Presented at IPC Printed Circuits Expo®
SMEMA Council APEX®
Designers Summit 04

Creating a New Optoelectronics Standard: Specifications for Process Carriers Used to Handle Optical Fibers in Manufacturing

Randy Heyler
Newport Corporation
Irvine, CA

Abstract
The lack of consistency and compatibility in process carrier designs was cited as an early barrier to automation in the nascent fiber-optics industry. Under the auspices of the National Electronics Manufacturing Initiative (NEMI), a working group comprised of companies from both the equipment and OEM sectors banded together to address this important technical area. As the group began work, the IPC brought an established standards development and deployment process to the table, which greatly enhanced the group's productivity and accelerated the eventual publication of the standard.

This paper will document the standards creation process as viewed from one of the working group authors, highlighting both the challenges and solutions derived during the development of IPC-8413-1.[1]

Introduction
The development of standards for manufacturing and design has a long history of demonstrated benefits to many industries, including the railroads, automobiles, and more recently semiconductor and electronics. Standards provide the biggest benefits in terms of reducing costs and product development time, and a good set of standards in an industry generally brings advantages to all participants in the supply chain as well as the consumer.

The introduction and rapid adoption of optoelectronics and fiber optics into the telecommunications networks during the past 10 years generated an incredible demand for these components while the technology was still quite immature. Mirroring newly developed industries and technologies of the past, thousands of new products were introduced by a multiplicity of suppliers without the foundation of a common form factor, controls interface, or even performance specifications and definitions. As a consequence – again following prior industry models – once this new industry hit its first (and inevitable) major contraction, the rush began to consolidate product portfolios and reduce costs. And as history has proven again and again, the development and adoption of rational standards for the design, test, and manufacturing of products will be required to enable the wholesale cost reductions that the industry now must meet.

Thankfully, a lot of standards infrastructure already exists under the auspices of standards organizations, industry trade associations, and private standards bodies (Table 1), so the *process* of developing, distributing and maintaining a standard already exists in many places. However, the *content* and the *desire to adopt* the standard still needs to be created. This can occur in many ways, including the banding together of interested parties to draft a proposed standard and issue it through one of the existing standards development organizations (SDOs). Alternatively, it can occur as an outgrowth of a "roadmapping" exercise, where industry participants from various parts of the supply chain get together to forecast technology and process needs.[2] It was this latter case that led to the formation of the working group and the eventual standard "IPC-8413-1: Specifications for Process Carriers Used to Handle Optical Fibers in Manufacturing."

Table 1 - Examples of Organizations Involved in the Development, Publication and Maintenance of Standards

ANSI – The American National Standards Institute	**IPC** – Association Connecting Electronics Industries
IEC – The International Electro-technical Commission	**SEMI** –Semiconductor Equipment and Materials International
JEDEC – Joint Electron Device Engineering Council	**TIA** – The Telecommunications Industry Association
Telcordia – Privately Owned Standards and Consulting	

Forming the Working Group

A good standard requires a good working group to both generate the content and affirm the participation and adoption of the standards within their companies. This means gathering a broad representation from interested and affected parties, getting adequate technical expertise, and securing the commitment of company management to resource the effort and utilize the outcome. It is also essential, as with any project, to elect a strong leader for the group. Occasionally, developing the standard will also require some experimentation, data collection and analysis, drafting, or other testing that would incur costs beyond the scope of personnel time, so it is important to assess the scope and cost in order to manage expectations appropriately.

In our case, our working group nucleated during the latter part of the fiber optics boom cycle (late 2001), under the auspices of the NEMI (the National Electronics Manufacturing Initiative) Technology Roadmap update. This roadmap, published every two years, already draws together many of the key constituencies required in generating a standard, including equipment manufacturers, OEMs, materials and component suppliers. One of the big issues we faced was interfacing various products with different assembly and test equipment, and eliminating a high yield cost element – fiber breakage during handling. There was a common perception that the use of a "standardized fiber carrier" could help solve both problems, and an open meeting was called immediately after one of the NEMI meetings to gather inputs and ideas. The only participation requirement was to submit an actual idea to the meeting.

From this first interaction, a list of individuals interested in working further on a standard emerged and work began. Since NEMI is not an SDO, an invitation was extended to IPC, which covers standards across the printed circuit, printed wiring and surface mount electronics industries, to join our meeting and discuss the standardization process. (It was determined that IPC's standards work in PC board manufacturing and surface mount equipment was most relevant to our case, vs. other SDOs dealing with devices or fiber-optics). IPC also offered a means to number, approve, publish and maintain any standard that we came up with, and provided a template for us to follow in the actual writing of the standard as well.

Scoping the Standard

The first, and probably the hardest part of the entire process is crafting the objective and the scope of the standard. This is especially difficult when dealing with new technologies, where proprietary methods and designs still play a large role in product differentiation. Therefore we worked quickly define what the standard would be used for, what exactly a "fiber carrier" was, and what elements of it could be easily agreed upon. This gave us a "lowest common denominator" against which we could test the resulting standard[1]:would a standard that defines just these elements be useful, and[2] would we all be willing to utilize the standard, (meaning see real benefits to it) in our next-generation designs?

The scope and objective statements, as finally crafted, then became our guiding principles throughout the writing process and were used to keep us on track:

- **Scope:** The purpose of the specification is to define standard practices for handling various kinds of optical fiber and to define the specifications and guidelines to be used in the design of carriers for these fibers in component manufacturing.
- **Objective:** The objective of this standard is not to define a particular carrier design, but to define enough requirements and guidelines to facilitate the use of fiber carriers in fiber optic component manufacturing, particularly in automated or semi-automated processes. It is the expectation of the authors of this standard that, over time, a variety of carriers will be designed that meet this standard. The marketplace will determine the subset of these designs that best satisfies the needs of the industry. Additional requirements will also emerge. These factors will lead to a small number of industry standard carriers.

Table 2 lists some of the elements that were agreed upon as having common utility across many possible carrier designs. Other areas, for example fiber retention, release, protection, and tensioning were all left in the "still proprietary" domain and intentionally not included in what would be specified, although some guidelines would be recommended. By agreeing not to debate areas of great uncertainty, complexity, or proprietary nature, we were able to confine the scope to something we were sure we could accomplish, and allowed us to accurately estimate the time, effort and cost involved to complete the standard.

