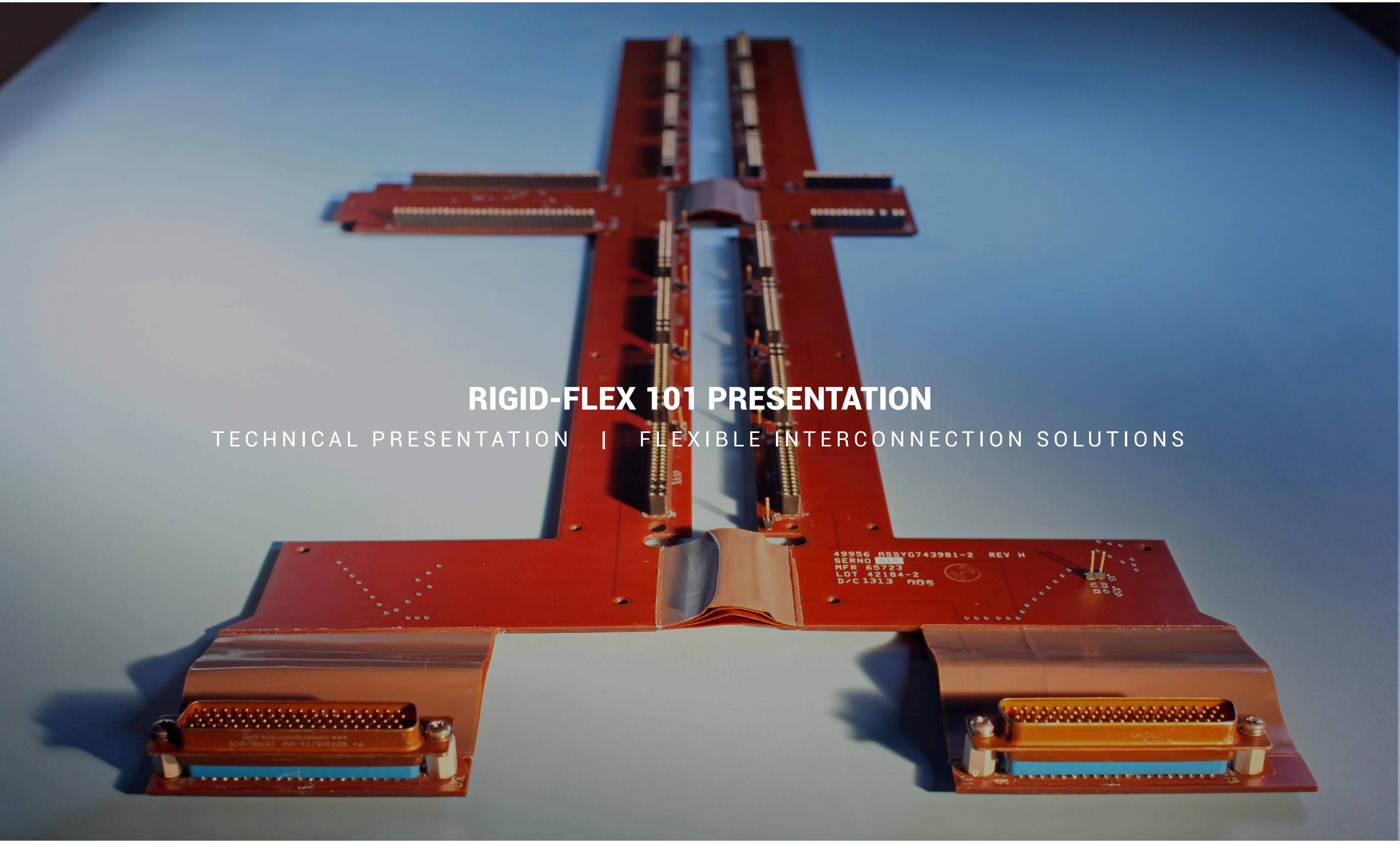
PIONEER CIRCUITS, INC.



RIGID-FLEX 101 PRESENTATION

TECHNICAL PRESENTATION | FLEXIBLE INTERCONNECTION SOLUTIONS

www.pioneercircuits.com

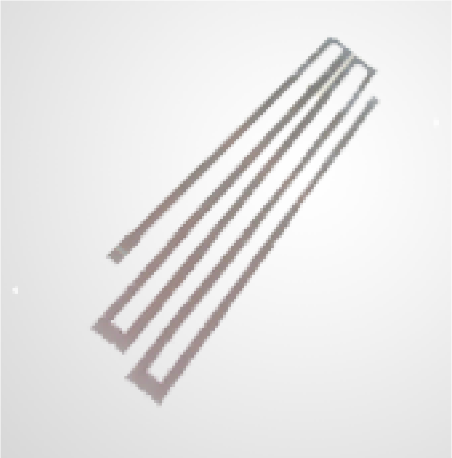
3000 S. Shannon St. Santa Ana, CA 92704 | P. (714) 641-3132 | F. (714) 641-3130

PRODUCT EXAMPLES

SPACEWAY COMMUNICATIONS SATELLITE

SPACEWAY COMMUNICATIONS SATELLITE

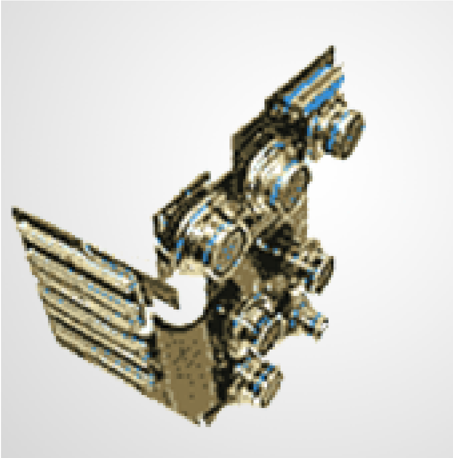
10 LAYER RIGID FLEX MARS ROVER CAMERA



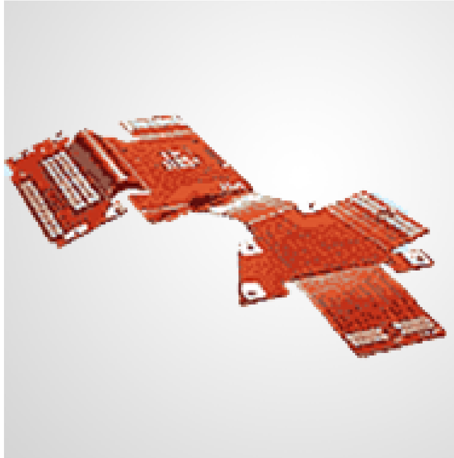
CONTINUOUS 22FT LONG STRIP LINE LVDS

30 LAYER RIGID FLEX MARS ROVER SOJOURNER (PATHFINDER)

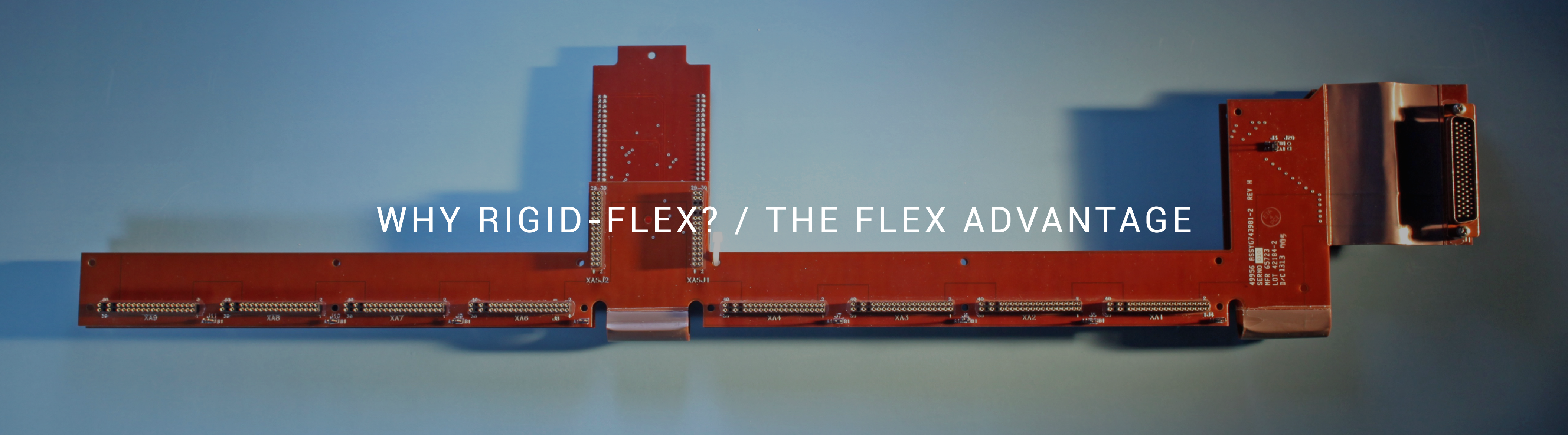
3, 14 LAYER RIGID FLEX NAIL HEAD PIN INTERCONNECT GLOBAL HAWK UAV



28 LAYER RIGID FLEX BOOKBINDER, M1 TANK



14 LAYER RIGID FLEX BOOKBINDER, F-18

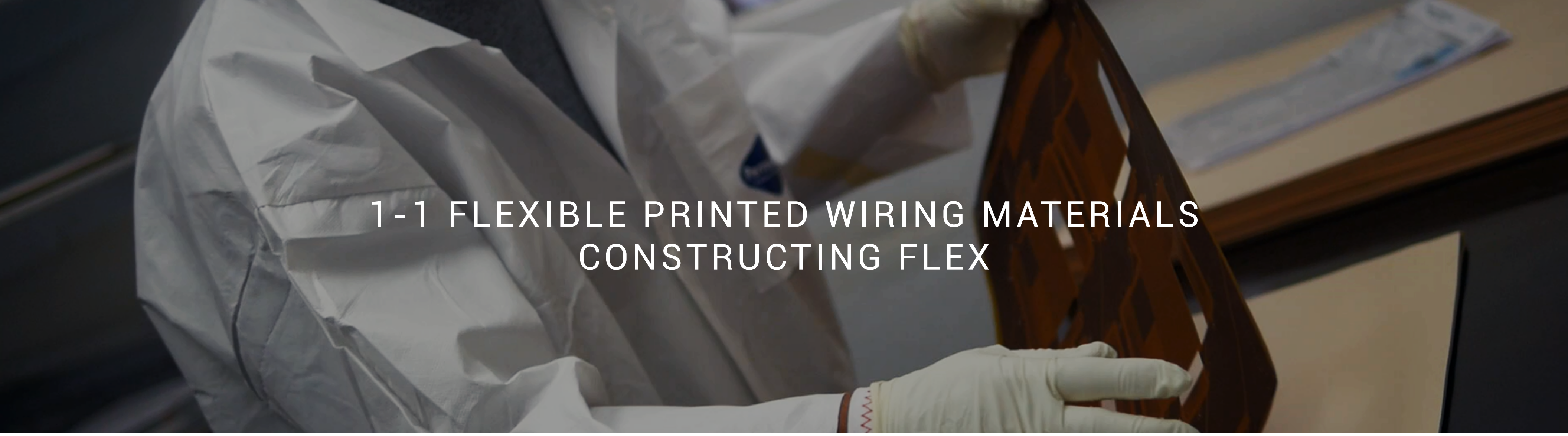


WHY RIGID-FLEX? / THE FLEX ADVANTAGE

- Weight Saving
- Eliminate connectors for rigid to rigid area routing
- Effective Use of Board Real Estate
- Signal Integrity
  - Device to Device Controlled Impedance, even across Flex Sections
- Artwork (Engineering) Controlled Conductor Routing (vs. round wire)
- Consistent Assembly (vs round wire)
- Reliability – Fewer Solder Joints / Interconnects
- When Evaluating Cost Must Review Best Total Value
  - (Total Cost Of Ownership)
- Part (Panel) Size Capability

