"Feeling" Orbital Mechanics

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We all intellectually "know" our orbital mechanics models "work", because we design space rendezvous profiles and astronauts actually carry them out successfully. But I recently had an opportunity to instinctively "feel" orbital at work, and I'd like to share the sensations.

Monday, September 4, 1995, was the second day of flight of the Russian Soyuz TM-22 spacecraft, its three man crew on its way to a 135-day mission aboard the Mir space station. Just by chance here in the Houston area we had a perfect Mir visibility pass northwest to southeast right overhead, at 8:28 PM. Skies were clear, and there looked to be a good chance to see not only the Mir but the pursuing Soyuz.

Guesstimating how far behind Mir to look was a challenge since Soyuz launches about an hour after the Mir flies over the launch site, and takes about 31 revs to make rendezvous, a catch-up rate of 2 minutes per rev is a good SWAG. Since the Houston flyover was going to occur about 6 revs before the rendezvous, the Soyuz would be significantly behind Mir, by about 12 minutes.

I set up camp in a neighbor's back yard, with some old rugs on the grass to lie on, in a shaded spot out of the glare of artificial lights. There were three or four of us making the attempt. Sure enough, Mir went by right on schedule, spectacularly bright with all the latest solar panels deployed, the brightest object in the sky besides the moon. Then our visual hunt began for the Soyuz.

Now, it's easy enough to make "back of the envelope" SWAGs of where Soyuz would appear. From previous experience I knew the basics: Earth's eastward rotation was carrying us out from under the Mir's orbital plane, so when Soyuz appeared, it should be along a path apparently parallel to Mir's, but displaced to the west. Earth rotates at 1000 mph at the equator, or about 700 mph at 30 degrees N, so in 12 minutes we'd be carried about 140-150 miles eastwards. That wasn't purely out-of-plane motion since the Mir ground track's azimuth across Houston was about 135 degrees (NW to SE). Again, roughing it with sines and cosines, I figured we'd be about a hundred miles farther away from the orbital plane. Since the Mir and Soyuz flew up around 200 miles altitude, our 100 mile horizontal physical displacement would lead to a substantial angular line-of-sight displacement. Or so the back-of-the-envelope theoretical guesstimating indicated.

Unfortunately, viewing any satellite in the western sky in the evening is a challenge, because its sunlit side is its western side,

and that is facing away from you. Also, this particular evening. toward the south, the moon was back-lighting some high cirrus clouds, creating a dappled visual camouflage for the sought-for Soyuz to hide behind. And Soyuz is physically much smaller than Mir. So we didn't even know if it could be done.

But we did it. Fourteen minutes after Mir's passage, at the point we were ready to give up, we spotted the Soyuz. As expected, it was dim, no brighter than the North Star, but it was fast, clearly faster than the Mir (or so it seemed). Although its actual orbital speed was truly faster than Mir's, the perceived higher angular rate was mainly a parallax effect of its lower altitude, or so my calculations told me. But a seat-of-the-pants perception of its cosmic chase across the sky told me it was just plain fast.

What was most thrilling was its track's displacement to the west, by about 30 degrees just as I'd guessed from rules of thumb. as the Soyuz zipped across the sky, above some trees, and into the moonlet cloud cover, I forced myself to "feel" its track and Mir's earlier track as defining a reference plane, stable in inertial space. With my back touching the solid Earth, I "felt" it moving, I suddenly "felt" the solid ground had slipped away to the east with me - and everyone else -- on it. Orbital planes and rotating Earth, inertial and geocentric frames of reference, overtaking rates as functions of delta altitude -- al1 these intellectual concepts that we manipulate so easily during the day became solid reality that evening. I had always "known" they were true, but once again I'd had to "feel" their truth with my own senses.

Such visual opportunities are rare but worth pursuing. I've watched satellites for 20 years in the Houston area and have seen only one other Russian rendezvous sequence (a few other opportunities were clouded out). Sometimes new launches include a payload and a tumbling, flashing booster 5, 10, or 20 minutes ahead of it. Orbiter flights with free-fliers usually involve smaller separations, although we just missed a chance to see STS-71 chasing Mir last June. Newer opportunities ought to be more frequent. It's a sight to see, with its particular insights for orbital mechanicians like us!