Using Process Step Verification (PSV) to Ensure Wafers Have Completed All Process Steps

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Presentation

- **Who is Delphi**
- **PSV Abstract**
- **Processing Without PSV**
- **Examples of Process Violations**
- **Cost of a Process Violation**
- **How Does PSV WORK**
- **Other Considerations for Implementation of PSV**
- **Conclusions**

Who Is Delphi?

- **Delphi is a world leader in mobile electronics and transportation components and systems technology**

- **Multi-national Delphi**
  - Conducts its business operations through various subsidiaries and has headquarters in Troy, Mich., USA, Paris, Tokyo and São Paulo, Brazil.

- **Delphi's two business sectors**
  - Dynamics, Propulsion, Thermal, and Interior Sector
  - Electrical, Electronics, and Safety Sector

- **Delphi has approximately 185,000 employees and operates 171 wholly owned manufacturing sites, 42 joint ventures, 53 customer centers and sales offices and 33 technical centers in 40 countries.**

Delphi

Serving Diverse Customers and Markets



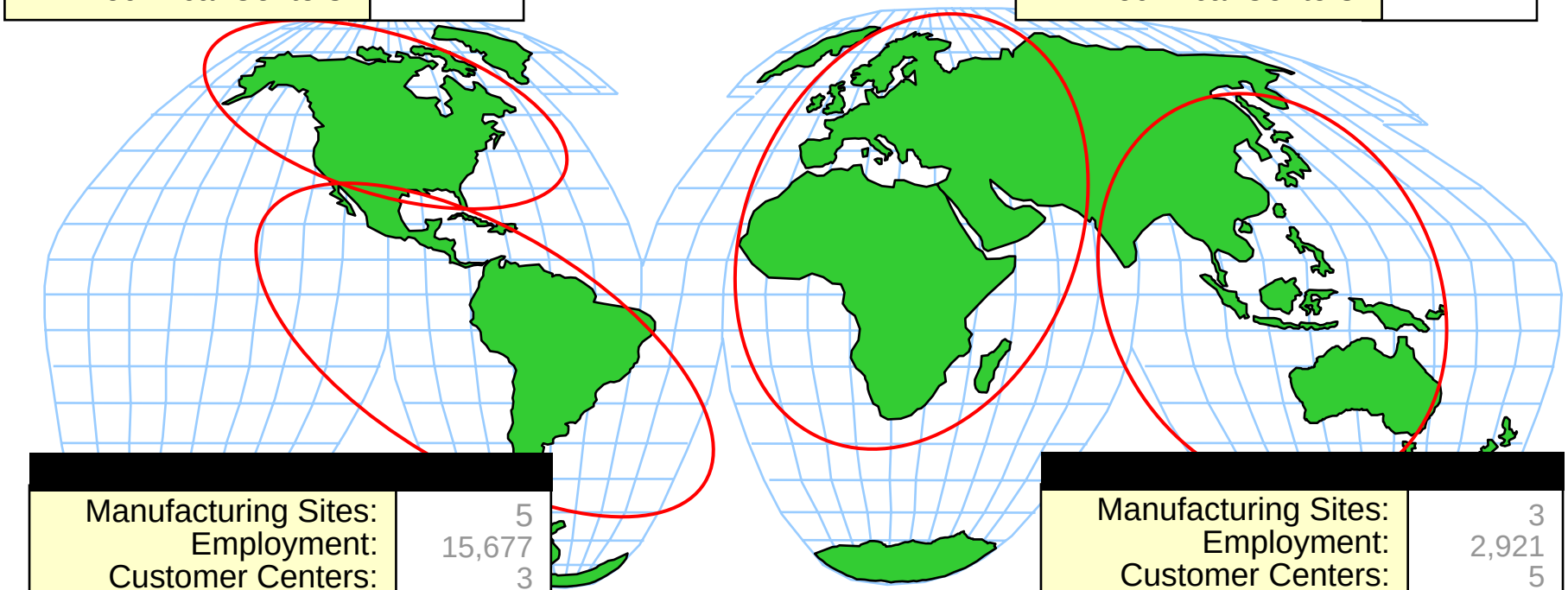


Automotive **Medical** **Truck** **Bus** **Marine**

Delphi Electronics & Safety Global Presence

Manufacturing Sites:	2
Employment:	7,381
Customer Centers:	3
Technical Centers:	6

