ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

IPC-2511-3

User's Guide

WORKING DRAFT

Work in progress

This document is intended to show the reader the direction the user guide is taking. All interested parties are encouraged to review the start of the working draft and to provide specific requests for of information they would like included in the users guide

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IPC 2511-3
March 2001

A standard developed by IPC

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Table of Contents

1 Concepts of the GenCAM User's Guide

1.1 General Information (Dieter)

1.2 Purpose and Users Guide audience

The User Guide provides instructions, with examples, on how to properly use GenCAM for recommended procedures and mandatory implementation concepts. The audience is expected to be knowledgeable in printed circuit board terminology and practices.

The purpose of the User's Guide is to assist operators and software developers in understanding the details of the IPC-2511 specification. That document defines the generic requirements for implementation of product manufacturing description data and transfer methodology. The subsets of the IPC-2511 (IPC-2512 through IPC-2518) provide the focus for various functions to which the GenCAM format can be put to use.

It should be understood that the User's Guide does not supercede the specification requirements. It provides useful information on how the various segments of the GenCAM file can be used to execute over 22 different functions that are part of the electronic manufacturing process.

It is expected that the reader of the User's Guide has some basic understanding of printed circuit technology. It is not the intent of the guide to go into details as to how printed boards are made, nevertheless where appropriate, the descriptions define sequences of manufacturing and relate them to the file structure contained within a specific GenCAM file.

The GenCAM format provides standard, and series of standards, that are focused on printed board manufacturing, assembly, inspection, and test. As such, there are particular products that can be manufactured from a GenCAM file. These products consist of:

Legal status of the information (Order of Precedence)

The users guide does not override the GenCAM specification, but it does expand on defining proper use of GenCAM for specific tasks.

Introduce the catalog of GenCAM *products* (Boards, Panels, Fixtures, and drawings)

1.2.1 Add a glossary of terms.

1.3 Organization of Information in a GenCAM file *(Dieter)*

Description of what is in each of the Sections and their rules (this will include a table of the sections of the GenCAM file along with a short description of the purpose of each section)

Illustrative description of the information tree within a GenCAM file. (This is not intended to be exhaustive)

Panels
Boards
Groups
Layers

Components
Devices with patterns
Padstacks
Artworks
Primitives

Start the discussion on groups and namespaces here. State that something must be defined before it can be referenced.

A software engineer can view GenCAM is a file based encoding of an internal memory representation of products such as printed circuit boards, printed circuit

1.4 Related Information and Files (references) (Michael)

How to use the URLs or references to other standards eg., IPC,IEEE JEDEC, ECIX etc.

The Data Transfer Solutiopns committee was able to reduce the size of the GenCAM standard considerably by referencing requirements whenever a preexisting document was available to define a capability needed in defining the IPC-2511. For instance, rather than adding detailed specifications of the material layers used to build a bare board the document references the IPC-6XXX? Series. The board dimension and tolerance requirements are defined by IPC-D-300. The general rule when deciding on the dimensions of a feature for a board or assembly design is to apply the existing rules defined in other IPC standards first. The IPC-2511 representation is a general container for design information and does not directly enforce many of these rules, but the existing IPC rules on design constraints still should be used.

This relaxed constraint on the data allowed in an IPC-2511 provides the community with a flexible format which can easiliy be adapted to the next generation of board design constraints. This approach also removes the need to repeat design rules which have been carefully defined by other committees of the IPC.

The preferred notation for the external resource is a World Wide Web URL. The referenced sources are of information needed by GenCAM whenever another source is available for defining a capability needed by GenCAM

1.5 Use of Layers in GenCAM (Dieter)

Be sure to reference section 7. Cover layers in general. Explain the use of layers, corrolating the use of layer types, such as:

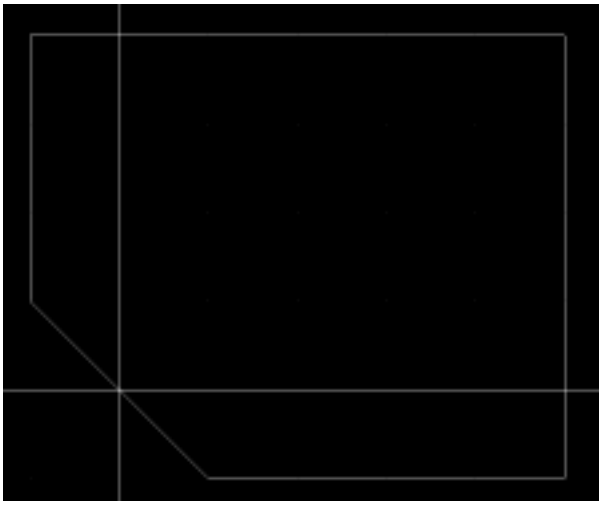
- a component layer,
- a glue dot layer,
- a non-conductive layers,
- a conductive layers,
- soldermask layer,
- an IMAGE?,
- a fixture layer with translation plates
- silk screen layer (called LEGEND)