Table 2 - Potential Common Elements for Specifying Fiber Carriers

Terms and definitions	Fiducial Markings
Form Factor	Fiber End Locations
Size and Dimension Limits	Fiber Bend Radii, Length, Slack, Wrapping Direction
Frame of Reference/Coordinate System	Stacking Provisions

Fortunately, the scope of this standard lent itself to a standard writing process that could be easily broken down, worked on independently, and then reviewed (mostly by phone or web conference to hold down costs) at regular intervals. We began with an outline of the standard and each of the elements that should be addressed, and divided up the work according to expertise and available resources. Additionally, an aggressive timetable was set for completion (9 months to complete the draft) and meetings were set with enough frequency (every 4-6 weeks) as to ensure the work was actually getting done. We met in person only 3 times during the entire standard development project: twice to get it started and once during an annual conference where most of the members were present anyway, which saved on costs for all the working group members.

Specifications vs. Guidelines

As we further outlined the standard we began to recognize the need to differentiate between the "shalls" and the "shoulds" of the document, i.e. where the standard would strictly *specify* vs. *recommend* a particular dimension, material, process, or method. Realizing that both the immaturity and variety of the processes, devices and equipment involved prohibited strict standards in all cases, we consciously addressed certain portions of the document at "guidelines" which were to be considered as recommended, but not required practice. Furthermore, we agreed to be very flexible on the methods to achieve the standard, focusing instead on the result. For example, where the fiber endface location and standoff dimensions were concerned, only dimensions and clearances were given and the means to achieve them (materials, clamping geometry, strain relief, etc.) were left open. This permitted flexibility in implementing the standard, which we felt was imperative to its success.

Details of the Specification

Figures 1 through 3 show diagrams from the standard that define some of the critical parameters of the carrier:

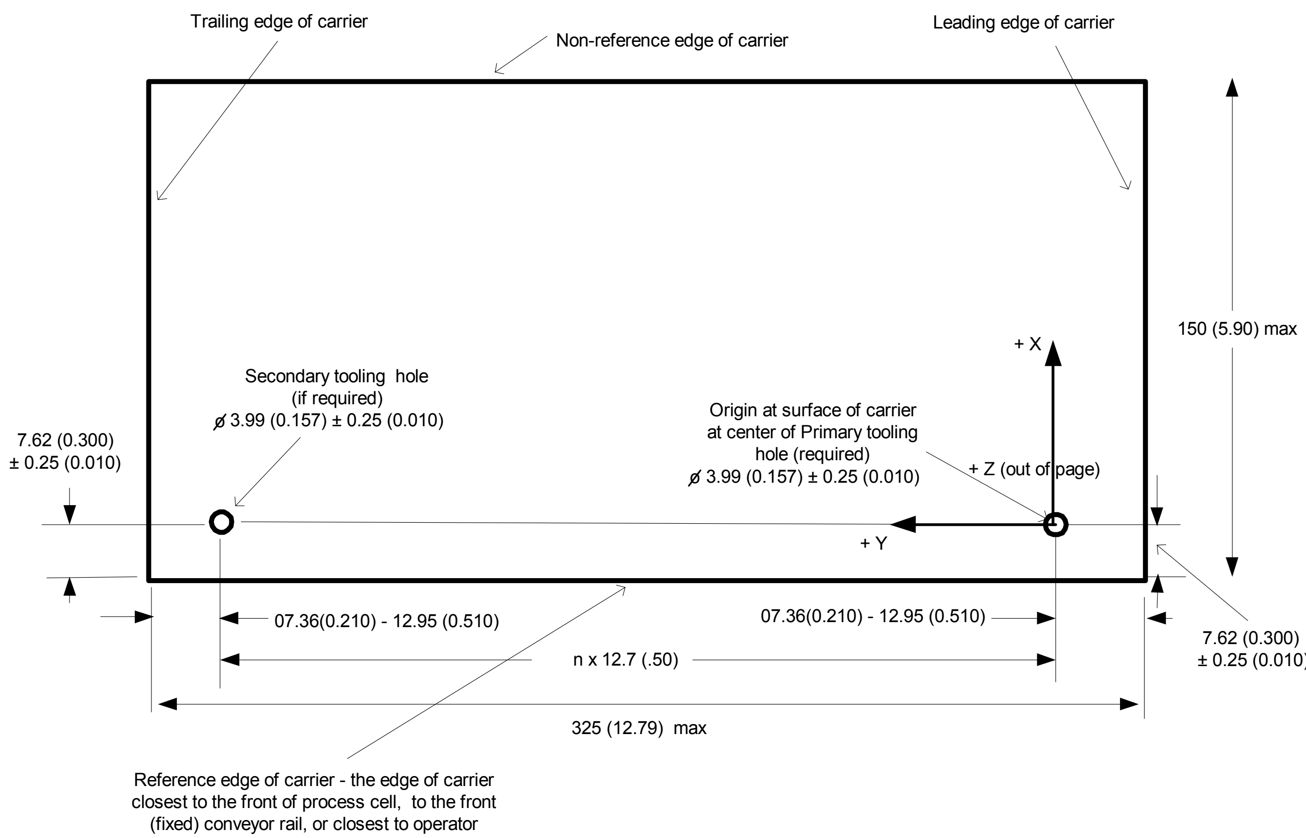


Figure 1 - Size and Frame of Reference Drawing

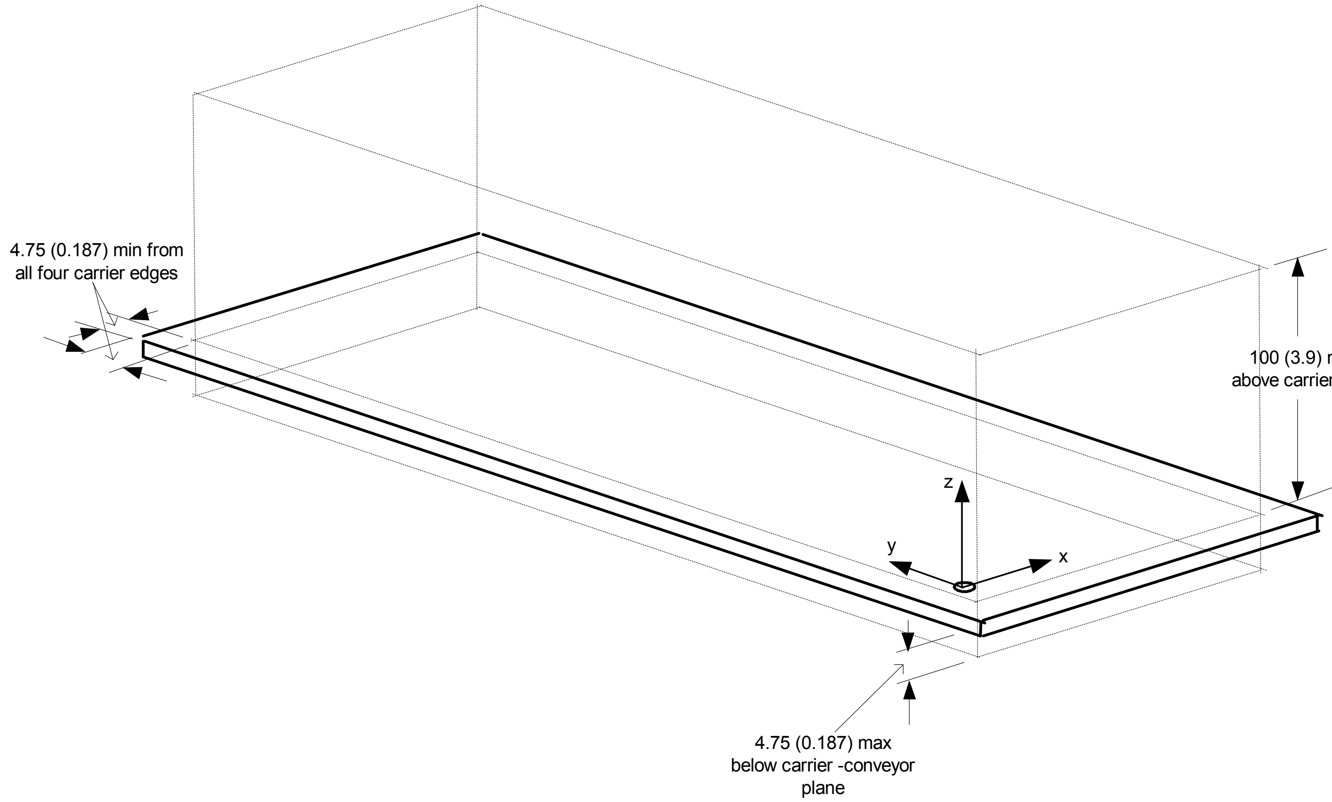


Figure 2 – Envelope Dimensions

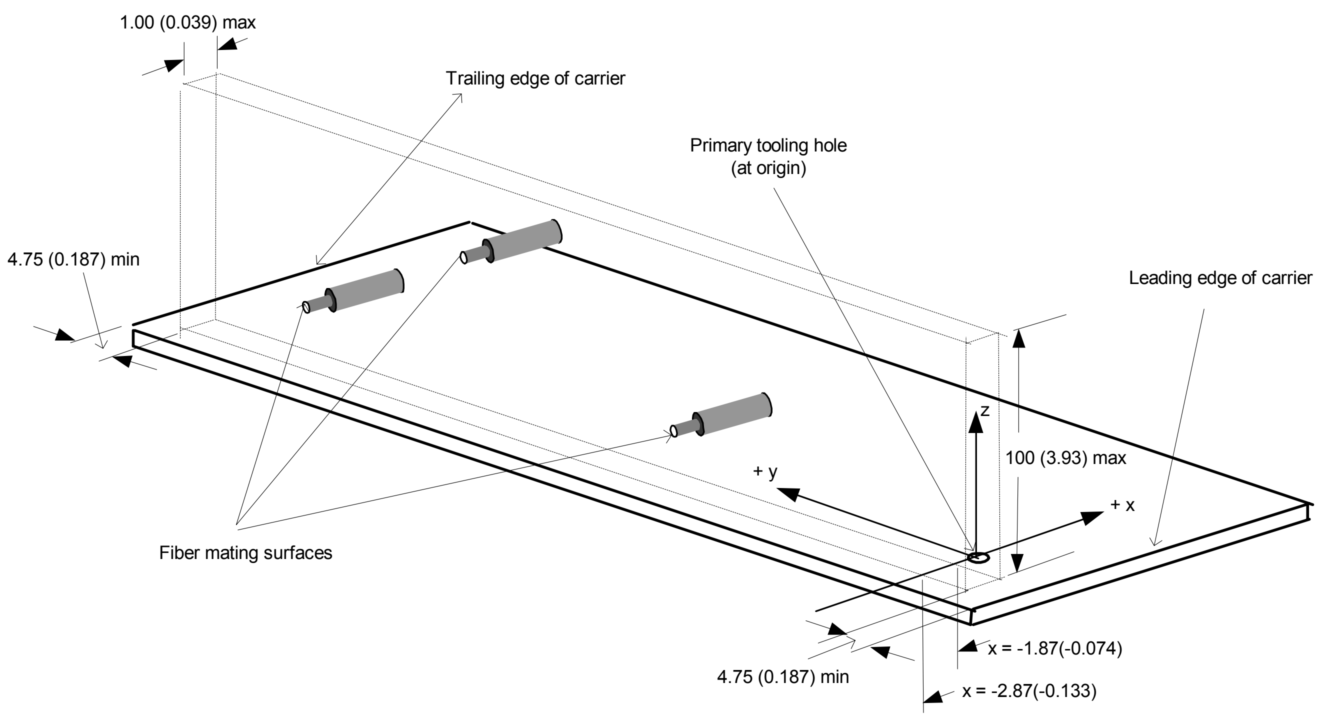


Figure 3 – Fiber Endface Locations

Document Organization, Approval and Publication

The completed draft of the specification was submitted to IPC on June 13, 2002, nearly exactly 9 months after our first organizing meeting. During that timeframe, IPC was proceeding with developing a documentation structure for all pending optoelectronics standards as defined in “IPC-0040 Optoelectronics Assembly and Packaging Technology”.[3] This document put forth a recommendation of standards that were either non-existent or needed expanding or enhancing, and established a documentation structure for numbering the standards as they were developed. This gave our standard an immediate “home” in the IPC standards library and facilitated the transition into the approval process.

As an ANSI-accredited SDO, IPC follows an established protocol for review, approval, and distribution of the standard. Within a few months the standard had been circulated to interested members of the IPC and others who had either contributed to or wished to be kept informed of the resulting standard. After an initial review period during which comments were solicited and reviewed, a final draft was circulated for final approval and voting by the working group members. Final approval was received at the beginning of 2003 and the standards was formally published in the spring.

Conclusions

This experience demonstrated that a new standard could be created by a motivated working group in a relatively short period. With a draft development process of only 9 months, the companies working on the standard could immediately begin utilizing the information in the standard in both their product strategy and design discussions, even though the final version of the standard would take another 6-9 months to issue. Additionally, having influence on critical definitions and design elements, as well building important relationships during the process, brought considerable advantage to those actively participating in the standard creation process.

