The origins of amateur radio satellites

From Sputnik to the Keplerian elements

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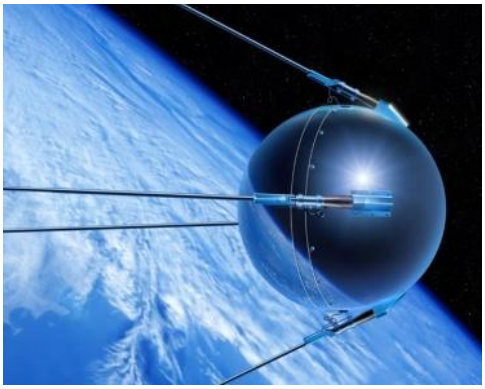
On 4 October 1957, shortly before midnight Moscow time, a metal sphere 58 centimetres in diameter left Baikonur, on the Kazakh steppe, aboard an R-7 rocket. A few minutes later, on 20 and 40 MHz, a simple beep-beep was picked up by hundreds of radio amateurs across the world. Sputnik 1 had just been born, and with it the idea - still distant - that satellites might one day be designed specifically for our service.

Before operating via satellite, it is worth understanding where the adventure comes from. This article retraces the history of the pioneers and presents the physical notions that allow an artificial object to keep turning above our heads. Practical operating in 2026 is the subject of a separate article, «Operating via satellite in 2026 - a practical beginner's guide».

1. Sputnik 1: the night the sky tipped over

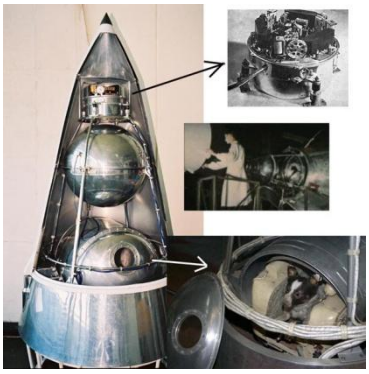
On 4 October 1957, the Baikonur cosmodrome witnessed the first successful launch of an artificial object into orbit around the Earth. Designed by Sergei Korolev's team, the sphere weighed 83 kg and circled our planet in an elliptical orbit ranging from 230 to 950 km in altitude, with a period of about 98 minutes. Its polished aluminum structure reflected enough light that it could be observed with the naked eye just before dawn and just after dusk.



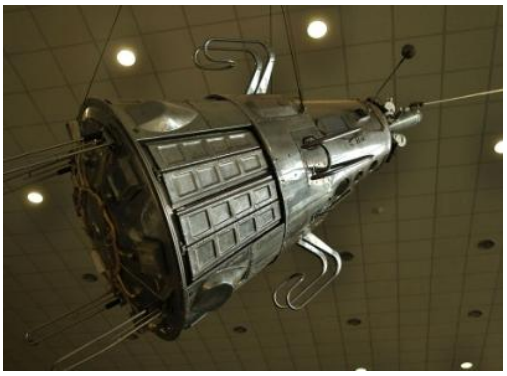
Sputnik 1

The genius of the Soviet design lay less in performance than in simplicity. Sputnik 1 carried two transmitters powered by three silver-zinc batteries, which over 22 days produced the famous alternating signal on 20.005 MHz and 40.002 MHz daily - frequencies carefully chosen to be receivable everywhere on the planet by amateurs equipped with classic HF receivers. In its own way, Sputnik was the first planetary-scale radio propaganda programme: you only had to listen to understand that something had just changed.

Less than a month later, on 3 November 1957, Sputnik 2 carried the dog Laika. The satellite this time weighed 508 kg; it was operational for only seven hours before the thermal system failed - Laika did not survive the launch. On 15 May 1958, after a first failure on 3 February, Sputnik 3 finally carried a Geiger counter which helped to map the Van Allen radiation belt, identified a few months earlier by the Americans.



