SUBORBITAL TRANSPORT MAPPING WITH TIME OF FLIGHT (TOF).

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Introduction: For the problem of finding the source or origin of some ejecta or strewn on a planet, suborbital transport dominates the spread of globally distributed strewn/ejecta, and significantly effects the spread of intercontinental-scale strewn/ejecta fields. The shape of strewn distribution and the patterns within are potentially rich with information relating to both the transport and emplacement processes.

Discussion: Suborbital transport mapping based on A-to-B suborbital mechanic allows the location of an impact structure and rough type of impact to be estimated based on some loft-time dependent criteria. Solving an A-to-(group of Bs) problem for a range of Time Of Flight (TOF) to every B point produces a solution set for comparison to possible ejection patterns from the suspected launch point A.

Accounting for Earth's rotation, a set of solutions for launch condition at point A required to reach point B may be determined. These solutions are unique, with only one of each a long-way and a short-way orbit between any two points A and B for each discrete TOF value. The short-long division falls at ½ of an orbital revolution. Similarly, there are two solution sets for each A-to-B problem. The solution sets vary with launch point and are compared against launch conditions (i.e. ejecta pattern estimates from testing).

Figure 1. A "short way" solution orbit (dotted black curve) from A to B [1]. The horizontal line segment is a radius of the blue planet, coincident with the major axis of the dotted elliptical orbit between A and B. The periapsis ***P*** is perigee in the terrestrial case. The conical or "internal" angle, NU$_A$ is measured from periapsis along the orbit path to launch point A [1].

Figure 1.

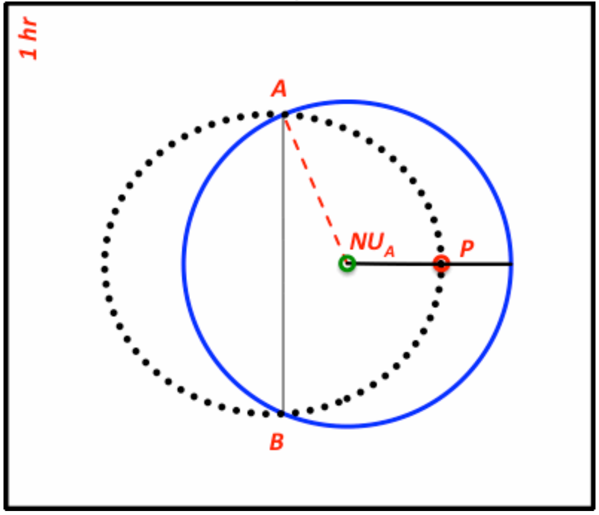

Figure 2. The circle is the planet. Dashed long-way orbits are shown with their equal-TOF short-way partners and corresponding periapses. Planet center is the left end of the horizontal line segment and TOF appears at the upper left of each frame.

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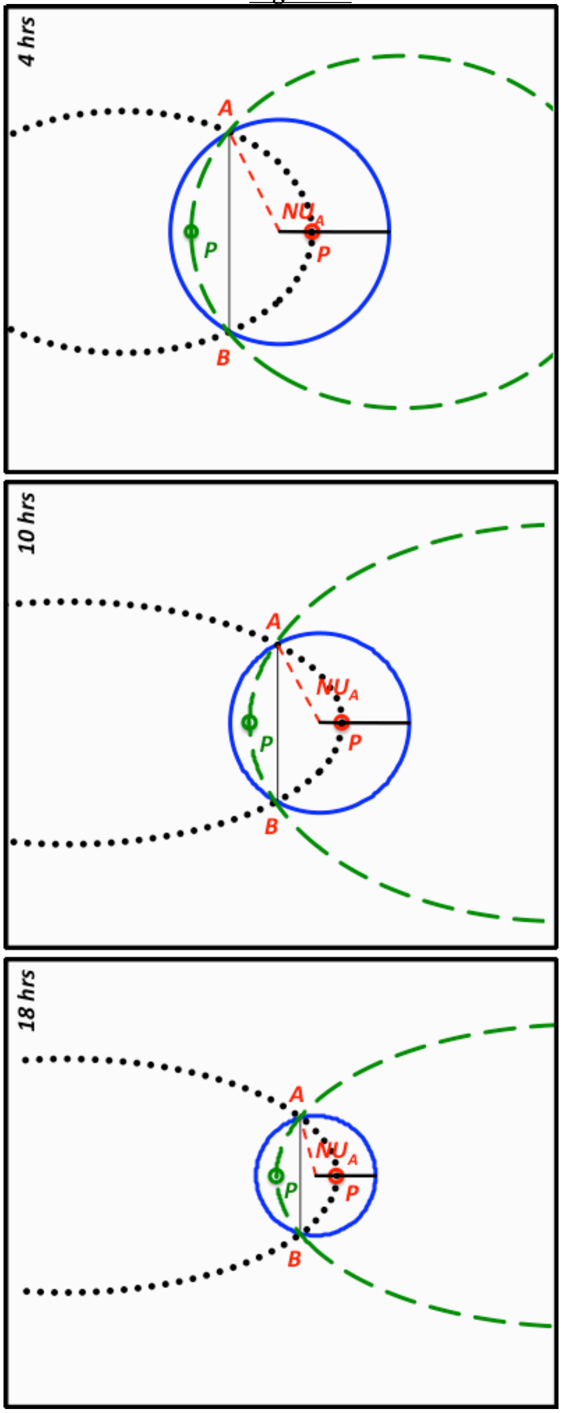
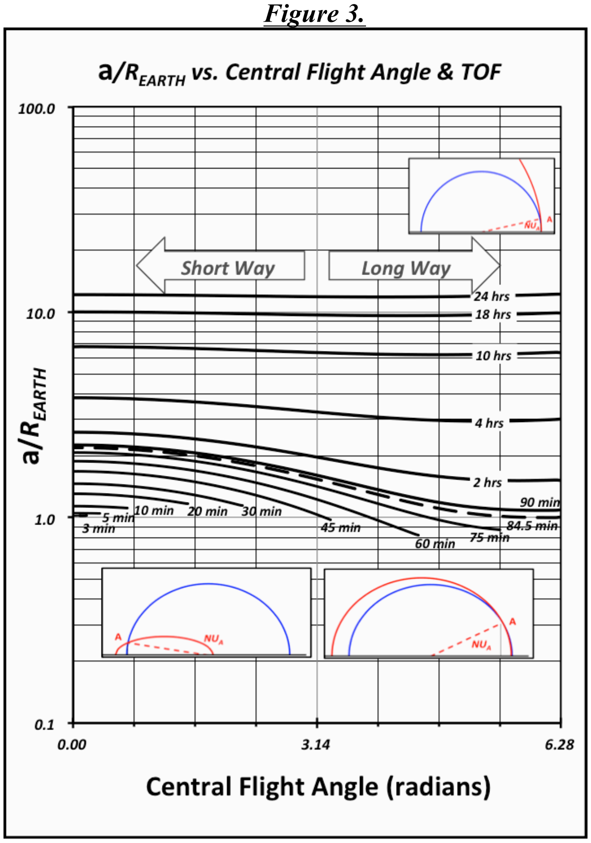