Manufacturing Sites:	8
Employment:	4,432
Customer Centers:	10
Technical Centers:	12



Manufacturing Sites:	5
Employment:	15,677
Customer Centers:	3
Technical Centers:	5

Manufacturing Sites:	3
Employment:	2,921
Customer Centers:	5
Technical Centers:	7

*Regional breakdown is consistent message throughout Delphi.

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Delphi Electronics & Safety

Breadth of Product

Body

- Body Electronics
- Climate Controllers
- Head-up Displays
- Instrument Clusters
- Security Systems
  - Vehicle
  - Content

Powertrain

- Standalone & Engine Management System Controllers
  - Engine
  - Machine and Heavy Duty
  - Powertrain
  - Transmission
- Power Modules
- Semiconductors
- Software

Safety

- Airbags
  - Frontal, Side, Curtain
  - Inflators, Cushions, Covers
- Antilock Brake Control
- Belt Tension Sensor
- Seat Belts
- Steering Wheels
- Suspension Electronic Control
- Forewarn® Collision Warning Systems
  - Smart Cruise Control
  - Back-up Aid
  - Side Alert
- Restraint Systems Electronics
  - Crash Sensing
  - Occupant Sensing
- Steering Electronic Control

Integrated Media Systems

- Acoustic Systems
- Advanced Digital Audio
  - Playback Devices
  - Satellite Receivers
  - Digital Receivers
- Amplifiers
- Fuba® Advanced Antenna Systems
- Hands-free Connectivity
- Navigation Systems
- Premium Audio Systems
- Rear Seat Entertainment Systems
- Receivers
- Satellite Data Services and Communication
- Truck PC
- Wireless Networking

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DELPHI

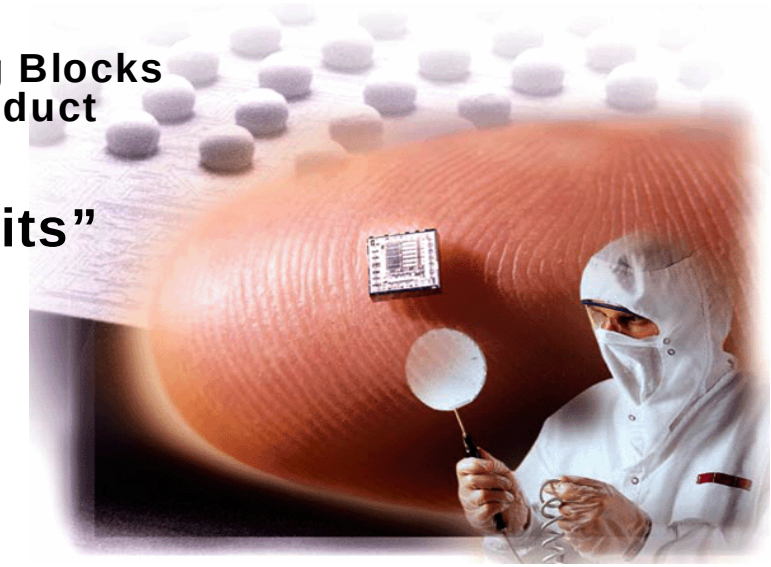
Delphi Electronics & Safety
Delphi Microelectronics Center

- **Flip Chip Bumping**
- **Chip Scale Package**
- **Interface Chips**
- **Micro Electromechanical Systems (MEMS)**
- **Power Devices**
- **Sensors**

Key Semiconductor Technologies

Harnessing the Power of Microelectronics

- **From the Miniature World of Microelectronics, We Generate "Big Solutions" for Our Customers**
  - **Progressing Beyond the Concept of Up-integration to Creating "Systems on a Chip"**
  - **Creating Platforms Geared to Specific Applications and Markets**
  - **Reusing High-quality, Reliable Building Blocks and Modules Selectively to Reduce Product Size, Cost and Complexity**
- **Results in Cost-effective "Toolkits" for Multiple Market Applications**



