PCB Design Best Practices

Stephen V. Chavez, MIT, CID+, CPCD

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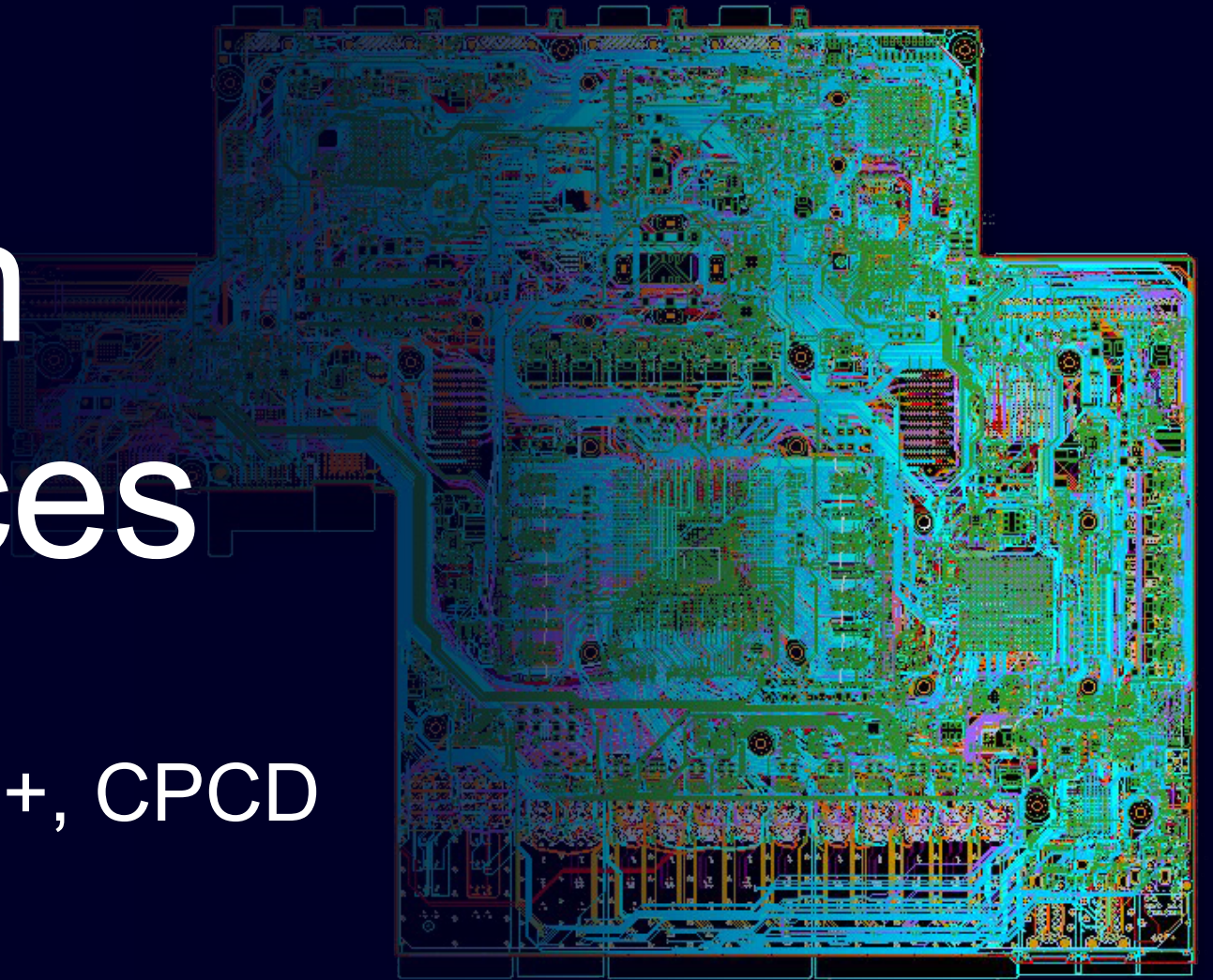
Investment up front pays off in the long term

"Shift left" in healthcare

Quality of life

Preventative care

Home care

Primary care

Acute care

Cost of care
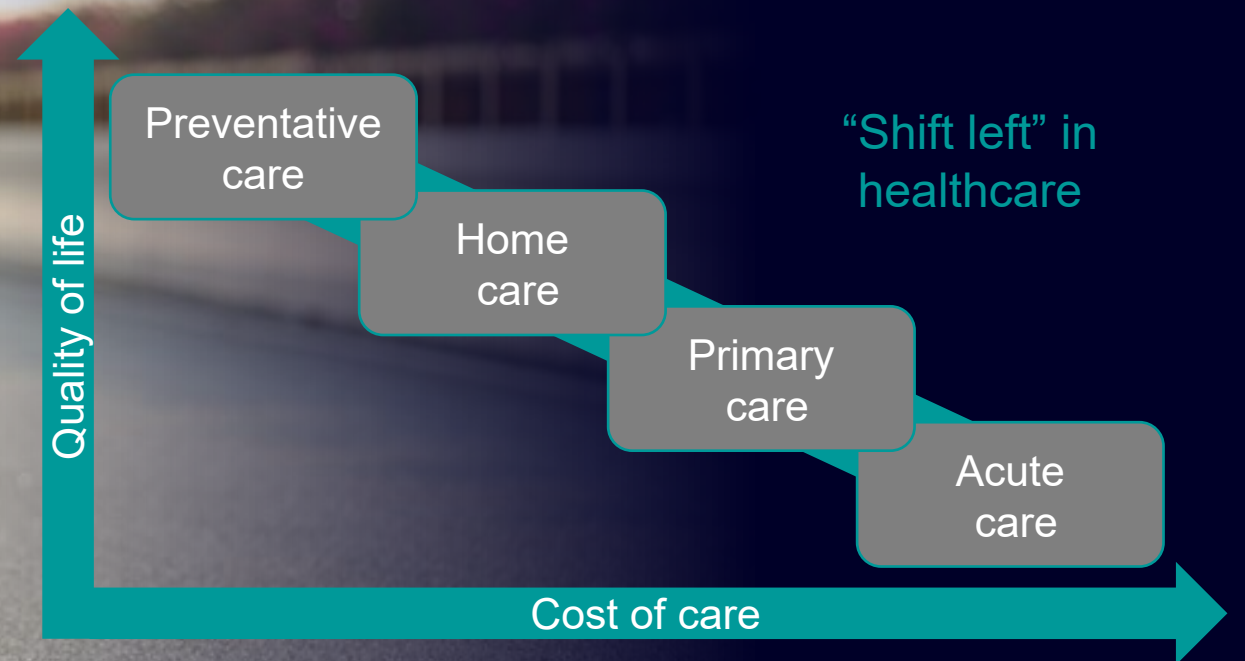
The state of design in electronics

Design teams **must deliver more complex products** on **even more compressed schedules**, but they **lose valuable time** with unproductive tasks. **Connect them** through all **engineering disciplines** and give them **best-in-class solutions** to thrive with a **collaborative** approach to **Electronic Systems Design**.

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Challenges in PCB Systems Design
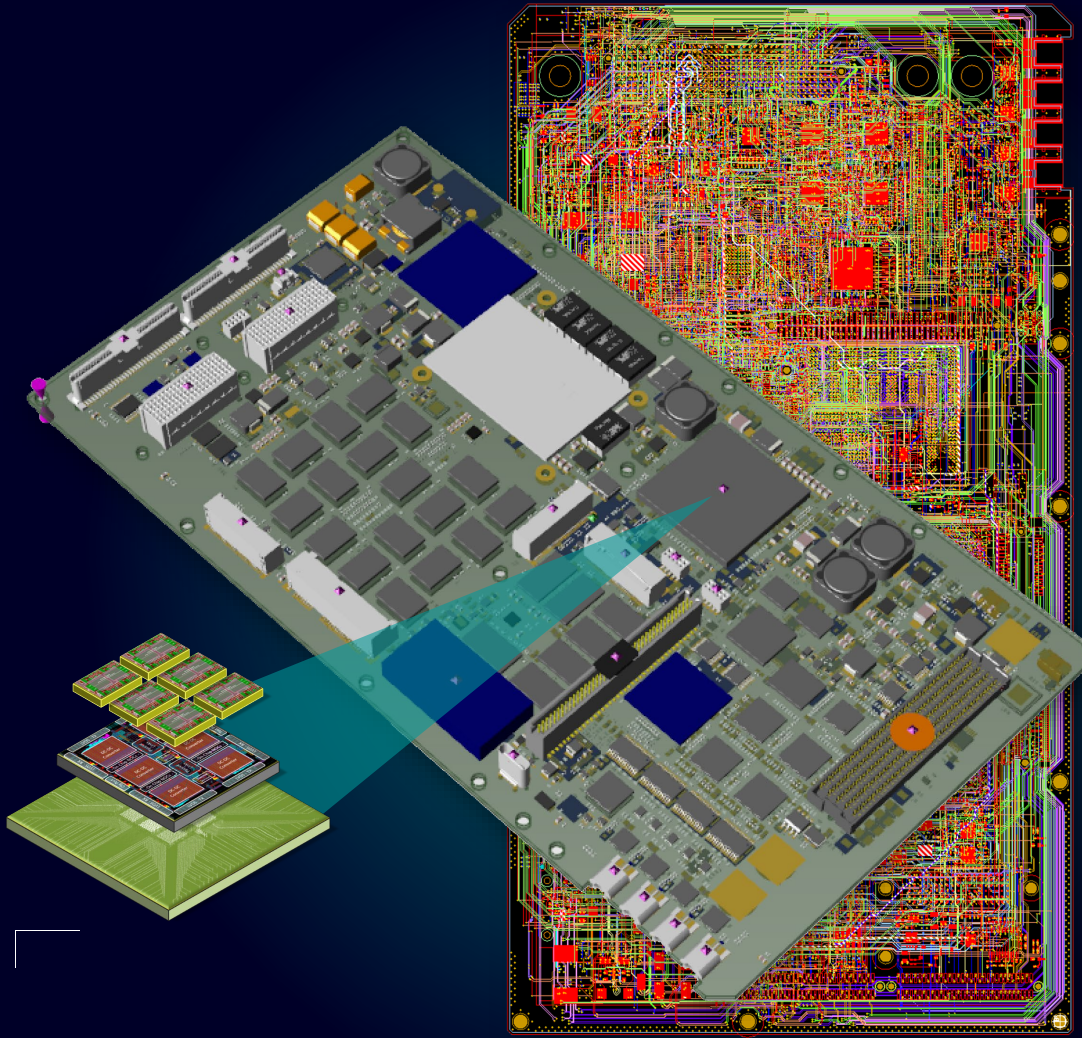
Product Complexity

Advanced packaging technologies · Transmission speeds · Multi-discipline co-design · Component count & density · Form-factor · Material technologies

Organizational Complexity

Collaboration across engineering disciplines · Collaboration across geographies · Knowledge management · Workforce productivity & efficiency

Process Complexity

User-experience · Integrated verification · Heterogenous tool chain · System engineering · System decomposition & verification · Streamline design to manufacturing
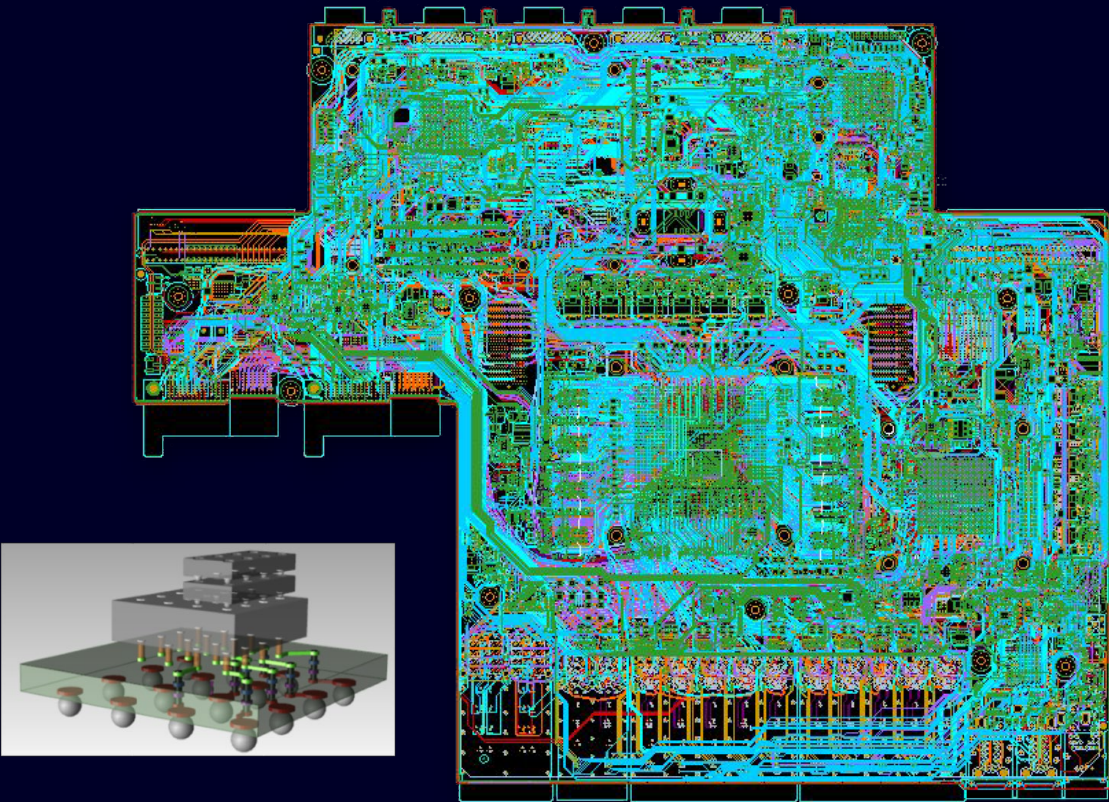
Supply Chain Complexity

