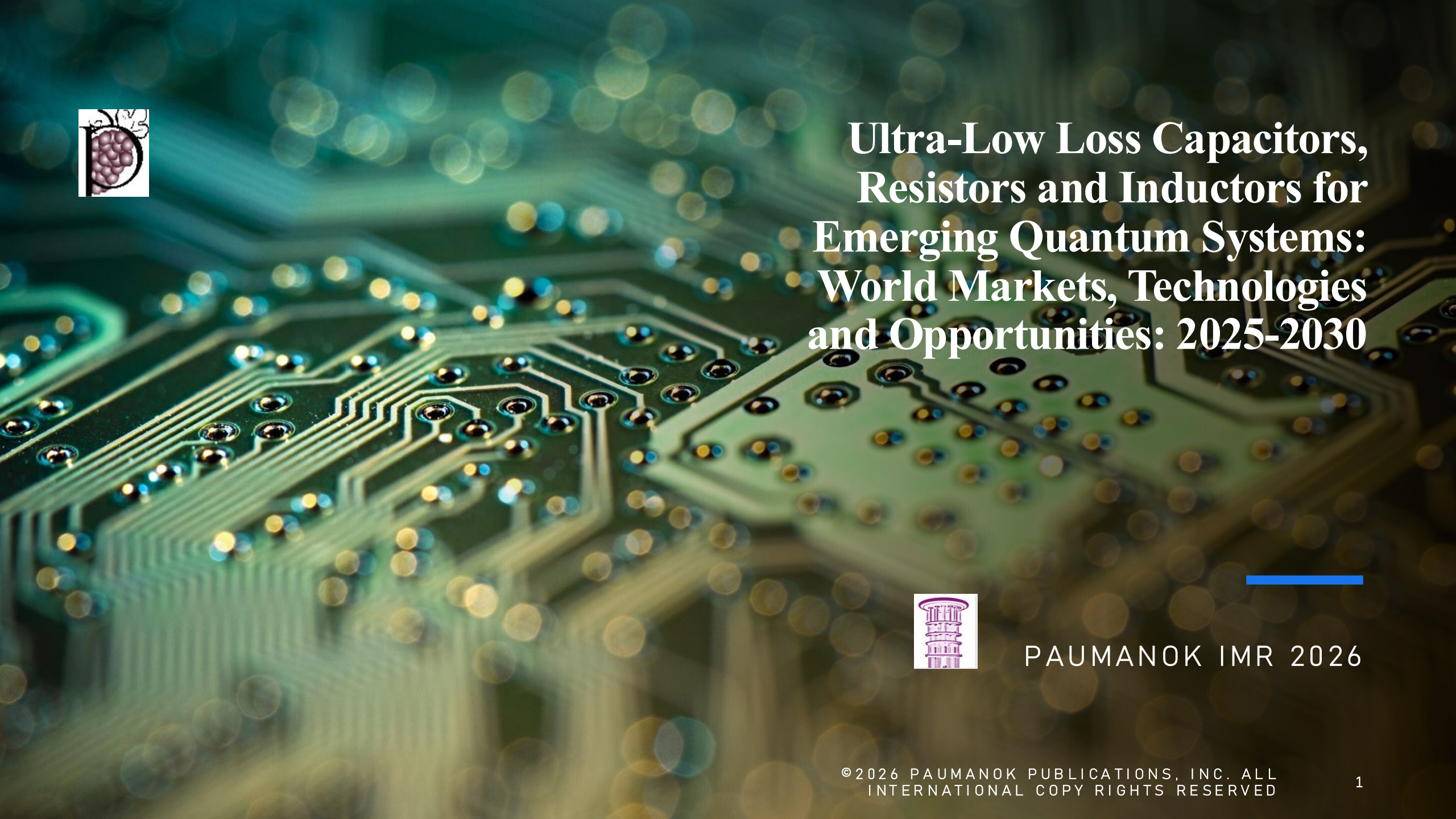

Ultra-Low Loss Capacitors, Resistors and Inductors for Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030

PAUMANOK IMR 2026

Ultra-Low Loss Capacitors, Resistors and Inductors for Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030

PRESENTED BY

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CONTENTS

TELECOMMUNICATIONS	COMPUTERS	AUTOMOTIVE	CONSUMER AV	INDUSTRIAL	SPECIALTY
Wireless Handsets	Notebook	ICE Electronics	TV Sets	Power Supplies	Military Specification Capacitors
Wireless Base Station	Desktop	Evx Electronics	Stereo Components	DC/DC Converter Bricks	Medical Implant Capacitors
Satellite Communications	Tablet	Hybrid ICE/EV	Speakers	SMPS Power Supplies	Medical Test and Scan Capacitors
Central Office Equipment	Server	Charging Stations	Amplifiers	Lighting Ballasts	Detonation Capacitors
Station Class Equipment	Motherboards	ICE UTH Electronics 125 C	Game Consoles	Power Transmission Grid	Railgun Capacitors
Motherboards	Semiconductor Chipsets	ICE Passenger Electronics	Handheld Games	Power Distribution Grid	Spacecraft and Satellite Electronics
Semiconductor Chipsets	Graphic s Cards	ICE Safety Electronics	Arcade Games	Motor and Drive Assemblies	Offworld Rover Electronics
Graphics Cards	Sound Cards	Engine Control Units	Cable Set Top Box	Variable Speed Drives	Laboratory Test Equipment
Sound Cards	Hard Disc Drives	ABS Cards (4)	Home Automation	Power Welding	Oilwell Electronics
Battery Management	Battery Management	SRS Electronics	DVD	HVAC Thermostats	Downhole Pumping and Logging Tools
		Powertrain Electronics	CD	Offshore Wind	Semiconductor Manufacturing Equipment
		DC Motors (Locks, Windows)	Projector	HVDC Lite PFC	Pulse Forming Networks
		FOBs and Security	DS Camera	Solar Farm DC Link	Civil Aircraft
		Radar and LiDar	DS Video Camera	Trains and Railroad	Buoys and Beacons
		Evx Propulsion	Electronic Toys and Games	Traction Capacitors	
		OB Charger	White Goods-Appliances	Furnace Capacitors	
		Inverter	Brown Goods-Appliances	Maglev Capacitors	
		Converter			
		Battery Management			
		Charger Station			
		Class 7 and 8 Trucks			

In Billions of USD

Source: Passive Electronic Components: World Market Outlook: 2026-2031 ISBN #:1-893211-99-1 (2026)
https://www.paumanokgroup.com/l/uplifw

$8.26

Handsets have been slow to recover

$12.3

Huge Growth in Semiconductor

+26% for Hyperscale YoY

$9.4

Huge Growth in Electric Propulsion

$3.3

Challenging Segment

$4.78

Growth in Alternative Energy

$1.03

7% AAG

Global Revenues for Passive Electronic Components: FY 2026

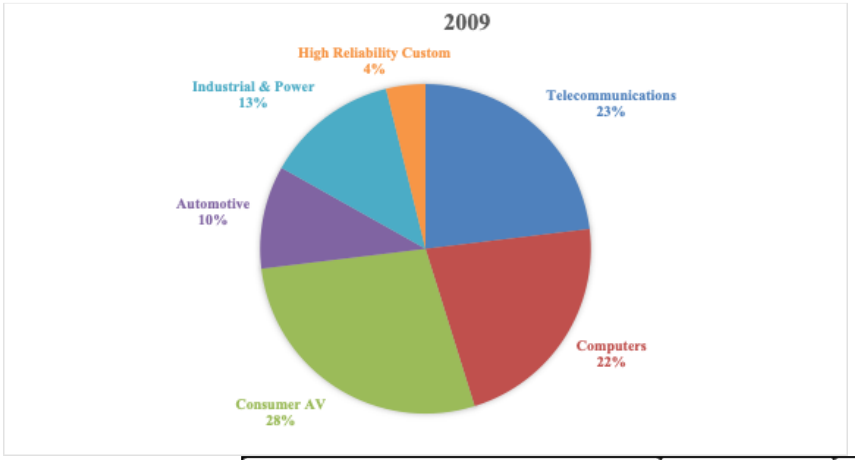
In Billions of US Dollars- Global

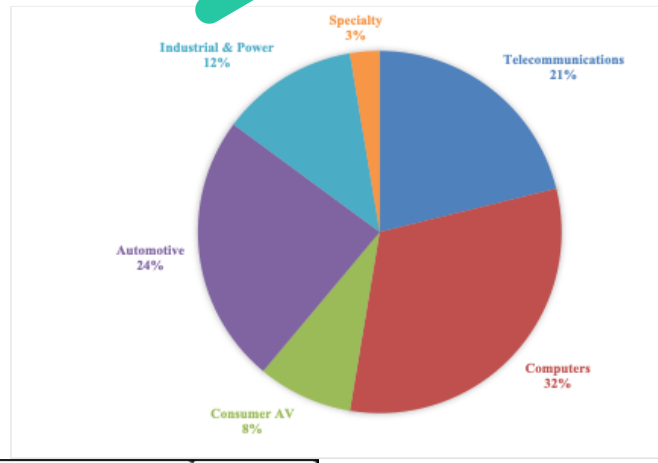
Dennis M Zogbi

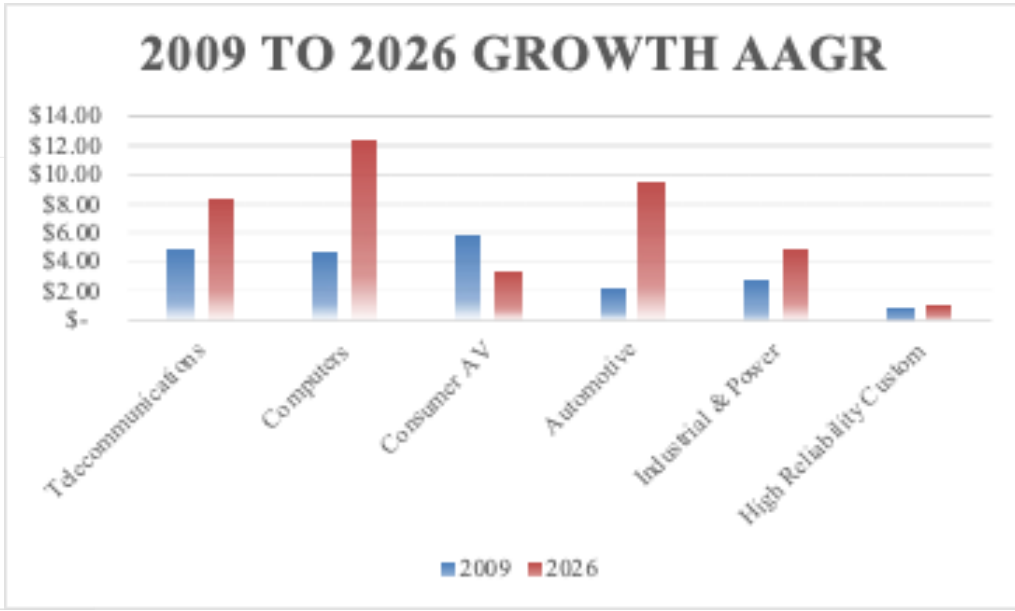
Changes in Passive Component Consumption Value Worldwide Over Time: 2009-2026

In Billions of USD

Source: Passive Electronic Components: World Market Outlook: 2026-2031 ISBN #:1-893211-99-1 (2026)
https://www.paumanokgroup.com/l/uplifw







Passives by End Market (CRL)	2009	2026	17 years CAGR
Telecommunications	$ 4.80	$ 8.26	72%
Computers	$ 4.60	$ 12.30	167%
Consumer AV Home Theatre	$ 5.80	$ 3.30	-43%
Automotive	$ 2.10	$ 9.40	347%
Industrial & Power	$ 2.70	$ 4.78	77%
High Reliability Custom	$ 0.80	$ 1.03	29%
Total	$ 20.80	$ 39.07	88%

