ADOPTING COTS TECHNOLOGY FOR UGV WHEEL DRIVE SYSTEM

Ken May, João Costa, Jake Boyd

Who is Allient?

- Founded in 1939
- **US** headquartered, public, with mature US manufacturing and supply chain
- Manufacturer of Motion, Control, Power and Lightweighting products
- 80% of revenue from non-defense products means:

  - Extensive COTS building blocks to leverage

  - Many vehicle ruggedized COTS at TRL/MRL=9

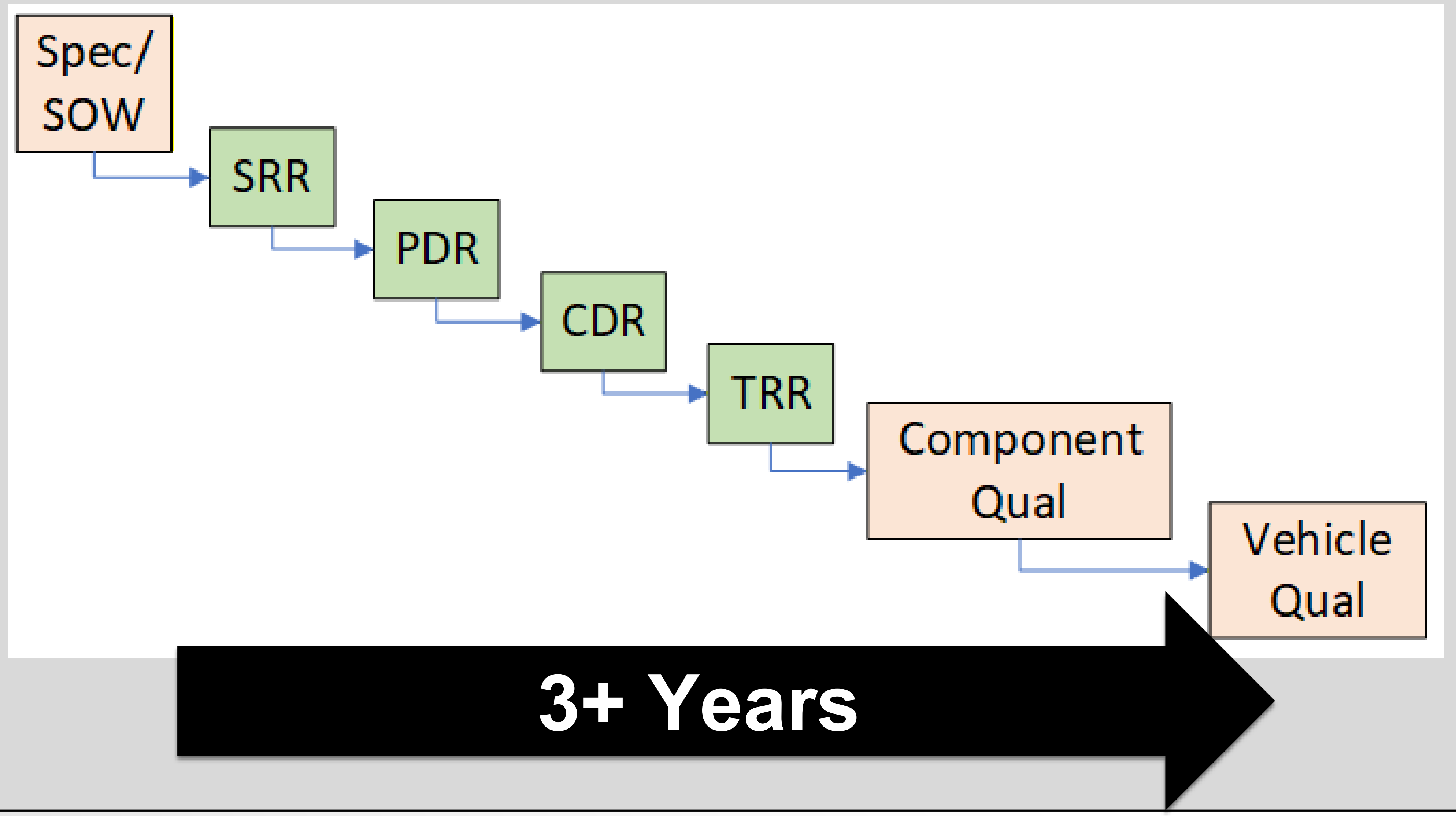
  - Qualified, tooled up with automated manufacturing