Global supply shortages · Contractor management & assessment · Alternate supply · Pricing volatility · Risk assessment · Sourcing visibility & knowledge
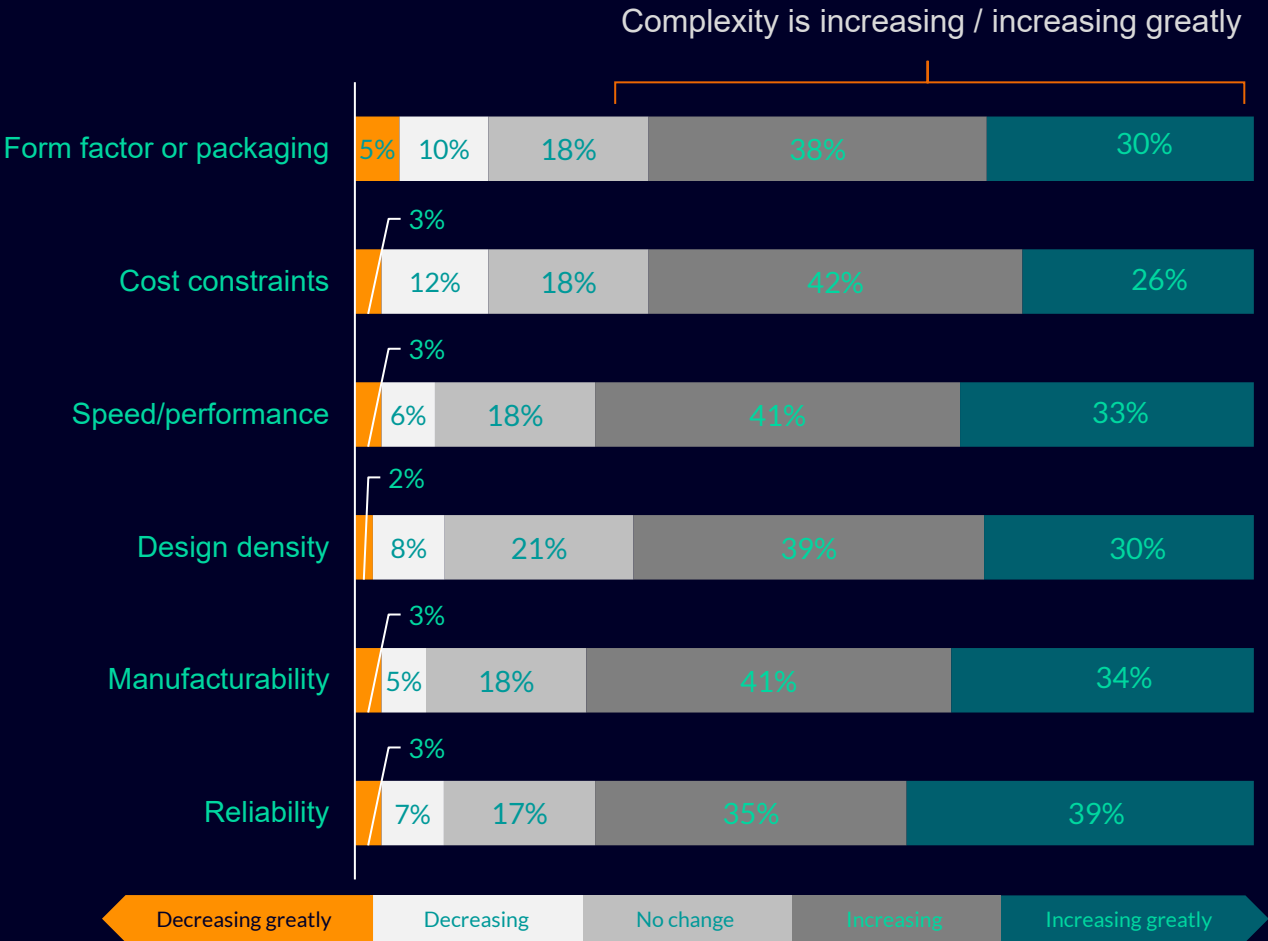
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Product Complexity

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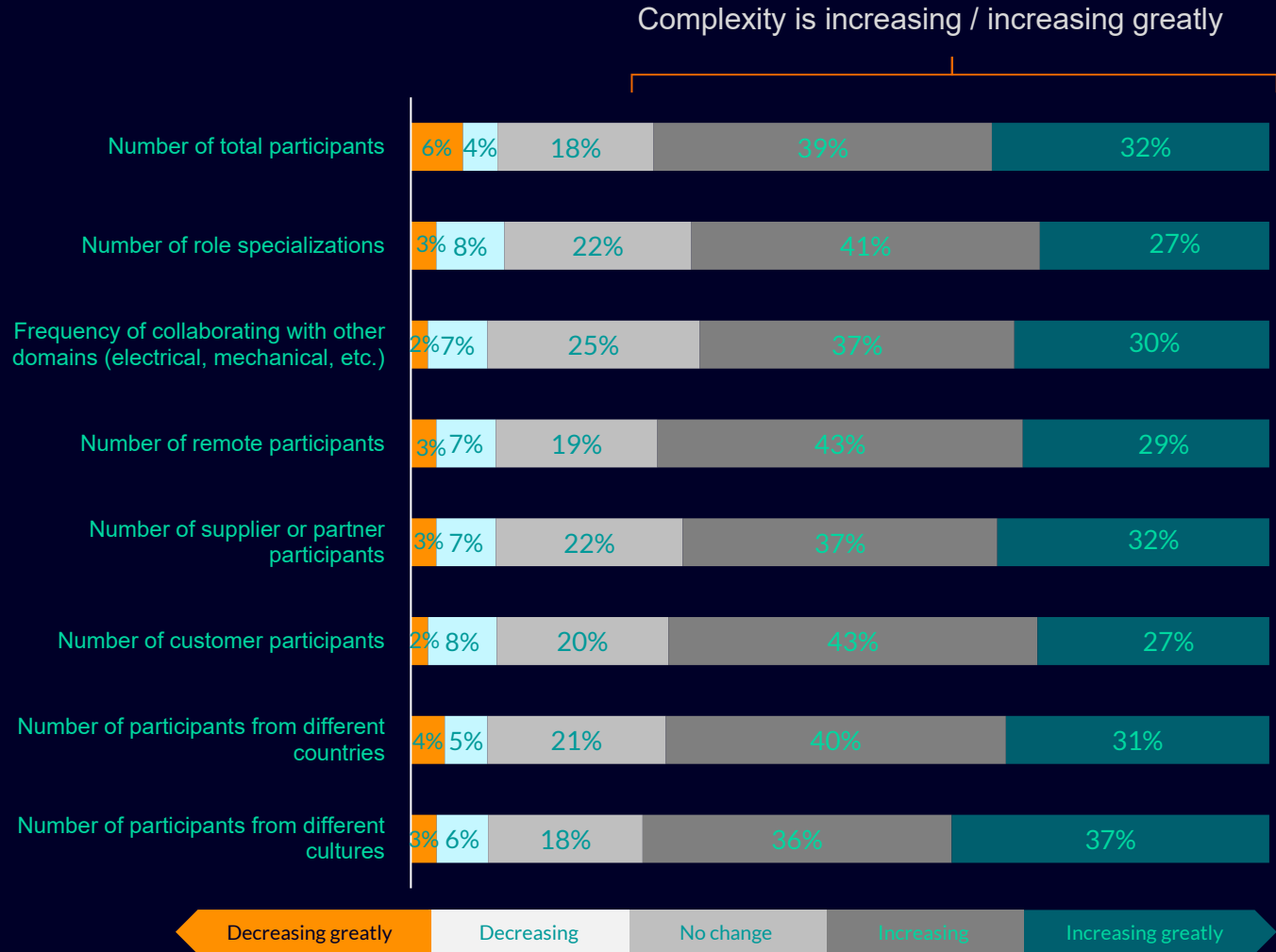

Infinera, 2020 Technology Leadership Awards

Complexity is increasing / increasing greatly

	Decreasing greatly	Decreasing	No change	Increasing	Increasing greatly
Form factor or packaging	5%	10%	18%	38%	30%
Cost constraints	3%	12%	18%	42%	26%
Speed/performance	3%	6%	18%	41%	33%
Design density	2%	8%	21%	39%	30%
Manufacturability	3%	5%	18%	41%	34%
Reliability	3%	7%	17%	35%	39%

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Organizational Complexity

Collaboration across engineering disciplines · Collaboration across geographies · Knowledge management · Workforce productivity & efficiency
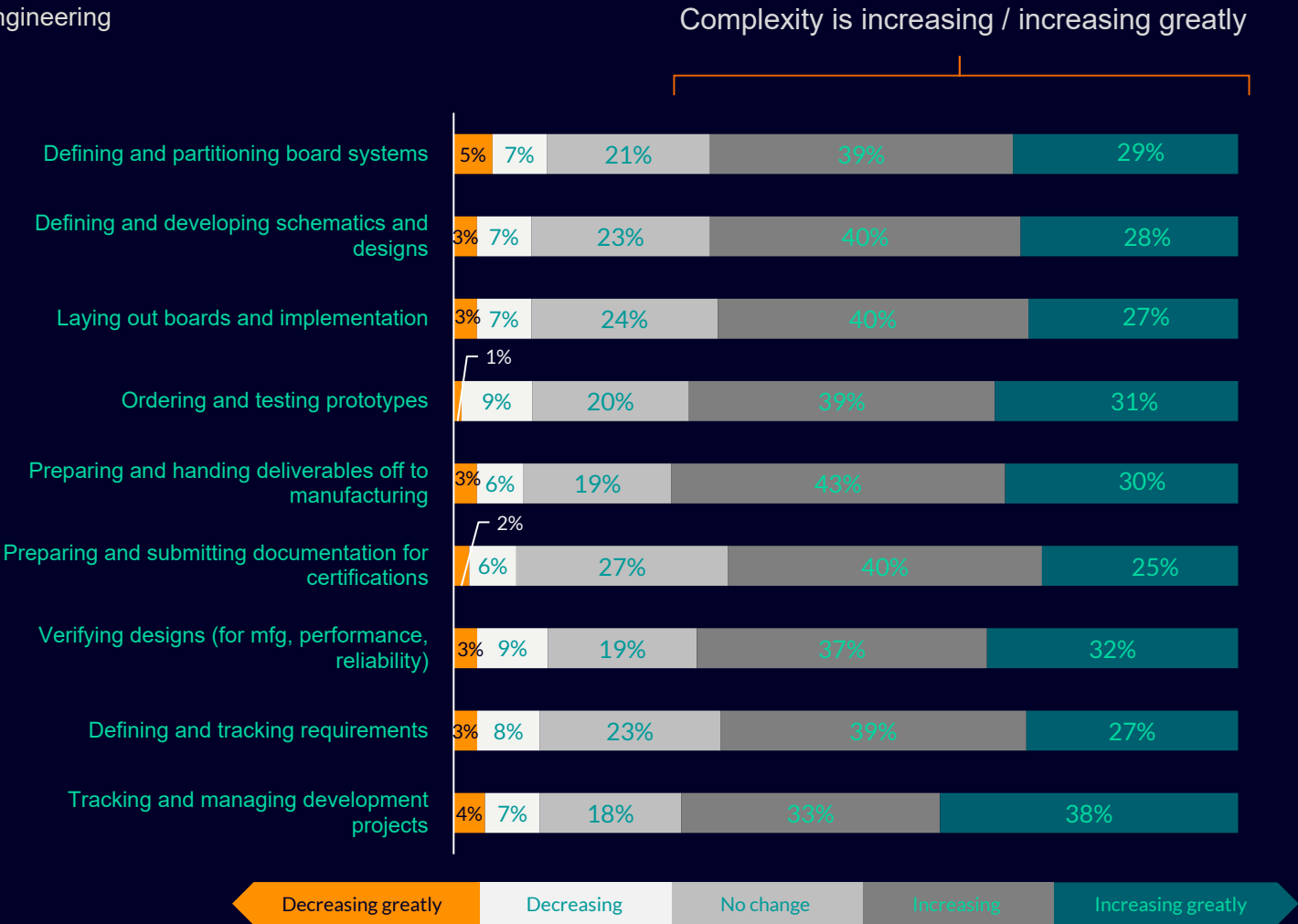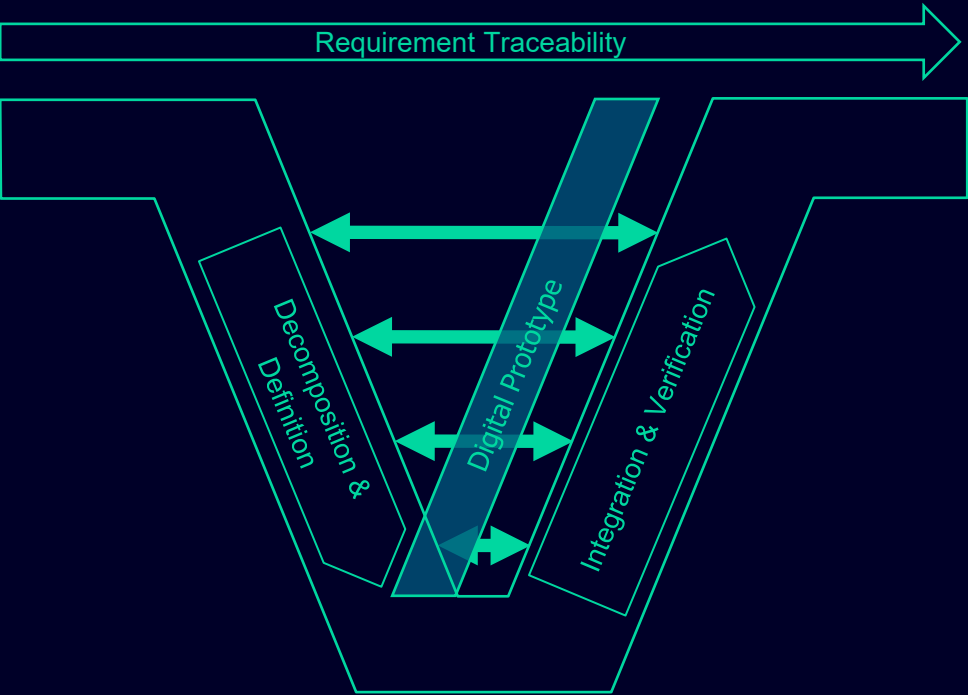
Complexity is increasing / increasing greatly

