OSAT Production Testing of 5G, Power Discrete & 3D Packaged ICs

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19TH INTERNATIONAL CONFERENCE & EXHIBITION ON DEVICE PACKAGING
FOUNTAIN HILLS, AZ • WWW.DEVICEPACKAGING.ORG • MARCH 13-16, 2023

Agenda

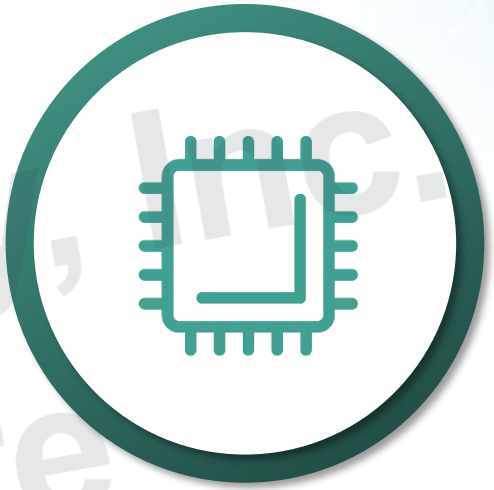
1. Test Markets
2. 5G
3. Power Discrete
4. 3D IC

Test Markets

Mobility,
Communications
& RF

Automotive

Power
SiC & GaN



Advanced
Packages 3D IC

Test Technologies are Evolving in all Markets

Agenda

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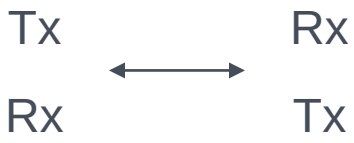
RF Technology Application Use Cases

Indoor
(Low Power)



1. Wi-Fi, BT, NFC, IoT
2. Carrier frequency
3. Bandwidth
4. Power at FC: Operational range
5. Number of users
6. Interferences

Outdoor
(High Power)

1. Cellphone 3GPP, BS, satellite
2. Carrier frequency
3. Bandwidth
4. Power at FC: Operational range
5. Number of users
6. Interferences

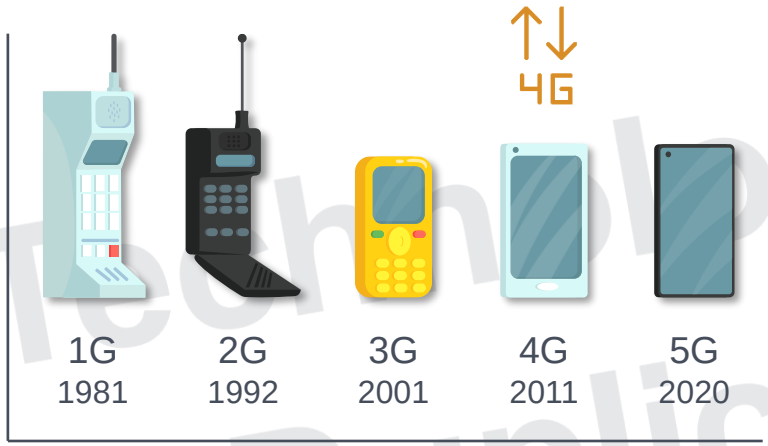
All RF Technologies, All Package Types, Including AiP

5G Test Transition & Challenge

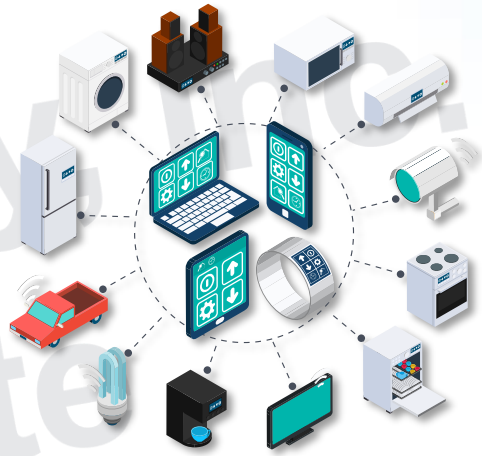
1G-4G

RF 600 MHz ~6 GHz

- Filters
- Switch
- PA
- FEM
- Attenuators



2.4 GHz & 5.8 GHz bands



Internet of Things

LoRa

Source: lora-alliance.org

~800 MHz band

Wi Fi™

Source: wi-fi.org

2.4 GHz & 5.8 GHz bands
802.11 A, B, G, N, AC

zigbee

Source: ezzigbee.com

2.4 GHz band

Bluetooth™

Source: bluetooth.com

2.45 GHz band

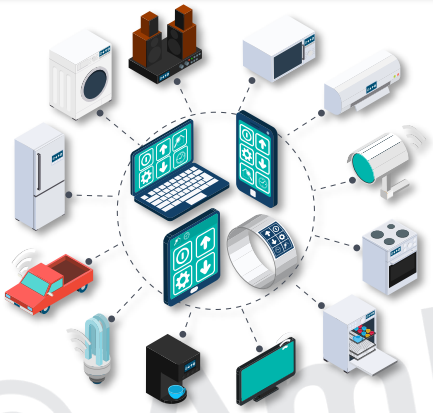
GNSS, GPS
~1.5 GHz band

Latency & Speeds (BW)

