Increase flight time and functionality with robust, efficient power delivery

High density power conversion for UAVs

8 things to know about UAVs for aerospace & defense

Power density improves Size, Weight, and Power capability (SWaP)

Added functionality requires more space and power

Higher efficiency equals longer range/flight time

Tethered UAVs need high voltage cabling

A&D applications require solutions that meet MIL-STDs

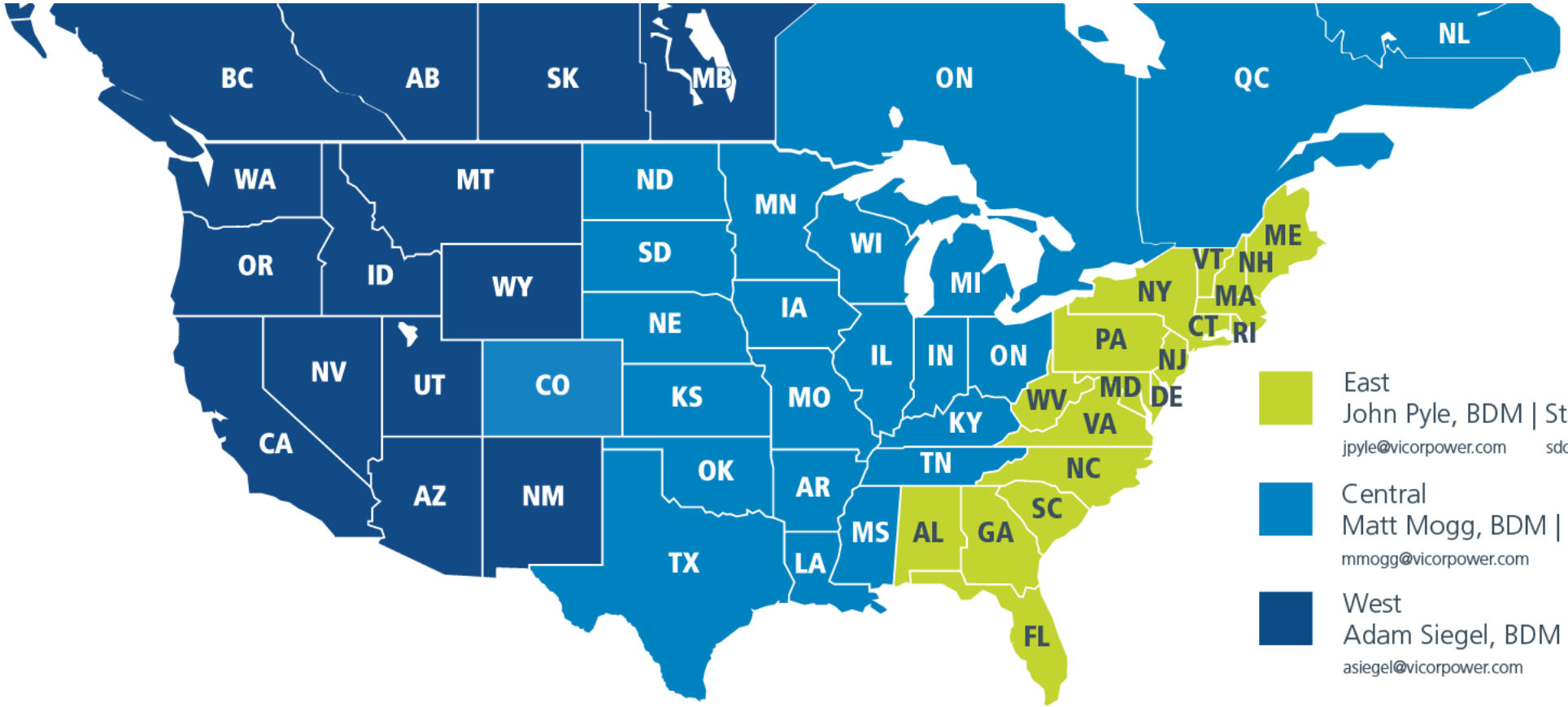
New applications require faster time-to-market

