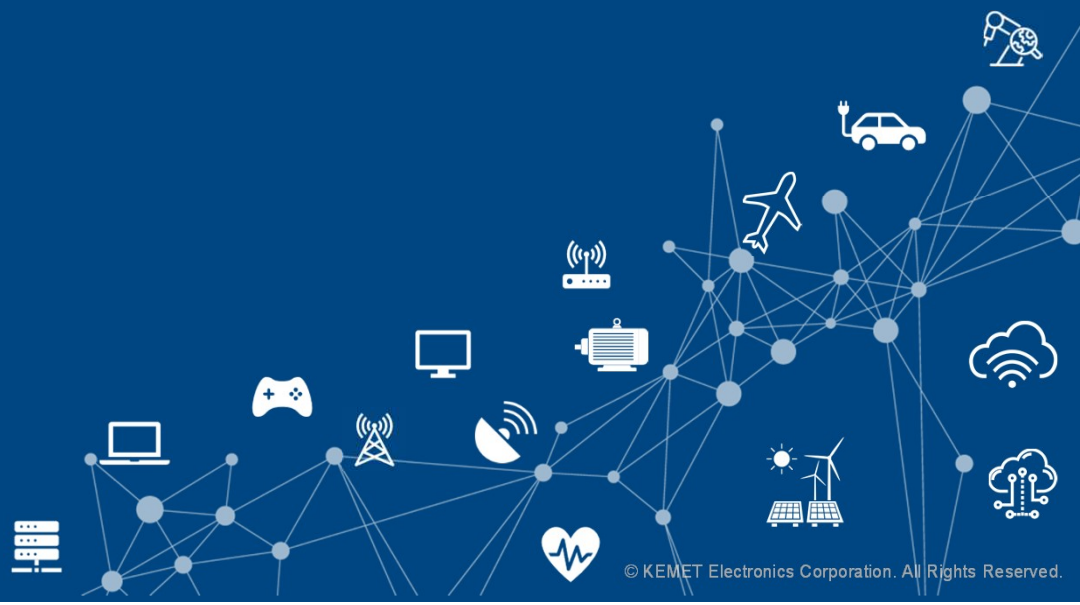
Ceramics and Tantalum Mil/Aero Space Product Hierarchy Up-date

João Pedroso
Technical Product Manager,
Tantalum & Hi-Rel Ceramics, EMEA

Ceramics and Tantalum Mil/Aero Space Product Hierarchy Up-date

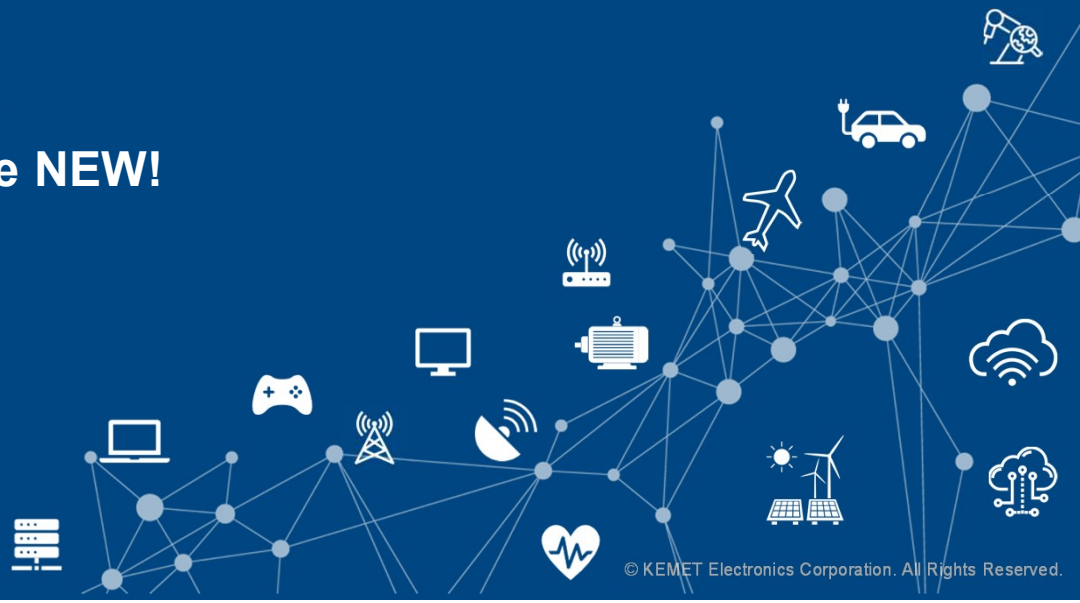
Purpose of Presentation: Provide a high level overview of Ceramics and Tantalum reliability grades and introduce the High-Rel Alternative (HRA) series

- Ceramics
- Tantalum
- Q&A



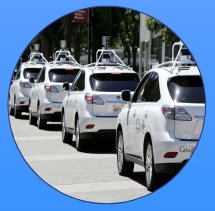
Ceramics Agenda

- Introduction
  - Reliability in Ceramic Capacitors
- Full Grade Range
  - Commercial
  - Automotive
  - COTS (Commercial off the Shelf)
  - **HRA High Reliability Alternative NEW!**
  - Military
  - Space
  - Custom



AUTOMATED ELECTRIFIED CONNECTED SHARED





MLCC's per car

ICE = 2,500 & growing

EV = >10,000 & growing

MLCC's per Smartphone

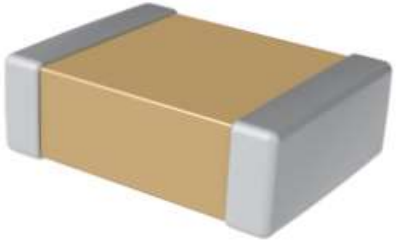
MLCC DEMAND DRIVERS





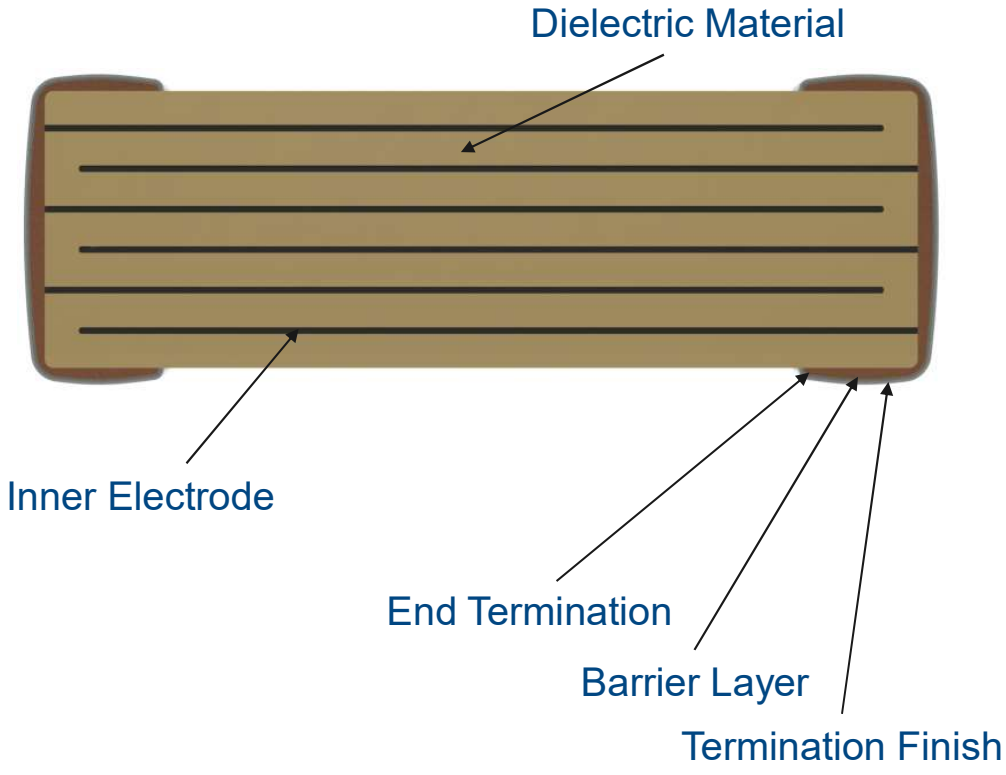

Why are Ceramic Capacitors so Popular?