5G Test Transition & Challenge

4G → 5G

FR1



NB Internet of Things

3GPP – FEM, SW/Trans. PA, LNA, Ant.
100 MHz – 800 MHz BW

Source: analog.com

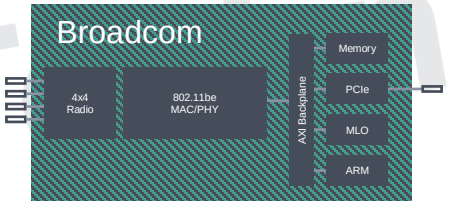
Source: wikipedia.org

802.11ad/ay (57-66 GHz),
~2 GHz BW: Transceivers

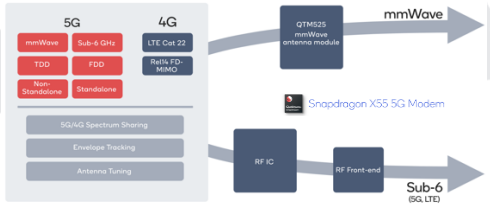
FR2

Wi-Fi 6,7

802.11ax/be
1024…4096 QAM
160-320 MHz BW



Source: broadcom.com



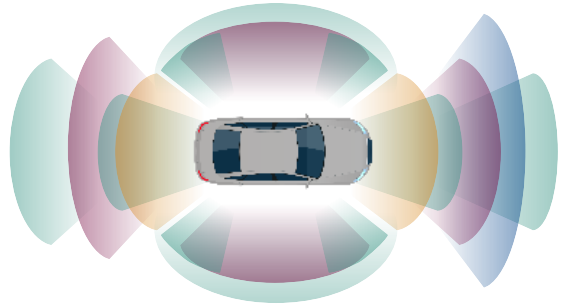
Source: qualcomm.com

Ultra-low Latency, Multi-Gb Throughput,
High Connection Count

Skyworks
Sky5

