West Coast Luncheon January 15, 2014

PROMEX INDUSTRIES INC.

MICROELECTRONICS ASSEMBLY TECHNOLOGIES

The QFN Platform as a Chip Packaging Foundation

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Topics

- QFN Overview
- **Overmolded QFNs**
- Open Cavity QFNs
- **Special QFNs**
- **LGA Based QFNs**
- **Harvey's SMT Issue**
- Conclusions

"The Package of Choice for
100 leads or less"

QFN Overview

Foundation 1: A Versatile Platform

Platform Versatility

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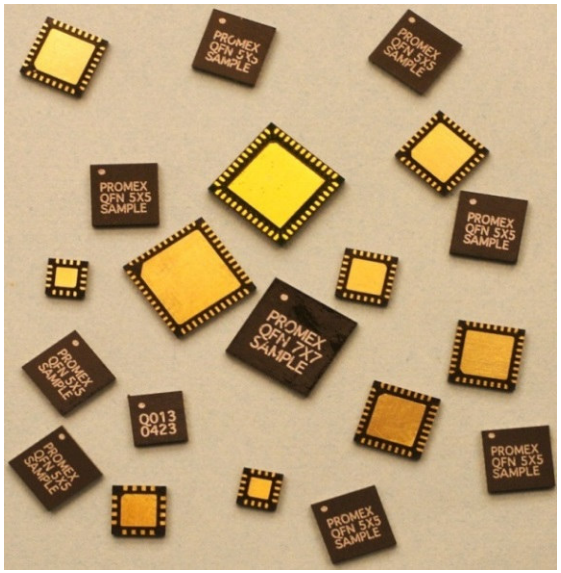
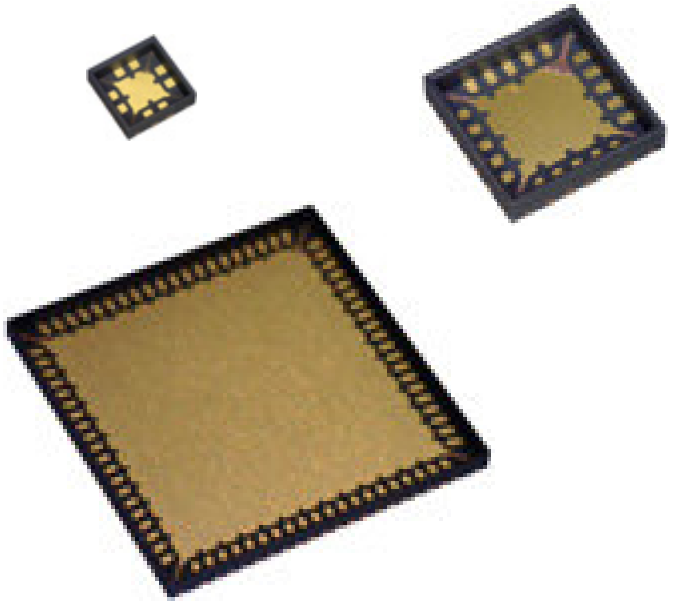


JEDEC Standard Plastic
Over Molded Versions



Open Cavity Plastic
Molded Versions

- QFNs, DFNs and LGAs are bottom terminated components (BTC's) as described by the IPC Standard 7093 in which Promex participated.
- QFNs are built using a standard lead frame array that fits a common mold. The lead frame array is customized for each new QFN size.

JEDEC QFN / DFN

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MO-220 package outline ranges (Quad – I/O's on 4 sides)

QFN Body size (mm)	Pitch Options (mm)	Lead Counts
2 x 2 through 12 x 12	0.8, 0.65, 0.5, 0.4	4 to 108

MO-229 package outline ranges (Dual – I/O's on 2 sides)

DFN Body size (mm) Square packages	Pitch Options (mm)	Lead Counts
1.5 x 1.5 through 5 x 5	0.95, 0.80, 0.65, 0.5	4 to 18
DFN Body size (mm) Rectangular packages	**Pitch Options (mm)**	**Lead Counts**
1.5 x 1 through 6 x 5	0.8, 0.5	4 to 18

Promex tooled sizes

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QFN Size, Pitch and Lead Counts					DFN Size, Pitch, Lead Counts	
QFN (mm)	**0.65 pitch**	**0.50 pitch**	**0.40 pitch**		DFN (mm)	**0.50 pitch**
3 x 3	8, 12	16	20		**2 x 2**	6, 8, 10
4 x 4	16	20, 24	28		**2 x 3**	10, 12
5 x 5	20	28, 32	36, 40		**3 x 3**	8, 10
6 x 6	40	56, 60			**3 x 4**	12
7 x 7	48	56, 60			**4 x 4**	12
8 x 8	52, 56	68				
9 x 9		64				
10 x 10		72				
12 x 12		80	100			

Customer demand pull – JEDEC open tooled packages at Promex

Demand Response

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Favored body sizes, pitch and lead count demand, custom versions trending

QFN Body size (mm)	Pitch Options (mm)	Lead Counts
2 x 2 through 12 x 12	0.8, 0.65, 0.5, 0.4	4 to 108
3 x 3 – 8 x 8	0.5	20 - 60

DFN Body size (mm) Square packages	Pitch Options (mm)	Lead Counts
1.5 x 1.5 through 5 x 5	0.95, 0.80, 0.65, 0.5	4 to 18
DFN Body size (mm) Rectangular packages	**Pitch Options (mm**	**Lead Counts**
1.5 x 1 through 6 x 5	0.8, 0.5	4 to 18
2 x 2 – 4 x 4 square	0.5	10 - 12

QFN Platform Advantages

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- Common mold tool saves significant NRE
- Lead frame spins in 4 – 6 weeks
- Standard and custom versions trivial to design, fabricate and manufacture
- Meets all "green" standards
- Industry standard processes
- QFN's penetrated in all markets

