Q-TECH Corporation — White Paper

Expanding "Spacescape" Impacting Oscillator Selection Criteria

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The vastly increasing number of low earth orbit satellite clusters is changing the traditional rules in the selection of high-performance crystal oscillators; New Space oscillators offer a lower cost, high-reliability solution for LEO clusters

High performance crystal oscillators have been and will remain a mainstay in orbital satellite applications. The spacescape – the range or orbits where satellites reside – is not a uniform environment. Geosynchronous (GEO) and Medium-altitude (MEO) satellites are often valued in the tens or even hundreds of millions of dollars and have a life expectancy of decades. As such, these very expensive systems demand maximum reliability for all components. LEO satellite clusters, in contrast, are made up of hundreds of far less expensive devices with life spans measured in years. In many of these applications, full space-qualified components are unnecessary and far too expensive.

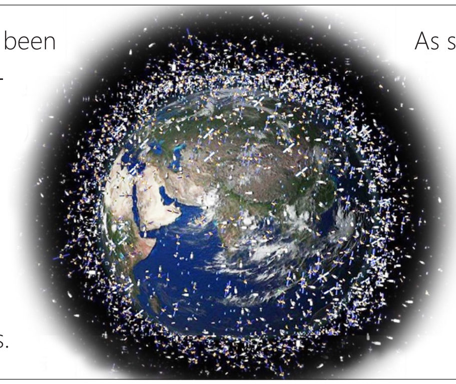

Figure 1. The spacescape is a crowded but not a uniform environment

This paper will delve into the questions of what constitutes a "space-qualified" crystal oscillator and what differences there are based on spacescape location. The paper will also attempt to address the question of the applicability of commercial-off-the-shelf (COTS) crystal oscillators and micro-electromechanical systems (MEMS) oscillators versus New Space crystal oscillators in emerging satellite constellation applications.

The Many Regions in the Spacescape

In a previously published Q-Tech white paper:; "New Space Applications Add to Mix of Space-Qualified Crystal Oscillators [1]," the spacescape is described as having four distinct regions – LEO, MEO, GEO and Deep Space. (Table 1)

Table 1. Typical Applications for Earth-Orbiting Satellites

Orbit	Typical Applications
LEO	Communications, Earth Observation, Research, Imagery, Manned Spaceflight (ISS), Military, Space Observation, Spacecraft Repair, Supply Transport (ISS), and Weather
MEO	Communications, Navigation
GEO	Communications, Earth Observation, Military, Research, Space Exploration, Space Observation, Weather
Deep Space	Exploratory Rover, Manned Spaceflight, Planet Exploration, Space Exploration

Satellite Applications by Orbit

As the distance from earth increases in these regions, the operational specifications and test criteria for electronic components become more stringent. For example, as noted in the afore- mentioned paper:

Solar ionizing radiation exposure increases with the altitude of orbit and the resulting reduction on the atmosphere's ability to absorb/reflect its effects. The ability of a device to withstand the operational performance and expected longevity of operation is determined by the device's ability to withstand a lifetime total ionizing dose (TID). The deeper into space, the higher the TID requirement.

Table 2. Typical ranges for Total Ionizing Dose (TID) based on Orbit

Orbit	Industry Typical	Q-Tech Devices
Deep Space	100 kRad	up to 300kRad+
GEO	100 kRad	100 kRad+
MEO	100 kRad	up to 100kRad
LEO	30 kRad	up to 50 kRad

In the rapidly expanding LEO region, fully qualified "traditional space" components that meet the higher TID and other are demanding requirements (Table 3) to assure long mission operational life are far too expensive.

Table 3. Traditional Space Components

Lower Quantity
Higher cost (up to $200,000 per Custom Device)
Long Mission Life
GEO / MEO Orbits and Deep Space
High Reliability
Full Screening
Long Lead Times (24-52 weeks)
High Radiation Tolerance

Radiation Hardness – TID and SEE

It is estimated that "New Space" clusters of communications satellites will crowd the LEO region with upwards of 50,000 units within the next ten years. Moreover, the life-expectancy of these devices is typically 1-3 years, so the demand for components for these devices will grow to tens of thousands per year. In contrast to "Full Space" components, "New Space" crystal oscillators have different attributes (Table 4).

Table 4. New Space Components

High quantity (constellations)
Lower cost ($60-$500) per device
Short mission life
LEO orbit
Lower-level screening or up-screening
Shorter delivery lead times (12-16 weeks)
Lower SWaP – Size, weight and power
Lower radiation tolerance

Components for LEO satellite constellation applications utilize quartz crystal oscillators in miniature, lightweight packages. These, less expensive "New Space" oscillators use the same high reliability manufacturing processes as full space devices and their performance specs are the same or very similar, though the crystal is typically mounted on only 2 points. They do not require extensive quality control inspection (QCI) which reduces costs and accelerates delivery. Even so, parts must still be fully screened to MIL-PRF-55310, level B plus PIND to verify performance.