1.5.1 Mapping of sublayers

Mapping of CAD layers, physical layers, and electrical layers vs GenCAM layer sets (conductive and non conductive layer sets)

1.5.2 Negative and Positive Layers

GenCAM does not have the concept of a negative layer. To create the equivalent, use a filled plane and erase as needed. (paint and scratch.)



1.6 Component Information *(Dieter)*

Description of how components are related to devices, mechanicals, packages, and patterns. Also discuss how the intelligence of the pin numbers are mapped through devices, patterns, and components. Describe how z-axis works when stacking patterns, components, and mechanicals using layers.

See section 6 for the details. Segment so that the discussion and the relationship between the various sections tracks with 6 i.e., 1.5.1, Devices relates to 6.1. device details.

1.7 Configuration Management and File Ownership Recommendations *(Dieter / Bob / Michael)*

Explain the intention of the Changes section. It is a minimal means for communicating a change that must be made to a previously defined GenCAM file. It is not a full featured CM system.

Managing feedback of the change files related to updating the history version and who has the authority to establish the official version. (who is the keeper of the history count and when is the count updated.) When is it proper to change a named object and who is allowed to do so. When should changes be integrated and the history count incremented.

If a changes file is applied then should the change be noted using a MODIFIED statement? When are MODIFIED statement dropped?

2 General GenCAM Standard specifications

2.1 Reading the GenCAM notation. *(Michael)*

The GenCAM specification, IPC-2511 is written in modified Backus Nauer Format (BNF)…

2.2 Character Codes and String Data *(Michael)*

Explain that the LANGUAGE statement just defines the language used by the author when writing strings in the GenCAM file. All strings are represented using UTS-8. Provide examples of 8bit encodings of text in several different languages. (Look at the Mozilla test page for some examples.) Discuss GLYPH and user defined character sets.

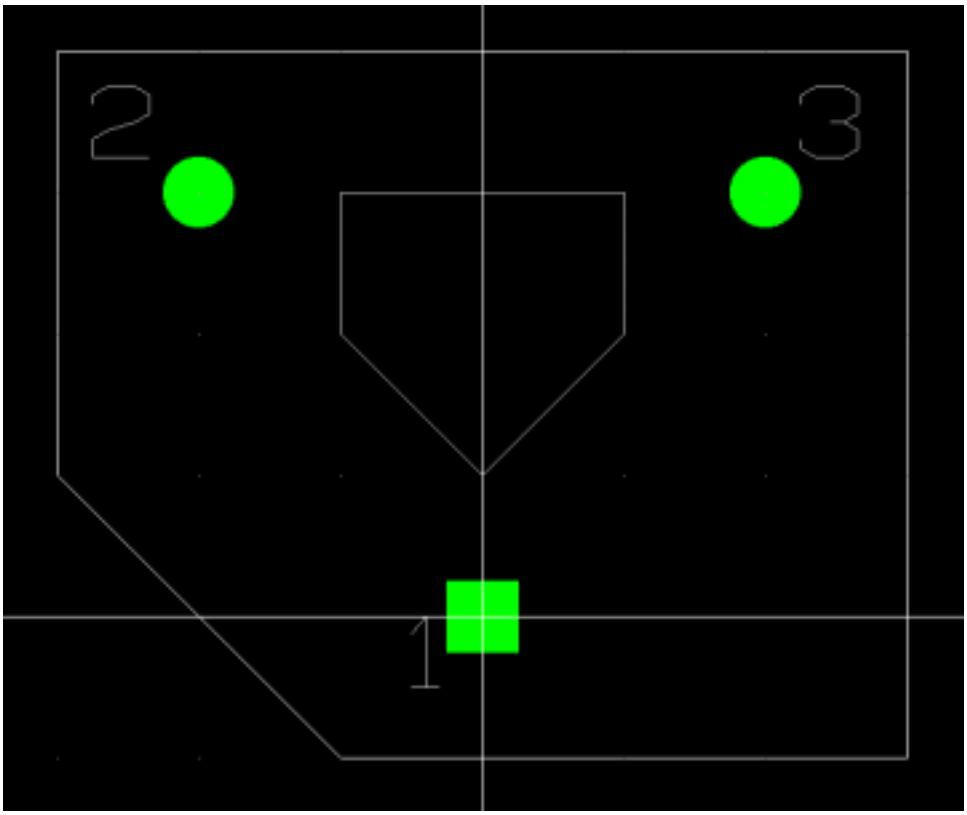
2.3 Unit statement and Interpretation *(Dieter / Michael)*

