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IMAPS 2022 Conference
Qorvo SHIP-RF

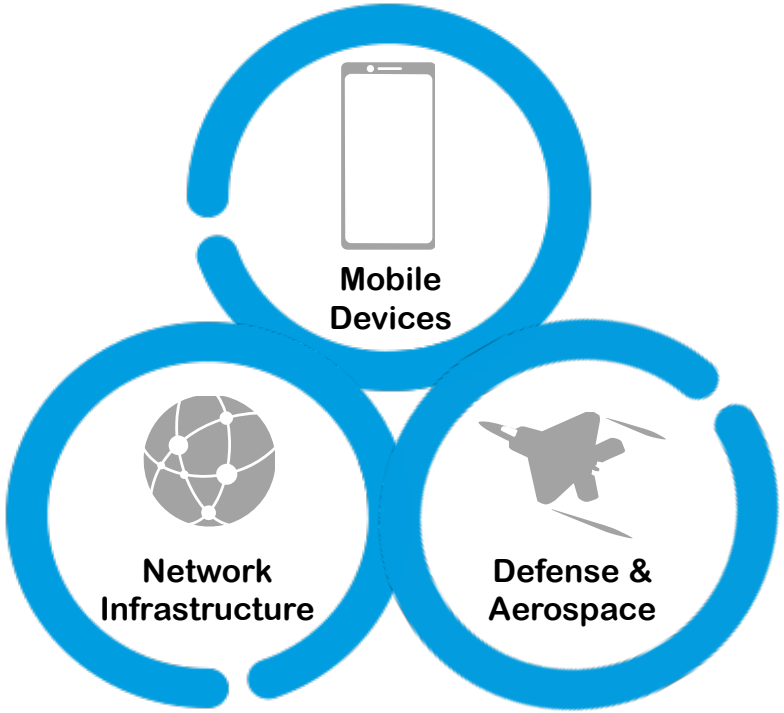
Ted Jones

09 Mar 2022

We Are Qorvo®

Innovative solutions for everything that connects our world

- We provide innovative RF and power solutions at the center of connectivity
- 8,400 global employees
- Trailing 12-month revenue: $4.5 billion
- Business Units
  - Mobile
  - Infrastructure & Defense Products
- An S&P 500 company – Nasdaq: QRVO



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Qorvo leverages commercial & defense business within SHIP-RF

- **Mobile Products (MP) - Commercial**
  - High-volume commercial products, manufacturing capabilities, and supply chain management that offer affordable operating costs/prices to all our customers
- **Infrastructure and Defense Products (IDP)**
  - SOTA RF expertise, custom products and innovative R&D to DoD customers
- **Wafer Foundry Business**
  - Serves defense and commercial customers
  - Provides significant experience in protecting customer IP
  - Provides proven operating model for SHIP-RF center

