Sky Track ISS Tracking Study

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Sky Track is a 3D program written several years ago to display recorded HFI and RPG tracks around military aircraft. In this study, Sky Track was modified to show a high resolution picture of the Earth with the International Space Station moving about its orbit. Attached to the top of the ISS is a parabolic dish facing zenith or straight up. The parabolic dish is modeled with the ability to pitch down 25 degrees from Zenith in any direction allowing it to track objects in space. In this study, TDRS 9 was selected as the object to track. Figure 1 shows a snapshot from the Sky Track display with ISS and parabolic dish.

Sky Track executes on a Microsoft Windows platform using XNA gaming software under C#. XNA provides a rich set of vector calculus functions which execute under DirectX on the Graphics Processing Unit, GPU. Performing the orbital track operations provided by Sky Track requires rather complex vector calculus operations made easier with the XNA library of functions.

Movement of the Earth, ISS, and other objects in space (in this study, TDRS 9) is derived from a 2-line standard format called TLE. Each object has an associated 2-line TLE data set which includes important orbital parameters, such as the satellite's position, velocity, and other relevant information at a specific epoch or time. For this study, a set of TLE data packets was on-hand from a previous study covering year 2022 day 57. Sky Track uses a MIT library of functions to process the TLE data.

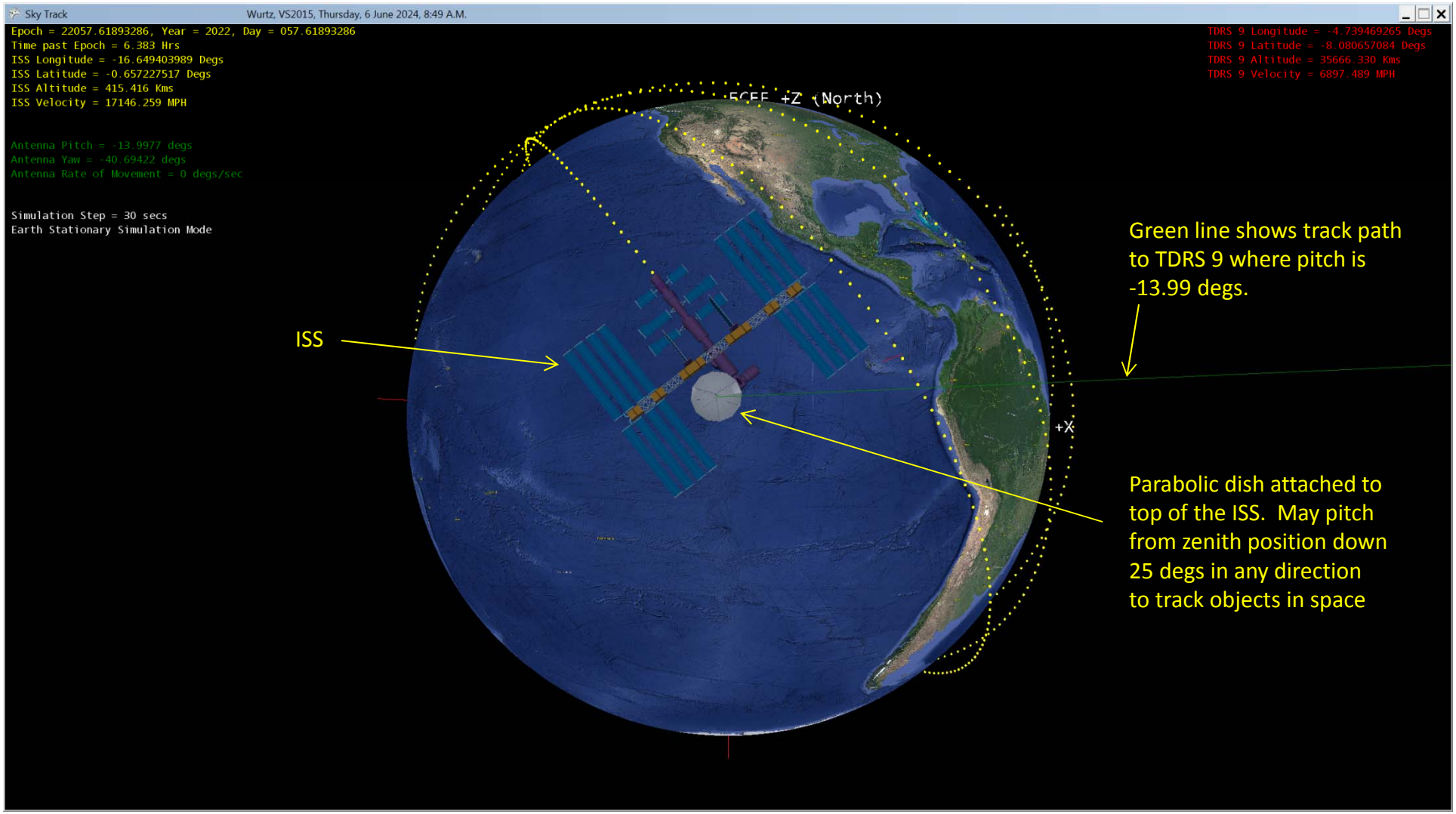

Figure 1. Snapshot from Sky Track showing ISS and Parabolic Dish

The purpose of this study, specifically, was to show periods of time or 24 hours that the ISS could track TDRS 9 with its parabolic dish limited to 25 degs of pitch. The simulation step is a user set variable and set to 30 seconds for this study. Accordingly, Sky Track shows the movement of the Earth, ISS, and TDRS 9 every 30 seconds as these objects move through their orbits. If the dish antenna pitch is less than 25 degs, a green line is show from the center of the dish to TDRS 9 indicating a good track for recoding data. If the dish antenna can not be moved to provide a good track, a red line is shown. Sky Track output is a file of records advancing in time with each 30 second simulation step. Each record reports epoch time, dish yaw, dish pitch, and rate of dish movement. Tables 1 through 5 show chunks of the output file where the parabolic dish was able to be oriented to track TDRS 9. Green records show dish information for good tracks when the antenna pitch is <25 degs. Red records report when the dish could not track TDRS 9 due to limited pitch.

