Defects Per Million Opportunities Project (DPMO)

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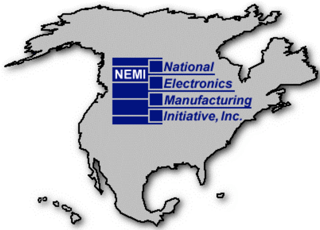


Agenda

- Project Introduction
- Background & Motivation
- Scope of Work

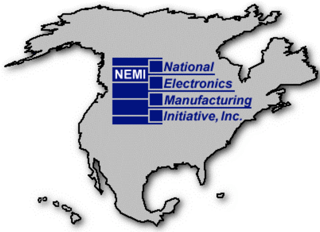
Tim Kruse
Plexus

- Database Structure
- Database Statistics

Andy Dugenske
Georgia Tech

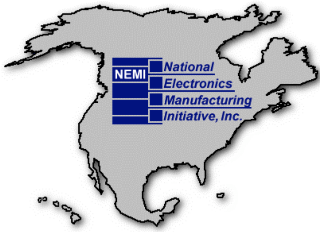
- Lessons Learned
- Future Activities
- Discussion

Dave Mendez
Solectron



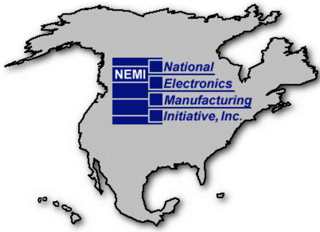
DPMO Project Participants

- Agilent
- Celestica
- Delphi Automotive
- Georgia Tech
- Hewlett Packard
- Mack Technologies
- Motorola
- Nortel
- Plexus
- Sanmina-SCI
- Shipley
- Solectron
- Teradyne
- Universal
- Vitronics-Soltec



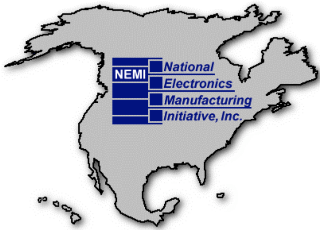
Background and Motivation

- The NEMI 2002 Roadmap required conversion cost reduction in the cost per I/O of each electronic assembly over time
- A factor in reducing conversion cost is enabling higher quality, thereby:
  - Reducing manufacturing costs through higher utilization
  - Shortening product cycle times
  - Reducing cost of test and inspection
- With data that quantifies the expected defect spectrum on a PCBA, manufactures can accurately assess:
  - the cost of assembly, test, repair and scrap
  - the estimated shipped product quality level of a product



DPMO Definition

- DPMO - Defects per Million Opportunities
- Defined in IPC-7912 and IPC-9261 as number of defects divided by number of defect opportunities, multiplied by 10^6
- Can be categorized by:
  - Process (SMT placement, reflow, wave, etc)
  - Defect type (placement, component, termination, assembly)
  - Manufacturing line
  - Package type



Background and Motivation

Yield vs. Number of Defect Opportunities

Estimated Yield = e^{-DPU}

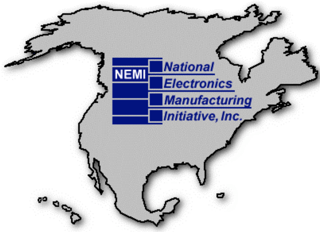
DPU = DPMO x # of Ops

IPC 9621

Estimated Yield: 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%

Defect Opportunities: 0, 10,000, 20,000, 30,000, 40,000

DPMO=10 DPMO=25 DPMO=50 DPMO=100 DPMO=250 DPMO=500 DPMO=1,000

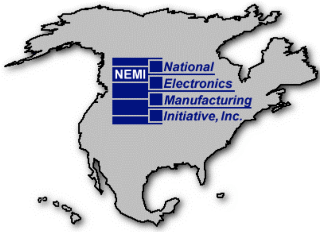


Purpose

The project objective is to provide tools that:

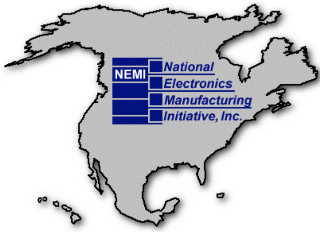
- Create an effective environment to continually improve the delivered quality of manufacturing processes
- Assist in reducing costs of assembly, test, rework, scrap and warranty
- Help improve line utilization and reduce cycle time
- Allow manufacturers to better prioritize the deployment of constrained resources
- Allow manufacturers to benchmark their DPMO rates to others in the industry

