   17003.89977446  .00001643  00000-0  65322-4 0  9997
2 40362  97.3706  85.1762 0006782 125.1453   1.8980 15.26693042112695
1 40362U 14088A   17004.21982252  .00001685  00000-0  66922-4 0  9998
2 40362  97.3705  85.4919 0006785 124.4246 320.5043 15.26694456112743
1 40362U 14088A   17004.55265133  .00001714  00000-0  68028-4 0  9999
2 40362  97.3706  85.8205 0006791 123.6444 349.3712 15.26695889112792
1 40362U 14088A   17004.87645491  .00001707  00000-0  67775-4 0  9993
2 40362  97.3704  86.1399 0006815 122.5179 329.0114 15.26696950112845
1 40362U 14088A   17005.20285824  .00001749  00000-0  69335-4 0  9991
2 40362  97.3704  86.4622 0006811 121.7112 322.6151 15.26698412112891
1 40362U 14088A   17005.53788520  .00001765  00000-0  69971-4 0  9992
2 40362  97.3704  86.7931 0006837 120.6573   3.8325 15.26699737112942
1 40362U 14088A   17005.86148072  .00001764  00000-0  69921-4 0  9994
2 40362  97.3704  87.1126 0006855 119.6266 342.2390 15.26700870112998
1 40362U 14088A   17006.24791668  .00001834  00000-0  72576-4 0  9990
2 40362  97.3703  87.4940 0006883 118.8923 305.5108 15.26702768113051
1 40362U 14088A   17006.52214924  .00001826  00000-0  72289-4 0  9998
2 40362  97.3702  87.7646 0006866 117.9583  12.6930 15.26703744113097
1 40362U 14088A   17006.72318264 +.00001799 +00000-0 +71235-4 0  9991
2 40362 097.3702 087.9631 0006863 117.4139 037.4328 15.26704334113128
1 40362U 14088A   17006.97849686  .00001796  00000-0  71115-4 0  9999
2 40362  97.3702  88.2149 0006859 116.5196   0.6655 15.26705201113167
1 40362U 14088A   17007.16390359  .00001837  00000-0  72674-4 0  9996
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2 40362  97.3702  88.3980 0006949 116.8384 298.7160 15.26706241113192
1 40362U 14088A   17007.49193439  .00001836  00000-0  72642-4 0  9996
2 40362  97.3702  88.7218 0006948 115.6663 301.6339 15.26707537113243
1 40362U 14088A   17007.83089050  .00001819  00000-0  71980-4 0  9992
2 40362  97.3703  89.0564 0006963 114.5861   4.4695 15.26708756113299
1 40362U 14088A   17007.96046193 +.00001811 +00000-0 +71700-4 0  9999
2 40362 097.3703 089.1843 0006970 114.0446 356.6962 15.26709134113315
1 40362U 14088A   17008.15283019  .00001841  00000-0  72832-4 0  9991
2 40362  97.3701  89.3741 0006965 113.6595 333.6884 15.26710097113347
1 40362U 14088A   17008.47480444  .00001844  00000-0  72945-4 0  9995
2 40362  97.3703  89.6919 0006967 112.6342 303.1978 15.26711394113392
1 40362U 14088A   17008.81351014  .00001846  00000-0  73015-4 0  9994
2 40362  97.3703  90.0263 0007007 111.5770   4.6401 15.26712723113446
1 40362U 14088A   17009.13596563  .00001877  00000-0  74180-4 0  9998
2 40362  97.3702  90.3447 0007012 110.3409 337.0059 15.26714115113498
1 40362U 14088A   17009.48128472  .00001877  00000-0  74197-4 0  9994
2 40362  97.3701  90.6855 0007016 109.2618  74.7984 15.26715494113545
1 40362U 14088A   17009.79558763  .00001867  00000-0  73801-4 0  9998
2 40362  97.3700  90.9956 0007026 108.1493   2.2635 15.26716612113596
1 40362U 14088A   17010.14084590  .00001865  00000-0  73712-4 0  9990
2 40362  97.3700  91.3362 0007053 107.7061  99.0887 15.26717889113644
1 40362U 14088A   17010.45435581  .00001863  00000-0  73630-4 0  9991
2 40362  97.3700  91.6459 0007087 106.9674  21.8283 15.26719074113698
1 40362U 14088A   17010.77597836  .00001804  00000-0  71392-4 0  9996
2 40362  97.3702  91.9634 0007088 106.2051 349.1505 15.26719882113747
1 40362U 14088A   17011.16222781  .00001739  00000-0  68939-4 0  9994
2 40362  97.3704  92.3452 0007085 105.3598 311.5289 15.26720754113804
1 40362U 14088A   17011.50254896  .00001706  00000-0  67667-4 0  9995
2 40362  97.3705  92.6812 0007101 104.1646  21.9923 15.26721788113858
1 40362U 14088A   17011.82728321  .00001623  00000-0  64492-4 0  9990
2 40362  97.3704  93.0017 0007105 103.6192   6.1921 15.26722374113904
1 40362U 14088A   17012.20443377  .00001595  00000-0  63447-4 0  9995
2 40362  97.3703  93.3740 0007134 103.4284 277.9457 15.26723448113962
1 40362U 14088A   17012.28162759  .00001581  00000-0  62900-4 0  9993
2 40362  97.3704  93.4502 0007141 103.0806 342.2934 15.26723635113979
1 40362U 14088A   17012.80971291  .00001511  00000-0  60237-4 0  9994
2 40362  97.3704  93.9714 0007149 101.5643   4.4075 15.26724883114058
1 40362U 14088A   17013.19316041  .00001478  00000-0  58991-4 0  9999
2 40362  97.3703  94.3499 0007145 100.6196 311.5043 15.26725863114114
1 40362U 14088A   17013.53627895  .00096521  00000-0  36728-2 0  9994
2 40362  97.3690  94.6980 0008806  99.4869  36.7576 15.26321444114163
1 40362U 14088A   17013.92630880 -.00221739  00000-0 -88399-2 0  9999
2 40362  97.3710  95.0800 0008298 142.0643 335.8762 15.26140209114227
1 40362U 14088A   17014.18234295 -.00046434  00000-0 -17981-2 0  9994
2 40362  97.3702  95.3262 0008863  95.5434 348.3106 15.26292883114262
1 40362U 14088A   17014.65109823  .00004676  00000-0  18285-3 0  9993
2 40362  97.3698  95.7931 0008812  94.2712  43.5762 15.26298965114339
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I. SATELLITE 40340

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1 40340U 14080C   17001.02134072 -.00000090  00000-0  00000+0 0  9991
2 40340  63.4046 190.5199 0056549 352.0807   7.9325 13.45161060101177
1 40340U 14080C   17001.46738361 -.00000090  00000-0  00000+0 0  9990
2 40340  63.4044 189.3748 0056553 352.0737   7.9396 13.45161096101232
1 40340U 14080C   17001.83908609 -.00000090  00000-0  00000+0 0  9995
2 40340  63.4045 188.4208 0056591 352.0955   7.9170 13.45161108101287
1 40340U 14080C   17002.06210770 -.00000090  00000-0  00000+0 0  9996
2 40340  63.4043 187.8477 0056679 352.0797   7.9336 13.45161144101315
1 40340U 14080C   17002.50815058 -.00000090  00000-0  00000+0 0  9995
2 40340  63.4043 186.7028 0056697 352.0729   7.9402 13.45161182101372
1 40340U 14080C   17002.73117198 -.00000090  00000-0  00000+0 0  9990
2 40340  63.4043 186.1302 0056721 352.0938   7.9184 13.45161188101408
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1 40340U 14080C   17002.87985309 -.00000090 +00000-0 +00000-0 0  9993
2 40340 063.4043 185.7487 0056721 352.0950 007.9178 13.45161196101425
1 40340U 14080C   17003.02853407 -.00000090  00000-0  00000+0 0  9993
2 40340  63.4042 185.3668 0056706 352.1015   7.9115 13.45161193101447
1 40340U 14080C   17003.54891766 -.00000090  00000-0  00000+0 0  9990
2 40340  63.4041 184.0311 0056730 352.1101   7.9033 13.45161221101519
1 40340U 14080C   17003.77193905 -.00000090  00000-0  00000+0 0  9995
2 40340  63.4041 183.4586 0056751 352.1398   7.8730 13.45161227101549
1 40340U 14080C   17004.14364160 -.00000090  00000-0  00000+0 0  9990
2 40340  63.4040 182.5045 0056767 352.1270   7.8864 13.45161253101596
1 40340U 14080C   17004.36666302 -.00000090  00000-0  00000+0 0  9997
2 40340  63.4040 181.9321 0056783 352.1268   7.8865 13.45161269101623
1 40340U 14080C   17004.81270595 -.00000090  00000-0  00000+0 0  9992
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1 40340U 14080C   17005.85347305 -.00000090  00000-0  00000+0 0  9991
2 40340  63.4037 178.1149 0057037 352.1606   7.8514 13.45161305101828
1 40340U 14080C   17006.07649474 -.00000090  00000-0  00000+0 0  9998
2 40340  63.4036 177.5421 0057052 352.1547   7.8585 13.45161307101857
1 40340U 14080C   17006.52253766 -.00000090  00000-0  00000+0 0  9993
2 40340  63.4036 176.3972 0057118 352.1831   7.8296 13.45161340101917
1 40340U 14080C   17006.67121873 -.00000090 +00000-0 +00000-0 0  9993
2 40340 063.4036 176.0155 0057138 352.2007 007.8119 13.45161331101931
1 40340U 14080C   17006.96858085 -.00000090  00000-0  00000+0 0  9996
2 40340  63.4038 175.2524 0057159 352.1980   7.8152 13.45161340101977
1 40340U 14080C   17007.48896436 -.00000090  00000-0  00000+0 0  9996
2 40340  63.4037 173.9168 0057207 352.2096   7.8037 13.45161362102043
1 40340U 14080C   17007.86066687 -.00000090  00000-0  00000+0 0  9995
2 40340  63.4039 172.9625 0057217 352.2158   7.7976 13.45161361102097
1 40340U 14080C   17008.08368834 -.00000090  00000-0  00000+0 0  9999
2 40340  63.4039 172.3899 0057244 352.2078   7.8057 13.45161378102128
1 40340U 14080C   17008.45539073 -.00000090  00000-0  00000+0 0  9995
2 40340  63.4039 171.4357 0057293 352.2300   7.7829 13.45161389102172
1 40340U 14080C   17008.67841230 -.00000090  00000-0  00000+0 0  9990
2 40340  63.4039 170.8628 0057309 352.2336   7.7793 13.45161374102201
1 40340U 14080C   17008.90143388 -.00000090 +00000-0 +00000-0 0  9996
2 40340 063.4040 170.2905 0057320 352.2424 007.7708 13.45161376102237
1 40340U 14080C   17009.12445542 -.00000090  00000-0  00000+0 0  9997
2 40340  63.4039 169.7178 0057340 352.2319   7.7816 13.45161380102263
1 40340U 14080C   17009.57049835 -.00000090  00000-0  00000+0 0  9991
2 40340  63.4040 168.5728 0057362 352.2530   7.7607 13.45161410102321
