Technical White Paper

IC Sourcing for Space: Pros and Cons of Up-Screening COTS Versus Space Enhanced Products (SEP)

Michael Seidl – Texas Instruments
Frederik Kuechen and Michael Moesken – TESAT Parts Agency

ABSTRACT

This white paper compares COTS up-screening versus space-qualified component sourcing across mission types—LEO constellations, MEO and GEO platforms, deep space, and legacy programs—examining the potential technical, cost, schedule, and risk tradeoffs to provide readers with a practical decision framework for improving component sourcing strategies.

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1 Introduction

The rise of commercial space services is accelerating the launch of low Earth orbit (LEO) constellations, while deep space, MEO (medium Earth orbit), and GEO (geostationary Earth orbit) missions still require the utmost reliability over long lifetimes; designers therefore contend with two opposing goals—minimizing cost versus maximizing reliability—pursued through the new space approach (cost focused LEO constellations) and the traditional space approach (risk focused deep space, MEO and GEO satellites).

Up screening commercial off the shelf (COTS) components can potentially lower bill of materials (BOM) costs for high volume LEO constellations, but the practice creates a distinct risk profile that must be quantified and mitigated. In contrast, space qualified parts deliver deterministic performance in the harsh space environment, often accompanied by proven flight heritage. These parts are typically the only viable option for longer duration missions that cannot tolerate any risk—such as MEO and GEO satellites, which must achieve extended lifetimes to amortize high launch costs and endure increased radiation from permanent proximity to the Van Allen belts—as well as deep space and legacy programs, albeit at a premium price.

The proliferation of mega-constellations (for example, broadband, Earth-observation, IoT) has shifted the economics of space hardware. Unit-mass BOMs that once justified the use of radiation-hardened (rad-hard) parts are now being re-evaluated against high-volume, potential low-cost COTS alternatives. While the *launch-once, fly-forever* mindset still applies to high-value GEO assets, LEO constellations demand rapid design cycles, aggressive price points, and the ability to iterate hardware generations. This white paper addresses the resulting tension between cost efficiency and mission assurance.

It compares the two approaches—COTS up screening versus directly sourcing space qualified components—through the lens of mission type taxonomy (new space LEO constellations, traditional MEO and GEO platforms, deep space probes, and hybrid legacy programs). The paper examines the technical attributes that make an integrated circuit *space ready*, outlines the practical considerations of a screening campaign, and quantifies the potential tradeoffs in cost, schedule, and total cost of ownership.

Key topics include:

- Mission type guidance – How cost, reliability, and lifetime requirements differ among new space LEO constellations, traditional MEO and GEO satellites, deep space probes, and mixed heritage programs.
- Critical screening parameters – Radiation hardness, thermal cycling endurance, outgassing, mechanical shock, and other hazard-specific tests, and how each maps to the hazard analyses defined for a given mission envelope.
- Screening campaign economics – Typical test assets, lot size considerations, engineering effort, and the resulting cost per screened part versus the unit cost of a qualified part.
- Risk mitigation strategies – Redundancy architectures, derating, spare parts pools, and in orbit health monitoring that allow designs based on COTS to meet reliability targets.
- Advantages of space qualified parts – Full characterization for the harsh environment in space with the availability of the corresponding datasheet, heritage flight record, and reduced program level risk for missions where failure cost is prohibitive.
- Lifecycle and total cost of ownership implications – How early component selection decisions affect constellation economics, yield and supply responsibility, upgrade pathways, and obsolescence management.

Readers of this document gain a practical decision framework that aligns component sourcing with a potential specific cost, risk, and schedule constraint of a specific mission class; enabling readers to make informed choices that balance economic efficiency with mission success in the current competitive space market.

2 Space - Electronics Design Landscape

The space-electronics design landscape is shaped by several critical environmental and material factors that must be addressed when selecting components for any mission, whether for a low-cost LEO constellation or a long-duration MEO, GEO, or deep-space probe.

Radiation hardness is highly process-dependent. Even devices fabricated on the same semiconductor node can display vastly different radiation responses because variations in circuit topology and the specific modules used affect susceptibility. In addition, many generalities about radiation tolerance are misleading. While a 65nm process is often considered immune to single-event latch-up (SEL), that immunity applies only to the low-voltage

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(≅1.1V and below) circuits. If a product incorporates higher-voltage blocks, those sections are more likely to be susceptible to SEL . Moreover, the presence of an epitaxial (epi) or silicon-on-insulator (SOI) substrate does not automatically guarantee SEL immunity for a CMOS device. For most CMOS products, an epi substrate has little effect on SEL susceptibility, and SOI provides SEL protection only when the field oxide (shallow trench isolation) extends completely through the active layer down to the buried oxide 1. Moreover, radiation hardness is not a standard control parameter in wafer fabs. Small changes in passivation thickness or stoichiometry between lots can cause dramatic shifts in total-ionizing-dose (TID) tolerance; one lot might survive 100krad (Si) while another from the same fab fails at just 10krad (Si). Consequently, radiation lot acceptance testing (RLAT) is essential for any part destined for space. Reliable qualification therefore demands a comprehensive testing regime that includes heavy-ion testing for single-event effects (SEE), displacement-damage (DD) testing, and total ionizing dose (TID) testing to characterize cumulative dose performance.