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Dept 8436 - Wafer Test, Saw and Sort

- **150 Products**
  - CMOS, Bipolar, Smart Power, IGBT, Micro Machine, and Sensors
  - Flip Chip and Pad Devices
- **87 Test Cells**
  - Teradyne A5xx, A3xx, J9xx - Sentry - SZ M3020 - LTX 77, CP80, Synchro HT, CX
  - EG2001, EG2010, EG4090 and TEL P8XL, WDF Probers
  - Offline Ink
- **Test 1,000,000 Die Per Day**
  - 3 Shifts, 5 Days/week Operation
- **Automatic Visual Inspect, Saw, and Sort**
- **Packaging and Final Test**

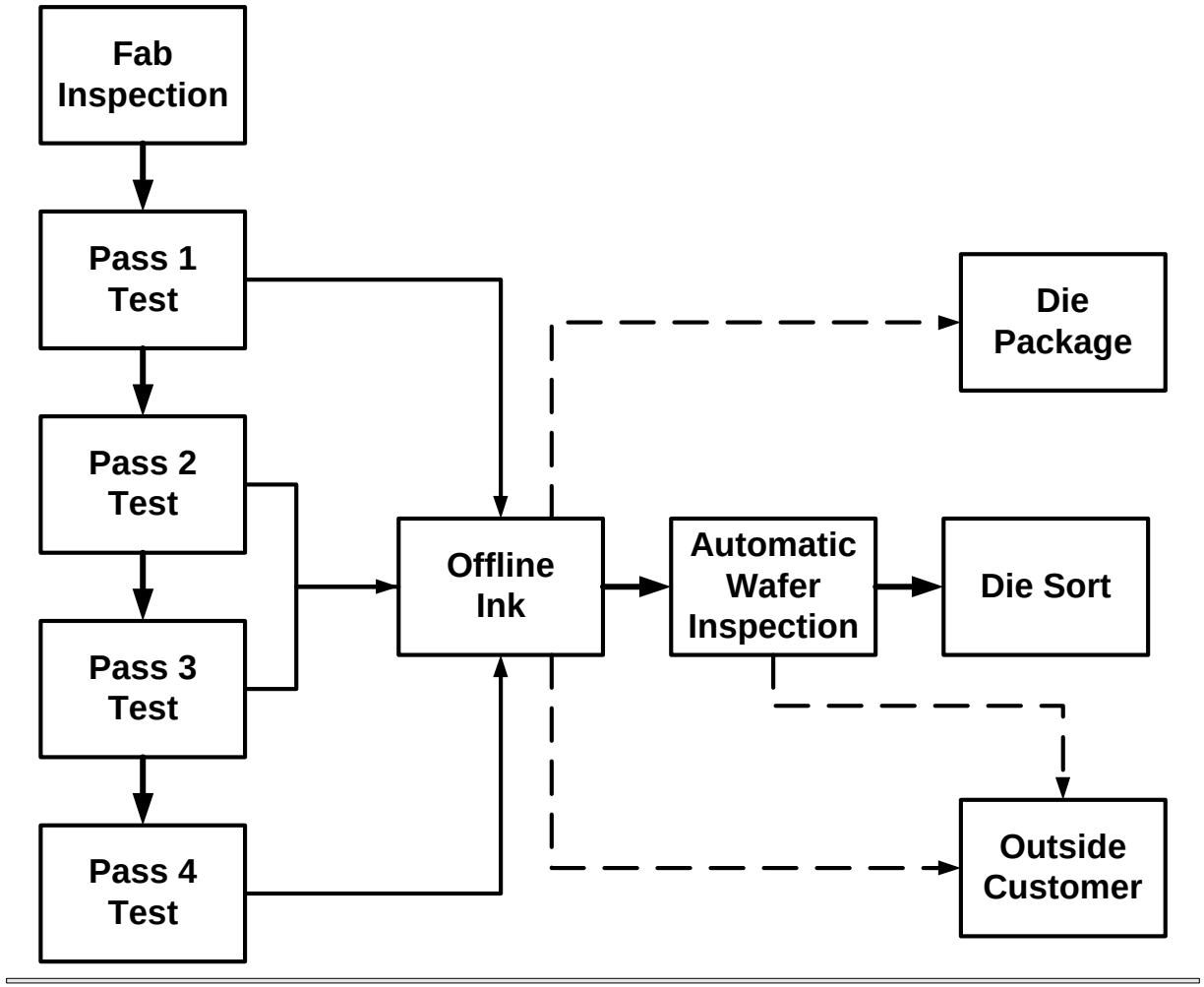
PSV Abstract

- **Process Step Verification (PSV)… provides a method to assure that wafers / lots will accurately flow through a pre-defined set of process steps.**
- **Wafers / Lots at any step in a process will not be tested or processed until they have completed all previous steps in the process.**
- **The system has been designed to be flexible such that it can be adapted to accommodate virtually any process, and can be integrated with equipment from third party vendors.**

Processing Without PSV

- **No problem with wafers that are tested once, inked and sorted.**
- **Multi-Pass Devices are at Risk**
  - Wafers that are tested, sent to bump room and come back for second pass test.
  - Wafers that go through 3-4 test passes.
  - Wafers that go through automatic visual inspection process.

DELPHI PROCESS FLOW



Processing Without PSV

- **Workforce Training and Awareness**
  - Cannot rely on the human element
- **Lot Flow Sheets**
  - Process information may not be filled out or may be filled out incorrectly.
- **FIS – Factory Information System**
  - Wafers dealt with as a lot.
  - Cannot track individual wafers.
- **Visual Wafer Map Indicators**
  - Changing the color of the previous pass bad die.
  - Visual cue is a help but not reliable.

Processing Without PSV

- **Automatic Visual Inspection**
  - Adds additional ink dots to identify visually defective die.
  - You cannot look at a wafer and know it has been inspected.
- **Die Sort**
  - New Lot Flow Sheet – cannot look at previous processes.
  - Sort by ink dot or whatever map is available.