Visible in Figure 2 is the fact that for longer TOF values, the short-way and long-way orbits have increasingly similar eccentricities; they look increasingly similar in shape as TOF increases. This happens as the increasing fraction of their suborbital paths become flight arc vs. subsurface arc.

Mapped variations. For a varying launch condition in launch azimuth (AZ) and elevation (EL), corresponding cross track and in-track changes of fall point ***B*** denote those principal directions over the surface of the planet. The gradients, contours and general character of the mapping transform or "mapped grid" have distinct trends and recognizable features, lending to a more optimized A-to-B trajectory solver tool after analytic reduction [2], [3], [4], and verification coding.

Figure 3. Continuity within the transition zone between short-way and long-way orbits is demonstrated in this plot of iso-Time Of Flight or "iso-TOF" curves vs. fraction of the planet's circumference traversed. As larger fractions of planetary diameter are traversed, there is less difference in semi-major axis ***a*** for a given TOF. The semi-major axis is normalized to planetary radius, Earth in this case, on the vertical axis. The horizontal axis is the central flight angle, or great circle radian angle for the flight portion of the orbit path.

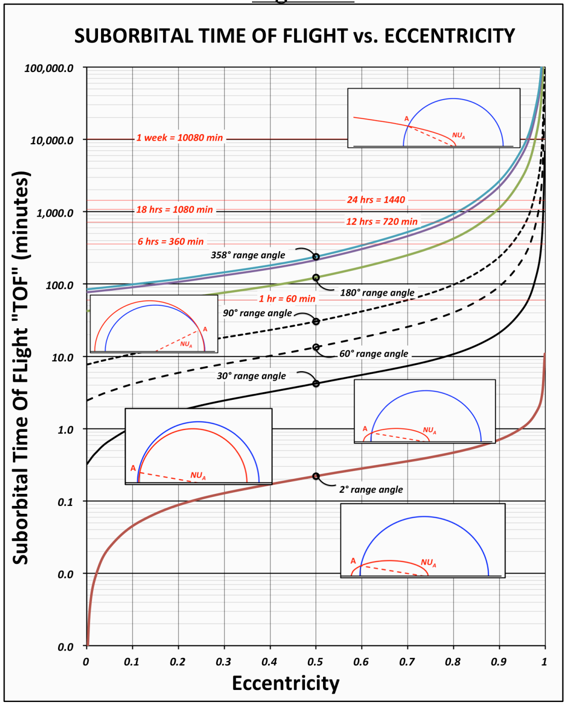
Figure 3.



For the case of Earth, the period of a circular orbital satellite at zero altitude is ~84.5 minutes. There is ~ one order of magnitude variation of semi-major axis from that case to a suborbital TOF of one full day. Local or regional ejecta/strewn reside in the "bubble" of short TOF curves in lower left of *Fig. 3*. More distal ejecta inhabit longer TOF regions of that diagram.

Figure 4. Ejection angle is more horizontal to the left and more vertical to the right in this plot. Eccentricity increases along the independent axis and TOF increases on the dependent axis. Each curve is a constant central flight angle, the great circle angle of suborbital flight. Times of 1 hour to 1 week are noted, as are associated low- and high ***e*** trajectory diagrams.

Figure 4.



Summary and Conclusion: Using Kepler's area rule and geometric symmetry of the suborbital definition, TOF was derived as a function of the orbital elements eccentricity ***e*** and semi-major axis ***a***. Combined with A-to-B chord lengths, those elements are preferred intermediate variables. Larger TOF values improve intercontinental transport via planetary rotation.

Variations in launch AZ and EL reveal principal cross track and in-track mapped direction grid over the surface. The mapped grid allows comparison to signatures observed and measured within the record.

References: [1] R.R. Bate, D.D. Muller, J.E. White, 1971, *Dover Publications*. [2] T.H.S. Harris, H. Povenmire, 2015, *Lunar and Planetary Science Conference,* abstract #1291. [3] T.H.S. Harris, 2015 *Meteoritics & Planetary Science,* abstract #5053. [4] T.H.S. Harris, 2015 *Meteoritics & Planetary Science,* abstract #5135.