DESIGN AND PERFORMANCE SPECIFICATIONS

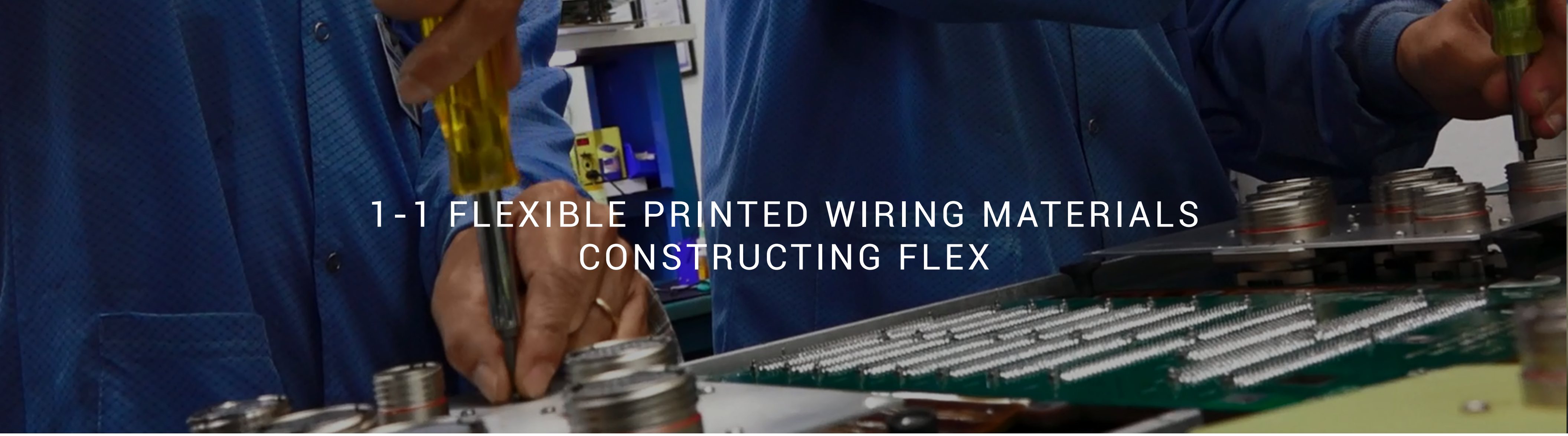
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Standard on Rigid Printed Wiring Board Design
IPC-2223	Sectional Design Standard for Flexible Printed Boards
IPC-6012	Qualification and Performance Specification for Rigidf Printed Boards
IPC-6013	**Qualification and Performance Specification for Flexible Printed Boards**



1-1 FLEXIBLE PRINTED WIRING MATERIALS
CONSTRUCTING FLEX

Flexible & Rigid-Flex Printed Wiring Materials

•Copper Foils: per **IPC 4562**
•Dielectric Film: per **IPC 4201**
•Pre-clad Flexible Substrates: per **IPC 4204**
•Coverlay: per **IPC 4203/1** (Kapton® / Acrylic)
•Bond-Ply: per IPC **4203/1** (Acrylic / Kapton® / Acrylic)
•Cast Adhesive Sheet : per **IPC 4203/18** (Acrylic)
•Rigid Laminates: per **IPC 4101**
•Pre-pregs: per **IPC 4101**
•Flexible Cover Material (Flexible Solder Mask): Per **IPC-SM-840**
(Surface Mount Features on Flex Product- TY 2 / 3 w/ Stiffener)



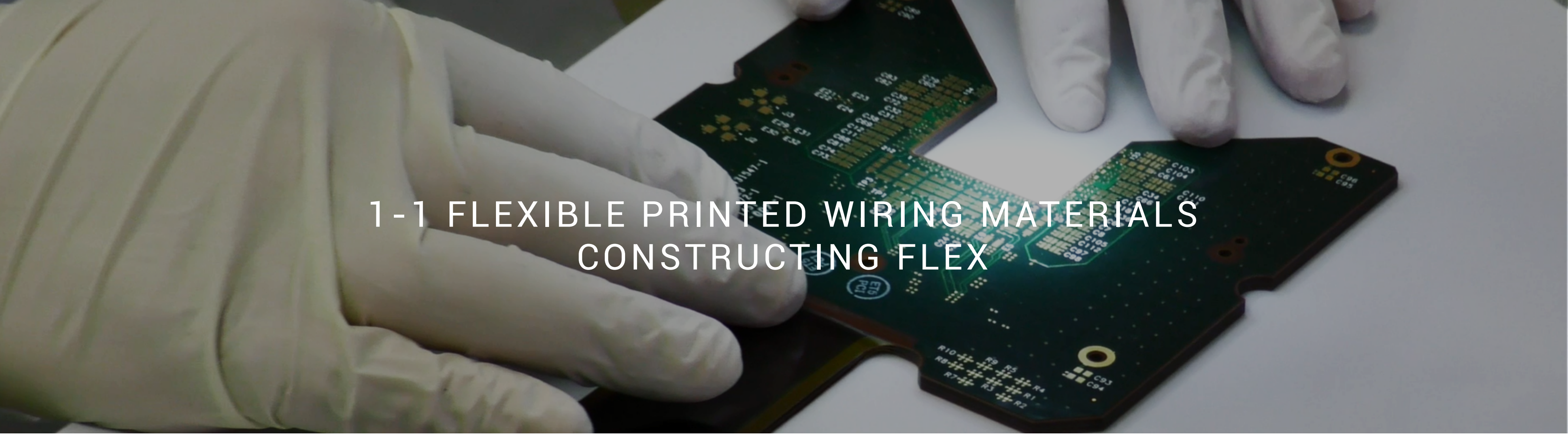
1-1 FLEXIBLE PRINTED WIRING MATERIALS
CONSTRUCTING FLEX

Flexible & Rigid-Flex Printed Wiring Materials

Rigid Materials: Polyimide – Glass
•Clad Laminates per IPC-4101/ 41 (No UL Specified) > Arlon 85N Typical
•Pre-Preg per IPC-4101/42 > Hitachi 671NA or Arlon 38N Typical
•Best Environmental / Thermal Performance
•(All Lead Free Compatible)

Rigid Materials: Epoxy – Glass Standard
•Clad Laminates per IPC-4101/ 26 (Meets UL 94-V0) > Arlon 45N Typical
•Pre-Preg per IPC-4101/6 > Arlon 49N Typical
•Lower Environmental / Thermal Performance
•(Not Lead Free Compatible – Lower Cost)

Rigid Materials: Epoxy – Lead Free
•Clad Laminates per IPC-4101/126 (Meets UL 94-V0) > Isola 370HR
•Pre-Preg per IPC-4101/126 > Isola 370HR (not for rigid-flex/not low flow)
•Lower Environmental / Thermal Performance than Polyimide
•Lead Free Compatible



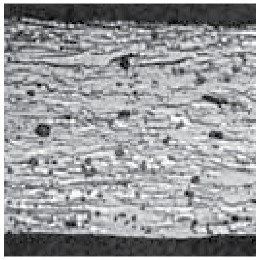
1-1 FLEXIBLE PRINTED WIRING MATERIALS CONSTRUCTING FLEX

Flexible Printed Wiring Materials

Copper Foils: per IPC-4562 GRADE 7 for flex

•Grade 7 - Rolled Annealed (RA), primarily used in flex applications
•Improved elongation properties vs. electro-deposited (ED)
•Greater resistance to work hardening / cracking due to bend stresses
•Incorporated into pre-clad layer (IPC-4204/1 and /11)
•Used in combination with bond ply or adhesive for outer layer “caps” or specific “windowed” constructions
•Very low profile (RA) compared to ED dendritic structure
•Dynamic Applications: Grain direction makes a difference (Refer to flex layout pages)

Rolled Annealed Foil



Electro-Deposited Foil

1-1 FLEXIBLE PRINTED WIRING MATERIALS
CONSTRUCTING FLEX

Flexible Printed Wiring Materials

Copper Thickness (in Ounces)	Copper Thickness (in Mils)	Copper Thickness (in Microns)	Resistance per Square (in mOhms)
1/4 Ounce	0.34 mils	8.5 microns	2.0 mOhms
1/3 Ounce	0.44 mils	12 microns	1.5 mOhms
1/2 Ounce	0.67 mils	17 microns	1.0 mOhms
1 Ounce	1.34 mils	34 microns	0.5 mOhms
2 Ounces	2.68 mils	68 microns	0.25 mOhms
3 Ounces	4.02 mils	102 microns	0.167 mOhms
4 Ounces	5.36 mils	136 microns	0.125 mOhms

The table also shows the approximate “resistance per square,” which is the edge to edge resistance of any size square area of that weight of copper. This is very useful for quickly calculating the DC resistance of a PCB trace by decomposing it into a series of squares. For example, a trace 20,000 mils (20 inches) long and 10 mils wide is made up of 2000 squares, each 10mils x 10mils, in series. If that trace is 1/2 ounce copper, the DC resistance would be 2000 squares x 1.0 mOhms / square = 2000 mOhms, or 2 Ohms. If you are running high current through that trace, 2 Ohms or even less may cause a substantial voltage drop. Suppliers can pr vide resistance values of specific lines if requested.

1-1 FLEXIBLE PRINTED WIRING MATERIALS
CONSTRUCTING FLEX

Flexible & Rigid-Flex Printed Wiring Materials

Rigid Materials: Polyimide – Glass

•Grade 3 – **High Temperature Elongation (HTE)**, used in **rigid applications and rigid layers of rigid-flex.**
•Improved elongation properties vs. standard electro-deposited (ED)
•Resistant to inner layer cracking (related to z-axis thermal expansion)
•Incorporated into rigid pre-clad laminates (IPC-4101)
•Used in combination with pre-preg for outer foil constructions- typical with surface micro-vias
•"Low" profile (dendritic structure) used in thin laminates

1-1 FLEXIBLE PRINTED WIRING MATERIALS
CONSTRUCTING FLEX

Flexible & Rigid-Flex Printed Wiring Materials

Cover : per IPC 4203/1 (Acrylic / Kapton®)

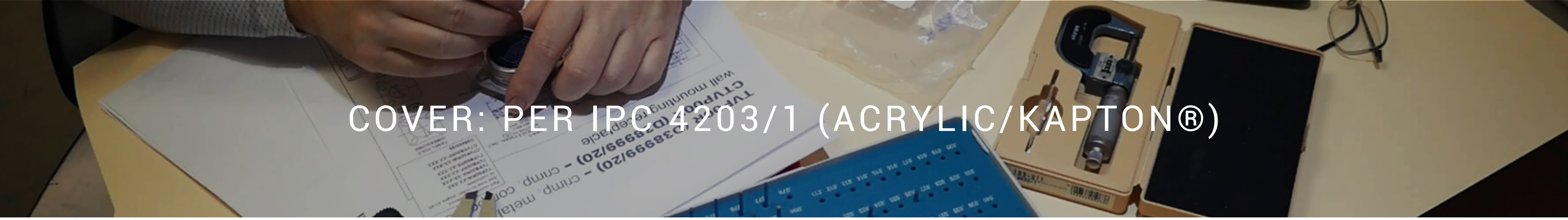
•Sample Specification Call-out:

IPC 4203/1 E1E1 M1

•Polyimide film thickness, E_ (1, 2, 3, 4 or 5) mils- and may vary due to controlled impedance dielectric requirements; 1 mil is typical)
•Acrylic adhesive is present on one side of polyimide film –at the same thickness. The "zero thickness side is listed as "N"
•Guideline: Use one mil of adhesive plus one additional mil for every ounce of copper to fill.

Use M1/N against half ounce copper (exception)
Use M2/N against one ounce copper.

•Flame retardant adhesive is not addressed in specification and must be specified if desired. (Material shall met UL94 V0). – Not typical for MIL applications to require UL. However, FR materials will tend to flow more than standard LF and adhesive thickness may be reduced.



COVER: PER IPC 4203/1 (ACRYLIC/KAPTON®)

Here are the guidelines for cover material adhesive thickness and copper "fill" regardless of the Kapton(r) dielectric (up to 2 mils).