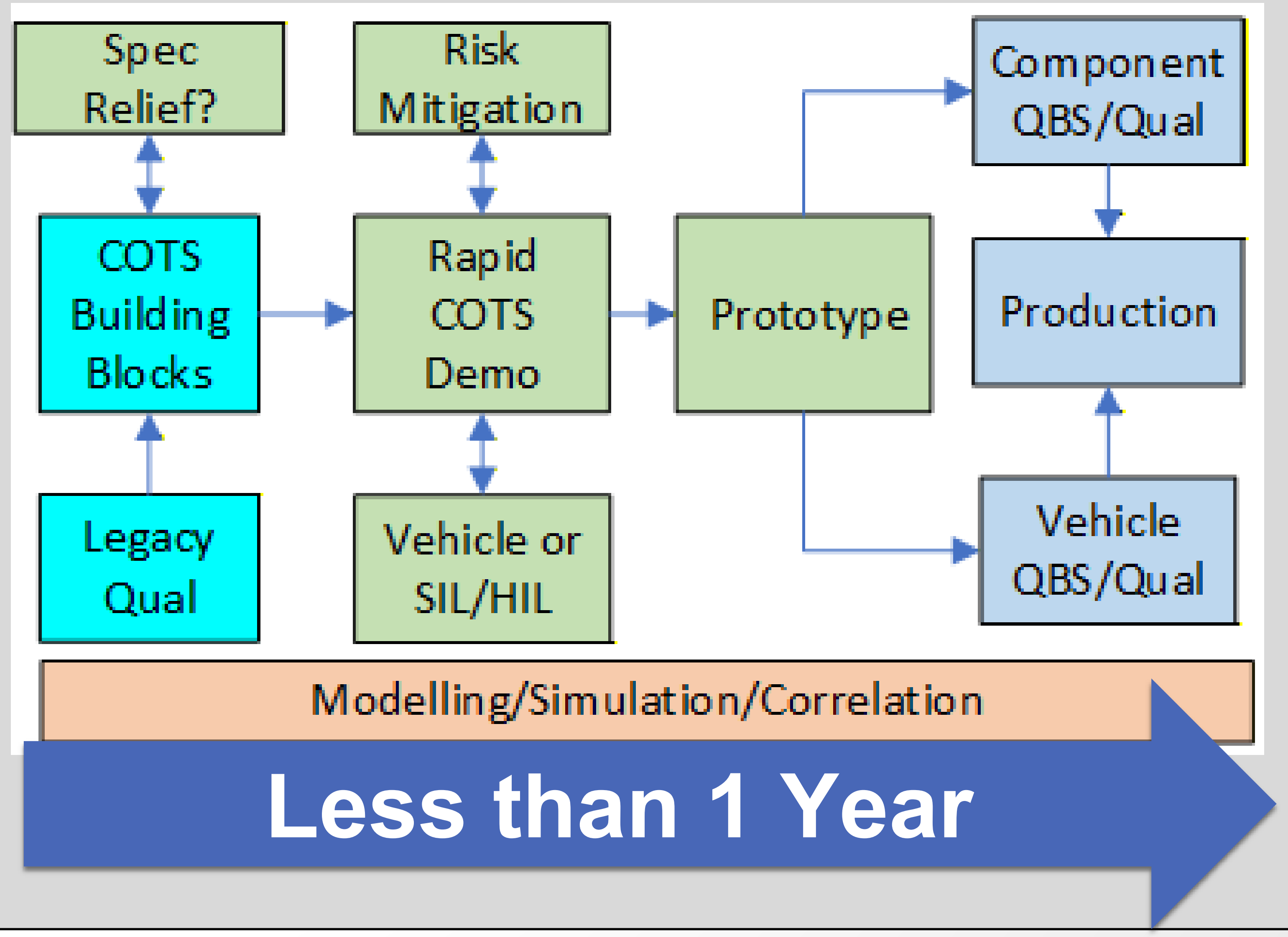
  - Leveraging volume with mature supply chains

  - Ability to scale while maintaining appropriate quality systems
- Allient Defense is a market focused vertical inside Allient that facilitates our ability to ***Adopt*** COTS into Defense systems

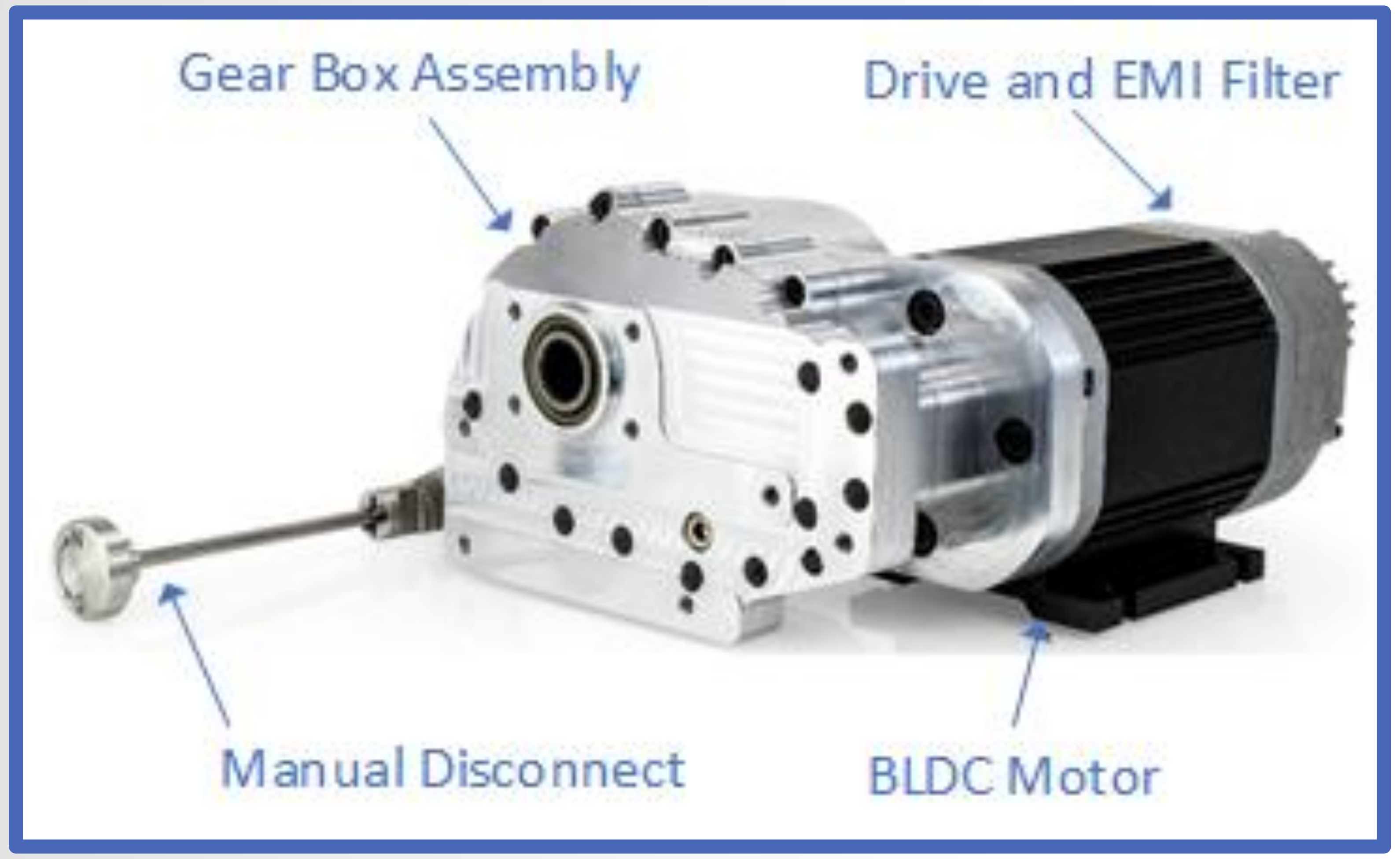
From Conventional Workflow to Agile: Why COTS?

