Designing Around Orthogonal Direct

06/04/2014

Silicon Valley / Texas / Boston / China

Acorn Product Development

- Silicon Valley, Boston, Texas, and China
  - 40 Employees
- Comprehensive product engineering for leading companies globally.
  - Server and Chassis Design
  - Consumer Products
  - Robotics
  - Medical Devices







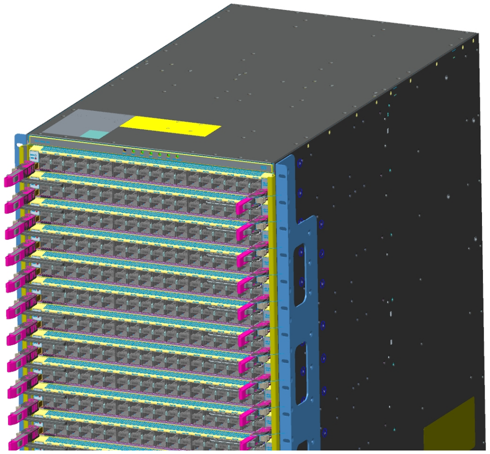
Acorn Product Development

- Areas of expertise:
    - Turnkey product development,
    - Engineering analysis,
    - Materials cost analysis,
    - and DFMA
- Robust designs that are fast to market

Overview

- Case study of high speed router product
- Design Goals
  - 4Sigma connector mating and gathering
  - Meet High Speed Signal requirements
  - Meet Thermal requirements
  - Low cost system
  - Thousands of units produced

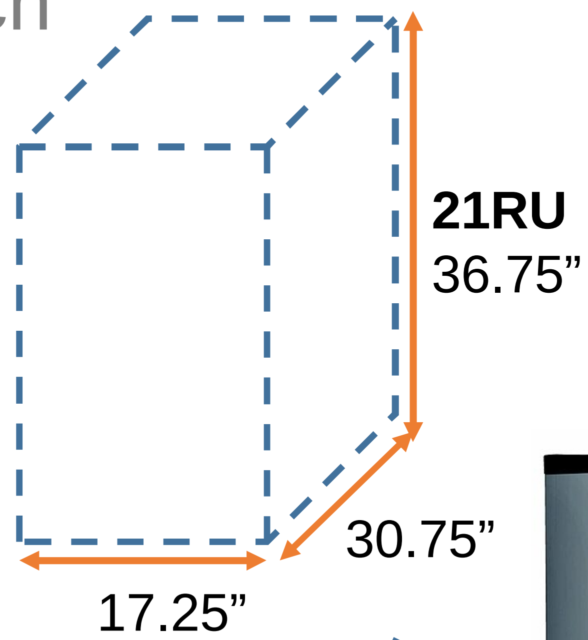
- Topics of Discussion
  - Design for Assembly
  - Design driven by tolerance analysis
  - Design for Manufacturability and cost

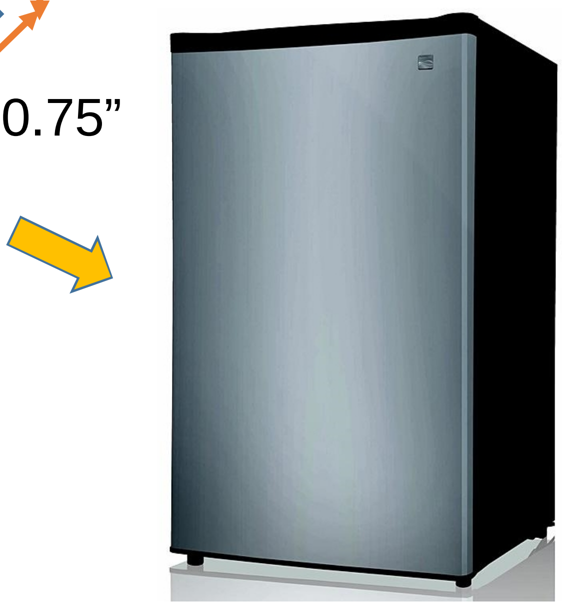


Case Study – High Speed Switch

Design Details

- Cloud Computing
  - Software Defined Networking, SDN
  - Development Operations, DevOps
- Potential Customers
  - Facebook, Google, etc.

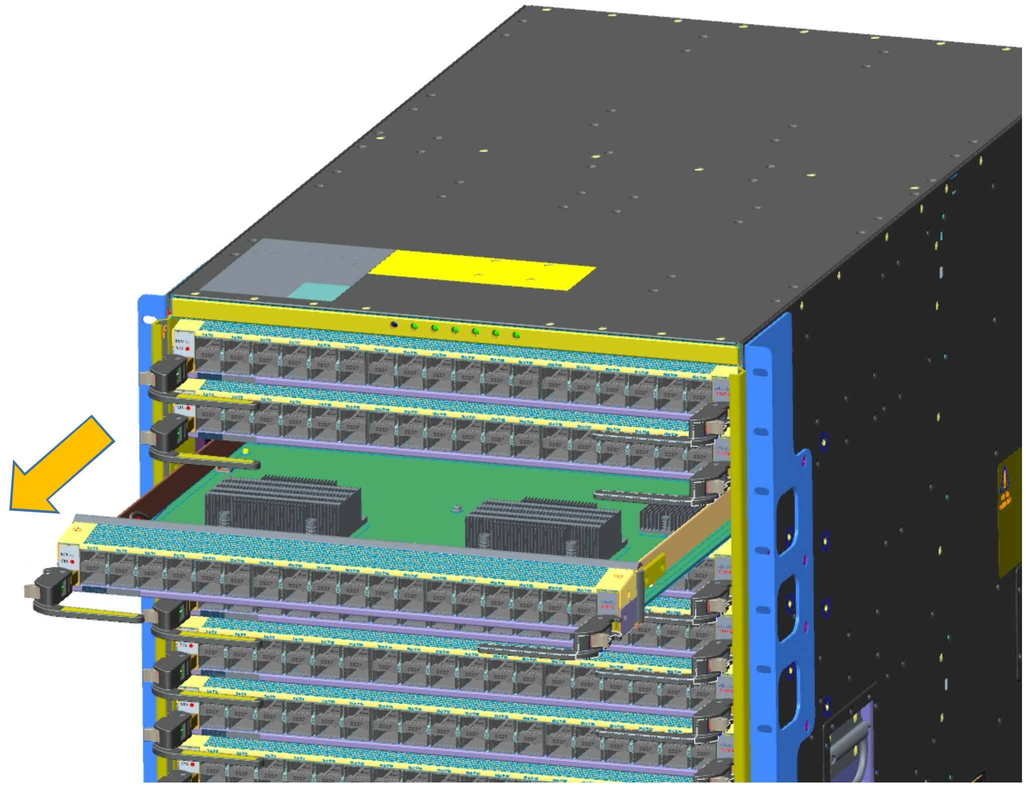




Case Study – High Speed Switch

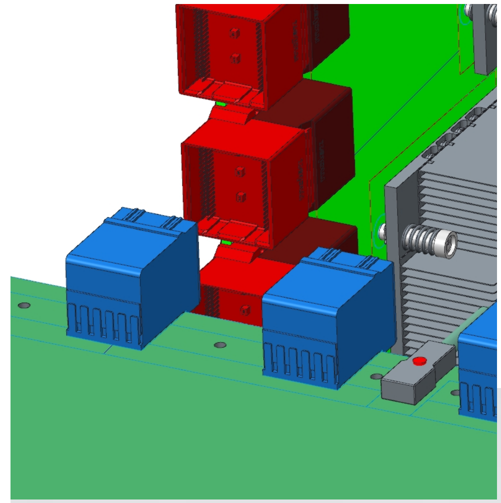
- Highly modular chassis
- Thermal Performance
  - Fully loaded system up to 25kW
  - 55C Inlet Temperature
- Module alignment and communication regardless of chassis configuration
- High speed connections, 100Gbps

- Molex Orthogonal Direct connector architecture



Molex Orthogonal Direct Architecture

- Module connectivity without backplane
  - Less connections allow for higher signal speeds
  - Improved Airflow due to lack of backplane
  - Saved highly complex Mid-plane board
    - Halved connector count
  - Introduced challenges in alignment and connector mating



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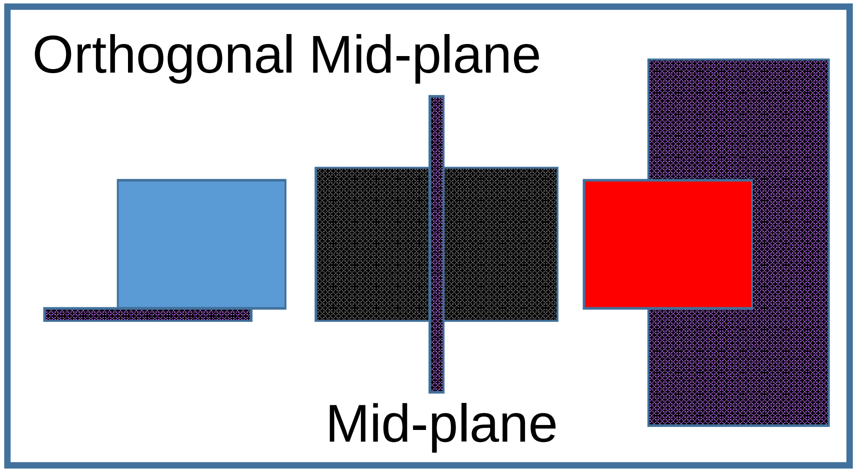
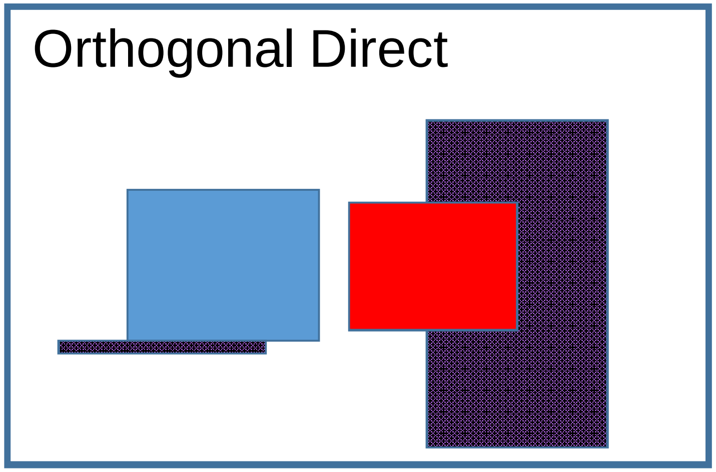