- Very reliable
  - Low ppm failure rates
  - Long life – Billions of hours
- Small form factor
- Wide operating temperature range
- Low cost



MLCCs

Detailed Cross Section



C = Design Capacitance

K = Dielectric Constant

A = Overlap Area

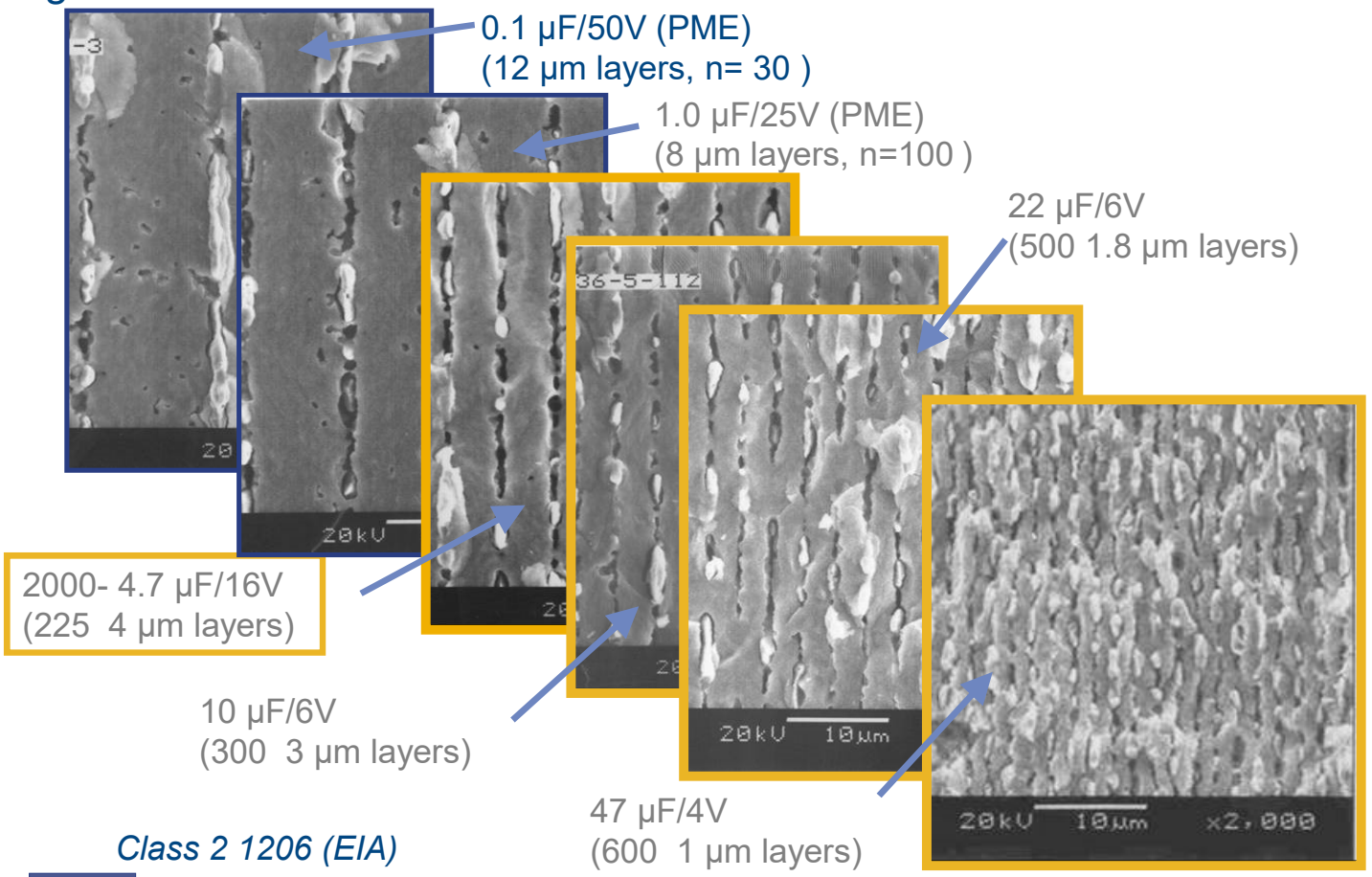
d = Ceramic Thickness

n = Number of Electrodes

$$C = \frac{\varepsilon_0 K A (n-1)}{d}$$

CV = Capacitance x Voltage

MLCCs
Layer Count Progression



Reliability in Ceramic Capacitors

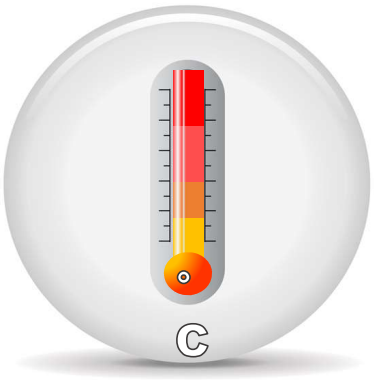
What do we mean?

Ability for the capacitor, under normal conditions, to operate within the specification over it's lifetime with few or no failures.

What we don't mean

Excessive Mechanical Stress (Flex)