In summary, the keys to the success of this program were:

- **Building the right team,** including representation from across the supply chain as well as technical and managerial expertise
- **Early definition of scope and objectives,** to eliminate “scope creep,” clarify the intended audience/user of the standard, and agree on the benefits of the desired output
- **Outlining of main elements of the standard**, allowing prioritization and division of the work
- **Avoiding unknowns in in the critical path,** staying away from uncertainties, areas where invention is required, and immature/proprietary issues as much as possible
- **Leverage the work of others,** for example using the existing infrastructure of existing SDOs and outlines of existing standards, and reference other standards to avoiding repeating any prior work

References

1. IPC-8413-1 “Specifications for Process Carriers Used to Handle Optical Fibers in Manufacturing.” IPC – Association Connecting Electronic Industries.
2. Heyler, R. “Developing Manufacturing Standards for Optoelectronics” – Proc. IEEE PhoPack Conference, San Francisco, CA August 2003.
3. IPC-0040 “Optoelectronics Assembly and Packaging Technology.” IPC – Association Connecting Electronic Industries.

Developing a Standard for Optoelectronics Assembly:

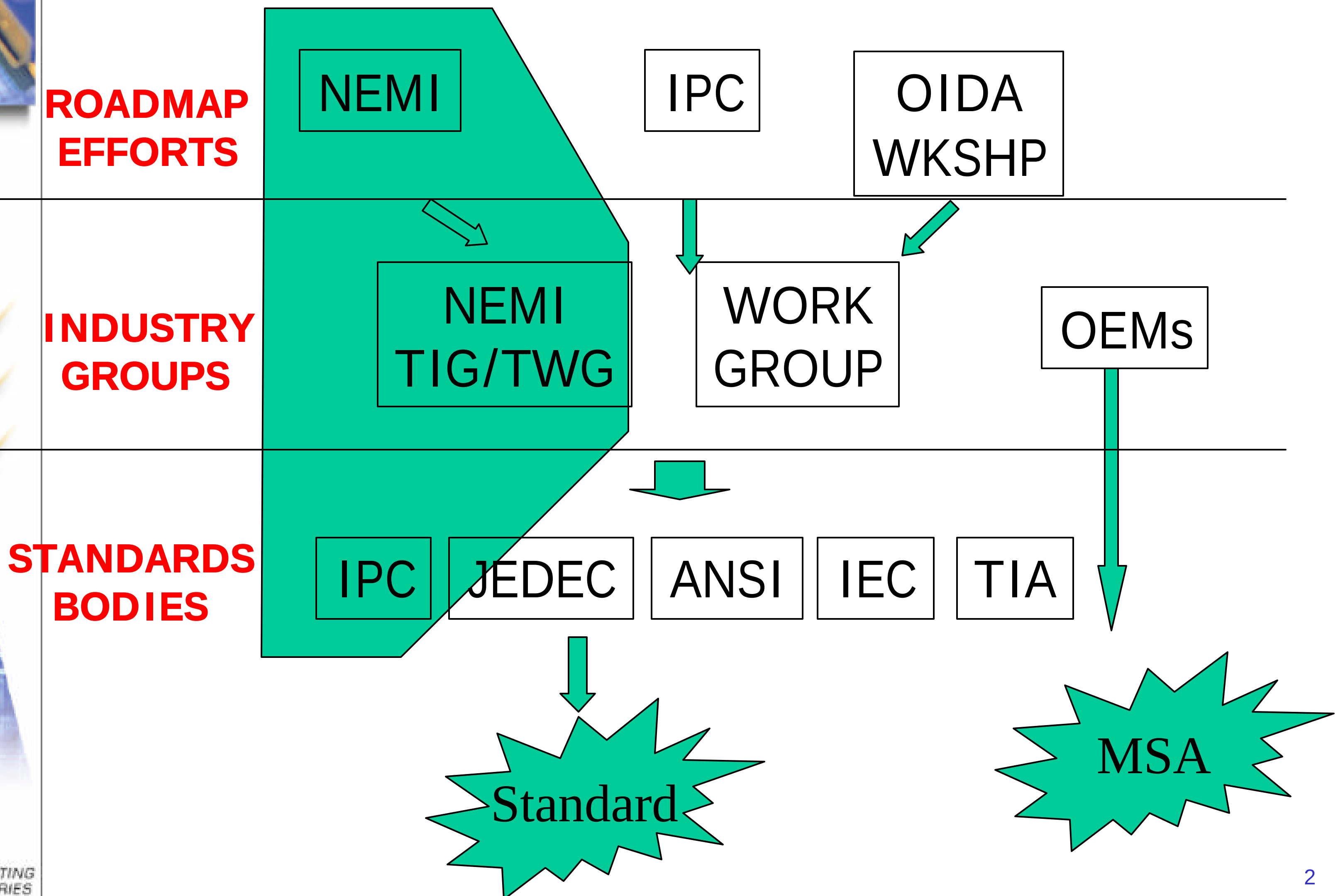
IPC-8413-1

Specifications and Guidelines

For Manufacturing Process Carriers for Optical Fiber

ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

How THIS Standard was created…



NEMI 2002 Roadmapping and Standards Work: The Optoelectronic Assembly Technical Integration Group (TIG)

Leader: Alan Rae, Cookson Electronics

- The Optoelectronic Assembly TIG was born out of the need to focus effort on defining standards and guidelines for optoelectronic assembly. This TIG has in turn crated several technical working groups (TWG's) looking at several processes in optoelectronics manufacturing:
  - Optical Fiber Splicing
  - Optical Fiber Carriers and Handling
  - Automated Selective Soldering
  - Connector Quality and Performance
  - Optical Adhesives
  - Optoelectronic Substrates

