Utilization Potential for Distinct Orbit Families in the Cislunar Domain

Phillip M. Cunio, Marcus Bever, Chris Ingram, Brien R. Flewelling, Greg McNeill
ExoAnalytic Solutions, Inc.

ABSTRACT
As human activity and infrastructure steadily and more thoroughly invest the spherical domain stretching from Geosynchronous Earth Orbit (GEO) to the neighborhood of lunar orbit and the associated libration points (a volume collectively known as cislunar space), understanding orbits in this volume becomes concomitantly more important.

At present, most experts have developed their intuition about orbital mechanics, and thus their understanding of the most effective ways to operate from space, based on knowledge of either the GEO or Low Earth Orbit (LEO) regimes. Therefore, most intuition regarding orbits is driven by a few shared presumptions: orbits are fixed rings around the Earth, constellations are strings of satellites on the same orbit, and satellite coverage is made of sliding conic sections projected onto the Earth's surface.

Although these intuitions are valuable, they do not necessarily apply in the larger cislunar domain, where the presence of a second body with an additional gravitational influence (Luna itself) and the vastly larger amount of empty volume (10X the range and 1000X the volume) greatly affect all considerations. For example, the conception of orbits as fixed rings near the Earth, while still technically accurate, to an extent clashes with the physics that allow libration points and associated halo configurations to maintain a perceived comparatively stable relationship to the Earth and the Moon. Additionally, even the simple fact of some cislunar regimes' having orbital periods longer than a day is at odds with the simpler intuition of orbits that pass overhead frequently or that hover in a fixed region of the sky – a highly-inclined circular orbit at some multiple of the GEO belt altitude would, e.g., trace a complex sinusoid in the sky from a ground observer's point of view.

The process of becoming familiar with the features of cislunar orbits can begin with the organization of cislunar space into logical regimes. Much as traditional orbits are classified into a small number of regimes (LEO, GEO, MEO, and HEO are widely understood) and some particular orbits are understood as special in these regimes (e.g., sun-synchronous, GEO walker, GPS, and Molniya), it is feasible to begin describing regimes in the much more expansive cislunar domain, and to start identifying orbits in these regimes which may be of especial interest.

This paper will develop a more systematic understanding of the cislunar domain, and will offer a definition of the cislunar domain, discuss reasonable delineations of regimes therein, and describe a few possible unique orbits in some regimes. Not all unique nor even all interesting orbit families in cislunar space may be described; knowledge of the entire cislunar domain and the uses to which satellites there may be put is still maturing, and there will undoubtedly be distinctions made in the future that cannot now be expected.

Once a few regimes have been suggested, and interesting orbits and missions described, a composited picture of the cislunar domain will be presented, giving all proposed domains and orbit families in context. Any apparent heuristics for orbit family/mission match will be described as well, and ways in which this overarching picture may be utilized as an early mission-planning tool will be discussed as well.

1. INTRODUCTORY DESCRIPTION OF CISLUNAR SPACE

1.1 Scale of Cislunar Space

The regions of space currently known under the overarching name of cislunar space extend from above the Geosynchronous Earth Orbit (GEO) neighborhood to the radial distance of the Lagrange point on the far side of Luna, Earth's moon. Altogether, this spheroidal region runs from an altitude of approximately 35,786 km above the equator to an altitude of nearly 450,000 km. Traditionally, missions other than scientific exploration have remained completely underneath these regions, although in the near future it is highly probable that many sorts of other human activities, including sociocultural activities, economic activities, and national defense efforts will grow into these regions. In the expectation of the need to understand cislunar space's soon reaching beyond NASA and astrophysicists, this paper presents a suggested breakdown of the volume.

Cislunar space begins at the highest altitude where most human spaceborne commerce and other activity ceases: the GEO belt. Because the ring around the equator (and the debris belts slightly above and below it) provide ideal geometry for communications and certain types of observation systems (e.g., weather satellites), this orbital regime is well-populated and maintained. It is also (to some extent) well-observed. However, the outside edges of cislunar space extend approximately ten times as far from the Earth as does GEO, meaning the total cislunar volume is approximately 1000 times that of the volume inside the GEO radius, and the optical brightness of objects at this outer edge is approximately $1/100^{th}$ of what it would be at the inner edge.

Accordingly, one natural unit for measuring distance inside the cislunar volume is the number of GEO radii – the inner edge (where a traditional understanding of space operations is applicable) is at 1.0 XGEO, and the outer edge is just past 10 XGEO. Figure 1 shows the scale of the cislunar volume; the Earth and the Moon are drawn approximately to scale (the Moon is invisible in the figure), and the dashed circles representing geosynchronous Earth orbit (GEO) and the orbit of the Moon about the Earth are shown to approximate accuracy as well.

