



## ***Lessons Learned from the IPC-2501 Testbed Prototype Performance Test at a Motorola Factory***

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### **Abstract:**

The IPC 2501 Web Service Definition for the exchange of XML data provides an XML middleware integration environment that enables the deployment of IPC Computer Aided Manufacturing using XML (CAMX) -based standards. A performance test was run in an actual production facility to determine the applicability of an XML web-native message broker utilizing XML, HTTP, SOAP, and MIME attachments for transporting large volumes of data. Performance tests on the Georgia Tech developed IPC 2501 test bed prototype determined the maximum throughput and maximum number of clients and subscribers to data from in-circuit testers. Configuration and administration requirements of the message broker in the factory environment are reviewed from the perspective of process engineers and supervisory shop floor personnel. Finally, the web services impact on faster and more flexible shop floor equipment integration is summarized based on the Motorola factory experience.

### **Introduction**

In early September of 2002, several key members of the IPC standards committee came to Motorola's Automotive Communications and Electronics Systems (ACES) factory in Seguin, Texas. In addition to various Motorola personnel, representatives from Agilent Technologies, Georgia Institute of Technology Manufacturing Research Center (Georgia Tech MARC), FUJI America Corporation, Motorola, Siemens -Dematic Electronics Assembly Systems AG, and Teradyne were on hand to perform an initial trial of the IPC-2501-based factory floor messaging system.

The new IPC 2501 standard is designed to significantly lower the cost of ownership of factory information systems by leveraging existing Internet infrastructure investments and providing enhanced communication of data from shop-floor equipment through the manufacturing enterprise into the supply chain.

The purpose of the trial was to test the robustness of the IPC-2501 standard in a live factory environment and to verify its compatibility with existing Intranet/Internet infrastructure.<sup>1</sup>

The initial trial was successful, and since then additional features have been implemented using the trial implementation as a baseline architecture for additional features.

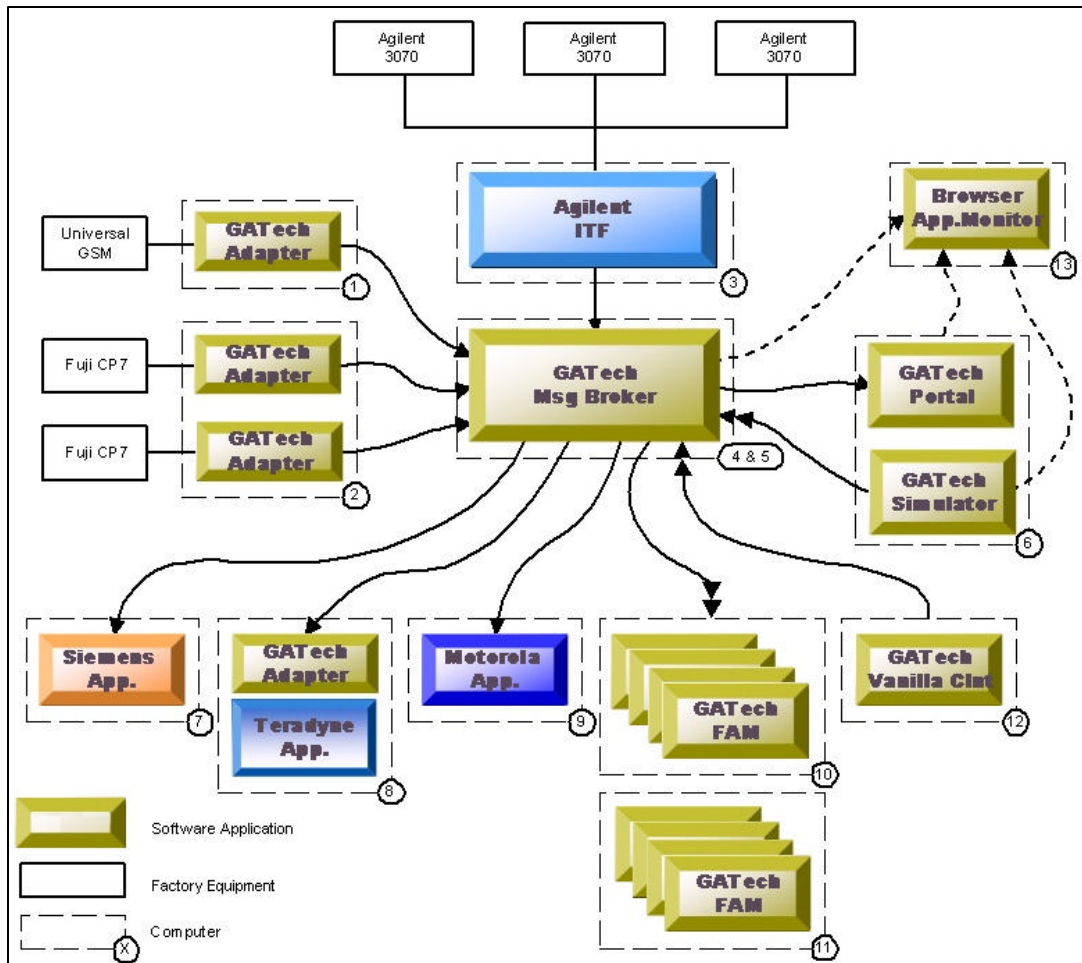


Figure 1: Deployment Diagram :

