Power Sources Manufacturers Association

A 5-Year Power Technology Roadmap

A summary of the PSMA workshop

held February 8, 2003 in Miami Beach, Florida

Presenter:

Charles E. Mullett

PSMA Chairman 2002-2003

Principal Systems Engineer ON Semiconductor®

Creating the 5-Year Power Technology Roadmap

Keynote Presentations

Mohan Mankikar – Micro-Tech Consultants

Fred Lee – CPES

End User Presentations

Thai Ngo / Randy Malik – IBM

Shawn Morrison – Nortel

Scott Wilson – Cisco

Bruce Miller – Dell

Ed Stanford – Intel

Power Supply Presentations

Lou Pechi – Power One

John Wanes – Celestica

Joseph Thottuvelil – Tyco

Trey Burns – Artesyn

Tom Duffy – Primarion

Component Technology Presentations

Jim Sarjeant, SUNY Buffalo (by proxy) – Capacitors

Lowell Bosley, Magnetics Div. of Spang – Magnetics

Cian O'Mathuna, NMRC (Ireland) – Packaging and Thermal Issues

Creating the 5-Year Power Technology Roadmap

Breakout Groups – a Key Ingredient

- Circuits and Architecture
- Packaging
- Components
- Oversight & Economics

The Scribes – Industry Experts

- Documented all presentations and discussions
- Scribes' inputs are included in the report.

The Organizing Committee

- Arnold Alderman – Anagenesis, Inc.
- Joe Horzepa – Horizon Consultants Ltd.
- Conor Quinn – Artesyn Technologies
- Chuck Mullett – ON Semiconductor
- Bob White – Artesyn Technologies

The 5-Year Roadmap Focus

- Three Categories
  - AC-DC “Front Ends”
    - 1000 W, Single Output with PFC
  - Isolated DC-DC Converters
    - 100 W “Bricks”
  - Nonisolated DC-DC Converters
    - Less than 200 W
  - All three are…
    - Fast growth markets
    - Key elements in distributed power systems

Power Supply User

Technical Challenges and Solutions

Future Power Technical Challenges

- Higher **Reliability** - MTBF
- Higher **Power Density**
- Higher **Transient Response** - di/dt
- Higher **Efficiency**
- Lower **Voltage** - Higher **Current**
- Voltage/Current **Distribution**
- Increased Number Of **Voltage Domains**
- Ability to **Hot Swap**
- Error and Status **Reporting**
- Increased Mobile Client **Power Needs**
- Lower **Cost**
- Shorter **Development Cycles**

Technology Solutions

- More **Integration**
- Higher **Switching Frequencies**
- Lower Switching and Conduction **Losses**
- **Topology** Influences
  - RES/ZVS/ZCS
- Better **EMI** Design
- Innovative **Design**
- Lower **Output Impedance**
- Thermal **Management**
- **Component Improvements**
  - Integrated Circuits
  - Battery Technology
  - Power Semiconductors
  - Capacitors
  - Interconnect