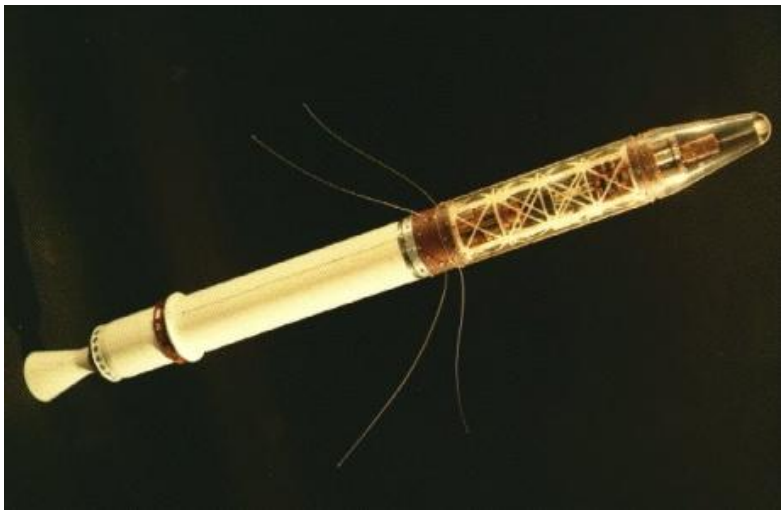
Sputnik 2



Sputnik 3

2. Explorer 1: the American response

On 1 February 1958, from Cape Canaveral, the United States launched Explorer 1, the first response to the Soviet lead. With its 13.97 kg, of which 8.3 kg of onboard scientific instrumentation - batteries included - the satellite was a dwarf compared with its Soviet cousins. Its orbit was more elongated: perigee at 358 km, apogee at 2,550 km, period of 114.8 minutes. The beacon transmitted on 108 MHz, a frequency that would soon yield precious information: it was Explorer 1 that confirmed the existence of the radiation belts suspected by James Van Allen.



Explorer 1

The gap between Sputnik and Explorer is more than a matter of altitude or mass: it is the whole spirit of an era. Where the Soviet Sputnik sought mass effect and political demonstration, Explorer sought scientific data. Radio amateurs would find their account in both approaches - the first democratising the listening of the sky, the second stimulating technical curiosity.

3. OSCAR 1: birth of the amateur radio satellite

It was on 12 December 1961, from the Vandenberg Air Force Base in California, that the true ancestor of all our current satellites appeared: OSCAR 1, launched as a passenger of a Discoverer XXXVI. The OSCAR acronym for **O**rbiting **S**atellite **C**arrying **A**mateur **R**adio - would give its name to the whole lineage.

For the first time, radio amateurs had designed, built and had their own satellite launched. The numbers are modest: 900 grams, a single 140 mW CW beacon transmitting «HI HI» on 144.983 MHz, an in-orbit lifetime of 22 days. But the impact was immense: more than 600 listening reports reached AMSAT (Radio Amateur Satellite Corporation) from 28 countries.

Oscar 1

Through the decades 92 OSCAR satellites would follow, some simple beacons, others equipped with sophisticated transponders. Even today, the OSCAR numbering remains authoritative: a satellite receives its number when it is put into service and recognised by AMSAT-NA. AO-7 (1974), QO-100 (2018), IO-117 (2022) are direct heirs.

4. RS-10/11 and RS-12/13: the Soviet golden age

For many old hands, the real beginnings were those of the Radio Sputnik RS-10/11 and RS-12/13, in service in the 1980s and 1990s. Their principle was elegantly simple: VHF uplink (145 MHz), 10-metre downlink (29 MHz). Mode A, as it was called, allowed modestly equipped stations - a simple quarter-wave VHF antenna, a decametric dipole - to establish QSOs in SSB or CW via satellite. Many operators saw their logbooks fill with hundreds of satellite QSOs thanks to this generation.

RS3

RS10

It was the era when one had to enter the Keplerian elements manually into software like InstantTrack to compute the next passes above Ronse or Brussels. These elements arrived via AMSAT bulletin or BBS packet, in the form of two mysterious lines (TLE, Two-Line Elements). The arrival of the internet, the Celestrak servers and later the AMSAT live status would radically change the picture.