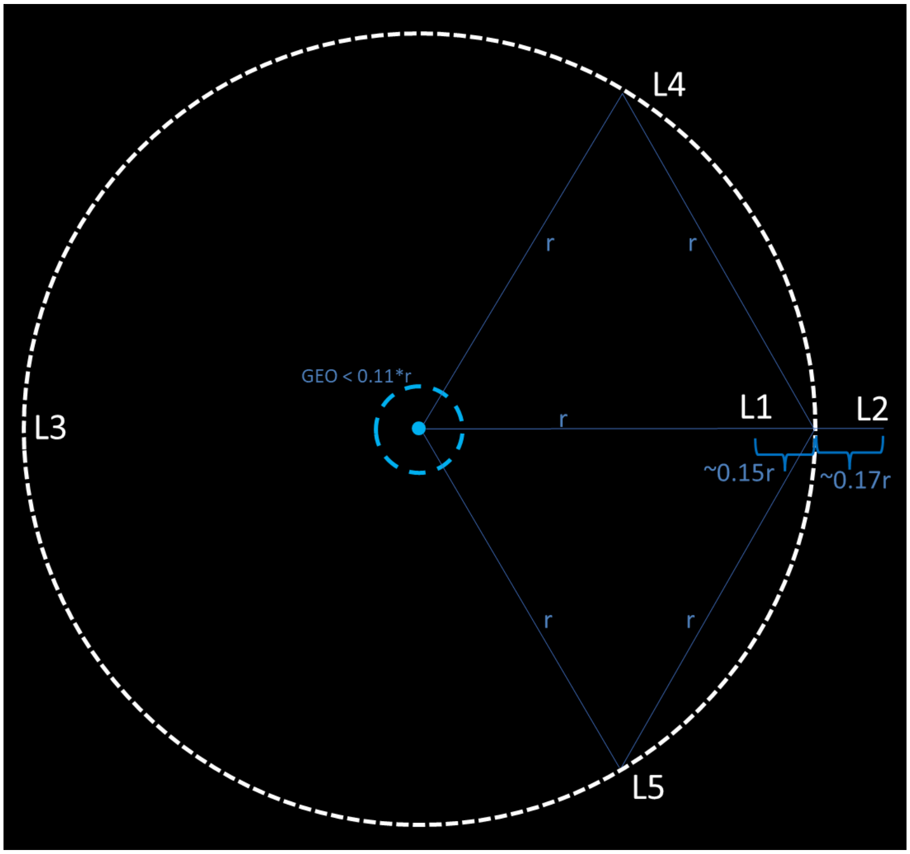

Figure 1. Approximate scale of cislunar space.

1.2 Importance of Traffic in Defining Regions

Note that the average orbital distance of the Moon from the Earth (labeled *r* in Figure 1) is about 385,000 km, and key distances are shown in fractions of *r*. Note that *r* is about equal to 9 XGEO, and the furthest Lagrange point (L2) is about 10.67 XGEO (note that this approximate value does not strictly account for all perturbations in the system). All five Lagrange points are indicated. The sketch of the distances in an orthogonal 2-dimensional plane helps to illustrate the scales. Even though all orbits are inherently three-dimensional in nature, the bulk of cislunar traffic is expected to fall within or nearly within the plane defined by the orbit of the Moon about the Earth, with exceptions for special purposes (some of which will be addressed in this paper).

The scale of the cislunar sphere is also captured by the recently-publicized *Primer on Cislunar Space* [1], as is the notion that traditional understanding of orbits does not extend well to cover orbits within the cislunar sphere. This document also highlights several other issues associated with understanding cislunar space and separates the cislunar sphere into a series of circular/spherical regions defined by relative gravitational influence. While the overlaps between the Primer's distinctions and the regimes presented in this paper are noteworthy, this paper seeks to define regions based on Space Traffic Management (STM) considerations, which extend with additional intricacy beyond gravitational influence. For example, consideration in defining regimes in cislunar space should be given to simplicity, as human comprehension of regimes and their contents may be a factor in successful traffic management.

2. REGIME DEFINTIONS IN CISLUNAR SPACE

Dynamics within the cislunar domain are dominated not only by the extreme ranges involved, but also by the presence of a second body: Luna, Earth's moon. The three-body dynamics and perturbations imposed upon a space vehicle in cislunar space influence what activities occur there.

2.1 Regimes Based on Traffic and Stable Centers

While there are many options available, we herein present an observation-driven classification scheme with six major regions (and two near-body zones) that can be leveraged. Five of these regions are associated primarily with the five libration points of the system; the sixth is the larger region surrounding the main body (the larger of the two planetary bodies). The two near-body zones are those within extremely close proximity of either of the two planetary bodies and are physically much smaller than any of the other six regions.

This system allows for an understanding of traffic within and between these zones. Each of the five librationally-associated regions will have a Lagrange point roughly at its center; these points are variously attractive for research or commerce and are likely to be occupied or somehow utilized. The sixth large region is centered on the main (larger) planetary body. This scheme allows for monitoring traffic with the simple heuristic that a stable location (either a libration point or a planetary surface) is at the heart of each region, meaning the range from a sensor located there to a position anywhere within the region is minimized. Emplacing sensors such that the range from any arbitrary location in the cislunar sphere to a nearby taskable sensor is minimized is a heuristic for assuring maximum detection, tracking, and custody capacity with optimal overall system lifecycle cost. Because observing the entirety of the cislunar sphere from a single location is not feasible, it makes sense to split the volume into several traffic regimes which can be managed individually. And because the loci most amenable to long-term sensor emplacement are likely to be either one of the 5 libration points or the two solid planetary surfaces, it makes sense to center these traffic regimes around these seven sites.

It very logically follows from these observations that an effective cislunar SSA/STM system must operate sensors in deep space, not just from the Earth's surface or even just from the Earth's surface and low orbit. A fully-effective cislunar SSA system will incorporate sensors emplaced in every regime, to focus on traffic operating in or transiting through that regime. Since some of these regimes are distant from Earth and Low Earth Orbit, some sensors should also be comparably distant.

2.2 Regime Definition Schemes

Defining the precise boundaries of the eight regions in the cislunar sphere is an exercise in optimal geometry crossed with an effort to minimize complexity and thereby facilitate human comprehension. There are multiple possible ways to define spatial regions which encompass most of the space within a certain range of one of the libration points or planetary centers, and additional mathematical techniques for fine-tuning basic shapes (such as a set of N of the regular polyhedra which are also plesiohedra [2] and theoretically can fully fill an arbitrary volume) such that a full spherical volume is encompassed.