SHIP-RF Program Overview

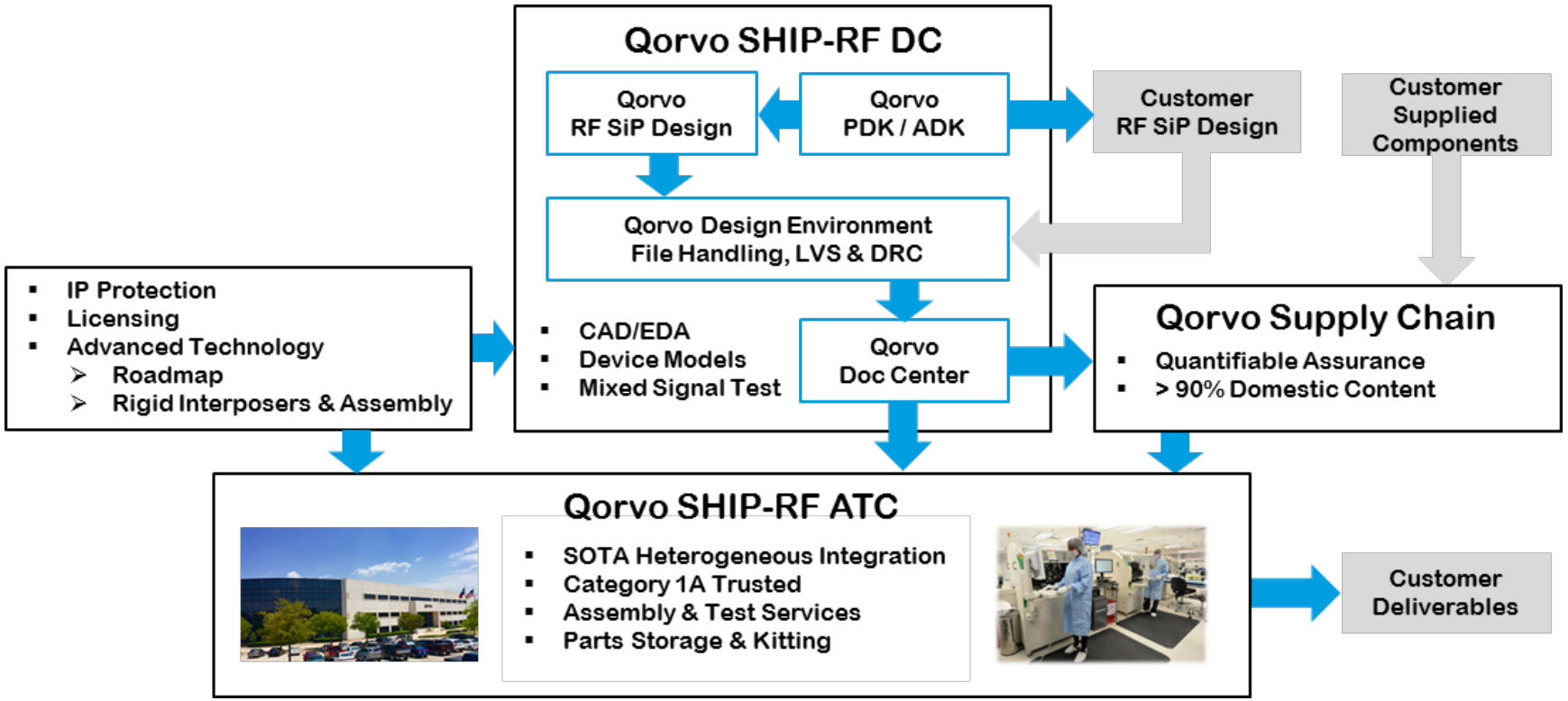
SHIP = State-of-the-Art Heterogeneous Integrated Packaging

- Goal: Establish domestic, secure, SOTA, cost effective, heterogeneously integrated packaging*
- 3-Phase program award spanning 4-yrs (Oct-2020 start)
  - Funded by OUSD (Office of the Under Secretary of Defense), executed through Navy Crane
  - Fits within DoD's Trusted and Assured Microelectronics (T&AM) strategic initiative
- Approach
  - Leverage Qorvo commercial industry expertise coupled with +30 yrs of DoD engagements aligning processes to packaging needs
  - Adapt Qorvo's Open Foundry Model to enable customer design into SHIP-RF
  - → Re-shore flip-chip High Volume Manufacturing capability
- SHIP-RF has three execution centers (based in Richardson TX):
  - SHIP-RF DC (Design Center)
  - SHIP-RF ATC (Assembly and Test Center)
  - Advanced Technology Development

** Assembly and packaging of multiple, separately manufactured integrated circuit die into a single package*

SHIP-RF Concept

Qorvo Open Design Center (DC) and Assembly & Test Center (ATC)



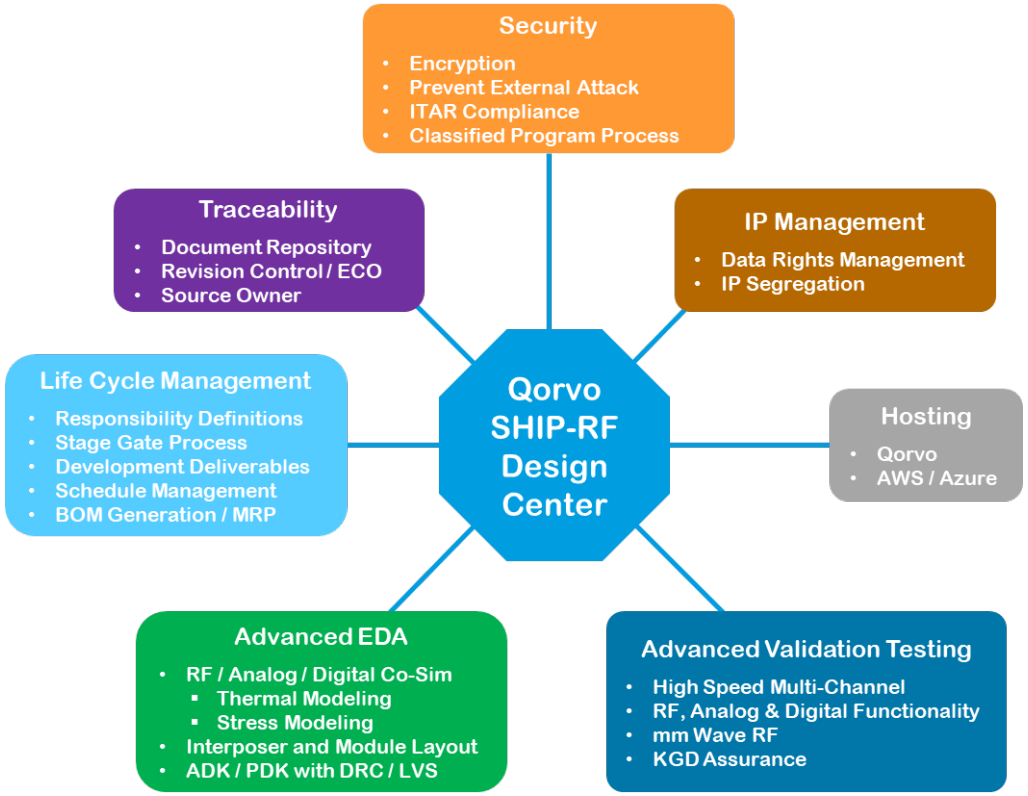
- ICs and components can come from non-Qorvo Sources
- Maximize domestic content – Quantifiable Assurance
- Design function applies to Heterogeneous packaging - Does not apply to integrated circuits
- Qorvo is creating Assembly Design Kits (ADKs) and Design Rule Checks (DRCs) ensuring customers create manufacturable designs for SHIP-RF ATC