Booming $16 billion market

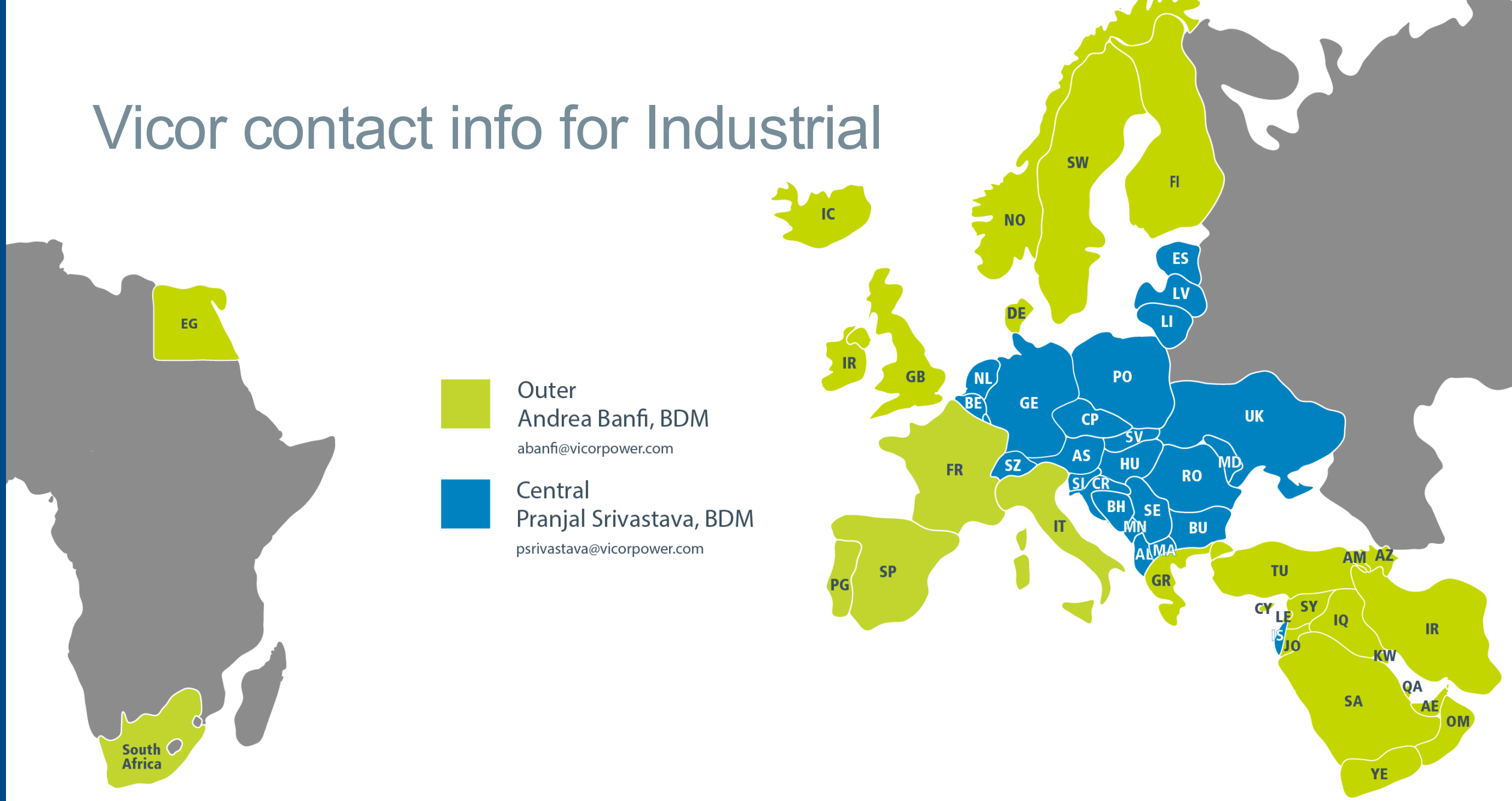
AI requires more processing power

Target customers

Vicor contact info for Industrial



Vicor contact info for Industrial



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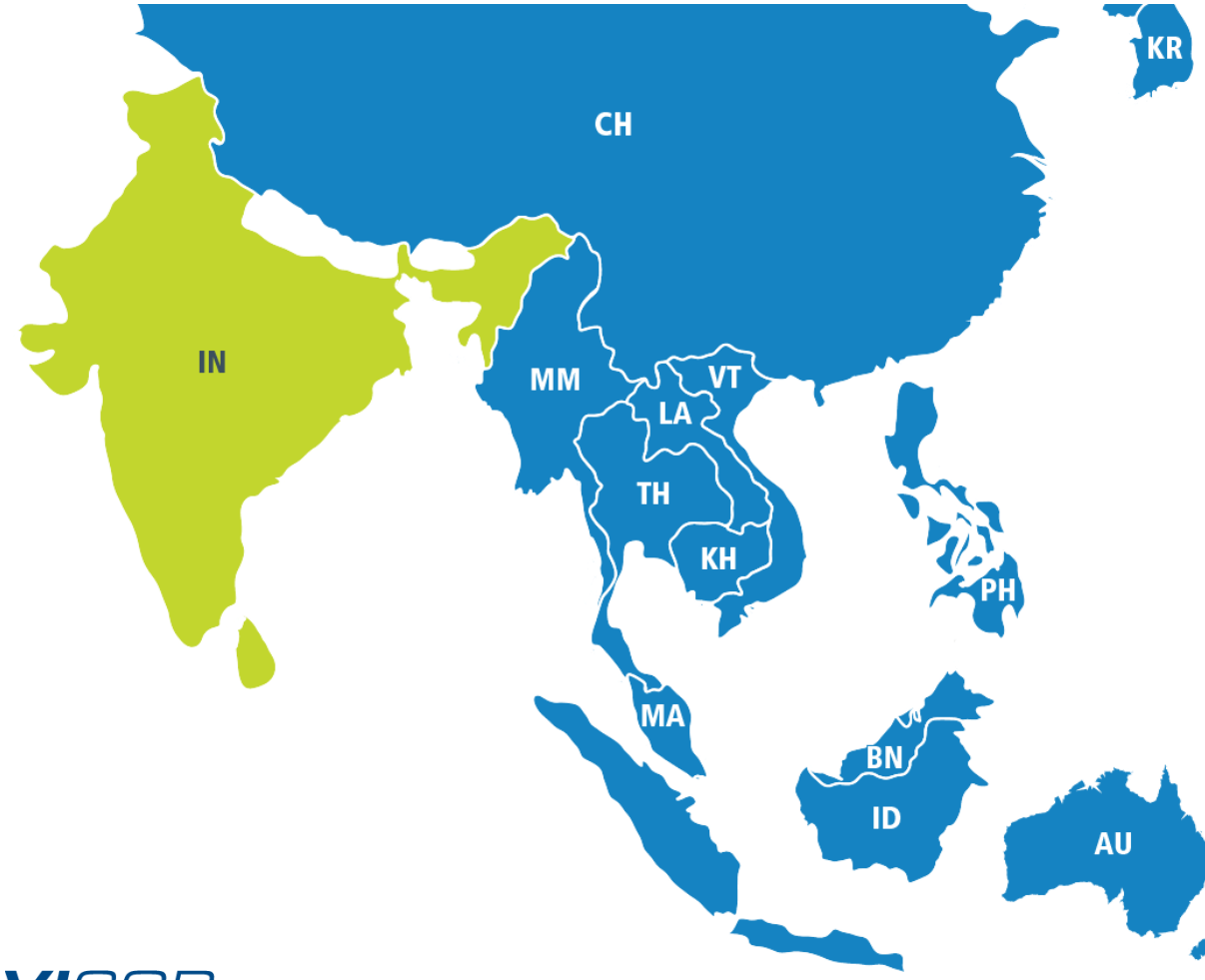

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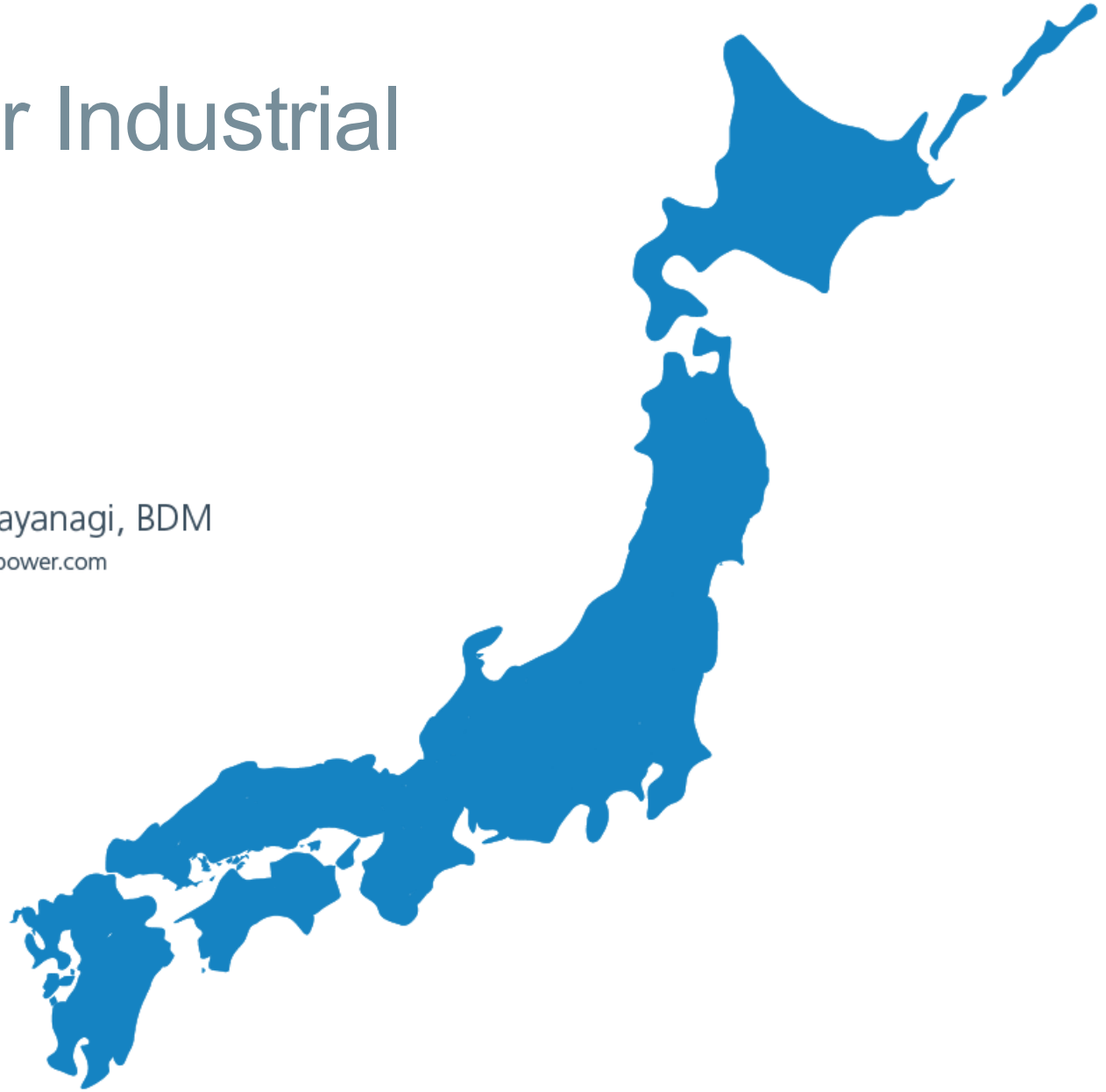


Where are the opportunities?

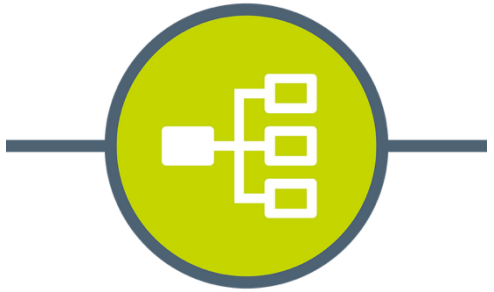
- When size, weight, and power are critical for functionality
- Smaller, untethered UAVs primarily powered by 28V and 48V batteries
- Larger UAVs powered by typical aircraft generators at 270V
- Tethered UAVs with 400V or 800V cables
- Time to market is critical for the UAV designers