  - Machine cannot tell which map it is using.
- **Offsite Wafer Processing (Packaging)**
  - No indication of what process steps the wafer has completed.
  - Correct wafer map must be provided.

Examples of Process Violations

- **Example One: Device ABCD is a flip chip IC used in a safety critical application in the vehicle.**
  - First pass functional test.
    - The last step of first pass test is to program some memory cells.
  - 24 hour retention bake and Second pass test.
    - Second pass test is to make sure the memory cells retain programming.
  - UV erase and a Third pass test
    - Ensure devices were erased properly.
  - Automatic visual inspection to check for mechanical or bump damage.

Examples of Process Violations

- **Result of a Missed Process Step**
  - A module level failure at final assembly
    - lost dollars due to scrap and replacement.
  - Latent failure after the module is placed in a vehicle.
    - Warranty return with associated cost
    - Loss of customer confidence

Examples of Process Violations

Example Two: Device XYZ is a flip chip used in an automotive application.

- Functional test before bump process.
  - No inking is done to the device after this step.
  - Wafer map is the only evidence wafer was tested.
- Bump process
  - The part may not come back to test for several days.
- Second pass test follows the first pass map
  - Second pass is not a full functional test.
- Automatic visual inspect and die sort.
- Module assembly
  - Full functionality of the specific IC cannot be tested due to it being a part of a circuit.

Examples of Process Violations

- **Result of a Missed Process Step**
  - Same cost as example 1
- **Additional cost**
  - Investment of engineering hours spent trying to salvage the material:
    - Risk Assessment
      - How many bad die did the customer receive?
      - What impact would there be on module functionality?
    - Typically, there will only be a few bad die in the reel.
      - In one instance there were 17 bad modules in a lot of 8000 modules.
      - Is there some way to sort out the 17 and ship the rest or do we have to scrap all 8000 units?