1) To fill .0005 to .0007 copper (1/2 oz / sq.ft. base copper) we would use one mil (.001") of either LF or FR adhesive
2) To fill .0010 to .0014 copper (1 oz / sq.ft. base copper) we would use one mil (.001") of FR adhesive (FR adhesive has more flow than LF). 2 mil thickness is also permissible.
3) To fill .0010 to .0014 copper (1 oz / sq.ft. base copper) we would use two mils (.002") of LF adhesive (LF adhesive has more flow than FR). or in general...
4) Plating per IPC-6013 Class 3 will add up to an additional .0015 to .0030 mils of copper in addition to the base copper, whether pattern, button or panel plated. We would need to test some applications: I would have a slight concern that plated buttons could "punch-through" the half mil Kapton(r).
5) One mil of FR adhesive is needed to fill each ounce of copper weight (or for each .0012 of copper thickness,- whether base copper or plated copper). The LF guideines are also acceptable.
6) One mil of LF adhesive, plus one additional mil of LF adhesive is needed to fill each ounce of copper weight (or for each .0012 of copper thickness,- whether base or plated copper)
7) Both FR and LF adhesives are covered by the cover material specification : IPC-4203/1 - IF FR adhesive is desired it must be specified or we would assume that LF materials, typically used in military applications are desired.
8) LF adhesives have slightly better peel strengths than FR adhesives, and we have had rare FR adhesive peel failures (delam) in tight bend radius applications, especially if there is some elevated thermal exposure in the bent condition. We normally recommend LF unless there are specific requirements for UL 94 (flame retardant) materials.
9) Use of FR adhesives also often permits less adhesive required for fill with a slight improvement in flexibility.
10) FR adhesive may not be desirable in that the adhesive is opaque, not clear like LF, and some customers want to be able to see the etched circuitry under the cover dielectric.
11) Where cover material is required in areas of surface mount devices, flexible solder mask per IPC-SM-840 (such as Taiyo FIXT-9000) is an appropriate alternative .
12) Most IPC-4203/1 cover material is based on a one mil (or sometimes 2 mil) polyimide film; half mil film is available from DuPont but is not part of our standard material inventory and may present material lead time of up to 2 weeks. Please advise what cover material usage changes related to LF7013 and FR7013 may be expected.

1-1 FLEXIBLE PRINTED WIRING MATERIALS CONSTRUCTING FLEX

Flexible & Rigid-Flex Printed Wiring Materials

Bond-Ply: per IPC 4203/1 (Acrylic / Kapton® / Acrylic)

•Sample Specification Call-out:

IPC 4203/1 E1E1 M1

•Polyimide film thickness, E_ (1, 2, 3, 4 or 5) mils- and may vary due to controlled impedance dielectric requirements; 1 mil is typical)

•**Acrylic adhesive** is present on both sides of polyimide film –at the same thickness.

•Guideline: Use one mil of **adhesive** plus one additional mil for every ounce of copper to fill.

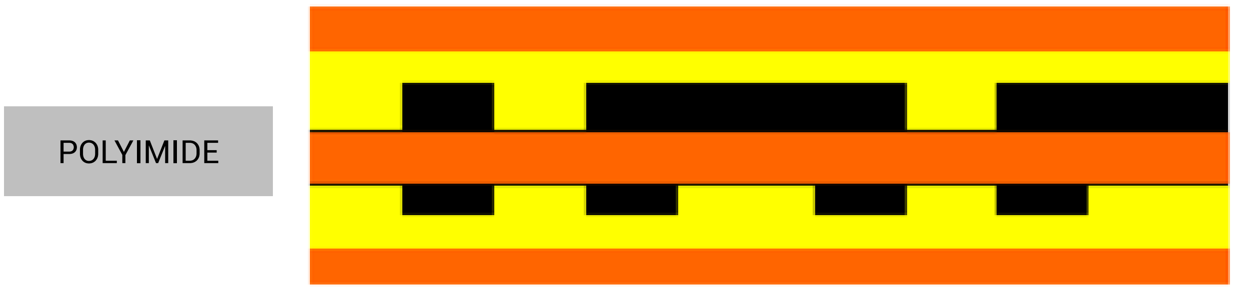
Use M1/1 against half ounce copper (exception)
Use M2/2 against one ounce copper.

•Flame retardant adhesive is not addressed in specification and must be specified if desired. (Material shall met UL94 V0). – Not typical for MIL applications to require UL.

FLEXIBLE CLAD SUBSTRATES ADHESIVELESS VS. STANDARD FLEX

Flexible Pre-Clad per IPC-4304 /11 & /1

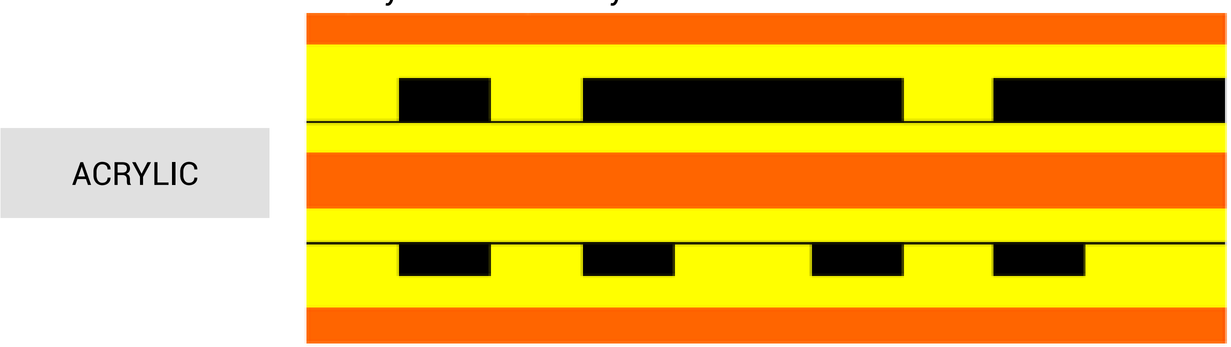
Adhesiveless "AP" Flex Layer with coverlay



AP
/11

IPC 1203/1 E1E1 M3/0
IPC-4204/1 E1E2Cu-W7 2S/2S
IPC-4203/1 E1E1 M3/0

Standard "LF" Flex Layer with coverlay



LF
/1

IPC 4203/1 E1E1 M3/0
IPC-4204/1 E1E2 M1/1 Cu-W7 2S/2S
IPC-4203/1 E1E1 M3/0

Acrylic descriptor

"ADHESIVELESS" simply means acrylic layers are not used to bond to the copper onto the polyimide core dielectric. On adhesiveless constructions, the copper is bonded directly to the polyimide film substrate. AP is DuPont's product code for their adhesiveless polyimide (IPC-4204/11) clad substrates. LF is DuPont's product code for their standard – acrylic / Kapton® (IPC-4204/1) clad substrates.

FLEXIBLE CLAD SUBSTRATES ADHESIVELESS VS. STANDARD FLEX

Flexible Pre-Clad per IPC-4304 /11 & /1

Adhesiveless "AP" Flex Layer with coverlay

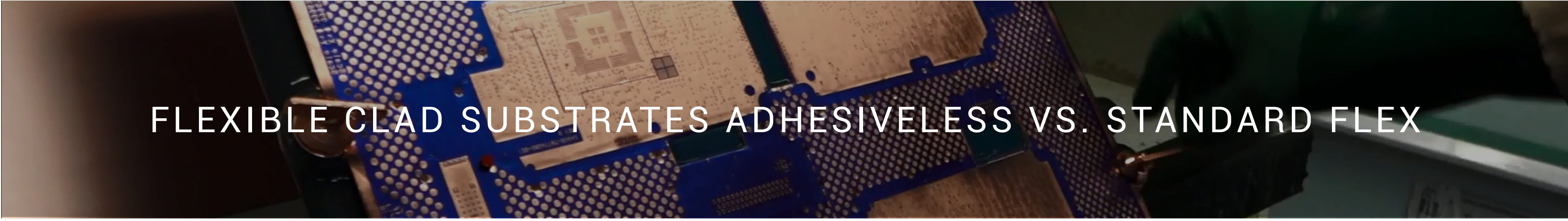
Standard "LF" Flex Layer with coverlay

Unlike AP, LF clads can be ordered single-sided as the drawing requires

[IPC-4204/1 E1E1 M1/0 Cu W7 HS/HS = LF- 8510
No acrylic on the non-copper side.

AP will always be ordered with copper on (2) sides.

LF material can be specified / ordered as single-sided or double sided. For silver epoxy (shield / plane) constructions where an LF clad is specified, use double-sided copper and remove the copper on the silver – epoxy sided to aid in silver –epoxy bond.



Why is Acrylic BAD?

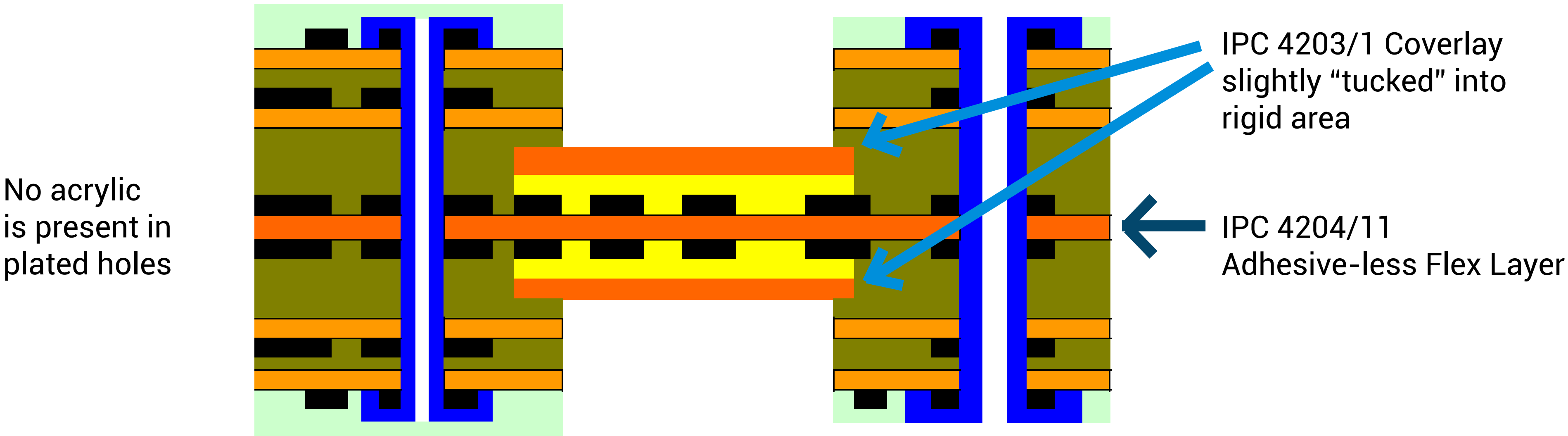
Acrylic is a great adhesive for flexible applications with desirable properties such as:

•High Peel strength
•Low modulus / good flexibility
•Excellent chemical resistance to acids, oils

Acrylic is a poor adhesive for rigid applications with undesirable properties such as:

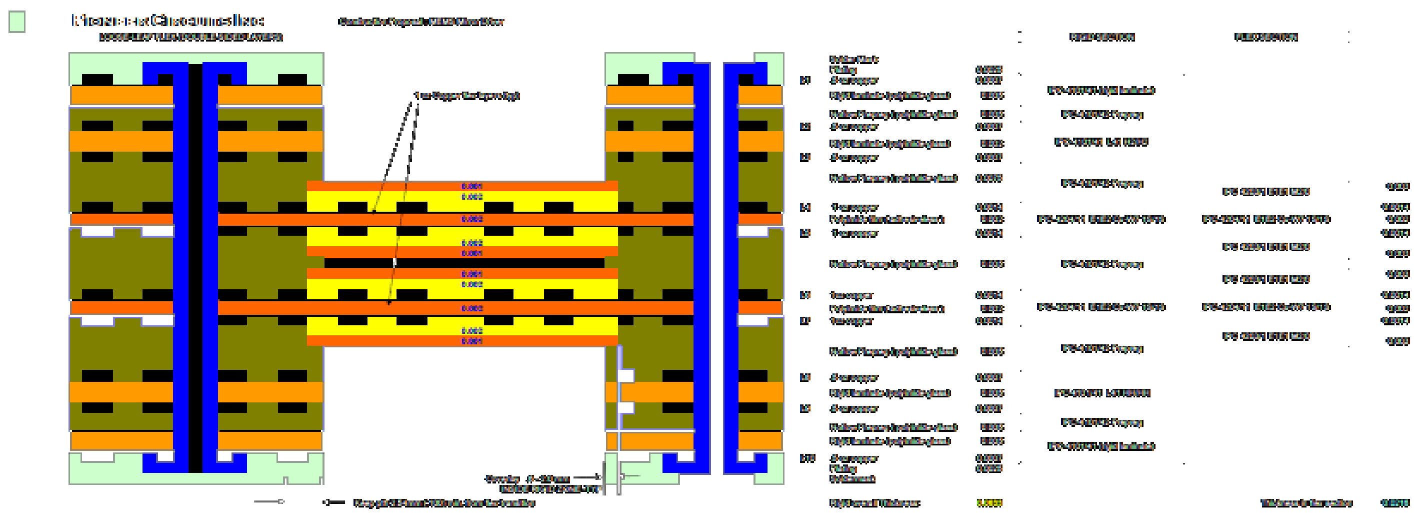
•High CTE X-Y (400ppm/deg C) vs. polyimide glass (30ppm/deg C)
-Can result in laminate voiding and small area of delamination due to CTE mismatch between flex & rigid materials
•High CTE Z (400ppm/deg C) vs. polyimide glass (30ppm/deg C)
-Can result in premature pth failures to work hardening of copper in multiple thermal excursions
•Low Tg - 105 deg F – but it behaves more like a thermal adhesive vs. thermoset (Classical thermoset definitions do not apply)

