When selecting an amplifier for a critical Space related mission, one must not only account for the effects of changing conditions related to radiation and temperature swings but also be aware of which base transistor metallization would be ideal candidates over other base metal transistors and why.

The effects of the space environment on an amplifier vary drastically depending on the orbital regime, mainly due to differences in radiation exposure, thermal extremes, and vacuum conditions. An amplifier on a satellite in low Earth orbit (LEO), medium Earth orbit (MEO), and deep space will face a unique set of challenges that affect its performance and longevity.

Low Earth Orbit (LEO)

LEO is generally between 60 and 1200 miles in altitude. Even though it is in orbit, a LEO satellite is still protected to some extent by the Earth's far-reaching atmosphere. While the earth's atmosphere as a conventional boundary technically extends out to 62 miles, the atmosphere extends out on a gradually thinning scale to over 300,000 miles (farther than the distance to the moon). At this distance though, it is merely a faint cloud of hydrogen atoms.

Environmental characteristics

- **Thermal Cycling:** Temperature swings from -150°C to +150°C can be experienced by a satellite as it passes in and out of the Earth's shadow. In a LEO orbit, that cycle occurs once every 90 minutes. While Hybrid amplifiers are tested and rated to withstand temperature swings of -55°C to +85°C, without adequate passive heating and ventilation, a low noise amplifier, like any active device, will reach the limits of its own capabilities due to material fatigue, weakening solder joints, and internal bond failures.

- **Radiation:** LEO satellites are somewhat shielded by the Van Allen belts but must continually contend with solar rays, solar energetic particles (SEPs), and the South Atlantic Anomaly (SAA), a region of weak magnetic field where the radiation belt dips closer to the Earth. Long-term TID exposure can, over time, cause a gradual accumulation of charge in the amplifier's transistors. Without shielding, this can increase leakage currents and voltage shifts, eventually leading to performance degradation. SEEs, or single-event effects, of High-energy particles from solar rays or other solar events can pass through the metal upper assembly cover into the KOVAR amplifier package and strike the amplifier's transistors, causing temporary damage, potential emitter shorts, or single-event latch-ups (SELs).

Medium Earth Orbit (MEO)

A satellite orbiting in a MEO is typically found 1,200 miles to 22,000 miles from Earth, where the most intense parts of the Van Allen radiation belts lie. Because MEO satellites orbit farther from Earth, they tend to experience fewer and shorter eclipses than those in low Earth orbits. There are tradeoffs here, of course; a MEO must endure more consistent solar events than a LEO, but also less frequent and less severe thermal cycling.

Environmental characteristics

- **Thermal Cycling:** For a satellite in a MEO, the extreme temperature swings can range from roughly -145°C to +60°C; slightly lower maximum temperatures than a LEO due in part to the earth's reflection contribution in a LEO orbit. Where satellites in a Low Earth Orbit (LEO) experience rapid thermal cycling, of roughly 90 minutes from minimum to maximum, MEO satellites endure slower, but longer exposure to solar thermal stresses due to the average 12-hour orbit cycle.

- **Radiation:** Satellites in a MEO orbit are constantly exposed to the Van Allen belts, which can significantly reduce the transistor's operational lifespan. This makes a MEO orbit one of the more hazardous radiation environments for a satellite. The constant bombardment by high-energy particles onto a circuit's transistors significantly increases the probability of damage within the transistor's metallization layers. To survive an MEO radiation environment, the amplifier's next-level assembly must be heavily shielded with some form of dense shielding; either Tungsten or Tantalum will generally stop high-energy electrons from penetrating the subassembly.

Deep Space

Deep space refers to regions *informally* beyond the moon, which puts it at roughly a 250,000-mile starting point.

Environmental characteristics

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Environmental Hazards

Environmental Hazard	Low Earth Orbit (LEO)	Medium Earth Orbit (MEO)	Deep Space
Primary Radiation	Milder South Atlantic Anomaly (SAA) and occasional solar flares.	Van Allen radiation belts (high proton and electron traffic).	Galactic cosmic rays (GCRs) and unpredictable solar events.
Total Ionizing Dosage (TID)	Cumulative dosage is a concern over the duration or term of the mission.	Higher cumulative dosage requires robust radiation countermeasures.	Continuous, low-level cumulative doses from Galactic cosmic rays (GCRs) over a long mission.
Single Event Effects (SEE)	Occasional exposure, with added SAA passes.	Frequent, due to constant exposure to energetic particles.	Exposure to High-energy Galactic cosmic rays (GCRs) poses a significant risk if unprotected to transistor damage.
Thermal Environment	Frequent and rapid thermal cycling during exposure and non-exposure cycles.	Longer time in direct sunlight, fewer thermal cycles.	Extreme variations between sunlight and deep shadow, with long periods of predicted thermal stress.
Reliability Approach	Manageable through component selection and screening.	Demands significant radiation countermeasures.	Requires the highest effort in radiation countermeasures.