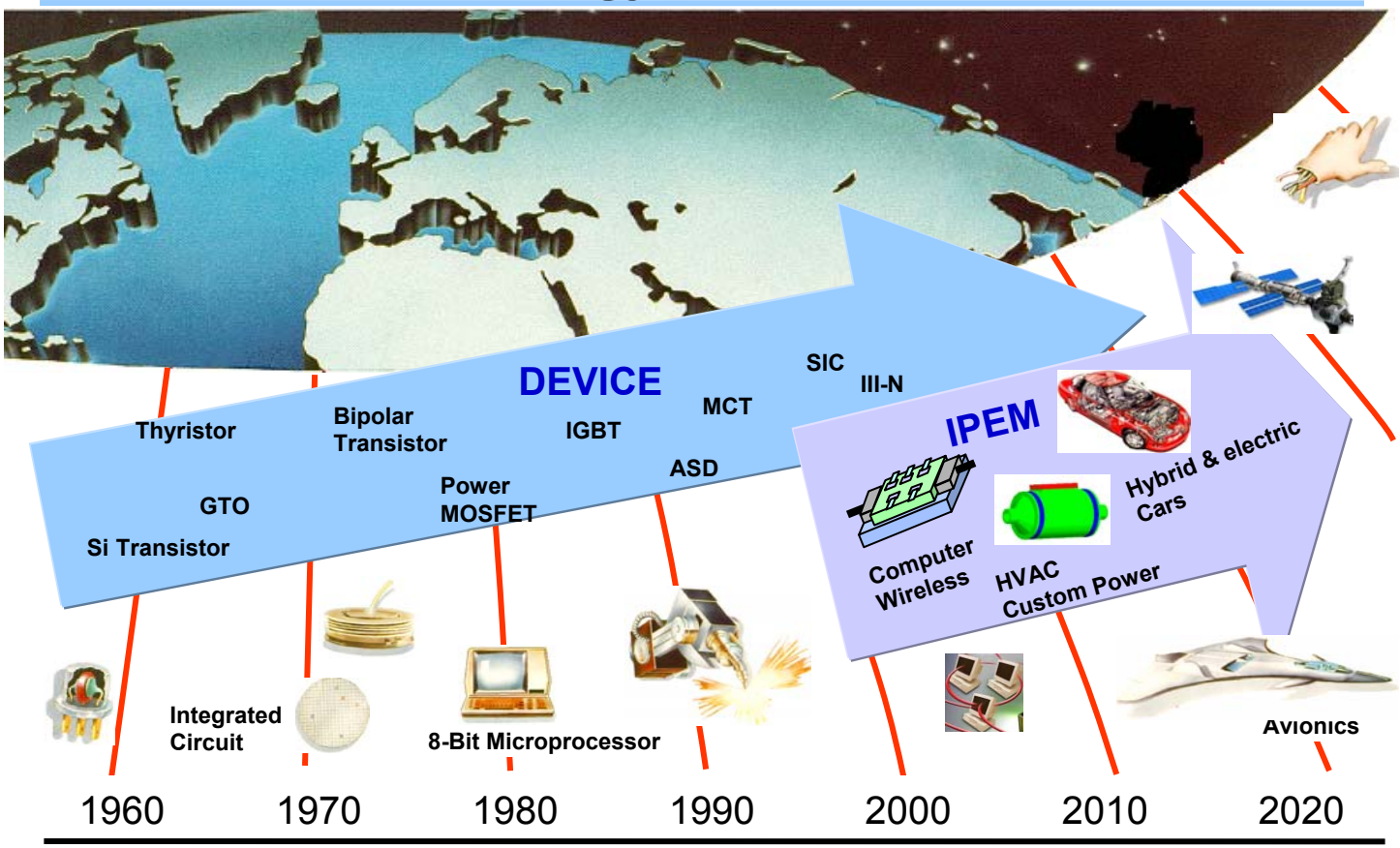
Summary of Opportunities

- **Power Switching Devices - The Backbone**
  - Tuned to evolving applications
  - Continued reduction in cost
- **Digital Control - A New Brain**
  - Potential is just now being tapped
  - Outstanding potential for converter performance and flexibility
- **Embedded Magnetics and Capacitors**
  - Higher frequencies enable smaller devices
  - Integration of passive components holds promise for higher performance and lower cost
- **Low impedance, high current interconnect between voltage regulators and high performance silicon**
- **Higher Density Energy Storage Capacitors**

ARTESYN TECHNOLOGIES

Fred Lee Presentation

Driving forces for power electronics technology and applications



*EPRI

THE POWER ELECTRONICS EVOLUTION

AC-DC "Front Ends"

	2003	2008
Cost ►	0.10 – 0.20 $/W	0.08 – 0.14 $/W
Time to Market (custom) ►	6 – 9 months	3 – 6 months
Density ►	3 – 10 W/in^3	10 – 25 W/in^3
MTBF ►	500 kh	750 – 1000 kh
Efficiency ►	80 – 85%	85 – 92%
Control ►	Analog	Digital
Switching Freq. ►	100 – 200 kHz	100 – 500 kHz
Monitoring ►	Analog & Digital	All Digital

AC-DC "Front Ends"

SUMMARY – Ratio of 2008 to 2003 values

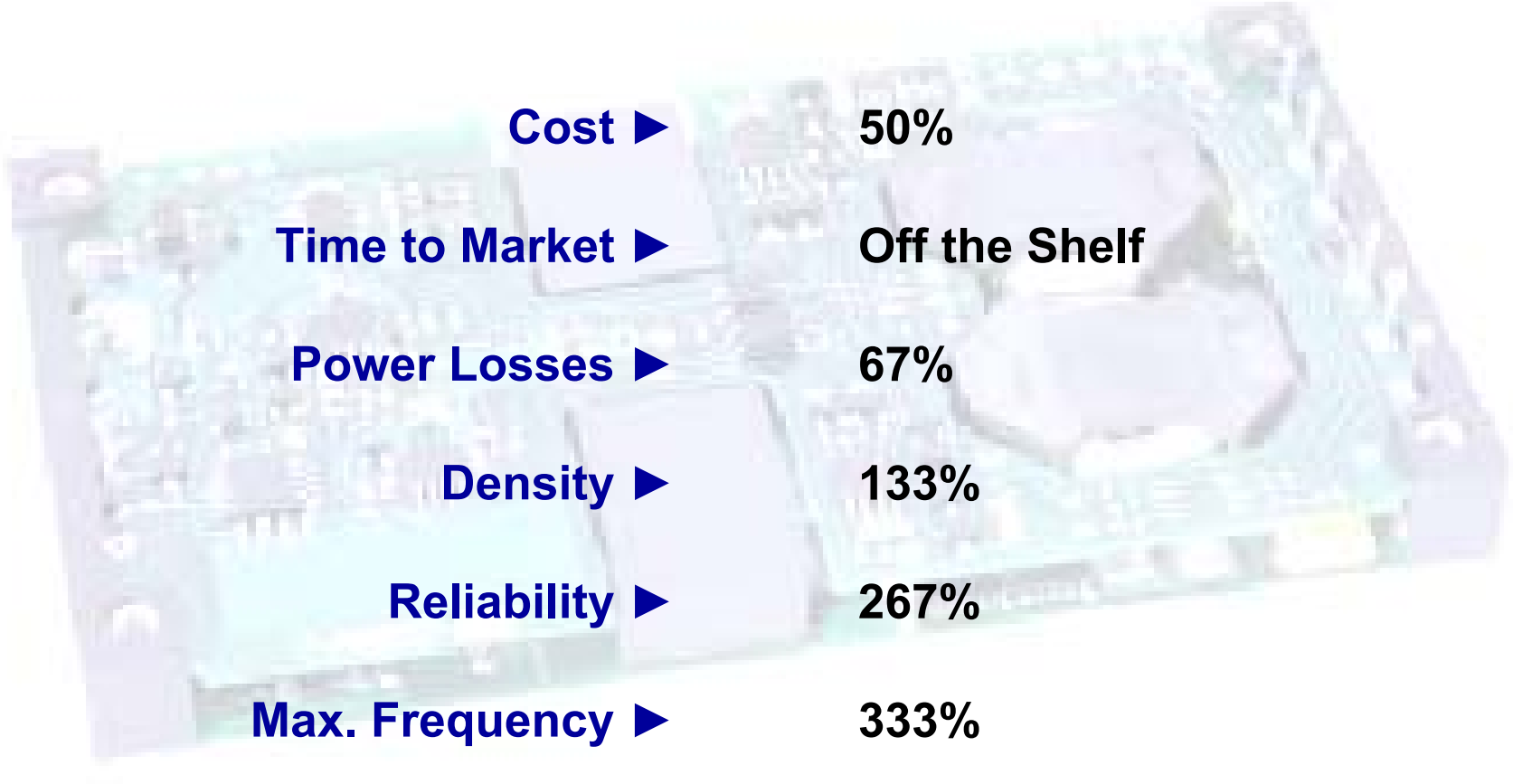
Cost ►	80%
Time to Market (custom designs) ►	60%
Density ►	300%
Power Losses ►	55%
Reliability (MTBF) ►	175%
Maximum Frequency ►	250%