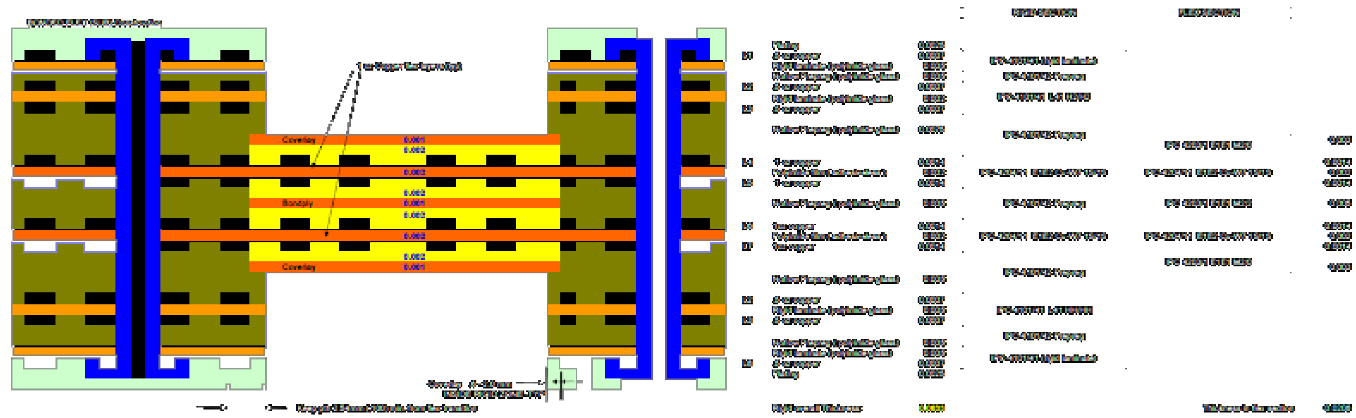
FLEXIBLE CLAD SUBSTRATES ADHESIVELESS VS. STANDARD FLEX



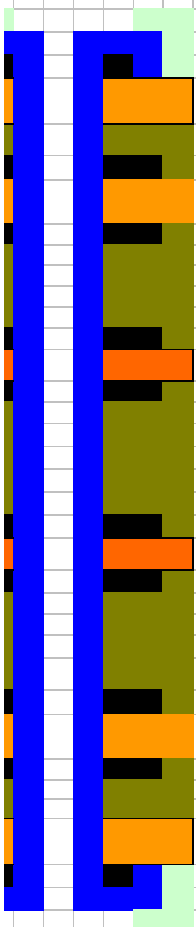
In adhesiveless rigid-flex (Type 4) constructions, the flexible coverlay outer insulation (which uses a Kapton® polyimide / acrylic dielectric layer) is present ONLY in the flex region and is slightly tucked into the rigid section. No plated through holes should be present in the area where the coverlay patch slightly extends in the rigid section – about .125 inside the flex / rigid transition edge. Acrylic has a very high CTE, coefficient of thermal expansion, - (400 ppm/deg c) versus other pwb / adhesiveless materials (30- 40 ppm / deg C). The high CTE can translate to a very high z—axis expansion well as PTH reliability concerns. Also the high CTE of acrylic (vs rigid material) results in internal stresses that may create internal delamination.

FLEXIBLE CLAD SUBSTRATES ADHESIVELESS VS. STANDARD FLEX





RIGID-FLEX STACK-UP & MATERIALS: EXCEL BASED MODELS



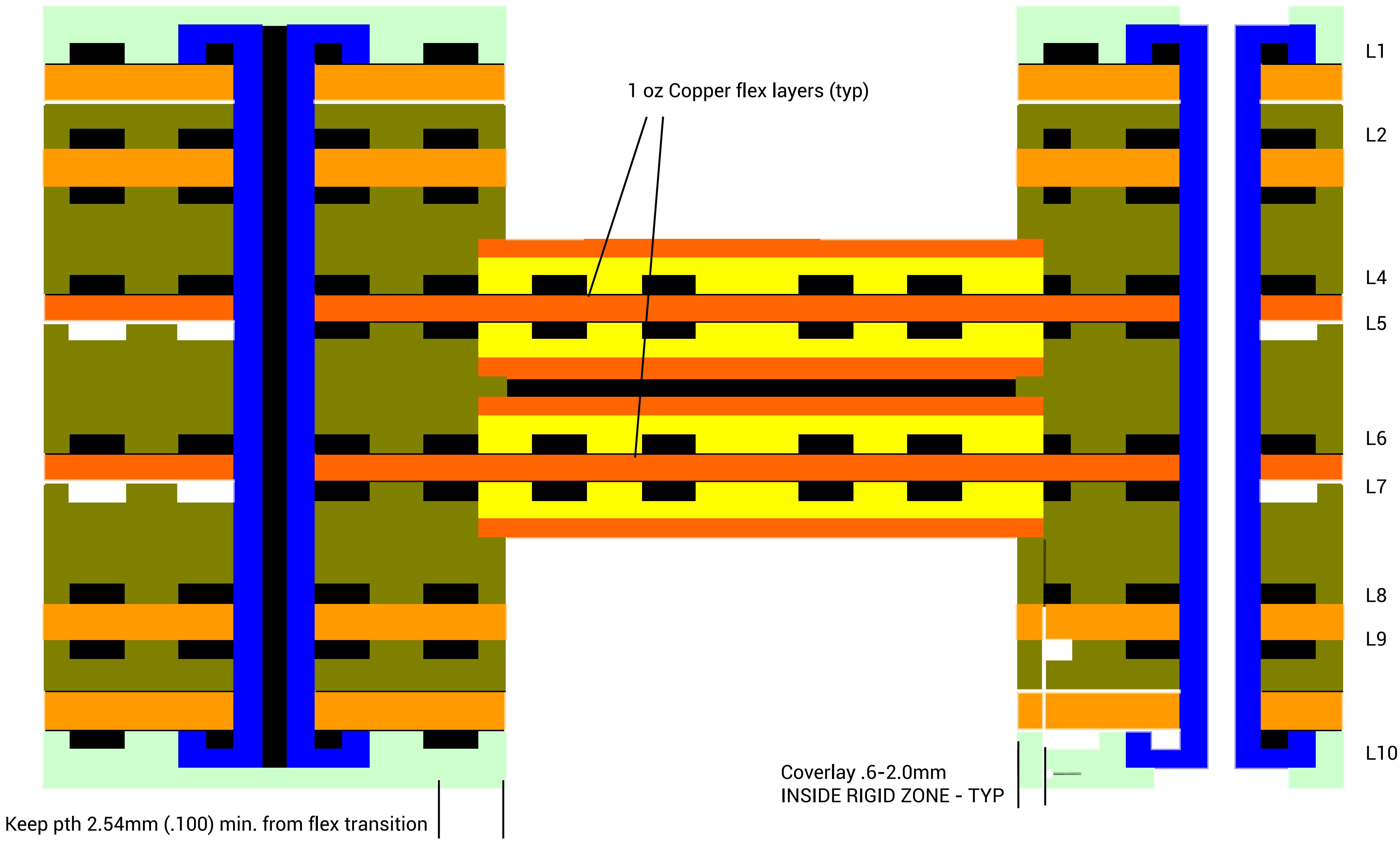
			RIGID SECTION	FLEX SECTION	
	Solder Mask				
	Plating	0.0025			
L1	.5 oz copper	0.0007			
	Rigid laminate (polyimide-glass)	0.005	IPC-4101/41 (rigid laminate)		
	Noflow Prepreg (polyimide-glass)	0.005	IPC-4101/42 Prepreg		
L2	.5 oz copper	0.0007			
	Rigid laminate (polyimide-glass)	0.002	IPC-4101/41 L41 H2/H2		
L3	.5 oz copper	0.0007			
	Noflow Prepreg (polyimide-glass)	0.0075	IPC-4101/42 Prepreg		0.003
				IPC 4203/1 E1E1 M2/0	
L4	1 oz copper	0.0014			0.0014
	Polyimide film (adhesiveless)	0.002	IPC-4204/11 E1E2 Cu-W7 1S/1S	IPC-4204/11 E1E2 Cu-W7 1S/1S	0.002
L5	1 oz copper	0.0014			0.0014
				IPC 4203/1 E1E1 M2/0	0.003
	Noflow Prepreg (polyimide-glass)	0.005	IPC-4101/42 Prepreg		
				IPC 4203/1 E1E1 M2/0	0.003
L6	1oz copper	0.0014			0.0014
	Polyimide film (adhesiveless)	0.002	IPC-4204/11 E1E2 Cu-W7 1S/1S	IPC-4204/11 E1E2 Cu-W7 1S/1S	0.002
L7	1oz copper	0.0014			0.0014
				IPC 4203/1 E1E1 M2/0	0.003
	Noflow Prepreg (polyimide-glass)	0.005	IPC-4101/42 Prepreg		
L8	.5 oz copper	0.0007			
	Rigid laminate (polyimide-glass)	0.005	IPC-4101/41 L41 HH/HH		
L9	.5 oz copper	0.0007			
	Noflow Prepreg (polyimide-glass)	0.005	IPC-4101/42 Prepreg		
	Rigid laminate (polyimide-glass)	0.005	IPC-4101/41 (rigid laminate)		
L10	.5 oz copper	0.0007			
	Plating	0.0025			
	Soldermask				
	Rigid overall Thickness:	**0.0633**		Thickness in flex section	0.0216

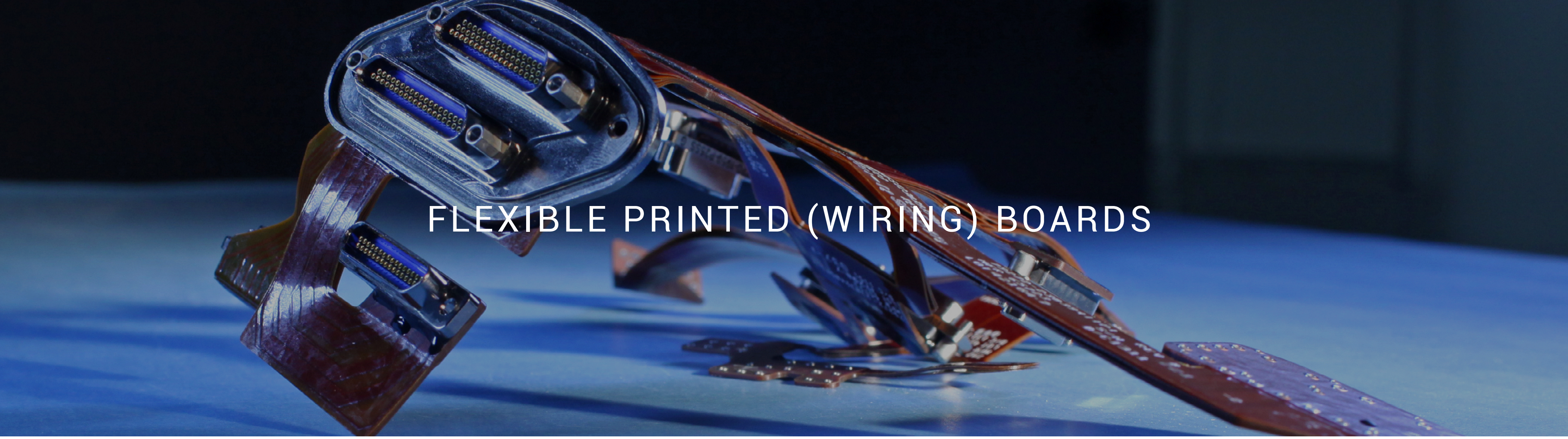
FLEXIBLE CLAD SUBSTRATES: LOOSE-LEAF (UN-BONDED) FLEX

PIONEER CIRCUITS, INC.