Tables 1 through 5 report that there are four windows of opportunity for the ISS to record or monitor TDRS 9 with a parabolic dish limited to a pitch of 25 degs over a 24 hour period. Namely, Window 1 with lines 571 to 589 provides 570 secs. Window 2 with lines 763 to 782 provides 600 secs. Window 3 with lines 2154 to 2176 provides 690 seconds. Finally, Window 4 with lines 2354 to 2362 provdes 270 seconds. The maximum dish antenna rate of movement is <0.076 degs/sec.

sky_track_record_file.csv - Microsoft Excel

	A	B	C	D	E	F	G	H	I
1	ISS_epoch	ISS_epoch_year	ISS_epoch_day	display_time(hrs)	dish_pitch(degs)	dish_yaw(degs)	dish_rate_of_movement(degs/sec)		
2	22057.61893	22	57.61893286	0	-75.7049	158.8402	NaN		
3	22057.61893	22	57.61893286	0.008333333	-72.64377	118.0728	0.1020378		
4	22057.61893	22	57.61893286	0.016666667	-73.50572	118.72	0.02873179		
5	22057.61893	22	57.61893286	0.025	-74.38343	119.3376	0.02925695		
6	22057.61893	22	57.61893286	0.033333333	-75.27577	119.9258	0.02974472		
7	22057.61893	22	57.61893286	0.041666667	-76.18166	120.4848	0.03019638		
8	22057.61893	22	57.61893286	0.05	-77.10004	121.0149	0.03061269		
9	22057.61893	22	57.61893286	0.058333333	-78.0299	121.5163	0.03099518		
10	22057.61893	22	57.61893286	0.066666667	-78.97025	121.9892	0.03134486		
11	22057.61893	22	57.61893286	0.075	-79.92013	122.434	0.03166275		
12	22057.61893	22	57.61893286	0.083333333	-80.87865	122.851	0.03195063		
13	22057.61893	22	57.61893286	0.091666667	-81.84491	123.2405	0.03220876		
14	22057.61893	22	57.61893286	0.1	-82.81807	123.6028	0.03243866		
15	22057.61893	22	57.61893286	0.108333333	-83.79732	123.9382	0.0326416		
16	22057.61893	22	57.61893286	0.116666667	-84.78185	124.2469	0.03281759		
17	22057.61893	22	57.61893286	0.125	-85.7709	124.5294	0.03296839		
18	22057.61893	22	57.61893286	0.133333333	-86.76375	124.7859	0.03309504		
19	22057.61893	22	57.61893286	0.141666667	-87.75968	125.0167	0.03319778		
20	22057.61893	22	57.61893286	0.15	-88.75802	125.2219	0.03327789		
21	22057.61893	22	57.61893286	0.158333333	-89.75809	125.4019	0.03333562		
22	22057.61893	22	57.61893286	0.166666667	-90.75925	125.5568	0.03337199		
23	22057.61893	22	57.61893286	0.175	-91.76088	125.6868	0.03338776		
24	22057.61893	22	57.61893286	0.183333333	-92.76237	125.7922	0.03338318		
25	22057.61893	22	57.61893286	0.191666667	-93.76317	125.8731	0.03335978		
26	22057.61893	22	57.61893286	0.2	-94.76266	125.9294	0.0333163		
27	22057.61893	22	57.61893286	0.208333333	-95.76029	125.9615	0.0332545		
28	22057.61893	22	57.61893286	0.216666667	-96.75554	125.9693	0.03317489		
29	22057.61893	22	57.61893286	0.225	-97.74784	125.9529	0.03307673		
30	22057.61893	22	57.61893286	0.233333333	-98.73669	125.9123	0.03296153		
31	22057.61893	22	57.61893286	0.241666667	-99.72155	125.8474	0.03282877		
32	22057.61893	22	57.61893286	0.25	-100.7019	125.7583	0.03267898		
33	22057.61893	22	57.61893286	0.258333333	-101.6773	125.6449	0.03251215		
34	22057.61893	22	57.61893286	0.266666667	-102.6471	125.507	0.03232854		
35	22057.61893	22	57.61893286	0.275	-103.611	125.3446	0.0321284		
36	22057.61893	22	57.61893286	0.283333333	-104.5683	125.1575	0.03191147		
37	22057.61893	22	57.61893286	0.291666667	-105.5187	124.9455	0.03167725		
38	22057.61893	22	57.61893286	0.3	-106.4614	124.7085	0.03142649		