	Decreasing greatly	Decreasing	No change	Increasing	Increasing greatly
Number of total participants	6%	4%	18%	39%	32%
Number of role specializations	3%	8%	22%	41%	27%
Frequency of collaborating with other domains (electrical, mechanical, etc.)	2%	7%	25%	37%	30%
Number of remote participants	3%	7%	19%	43%	29%
Number of supplier or partner participants	3%	7%	22%	37%	32%
Number of customer participants	2%	8%	20%	43%	27%
Number of participants from different countries	4%	5%	21%	40%	31%
Number of participants from different cultures	3%	6%	18%	36%	37%

Legend: Decreasing greatly · Decreasing · No change · Increasing · Increasing greatly

PCB Schematic
PCB Layout
System Requirements
Signal & Power Integrity
Component Engineering
Software Engineering
Manufacturing Engineering
Mechanical Engineering
Electrical Engineering

Lifecycle Insights, September 2021

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Process Complexity

User-experience · Integrated verification · Heterogenous tool chain · System engineering · System decomposition & verification · Streamline design to manufacturing

Complexity is increasing / increasing greatly

Process	Decreasing greatly	Decreasing	No change	Increasing	Increasing greatly
Defining and partitioning board systems	5%	7%	21%	39%	29%
Defining and developing schematics and designs	3%	7%	23%	40%	28%
Laying out boards and implementation	3%	7%	24%	40%	27%
Ordering and testing prototypes	1%	9%	20%	39%	31%
Preparing and handing deliverables off to manufacturing	3%	6%	19%	43%	30%
Preparing and submitting documentation for certifications	2%	6%	27%	40%	25%
Verifying designs (for mfg, performance, reliability)	3%	9%	19%	37%	32%
Defining and tracking requirements	3%	8%	23%	39%	27%
Tracking and managing development projects	4%	7%	18%	33%	38%

Lifecycle Insights, September 2021

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Supply Chain Complexity

Global supply shortages · Contractor management & assessment · Alternate supply · Pricing volatility · Risk assessment · Sourcing visibility & knowledge

Supply — **Design** — **Manufacturing**

91%
Indicate sourcing issues have caused product launch delays

81%
Report commodity availability has forced expensive spot buys

79%
Say collaboration issues have caused delays in new product introductions

63%
Express the number of indented levels of a BOM have increased significantly

Sources: Dimensional Research, State of Electronics Sourcing: A Survey of Sourcing Decision-Makers, 2020
Lifecycle Insights, NPI and Sourcing Study, 2021

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Best Practices

Definition per Merriam-Webster
A procedure that has been shown by research and experience to produce optimal results and that is established or proposed as a standard suitable for widespread adoption

What are they!
- Best practices are standards or guidelines that are known to produce good outcomes if followed

Best Practice Benefits
- Optimized processes and team collaboration
- Reduced design time, respins and eng. costs
- Faster time to market
- Increased reliability and quality of designs

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Common Reasons for Status Quo in PCB Design

Problem!

"Always did it that way"

Roadblocks!

- Current process 'works' (a manual approach)
- Don't trust today's EDA tools
- Internal company culture resistance to change
- No time to learn or train on new functions in tool

Best Practice

- Constantly seek to optimize internal processes
- Keep up-to-date with today's EDA tool capabilities and functionalities
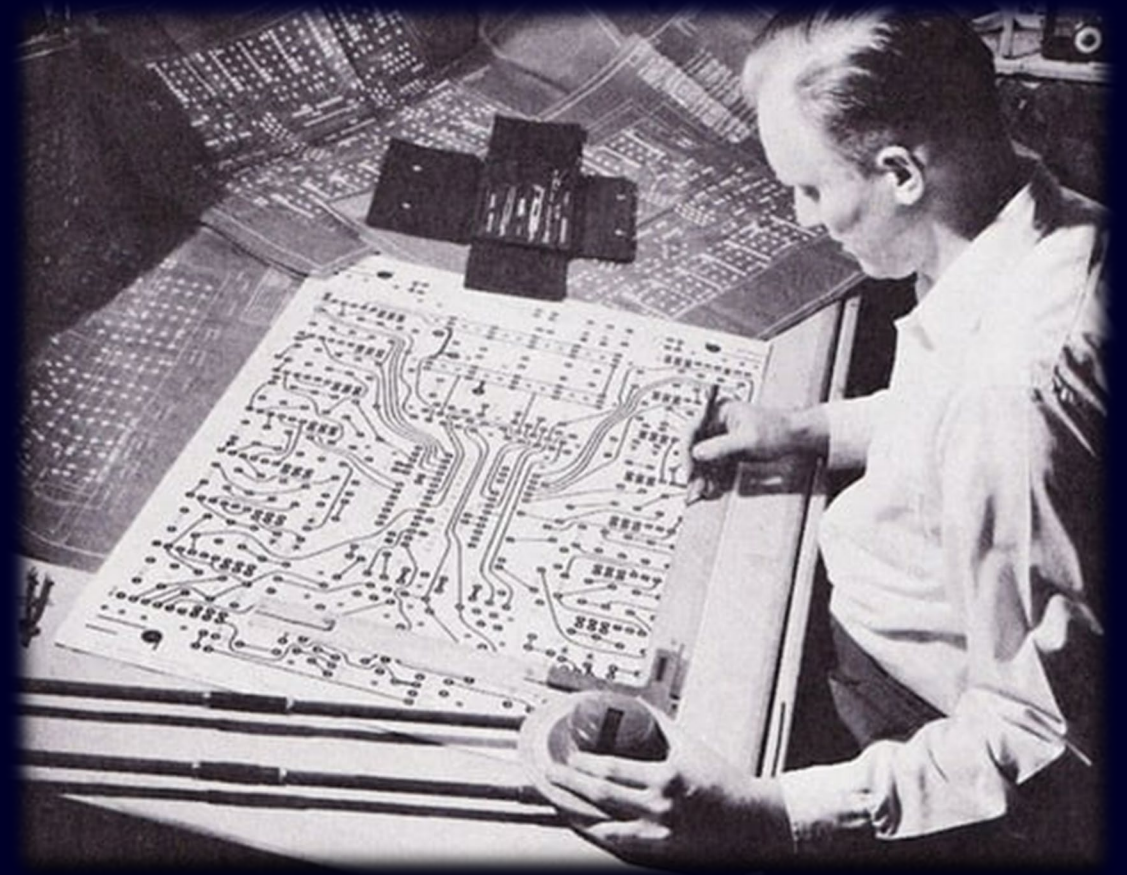
Drawing a PCB with tape and mylar before EDA arrived

Image from *A Manual of Engineering Drawing for Students and Draftsmen, 9th Ed.,* by French & Vierck,1960, p. 487.
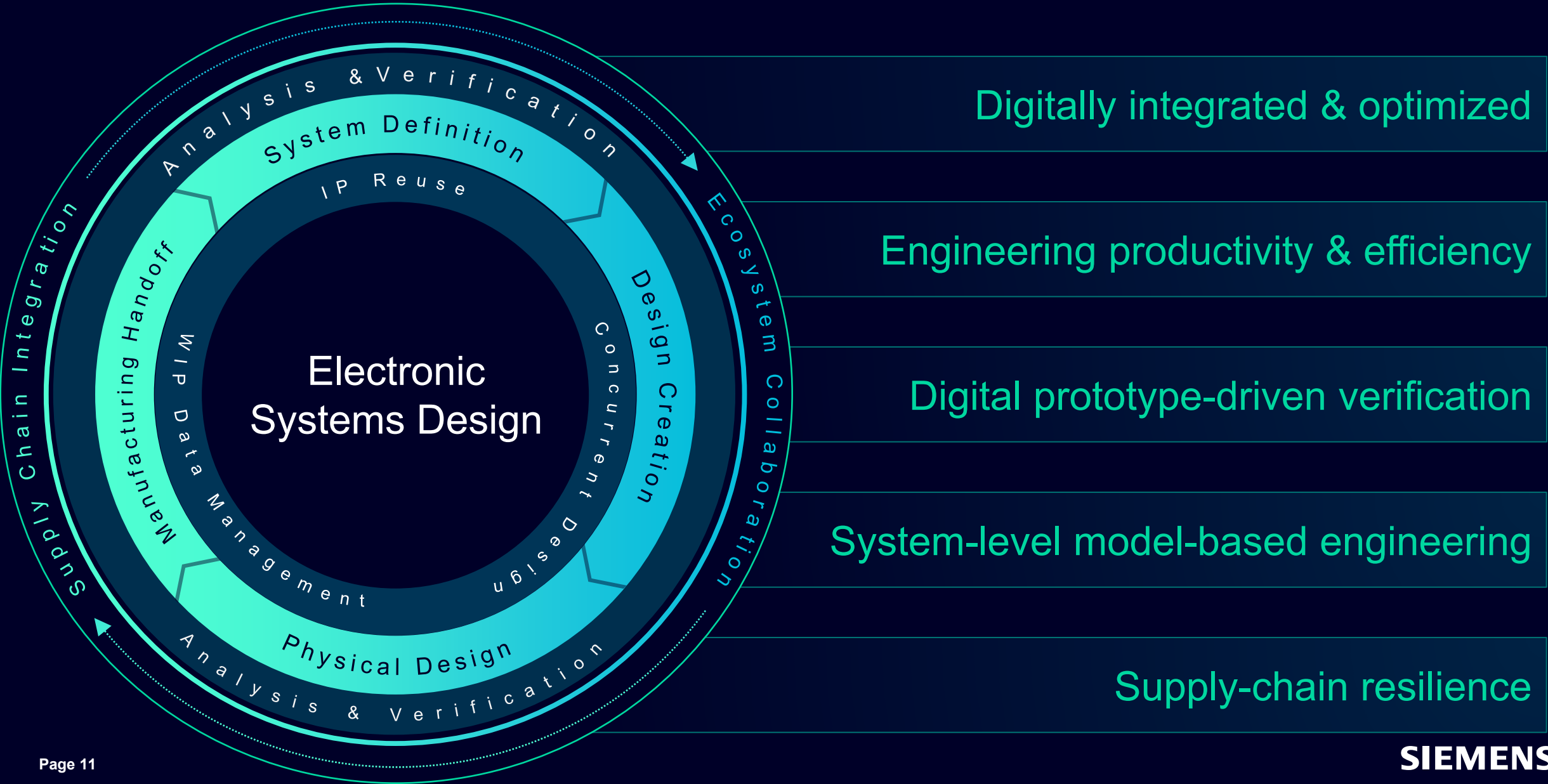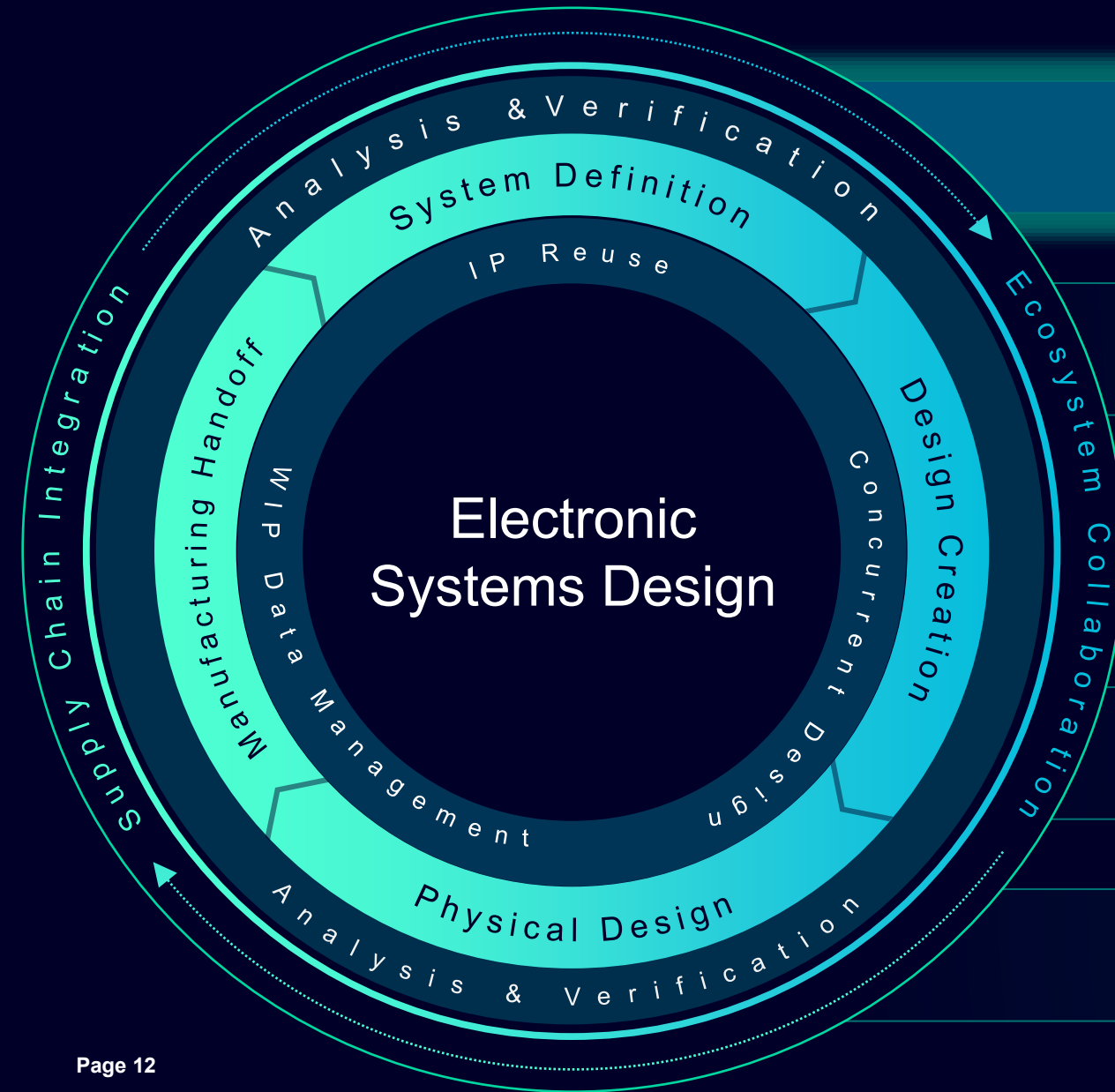
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Pillars of Best Practices