100 W "Bricks"

	2003	2008
Cost ►	0.40 – 0.60 $/W	0.20 – 0.45 $/W
Density ►	75 W/in^3	100 W/in^3
Time to Market ►	Off The Shelf	Off The Shelf
MTBF ►	1 – 2 Mh	4 Mh
Efficiency ►	85 – 93%	90 – 95%
Control ►	Limited Digital	All Digital
Switching Freq. ►	200 – 300 kHz	300 – 1000 kHz
Magnetics ►	Planar Ferrite 10% Custom Shapes	5% Thin Film 50% Custom Shapes

100 W “Bricks”

SUMMARY – Ratio of 2008 to 2003 values



Cost ►	50%
Time to Market ►	Off the Shelf
Power Losses ►	67%
Density ►	133%
Reliability ►	267%
Max. Frequency ►	333%

Non-Isolated DC-DC Converters (Under 200 W)

	2003	2008
Cost ►	0.15 – 1.00 $/A	0.10 – 0.50 $/A
Density ►	50 A/in^3	75 A/in^3
Time to Market ►	Off the shelf	Off the shelf
MTBF ►	4 Mh	4 Mh
Efficiency ►	83 – 95%	85 – 97%
Control ►	Mostly Analog	Mostly Digital
Switching Freq. ►	0.5 – 1 MHz (per phase)	1 – 2 MHz (per phase)
Switch Package ►	SO-8 and Derivatives	Chip Scale Packages

Non-Isolated DC-DC Converters (Under 200 W)

SUMMARY – Ratio of 2008 to 2003 values

Cost ►	50%
Time to Market ►	Off the Shelf
Power Losses ►	60%
Density ►	150%
Reliability (MTBF) ►	100%
Maximum Frequency ►	200%

Average of all Three Categories

Parameter	Ratio, 2008/2003
Cost ►	**60%**
Time to Market ► (Custom Designs)	**60%**
Power Losses ►	**60%**
Density ►	**200%**
Reliability (MTBF) **►**	**180%**
Frequency ►	**250%**

Future Power Supplies

Not Seen

Not Heard

Not Hot

Not Expensive

How do we get there?

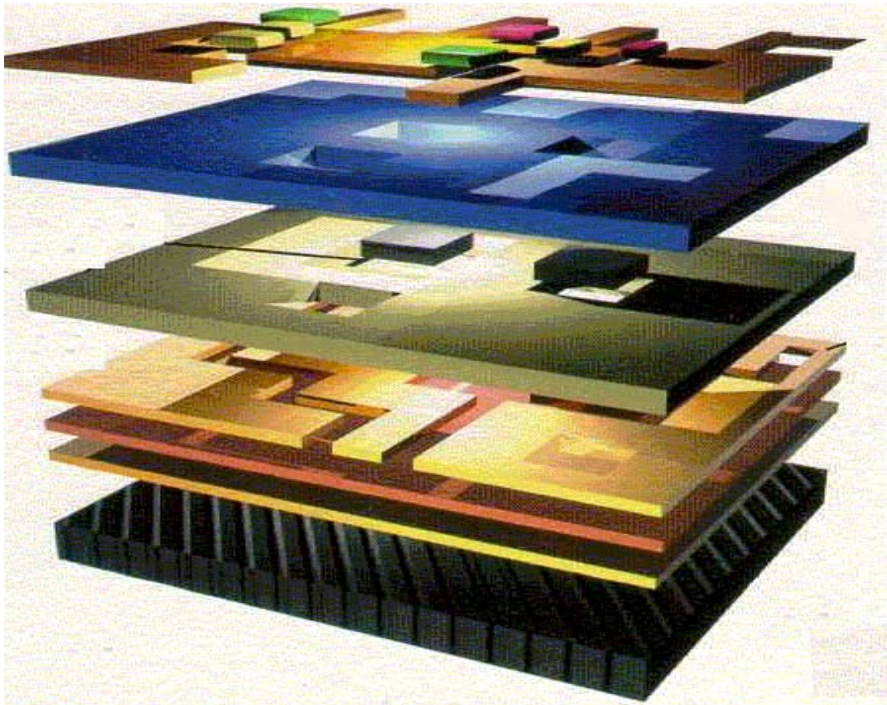
Solutions

- **Packaging**
- **Circuits & Technology**
- **Passive Components**
- **Semiconductors**

Solutions

Packaging

- **Better use of space, integration of components**
- **Better thermal management**



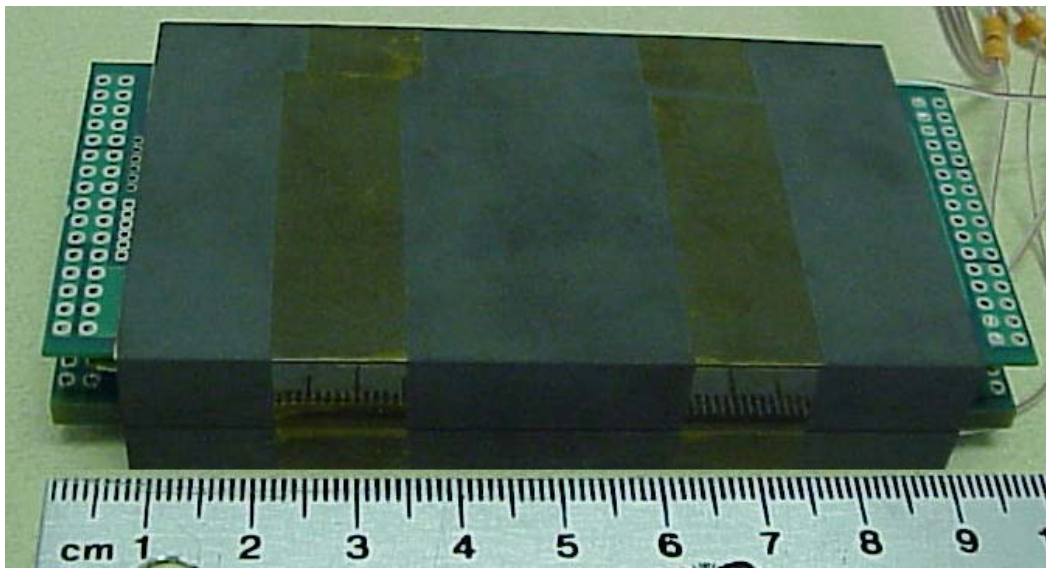
Circuits & Topology

- **Soft-switching techniques to minimize switching losses**
- **Topologies that minimize parasitic losses**