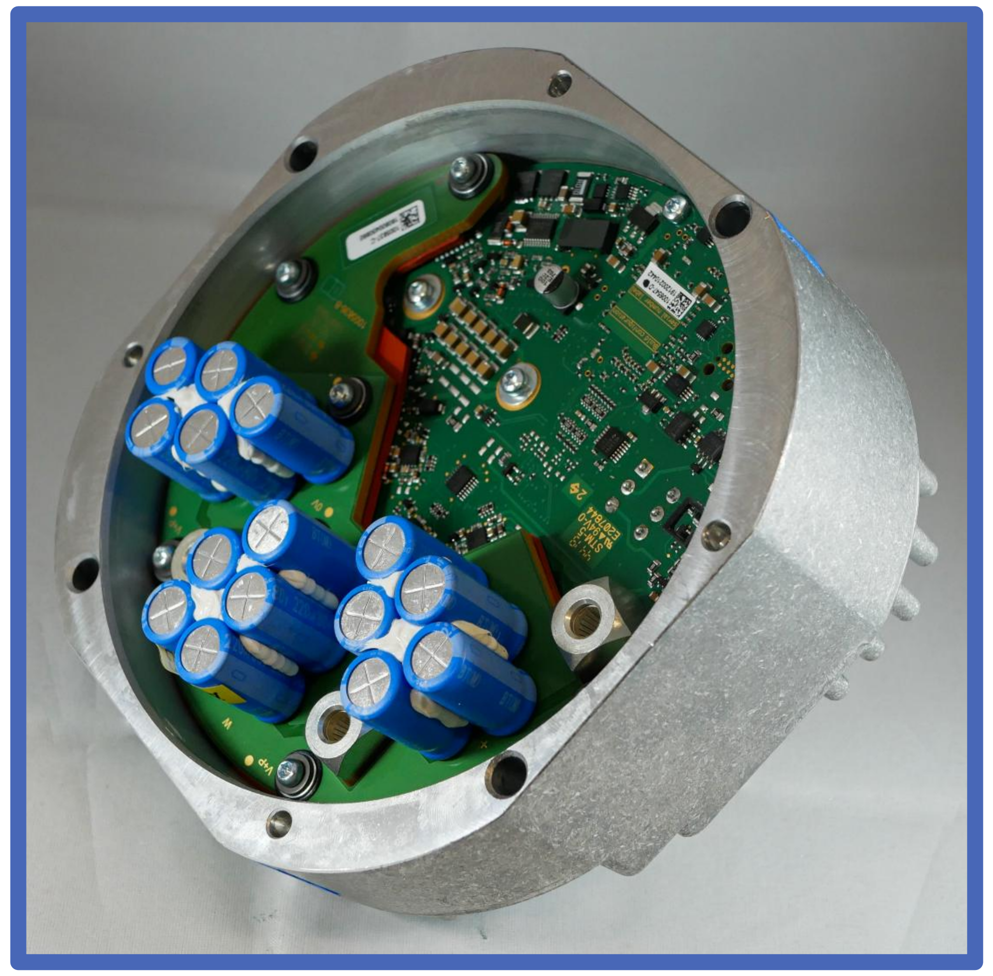
Conventional Workflow	Agile COTS Workflow
• Gated & sequential phases • 100s of fixed 'Shalls', and dozens of MIL-STDs • Requirements driven, bespoke solutions • Limited design reuse • Slow to adapt to the evolving defense landscape	• Challenge & negotiate requirements • Spec relief: 80–95% "COTS as-is" now • COTS building blocks (TRL/MRL 9) • Minimal design changes • Delta qualification assessment