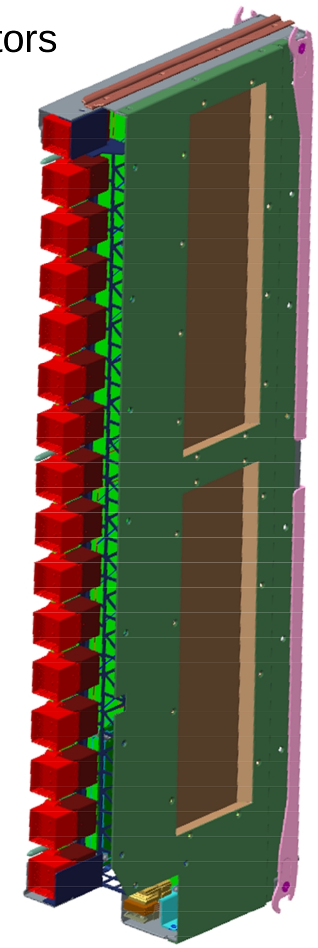
Module Overview

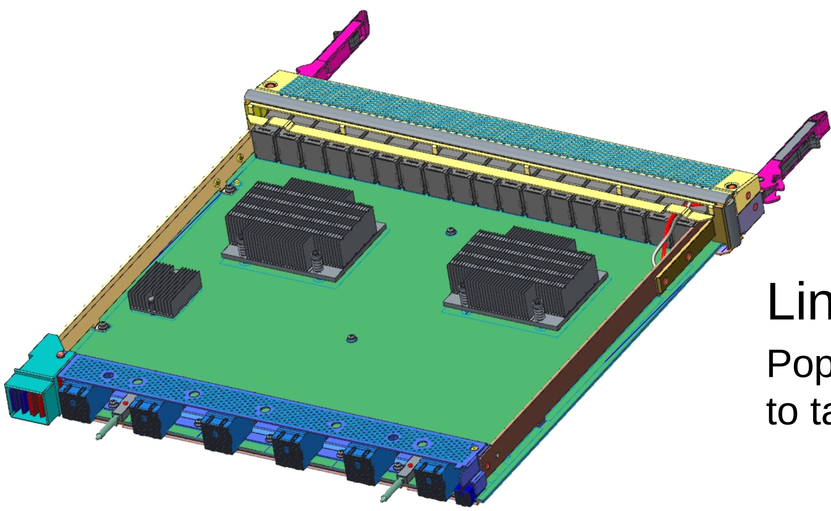
Five major module types

- **Line Card [LC]** **x 16**
- **Fabric Module [FM]** **x 6**
- Supervisor x 2
- SC x 2
- PSU x 10

Fabric Module [FM]

Populated with 16 connectors
to talk to 16 Line Cards





Line Card [LC]

Populated with 6 connectors
to talk to 6 Fabrics Modules

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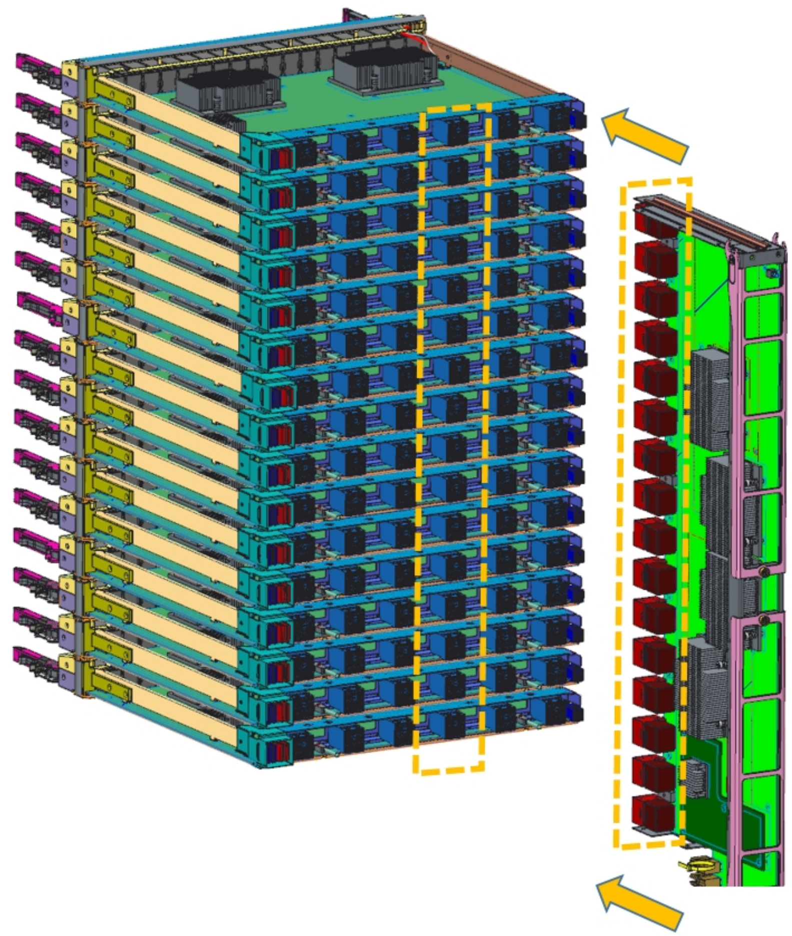
Chassis Design – Mechanical Challenges

- Module to Module connectivity
  - Connector Lead-in without binding
    - Simultaneous alignment of up to 16 modules
    - Never been done at this scale
- Structural Integrity
  - Structural analysis to ensure chassis could with stand module insertion loads
  - Force of FM into 16 LC modules ~250 lbf
- Thermal Performance
  - Densely packed electronics
- Self Fixturing Design



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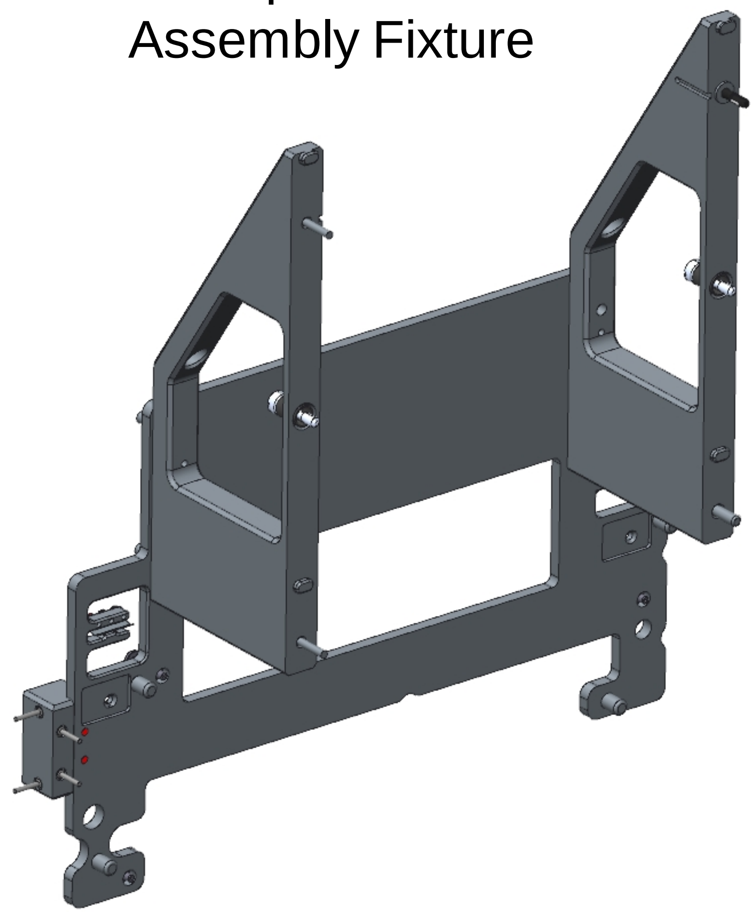
Self Fixture vs. Assembly Fixture

- Major chassis components designed to be self aligning (self fixture)
  - Ease of assembly, no extra processes
- Increased design effort
  - Definition of assembly procedure
  - Specific direction of assembly
- Original chassis assembly required no external fixtures
  - Current chassis requires one fixture

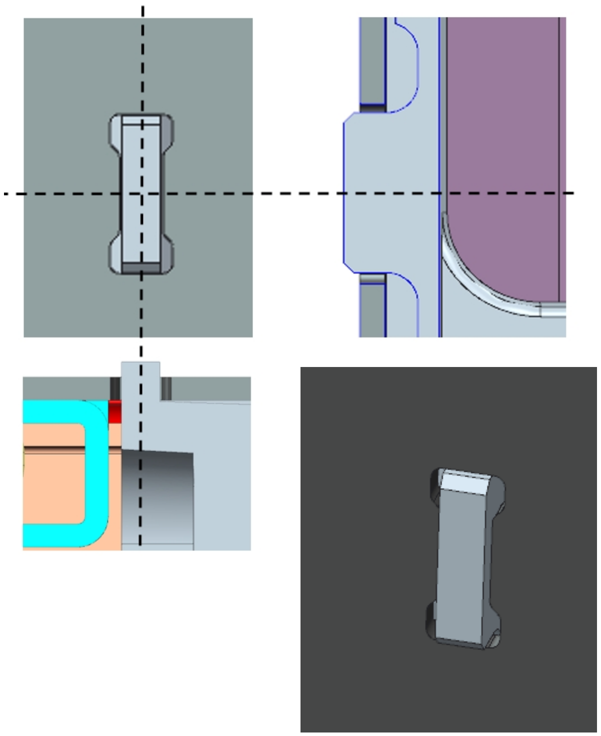
Example:
Assembly Fixture



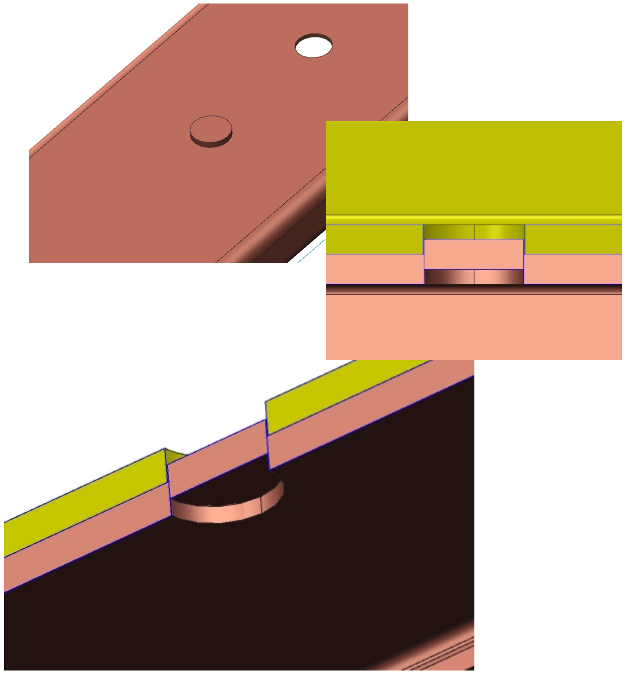
Self Fixture vs. Assembly Fixture

- Self Aligning features:

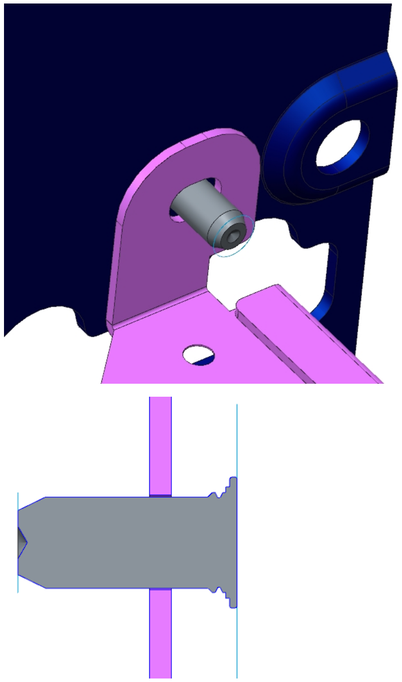
Slot and Tab



Half Shear

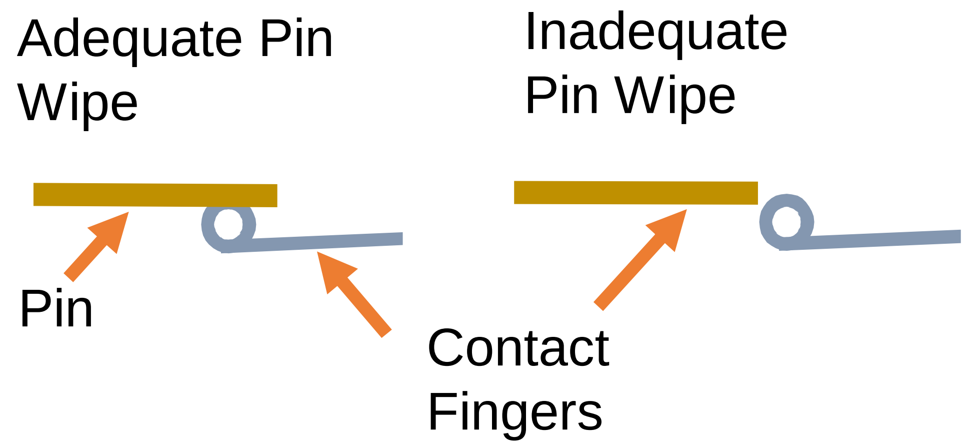


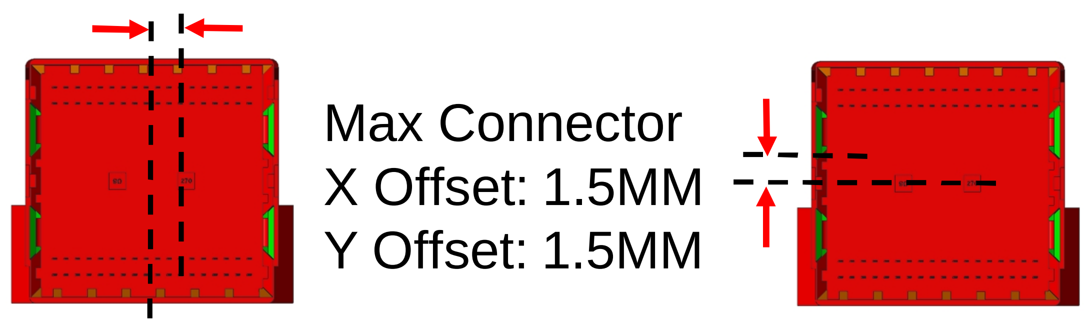
Guide Pins



Module Connectivity

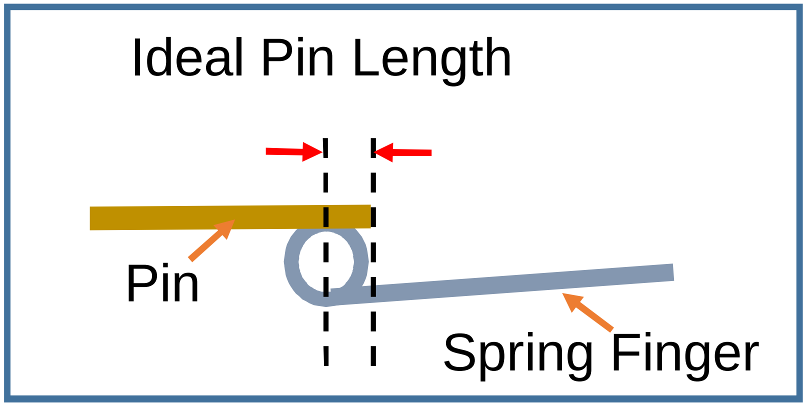
- Module Wipe
  - Mate ensures pin contact?
- Module Gathering/ Binding
  - Connector misalignment within Max Connector Offset spec
  - Are all connectors able to mate fully without interference

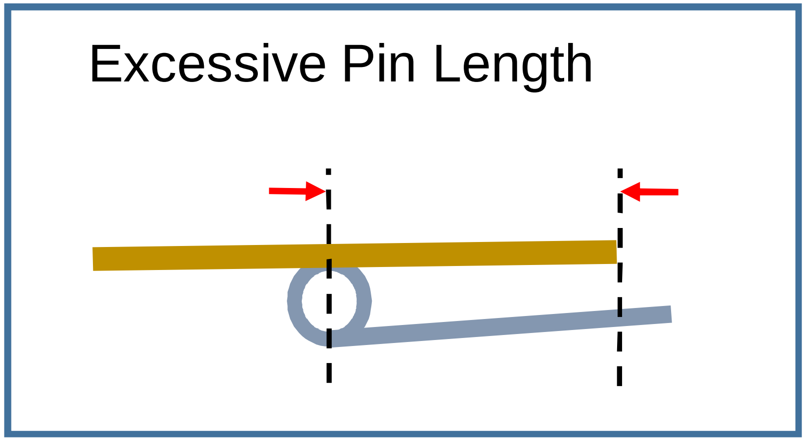




Module Connectivity - Wipe

- Design Limits
  - Shortest OD pin length of 1.42MM
    - Minimize length of pin
    - Reflections off tip of pin will create reflections interfering with signal
  - Entire 1.42MM pin length not available
    - Connectors bottom out
    - Over insertion creates excessive loading on boards
    - Ejectors might not fully close





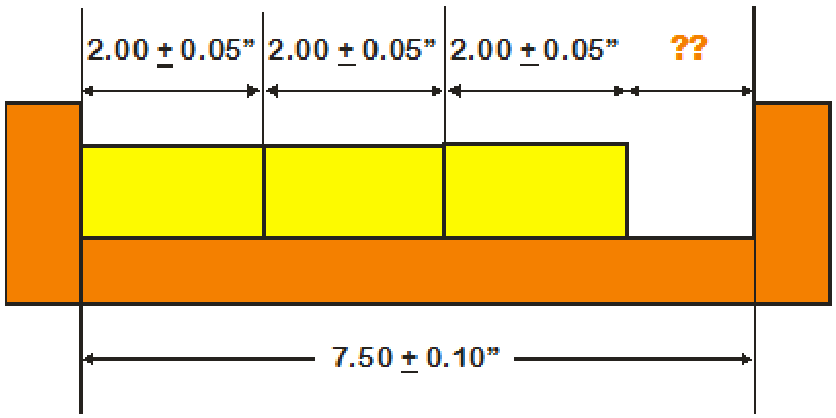
Tolerance Analysis

- Determine if assembly can meet functional quality goal
  - Tolerance values derived from supplier statistical data
- Statistical Tolerance Analysis
  - Similar to RSS Analysis
    - Accounts for process capability

RSS Equation

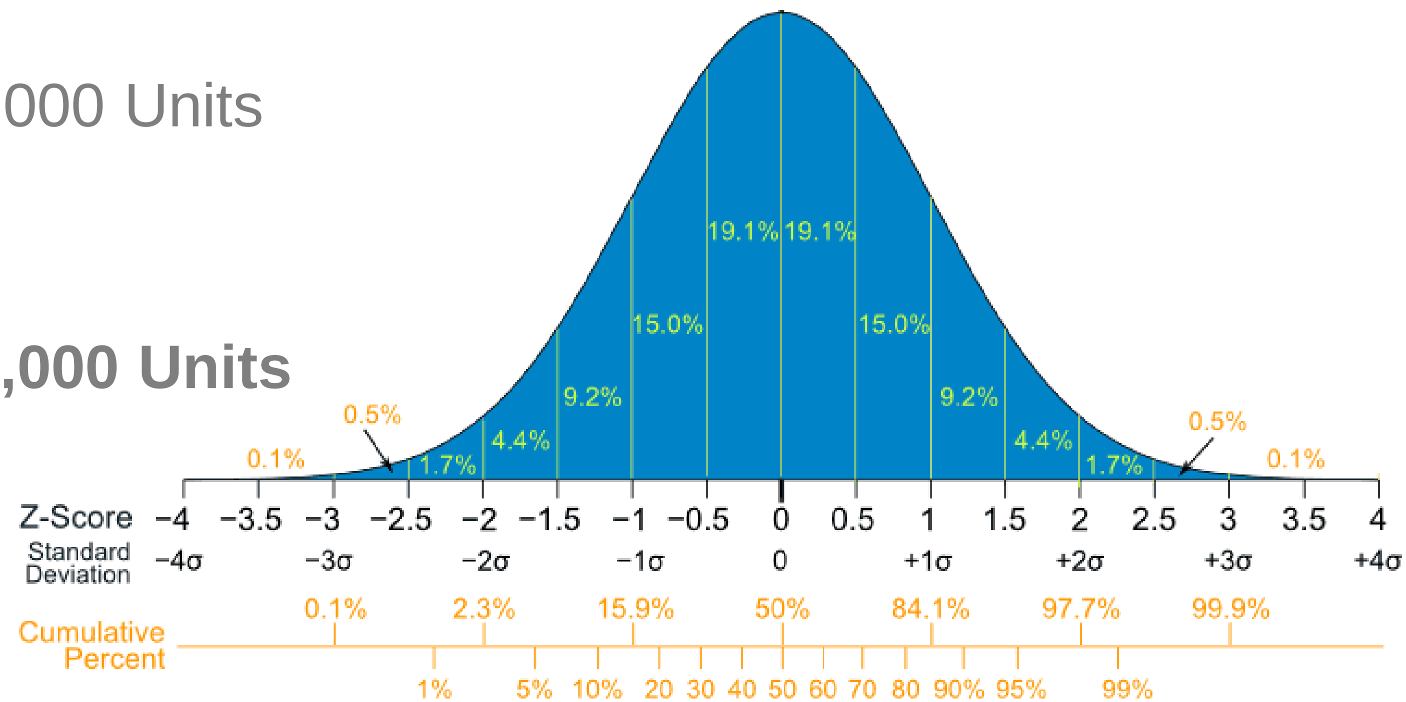
$$T_{Total} = \sqrt{(T_1{}^2 + T_1{}^2 + \cdots + T_1{}^2)}$$

Generic Tolerance Loop



Tolerance Analysis – Sigma Values

- Also known as Z Value
- Percentage of population that is within or out of spec
  - 3Sigma
    - 669 Defects/ 10,000 Units [6.7%]
  - **4Sigma**
    - **63 Defects/ 10,000 Units [0.6%]**