SHIP-RF Design Center

SHIP DC delivers an Integrated, Secure, Easy to Use Design Platform

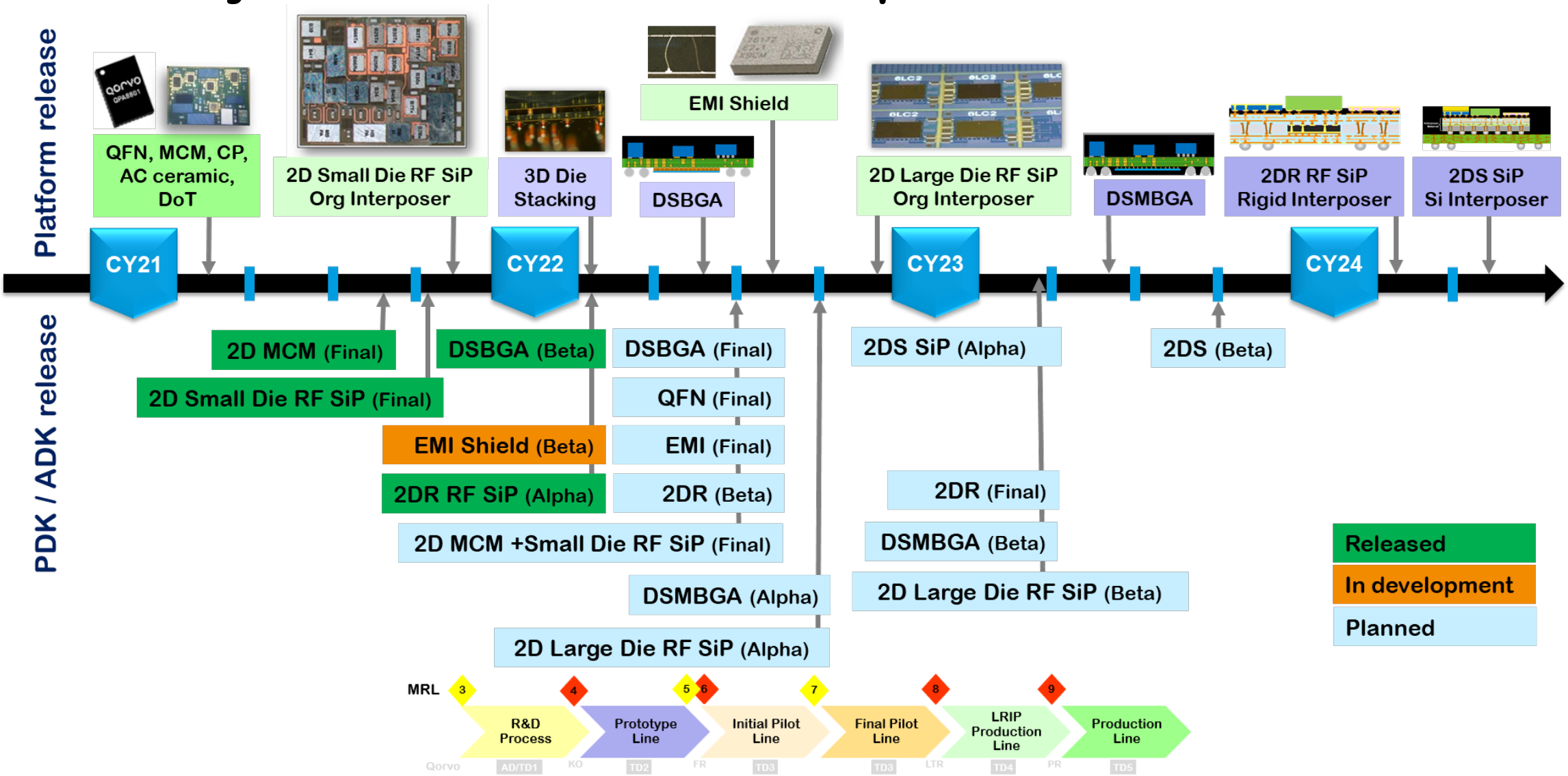
SHIP Design Center will be the focal point where customers will be able to