LOOSE-LEAF FLEX (DOUBLE-SIDED LAYERS)

Construction Proposal: MEMS Mirror Driver





FLEXIBLE PRINTED (WIRING) BOARDS

IPC-2223 for Design
IPC-6013 for Product Acceptance

Type:

1 - Single-Sided

2 - Double-Sided

3 - Multilayer

4 - Rigid-Flex (with Plated through Holes)

5 - Flexible or Rigid-Flex ≥ 2 Layers & no plated through holes

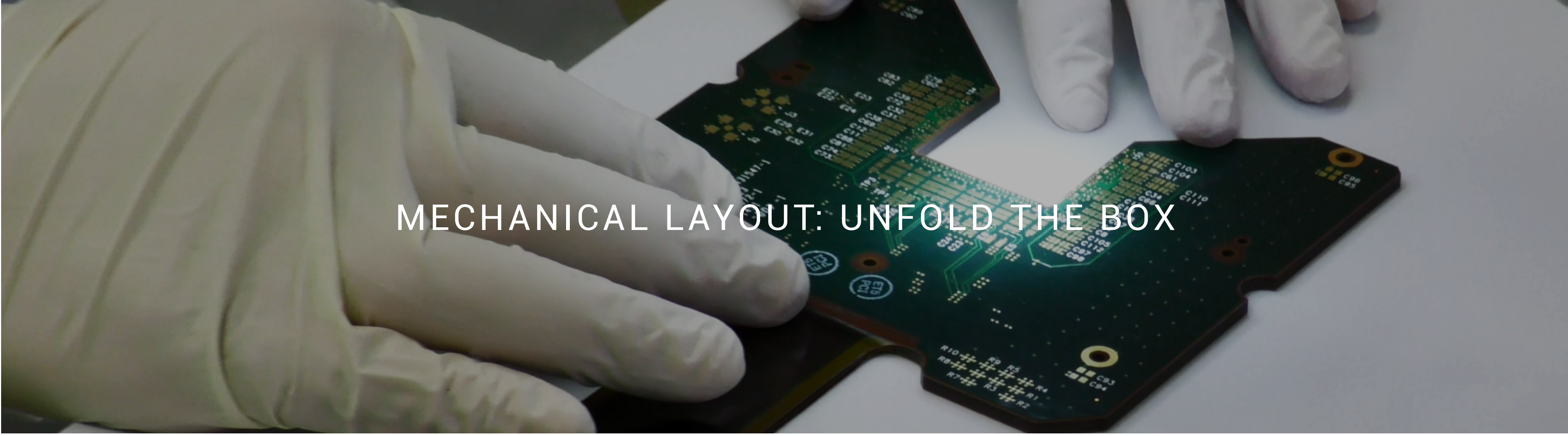
Uses:

A - Flex to Install

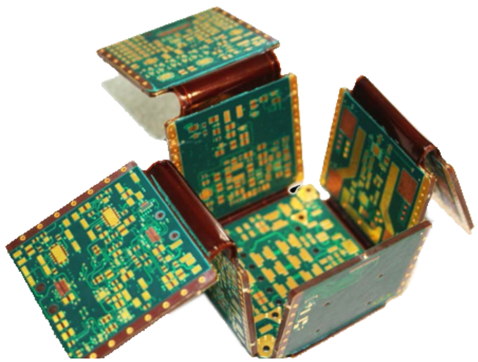
B - Dynamic / continuous flexing cycles per drawing

C - High Temperature (> 105C)

D - UL REcognition



MECHANICAL LAYOUT: UNFOLD THE BOX



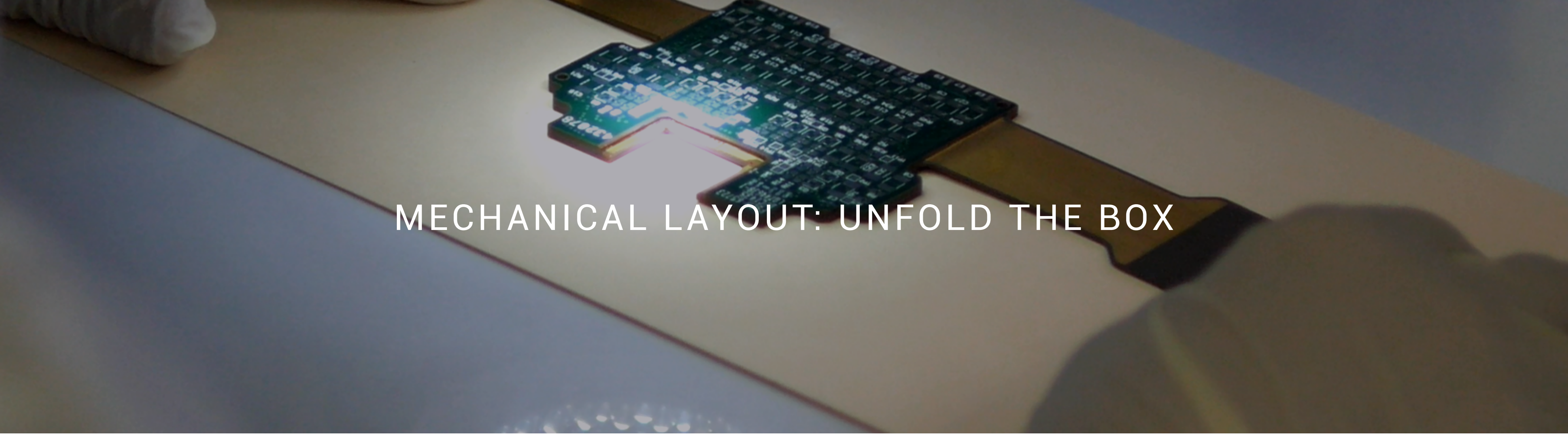
Determine Envelope Dimensions

-Unfold the Box – Determine (Max) Preliminary Outline

•Identify & Locate Components / Connectors on Unfolded Surfaces

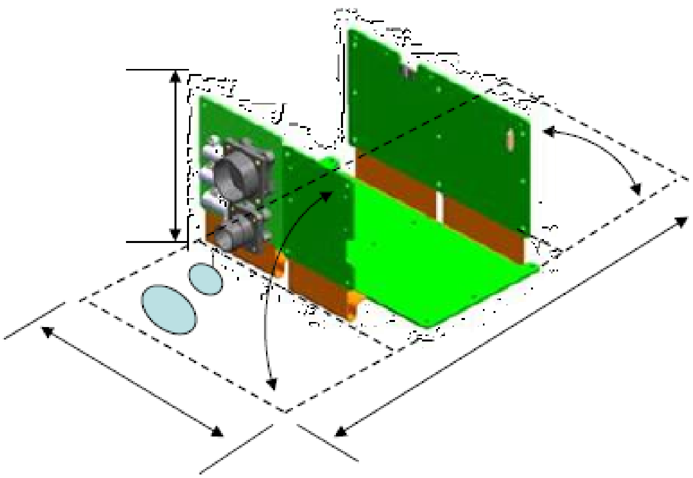
-Keep Pin-Outs Unassigned (when possible)

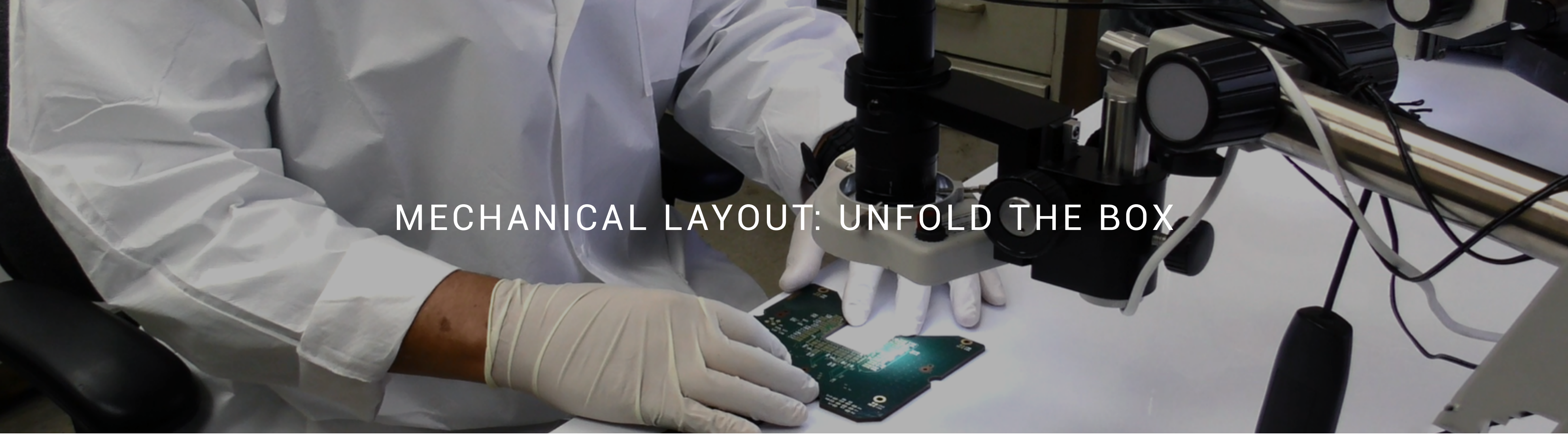
•Add Service Loops for Flex Length



MECHANICAL LAYOUT: UNFOLD THE BOX

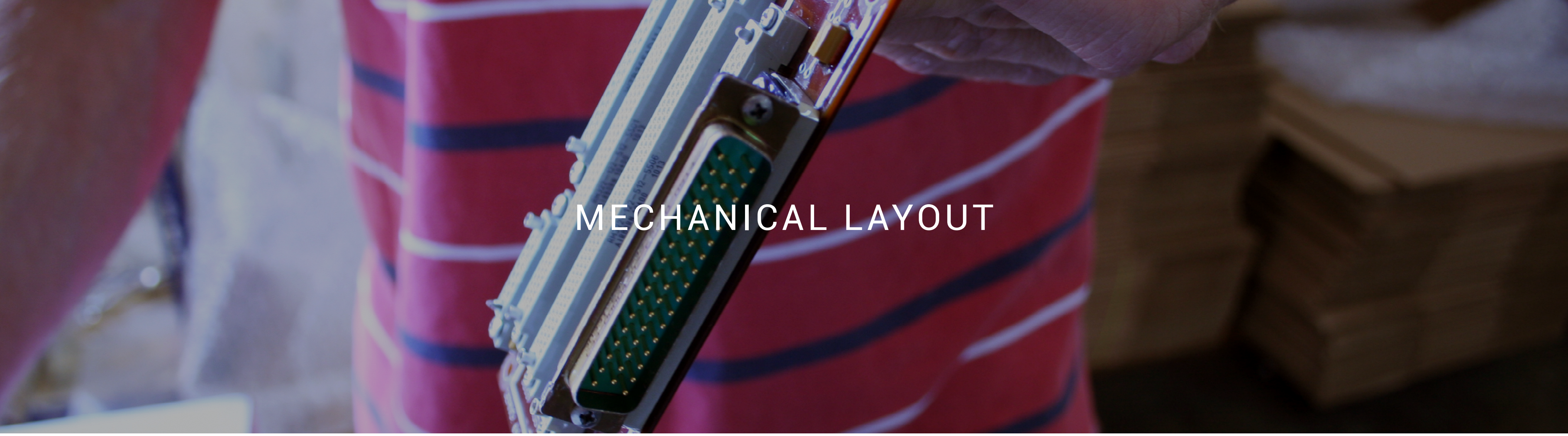
- •Determine Envelope Dimensions
    - -Unfold the Box – Determine (Max) Preliminary Outline
- •Identify & Locate Components / Connectors on Unfolded Surfaces



