WHITEPAPER

READY FOR LAUNCH: UNDERSTANDING THE NUANCES OF SPACE-LEVEL QUALIFICATION AND SCREENING OF FILTERS

Selecting high-quality, high-reliability electronic components is a necessity for meeting the rigorous requirements of space applications. After all, when launching expensive mission-critical equipment and people into space, there is absolutely no room for failure. When it comes to space-qualified components, Knowles Precision Devices has proven space heritage as we have been developing space-ready filters and other components for nearly two decades. While we enjoy the challenges associated with ensuring our components are designed to maintain reliability in incredibly challenging environments like space, we are not the end users of these parts and ultimately cannot determine the suitability of a part for a particular application. However, we do want to be sure our customers are aware of the many possibilities available to them for doing this so that they are confident the components they select are space-qualified and ready to meet their application needs.

For starters, space-qualified has a very specific meaning. A space-qualified part has been designed, manufactured, and tested to meet the special electrical, mechanical, or environmental requirements for use in the launch and deployment of satellites or high-altitude flight systems. In addition to helping customers simply determine which parts, such as filters, are the right fit for their applications, we want potential customers to know that they can look to our experts to understand the different standards and options available for screening a part for space flight. This white paper aims to accomplish this by first providing an overview of some of the most common standards and terminology to know when qualifying products for space. Then, we walk through a hypothetical example of how to use a selected standard and subset of tests to space-qualify a filter.

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Common Space-Qualification Standards and Terminology

Before diving into the nuances of how to space qualify a part, let's first look at some of the common standards and terminology one should be familiar with when developing an application for space.

MIL-PRF-38534

MIL-PRF-38534 is a U.S. Department of Defense (DoD) performance specification for hybrid microcircuits and multi-chip modules (MCMs). Hybrid microcircuits, or hybrid integrated circuits (ICs), are miniaturized electronic circuits consisting of individual devices including semiconductors or passive devices such as resistors inductors, transformers, and capacitors. MCMs are electronic assemblies where multiple ICs or "chips", semiconductor dies, or other discrete components are typically integrated onto a unifying substrate. This specification details the verification and validation requirements for ensuring these devices meet the applicable performance requirements for military and space applications.

MIL-STD-202 and MIL-STD-883

The MIL-STD-202 and MIL-STD-883 standards, which were also developed by the U.S. DoD, are generally used in tandem to establish uniform methods for basic environmental tests. These tests can determine resistance to deleterious effects of natural elements and conditions surrounding military operations. The MIL-STD 202 standard is broader as it applies at the electronic and electrical components level. This standard is intended to cover small component parts, which is defined as parts weighing up to 300 pounds, or those that have a root mean square test voltage of up to 50,000V, unless otherwise specifically invoked. MIL-STD-883 is more focused on testing of microelectronic devices used within military and aerospace electronic systems including multi-chip, monolithic, hybrids, arrays, and the components from which the arrays and circuits are developed.

NASA EEE-INST-002

The purpose of NASA specification EEE-INST-002 is to establish baseline criteria for selection, screening, qualification, and derating of electrical, electronic, and electromechanical (EEE) parts used for NASA Goddard Space Flight Center (GSFC) flight projects. The standard defines three levels of screening:

- Level 1: The highest reliability standard for missions five years or longer
- Level 2: A high-reliability standard for missions one to five years
- Level 3: A standard reliability, standard lot acceptance inspection for missions 12 to 18 months

Class H – Military

Class H is the standard military quality level. Class H devices must be tested to meet the Class H tests and inspections of Appendices C and E of MIL-PRF-38534. At a high-level, appendix C is targeted towards manufacturers developing their baseline flow of processes, tests, and inspections. This appendix covers a five-step approach for this that consists of incoming inspection flow, the in-process inspection flow, the screening flow, conformance inspection, and periodic inspection flow. Appendix E covers the general design and construction criteria manufacturers need to address.

Class K is the highest reliability level provided for in the MIL-PRF-38534 specification as it is intended to be used to qualify parts used in space applications.

Class K - Space

Class K is the highest reliability level provided for in the MIL-PRF-38534 specification as it is intended to be used to qualify parts used in space applications. Beyond meeting all the baseline requirements set for Class H components, there are additional pre-build component and post-build inspections and testing that manufacturers must perform to provide more confidence the parts are of high initial quality. An example of an additional test that is not required for Class H components required under Appendix C is a non-destructive bond pull test.