1 40340U 14080C   17009.71917929 -.00000090  00000-0  00000+0 0  9995
2 40340  63.4040 168.1911 0057408 352.2472   7.7656 13.45161392102342
1 40340U 14080C   17010.01654138 -.00000090  00000-0  00000+0 0  9990
2 40340  63.4040 167.4278 0057423 352.2451   7.7686 13.45161411102383
1 40340U 14080C   17010.46258418 -.00000090  00000-0  00000+0 0  9990
2 40340  63.4040 166.2829 0057446 352.2404   7.7734 13.45161452102441
1 40340U 14080C   17010.83428666 -.00000090  00000-0  00000+0 0  9995
2 40340  63.4044 165.3288 0057512 352.2341   7.7797 13.45161481102494
1 40340U 14080C   17011.05730799 -.00000090  00000-0  00000+0 0  9993
2 40340  63.4044 164.7564 0057531 352.2245   7.7886 13.45161499102520
1 40340U 14080C   17011.50335089 -.00000090  00000-0  00000+0 0  9996
2 40340  63.4046 163.6112 0057604 352.2638   7.7491 13.45161537102587
1 40340U 14080C   17011.65203194 -.00000090  00000-0  00000+0 0  9993
2 40340  63.4046 163.2293 0057609 352.2611   7.7521 13.45161528102606
1 40340U 14080C   17011.87505341 -.00000090 +00000-0 +00000-0 0  9997
2 40340 063.4044 162.6567 0057633 352.2750 007.7385 13.45161539102635
1 40340U 14080C   17012.09807483 -.00000090  00000-0  00000+0 0  9993
2 40340  63.4045 162.0840 0057666 352.2726   7.7411 13.45161566102666
1 40340U 14080C   17012.32109619 -.00000090  00000-0  00000+0 0  9995
```

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2 40340  63.4045 161.5116 0057711 352.2822   7.7309 13.45161583102692
1 40340U 14080C   17012.76713910 -.00000090  00000-0  00000+0 0  9998
2 40340  63.4048 160.3666 0057739 352.2948   7.7185 13.45161614102755
1 40340U 14080C   17012.99016057 -.00000090  00000-0  00000+0 0  9991
2 40340  63.4050 159.7943 0057764 352.2854   7.7280 13.45161638102787
1 40340U 14080C   17013.43620342 -.00000090  00000-0  00000+0 0  9999
2 40340  63.4051 158.6492 0057773 352.2791   7.7348 13.45161676102849
1 40340U 14080C   17013.51054375 -.00000090  00000-0  00000+0 0  9995
2 40340  63.4082 158.4518 0057800 352.4925   7.5199 13.45146083102850
1 40340U 14080C   17013.80790983 -.00000090  00000-0  00000+0 0  9999
2 40340  63.4052 157.6953 0057788 352.2998   7.7329 13.45161669102892
1 40340U 14080C   17014.03092728 -.00000090  00000-0  00000+0 0  9997
2 40340  63.4052 157.1227 0057818 352.2621   7.7518 13.45161706102924
1 40340U 14080C   17014.47696993 -.00000090  00000-0  00000+0 0  9999
2 40340  63.4053 155.9777 0057824 352.2855   7.7274 13.45161728102986
1 40340U 14080C   17014.84867265 -.00000090  00000-0  00000+0 0  9992
2 40340  63.4054 155.0234 0057892 352.2737   7.7396 13.45161702103034
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J. SATELLITE 40339

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1 40339U 14080B   17001.09571523 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4059 189.5379 0056701 351.9320   8.0793 13.45160236101204
1 40339U 14080B   17001.31873684 -.00000090  00000-0  00000+0 0  9990
2 40339  63.4058 188.9654 0056706 351.9203   8.0911 13.45160252101230
1 40339U 14080B   17001.76477994 -.00000090  00000-0  00000+0 0  9993
2 40339  63.4059 187.8205 0056737 351.9475   8.0629 13.45160285101294
1 40339U 14080B   17002.06214233 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4057 187.0568 0056783 351.9321   8.0798 13.45160321101330
1 40339U 14080B   17002.43384486 -.00000090  00000-0  00000+0 0  9991
2 40339  63.4057 186.1029 0056809 351.9224   8.0888 13.45160357101387
1 40339U 14080B   17002.65686643 -.00000090  00000-0  00000+0 0  9995
2 40339  63.4057 185.5303 0056816 351.9452   8.0656 13.45160377101415
1 40339U 14080B   17002.87988811 -.00000090 +00000-0 +00000-0 0  9992
2 40339 063.4056 184.9577 0056866 351.9457 008.0648 13.45160374101441
1 40339U 14080B   17003.02856929 -.00000090  00000-0  00000+0 0  9993
2 40339  63.4056 184.5759 0056876 351.9451   8.0659 13.45160381101466
1 40339U 14080B   17003.47461251 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4055 183.4311 0056884 351.9346   8.0766 13.45160418101526
1 40339U 14080B   17003.69763407 -.00000090  00000-0  00000+0 0  9994
2 40339  63.4055 182.8586 0056894 351.9463   8.0644 13.45160431101557
1 40339U 14080B   17003.92065573 -.00000090 +00000-0 +00000-0 0  9990
2 40339 063.4054 182.2863 0056896 351.9513 008.0595 13.45160435101588
1 40339U 14080B   17004.14367738 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4053 181.7137 0056914 351.9378   8.0733 13.45160450101610
1 40339U 14080B   17004.29235838 -.00000090  00000-0  00000+0 0  9993
2 40339  63.4054 181.3320 0056921 351.9457   8.0649 13.45160455101630
1 40339U 14080B   17004.73840151 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4055 180.1869 0056975 351.9697   8.0406 13.45160503101692
1 40339U 14080B   17005.03576383 -.00000090  00000-0  00000+0 0  9999
2 40339  63.4054 179.4235 0056981 351.9663   8.0451 13.45160520101733
1 40339U 14080B   17005.48180695 -.00000090  00000-0  00000+0 0  9995
2 40339  63.4054 178.2783 0057085 351.9981   8.0126 13.45160567101793
1 40339U 14080B   17005.63048812 -.00000090  00000-0  00000+0 0  9996
2 40339  63.4054 177.8966 0057100 352.0124   7.9985 13.45160573101811
1 40339U 14080B   17005.85350981 -.00000090 +00000-0 +00000-0 0  9994
2 40339 063.4053 177.3241 0057143 352.0045 008.0060 13.45160554101848
1 40339U 14080B   17006.07653156 -.00000090  00000-0  00000+0 0  9998
2 40339  63.4055 176.7515 0057179 352.0145   7.9966 13.45160577101878
1 40339U 14080B   17006.52257484 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4054 175.6068 0057182 352.0118   7.9996 13.45160591101938
1 40339U 14080B   17006.67125585 -.00000090 +00000-0 +00000-0 0  9995
2 40339 063.4055 175.2250 0057224 352.0322 007.9780 13.45160579101951
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1 40339U 14080B   17006.96861824 -.00000090  00000-0  00000+0 0  9999
2 40339  63.4054 174.4618 0057239 352.0310   7.9802 13.45160576101998
1 40339U 14080B   17007.48900203 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4054 173.1262 0057278 352.0312   7.9805 13.45160620102066
1 40339U 14080B   17007.86070478 -.00000090  00000-0  00000+0 0  9996
2 40339  63.4054 172.1723 0057308 352.0370   7.9741 13.45160600102118
1 40339U 14080B   17008.08372641 -.00000090  00000-0  00000+0 0  9998
2 40339  63.4054 171.5996 0057339 352.0460   7.9653 13.45160617102140
1 40339U 14080B   17008.45542912 -.00000090  00000-0  00000+0 0  9999
2 40339  63.4054 170.6457 0057377 352.0591   7.9520 13.45160628102199
1 40339U 14080B   17008.67845077 -.00000090  00000-0  00000+0 0  9991
2 40339  63.4054 170.0730 0057392 352.0782   7.9328 13.45160621102229
1 40339U 14080B   17008.90147251 -.00000090 +00000-0 +00000-0 0  9997
2 40339 063.4056 169.5006 0057424 352.0735 007.9378 13.45160628102259
1 40339U 14080B   17009.12449415 -.00000090  00000-0  00000+0 0  9998
2 40339  63.4055 168.9280 0057440 352.0757   7.9358 13.45160631102282
1 40339U 14080B   17009.57053735 -.00000090  00000-0  00000+0 0  9993
2 40339  63.4056 167.7830 0057462 352.0898   7.9219 13.45160664102340
1 40339U 14080B   17009.64487784 -.00000090  00000-0  00000+0 0  9996
2 40339  63.4057 167.5921 0057470 352.1043   7.9071 13.45160664102359
1 40339U 14080B   17010.01658059 -.00000090  00000-0  00000+0 0  9994
2 40339  63.4056 166.6383 0057489 352.0992   7.9125 13.45160670102405
1 40339U 14080B   17010.46262375 -.00000090  00000-0  00000+0 0  9995
2 40339  63.4057 165.4935 0057502 352.0965   7.9155 13.45160706102461
1 40339U 14080B   17010.83432640 -.00000090  00000-0  00000+0 0  9990
2 40339  63.4058 164.5392 0057543 352.1237   7.8881 13.45160719102512
1 40339U 14080B   17010.98300746 -.00000090  00000-0  00000+0 0  9997
2 40339  63.4058 164.1575 0057552 352.0963   7.9157 13.45160730102538
1 40339U 14080B   17011.50339104 -.00000090  00000-0  00000+0 0  9996
2 40339  63.4059 162.8219 0057555 352.1061   7.9056 13.45160768102609
1 40339U 14080B   17011.65207206 -.00000090  00000-0  00000+0 0  9999
2 40339  63.4060 162.4400 0057556 352.1007   7.9108 13.45160760102622
1 40339U 14080B   17011.87509367 -.00000090 +00000-0 +00000-0 0  9997
2 40339 063.4061 161.8674 0057596 352.0925 007.9190 13.45160772102658
1 40339U 14080B   17012.09811524 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4060 161.2946 0057609 352.0842   7.9274 13.45160781102682
1 40339U 14080B   17012.32113676 -.00000090  00000-0  00000+0 0  9991
2 40339  63.4061 160.7223 0057674 352.1248   7.8864 13.45160818102717
1 40339U 14080B   17012.76718001 -.00000090  00000-0  00000+0 0  9992
2 40339  63.4065 159.5774 0057717 352.1637   7.8475 13.45160845102772
1 40339U 14080B   17012.99020175 -.00000090  00000-0  00000+0 0  9995
2 40339  63.4063 159.0051 0057723 352.1415   7.8707 13.45160861102804
1 40339U 14080B   17013.43624473 -.00000090  00000-0  00000+0 0  9996
2 40339  63.4064 157.8605 0057732 352.1503   7.8618 13.45160910102866