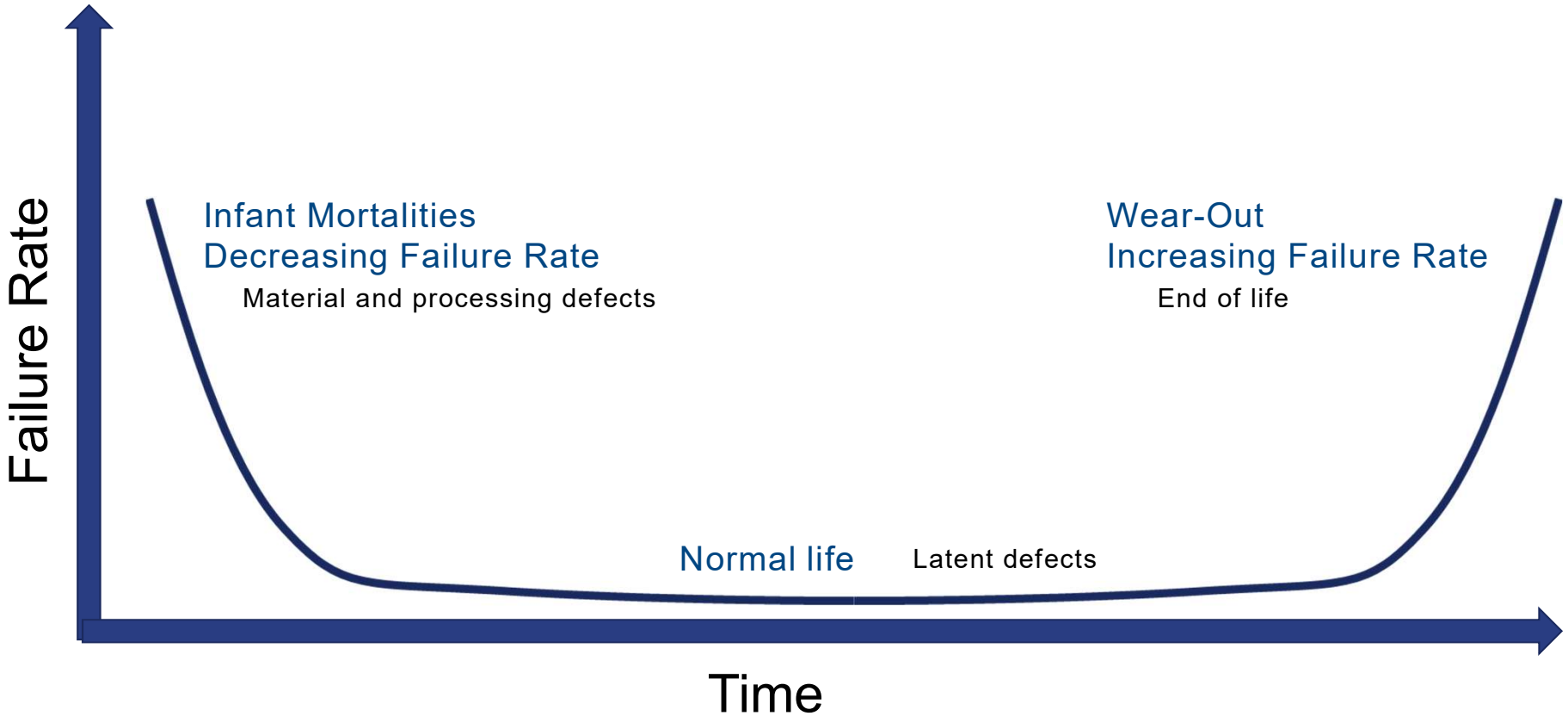
Excessive Voltage



Excessive Temperature

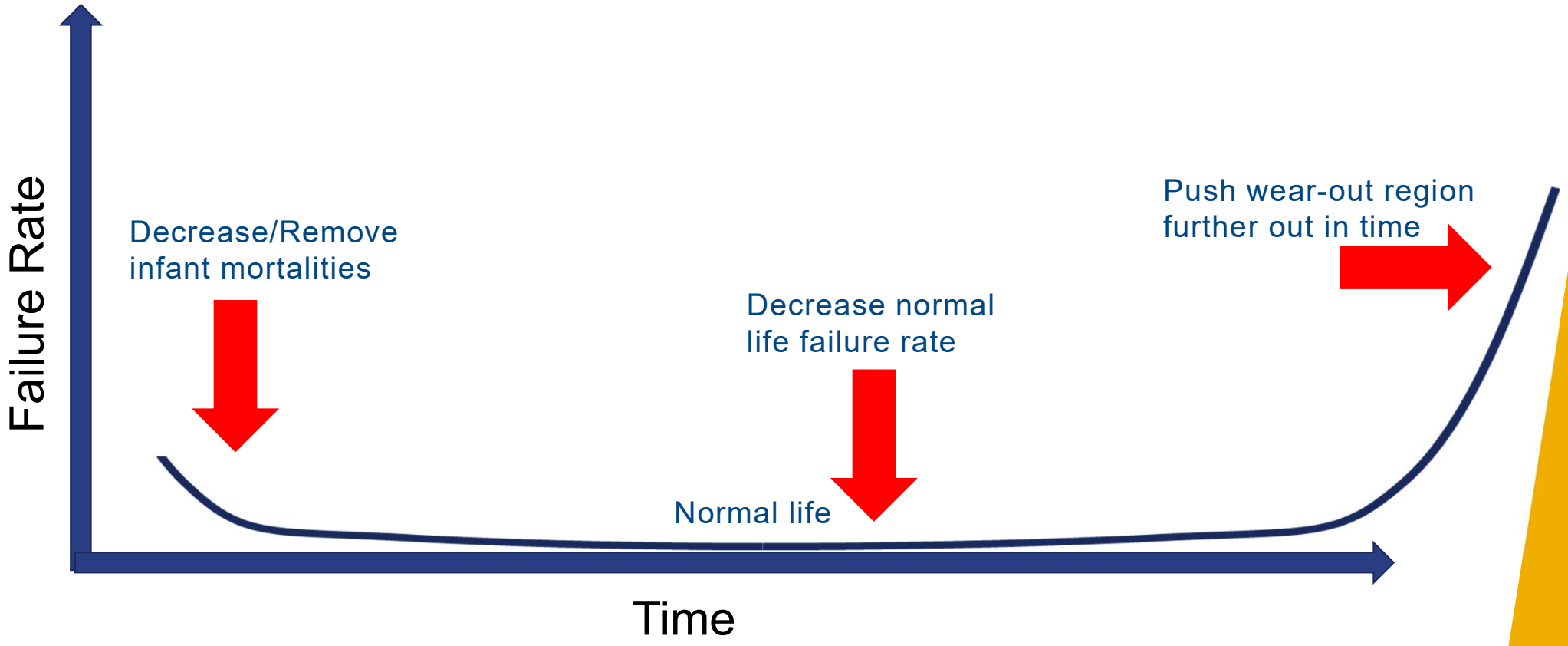
Voltage Transients

The Bathtub Curve



The Bathtub Curve

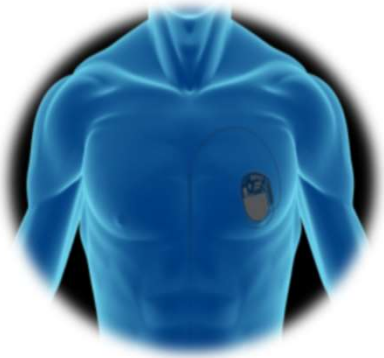
What does higher reliability do?



Increasing Reliability in Ceramic Capacitors

How is it done?

What Drives Higher Reliability in Capacitors?

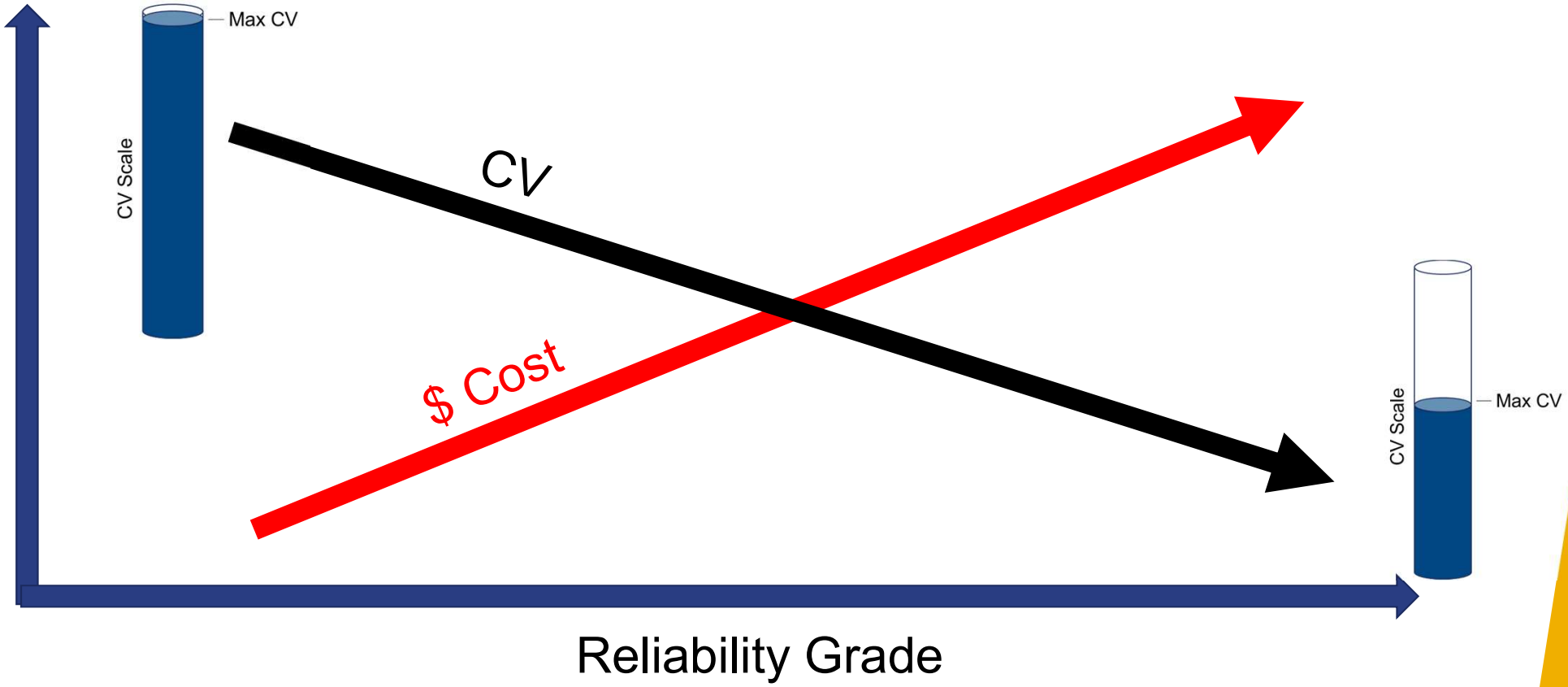


Cost of Failure

Inability to Fix

Safety

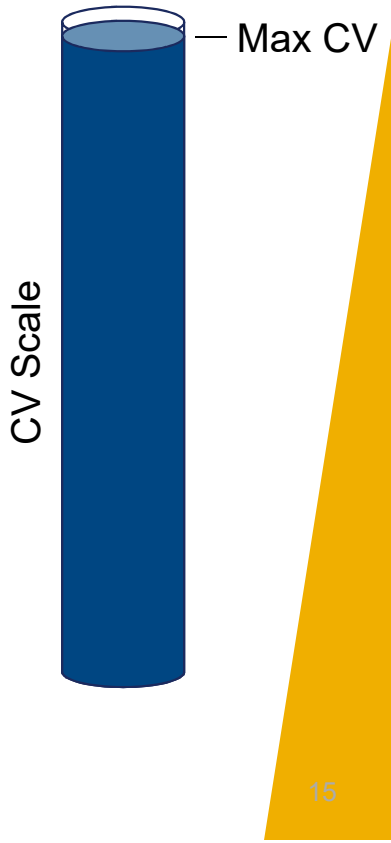
There's Always a Tradeoff



KEMET Ceramics Reliability Grades

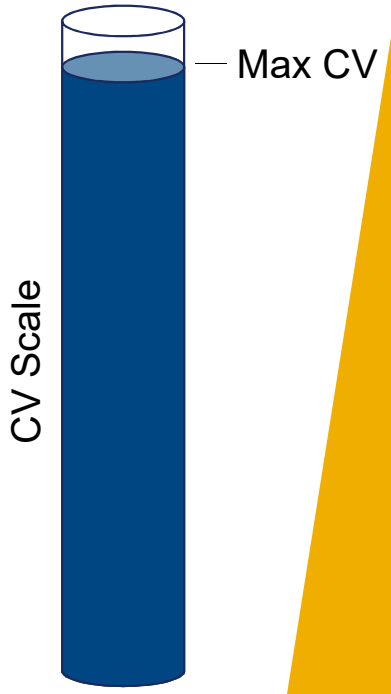
Commercial Grade

- **Features**
  - Highest CVs possible
  - Smallest case sizes
  - Highest volumes
  - Lowest Cost
- **Qualification** – Determined by manufacturer
- **Base Testing Protocol**:
  - Electrical Testing - 100% Cap / DF / IR & DWV
  - Physical Inspection - 100% Sample basis
  - Solderability - 100% Sample basis
  - Product change notification only
- **Applications** – General purpose, consumer electronics, etc