Leader in high density power conversion

Highest power density modules

6x more power density

Most efficient power conversion for 28V and 48V power delivery networks

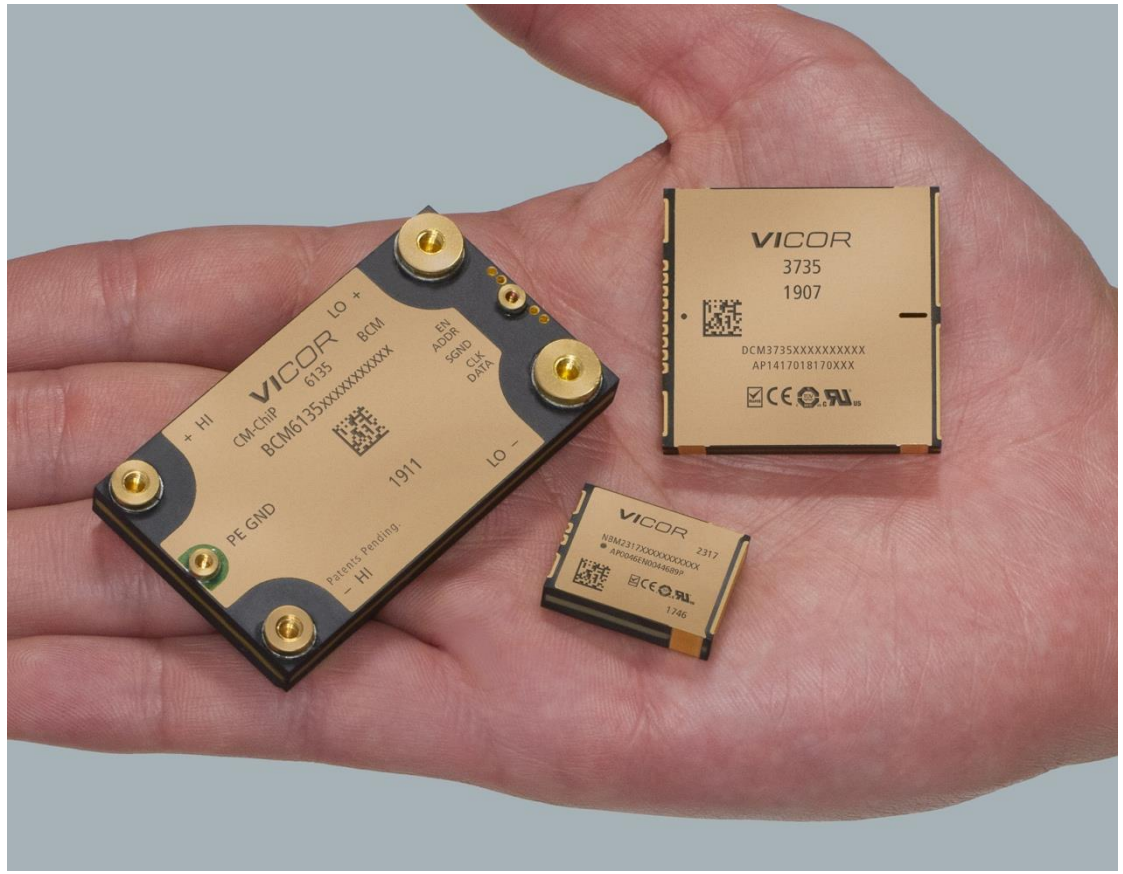


Complete portfolio of 28V, 48V, 400V, and 800V products enabling rapid deployment

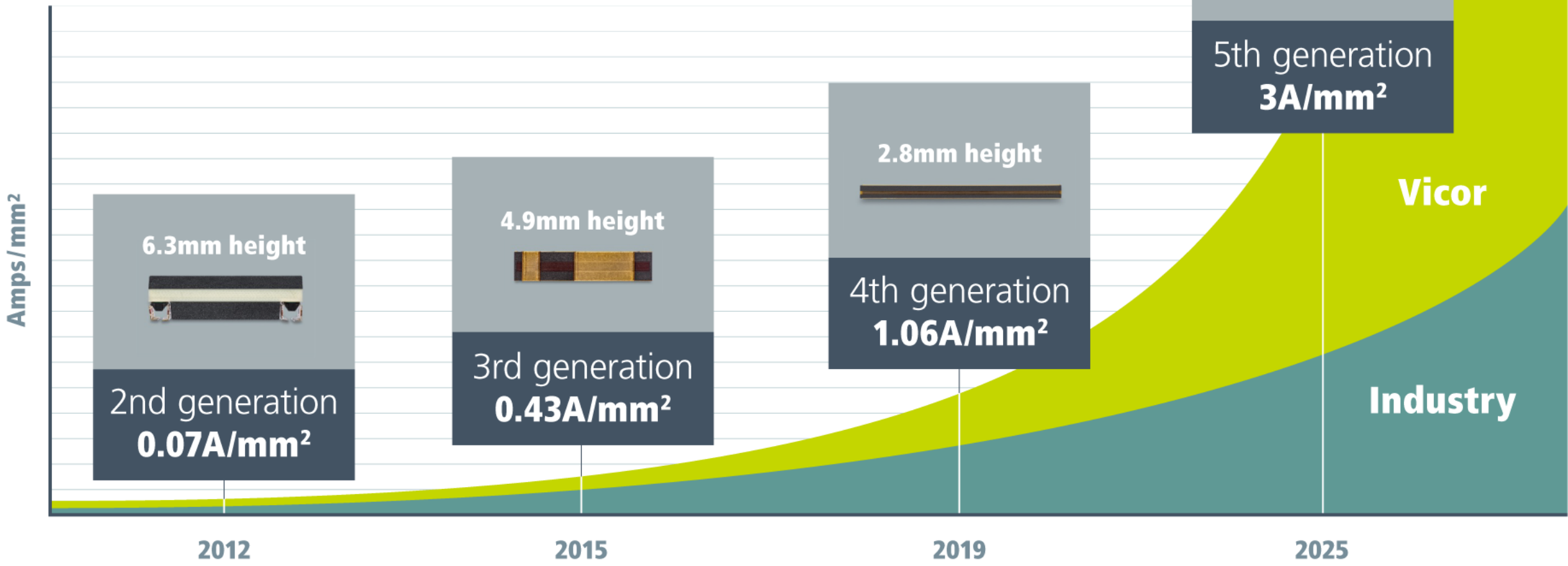
Rugged, reliable power modules that meet MIL-STDs

Highest density power modules

- Solving the toughest problems
- Modules with 6x power density
- Leading innovation
- Highest power density for 40+ years



Continually providing the highest density power solutions



Industrial systems are transitioning to 48V

Communications was the first to use 48V to decrease power losses over long distances

↓

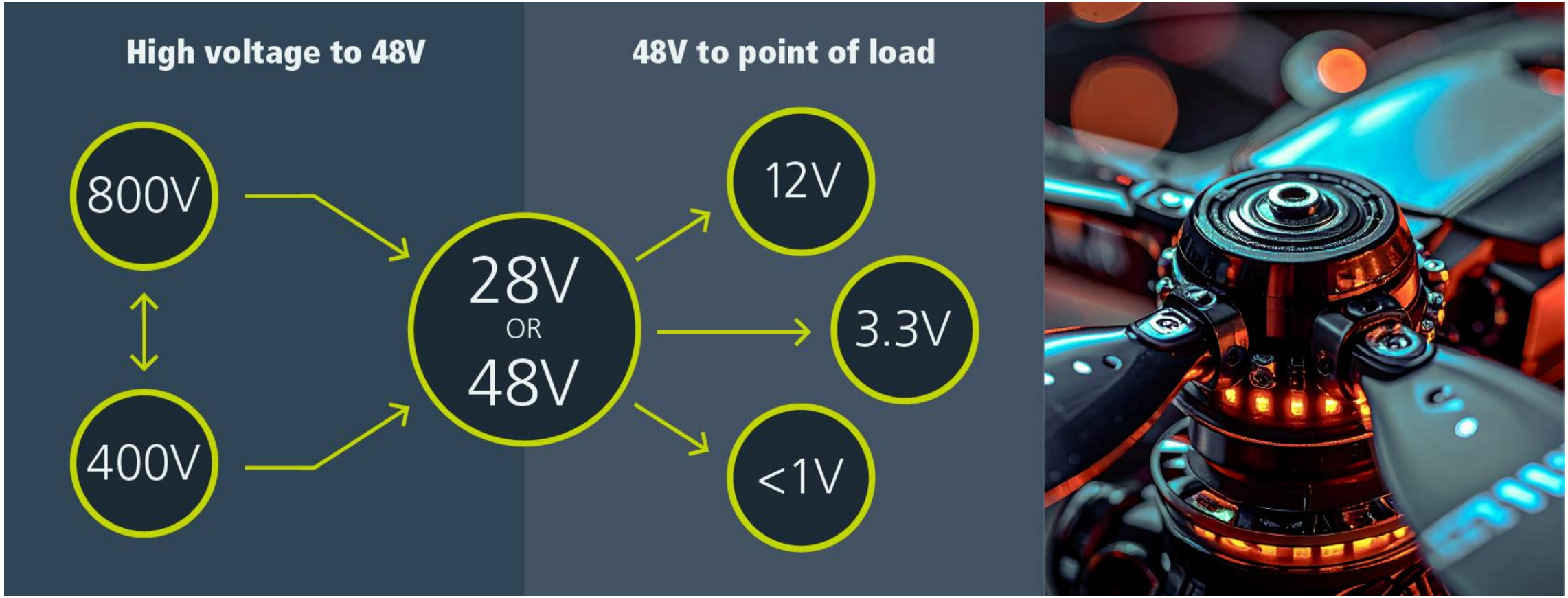
High performance computing adopted 48V to meet the power demands of large data centers