Temperature extremes pose another major challenge. Spacecraft encounter wide temperature swings, requiring a design envelope of roughly –55°C to +125°C for robust operation. This range is far broader than the typical commercial (0°C to +70°C) or automotive Grade 3 (–40°C to +85°C) standards. Many COTS and automotive parts are only guaranteed within the limited commercial limits, so components must be assessed across the full temperature span for reliable performance in space.

Tin-whisker risk arises from the pure-tin (Sn) terminations that are common on many cost-sensitive COTS and automotive devices (Figure 2-1). Under the thermal-mechanical stresses of space, tin whiskers can grow, leading to short circuits between adjacent pins or to intermittent shorts when whiskers break off and contact other circuitry. Although conformal coatings provide some mitigation, these coatings do not eliminate the risk. Reliable space designs therefore avoid pure-tin finishes and instead use Sn-Pb alloy, nickel-palladium-gold (Ni-Pd-Au) plating, or similar terminations that suppress whisker formation.

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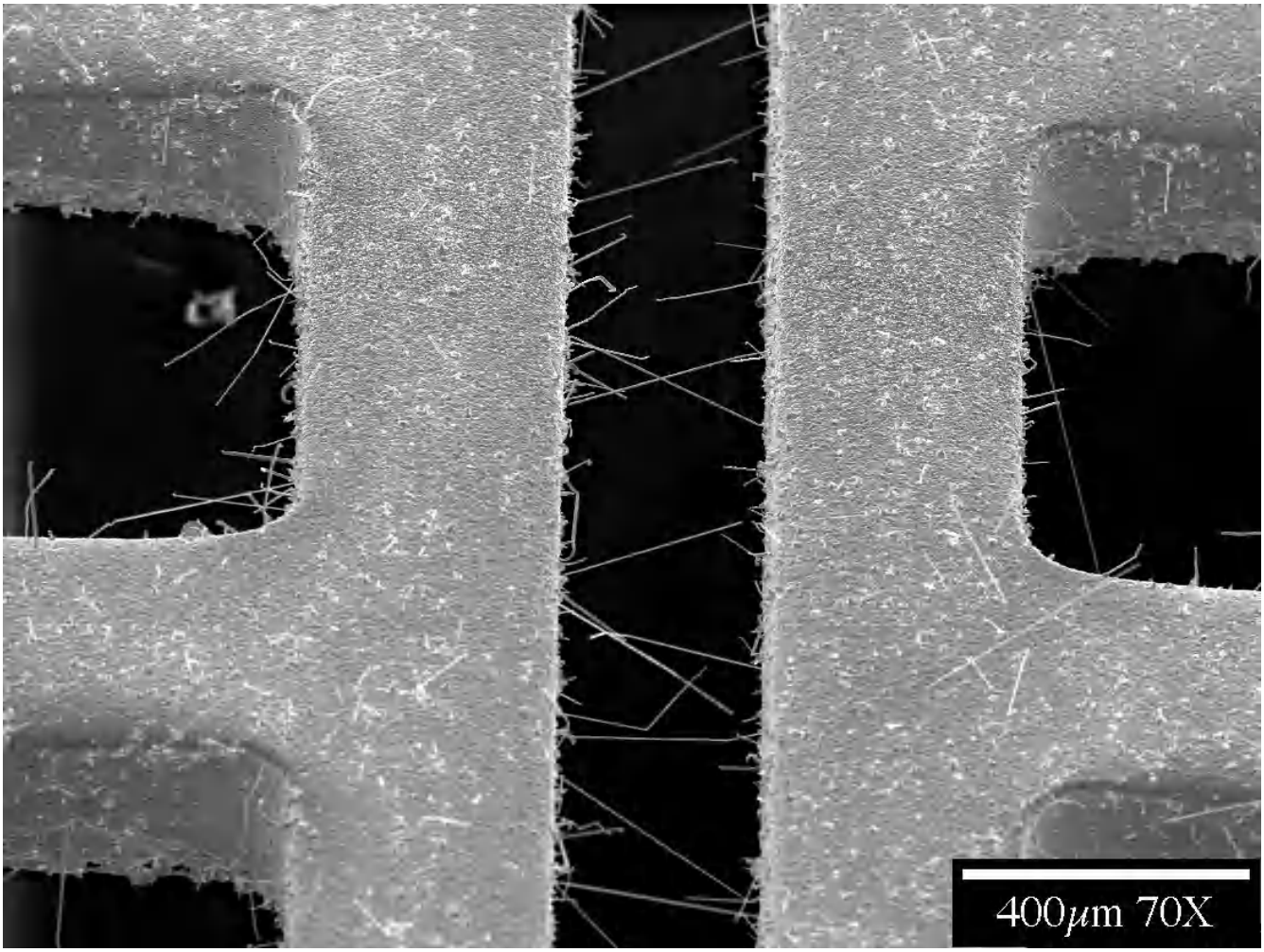

Figure 2-1. Tin Whisker Development

Bond-wire material considerations also influence reliability. Gold (Au) bond wires are preferred because these wires offer better performance under repeated thermal cycling due to the low temperature coefficient and resistance to corrosion of these wires. Copper (Cu) bond wires are increasingly used to reduce cost, but these wires require tighter process control. Cu wires have a higher temperature coefficient, making these wires more susceptible to neck-break failures during rapid temperature cycles—a common condition in LEO. In harsh space environments, gold bond wires remain the preferred choice to minimize bond-integrity failures.

