

Satellite Collision Avoidance

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Outline

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- Track satellites to see how likely they were collide.
- See how often they got within 100 km of each other.
- Analyze those results to see what satellites showed up the most.

Kessler Syndrome

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A scenario in which the density of objects in Low Earth Orbit (LEO) is high enough that each collision creates debris that increases the likelihood of more collisions.

3D Plot

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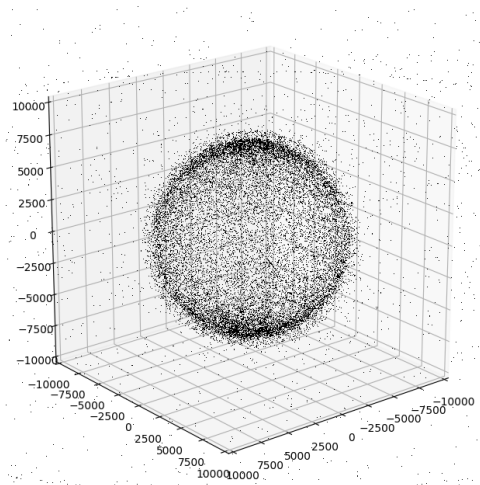
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Conjunction Plots

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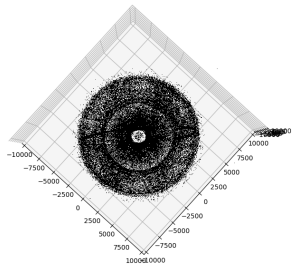
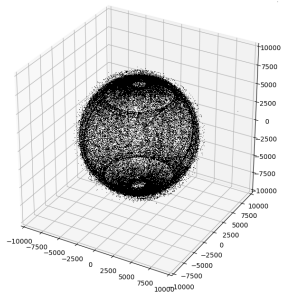
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Satellite Point of View

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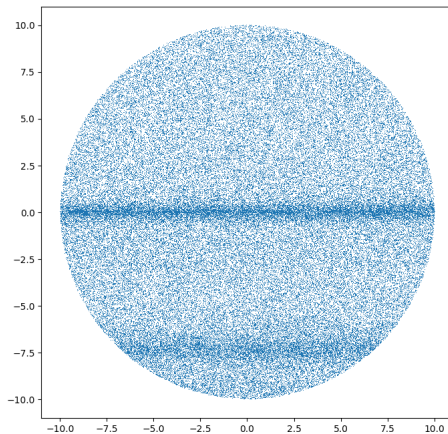
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Dot Product

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```
def mindist_and_time(pairpos_vels):  
    deltas = pairpos_vels[:, 1] - pairpos_vels[:, 0]  
    r = deltas[:, 0, :]  
    v = deltas[:, 1, :]  
    rnorm = np.sqrt(np.sum(r ** 2, axis=-1))  
    vnorm = np.sqrt(np.sum(v ** 2, axis=-1))  
    rdotv = np.sum(r * v, axis=-1)  
    costheta = rdotv / (rnorm * vnorm)  
    sintheta = np.sqrt(1 - costheta ** 2)  
    distance = rnorm * sintheta  
    # the distance it has to travel to the minimum distance point  
    travel = -rnorm * costheta  
    time = travel / vnorm  
    return distance, time
```

Figure: Dot Product


```
def pairs_for_time(satellites, time, search_radius=100, maxdistance=10, timestep=10):  
    pos_vels = satellitepos_vels(satellites, time)  
    if np.any(np.isnan(pos_vels)):  
        print(pos_vels.shape, np.count_nonzero(np.isnan(pos_vels[:, 0, 0])), "invalidpositions")  
        pos_vels = np.nan_to_num(pos_vels)  
    pairs, distances, delta_times = findpairs(pos_vels, search_radius=search_radius,  
                                              maxdistance=maxdistance, timestep=timestep)  
    times = time + delta_times / seconds_per_day  
    pair_type = np.dtype [("time_jd", float), ("sat_names", "U30", 2), ("catnums", int, 2),  
                          ("positions", float, (2, 3)), ("velocities", float, (2, 3)),  
                          ("distance", float), ("extrapolated_distance", float)]  
    result = np.zeros(len(distances), dtype=pair_type)  
    result["extrapolated_distance"] = distances  
    for i in range(len(distances)):  
        result[i]["time_jd"] = times[i].tt  
        for j, satnum in enumerate(pairs[i]):  
            sat = satellites[satnum]  
            geocentric = sat.at(times[i])  
            result[i]["positions"][j] = geocentric.position.km  
            result[i]["velocities"][j] = geocentric.velocity.km_per_s  
            result[i]["sat_names"][j] = sat.name  
            result[i]["catnums"][j] = sat.model.satnum  
  
    delta_pos = np.diff(result["positions"], axis=1)[:, 0, :]  
    new_distance = np.sqrt(np.sum(delta_pos ** 2, axis=-1))  
    result["distance"] = new_distance
```

Results

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```
[(2459793.49996586, [b'STARLINK-2686', b'STARLINK-4016'], [48464, 52603], [
(2459793.49995395, [b'COSMOS 2251 DEB', b'FENGYUN 1C DEB'], [36052, 37578],
(2459793.50000893, [b'STARLINK-1477', b'STARLINK-3763'], [45754, 52556], [
```

```
[-1794.74737479, 4644.46295733, 4803.81598868], [-1796.996286 , 4637.41754928, 4798.27287065]], [
], [[-1035.20786393, 1826.2946224 , -6772.34418336], [-1035.9581627 , 1830.56719824, -6771.60789707]]
[[ 3043.82085744, 3832.24481974, 4890.72523754], [ 3040.55030319, 3828.28038801, 4885.57477159]], [
```

```
[-6.96578649, 0.41137309, -2.99202699], [-4.81553841, -5.02496521, 3.04540734]], 9.24237707, 9.24234973],
[[-4.84987248, -5.65995379, -0.78727613], [ 6.36757837, -3.49630711, -1.91743309]], 4.39999659, 4.40001189],
[-6.81385665, 1.79480535, 2.82645312], [-3.28465361, 6.23568948, -2.83285029]], 7.27602526, 7.27602899),
```

```
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```

Why is this important?

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- Prevents Collisions
- Keeping tabs on growing constellations
- Understanding satellite movement

Future Work

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- Conjunction Plots
- Starlink orbital readjustments
- Future Collisions

Acknowledgements

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I would like to thank my mentor, David Palmer, for everything he has taught me.

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