**Background:**

Subsequent to the 1996 release of the National Electronics Manufacturing Initiative's (NEMI) roadmap, the Plug and Play Factory Project was created to develop interoperability standards for electronics assembly, inspection, and test equipment. The Plug and Play team addressed the issues of how to more easily integrate assembly equipment into a shop floor information system; and secondarily, to address the issues related to the vast amounts of data

available in today's electronics manufacturing. The Plug and Play Factory Project was completed in December 1999. In the 1998 Roadmap, NEMI then extended its focus to the supply chain and launched the Virtual Factory Information Interchange Project (VFIIIP) to develop standards that facilitate the exchange of technical data among OEMs, EMS providers, and their suppliers.<sup>2</sup>

The 1997-99 Plug and Play Project spurred much activity in the industry. Within many

OEMs, factory and IT personnel were busy implementing a Generic Equipment Model/SEMI Equipment Communication Standard (GEM/SECS-II) communications infrastructure in many of their factories. While GEM had some success in the wafer and component processing industries, by the late nineties it was apparent that the GEM standard suffered from many debilitating problems:

- GEM/SECSII has not been a very practical standard. GEM does not expressly dictate many aspects of machine communications necessary for plug-and-play. Messaging formats, data types, and content vary widely from vendor to vendor.
- GEM was originally designed to work over the RS-232 wire protocol. While it has been updated to work over Ethernet, the original design still suffers from the point-point legacy of serial communications.

- That being said, GEM is a sophisticated standard. It does try to cover a great many aspects of factory operation, from remote control, to Reliability/Availability/Maintainability (RAM) metrics, to recipe management, GEM can do it all. However, application development issues resulting from this sophistication result in costly in-house or custom software. A simple prototype application to monitor parametric data from machines on a single line can exceed \$200,000.<sup>3</sup>
- A GEM interface option for SMT equipment can exceed \$10,000. Equipment vendors have sunk many staff-months of development time into these communications options; early results were often discouraging, resulting in GEM equipment options that were largely ignored in the marketplace. Some would argue, however, that CAMX-compliant machines may be even costlier. Only time will tell.

In addition to OEM work on GEM applications, the additional efforts were underway at the Manufacturing Research Center (MARC) at Georgia Tech. While the initial framework was defined by the Plug & Play efforts, the work ongoing work at Georgia Tech's Framework Implementation Project began to

### Side Bar: Acronyms Defined

- **CAMX**
  - Computer Aided Manufacturing using XML; a set of IPC standards for shop floor communication ([webstds.ipc.org](http://webstds.ipc.org)).
- **GA Tech / MARC**
  - Georgia Institute of Technology / Manufacturing Research Center. Neutral ground where competitors, customers, researchers can work together on common issues.
- **IPC**
  - Formerly Institute of Interconnecting and Packaging electronic Circuits, formerly Institute for Printed Circuits; now just 'IPC'. Mission includes networking and technical exchange, as well as standards work on IPC-2501 and many other standards.
- **GEM**
  - Generic Equipment Model for communications and control of manufacturing equipment; SEMI standards that define the behavior of semiconductor equipment as viewed through a communications link. The SEMI E5 (SECS-II) standard provides the definition of messages and related data items exchanged between host and equipment. The GEM standard defines which SECS-II messages should be used, in what situations, and what the resulting activity should be.
- **NEMI**
  - National Electronics Manufacturing Initiative – industry-led consortium focused on facilitating leadership of the North American electronics industry. Roadmapping efforts identify gaps that, if addressed, will simplify and improve supply chain communications in the electronics manufacturing supply chain ([www.nemi.org](http://www.nemi.org)).
- **RosettaNet:**
  - a consortium of computer makers, resellers, and users creating e-commerce standards for transaction-centered data exchanges using a standardized set of terms for product, partner and transaction properties ([www.rosettanet.org](http://www.rosettanet.org)).
- **SEMI**
  - Semiconductor Equipment and Materials International; an international trade association of companies participating in the semiconductor and flat panel display equipment, materials and services markets ([www.semi.org](http://www.semi.org)).
- **XML**
  - Extensible Mark-up Language; the universal format for structured documents and data on the World Wide Web ([www.xml.org](http://www.xml.org) or [www.w3c.org](http://www.w3c.org)).

develop a more complete framework. Project team members representing a broad section of the electronics industry have created a generic structure to transfer information within a framework for a factory information system (FIS). An XML schema for the framework has been proposed as the IPC-2501 standard, and additional XML schemas which define equipment messages have been standardized (IPC-2541, IPC-2546 and IPC-2547).