Plastic outgassing and moisture absorption present further concerns. Package materials for plastic-encapsulated parts are typically organic mold compounds that can both absorb moisture and outgas volatile organic species when exposed to vacuum and temperature extremes. The absorbed moisture lowers the dielectric strength of the package, which can lead to premature failures, while the outgassed contaminants can potentially condense on nearby components—especially optics, imaging sensors, and high-impedance circuitry—degrading performance and reliability of the components.

Selecting packages made from low-outgassing materials—those with total mass loss (TML) below 1% and collected volatile condensable material (CVCM) below 0.1%—and subjecting these packages to extended bake-out and qualification testing mitigates these risks (1).

Taken together, these considerations form a comprehensive hazard-analysis summary. Radiation hazards (TID, SEE, and DD) require parts that have been characterized for the specific process, validated through RLAT, and possibly supplemented with shielding or derating. Temperature extremes demand components rated to –55°C/+125°C and verification across the full range. Tin-whisker concerns are addressed by avoiding pure-Sn terminations in favor of alloyed or plated finishes. Bond-wire reliability is maintained by selecting gold wires or, if copper is used, enforcing strict process controls and life testing is needed. Finally, outgassing and moisture

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issues are mitigated by choosing low TML and CVCM mold compounds and performing appropriate bake-out and qualification procedures.

These generic considerations constitute the backbone of the space-electronics design landscape and guide the selection of components—whether screened COTS or fully space-qualified—across the entire spectrum of missions, from commercial LEO constellations to long-duration MEO and GEO and deep-space endeavors.

3 Importance of a Single Controlled Baseline

When a COTS or automotive component is sourced for space applications, the preferred strategy is to buy sufficient material from a single lot. In practice, however, manufacturers often spread production across multiple wafer fabs and assembly sites. Each fab potentially uses slightly different equipment, process settings, or material recipes, and each assembly plant can employ distinct mold compounds and bond-wire materials. While these variations normally have no effect on performance as long as the part operates within the datasheet limits, these variations can become critical when the component is pushed beyond those limits, especially under the harsh radiation environment of space.

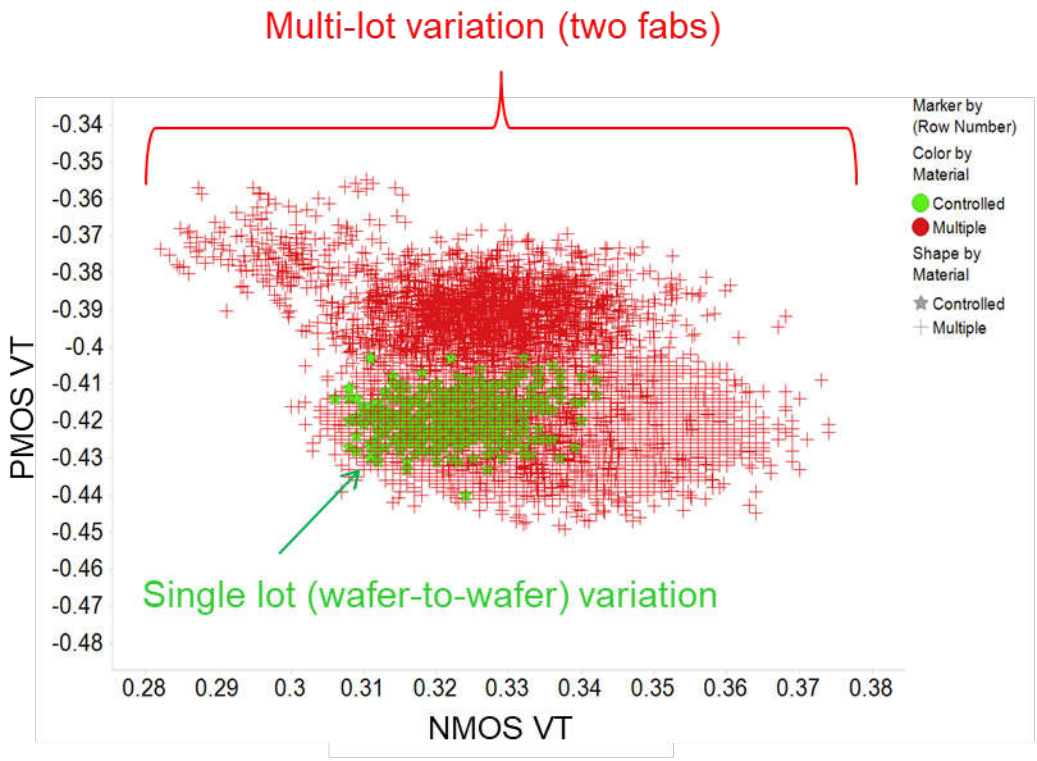

Figure 3-1. Transistor Voltage Thresholds Over Multi-Lot Variations Together With Expected Drifts from Radiation (TID) Can Significantly Compromise the Life Cycle in Space for a Single Unit