Voltage
Frequency
Temperature

- Defense Mil-Spec Components
- Civil Aviation and Radar
- **Spacecraft and Satellites**
- Telecommunications Infrastructure
- Medical Implants
- Medical Test and Scan
- Oil & Gas Electronics

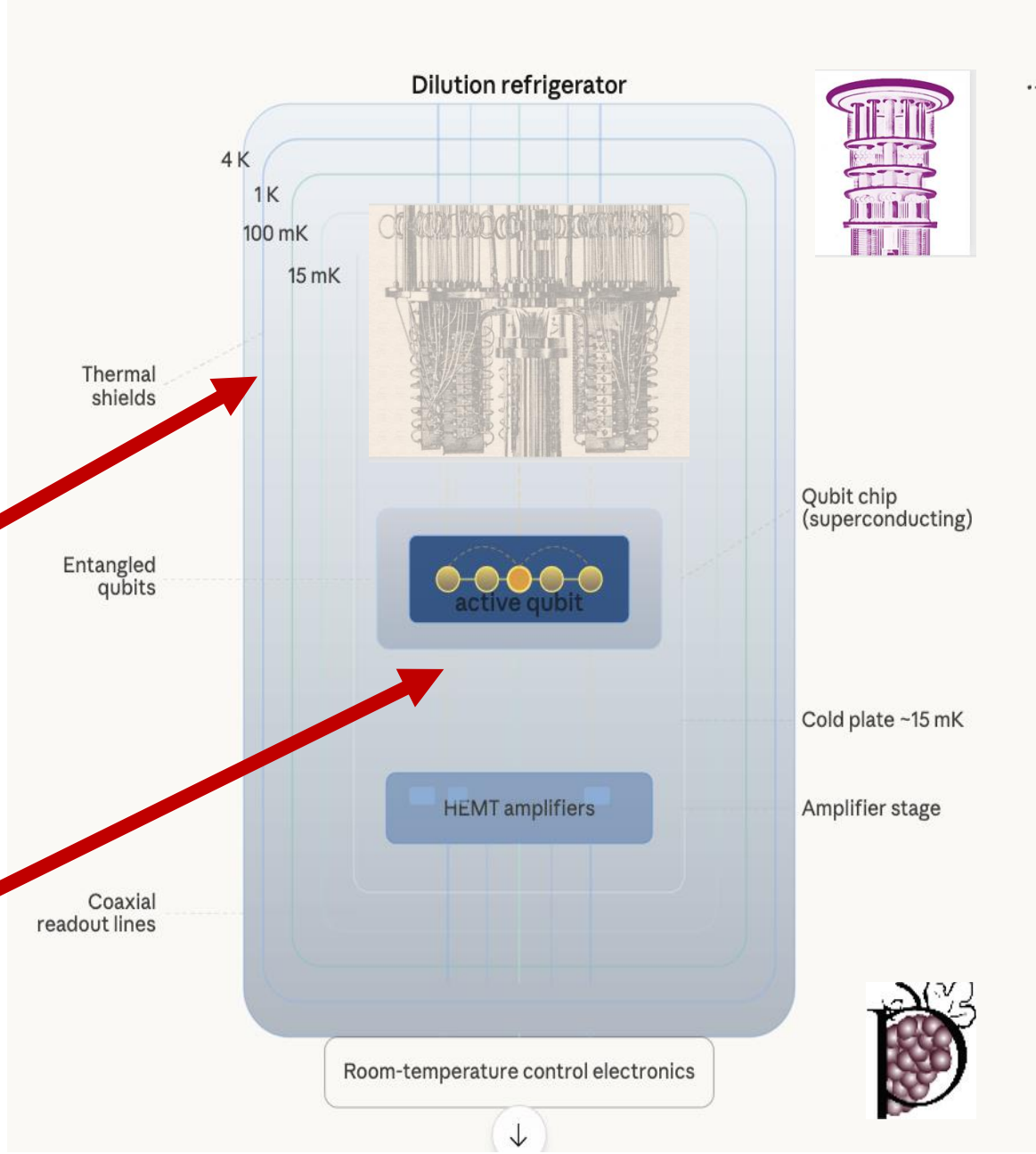
The Quantum Computing Environment for Passive Electronic Components- Ruggedized for Cold

A cross-section illustration of a superconducting quantum computer

The whole system is a dilution refrigerator, which cools the qubit chip down to around 15 millikelvin — colder than outer space — to eliminate thermal noise

The nested cylinders are thermal shields at progressively colder temperatures (4K → 1K → 100mK → 15mK) as you move inward.

At the heart is the qubit chip, where small superconducting circuits act as qubits. The glowing amber dot in the center represents an active qubit.

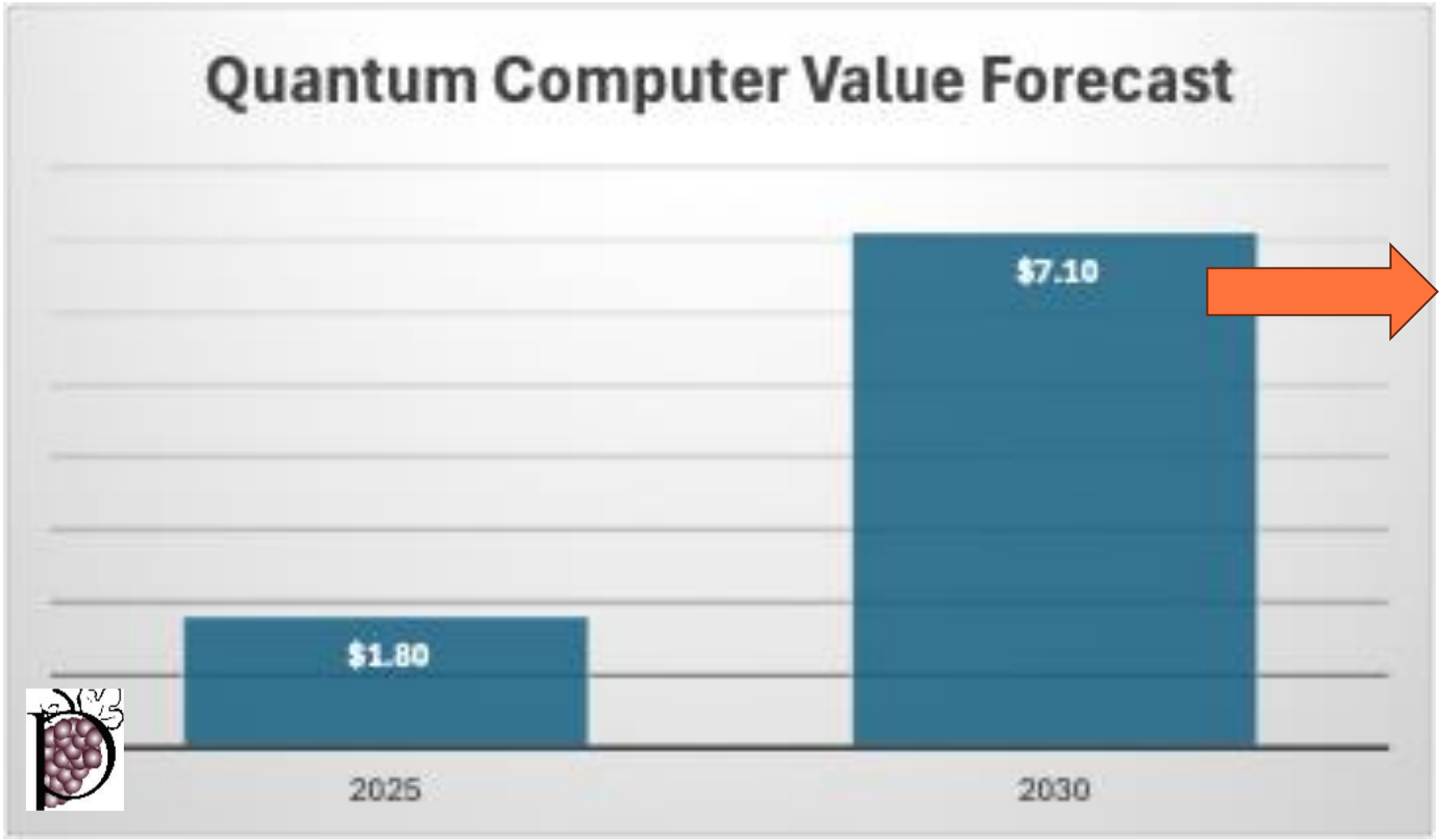


The unique challenges and requirements of passive components in quantum computing systems include-

- The extreme environmental conditions (cryogenic temperatures, electromagnetic sensitivity)
- Different types of capacitors used - ceramic, film, silicon, electrolytic and dielectrics designed specifically for Quantum Computing)
- Different types of resistors used (nickel chromium film, wire and foil, tantalum nitride, ruthenium and ruthenates)
- Different types of magnetics- ferrites and mixed metal oxides
- Future trends and emerging technologies (Silicon, **Hexagonal Boron Nitride, Diamond Like Capacitors**, Other)

INSIGHT- The eye of a few select migratory birds engage in quantum bio-mechanics at room temperature for detailed NAVIGATION.

Quantum Computer Hardware Value Forecast: Global: FY 2025-2030 (In Billions of US Dollars)



Hardware $ Value Only

"NOTED AND INSIGHTS-The potential asset value of quantum computing for navigation, sensing and communications is significant and measured in the trillions of dollars

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

A End Markets Driving Quantum Computer Demand Through 2030 And Beyond

- Healthcare (MedTech Test and Scan-Quantum Biology)
- Supply Chain Optimization (Wave Efficiency; Photosynthesis)
- Materials Science (Particles and Waves)
- Communications Infrastructure (Quantum Tunneling)
- Navigation, Time and Location (Magneto-Receptive)

B Why These Markets Drive Demand

- Problem Complexity:
- High Economic Value:
- Established Infrastructure:
- Early Mover Advantage:

C Major Quantum Computer Research and Development

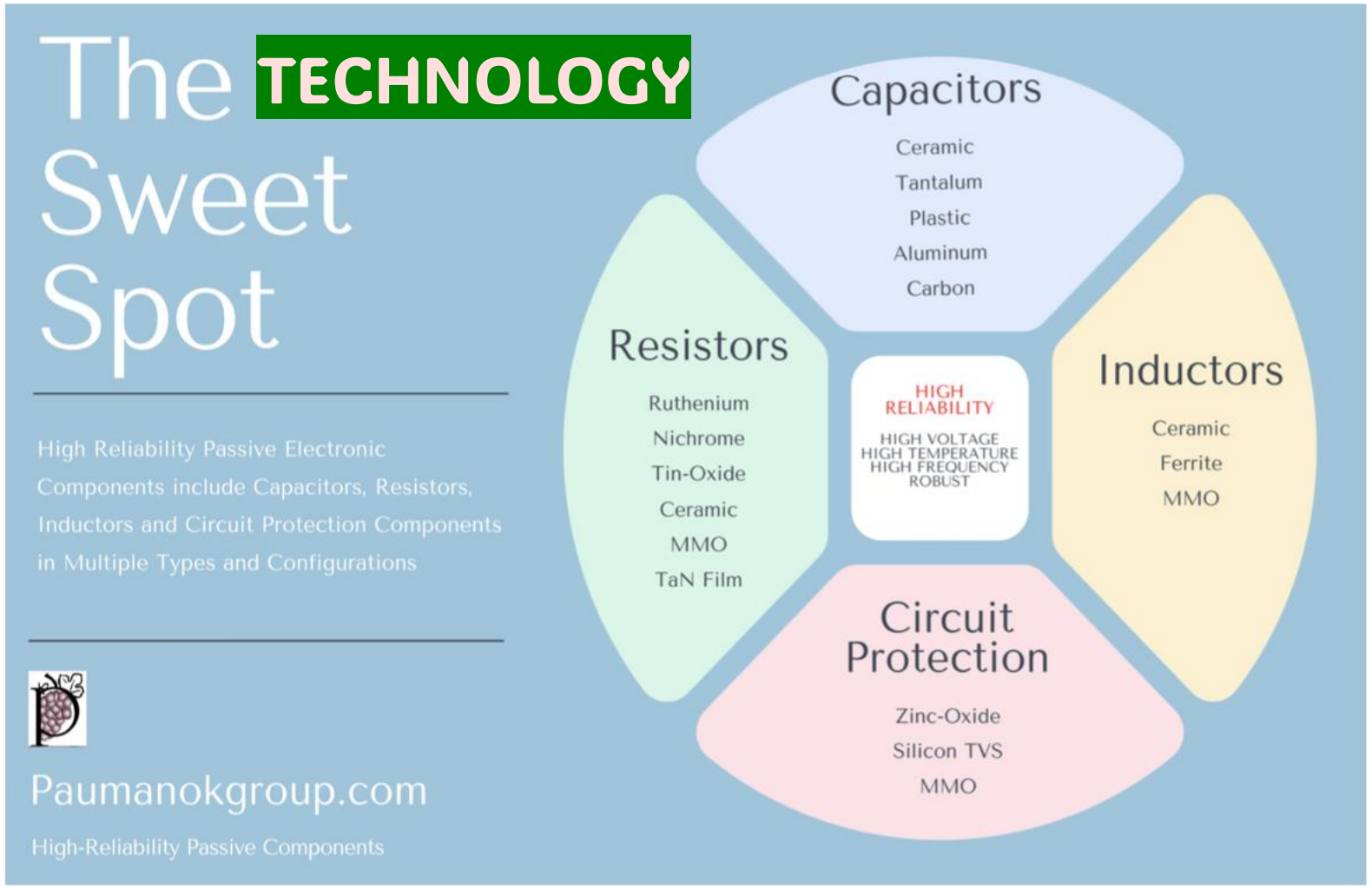
- IBM (Superconducting Qubits)
- Google (Alphabet) (Superconducting Qubits)
- Microsoft
- Intel
- Amazon

D Specialized Quantum Computing Research and Development

- IonQ (Trapped Ions)
- Quantinuum (Trapped Ions)
- D-Wave Systems (Quantum Annealing)
- Rigetti Computing (Superconducting Qubits)
- Oxford Ionics (Trapped Ions)
- Atom Computing (Neutral Atoms)
- Diraq (Silicon Spin Qubits)
- Quantum Motion (Silicon Spin Qubits)
- Photonic, Inc. (Photonic Particles)

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

High Reliability Passive Electronic Components



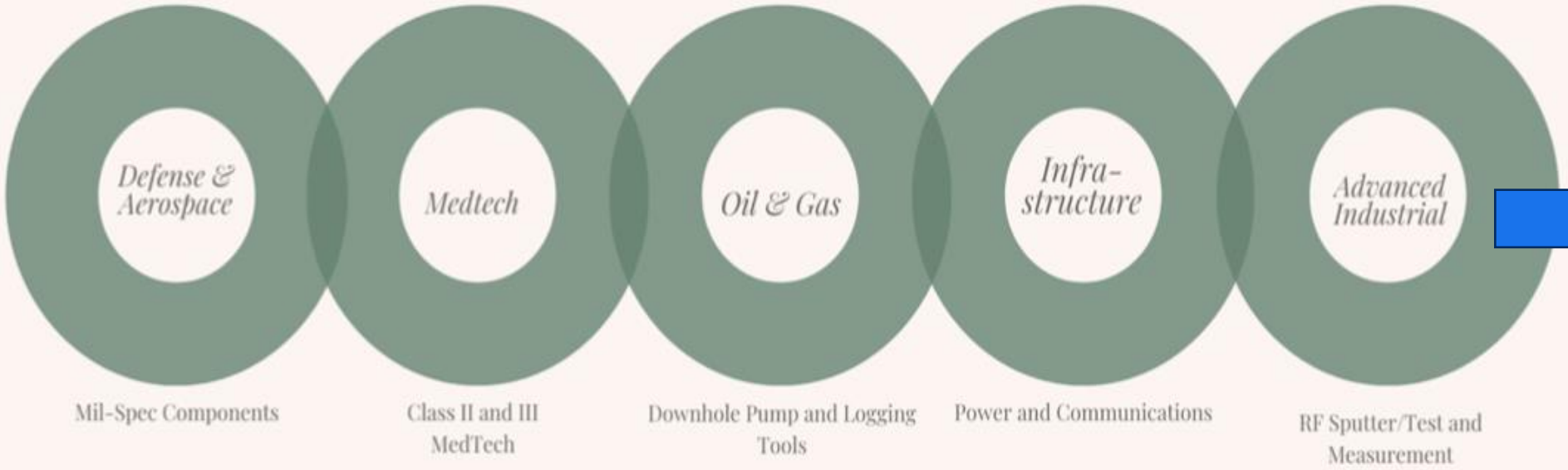
High-Reliability Technology Signature

- Voltage
- Frequency
- Temperature

Rugged Customization

- Stacking
- Derivative Electrodes
- Open Mode Design
- Flexible Terminations
- J-Leads

Source; High-Reliability Passive Electronic Components: World Markets, Technologies and Opportunities: 2023-2028- DEEP DIVE ANALYSIS- ISBN: 1-89-3211-38-X



Exciting and New

Quantum Computing

Qubit Decoupling + Cryogenic Passive Components

Source; High-Reliability Passive Electronic Components: World Markets, Technologies and Opportunities: 2023-2028- DEEP DIVE ANALYSIS- ISBN: 1-89-3211-38-X

RUGGED CUSTOMIZATION

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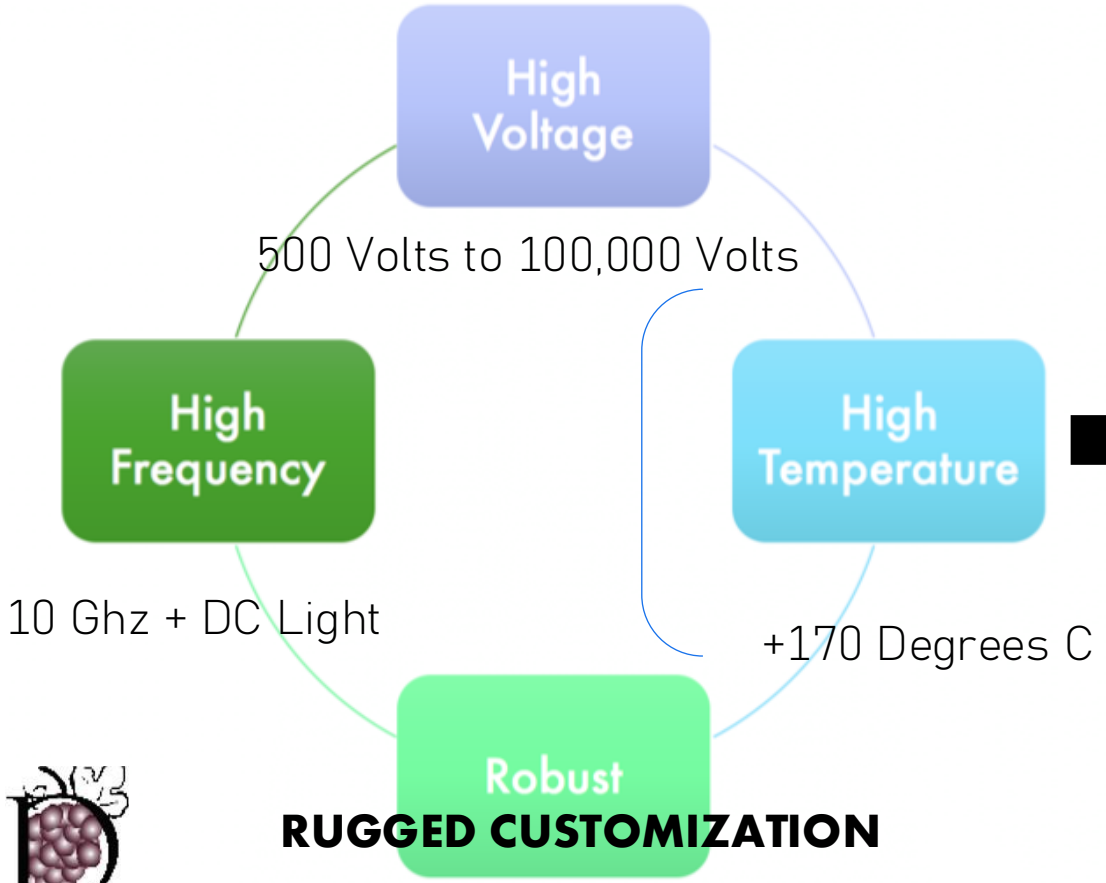
High Reliability End-Markets

Technology Indicators of Advanced Ecosystems

Ultra-Low Loss Passive Components- Capacitors, Resistors, Inductors



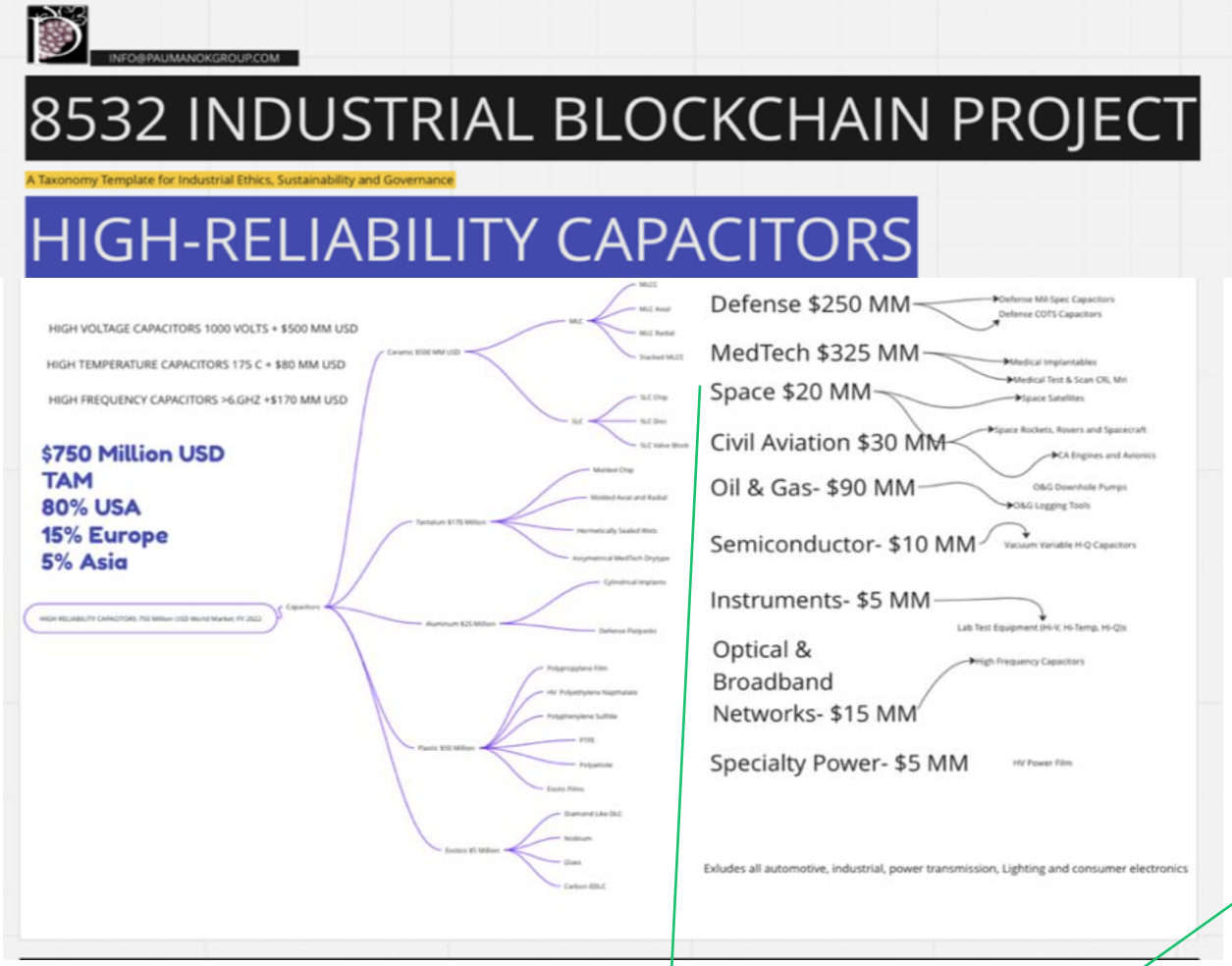
EXPANDS TO INCLUDE
LOW TEMPERATURE
Extreme Temperature
A Spectrum That
Includes "4K" and "77K"
Catalog Descriptions for
Passive Electronic Components