5G NR ultra high band Tx, Rx, MIMO, BT, GPS, Wi-Fi, ant: Mux, ant tuning SW, PA

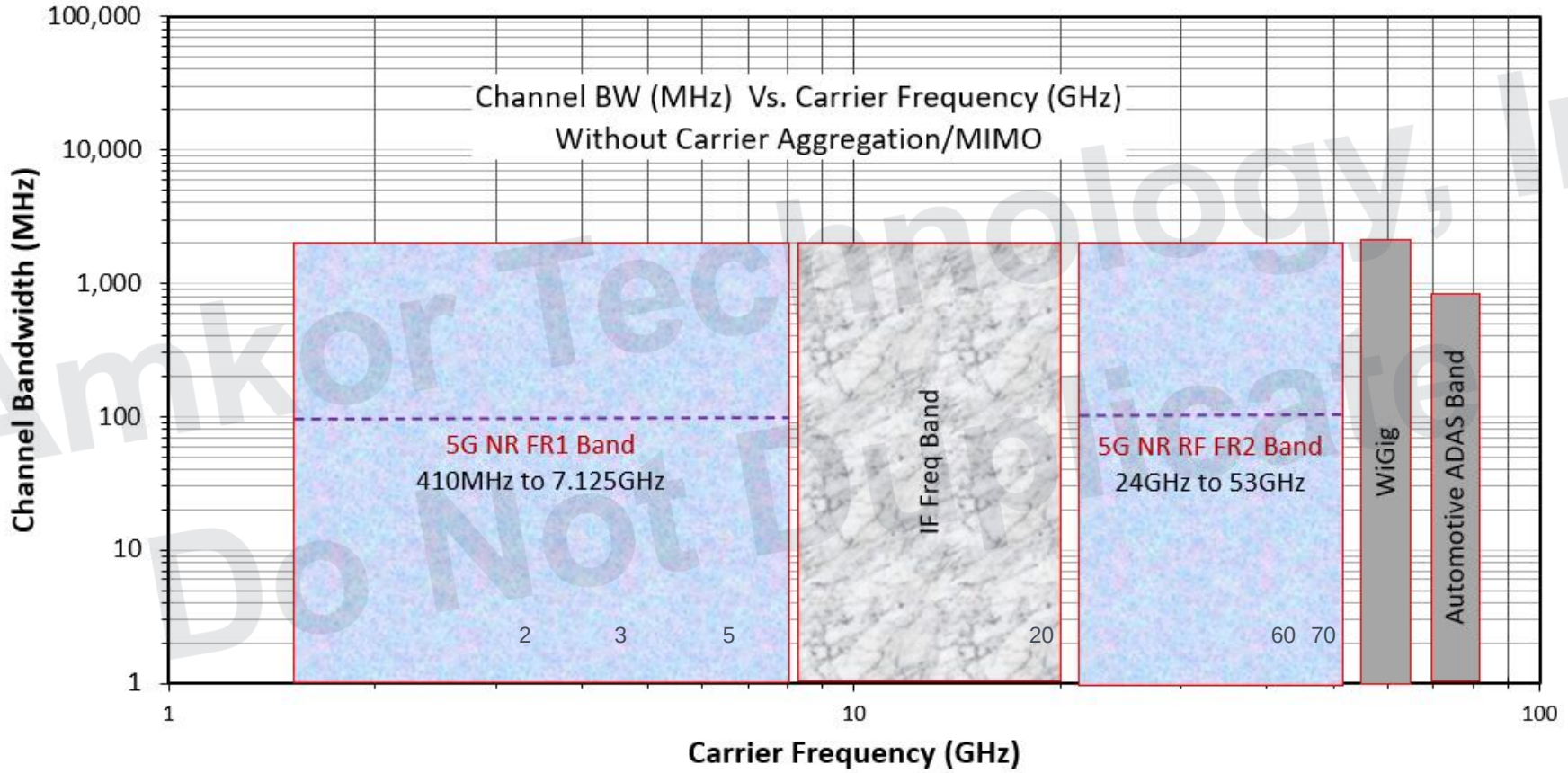
Large product volumes



Automotive Radar

Automotive (76-81GHz),
0.6-4 GHz BW; transceiver

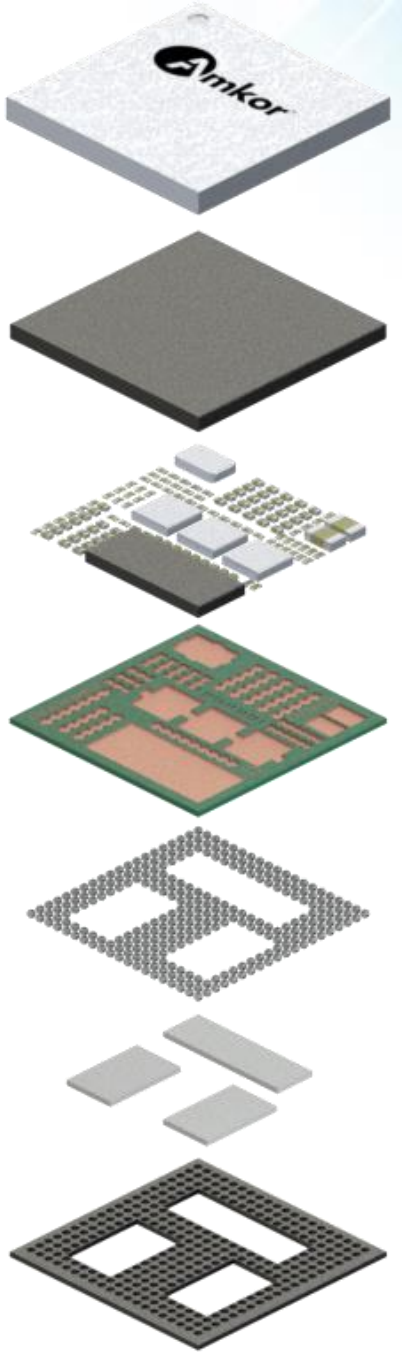
RF 5G & mmWave Band Segmentation



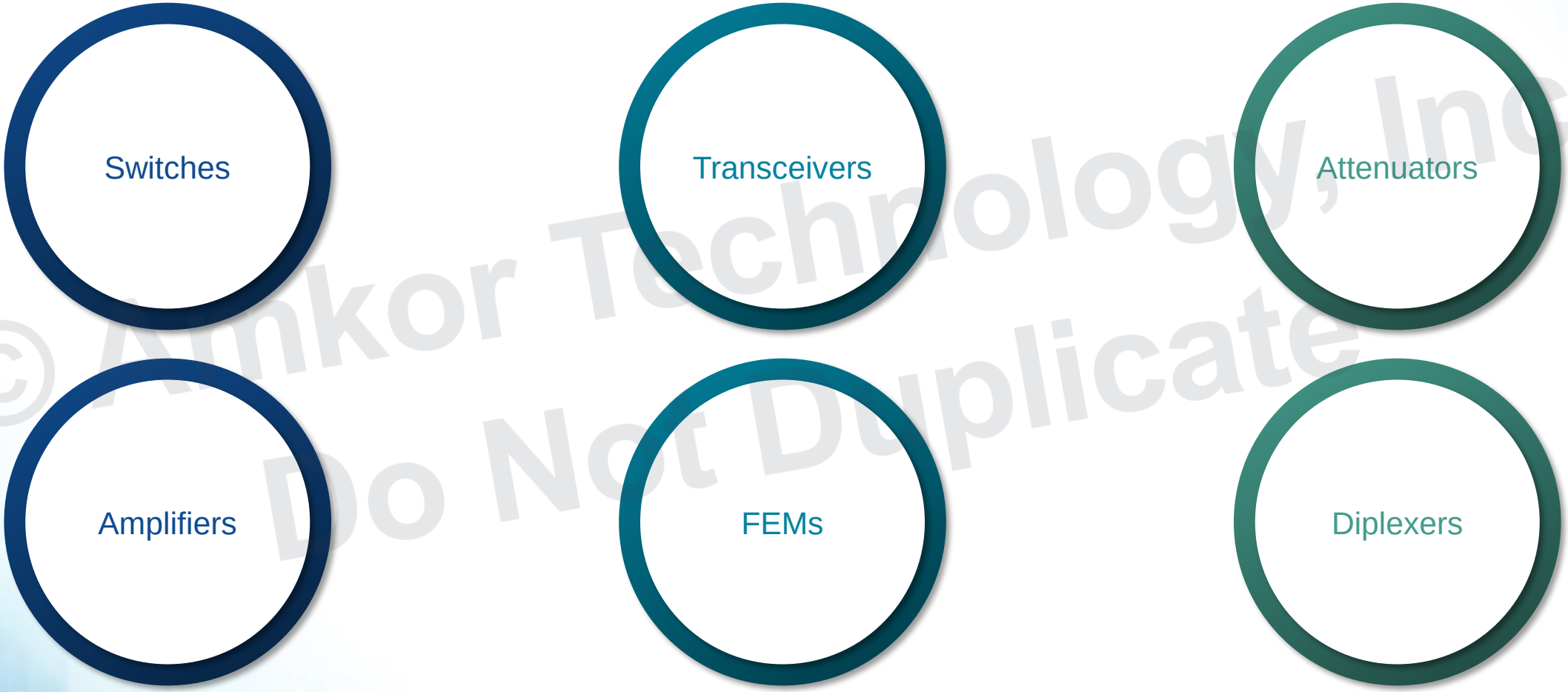
Amkor RF Products in All Bands!

Amkor’s DSMBGA RFFE

- Double sided component attach
- Double sided mold
- Conformal & shielding
- RFFE: LNA, PA, switch, filters & duplexers
- Production test