Table 1. Sky Track Output

558	22057.61893	22	57.61893286	4.633333333	-49.0957	22.96515	0.06572609
559	22057.61893	22	57.61893286	4.641666667	-47.11954	23.53157	0.06587194
560	22057.61893	22	57.61893286	4.65	-45.14037	24.17299	0.06597226
561	22057.61893	22	57.61893286	4.658333333	-43.15982	24.89883	0.06601855
562	22057.61893	22	57.61893286	4.666666667	-41.17976	25.72032	0.06600189
563	22057.61893	22	57.61893286	4.675	-39.2025	26.6509	0.06590881
564	22057.61893	22	57.61893286	4.683333333	-37.23071	27.70681	0.06572621
565	22057.61893	22	57.61893286	4.691666667	-35.26766	28.90764	0.0654349
566	22057.61893	22	57.61893286	4.7	-33.3173	30.27728	0.06501223
567	22057.61893	22	57.61893286	4.708333333	-31.38445	31.84478	0.0644282
568	22057.61893	22	57.61893286	4.716666667	-29.47509	33.64587	0.06364517
569	22057.61893	22	57.61893286	4.725	-27.59669	35.72423	0.06261361
570	22057.61893	22	57.61893286	4.733333333	-25.75861	38.13355	0.06126925
571	22057.61893	22	57.61893286	4.741666667	-23.97277	40.93909	0.05952778
572	22057.61893	22	57.61893286	4.75	-22.2544	44.21944	0.05727901
573	22057.61893	22	57.61893286	4.758333333	-20.62298	48.06656	0.05438067
574	22057.61893	22	57.61893286	4.766666667	-19.10335	52.58286	0.05065454
575	22057.61893	22	57.61893286	4.775	-17.72671	57.87202	0.04588782
576	22057.61893	22	57.61893286	4.783333333	-16.53111	64.0187	0.03985335
577	22057.61893	22	57.61893286	4.791666667	-15.56036	71.05384	0.03235842
578	22057.61893	22	57.61893286	4.8	-14.8603	78.90873	0.02333543
579	22057.61893	22	57.61893286	4.808333333	-14.47159	87.37631	0.01295703
580	22057.61893	22	57.61893286	4.816666667	-14.42029	96.11402	0.001709874
581	22057.61893	22	57.61893286	4.825	-14.71037	104.7104	0.009669336
582	22057.61893	22	57.61893286	4.833333333	-15.32241	112.7912	0.02040148
583	22057.61893	22	57.61893286	4.841666667	-16.21959	120.1038	0.02990576
584	22057.61893	22	57.61893286	4.85	-17.35698	126.5393	0.03791301
585	22057.61893	22	57.61893286	4.858333333	-18.68972	132.1025	0.04442488
586	22057.61893	22	57.61893286	4.866666667	-20.17788	136.8658	0.04960512
587	22057.61893	22	57.61893286	4.875	-21.78817	140.9296	0.05367648
588	22057.61893	22	57.61893286	4.883333333	-23.49391	144.3984	0.05685781
589	22057.61893	22	57.61893286	4.891666667	-25.27407	147.3679	0.05933882
590	22057.61893	22	57.61893286	4.9	-27.11223	149.9211	0.06127205
591	22057.61893	22	57.61893286	4.908333333	-28.99555	152.1272	0.06277714
592	22057.61893	22	57.61893286	4.916666667	-30.9139	154.0435	0.06394526
593	22057.61893	22	57.61893286	4.925	-32.85929	155.7167	0.06484636
594	22057.61893	22	57.61893286	4.933333333	-34.82532	157.185	0.06553421
595	22057.61893	22	57.61893286	4.941666667	-36.80681	158.4792	0.0660497
596	22057.61893	22	57.61893286	4.95	-38.79955	159.6251	0.06642469
597	22057.61893	22	57.61893286	4.958333333	-40.80009	160.6436	0.06668447

Window 1
570 secs

Table 2. Sky Track Output (continued)