At present, there remain minor gaps in the theoretical study of such spatial tessellation [3], and a full recapitulation of relevant work is somewhat beyond the scope of this paper. It suffices at present to note that a full packing of the cislunar sphere with a single non-overlapping regular polyhedron is not expected to be feasible – admittedly, it might be possible with convolutory shapes, but the need for rapid human comprehension argues in favor of simple convex shapes. Furthermore, to tesselate a sphere appropriately, a large number of smaller shapes might be necessary, and simplicity, human limitations, and the prior analyses of the likely spatial centers of interest emphasize the utility of volumes with adjusted, rather than uniform, outer contours.

Accordingly, multiple near-optimal schemes for division could well be proposed. This paper will emphasize only a very straightforward one, which projects along spherical sectors simple near-polygonal regions. Because all stable locations effectively lie in or very near the ecliptic plane of the two-body system, these regions can be reasonably defined in two dimensions and projected vertically to their intersections with the spherical boundary.

Figure *2* shows such two-dimensional zones superimposed on a map of the ecliptic plane of the cislunar sphere. These zones are mapped approximately according to the Voronoi diagram's equidistance criterion [4].

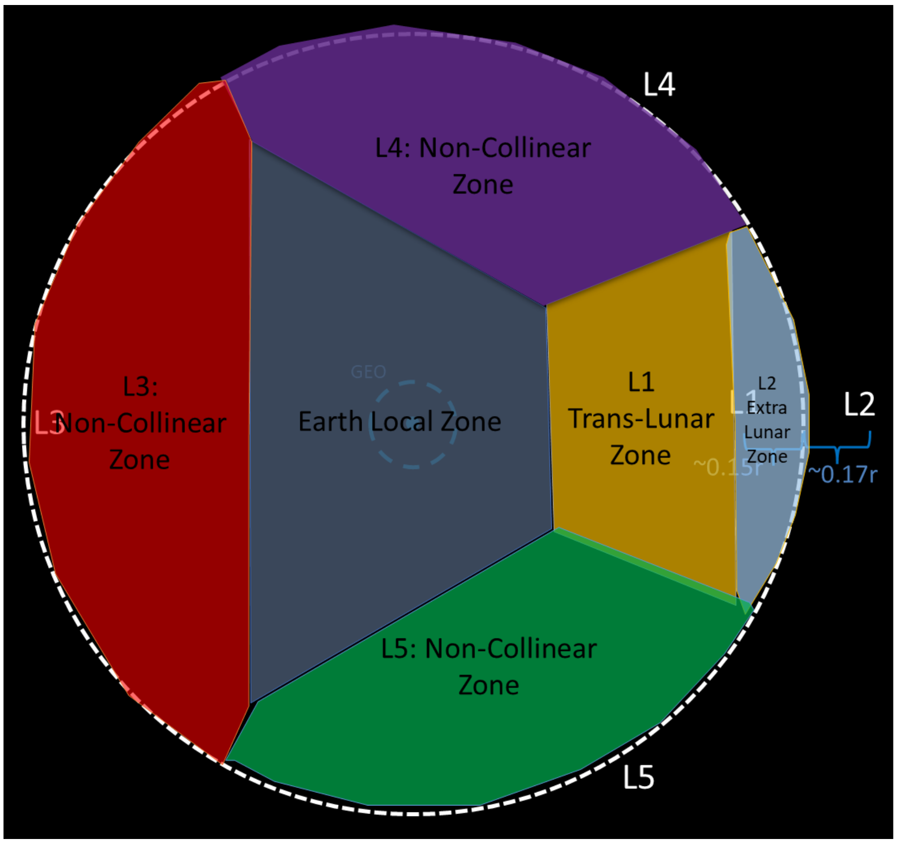

Figure 2. Six major regions of cislunar space.

The six large regions are the Earth local, the translunar, the supralunar, and the tertiary, quaternary, and quinary librational. The perilunar and periterrestrial regions are the other two smaller regions, encompassing hollow spherical sections nearest the two solid planetary body surfaces. These regions may also be defined as the roughly-polygonal areas around the seven sites where infrastructure placement is feasible: five libration points and two planetary surfaces.

2.3 Simple Polygonality of Regimes

Mapping these zones into approximately-polygonal shapes allows the use of adapted mathematical techniques, such as Voronoi blocks, and also matches the rough contours of Air Traffic Control (ATC) zones, as exemplified in [5]. Note that not all ATC sectors are polygonal, but many are approximately textured quadrilaterals. This is no doubt due to the need for strict and continuous human oversight in ATC, and the associated facts that humans can process some types of complexity only at great expense of time and attention, and thus careful design of traffic control structures is desirable to help manage human workload [6, 7].

Spaceborne STM sectors need not *necessarily* be similarly constrained, but even with extensive application of automated systems to the relevant problems in space traffic, there will still arise situations wherein human attention is desirable. In these cases, simplicity of organization may well be a virtue, and roughly polygonal shapes may prove easier for humans to comprehend than would complex gerrymanders. (Incidentally, this may also militate toward the use of mapped regions based on two-dimensional representations of cislunar space, e.g. the regimes as seen in Figure *2* extended vertically.)

3. ORBITAL REGIMES AND TRAFFIC IN CISLUNAR SPACE

The six major and two minor regions, along with some characteristic missions, are listed in Table 1. Also given are examples of missions for each region, some particular orbits for regions, and the spatial (approximate) centers.

Table 1. Delineation of Cislunar Regimes.