Overmolded QFNs

Foundation 2: Easily Modified

Overmolded LF Array

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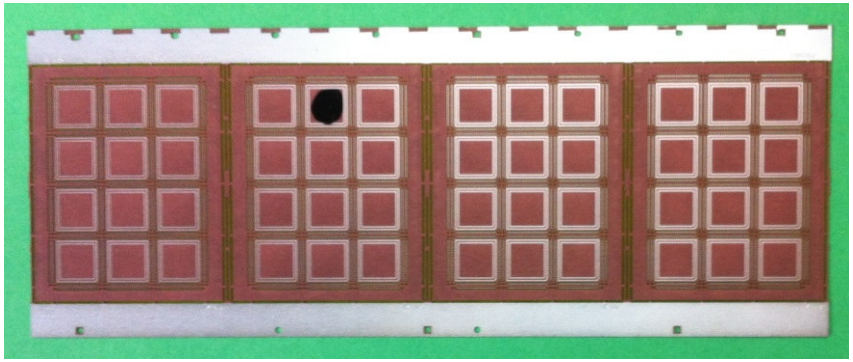
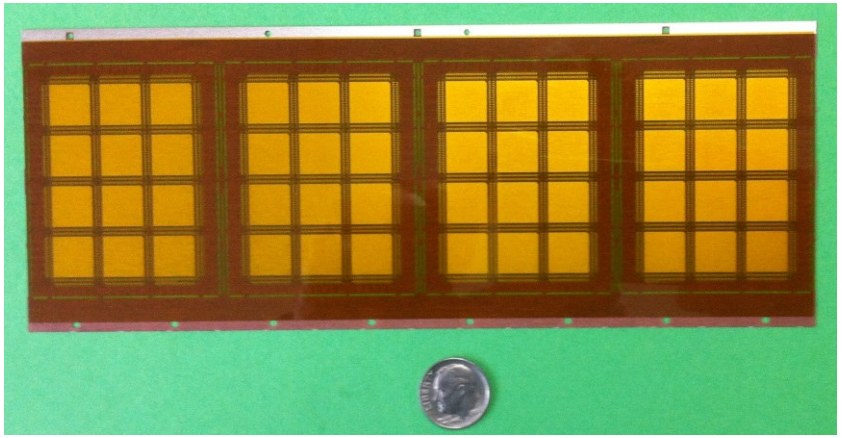
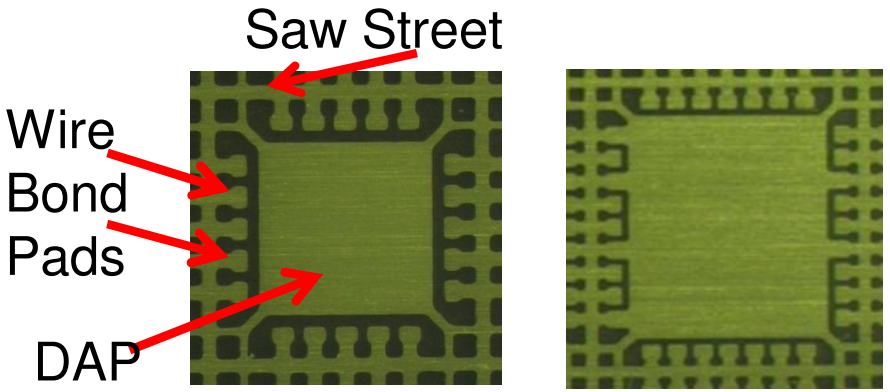


Top: die attach side
(bare copper & NiPdAu plating)

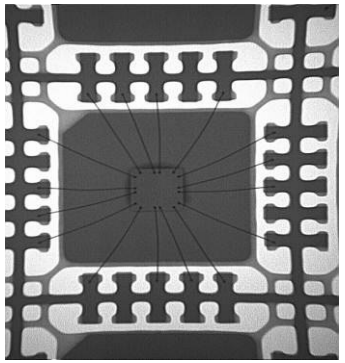


Bottom: SMT side showing polyimide tape prior to molding (NiPdAu plating)



JEDEC standard
"site"

Custom "site"
~ 5 weeks lead
time



X-ray of
Die & w/b

Typical QFN Overmolded Process Flow

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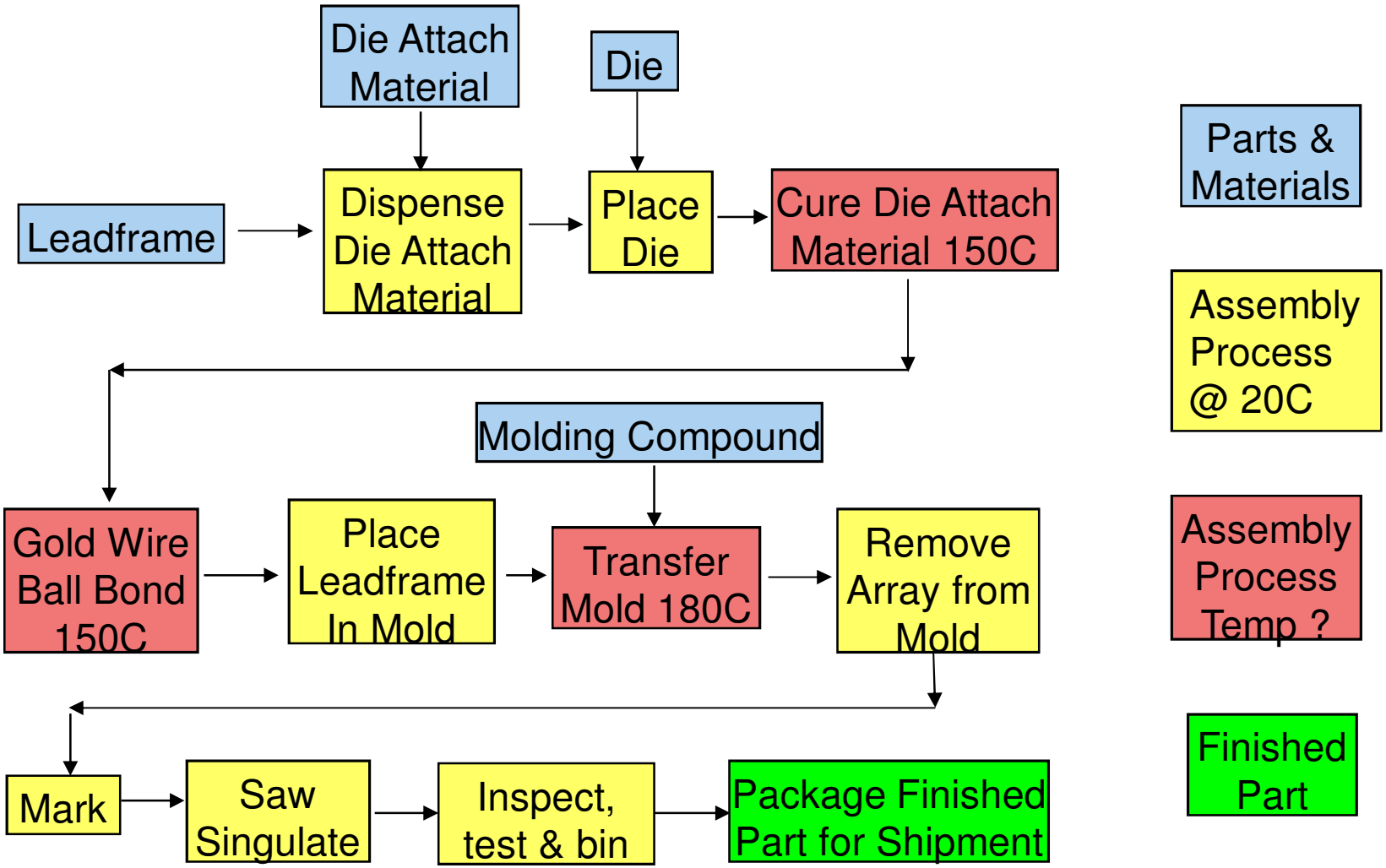