↓

Automotive migrated to 48V to reduce the weight of EVs

Industrial is now leveraging the experience of these industries to also gain the benefits of 48V

Vicor portfolio

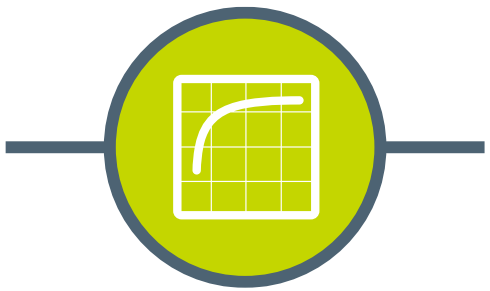


Discovery questions to ask

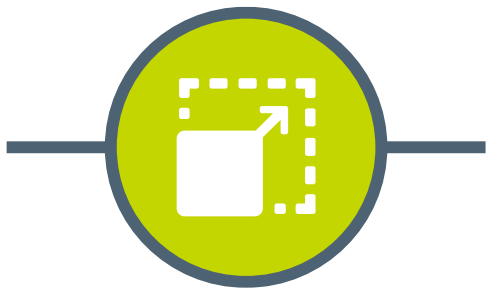
- Is your design restricted by space?
- Do you have higher power requirements in the same physical space later?
- Is your current solution limiting performance/range?
- Is time-to-market or easy scalability important?
- Which outputs, if any, require isolation from the battery?
- What MIL-STDs are you required to meet?

UAV solutions

Key Vicor benefits



High density and efficiency



Scalable to higher power

Low height and lightweight

Tested to MIL-STDs

UAVs – the power challenges

- **More autonomous functionality**

  Growing demand for more computing power in more sophisticated ROVs

- **Optimize performance**

  Looking for the perfect balance of efficiently delivering power and containing the size and weight of the ROV for longer run times

- **Get to market faster**

  Overcome the lack of power expertise and quickly implement a 48V architecture

UAVs – the power module advantage

- **Power dense and efficient**

  Kilowatts of power in the industry's smallest form factor

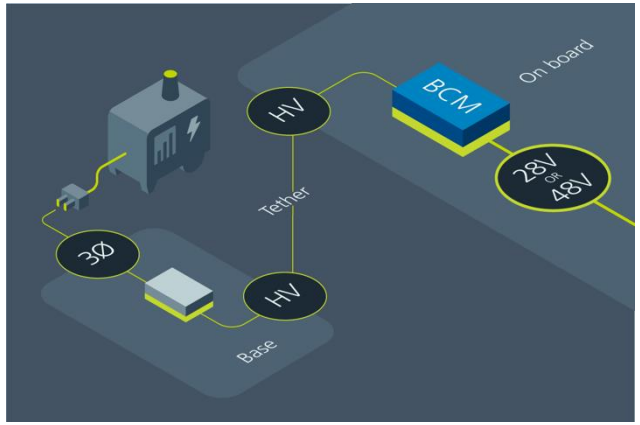
- **Improved thermal management**

  Significantly reduces heat that is generated, increasing the ROVs reliability and agility

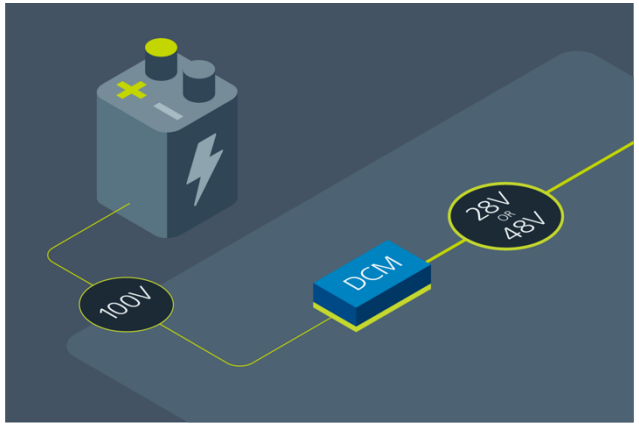
- **Simple to design**

  Certified, qualified modules easy to design-in and update to meet evolving power requirements

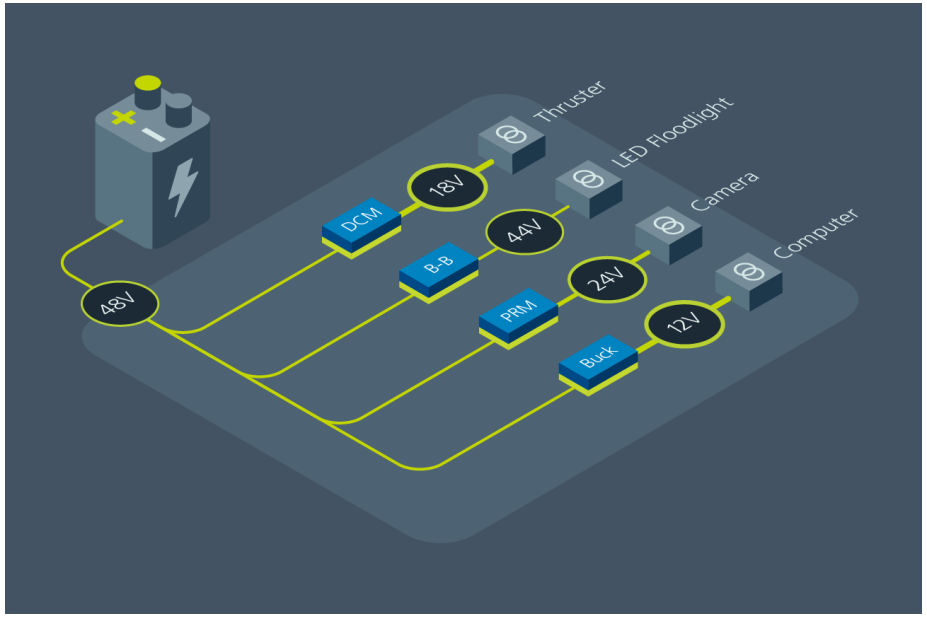
Power Delivery Network



Converting high voltage to a 48V or 28V bus

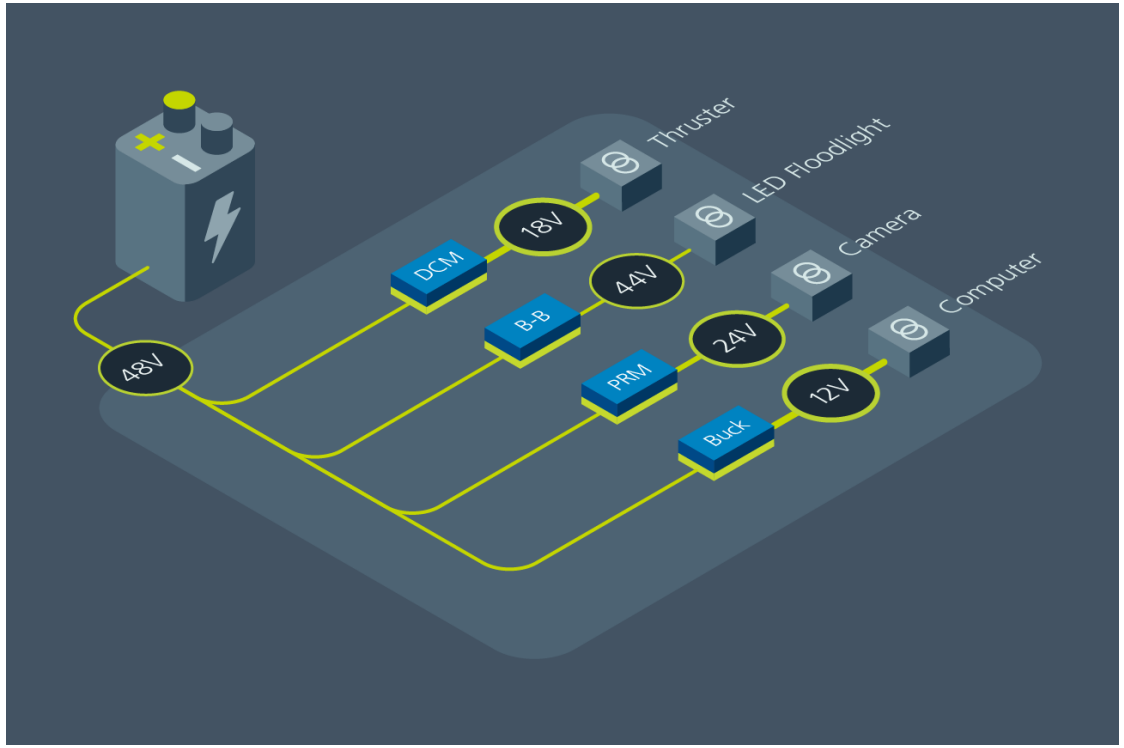


Converting batteries to a 48V or 28V bus



Powering loads

The Power Delivery Network – to PoL



Powering loads on a 48V bus

Power modules optimized for a 48V architecture

BCM® bus converter

Isolated fixed-ratio

Input: 800 – 48V

Output: 2.4 – 55.0V

Current: Up to 150A

Peak efficiency: 98%

As small as 22.0 x 16.5 x 6.7mm

vicorpower.com/bcm

DCM™ DC-DC converter

Isolated regulated

Input: 9 – 420V

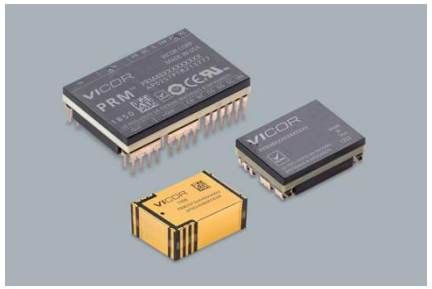
Output: 3.3, 5, 12, 13.8, 15, 24, 28, 36, 48V