1. Access design simulation, verification and layout tool kits for design at their facilities
2. Collaborate and/or co-design with project partners, including Qorvo
3. Architect Next Gen System in Package (SiP) platforms using SHIP DC IP Block Libraries
4. Design and Verify Circuit and Layout using an Integrated Mixed Signal EDA platform
5. Validate SiP prototypes using SHIP DC Multichannel and Mixed Signal Test Systems
6. Project manage programs with advanced Life Cycle Management tools



All in a managed ecosystem where project IP is secure and segregated for other SHIP programs

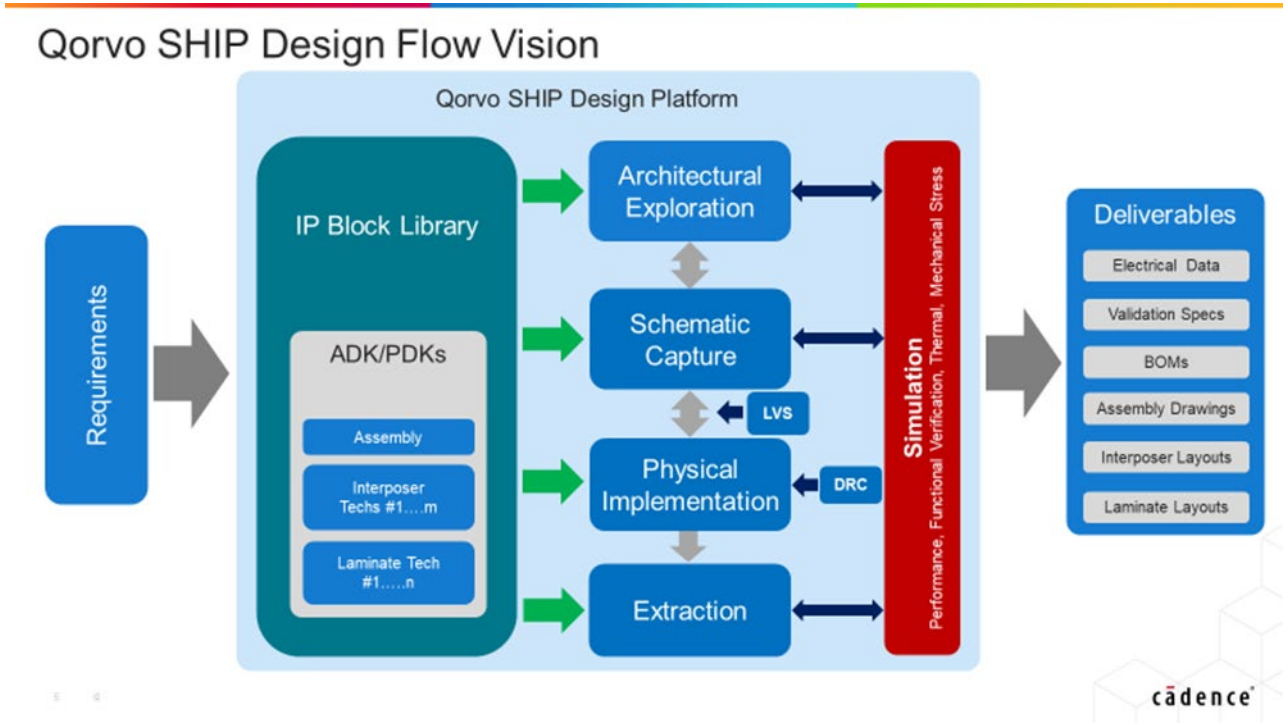
Design Center & Assembly and Test Center Roadmap