Over Molded Array

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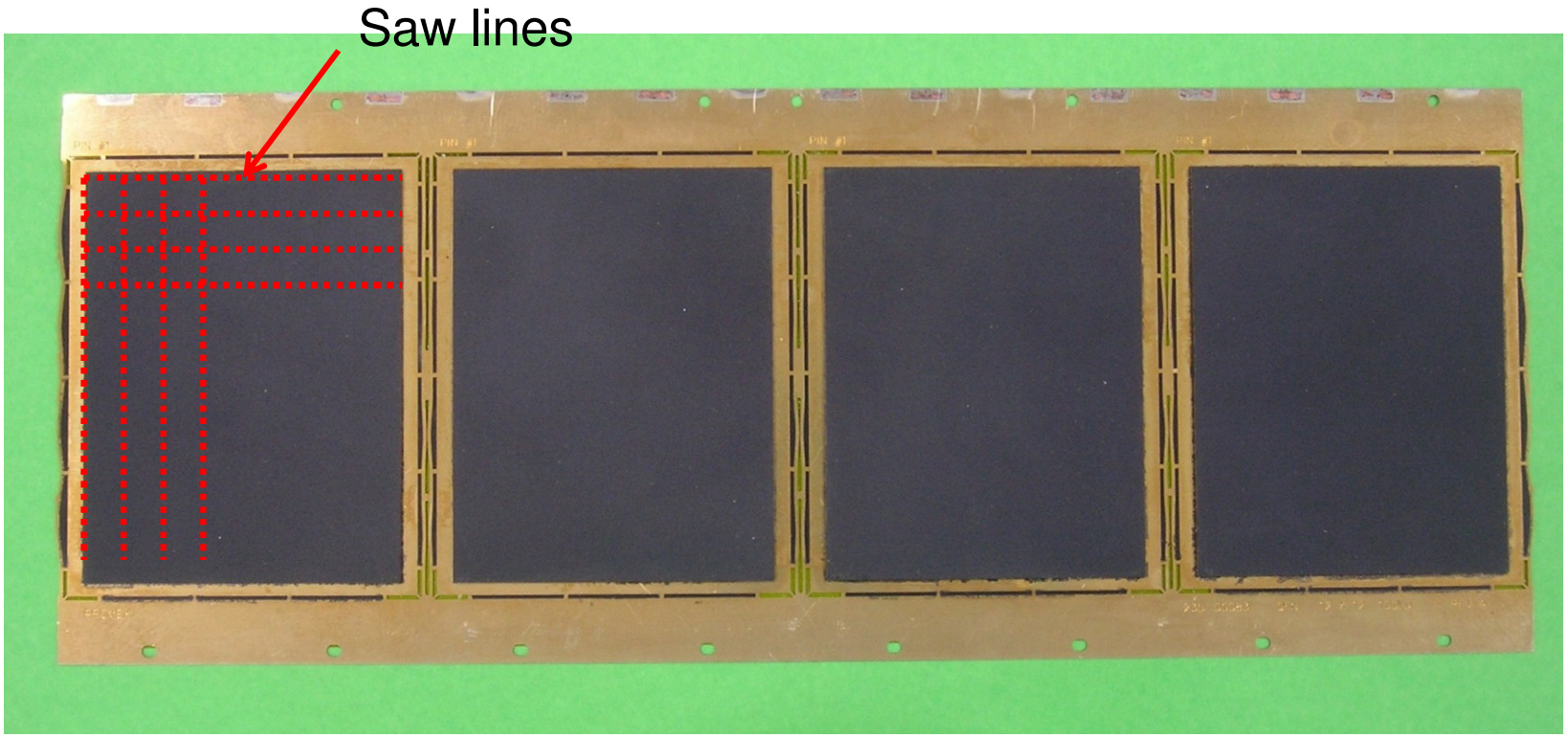

- Completed process steps: die attach, wire bonding, over molding.
- The standard 1 mm thickness can be varied from 0.4 mm to 2.0 mm.
- Next process steps: marking/identification, saw singulate, inspect, test, ship.

Open Cavity QFNs

Foundation 3: A Versatile Alternate

Open Cavity QFN

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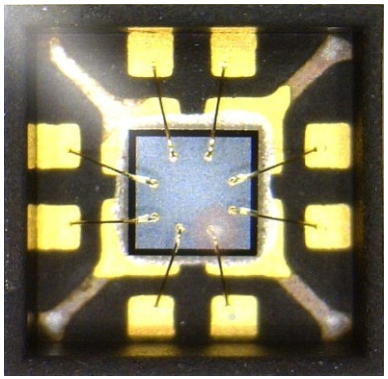
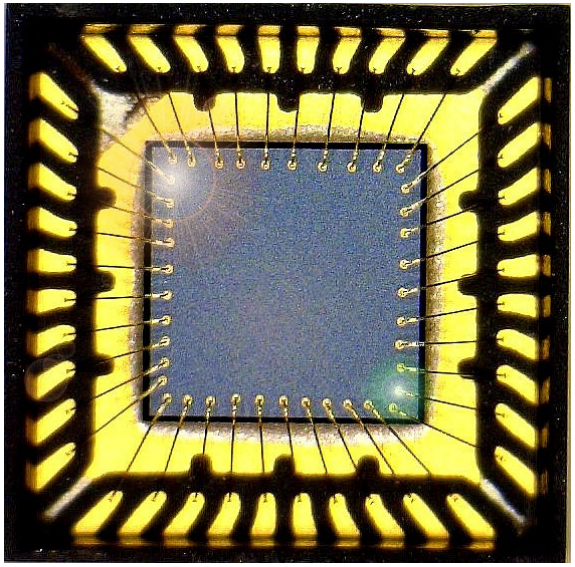


3x3 QFN Open Cavity 8L



5x5 QFN Open Cavity 40L

- Allows test probing
- MEMS device packaging
- RF air cavity applications
- Optical device packaging
- Lids available
- **NiPdAu lead frame**
- **Quick assembly by filling cavity**