Power: Up to 1300W

Peak efficiency: 96%

As small as 24.8 x 22.8 x 7.21mm

vicorpower.com/dcm



PRM™ regulator

Non-isolated regulated

Input: 48V (36 – 75V)

Output: 48V (5 – 55V)

Power: Up to 600W

Peak efficiency: 98%

As small as 22.0 x 16.5 x 6.73mm

vicorpower.com/prm

ZVS buck regulator

Non-isolated regulated

Inputs: 12V (8 – 18V), 24V (8 – 42V), 48V (30 – 60V)

Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as 10.0 x 10.0 x 2.56mm

vicorpower.com/buck

ZVS buck-boost regulator

Non-isolated regulated

Input: 8 – 60V

Output: 10 – 54V

Power: Up to 150W continuous

Peak efficiency: 98%

10.5 x 14.5 x 3.05mm

vicorpower.com/buck-boost

UAV case studies

Agricultural UAVs
Delivery UAVs
HALE UAVs
Inspection UAVs
Media and entertainment UAVs
Surveillance UAVs
Tethered UAVs
Unmanned aircraft for communications

Case study – Agricultural UAVs

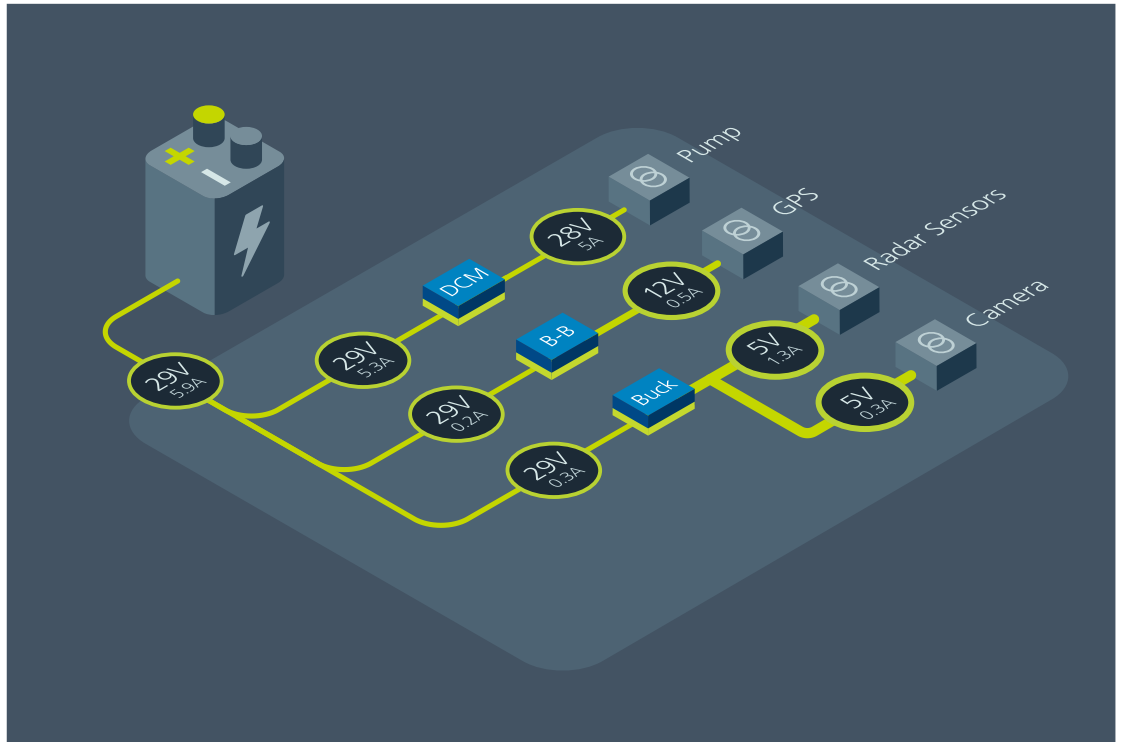
Customer challenges

- Significantly reduce power supply weight and maximize space on-board for payload
- Extend flight time for more productivity
- Handle a wide range of input voltages

Vicor solution

- Higher efficiency to extend flight times and range of operation
- Power modules support a variety of input voltages for PoL devices
- Advanced packaging and topologies

Case study – Agricultural UAVs



- The Vicor DCM™ DC-DC converter is a highly efficient isolated, regulated module
  - Utilizes a high-frequency Zero-Voltage Switching (ZVS) topology
  - Operates from an unregulated, wide range input to generate an isolated output
- ZVS buck and buck-boost regulators support efficient non-isolated power distribution to point-of-loads

Case study – Agricultural UAVs

DCM™ DC-DC converter

Isolated regulated

Input: 9 – 420V

Output: 3.3, 5, 12, 13.8, 15, 24, 28, 36, 48V

Power: Up to 1300W

Peak efficiency: 96%

As small as 24.8 x 22.8 x 7.21mm

vicorpower.com/dcm

ZVS buck regulator

Non-isolated regulated

Inputs: 12V (8 – 18V), 24V (8 – 42V), 48V (30 – 60V)

Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as 10.0 x 10.0 x 2.56mm

vicorpower.com/buck

ZVS buck-boost regulator

Non-isolated regulated

Input: 8 – 60V

Output: 10 – 54V

Power: Up to 150W continuous

Peak efficiency: 98%

10.5 x 14.5 x 3.05mm

vicorpower.com/buck-boost

Case study – Delivery UAVs

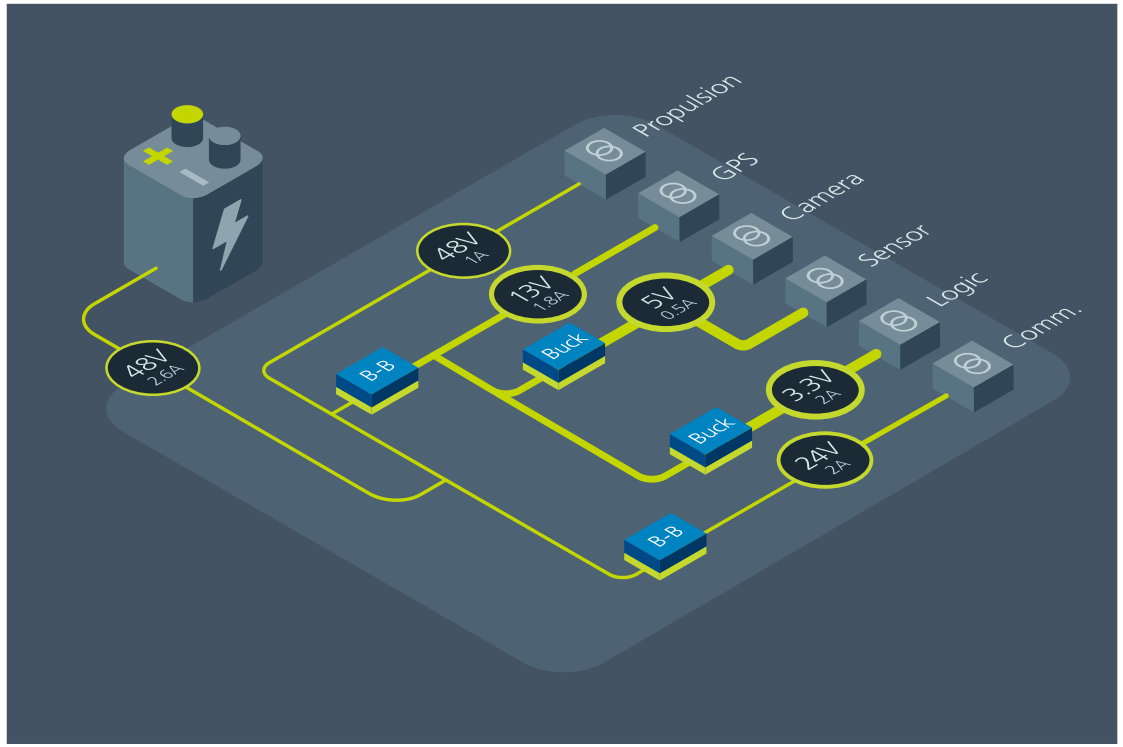
Customer challenges

- Increase flight time to reach greater distances
- Compact and lightweight solution so the UAV can carry heavier loads
- Supporting a variety of point-of-load voltages