Digitally integrated & optimized

Engineering productivity & efficiency

Digital prototype-driven verification

System-level model-based engineering

Supply-chain resilience

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Supply-chain resilience

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Electronic-Mechanical Co-design

Problem!

Error prone and inefficient process

Roadblocks!

- Organizational resistance to change
- Siloed teams and independent toolsets
- Unfamiliar with latest format standards

Best Practice

- Adopt latest exchange formats (IDX)
- Look at methodologies that enables context-based, incremental collaboration between domains

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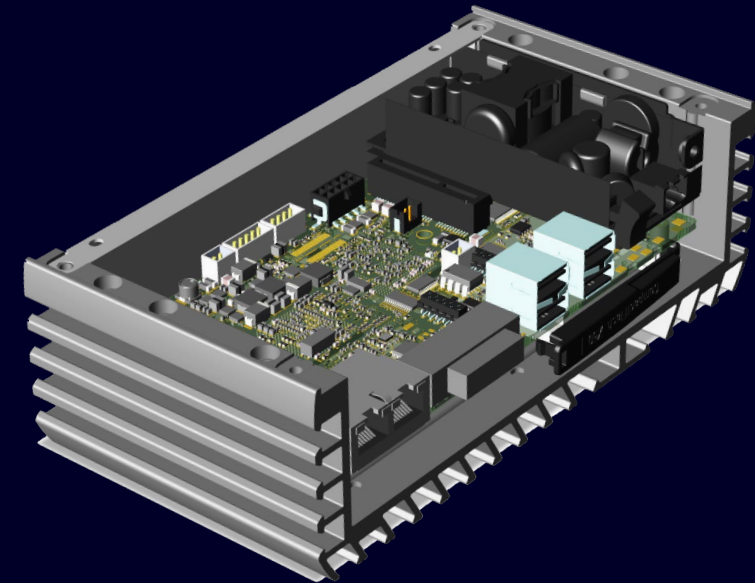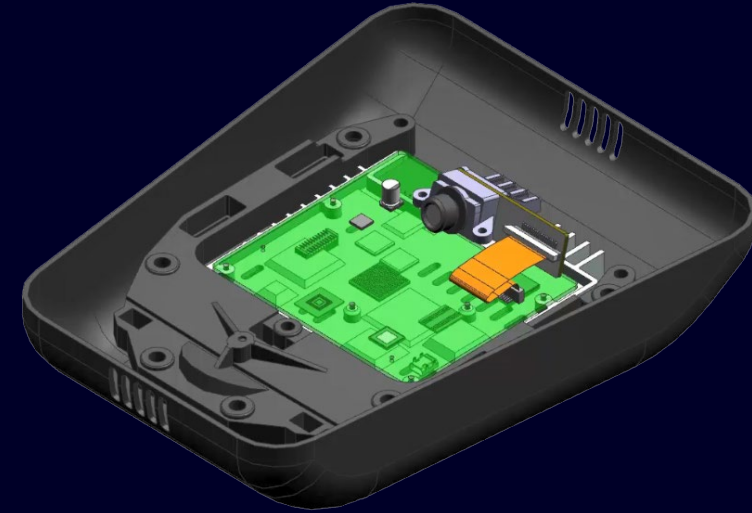
Design / Manufacturing

Problem!

Data not addressing producibility or manufacturability passed to manufacturing

Roadblocks/Inhibitors!

- Competitive pressure on Fab house to accept poor data
- No time to run DFM analysis

Best Practice

- Optimize integration between design and MFG
- Enable lessons learned in MFG to influence designs (enable feedback loop)
- Utilize intelligent data format (ODB++, IPC-2581)

Traditional iterative design flow

Design

Hand off to Manufacturing

Respins

Manufacturer's Feedback

Concurrent DFM

Design → Analysis with Manufacturer Specifications → Hand off to Manufacturing

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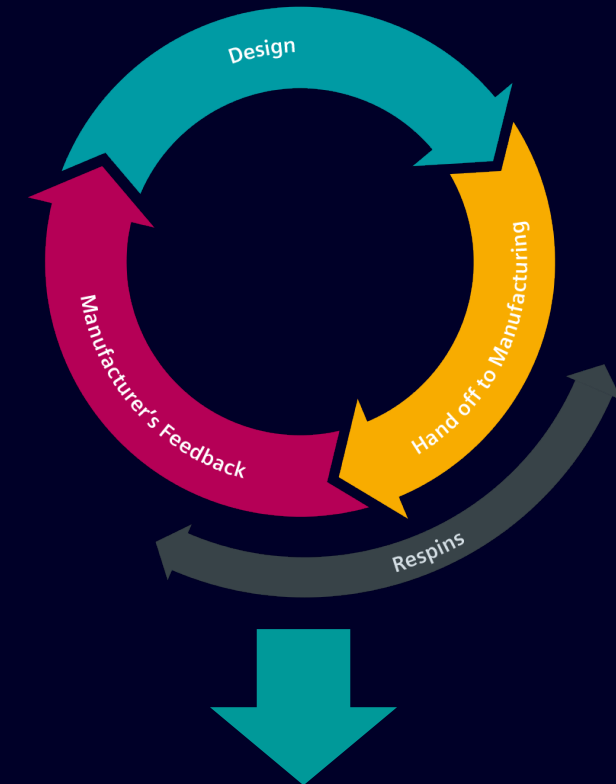
Library and Data Management

Problem!

Ineffective collaboration across teams

Roadblocks!

- Product/organizational/process complexities
- Too much overhead to maintain
- No experience/specialist

Best Practice

- Establish internal guidelines & processes
- Utilize industry standards
- Organize and control your library and data

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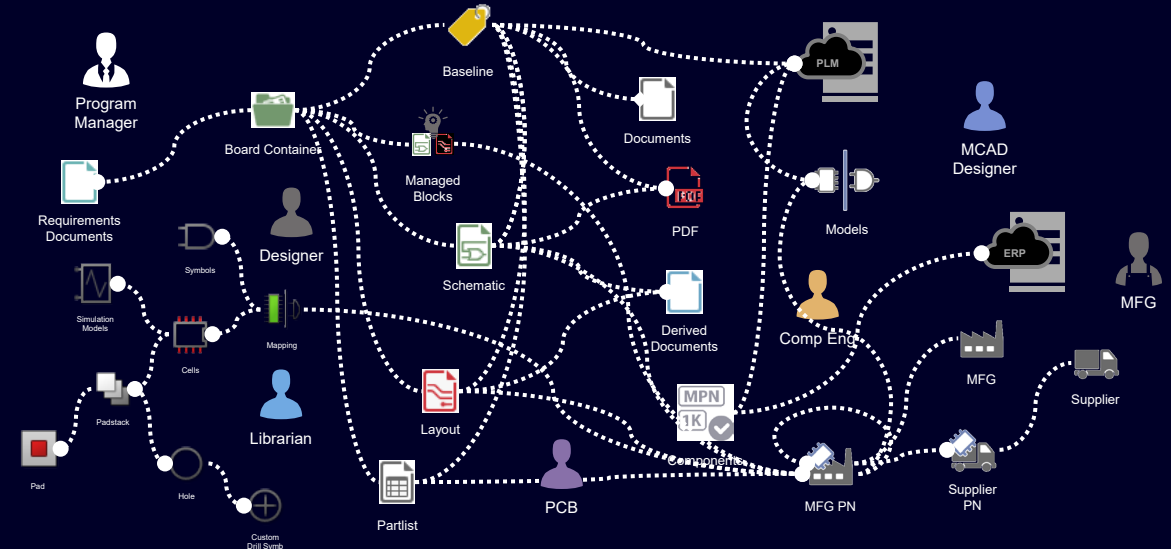
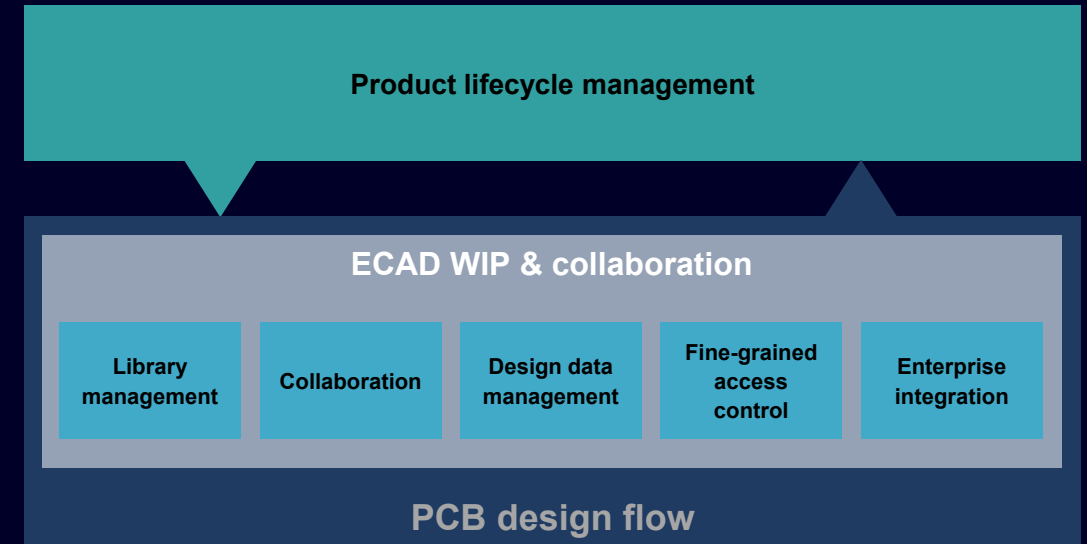# Work-in-progress Design Management

Problems!