754	22057.61893	22	57.61893286	6.266666667	-42.28131	-9.8167	0.0698981
755	22057.61893	22	57.61893286	6.275	-40.17959	-10.55338	0.07005742
756	22057.61893	22	57.61893286	6.283333333	-38.07449	-11.37082	0.07016983
757	22057.61893	22	57.61893286	6.291666667	-35.9677	-12.28356	0.07022642
758	22057.61893	22	57.61893286	6.3	-33.86127	-13.30973	0.0702142
759	22057.61893	22	57.61893286	6.308333333	-31.75773	-14.4721	0.07011827
760	22057.61893	22	57.61893286	6.316666667	-29.66018	-15.79954	0.06991813
761	22057.61893	22	57.61893286	6.325	-27.57261	-17.32931	0.06958573
762	22057.61893	22	57.61893286	6.333333333	-25.50012	-19.10986	0.06908302
763	22057.61893	22	57.61893286	6.341666667	-23.44943	-21.20523	0.06835639
764	22057.61893	22	57.61893286	6.35	-21.42955	-23.70089	0.06732934
765	22057.61893	22	57.61893286	6.358333333	-19.45287	-26.71228	0.06588916
766	22057.61893	22	57.61893286	6.366666667	-17.53681	-30.39604	0.06386872
767	22057.61893	22	57.61893286	6.375	-15.70632	-34.96387	0.06101631
768	22057.61893	22	57.61893286	6.383333333	-13.9977	-40.69421	0.0569541
769	22057.61893	22	57.61893286	6.391666667	-12.46368	-47.92701	0.05113414
770	22057.61893	22	57.61893286	6.4	-11.17859	-57.00203	0.04283625
771	22057.61893	22	57.61893286	6.408333333	-10.2384	-68.0756	0.03133949
772	22057.61893	22	57.61893286	6.416666667	-9.744646	-80.80576	0.01645857
773	22057.61893	22	57.61893286	6.425	-9.765738	-94.16192	0.000703049
774	22057.61893	22	57.61893286	6.433333333	-10.29829	-106.7836	0.01775173
775	22057.61893	22	57.61893286	6.441666667	-11.26921	-117.6924	0.03236389
776	22057.61893	22	57.61893286	6.45	-12.57611	-126.5997	0.0435633
777	22057.61893	22	57.61893286	6.458333333	-14.12443	-133.6876	0.05161072
778	22057.61893	22	57.61893286	6.466666667	-15.8417	-139.3008	0.05724246
779	22057.61893	22	57.61893286	6.475	-17.67674	-143.7753	0.06116807
780	22057.61893	22	57.61893286	6.483333333	-19.59437	-147.3839	0.06392097
781	22057.61893	22	57.61893286	6.491666667	-21.57037	-150.3334	0.06586647
782	22057.61893	22	57.61893286	6.5	-23.58782	-152.7763	0.06724834
783	22057.61893	22	57.61893286	6.508333333	-25.63467	-154.8255	0.06822834
784	22057.61893	22	57.61893286	6.516666667	-27.70213	-156.5643	0.0689153
785	22057.61893	22	57.61893286	6.525	-29.78365	-158.0554	0.069384
786	22057.61893	22	57.61893286	6.533333333	-31.87423	-159.3462	0.06968613
787	22057.61893	22	57.61893286	6.541666667	-33.97	-160.4733	0.06985893
788	22057.61893	22	57.61893286	6.55	-36.06788	-161.465	0.0699295
789	22057.61893	22	57.61893286	6.558333333	-38.16544	-162.3438	0.06991844
790	22057.61893	22	57.61893286	6.566666667	-40.26062	-163.1277	0.0698396
791	22057.61893	22	57.61893286	6.575	-42.35181	-163.8308	0.06970622

Window 2
600 secs

Table 3. Sky Track Output (continued)

2144	22057.61893	22	57.61893286	17.85	-46.49136	-3.667388	0.07069524
2145	22057.61893	22	57.61893286	17.85833333	-44.35898	-3.693135	0.07107913
2146	22057.61893	22	57.61893286	17.86666667	-42.21534	-3.722964	0.07145475
2147	22057.61893	22	57.61893286	17.875	-40.06073	-3.757222	0.07182045
2148	22057.61893	22	57.61893286	17.88333333	-37.89546	-3.796351	0.07217547
2149	22057.61893	22	57.61893286	17.89166667	-35.7199	-3.840947	0.07251867
2150	22057.61893	22	57.61893286	17.9	-33.53445	-3.89179	0.07284851
2151	22057.61893	22	57.61893286	17.90833333	-31.33953	-3.949888	0.07316399
2152	22057.61893	22	57.61893286	17.91666667	-29.13561	-4.016606	0.07346389
2153	22057.61893	22	57.61893286	17.925	-26.92319	-4.093834	0.07374725
2154	22057.61893	22	57.61893286	17.93333333	-24.70281	-4.184099	0.07401269
2155	22057.61893	22	57.61893286	17.94166667	-22.47505	-4.29101	0.07425887
2156	22057.61893	22	57.61893286	17.95	-20.2405	-4.419914	0.07448489
2157	22057.61893	22	57.61893286	17.95833333	-17.99982	-4.578835	0.07468923
2158	22057.61893	22	57.61893286	17.96666667	-15.75371	-4.78056	0.07487036
2159	22057.61893	22	57.61893286	17.975	-13.50292	-5.046662	0.07502639
2160	22057.61893	22	57.61893286	17.98333333	-11.24829	-5.416524	0.07515437
2161	22057.61893	22	57.61893286	17.99166667	-8.990855	-5.969979	0.07524779
2162	22057.61893	22	57.61893286	18	-6.732099	-6.896197	0.07529187
2163	22057.61893	22	57.61893286	18.00833333	-4.475046	-8.772295	0.0752351
2164	22057.61893	22	57.61893286	18.01666667	-2.232065	-14.52083	0.07476604
2165	22057.61893	22	57.61893286	18.025	-0.4558382	-102.8854	0.05920756
2166	22057.61893	22	57.61893286	18.03333333	-2.389129	-171.6483	0.06444304
2167	22057.61893	22	57.61893286	18.04166667	-4.633986	-176.4111	0.07482857
2168	22057.61893	22	57.61893286	18.05	-6.890801	-177.494	0.07522716
2169	22057.61893	22	57.61893286	18.05833333	-9.14878	177.6341	0.07526595
2170	22057.61893	22	57.61893286	18.06666667	-11.40509	177.5272	0.07521038
2171	22057.61893	22	57.61893286	18.075	-13.6583	177.3732	0.07510703
2172	22057.61893	22	57.61893286	18.08333333	-15.90741	177.2219	0.07497022
2173	22057.61893	22	57.61893286	18.09166667	-18.15157	177.0839	0.07480548
2174	22057.61893	22	57.61893286	18.1	-20.39005	176.9596	0.07461593
2175	22057.61893	22	57.61893286	18.10833333	-22.62215	176.847	0.07440338
2176	22057.61893	22	57.61893286	18.11666667	-24.84723	176.7442	0.07416941
2177	22057.61893	22	57.61893286	18.125	-27.06469	176.6491	0.07391523
2178	22057.61893	22	57.61893286	18.13333333	-29.27397	176.5603	0.0736426
2179	22057.61893	22	57.61893286	18.14166667	-31.47452	176.4766	0.07335179
2180	22057.61893	22	57.61893286	18.15	-33.66586	176.397	0.07304465
2181	22057.61893	22	57.61893286	18.15833333	-35.84753	176.321	0.07272211