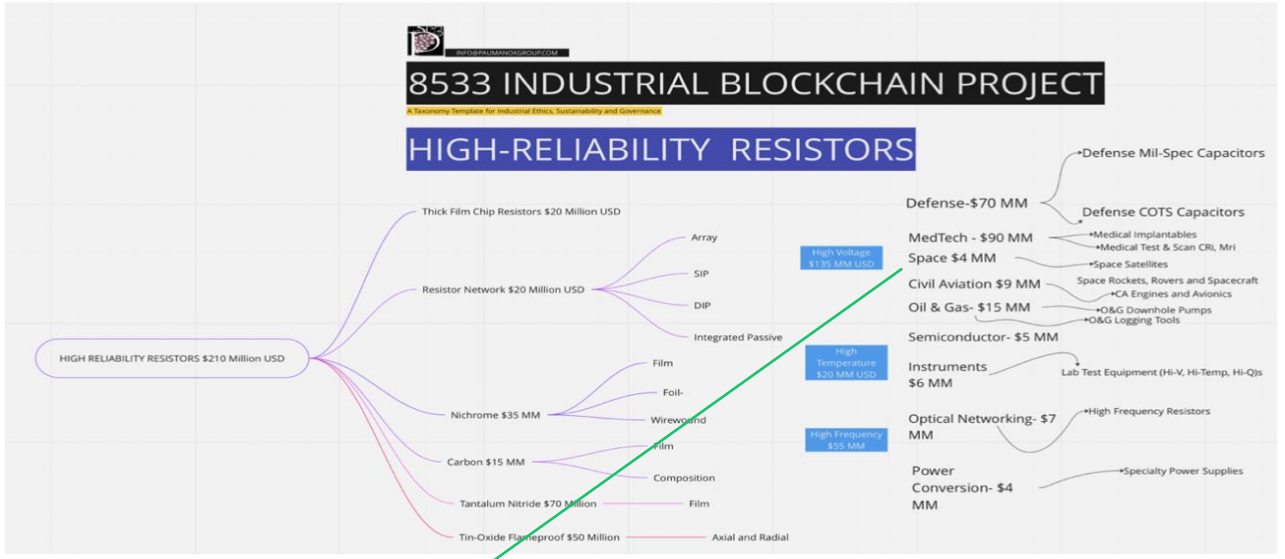
*** 4K refers to an operating environment at or near 4 Kelvin (approximately -269°C)**

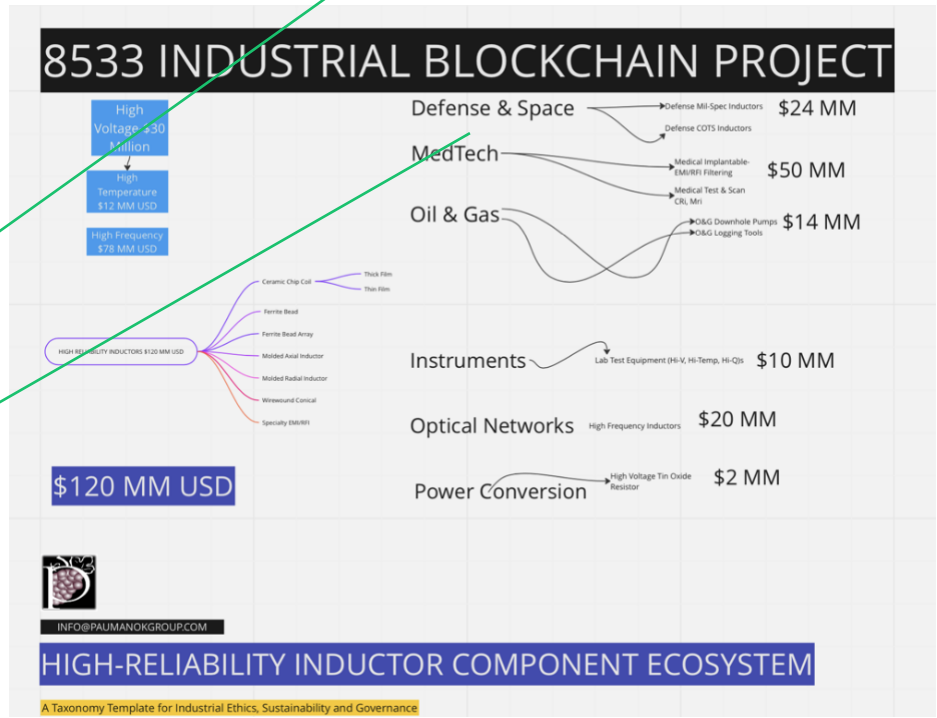
** In passive component grading for quantum and cryogenics, the number **77** refers to **77 Kelvin (K) -196C or the boiling point of liquid nitrogen**

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

Source; High-Reliability Passive Electronic Components: World Markets, Technologies and Opportunities: 2023-2028- DEEP DIVE ANALYSIS- ISBN: 1-89-3211-38-X







Prior experience in THE COLD OF "Space Electronics"

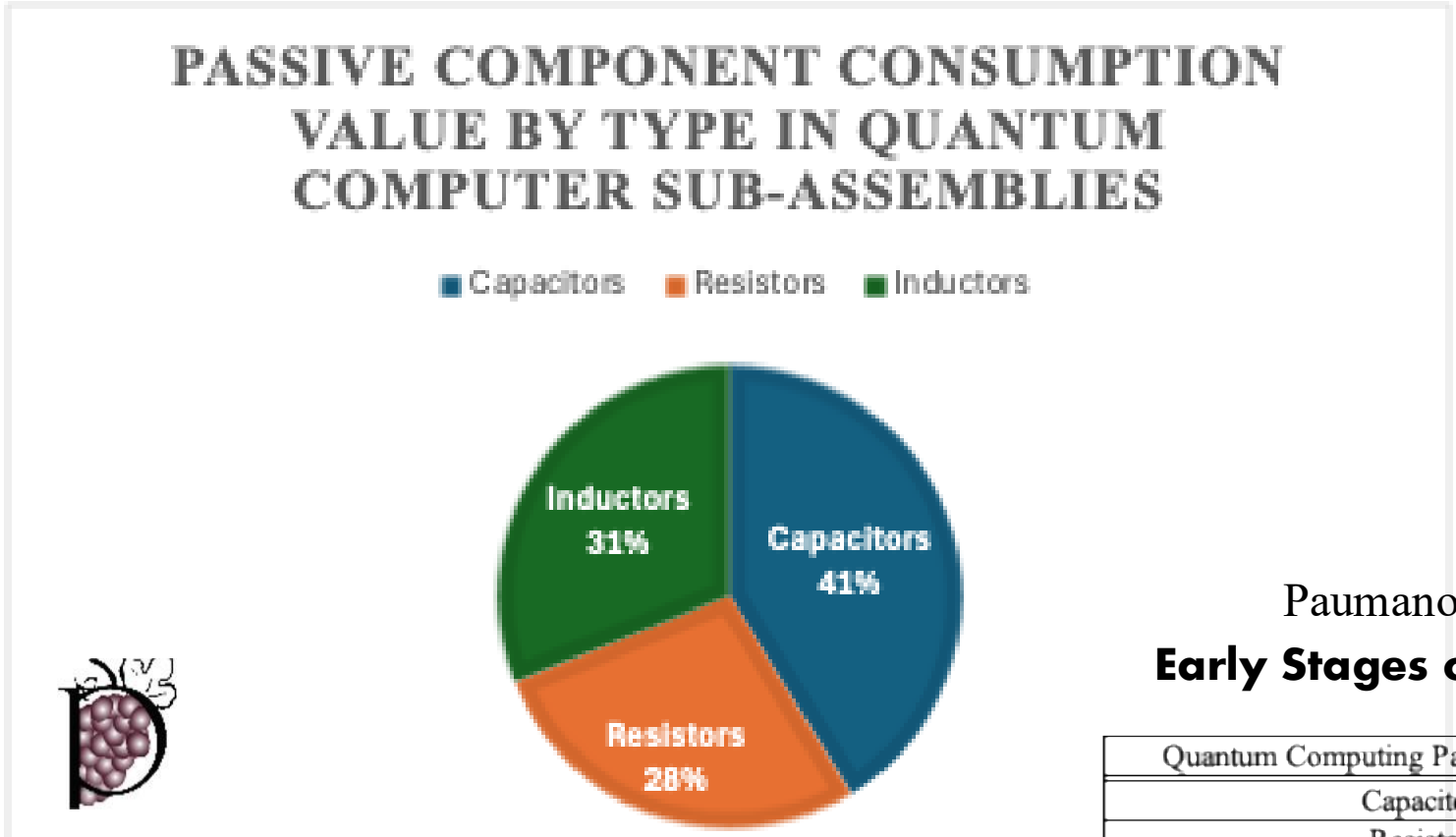
Quantum Cryogenic Passive Components

$18.7 MM

Source; High-Reliability Passive Electronic Components: World Markets, Technologies and Opportunities: 2023-2028- DEEP DIVE ANALYSIS- ISBN: 1-89-3211-38-X

Quantum Passive Component Market Shares by Technology

- ***Market Segmentation and Growth Dynamics***
- *Passive Electronic Component Consumption in Quantum Computers by Type (Capacitors, Resistors and Inductors): FY 2025*



Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

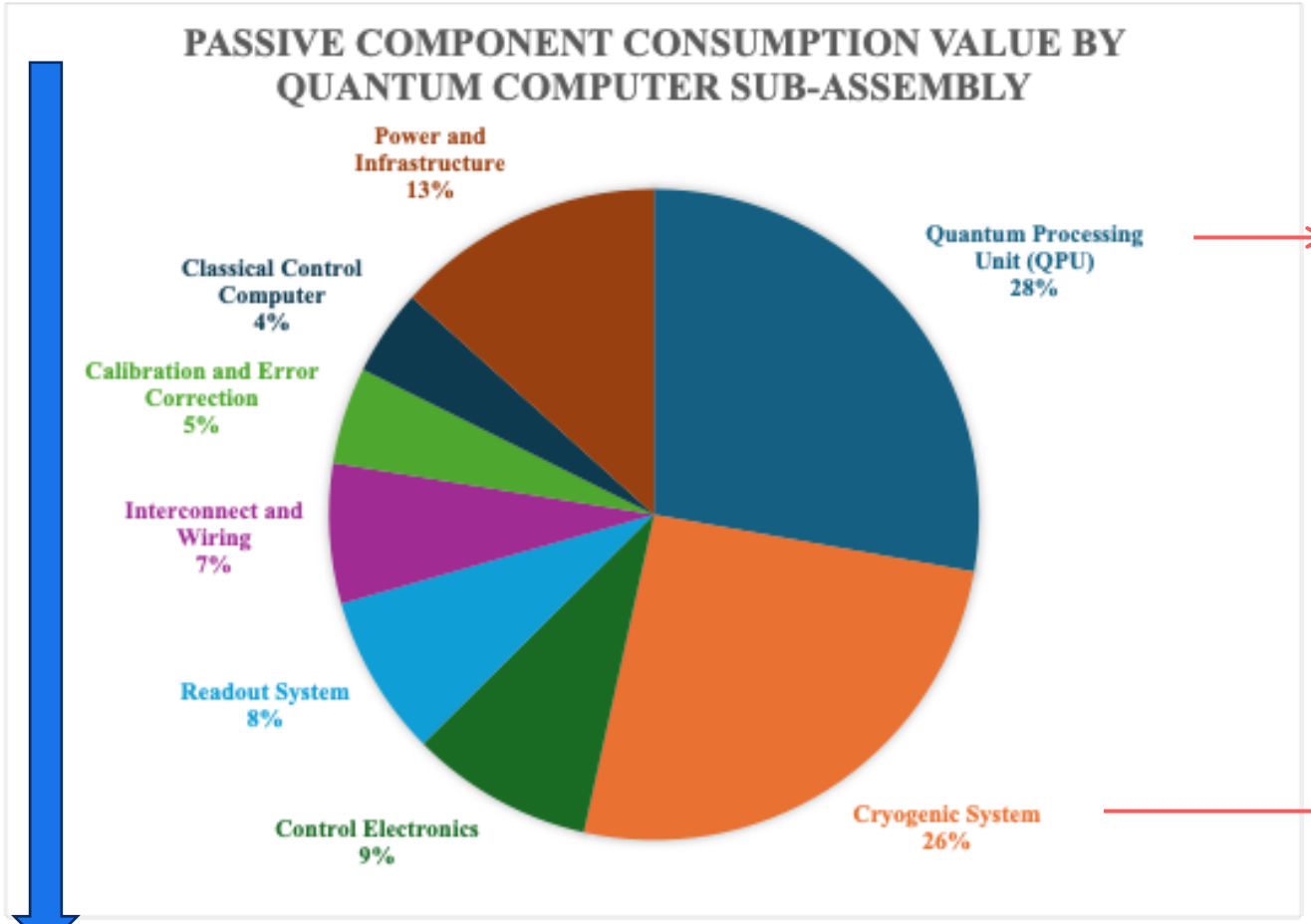
Paumanok Estimates; In MM of USD

Early Stages of Global Market Development

Quantum Computing Passive Components	2025	% OF TOTAL
Capacitors	$7.70	41%
Resistors	$5.20	28%
Inductors	$5.80	31%
TOTAL	$18.70	100%

Passive Electronic Component Usage in Quantum Computers By Sub-Assembly

- Passive Component Consumption (CRL) in Quantum Computers by Sub-Assembly FY 2025



Silicon Nitride
Sapphire
Hexagonal Boron Nitride
Graphene Carbon
Diamond
Superconductor

Porcelain Ceramic NP0
Metallized Polypropylene
Silvered Mica
Tantalum Nitride
Nichrome Film
Nichrome Bulk Metal Foil®
Nichrome Wirewound
Ferrite Core
Ferrite Bead

MLCC X7R
Metallized Polypropylene
Polymer Tantalum
Polymer Aluminum
Porcelain NP0

Nichrome
Ruthenium
Ferrites

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025)
https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

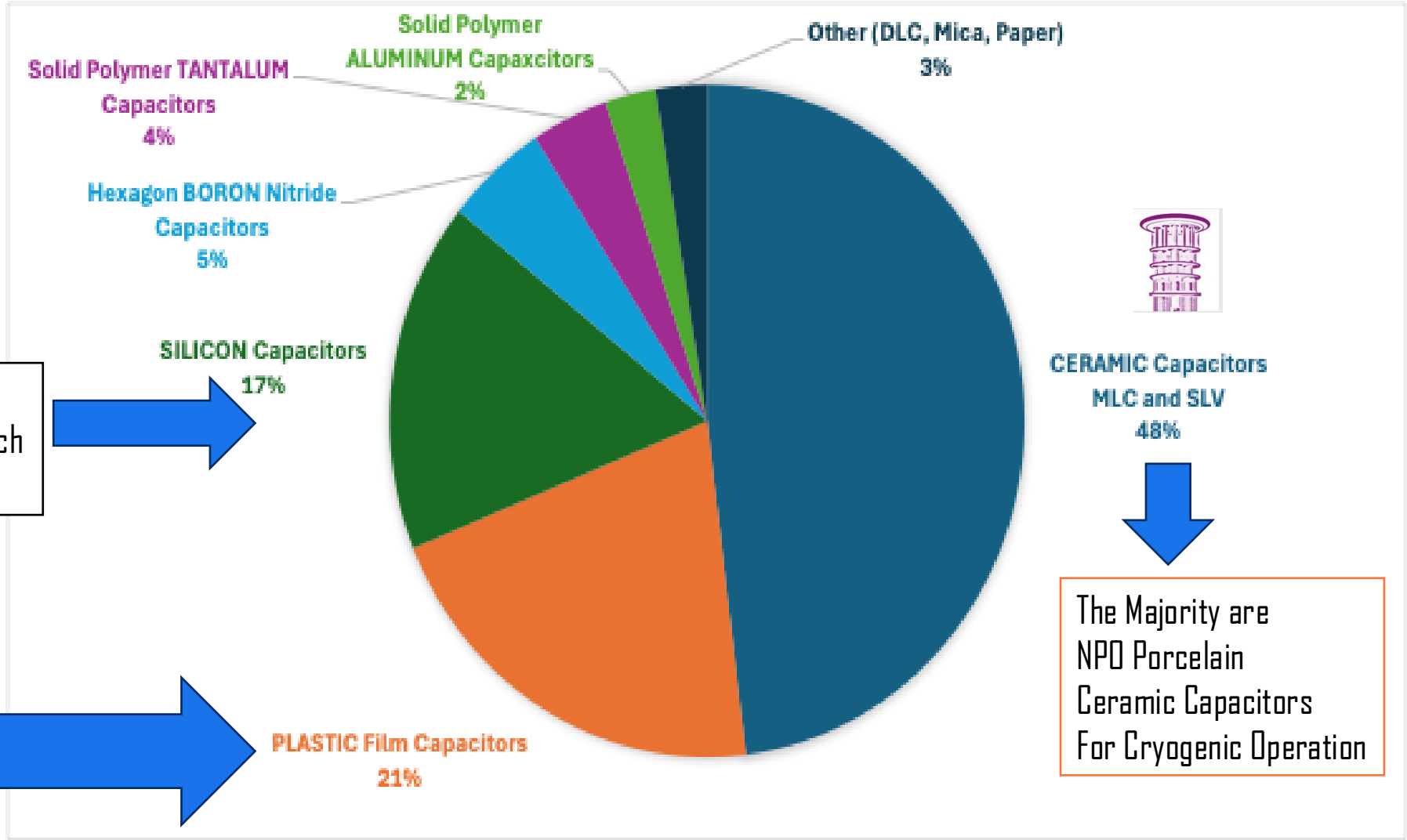
Technology Requirements Are Focused on Complete Noise Elimination

Thermal Noise *Elimination*

- ***Requires Important Component Design Considerations***
- **Performance Stability at Cold Temperatures -269 Degrees C**
- Minimal drift in electrical parameters with temperature **cycling**
- **Low Noise Characteristics**
- Josephson junction noise must be minimized

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025)
https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

Capacitor Consumption Value in Quantum Computing by Type/Dielectric: FY 2025



The Majority are Silicon Nitride Embedded/Trench Capacitors

The Majority are Metalized Polypropylene For Cryogenic Operation

The Majority are NPO Porcelain Ceramic Capacitors For Cryogenic Operation

$7.7 MM USD Global Market FY 2025

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

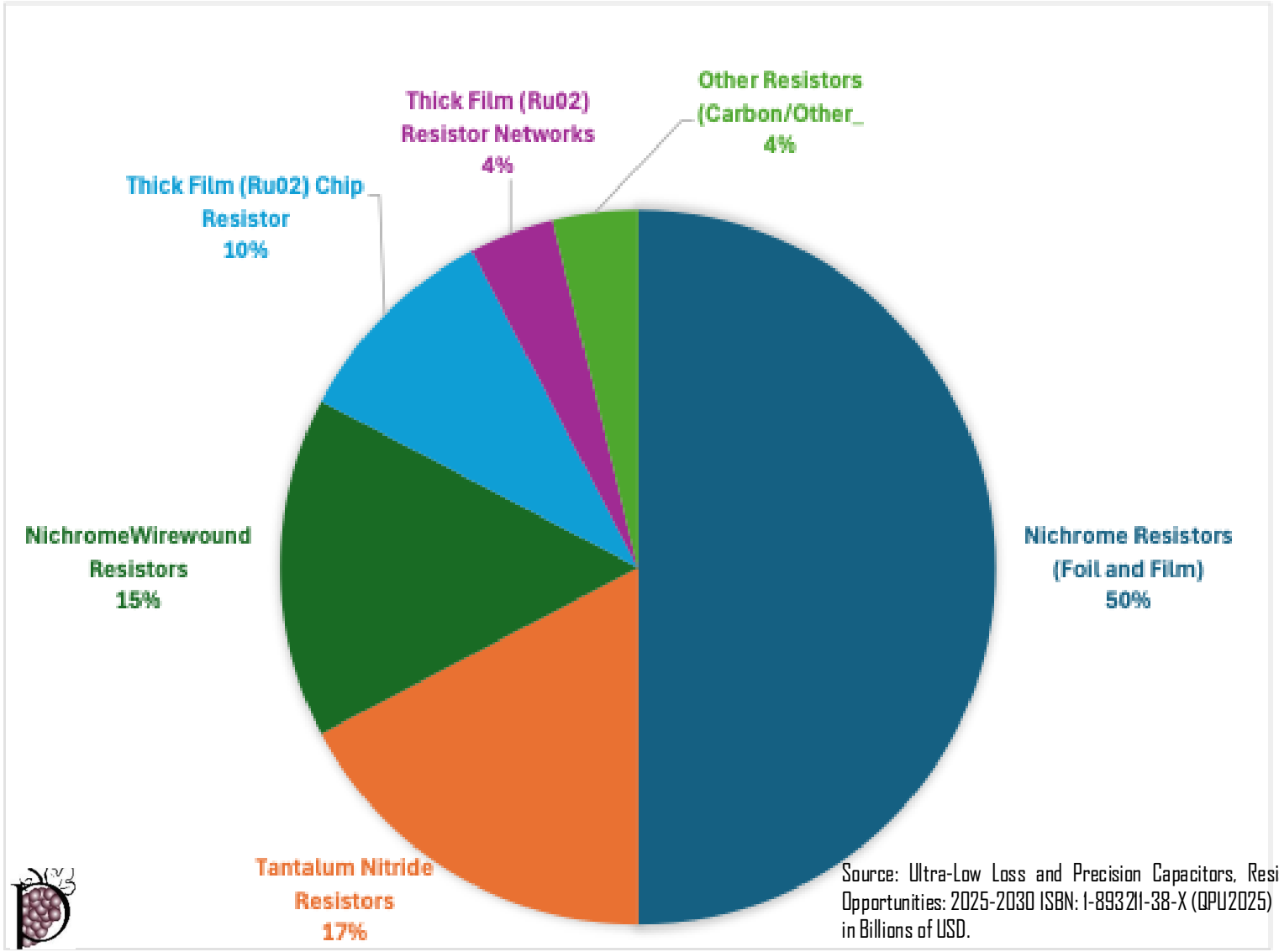
Capacitor Manufacturers Serving Quantum Computing