5. Why Newton and Kepler still concern us

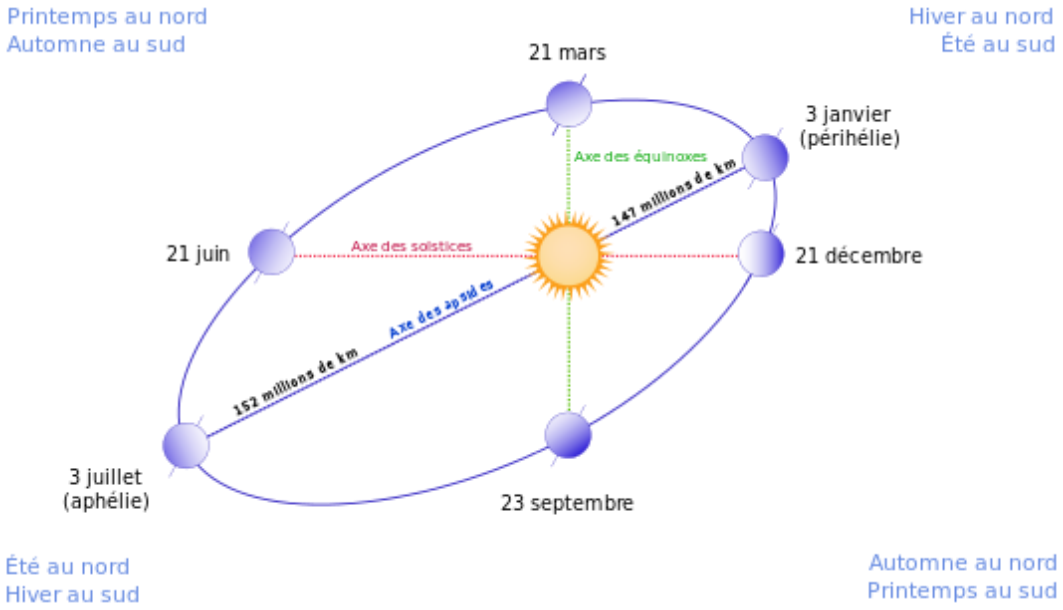
A satellite, whether natural like the Moon or artificial like our OSCARs, obeys the same universal laws. These laws were formulated in two stages. Johannes Kepler (1571-1630) discovered empirically, from the meticulous observations of Tycho Brahe, the three mathematical relations that govern planetary motion. Isaac Newton (1643-1727) then demonstrated that these relations followed from a deeper principle: the law of universal gravitation.

This law fits in a single sentence, which one must know: any two bodies attract each other in direct proportion to the product of their masses and in inverse proportion to the square of the distance between their centres of gravity. It is this law that keeps our feet on the ground, that produces the tides, that maintains the Moon around the Earth - and that prevents AO-7 from drifting into space fifty-one years after its launch.

For a satellite in stable orbit, the equilibrium is subtle: its translational velocity gives it a trajectory that «continuously misses» the Earth, exactly at the rate at which gravity pulls it towards us. If it were slower, it would crash; faster, it would escape. This equilibrium speed depends on altitude - about 28,000 km/h in low orbit (LEO, around 400 km), a little under 11,000 km/h in geostationary orbit (GEO, at 36,000 km).