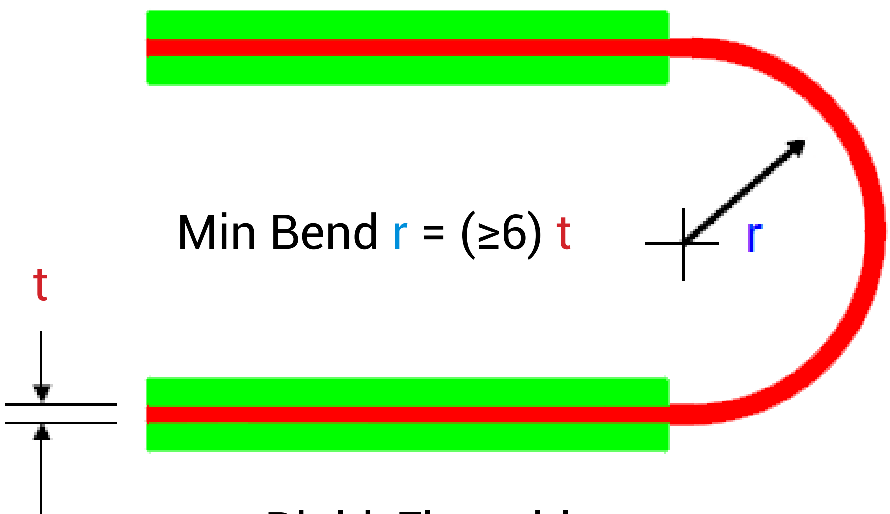


MECHANICAL LAYOUT: UNFOLD THE BOX

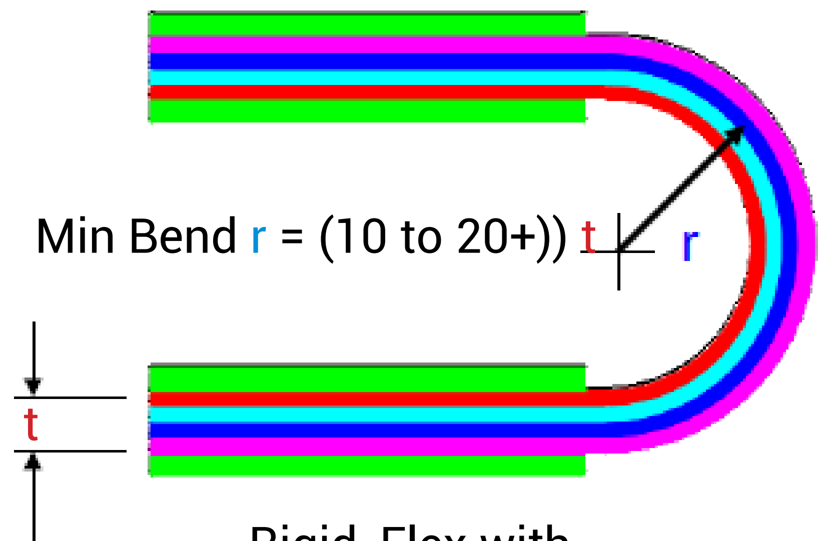
- Consider Potential Stress Risers (Flex To Install)
- Service Loop Length – longer flex bend area may distribute stress
- Bonded Flex or “Loose Leaf” (Double-Sided Flex Layers) Considerations
- S-Bends (in same axis) – Use “Loose – Leaf”
- Thicker flex section will resist bending due to material “memory”
- Is a Staggered – Length Rigid-Flex (Bookbinder) really needed?



MECHANICAL LAYOUT

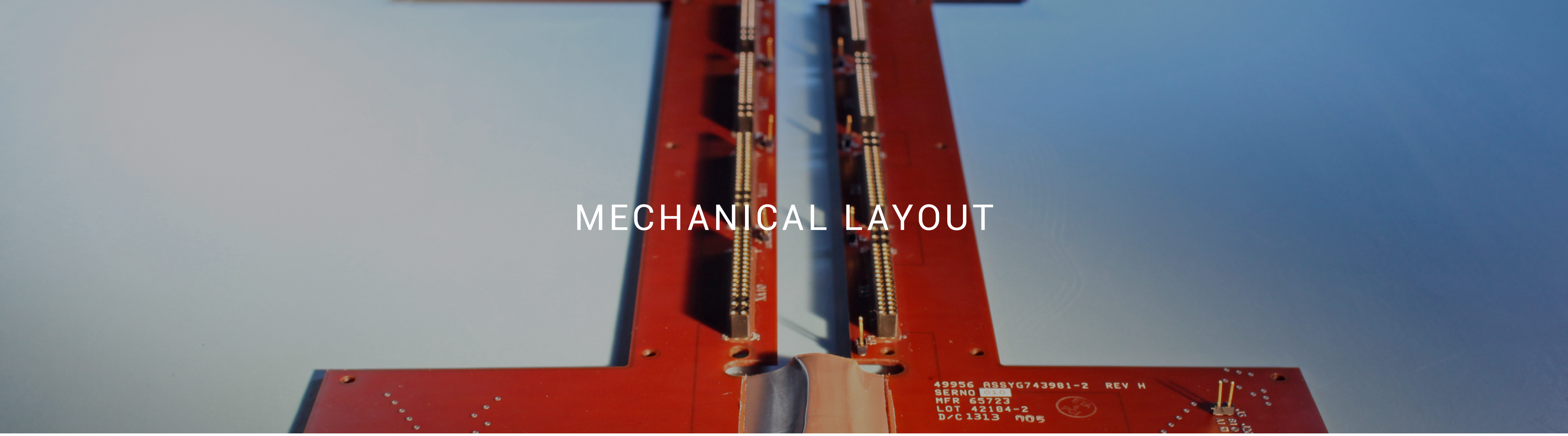


Rigid-Flex with
single-sided or double-sided flex layer



Rigid-Flex with
bonded multilayer flex
(>3 conductive layers)

When considering installation and forming:
Flex is not sheet metal. Flex is more like a rope.

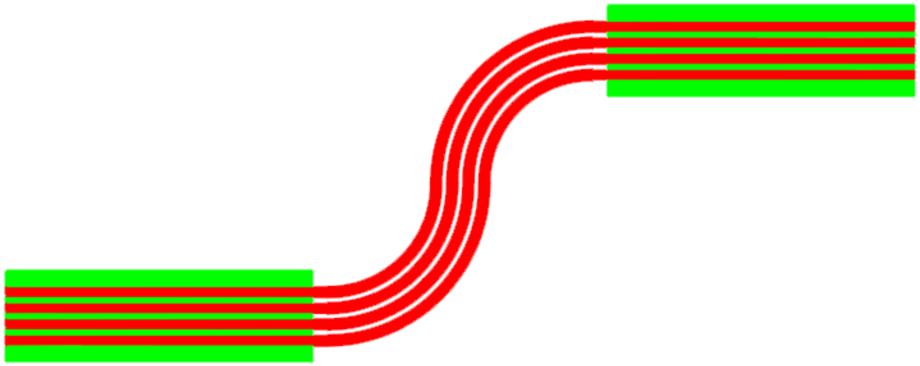


MECHANICAL LAYOUT

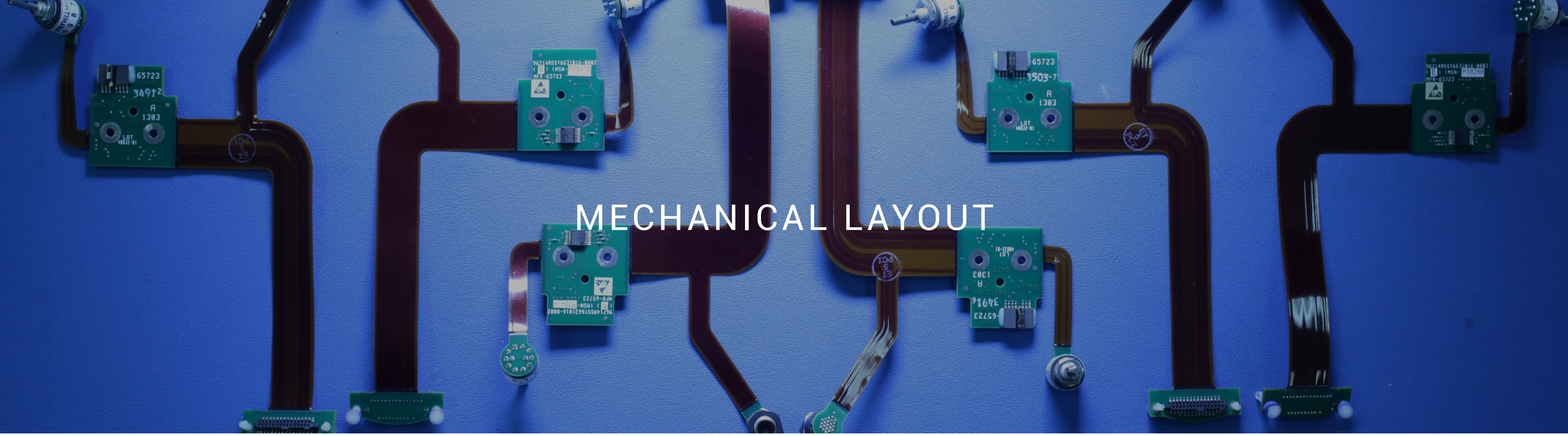
The “Bends” – Flex to install considerations:

Rigid-Flex with multiple “loose-leaf” (single or double sided flex layers)

No flex-section stress if rigid boards are horizontally in same plane



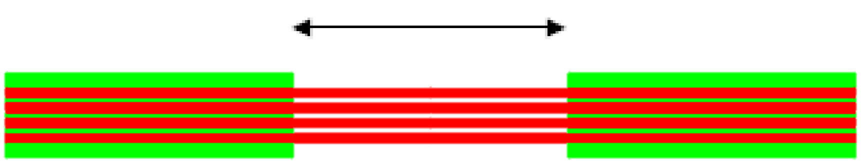
No flex-section stress if rigid boards are horizontally offset- All Flex layers will be same length.

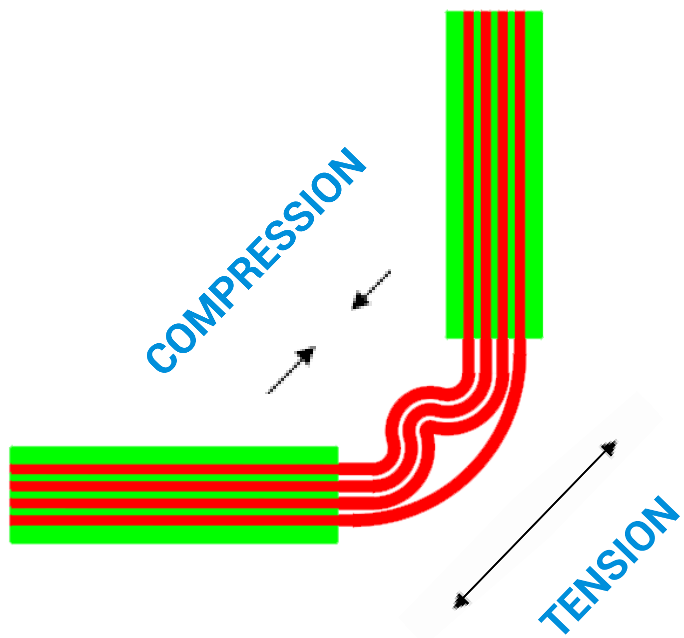


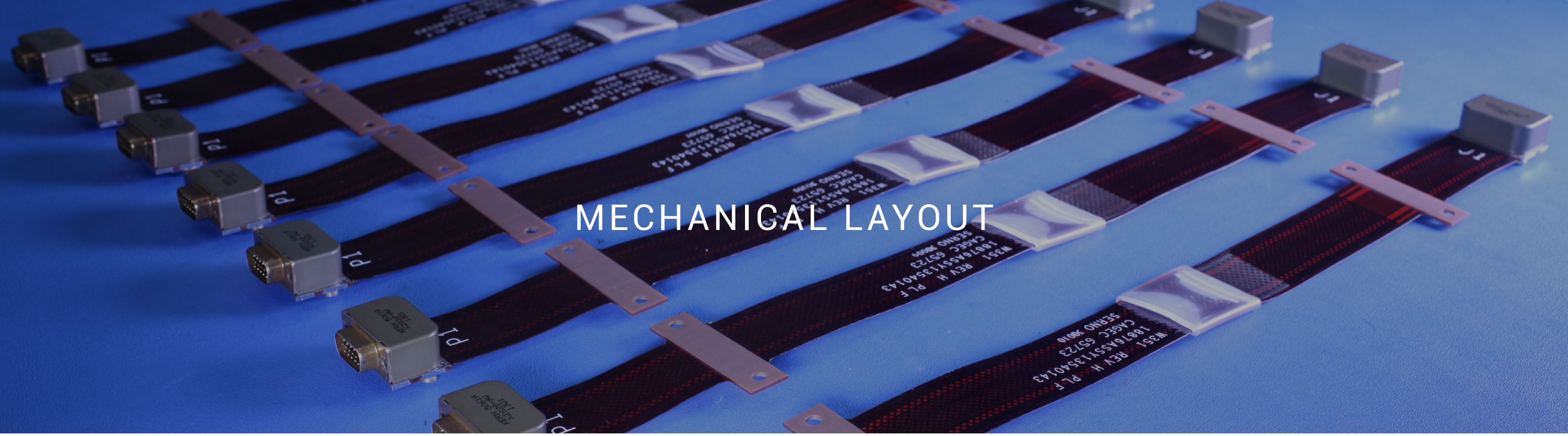
MECHANICAL LAYOUT

The “Bends” – Flex to install considerations:

Ability to Effectively Install Rigid Flex
•Thickness and Flexibility of Flex Area
•Length Of Flex “Service Loop”







The “Bends” – Flex to install considerations:

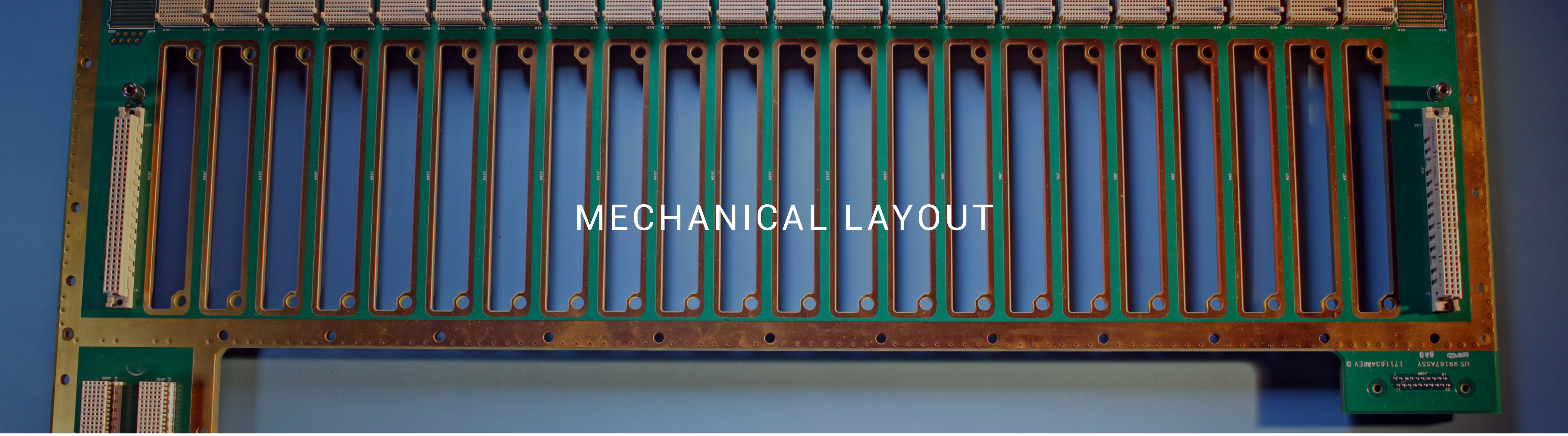
Consider a “staggered length” bookbinder when:

-More than two or three double sided flex layers (also copper weight dependant)

-Very little stress desired in installed condition

Rigid-Flex:
(4) Double-sided flex Layers

Rigid-Flex “Bookbinder”:
(4) Double-sided flex Layers

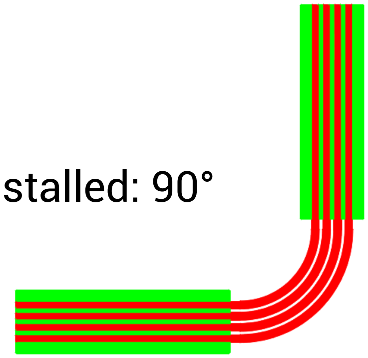


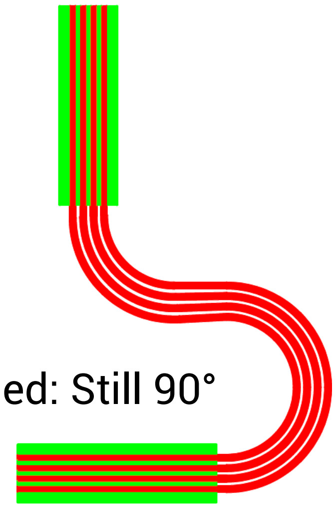
MECHANICAL LAYOUT

“Bookbinder” Rigid-Flex

“As Built” Configuration

As-Installed: 90°





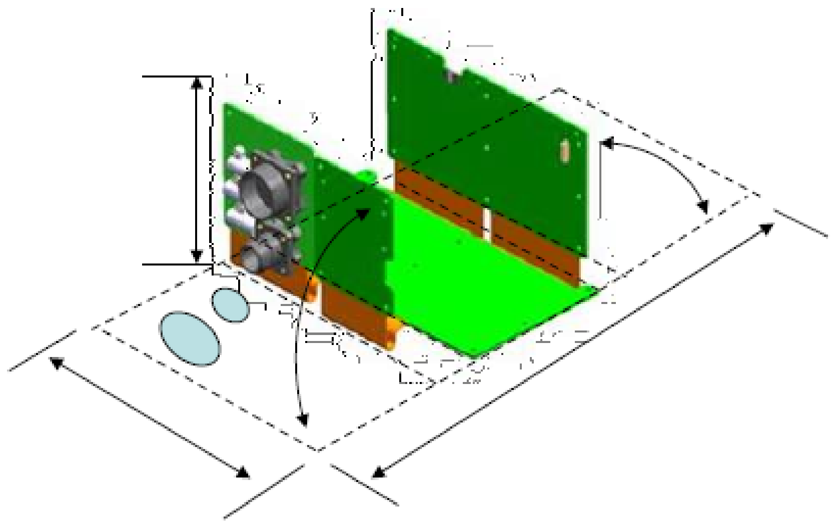
As-Installed: Still 90°

As-Installed: 180°

Design Activity: Flat “2D” Un-stretched Layout
Fabricator: Calculate Staggered Flex Length & Tool for Fold Direction

MECHANICAL LAYOUT

Drawing "ISO" or other views must describe bend or fold direction for bookbinder designs.

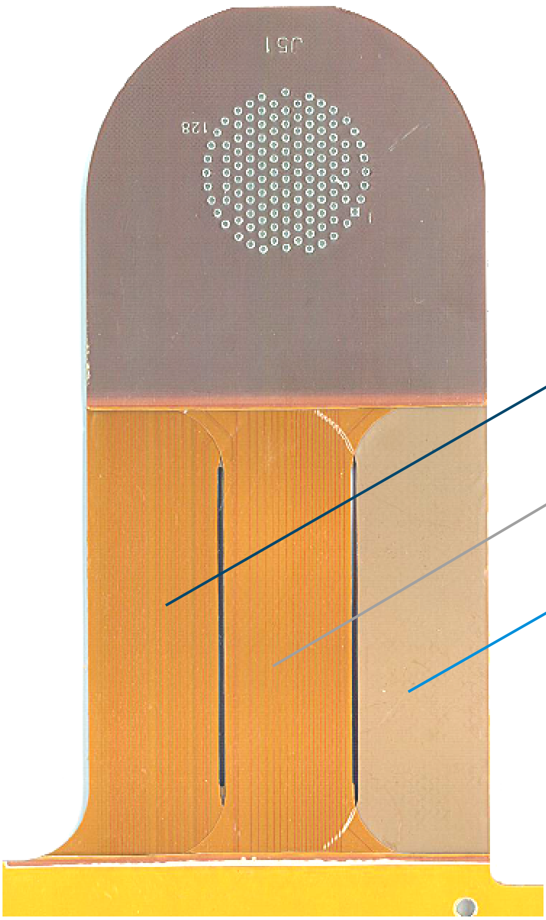


Both flex areas will be "hump down" or longer flex lengths on bottom side

COST AVOIDANCE STRATEGIES: BOOKBINDER ALTERNATIVE

Raytheon

Submission to IPC-2223



Reduce layers in bend areas by distributing layer routs into segregated sections

Layers 2/3 & 4/5

Layers 6/7 & 8/9

Layers 10/11 & 12/13

12 layers are routed through a flex area, but have the flexibility of only (2) double-sided flex layers

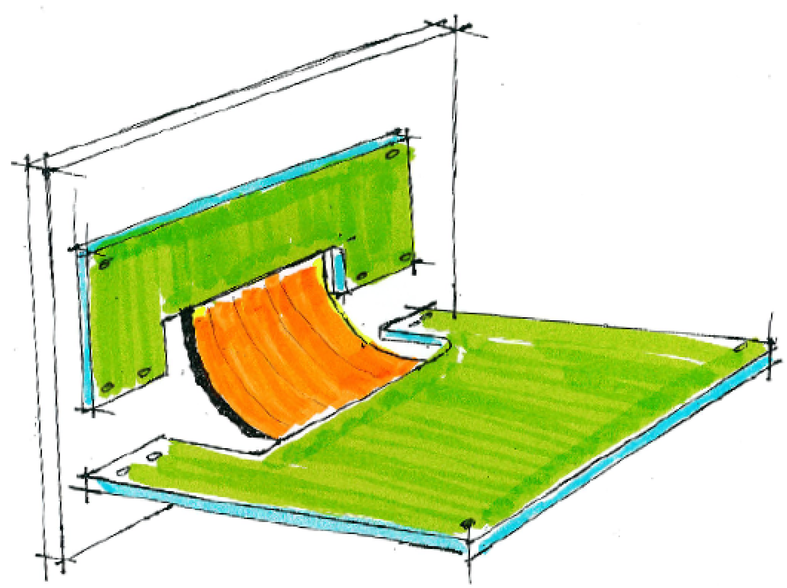
RIGID-FLEX PROFILE: OUTLINE CONSIDERATIONS

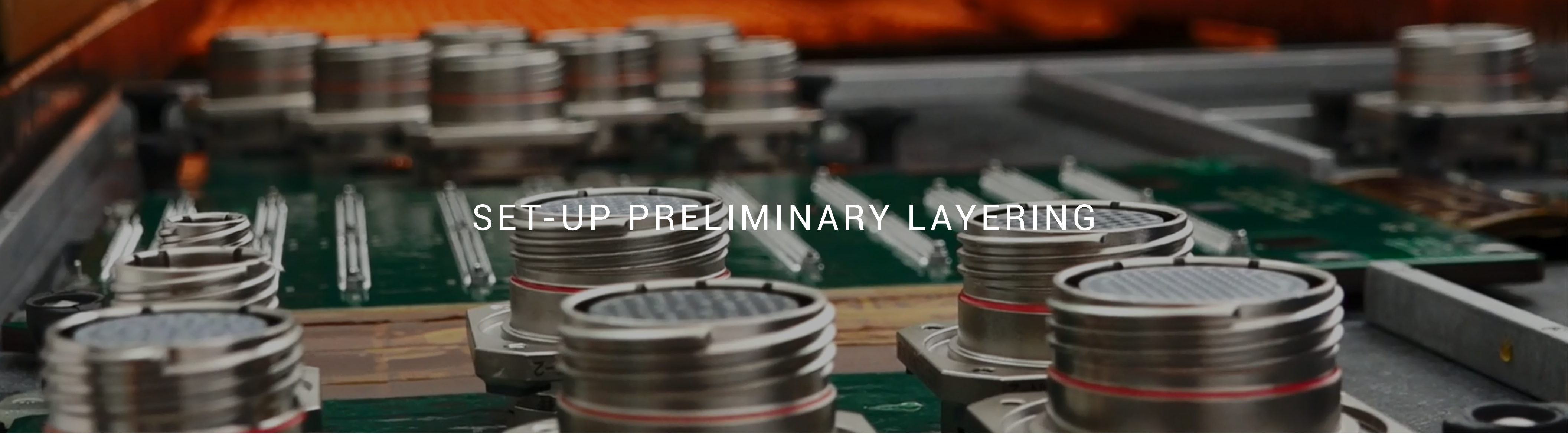
•Chassis / Box Location: Initiation of flex bend area