DIELECTRIC	CAPACITORS	COUNTRY	DIELECTRIC NOTES	TECHNOLOGY	RATED TO	ADDED NOTES
SILICON	KAVX	USA	Silicon Deep Trench	MIM		
SILICON	Murata/IPDIA	FRANCE	Silicon Deep Trench	MIM PICS	4 Milikelvin	Documented Cryogenic Silicon Capacitor Data- Interesting
SILICON	ST Microelectronics	FRANCE	Silicon BiCMOS	MIM		Cryo-CMOS Process Fabrication
SILICON	TSMC	CHINA	Silicon Embedded Trench	CoWoS		Integrated Passive Device Technology
SILICON	Global Foundries	USA	Silicon Embedded Trench	22FDX-FD SOI		Direct Quantum Computer Partnering
SILICON	Mini-Systems	USA	Silicon Dielectric	MSMT 210-0418	4 Milikelvin	
SILICON	ROHM Company	JAPAN	Silicon Deep Trench			Temperature Focused; Silicon Carbide Trends
SILICON	IONQ	USA	Integrated Passive Structures			Trapped Ion Systems
SILICON	Smoltek	USA	CNF-MIM	MIM		
SAPPHIRE	Knowles (Syfer)	UK	Sapphire	Sapphire		Variable capacitors for RF Applications; Ruggedized
SAPPHIRE	Lake Shore	USA	Sapphire/DLC	CS-501 GR	77 K	No Magnetic Field
PLASTIC	Knowles (CDE/NWL)	USA	Polypropylene	Metallized PP		Quantum Computing Power Supplies
PLASTIC	Vishay Roederstein	GERM	Polypropylene	Metallized PP	4 Milikelvin	Quantum Computing Power Supplies
PLASTIC	WIMA	GERM	Polypropylene	Metallized PP	-55	Liquid Helium Electronics
PLASTIC	YAGEO-KEMET-ARCO	ITALY	Polypropylene	Metallized PP	-55	Arcotronics
PLASTIC	Cryogenic Control Sys.	USA	Plastic Dielectric Films			Custom Plastic Film Capacitors specifically for quantum.
MICA	Exellia	FRANCE	Silvered MICA	CMR Series	-55	
CERAMIC	Presidio	USA	Ceramic Dielectric	CRX	4 Milikelvin	Space & Cryogenics
CERAMIC	KAVX	USA	Ceramic Dielectric	Porcelain	4 Milikelvin	The ATC 700 porcelain
CERAMIC	Knowles	USA	Ceramic Dielectric	Porcelain		Custom Assemblies- Ruggedized
CERAMIC	Johanson	USA	Ceramic Dielectric	Porcelain		Custom Assemblies- Ruggedized
CERAMIC	CryoCircuits	USA	Ceramic Chip	CFC	77 K	
CERAMIC	MTECH Labs	USA	Ceramic Chip	CCAP	77 K	Electric Ship
CARBON	NASA	USA	(KSC-TOPS-62) Carbon Aerogel		Flux	Carbon Aerogel
BORON NITRIDE	MIT	USA	Hexagonal Boron Nitride			
ASSEMBLIES	Oxford Instruments	UK	Cryogenic Capacitor Assemblies			Dilution Refrigeration
ASSEMBLIES	Cryotherm SWISS	SWISS	Cryogenic Capacitor Assemblies			Dilution Refrigeration
ASSEMBLIES	Radi-Quant Technologies	USA	Quantum Specific Passives			

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm

in Billions of USD.

Resistor Consumption Value in Quantum Computing by Type/Dielectric: FY 2025



Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

Nickel + Chromium (Nichrome)

- Bulk Metal Nichrome Foil
- Wirewound Nichrome
- Thin Film Nichrome

Tantalum Nitride

- Integrated Passive Devices

Other

- Ruthenium Based
- Tin-Oxide
- Carbon
- Chrome Silicide
- Nickel Phosphor

$5.2 MM USD Global Market FY 2025

Resistor Manufacturers Serving Quantum Computing

ELEMENT	RESISTOR	COUNTRY	RESDISTOR NOTES	TECHNOLOGY	RATED TO
TANTALUM	Mini-Systems	USA	Tantalum Nitride	TaN + Silicon	4 Milikelvin
TIN-OXIDE	Lake Shore	USA	Antimony-Tin	ROX Tin Oxide	4 Milikelvin
TANTALUM	Vishay-EFI	USA	Tantalum Nitride	TaN + Silicon	Specialized cryogenic product lines including Z-series and RN-series
TANTALUM	TT Electronics IRC	UK/USA	Tantalum Nitride	TaN + Silicon	
TAN + SILICON	Mini-Systems	USA	R/C Network	TaN + Silicon	4 Milikelvin
RUTHENIUM	KOA Speer	JAPAN	Ruthenium	PSF series	verified for quantum computing applications
RUTHENIUM	Bourns	USA	Ruthenium	CSS series current sense resistors	
NICHROME	Mini-Systems	USA	Nichrome	Thin Film	4 Milikelvin
NICHROME	VPG Foil Resistors	ISRAEL	Bulk Metal Foil	Nichrome	Neg 200CVSMP0805
NICHROME	Alpha Electronics	JAPAN	Wirewound Nicrhome	Nichrome	Quantum Magnet Control
NICHROME	Isanbellehutte	GERM	Nichrome Film	Nichrome	Current Sense Resistors for Cryogenics
NICHROME	Vishay Dale	USA	Wirewound Nichrome	WSL serie	current sensing resistors with ultra-low temperature coefficients
OTHER	BlueFors	FINLAND		Specialized Cryogenic Resistors	
OTHER	Leiden Cryogenics	HOLLAND		Specialized Cryogenic Resistors	

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

- **Quantum/Cryogenic Parts**
- Vishay Intertechnology (EFI, Dale)
- VPG Sensors
- Mini-Systems
- Alpha Electronics
- Isenbellehutte

$5.2 MM USD Global Market FY 2025

Inductor Manufacturers Serving Quantum Computing

ELEMENT	INDUCTORS	COUNTRY	INDUCTOR NOTES	TECHNOLOGY
FERRITE	Lodestone Pacific	USA	Ferrite Cores	Custom Ruggedized Ferrite Toriodal Cores
FERRITE	Triad Magnetics	USA	Ferrite Cores	Custom Ruggedized Ferrite Toriodal Cores
FERRITE	Agile Magnetics	USA	Ferrite Cores	Custom Ruggedized Ferrite Toriodal Cores
FERRITE	Dexter Electronic Materials	USA	Ferrites + MMO	Custom for Cryogenics and Quantum
FERRITE	Arnold Magnetic Technologies	USA	Ferrites + MMO	Custom for Cryogenics and Quantum
SUPERCONDUCTOR	HYPRES Inc.	USA	SuperConducting	RSFQ (Rapid Single Flux Quantum) applications
SUPERCONDUCTOR	SeeQC-IBM	USA	SuperConducting	
FERRITE	Delevan	USA	Air Core & Ferrite	to -55 C
FERRITE	Exellia	FRANCE	Air Core & Ferrite	To -55 C
FERRITE	Gowanda	USA	Air Core & Ferrite	To -55C

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
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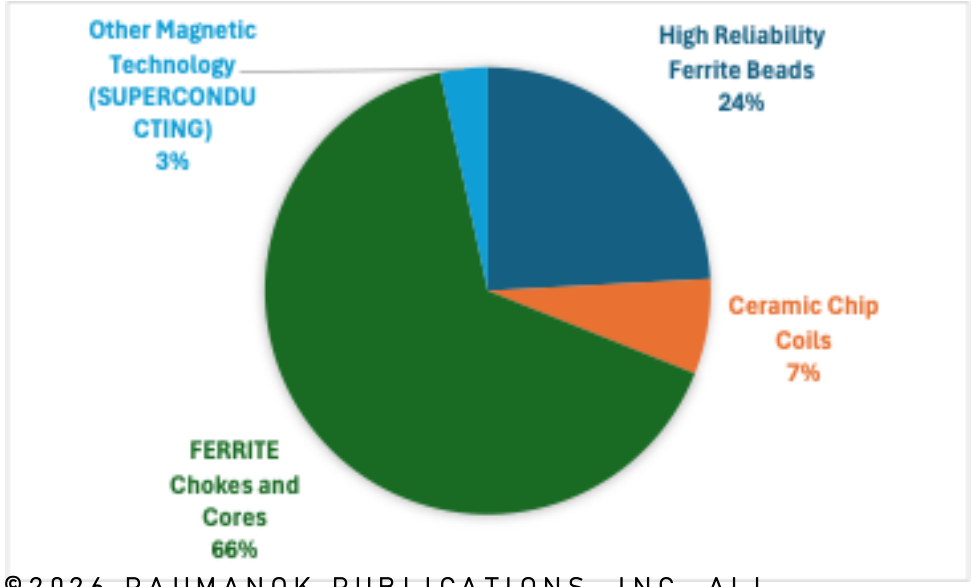


UNDERSERVED MARKET

$5.8 MM USD Global Market FY 2025

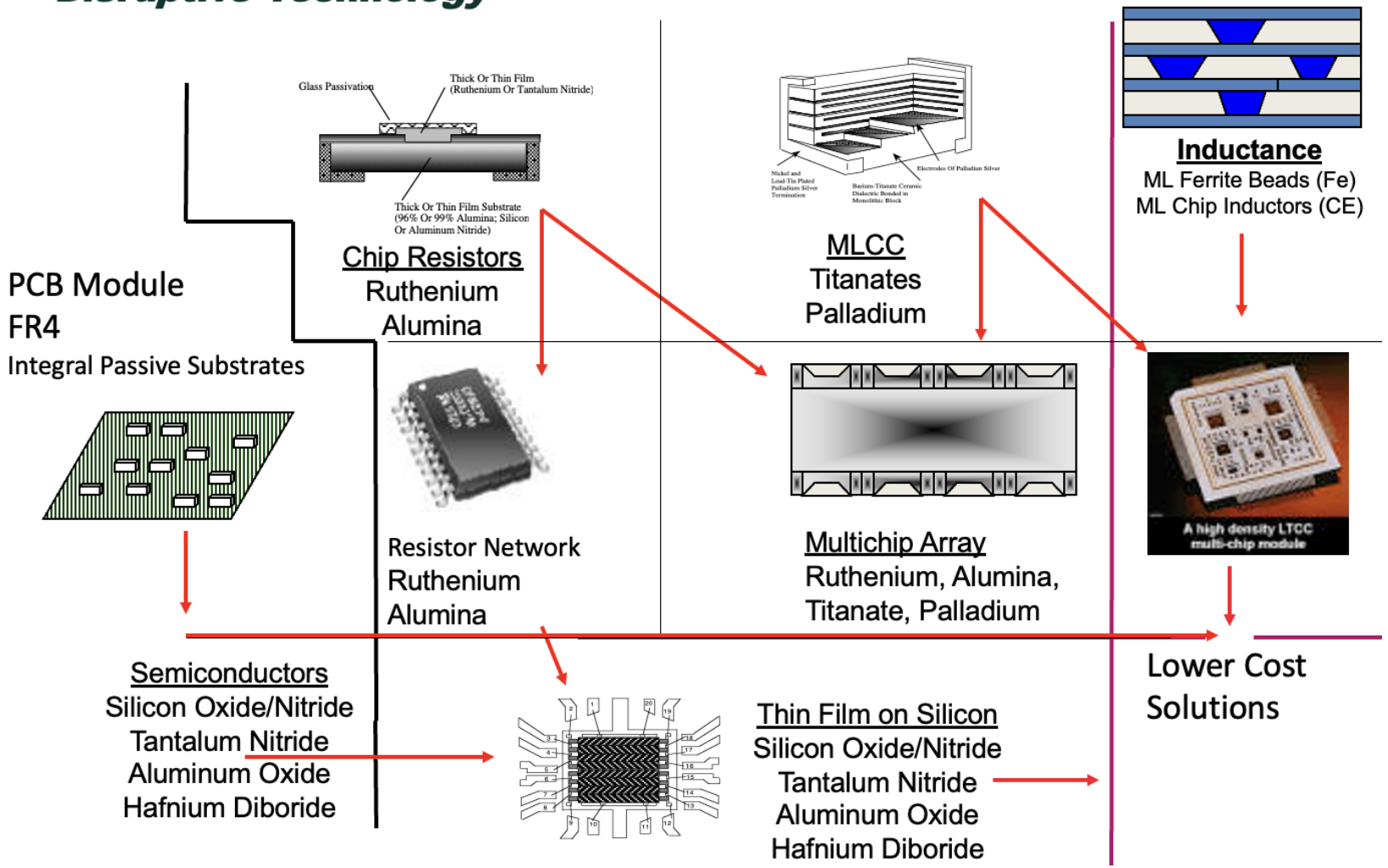
Inductor Raw Materials For Quantum Computing