Window 3
690 secs

Table 4. Sky Track Output (continued)

2339	22057.61893	22	57.61893286	19.475	-46.87717	28.78241	0.06067886
2340	22057.61893	22	57.61893286	19.48333333	-45.07075	29.96323	0.06021398
2341	22057.61893	22	57.61893286	19.49166667	-43.28165	31.25797	0.05963656
2342	22057.61893	22	57.61893286	19.5	-41.51375	32.67993	0.05893008
2343	22057.61893	22	57.61893286	19.50833333	-39.77156	34.24413	0.05807304
2344	22057.61893	22	57.61893286	19.51666667	-38.06029	35.9674	0.05704231
2345	22057.61893	22	57.61893286	19.525	-36.38601	37.8686	0.05580953
2346	22057.61893	22	57.61893286	19.53333333	-34.75575	39.96847	0.05434176
2347	22057.61893	22	57.61893286	19.54166667	-33.17769	42.28959	0.052602
2348	22057.61893	22	57.61893286	19.55	-31.66128	44.85588	0.05054703
2349	22057.61893	22	57.61893286	19.55833333	-30.2174	47.69192	0.0481294
2350	22057.61893	22	57.61893286	19.56666667	-28.85846	50.82151	0.04529794
2351	22057.61893	22	57.61893286	19.575	-27.59846	54.26567	0.0420002
2352	22057.61893	22	57.61893286	19.58333333	-26.45284	58.03985	0.03818709
2353	22057.61893	22	57.61893286	19.59166667	-25.43825	62.15002	0.0338199
2354	22057.61893	22	57.61893286	19.6	-24.57193	66.58858	0.02887726
2355	22057.61893	22	57.61893286	19.60833333	-23.87083	71.32999	0.02336979
2356	22057.61893	22	57.61893286	19.61666667	-23.35045	76.32794	0.01734606
2357	22057.61893	22	57.61893286	19.625	-23.0234	81.51494	0.0109019
2358	22057.61893	22	57.61893286	19.63333333	-22.89806	86.80567	0.004177793
2359	22057.61893	22	57.61893286	19.64166667	-22.97761	92.10423	0.002651596
2360	22057.61893	22	57.61893286	19.65	-23.25956	97.31378	0.009398333
2361	22057.61893	22	57.61893286	19.65833333	-23.73609	102.3466	0.01588434
2362	22057.61893	22	57.61893286	19.66666667	-24.39497	107.1319	0.02196255
2363	22057.61893	22	57.61893286	19.675	-25.22089	111.6197	0.02753086
2364	22057.61893	22	57.61893286	19.68333333	-26.19689	115.7809	0.0325332
2365	22057.61893	22	57.61893286	19.69166667	-27.30554	119.6054	0.03695513
2366	22057.61893	22	57.61893286	19.7	-28.52995	123.0972	0.04081357
2367	22057.61893	22	57.61893286	19.70833333	-29.85435	126.2704	0.0441466
2368	22057.61893	22	57.61893286	19.71666667	-31.26442	129.1454	0.04700228
2369	22057.61893	22	57.61893286	19.725	-32.74743	131.7459	0.0494339
2370	22057.61893	22	57.61893286	19.73333333	-34.29223	134.0964	0.0514932
2371	22057.61893	22	57.61893286	19.74166667	-35.88911	136.2212	0.05322952
2372	22057.61893	22	57.61893286	19.75	-37.52969	138.1433	0.05468597
2373	22057.61893	22	57.61893286	19.75833333	-39.20675	139.8838	0.05590184
2374	22057.61893	22	57.61893286	19.76666667	-40.91405	141.462	0.0569102
2375	22057.61893	22	57.61893286	19.775	-42.64628	142.8951	0.05774079
2376	22057.61893	22	57.61893286	19.78333333	-44.39879	144.1985	0.058417

Window 4
270 secs

Table 5. Sky Track Output (continued)

Figure 2 shows the Sky Track display at 29.558 hours while in a mode where the Earth is rotating. This snapshot shows that the dish antenna pitch is -18.15 degs and, accordingly, able to monitor TDRS 9. For further information, a dish yaw of 0 degs implies that the dish azimuth is facing in the forward movement of the ISS. A -7.59 deg yaw indicates the dish antenna is turned counterclockwise 7.59 degs from forward movement of the ISS and a pitch of -18.15 degs implies that the dish is tilted down by 18.15 degs from zenith to directly point at TDRS 9.

Figure 3 shows the Sky Track display at 29.550 hours while in a mode where the Earth is not moving, or stationary. The green path drawn from the ISS parabolic dish to TDRS 9 indicates that the dish antenna is able to point directly at TDRS 9 for best reception with yaw of -6.44 degs and pitch of -20.36 degs. More specifically, the dish antenna is turned in azimuth counterclockwise by 6.44 degs from ISS forward movement and tilted down from zenith (zenith implies straight up from ISS) by 20.36 degs. If the pitch had been greater than 25 degs tilted down from Zenith (or -25 degs) for example and consequently beyond the movement range of the antenna, the path would have been shown in red.