In-process status visibility not adequately shared across functions

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Roadblocks!

- Home grown manual processes in place
- Too much overhead to maintain / complexities
- Unaware of opportunities to be better optimized

Best Practice

- Deliver instant status updates and visibility
- Facilitate team integration & optimization
- Attack multi-domain roadblocks instantly and on the fly

Product lifecycle management

ECAD WIP & collaboration

| Library management | Collaboration | Design data management | Fine-grained access control | Enterprise integration |

PCB design flow

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Problem!

Lacking product management and tool integration

Roadblocks!

- Local server or computer is used as data hub
- Too much overhead to maintain, access issues
- No experience/specialist

Best Practice

- Provide superior control and tracking of product data with:
  - Master version of the truth
  - Where-used / traceability / status / approvals
  - Data security / archiving

Control your CAD

Automate processes, including change

Organize your documents

Adopt industry best-practices

Collaborate with visualization

Your starting point

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Digitally integrated & optimized

Engineering productivity & efficiency

Digital prototype-driven verification

System-level model-based engineering

Supply-chain resilience
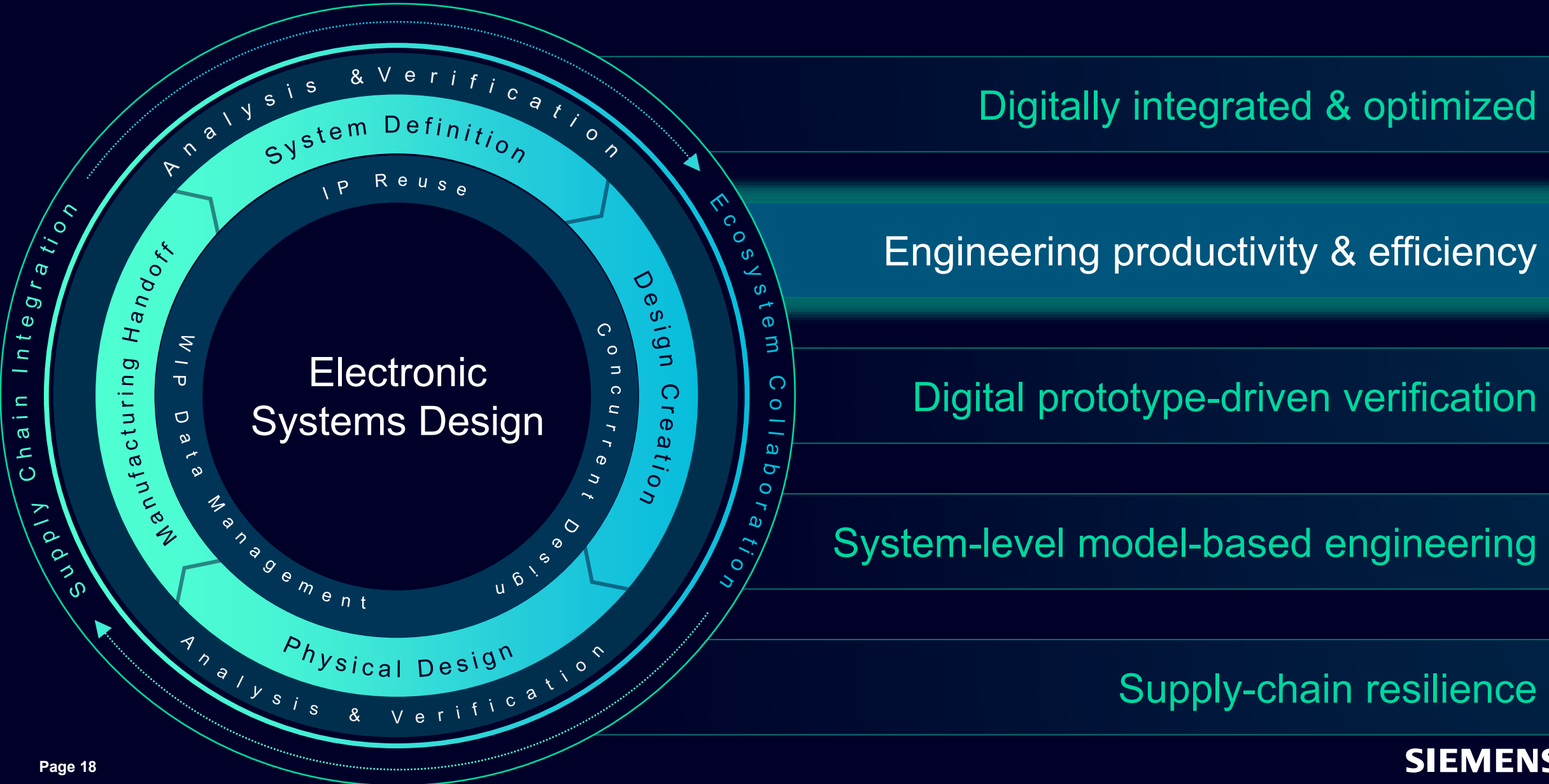
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Problem!

Legacy methodologies can't meet today's design complexities

Roadblocks!

- Unfamiliar with automated functions in tool
- Feeling of less control of design, don't trust
- Legacy practices are the standard

Best Practice

- Assign parts to groups/clusters
- Route using a combination of interactive and automated routing
- Generate outputs utilizing built-in automation functionality

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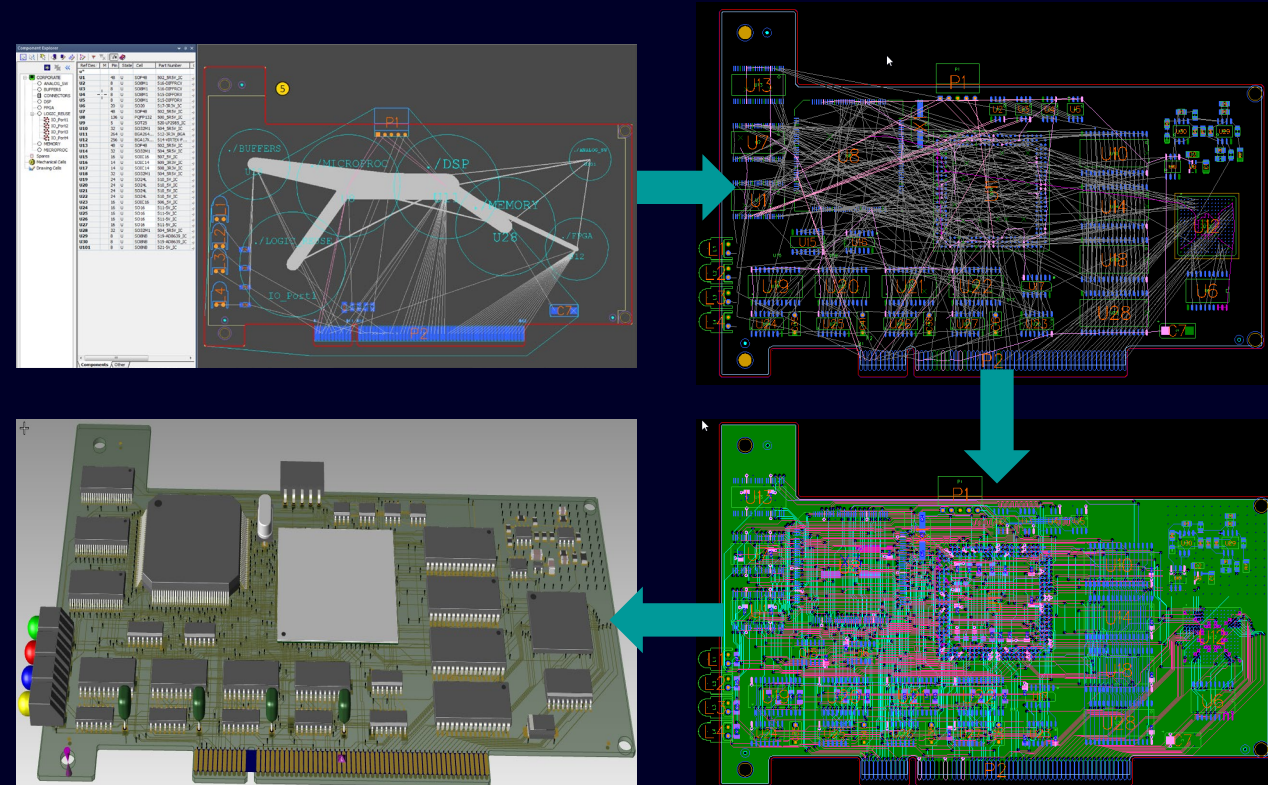
Analog/Digital/RF Co-design

Problem!

RF circuits are not optimally integrated into the design

Roadblocks!

- Disparate disciplines working in isolation
- Outsource to specialist or SME
- Siloed organizations/specialists

Best Practice

- Implement co-design and integration between Analog/Digital/RF engineers
- Integrate RF circuitry concurrently in design
- Adopt latest exchange formats

Traditional Serial Design Layout

Design Entry
Analog Layout
Digital Layout
RF Layout

Simultaneous Design Layout

Design Entry
Analog Layout — Constraints
Digital Layout — Constraints
RF Layout — Constraints

Desired Product Roll-Out

Cycle Time Reduction

Time

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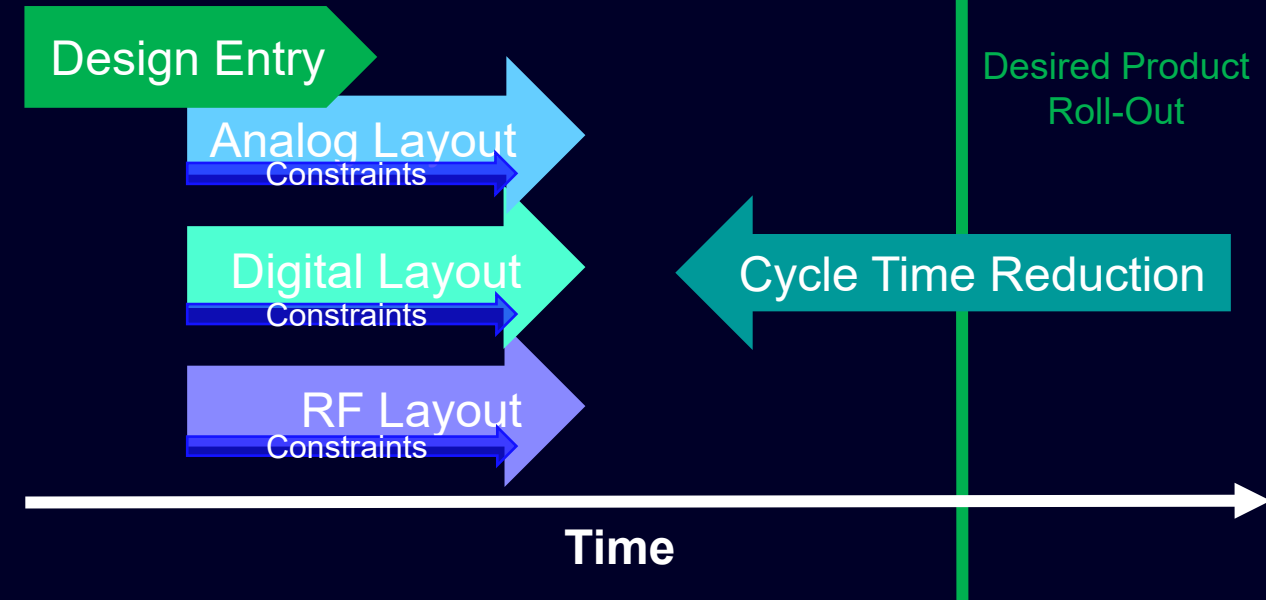
Concurrent Design – Schematic / Layout

Problem!

Legacy serial approach is inefficient

Roadblocks!