Open Cavity QFN

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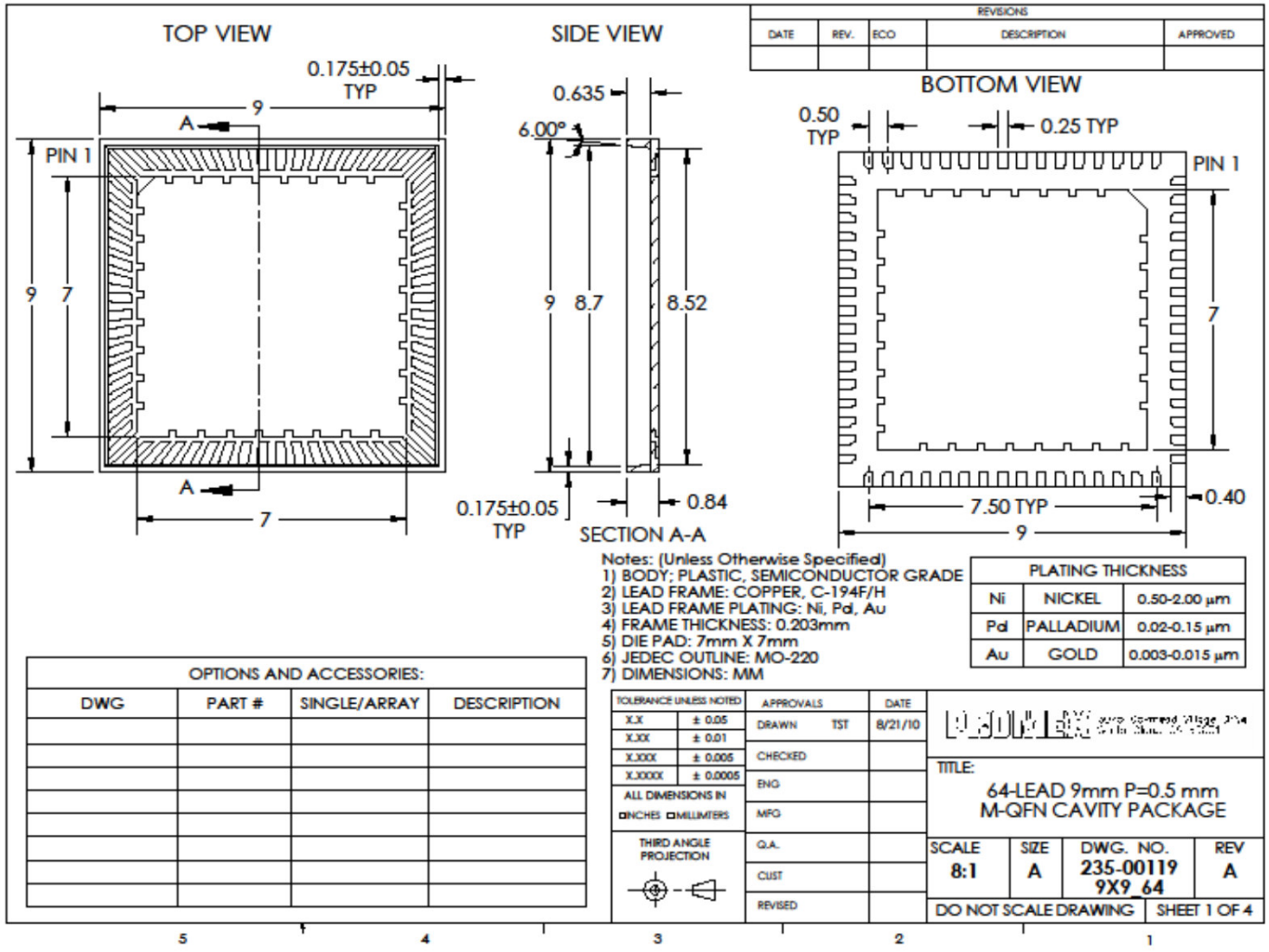

40 sizes currently available spanning:
3x3 to 12x12

20 more "soft" tooled

Open Cavity Availability

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- **Off-the-Shelf from:**
  - www.mirrorsemi.com
- Web site has many “tools”
  - available sizes
  - variety of drawings
  - Lids
  - **Etc.**

MSL & Parastic Properties

Package Performance

Foundation 4: Performance

Typical MSL Results

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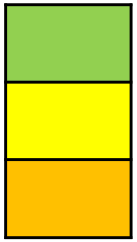
PROMEX Industries Plastic Over Molded QFNs: MSL Testing Compilation Via Third Parties				
QFN Size, mm x mm	# Leads	Lead Pitch, mm	Die attach pad, mm x mm	Die size, mm x mm
3x3	16	0.5	1.65	1.05
4x4	20	0.5	2.35	1.75
5x5	20	0.65	3.65	3.05
5x5	32	0.5	3.65	3.05
5x5	40	0.4	3.70	3.10
6x6	40	0.5	4.52	3.92
7x7	48	0.5	5.65	5.05
7x7	56	0.4	5.65	5.05
8x8	52	0.5	6.65	6.05
9x9	64	0.5	7.65	7.05
10 x10	72	0.5	8.10	7.50
12x12	100	0.4	10.10	9.50

MSL-1
MSL-3
MSL-5



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Project Goals: Promex, Eric Bogatin Collaboration

- Develop a simple technique to characterize electrical parasitics in QFNs at GHz frequencies
  - Include coupling between leads
  - Using a model that is usable by ALL simulator engines (transportable)
  - Characterize for a variety of package sizes and lead location within a packge
- The solution:
  - Described with LC matrix elements
  - Describe as single ended characteristic impedance
  - Describe as a differential impedance
- Constraints
  - Only have access to the leads outside the package
  - Surrogate chips with opens or shorts can be added inside die cavity
  - Address multiple package sizes
  - Dry gold to gold contact to external leads- no soldering
  - *Low cost, simple and robust*

The full project report is available via log-in: www.promex-ind.com

Parasitic Project

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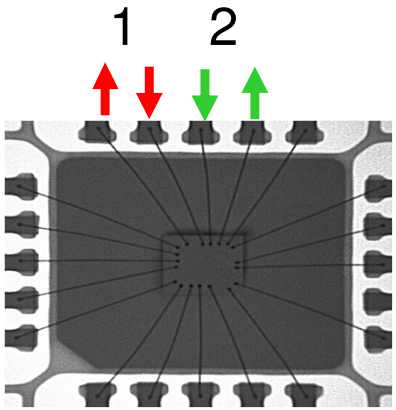
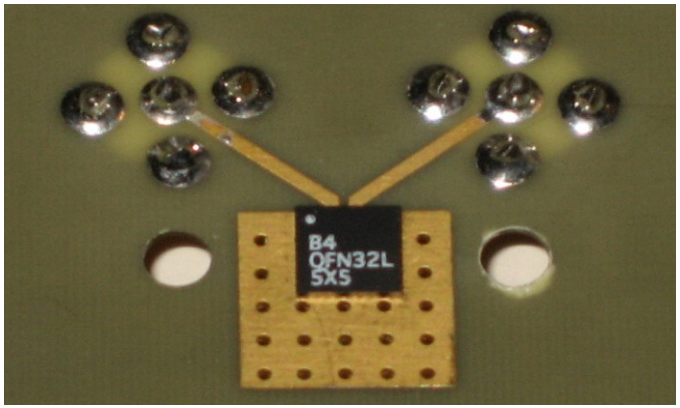
The Process of Extracting Model Parameters from a Measurement

1. For each package, build 2 identical packages with dummy die inside:
   - At die, all leads shorted to return
   - At die, all leads open
2. Build low cost fixture board between SMA connectors and 2 adjacent signal leads- with contact to return paths.
3. Measure fixture board only, open and shorted at far end
   - Extract C, L matrix of fixture board
4. Measure fixture board + package open and shorted at far end with dummy die
5. Extract package only C, L matrix elements from low frequency measurement
6. Build higher bandwidth transmission line model from LC matrix elements
7. Verify models to as high a bandwidth as the measurements.