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Meanwhile, back at IPC…

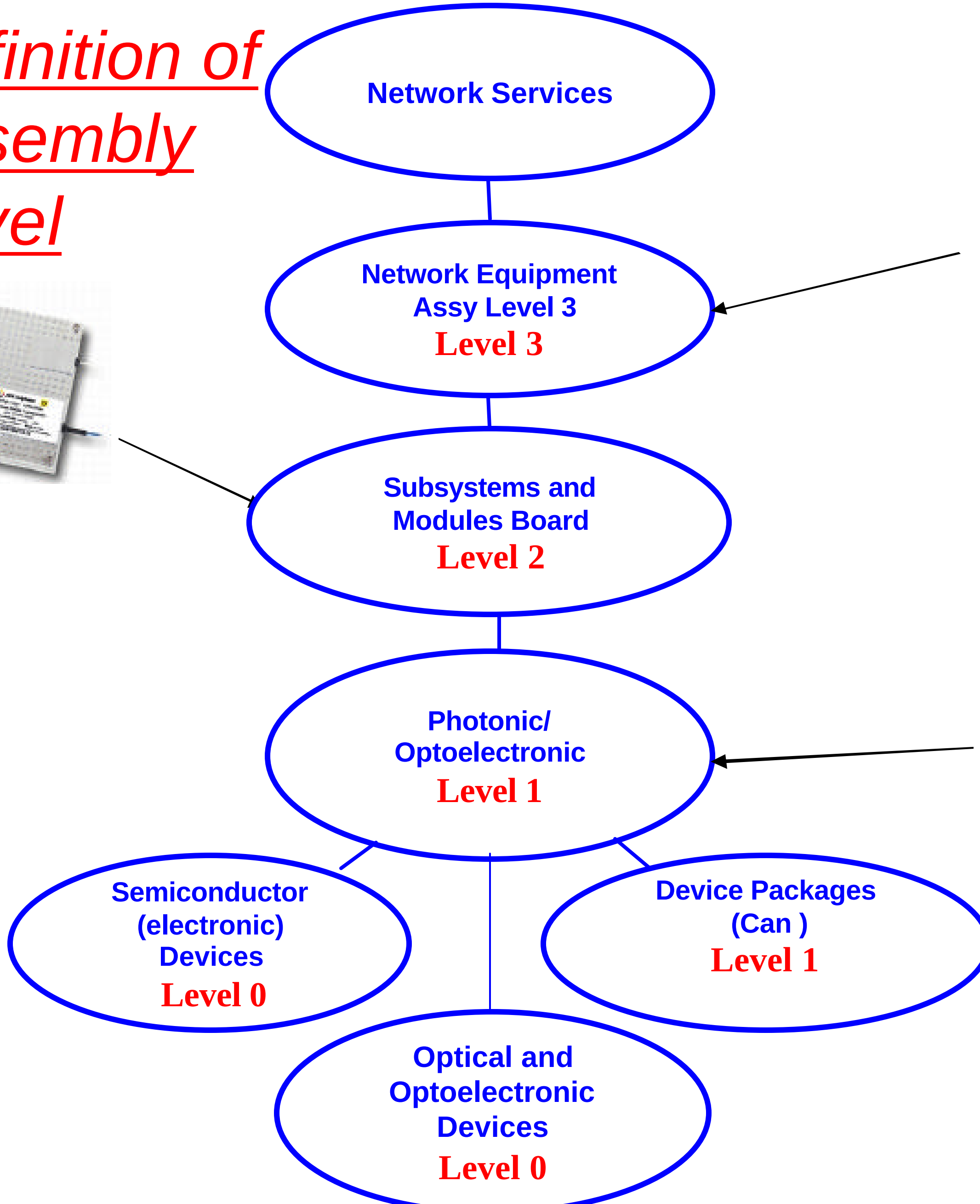
IPC-0040 was being created...

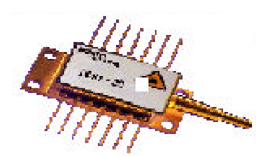
- Developed as an "Umbrella Standard" and reference document on Optoelectronic Assembly and Packaging Technology

- IPC-0040 on optoelectronics provides a roadmap for optoelectronic standards, not a roadmap for optoelectronics technology.

- Based on this umbrella document, an IPC document control system was established to contain the Standards and Guidelines for Optoelectronics:

Definition of Assembly Level





Hierarchy and Levels of Assembly

Process	Devices Level 0	Component Level 1	Board Level 2	Subsystem Level 3
Die Attach		X		
Wire bond		X		
Fiber Metallization		X		
Substrate Preparation	X			
Waveguide Development	X			
Flip Chip attach		X		
Active alignment		X		
Passive alignment		X		
Encapsulation		X		
Fiber Bond / Weld		X		
Fiber Splice (Mechanical/Fusion)		X	X	X
Electrical Attachment		X	X	
Fiber Termination		X	X	X
Fiber Polish / Cleaning		X	X	
Fiber Management		X	X	X
Mechanical Assembly		X	X	X
Functional Test		X	X	X
HASS Test		X	X	X
Modification and Rework		X	X	X

IPC ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

IPC-0040 Summary of Needed Optical Standards

301 Fiber arrangement and routing
302 Fiber splicing and test
303 Handling photonic components and optical cable
304 Connector socket design and assembly
305 Optical Power loss budget requirements
306 Optical fiber identification or coding systems
307 Optoelectronic coupling design for long term reliability
308 Hermetic control for Optoelectronic packaging
309 Quality Assurance of Optoelectronic components and Assemblies
310Cleaning and cleanliness/contamination testing
311 Moisture absorption precautions for optoelectronic packages
312 Thermo-mechanical engineering requirements

Needed Optical Standards

(continued)

313 Material requirements for optical interconnecting substrates
314 Optical board interconnection performance requirements
315 Attachment materials for optoelectronic assembly
316 Design requirements for optoelectronic assemblies
317 Configuration management of optoelectronic assemblies
318 Methods for optoelectronic component attachment and alignment
319 Heterogeneous optoelectronic assembly requirements
320 Tools/procedures for optoelectronic assembly/repair
321Test methods for optoelectronic components
322 Test methods for optoelectronic assembly verification
323 Quality and Reliability Requirements of Level 2 Optoelectronic Boards and Transponders

IPC Document Structure for Standards

Project Segmentation Matrix

Opto Level	Admin 1	Design 2	Components 3	Materials 4	Board Fab 5	Board Physical 6	Assembly 7	Assy Physical 8	Test/ Reliability 9
0 (840)	306								309
1 (841)	306	304 305 307 316	302 303 304 308 311 312	310 313 315	JPCA/IPC	314	301 302 303 304 318 319 320	309 322	305 308 309 310 311 321 322
2 (842)	306 317	305 307 316	311 312	310 313 315	JPCA/IPC	314	301 302 303 304 318 319 320	309 322	305 307 309 310 321 322 323
3 (843)	306 317	305 307	312	313	JPCA/IPC	314	301 318		305 307

Select projects 303, 318, 315, 309, 313, & 311

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Where does it fit….?
=> <u>Prioritization of Standards</u>

Handling of photonic components fiber optic cable

IPC-8413-1 (Opto Level 1) COMPONENT standard
IPC-8417-2 (Opto Level 1) ASSEMBLY standard
IPC-8427-2 (Opto Level 2) ASSEMBLY standard

Methods for optoelectronic component attachment and alignment

IPC-8417-1 (Opto Level 1) ASSEMBLY standard
IPC-8427-1 (Opto Level 2) ASSEMBLY standard
IPC-8437-1 (Opto Level 3) ASSEMBLY standard

Attachment materials for optoelectronic assembly

IPC-8414-1 (Opto Level 1) MATERIALS standard
IPC-8424-1 (Opto Level 2) MATERIALS standard

IPC ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Prioritization of Standards (Cont.)