- Not wanting others to touch/modify their work
- Inefficient work distribution / working in silo's
- No incentive to change

Best Practice

- Utilize advanced capabilities - schematic/layout
- Optimize multidiscipline integration in database
- Optimize team utilization

Electrical Engineer(s)

Mechanical Engineer(s)

Layout Designer(s)

Team Design

Supply Chain

SI/PI/Thermal Engineer(s)

Manufacturing / Producibility Engineer(s)

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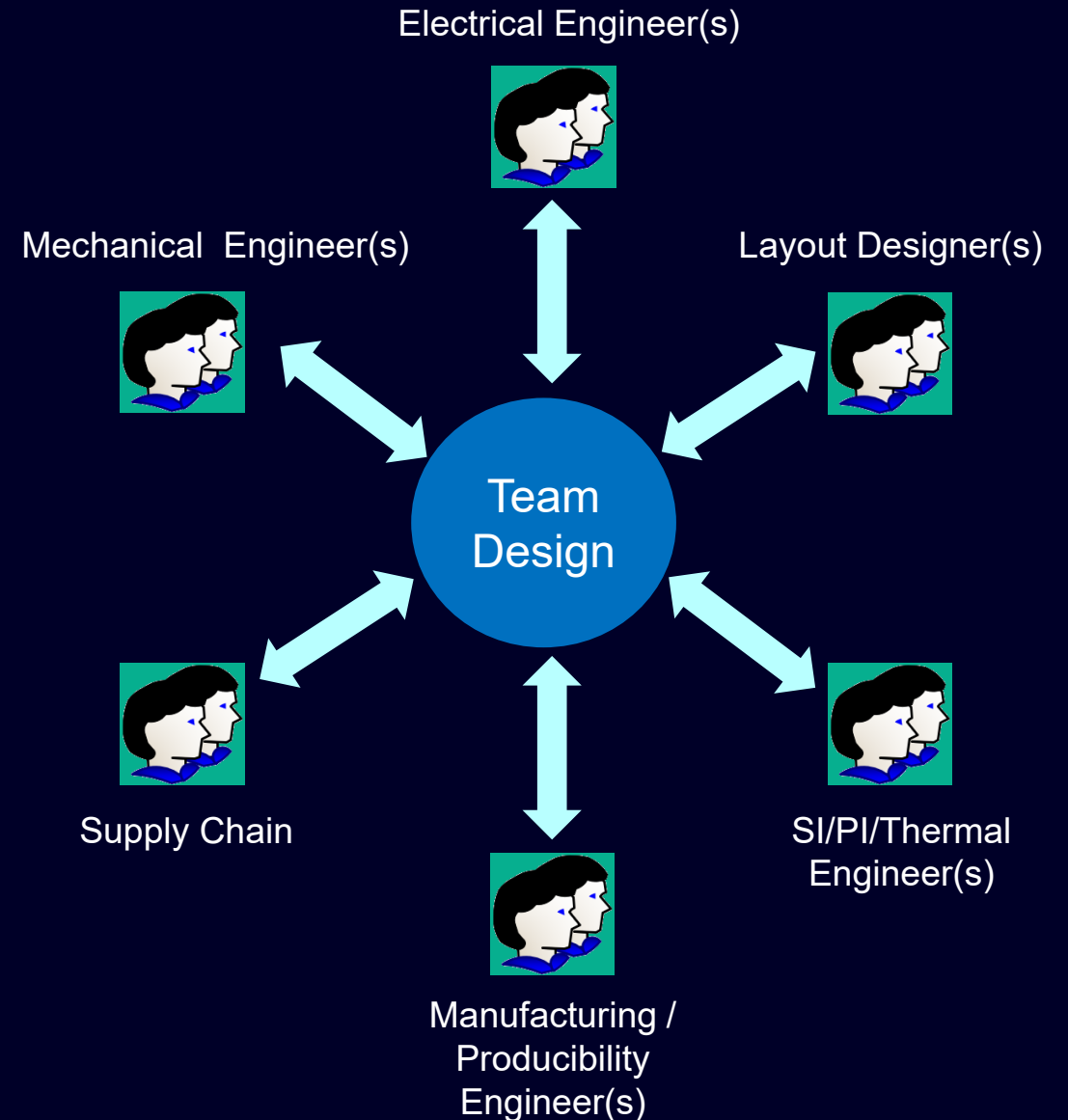
Design Reuse

Problem!

Re-inventing the wheel and poor enterprise utilization

Roadblocks!

- Inefficient process for sharing data
- Don't trust another engineer's circuit/layout
- No pressure to improve current methodology

Best Practice

- Utilize proven circuitry and layouts – lower risk
- Manage modules same as individual components
- Share validated HW IP throughout enterprise
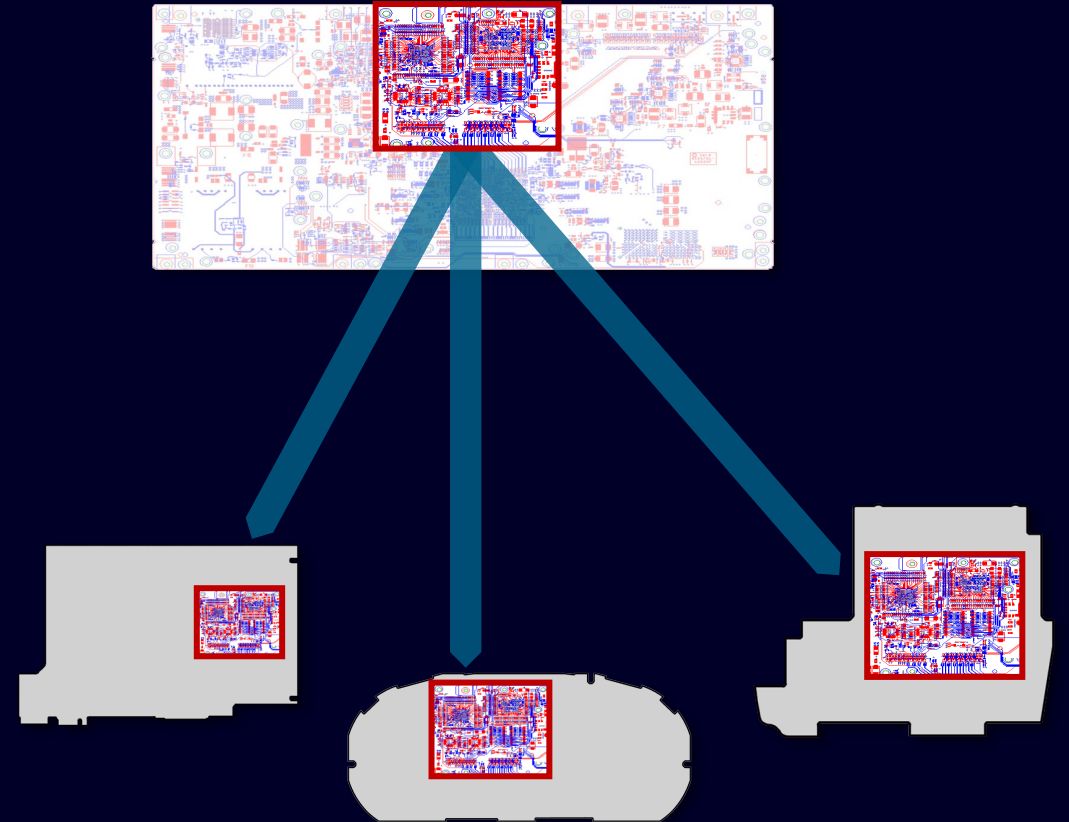
Constraint Driven Design

Problem!

Inefficient implementation of design rules

Roadblocks!

- Too much overhead to setup/implement/maintain
- Takes too long to implement
- Not familiar/proficient with tool

Best Practice

- Establish constraint management process
- Utilize automation to control, meet, and verify requirements were implemented

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Problem!

Rigid-flex design using rigid structures is inefficient and error prone

—————

Roadblocks!

• Not familiar/proficient with tool and or subject
• Use standard rigid PCB approach for everything
• Requires specialist/SME

—————

Best Practice

• Utilize updated rigid-flex design methodology to efficiently define board outlines, stack-ups, and regional constraints

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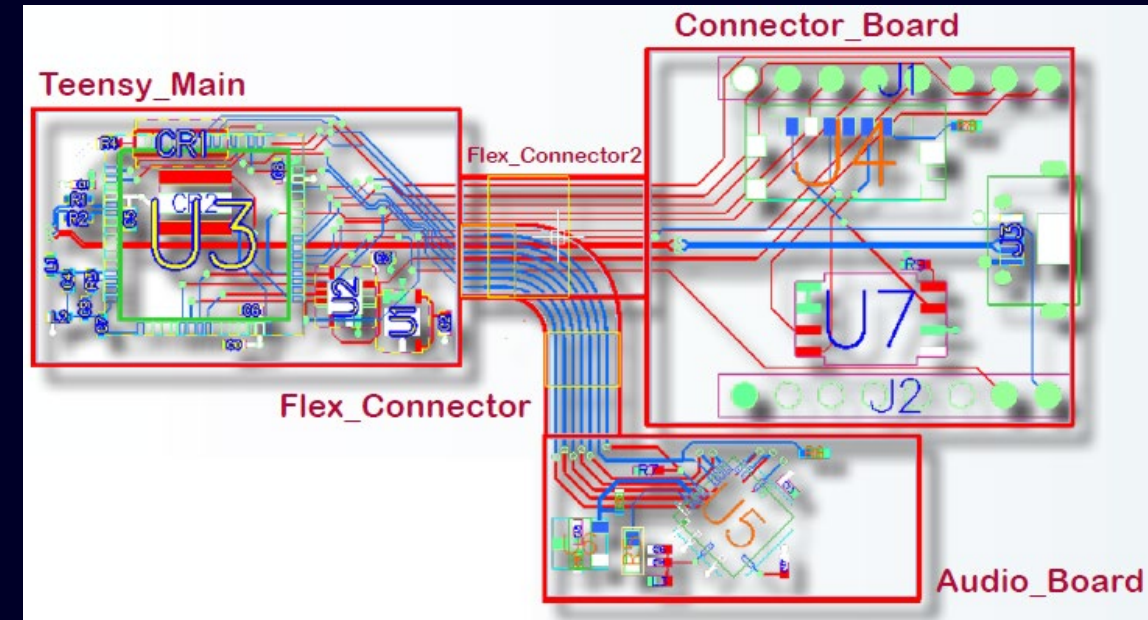
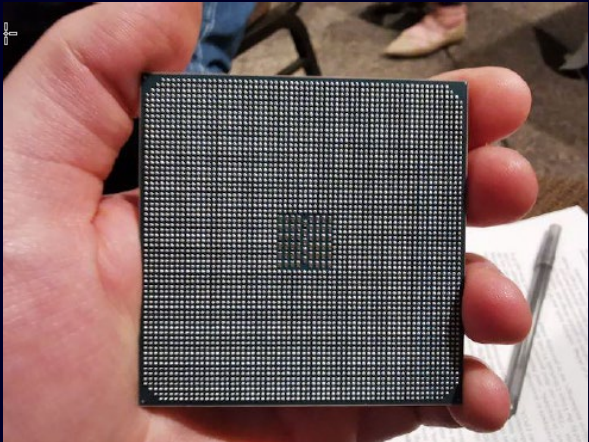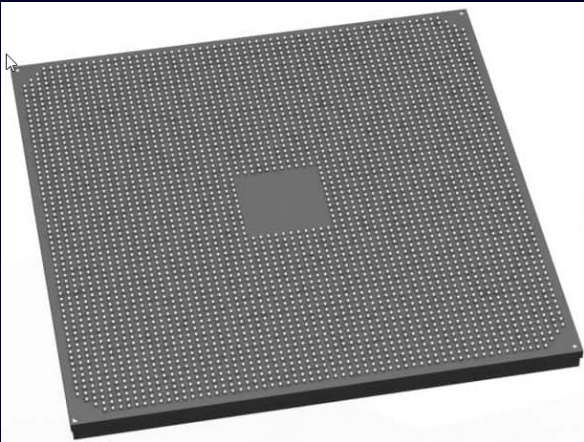# Advanced Design – High Density Interconnect (HDI)

Problem!

Implementing traditional via structures results in delays/cost

Roadblocks!

- Not familiar/proficient with tool and or subject
- Inefficient processes reduce opportunities to use HDI

Best Practice

- Capabilities are commonly available in most tools… stop doing work-arounds!

AMD Xilinx - IC FPGA VIRTEX-UP 3824FCBGA (65x65)

N Layers	A	B	C	D	E	F	G
	THRU-HOLE	HDI BLIND	HDI BL/BU	1BU BLIND	2BU BLIND	2BU BL.BU	2BU BL.BU
	N	1+N+1	1+bN+1	1+N+1	2+N+2	2+bN+2	2+bN+2
	blind via*	L1-L2	L1-L2	skip via L1-L3	staggered L1-L2, L2-L	skip via L1-L3	staggered L1-L2, L2-L
	buried via	none	L2-L(N-1)	L2-L(N-1)	none	L2-L(N-1)	L3-L(N-2)

Examples of HDI constructions types and methodologies

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Pillars of Best Practices

Digitally integrated & optimized

Engineering productivity & efficiency

Digital prototype-driven verification

System-level model-based engineering

Supply-chain resilience

Electronic Systems Design

Analysis & Verification

System Definition

IP Reuse

Supply Chain Integration

Manufacturing Handoff

WIP Data Management

Concurrent Design

Design Creation

Ecosystem Collaboration

Physical Design

Analysis & Verification

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Shift Left – Analysis (Part 1- Analysis)

Problem!

Re-spins are normalized due to analysis not being run

Roadblocks!