Describe metric vs. English with examples. Define how to mix devices defined with different units. Use a land pattern that is metric for a part that is in SAE units and the pattern is to be placed on an English unit board and the board is placed on a metric panel.

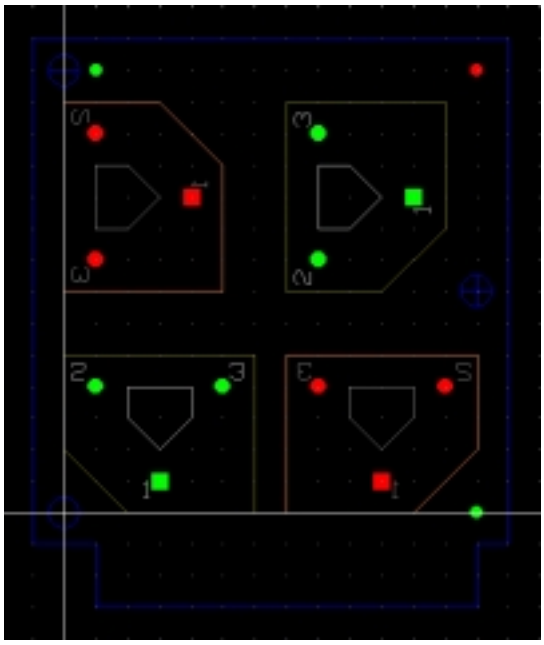
Explain why GenCAM works this way. (something about Mars mission….)

2.4 Transform Characteristics and Rules for Use *(Michael / Dino)*

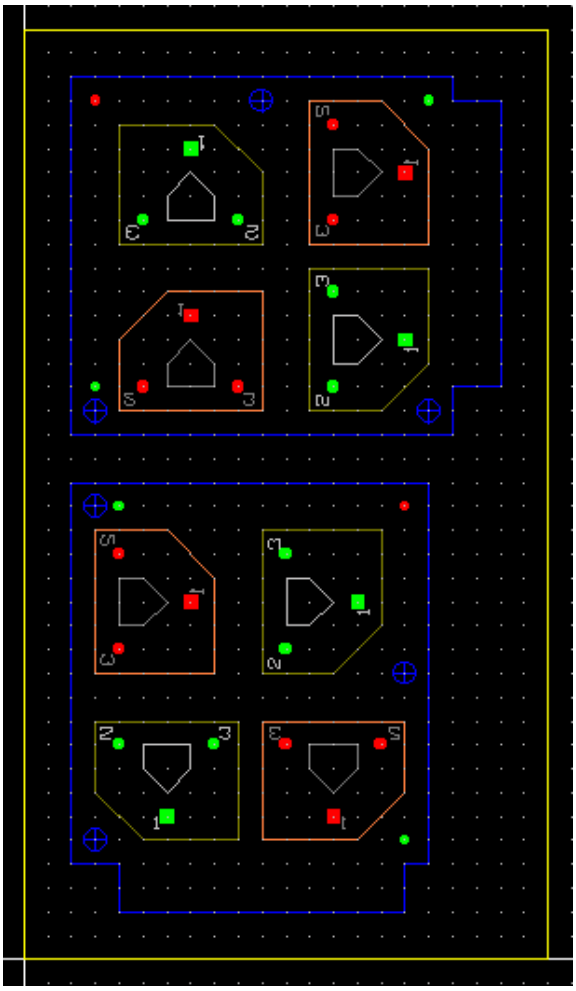
Nesting of Transforms and how they are applied. Give examples of 3x3 transform matrices and show the mapping from the xform to those matrices. Include Figure 5-1 from the Component section and explain the effect of mirror and layer swap on the transformation of drawn geometry and physical part placement. (What about fabricated components.)



```
$HEADER
. . .
$ENDHEADER

$ADMINISTRATION
. . .
$ADMINISTRATION

$PRIMITIVES
  GROUP: "IPCcolor_1";
    COLOR: "BLACK", 0,0,0;
    COLOR: "WHITE", 255,255,255;
    COLOR: "RED",0,255,255;
    COLOR: "GREEN",255,0,255;
    COLOR: "BLUE",255,255,0;
    COLOR: "ORANGE",,,;
  GROUP: "prim.rsi";
    COLOR: "YELLOW",?,?,?;
$ENDPRIMITIVES

$LAYERS
  GROUP: "lay.Board_1";
    LAYERS:
$ENDLAYERS

$ARTWORKS
  GROUP: "art.Board_1";
    ARTWORKDEF: "Comp_Courtyard";
        LINE: (0.100, -0.100), (-0.100, 0.100);
        LINE: (-0.100, 0.100), (-0.100, 0.400);
        LINE: (-0.100, 0.400), (0.500, 0.400);
        LINE: (0.500, 0.400), (0.500, -0.100);
        LINE: (0.500, -0.100), (0.100, -0.100);
$ENDARTWORKS



$PATTERNS
  GROUP: "pat.Board_1";
    PATTERNDEF: "Comp_Sample";
      PADSTACKREF: "pad.Board_1"."PadStack050Sq", "1", (0, 0),0;
      PADSTACKREF: "pad.Board_1"."PadStack050Rd", "2", (-0.2, 0.3),0;
      PADSTACKREF: "pad.Board_1"."PadStack050Rd", "3", (0.2, 0.3),0;
      ARTWORKREF: "Comp_Courtyard", "layer.global"."Courtyard_Top", ,
                  (-0.2, 0),0;
      INLINEARTWORK: "layer.global"."Silkscreen Top";
        LINE: (-0.100, 0.300), (0.100, 0.300);
        LINE: (0.100, 0.300), (0.100, 0.200);
        LINE: (0.100, 0.200), (-0.000, 0.100);
        LINE: (-0.000, 0.100), (-0.100, 0.200);
        LINE: (-0.100, 0.200), (-0.100, 0.300);
$ENDPATTERNS
```