1 40339U 14080B   17013.58492572 -.00000090  00000-0  00000+0 0  9995
2 40339  63.4065 157.4802 0057560 353.0412   6.9627 13.45142940102885
1 40339U 14080B   17013.80795405 -.00000090  00000-0  00000+0 0  9991
2 40339  63.4063 156.9062 0057799 352.1856   7.8588 13.45160928102917
1 40339U 14080B   17014.03096895 -.00000090  00000-0  00000+0 0  9994
2 40339  63.4063 156.3338 0057816 352.1739   7.8385 13.45160949102948
1 40339U 14080B   17014.47701190 -.00000090  00000-0  00000+0 0  9993
2 40339  63.4063 155.1885 0057816 352.1812   7.8307 13.45160976103006
1 40339U 14080B   17014.84871489 -.00000090  00000-0  00000+0 0  9993
2 40339  63.4065 154.2342 0057886 352.1919   7.8211 13.45160979103053
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K. SATELLITE 40338

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1 40338U 14080A   17001.09550874 -.00000090  00000-0  00000+0 0  9997
2 40338  63.4050 189.5194 0056621 351.9275   8.0837 13.45160331101204
1 40338U 14080A   17001.54155197 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4050 188.3745 0056637 351.9132   8.0980 13.45160366101265
1 40338U 14080A   17001.76457354 -.00000090  00000-0  00000+0 0  9990
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2 40338  63.4052 187.8018 0056698 351.9525   8.0581 13.45160388101291
1 40338U 14080A   17002.06193587 -.00000090  00000-0  00000+0 0  9999
2 40338  63.4050 187.0381 0056731 351.9604   8.0513 13.45160409101334
1 40338U 14080A   17002.43363847 -.00000090  00000-0  00000+0 0  9998
2 40338  63.4051 186.0841 0056754 351.9412   8.0704 13.45160447101386
1 40338U 14080A   17002.87968171 -.00000090  00000-0  00000+0 0  9997
2 40338  63.4051 184.9391 0056770 351.9736   8.0377 13.45160466101444
1 40338U 14080A   17003.02836280 -.00000090  00000-0  00000+0 0  9990
2 40338  63.4050 184.5575 0056772 351.9756   8.0358 13.45160477101460
1 40338U 14080A   17003.47440603 -.00000090  00000-0  00000+0 0  9999
2 40338  63.4049 183.4125 0056785 351.9780   8.0336 13.45160498101524
1 40338U 14080A   17003.69742761 -.00000090  00000-0  00000+0 0  9993
2 40338  63.4050 182.8400 0056791 351.9922   8.0190 13.45160503101558
1 40338U 14080A   17003.92044930 -.00000090 +00000-0 +00000-0 0  9993
2 40338 063.4049 182.2677 0056795 351.9960 008.0154 13.45160504101586
1 40338U 14080A   17004.14347095 -.00000090  00000-0  00000+0 0  9995
2 40338  63.4050 181.6951 0056807 351.9994   8.0125 13.45160527101614
1 40338U 14080A   17004.58951411 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4050 180.5502 0056835 352.0202   7.9915 13.45160562101679
1 40338U 14080A   17004.73819519 -.00000090  00000-0  00000+0 0  9995
2 40338  63.4051 180.1685 0056865 352.0388   7.9723 13.45160553101695
1 40338U 14080A   17005.03555752 -.00000090  00000-0  00000+0 0  9995
2 40338  63.4050 179.4050 0056886 352.0337   7.9785 13.45160567101736
1 40338U 14080A   17005.48160078 -.00000090  00000-0  00000+0 0  9997
2 40338  63.4050 178.2600 0056963 352.0573   7.9546 13.45160596101795
1 40338U 14080A   17005.85330358 -.00000090  00000-0  00000+0 0  9998
2 40338  63.4052 177.3060 0056976 352.0643   7.9476 13.45160594101845
1 40338U 14080A   17006.07632522 -.00000090  00000-0  00000+0 0  9991
2 40338  63.4053 176.7334 0057002 352.0611   7.9508 13.45160612101879
1 40338U 14080A   17006.52236845 -.00000090  00000-0  00000+0 0  9999
2 40338  63.4053 175.5887 0057006 352.0738   7.9382 13.45160628101937
1 40338U 14080A   17006.67104953 -.00000090 +00000-0 +00000-0 0  9990
2 40338 063.4052 175.2070 0057007 352.0730 007.9387 13.45160610101958
1 40338U 14080A   17006.96841176 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4052 174.4438 0057028 352.0698   7.9418 13.45160602101993
1 40338U 14080A   17007.48879564 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4053 173.1082 0057040 352.0619   7.9506 13.45160630102060
1 40338U 14080A   17007.86049833 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4053 172.1542 0057073 352.0658   7.9458 13.45160611102110
1 40338U 14080A   17008.08352000 -.00000090  00000-0  00000+0 0  9994
2 40338  63.4052 171.5817 0057093 352.0661   7.9457 13.45160617102141
1 40338U 14080A   17008.45522273 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4053 170.6277 0057122 352.0901   7.9218 13.45160627102193
1 40338U 14080A   17008.67824438 -.00000090  00000-0  00000+0 0  9998
2 40338  63.4053 170.0551 0057138 352.0962   7.9153 13.45160612102222
1 40338U 14080A   17008.90126613 -.00000090 +00000-0 +00000-0 0  9995
2 40338 063.4052 169.4822 0057167 352.0848 007.9271 13.45160597102255
1 40338U 14080A   17009.12428775 -.00000090  00000-0  00000+0 0  9993
2 40338  63.4052 168.9096 0057189 352.0873   7.9246 13.45160601102285
1 40338U 14080A   17009.57033095 -.00000090  00000-0  00000+0 0  9999
2 40338  63.4054 167.7645 0057196 352.0881   7.9243 13.45160640102348
1 40338U 14080A   17009.71901192 -.00000090  00000-0  00000+0 0  9997
2 40338  63.4053 167.3827 0057252 352.0736   7.9372 13.45160607102365
1 40338U 14080A   17010.01637426 -.00000090  00000-0  00000+0 0  9998
2 40338  63.4053 166.6195 0057279 352.0661   7.9456 13.45160624102408
1 40338U 14080A   17010.46241741 -.00000090  00000-0  00000+0 0  9998
2 40338  63.4054 165.4747 0057296 352.0599   7.9520 13.45160657102462
1 40338U 14080A   17010.83412009 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4056 164.5205 0057377 352.0633   7.9481 13.45160671102510
1 40338U 14080A   17011.05714171 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4055 163.9480 0057406 352.0502   7.9611 13.45160684102547
1 40338U 14080A   17011.50318487 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4055 162.8027 0057457 352.0631   7.9482 13.45160713102607
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1 40338U 14080A   17011.65186590 -.00000090  00000-0  00000+0 0  9990
2 40338  63.4057 162.4209 0057466 352.0663   7.9447 13.45160710102622
1 40338U 14080A   17012.02356863 -.00000090  00000-0  00000+0 0  9994
2 40338  63.4070 161.4633 0057928 352.0886   7.9239 13.45161272102675
1 40338U 14080A   17012.17224928 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4059 161.0851 0057539 352.0701   7.9389 13.45160733102693
1 40338U 14080A   17012.39527133 -.00000090  00000-0  00000+0 0  9994
2 40338  63.4060 160.5124 0057619 352.0932   7.9180 13.45160770102721
1 40338U 14080A   17012.84131461 -.00000090  00000-0  00000+0 0  9999
2 40338  63.4064 159.3676 0057621 352.0867   7.9249 13.45160796102783
1 40338U 14080A   17012.98999560 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4065 158.9861 0057660 352.0947   7.9164 13.45160813102806
1 40338U 14080A   17013.43603883 -.00000090  00000-0  00000+0 0  9997
2 40338  63.4066 157.8413 0057702 352.1029   7.9086 13.45160852102869
1 40338U 14080A   17013.58471984 -.00000090  00000-0  00000+0 0  9998
2 40338  63.4088 157.4551 0058716 352.0106   7.9828 13.45143069102880
1 40338U 14080A   17013.80774753 -.00000090  00000-0  00000+0 0  9993
2 40338  63.4068 156.8874 0057716 352.1115   7.9293 13.45160868102915
1 40338U 14080A   17013.88208198 -.00000090  00000-0  00000+0 0  9996
2 40338  63.4087 156.6944 0058090 352.0846   7.9264 13.45161176102920
1 40338U 14080A   17014.03076292 -.00000090  00000-0  00000+0 0  9992
2 40338  63.4068 156.3151 0057763 352.0931   7.9177 13.45160902102948
1 40338U 14080A   17014.47680608 -.00000090  00000-0  00000+0 0  9992
2 40338  63.4070 155.1700 0057794 352.1230   7.8878 13.45160932103003
1 40338U 14080A   17014.69982777 -.00000090  00000-0  00000+0 0  9998
2 40338  63.4072 154.5974 0057821 352.1259   7.8849 13.45160923103034
1 40338U 14080A   17014.99718998 -.00000090  00000-0  00000+0 0  9993
2 40338  63.4071 153.8337 0057846 352.1170   7.8948 13.45160944103074
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L. SATELLITE 39358

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1 39358U 13057A   17001.18315363  .00000134  00000-0  18851-4 0  9998
2 39358  74.9741   1.6112 0020564 269.2089  90.6716 14.85319164173008
1 39358U 13057A   17001.51993340  .00000131  00000-0  18494-4 0  9992
2 39358  74.9742   0.9807 0020562 268.5815  91.3016 14.85319268173050
1 39358U 13057A   17001.85671244  .00000160  00000-0  21777-4 0  9995
2 39358  74.9740   0.3500 0020564 267.8266  92.0569 14.85319612173106
1 39358U 13057A   17002.19349168  .00000111  00000-0  16126-4 0  9998
2 39358  74.9741 359.7195 0020598 266.9989  92.8812 14.85319219173154
1 39358U 13057A   17002.53027153  .00000100  00000-0  14890-4 0  9997
2 39358  74.9743 359.0890 0020579 266.2689  93.6142 14.85319247173202
1 39358U 13057A   17002.86705070  .00000104  00000-0  15343-4 0  9992
2 39358  74.9742 358.4584 0020594 265.4947  94.3887 14.85319386173252
1 39358U 13057A   17003.20382998  .00000065  00000-0  10854-4 0  9999