Cost of a Process Violation

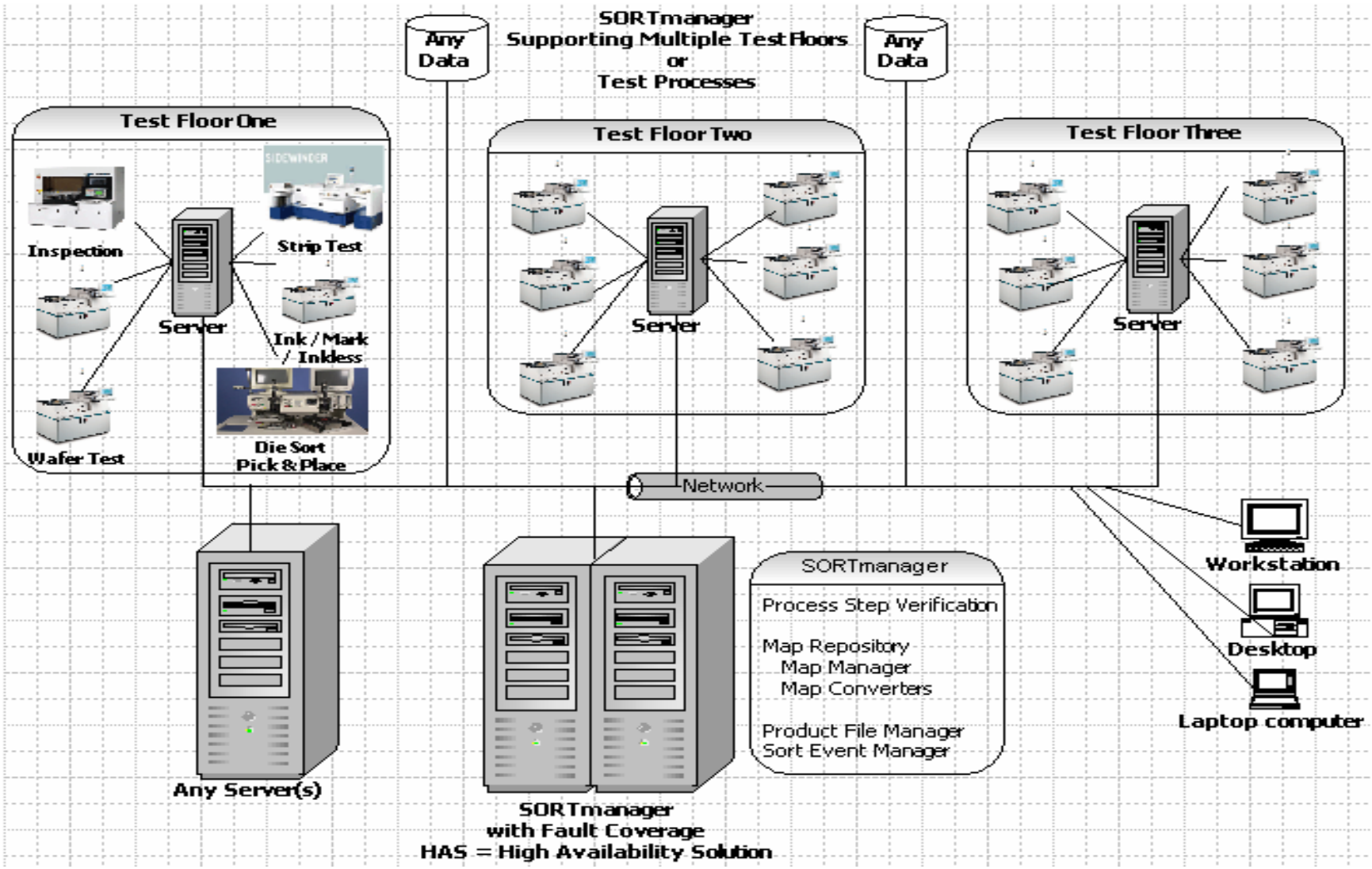
25 X $1000	=	$25,000	Wafer Cost
4 hours X $250	=	$ 1,000	Engineering Time
Replacement Cost	=	$25,000	Product Replacement
OT/Premium Ship	=	$ 9,000	Additional Cost
Total Material/Labor Cost	=	**$60,000**	
Total Cost	=	?? (Loss of Customer Confidence)	