… regardless of board complexity



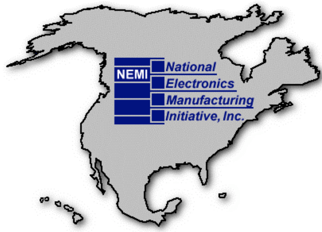
Scope of Work

- Implement methods to protect confidentiality of data
- Define how data will be shared between team members and with outside parties
- Define data collection methods around existing IPC standards
  - IPC 9261 In-Process DPMO and Estimated Yield for PWAs
  - IPC 7912 Calculation of DPMO and Manufacturing Indices for PCBAs



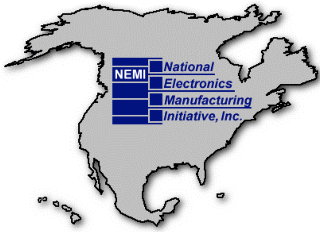
Scope of Work - continued

- Align efforts with other organizations (IPC & SMART Group)
- Define data stratification and classification methods
- Gather data from several component types into database
- Summarize data and generate reports and documents
- Lay foundation for ongoing DPMO metric efforts



Data Sharing Policies

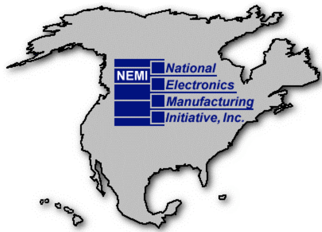
- Data shared with the industry
  - Methodology, database format, & data classifications
  - Statistics detailing the size and content of the database
  - DPMO level for all board types averaged together within each company
- Package-level DPMO data will not be shared with the industry
- Project participants receive the entire database



Confidentiality of Collected Data

- Established a secure website for project information
- Participants submitted data to a neutral party in the pre-defined formats
- The neutral party replaced the company names with non-descript IDs
- The data was combined into a single database
- The combined database will be distributed to project participants

- Georgia Tech was the neutral party



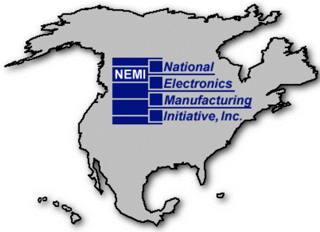
Database Structure

Opportunities
- Company
- Assembly
- Package
- Side
- AssemblyOps
- PlacementOps
- TerminationOps
- ComponentOps
- Operation

Assemblies
- **Company**
- **Assembly**
- Technology
- Standard
- **Batch**
- Quarter
- Year
- Total

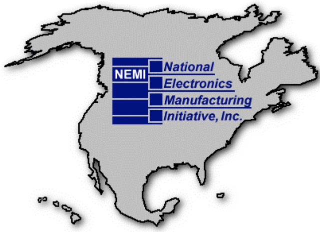
Tests
- Company
- Assembly
- TestOperation
- Coverage

Defects
- Company
- Assembly
- Serial
- Batch
- TestOperation
- Defect
- Location
- Side
- Package
- Quantity
- Operation



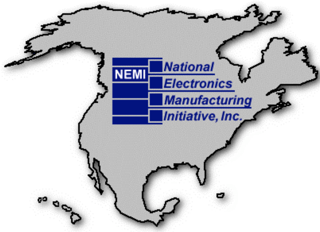
Defect Types

NEMI DPMO Project Defect Name	IPC Defect Classification
PASTE INSUFFICIENT	Assembly
PASTE SMEARING	Assembly
PASTE BRIDGING	Assembly
PASTE SCOOPING	Assembly
OTHER PASTE DEFECT	Assembly
SOLDER TERMINATION BRIDGE - SHORT	Termination
SOLDER TERMINATION OPEN	Termination
SOLDER INSUFFICENT	Termination
SOLDER TERMINATION SHAPE (excess/void/other)	Termination
SOLDER BALL	Termination
OTHER TERMINATION DEFECT	Termination