Quality Assurance of Optoelectronic components and Assemblies

IPC-8409-1 (Opto Level 0) TEST AND RELIABILITY standard
IPC-8419-1 (Opto Level 1) TEST AND RELIABILITY standard
IPC-8429-1 (Opto Level 2) TEST AND RELIABILITY standard

Material requirements for optical interconnecting substrates

IPC-8414-2 (Opto Level 1) MATERIALS standard
IPC-8424-2 (Opto Level 2) MATERIALS standard
IPC-8434-1 (Opto Level 3) MATERIALS standard

Moisture absorption precautions for optoelectronic packages

IPC-8413-2 (Opto Level 1) COMPONENT standard
IPC-8423-1 (Opto Level 2) COMPONENT standard
IPC-8419-2 (Opto Level 1) TEST AND RELIABILITY standard

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

IPC-8413 Scope and Objective

Scope

The purpose of the specification is to define standard practices for handling various kinds of optical fiber and to define the specifications and guidelines to be used in the design of carriers for these fibers in component manufacturing.

Objective

The objective of this standard is not to define a particular carrier design, but to define enough requirements and guidelines to facilitate the use of fiber carriers in fiber optic component manufacturing, particularly in automated or semi-automated processes.

Goals and Issues

- Wanted commonality, but allowance for innovation and proprietary methods
  - Establish common elements of form factor, fiber locations, etc.
- Wanted to define “good practices” for bend radius and handling
- Wanted to enable some compatibility for stacking and moving carriers
- Did not want to define a specific carrier
  - Lack of standard tools and processes prohibited such

Standards Working Group Composition

- Equipment Suppliers
  - Newport, Adept, Palomar, Sagitta, kSaria, Unitek-Miyachi,
- Fiber Suppliers
  - Nextrom
- Materials and Carrier Suppliers
  - Cookson
  - Soldering Technology International
  - Auer Precision
- OEMS
  - JDSU, Dicon Fiberoptics, Zyvex
- Associations
  - NEMI, IPC

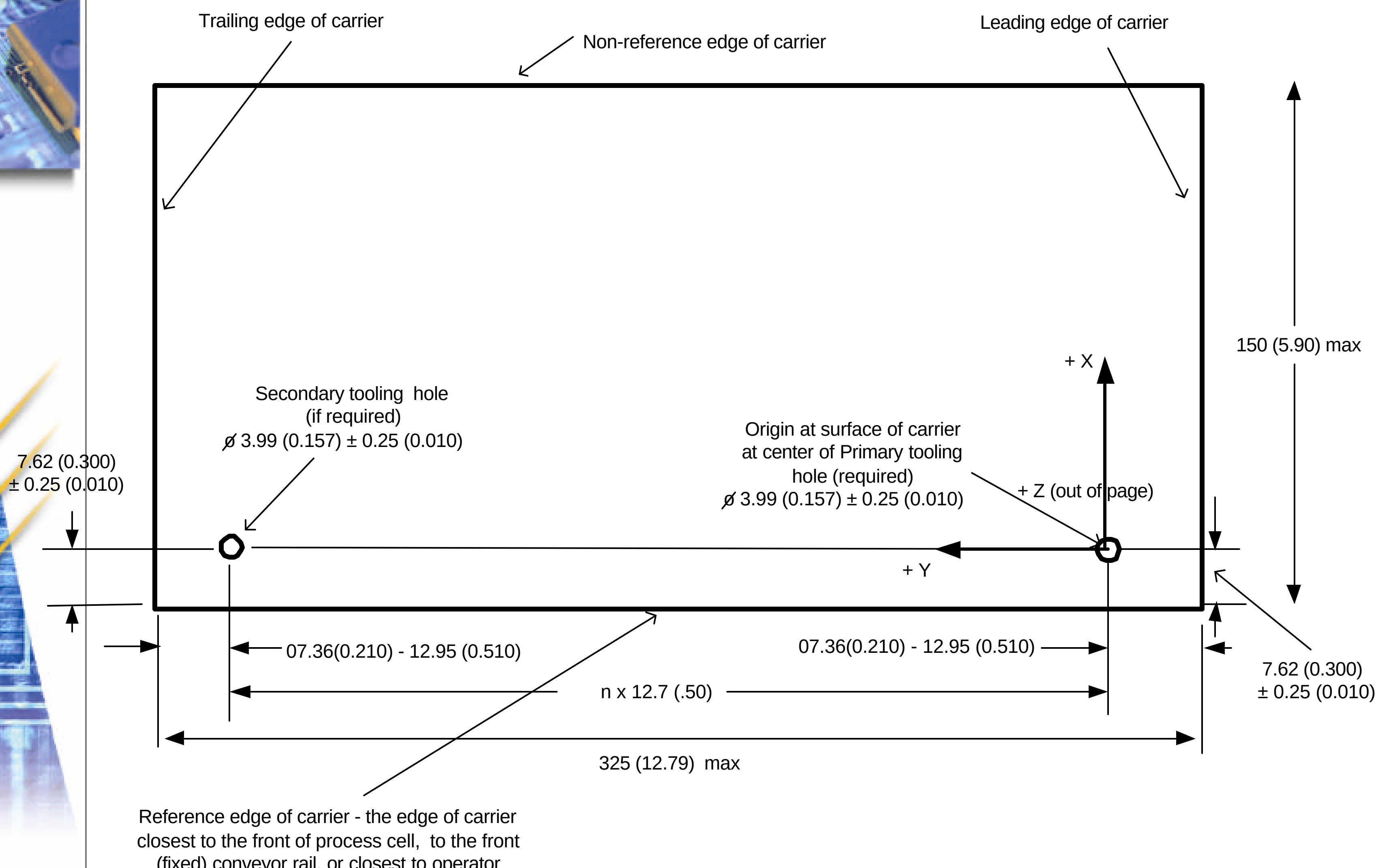
IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Key Elements of IPC-8413-1