Vicor solution

- High-power density – compact and lightweight
- Higher efficiency to extend flight times and range of operation
- Compact Vicor regulators enable redundancy when duplicated at the point of loads

Case study – Delivery UAVs



- Compact and power-dense ZVS buck and ZVS buck-boost regulators allow multiple point-of-load converters to save on cabling while powering multiple devices with multiple power buses to create the redundancy needed to ensure safe and reliable delivery operations

Case study – Delivery UAVs

ZVS buck regulator

Non-isolated regulated

Inputs: 12V (8 – 18V), 24V (8 – 42V), 48V (30 – 60V)

Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as 10.0 x 10.0 x 2.56mm

vicorpower.com/buck

ZVS buck-boost regulator

Non-isolated regulated

Input: 8 – 60V

Output: 10 – 54V

Power: Up to 150W continuous

Peak efficiency: 98%

10.5 x 14.5 x 3.05mm

vicorpower.com/buck-boost

Case study – HALE UAVs

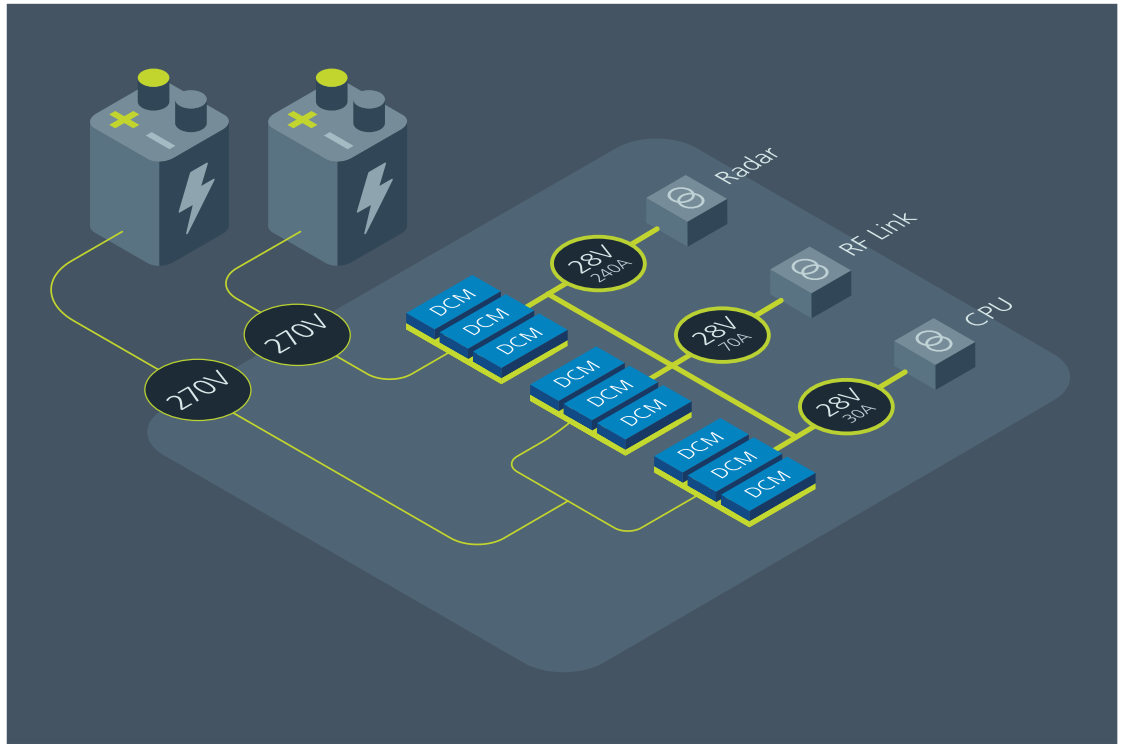
Customer challenges

- Scalable power to adapt to future needs
- A robust and reliable design to maintain continued operation
- A compact and lightweight power supply

Vicor solution

- The DCM™ can be paralleled to accommodate system expansion
- Advanced packaging to manage thermal loads
- An 11kW solution, weighing only 215g

Case study – HALE UAVs



- Three arrays of three 1.3kW DCM5614 converters were paralleled to provide the regulated 28V bus
- Inputs were split between two different generators to provide redundancy of power source
- The arrays automatically power shared across all nine converters — though their input voltages differed — helping improve system reliability
- Small size, low profile and low weight
- Allows for double the output power without exceeding allocated space constraints
- High efficiency (96%) reduced the size of the heat sink required, saving more space
- Easy to parallel for future increased power needs

Case study – HALE UAVs

DCM™ DC-DC converter

Isolated regulated

Input: 9 – 420V

Output: 3.3, 5, 12, 13.8, 15, 24, 28, 36, 48V

Power: Up to1300W

Peak efficiency: 96%

As small as 24.8 x 22.8 x 7.21mm

vicorpower.com/dcm

Case study – Inspection UAVs

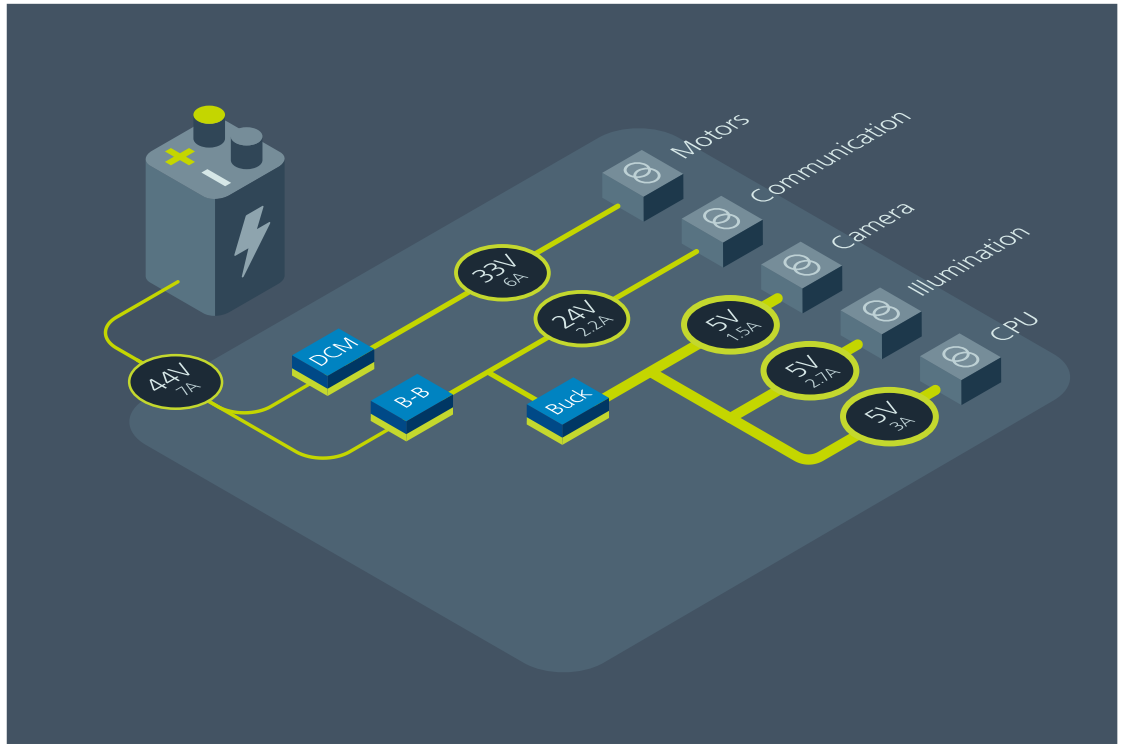
Customer challenges

- Extend range and flight time
- Reduce size and weight
- Reliability to minimize chance of failure during flight

Vicor solution

- High-power density to enable smaller form factor and lower weight
- Minimal electromagnetic interference (EMI)
- ZVS topology provides up to 98% efficiency

Case study – Inspection UAVs



- The compact DCM™ DC-DC converter delivers high power to the motors
- Buck and buck-boost regulators operate with a wide input range to allow loads to be powered by the full range of the battery, providing a reserve for safe landing and recovery
- The compact modules allow for the use of a smaller magnetic shield, thereby reducing that weight in addition to the weight savings of the Vicor modules