5G Broadband Products

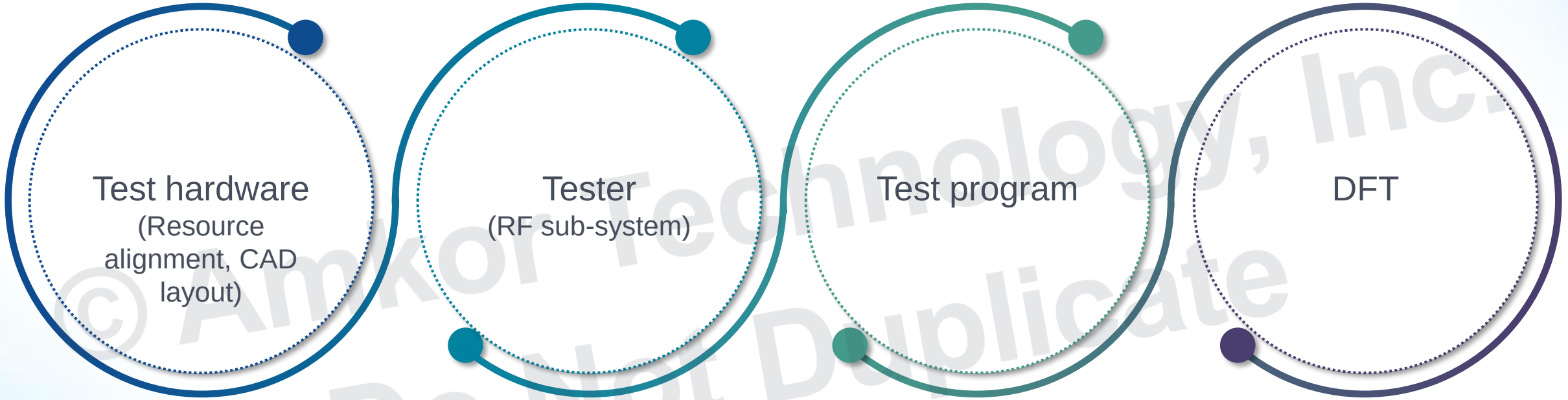


Base Station + User Equipment

WLCSP, LGA, BGA

Antenna Integration

Production Test Challenges



5G is Forcing All Aspects of Production Application Design to Evolve

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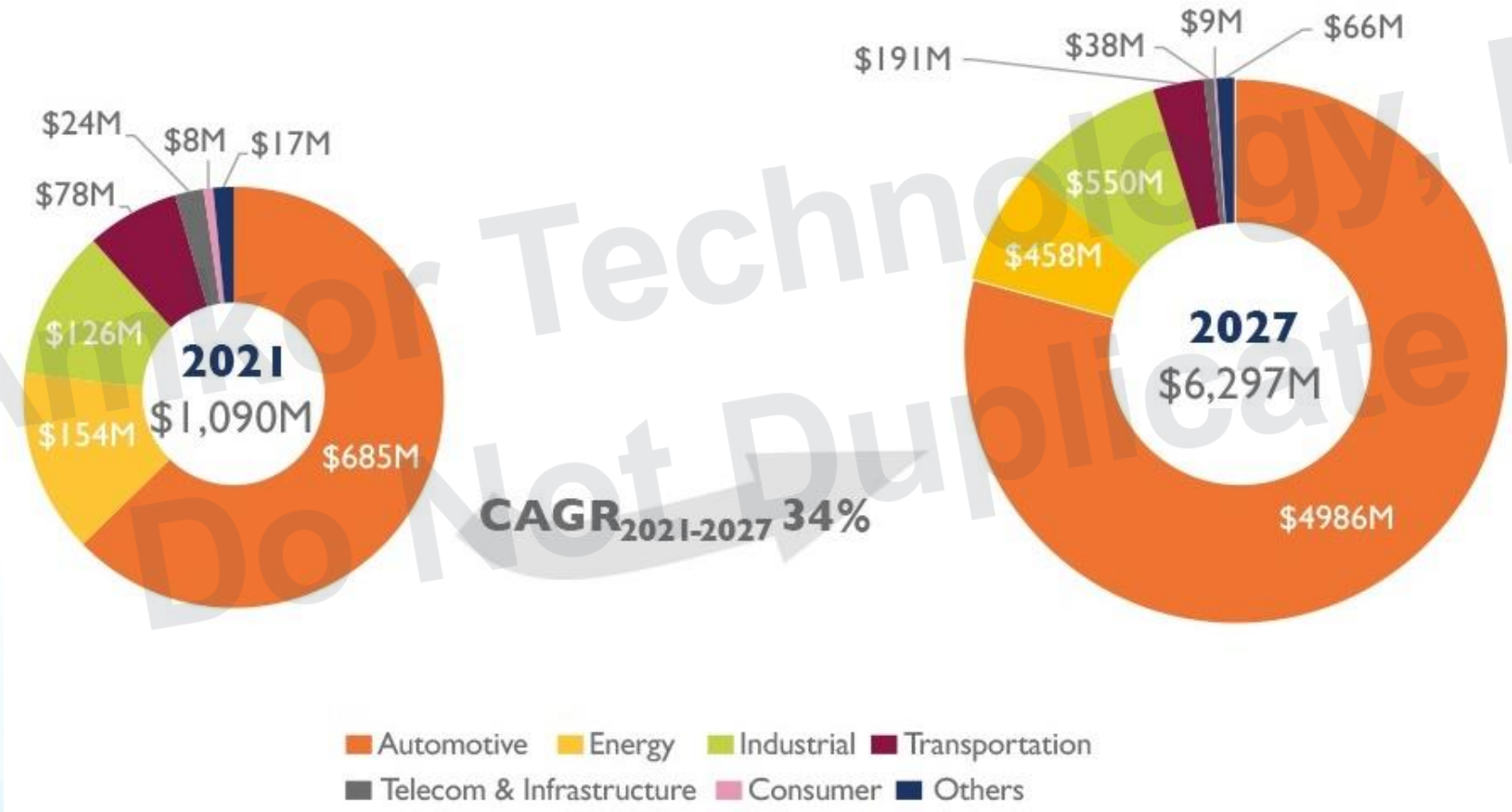
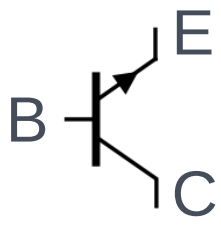
2021-2027 Power SiC Devices by Market Segment