Region Name	Region Code	Missions	Example Orbits	Reference Feature
Periterrestrial	PTZ	Wx, Earth obs, RF comms, etc.	LEO or GSSAP drifter	Earth surface
Earth local	ELZ	Comms, regional SSA	HOPE	GEO
Translunar	TRZ	Tourism, transshipping	Apollo free-return	L1
Supralunar	SUZ	Science, hazardous mfg, human expl., radioastronomy	Lunar halo	L2
Periselenic	PSZ	Mining transfer, science	LLO at frozen inclination	Lunar surface
Tertiary librational	LI3	Science	Vertical	L3
Quaternary librat.	QL4	Habitation	Vertical	L4
Quinary librational	QL5	Habitation	Vertical	L5

It should also be apparent that there are roughly three types of active or in-use traffic objects (as distinct from debris and natural objects): stationarily-orbiting objects, sedately-transiting objects, and forcefully-transiting objects. (These may loosely albeit imprecisely be analogized to steady orbits, drifting orbits, and active maneuvers.)

3.1 Three Traffic Types

A stationarily-orbiting object may be considered to approximately retain a position at or near a libration point or planetary surface (from the point of view of cislunar traffic control, all objects within the periterrestrial or perilunar spheres are stationarily-orbiting), and thus remain entirely within a region. All stationarily-orbiting objects are consistently within view of (barring solar or stellar exclusions or occlusion by other vehicles) and inside a certain minimjm range of an observation system placed at the region's spatial center. A sedately-transiting object passes between regions over the course of days to months, typically maneuvering so as to afford maximum propellant efficiency. A forcefully-transiting object passes between regions over the course of hours to days, typically on a least-time trajectory. Transiting objects are likely to be passed from being primarily observed by the sensors of a given region to the sensors of another. Nothing prohibits sensors from any region from being used in tandem, although presumably the nearest sensor to any object is the easiest to prioritize for that object.

These three types of objects also roughly correspond to missions. A stationarily-orbiting vehicle is likely a long-term installation (crewed or automated) or infrastructural element and may be expected to minimize maneuvers beyond stationkeeping and possible collision avoidance; a sedately-transiting object is likely either nonhuman resources in transit or a long-term infrastructural element (e.g., a navigational beacon or SSA/STM overwatch sensor); a forcefully-transiting object is most probably related to human presence in cislunar space or is emplacing a highly valuable automated system. This distinction can be used to guide observation priorities, in that forcefully-transiting objects (which may be related to national security interests or human life) will almost always be of maximum observational interest, followed by (likely valuable and critical) stationarily-orbiting objects and then by sedately-transiting objects.

3.2 Traffic Analysis

A simple analysis of the likely traffic patterns in the future may inform the deployment path for a full cislunar-encompassing STM regime. Table 2 lists, by region, assessments of the likely traffic evaluated for total volume (estimate of the number of vehicles likely to be operating at various time points) and traffic types (in percentages, of those vehicles which are stationarily orbiting in a regime, sedately transiting, or forcefully transiting). Traffic predictions are estimates only – a full and precise traffic estimate, entailing deep review of all upcoming manifested vehicles and estimates of deorbit dates for current vehicles, is beyond the scope of this paper – but offer a reasonable assessment of a possible traffic growth path in a scenario reflecting an optimistic view of space commerce.

Table 2. Exemplar Prediction of Likely Traffic.

Region	**Traffic examples**	**2025 traffic**	**2035 traffic**	**2050 traffic**	**% Stat / Sed / For**	**Center**
Periterrestrial	Wx, Earth obs, RF comms, etc.	Extensive ~5000	~25000	~75000	99.5 / 0 / 0.5	Earth surf
Earth local	Science, PNT	~10-15	20-30	30-50	98 / 1 / 1	GEO
Translunar	PNT, Gateway	1-2	2-4	5-8	50 / 25 / 25	L1
Supralunar	Communications	0	1-3	3-5	100 / 0 / 0	L2
Periselenic	PNT, ore transshipments, human crew	0	1-5	5-15	20 / 20 / 60	Lunar surf
Tertiary librational	Science	0-1	1-3	5-7	100 / 0 / 0	L3
Quaternary	Expl., science	0-1	1-3	8-10	70 / 20 / 10	L4
Quinary	Expl., science	0-1	1-3	8-10	70 / 20 / 10	L5

*NB: SSA/STM missions not listed

Additional assessments of traffic and likely traffic growth can be used along with weighting factors and precise information about upcoming and launched missions to maintain updated priorities for deploying region-covering SSA assets. That is, knowledge of which region is likely to be heavily-trafficked first can be used to guide the order in which sensors assets are deployed to the nearest center loci.

For example, a simple weighting scheme that posits a critical need to observe and manage a fraction of objects based on traffic type is shown below. The scheme assigns critical priority to 0.01% of all stationarily-orbiting objects, 0.1% of all sedately-transiting objects, and 1% of all forcefully-transiting objects. Put another way, more aggressive traffic types are assumed to be more likely to be behaving in ways that demand additional care in management, and regions with the highest amount of aggressive traffic are assumed to need the most attention. It is these regions which can thus be first to receive deployment of spaceborne SSA sensors.

Region	2025	2035	2050	Stat %	Sed %	For %		Ncrit-25	Ncrit-35	Ncrit-50	Priority
Periterr	5000	25000	75000	99.95	0	0.05		52.48	262.38	787.13	1
Earth loc	12.5	25	40	98	1	1		0.26	0.52	0.83	5
Translun	1.5	3	6.5	50	25	25		0.42	0.84	1.82	3
Supralun	0	2	4	100	0	0		0.00	0.02	0.04	7
Perisel	0	3	10	20	20	60		0.00	1.87	6.22	2
L3	0.5	2	6	100	0	0		0.01	0.02	0.06	6
L4	0.5	2	9	70	20	10		0.06	0.25	1.14	4
L5	0.5	2	9	70	20	10		0.06	0.25	1.14	4

Figure 3. Weighting and prioritization notional example.