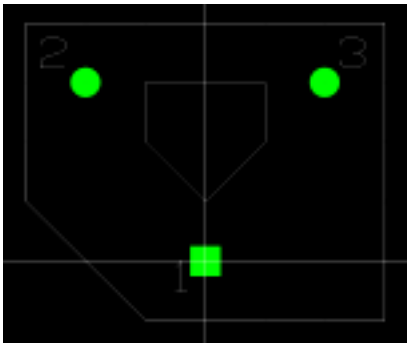
```
$COMPONENTS
  GROUP: "cmp.Board_1";
    COMPONENT: "X1", "layer.global"."COMPTOP", (0.3, 0.1), 0;
      PATTERNREF: "pat.Board_1"."Comp_Sample";
    COMPONENT: "X2", "layer.global"."COMPTOP", (1.1, 1), 90;
      PATTERNREF: "pat.Board_1"."Comp_Sample";
    COMPONENT: "X3", "layer.global"."COMPBOT", (1, 0.1), 0, MIRROR;
      PATTERNREF: "pat.Board_1"."Comp_Sample";
    COMPONENT: "X4", "layer.global"."COMPBOT", (0.4, 1), 90, MIRROR;
      PATTERNREF: "pat.Board_1"."Comp_Sample";
$ENDCOMPONENTS
```



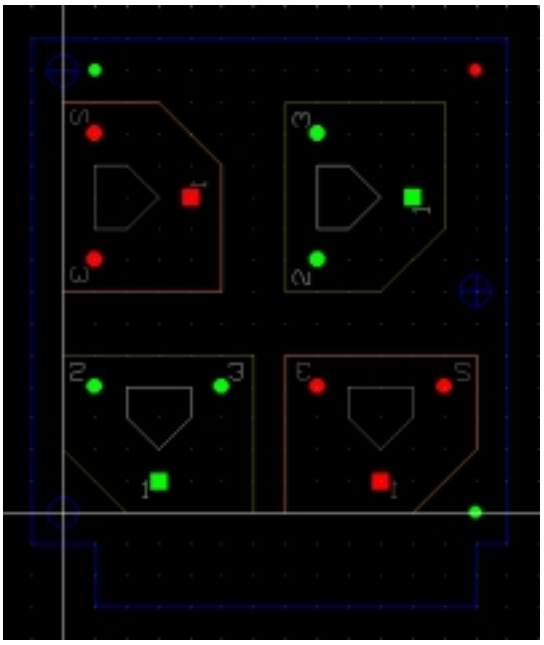
```
$PANELS
  PANEL:"Panel_1";
    OUTLINE: "outline1", "layer.global"."PANEL_OUTLINE";
      POLYGON: "prim.global"."LINEDESC0", "prim.global"."HOLLOW";
        STARTAT: (0.000, 0.000);
        LINETO: (2.200, 0.000);
        LINETO: (2.200, 3.900);
        LINETO: (0.000, 3.900);
        ENDLINE: ;
  PLACEMENT: "Board_1", (0.3, 0.5), 0 ;
  PLACEMENT: "Board_1", (1.7, 2.3), 90 ;
$ENDPANELS
```