Plane under trace is return path

Summary Data 0.5mm Pitch

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Over molded QFN's are viable candidates for frequencies up to 20 GHz

0.5 mm pitch		C11 (pF)	C21 (pF)	L11 (nH)	L21 (nH)
Center	3X3	0.153	0.055	0.926	0.393
	5X5	0.225	0.060	0.919	0.389
	7X7	0.208	0.053	0.800	0.458
Corner	3X3	0.227	0.014	1.010	0.478
	5X5	0.258	0.018	1.050	0.530
	7X7	0.268	0.012	1.340	0.598

Advanced Packaging

Foundation 5: Platform & Process Leverage

Multiple Die Packaging

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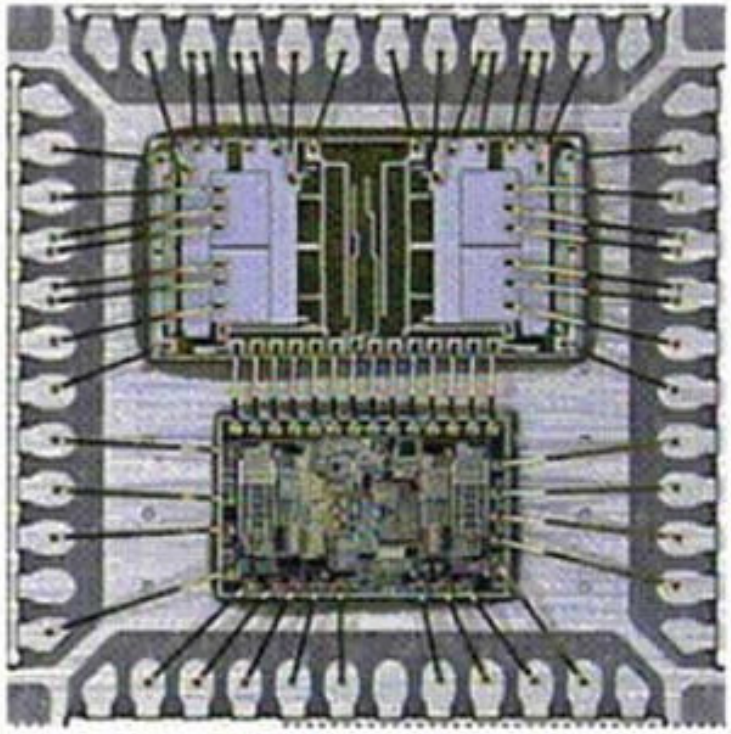
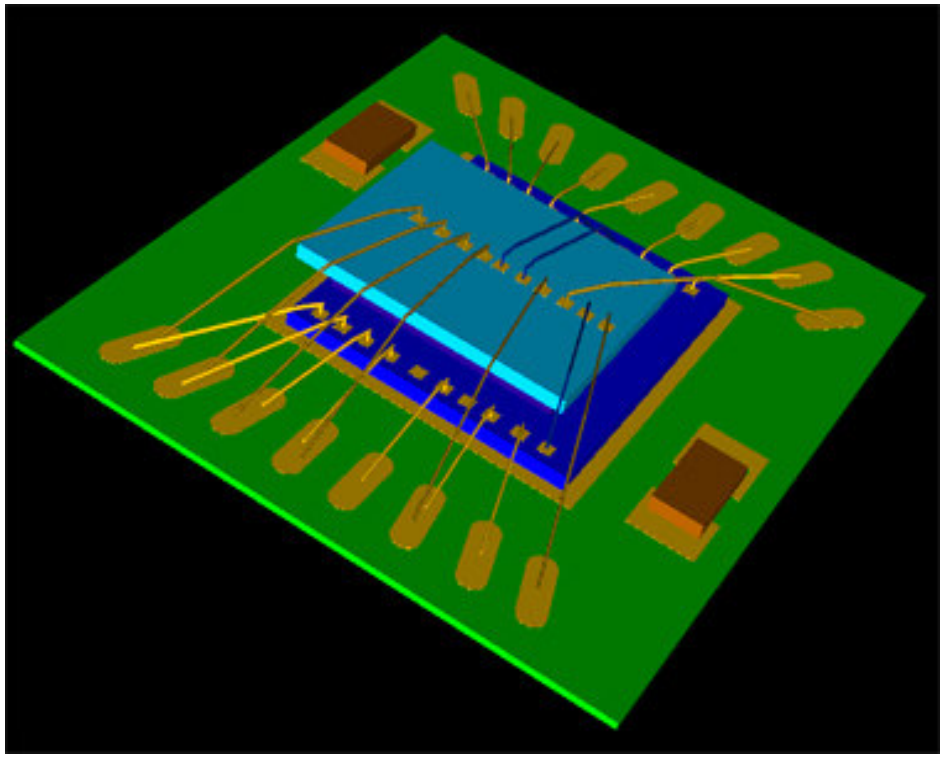


Lead frame based, dual die with die-to-die wire bonding



Stacked die on a substrate

Open Cavity Applications

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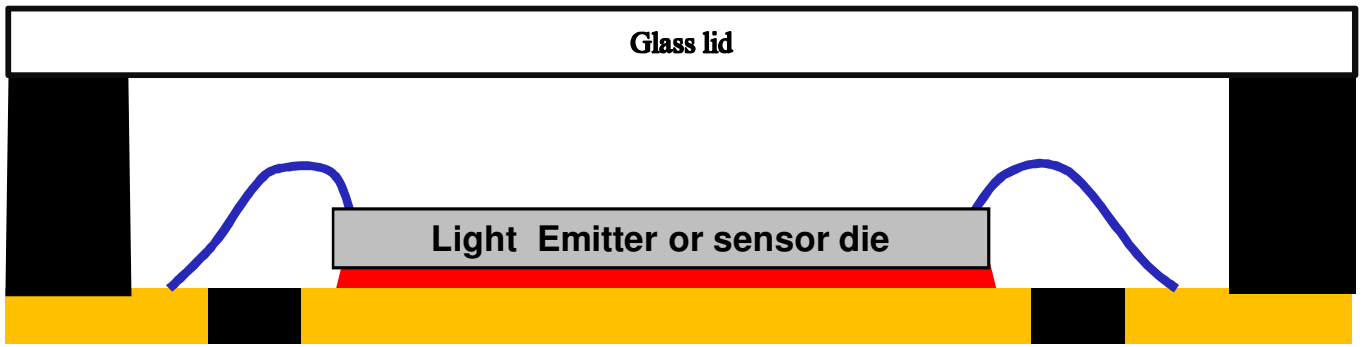
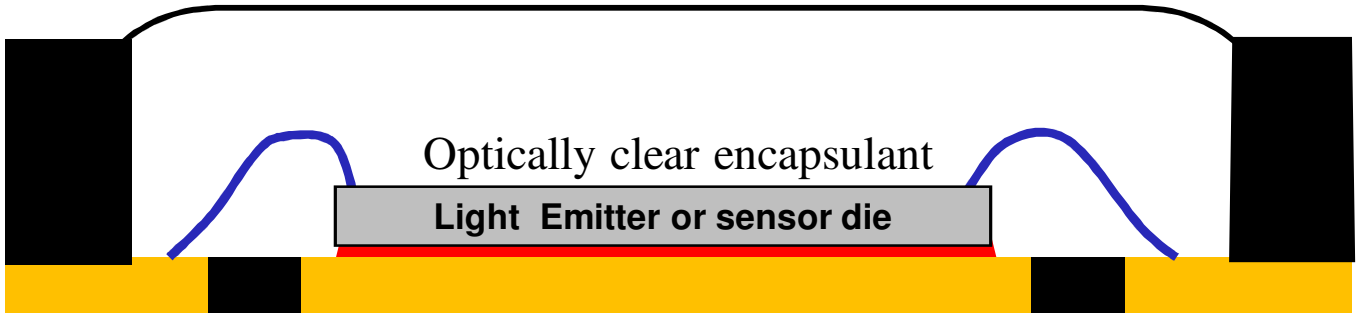
Optical Window Options