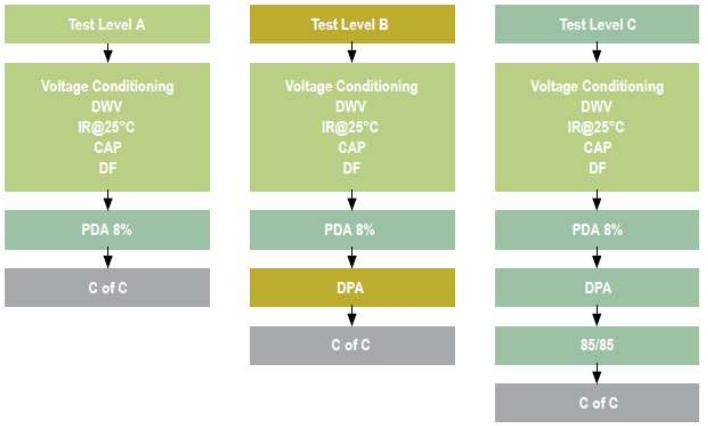
Automotive Grade

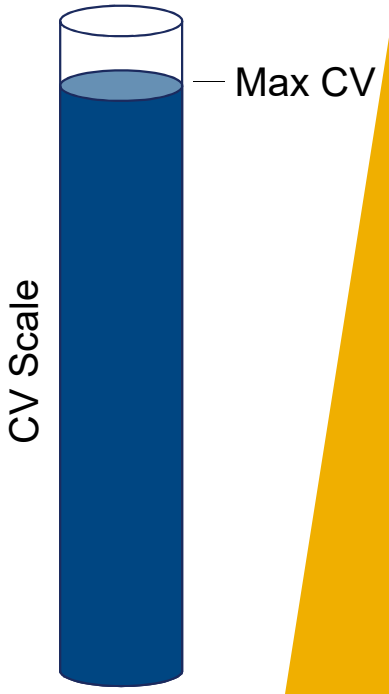
- **Features**
  - Increased Reliability vs Commercial Grade
  - High CVs (close to Commercial)
  - Small case sizes
  - Market size <10% of commercial
  - Low cost slightly above commercial
- **Qualification** - Automotive Electronics Council's AEC-Q200
- **Base Testing Protocol + Additions**:
  - 100% Visual Inspection
  - End of Line Testing
  - PPAP
  - Product Change Notification with approval
- **Applications** – Under the hood, power train, sensors, infotainment



COTS
Commercial Off the shelf

- **Features**
  - Higher Reliability Applications
  - High CVs (close to Commercial and Automotive)
  - Much lower volumes than Commercial and Automotive
  - Slightly Lower Cost vs Military Grade
- **Qualification** – By manufacturer. KEMET's COTS based on AEC-Q200
- **Base Testing Protocol + Additions**:
  - 100% Visual Inspection
  - Burn-in, Voltage conditioning with PDA
  - Electricals with PDA
  - Destructive Physical Analysis (DPA)
  - Humidity Testing
  - Customizable with drawing
- **Applications** higher reliability applications
  eg. Industrial, medical equipment, military, avionics, etc)

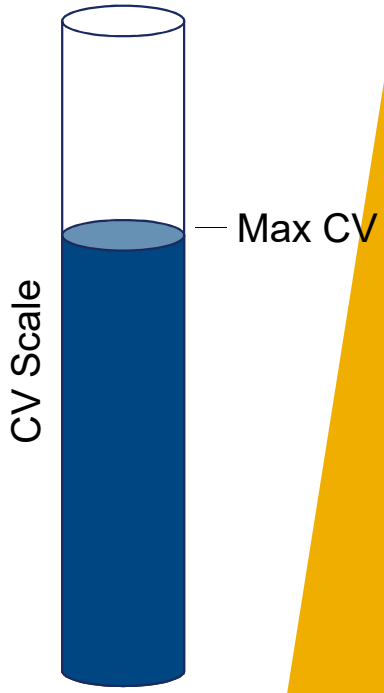




Military Grade

"Standard" and "Established" Reliability

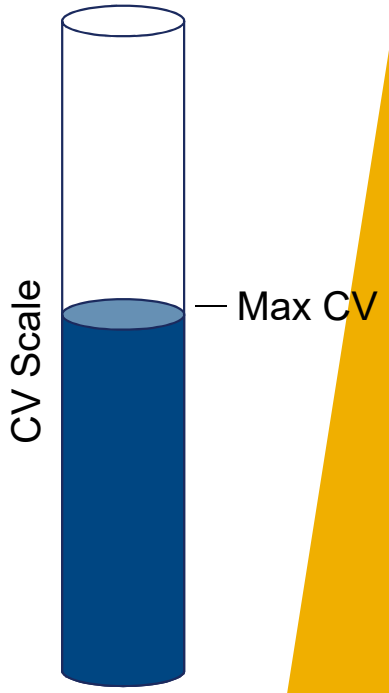
- **Features**
  - Military Defined Standard and Established Reliability
  - Very conservative designs
  - Constructed per MIL Standards
  - Lower CVs
- **Qualification and Testing** – Defined by DLA (Defense Logistics Agency)
  - MIL-PRF-55681
  - MIL-PRF-32535 M-Level
- **Additional**
  - Periodic inspection for electrical, environmental, and mechanical.
  - Group Data and Test Summaries
  - Complete material traceability to raw materials
- **Applications** – Non-critical military applications such as communications devices, ground weapons, military equipment not used for navigation and Safety



Space Grade

"High Reliability"

- **Features**
  - Military Defined High Reliability
  - Very conservative designs
  - Constructed per MIL Standards
  - Lowest CVs
- **Qualification and Testing** – Defined by DLA (Defense Logistics Agency)
  - MIL-PRF-123
  - MIL-PRF-32535 T-Level
- **Additional**
  - Every lot receives electrical, environmental, and mechanical.
  - Group Data and Test Summaries
  - Single Lot Date Code
- **Applications** – Space, missiles, avionic safety and navigation equipment



Inspection	Test Method	MIL-PRF-32535 M-Level	MIL-PRF-32535 T-Level
In-Process Inspection			
Nondestructive internal examination (pre-termination)	MIL-PRF-32535 Method 4.6.1	Not required	Yes (100%)
Visual examination (post-termination)	MIL-PRF-32535 Method 4.6.2	Not required	Yes (100%)
Group A Inspection			
Thermal shock	MIL-PRF-32535 Method 4.6.3	Not required	Yes (100%)
Nondestructive internal examination (case sizes ≥ 0805 only)	MIL-PRF-32535 Method 4.6.1	Not required	Yes (100%)
Voltage conditioning	MIL-PRF-32535 Method 4.6.3	Yes (100%)	Yes (100%)
Visual and mechanical inspection	MIL-PRF-32535 Method 4.6.2	Yes (per inspection lot)	Yes (production lot sample)
Destructive physical analysis (DPA)	MIL-PRF-32535 Method 4.6.8	Not required	Yes (production lot sample)
Solderability (solder dipped and solder plated terminations only)	MIL-PRF-32535 Method 4.6.11	Yes (per inspection lot)	Yes (production lot sample)
Wire bond strength (gold-plated terminations only)	MIL-PRF-32535 Method 4.6.12	Yes (per inspection lot)	Yes (production lot sample)
Group B Inspection			
Thermal shock	MIL-PRF-32535 Method 4.6.3	Yes (periodic)	Yes (production lot sample)
Life	MIL-PRF-32535 Method 4.6.16	Yes (periodic)	Yes (production lot sample)
Temperature humidity bias (load humidity)	MIL-PRF-32535 Method 4.6.15	Yes (periodic)	Yes (production lot sample)
Voltage - temperature limits/temperature characteristic	MIL-PRF-32535 Method 4.6.14	Yes (periodic)	Yes (production lot sample)
Dielectric breakdown voltage (UVBD)	MIL-PRF-32535 Method 4.6.17	Yes (periodic)	Yes (production lot sample)
Group C Inspection			
Board flex	MIL-PRF-32535 Method 4.6.9	Yes (periodic)	Yes (periodic)
Shear stress	MIL-PRF-32535 Method 4.6.10	Yes (periodic)	Yes (periodic)
Resistance to soldering heat	MIL-PRF-32535 Method 4.6.13	Yes (periodic)	Yes (periodic)