Case study – Inspection UAVs

DCM™ DC-DC converter

Non-isolated regulated

Input: 9 – 420V

Output: 3.3, 5, 12, 13.8, 15, 24, 28, 36, 48V

Power: Up to 1300W

Peak efficiency: 96%

As small as 24.8 x 22.8 x 7.21mm

vicorpower.com/dcm

ZVS buck regulator

Non-isolated regulated

Inputs: 12V (8 – 18V), 24V (8 – 42V), 48V (30 – 60V)

Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as 10.0 x 10.0 x 2.56mm

vicorpower.com/buck

ZVS buck-boost regulator

Non-isolated regulated

Input: 8 – 60V

Output: 10 – 54V

Power: Up to 150W continuous

Peak efficiency: 98%

10.5 x 14.5 x 3.05mm

vicorpower.com/buck-boost

Case study – Media and entertainment UAVs

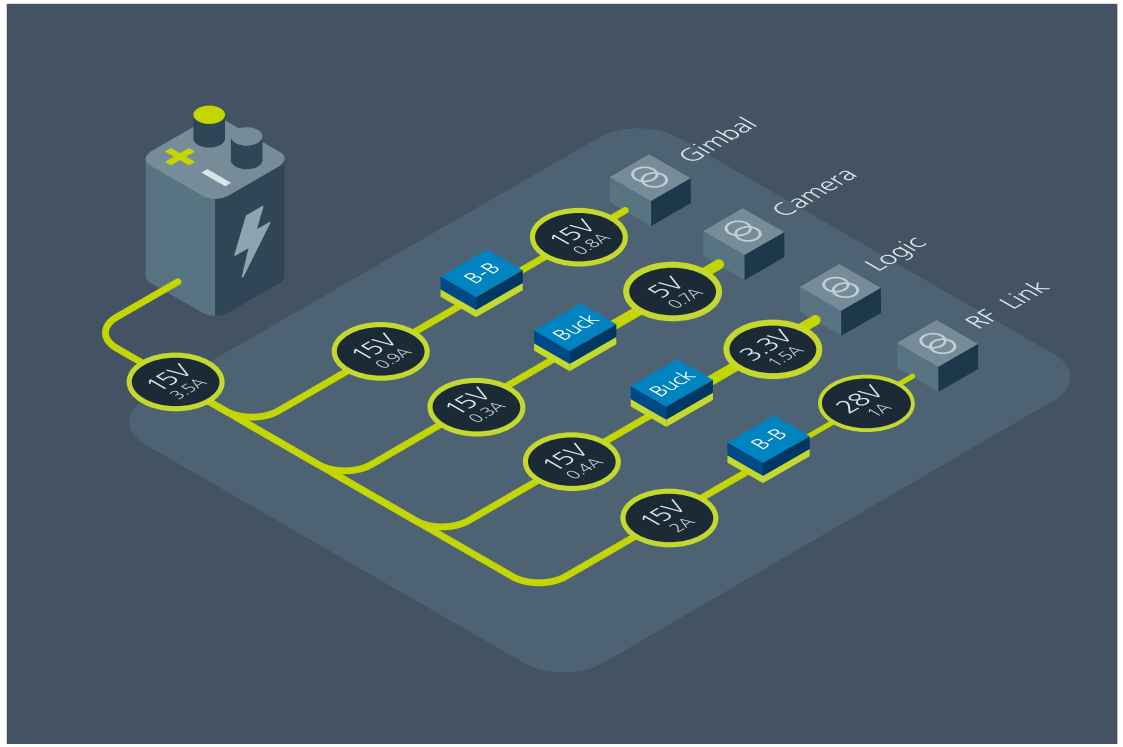
Customer challenges

- Compact and lightweight solution
- Supporting multiple configurations to accommodate changes in requirements
- Optimized power delivery for longer operation

Vicor solution

- Wide range of input and output voltages
- High efficiency
- High power density

Case study – Media and entertainment UAVs



- Vicor Zero-Voltage Switching (ZVS) buck and buck-boost regulators have wide input and output ranges
- They can be paralleled for high power applications
- Vicor high-density modular power solutions not only consume minimal space, but they also help future proof drone power needs where flexibility to change specs is a key advantage

Case study – Media and entertainment UAVs

ZVS buck regulator

Non-isolated regulated

Inputs: 12V (8 – 18V), 24V (8 – 42V), 48V (30 – 60V)

Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as 10.0 x 10.0 x 2.56mm

vicorpower.com/buck

ZVS buck-boost regulator

Non-isolated regulated

Input: 8 – 60V

Output: 10 – 54V

Power: Up to 150W continuous

Peak efficiency: 98%

10.5 x 14.5 x 3.05mm

vicorpower.com/buck-boost

Case study – Surveillance UAVs

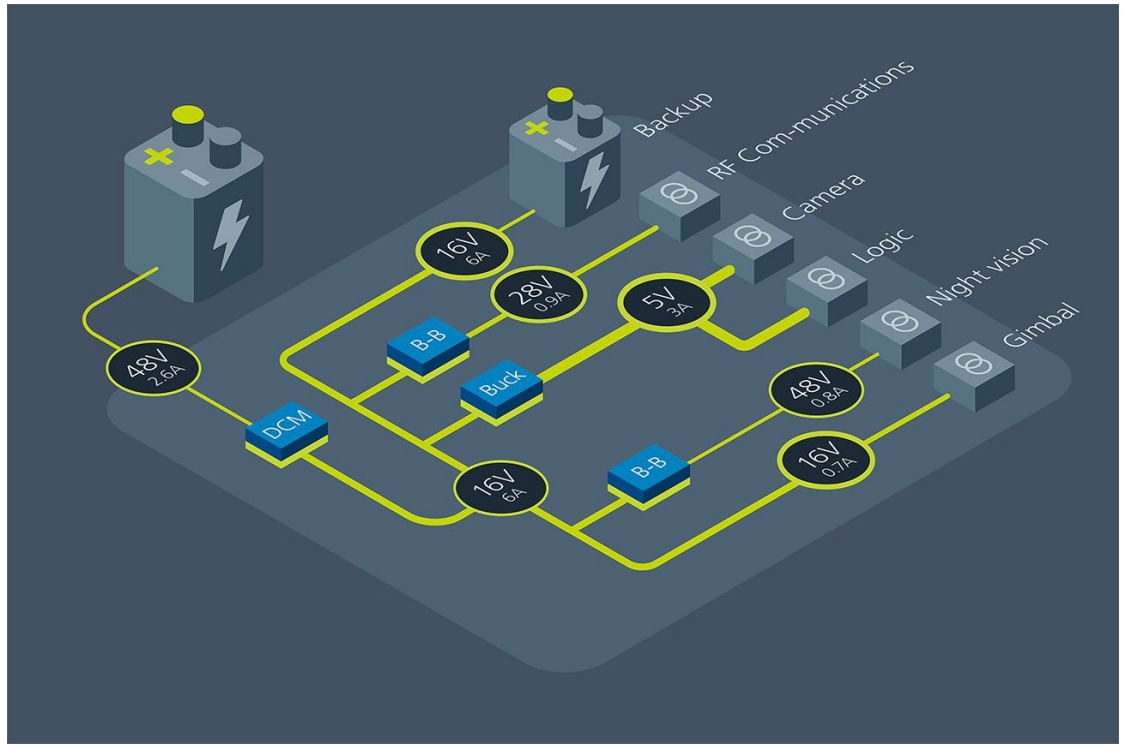
Customer challenges

- Increase flight time
- Support power-hungry functions without adding size and weight
- High-efficiency and simplified thermals

Vicor solution

- DCM best-in-class power density
- High efficiency extends flight time
- Keeps backup battery charged

Case study – Surveillance UAVs



- Power dense Vicor DCM™ DC-DC converters convert the 48V battery to a manageable voltage
- Compact Zero-Voltage Switching (ZVS) buck and buck-boost regulators power UAV system loads at various voltages
- The DCM converters can also keep the UAV backup battery charged to ensure safety through redundancy

Case study – Surveillance UAVs

DCM™ DC-DC converter

Isolated regulated

Input: 9 – 420V

Output: 3.3, 5, 12, 13.8, 15, 24, 28, 36, 48V

Power: Up to 1300W

Peak efficiency: 96%

As small as 24.8 x 22.8 x 7.21mm

vicorpower.com/dcm

ZVS buck regulator

Non-isolated regulated

Inputs: 12V (8 – 18V), 24V (8 – 42V), 48V (30 – 60V)