Custom die attach pad for thermal efficiency if needed

Expanding the Process

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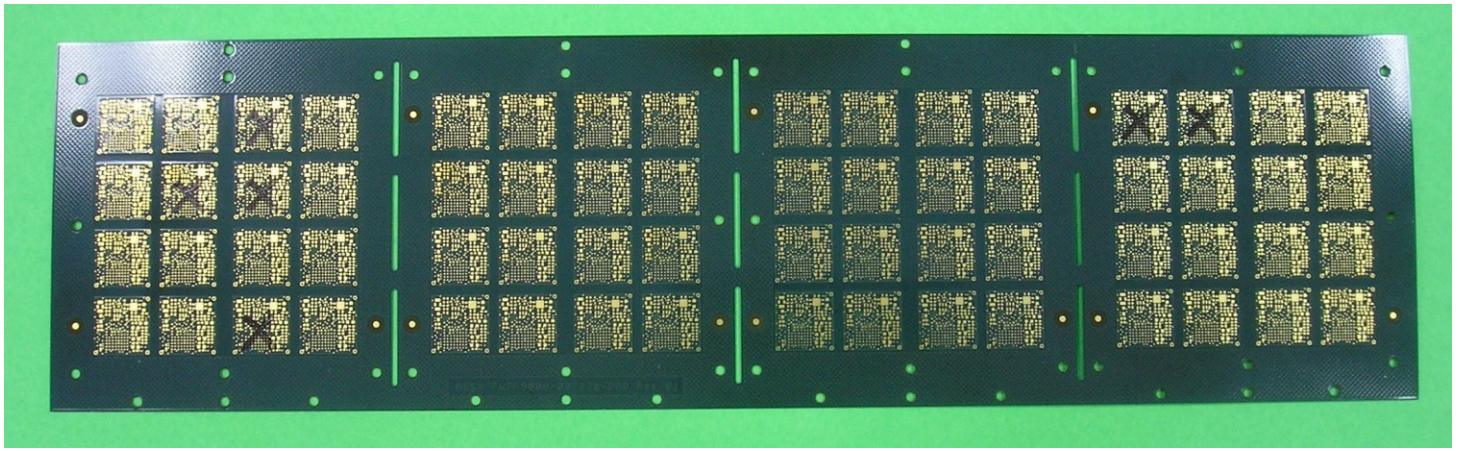
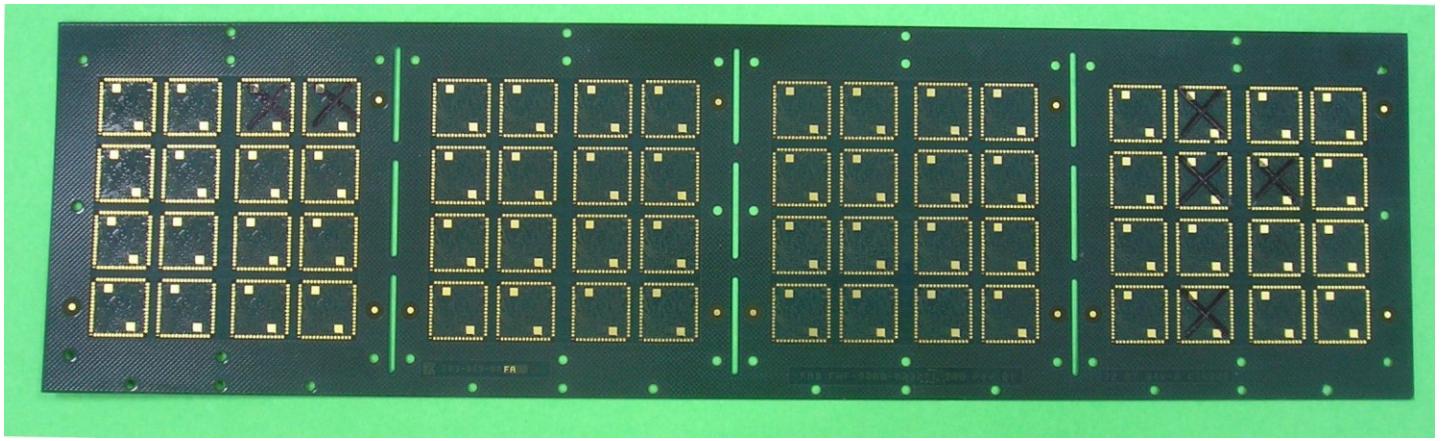
Typical LGA (Land Grid Array) Format



Top side: component to substrate termination



Bottom side: substrate to board termination

Substrate Options:
FR-4, 5, BT
Rogers Material

System-in-Package

Substrate versions

Horizontal placement

wire bonded

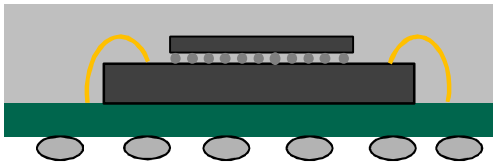
flip chip
(solder bumps / Cu pillars)