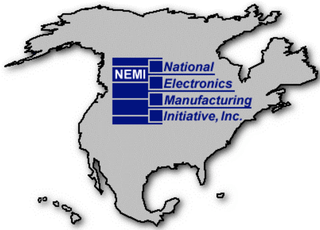
Defect Types - continued

NEMI DPMO Project Defect Name	IPC Defect Classification
COMPONENT WRONG	**Placement**
COMPONENT ORIENTATION (90/180/270)	**Placement**
COMPONENT MISSING	**Placement**
COMPONENT PLACEMENT (misaligned, billboard…)	**Placement**
COMPONENT LEAD BENT or MISSING LEAD	**Component**
COMPONENT ELECTRICALLY DEFECTIVE	**Component**
COMPONENT DAMAGED	**Component***
MECHANICAL ASSEMBLY DEFECT (heatsink,screw…)	**Component**
BARE BOARD DEFECT (trace/warp)	**Component**
OTHER COMPONENT DEFECT (electrical /mechanical)	**Component**
OTHER DEFECT	**Assembly**



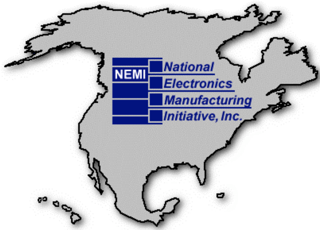
Package Types

Package Name	Package Description
BGA	Ball Grid Array. Standard pitch is 1mm (or 0.039"). Includes plastic, ceramic, eutectic, high-melt.
BGA FP	BGA - Fine Pitch. Anything less than standard BGA pitch (1mm or 0.039") may require special handling. Includes CSPs
BGA CONN	Includes any BGA connector regardless of pitch.
CGA	Column Grid Array, similar to BGA except terminations are small columns of solder
CGA FP	Column Grid Array, fine pitch, Anything less than standard BGA pitch (1mm or 0.039") may require special handling.
FLIP CHIP ARRAY	FCA - Flip Chip Array - a chip on board technology that has bumps attached to the silicon die, is flipped, and mounted directly to a printed wiring board.
PGA	Ball Grid Array. Standard pitch is 1mm (or 0.039"). Includes plastic, ceramic, eutectic, high-melt.
GW 16 MIL	16 mil gull wing QFP, SOIC, SOP, SSOP, TSOP, TSSOP and hardware (sockets, switches), also includes 12 mil gull wing
GW 20 MIL	20 mil gull wing QFP, SOIC, SOP, SSOP, TSOP, TSSOP and hardware (sockets, switches)
GW 25 MIL	25 mil gull wing QFP, SOIC, SOP, SSOP, TSOP, TSSOP and hardware (sockets, switches)
GW GT 25 MIL	greater than 25 mill gull wing components and hardware (sockets, switches), SOT - Small Outline Transitors, SOD, DPAKs
GW CONN	Gullwing connectors, regardless of pitch, (does not include Mictor or Straddle Mount)



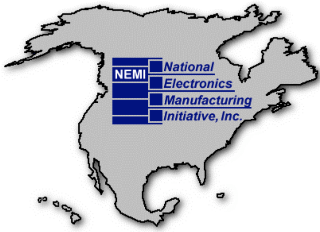
Package Types - continued

Package Name	Package Description
J LEAD	SOJ - Small Outline J-leads, PLCC - Plastic Leaded Chip Carriers, sockets
LABEL	Labels
LAND GRID ARRAY	land grid array
LCC	LCC- Leadless Chip Carrier, also LCCC- leadless ceramic chip carrier, both have solderable castellations for terminations
MECH ASSEM	Bearing, chassis, faceplates, fan guard, fuse holder, handle, heatsink, plastic part, RF sheilds,
MECH FASTENER	Bolt, clip, kit, nut, pin, rivet, screw, spacer, spring, standoff, washer,
MICTOR CONN	Mictor connector has both SMT and PTH pins
STRADDLEMOUNT CONN	Edge connector with SMT leads on both sides of the board, Includes Straddlemount Mictors
MULTICHIP MODULE	Consider 1 component
OPTIC	Fiber Optic cables and components
SMT MISC	A SMT component that falls into no other category (EMI shields, ground planes, inductors, MELF components, non-leaded)
PRESS FIT	Press fit connectors and components that are hand pluged, includes ICs hand placed into chip carriers