If a space program purchases parts from a possibly mixed lot, the lot qualification or testing can potentially differ from the lot that is used for launch, creating a hidden reliability risk. Even more problematic is the situation where a design that has proven successful in flight must be scaled up to meet growing demand. New production lots can incorporate process optimizations, different materials, or design tweaks aimed at improving yield and reducing cost. Those changes can degrade the very radiation hardness or reliability that the original lot exhibited, so the new lots potentially no longer pass the original qualification. Over time, this risk grows because suppliers continually refine processes, and the original *flight-heritage* configuration can become unavailable. The consequence is, that a component, board or module, that has accumulated years of flight heritage potentially needs to be redesigned and requalified or delta-qualified, if the exact original version can no longer be sourced, thereby the heritage value is lost.

Automotive parts, in particular, are produced in very high volumes and are subject to frequent cost- and yield-driven changes, often requiring multiple fabrication pathways to maintain supply resilience. Due to the

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constant evolution of these parts, these parts can actually be poorer candidates for up-screening into space applications, where stability and traceability of the manufacturing process are essential. The risks outlined above can be addressed through one of two approaches: either investing in an assured production run from a single wafer or lot—which carries potential additional costs—or accepting the inherent risk by procuring a complete component reel on the assumption of homogeneous production.

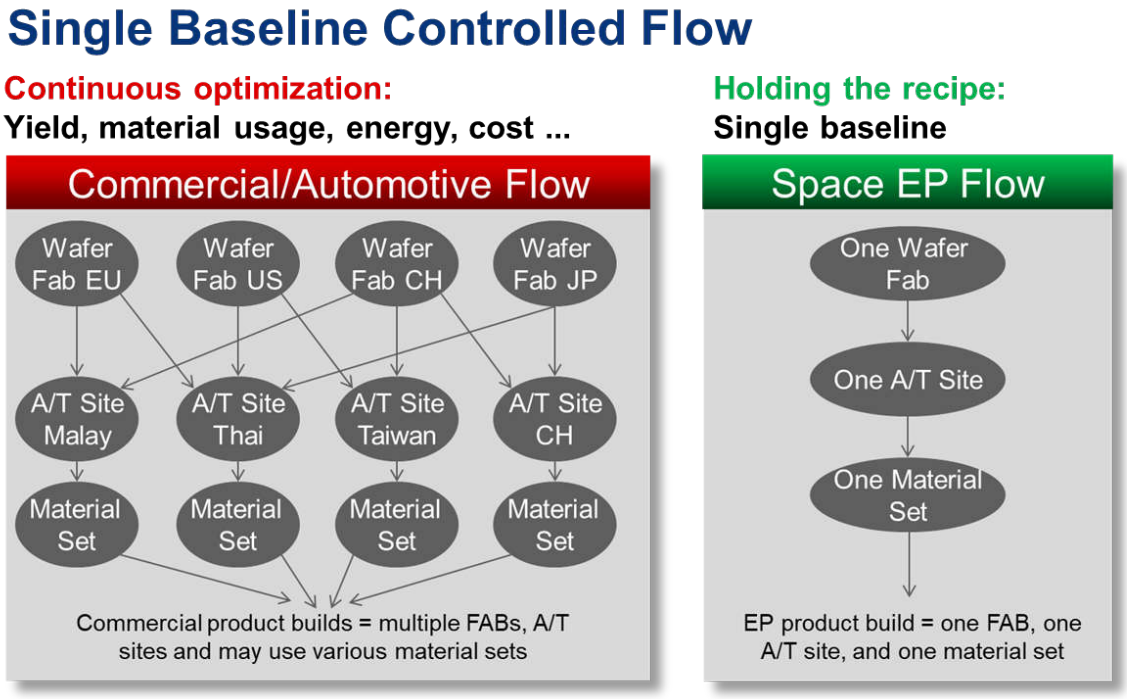

Figure 3-2. Space-Grade Products from TI, Including Space EP (SEP) Products Follow a Single Baseline Controlled Flow

Thus, establishing a single, controlled baseline—by fixing the wafer fab, assembly site, and material set (including mold compound and bond-wire type) plus performing a radiation lot acceptance test (RLAT) for every new lot produced—is essential so that every part used in a space system matches the qualified unit, thereby preserving reliability and heritage throughout the life cycle of the program.