Solutions

Passive Components

- **Magnetic materials with lower losses**
- **Capacitors with lower parasitic inductance and resistance**
- **Integrated passive component modules**

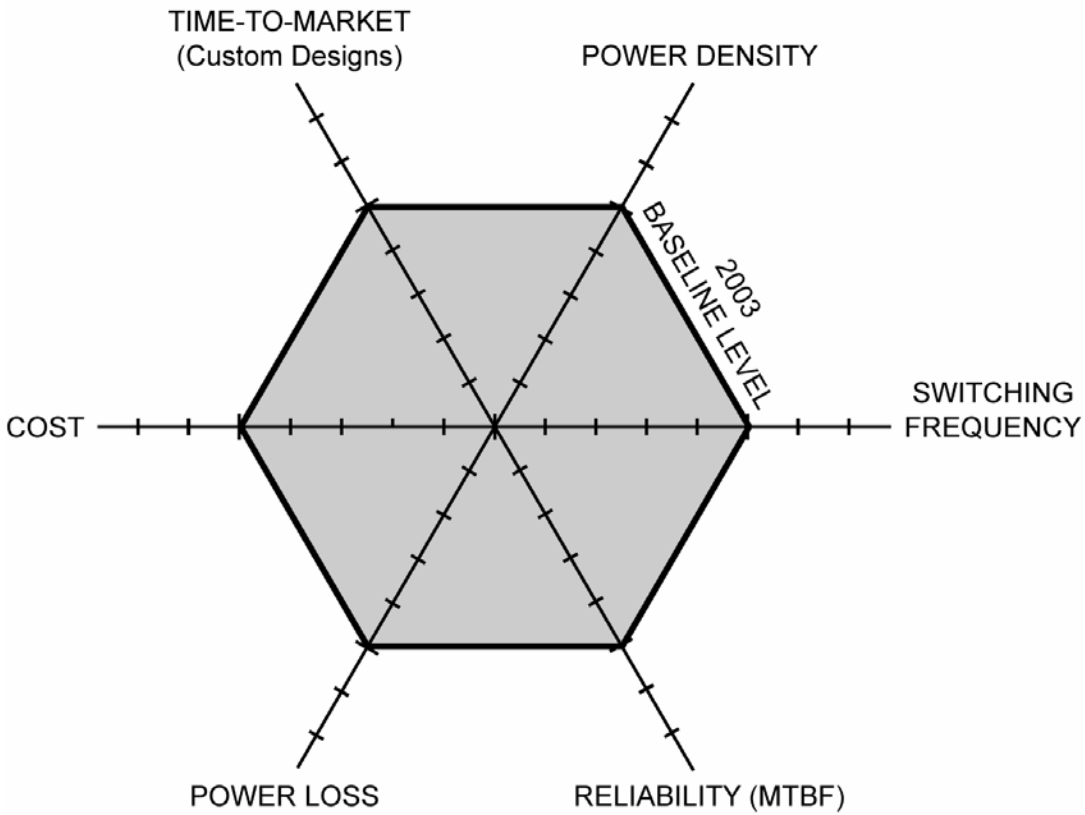


Solutions

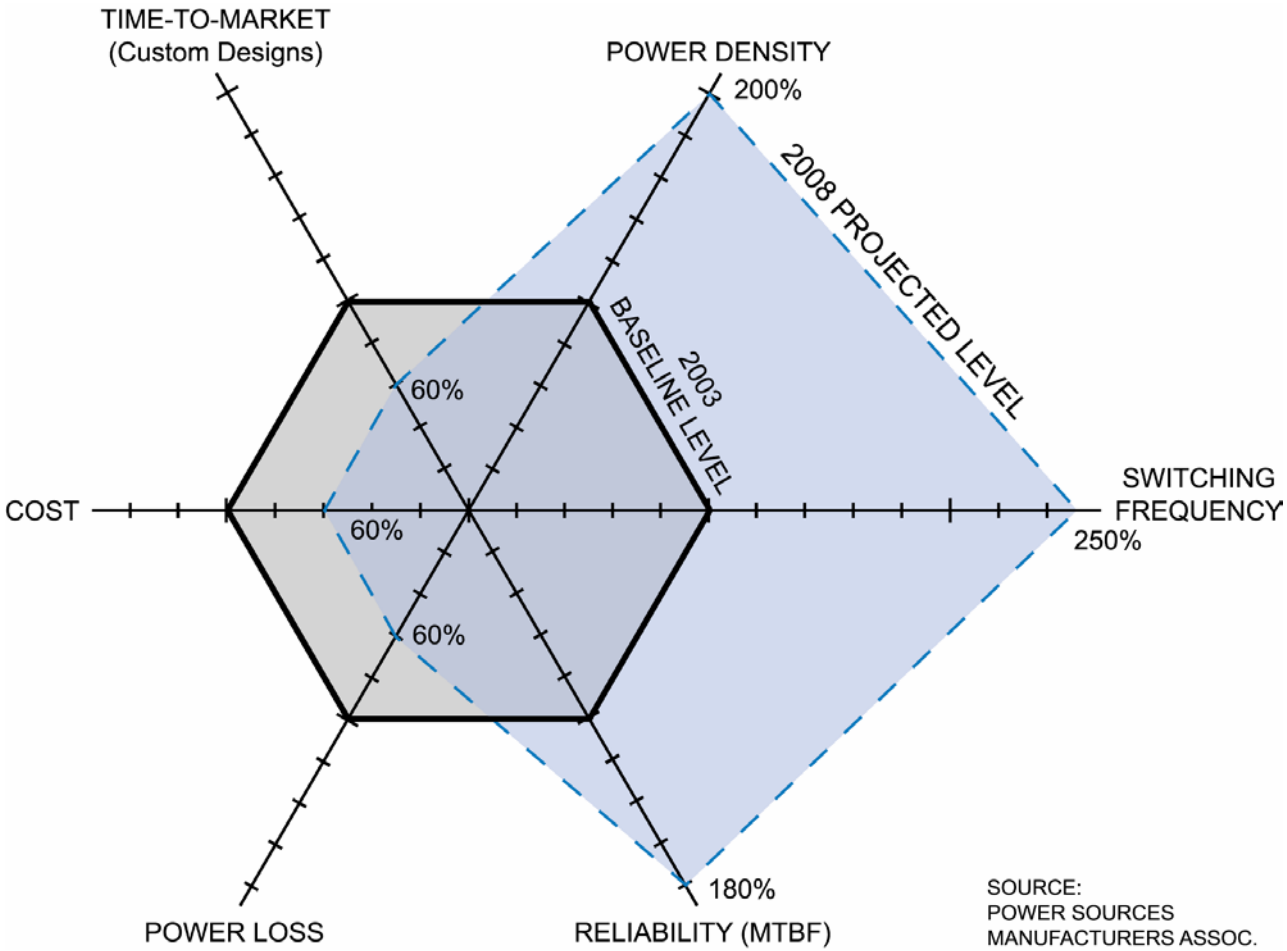
Semiconductors

- **Better fundamental elements**
  (bipolar, MOS transistors, etc.)