Groups A, B, C, and D Testing

Group A testing covers electrical parametric testing, which at a minimum must include subgroups 1, 2, and 3 as defined in Table 1 below, plus subgroups 4, 7, and 9, as applicable, and any other subgroups required by the device specification.

Subgroup	Parameters	Quantity (accept number)
1	Static test at +25°C	116 (0)
2	Static tests at maximum rated operating temperature	76 (0)
3	Static tests at minimum rated operating temperature	45 (0)
4	Dynamic tests at +25°C	116 (0)
5	Dynamic tests at maximum rated operating temperature	76 (0)
6	Dynamic tests at minimum rated operating temperature	45 (0)
7	Functional tests at +25°C	116 (0)
8	Functional tests at maximum and minimum rated operating temperatures	76 (0)
9	Switching tests at +25°C	116 (0)
10	Switching tests at maximum rated operating temperature	76 (0)
11	Switching tests at minimum rated operating temperature	45 (0)

Table 1 This is Table C-Xa from the MIL-38534 Standard, which is used to define the different test parameters for Group A electrical testing in accordance with this standard.

Group B testing covers the parameters for verification of physical dimensions, resistance to solvents, internal visual and mechanical inspections, wire bond strength inspection, die sheer testing, solderability, and seal testing.

Qualification tests such as thermal and mechanical shock and life testing fall under Group C. For Class H products, samples for Group C testing will be drawn from the first inspection lot submitted. For Class K products, Group C testing shall be performed on the first inspection lot submitted and as required to evaluate or qualify changes.

Group D tests cover parameters for special interest tests such as thermal shock, salt atmosphere, metal package isolation, and lead integrity. Group D inspections shall be performed on the first inspection lot submitted and then at intervals not exceeding 26 weeks for additional inspection lots.

Parts Qualification

Parts qualification is a sample-based approach to mechanical, electrical, and environmental testing at the parts level. This testing is intended to verify that the materials, design, performance, and long-term reliability of parts on the same production line are consistent with a certain specification.

Parts Screening

Parts screening is a series of tests and inspections at the parts level intended to remove nonconforming and/or infant mortal parts to increase confidence in the parts selected for use.

COTS Plus

For many years, commercial-off-the-shelf (COTS) components could not be used for aerospace and defense applications that had to meet military standards since the specifications for these parts are controlled solely by vendors and manufacturers. However, in the mid-1990s, it became acceptable to start using some COTS parts in military-grade equipment. This let organizations building equipment for military applications take advantage of the time-to-market and innovation the industrial, medical, and automotive sectors were experiencing by using COTS components.

However, it was clear that these COTS components would need an additional level of testing to ensure quality and reliability. This is now known as COTS Plus, or COTS parts that are supplemented with additional test data for military and aerospace end users to have further reassurance regarding reliability. Information provided with COTS Plus parts to ensure performance is consistent with the manufacturer's data sheet and includes data on random failure-rate assumptions and methods to exclude infant mortal parts, parts with latent defects, weak parts, or counterfeit parts.

Working with Your Vendors to Qualify Components for a Space Program

For some more risk-tolerant programs, such as new space satellites being put into low-earth orbit, qualification can be performed using the COTS Plus approach described above to reduce overall production costs.

It is important to note that the exact approach for how each part is qualified will ultimately be determined by the customer and will depend on factors such as the program level as defined in EEE-INST-002 and the next level assembly screening and qualification that needs to be performed. For some more risk-tolerant programs, such as new space satellites being put into low-earth orbit, qualification can be performed using the COTS Plus approach described above to reduce the overall production costs. But this approach will likely not be sufficient for applications that require a larger investment, such as satellites being put into geosynchronous orbit, or need to take human-safety into account. Since not every space application requires this same level of testing rigor, there are infinite possibilities when it comes to the testing that needs to be performed to qualify a part for space.

In this next section, we will walk through an example of how we could perform an element evaluation on a part that will then undergo 100 percent screening in production. For this example, we will use MIL-PRF-38534 class K as our guide for qualifying and screening our catalog part B096QC2S, which is a 10 GHz surface-mount bandpass filter.