2 39358  74.9743 357.8278 0020599 264.6342  95.2474 14.85319110173304
1 39358U 13057A   17003.47325382  .00000049  00000-0  90035-5 0  9994
2 39358  74.9744 357.3233 0020569 263.9995  95.8845 14.85319063173343
1 39358U 13057A   17003.81003299  .00000082  00000-0  12750-4 0  9996
2 39358  74.9743 356.6928 0020600 263.2158  96.6701 14.85319440173399
1 39358U 13057A   17004.14681190  .00000068  00000-0  11140-4 0  9991
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1 39358U 13057A   17004.55094705  .00000096  00000-0  14365-4 0  9999
2 39358  74.9744 355.3059 0020596 261.4788  98.4081 14.85319773173507
1 39358U 13057A   17004.82036993  .00000120  00000-0  17165-4 0  9993
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1 39358U 13057A   17005.22450497  .00000087  00000-0  13377-4 0  9990
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1 39358U 13057A   17006.63897789 +.00000092 +00000-0 +13999-4 0  9991
2 39358 074.9745 351.3963 0020618 256.7423 103.1468 14.85320191173819
1 39358U 13057A   17006.90840109  .00000098  00000-0  14632-4 0  9996
2 39358  74.9744 350.8919 0020629 256.1591 103.7308 14.85320343173857
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1 39358U 13057A   17007.78402645  .00000126  00000-0  17928-4 0  9995
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1 39358U 13057A   17014.45224799  .00000112  00000-0  16297-4 0  9992
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M. SATELLITE 39241

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1 39241U 13046C   17001.32623620 -.00000090  00000-0  00000+0 0  9995
2 39241  63.4133 332.6994 0117625   2.9230 357.2456 13.45159726163785
1 39241U 13046C   17001.69793923 -.00000090  00000-0  00000+0 0  9999
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1 39241U 13046C   17010.09842722 -.00000090  00000-0  00000+0 0  9995
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1 39241U 13046C   17014.78188426 -.00000090  00000-0  00000+0 0  9999
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N. SATELLITE 39240

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1 39240U 13046B   17001.32644318 -.00000090  00000-0  00000+0 0  9991
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2 39240  63.4131 308.4074 0117686   3.0687 357.1038 13.45159992165082
1 39240U 13046B   17011.51110715 -.00000090  00000-0  00000+0 0  9992
2 39240  63.4129 307.4526 0117705   3.0648 357.1079 13.45160034165139
1 39240U 13046B   17011.73412882 -.00000090  00000-0  00000+0 0  9996
2 39240  63.4129 306.8802 0117725   3.0598 357.1130 13.45160069165164
1 39240U 13046B   17012.03149105 -.00000090  00000-0  00000+0 0  9995
2 39240  63.4131 306.1169 0117728   3.0592 357.1139 13.45160126165201
1 39240U 13046B   17012.47753425 -.00000090  00000-0  00000+0 0  9999
2 39240  63.4130 304.9722 0117777   3.0552 357.1174 13.45160198165265
1 39240U 13046B   17012.62621530 -.00000090  00000-0  00000+0 0  9997
2 39240  63.4131 304.5906 0117751   3.0508 357.1220 13.45160218165286
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1 39240U 13046B   17012.84923689 -.00000090 +00000-0 +00000-0 0  9992
2 39240 063.4132 304.0182 0117749 003.0484 357.1243 13.45160262165316
1 39240U 13046B   17013.07225848 -.00000090  00000-0  00000+0 0  9999
2 39240  63.4133 303.4459 0117777   3.0559 357.1163 13.45160293165349
1 39240U 13046B   17013.44396121 -.00000090  00000-0  00000+0 0  9993
2 39240  63.4131 302.4916 0117827   3.0332 357.1389 13.45160357165395
1 39240U 13046B   17013.74132339 -.00000090  00000-0  00000+0 0  9995
2 39240  63.4132 301.7286 0117791   3.0314 357.1413 13.45160395165433
1 39240U 13046B   17013.89000430 -.00000090 +00000-0 +00000-0 0  9998
2 39240 063.4132 301.3467 0117854 003.0304 357.1410 13.45160421165458
1 39240U 13046B   17014.11302606 -.00000090  00000-0  00000+0 0  9993
2 39240  63.4132 300.7741 0117905   3.0382 357.1335 13.45160451165481
1 39240U 13046B   17014.48472878 -.00000090  00000-0  00000+0 0  9992
2 39240  63.4130 299.8194 0117947   3.0276 357.1444 13.45160502165531
1 39240U 13046B   17014.78209096 -.00000090  00000-0  00000+0 0  9995
2 39240  63.4130 299.0561 0117979   3.0306 357.1412 13.45160534165574
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O. SATELLITE 39239

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1 39239U 13046A   17001.10319865 -.00000090  00000-0  00000+0 0  9991
2 39239  63.4125 334.1063 0116857   3.1499 357.0232 13.45159969163737
1 39239U 13046A   17001.32622058 -.00000090  00000-0  00000+0 0  9996
2 39239  63.4127 333.5340 0116851   3.1522 357.0216 13.45159985163764
1 39239U 13046A   17001.69792345 -.00000090  00000-0  00000+0 0  9993
2 39239  63.4125 332.5796 0116900   3.1390 357.0346 13.45160015163810
1 39239U 13046A   17002.06962642 -.00000090  00000-0  00000+0 0  9994
2 39239  63.4125 331.6251 0116965   3.1438 357.0295 13.45160031163866
1 39239U 13046A   17002.44132950 -.00000090  00000-0  00000+0 0  9997
2 39239  63.4127 330.6709 0116974   3.1520 357.0219 13.45160052163912
1 39239U 13046A   17002.66435126 -.00000090  00000-0  00000+0 0  9992
2 39239  63.4126 330.0985 0116975   3.1522 357.0218 13.45160057163941
1 39239U 13046A   17002.88737300 -.00000090 +00000-0 +00000-0 0  9996
2 39239 063.4127 329.5260 0116995 003.1544 357.0196 13.45160076163976
1 39239U 13046A   17003.18473548 -.00000090  00000-0  00000+0 0  9990
2 39239  63.4135 328.7594 0117332   3.1609 357.0119 13.45160116164010
1 39239U 13046A   17003.33341695 -.00000090  00000-0  00000+0 0  9994
2 39239  63.4129 328.3813 0117043   3.1598 357.0154 13.45160086164036
1 39239U 13046A   17003.77946025 -.00000090  00000-0  00000+0 0  9990
2 39239  63.4127 327.2361 0117100   3.1535 357.0206 13.45160099164093
1 39239U 13046A   17004.07682259 -.00000090  00000-0  00000+0 0  9990
2 39239  63.4127 326.4728 0117117   3.1583 357.0158 13.45160119164136
1 39239U 13046A   17004.44852555 -.00000090  00000-0  00000+0 0  9999
2 39239  63.4127 325.5184 0117155   3.1497 357.0246 13.45160130164184
1 39239U 13046A   17004.59720663 -.00000090  00000-0  00000+0 0  9999
2 39239  63.4128 325.1370 0117153   3.1519 357.0220 13.45160135164201
1 39239U 13046A   17004.89456901 -.00000090 +00000-0 +00000-0 0  9994
2 39239 063.4127 324.3735 0117212 003.1559 357.0179 13.45160153164243
1 39239U 13046A   17005.04325021 -.00000090  00000-0  00000+0 0  9999
2 39239  63.4127 323.9916 0117266   3.1637 357.0096 13.45160152164264
1 39239U 13046A   17005.48929394 -.00000090  00000-0  00000+0 0  9990
2 39239  63.4126 322.8465 0117292   3.1653 357.0093 13.45160155164324
1 39239U 13046A   17005.63797505 -.00000090  00000-0  00000+0 0  9994
2 39239  63.4126 322.4649 0117294   3.1632 357.0110 13.45160159164349
1 39239U 13046A   17005.86099681 -.00000090 +00000-0 +00000-0 0  9990
2 39239 063.4128 321.8927 0117291 003.1666 357.0079 13.45160184164372
1 39239U 13046A   17006.08401852 -.00000090  00000-0  00000+0 0  9991
2 39239  63.4127 321.3201 0117320   3.1654 357.0088 13.45160187164408
1 39239U 13046A   17006.30704031 -.00000090  00000-0  00000+0 0  9991
2 39239  63.4128 320.7477 0117345   3.1671 357.0071 13.45160191164433
1 39239U 13046A   17006.53006211 -.00000090  00000-0  00000+0 0  9991
2 39239  63.4127 320.1750 0117362   3.1631 357.0114 13.45160196164461
1 39239U 13046A   17006.67874324 -.00000090  00000-0  00000+0 0  9994
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2 39239  63.4127 319.7934 0117363   3.1589 357.0156 13.45160206164482
1 39239U 13046A   17007.05044612 -.00000090  00000-0  00000+0 0  9996
2 39239  63.4128 318.8394 0117353   3.1660 357.0085 13.45160221164536
1 39239U 13046A   17007.49648952 -.00000090  00000-0  00000+0 0  9991
2 39239  63.4127 317.6941 0117412   3.1587 357.0158 13.45160248164590
1 39239U 13046A   17007.64517063 -.00000090  00000-0  00000+0 0  9996
2 39239  63.4127 317.3127 0117435   3.1581 357.0159 13.45160254164613
1 39239U 13046A   17007.94253302 -.00000090 +00000-0 +00000-0 0  9993
2 39239 063.4128 316.5492 0117456 003.1630 357.0114 13.45160268164658
1 39239U 13046A   17008.09121416 -.00000090  00000-0  00000+0 0  9999
2 39239  63.4130 316.1673 0117515   3.1685 357.0054 13.45160281164674
1 39239U 13046A   17008.53725774 -.00000090  00000-0  00000+0 0  9995
2 39239  63.4128 315.0215 0117602   3.1636 357.0112 13.45160314164733
1 39239U 13046A   17008.68593882 -.00000090  00000-0  00000+0 0  9994
2 39239  63.4128 314.6402 0117602   3.1615 357.0129 13.45160318164757
1 39239U 13046A   17009.05764172 -.00000090  00000-0  00000+0 0  9998
2 39239  63.4131 313.6859 0117654   3.1684 357.0060 13.45160351164806
1 39239U 13046A   17009.42934475 -.00000090  00000-0  00000+0 0  9994
2 39239  63.4130 312.7321 0117671   3.1756 356.9997 13.45160375164856
1 39239U 13046A   17009.80104755 -.00000090  00000-0  00000+0 0  9996