- **Integrated devices with better thermal management**
- **Controllers that optimize both standby and active modes**

5-Year Trend of Key Parameters



5-Year Trend of Key Parameters



The Pieces of the Puzzle

More Integration

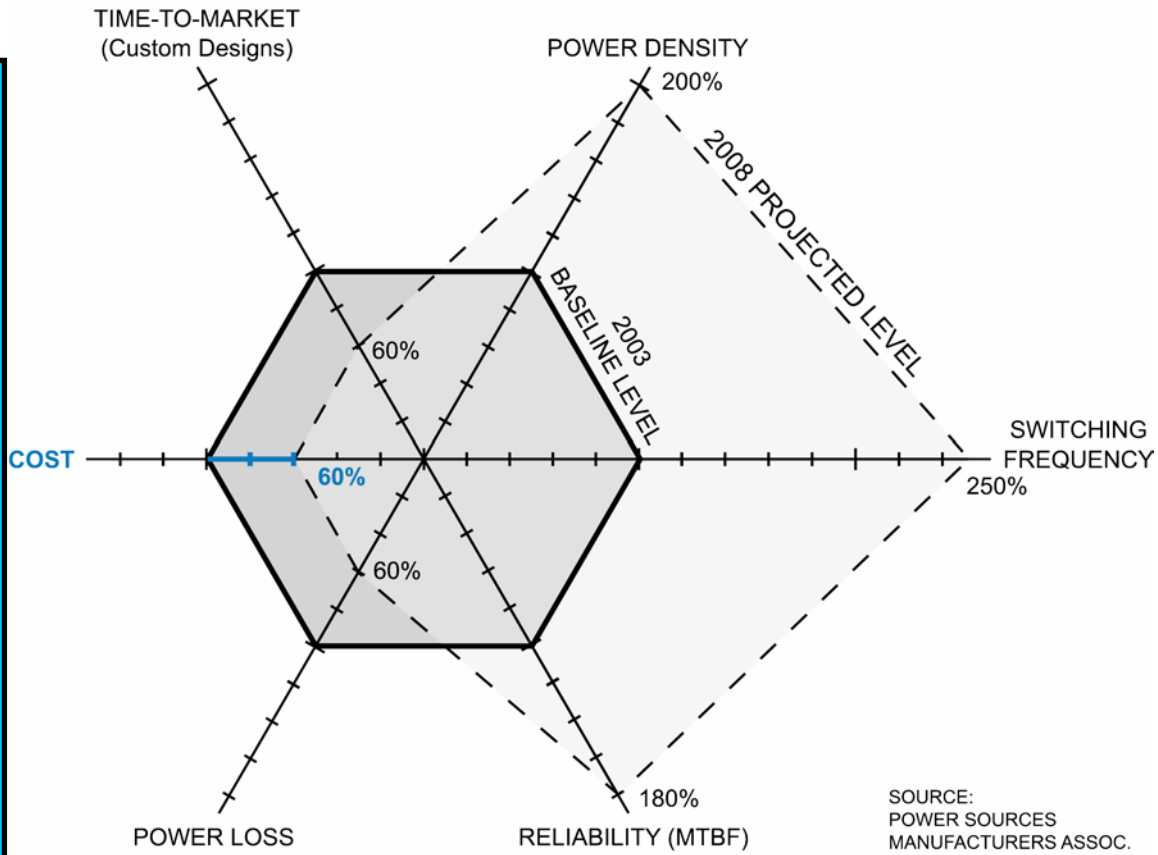
Better/Cost Effective Components (ICs, Power Semi's, etc.)