Key Raw Materials

- Ferrite powders: MnZn, NiZn, MgZn, Iron Oxide, Ni-Iron, Other to 500 MHz.
- Inductor Wire: 155C Bonding Enamel Copper Wire;
- Ceramic Dielectric Materials: Low Loss P90 Porcelain Ceramics; Barium Strontium Titanate (Thin Inductor Films), Neodymium Titanate To 5 GHz.
- Further Study: Neodymium, Strontium, Samarium Cobalt, FerroFluid.

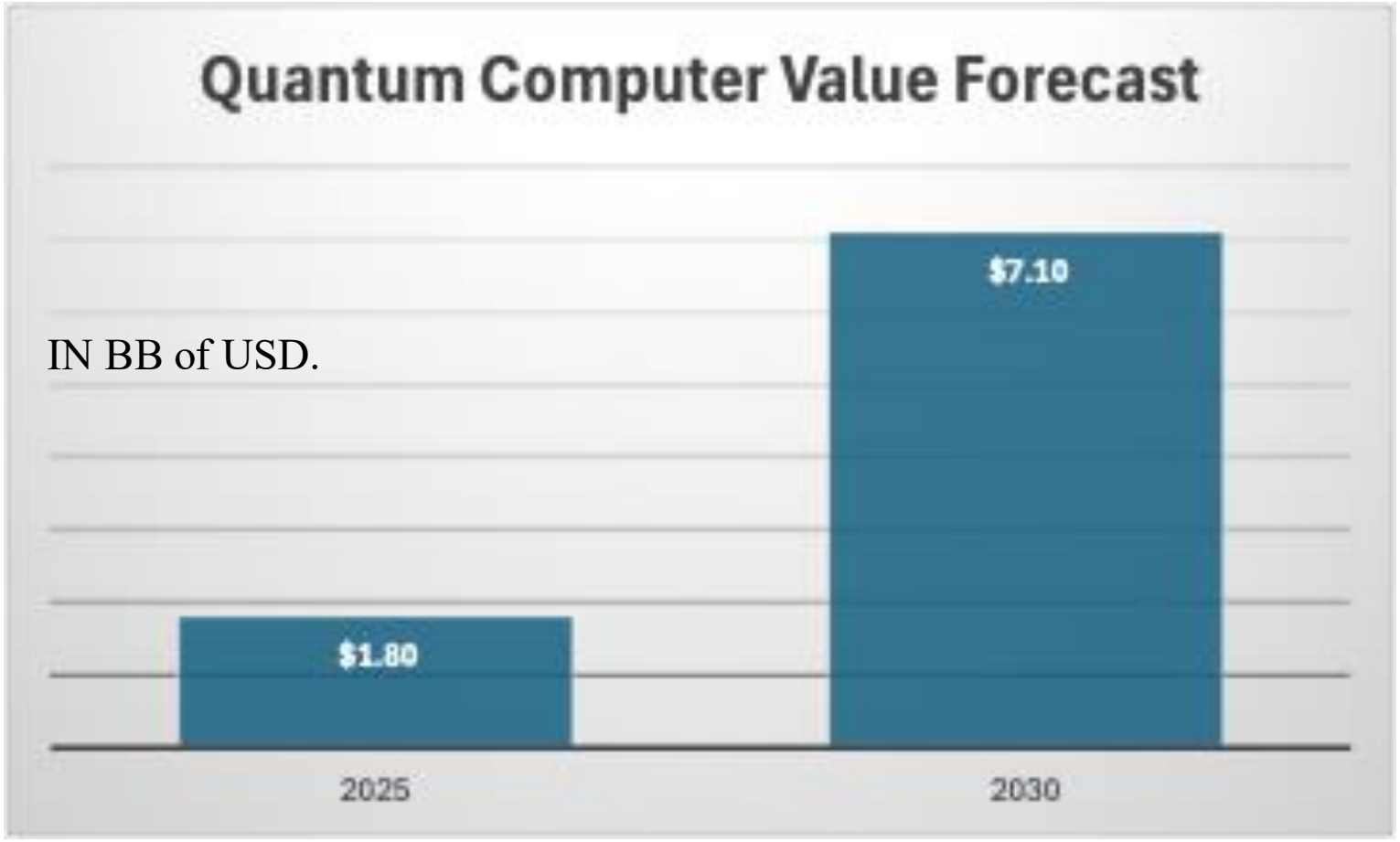
Integration Trends in Passive Components

Integration Solutions for Passive Components
"Disruptive Technology"



Integrated Passive Devices

Quantum Computer Hardware Value Forecast: Global: FY 2025-2030



Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
in Billions of USD.

Capacitor, Resistor and Inductor Forecasts in Quantum Computers: FY 2025-2030

Quantum Computing Passive Components	2025	2030
Capacitors	$ 7.7	$ 101
Resistors	$ 5.2	$ 56
Inductors	$ 5.8	$ 71
TOTAL	$ 18.7	$ 228

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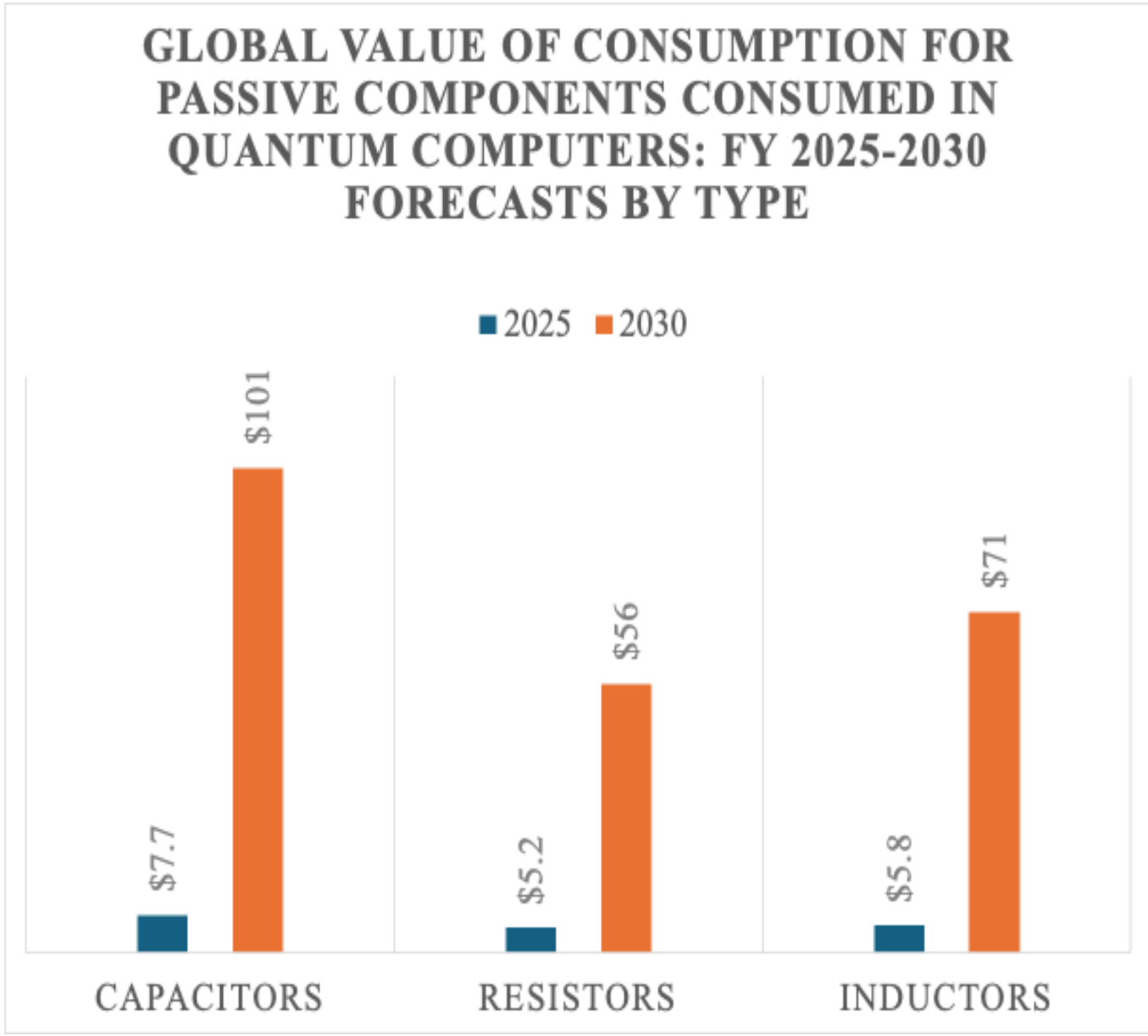
In MM of USD



FORECASTS- Passive Components for Quantum Computing; 2025-2030

Passive Components for Quantum Forecasts	2025	% of Total 2025	2030	% of Total 2030
CERAMIC Capacitors All Types	$ 3.70	48%	$ 41	41%
PLASTIC Film Capacitors	$ 1.60	21%	$ 10	10%
SILICON Capacitors	$ 1.30	17%	$ 25	25%
Hexagon BORON Nitride Capacitors	$ 0.40	5%	$ 5	5%
Solid Polymer TANTALUM Capacitors	$ 0.30	4%	$ 3	3%
Solid Polymer ALUMINUM Capaxcitors	$ 0.20	3%	$ 1	1%
Other (DLC, Mica, Paper)	$ 0.20	3%	$ 16	16%
Grand Total Capacitors	$ 7.70	100%	$ 101	100%
Nichrome Resistors (Foil and Film)	$ 2.60	50%	$ 24	43%
Tantalum Nitride Resistors	$ 0.90	17%	$ 11	20%
NichromeWirewound Resistors	$ 0.80	15%	$ 5	9%
Thick Film (Ru02) Chip Resistor	$ 0.50	10%	$ 5	9%
Thick Film (Ru02) Resistor Networks	$ 0.20	4%	$ 5	9%
Other Resistors (Carbon/Other_	$ 0.20	4%	$ 6	11%
Grand Total Resistors	$ 5.20	100%	$ 56	100%
High Reliability Ferrite Beads	$ 1.40	24%	$ 20	28%
Ceramic Chip Coils	$ 0.40	7%	$ 10	14%
FERRITE Chokes and Cores	$ 3.80	66%	$ 34	48%
Other Magnetic Technology (SUPERCONDUCTING)	$ 0.20	3%	$ 7	10%
Grand Total Magnetcs	$ 5.80	100%	$ 71	100%
GRAND TOTAL ALL	$ 18.70		$ 228	