Figure 4 shows a close up view of the Sky Track display at 29.600 hours with the Earth not moving. The yellow dots show the ISS orbital tracks about the Earth over the time period. This is the typical view shown in literature illustrated with Figure 5 and serves to provide a "sanity check" on the validity of Sky Track.

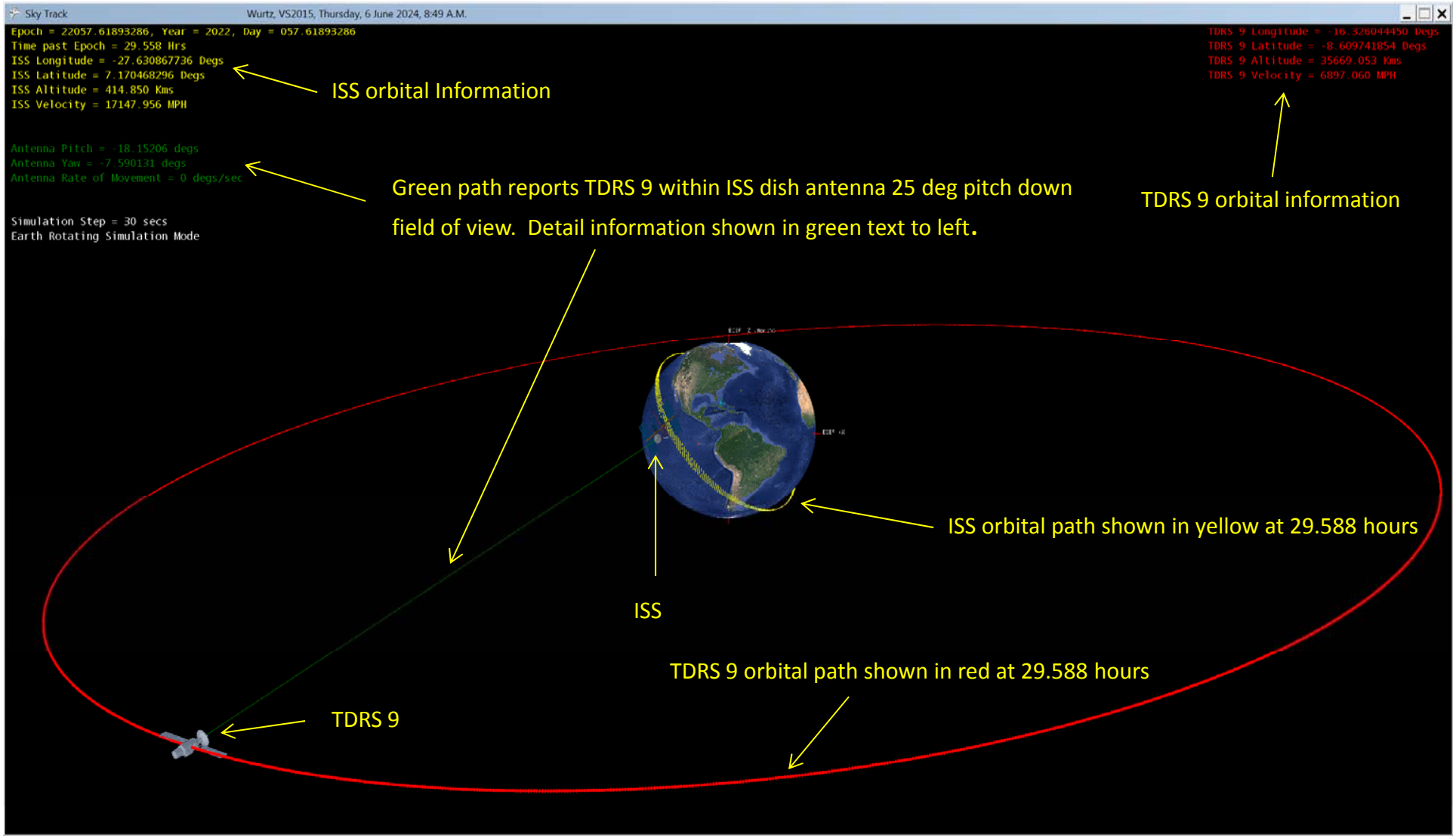

Figure 2. Sky Track in Earth Rotating Mode with TDRS 9 Orbital Path at 29.588 Hours