- Multiple re-spins already planned in schedule
- "No time to complete analysis" mentality
- Too much overhead to setup/implement/maintain

Best Practice

- Account for analysis in the initial project schedule
- Don't eliminate analysis in trying to reduce project schedule and cost
- Shift left multidiscipline analyses of Schematic, Thermal, SI/PI, AMS, DFM, Specialist/Design Author, HASS/HALT, DFT to eliminate errors

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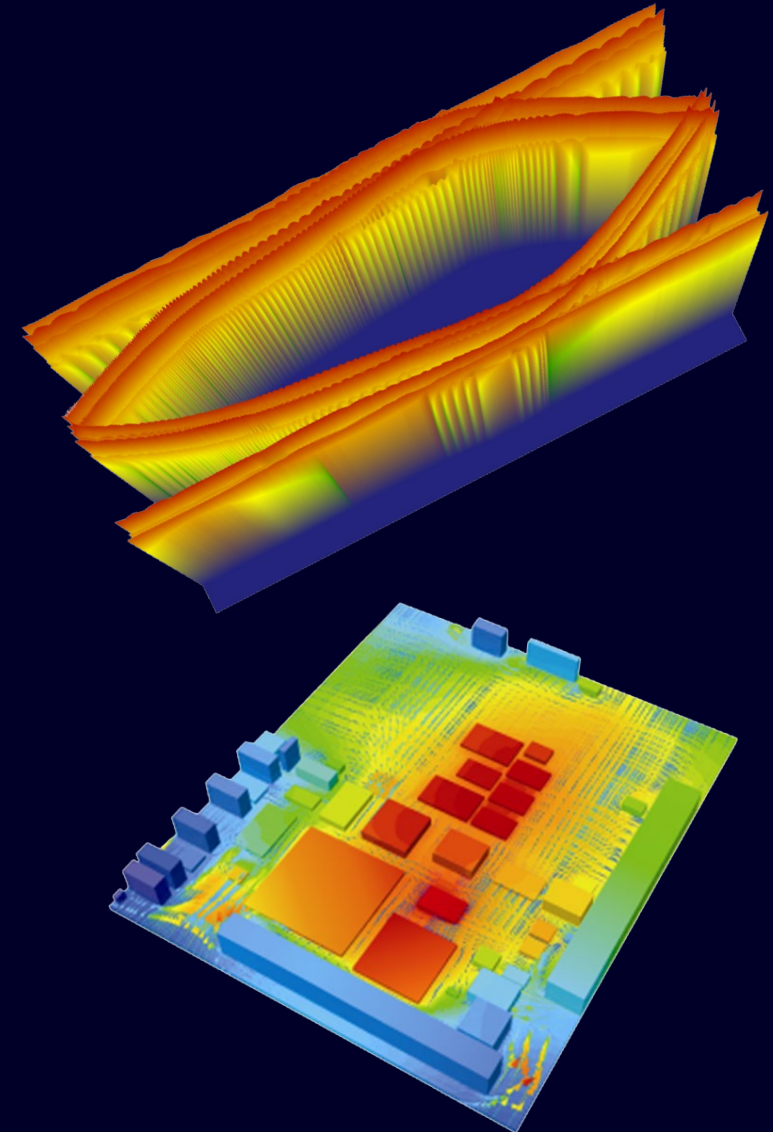
Shift Left – Analysis (Part 2 – Domain Specialist)

Problem!

Domain specialists working in silos and too far downstream
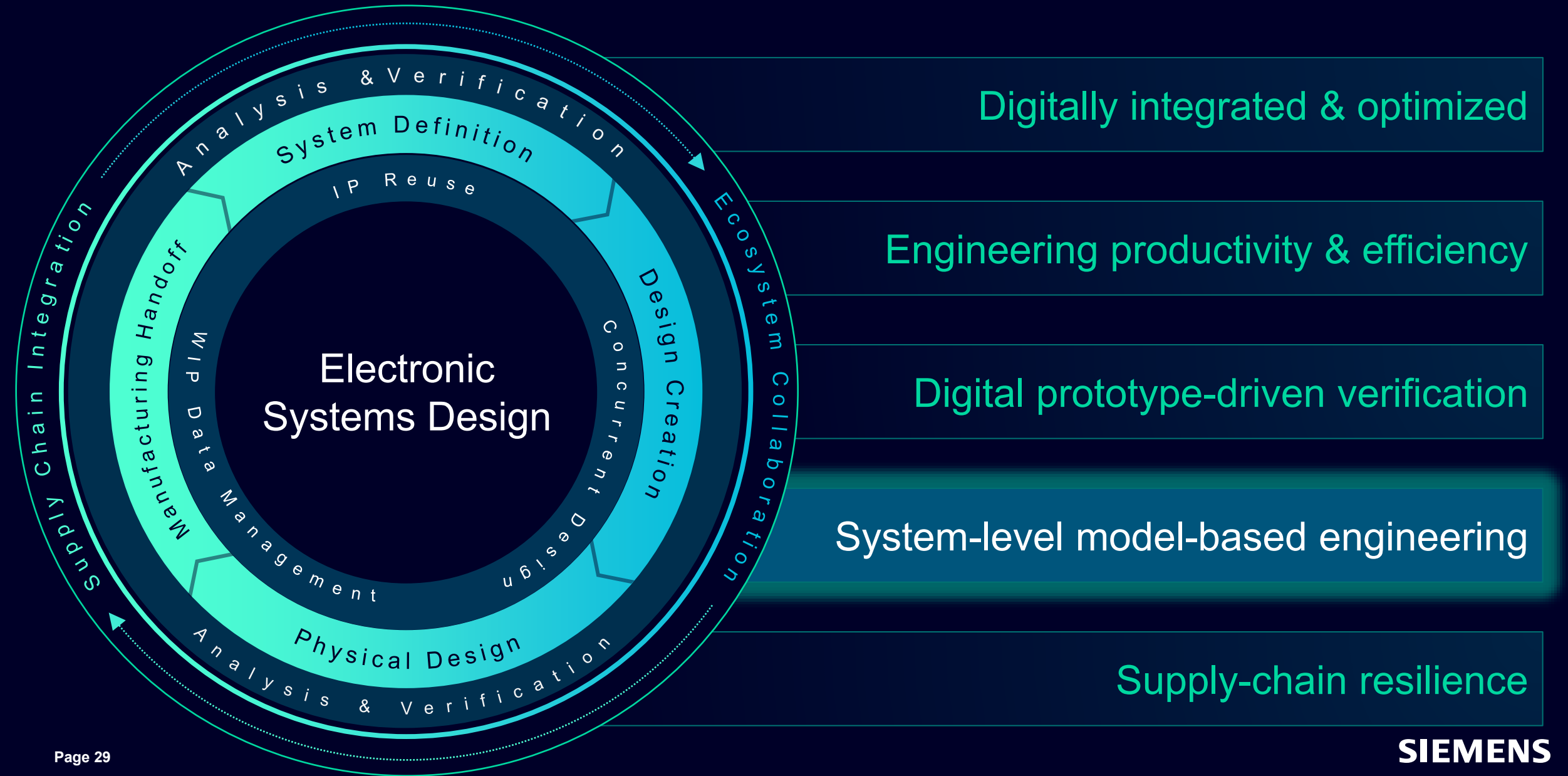
Roadblocks!

- No domain specialist available
- Design process not optimized for analysis
- "That's not my job" mentality

Best Practice

- Optimize multi-domain collaboration/integration
- Utilize domain specialist earlier in the process
- Utilize today's advanced capabilities within tools
- Cross-train skillset (remove single source)

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Pillars of Best Practices

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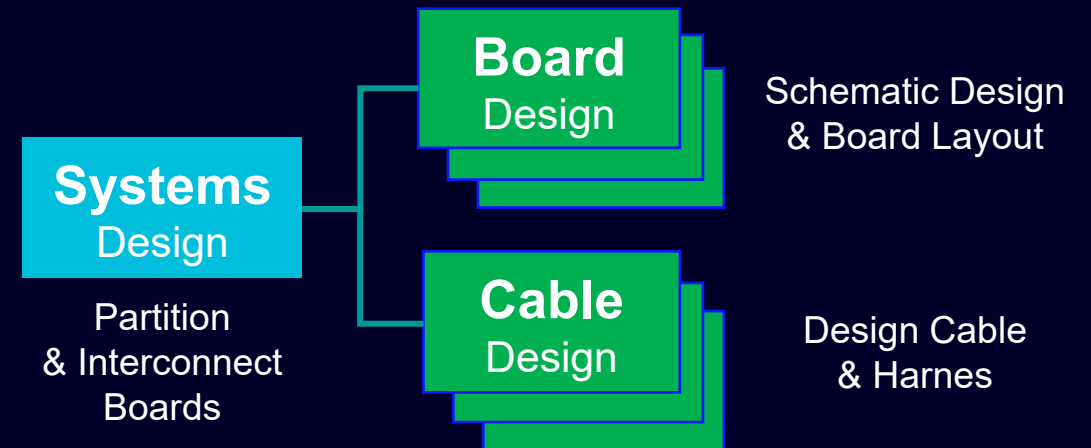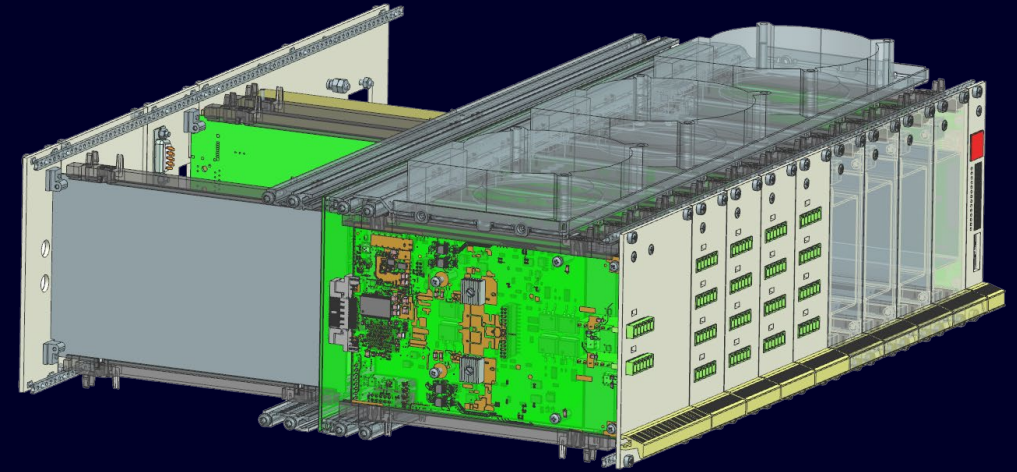SIEMENS

Multi-board Design

Problem!

Full systems design done in a vacuum, and by siloed team members

Roadblocks!

- Not familiar/proficient with tool
- Too much overhead to setup/implement/maintain
- Too expensive to implement

Best Practice

- Implement multi-board model-based engineering for cross-system optimization options (size / performance)
- Remove siloed engineering approach

Board
Design

Schematic Design & Board Layout

Systems
Design

Cable
Design

Partition & Interconnect Boards

Design Cable & Harnes

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FPGA/PCB Optimization

Problem!

FPGA design methodology is inefficient in its ability to optimize FPGA pin-out configurations
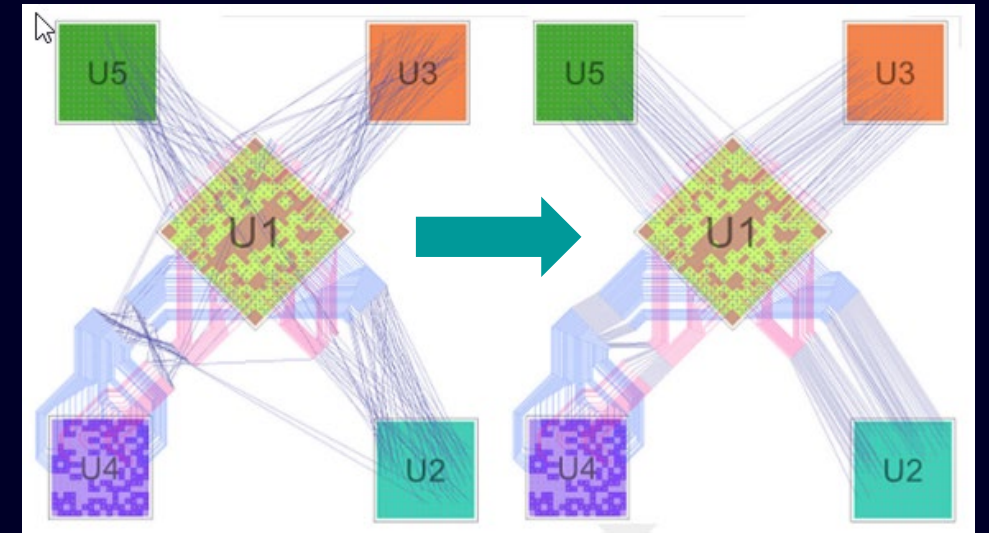
Roadblocks!