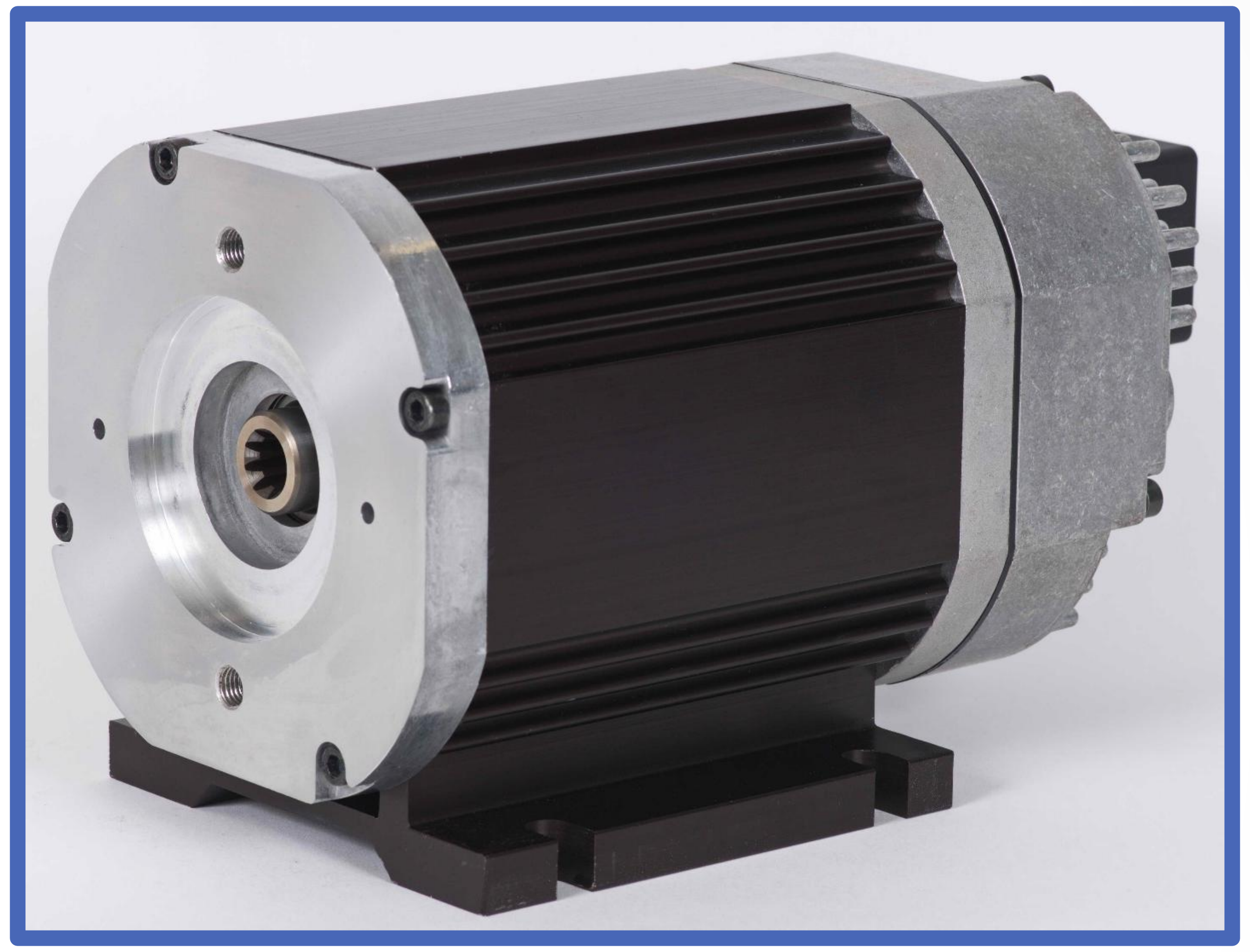


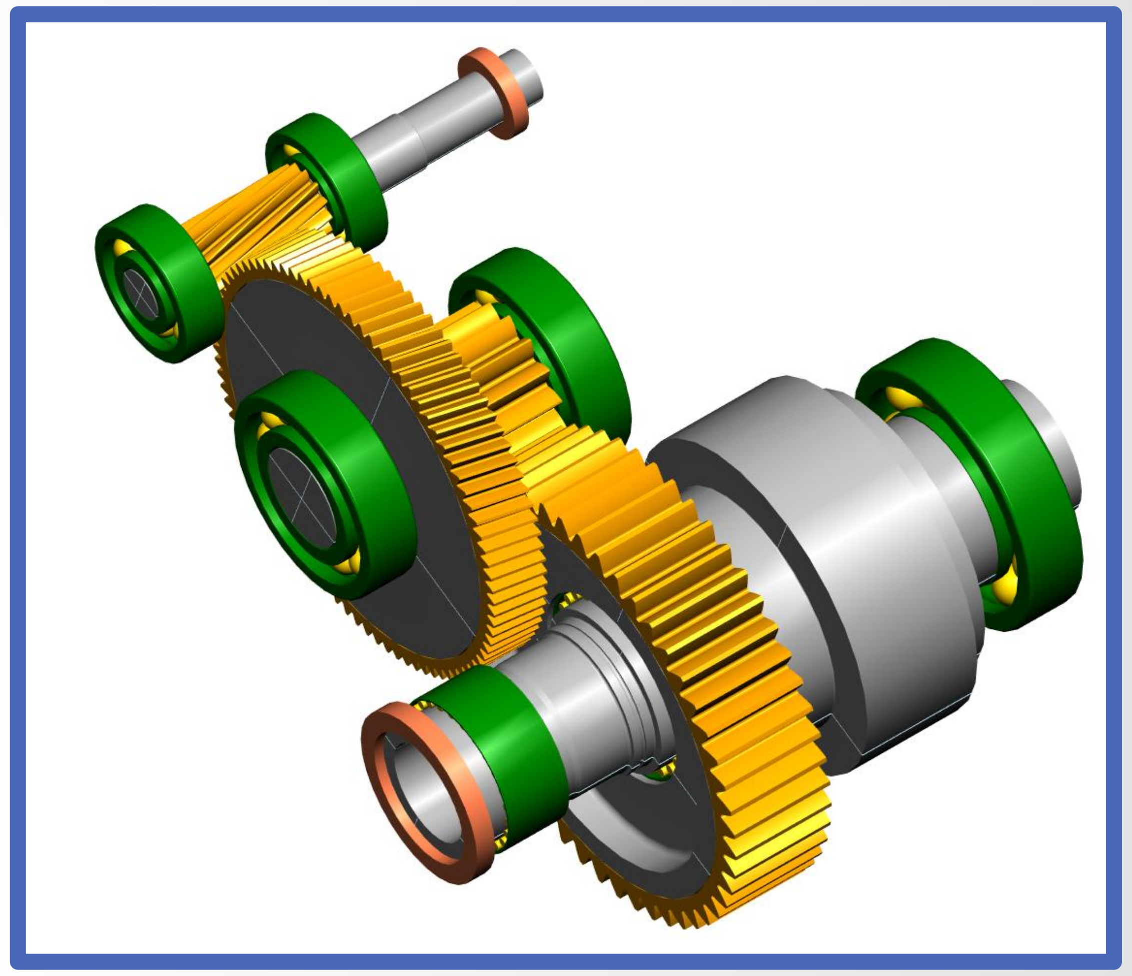


Traction Wheel Drive System: System Architecture









48V Lithium-ion Battery & BMS | EMI Filter | Bus Link | Inverter | Current Sense | Motor | 2-Stage Gearing | Manual Disc. | Wheel