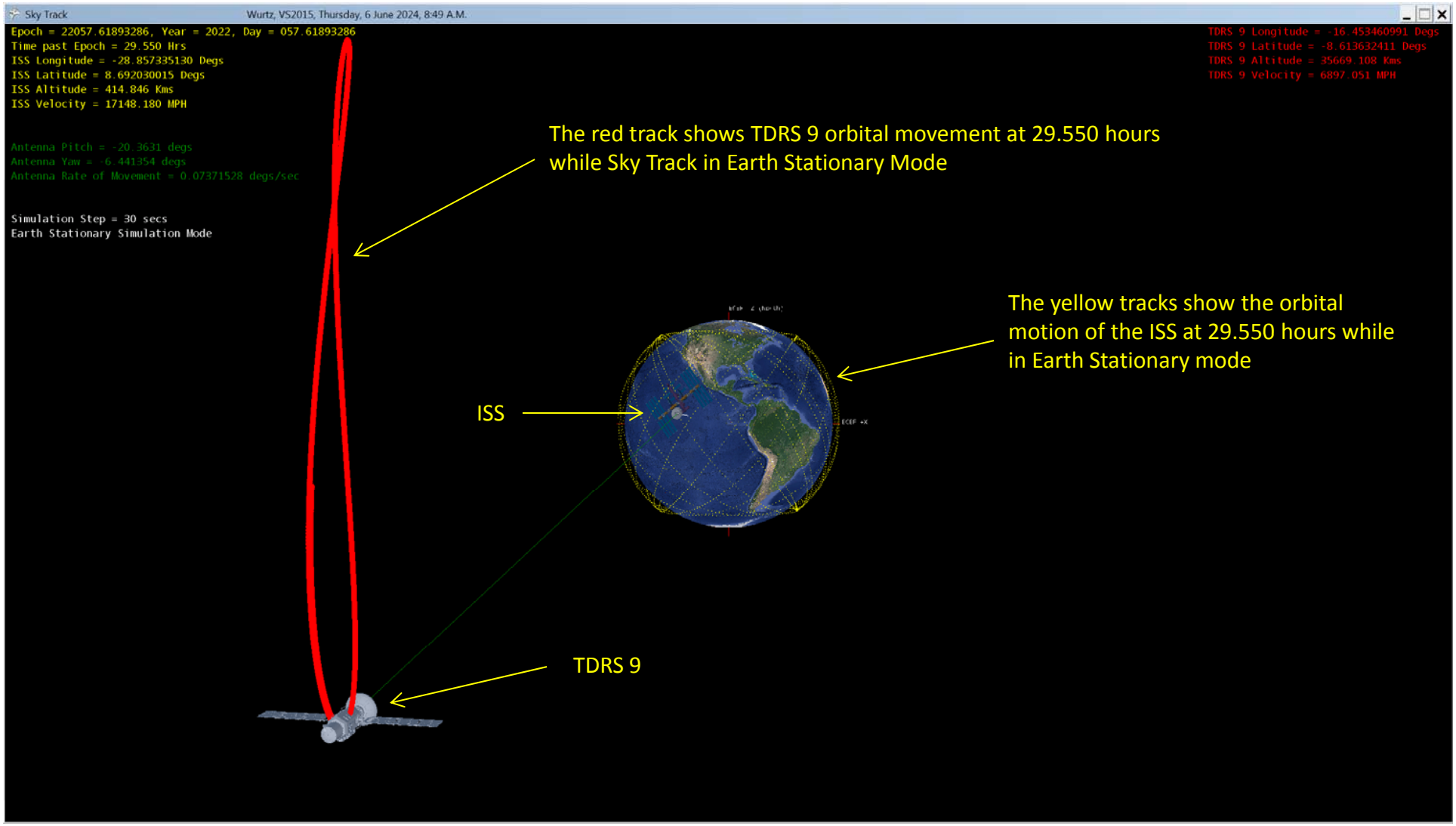

Figure 3. Sky Track in Earth Stationary Mode showing the TDRS 9 Orbital Path at 29.550 hours