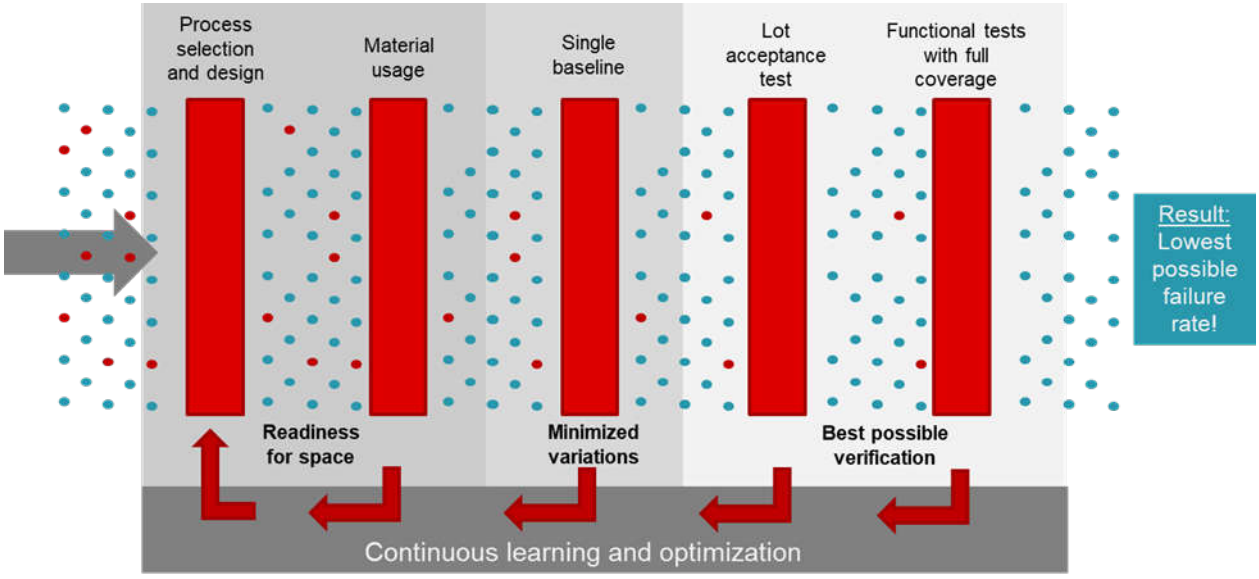

Figure 3-3. Quality Assurance (QA) is a Systematic Process from the Ground-Up

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4 The Steps to Take to Upscreen a COTS Device

Although the previous arguments strongly favor space-grade parts, ignoring the possibility of up-screening commercial-off-the-shelf (COTS) devices is naïve. Two main motivations drive the evaluation of a commercial part for space-flight:

1. Cost per unit
2. Performance within a given SWaP-C budget

With the space sector increasingly funded by private capital, return on investment (ROI) becomes a critical factor. Choosing the safest option can result in components that are potentially too costly, too heavy, too large, too power-hungry, or insufficient in performance to meet the business case for an innovative new space satellite program.

In such cases, up-screening COTS parts can be a viable alternative. The following section outlines a typical up-screening campaign performed by TESAT for relatively simple commercial components of lower complexity, such as op-amps, logic gates, or buffer devices. The section provides general rules to help designers understand the typical cost, schedule, and residual risk associated with these campaigns—knowledge gained from TESAT's evaluation of more than 200 commercial/AEC-Q parts for space use.

4.1 Step 1 – Identifying the Candidates

TESAT advises selecting a relatively large pool of devices for a given function—typically five candidates. Based on the mission profile (radiation environment, duration, orbit, and acceptable residual risk), TESAT leverages experience evaluating the technology node and other factors that affect overall success probability. On average, about 10% of the candidates are eliminated at this initial stage, leaving a test campaign with four to five units to proceed.

4.2 Step 2 – Preparation for Single-Event Effect (SEE) Testing (Opening)

The goal of SEE testing is to find out how a device reacts when the device is struck by a single particle—such as a heavy ion or proton in space, a neutron on Earth, or an alpha particle from packaging materials.

SEE tests are normally carried out at an accelerator facility capable of generating high energy heavy ions or protons. The device under test (DUT) is powered up and operated under the normal bias and functional conditions for the device. During the test, key parameters such as supply current and output status are monitored continuously. While the DUT is exposed to the ion or proton beam, any transient changes in current or output are recorded.

For space applications, performance under heavy ion radiation is a major concern. If a device is sensitive to low energy heavy ions, the device is likely also sensitive to high energy protons. Consequently, space qualification programs usually employ heavy ion or proton beams. For research purposes, other localized charge injection sources—such as pulsed lasers—can also be used.

In a heavy ion test, the DUT is placed directly in the ion beam and the DUT operation is observed in real time. The beam is produced by a particle accelerator (for example, a cyclotron or Van de Graaff generator). In orbit, heavy ions can have enough energy to traverse a packaged IC and any shielding present. Most test facilities, however, can only deliver ions with enough energy to penetrate 40µm–400µm of silicon, which is insufficient to go through a fully sealed package. Therefore, the package must be opened to expose the die while the device remains functional.