NPO PORCELAIN CERAMIC
METALLIZED POLYPROPYLENE
SILICON EMBEDDED AND TRENCH

NICHROME
TANTALUM NITRIDE

FERRITES

In MM of USD

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
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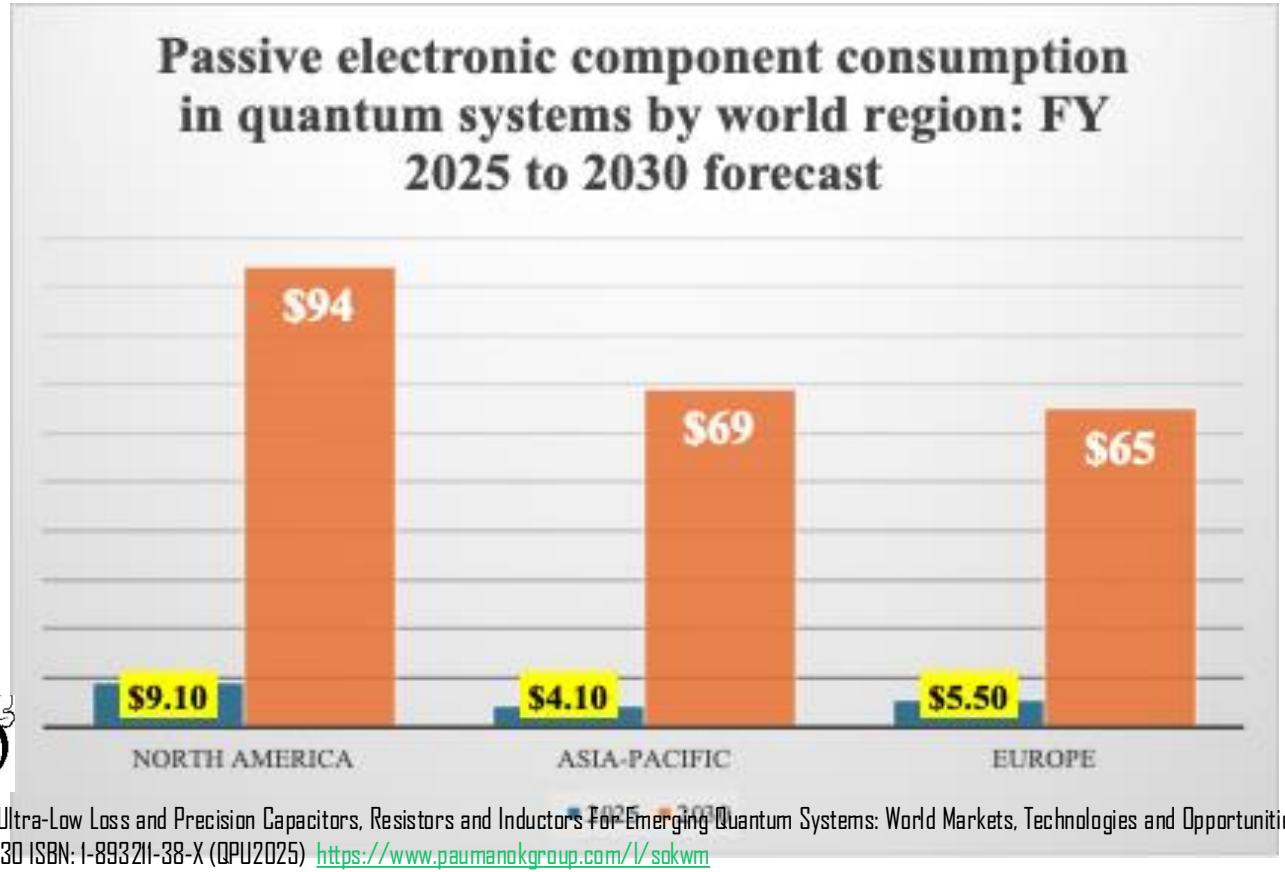
FORECASTS BY WORLD REGION

Passive Component Consumption Value Forecasts by World Region for Applications in Quantum Computing: FY 2025-2030

Region	2025	%	2030	%
North America	$9.10	49%	$94	41%
Asia-Pacific	$4.10	22%	$69	29%
Europe	$5.50	29%	$65	29%
Grand Total	$18.70	100%	$228	100%



- **North America ($9.1 → $94M)**
- Largest market driven by commercial quantum companies and $2.8B annual federal investment
- California leads with 35% of demand (Google, Rigetti), Northeast 28% (IBM)
- Strong emphasis on superconducting quantum systems drives higher cryogenic component demand
- Government policies increasingly emphasize domestic sourcing and supply chain security
- **Europe ($4.1 → $69M):**
- Second-largest market with 1bb Quantum Flagship program driving coordinated development
- Germany leads (32%), France (24%), UK (18%) despite Brexit
- Strong precision manufacturing base and quantum communication emphasis
- Cross-border collaboration and standards development provide competitive advantages
- **Asia-Pacific ($5.5M → $65M):**
- China dominates with 52% regional share, $4.5B annual government investment
- Japan (28%) and South Korea (13%) emphasize industrial applications
- Government-led strategies prioritize technology sovereignty and indigenous supply chains
- Existing electronics manufacturing provides scaling advantages

Source: Paumanok IMR; in MM of USD

Source: Ultra-Low Loss and Precision Capacitors, Resistors and Inductors For Emerging Quantum Systems: World Markets, Technologies and Opportunities: 2025-2030 ISBN: 1-893211-38-X (QPU2025) https://www.paumanokgroup.com/l/sokwm
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FORECAST- Capacitors, Resistors and Inductors for Quantum Computing: Consumption by Quantum Computing Sub-Assembly-FY 2025-2030

Quantum Computing Passive Components	2025	2030	Quantum Notes
Quantum Processing Unit (QPU)	$ 5.2	$ 60	Silicon Nitride, Silicon Dioxide, Tantalum Nitride Film, Hexagonal Boron Nitride, Graphene, Diamond, Ferrite
Cryogenic System	$ 4.8	$ 55	Porcelain Ceramic, Polypropylene, Polyphenylene Sulfide, Vacuum Variable, Tantalum Nitride Film, Silicon
Control Electronics	$ 1.7	$ 25	MLCC and SLC, Polymer Tantalum, Polymer Aluminum
Readout System	$ 1.5	$ 20	Ceramic Capacitors and Inductors
Interconnect and Wiring	$ 1.3	$ 15	Resistors and Inductors
Calibration and Error Correction	$ 0.9	$ 10	Resistors and Inductors
Classical Control Computer	$ 0.8	$ 10	All Capacitors, Resistors and Inductors
Power and Infrastructure	$ 2.5	$ 33	Aluminum, Tantalum and Film Capacitors
Total	$ 18.7	$ 228.0	All Capacitors, Resistors and Inductors

New Capacitors Developed for Qubit Processing

- Hexagonal **Boron Nitride** in Quantum Capacitors: MIT researchers used hexagonal boron nitride to build much smaller capacitors for superconducting qubits, enabling them to shrink the footprint of a qubit by two orders of magnitude without sacrificing performance.
    - Ultra-thin **Graphene**: Nanocapacitors made of graphene and hexagonal boron nitride films can achieve superior capacitor properties, overcoming the "dead-layer" effect that typically decreases capacitance in extremely small nanostructure

- **Diamond**-Like Carbon Capacitors- DLC Capacitors For high voltage rugged applications.

Innovation for Qubit Processing

- *Integrated Passive Structures (CRL)*
- *Silicon Capacitors, TaN Resistors*
- *Superconducting Environment*

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NATURE'S QUANTUM BLUEPRINT

From Bird Eyes to Battlefield — Quantum Sensing Across Species

AVIAN COMPASS

Mechanism: Cryptochrome 4 in the retina forms radical pairs via blue light absorption. Quantum spin entanglement of electron pairs is modulated by Earth's magnetic field, encoding compass direction as a visual overlay.

Key Quantum Effect:
Radical-Pair Mechanism (RPM) — spin coherence maintained for microseconds in a warm, wet biological environment.

Precision:
< 5° heading accuracy across 1,000s of miles.

◇ GHOST MURMUR

Device: CIA / Lockheed Skunk Works quantum magnetometer using nitrogen-vacancy (NV) centers in synthetic diamond.

Principle:
NV-center electron spins precess in response to ultra-weak magnetic fields (heartbeat EMF). AI filters the signal from a 1,000 sq-mile electromagnetic noise floor.

Result (Apr 2026):
Heartbeat detected from ~40 miles — first operational field use. "If your heart is beating, we will find you."

SALMON CHEMOSENSE

Mechanism: Two-phase navigation: geomagnetic imprinting in open ocean + olfactory chemical fingerprinting in the final phase. Natal stream odors are encoded via NMDA receptor LTP during juvenile development.

Proposed Device:
Quantum-coupled chemical sensor array mimicking DFAA (dissolved free amino acid) recognition — persistent molecular 'memory' of chemical gradients encoded at the quantum level.

Application:
GPS-free underwater navigation, submarine trail-following, covert chemical detection.

The Unifying Insight: Biology solved quantum sensing millions of years before engineers did. The radical-pair compass of a songbird, the diamond NV-center of Ghost Murmur, and the geochemical memory of salmon all exploit the same truth — ***quantum coherence can survive in warm, noisy environments long enough to be useful.***

Quantum Tool Developments 2026

Dark Ice Magnetic Navigator	GPS-free positioning using NV diamond magnetometer overlaid with Earth magnetic anomaly maps; achieves true field vector output	Navigation	Dark Ice portfolio
Magnetic Communications Relay	Demonstrates use of Earth's magnetic field to transmit signals through barriers that block all traditional radio frequencies	Navigation	Dark Ice portfolio
Moving Vehicle Tracker	Real-time tracking of vehicles using quantum magnetic anomaly signatures detected passively from the air	Navigation	Dark Ice portfolio
Quantum Magnetocardiograph	Detects the ~1 picotesla magnetic field of a beating human heart; core sensing layer of Ghost Murmur program	Biological	Classified / pending
DARPA AMBIENT Gradient Sensor	Detects biological magnetic signals in Earth's ambient field without shielded rooms; key DARPA program Lockheed is executing	Biological	DARPA RoQS
DNV-Based Hydrophone	Uses NV diamond magnetic sensor as ultra-sensitive underwater acoustic detector, replacing conventional pressure sensors	Acoustic	US (Justia)
Ionic Fluid Acoustic Detector	Detects acoustic signals transmitted through conductive fluids via magnetic field perturbation; passive sonar capable	Acoustic	US (Justia)

	conventional pressure sensors		
Ionic Fluid Acoustic Detector	Detects acoustic signals transmitted through conductive fluids via magnetic field perturbation; passive sonar capable	Acoustic	US (Justia)
DNV Material Quality Probe	Measures quantum energy levels of DNV diamond to certify material is suitable for sensor-grade manufacturing	Materials	US (Justia)
Phonon Spectrum Magnetometer	Acoustically drives the diamond to manipulate its phonon spectrum, enhancing fluorescence and increasing magnetic sensitivity	Materials	US (Freshpatents)
AI Cardiac Signal Isolator	Adaptive filtering and waveform recognition algorithms that isolate a single heartbeat signature from broadband electromagnetic noise at range	AI processing	Classified

Navigation → **Sensing** → **Measuring**

Quantum Patents Point Toward the Development of Quantum Tools for Navigation, Sensing and Measuring

Q & A for Coherence

Q&A

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