2 39239  63.4131 311.7782 0117700   3.1746 357.0006 13.45160403164900
1 39239U 13046A   17010.09840978 -.00000090  00000-0  00000+0 0  9993
2 39239  63.4132 311.0151 0117707   3.1752 356.9994 13.45160413164947
1 39239U 13046A   17010.47011256 -.00000090  00000-0  00000+0 0  9994
2 39239  63.4131 310.0608 0117731   3.1594 357.0156 13.45160458164999
1 39239U 13046A   17010.69313416 -.00000090  00000-0  00000+0 0  9991
2 39239  63.4132 309.4885 0117748   3.1506 357.0241 13.45160477165021
1 39239U 13046A   17010.91615579 -.00000090 +00000-0 +00000-0 0  9992
2 39239 063.4132 308.9158 0117791 003.1740 356.9996 13.45160472165059
1 39239U 13046A   17011.13917777 -.00000090  00000-0  00000+0 0  9991
2 39239  63.4132 308.3427 0117850   3.1780 356.9965 13.45160472165081
1 39239U 13046A   17011.51088065 -.00000090  00000-0  00000+0 0  9992
2 39239  63.4131 307.3884 0117867   3.1769 356.9981 13.45160490165135
1 39239U 13046A   17011.73390234 -.00000090  00000-0  00000+0 0  9990
2 39239  63.4131 306.8161 0117883   3.1759 356.9992 13.45160507165168
1 39239U 13046A   17012.03126458 -.00000090  00000-0  00000+0 0  9999
2 39239  63.4131 306.0528 0117889   3.1776 356.9974 13.45160517165208
1 39239U 13046A   17012.47730809 -.00000090  00000-0  00000+0 0  9998
2 39239  63.4130 304.9078 0117926   3.1851 356.9904 13.45160532165266
1 39239U 13046A   17012.62598914 -.00000090  00000-0  00000+0 0  9994
2 39239  63.4130 304.5262 0117925   3.1804 356.9950 13.45160544165280
1 39239U 13046A   17012.70033940  .00000035  00000-0  10000-3 0  9999
2 39239  63.4093 304.3289 0118656   3.4000 356.8196 13.45160310165291
1 39239U 13046A   17012.84901077 -.00000090 +00000-0 +00000-0 0  9997
2 39239 063.4130 303.9540 0117938 003.1808 356.9945 13.45160566165312
1 39239U 13046A   17013.07203243 -.00000090  00000-0  00000+0 0  9992
2 39239  63.4131 303.3815 0117962   3.1854 356.9893 13.45160568165347
1 39239U 13046A   17013.51807586 -.00000090  00000-0  00000+0 0  9991
2 39239  63.4130 302.2363 0117981   3.1749 357.0005 13.45160593165408
1 39239U 13046A   17013.74109746 -.00000090  00000-0  00000+0 0  9999
2 39239  63.4130 301.6640 0117987   3.1740 357.0013 13.45160614165432
1 39239U 13046A   17013.88977851 -.00000090 +00000-0 +00000-0 0  9995
2 39239 063.4130 301.2822 0118019 003.1772 356.9975 13.45160618165453
1 39239U 13046A   17014.11280027 -.00000090  00000-0  00000+0 0  9993
2 39239  63.4130 300.7098 0118053   3.1806 356.9939 13.45160611165484
1 39239U 13046A   17014.48450311 -.00000090  00000-0  00000+0 0  9998
2 39239  63.4128 299.7549 0118112   3.1787 356.9962 13.45160630165536
1 39239U 13046A   17014.78186541 -.00000090  00000-0  00000+0 0  9992
2 39239  63.4129 298.9917 0118131   3.1805 356.9949 13.45160656165576
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P. SATELLITE 39210

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1 39210U 13037C   17001.90631142  .00000010  00000-0  10014-4 0  9995
2 39210  98.0043  15.9660 0003669 333.5069  26.5950 14.67925495187501
1 39210U 13037C   17002.86061084  .00000038  00000-0  14887-4 0  9995
2 39210  98.0047  16.8996 0003634 330.3177  29.7825 14.67925816187642
1 39210U 13037C   17003.88307419  .00000011  00000-0  10310-4 0  9991
2 39210  98.0048  17.8988 0003622 326.8544  33.2423 14.67925918187793
1 39210U 13037C   17004.90553790  .00000039  00000-0  15047-4 0  9992
2 39210  98.0052  18.8988 0003516 323.0238  37.0736 14.67926250187946
1 39210U 13037C   17005.85983705 +.00000055 +00000-0 +17893-4 0  9999
2 39210 098.0053 019.8322 0003436 319.5086 040.5867 14.67926400188089
1 39210U 13037C   17006.67780739 +.00000003 +00000-0 +88111-5 0  9997
2 39210 098.0055 020.6320 0003415 316.5183 043.5740 14.67926357188209
1 39210U 13037C   17007.97292792 +.00000055 +00000-0 +17902-4 0  9994
2 39210 098.0056 021.8988 0003365 311.7119 048.3815 14.67926820188394
1 39210U 13037C   17008.79089826 +.00000041 +00000-0 +15491-4 0  9993
2 39210 098.0056 022.6987 0003317 308.9425 051.1482 14.67926841188516
1 39210U 13037C   17009.81336089  .00000029  00000-0  13380-4 0  9994
2 39210  98.0053  23.6989 0003244 304.4393  55.6501 14.67927113188660
1 39210U 13037C   17010.90398786 +.00000020 +00000-0 +11822-4 0  9998
2 39210 098.0051 024.7656 0003174 300.4802 059.6075 14.67927240188823
1 39210U 13037C   17011.85828682  .00000070  00000-0  20462-4 0  9991
2 39210  98.0047  25.6984 0003072 295.3404  64.7504 14.67927690188967
1 39210U 13037C   17012.67625600  .00000055  00000-0  17922-4 0  9997
2 39210  98.0044  26.4985 0003050 291.3103  68.7764 14.67927876189084
1 39210U 13037C   17012.94891296 +.00000063 +00000-0 +19357-4 0  9996
2 39210 098.0044 026.7647 0003044 290.3260 069.7624 14.67928004189123
1 39210U 13037C   17013.90321169 +.00000013 +00000-0 +10641-4 0  9992
2 39210 098.0039 027.6981 0002996 285.8145 074.2735 14.67927790189264
1 39210U 13037C   17014.92567402 +.00000052 +00000-0 +17385-4 0  9992
2 39210 098.0038 028.6976 0002967 280.8009 079.2872 14.67928185189413
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Q. SATELLITE 39013

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1 39013U 12066C   17001.13342845 -.00000048  00000-0  68362-4 0  9992
2 39013  63.3793 184.3436 0135309   4.5004 355.7203 13.45159242201523
1 39013U 12066C   17001.28210955 -.00000048  00000-0  68362-4 0  9994
2 39013  63.3793 183.9616 0135309   4.5014 355.7194 13.45159255201544
1 39013U 12066C   17001.72815241 -.00000048  00000-0  68362-4 0  9992
2 39013  63.3791 182.8142 0135229   4.4985 355.7209 13.45159250201600
1 39013U 12066C   17002.02551484 -.00000048  00000-0  68362-4 0  9992
2 39013  63.3791 182.0502 0135229   4.5004 355.7203 13.45159275201640
1 39013U 12066C   17002.47155808 -.00000048  00000-0  68362-4 0  9991
2 39013  63.3791 180.9041 0135229   4.5034 355.7174 13.45159313201705
1 39013U 12066C   17002.69457969 -.00000048  00000-0  68362-4 0  9998
2 39013  63.3791 180.3310 0135229   4.5049 355.7159 13.45159332201731
1 39013U 12066C   17002.84326077 -.00000048 +00000-0 +68362-4 0  9990
2 39013 063.3791 179.9490 0135229 004.5059 355.7149 13.45159345201750
1 39013U 12066C   17002.91760130 -.00000132  00000-0 -67057-4 0  9995
2 39013  63.3796 179.7558 0135332   4.5230 355.6921 13.45158825201764
1 39013U 12066C   17003.58666772 -.00000028  00000-0  10000-3 0  9994
2 39013  63.3798 178.0392 0135054   4.5852 355.6426 13.45159624201853
1 39013U 12066C   17003.80968825 -.00000028  00000-0  10000-3 0  9993
2 39013  63.3798 177.4661 0135076   4.5854 355.6366 13.45159613201885
1 39013U 12066C   17003.95836946 -.00000028  00000-0  10000-3 0  9997
2 39013  63.3798 177.0838 0135092   4.5811 355.6416 13.45159628201903
1 39013U 12066C   17004.47875317 -.00000028  00000-0  10000-3 0  9990
2 39013  63.3798 175.7462 0135146   4.5849 355.6375 13.45159677201977
1 39013U 12066C   17004.62743432 -.00000028  00000-0  10000-3 0  9999
2 39013  63.3798 175.3640 0135146   4.5889 355.6329 13.45159655201992
1 39013U 12066C   17004.85045613 -.00000028 +00000-0 +10000-3 0  9990
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2 39013 063.3799 174.7909 0135169 004.5900 355.6323 13.4515965620202З
1 39013U 12066C   17005.07347784 -.00000028  00000-0  10000-3 0  9999
2 39013  63.3799 174.2178 0135169   4.5914 355.6317 13.45159684202058
1 39013U 12066C   17005.51952096 -.00000028  00000-0  10000-3 0  9996
2 39013  63.3798 173.0713 0135206   4.5929 355.6297 13.45159716202117
1 39013U 12066C   17005.74254264 -.00000028  00000-0  10000-3 0  9993
2 39013  63.3799 172.4978 0135305   4.5731 355.6474 13.45159668202141
1 39013U 12066C   17005.89122413 -.00000028 +00000-0 +10000-3 0  9999
2 39013 063.3797 172.1155 0135566 004.5626 355.6643 13.45159902202166
1 39013U 12066C   17006.11424479 -.00000028  00000-0  10000-3 0  9992
2 39013  63.3797 171.5424 0135566   4.5605 355.6621 13.45159925202199
1 39013U 12066C   17006.33726632 -.00000028  00000-0  10000-3 0  9992
2 39013  63.3797 170.9694 0135565   4.5620 355.6607 13.45159953202226
1 39013U 12066C   17006.48594733 -.00000028  00000-0  10000-3 0  9993
2 39013  63.3797 170.5868 0135555   4.5603 355.6614 13.45159928202247
1 39013U 12066C   17006.63464071  .00000000  00000-0  00000+0 0  9995
2 39013  63.3799 170.2022 0135390   4.6197 355.6510 13.45158963215915
1 39013U 12066C   17006.70896903 -.00000028 +00000-0 +10000-3 0  9992
2 39013 063.3796 170.0135 0135593 004.5618 355.6594 13.45159899202273
1 39013U 12066C   17007.00633138 -.00000028  00000-0  10000-3 0  9995
2 39013  63.3795 169.2490 0135619   4.5506 355.6712 13.45159905202316
1 39013U 12066C   17007.45237459 -.00000028  00000-0  10000-3 0  9990
2 39013  63.3795 168.1027 0135719   4.5626 355.6577 13.45159909202373
1 39013U 12066C   17007.82407802 -.00000028  00000-0  10000-3 0  9992
2 39013  63.3795 167.1474 0135722   4.5552 355.6666 13.45159831202429