Typical methods for exposing the die include:

- Jet etching or selective chemical etching.
- Pre-thinning to a near visible layer.
- Hybrid approaches (combining etching and thinning) for three dimensional structures.
- Flip chip preparation where the die surface faces down and the back side of the die must be exposed and thinned enough for the ion beam to reach the front-side active area of the device.

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Table 4-1. Typical Methods for Exposing the Die in Preparation for SEE Testing

Method	Description	Typical applicability
Jet etching | Selective chemical etching	Removes package material locally to uncover the die	Widely used for small-die, low-pin-count parts
Pre-thinning	Thins the package to a few microns before testing	Appropriate for thin-film or MEMS devices
Hybrid approaches	Combination of etching and thinning for 3D structures	Required for stacked or heterogeneous ICs
Flip-chip preparation	Removes the substrate and bonds the die directly to a test board	Used for high-performance or high-pin-count devices

Each technique requires specific expertise; in some cases a particular method is not applicable, and occasionally the device architecture (for example, with 3D stacking) simply does not allow die exposure while maintaining functionality. TESAT reports that roughly 10% of the candidates examined so far had to be discarded for this reason. An example of an opened device is shown below in Figure 4-1.

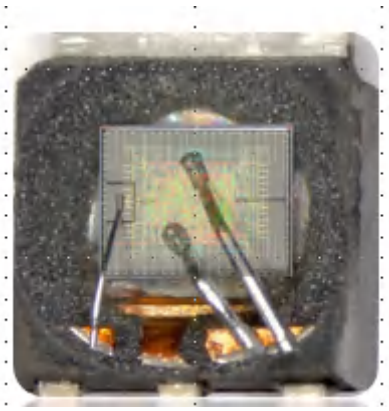

Figure 4-1. Exposing the Die is Far from Being a Trivial Task

4.3 Step 3 – Single-Event Effect (SEE) Testing

During actual SEE testing at 60MeV, the typical attrition pattern is:

- ≅25 % of the remaining candidates fail outright.
- ≅50 % pass but only with constraints (for example, limited voltage, temperature range, drifts, and so forth).
- ≅25 % pass without any constraints, leaving usually three devices from the originally assumed five candidates for further evaluation.

Note

Power FETs or power devices in general have a significantly lower success probability.

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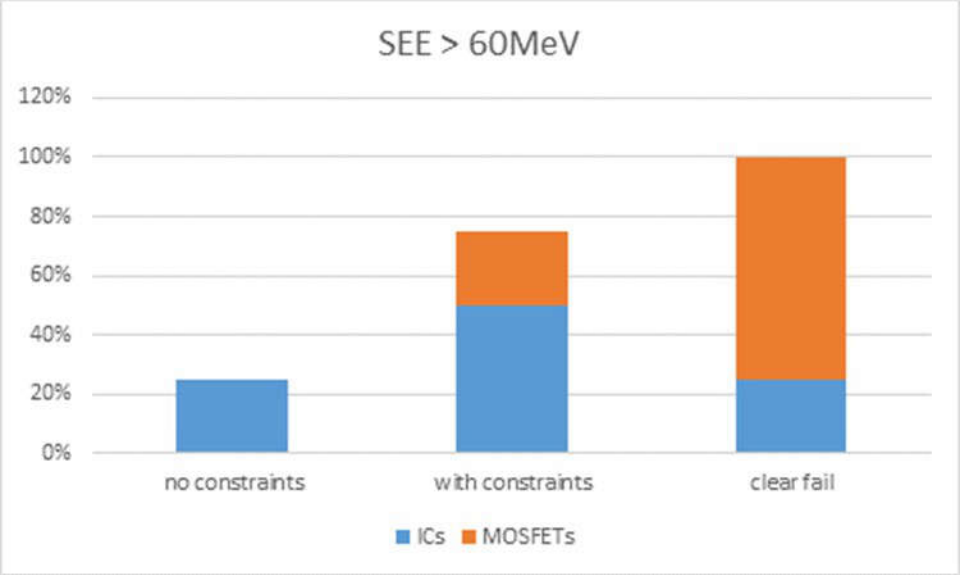

Figure 4-2. Power FETs (MOSFETs) or Power Devices in General Have a Significantly Lower Success Probability

Further, complex ICs such as MCUs or ADCs—with many configuration options—require sophisticated test software. In practice a tradeoff must be made between the effort invested in developing a comprehensive test program and the time and residual risk incurred by incomplete test coverage. Typically, the test program ends up being rather use-case specific, which needs to be kept in mind if the results are considered for future designs and use cases as well.

4.4 Step 4 – Running TID Tests and Evaluating Radiation Lifetime

The next step is to assess the effect of the total ionizing dose (TID) that the device is expected to accumulate while in orbit. TESAT's customers typically require a minimum tolerance of 15krad to 30krad, and these customers also want to know the dose at which the critical device parameters fail completely.

As a general rule, roughly another 25% of the candidates do not pass this test.