Stacked structure

wire bonded

wire bonded & flip chip

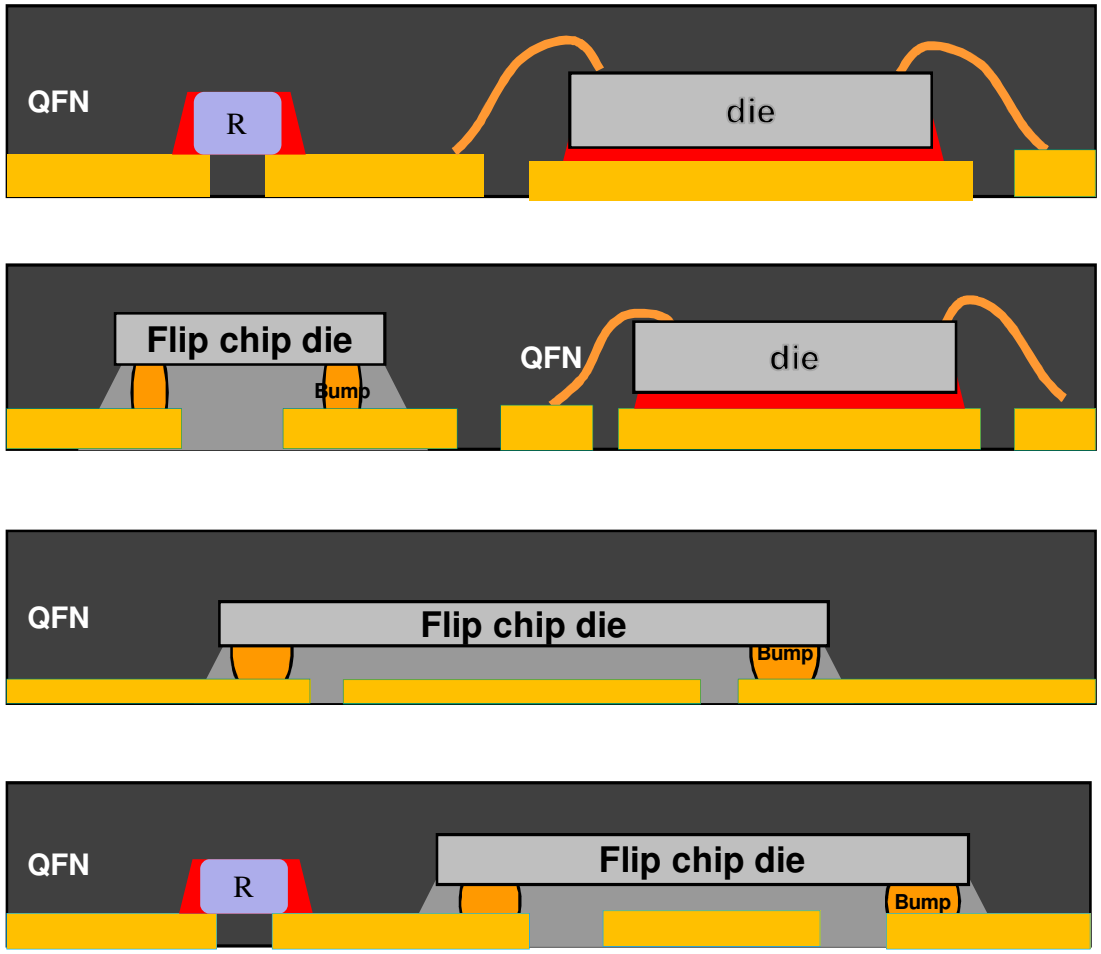
Direct connection between dice



wire bonded + flip chip
(CoC version)

Source: iNEMI

Lead frame versions



RF Modules

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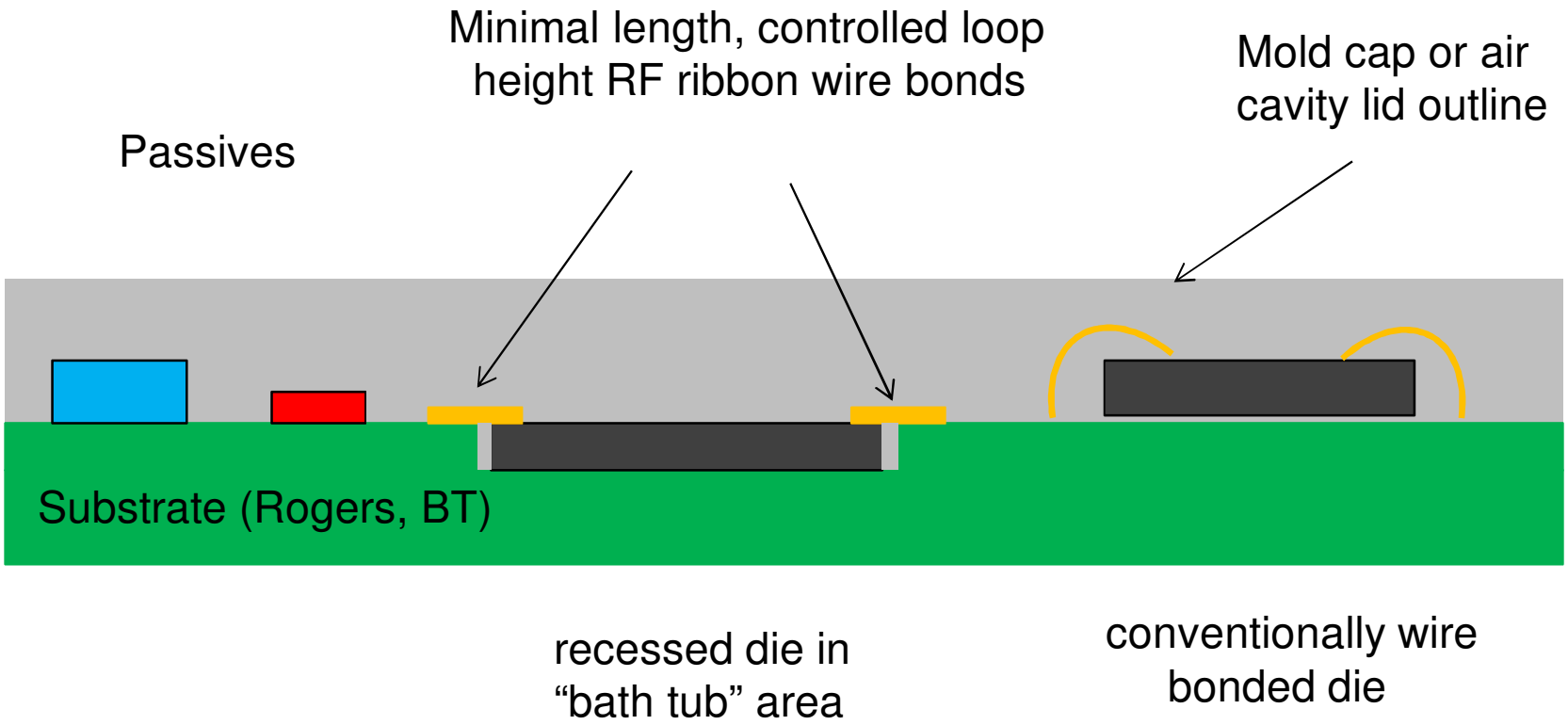