Q-Tech Manufacturing and Screening of New Space Oscillators

As noted above, Q-Tech crystal oscillators, regardless of qualification level are manufactured utilizing the same production processes. All of Q-Tech's oscillators are manufactured under strict clean room contamination controls. After oscillator assembly is completed, Q-Tech is able to perform almost all testing in-house. Testing becomes extremely important for applications where the aging characteristics of the oscillator are crucial. A sample list of the tests performed can be found on the next page. (Table 5)

Table 5. New Space Component Test Requirements

Tests performed on Q-Tech New Space oscillators:

Standard Screening Tests per modified MIL-PRF-55310, Level B

• **Temperature Cycling:** MIL-STD-883, Method 1010, Condition B
• **Constant Acceleration:** MIL-STD-883, Method 2001, Condition A, Y1 only (5000 g's)
• **Seal (Fine and Gross Leak):** MIL-STD-883, Method 1014, Condition A1 and C
• **Particle Impact Noise Detection (PIND):** MIL-STD-883, Method 2020, Condition B
• **Burn-in:** MIL-STD-883, Method 1015, +125°C, nominal supply voltage and burn-in load, 160 hours minimum
• **Final Electrical Test:** For Specified Parameters, Nominal and extreme supply voltages, specified load,
+25°C and temperature extremes. PDA = 10% or 1 part
• **External Visual:** MIL-STD-883, Method 2009

Optional Tests

GROUP A per MIL-PRF-55310 Level B

- **Electrical:** Supply Voltage, Input Current, Output Waveform, Rise and Fall Times, Duty Cycle, Start-Up Time, Overvoltage Survivability, and 10-point frequency stability test

GROUP B

- **Ageing:** Oscillator is energized in an oven for a continuous period of 30 days at 70ºC ±3ºC. The Output frequency is measured within an interval of 72 hours maximum per MIL-PRF-55310

Where Do COTS Devices Fit In?

With the pressures of high demand and lower costs, the temptation of resorting to COTS devices is understandable. But, even with the lower life expectancy of these LEO constellation satellites, the costs can be in excess of a million dollars per system. So, saving as little as $50 to use a device not fully tested for space application is a false choice.

At a recent SPACE TECH EXPO webinar [3], Chris Winslett of Lockheed Martin indicated that COTS devices were sometimes considered based on project development schedule and costs. He asked the question, "What's the mission?"

Non fully qualified space components are a useful choice when proving the mission. As Winslett said, "You don't know the whole network until you get assets in orbit."

We are in total agreement. COTS devices that are not certified for flight are an acceptable choice for bench testing and early program development, but in our opinion, simply not for space deployment with the exception of proof of mission.

How About MEMS Oscillators?

In an earlier white paper titled, "Putting Crystal Oscillators in Their Rightful Place [2]," we provided a comparison of Crystal Oscillators vs. MEMS. In our view, as stated in that document, *"...there are an enormous number of applications where MEMS oscillators are the preferred solution. The lower cost and acceptable performance levels make these devices ideal for high-volume consumer products including mobile phones, toys, games, automotive entertainment/navigation systems, to name a few.*

In some aerospace applications, where short-term performance (one and done) is important but long-term stability is not, MEMS might also be considered."

"MEMS technology is making great inroads into oscillator applications where their lower cost offers an attractive solution. But the world of ultra-high reliability is and will remain the realm of the venerable crystal oscillator."

Conclusion

The vast expansion of LEO satellite clusters is driving the demand for low cost yet highly reliable crystal oscillators. New Space components, manufactured using the same processes and materials as full-space qualified components and tested to a restricted but rigorous set of standards provide a cost effective solution without the reliability compromises that would result if COTS or MEMS devices were used.

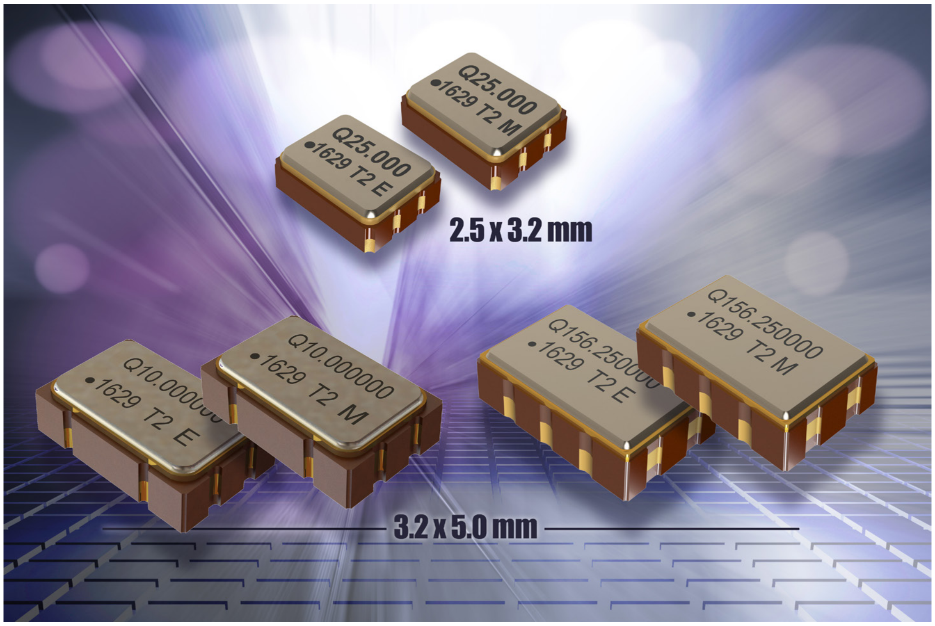

Figure 1. The Q-Tech QT723 and QT735 Series Crystal Oscillators are examples of fully space-qualified components with packaging and performance optimized for LEO satellite clusters.

[1] New Space Applications Add to Mix of Space-Qualified Oscillators, Q-Tech White Paper, July 2020
[2] Putting Crystal Oscillators in Their Rightful Place, Q-Tech White Paper, June 2019
[3] Striking a Balance Between COTS and Custom-Made Space-Grade Components, March 23, 2021