RTT TECHNOLOGY TOPIC
November 2021

Orbital Value

RTT technology topics over the past few months have looked at the relative value of RF and optical assets over time and the relative value of terrestrial and non-terrestrial assets.

For both the terrestrial and space sector, RF assets are essentially radio spectrum and the radio infrastructure needed to support that spectrum.

The spectrum assets of terrestrial operators have well established valuation criteria determined on a country by country basis by auctions which have come to dominate the spectral allocation process. In space, spectrum assets for example in L Band, C band, X band, Ku and Ka and V band have traditionally been awarded on the basis of launch and build commitments.

A major difference is that radio spectrum in space is allocated globally by company rather than country. Another major difference is that RF and now optical asset value in space is directly coupled to GSO, MEO and LEO orbit rights. In this month's technology topic we explore the theory and practice of orbit analysis and the ways in which new orbits are opening up new market opportunity.

Read on

Added value from space is a product of available bandwidth (RF and optical) and orbital assets and can be assessed on the basis of economic gains across multiple domains including security and defence and social, economic and environmental gain.

Selling space on the basis of environmental gain might seem far-fetched but in practice a rocket launch has a similar carbon footprint to a passenger plane crossing the Atlantic. Applications such as environmental monitoring could therefore potentially deliver a negative carbon footprint over the life of a satellite. In the longer term, optical storage and optical computing in space might become feasible (see August 2021 Technology Topic [Smart Servers from Space)](#).

The valuation methodology of satellites in geostationary and geosynchronous orbit is well established with historic cost and income and risk data as a starting point. For LEO orbits (100 km to 2000 km) and MEO orbits (2000-20,000 kilometers) a larger mix of variables make economic modelling more complex.

On the cost side, the risk of radiation damage and the impact of atmospheric density has to be estimated with both having an impact on network viability.

GSO, MEO and LEO orbits all have some level of radiation exposure with the exposure varying over time depending on the sun cycle and other factors.

The risks per orbit are subtly different. For LEOS and MEOS the risk is from a high concentration of protons in the Inner Van Allen Belt between 1000 and 12,000 kilometres (620 and 7500 miles). The belt can reduce temporarily to 200 miles between Africa and South America (The South Atlantic Anomaly).

The outer Van Allen belt between 30,000 kilometres and 60,000 kilometers has a high concentration of electrons. Either can damage on board electronics and RF hardware. The Globalstar Constellation had a number of RF hardware failures due to a surge of solar activity in 2001. Another Carrington event could take out everything electronic in space.

Atmospheric density is more benign but ultimately determines the life span of every LEO. A Standard model of atmospheric density was established in 1976. The model assumed that density decreased exponentially with altitude but this could be as much as 15% away from actual density due to latitude variations (the earth's oblateness), diurnal variations and the 11 year solar cycle.

Because the Earth's equatorial diameter is approximately 20 km greater than the polar diameter, a satellite in a circular, inclined orbit has a higher altitude at higher latitudes. Satellites will pass through a region of higher density closer to the equator than at higher latitudes.

Diurnal variations are caused by the Earth's rotation. When the side of the Earth exposed to the sun is heated, the atmosphere expands. At a given altitude, density is higher because the atmosphere is pushed up from lower altitudes. At night, the atmosphere cools and contracts and density reduces.

The 11-year solar cycle affects the atmospheric density because the solar radiation varies with time. At the solar maximum, the sun releases more energy and the atmosphere expands as the Earth receives more radiation. All of the above determine the atmospheric drag experienced through the life of a satellite which in turn dictates the life of the satellite and other factors including fuel payload which in turn dictates launch weight and cost.

The complexity of this calculation becomes evident when you apply it to Starlink's present five shell configuration with a first shell of 1440 satellites at 550 km at 53 degree inclination, a second shell of 1440 satellites at 540 km at 53.2 degree inclination, a third shell of 720 satellites at 570 km at 70 degree inclination and two polar shells with 336 satellites at 560 km at 97.6 degrees and 172 satellites at 560 km at 97.6 degrees.

Fortuitously it is now possible to calculate the individual drag experienced by each satellite by using an atmospheric model that gets more accurate over time due to the ability to recalibrate the model from individual GPS coordinates (measuring the position and speed of each satellite through life) but calculating satellite life expectation remains a complex process.

There are plenty of other existential risks in space including collision and/or debris damage which includes the risk of third party litigation if station keeping good practice has not been observed. Rockets can also explode, fail to get to orbit or place satellites in the wrong orbit. The orbit destination determines the amount of launch power needed which in turn determines the size of rocket needed and fuel pay load and cost.

On the income side, economic modelling is equally complex and is determined by multiple factors including ground track, orbit time and synchronicity (sun synchronous orbits pass the same place at the same time every day). Orbit height and inclination determines latency and the link budget (flux density) which also determines capacity and throughput. Crucially the operator with the largest number of satellites will by definition have the best latency and link budget due to being nearly overhead nearly all the time. The first mover economic advantage that this confers on Starlink is substantial.

Added value is also obviously a product of the payload mix, coupling sub metre multi spectral imaging with GNSS (the high Doppler and flux density of LEO's confers an advantage over MEO

GPS) and connectivity. Adding high accuracy atomic clocks will increase station keeping autonomy but will also support a new generation of super accurate location and positioning services.

There are of course plenty of other orbits to choose from including highly elliptical (Molnya and Tundra) orbits which provide long dwell times over specific geographic areas.

In the longer term, the biggest value gain may potentially come from inter satellite and inter constellation connectivity. Think of a unified space network as a very large electronic circuit in which the Earth acts as a ground plane and you get close to a vision of what global telecommunications might look like in 2045, one hundred years on from that now very famous article in Wireless World*.

Science fiction has a habit of becoming fact but sometimes takes longer than expected.

*Arthur C Clarke article *Extra-Terrestrial Relays* published in the 1945 November issue of *Wireless World*

Ends

For more background on these topics, buy a copy of our latest book

5G and Satellite Spectrum, Standards and Scale

Available from Artech House, you can order a copy on line using the code VAR25 to give you a 25% discount.

http://uk.artechhouse.com/5G-and-Satellite-Spectrum-Standards-and-Scale-P1935.aspx

For information on our South East Asia consultancy services, bespoke research and in house virtual or on site/off site facilitation workshops e-mail **daniel@nichemarketsasia.com**

About RTT Technology Topics

RTT Technology Topics reflect areas of research that we are presently working on. We aim to introduce new terminology and new ideas to help inform present and future technology, engineering, market and business decisions.

The first technology topic (on GPRS design) was produced in August 1998. 22 years on there are over 240 technology topics **archived on the RTT web site**.

Do pass these Technology Topics and related links on to your colleagues, encourage them to join our **Subscriber List** and respond with comments.

Contact RTT

RTT, and **Niche Markets Asia** are presently working on research and forecasting projects in the mobile broadband, public safety radio, satellite and broadcasting industry and related copper, cable and fibre delivery options.

If you would like more information on this work then please contact **geoff@rttonline.com**
00 44 7710 020 040