Dino’s original

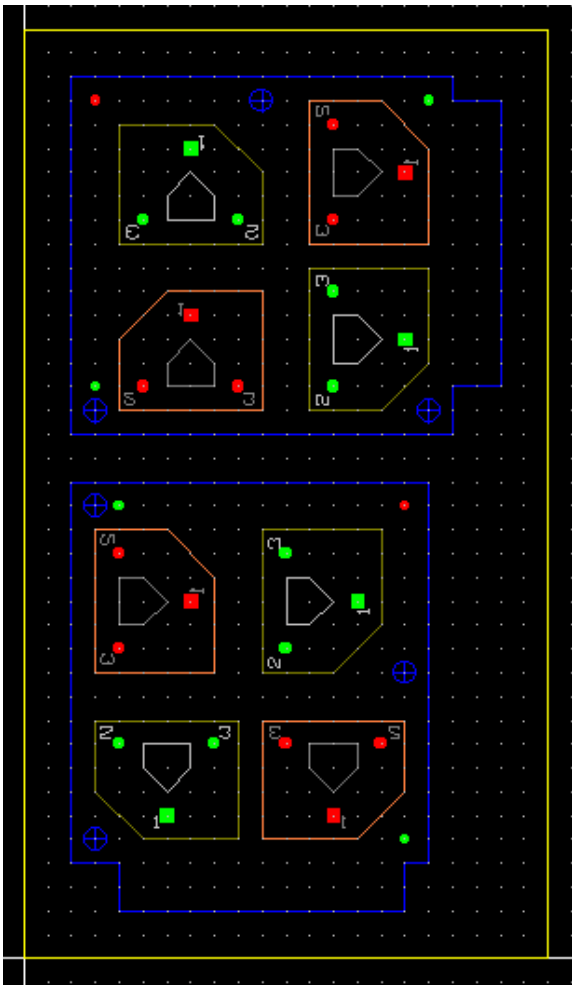
```
$ARTWORKS
  GROUP: "art.Board_1";
    ARTWORKDEF: "Comp_Courtyard";
        LINE: (0.100, -0.100), (-0.100, 0.100);
        LINE: (-0.100, 0.100), (-0.100, 0.400);
        LINE: (-0.100, 0.400), (0.500, 0.400);
        LINE: (0.500, 0.400), (0.500, -0.100);
        LINE: (0.500, -0.100), (0.100, -0.100);
$ENDARTWORKS
```




```
$PATTERNS
  GROUP: "pat.Board_1";
    PATTERNDEF: "Comp_Sample";
      PADSTACKREF: "pad.Board_1"."PadStack050Sq", "1", (0, 0), 0 ;
      PADSTACKREF: "pad.Board_1"."PadStack050Rd", "2", (-0.2, 0.3), 0 ;
      PADSTACKREF: "pad.Board_1"."PadStack050Rd", "3", (0.2, 0.3), 0 ;
      ARTWORKREF:  "Comp_Courtyard",  "layer.global"."Courtyard_Top",  ,(-
0.2, 0),0;
      INLINEARTWORK: "layer.global"."Silkscreen Top";
        LINE: (-0.100, 0.300), (0.100, 0.300);
        LINE: (0.100, 0.300), (0.100, 0.200);
        LINE: (0.100, 0.200), (-0.000, 0.100);
        LINE: (-0.000, 0.100), (-0.100, 0.200);
        LINE: (-0.100, 0.200), (-0.100, 0.300);
$ENDPATTERNS
```



```
$COMPONENTS
  GROUP: "cmp.Board_1";
    COMPONENT: "X1", "layer.global"."COMPTOP", (0.3, 0.1), 0;
      PATTERNREF: "pat.Board_1"."Comp_Sample";
    COMPONENT: "X2", "layer.global"."COMPTOP", (1.1, 1), 90;
      PATTERNREF: "pat.Board_1"."Comp_Sample";
    COMPONENT: "X3", "layer.global"."COMPBOT", (1, 0.1), 0, MIRROR;
      PATTERNREF: "pat.Board_1"."Comp_Sample";
    COMPONENT: "X4", "layer.global"."COMPBOT", (0.4, 1), 90, MIRROR;
      PATTERNREF: "pat.Board_1"."Comp_Sample";
$ENDCOMPONENTS
```



```
$PANELS
  PANEL:"Panel_1";
    OUTLINE: "outline1", "layer.global"."PANEL_OUTLINE";
      POLYGON: "prim.global"."LINEDESC0", "prim.global"."HOLLOW";
        STARTAT: (0.000, 0.000);
        LINETO: (2.200, 0.000);
        LINETO: (2.200, 3.900);
        LINETO: (0.000, 3.900);
        ENDLINE: ;
  PLACEMENT: "Board_1", (0.3, 0.5), 0 ;
  PLACEMENT: "Board_1", (1.7, 2.3), 90 ;
$ENDPANELS
```