The rightmost column of Figure 3 indicates an approximate priority order. However, when time evolution of traffic is considered, nuances in priority may also be considered, based on which regions show the highest concentrations of expected critical traffic at which time.

For example, Figure 4 shows the extreme dominance of the periterrestrial regime, suggesting a need to fill out observation and traffic management capabilities in this regime first. Fortuitously, this regime is known to be well-covered by existing government and commercial capacity.

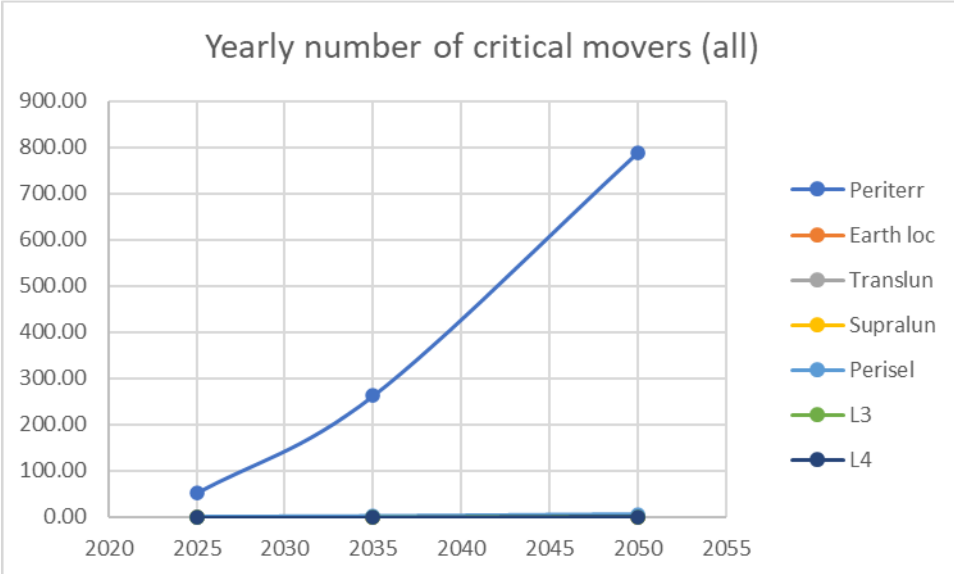

Figure 4. Exemplar traffic analysis output, showing the dominance of periterrestrial traffic.

Similarly, Figure 5 shows the regimes other than periterrestrial (NB: in both figures, the L4 and L5 lines are exactly the same, so only L4 is shown).

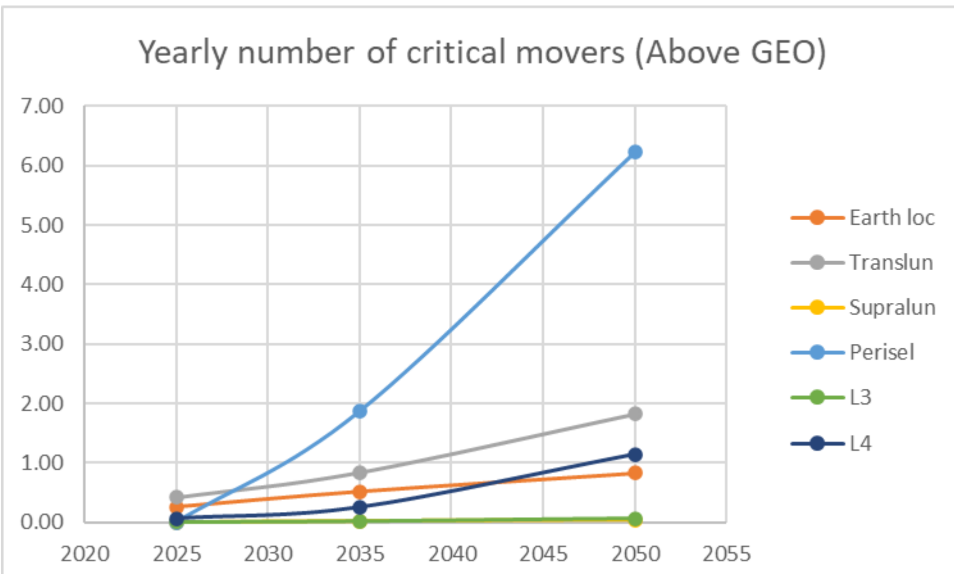

Figure 5. Exemplar traffic analysis output, showing the relative criticality and growth of regimes above GEO.

Note that the periselenic region grows to a high dominance (as a growing lunar surface infrastructure is assumed to need support from a matching infrastructure in low lunar orbit), although it begins as a lower priority. However, the third priority is not so clear, as L4 and L3 switch places. The weighting and traffic assessment scheme used here assume rapid and strong growth in lunar surface activity, pursuant to long-range US space exploration goals focused on exploitation of lunar resources.

Coverage priorities can be mapped according to these outcomes if the underlying assumptions hold, and as such a logical order of deployment of STM resources to sectors is as follows: periterrestrial, periselenic, translunar, Earth local, quaternary and quinary librational, tertiary librational, supralunar.

4. UNIQUE ORBITS FOR SPACEBORNE COVERAGE

A key element of cislunar space traffic management is the ability to observe traffic operating within cislunar regions. This need to observe would theoretically drive the placement of sensor systems for STM at the libration points, although every STM system that occupies a central orbital slot at a libration point leaves less room for other revenue-generating traffic. Furthermore, an STM system that operates in a range of positions across the regime it serves is more effective over time than one which simply remains in a fixed slot.

As such, there are several orbits, some relatively unique, which are of great interest for the purposes of STM in a cislunar volume. These orbits are those which allow a sensor system to operate within a volume of cislunar space, and thus provide coverage for the bulk of a given traffic regime, without remaining solely approximately stationary at the stable center of the regime.