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vicorpower.com/buck

ZVS buck-boost regulator

Non-isolated regulated

Input: 8 – 60V

Output: 10 – 54V

Power: Up to 150W continuous

Peak efficiency: 98%

10.5 x 14.5 x 3.05mm

vicorpower.com/buck-boost

Case study – Tethered UAVs

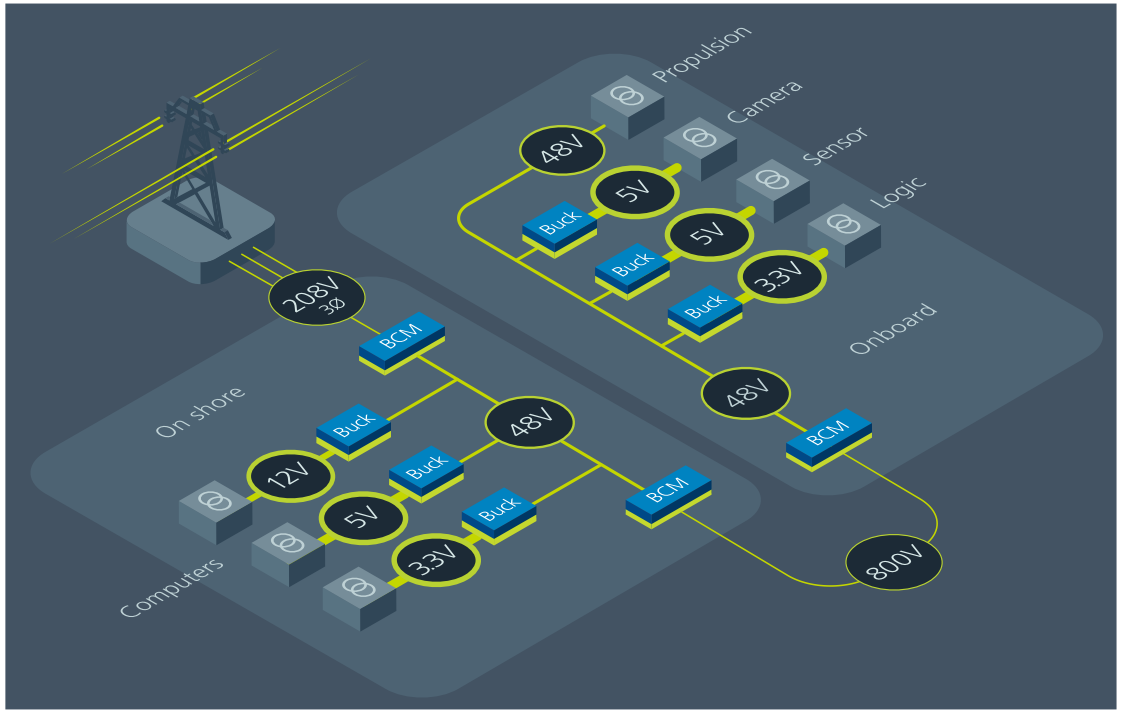
Customer challenges

- Optimize the power delivery through the tether
- Rugged, highly integrated power supply for high reliability
- Efficiently convert high voltage to safe 48V

Vicor solution

- Significantly reduces tether size, weight, and drag
- Lightweight, efficient conversion of HV tether to SELV bus
- Modular design supports flexible design requirements

Case study – Tethered UAVs



- At the ground station, the BCM4414 isolates and steps-down the rectified output from a single or 3-phase AC supply to 48V
- A second BCM4414 steps-up the 48V to 800V for transmission across the tether
- A third BCM4414 is used to step-down the 800V to 48V onboard the vehicle
- The BCM provides 1.8kW of power for either step-up or step-down conversion at 97%+ efficiency
- The size and weight of the ground supply and UAV are significantly reduced, as are the diameter and weight of the tether itself

Case study – Tethered UAVs

BCM® bus converter

Isolated fixed-ratio

Inputs: 800 – 48V

Output: 2.4 – 55.0V

Current: Up to 150A

Peak efficiency: 98%

As small as 22.0 x 16.5 x 6.7mm

vicorpower.com/bcm

ZVS buck regulator

Non-isolated regulated

Inputs: 12V (8 – 18V), 24V (8 – 42V), 48V (30 – 60V)

Output: 2.2 – 16V

Current: Up to 22A

Peak efficiency: 98%

As small as 10.0 x 10.0 x 2.56mm

vicorpower.com/buck

Case study – Unmanned aircraft for communications

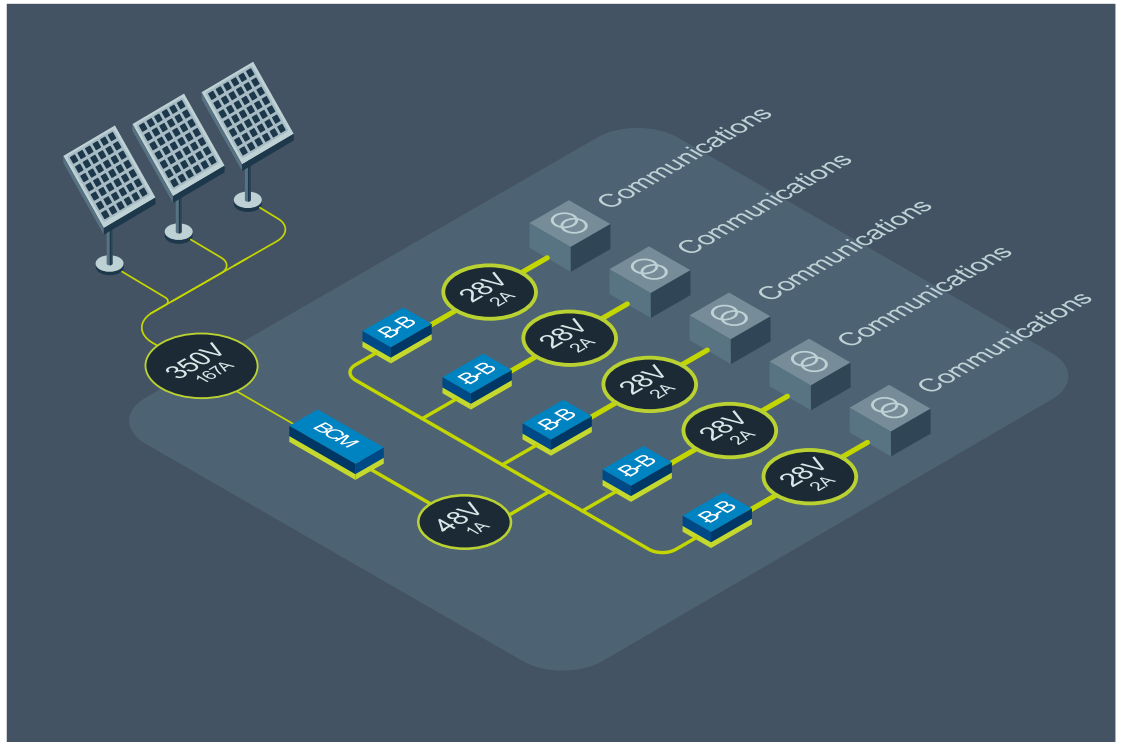
Customer challenges

- Efficient high voltage to SELV conversion
- A compact and lightweight solution to keep the drone as light as possible
- A robust and reliable solution

Vicor solution

- Efficiently convert high voltages to SELV
- Lightweight power delivery network
- Wide input range at point-of-load conversion

Case study – Unmanned aircraft for communications



- BCM6123 provides the isolated conversion of the 350V to a 48V intermediate bus
- ZVS buck-boost regulators with a very wide range input voltage operating capability provides a tightly regulated 28V output for various UAV loads

Case study – Unmanned aircraft for communications

BCM® bus converter

Isolated fixed-ratio

Inputs: 800 – 48V

Output: 2.4 – 55.0V

Current: Up to 150A

Peak efficiency: 98%

As small as 22.0 x 16.5 x 6.7mm

vicorpower.com/bcm

ZVS buck-boost regulator

Non-isolated regulated

Input: 8 – 60V

Output: 10 – 54V

Power: Up to 150W continuous

Peak efficiency: 98%

10.5 x 14.5 x 3.05mm

vicorpower.com/buck-boost

UAV resources

- UAV web pages
- Whitepapers
  - Overcoming tethered UAV challenges with a high-voltage, compact, module-based power delivery network
  - High-density, modular power delivery networks optimize mobile robot performance
- eBooks
  - Highest power density conversion for better UAVs
- App notes, case studies and articles in our website resource library

Takeaways

- There’s significant business opportunities in the market, where long operating times are crucial
- The industry needs high voltage bus converters (600 – 800V) to reduce tether diameter and weight while increasing distance
- Density is necessary to support greater functionality and autonomy (AI, cloud communications, GPU, peripherals)
- Vicor is the best solution because of the high reliability under continuous operation – no down time