KEMET Custom

Per customer request

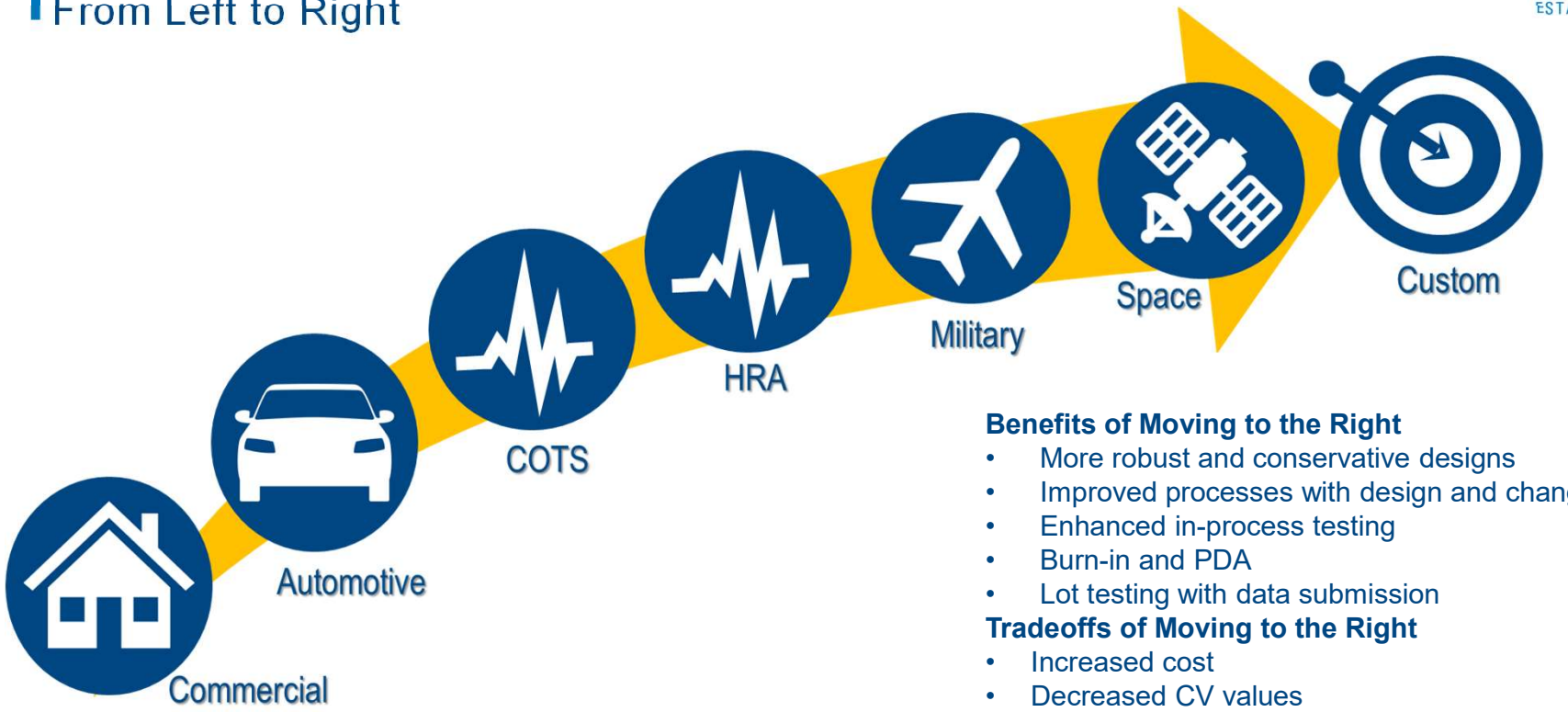
- Customer Drawing

  - ✓ Design per customer spec
  - ✓ Custom In Process Screening
  - ✓ Custom Group Testing
  - ✓ Application Specific SCD's
  - ✓ Group Data and Test Summaries
  - ✓ Material Analytics & Test Reports
  - ✓ Single Lot Date Code per spec

- Qualification per customer spec.
- Change Control per spec.

Summarizing KEMET Ceramics Reliability Grades

From Left to Right



Benefits of Moving to the Right

- More robust and conservative designs
- Improved processes with design and change control
- Enhanced in-process testing
- Burn-in and PDA
- Lot testing with data submission

Tradeoffs of Moving to the Right

- Increased cost
- Decreased CV values

Effect on Reliability

- Reduction and/or elimination of infant mortals
- Reduction of normal life failures
- Increase in MTTF

What is the Issue with COTS?
Perception

Customer A

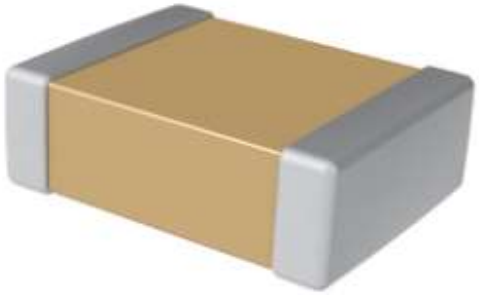
COTS is a high reliability part type for critical applications

Customer B

Since it has "Commercial" in the name, COTS has the connotation that it's a commercial grade part so I can't use it in my higher reliability application.

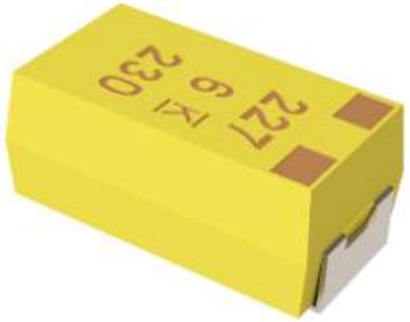
“KEMET COTS”

Ceramic COTS



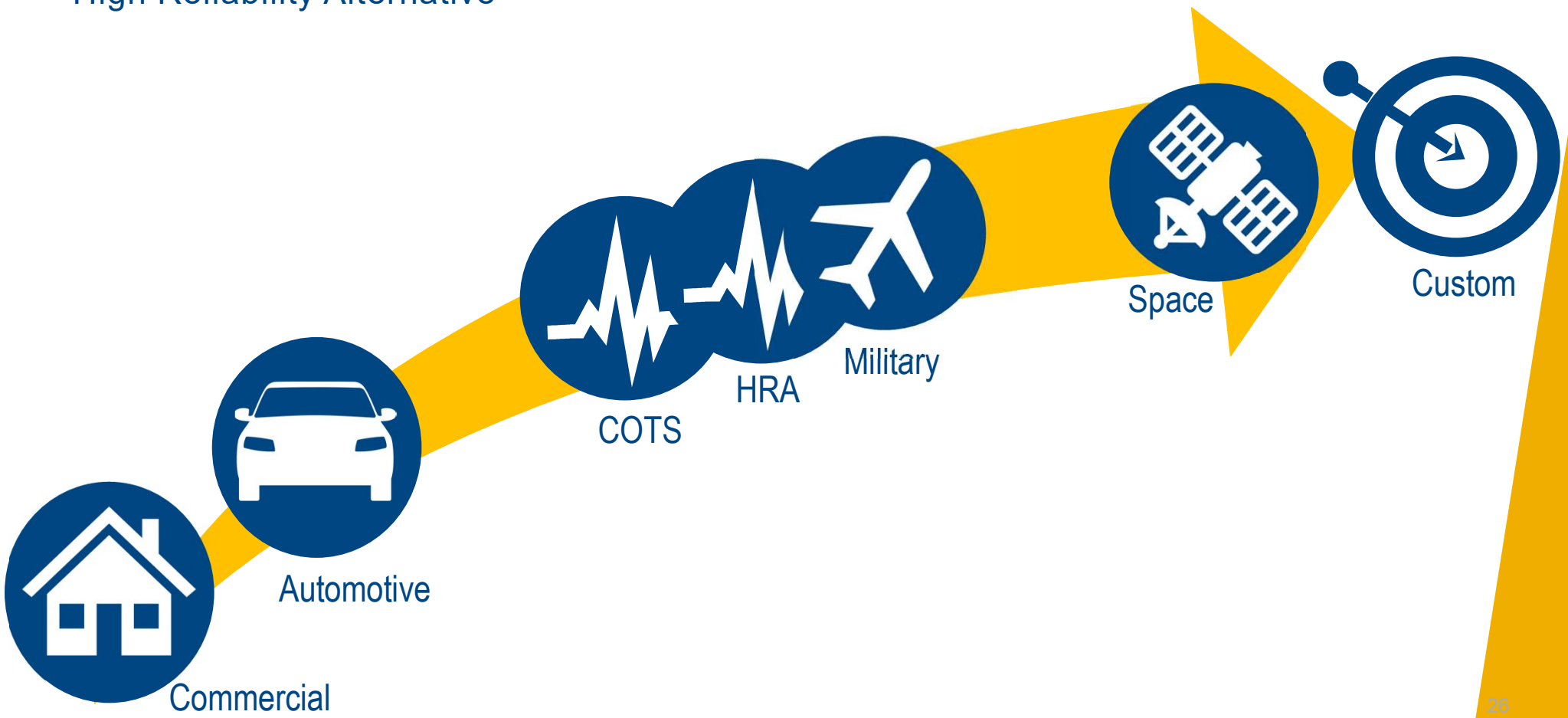
≠

Tantalum COTS



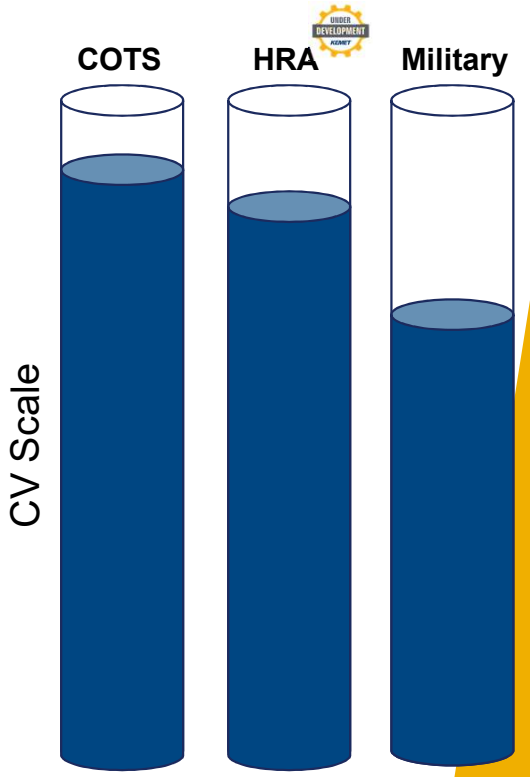
What are Customers Asking for?