Some of these are listed in Table 3. Note that all regions are covered by multiple orbit families; and conversely some orbits span multiple regions. Periterrestrial and perilunar regimes may be densely trafficked and experience more complicated perturbations and other factors (such as transiting launches to other regimes) which incline the treatment of these regimes to handling via a separate analysis, but in general the periterrestrial regime can be assumed to be well-addressed by ground-based sensors or sensors operating within the periterrestrial regime. The periselenic regime may also be well-addressed by sensors placed on the lunar surface and in Low Lunar Orbit (LLO); however, it is likely desirable to accompany any such sensors with backups in the translunar or supralunar regimes. The lunar surface is known to be an extremely challenging environment for long-term automated emplacements, and LLO does not necessarily afford stable orbits save for a few inclinations that are likely to be prime locations for other (non-STM) infrastructure.

Table 3. Approximate matching of STM regimes and interesting orbits.

Region	Example Orbits
Periterrestrial	Ground-based
Periselenic	LLO frozen, HOPE
Translunar	HOPE, W4/W5, DRO
Earth local	5X GEO
Quaternary/Quinary librational	V4 / V5
Tertiary librational	V3
Supralunar	W4/W5, L2 Halo, DRO

If the regime deployment order reflected in Table 3 is followed by deploying to the matching orbits shown, then an orbital deployment order may be: HOPE, W, 5XGEO, Vertical, L2 Halo.

4.1 HOPE Orbit

The HOPE orbit family [8] is primarily contained within the Earth local regime, and features paired highly-elliptical orbits that have low perigees near the Earth. These orbits allow the vehicles occupying them to maintain a lengthy hangtime near apogee, at a point approximately 5 XGEO over the north or south poles, slightly inclined to minimize exposure to the Van Allen belts.

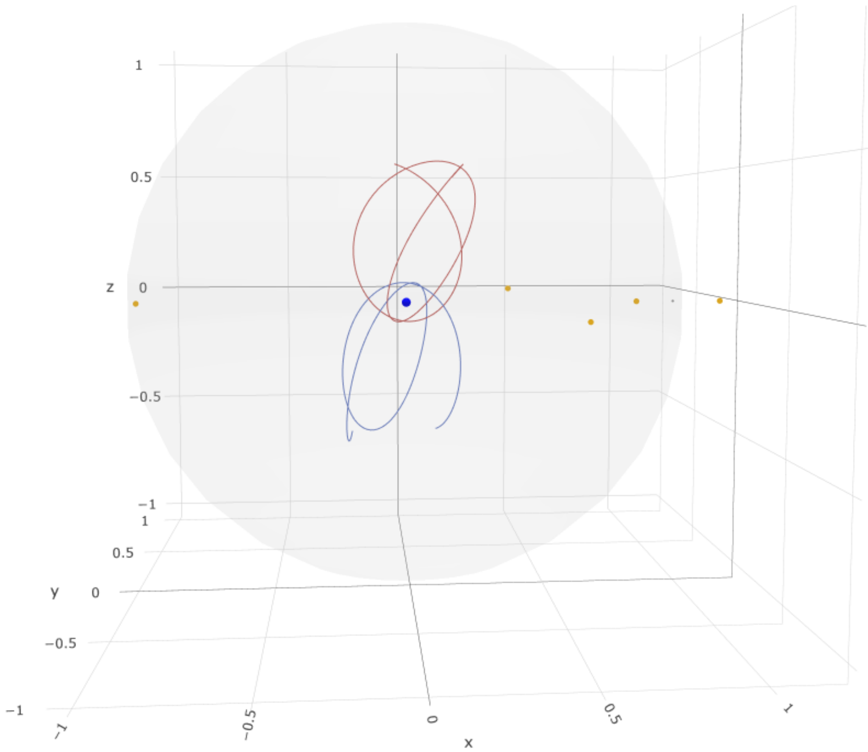

Figure 6. HOPE orbit sketch.

HOPE orbits provide some advantage in eliminating the solar exclusion for orbits near the translunar, supralunar, and periselenic regimes. However, they also require dedicated transit systems to arrive in their unique slots, and can suffer from increased radiation exposure. They also do not offer particularly low observation ranges to their preferred targets.

4.2 W4/W5 Orbits

The W-class orbit family [9] covers the translunar and supralunar regimes noticeably well. W orbits are typically associated primarily with the L4 and L5 points.

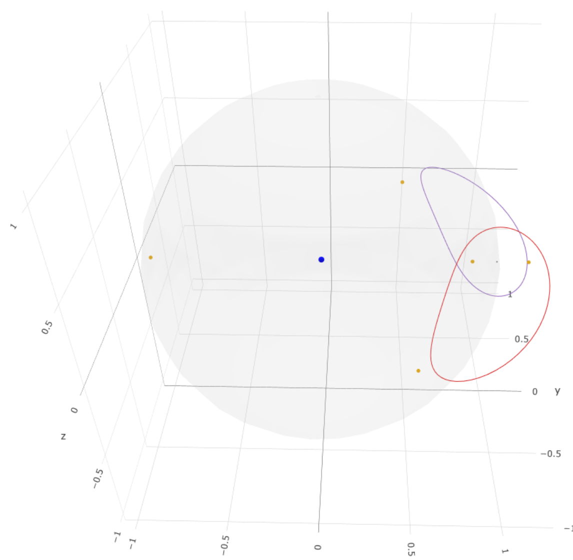
Figure 7. W orbit sketch.