1 39013U 12066C   17008.04709973 -.00000028  00000-0  10000-3 0  9991
2 39013  63.3793 166.5731 0135762   4.5432 355.6791 13.45159831202459
1 39013U 12066C   17008.49314287 -.00000028  00000-0  10000-3 0  9990
2 39013  63.3794 165.4266 0135798   4.5617 355.6596 13.45159843202518
1 39013U 12066C   17008.64182421 -.00000028  00000-0  10000-3 0  9990
2 39013  63.3794 165.0442 0135845   4.5473 355.6737 13.45159802202537
1 39013U 12066C   17008.86484607 -.00000028 +00000-0 +10000-3 0  9995
2 39013 063.3794 164.4711 0135854 004.5512 355.6709 13.45159808202561
1 39013U 12066C   17009.08786771 -.00000028  00000-0  10000-3 0  9997
2 39013  63.3793 163.8978 0135850   4.5497 355.6727 13.45159822202595
1 39013U 12066C   17009.53391085 -.00000028  00000-0  10000-3 0  9997
2 39013  63.3793 162.7515 0135850   4.5565 355.6656 13.45159844202658
1 39013U 12066C   17009.68259200 -.00000028  00000-0  10000-3 0  9995
2 39013  63.3794 162.3693 0135854   4.5536 355.6682 13.45159814202672
1 39013U 12066C   17010.05429474 -.00000028  00000-0  10000-3 0  9990
2 39013  63.3794 161.4142 0135854   4.5560 355.6667 13.45159861202729
1 39013U 12066C   17010.50033779 -.00000028  00000-0  10000-3 0  9999
2 39013  63.3794 160.2681 0135854   4.5590 355.6638 13.45159916202782
1 39013U 12066C   17010.87204032 -.00000028  00000-0  10000-3 0  9991
2 39013  63.3794 159.3130 0135854   4.5615 355.6614 13.45159963202830
1 39013U 12066C   17010.94638082 -.00000028  00000-0  10000-3 0  9995
2 39013  63.3794 159.1220 0135854   4.5619 355.6610 13.45159972202849
1 39013U 12066C   17011.46676433 -.00000028  00000-0  10000-3 0  9995
2 39013  63.3794 157.7849 0135854   4.5654 355.6576 13.45160037202912
1 39013U 12066C   17011.61544533 -.00000028  00000-0  10000-3 0  9997
2 39013  63.3794 157.4029 0135854   4.5664 355.6566 13.45160056202932
1 39013U 12066C   17011.91280732 -.00000028 +00000-0 +10000-3 0  9998
2 39013 063.3794 156.6388 0135854 004.5684 355.6547 13.45160093202977
1 39013U 12066C   17012.13582881 -.00000028  00000-0  10000-3 0  9993
2 39013  63.3794 156.0657 0135854   4.5698 355.6533 13.45160121203007
1 39013U 12066C   17012.35885029 -.00000028  00000-0  10000-3 0  9997
2 39013  63.3794 155.4927 0135854   4.5713 355.6518 13.45160148203033
1 39013U 12066C   17012.73055275 -.00000028  00000-0  10000-3 0  9991
2 39013  63.3794 154.5376 0135854   4.5738 355.6494 13.45160195203088
1 39013U 12066C   17013.02791471 -.00000028  00000-0  10000-3 0  9999
2 39013  63.3794 153.7735 0135854   4.5758 355.6345 13.45159830203124
1 39013U 12066C   17013.17659841 -.00000028  00000-0  10000-3 0  9999
2 39013  63.3794 153.3915 0135854   4.5767 355.6466 13.45159849203146
```

```
1 39013U 12066C   17013.39961994 -.00000028  00000-0  10000-3 0  9998
2 39013  63.3794 152.8184 0135854   4.5782 355.6451 13.45159877203173
1 39013U 12066C   17013.84566323 -.00000028  00000-0  10000-3 0  9995
2 39013  63.3806 151.6715 0135980   4.5752 355.6482 13.45159958203232
1 39013U 12066C   17013.99434425 -.00000028  00000-0  10000-3 0  9998
2 39013  63.3806 151.2895 0135980   4.5761 355.6473 13.45159977203250
1 39013U 12066C   17014.44038745 -.00000028  00000-0  10000-3 0  9994
2 39013  63.3808 150.1431 0136029   4.5788 355.6437 13.45159981203312
1 39013U 12066C   17014.66340917 -.00000028  00000-0  10000-3 0  9995
2 39013  63.3808 149.5698 0136046   4.5869 355.6356 13.45159960203348
```

R. SATELLITE 39012

```
1 39012U 12066B   17001.20795761 -.00000033  00000-0  92085-4 0  9991
2 39012  63.3767 184.9183 0135266   4.7154 355.5112 13.45159099201514
1 39012U 12066B   17001.95136382 -.00000107 +00000-0 -26466-4 0  9994
2 39012 063.3772 183.0076 0135428 004.7085 355.5179 13.45158746201616
1 39012U 12066B   17002.54608783 -.00000027  00000-0  10088-3 0  9991
2 39012  63.3771 181.4789 0135477   4.7096 355.5165 13.45159159201696
1 39012U 12066B   17002.91779076 -.00000105  00000-0 -23345-4 0  9995
2 39012  63.3775 180.5231 0135509   4.6917 355.5342 13.45158870201741
1 39012U 12066B   17002.91779074 -.00000056 +00000-0 +54448-4 0  9995
2 39012 063.3772 180.5236 0135444 004.7109 355.5155 13.45159032201748
1 39012U 12066B   17003.88421825 -.00000127 +00000-0 -58453-4 0  9990
2 39012 063.3776 178.0397 0135550 004.7244 355.5027 13.45158779201879
1 39012U 12066B   17004.25592103 -.00000147  00000-0 -91276-4 0  9992
2 39012  63.3775 177.0843 0135566   4.7282 355.4981 13.45158636201928
1 39012U 12066B   17004.92498635 -.00000143 +00000-0 -84112-4 0  9998
2 39012 063.3778 175.3648 0135569 004.7421 355.4855 13.45158615202011
1 39012U 12066B   17005.51971062 -.00000118  00000-0 -44743-4 0  9992
2 39012  63.3775 173.8366 0135589   4.7404 355.4863 13.45158681202091
1 39012U 12066B   17005.89141392 -.00000143 +00000-0 -85054-4 0  9996
2 39012 063.3782 172.8805 0135618 004.7492 355.4793 13.45158550202149
1 39012U 12066B   17006.63481943 -.00000131  00000-0 -64490-4 0  9996
2 39012  63.3780 170.9700 0135622   4.7574 355.4706 13.45158590202245
1 39012U 12066B   17006.70915980 -.00000097 +00000-0 -11251-4 0  9995
2 39012 063.3781 170.7795 0135581 004.7702 355.4582 13.45158773202251
1 39012U 12066B   17007.89860865 -.00000060  00000-0  48541-4 0  9998
2 39012  63.3781 167.7226 0135653   4.7912 355.4379 13.45159036202414
1 39012U 12066B   17008.04728964 -.00000044 +00000-0 +74810-4 0  9999
2 39012 063.3780 167.3405 0135659 004.7939 355.4351 13.45159122202431
1 39012U 12066B   17008.93937609 -.00000023 +00000-0 +10729-3 0  9990
2 39012 063.3780 165.0476 0135684 004.7972 355.4321 13.45159320202559
1 39012U 12066B   17009.16239755 -.00000001  00000-0  14247-3 0  9998
2 39012  63.3779 164.4744 0135698   4.7980 355.4311 13.45159447202584
1 39012U 12066B   17009.90580220 +.00000086 +00000-0 +28277-3 0  9996
2 39012 063.3781 162.5622 0135783 004.7910 355.4382 13.45160168202680
1 39012U 12066B   17010.20316423  .00000076  00000-0  26634-3 0  9997
2 39012  63.3776 161.7976 0135783   4.8014 355.4283 13.45160197202720
1 39012U 12066B   17010.94657079 -.00000130 +00000-0 -62853-4 0  9990
2 39012 063.3778 159.8865 0136008 004.7949 355.4345 13.45159081202824
1 39012U 12066B   17011.46695442 -.00000109  00000-0 -30118-4 0  9999
2 39012  63.3778 158.5494 0136036   4.7894 355.4395 13.45159194202895
1 39012U 12066B   17011.83865734 -.00000113 +00000-0 -36214-4 0  9991
2 39012 063.3778 157.5936 0136166 004.7787 355.4504 13.45159178202940
1 39012U 12066B   17012.50772185 -.00000039  00000-0  82675-4 0  9991
2 39012  63.3780 155.8743 0136282   4.7732 355.4557 13.45159646203038
1 39012U 12066B   17012.65641296 -.00000006  00000-0  00000+0 0  9996
2 39012  63.3781 155.4891 0136632   4.7600 355.5131 13.45158983203056
1 39012U 12066B   17012.95376490 -.00000042 +00000-0 +77355-4 0  9992
2 39012 063.3783 154.7275 0136273 004.7749 355.4541 13.45159674203097
1 39012U 12066B   17013.84585166 -.00000042  00000-0  77372-4 0  9992
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2 39012  63.3788 152.4351 0136357   4.7650 355.4638 13.45159563203214
1 39012U 12066B   17014.06887327 -.00000049 +00000-0 +66323-4 0  9992
2 39012 063.3786 151.8619 0136356 004.7669 355.4621 13.45159536203246
1 39012U 12066B   17014.21755423  .00000673  00000-0  12227-2 0  9994
2 39012  63.3800 151.4782 0136641   4.7773 355.4501 13.45160658203269
1 39012U 12066B   17014.96096067 -.00000217 +00000-0 -20255-3 0  9995
2 39012 063.3793 149.5700 0136481 004.7689 355.4602 13.45158663203362
```

S. SATELLITE 39011

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1 39011U 12066A   17001.95113936 -.00000150 +00000-0 -95769-4 0  9993
2 39011 063.3776 182.9747 0135528 004.8003 355.4288 13.45158989201602
1 39011U 12066A   17002.17416087 -.00000147  00000-0 -90441-4 0  9999
2 39011  63.3775 182.4014 0135564   4.8101 355.4183 13.45158989201639
1 39011U 12066A   17002.91756634 -.00000109 +00000-0 -29513-4 0  9996
2 39011 063.3781 180.4913 0135594 004.8097 355.4197 13.45159205201737
1 39011U 12066A   17003.14058776 -.00000191  00000-0 -16156-3 0  9993
2 39011  63.3782 179.9182 0135622   4.7960 355.4312 13.45158853201769
1 39011U 12066A   17003.88399380 -.00000191 +00000-0 -16212-3 0  9996
2 39011 063.3783 178.0077 0135636 004.8155 355.4141 13.45158745201866
1 39011U 12066A   17004.25569627 -.00000147  00000-0 -91208-4 0  9991
2 39011  63.3780 177.0520 0135670   4.8206 355.4086 13.45158913201911
1 39011U 12066A   17004.92476147 -.00000151 +00000-0 -97055-4 0  9990
2 39011 063.3779 175.3324 0135665 004.8408 355.3897 13.45158835202003
1 39011U 12066A   17005.51948547 -.00000099  00000-0 -14350-4 0  9992
2 39011  63.3777 173.8041 0135682   4.8371 355.3924 13.45159026202080
1 39011U 12066A   17005.89118817 -.00000053 +00000-0 +60156-4 0  9996
2 39011 063.3779 172.8487 0135624 004.8695 355.3617 13.45159223202134
1 39011U 12066A   17006.63459418 -.00000113  00000-0 -35813-4 0  9994