Overall, as summarized in Table 4-2, TESAT estimates a success probability of about 40% for non power, lower complexity devices, but often with notable derating requirements.

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Table 4-2. Typical Success Rate for Non-Power, Lower-Complexity ICs Observed by TESAT

Typical Success Rate from Experience – 5 Candidates IC		
Step	**Typical Success Rate**	**Remaining Candidates**
Technology evaluation	90%	4
Opening	90%	4
SEE	75%	3
TID	75%	2
Other (T&C, commercial, and so forth)	95%	2
Total	**43%**	**2 out of 5**

Successful execution of these test campaigns requires a robust allocation of both capital and time. Decision-makers must anticipate a project timeline of approximately 20 weeks. Total investment levels fluctuate based on the availability of specialized test equipment, custom adapters, and necessary tooling. To mitigate these costs and accelerate throughput, leveraging automated testing stations—such as those implemented in TESAT—is highly recommended. These systems enable parallel component testing, providing significant scalability and efficiency advantages during large-scale up-screening phases. The break-even point of an up-screening compared to purchasing space-grade parts with high unit prices is roughly at 1,000 units. In the space market this constitutes a relatively high volume, so both, TESAT and TI advise negotiating pricing with the vendor before launching a screening campaign. This is especially true for space infrastructure programs like constellations, with quantities of identical satellites, since the space industry strives for series production approaches and is in the range to reach the above component numbers.

For space equipment manufacturers with interest in more details on component up-screening or services for EEE (electrical, electronic and electromechanical) parts, visit the TESAT Parts Agency website.

The TESAT CAMPUS on-site training offers further insights, conducted by TESAT senior engineering and EEE experts.

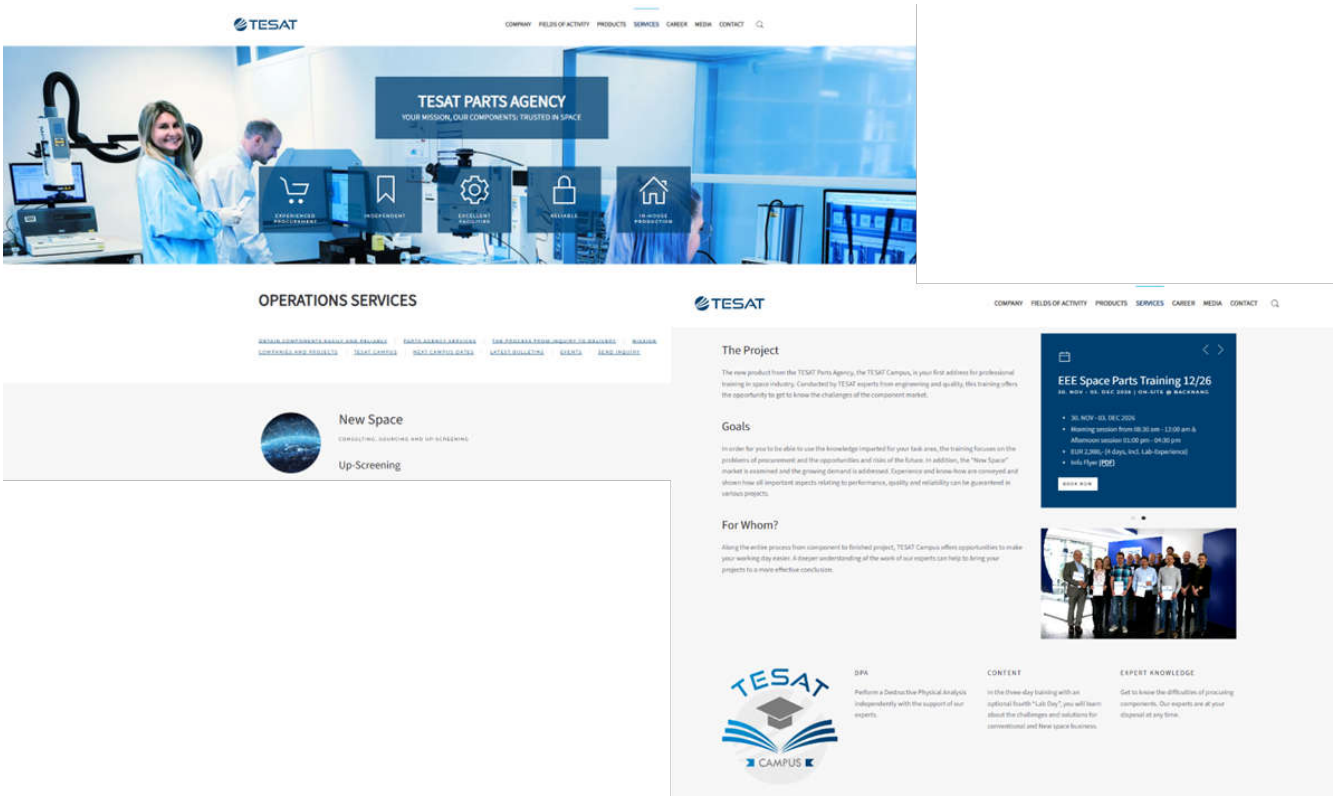

Figure 4-3. More Details and Insights on Component Up-Screening or Services for EEE (Electrical, Electronic and Electromechanical) Parts Can be Found on the TESAT Webpage