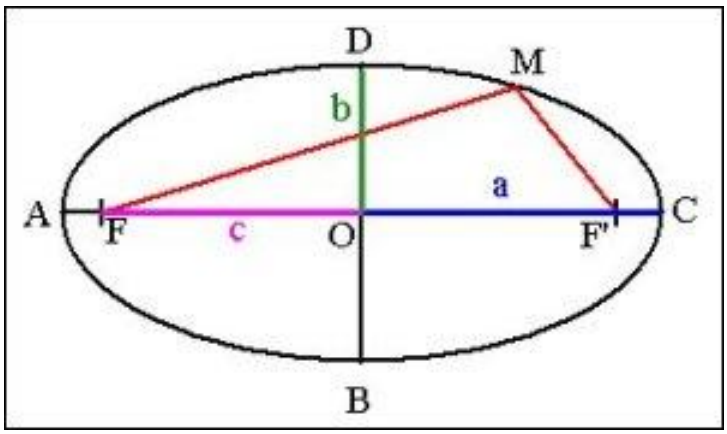
6. Kepler's three laws

First law - each planet describes an ellipse with the Sun occupying one of the foci. For our artificial satellites, it is the Earth that occupies that focus. The orbit can be very close to a circle (circular orbit, like that of the International Space Station at about 400 km constant altitude) or very elongated (elliptical orbit, as was that of OSCAR 13 with a perigee at 1,500 km and an apogee at 36,000 km).



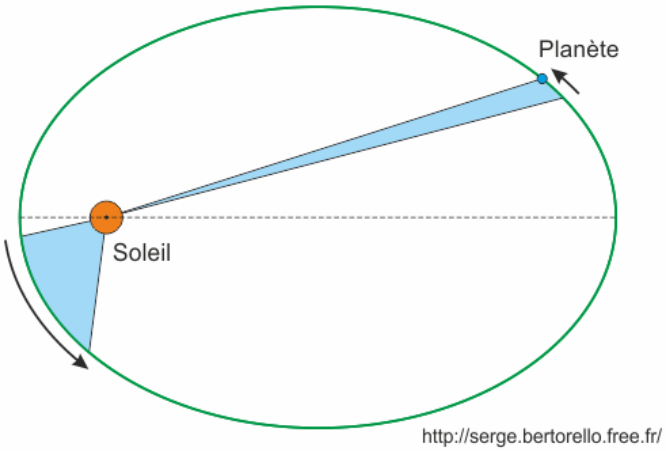
Position of the earth and the sun

The eccentricity of an orbit is calculated with the formula **e = c / a**, where **c** is the distance between the centre of the ellipse and one of its foci, and **a** the length of the semi-major axis. For a perfect circle, c = 0 and thus e = 0. For Earth's orbit around the Sun, with a major axis of 299 million km (152 + 147 million km), the eccentricity is barely 0.0068 - in other words almost a circle. At the other extreme, a very elongated ellipse can reach an eccentricity of 0.7 or more.



Geometric representation of the first law

Second law - the radius vector of the planet sweeps out equal areas in equal times. That sounds abstract, but the practical consequence is essential for the radio amateur: the satellite's speed varies along its orbit. At apogee, the farthest point, it moves slowly and remains visible for a long time. At perigee, the closest point, it streaks past and passes in a few minutes. For elliptical satellites like OSCAR 13 was, traffic was therefore preferred at apogee: long passes of several hours, antennas hardly needing to track.



Geometric representation of the first law

Third law - the square of a planet's orbital period is proportional to the cube of the semi-major axis of its orbit. In modern notation: $T^2 = k \times a^3$, where k is a constant depending only on the mass of the central body. It is this law that allows, knowing only the period of a satellite, to deduce its mean altitude.

7. Practical verification: is T^2 / SMA^3 really constant?

To verify that all this works, let us take three well-known satellites with very different orbits: RS-10 (low circular orbit), RS-15 (medium circular orbit) and OSCAR 13 (very elliptical orbit). For each, we compute from the Mean Motion (number of revolutions per day) the period T in minutes, then relate the square of the period to the cube of the semi-major axis (Semi-Major Axis).

For RS-10, the Mean Motion is 13.72 rev/day, giving a period of 104.9 minutes (24 h divided by 13.72 gives 1.75 h, i.e. 60 + 44.9 minutes). The SMA is 7,369 km. We obtain T^2 / SMA^3 = 104.9^2 / $7{,}369^3$ ≈ 11,004 / 400.2 billion ≈ 2.7497×10^{-8}.