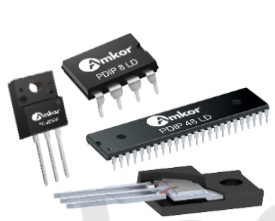


Source: Yole Intelligence March 2022

Power Technology Target Specifications

IGBT, MOSFET – Si, SiC, GaN Single & Modules





TO-220/TO-251
IPAK/IPM DIP

HSON/DPAK/
D2PAK/PQFN

LFPAK/SO8-FL/
TOLL/PSMC/SOD

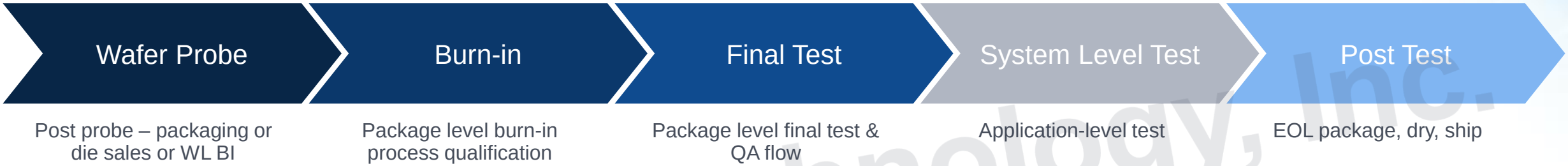
Pathfinding/Definition/Development	Deployment

Perf Attribution	Si (1.1eV)	GaN (3.4eV)	SiC (3.2eV)
DC V_{CE}, V_{BE}, I_D, Gain, R_{DS-On} Temp	~100V, nom power density, efficiency	~150V, med-power density, efficiency	~1800V, high power density; high efficiency
AC Frequency, I_{Pulse}, C_g, T_{On}, T_{Off}, UIS, T_{rr}	Nom SW frequency	Hi SW frequency	Med-high SW frequency

Higher Power, Higher Thermal Considerations During Product Test

Power Technology Target Specifications

Test Flow



- In production (today)
  - Final test & post test
  - Max envelope: 900V/10A-75V/160A
- Explore
  - Probe, burn-in, system level test
  - Wider discrete, modules
  - Max envelope: >2000V/700A

Test Equipment Suppliers

Teradyne	UNITES	PowerTECH	SPEA
Tesec	AccoTEST	Microtest	Focused Test
ADVANTEST	LEMSYS	Shibasoku	CREA

Tester, Package Handler and Burn-in Platforms are Being Deployed

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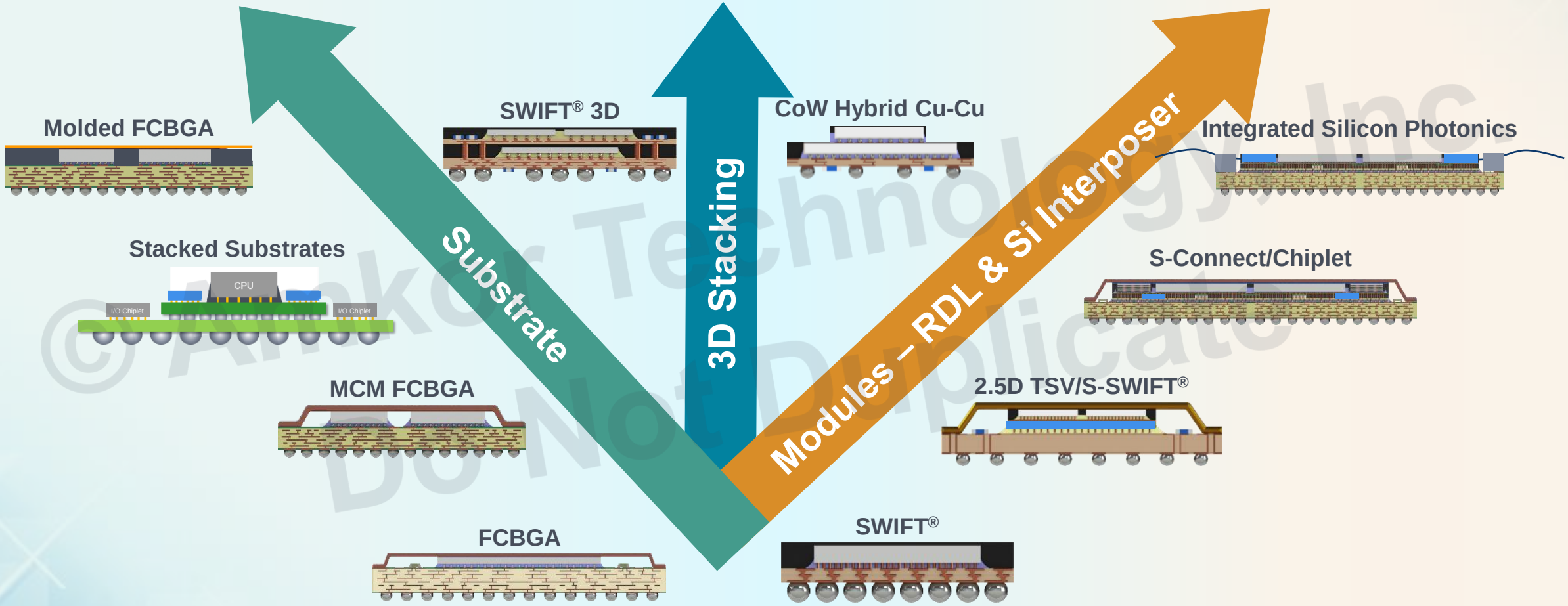
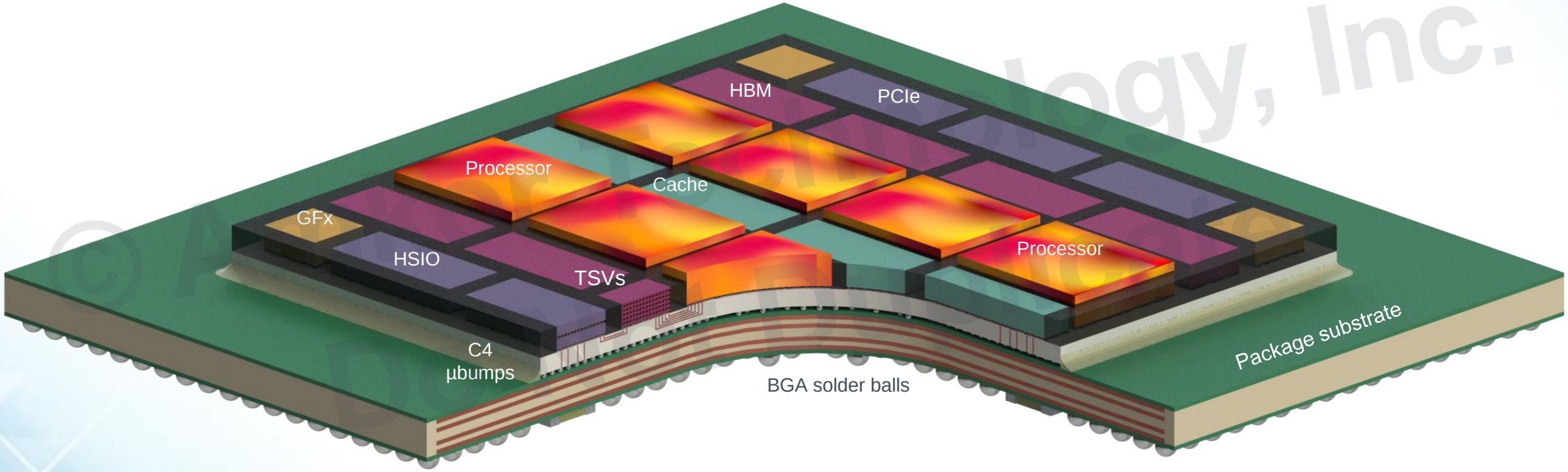
Amkor Multi-Die Package Technologies