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5 Lead-Time and Yield Responsibility

An additional key factor is the lead time of the desired space-grade device. High-reliability (HiRel) parts can have long procurement cycles. To mitigate this, TI maintains a buffer stock of space-grade components and displays real-time inventory levels on TI's online store. Customers can verify availability and reserve parts early in their program. If no stock appears, TI encourages customers to contact the company for information on upcoming replenishment. Alternatively, customers can consult parts agencies such as TESAT, which maintain direct contact with TI.

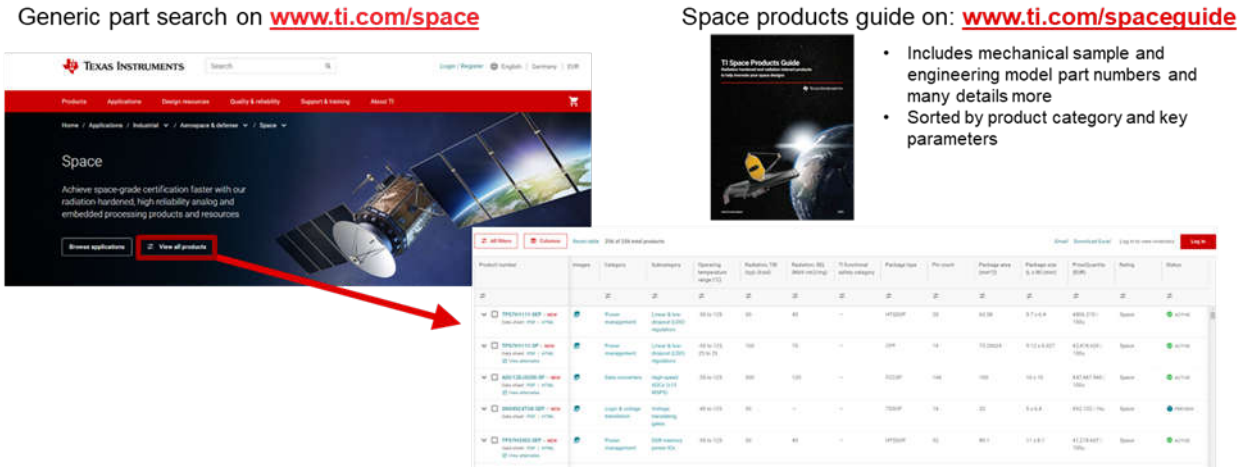

Figure 5-1. Finding Space-Qualified Parts on TI.com Including all Documentation, Reports, Price Indication, and Inventory Levels

For an up-screening campaign, design engineers must also assume responsibility for yield. In practice, this means forecasting two variables:

- The total number of devices required for the program.
- The proportion of those devices that can pass the screening tests.

Accurate predictions are critical because any shortfall directly impacts schedule and cost.

Up-screening COTS parts always entails multidimensional risks as well as opportunities—risks must be carefully managed, and opportunities must be thoroughly weighed throughout design and manufacturing for consuming valuable resources at every step. To mitigate these challenges, TI provides not only fully qualified rad-hard devices that comply with the QML-V-RHA standard of the Defense Logistics Agency (DLA), but also a family of space-enhanced products (SEP). SEP parts—identified by the -SEP suffix—offer a balanced tradeoff between potential cost and residual risk, allowing designers to meet typical LEO-satellite mission requirements without the long lead times and uncertainties of a screening campaign. The industry generally classifies this quality level as *radiation tolerant*. Consequently, when a radiation-tolerant part is available which meets all technical and environmental requirements, this part is generally the preferred option, provided the part is commercially viable.

6 Summary

Qualifying semiconductor products for spaceflight is a highly complex undertaking. Leverage the expertise of your parts agency and semiconductor manufacturers when making decisions, as up-screened components and catalogued space-grade parts can complement each other effectively.

When strong technical or commercial drivers necessitate up-screening, be mindful of the associated risks and adopt a proactive stance:

- Monitor parameter drifts, yield, and the timely evaluation of additional devices or even complete lots.
- Recognize that quality assurance responsibility rests with you.
- Strive for the most efficient up-screening approach.
- Engage in dialogue with EEE experts, such as the TESAT Parts Agency, for component services to tailor a procurement strategy that aligns your specific program and quality needs.

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Whenever an appropriate space-grade device exists, that device is usually the preferred choice. Space-grade parts offer several advantages:

- Proven, ground-up quality assurance.
- Reorderable and reusable for future designs.
- Long term process stability that builds flight heritage over time.

If cost is a concern—especially for higher volumes (1,000 + units)—engage in dialogue with suppliers such as Texas Instruments to explore pricing options.

Remember: Quality cannot be tested into a part (Staerk, 2000).

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