•Flex to Rigid: Flex edge to rigid edge mini mums (.125" Min. Preferred)

•No Rigid "Islands"

•May need to add Clearance Holes (NPTH .300" dia. in rigid) in flex areas of long flex (>10") to rigid area for internal tooling





SET-UP PRELIMINARY LAYERING

•Determine Controlled Impedance Requirements

•Stripline / Micro-strip, Reference Planes

•Rigid / Flex Sections

•Power vs Signal Requirements (Determine Current Requirements)

•Shielding Requirements

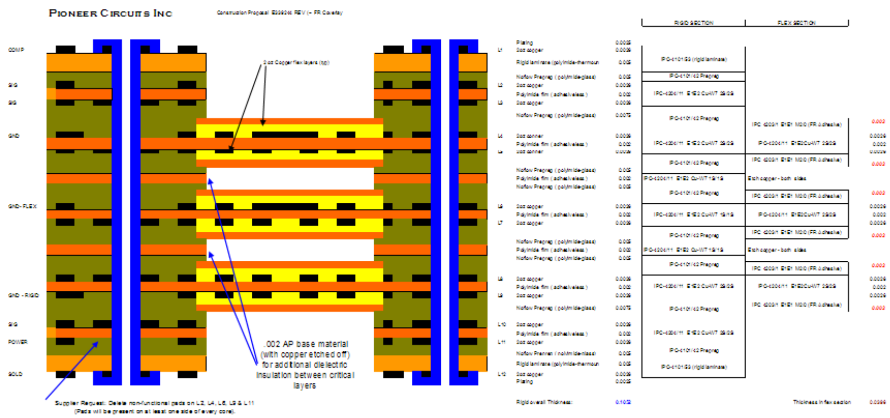
•Copper Weights

•Line & Space Rules

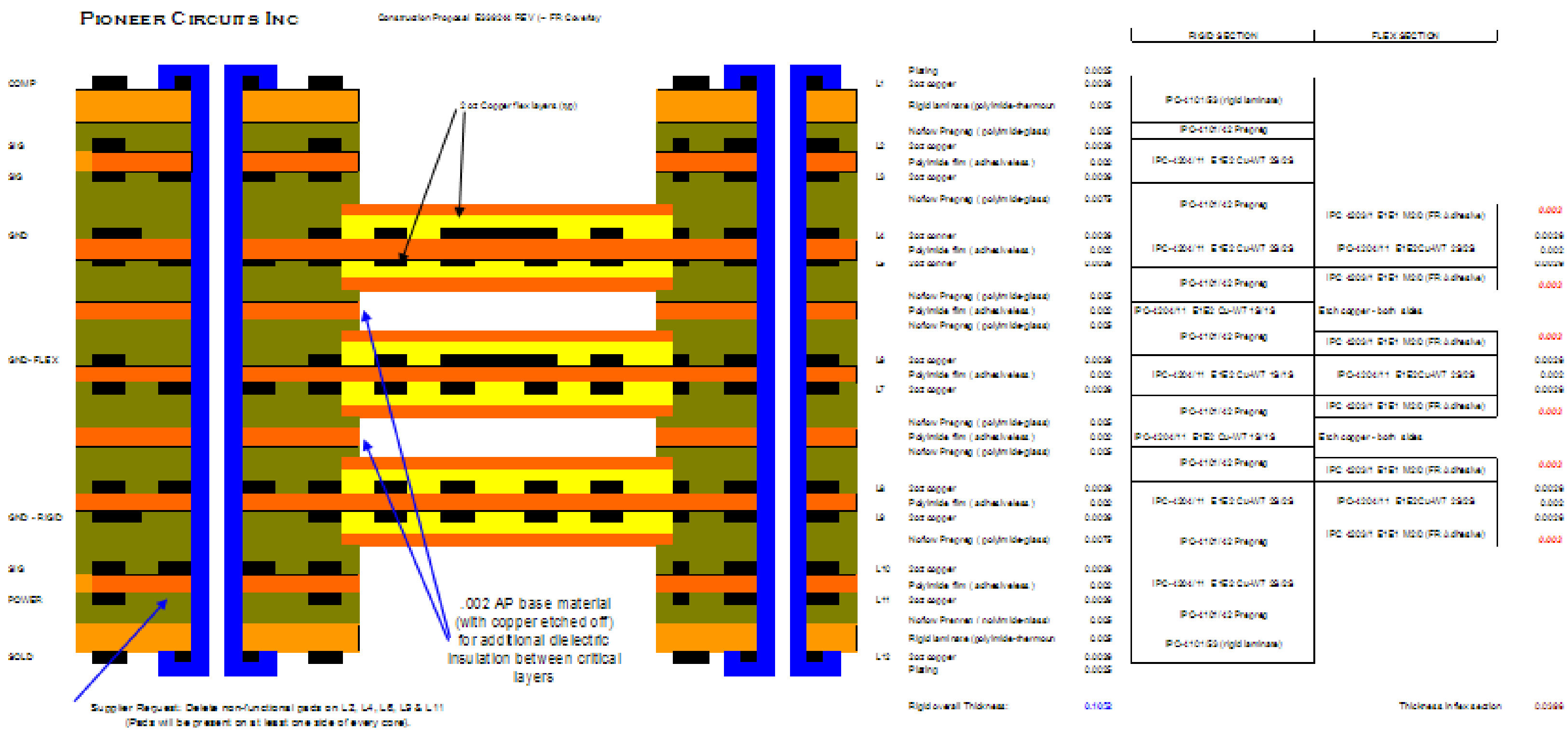
•Review Constricted Area Profiles (May add to Layer Count)

•Need A Mechanical Mock-Up?

•Evaluate Bend R for Flex Thickness Rules



SET-UP PRELIMINARY LAYERING



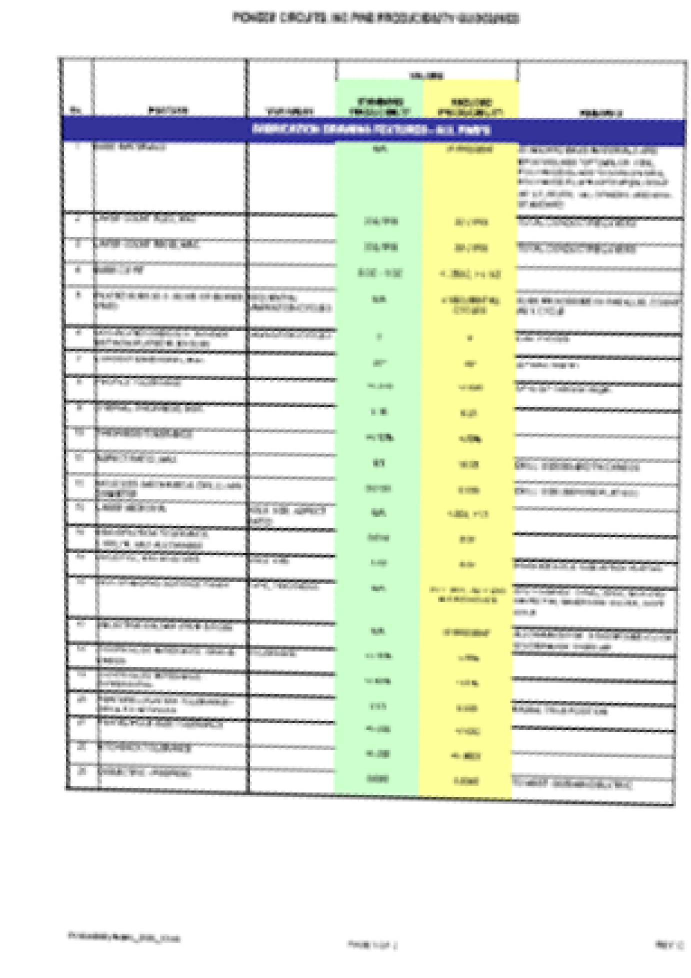
Avoid “1/2” Rigid Cap Construction

Use Single –sided outer layers

All single-sided layers used double sided laminate with copper etchoff from one side.

CONDUCTOR ROUTING

- •Avoid Stress Risers
    - •Use Nested Radii / Avoid Angular Transitions
- •Rout Flex Lines Perpendicular to Bend Axis
    - •Avoid I-Beam Layout on Double-Sided Flex
- •Electrical Considerations
- •Emi / Isolation Shielding Methods:
    - •X-Hatch
    - •Silver Epoxy
    - •Full Copper / Stitched Vias
- •Use “Best Practice” Producibility Data from Supply Base
    - •Design for Manufacturability
    - •Design for Test
    - •Design for Assembly

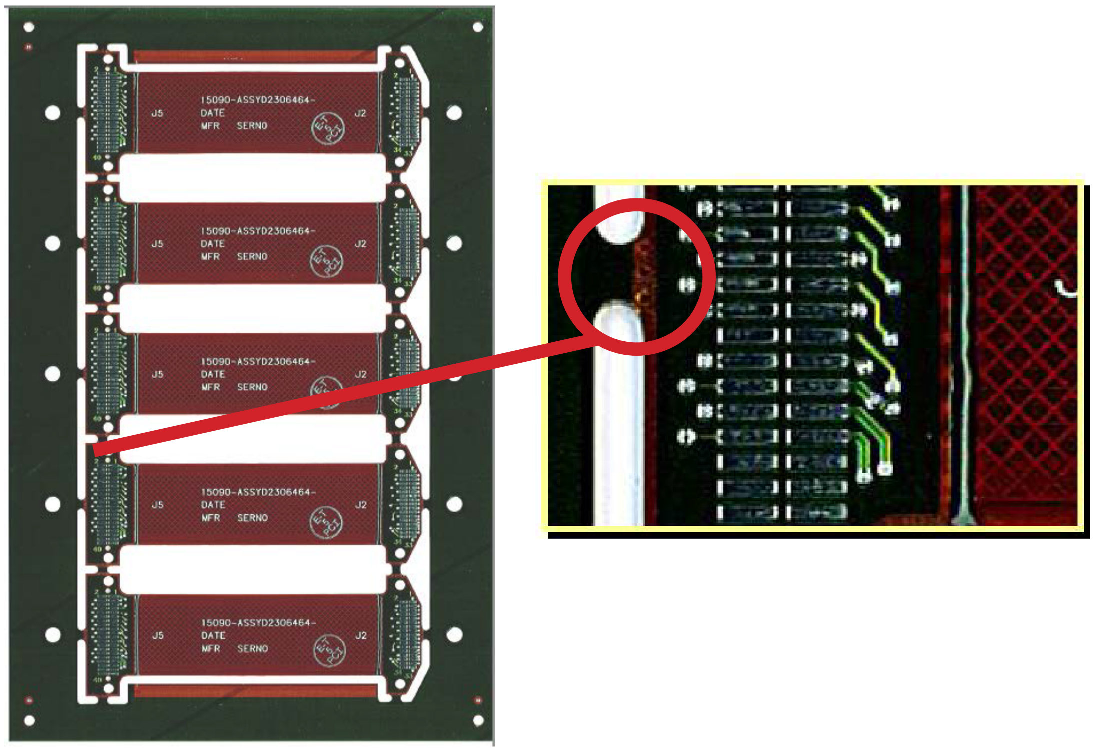


COST DRIVERS: GUIDELINES

- It's About Panel Size, Layer Count & Producibility:
- Cost Will Increase If Part Not Conducive to Multi-Up Panel Size or Nested Parts
- Avoid Crossing Flex Legs
- Sequential Laminations
    - Different Thickness In Rigid Sections (Avoid)
    - Surface Micro-vias
    - Buried Micro-vias
- Keep Every Layer Present in the Rigid Area - Even If Not Used
    - (Keep the Same Thickness)
    - Remove Flex "Dead Legs" (Flex Regions with No Conductors on Flex Layers)
- Multiple / Selective Surface Finishes (HASL is Standard)
- Loose Leaf (2 sided flex) > Bonded Flex > Bookbinder
- Review Suppliers Producibility / Capability Data
    - Hole to Pad, Line Width, Etc.

ASSEMBLY: FLEX PRACTICES

Parts supplied in a array with “break-away” tabs and mouse bite holes.



These small holes located at the array tabs work fine to “singulate” rigid boards after assembly but can damage flex parts if the array is twisted or bent to remove the single flex. Unlike rigid boards, rigid flex parts contain flex film layers that will not crack when bent, but could cause delamination. These tabs should be removed by routing or methods other than bending the array.