- **Customer loss is difficult to compute due to unknown impact on customer confidence and impacts to their scheduling and downstream end users / customers.**
- **Supplier has seven (7) process violations per year.**
- **Annual loss = 7 X $60,000 = $420,000**

How Does PSV Work

- **Process result maps are generated at the first test or visual inspection step.**
- **All subsequent process steps utilize / follow this result map processing only good die.**
- **If a process step is missed the subsequent process step will not follow or process a wafer map that does not have the correct information.**

Process Step Verification Integration



Process Monitoring Solutions

- **Traditional Solutions**
  - Weaknesses
    - Lot based verification
- **Process Step Verification**
  - Advantages
    - Integrates to MES
    - Lot, Wafer and individual Die based verification
    - Alarms / Messages to equipment / process owners of process violations

How Does PSV Work

- **PSV involves putting flag(s) in the wafer map file which tracks process step(s) the wafer has been through.**
- **The wafer mapping system has a database / wafer map repository that monitors and validates all process steps for each product type.**

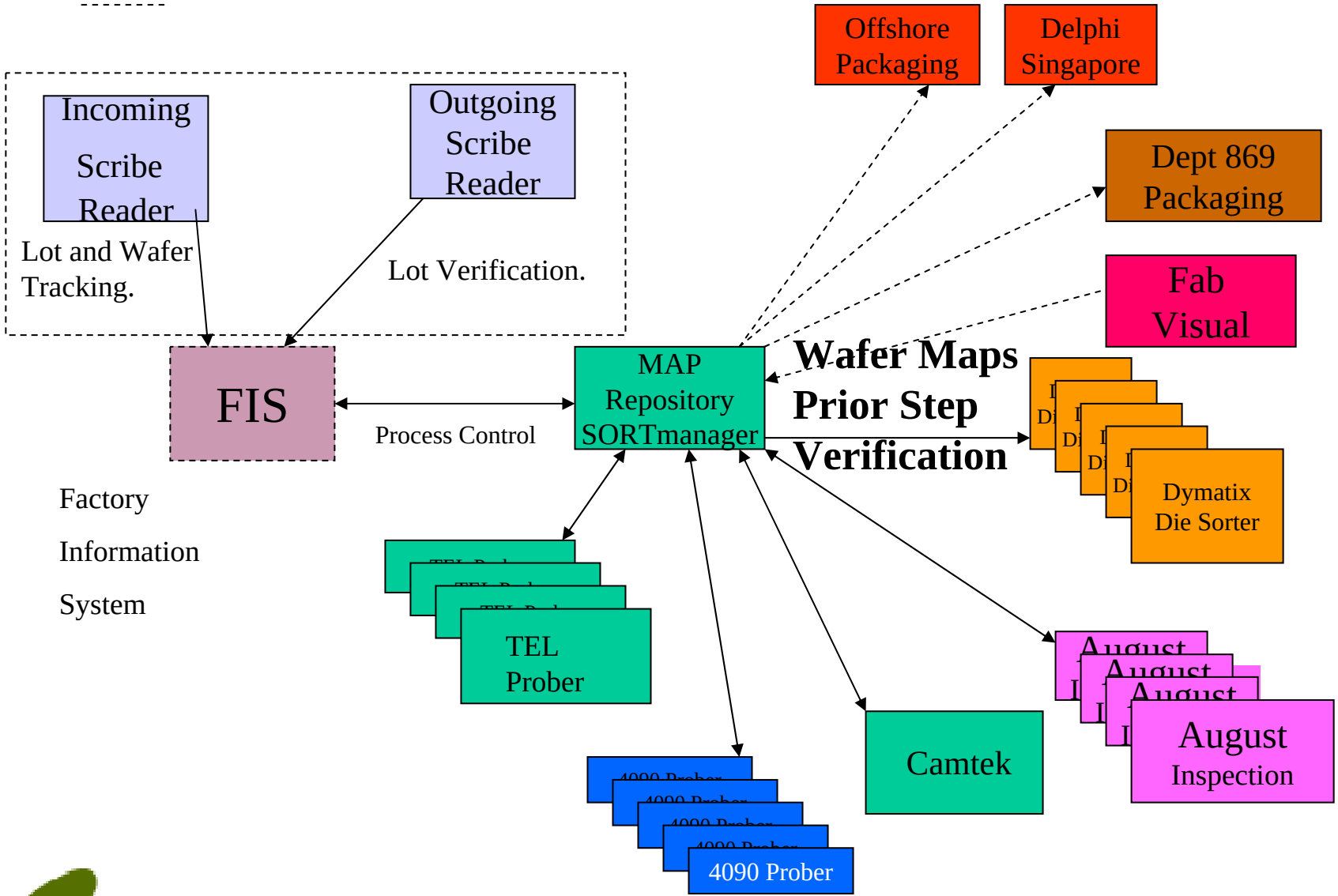
How PSV Works - PSV Flow

- **Wafer Begins the Test Process at Pass 1**
  - A wafer map containing X/Y coordinate and bin information is created and stored in the map repository with unique Wafer ID.
  - The lot header information includes the prior process step flag which is unique to the device and process.
- **Wafer is Ready for the Next Step in the process, Pass 2**
  - A dummy (0 bin) wafer map is sent to the wafer map repository.
    - This map contains a prior process step flag specific to the process flow and process step of this device.
  - The wafer map repository checks to see if a map is available with the previous process step flag and if it is the correct process step in the process flow.
    - If everything is ok a map is sent to the machine and processing continues
    - If everything is not ok a message is sent to the operator, telling them to check the wafer for correct processing.
- **PSV Continues for all Process Steps for the Device**

PSV with Standalone Systems Visual Inspection & Die Sort

- When offline ink is completed a wafer map will be placed in a read only folder accessible by visual inspection process
- The next process after offline ink is visual inspection