Package Development

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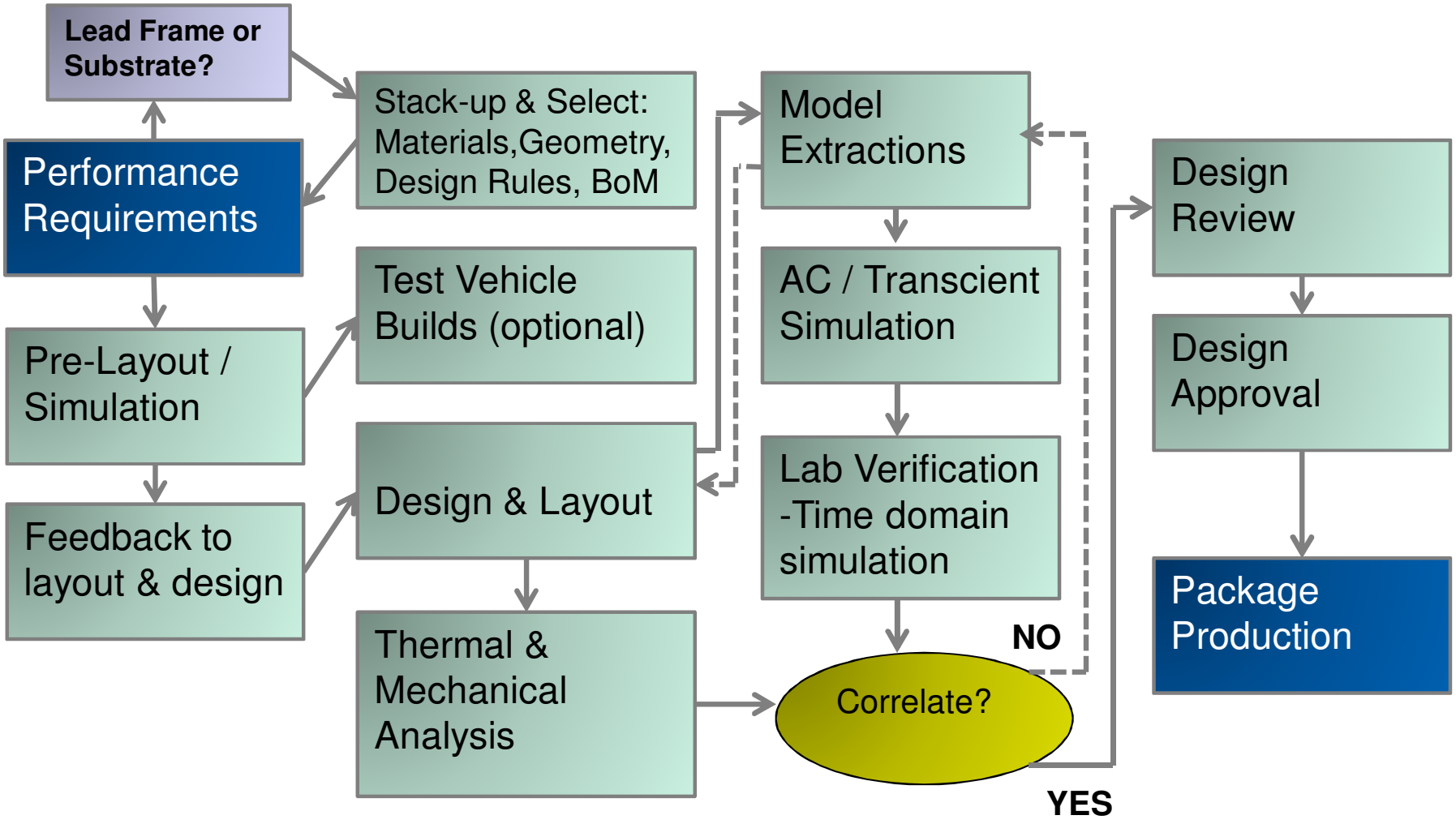

Typical Advanced Package Design Flow

Typical LGA or SiP Process

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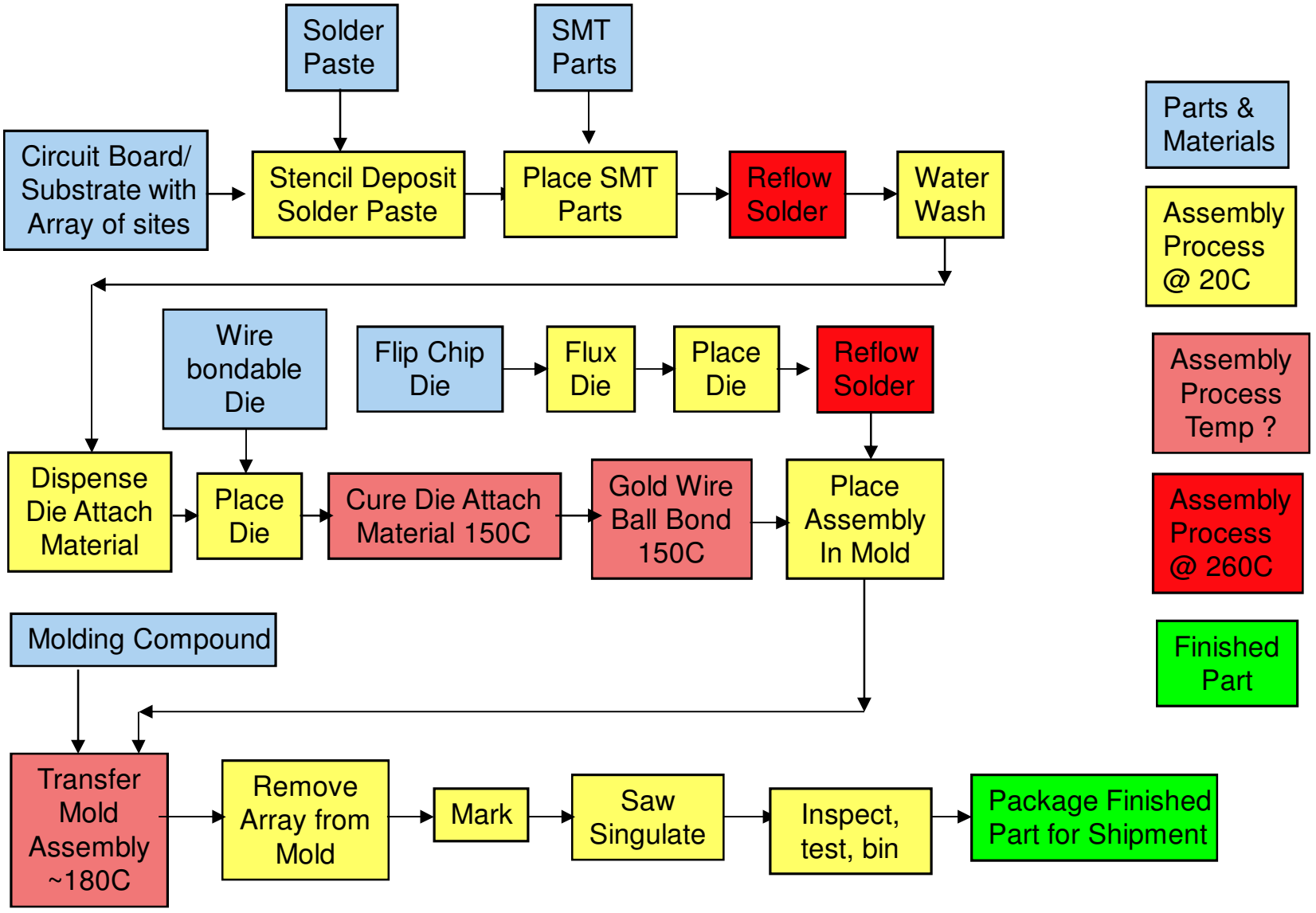

Harvey's Issue

A BTC Assembly Issue: solder voids

Harvey's Issue

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Voiding in BTC/QFN SMT assembly

- **Vendors recommend voiding of 50% or less of the die pad area for BTC components**

- Voiding is hard to eliminate in BTC components
  - Results from gases escaping from the solder past
  - Can be minimized by stencil design and controlled solder deposition
  - Voiding can be measured with X-ray and CSAM

- Amount of allowable voiding depends on the application
  - When voiding is important, need careful layout and process design

- For low power and/or non RF devices, concerns are minimal.

Conclusions

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- ✓ **Significantly lower tooling NRE and lead time**
- ✓ Reduces time-to-market
- ✓ **Proven packaging methodology**
- ✓ **Versatility, flexibility, performance**
- ✓ Single die and complex advanced packaging
- ✓ **Compatibility with future innovations:**
  - routed substrates, 3D printed substrates, embedded die and components, new materials …

Discussion, Questions