- Too much overhead to setup/implement/maintain
- FPGA tools good enough (even if they don't consider layout)

Best Practice

- Utilize FPGA/PCB integration
- Configure FPGA pin-out for routing optimization
- Enable efficient FPGA pin-swapping capability
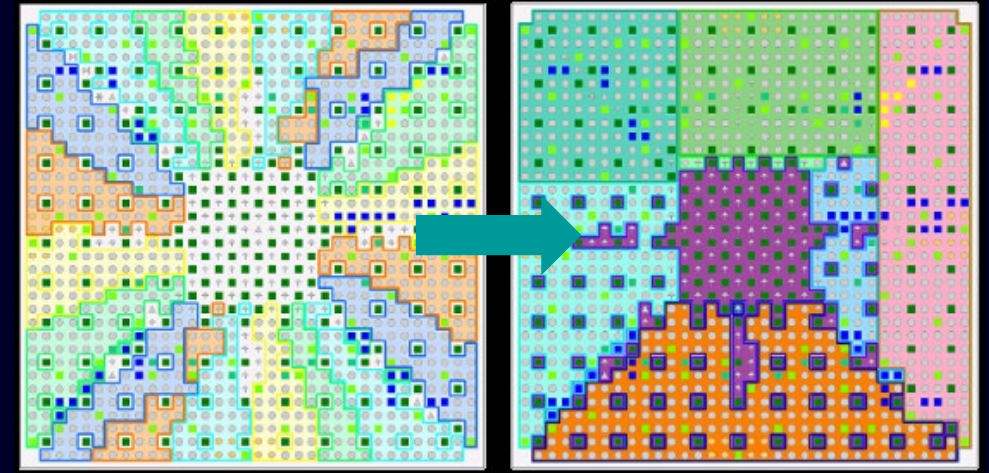
Ten banks partitioned into seven custom pins groups

Connectivity needs to be optimized across multiple devices
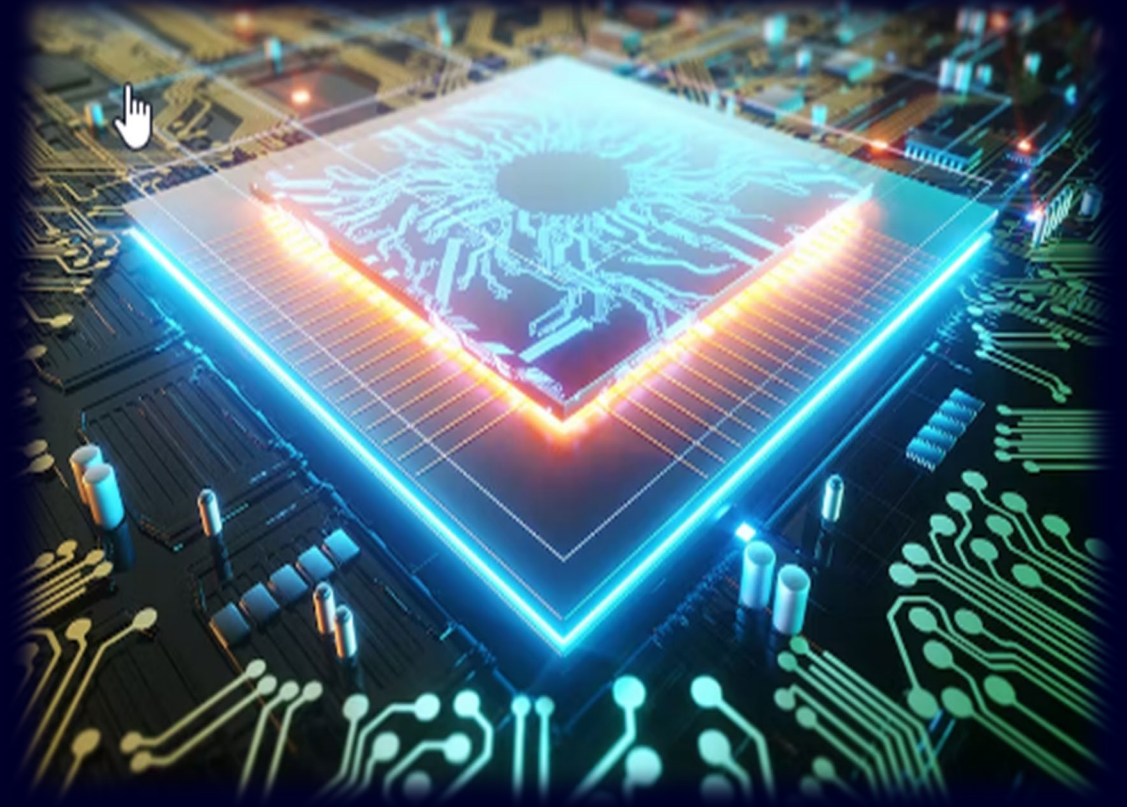
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IC/Package/PCB

Problem!

Inefficient IC/package/PCB optimization, not considering all "fabrics" simultaneously

Roadblocks!

- Not familiar/proficient with tool
- Too much overhead to setup/implement/maintain
- Too expensive to implement

Best Practice

- Utilize Systems-Level Model Based Engineering
- Optimize the system IO
- Enable digital twin

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Pillars of Best Practices

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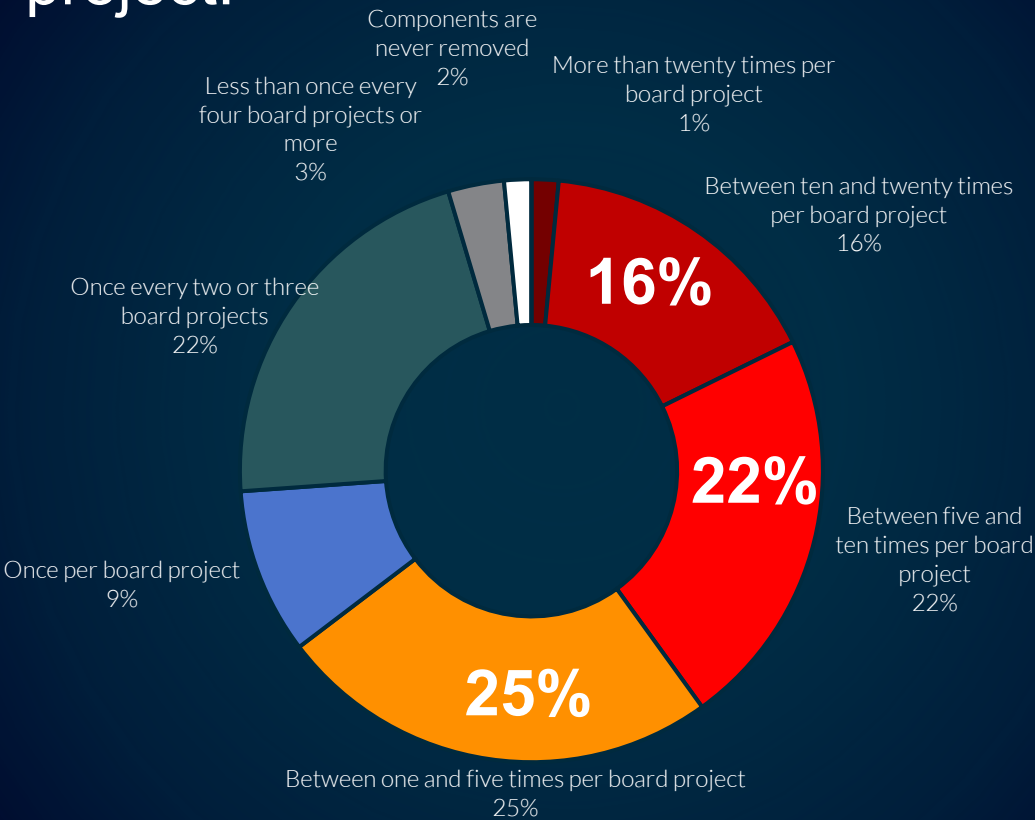Supply-chain resilience

SIEMENS
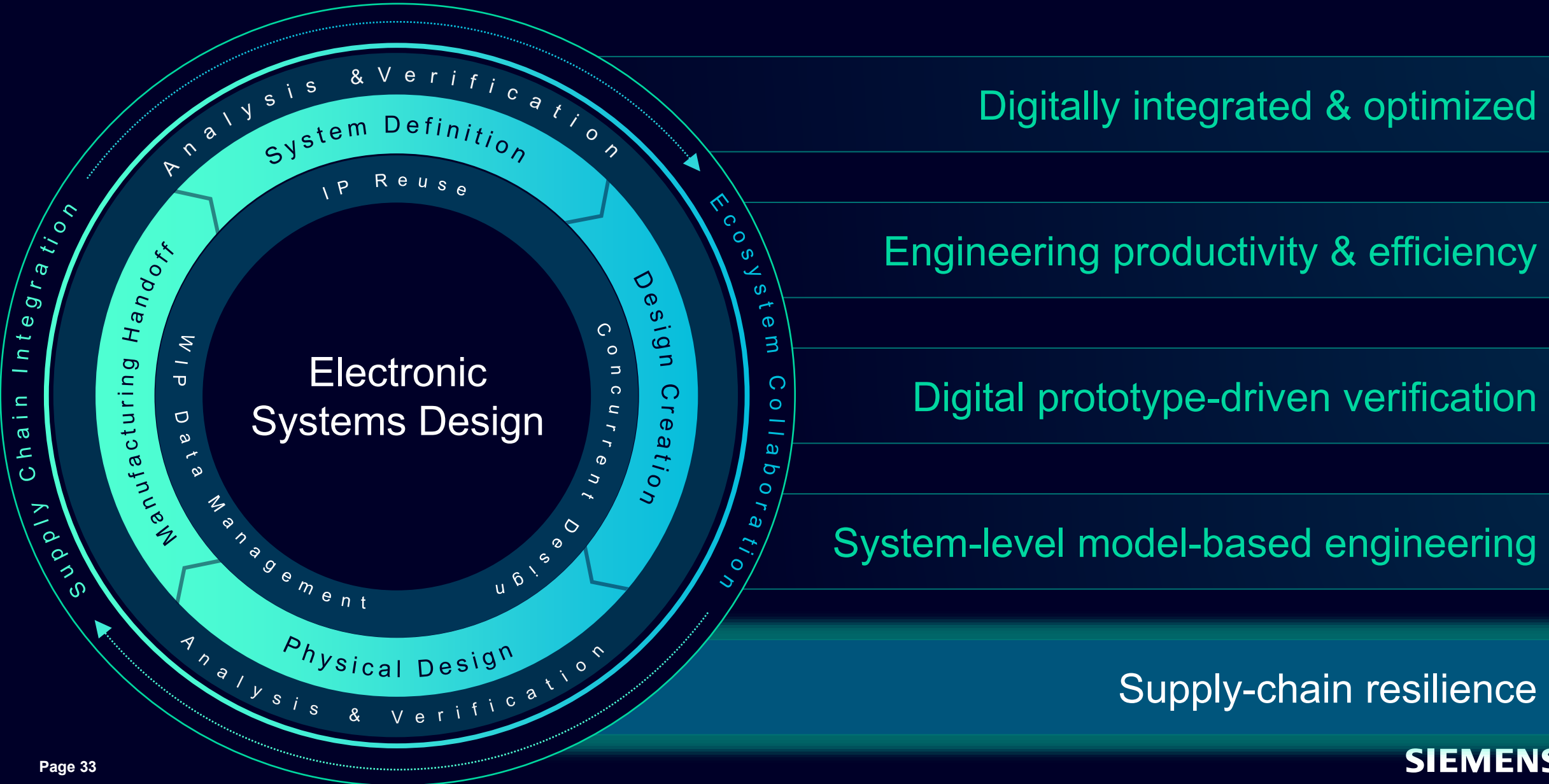
Supply-Chain Resilience

> ❝ The only abundance seen lately in the electronic components market is the quantity of calendar pages marking how long the supply shortage has lasted…the shortage has no clear end in sight, as the market continues to navigate a perfect storm of high demand and short supply for electronic products.
>
> Jabil

✓ **Integrated** sourcing an engineering collaboration bringing supply-chain information into the engineer's desktop

✓ **Accurate & up-to-date** component information available in enterprise libraries

✓ **Early sourcing optimization decision** with direct BoM integration

39% are removing components between five to twenty times per PCB project!

Components are never removed 2%

More than twenty times per board project 1%

Less than once every four board projects or more 3%

Between ten and twenty times per board project 16%

Once every two or three board projects 22%

16%

22%

Between five and ten times per board project 22%

Once per board project 9%

25%

Between one and five times per board project 25%

The average number of times engineers must remove an electronic component from their board design due to availability, lifecycle, or compliance.

Source: Lifecycle Insights April 2022

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Design for Resilience

Problem!

Siloed teams, legacy processes and ineffective risk management

Roadblocks!

- Just-in-time approach current mode of operation
- Not sure how to address supply chain issues
- Too much overhead to setup/implement/maintain

Best Practice

- Implement outside-in approach with supply-chain intelligence by shifting left best-known part availability, BOM validation, and validation of alternates at point of design
- Remove barriers from siloed teams and optimize operations and communications

Supply Chain Disruptions

+

Inefficient Operations

Image: Inefficient Mapping by Linda Knight

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Summary
Best Practices

- Understand the decisions made upstream and their effects down stream
- Utilize today's EDA tool automation and horsepower to your advantage
- Be open to new methodologies
- Know that company culture can be the ultimate roadblock
- Design for resilience

Questions?

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Thank You!

[Link to Building an effective PCB design flow - 36 video series](#)

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