2.5 File format grammar (Jerry)

Explain the that keywords must be at the beginning of line and parameter lists can use line-breaks at comas (when is whitespace allowed.) Use whitespace at beginning of statements to indicate nesting to improve readability.) All text before “\n$HEADER” is ignored and all text following “\n$$” is ignored. All lines starting with “\n#” are ignored.

2.6 Keyword Rules (Jerry)

All names defined in uppercase, Section keywords start with a '$' and must not have whitespace before the '$'. Statement keywords must be the first non-whitespace on a line and must be followed by a ':'. (Repeat the explanation from 3.3 of the GenCAM specification.)

2.7 Parameter Rules (Jerry)

Comma separators between parameters. Use ',,' for omitted parameters. Terminating ';' use. Keywords are ALL CAPS. String literals are quoted. Quotes are double quoted. The ':' character is not allowed in the group name portion of a qualified string, or in the definition of top level names, i.e. names of products, persons, groups, and enterprises. See section 3.5 and 3.2 of the GenCAM specification to complete the list of rules.

2.8 Data Organization and Identification (Jerry)

Information is associated by defining names for objects and by referencing those names from within other objects to define an information network. This creates a dependency between sections, but removes redundant information.

2.8.1 Design rule DFM relationships

Describe design rule relationships and design for manufacturability feedback as covered in the AUDIT statement identified in section 5.1.3 of the GenCAM file. Show the process flow of how this information is fed back to the user (owner) of the file.

2.8.2 Reference to other standards

The ATTRIBUTE statement can be used to attach parametric information as defined in other IPC standards to keyword statements in the GenCAM file.

2.9 General Supplementary Data (Dieter)

Attribute, Audit and Modified keyword statements. Discuss how ATTRIBUTE groups are registered, how MODIFIED statement tracks CHANGES and how the e AUDIT statement tracks the IPC-252X standards.

3 Administrative Sections of GenCAM *(Harry)*

3.1 Mandatory Requirements

Discuss the required keyword statements in HEADER and ADMINISTRATION and explain why these are required.

3.2 Using GenCAM for Purchase Orders

Describe which statements are required in HEADER and ADMINISTRATION

3.3 Using GenCAM for Requesting a Quote

3.4 Using GenCAM for Change orders

Describe

3.5 Using GenCAM for Proposal requests

Describe

3.6 Using the GenCAM Audit feature

Describe

3.7 Updating Rules and Recommendations

Describe

4 Managing and Handling Graphic Shapes *(Dieter / Michael)*

4.1 Naming conventions

Grouping of data for multiple product usage. Building libraries of primitives in groups to facilitate reuse between different products. Illustrate how to subset the primitives or artworks, or patterns to facilitate sharing them between different designs.

4.2 Use of PRIMITIVE and ARTWORK Sections in combination

Defining and using "In-process" primitives: <polyline_builder>, <polygon_builder>, <closed_shape>, <shape_builder>

Combining primitive shapes to create artworks (Logos, Features, Targets, Thermals)

Contrast the use of graphic primitives in drawings (schematics) verses fabrication (conductors and silkscreens)

4.3 Shape Texture and Substance Enhancements

Using LINEDESC to modify the drawing characteristics of a line. Also describe how a line with <line_type> of ERASE works.

