# Satellite Collision Avoidance

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August 3, 2022

# Outline

# Project Goals

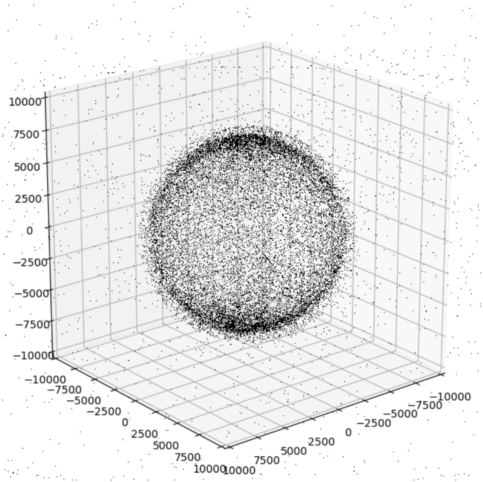
- Track satellites to see how likely they were collide.
- See how often they got within 100 km of each other.
- Analyze those results to see what satellites showed up the most.

# Kessler Syndrome



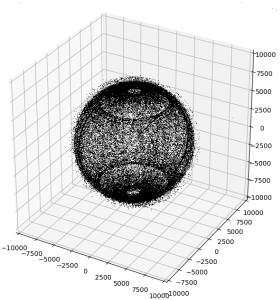
A scenario in which the density of objects in Low Earth Orbit (LEO) is high enough that each collision creates debris that increases the likelihood of more collisions.

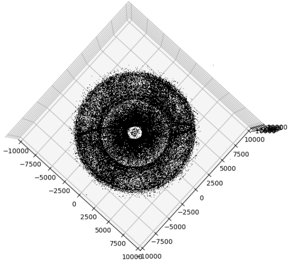
# 3D Plot


10000
7500
5000
2500
0
−2500
−5000
−7500
−10000
−10000
−7500
−5000
−2500
0
2500
5000
7500
10000
10000
7500
5000
2500
0
−2500
−5000
−7500
−10000

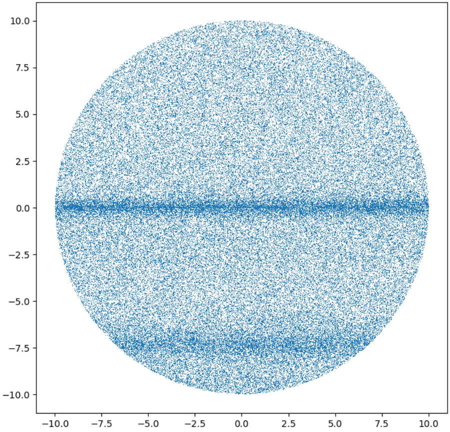
# Conjunction Plots





# Satellite Point of View



# Dot Product

```
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

```python
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



```
[(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),
```


```
[(2459793.49996586, [b'STARLINK-2686', b'STARLINK-4016'], [48464, 52603], [
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[-6.81385665,  1.79480535,  2.82645312], [-3.28465361,  6.23568948, -2.83285029]], 7.27602526,
```

# Why is this important?

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

# Future Work





- Conjunction Plots
- Starlink orbital readjustments
- Future Collisions

# Acknowledgements

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

I would also like to thank the Institute for Computing in Research and everyone involved for giving me and my fellow interns this opportunity.

# References



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2 Mann, A., Pultarova, T., Howell, E. (2022, April 14). SpaceX Starlink Internet: Costs, Collision Risks and How it Works. Available at https://www.space.com/spacex-starlink-satellites.html

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