Space-Level Element Evaluation

According to MIL-PRF-38534, the purpose of element evaluation is to:

> Verify that procured materials and devices meet their specified characteristics and are adequate to perform as intended under the conditions experienced in the application. Element characteristics required to assure device performance and assembly process capability shall be identified.

In short, an element evaluation is done when a potential customer identifies a part that meets their needs on paper, but they need to verify this with testing before going into production. To do this, the supplier can perform the identified tests on a sample set of parts to make sure the design and process passes the requirements laid out. Since the B096QC2S bandpass filter is a planar microstrip filter, for this example, we will follow table C-V for substrate evaluation or C-VII for integral substrate/package evaluation from MIL-PRF-38534 as showing in Tables 2 and 3 below.

Subgroup	Class		Test	MIL-STD-883 Method	Quantity (accept number)	Reference paragraph
	K	H				
1	X	X	Electrical testing		100 percent	C.3.7.3
2	X	X	Visual inspection	2032	100 percent	C.3.7.4
3	X	X	Physical dimensions	2016	5 (0)	C.3.7.5.1.1
	X	X	Visual inspection	2032		C.3.7.5.1.2
	X	X	Electrical			C.3.7.5.1.3
4	X	X	Conductor thickness or conductor resistivity		3 (0)	C.3.7.5.2.1
	X	X	Film adhesion			C.3.7.5.2.2
	X	X	Solderability			C.3.7.5.2.3
5	X	X	TCR		2 (0)	C.3.7.5.2.4
	X	X	Wire bond evaluation	2011	10 (0) wires or 20 (1) wires	C.3.7.5.3.1
		X	Die shear evaluation	2019	2 (0)	C.3.7.5.3.2

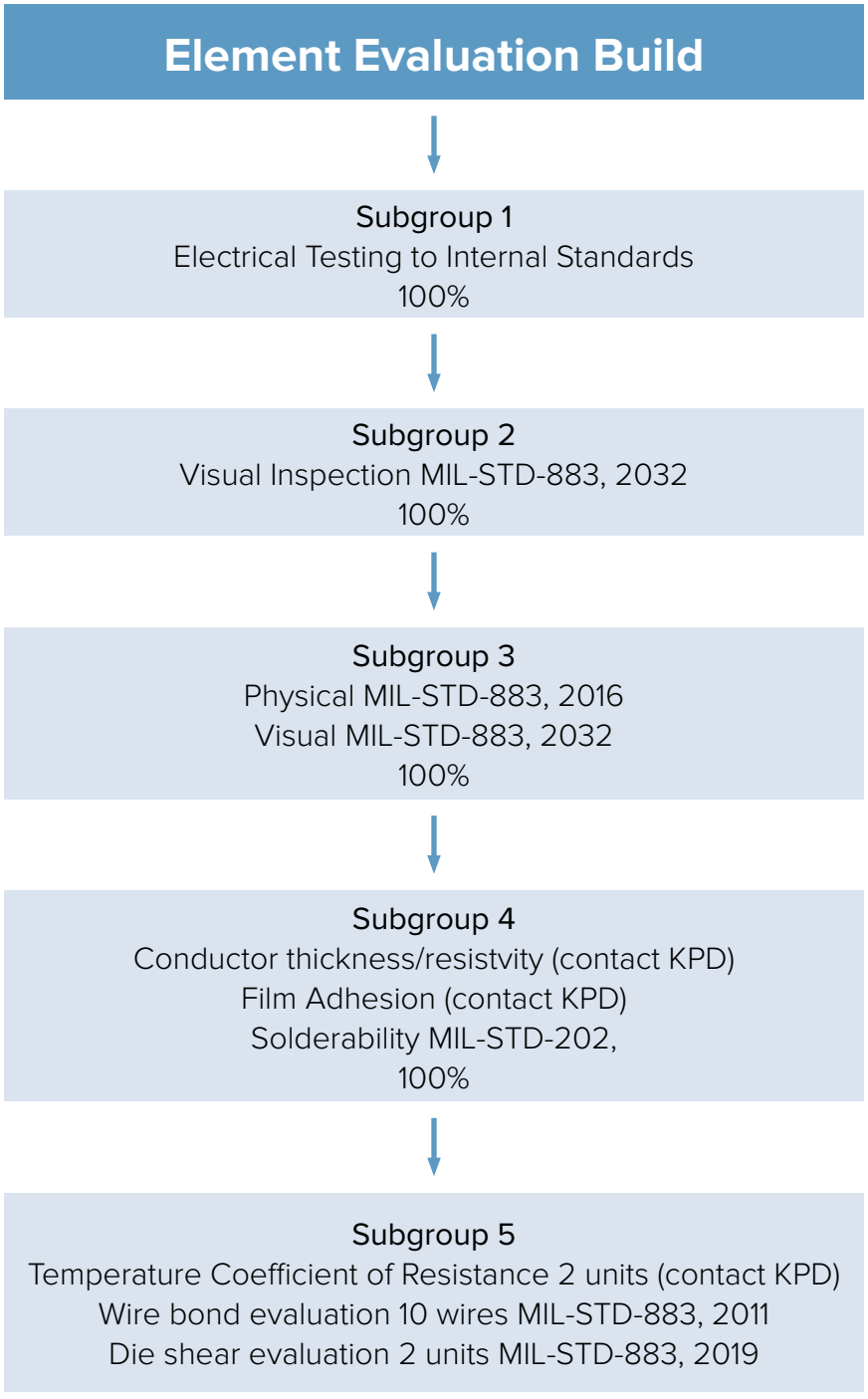
Table 2 Table C-V from MIL-PRF-38534 outlines the requirements for a variety of tests for evaluating a substrate.