4.3 5XGEO Orbit

The 5XGEO circular orbit, which is still primarily contained within the Earth local zone (but also crosses into the librational and translunar zones under most definitions of these regimes), serves the purpose of maintaining a reasonably-low distance at all points from vehicles occupying the Earth local and periterrestrial zones, while still approaching some traffic in other regimes to roughly the same distance. Put bluntly, this orbit allows for a maximum range of 5 XGEO to many other vehicles and regions for a large fraction of circumstances, making it something of a minimax option.

The 5XGEO circular orbit also has the comparative advantage of being isolated from almost all other traffic, although it has the countervailing disadvantages of requiring dedicated launch and management/communications infrastructure, to some extent.

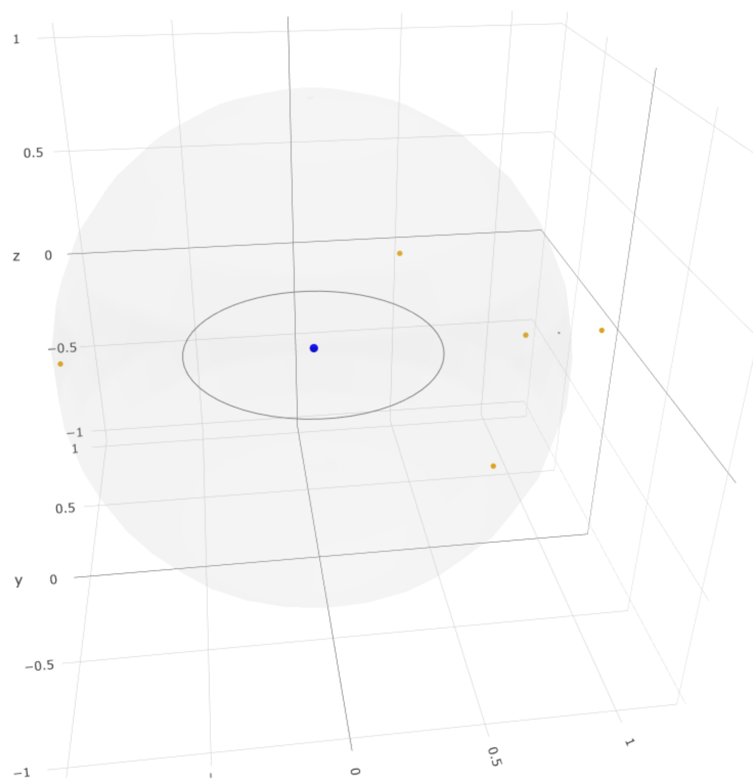

Figure 8. 5XGEO circular orbit sketch.

4.4 Vertical Orbit

The Vertical (or V) orbits are defined in [9] and consist of paths that transit through and about the tertiary, quaternary, and quinary libration points.

These orbits serve a function much like Clarke constellations do for Earth: provide lines of sight from the outer edge to all parts of the inside volume.

Although the V orbits cross over into the Earth local and translunar regimes, they are primarily associated with the libration points (one point per orbit). The primary challenges associated with operating an STM sensor vehicle in these orbits will likely center around either the need to point communications antennas at high angles (when the V sensors are at the northern and southern extrema) or to address passing traffic and collision avoidance with other systems operating very near the libration points (when near the central loci of these orbits, on the ecliptic).

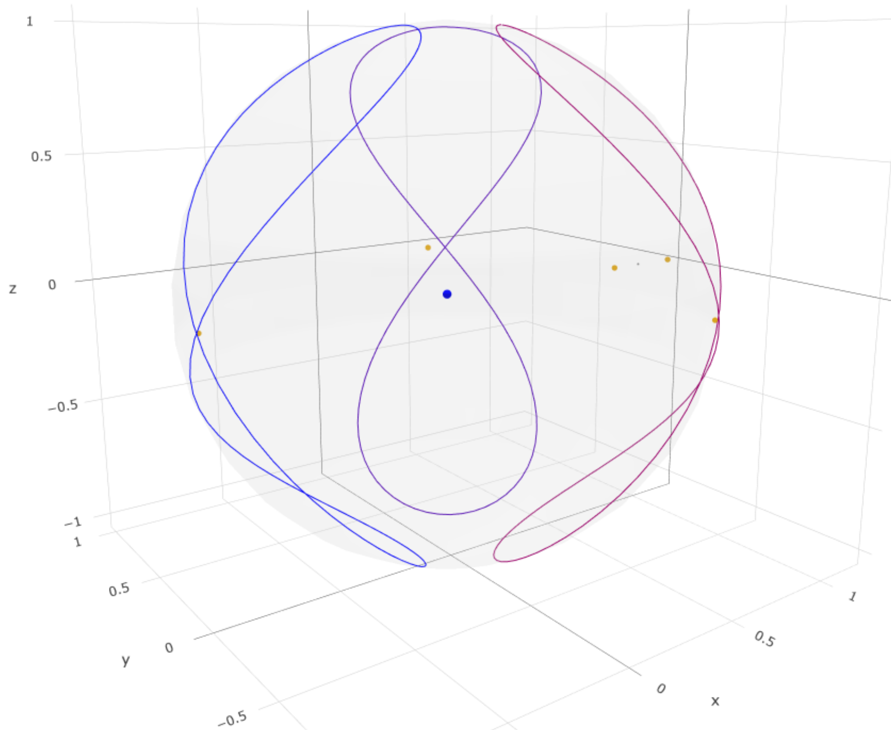

Figure 9. Vertical orbit sketch.

4.5 L2 Halo Orbit

Halo orbits are rings centered around the L2 point, beyond Luna. These orbits offer the advantage of providing line-of-sight links between the Lunar Farside and terrestrial ground stations.

They also offer good coverage from a short range of the supralunar regime.