2 39011  63.3780 170.9372 0135791   4.8738 355.3574 13.45158968202239
1 39011U 12066A   17006.63460348  .00000017  00000-0  27996-4 0  9992
2 39011  63.3770 170.9320 0136252   4.8344 355.4428 13.45159114202230
1 39011U 12066A   17006.63460336  .00000012  00000-0  18669-4 0  9991
2 39011  63.3776 170.9365 0135651   4.8883 355.3898 13.45159314234131
1 39011U 12066A   17006.70893470 -.00000106 +00000-0 -24977-4 0  9993
2 39011 063.3780 170.7462 0135788 004.8746 355.3567 13.45159004202247
1 39011U 12066A   17007.89838310 -.00000069  00000-0  33412-4 0  9997
2 39011  63.3783 167.6889 0135851   4.8946 355.3373 13.45159343202400
1 39011U 12066A   17008.04706411 -.00000065 +00000-0 +40222-4 0  9994
2 39011 063.3782 167.3067 0135862 004.8928 355.3387 13.45159366202428
1 39011U 12066A   17008.93915014 +.00000001 +00000-0 +14692-3 0  9993
2 39011 063.3783 165.0139 0135894 004.8962 355.3359 13.45159797202547
1 39011U 12066A   17009.16217161  .00000011  00000-0  16174-3 0  9995
2 39011  63.3782 164.4407 0135901   4.8979 355.3341 13.45159873202573
1 39011U 12066A   17009.90557663 +.00000040 +00000-0 +20929-3 0  9996
2 39011 063.3782 162.5301 0136041 004.8790 355.3527 13.45160182202674
1 39011U 12066A   17010.20293899  .00000012  00000-0  16368-3 0  9990
2 39011  63.3779 161.7658 0136112   4.8753 355.3569 13.45160059202718
1 39011U 12066A   17010.94634451 -.00000042 +00000-0 +77879-4 0  9993
2 39011 063.3784 159.8552 0136259 004.8736 355.3580 13.45159805202819
1 39011U 12066A   17011.46672828 -.00000141  00000-0 -81622-4 0  9993
2 39011  63.3784 158.5179 0136320   4.8630 355.3681 13.45159423202887
1 39011U 12066A   17011.91277149 -.00000107 +00000-0 -26116-4 0  9999
2 39011 063.3785 157.3719 0136321 004.8675 355.3646 13.45159575202941
1 39011U 12066A   17012.50749486 -.00000029  00000-0  98081-4 0  9995
2 39011  63.3785 155.8433 0136323   4.8652 355.3659 13.45160030203026
1 39011U 12066A   17012.95353848 -.00000085 +00000-0 +89560-5 0  9992
2 39011 063.3784 154.6966 0136348 004.8738 355.3581 13.45159716203084
1 39011U 12066A   17013.84562527 -.00000154  00000-0 -10163-3 0  9996
2 39011  63.3796 152.4033 0136611   4.8297 355.4010 13.45159311203204
1 39011U 12066A   17014.06864694 -.00000159 +00000-0 -11057-3 0  9999
2 39011 063.3794 151.8300 0136615 004.8298 355.4010 13.45159241203232
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1 39011U 12066A   17014.88639314 -.00000175  00000-0 -13577-3 0  9995
2 39011  63.3798 149.7281 0136664   4.8411 355.3901 13.45159050203349
1 39011U 12066A   17014.96073369 -.00000176 +00000-0 -13715-3 0  9991
2 39011 063.3797 149.5368 0136672 004.8389 355.3922 13.45159026203352
```

T. SATELLITE 36596

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1 36596U 10027A   17001.91349373  .00000991  00000-0  93467-4 0  9999
2 36596  97.5886   9.9226 0010457 226.7936 133.2411 14.95910632357037
1 36596U 10027A   17002.84996352  .00000742  00000-0  71246-4 0  9992
2 36596  97.5889  10.8301 0010544 223.6478 136.3911 14.95910788357175
1 36596U 10027A   17003.92021430  .00000475  00000-0  47430-4 0  9999
2 36596  97.5893  11.8675 0010582 220.0413 140.0020 14.95910647357332
1 36596U 10027A   17004.72290293  .00000191  00000-0  22024-4 0  9990
2 36596  97.5895  12.6457 0010633 217.4093 142.6359 14.95909552357451
1 36596U 10027A   17004.92357553 +.00000140 +00000-0 +17528-4 0  9992
2 36596 097.5896 012.8403 0010665 216.6255 143.4228 14.95909335357487
1 36596U 10027A   17005.86004673 -.00000122 +00000-0 -58595-5 0  9990
2 36596 097.5899 013.7485 0010750 213.3267 146.7272 14.95907891357628
1 36596U 10027A   17006.72962763 -.00000332 +00000-0 -24642-4 0  9997
2 36596 097.5899 014.5914 0010790 210.2179 149.8403 14.95906376357757
1 36596U 10027A   17008.00055408 -.00000382 +00000-0 -29133-4 0  9994
2 36596 097.5898 015.8236 0010914 205.6921 154.3777 14.95905482357941
1 36596U 10027A   17008.80324430 -.00000301 +00000-0 -21857-4 0  9992
2 36596 097.5896 016.6016 0010969 202.6043 157.4713 14.95905407358061
1 36596U 10027A   17009.80660630 -.00000168  00000-0 -99614-5 0  9996
2 36596  97.5896  17.5737 0011067 199.1326 160.9492 14.95905903358216
1 36596U 10027A   17010.80996813 -.00000095 +00000-0 -35183-5 0  9993
2 36596 097.5891 018.5457 0011270 195.4300 164.6598 14.95906394358367
1 36596U 10027A   17011.81332923  .00000020  00000-0  68024-5 0  9997
2 36596  97.5888  19.5179 0011383 191.9959 168.0991 14.95907218358519
1 36596U 10027A   17012.81669029  .00000129  00000-0  16534-4 0  9996
2 36596  97.5888  20.4900 0011501 188.3802 171.7228 14.95908189358669
1 36596U 10027A   17014.02072325 +.00000226 +00000-0 +25208-4 0  9994
2 36596 097.5886 021.6569 0011608 184.2983 175.8165 14.95909435358844
1 36596U 10027A   17014.82341075 +.00000247 +00000-0 +27034-4 0  9995
2 36596 097.5884 022.4346 0011726 181.0817 179.0372 14.95910099358963
```

U. SATELLITE 36415

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1 36415U 10009C   17001.53089130 -.00000035  00000-0  79135-4 0  9995
2 36415  63.4021 260.0024 0233026   3.4291 356.8277 13.45161535335492
1 36415U 10009C   17001.97693372 -.00000042 +00000-0 +69566-4 0  9997
2 36415 063.4020 258.8557 0232912 003.4344 356.8215 13.45161563335559
1 36415U 10009C   17002.86901981 -.00000079  00000-0  15882-4 0  9996
2 36415  63.4018 256.5632 0233024   3.4430 356.8134 13.45161553335678
1 36415U 10009C   17002.94336026 -.00000073 +00000-0 +24135-4 0  9992
2 36415 063.4018 256.3722 0233029 003.4434 356.8129 13.45161585335685
1 36415U 10009C   17003.90978646 -.00000079  00000-0  16660-4 0  9999
2 36415  63.4012 253.8881 0233065   3.4527 356.8041 13.45161655335816
1 36415U 10009C   17003.90978644 -.00000089 +00000-0 +13770-5 0  9998
2 36415 063.4012 253.8881 0233051 003.4521 356.8046 13.45161603335813
1 36415U 10009C   17004.95055295 -.00000056 +00000-0 +49634-4 0  9993
2 36415 063.4009 251.2136 0233167 003.4452 356.8114 13.45161887335950
1 36415U 10009C   17005.24791479 -.00000024  00000-0  94971-4 0  9996
2 36415  63.4007 250.4486 0233371   3.4385 356.8176 13.45162026335997
1 36415U 10009C   17005.91697915 -.00000067 +00000-0 +32877-4 0  9994
2 36415 063.4003 248.7294 0233420 003.4351 356.8211 13.45161886336082
1 36415U 10009C   17006.51170279 -.00000051  00000-0  56686-4 0  9997
2 36415  63.4002 247.2014 0233408   3.4359 356.8207 13.45161991336160
1 36415U 10009C   17006.73472473 -.00000122 +00000-0 -45094-4 0  9993
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2 36415 063.4002 246.6282 0233477 003.4455 356.8111 13.45161636336196
1 36415U 10009C   17007.84983227 -.00000109  00000-0 -27467-4 0  9999
2 36415  63.4001 243.7624 0233706   3.4445 356.8123 13.45161565336348
1 36415U 10009C   17008.07285357 -.00000082 +00000-0 +11312-4 0  9995
2 36415 063.4001 243.1894 0233682 003.4413 356.8158 13.45161687336375
1 36415U 10009C   17008.89059912 -.00000133  00000-0 -61078-4 0  9993
2 36415  63.3997 241.0880 0233759   3.4460 356.8107 13.45161409336485
1 36415U 10009C   17008.96493960 -.00000127 +00000-0 -52843-4 0  9999
2 36415 063.3997 240.8970 0233758 003.4475 356.8095 13.45161437336495
1 36415U 10009C   17009.93136582 -.00000069 +00000-0 +31165-4 0  9999
2 36415 063.4001 238.4131 0233899 003.4478 356.8095 13.45161693336622
1 36415U 10009C   17010.22872756 -.00000065  00000-0  35654-4 0  9996
2 36415  63.3998 237.6487 0233905   3.4428 356.8140 13.45161722336662
1 36415U 10009C   17010.97213218 -.00000056 +00000-0 +49574-4 0  9996
2 36415 063.3997 235.7387 0233910 003.4437 356.8133 13.45161825336762
1 36415U 10009C   17011.56685563 -.00000017  00000-0  10525-3 0  9998
2 36415  63.4004 234.2103 0233871   3.4517 356.8059 13.45162109336849
1 36415U 10009C   17011.93855827 -.00000077 +00000-0 +19536-4 0  9999
2 36415 063.3999 233.2548 0233882 003.4547 356.8027 13.45161772336893
1 36415U 10009C   17012.83064424 -.00000134  00000-0 -62561-4 0  9995
2 36415  63.3981 230.9605 0234068   3.4732 356.7852 13.45161456337014
1 36415U 10009C   17012.97932512 -.00000102 +00000-0 -16124-4 0  9991
2 36415 063.3980 230.5782 0234098 003.4711 356.7876 13.45161629337035
1 36415U 10009C   17014.02009079 +.00000035 +00000-0 +18061-3 0  9996
2 36415 063.3982 227.9035 0234148 003.4771 356.7815 13.45162474337177
1 36415U 10009C   17014.24311209  .00000033  00000-0  17690-3 0  9996
2 36415  63.3982 227.3303 0234150   3.4765 356.7822 13.45162519337207
1 36415U 10009C   17014.91217644 -.00000075 +00000-0 +22206-4 0  9995
2 36415 063.3982 225.6110 0234237 003.4740 356.7841 13.45162140337293
```

V. SATELLITE 36413

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1 36413U 10009A   17001.08458252 -.00000053  00000-0  54043-4 0  9999
2 36413  63.4013 261.0045 0231690   3.5373 356.7221 13.45161698335445
1 36413U 10009A   17001.82798732 -.00000053 +00000-0 +54386-4 0  9991