Ceramics HRA Series
High Reliability Alternative



Ceramics HRA Series
High Reliability Alternative

- **Features**
  - Conservative offering vs COTS and Auto Grade
  - Higher CVs not available in MIL-PRF
  - Auto Grade designs
  - Customizable using SCD/C-SPEC
- **Qualification and Testing** - Internal
  - References Automotive AEC-Q200 and MIL-PRF-32535 methods
- **Additional**
  - Group A and B per MIL-PRF-32535
  - Periodic inspection for electrical, environmental, and mechanical
  - Test Summaries and CoC
  - Complete material traceability to raw materials
- **Applications** – Short duration or limited life i.e. satellites (<5 Years), Launch Vehicles, Avionics, ground systems

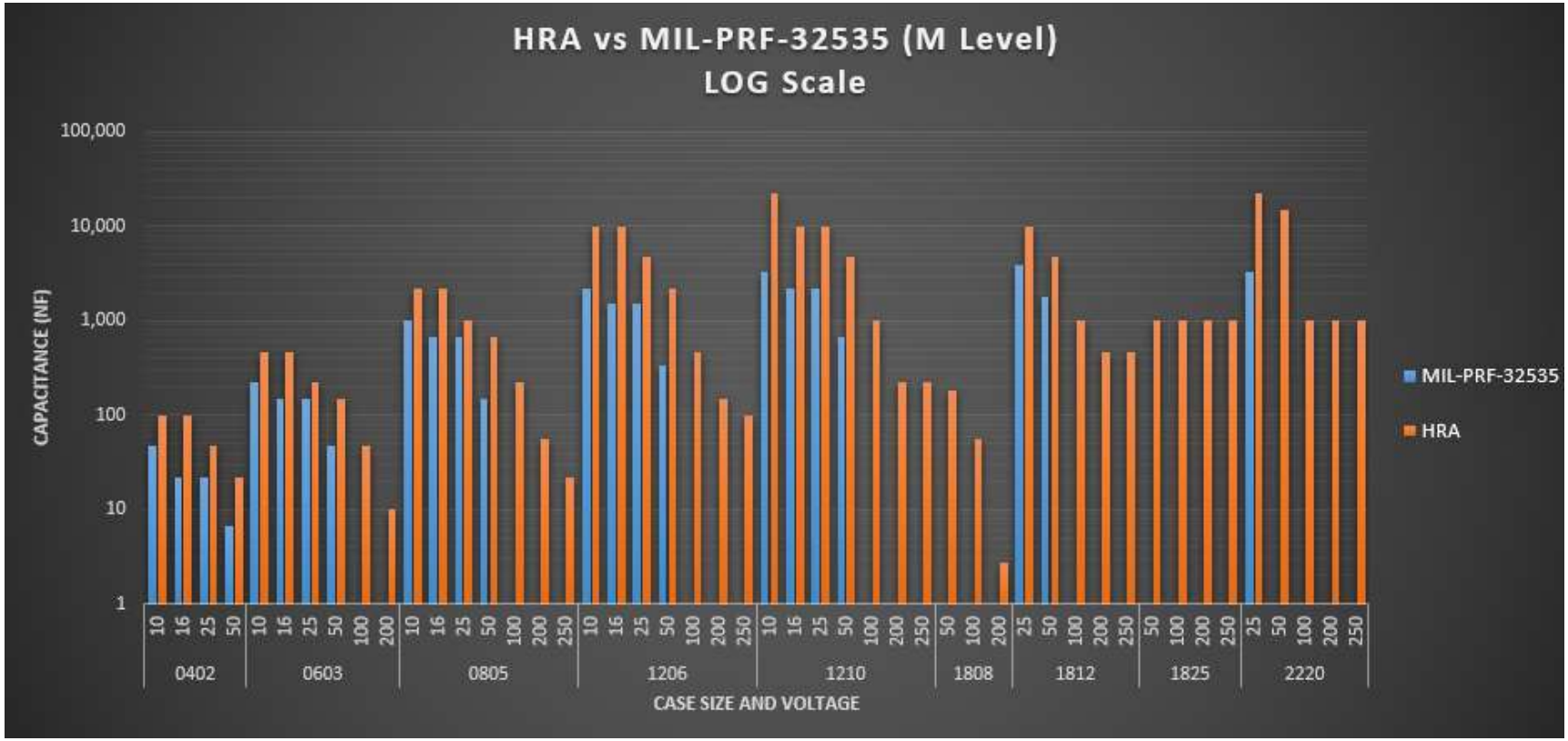


Ceramics HRA Series
High Reliability Alternative

UNDER DEVELOPMENT
KEMET

100 YEARS KEMET ESTABLISHED 1919

Up to a 600% increase in HRA vs MIL-PRF-32535!!!!

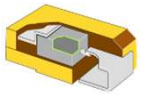


Some voltage offerings not shown

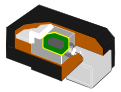
Tantalum Agenda

- Introduction
  - Reliability in Tantalum Capacitors - Pyramid
- Full Grade Range
  - Commercial
  - Automotive
  - COTS (Commercial off the Shelf) **REBRANDING**
  - **HRA High Reliability Alternative NEW!**
  - Military
  - Space
  - Custom
- Conclusion

Tantalum Hierarchy Pyramid Up-date



CWR (T409/19/29)
DLA (T493, T495…)
Space Grade
(T493, T497, T510)



T580/T581
T583/T584
T540/T541 Spec Dwg

Space / Mil PRF / ESA Grades Series

T493, T428, T495, T497
T513, T496

T540/T541

High Reliability Alternative Series

COTS

COTS REBRANDING
Fit to Design / Manufacturing

T49x AUTO
T510 AUTO

T591/8/9

AUTOMOTIVE Series

T543

Up-screen Commercial Series

T49x
T510

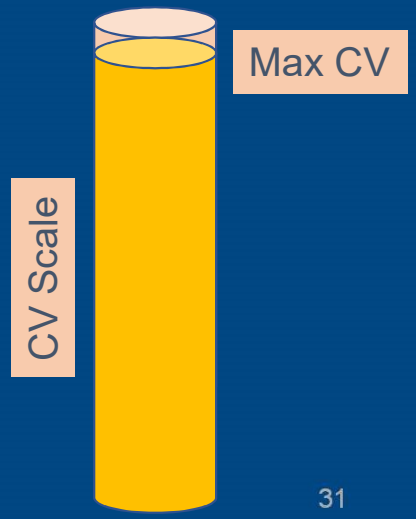
T520,1,2, 3,5,7,8,9
T530
T545/T548…

Commercial Series

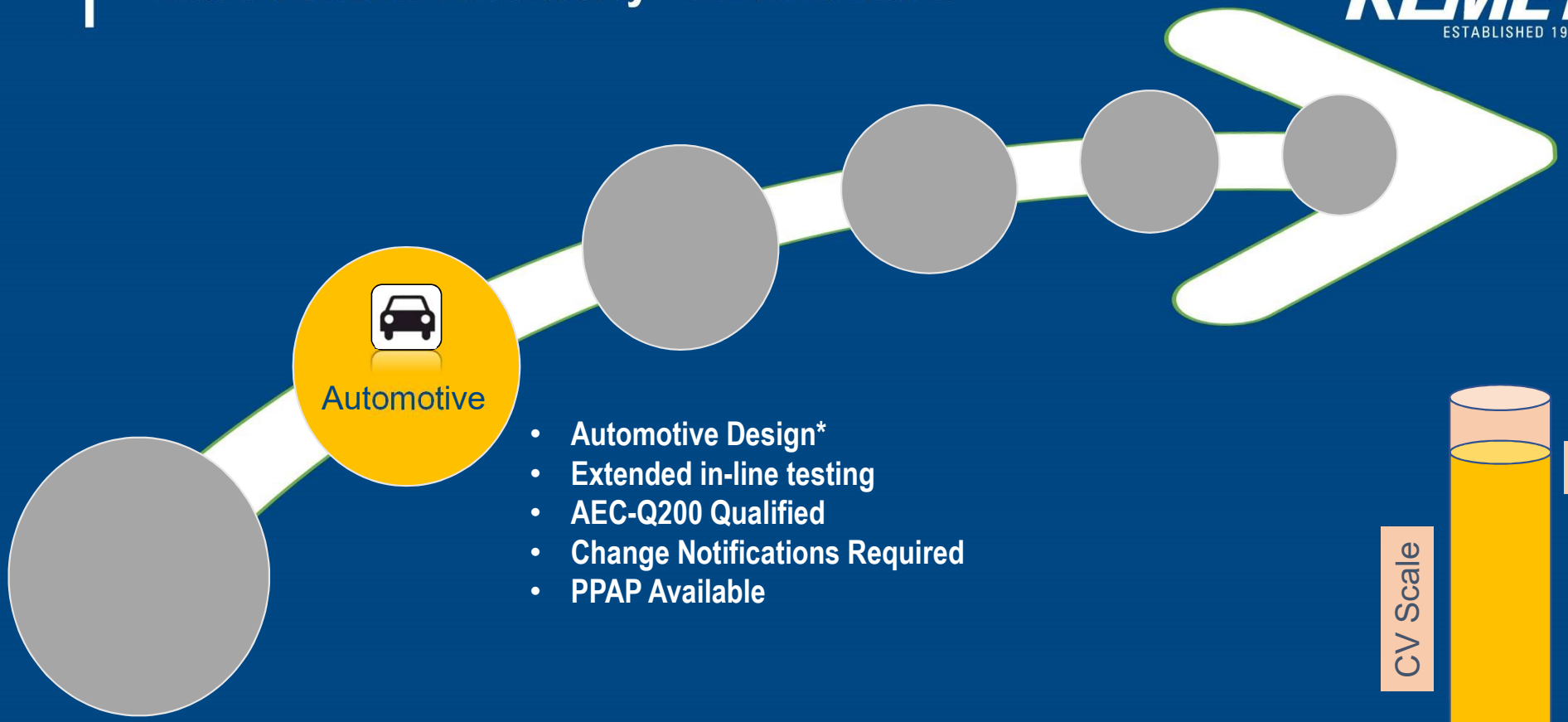
The Product Hierarchy - Commercial

Commercial & Up-screen Commercial

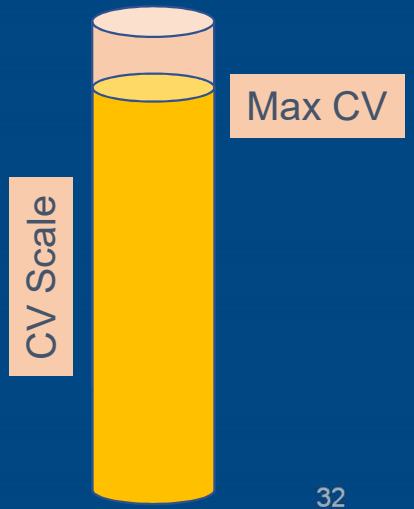
- 100% Electrical Testing
- Non-Established Reliability
- Commercial & Continuous Design Improvement
- Broadest Product Selection
- High Volume Manufacturing
- Up-screen Commercial allows Surge Options