Software

Blue = COTS Item (No modifications made), Orange = Minor changes, Purple = Custom-designed

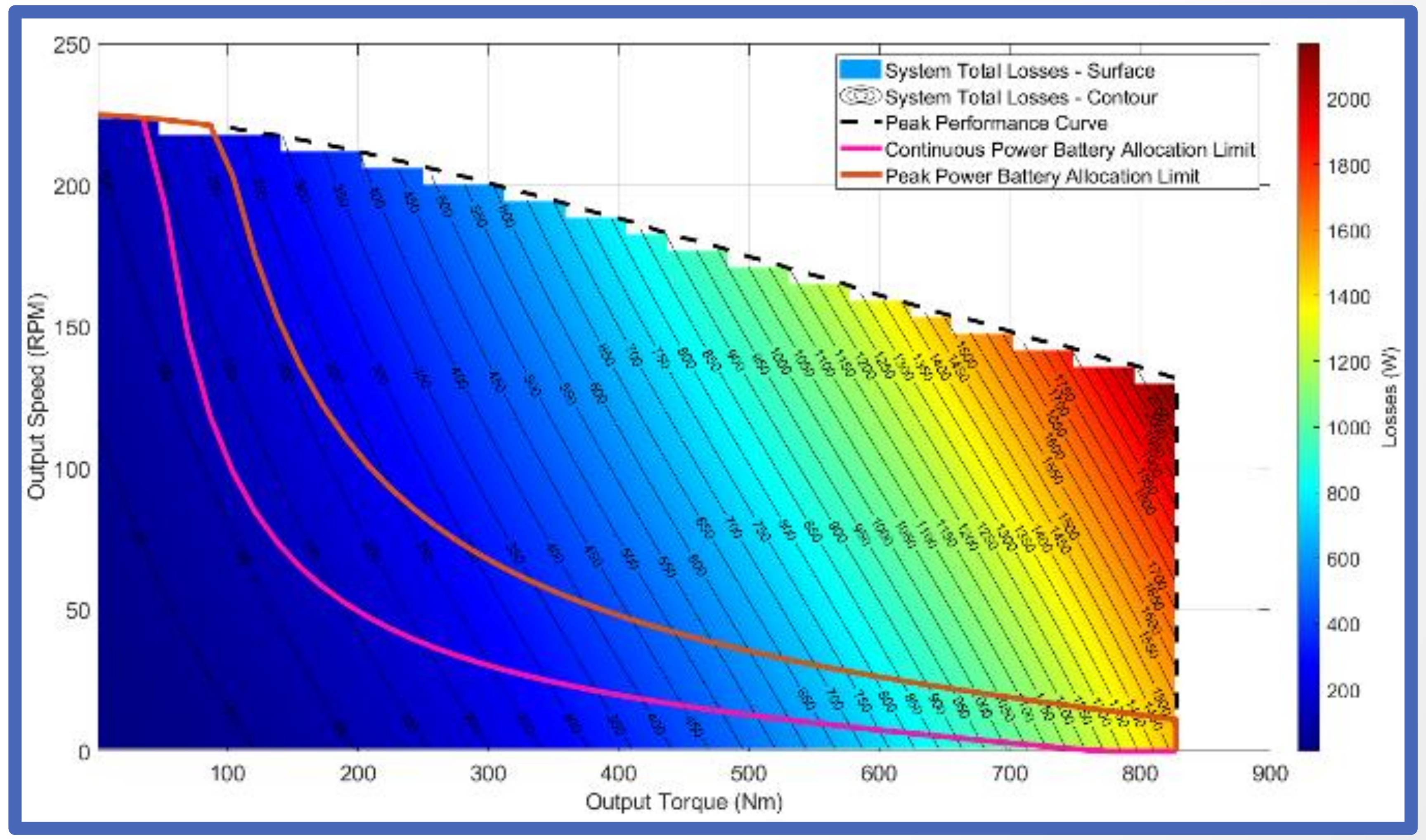
Modeling & Simulation - MATLAB Simulink

Physics Modeled

- Battery: SOC%, input impedance
- Drive losses: quiescent, conduction, switching
- Motor losses: eddy current/hysteresis, copper (temp-dependent)
- Gear losses: static friction, forward & back-drive efficiency
- Thermal: resistance & time constants (MOSFETs, stator)
- Software: thermal protection & performance control
- Duty cycles, mission profiles, boundary conditions

Model Outputs

- Total losses map (drive, motor, gear)
- Battery current & power draw per wheel
- Transient & steady-state temperatures
- 4-quadrant torque-speed envelopes