SHIP-RF Mixed Signal Design Flow

Next Generation Co-Simulation for Integrated Packaging

- System architecture simulation to optimize line up and functional blocks
- Component Block Libraries for IC or project specific building block
  - Qorvo's standard GaAs and GaN MMIC product families
  - Customer and third-party behavioral models
- Simulation and layout for interposer or MCM laminate layout design
  - Using Qorvo SHIP ADKs/PDKs preloaded into EDA platform
- Incorporate electrical simulation options such as:
  - Timing
  - Harmonic balance
  - EM models
  - Passive component model
- Layout rules: DRC and LVS verification tools
- Thermal and mechanical stress modeling
- Design flow output all deliverables needed to support design verification for:
  - Design reviews
  - BOMs, assembly drawings
  - Validation test plans,
  - Interposer and laminate layout files

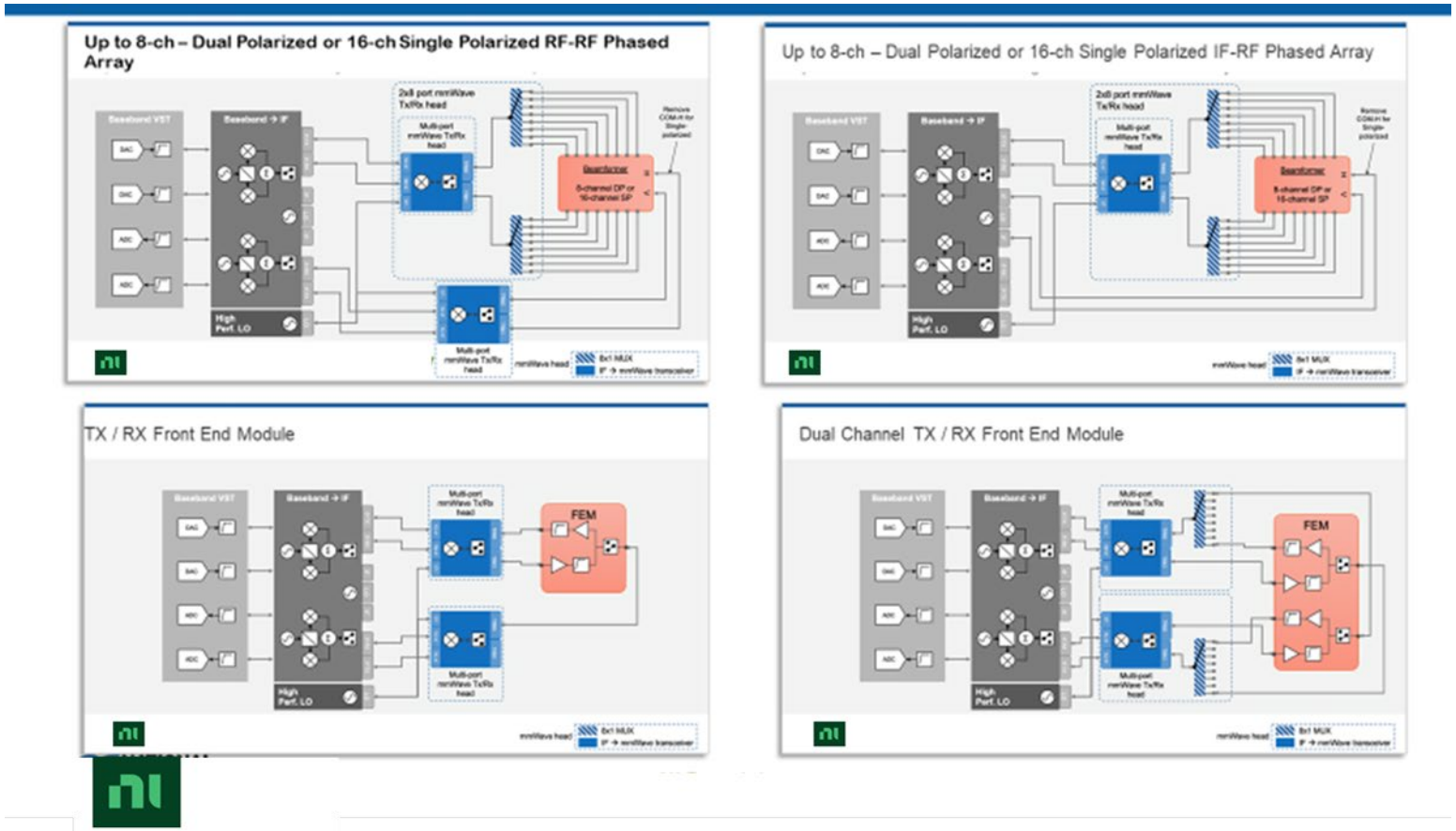


Flexible Configuration Design Validation

RF Front End (RFFE) Testing

Design Center capabilities to address multi function, multichannel, miniaturized RFFE packaging