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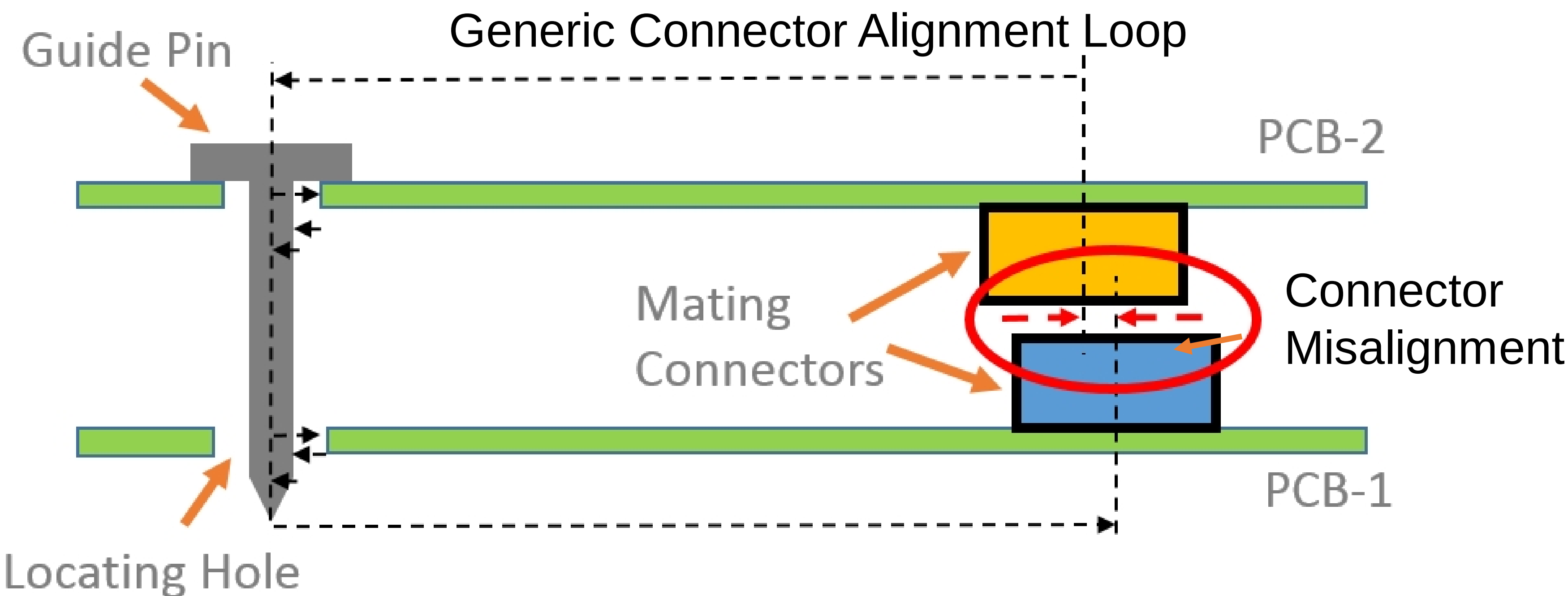
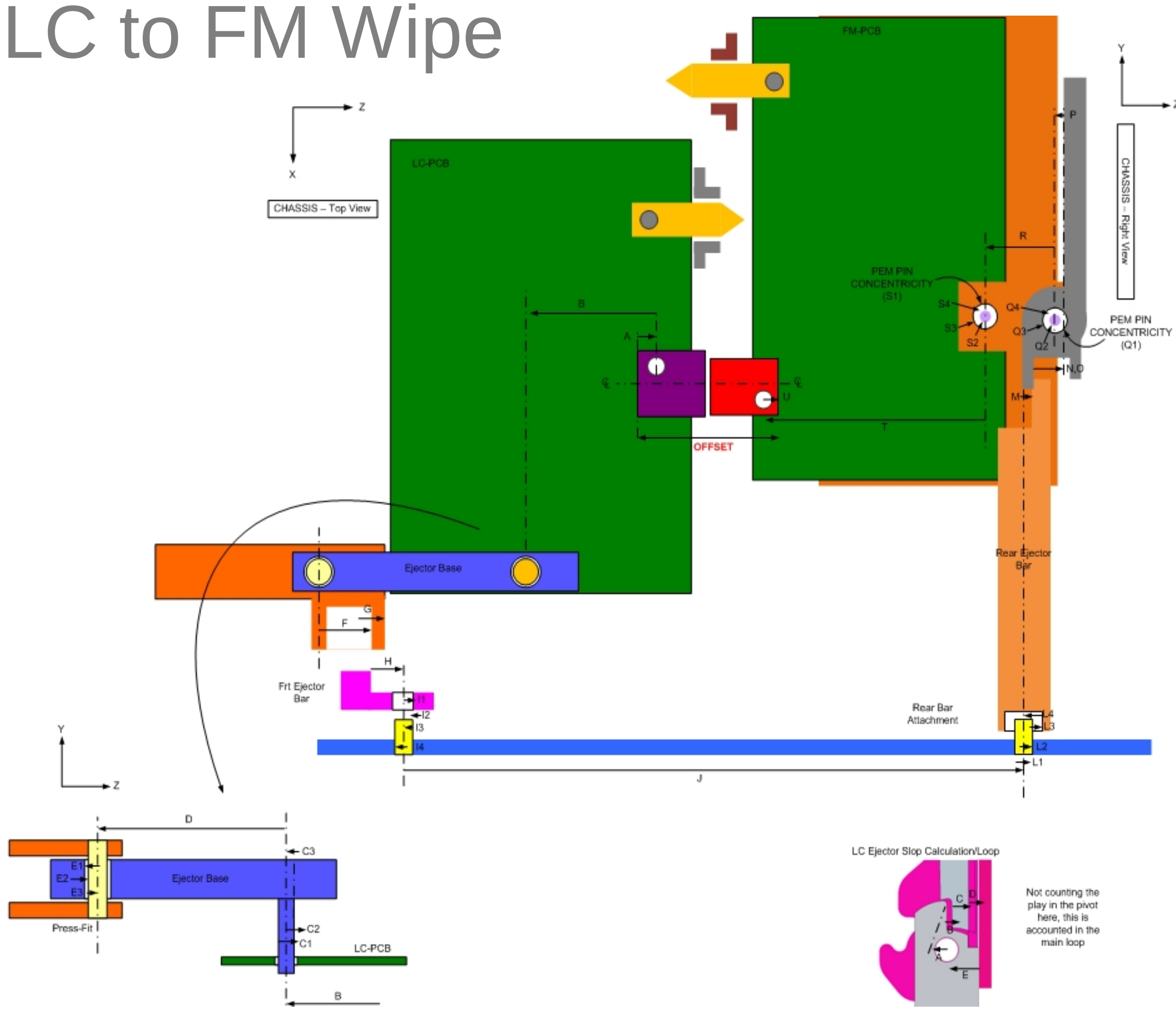
Tolerance Analysis – Where Used

- Connector Mating
- Connector Alignment
- Bus Bar Mating
- Module to Module Gap Definition
- EMI Gasket Compression
- Ejector Geometry



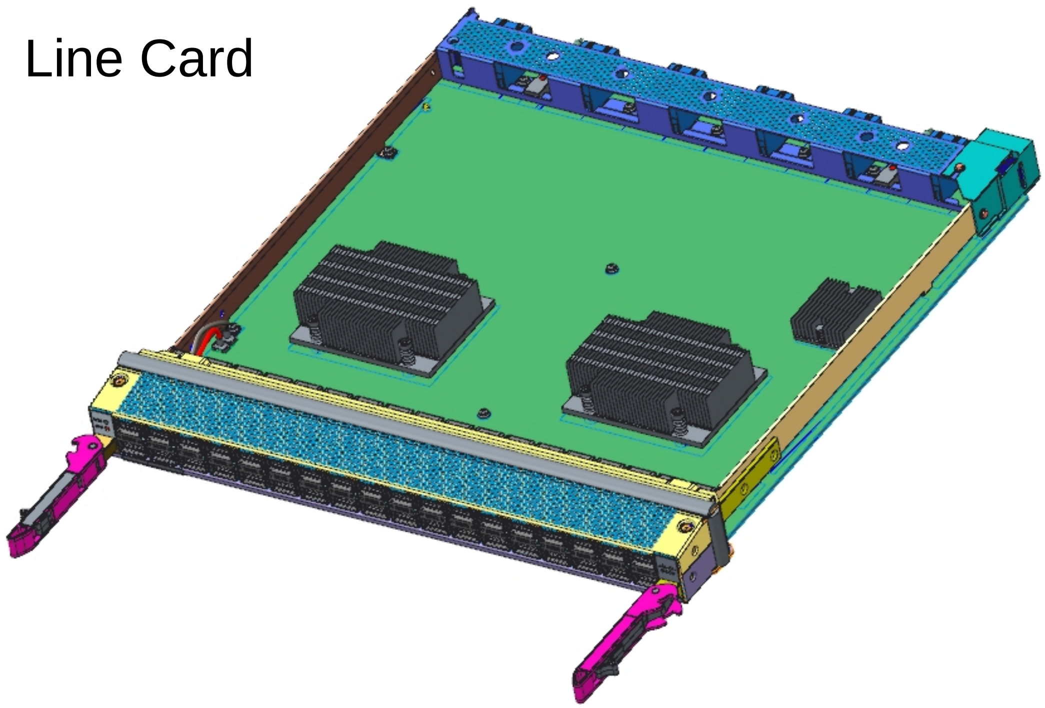
Tolerance Loop – LC to FM Wipe

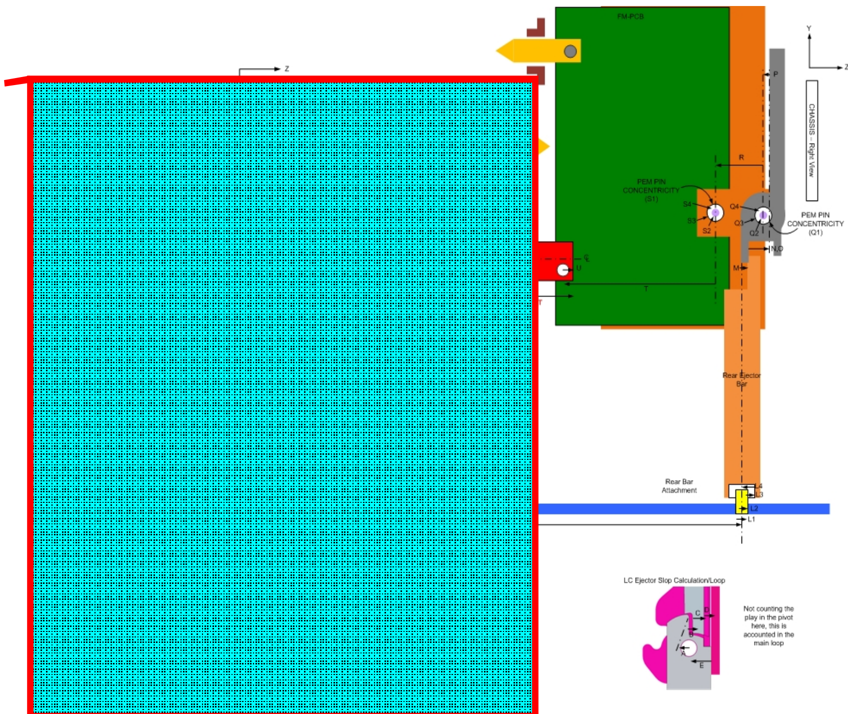
Element Name
A1 - Molex Ref Edge to Pin 1
A2 - Molex Pin to PCB - Press Fit
B1 - Conn. Row A Pin PCB Hole to Ref Hole
B2 - PCB Ref hole to Ejector PCB Hole
C1 - PCB Hole Radius
C2 - Clearance, Pressed Pin Radius to PCB
C3 - Pressed Pin Radius
D - Die-Cast Ejector Base, Boss to Bore
E1 - Die-Cast Bore Radius
E2 - Pin Clearance, Radial
E3 - Pin Radius
F - Die-Cast feature to feature
G - Slop, Ejector Lock
H - Post op Machining feature-to-hole
I1 - PEM Concentricity Tolerance
I2 - TPS Pem Pin Radius
I3- Pin to SM Clearance
I4 - Sheetmetal hole radius
J - Side Panel, Like Punch to Punch
L1 - Hole Radius, SM
L2- Pin to SM Hole Clearance
L3 - Dowel Pin Radius
L5 - Gap, Pin to CNC hole in ejector
L6 - Hole Radius, CNC
M - Machined Feature to Feature
Gap / Interference; Eject / Chassis
N - SM Feature to Feature
O - Ejector to thumbscrew face (cut to bend)
P - Tray thumbscrew face to pivot (bend to cut)
Q1 - Pivot Concentricity Tolerance
Q2 - Pivot radius
Q3 - SM Hole Radius
Q4 - Gap, radial, hole to pivot
R - SM Hole to Hole, Unlike features
S1 - PEM Concentricity Tolerance
S2 - TPS Pin Radius
S3- Gap, Pin to PCB Clearance
S4 - PCB hole radius
T1 - Conn. Row A Pin PCB Hole to Ref Hole
T2 - PCB Ref hole to Ejector PCB Hole
T3 - Molex Pin to PCB - Press Fit
U - FM-PCB Pin A Location to SC Conn Rear