Filling <closed_shape> with PAINDESC and VOID parameters

4.4 Text and Font Descriptions

Understanding how the bounding box works. Describe how fonts are drawn in the box, when it is acceptable to substitute a similar font. Describe rotation and mirroring of fonts. Describe the creation of user defined charactersets using GLYPHs.

4.5 Use of Color

Describe how the emission spectrum RGB to defines a color (hue and intensity) Define when it is appropriate to specify a color. (for silk screen, but not for copper)

4.6 Representing External CAD data as GenCAM Primitives and Artwork

This section describes how CAD representations map into manufacturing representations. For example, this would include a discussion of how layers in a CAD system map into layers in a GenCAM file and how

4.7 Hole Definition, Representation and Instantiation (Board, Panel, Fixture)

5 Padstacks and Patterns *(Dieter)*

Describe the relationship between geometries, origins, layers, pads, anti-pads, centroids, courtyards, keepouts, through-holes, pins via, testpads, single-pad padstacks. Illustrate building a complex padstacks – a combination of elements, e.g., a surfacemount pad, testpad, a trace, and a primitive with a hole through it. Any pad shape that cannot be defined using a single primitive geometry.

6 Packages, Devices, Mechanicals and Components *(Harry)*

Explain the relationship of a component as an instance of a device. Explain how a package can be used as the package type for multiple devices. Also discuss how a component can have a device and multiple mechanicals.

6.1 Mechanicals

Describe the use of the MECHANICALS section to identify the part that performs a mechanical function. This would include something that you would purchase from a manufacturer, the part number, etc. Also cover a uniquely manufactured part such as a heatsink, card puller, stiffener, etc. where the heatsink is identified using GenCAM code and a detail drawing is created identified the dimensions, notes, and details of the heatsink and a number assigned to it which is then referenced from the Mechanicals to the Component section.

6.2 Packages

6.3 Devices

6.4 Components

6.5 Component Preparation

Describe the manner in which component lead bending or other modification characteristics are accomplished on any of the components identified in the previous sections and how this is implemented and at what section the details are described. Give illustrations from IPC-2221 to show lead configuration details.

Pick up the illustration for lead flattening (coining) described in IPC-2221.

7 Layering and Layer Concepts *(Harry)*

Using Layer Sets to define build and sequence requirements

Discussion on how layerswap works and how it, with mirroring, affects component orientation.

The concept of layer also includes component and fixture layers. Layers in this usage are a means for specifying z-axis sequencing.

8 Connecting things with Routes (Dino)

Routes, like components glue physical things together and associate them with logical things. Describe how to use connector pins, component pins, via, the size of conductors and how to change the width of a route in midstream, planes… Describe how tolerances apply to a geometry in route. A <net_class> of UNUSED is an unconnected route.

Give an example of building a board with a net that has a split in the copper of the ROUTE path. When the assembly is built a part with 0 ohms is attached to two pads on the disjoint parts of the path to connect the route into a single conductor.

Describe the relationship between a padstack within pattern when it is instanced in a component and how the geometry from the padstack is then included into the route geometry through the COMPPIN reference to a <component_ref> and a <pattern_pin_ref>. This would best be described using a cutaway perspective diagram of a route with a component attached to a board that is used in conjunction with the. Use a Gull-wing, four-sided flat-pack with fanout from IPC-SM782. Include examples where probing access is not the same as the pad location and where probing attributes are used.

Discuss the rules of the order based application of a plane of copper with an inner void plane with a nested plane of copper within that.

Defining geometries of a path in a route in layer order is preferred.

9 Board Methodology *(Michael / Dieter / Jerry)*

Discuss build up of a multilayer board and the relationship of layers of conductive and non-conductive layers. Correlate the methodology for dimensioning according to the Cartesian coordinate system to establish the three perpendicular datum reference planes. Relate this to the tooling features that are on the board with multiple secondary and tertiary planes (ridged flex.).

Establish methods of calling out plating and plating tolerances on both the surface and the inside plated through holes and buried blind and micro-vias. Show techniques for use of cutouts, slots, grooves, and wells and their plating. Show the relationship of materials and how they are called out or thermal planes. Include references to material specifications. Discuss the electrical definition of buried resistive and capacitive layers that are created as part of the board manufacturing sequence. Also describe embedding previously manufacturing components. (describe the difference between fabricated components and assembled components, regardless of whether they are buried or not.)