Optimal Topologies

Innovative Design

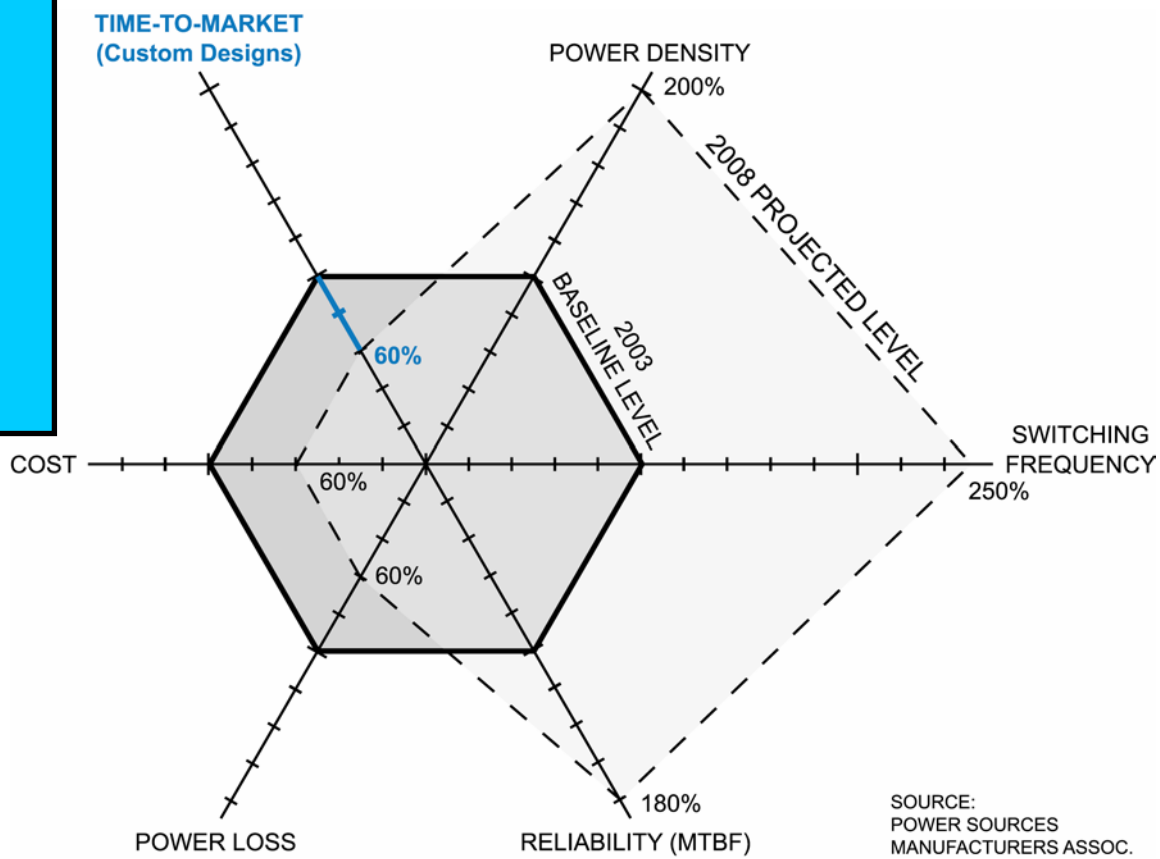
Manufacturing Techniques

Lower Losses (Reduces cost of package)