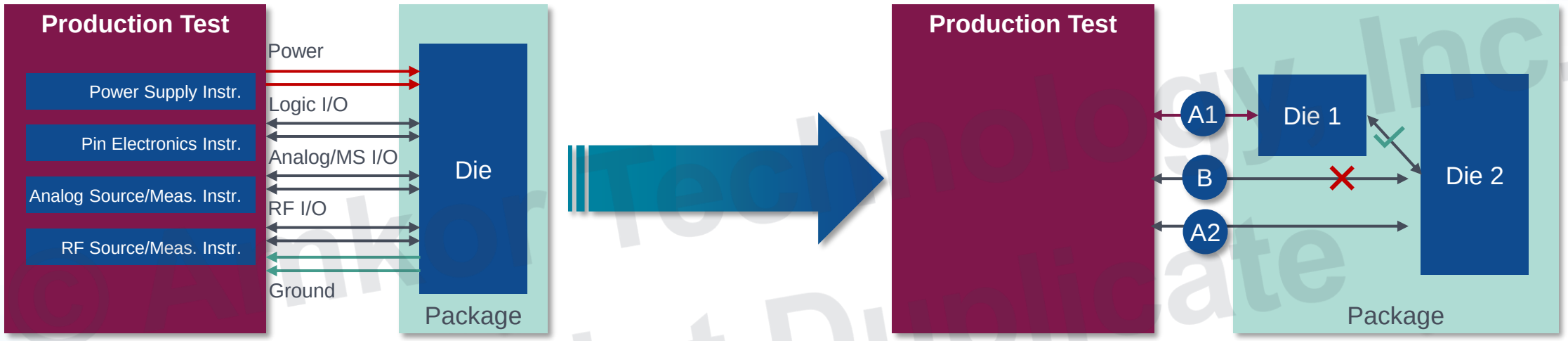


Die Disaggregation to Allow Higher Levels of Integration!

Amkor Package Assembly Topologies



Production Test Challenges



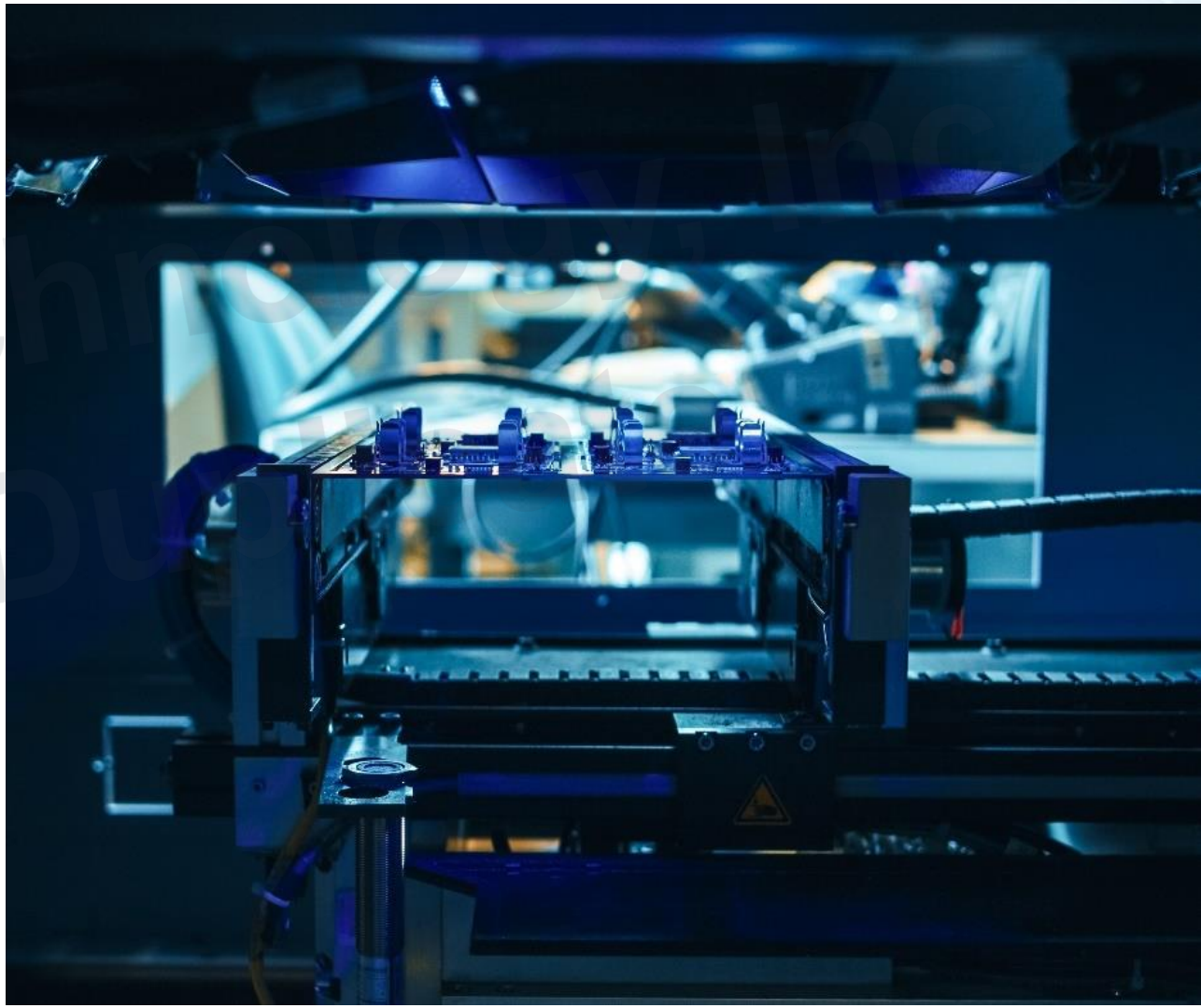
- No direct access
- Radiative access
- Digital system bus protocol