For RS-15, the Mean Motion is 11.28 rev/day, giving 127.7 minutes for one orbit, with an SMA of 8,401 km. The ratio T^2 / SMA^3 gives 16,307 / 592.9 billion ≈ 2.7506×10^{-8}.

For OSCAR 13, which was on a highly elliptical Molniya orbit, the Mean Motion is only 2.10 rev/day, that is a period of 686.6 minutes (more than 11 hours!). The SMA, which is the average of the distances at perigee and apogee, is 25,781 km. The ratio T^2 / SMA^3 gives 471,420 / 17,135 billion ≈ 2.7512×10^{-8}.

QED: the constant is the same to within 0.1%. Three satellites in radically different orbits, and yet an identical ratio between the square of the period and the cube of the semi-major axis. The Kepler-Newton law still holds, nearly four centuries after its formulation.

8. The Keplerian elements: the identity card of an orbit

To fully describe a satellite's orbit, seven parameters suffice (six orbital elements and a timestamp), supplemented by an atmospheric drag term for low orbits. These «Keplerian elements» - keps to those in the know - are traditionally presented in the form of two lines (Two-Line Elements, TLE), a format developed by NASA in the 1960s and still in use today.

The essential parameters found in any tracking software are the following:

– Epoch time - the reference instant for which the elements are valid

– Mean motion - the number of revolutions per day

– Semi-major axis (SMA) - the semi-major axis of the ellipse

– Eccentricity - the eccentricity of the ellipse (between 0 and 1)

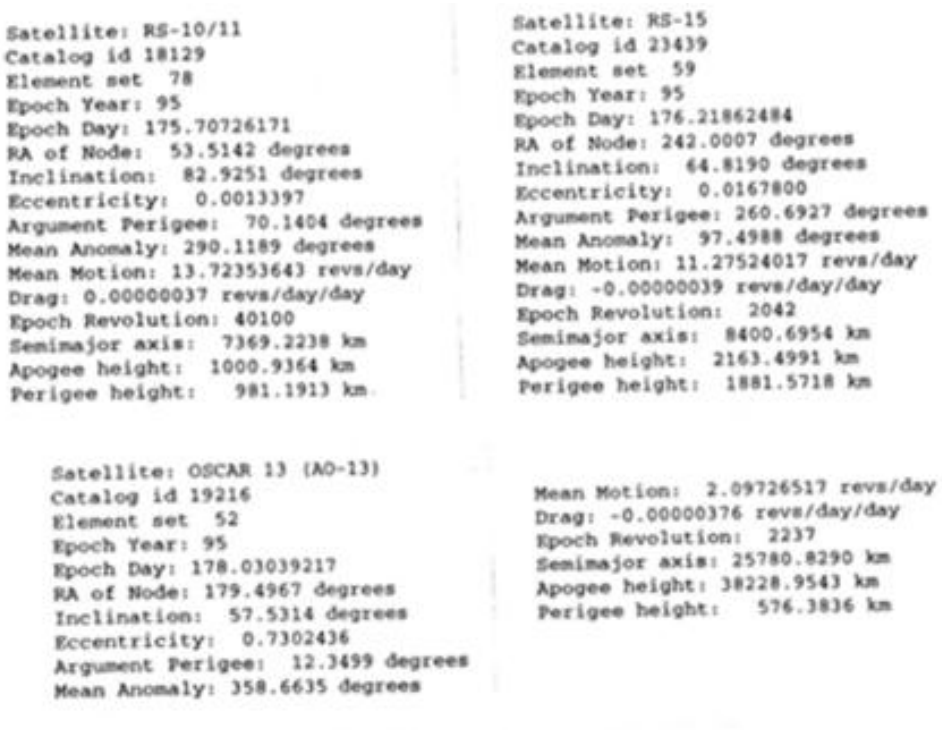
– Inclination - the angle between the orbital plane and the Earth's equator

– Right Ascension of Ascending Node (RAAN) - the right ascension of the ascending node

– Argument of perigee - the angular position of the perigee on the orbit

– Mean anomaly - the angular position of the satellite at the reference instant

In the heroic era, these values were entered by hand into the tracking software, from AMSAT bulletins received by packet or fax. Today, GPredict, SatPC32, Look4Sat and their competitors automatically download the keps, updated daily on Celestrak or amsat.org. One can therefore forget the mechanics, but understanding what lies behind them remains useful: if one of these values seems absurd to you, chances are your predictions will be too.