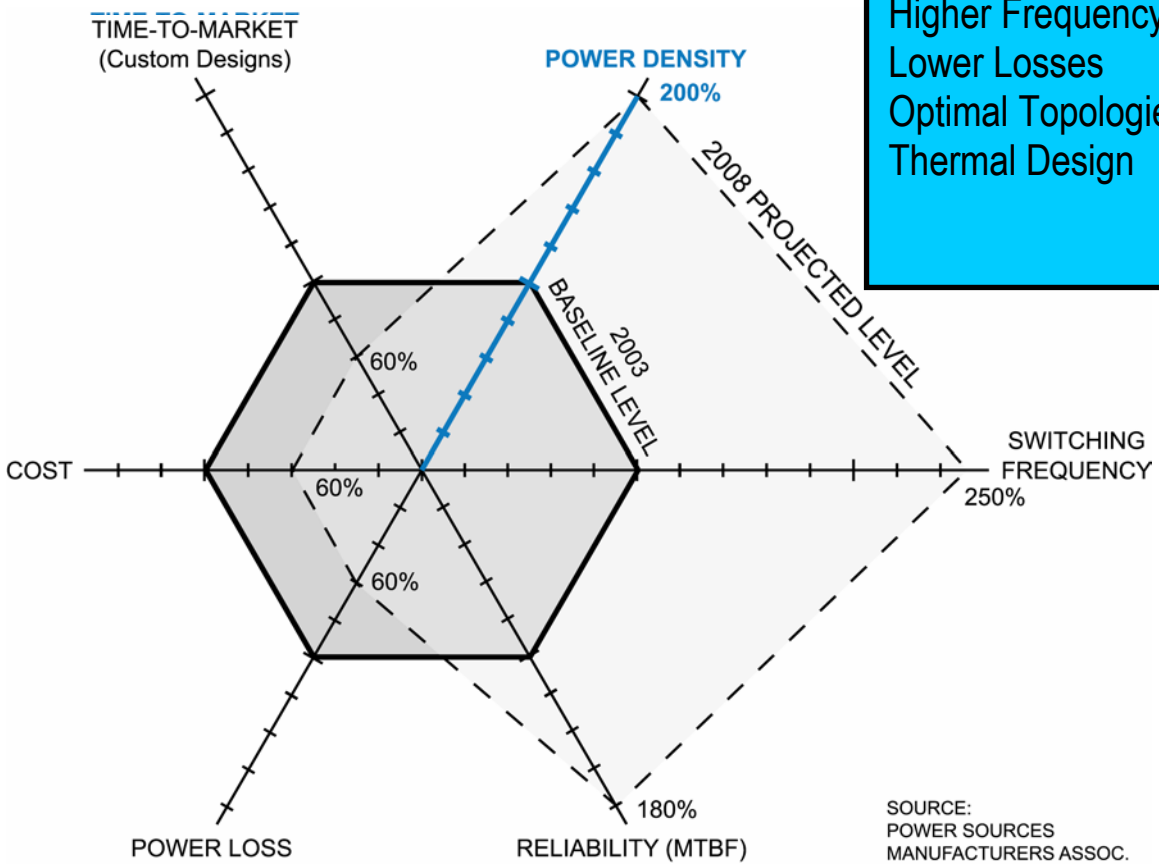
The Pieces of the Puzzle

- Integration
- Design Software
- Models
- Kit Solutions
- Technical Support

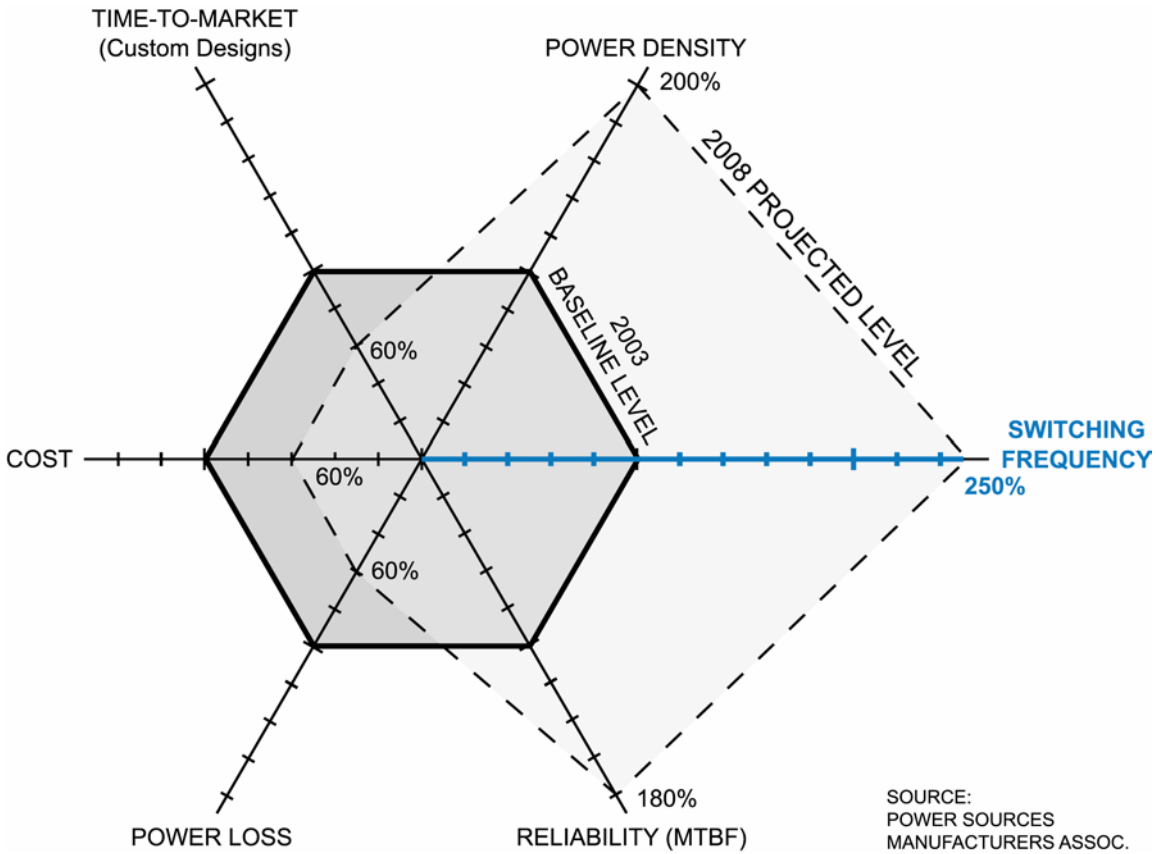


The Pieces of the Puzzle

More Integration	Better Components
Higher Frequency	ICs
Lower Losses	Power Semi's
Optimal Topologies	Capacitors
Thermal Design	Magnetics
	Materials
	Structures

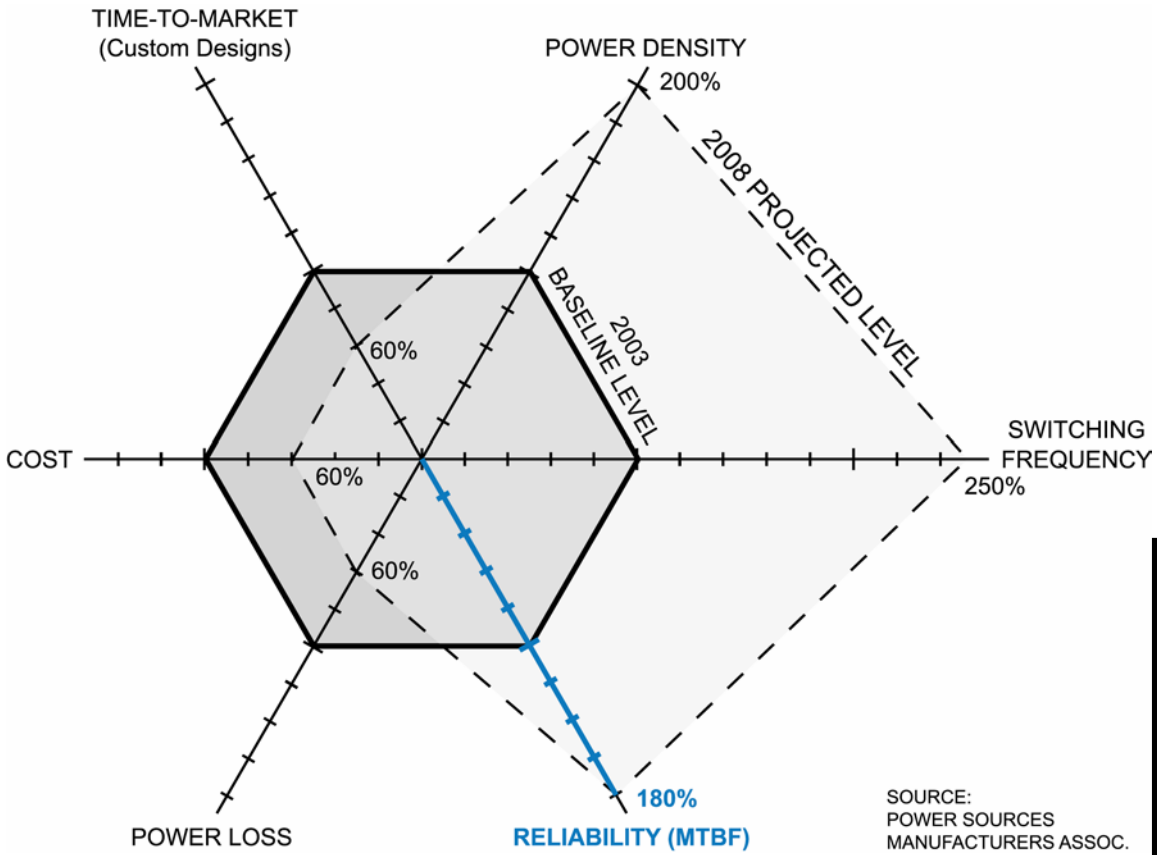


The Pieces of the Puzzle



- Lower Losses
- Optimal Topologies
- Thermal Design
- Better Components
  - ICs
  - Power Semi's
  - Capacitors
  - Magnetics
    - Materials
    - Structures