This testbed allowed implementation difficulties and architectural incompatibilities to be identified in the academic environment rather than on the production floor, thus reducing the risks and costs associated with adoption of standards that emerged from the project. In addition, the time to develop standards was greatly reduced as proposals were tested and feedback generated in months rather than the years associated with the more typical process where standards feedback is not available until drafts are released and independently implemented.

### Methodology:

To run the trial, the team had to deploy a number of software modules developed by Georgia Tech. The central message broker, shown in figure 1 above, was developed in Georgia Tech as well as numerous adaptors, configuration clients and monitors. For example, in order to transform the GEM/SECSII message stream from the placement equipment into CAMX messages, a GEM→CAMX adaptor was deployed for each Fuji and Universal placement machine. The Agilent 3070 in-circuit testers were made CAMX compliant with the deployment of Agilent's Intelligent Test Framework components.

Additional software components deployed include the Manufacturing Pulse(tm) monitoring and execution software developed by the Motorola Global Software Group, a Siplace line optimization application and Teradyne Manufacturing Software Group's SCE collaborative manufacturing execution system. These web-based applications were used to monitor several sets of manufacturing equipment, including XML-ready Agilent 3070 in-circuit testers, Fuji CP-7 and Universal GSM pick-and-place machines. The team members gathered performance and functional feedback data on the performance, reliability and scalability of the standard over a three-day period. All the applications and equipment involved in the trial exchanged messages through an IPC-2501 compliant message broker produced by the Georgia Institute of Technology.

### Results:

The initial performance of the complete system as shown in figure 1 was not up to the baseline performance of a GEM-only system, or a GEM system with proprietary enhancements for non-GEM equipment. Transactions per minute (hour) (TPM/TPH) and Cost(\$ per TPM) were at least half that of similar GEM-only solution. Reasons for the performance discrepancy are not clear, but there is at least anecdotal evidence of poor Java performance as well as bottlenecks in the broker transactions scheme. This seems reasonable considering that the additional broker component aids application development but can easily become a communications bottleneck.

Additional testing has been underway with a new deployment based only on an update of the Agilent ITF and additional client

controls developed since the initial trial. These tests show that the performance and

scalability issues first seen last September can be overcome.

Test Setup	Description	TPM	\$/TPM	Notes
Initial Test Setup (Figure1)	Includes MOM Broker and Adapters for GEM, ITF for Agilent's 3070 In-Circuit Testers.	639	?	
Baseline Setup	GEM-Only	943	?	
Baseline plus Proprietary Comms for Fuji, etc.	GEM plus Proprietary (Serial, File Access Monitoring) schemes for datalogging.	839	?	Consistent to average of about 1MB/Machine/Hour
Final Test setup	Same as above plus DataOut client for ITF	822	?	

**Conclusions:**

"This successful factory trial demonstrated that no technical barriers exist that might impede the implementation of a simple, standard and ubiquitous data format, "The IPC 2501 standard is compatible with Seguin's network infrastructure from both the network and security perspectives. The XML data streams from the equipment provided a common format to support all of our data collection and reporting requirements. The standard was robust and scalable enough to handle the large amounts of data required to optimize our manufacturing process."

- Brent Bohmont, senior manufacturing engineer, Motorola.

All of the participants in the initial deployment trial agreed that this new standard offers a great deal of promise to reduce costs, increase flexibility, and provide more functionality to manufacturers, and that the Seguin deployment trial demonstrated that it is ready for industry adoption. To speed up the adoption of IPC 2501 and enhance the standard, IPC Standards committee

members are planning two more deployment trials during the first quarter of next year. These two trials are scheduled to be at NACOM and Nortel Networks.

Regarding the possibility of a performance hit, it should also be noted that the original test setup in figure 1 performed adequately for most factory environments. Certainly, the added benefits of increased interoperability outweigh the additional cost of performance that may be incurred due to the addition of the broker and adaptor components. While we found that additional performance gains were possible with some tweaking, our customers' demand for data and equipment interoperability will ensure that pragmatic concerns don't fall victim to "creeping elegance."

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**References:**

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<sup>1</sup> Andrew Dugenske, Doug Furbush, Dave Morris, Tony Wong, "Method of Test for the Performance Evaluation of Message Broker III" Published on-line at <http://www.fis.marc.gatech.edu/framework/>

<sup>2</sup> "Plug and Play Creates Manufacturing Interoperability," Allan Fraser, Robert Voitus and Andrew Dugenske, Electronic Packaging & Production, December 2000

<sup>3</sup> "The Framework Implementation Project" Andrew Dugenske, P.E. Circuits Assembly MARCH 2001