- 11kW peak output power @ 53V
- 865Nm peak torque
- 230RPM no-load speed

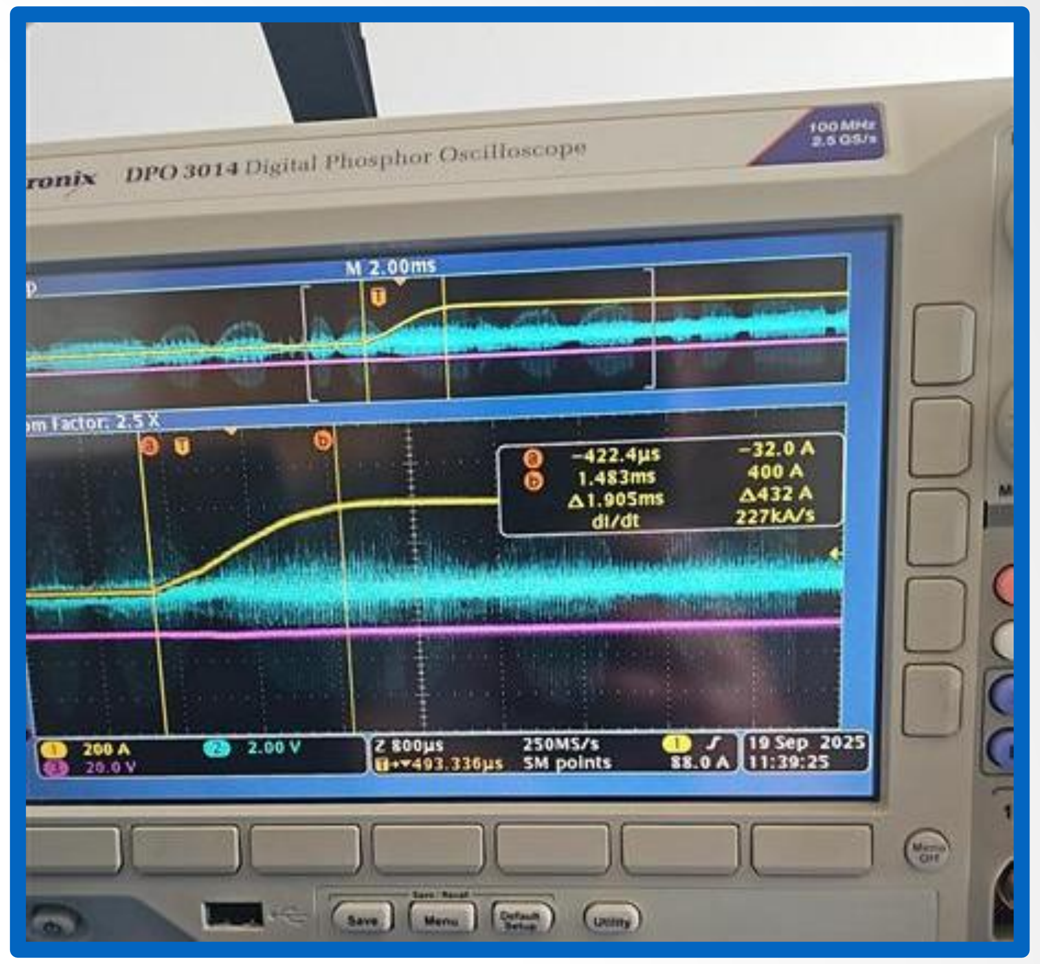
The traction system is the vehicle's primary energy consumer.
Optimized design drives efficiency gains which directly translate to increased range.

Risk Mitigation Strategy

Voltage Derating

Motor risk: minimal – insulation & connectors have ample margin.

Drive risk: limited component updates only; zero PCB changes.



Battery & BMS Integration

Representative 48V Li-ion + BMS tested with matched cable impedance.

No anomalous inrush, bus transients, or warnings observed.

Cold Soak Testing

Cold soak start capability verified. Additional environmental risk activities conducted as part of systematic risk-reduction.

Risk Mitigation Strategy

Destructive Thermal Failure Test

Thermal limit explored by stall at peak phase current, with all thermal protections disabled.

Software Thermal Protection

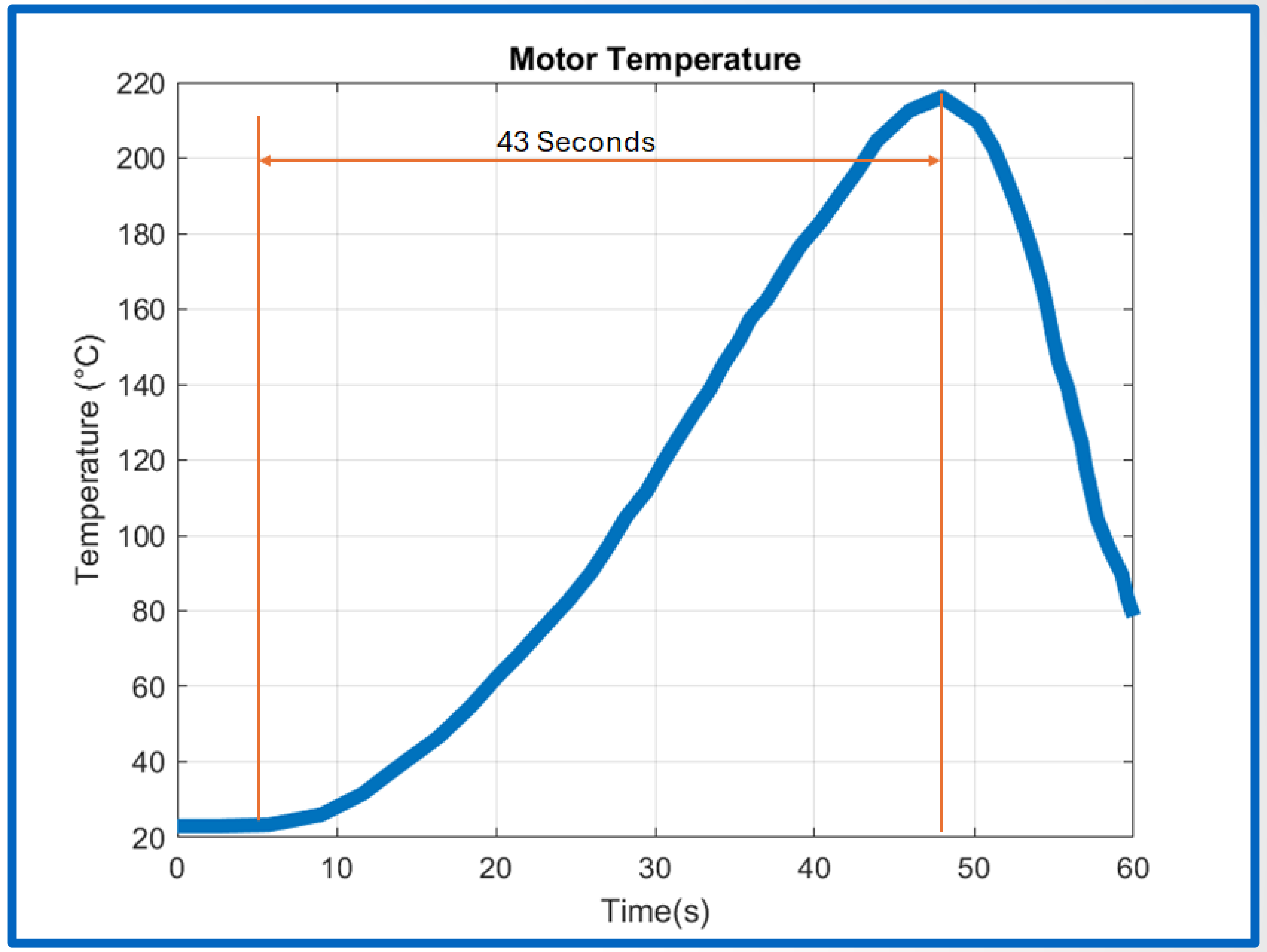
The legacy application had lower transient loading. New scheme combines drive/motor temp faults with I^2T foldback algorithm to prevent localized overheating.