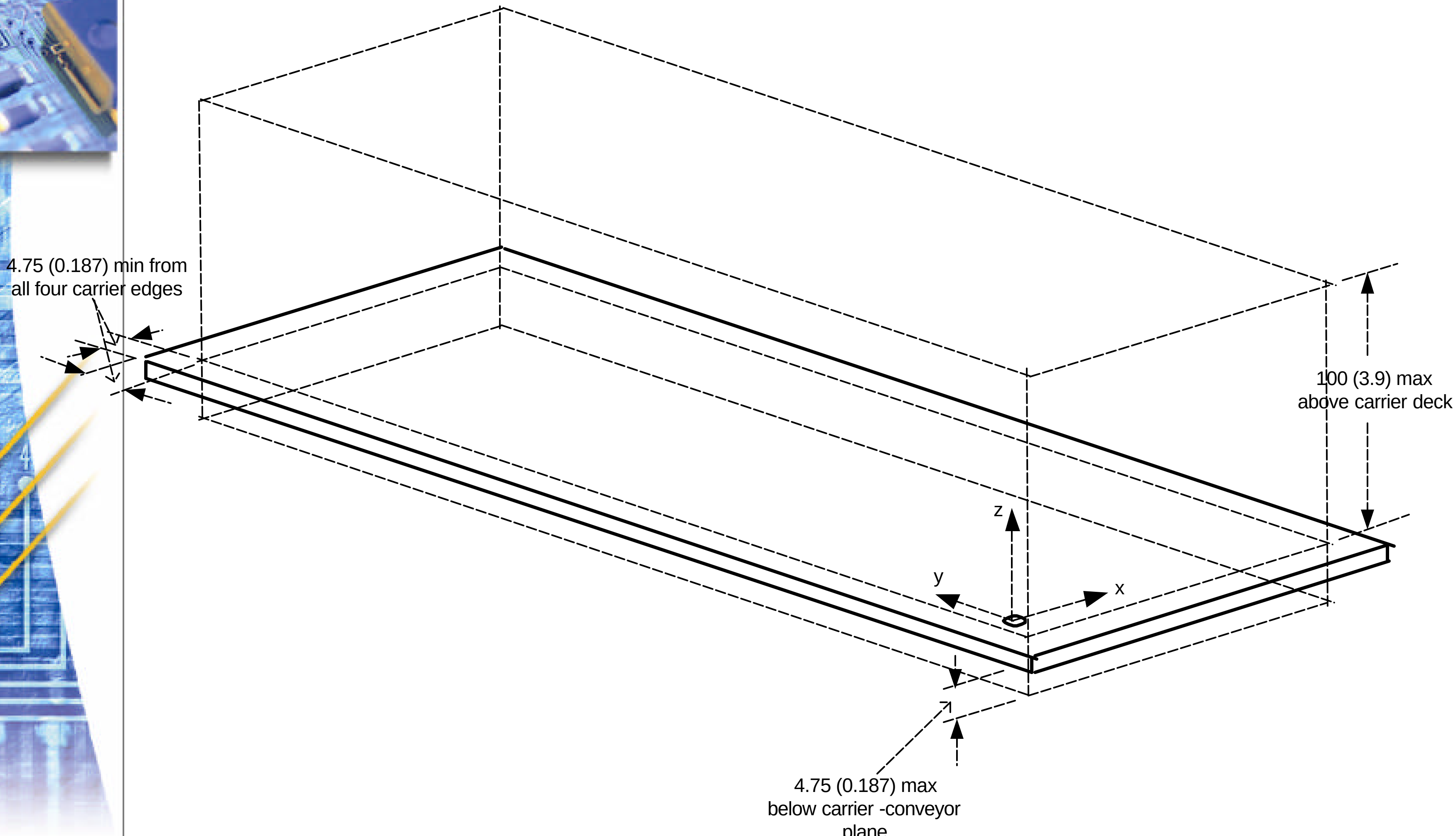
- Definitions
- Form Factor, Size and Dimension Limits
- Frame of Reference and Origin Definitions
- Working Envelope
- Fiducial Markings
- Fiber End Location Zone(s)
- Fiber Bend Radius, Length, Wrapping, Slack Guidelines
- Stacking Provisions

IPC ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Size and Frame of Reference