9.1 Assembly preparation

Address assembly preparation of the board in such instances where insulation sections need to be provided i.e., prepreg, conformal coating to protect conductive surfaces that will be underneath a component such as a large transformer. These are techniques for making sure the assembly operation goes smoothly and are normally identified as the first actions required on the

assembly drawing. Include the addition of a stiffener that must be riveted prior to assembly of components in the explanation and how this is described in the GenCAM file.

9.2 Board outline

Describe how the board outline statement defines the perimeter of the board or panel. It's not a routing command, it's not a CNC path, it is the finished form of the board.

10 Panel and Board Relationships *(Harry)*

Describe how boards and panels are placed on panels.

11 Test and Inspection methodology *(Bob / Jerry)*

Generate test and inspection programs using GenCAM data.

11.1 Bareboard tests

11.2 In-circuit test

Describe the manner in which a netlist can be extracted from the GenCAM file, also component location and pin number information.

11.3 Board Inspection

11.3.1 Manual techniques

11.3.2 Automated AOI

11.3.3 Stress testing followed by inspection

11.4 Assembly inspection

11.4.1 Manual techniques

11.4.2 Automated AOI

11.4.3 X-ray inspection

11.4.4 Stress testing followed by inspection

12 Fixtures and how to Apply them to Assembly and Test Sequences

12.1 Jigs and Tooling (Harry)

12.2 Bareboard(Harry)

12.3 ICT *(Jerry)*

Describe how

13 Use of Cutouts, Holes, Wells, Slots, and Grooves *(Dieter)*

Describe each of the features and then by example show their intended use

13.1 Milled features

13.2 Depanelization

Describe how to use groves to be creating scroing groves. Example two would use slots and tabs.

14 Plating Requirements and Descriptions *(Dieter)*

Describe how

15 How to Apply Tolerances to GenCAM Features (Dieter)

Describe how

16 Silkscreen, Ledgend and Soldermask Definitions *(Harry)*

Describe how

17 Glue dot and Stencil Descriptions *(Harry)*

Describe how a user would implement the aspects of glue dots. This may be done by adding the information on the glue dot to the package so that when the component is placed on the board, the glue dot automatically comes with it. A layer must be identified as the glue dot layer and should clearly annotate the relationship between the component and the material of the glue dot. (You'll need to use a BODY keyword statement for the glue dot geometry.)

Another way to handle glue dots is to identify the glue dot using the primitive shape and an artwork layer content. This <artwork_ref> would then be placed on a panel at strategic xy locations for preparing a panel for the attachment of components. (You'll need to use an IMAGE statement for the glue dot geometry.)

Example GenCAM code showing how glue dot's implemented.

18 Board and panel assembly

Describe the relationship of boards to panels as defined in board to panel section (currently section 11). Discuss the issues in assembling boards in array format vs. single image board. Correlate relationship when more than one assembly type is positioned on the same array panel (3 assemblies wired together and delivered in panel format). Relate the conditions of tooling features described in section 11 and their use in the assembly operation and how they should be handled in the GenCAM file.

Correlate stencils or other tools needed that must match the assembly condition. Relate this information to the section on depanelization and electrical testing of the board assembly covering such issues as tooling holes for individual boards vs. tooling holes for assemblies tested in an array format.

Note: pick up figure on depanelization from IPC-2221.

19 Bill of materials

How to extract a bill of materials from the GenCAM file. How the information is represented in the GenCAM file.

20 Mapping GenCAM data to external CAM and machine component libraries

Correlate device information in the GenCAM data files to their counterparts within the libraries of the CAM tools. Establish relationship between corresponding entries for package and device parameter information to enable the implementer to understand the relative namespace for these entries.

21 Drawing Descriptions and how to add Intelligence (John)

Describe how

22 Representing Changes *(Michael)*

Describe how

Chapter 1.5 and 6.0

Component Information

Description of how components are related to devices, mechanicals, packages, and patterns. Also discuss how the intelligence of the pin numbers are mapped through devices, patterns, and components. Describe how z-axis works when stacking patterns, components, and mechanicals using layers.

A component placed on the board in GenCAM is actually a collection of data from various GenCAM sections.

Component
- Pattern
  - Artwork
  - Pad Stack
    - Pad
- Mechanical
- Package
- Device
  - Xform

Chapter 2.3

Transform Characteristics and Rules for Use