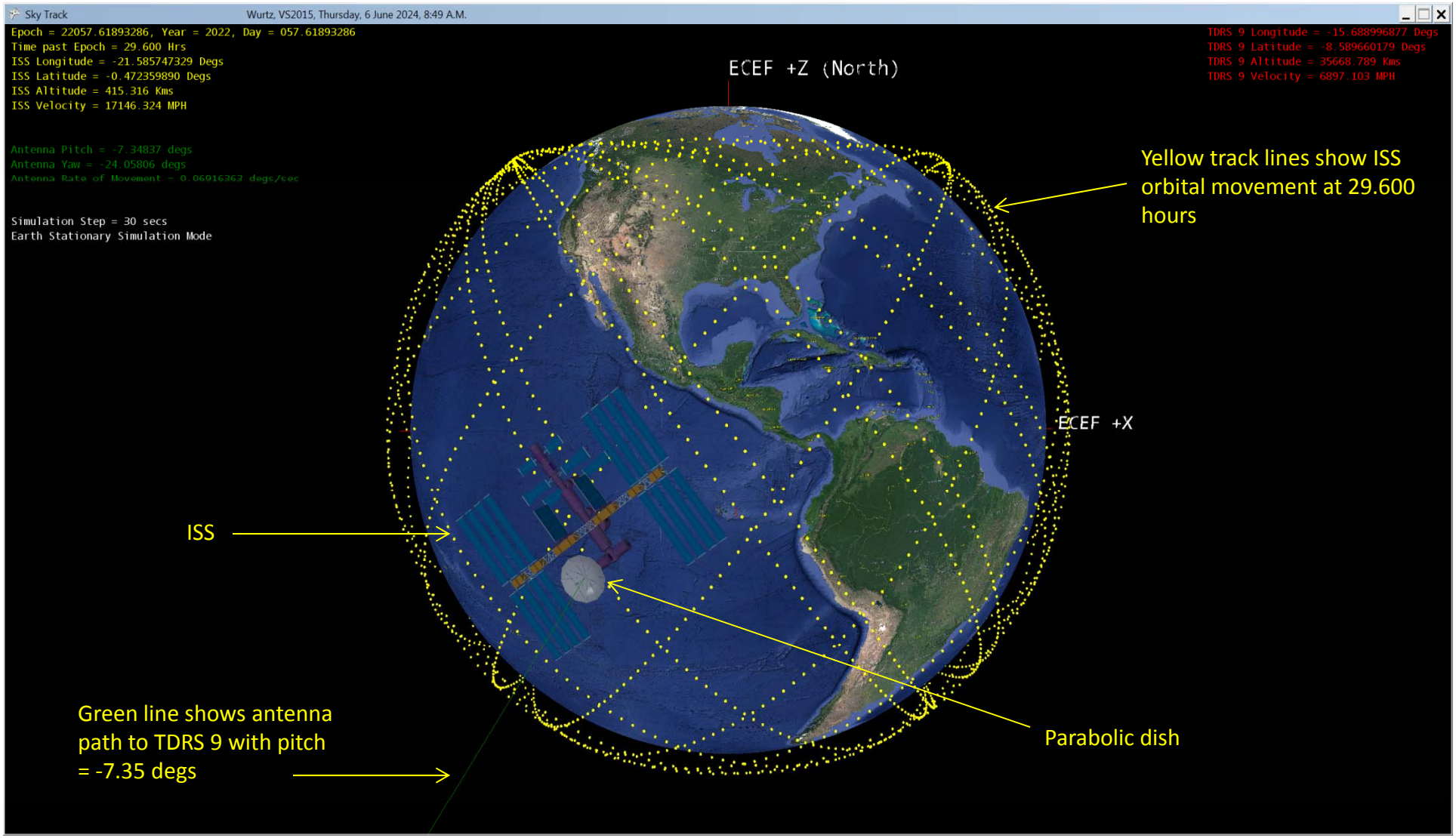

Figure 4. Close up view of Sky Track display in Earth Stationary Mode at 29.600 hours

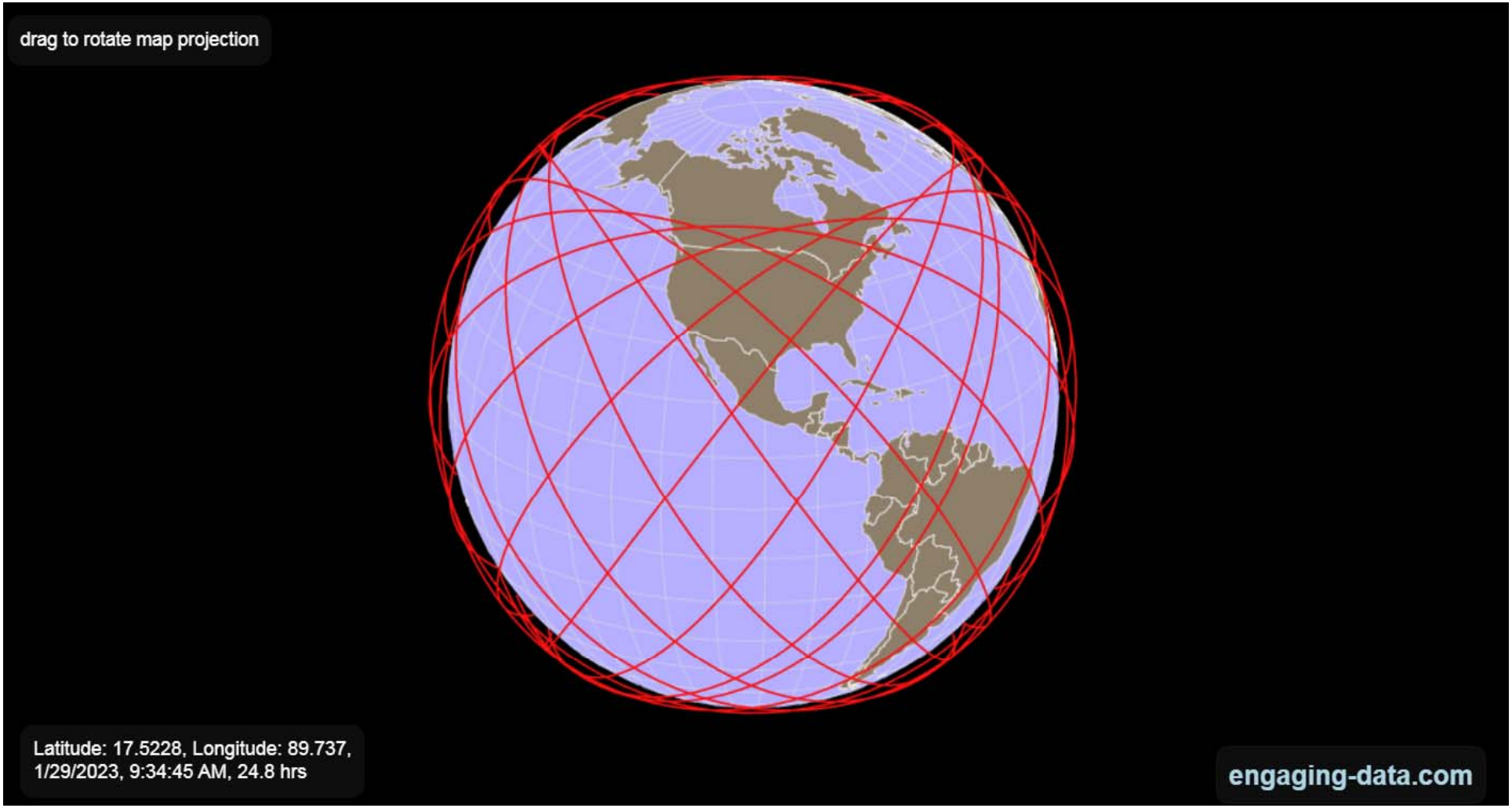

Figure 5. View of ISS Orbital Movement from "engaging-data.com" source

Additional Personal Notes

- **High resolution .WMV and .MP4 video files available documenting Sky Track simulation displays for each 30 sec simulation step.**