Package Types - continued

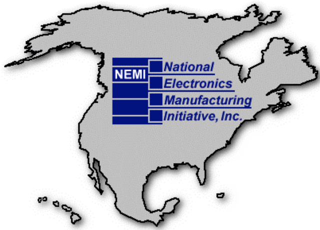
Package Name	Package Description
PTH COMP	Pin Through Hole Componenet, SIP, DIP, radial and axial mount components, Also jumpers,
PTH CONN	Pin Through Hole Array, connectors, sockets - above 50 mil
PTH CONN FP	Pin Through Hole Array, connectors, sockets - 50 mil and below
PWB	Printed Wiring (or PCB-Circuit) Board, includes gold fingers, buried capacitors/resistors
SMT PASSIVE NETWORKS	Resistor networks, capacitor networks, RPACK, (only if device has solderable castellations, if leaded falls into corresponding category (PTH COMP, GW, etc)
0201	0201 chip components
0402	0402 chip components
0603	0603 chip components
0805	0805 chip components
GT 0805	greater than 0805 chip components (excluding Tantalum)
TANT	Tantalum capacitors
WIRE ADDS / CUTS	Wire additions and/or trace cuts due to design modifications



Potential Database Queries

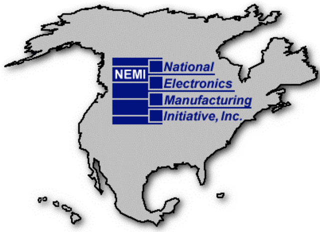
Several queries could be run to determine:

- Database integrity
- DPMO by package type
- DPMO by mfg process
- DPMO by board side
- DPMO by board type
- Any combinations of the above list
- Range and standard deviation for any DPMO statistic
- Compare actual yield to predicted yield (e^{-DPU})
- Correlation of test coverage/strategy to DPMO rates
- Etc…



Overall Database Statistics

Data contributing companies / mfg sites	8 / 11
# of different board types	466
Number of boards	397,330
Average volume per board type	853
Minimum volume per board type	2
Maximum volume per board type	73,000+
Number of opportunities in database	29 Billion



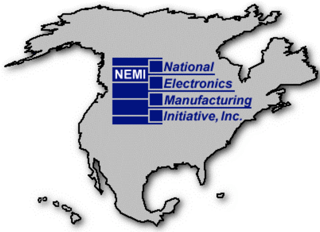
DPMO Levels by Company

Range of DPMO Performance among Companies			
	Lowest	Average	Highest
DPMO Index	7	63	150

Caution must be used when applying this data!!!

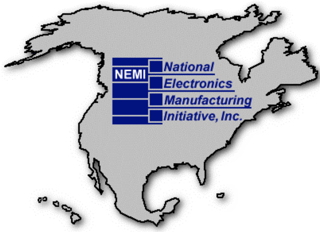
- This is preliminary data that has not been fully analyzed
- DPMO rates can be swayed by several factors

$$DPMO\,Index = \left[\frac{\sum d_c + \sum d_p + \sum d_t}{\sum o_c + \sum o_p + \sum o_t}\right] \times 10^6$$



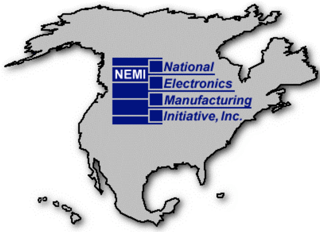
Lessons Learned

- Significant challenges to gather DPMO data
- Involvement of numerous companies extended project timeline
- Things we'd do differently
  - Establish standard so companies could automate data gathering
  - Potentially modify defect/package categories based on DPMO distributions
- Caution must be used when interpreting data
  - Cannot perform blind comparisons based solely on DPMO
  - Effectiveness of test/inspection steps can significantly raise total DPMO
  - Must define a method for normalizing such factors



Remaining Activities

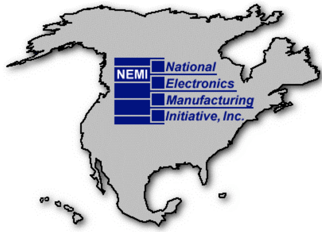
- Remaining data analysis
- Possible data exchange with SMART Group
- White paper explaining how to collect data for calculating package level DPMO
- Project Results that will be shared with the public will be available at: http://www.nemi.org/projects/ba/dpmo.html



Possible Follow-on Activities

- Develop a standard for Package-Level DPMO
- Define method(s) for between group comparison
- Repeat project / update database at regular intervals
- Expand database for follow-on projects
  - Component specific DPMO
  - Inclusion of additional in-process parameter data (chemistry, equipment type, etc.)
- Assess impact of process variables (lead free) to DPMO

- Gage interest of other companies involvement in such projects



Question & Answer / Discussion