Subgroup	Class		Test	Specification or standard	MIL-STD-883		Quantity (accept number)	Reference paragraph
					Method	Condition		
1	X	X	Electrical testing	Acquisition document			100 percent	C.3.9.3
2	X	X	Visual inspection 1/		2032 and 2009		100 percent	C.3.9.4
3	X	X	Device finish used 2/	MIL-PRF-38534	N/A	Acquisition document	3 (0)	C.3.9.5
4	X	X	Physical dimensions	MIL-STD-883	2016	Acquisition document	3 (0)	C.3.9.6
5	X	X	Wire bond evaluation	MIL-STD- 883	2011		10 wires (0) 20 wires (1)	C.3.9.7
6	X	X	Thermal shock	MIL-STD- 883	1011	C	3 (0)	C.3.9.2 and C.3.9.8
	X	X	Lead integrity	MIL-STD-883	2004	A1 (braze attached leads, 3 lead minimum). B1 (rigid leads and terminals only) B2 (lead fatigue) D (pad adhesion of leadless chip carriers) E (plating integrity of flexible and semi-flexible lead, 3 leads minimum).		
					2028 3/	Pin grid array leads		
	X	X	Seal	MIL-STD-883	1014	A4		
7	X	X	Solderability	MIL-STD- 883	2003	Solder temperature +245°C + 5°C	3 (0)	C.3.9.9
8	X	X	Salt atmosphere	MIL-STD-883	1009	A	3 (0)	C.3.9.10

1/ JESD 9 may be used as a guideline to enhance MIL-STD-883, method 2009.
2/ Using a recognized methodology (e.g. EDS, XRF) verify that finishes containing tin (Sn) have a minimum of 3 percent lead (Pb) by weight per MIL-PRF-38534 (JESD213 is also acceptable). Not required on packages with gold plated bodies and pins.
3/ B1 of method 2004 can be used as an option.

Table 3 Table C-VII-1 from MIL-PRF-38534 covers the requirements for a variety of tests that may be required for sub-assembly element evaluation.

Figure 1 This diagram shows an example of the tests we could perform on this part using the requirements set forth by the tables from Appendix C of the MIL-PRF-38534L standard.



Once the element evaluation is complete, depending on the customer's requirements and their application, they may elect to go directly into production. Or, depending on the application if they were performing Class K space-level screening, they may need their supplier to perform 100 percent screening on either a whole lot or a specified sample set.

To eliminate products that do not meet performance requirements under MIL-PRF-38534, screening, which is a series of tests and inspections performed on a specified number of parts in each lot, can be performed.

Screening and Inspection of Space-Level Components

To eliminate products that do not meet performance requirements under MIL-PRF-38534, screening, which is a series of tests and inspections performed on a specified number of parts in each lot, can be performed. Screening is required under Class K MIL-PRF-38534. For the product in this example, the B096QC2S bandpass filter, we would typically conduct screening based on table C-IX with conformance and periodic inspection based on table C-X from MIL-PRF-38534. Table 4 below shows how we can perform various screening options using the requirements set in Appendix C of the MIL-PRF-38534L standard and Table 5 shows Table C-IX from the standard. Figure 2 walks through an example of how we can perform production lot screening based on this standard.

Stage	Table	Initial Production Lot	Each Subsequent Lot
Device Screening	Perform on whole lot per table C-IX and customer requirements	■	■
Group A Conformance Inspection	Electrical testing on whole lot per C-Xa and customer requirements	■	■
Group B Periodic Inspection	Mechanical type tests, sample testing per C-XI and customer requirements	□	□
Group C Periodic Inspection	Qualification type tests, sample testing per C-Xc and customer requirements	□	
Group D Periodic Inspection	Package related test, in-line sample testing per C-Xd and customer requirements	□	

Solid = whole lot Outline = sample testing

Table 4 This table shows how different tests under different Groups in MIL-PRF-38534 can be screened. Please refer to MIL-PRF-38534 for more details on the tables and subsections of the standard referenced.

Test or inspection	MIL-STD-883		Requirement		Reference paragraph
	Method	Condition	Class K	Class H	
Preseal burn-in	1030		Optional	Optional	C.5.3
Non-destructive bond pull	2023		100 percent	Optional	C.5.4
Internal visual	2017		100 percent	100 percent	C.5.5
Temperature cycling	1010	C, 10 cycles	100 percent	100 percent	C.5.6
Mechanical shock or constant acceleration	2002				
2001	B, (Y1 direction only) 3,000 g's, Y1 direction only	100 percent	100 percent	C.5.6	
PIND	2020	Condition A shall be used for Class K, unless otherwise specified	100 percent	Optional	C.5.7
Pre-burn-in electrical test	In accordance with applicable device specification		100 percent	Optional	C.5.8
Burn-in	1015		100 percent	100 percent	C.5.9
Final electrical test	In accordance with applicable device specification		100 percent	100 percent	C.5.10
Seal (fine and gross)	1014		100 percent	100 percent	C.5.11
Radiographic	2012		100 percent	Optional	C.5.12
External visual screen	2009		100 percent	100 percent	C.5.13

Table 5 Table C-IX from MIL-PRF-38534 that details the testing requirements for device screening.

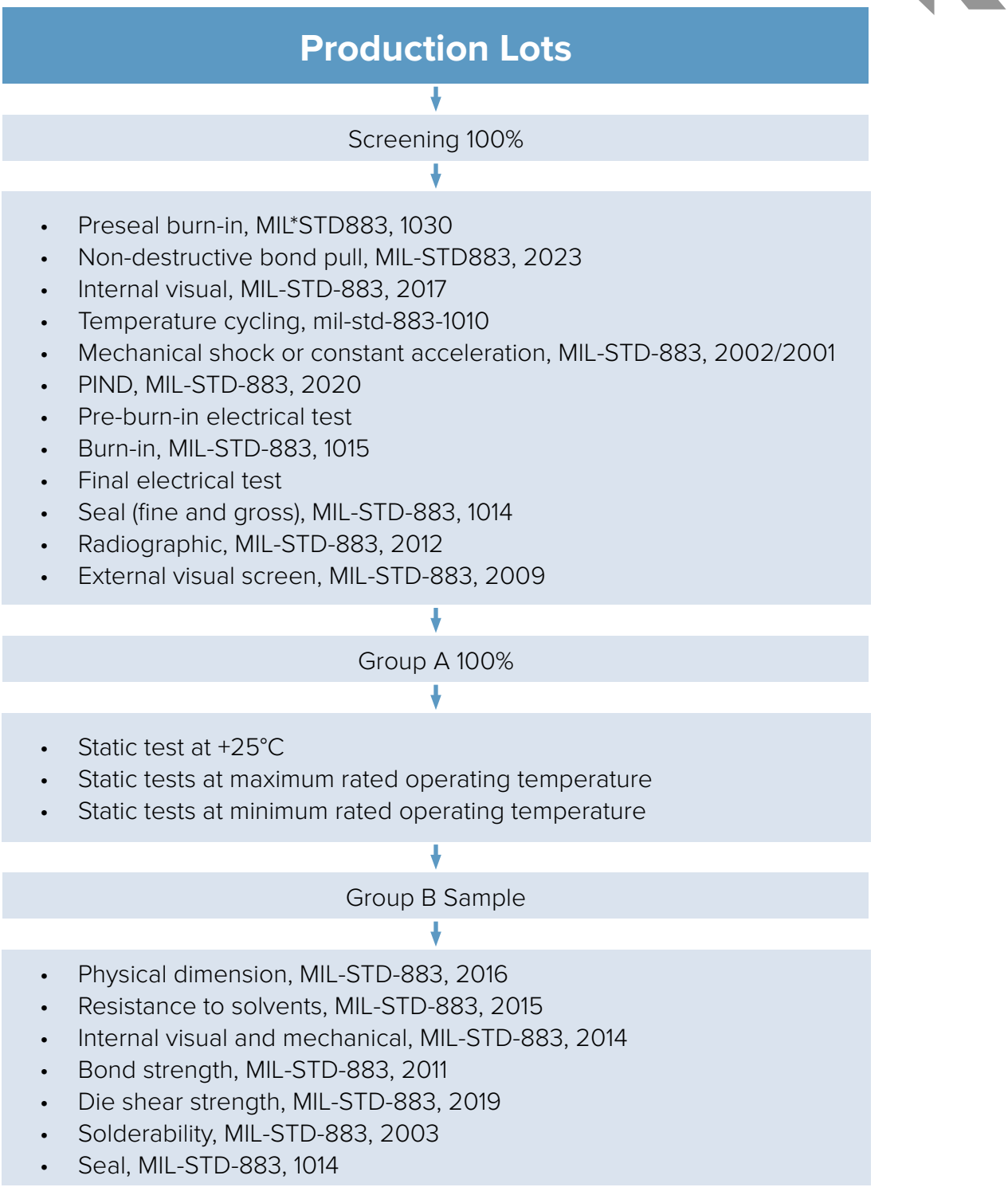
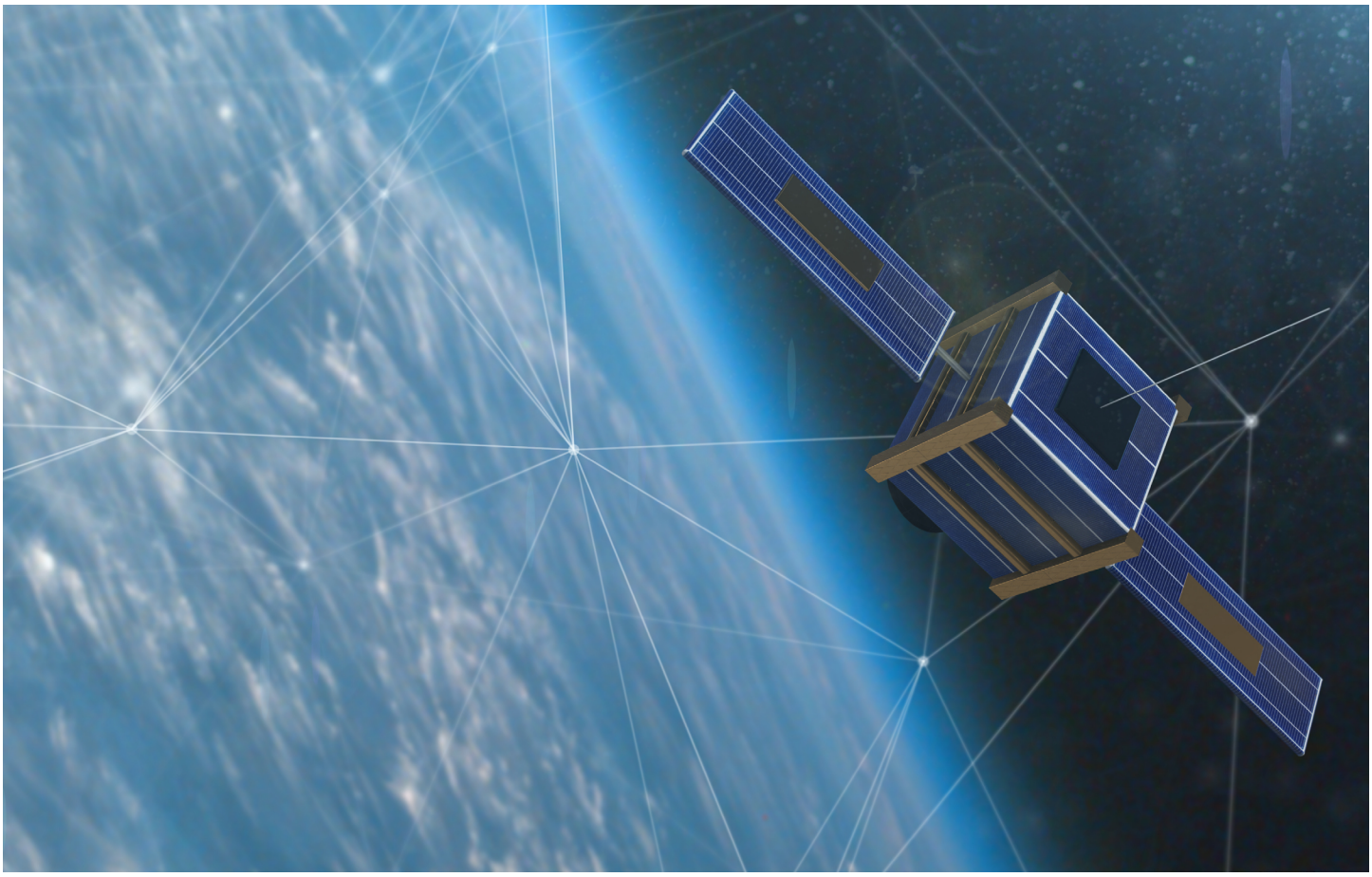


Figure 2 This diagram shows an example of how we can perform production lot screening based on the MIL-PRF-38534L standard

Performing Space Qualification Testing In-House

Knowles Precision Devices is a leader in supplying high-reliability parts for these mission-critical space applications.

When it comes to space-qualified components, Knowles Precision Devices is a leader in supplying high-reliability parts for these mission-critical applications. We work with a number of materials and produce various parts that are already space qualified. We are also equipped to perform the various qualification and screening tests to the appropriate standard as described throughout this paper in-house at our microwave production facilities in the US. Table 6 shows a brief overview of the tests and methods we can perform at our two facilities.



Facility	Tests	MIL-STD-202	MIL-STD-883	To Customer Specification
KPD Cazenovia NY	100% Electrical Test - To Customer Specification			
KPD San Diego CA	100% Electrical Test - To Customer Specification			
KPD Cazenovia NY	Acceleration	212		
KPD Cazenovia NY	Altitude	105		
KPD Cazenovia NY	Ball shear		2011	
KPD Cazenovia NY	Bond Strength		2011	
KPD Cazenovia NY	Die shear		2019	
KPD San Diego CA	Fine Leak Testing	112	1014	
KPD San Diego CA	Gross Leak Testing	112	1014	
KPD San Diego CA	Humidity	103		
KPD Cazenovia NY	Humidity	103		
KPD San Diego CA	Life Test	108	1016	
KPD Cazenovia NY	Mechanical Shock	213		
KPD San Diego CA	Mechanical Shock	213	2002	
KPD San Diego CA	Moisture Resistance	116	1004	
KPD San Diego CA	Radiographic Inspection	209	2012	
KPD Cazenovia NY	Radiographic Inspection	209		
KPD Cazenovia NY	Resistance to Solder Heat	210		
KPD San Diego CA	Solderability	208		
KPD Cazenovia NY	Thermal Cycle		1010	
KPD Cazenovia NY	Thermal Shock	107		
KPD San Diego CA	Thermal Shock	107	1011	
KPD San Diego CA	Vibration Testing	201/204	2026	
KPD Cazenovia NY	Vibration Testing	201/204		
KPD Cazenovia NY	Visual Inspection		2032	
KPD San Diego CA	Visual Inspection			

Table 6 This table shows tests a sampling of the space-qualification tests we can perform at our two US-based facilities.

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When it comes to qualification and screening of space components, there is a huge “menu” of options available to the companies developing these applications. While this white paper just started to scratch the surface of what is possible, at Knowles Precision Devices, we are well-qualified to perform a large number of qualification and screening tests. Even though it is ultimately up to our customers to select the tests that will best meet their needs, our experts will work with customers to establish a custom qualification and screening plan that can meet the level of testing required. Whether you are working with small satellites in the new space industry or on a deep space probe, we can dial up or down the qualification and screening program to meet your budget and the level of reliability required. And, if you are in doubt about the tests you may need to perform, talk to one of our experts.

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