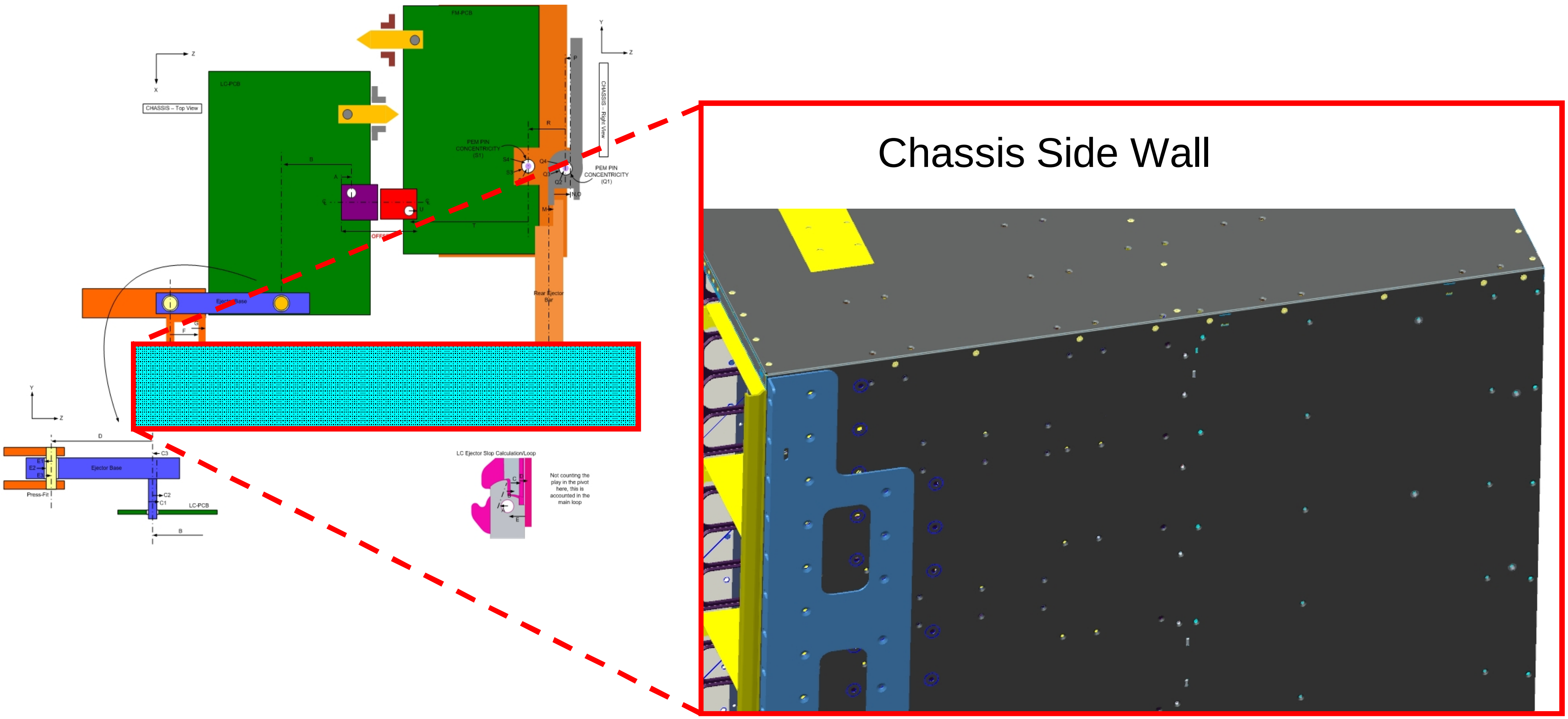
Tolerance Loop - Wipe

Line Card

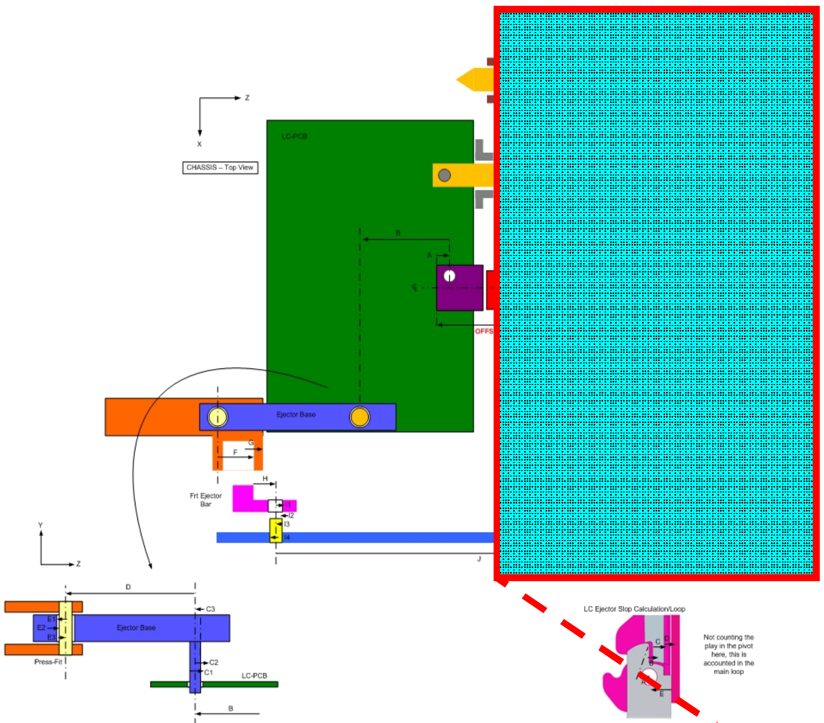




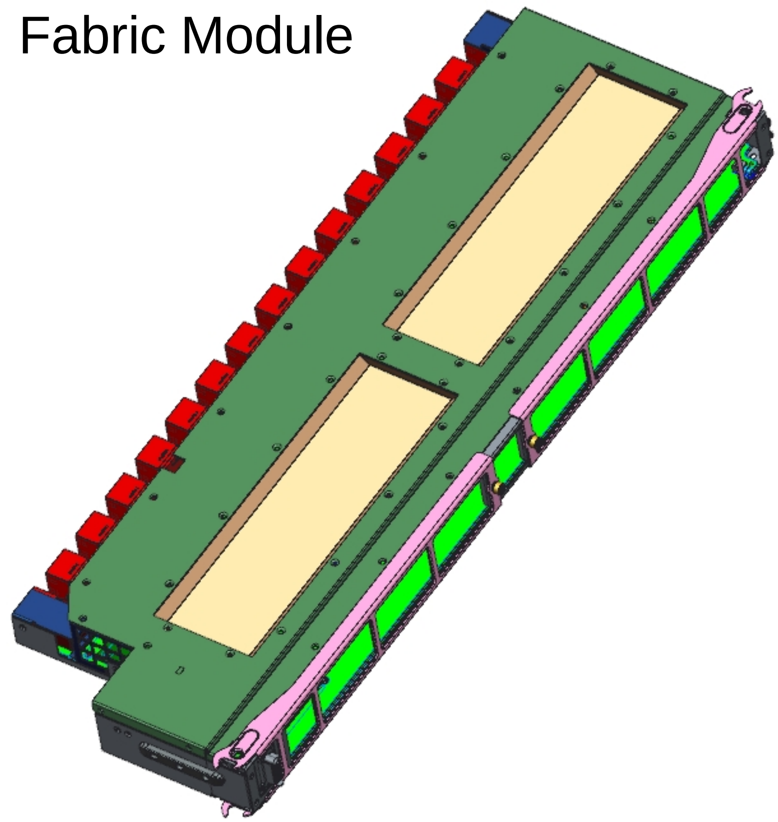
Tolerance Loop - Wipe



Tolerance Loop - Wipe

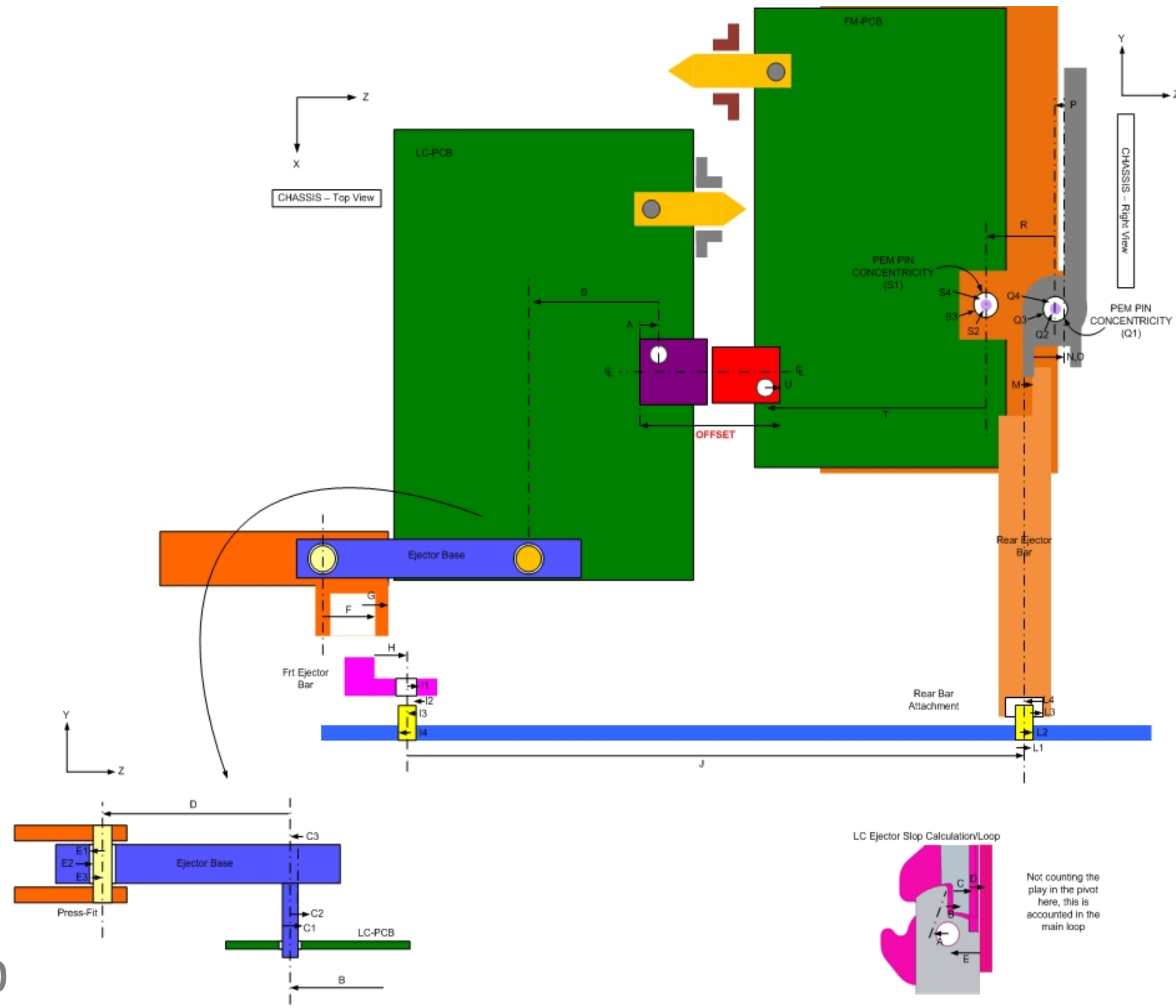


Fabric Module



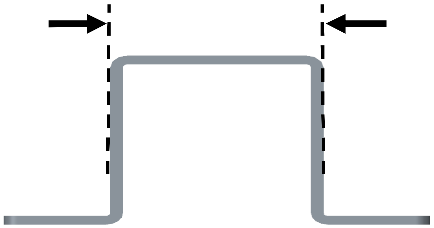
Tolerance Loop - Wipe

- LC to FM tolerance loop comprised of numerous elements:
  - Connector body tolerance
  - Connector press fit misalignment
  - PCB routing tolerance
  - Manufacturing tolerance
  - Gaps within chassis
- Goal: Minimize major contributors in tolerance loop