2 36413 063.4012 259.0937 0231800 003.5334 356.7265 13.45161792335545
1 36413U 10009A   17002.19968962 -.00000028  00000-0  89716-4 0  9993
2 36413  63.4012 258.1385 0231828   3.5368 356.7243 13.45162056335594
1 36413U 10009A   17002.57139163 -.00000019 +00000-0 +10293-3 0  9991
2 36413 063.4010 257.1833 0231848 003.5380 356.7228 13.45162199335642
1 36413U 10009A   17003.46347730 -.00000024  00000-0  95382-4 0  9990
2 36413  63.4008 254.8903 0231926   3.5491 356.7120 13.45162217335766
1 36413U 10009A   17003.90951984 -.00000030 +00000-0 +87326-4 0  9997
2 36413 063.4006 253.7437 0232023 003.5555 356.7035 13.45162189335824
1 36413U 10009A   17004.57858413 -.00000011  00000-0  11428-3 0  9992
2 36413  63.4006 252.0245 0231879   3.5689 356.6956 13.45162509335916
1 36413U 10009A   17005.02462603 -.00000010  00000-0  11562-3 0  9993
2 36413  63.4005 250.8781 0231900   3.5749 356.6857 13.45162536335974
1 36413U 10009A   17005.69369037 -.00000006 +00000-0 +12157-3 0  9999
2 36413 063.4004 249.1584 0232186 003.5559 356.7051 13.45162695336065
1 36413U 10009A   17006.13973285 -.00000018  00000-0  10337-3 0  9996
2 36413  63.4003 248.0118 0232276   3.5628 356.6962 13.45162610336126
1 36413U 10009A   17006.43709500 -.00000022 +00000-0 +98954-4 0  9993
2 36413 063.4001 247.2475 0232291 003.5625 356.6985 13.45162608336161
1 36413U 10009A   17007.03181841 -.00000040  00000-0  72033-4 0  9992
2 36413  63.3998 245.7188 0232132   3.5907 356.6698 13.45162413336240
1 36413U 10009A   17007.70088306 -.00000048 +00000-0 +60204-4 0  9993
2 36413 063.3999 243.9995 0232428 003.5667 356.6951 13.45162440336330
1 36413U 10009A   17008.14692560 -.00000048  00000-0  60938-4 0  9999
2 36413  63.3996 242.8528 0232500   3.5702 356.6910 13.45162466336397
1 36413U 10009A   17008.44428744 -.00000057  00000-0  47873-4 0  9996
2 36413  63.3995 242.0887 0232341   3.5922 356.6700 13.45162353336430
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1 36413U 10009A   17008.81598971 -.00000074 +00000-0 +23487-4 0  9991
2 36413 063.3992 241.1333 0232583 003.5792 356.6807 13.45162229336481
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W. SATELLITE 28414

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1 28414U 04035B   17014.18071500  .00000423  00000-0  45096-4 0  9993
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1 28414U 04035B   17014.51560505  .00000479  00000-0  50427-4 0  9993
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1 28414U 04035B   17014.85049494  .00000531  00000-0  55290-4 0  9991
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## X.	SATELLITE 28413

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Y. ISS

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LIST OF REFERENCES

[1] M. Griffin and J. French, *Space Vehicle Design*, 2nd ed. Reston, VA: American Institute of Aeronautics and Astronautics, 2004, p. 103.

[2] D. Vallado and W. McClain, *Fundamentals of Astrodynamics and Applications*, 1st ed. El Segundo, Calif.: Microcosm Press, 2001, pp. 1-11.

[3] D. Vallado, P. Crawford, R. Hujsak and T. Kelso, "Revisiting spacetrack report #3: rev 2", American Institute of Aeronautics and Astronautics, Rep. AIAA 2006-6753, 2006.

[4] F. Moulton, *An Introduction to Celestial Mechanics*, 1st ed. New York: Dover Publications, 1970, pp. 29-33.

[5] J. Sellers and W. Astore, *Understanding Space*, 1st ed. New York: McGraw-Hill, 2005.

[6] J. Wertz, W. Larson, D. Kirkpatrick and D. Klungle, *Space Mission Analysis and Design*, 3rd ed. El Segundo, CA: Space Technology Library published jointly by Microcosm, 2005.

[7] D. Bursch, "Orbits in 3D, part 1", class notes for Orbital Mechanics, Space Systems Academic Group, Naval Postgraduate School, Monterey, CA, winter 2016.

[8] R. Olsen, *Introduction to the space environment*, 1st ed. unpublished, 2005, pp. 143-150.

[9] D. Bursch, "Understanding orbits", class notes for Space Technology and Applications, Space Systems Academic Group, Naval Postgraduate School, Monterey, CA, summer 2015.

[10] Wikipedia. (2017). Satellite navigation. [Online]. Available: https://en.wikipedia.org/wiki/Satellite_navigation. Accessed Apr. 28, 2017.

[11] Gps.gov. (2017) Space segment. [Online]. Available: http://www.gps.gov/systems/gps/space/. Accessed Jun. 7, 2017.

[12] J. Sellers. (2015, Mar. 19), Astronautics primer. [Online]. Available: https://agi.widencollective.com/portals/qmfuawn4/EAPCurricula. Accessed: Mar. 7, 2017.

[13] D. Brouwer, "Solution of the problem of artificial satellite theory without drag", *Astronomical Journal*, vol. 64, no. 1274, pp. 378-397, Nov. 1959.

[14] Wikipedia. (2017). Legendre polynomials. [Online]. Available: https://en.wikipedia.org/wiki/Legendre_polynomials. Accessed Mar. 7, 2017.

[15] F. Hoots, P. Schumacher and R. Glover, "History of analytical orbital modelling in the United States space surveillance system", *Journal of Guidance, Control, and Dynamics*, vol. 27, no. 2, pp. 174-185, 2004.

[16] L. Jacchia, "Variation in the Earth's upper atmosphere as revealed by satellite drag,"*Reviews of Modern Physics*, vol. 35, no. 4, pp. 973-991, 1963.

[17] J. Bacon, "Orbital debris and the safety implications of Earth atmosphere reentry," lecture for the Space Systems Academic Group, Naval Postgraduate School, Monterey, CA, winter 2017.

[18] D. Hathaway. (2017, Mar. 23). The sunspot cycle. [Online]. Available: https://solarscience.msfc.nasa.gov/SunspotCycle.shtml. Accessed: Apr. 30, 2017.

[19] W. Compton and C. Benson, *Living and Working in Space: A History of Skylab*, 1st ed. Washington, DC: National Aeronautics and Space Administration, 1983, p. 361.

[20] Analytical Graphics, Inc. (2017, Apr.). Orbit propagators for satellites. [Online]. Available: http://help.agi.com/stk/index.htm#stk/vehSat_orbitProp_choose.htm. Accessed: Apr. 30, 2017.

[21] J. Moltz, *The Politics of Space Security*, 1st ed. Stanford, CA: Stanford Univ. Press, 2011, pp. 69-124.

[22] Wikipedia. (2017). Project Space Track. [Online]. Available: https://en.wikipedia.org/wiki/Project_Space_Track. Accessed: Feb. 19, 2017.

[23] Y. Kozai, "The Earth gravitational potential derived from satellite motion", *Space Science Reviews*, vol. 5, no. 6, pp. 818-879, 1966.

[24] D. Brouwer and G. Hori, "Theoretical evaluation of atmospheric drag effects in the motion of an artificial satellite," *Astronomical Journal*, vol. 66, no. 5, pp. 193-225, 1961.

[25] R. Lydanne, "Small eccentricities or inclinations in the brouwer theory of an artificial satellite," *Astronomical Journal*, vol. 68, no. 8, pp. 555-558, 1963.

[26] P. Schumacher and R. Glover, "Analytical orbital model for U.S. Naval space surveillance: an overview," AAS Publications, San Diego, CA, Rep. AAS 95-427, 1995.

[27] SAIC, under contract to JFCC SPACE/J3. (2017). Basic description of the two line element (TLE) Format. [Online]. Available: https://www.space-track.org/documentation#/tle. Accessed: Mar. 15, 2017.

[28] Y. Kozai, "The motion of a close Earth satellite," *Astronomical Journal*, vol. 64, no. 1274, pp. 367-377, Nov. 1959.

[29] C. Hilton and J. Kuhlman, "Mathematical models for the space defense center", Philco-Ford Corp, Newport Beach, CA, Rep. U-3871, 1966.

[30] M. Lane and K. Cranford, "An improved analytical drag theory for the artificial satellite problem," American Institute of Aeronautics and Astronautics, Rep. AIAA 69-925, 1969.

[31] G. Wagner (2014, Oct. 24). Navy transfers space surveillance mission to Air Force. [Online]. Available: http://www.navy.mil/submit/display.asp?story_id=15597. Accessed: May 31, 2017.

[32] *Position and Partials as functions of Time (PPT3)*. Naval Space Command, Astrodynamics and Computation (Air Force Space Command, Space & Missile Systems Center), Dahlgren, VA, 1992.

[33] J. Calusdian, "Programming in MATLAB", class notes for Introduction to Scientific Programming, Department of Electrical and Computer Engineering, Naval Postgraduate School, Monterey, CA, fall 2016.

[34] M. Mahooti. (2017). *SGP4*. [Online]. Available: https://www.mathworks.com/matlabcentral/fileexchange/62013-sgp4. Accessed May 26, 2017.

[35] M. Sohrabinia. (2012). *jl2normaldate*. [Online]. Available: https://www.mathworks.com/matlabcentral/fileexchange/36901-convert-julian-date-to-normal-date. Accessed May 26, 2017.

[36] F. Hoots and R. Roelrich, "Spacetrack report no. 3: Models for mropagation of NORAD element sets", U.S. AIr Force Aerospace Defense Command, Colorado Springs, CO, Dec. 1980.

[37] R. Olsen, *Remote Sensing from Air and Space*, 1st ed. Bellingham, WA: SPIE Press, 2007.

[38] D. Bursch, "The two body problem part 1", class notes for Orbital Mechanics, Space Systems Academic Group, Naval Postgraduate School, Monterey, CA, winter 2016.

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