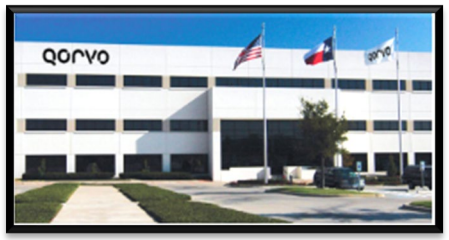
- 5-45 GHz
- RF Front End Module testing
  - TX and RX parameters
  - TX to RX cross talk
  - Multichannel isolation
- Sub array beamformer evaluation
  - Up to 16 channels
  - Cross talk
  - RF to RF
  - IF to RF



New Qorvo AMMA (SHIP-RF Assembly & Test Center)

Advanced, Domestic, Secure and Cost-Effective

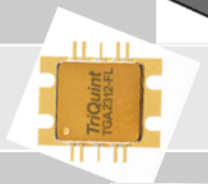
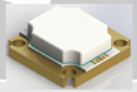
- Extension of existing Qorvo Advanced Microwave Module Assembly (AMMA) facility located in Richardson TX
- Create a highly automated, US based, assembly & test factory offering access to SOTA manufacturing technologies at commercially competitive pricing.



- High throughput & automation ➔ <u>domestic, secure and cost-effective</u>
- Build on Qorvo's proven commercial SOTA packaging technologies running at HVM rates offshore.
- Setup and qualify highly integrated packaging technologies.
- Leverage Qorvo's microelectronics factory scale in Texas (AMMA).

Package Types Supported in AMMA

Large breadth of package types supported

Package		Primary Markets
Over-mold QFN		Defense, BTS
Over-mold Laminates		Defense, BTS
Die on Tab		Defense
Air Cavity Ceramic		Defense, BTS
Air Cavity Laminates		Defense
Metal Ceramic (incl. hermetic)		Space, Defense
Next Gen High Power Modules (CP, LCOR)		Defense
Evaluation BoardsVBs		Space, Defense, BTS
Box Build, Racks		Defense, Instrumentation