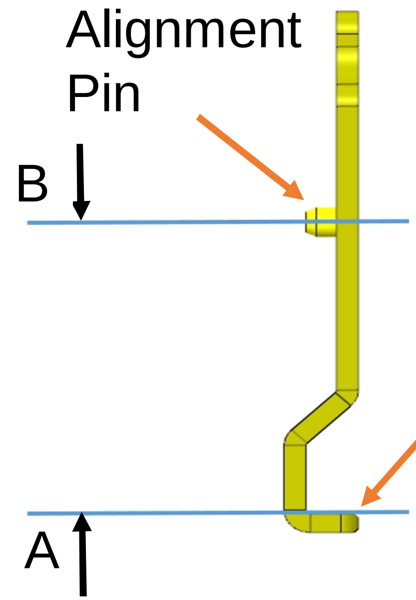


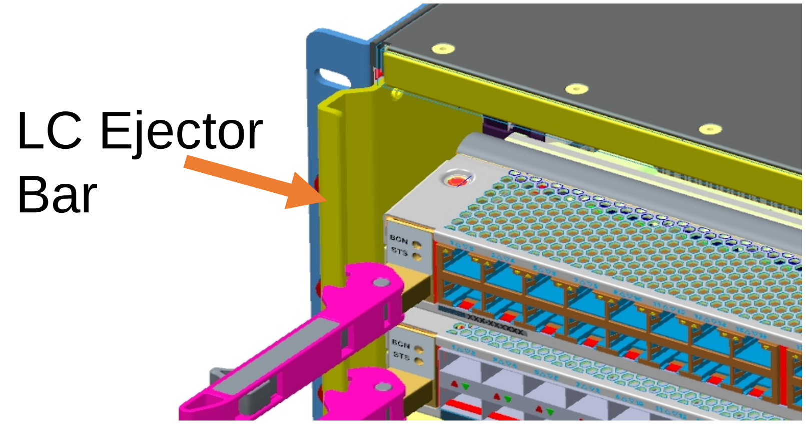
Tolerance Loop – LC Ejector Bar

- Sheetmetal construction
- Critical wipe dimension between Surface A and Centerline B
  - Passes through 3 sheet metal bends
  - Pilot hole for Guide Pin B post machined after bending using surface A as datum
- Achieved 4Sigma for OD connector wipe connectivity



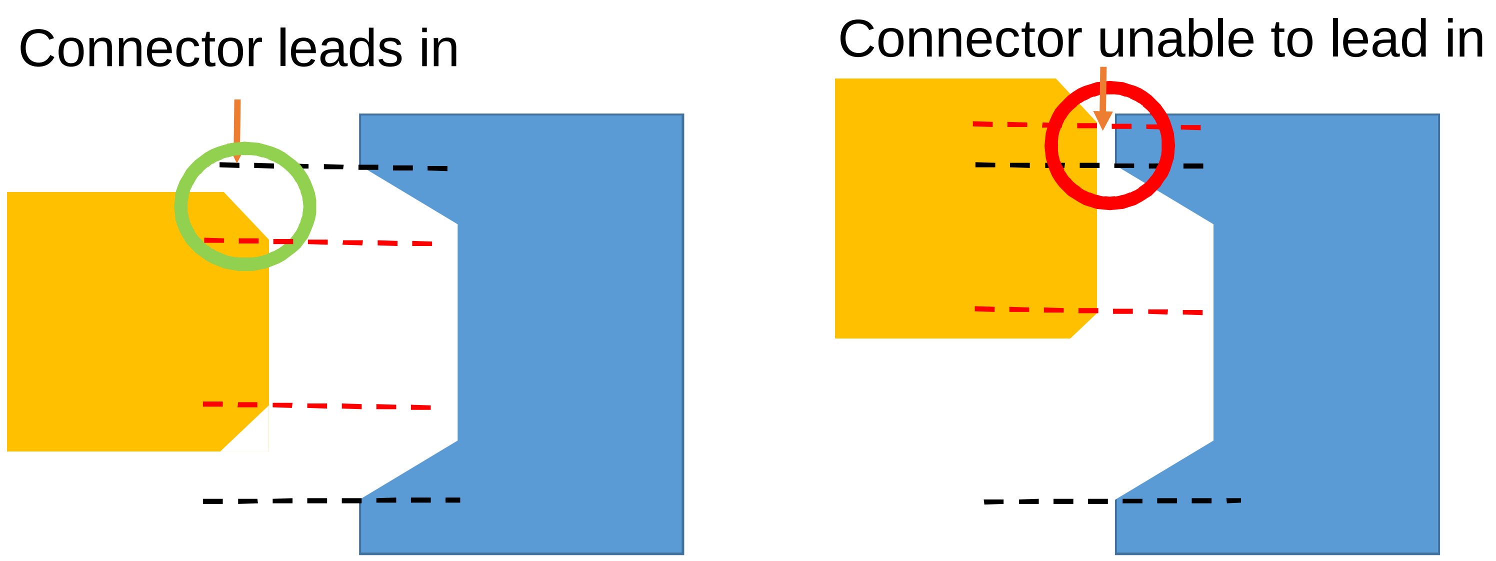
Sheetmetal
Bend to Bend
X.XX ± 0.25MM





Module Alignment - Gathering

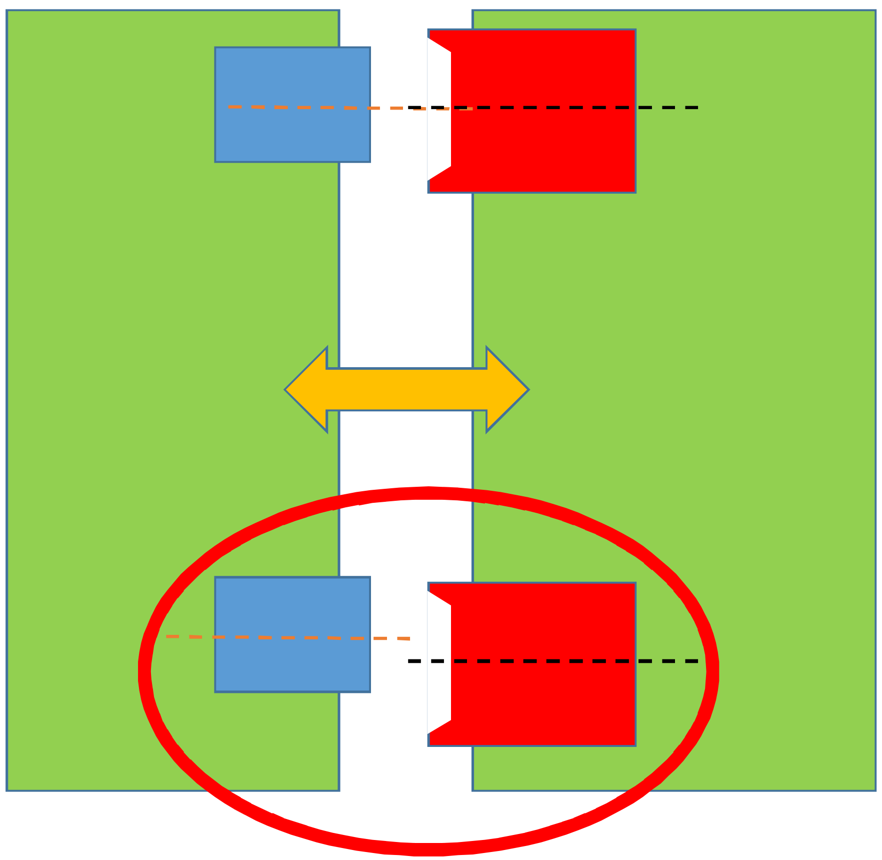
- Module Gathering
  - Can we generate enough rough alignment that the connectors will lead in?
    - Chamfered edges of connector contacts to guide connectors into alignment



Module Alignment

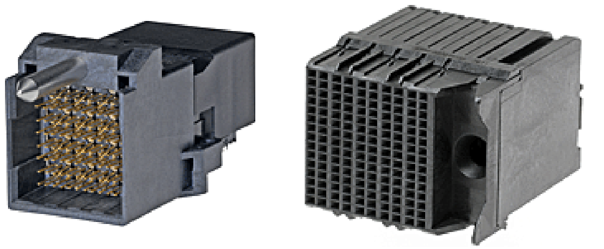
- Module Binding
  - Are all connectors able to mate fully without interference?
    - Prevents module insertion
    - Or increased insertion resistance

Connectors Aligned

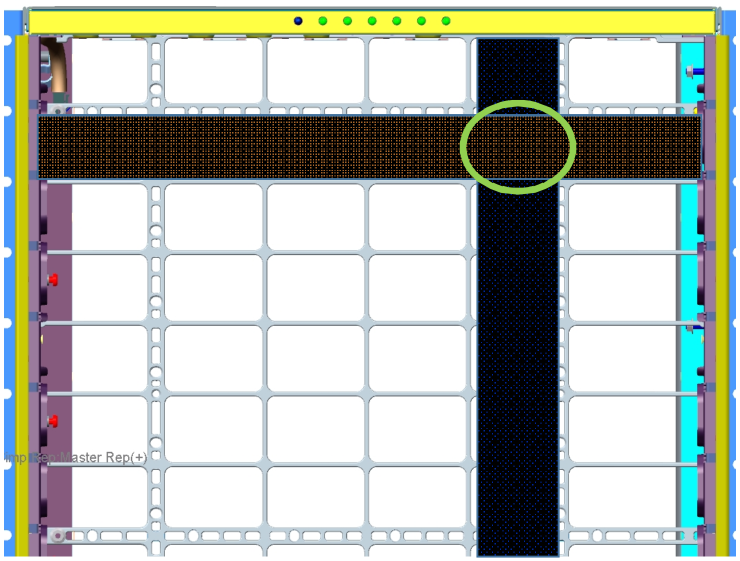


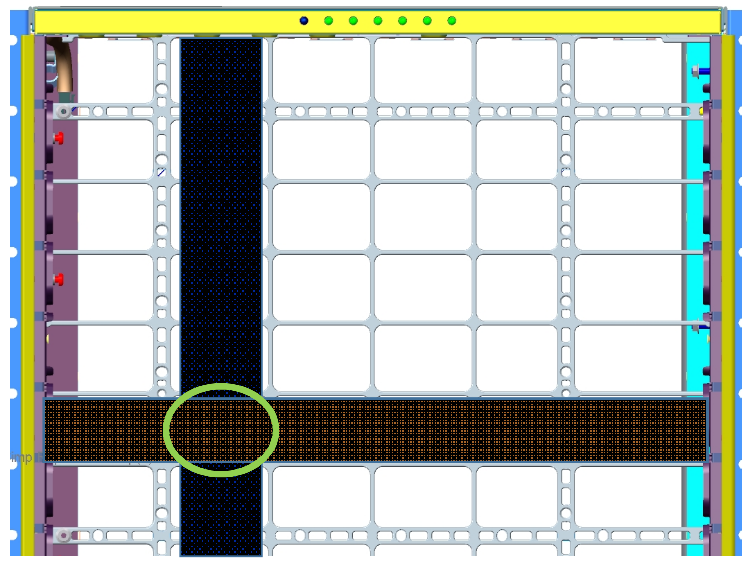
Connectors Misaligned

Tolerance Loop - Alignment



- Rough alignment for connector lead-in
  - OD connectors OTS with Guide Pin/ Shroud
    - Blocked airflow
    - Required population across all connectors
      - Extra cost