The Product Hierarchy - Automotive



- **Automotive Design***
- **Extended in-line testing**
- **AEC-Q200 Qualified**
- **Change Notifications Required**
- **PPAP Available**

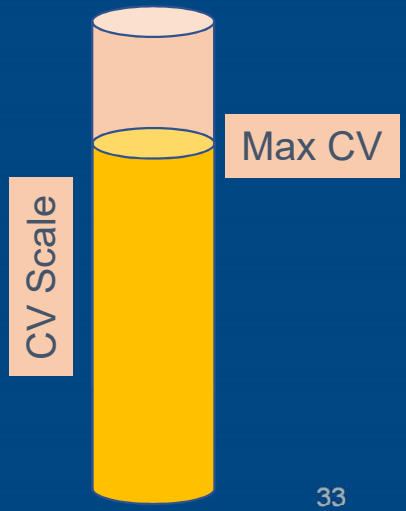


* Anode design more robust than commercial

The Product Hierarchy – COTS → HRA

HRA
High Reliability Alternative

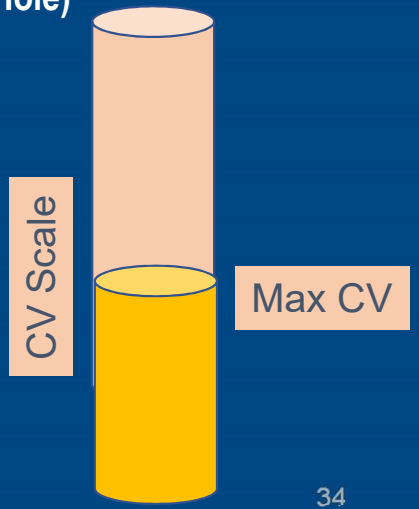
- Conservative Military Design*
- Military Screening Options
- MIL-PRF "like" Qualification
- 100% Burn-In
- Established Reliability
- Certificate of Compliance



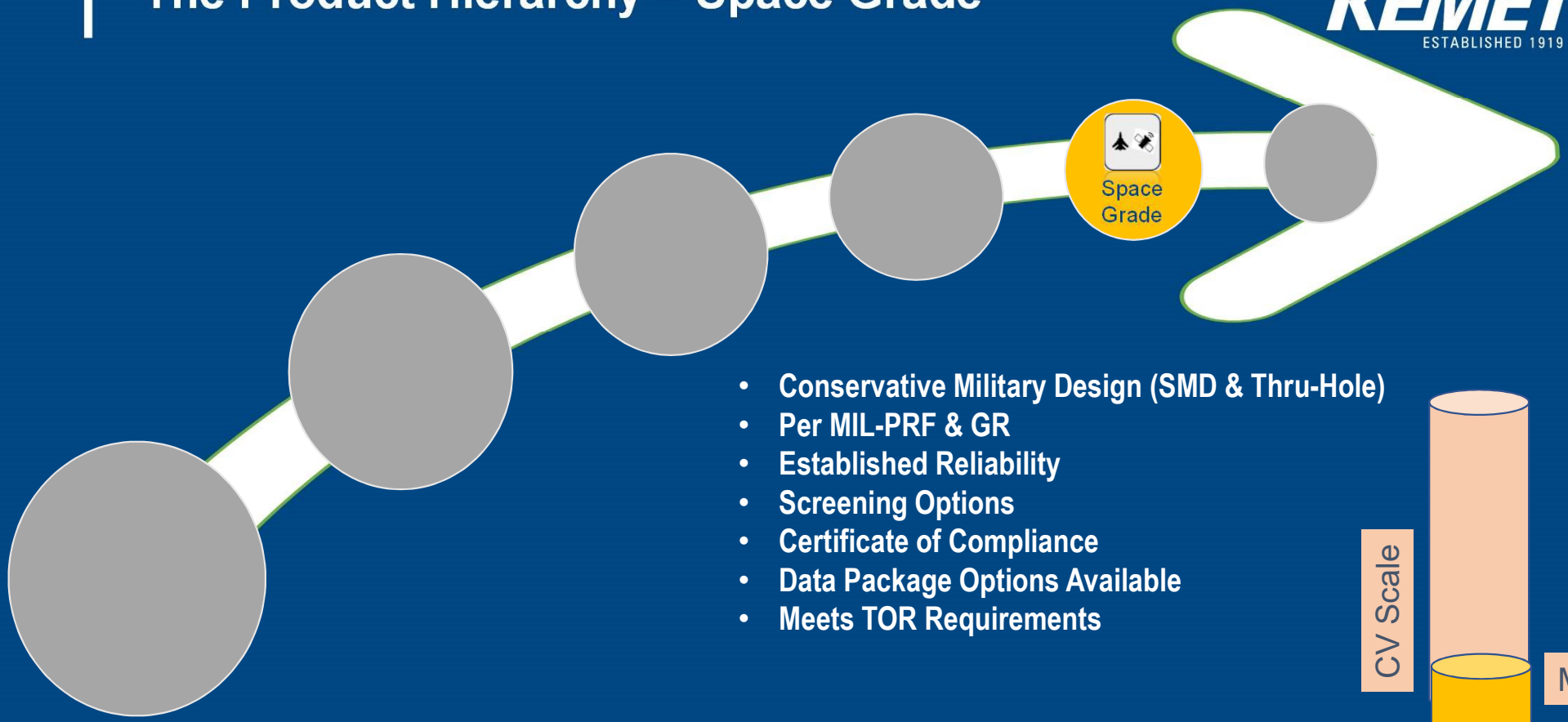
* Anode design more robust than Automotive

The Product Hierarchy – MIL-PRF Grade

- Conservative Military Design (SMD and Thru-Hole)
- Qualification Per MIL-PRF
- Mil Maintenance Program
- Established Reliability
- Certificate of Compliance
- Group Data if Applicable

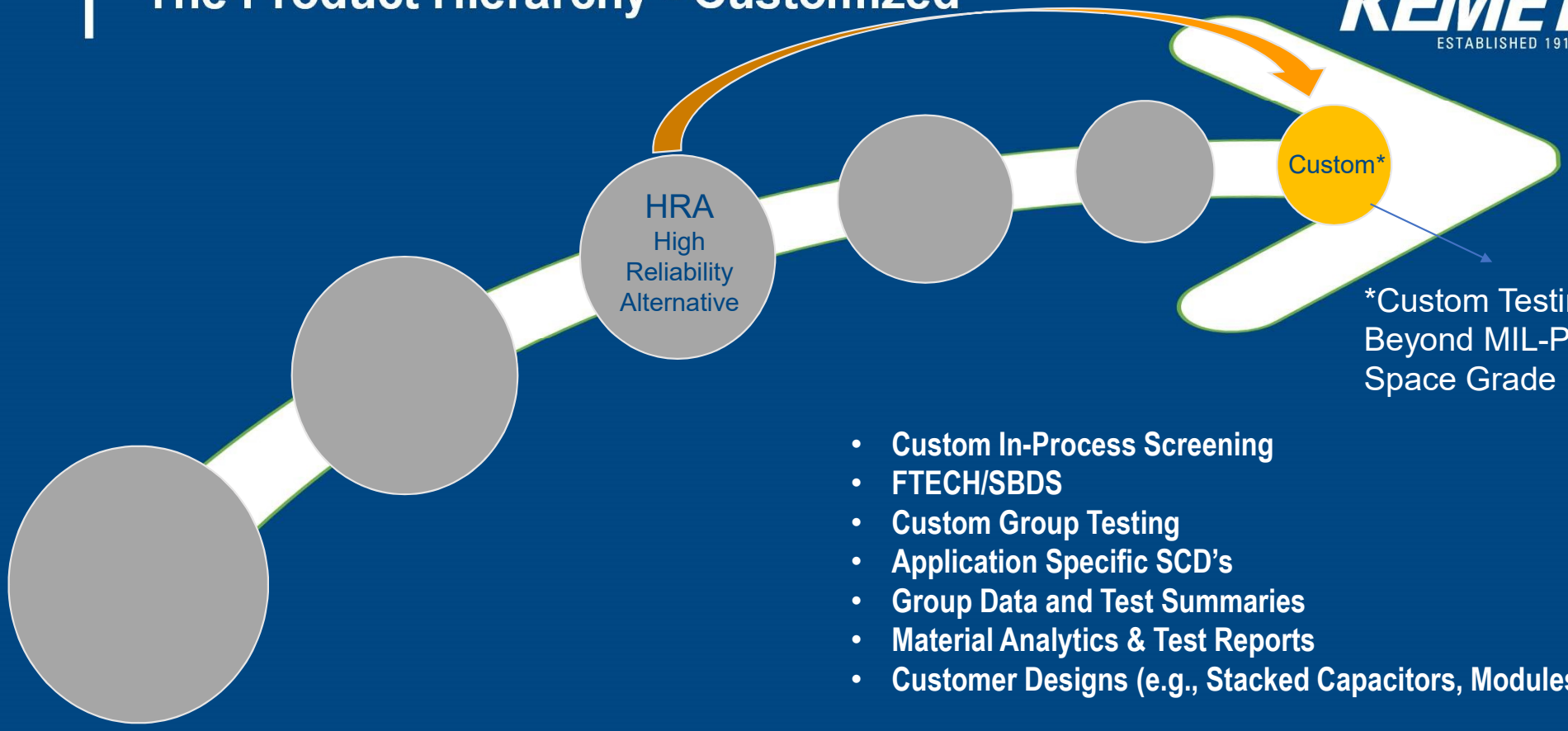


The Product Hierarchy – Space Grade



- Conservative Military Design (SMD & Thru-Hole)
- Per MIL-PRF & GR
- Established Reliability
- Screening Options
- Certificate of Compliance
- Data Package Options Available
- Meets TOR Requirements