- Majority of items used in commercial space

AMMA Factory

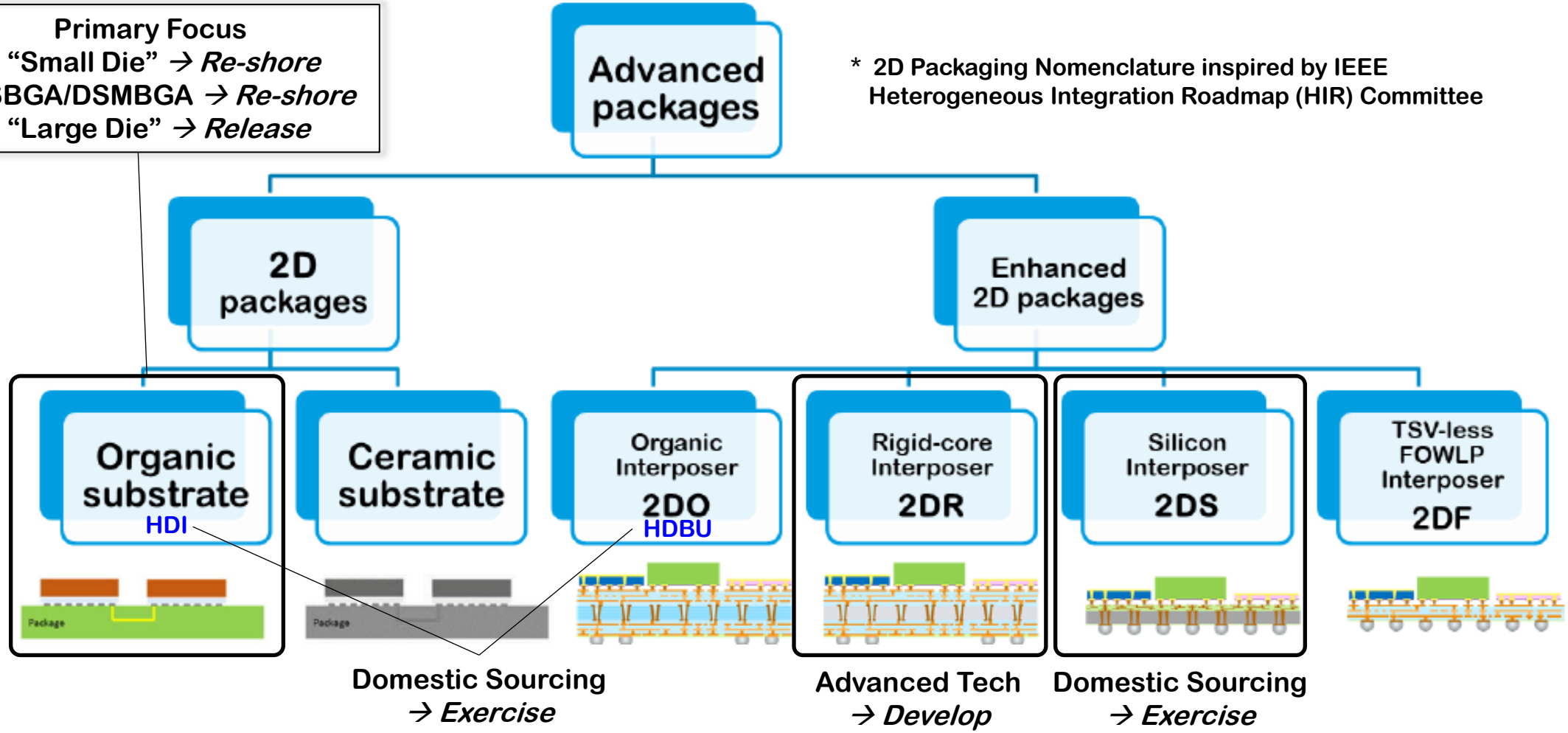
New and Expanded Capability

- High Speed / Fine Pitch Flip Chip Lines
- Die Attach (vacuum reflow & sintered)
- Mold – Transfer
- Mold - Compression
- Package Thinning
- Laser Ablation
- Wafer Level Packaging
- Automated Inspection
- Ball Mount
- EMI Shielding

SHIP-RF Integration Technology

Enhanced 2D Packaging Nomenclature* with SHIP-RF focus

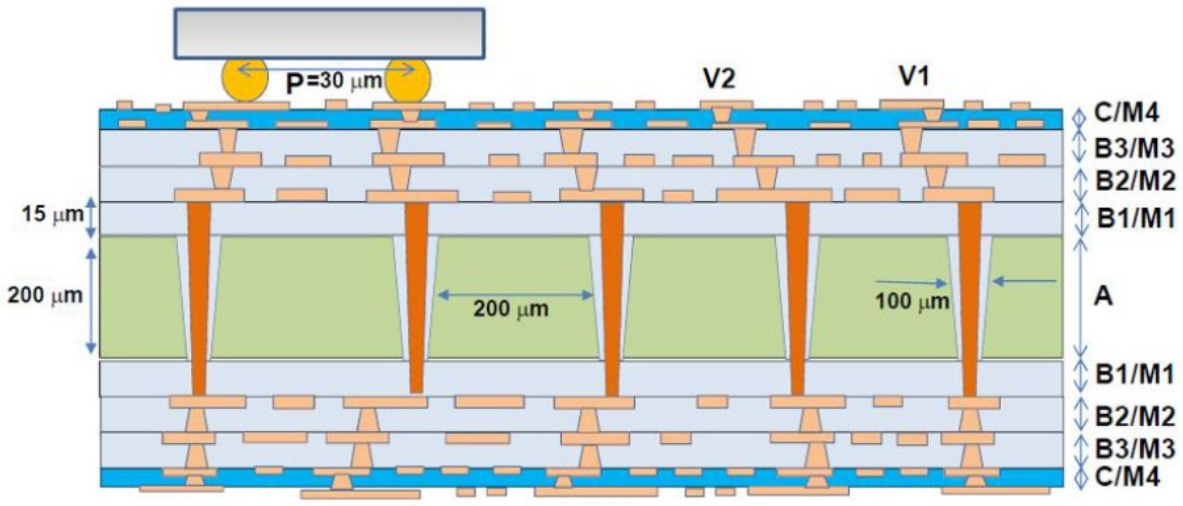
Primary Focus
1. 2D "Small Die" → *Re-shore*
2. DSBGA/DSMBGA → *Re-shore*
3. 2D "Large Die" → *Release*



* 2D Packaging Nomenclature inspired by IEEE Heterogeneous Integration Roadmap (HIR) Committee