The Pieces of the Puzzle



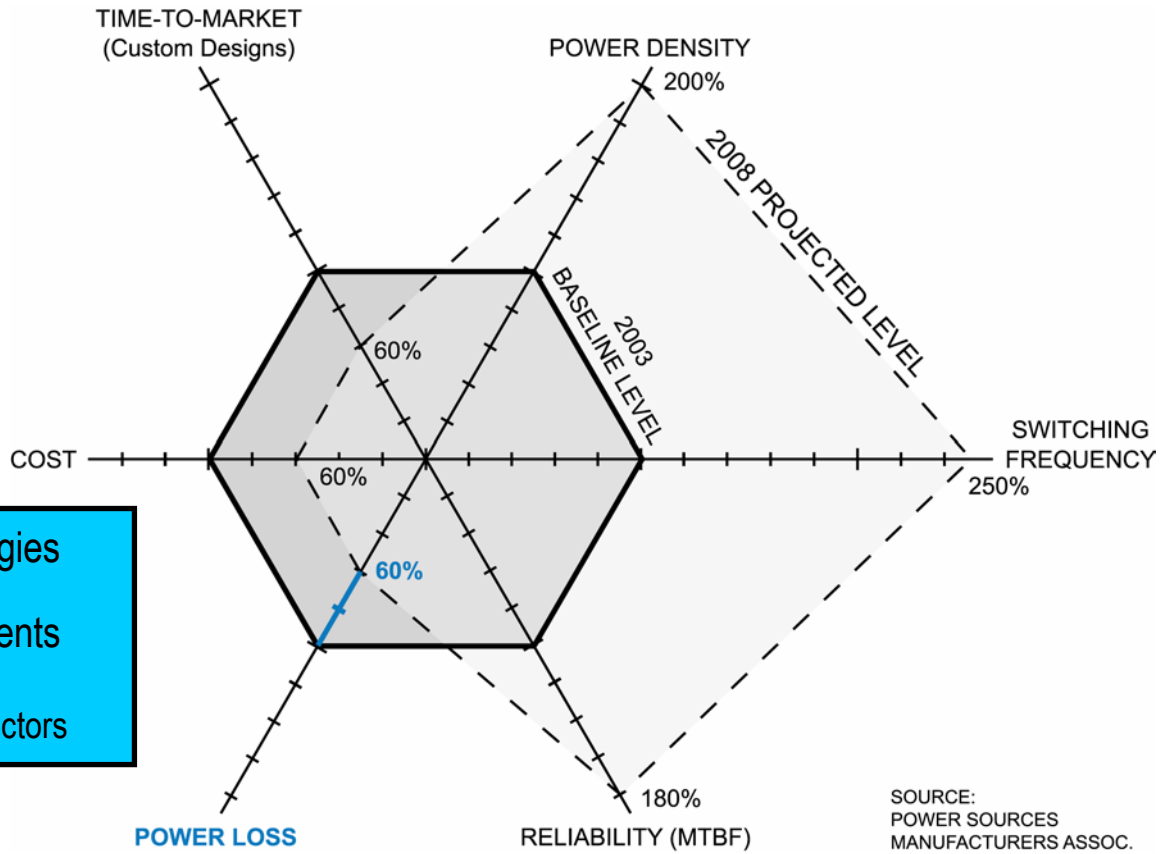
Better Components

Thermal Design

Better Design
Stress Analysis

Hot Swap
Infrastructure

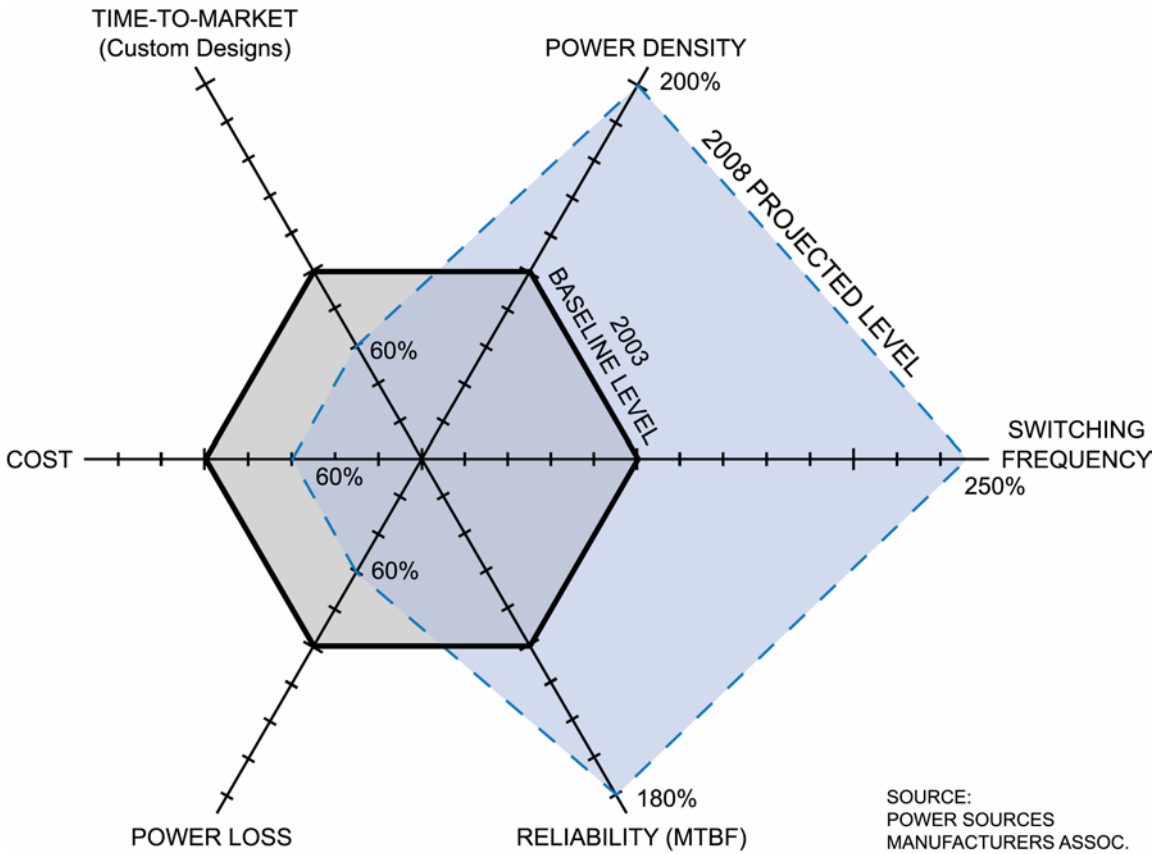
The Pieces of the Puzzle



Optimal Topologies

Better Components
ICs
Power Semiconductors

5-Year Trend of Key Parameters



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