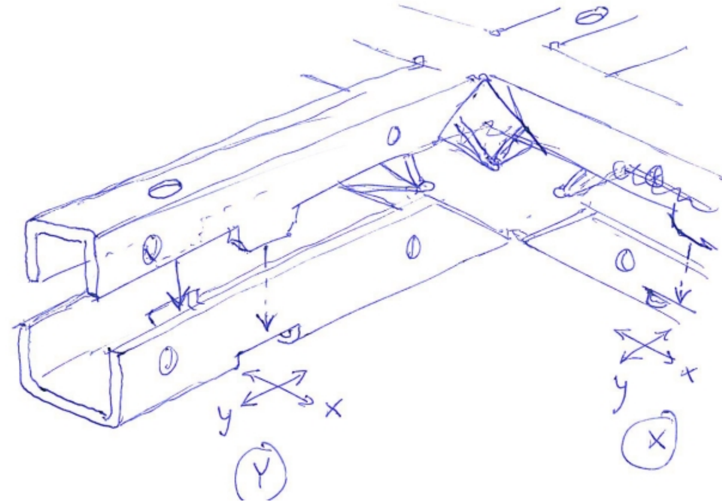


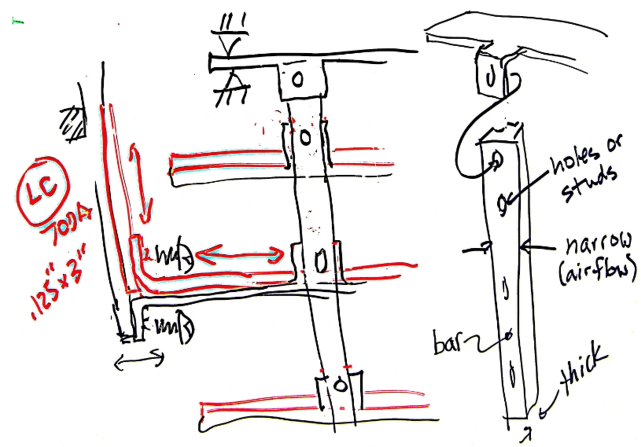


Brainstorm - Module Alignment

- Brainstorms held for module alignment
  - Suppliers, clients, and engineers directly collaborate on ideas and potential solutions to problems
  - Shotgun approach to concept generation
  - Analysis and development follows to determine which ideas are viable

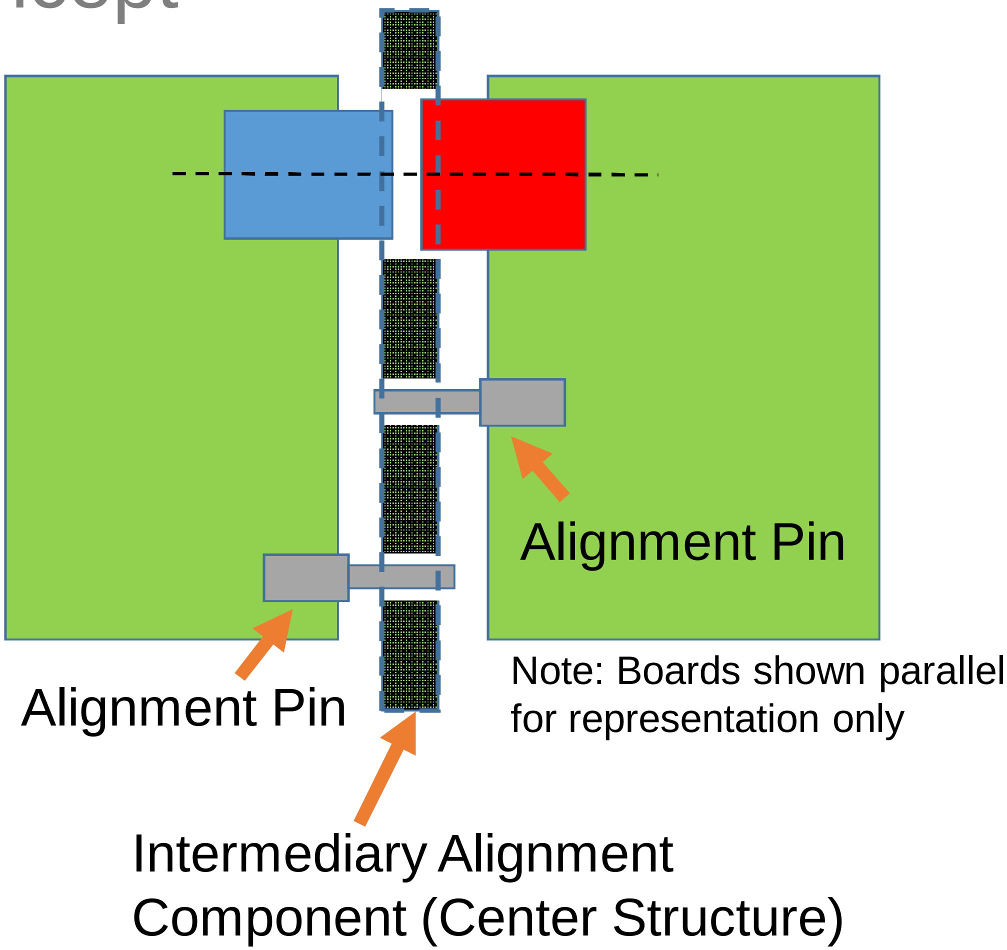
Note: Not actual representation of Acorn Brainstorm





Board to Board Alignment Concept

- Board to Board alignment scheme
  - Pre-alignment for boards rather than individual shrouds
  - Boards will align to intermediary alignment feature
  - No guide pins on connectors
- Intermediary alignment component required
  - Center Structure



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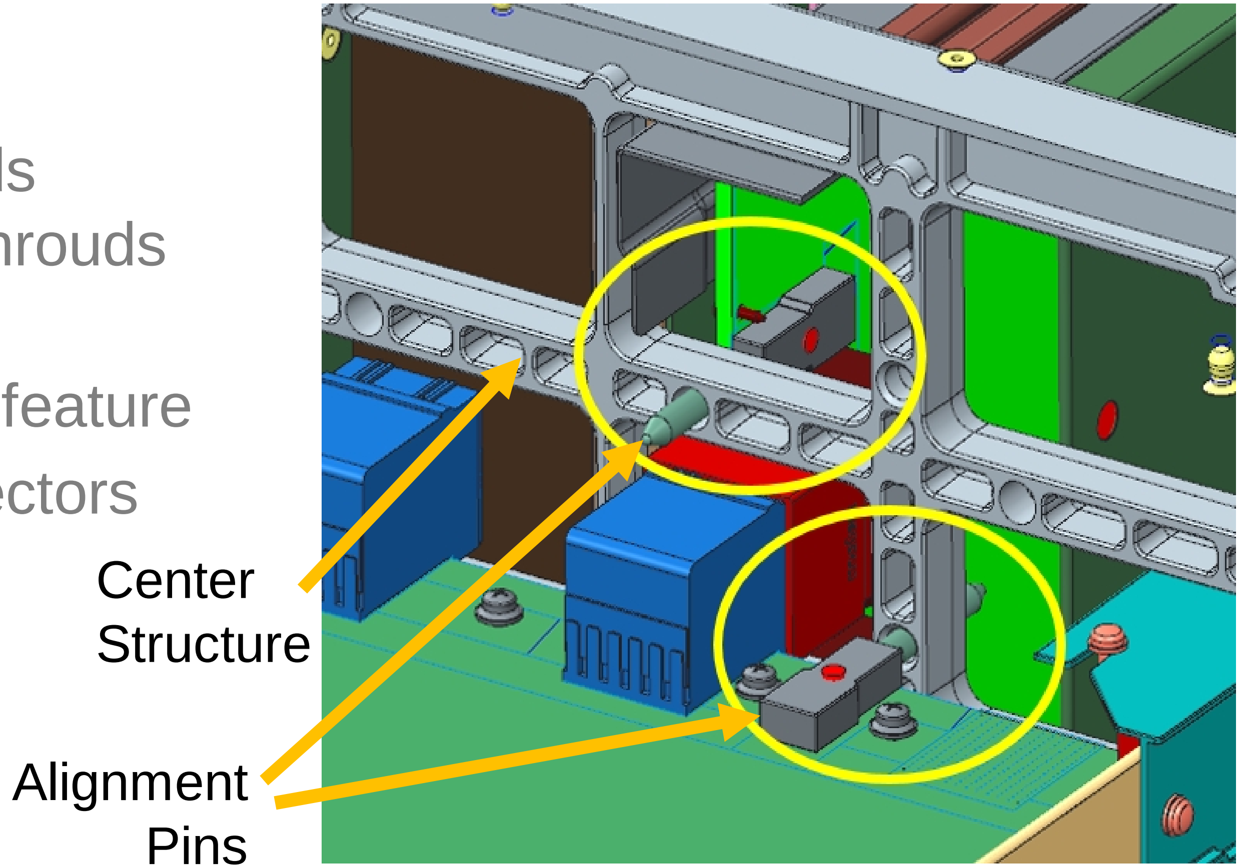
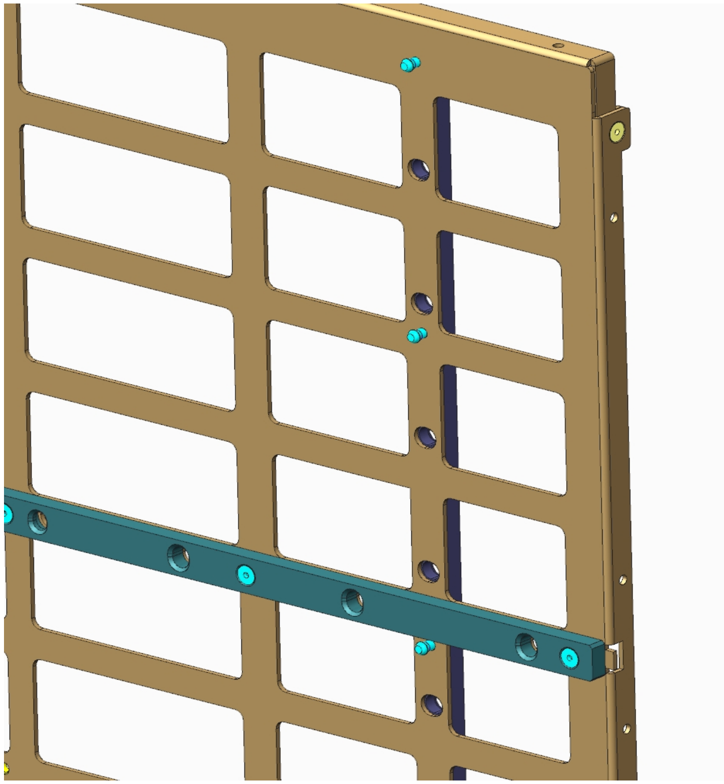


Center Structure - Construction

- Two primary concepts
  - Sheetmetal and extrusion assembly
  - Die Cast structure

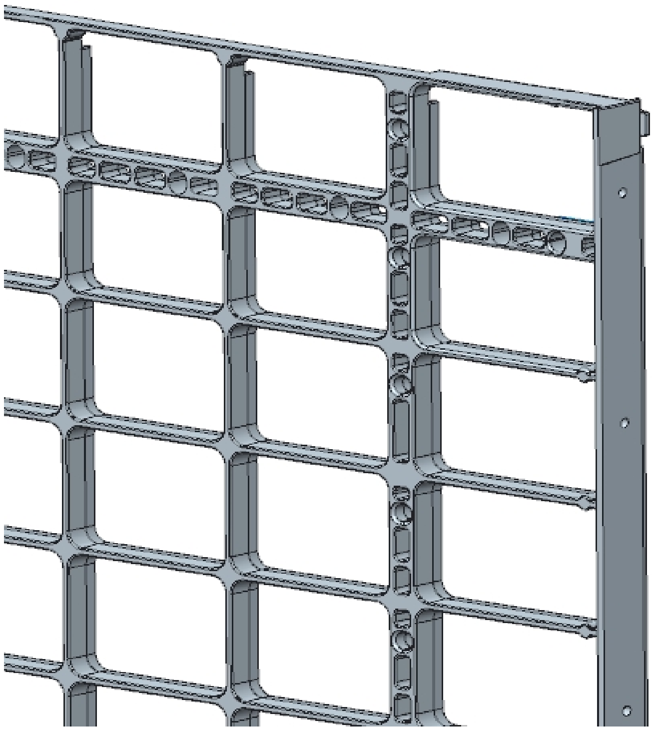
- Originally pursued sheetmetal/ extrusion concept
  - Worked for alignment
  - Difficult to assemble and align pieces
  - Didn't provide enough structure