SHIP-RF Advanced Technology

Rigid Core Interposer Plan

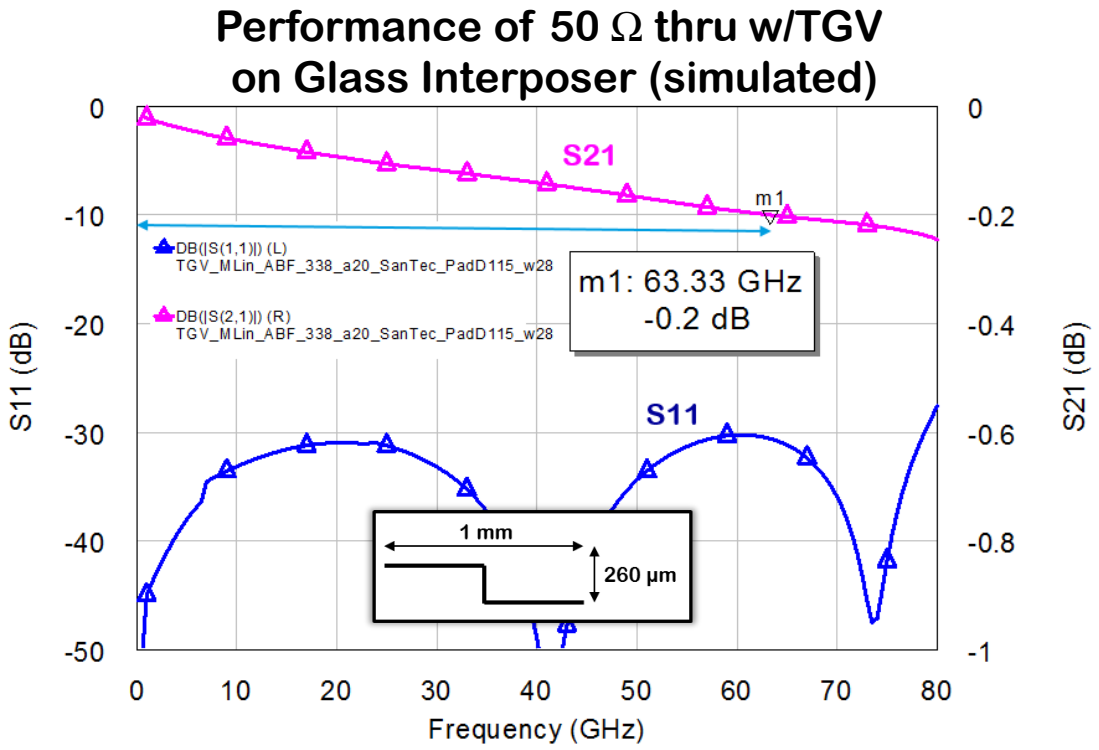


Embedded Glass interposer with TGVS

Image courtesy of GaTech PRC

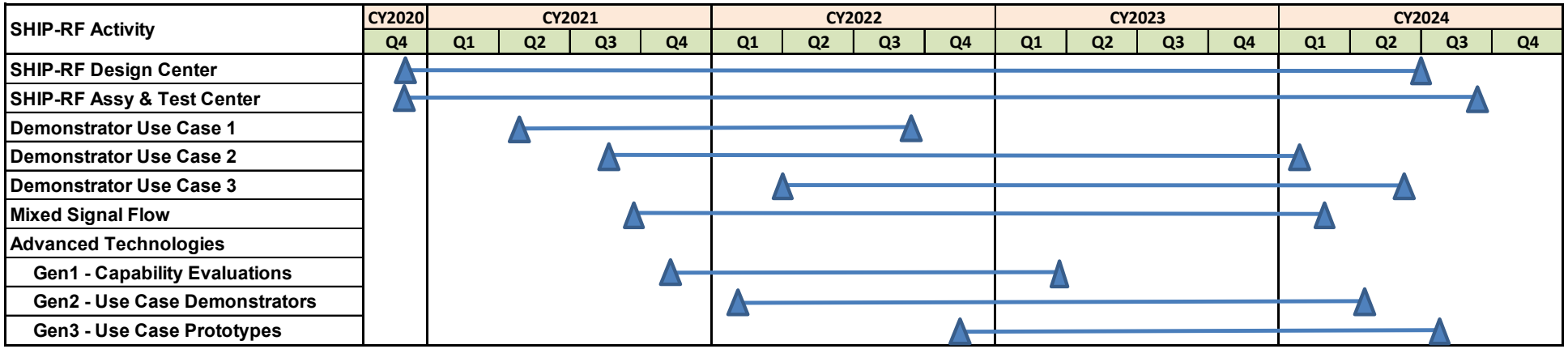
Proposed Development Plan

- Gen-1: 2DR Capability Evaluation
- Gen-2: Customer Use Case Demonstrator
- Gen-3: Establish Pilot 2DR Platform



Summary

SHIP-RF is Real



- SHIP-RF use case "demonstrators" are being developed to evaluate the advanced packaging business process, exercising DC and ATC
- SHIP-RF Assembly Design Kits (ADKs)
  - ✓ 2D Multichip Module (MCM)
  - ✓ 2D RF SiP Small Die
  - 2D RF SiP Large Die
  - Double Sided BGA (DSBGA)
  - Double Sided Molded BGA (DSMBGA)
- Advanced Technology focus
  - RF-optimized packaging technology study (completed May-2021)
  - Advanced RF Interposer technology development (in work)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