TLAs

Meaning of the TLAs from the image above:

RS10:

Mean Motion : 13,72353643 (rv/day)
24 H / 13.72353643 = 1.74882036583 (period of one orbit)
60 min + 44,9292219498 (60*0,74882036583) min = 104,9 min.
S.M.A. 7.369,2238 Km MA => X2 = 14.738,4476 KM (X 3,14 = 46.278,725464 KM ….OK !)
T^2 / MA^3 = $104,9^2$ = 11,004.01 and MA^3 = $7.369,2238^3$ = 400.189.083.987
11.004,01 / 400.189.083.987= 2,7497026881316585^{e}-8 =0,00000002749702688131658 5

RS15:

Mean Motion : 11,27524017 (rv/day)
24 H / 11.27524017 = 2.12855776357 (period of one orbit)
120 min + 7,7134658142 min (60*0,12855776357) = 127,7 min.
S.M.A. 8400,6954 Km MA = X2 = 16.801,3908 KM (X 3,14 = 52.756,367112 KM ….OK !)
T^2 / MA^3 = $127,7^2$ = 16,307.29 and MA^3 = $8.400,6954^3$ = 592.851.214.458,5817
16.307,29 / 592.851.214.458,5817 = 2,7506547346609638 e-8=
0,00000002750654734660963 8

OSCAR 13:

Mean Motion : 2,09726517 (rv/day)
24 H / 2.09726517 = 11.4434742651 (period of one orbit)
660 min + 26,608455906 min (60*0,4434742651) = 686,6 min.
S.M.A. 25.780,8290 Km MA = X2 = 51.561,658 KM (X 3,14 = 161. 903,60612 KM ….OK !)
T^2 / MA^3 = $686,6^2$ = 471,419.56 and MA^3 = $25.780,8290^3$ =17.135.257.486.242,591

471.419,56 / 17.135.257.486.242,591=2,7511670622894886^{e}-8
=0,00000002751167062289488 6

9. And today?

The early years of amateur radio satellites were those of studious listening, of manual calculation, of CW decoding. Sixty-five years after OSCAR 1, the scene has changed: a Belgian radio amateur today has at hand a geostationary transponder (QO-100), a dozen linear-transponder satellites, FM repeaters in the sky, a digipeater (GreenCube), regular opportunities to contact the International Space Station. And all of this from equipment at a much more modest cost than in the heroic era.

But before setting up a station, one must know which satellites really work, how to catch them, and what pitfalls to avoid. That is the whole subject of the companion article, «Operating via satellite in 2026 - a practical beginner's guide», which takes over from here, addressed to the OM who is concretely wondering how to begin.

The Keplerian elements in three languages

For OMs who consult international documentation, here is the correspondence of the essential terms in the three languages of the club.

English	**Français**	**Nederlands**
Epoch time	Époque	Tijdstip
Mean motion	Mouvement moyen	Gemiddelde beweging
Semi-Major Axis (SMA)	Demi-grand axe	Halve grote as
Mean Anomaly	Anomalie moyenne	Gemiddelde anomalie
Right Ascension of Ascending Node	Ascension droite du nœud ascendant	Rechte klimming van de stijgende knoop
Argument of perigee	Argument du périgée	Argument van het perigeum
Eccentricity	Excentricité	Uitrekking
Inclination	Inclinaison	Inclinatie
Epoch revolution	Nombre de révolutions	Aantal omlopen
Decay rate	Terme de freinage	Weerstandsfactor