Sheetmetal/ Extrusion Center Structure

Center Structure - Construction

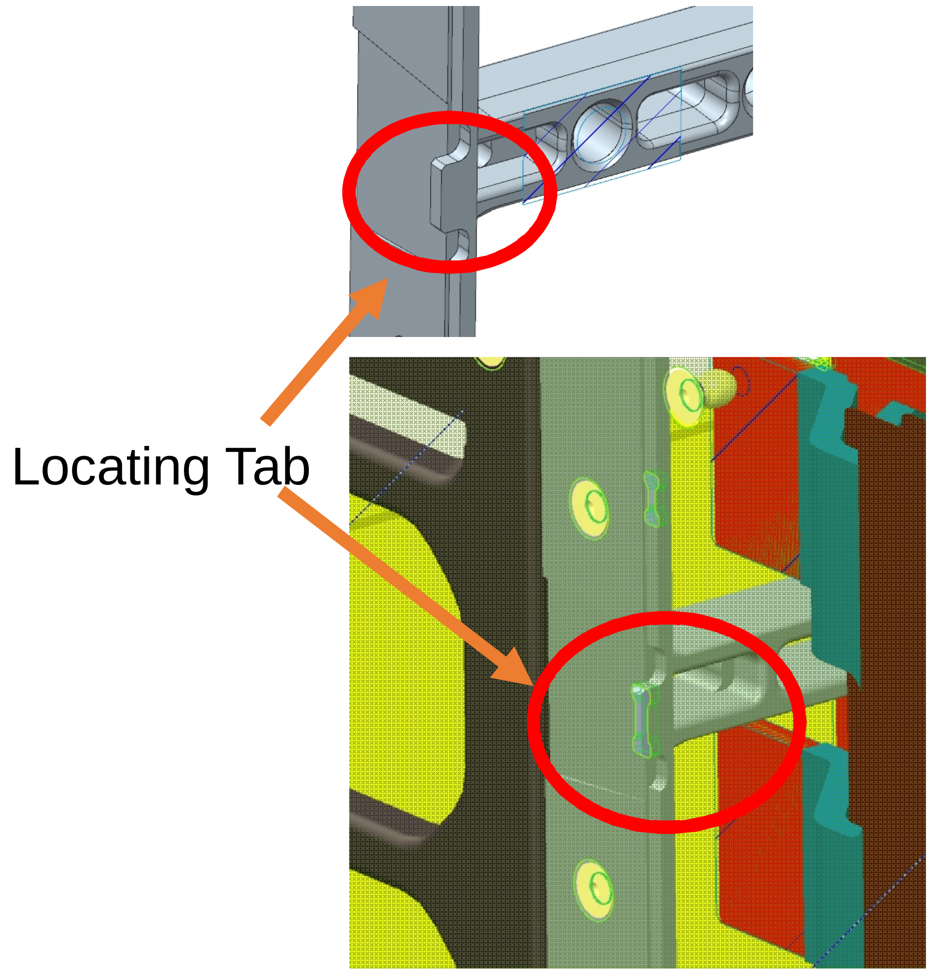
- Die Cast structure
  - Non-Critical tolerance at NADCA (North American Die Cast Association) standard
  - Crucial alignment features created using secondary machining operation
    - Machining features designed for single setup from one side
- Machined Construction temporarily implemented for initial runs and prototype
  - Long lead time for die cast tooling
  - Expensive tooling cost



Die Cast
Center Structure

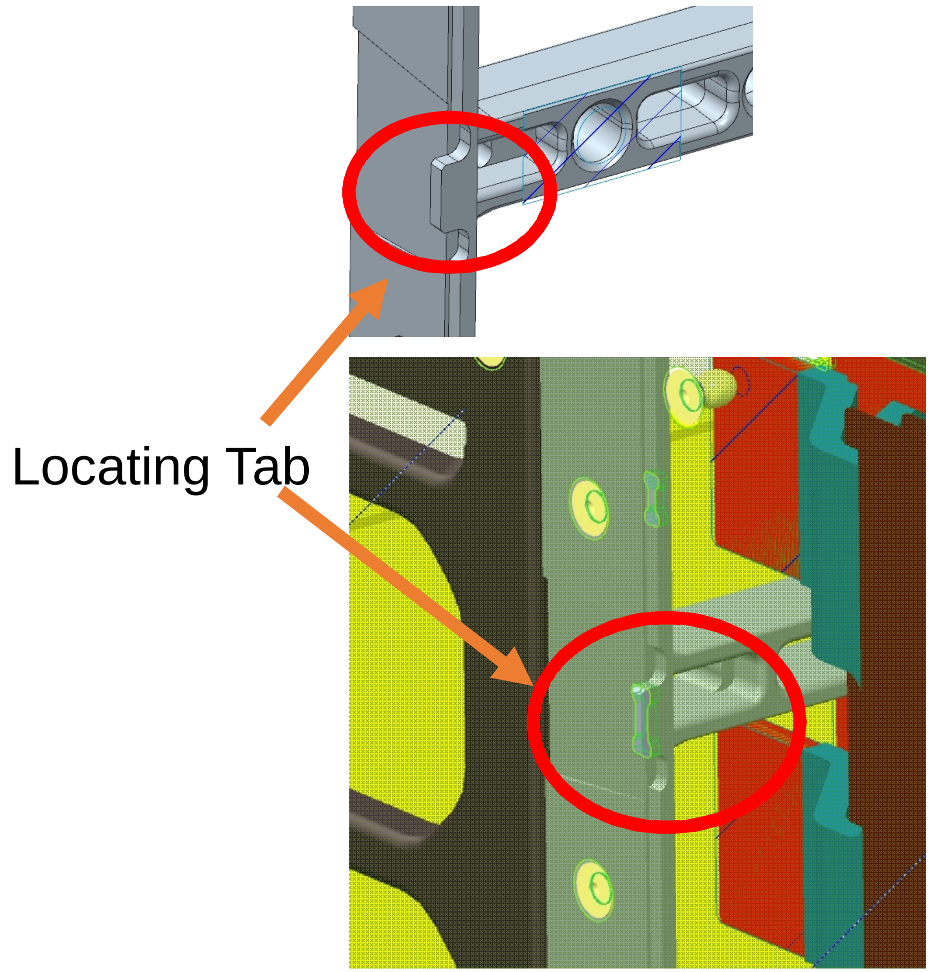
Center Structure – Manufacturing Challenges

- Open lattice structure
  - Warping due to casting
    - Difficulty defining machining datum
  - Flexible structure deformed during machining
    - Reduced accuracy of machining process
- Worked with suppliers to determine what tolerances were achievable



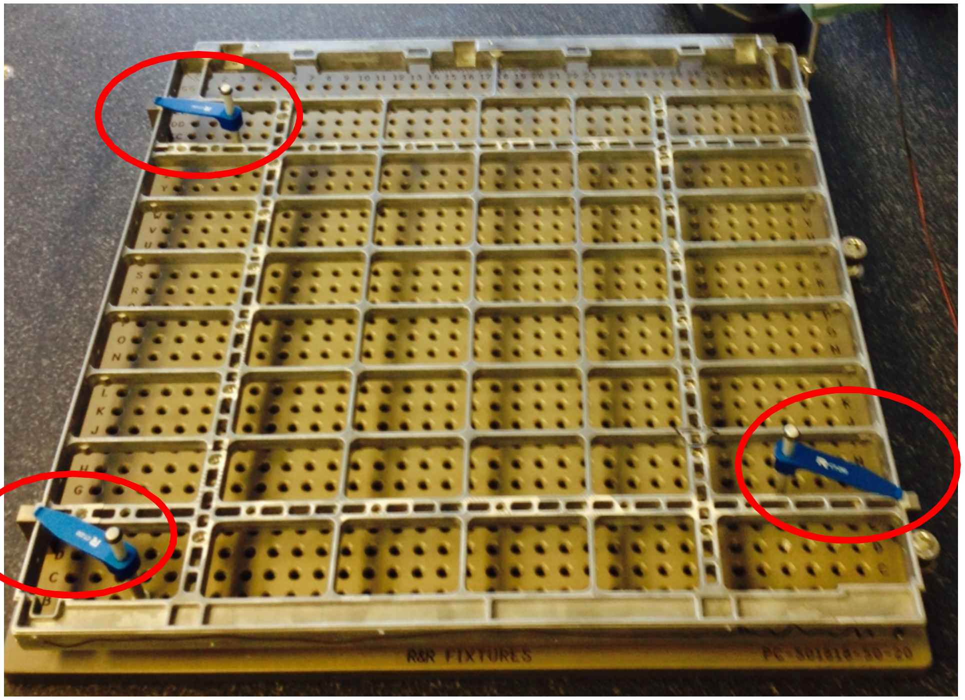
Center Structure – Manufacturing Process

- Center structure location in XYZ defined by locating tabs on sides of component
    - Initial machining pass to create rear surface of tabs
- Part clamped using 3 surfaces to create machining datum
- Initially wanted to machine and inspect in unclamped state
    - Excessive process complexity and cost
    - Assembly tolerances monitored



Center Structure – Manufacturing Challenges

- Tolerance Analysis revisited
  - Geometry updated based on new data
- Results
  - Able to maintain 4Sigma design
  - Comparable tolerances and structure to CNC design
  - ~90% cost reduction from CNC component



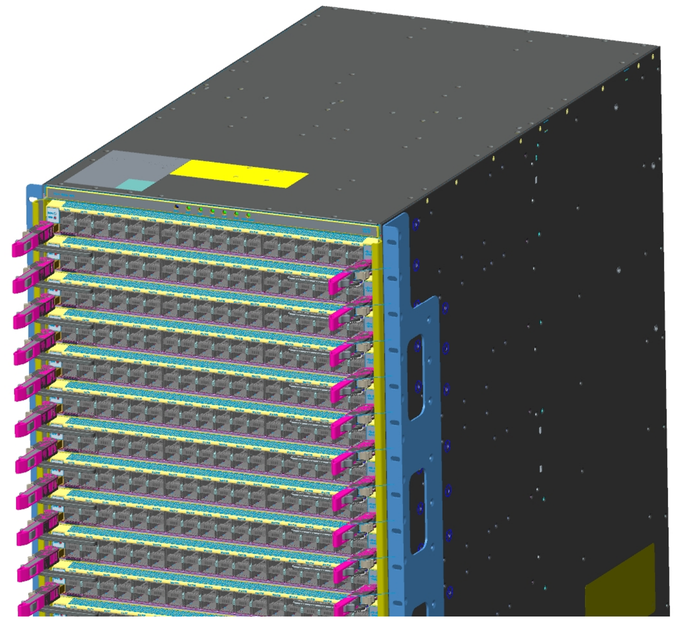
Concluding Thoughts

What was achieved

- 4Sigma Design for connector mating and gathering
- High Speed Signal requirements met
- Thermal requirements met
- Cost optimized system

Keys to success

- Heavy upfront work to understand problem and create optimal solution
- Close relationship with clients and suppliers
    - Optimize cost, manufacturability, performance



Questions/ Contacts

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Designing Around Orthogonal Direct

06/04/2014

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