  - The presence or lack of a wafer map indicates that the previous process step has been completed.
  - The prior step flag will still be updated to reflect that visual process has been completed.
- This process is repeated for Die Sort

Future Integration Projects



Other Considerations for Implementation of PSV

- **First Die Integrity at Every Process Step**
  - If first die is not correct, PSV will be of no value.
- **Computer Hardware and Networking Infrastructure Must be 99.9 +% Dependable**
  - If one goes back to a manual process they can no longer guarantee a device has seen all of the process steps and that the resultant IC is a KGD.
- **Standard Wafer Map Format**
  - Format that can be specified to any equipment vendor.
  - Compatibility with equipment used by offshore assembly houses.
- **Robust Wafer Laser Scribe Process**
  - Laser scribe integrity becomes the most important step in the Fab process.

Conclusion

- **Customer Expectations**
  - Known Good Die
    - An unpackaged IC chip which will meet or exceed the electrical specifications and reliability established for the packaged part.
    - Meet or exceed the requirements of the intended hybrid or MCM (Multi-Chip Module) application.
      - Die cost 60 cents : Module cost $100.00
      - Full IC functionality (hot/room/cold) cannot be tested at module level test.
  - Customers expect 0 PPM

Conclusions

- Effective process management requires the ability to take corrective action quickly when an out-of control process condition occurs.
- Prompt corrective action requires obtaining and managing data from a variety of sources and presenting those data in a manner that facilitates quick decision-making.
- Since every manufacturing environment is different, any solution must support extensible and unique customization.
- Users tend to be widely dispersed geographically– from corporate headquarters to remote locations, customer sites, and supplier facilities – collaboration requires a solution with both local and remote access via the Internet.
- PSV is that solution at Delphi.

Conclusions

- **PSV Results**
  - Since the implementation of Process Step Verification at Delphi we have not had a missed process step or experienced any quality spills to any of our customers.
  - Delphi ROI (return on investment) for (PSV) was 0.5 years (6 months) based on investment, throughput optimization and scrap savings.