The Product Hierarchy - Customized

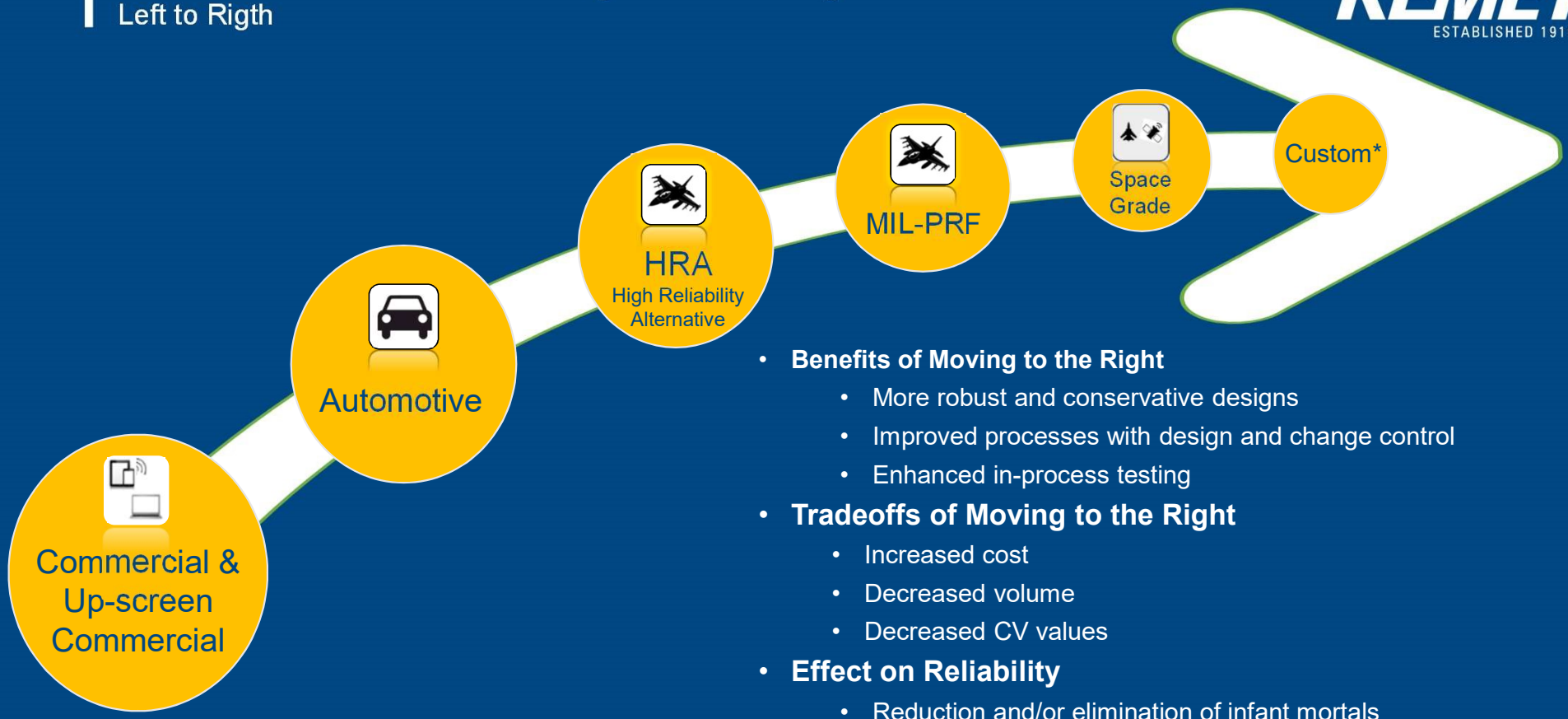


*Custom Testing Beyond MIL-PRF and Space Grade

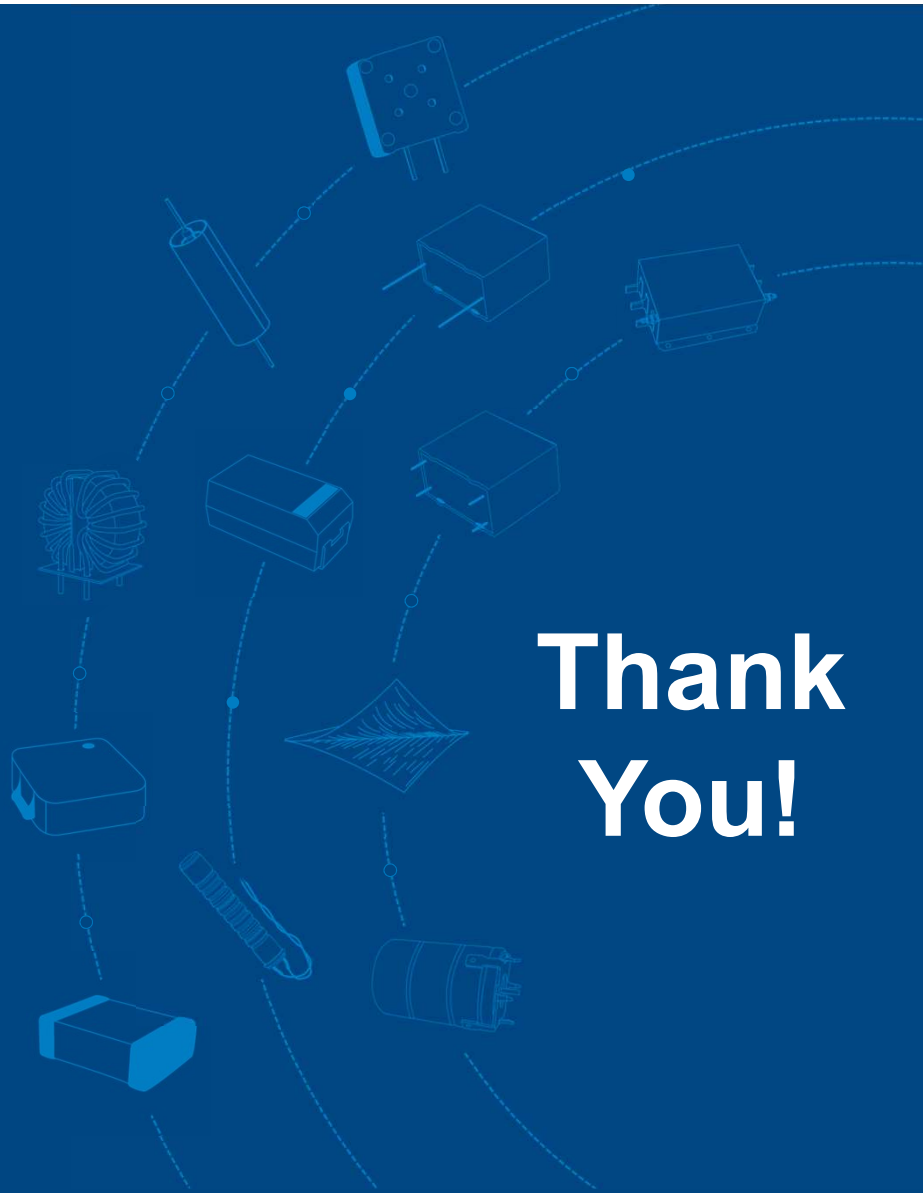
- **Custom In-Process Screening**
- **FTECH/SBDS**
- **Custom Group Testing**
- **Application Specific SCD's**
- **Group Data and Test Summaries**
- **Material Analytics & Test Reports**
- **Customer Designs (e.g., Stacked Capacitors, Modules)**

The Product Hierarchy Summary

Left to Rigth



- **Benefits of Moving to the Right**
  - More robust and conservative designs
  - Improved processes with design and change control
  - Enhanced in-process testing
- **Tradeoffs of Moving to the Right**
  - Increased cost
  - Decreased volume
  - Decreased CV values
- **Effect on Reliability**
  - Reduction and/or elimination of infant mortals
  - Reduction of normal life failures
  - Increase in MTTF



Thank You!

100 YEARS KEMET ESTABLISHED 1919