Die 2 interface physically

- A Pinned out
- B Not pinned out

Production Test Methodology – DFT

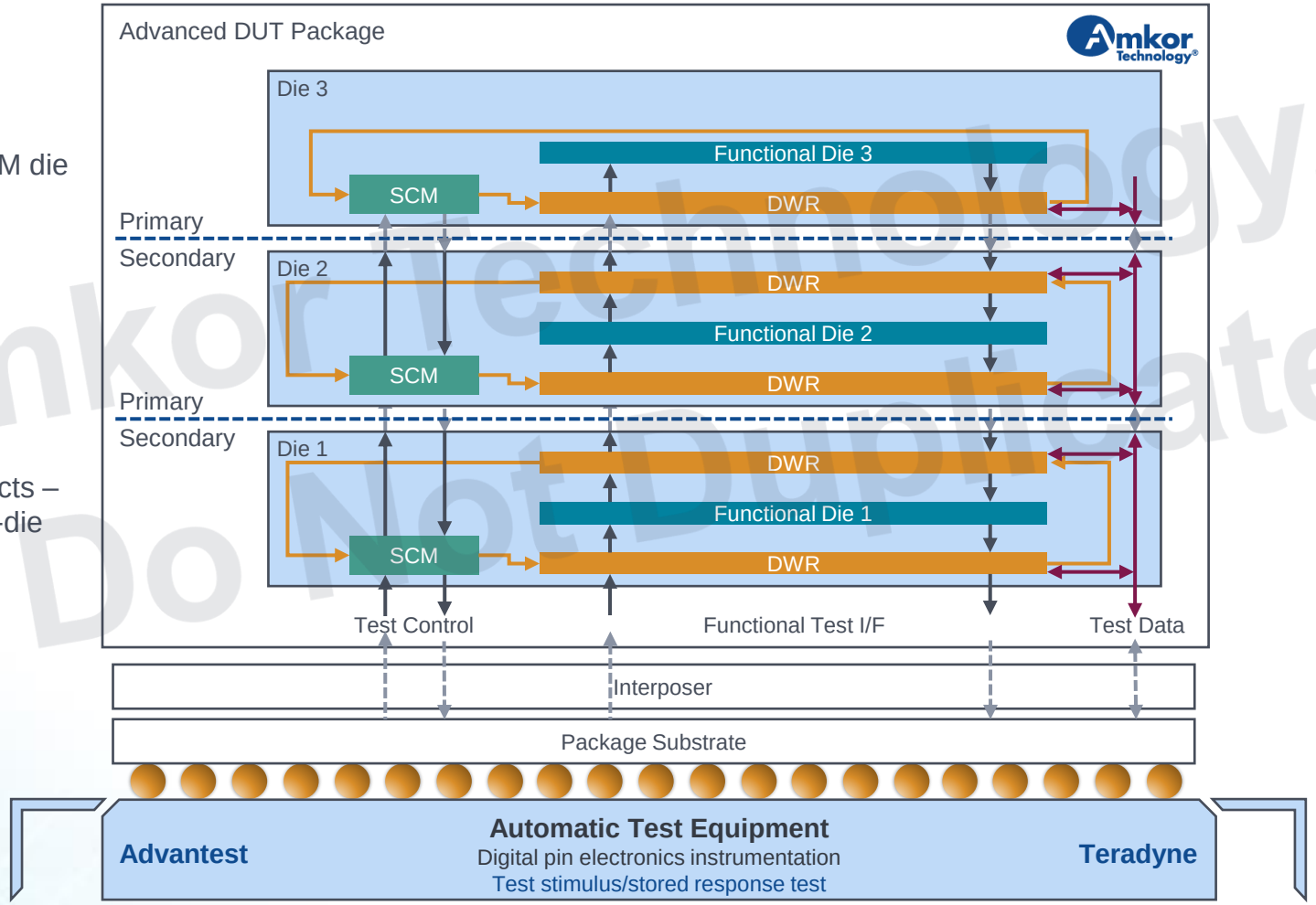
- Functional & structural test content
  - BIST, SBFT, scan – IEEE 1149.x, 1500, 1687, 1838
- Digital test instrumentation features
- Concurrent testing