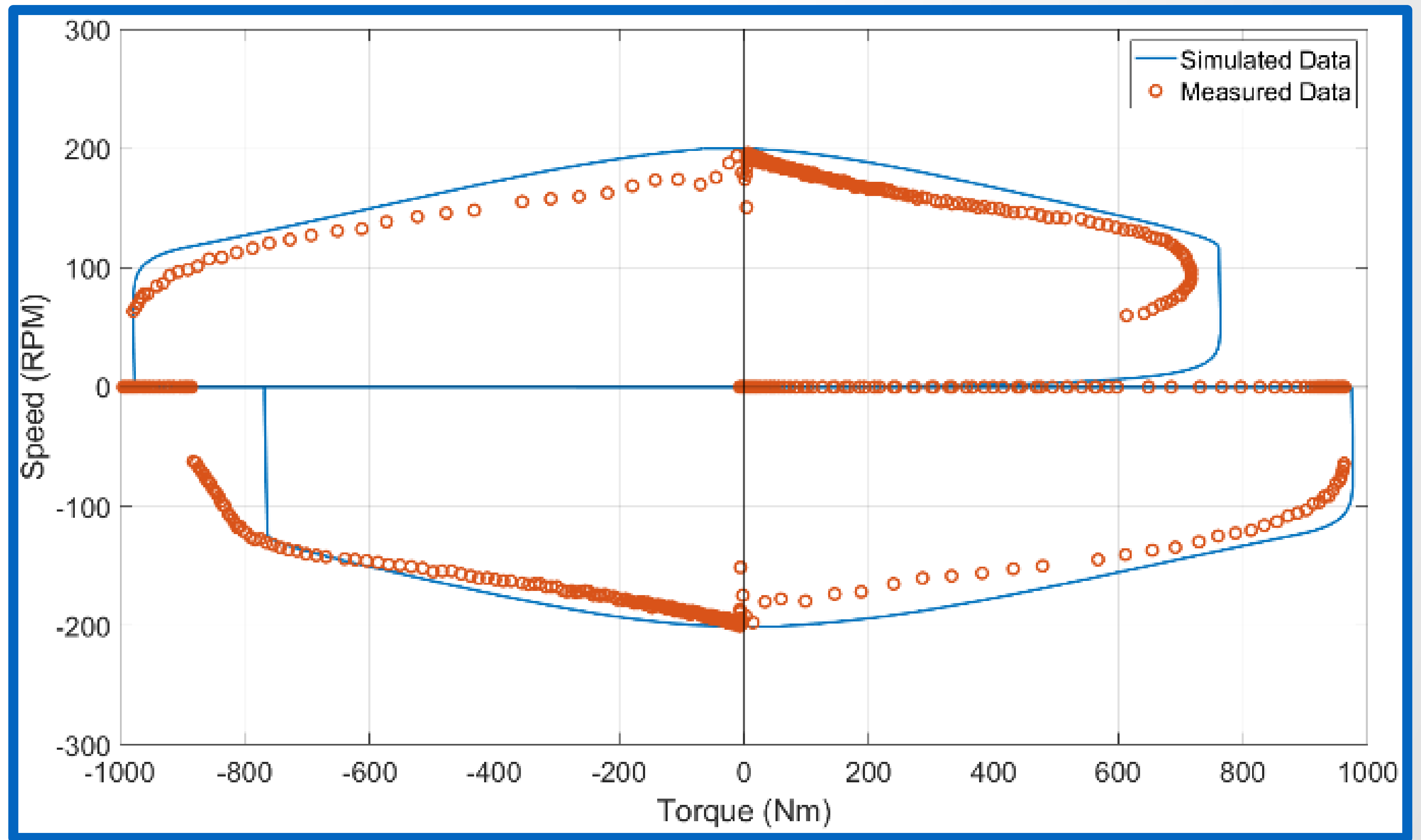
Four Quadrant Operation

Legacy application was only single quadrant operation.