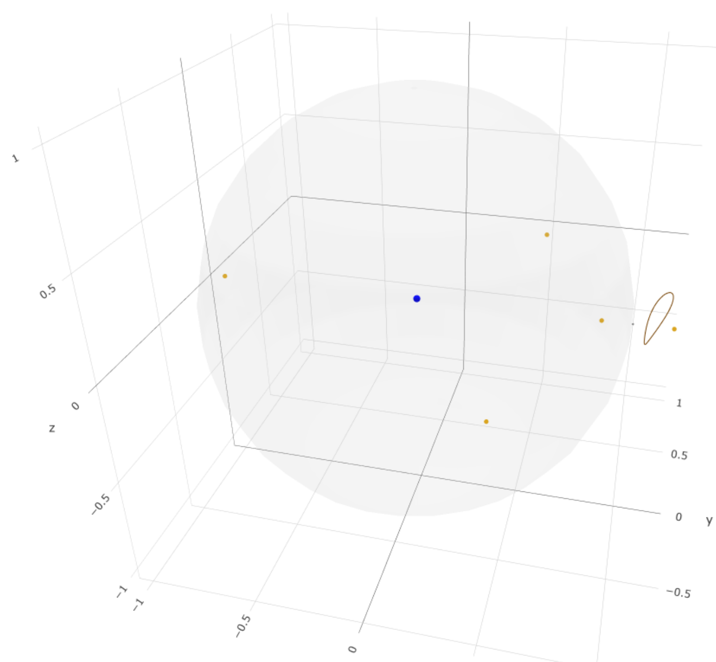

Figure 10. L2 Halo orbit sketch.

These orbits highlight some of the ways in which specific unique orbits can contribute to SSA coverage of the sectors of the cislunar sphere.

5. A FUTURE HIGH-TRAFFIC ENVIRONMENT

The results shown are potentially applicable to future scenarios of high traffic across all regimes in the cislunar volume, and traffic analyses may provide insight into deployment order. For instance, to cover the regimes in the above-GEO regions in order, periselenic and translunar regimes would be covered first, followed by the Earth local and then librational and supralunar regions. Accordingly, a logical deployment order of SSA systems might be: HOPE, W, 5XGEO, V, Halo.

As illustrated in Figure 11, when all STM sensors proposed in this paper are deployed to the orbits identified, there will be dispersed coverage across all regimes (with coverage in the periterrestrial and perilunar spheres too dense to be illustrated on this scale), with some noticeable concentration on the translunar and Earth local regimes, which are the two most likely to be traversed by traffic to and from economic activity on the moon.

A future high-traffic environment in the entirety of the cislunar sphere could benefit from a developed STM sensor infrastructure deployed in this manner to maintain overwatch on vehicles within and crossing the regimes.

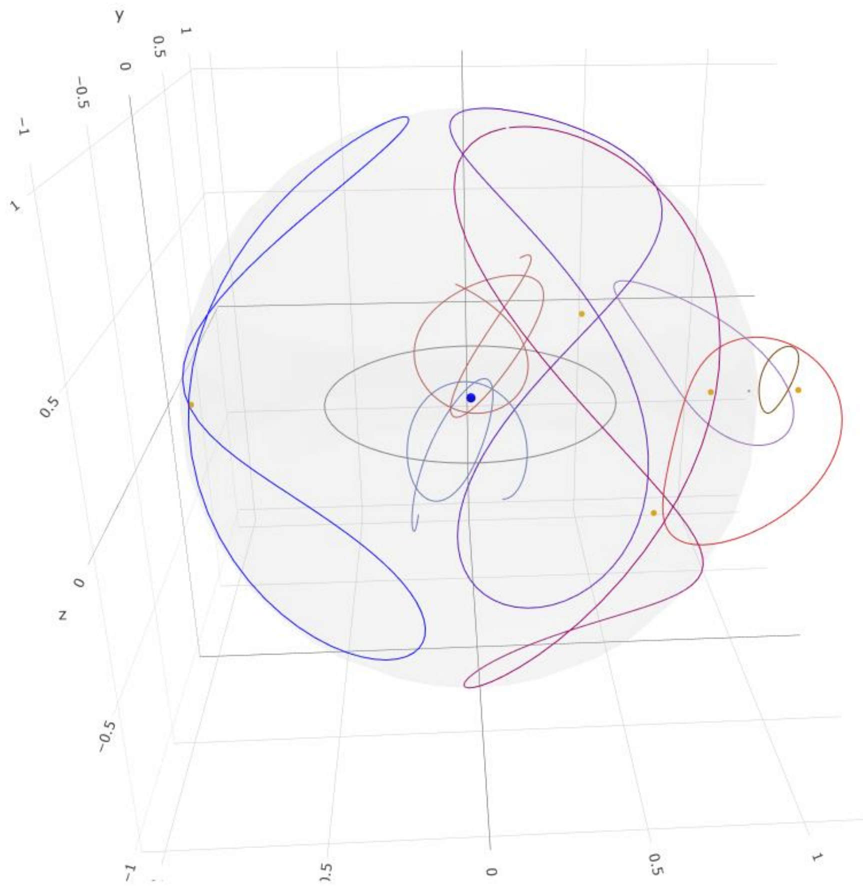

Figure 11. Cislunar sphere with all STM orbits shown simultaneously.

6. SUMMARY

This paper has described some of the characteristics of the cislunar sphere, giving attention to the division of the sphere into logical regions centered around the five libration points and the two solid planetary surfaces that make up the most salient features of the sphere.

These terrain elements have been used to develop a scheme of traffic management regimes: eight smaller volumes that comprise the cislunar sphere, shaped in roughly low-order polyhedral to minimize the number of sectors while maximixing comprehensibility.

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