3D IC Test View

CPU (logic), GPU, DDR/HBM die

Test challenge: Interconnects – substrate, interposer, die-to-die

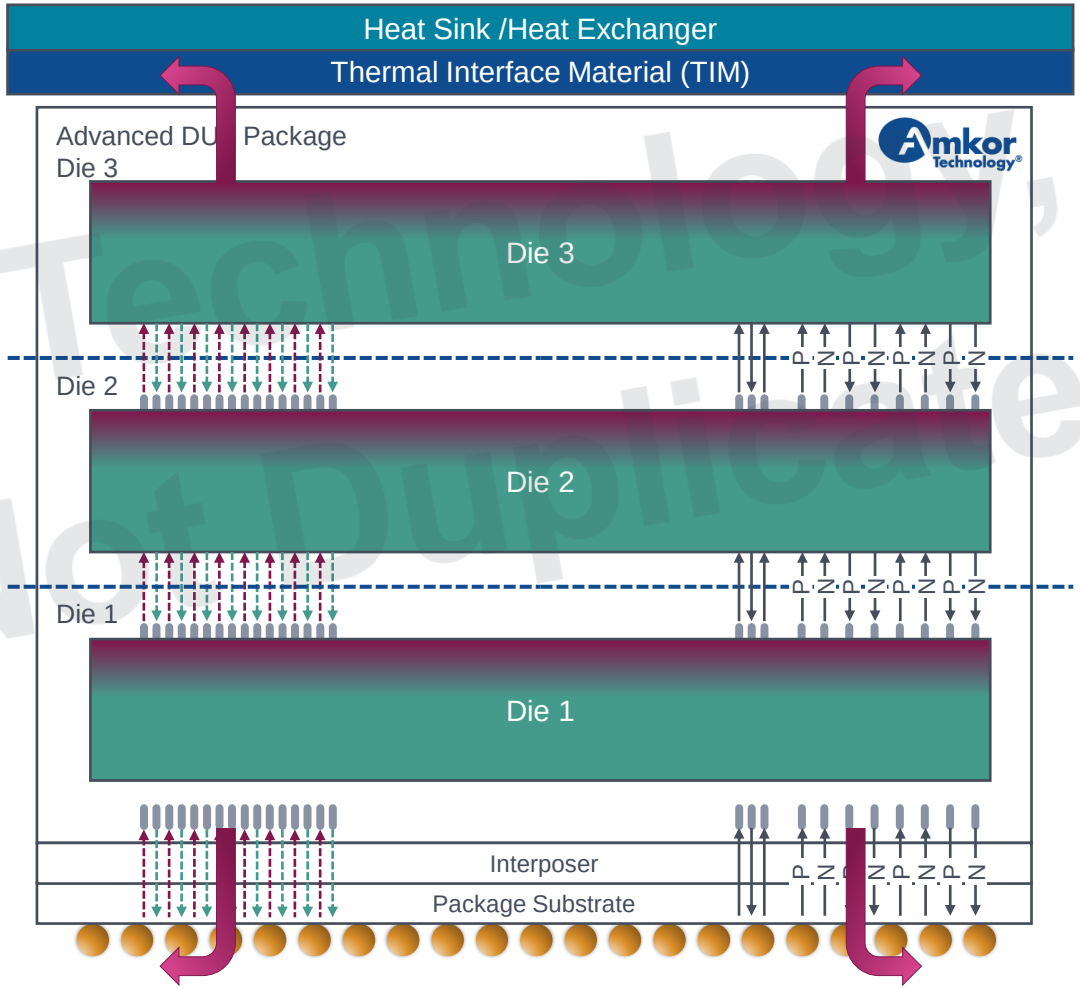


DWR: Die Wrapper Register
SCM: Serial Control Mechanism
FPP: Flexible Parallel Port

Source: IEEE1838-2019

3D IC Test Challenge

- Power
  - Cu pillar & µbump – contact resistance
- Signal
  - Capacitive loading for signal & ground
  - Crosstalk & increased noise in Si substrate
  - Insertion loss & return loss – via/bump interface
- Thermal
  - Interconnect/underfill layers
  - End-of-the-line layers
  - Bulk silicon
  - µbump
  - Heat sink



Call for Action

- Production test simplification
- Standardization
- Enable re-use

Production Test – Impact to Test Flow

Single chip production test flow

Alter Test Flow

Test Content Re-distribution

Platform Level Test Quality

Summary

- Multi-die packages allow for denser integration
- Business continues to have economic and performance challenges
- Call to action – advanced test methods
- Amkor is the industry leader in advanced packaging and production test solutions

Amkor Test Services

24/7

Operation of fully networked test floors

Accurate and Thorough Test Services

Wafer probe, final test, strip test, film frame test, system level test, opens/shorts test, burn-in and complete end-of-line

Full End-of-Line Processing

Bake, scan, pack, ship and finished good services

Test Development

Software & hardware for probe, strip, final and system level test

Testing for Commercial, Industrial & Automotive Devices

Discrete, power, mixed-signal, memory, RF, MEMS and SiP devices

>3,600 Testers in 7 Locations

3,000 + Amkor, 600 + consigned

Tested Annually

10 Billion units

7-9 Million wafers

Test is an integral part of the overall Amkor business

Over 40 years of Automotive test experience

amkor.com/test-services

Thank You

Vineet Pancholi, Vineet.Pancholi@amkor.com

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Abstract: OSAT Production Testing of 5G, Power Discretes & 3D Packaged ICs

- The presentation will be segmented into three. OSAT production testing challenges of three vital product families that are important to our semiconductor industry will be showcased in each segment. The first segment will describe the products and impacts to RF production testing of both Sub-8GHz carrier frequency range and the mmWave frequency range of operation. The second segment will explore emerging MOSFET technologies that enable faster switching rates and higher voltage and current topologies. The third segment will describe the challenges of production test content for 3D-stacked advanced packages.
- 5G RF has enabled mmWave carrier frequencies, small cell deployment, massive MIMO (Multiple In, Multiple Out), beam forming, and full duplex wireless transmission and reception operations. These features require new production test methodologies.
- There is an astronomical rise in battery powered applications like toys, consumer goods, automotive and trains. Power path turn on/off with MOSFETs is in the critical path. The technology has advanced from the traditional Si to GaN and SiC based products that have a smaller size and allow for higher application efficiencies. Test specifications and limits are improving and production testing methods are evolving to account for these changes.
- Advanced packaging has enabled the path to integrate chiplets within a single package. Heterogeneous Integration (HI) is a powerful design innovation that allows tighter integration and, in some cases, improved signal and power performance at the system level. Production test methodologies are being streamlined to make test a competitive advantage for our customers.