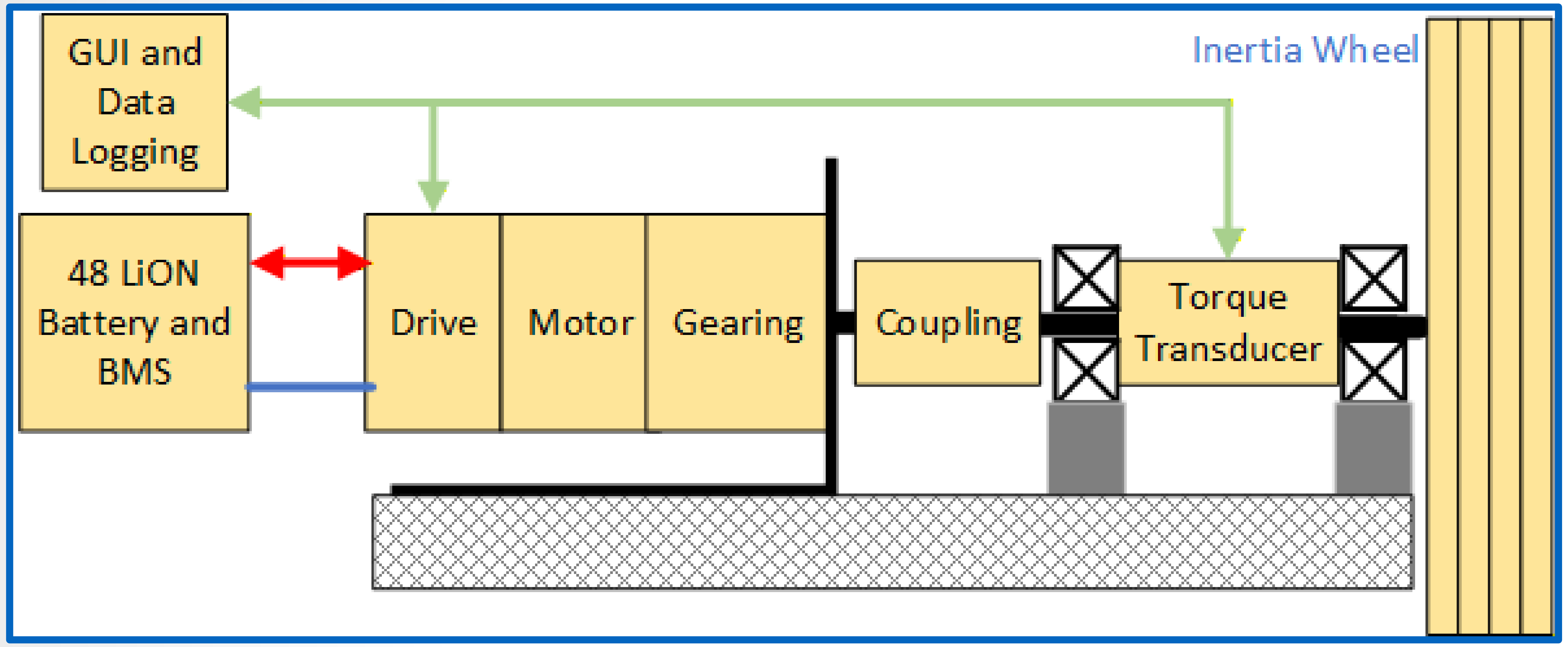
New system: ~2x speed, ~1.5x peak current, ~3x power vs. legacy.

Bidirectional energy flow verified on inertia dyno.





Test Methods: Inertia Dynamometer



- **Passive:** No active motor needed – rotating inertia absorbs and returns kinetic energy naturally
- **Vehicle-equivalent loading:** Inertia wheel → GVW kinetic energy ÷ N driven wheels → realistic power & energy flow
- **Four-quadrant power flow:** Enables max acceleration, max deceleration, and regen braking in a single setup
- **No active limitations:** Avoids thermal limits, maintenance burden, and is to be free of component wear
- **Fault injection:** Can replicate vehicle-level integration faults for root-cause analysis
- **Adaptable**: modular, scalable dynamometer fixture design

Cyclic Testing & Thermal Model Validation

Full 4 Quadrant Power and Energy Flow

Thermal Performance / Model Validation

Durability Testing of the Custom-Designed Gearing System

Mechanical System – Key Test Considerations	Thermal Validation – What we Learned
• Lubrication type, quantity, and effectiveness • Four-quadrant energy & power flow • Realistic shaft, gear & bearing loading (axial, tangential, and radial) • Realistic thermal use conditions • Operational speeds up to 2x legacy product	• Thermal imaging reveals unexpected hot spots • Motor stator temperature measured during cyclic duty • PCB hot-spot near output-stage MOSFETs monitored • Data used to calibrate MATLAB Simulink thermal model • Correlated model enables performance prediction across other missions & vehicles

Qualification by Similarity (QBS)

Requirement	Typical Defense Qual	Legacy Qual Standard	Compliant?
Ambient Temp (max)	MIL-STD-810, 71°C	ISO 16750-4, 90°C	Y
Ambient Temp (min)	MIL-STD-810, -40°C	ISO 16750-4, -55°C	Y
Storage Temperature	MIL-STD-810, -51°C to 71°C	ISO 16750-4, -55°C to 90°C	Y
Ingress Protection	MIL-STD-810	ISO 20653 IPX9K	Y
Shock & Vibration	MIL-STD-810	IEC 60068-2-64	Y
Climatic Conditions	MIL-STD-810	ISO 16750-4	**Partial**
Chemical Conditions	MIL-STD-810	ISO 16750-5	**Partial**
Life Testing	As required	ISO 16750-1:2006	**Partial**
EMC (CE, CS, RE, RS, ESD, BCI)	MIL-STD-461	IEC CISPR 25	**Partial**

Speed of play may not allow full MIL-STD-810 / MIL-STD-461 **component-level** qualification. QBS leverages the legacy product's existing qualifications, PPM field failure rates (outperform customer and application requirements), and systematically compares them to defense requirements.

Key Takeaways

Challenge Requirements Early

Is this requirement necessary as written? Can we succeed at 80-95% of spec using “COTS as-is” today?

Approach to Program Shift

Speed of play demands creative engagement with primes, willingness to negotiate, and a “COTS first” design philosophy.

Model-Based Engineering

A validated, correlated MATLAB Simulink model allows for correct sizing and confident prediction across different mission profiles and vehicles.

Risk Mitigation Strategy

Destructive tests early reveal failure modes – thermal, voltage-related, 4-quadrant.

Qualification by Similarity

Leverage legacy qualification data systematically, identify any gaps, limit delta qualification to critical items.

Leverage COTS Availability

Immediate, low-cost assets enable fast speed of play, HIL/SIL integration and risk testing without major schedule impact.

Questions & Answers