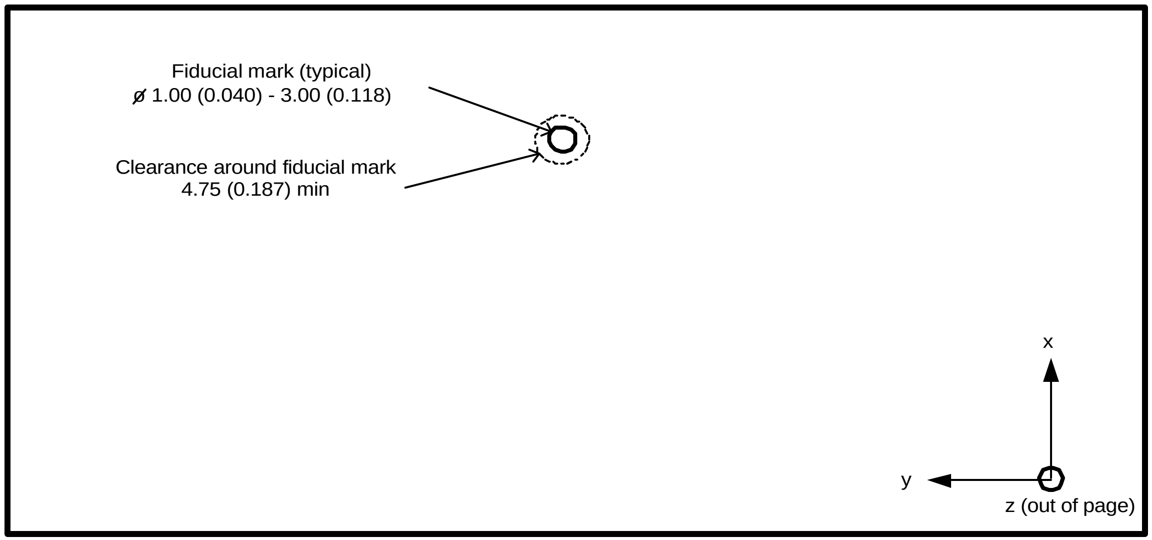


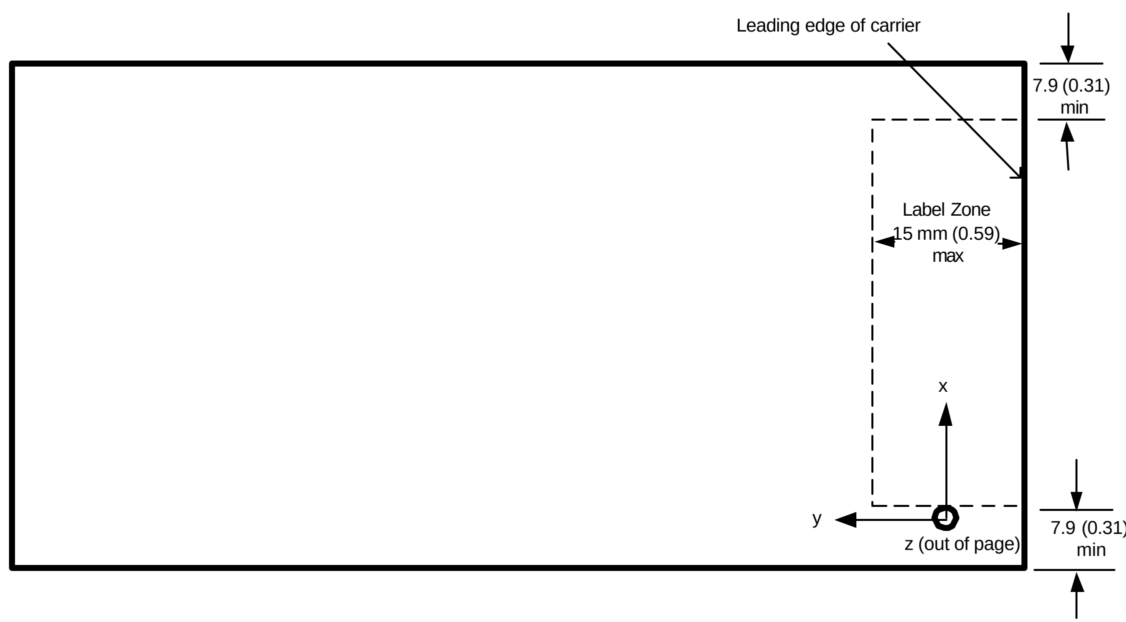
Envelope



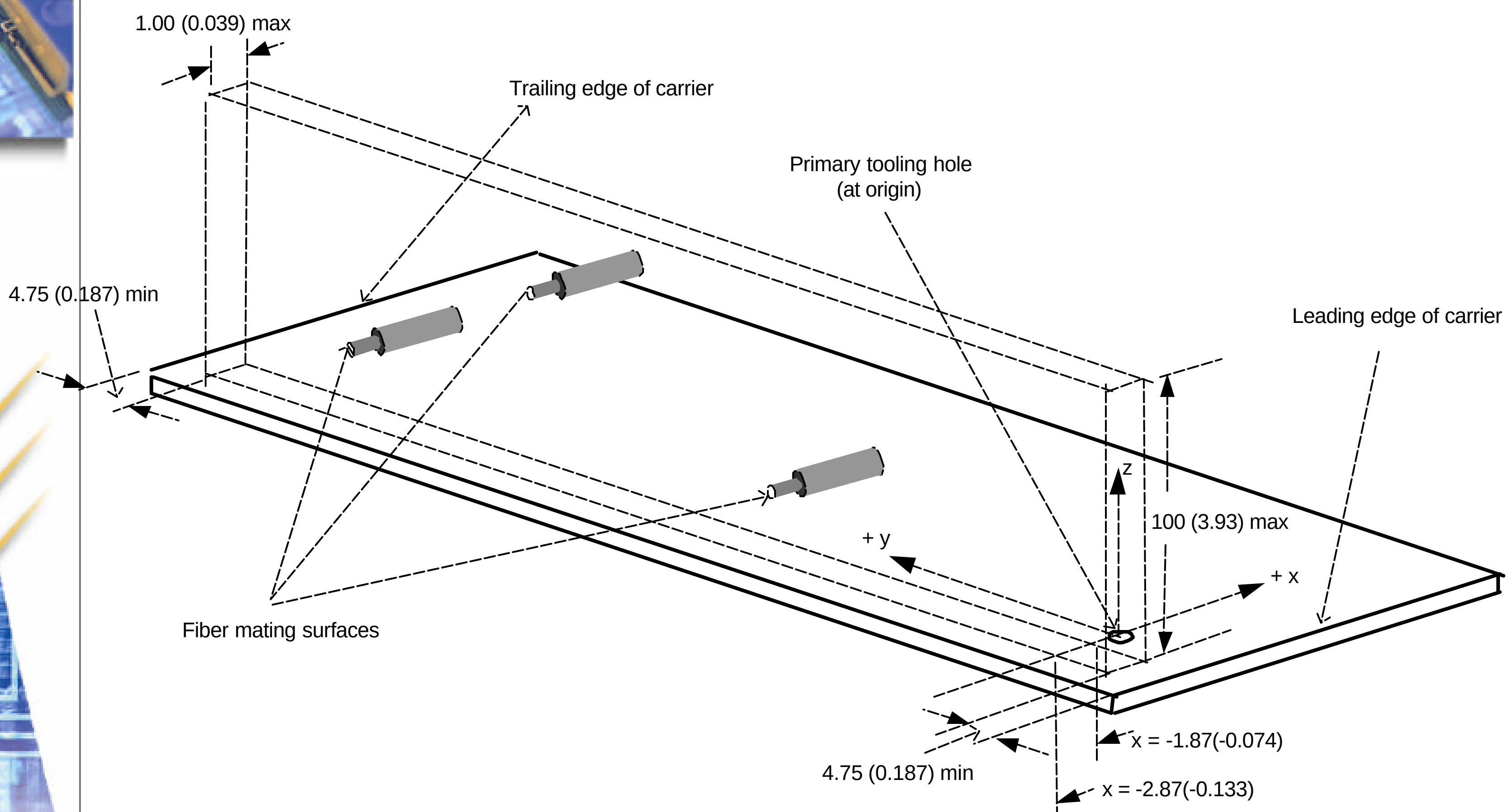
4.75 (0.187) min from
all four carrier edges
100 (3.9) max
above carrier deck
z
y
x
4.75 (0.187) max
below carrier -conveyor
plane

Fiducials and Labeling Zones





Fiber End Location(s)



Timetable

- September 2001 - Group formed under NEMI
- October 2001 - IPC Identified as appropriate Standards Development Organization (SDO)
- October2001-May 2002 – Working meetings
- June 2002 - First Draft completed and submitted to IPC
- August 2002 – IPC Issues Draft for Approval (60 day comment period)
- November 2002 – February 2003 – Comments resolution, typesetting, ballot preparation
- February, 2003 – IPC Issues Interim Final for Voting (30 day voting period)
- April 2002 – IPC-8413-1 Issued

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Lessons Learned

- Get the right participation
  - Recruit from key players in all applicable areas
  - This generates “automatic buy-in”
- Work to closely define scope, objectives, and audience of the standard
  - Keep it focused and avoid “scope creep”
  - Define “lowest common denominator” elements that the group will be able to gain agreement on
  - “Who is the customer for the document, and what are it’s benefits to them?”
- Agree on main elements and organize the document before generating any content

Lessons Learned (cont.)

- Do not try to specify areas where technology is not yet defined or mature
- Treat the project like a product development !
  - Set a REALISTIC BUT TIMELY objective and schedule monthly meetings to make sure progress occurs
  - Appoint a strong project manager
  - Develop in parallel vs. in series
- Leverage (i.e. "liberally plagiarize" but acknowledge) the work of others
  - Look to existing standards across industries and geographies
  - Use examples of other standards wherever possible

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES