

# The Artisan Product Line.



# Safety First.

- Self swapping battery system enables a safe and quick battery swap option
- Zero safety incidents with self swapping to date
- Less risk compared to traditional battery swaps using a crane



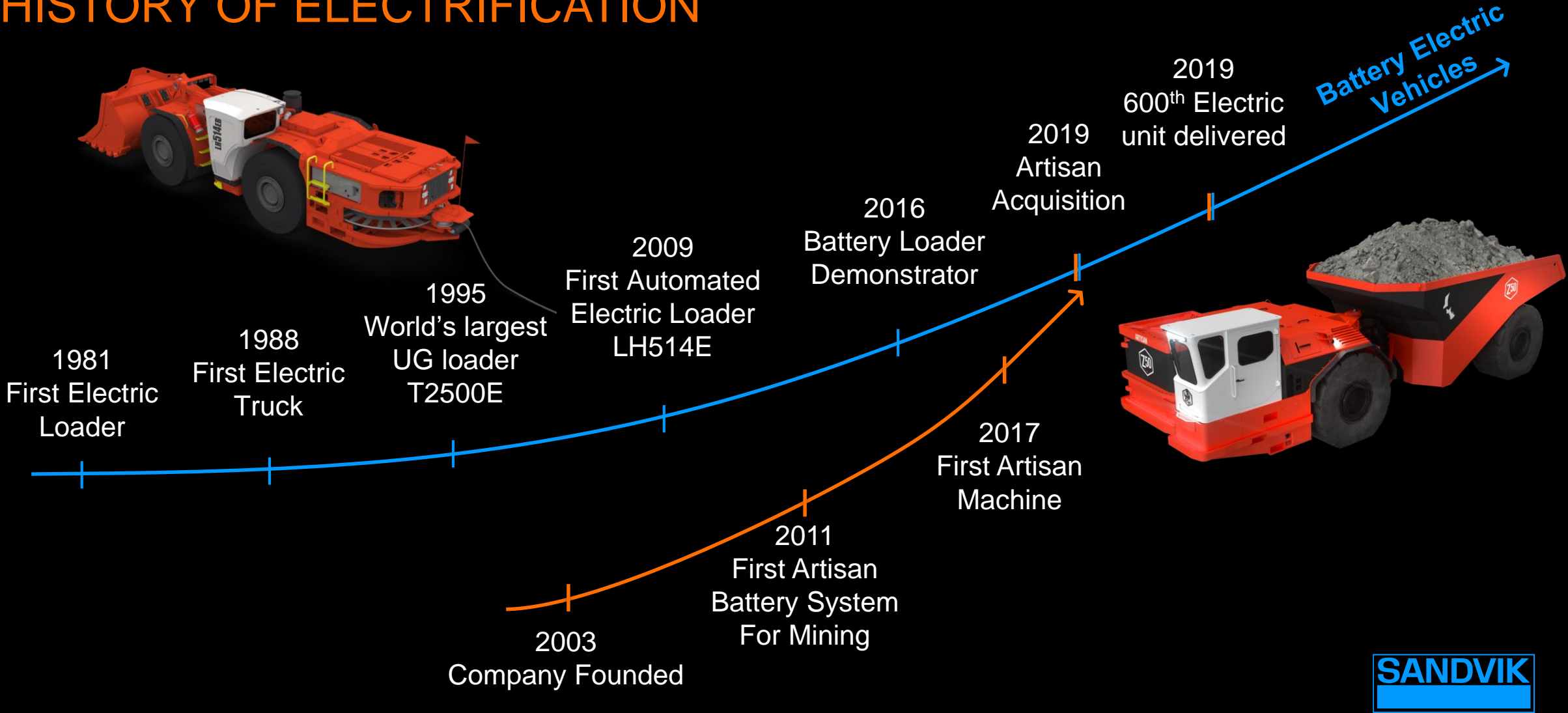
# REAL.

- **Over 400,000 Operating Hours**
- **40+ Machines With Our Powertrain**
- **Eight Sites Using Our Equipment**
- **Three Models Available Today**
- **Complete Line In Development**

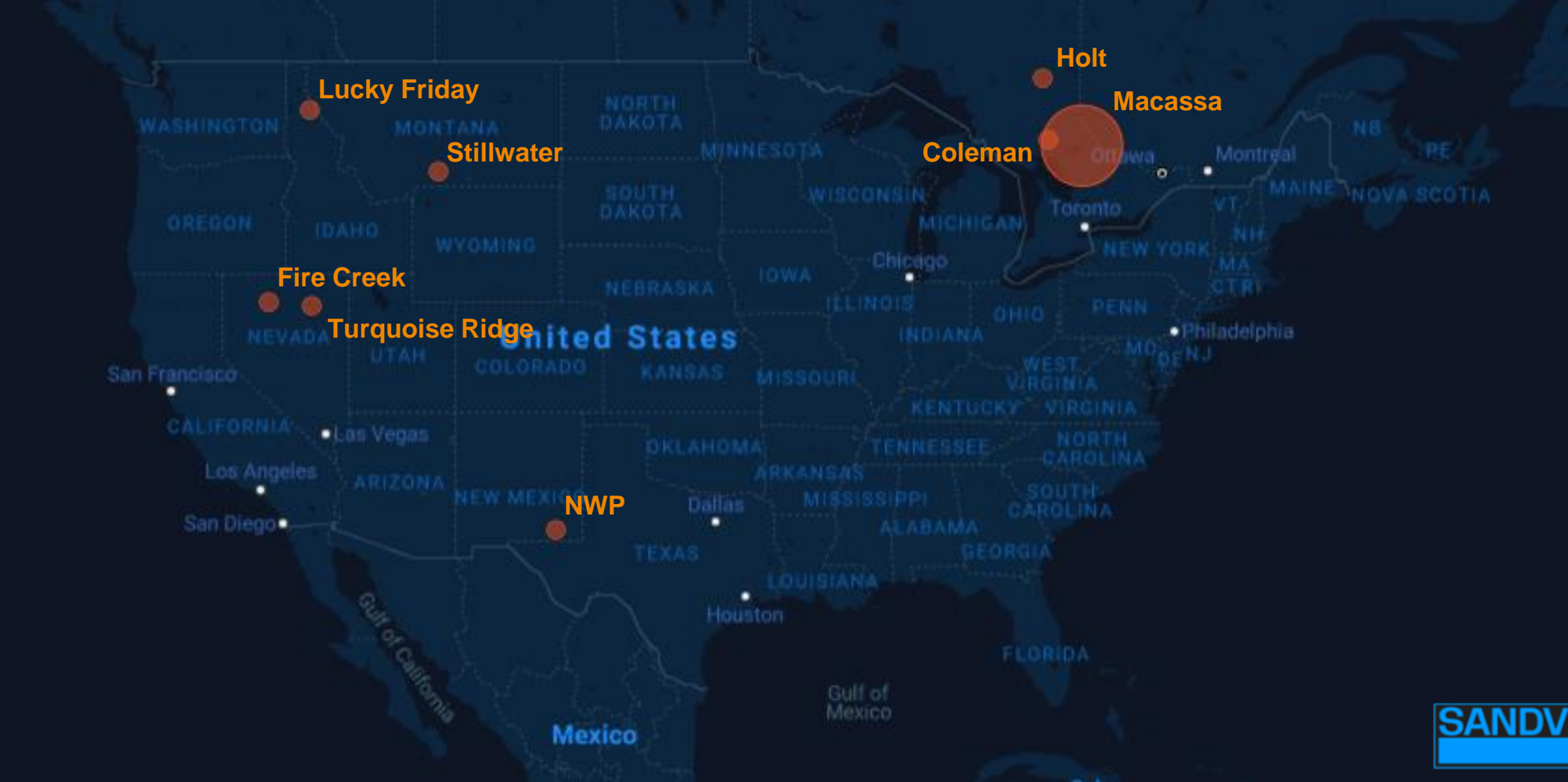


# SANDVIK AND ARTISAN

## HISTORY OF ELECTRIFICATION



# Vehicles in the Field.



# What We've Learned.

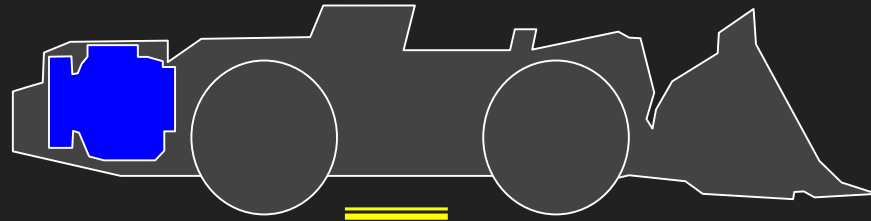
It's not enough to Replace.

It's not enough to Redesign.

This technology compels us to  
**ReThink** the entire machine.

# ReThink the Entire Machine.

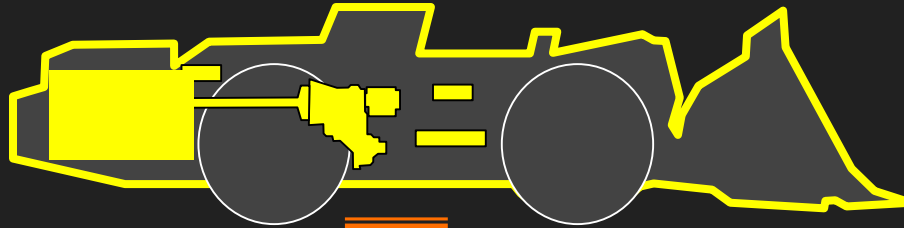
Generation 1



Replace



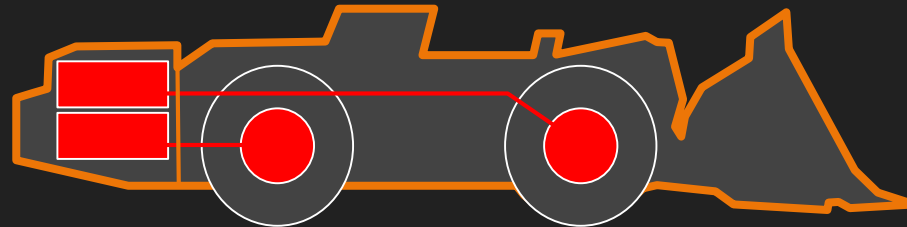
Generation 2



Redesign



Generation 3

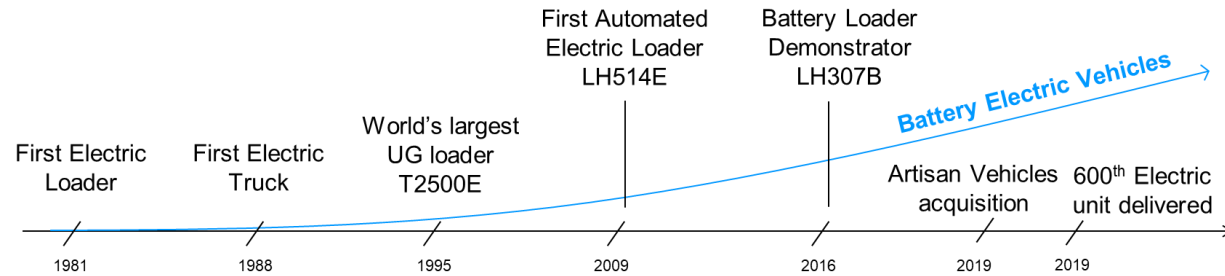


ReThink



# Loading and Hauling Electrification

## CURRENT ELECTRIC OFFERING



SANDVIK LH409E



SANDVIK LH514E



SANDVIK LH625iE



ARTISAN A4



ARTISAN A10

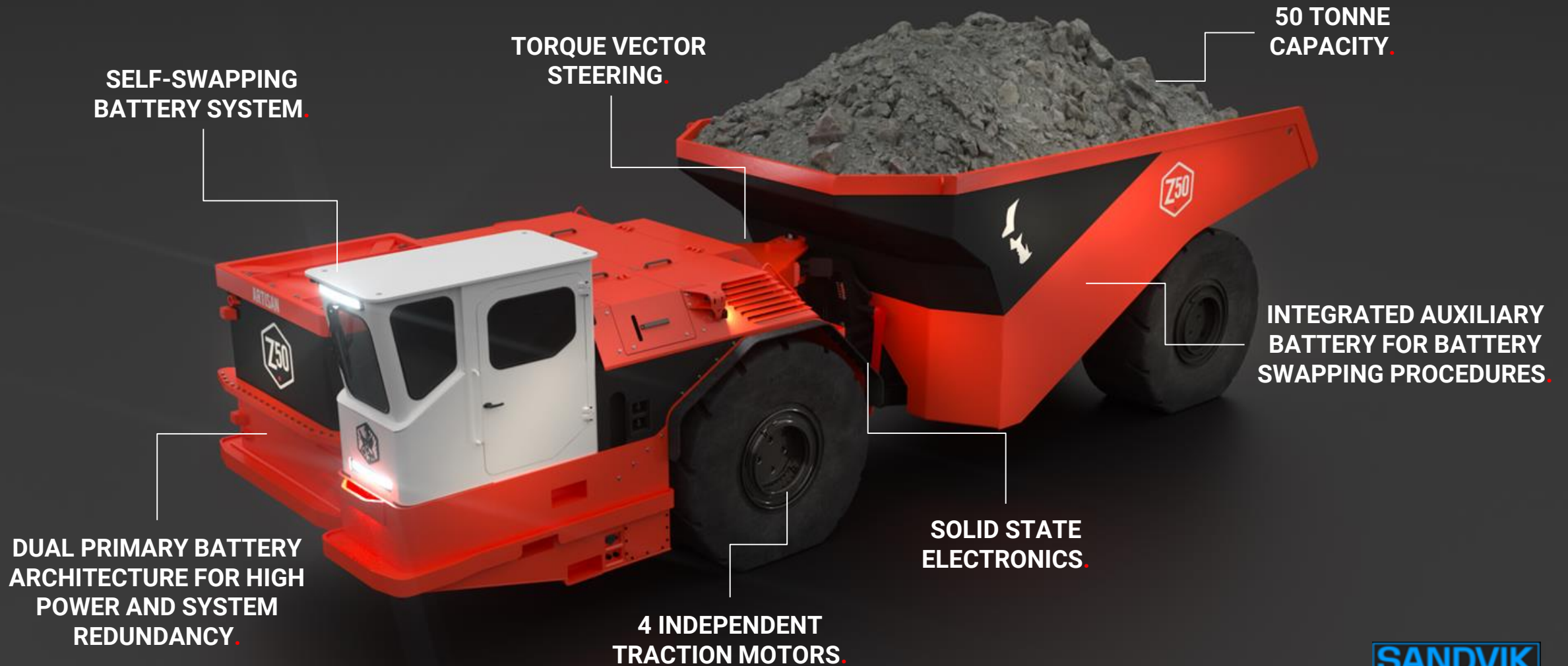


ARTISAN Z50

## FULL-RANGE ELECTRIC OFFERING 2022



# ReThink Haul Trucks.



# ReThink the Future.

## Future Proof

*Swap to Deploy  
New Technologies*

Future Battery Technology

Trolley Line Option

**SANDVIK**

# ReThink Battery Swap.



ARTISAN Z50 BATTERY SWAP TIMING • 6.5X SPEED

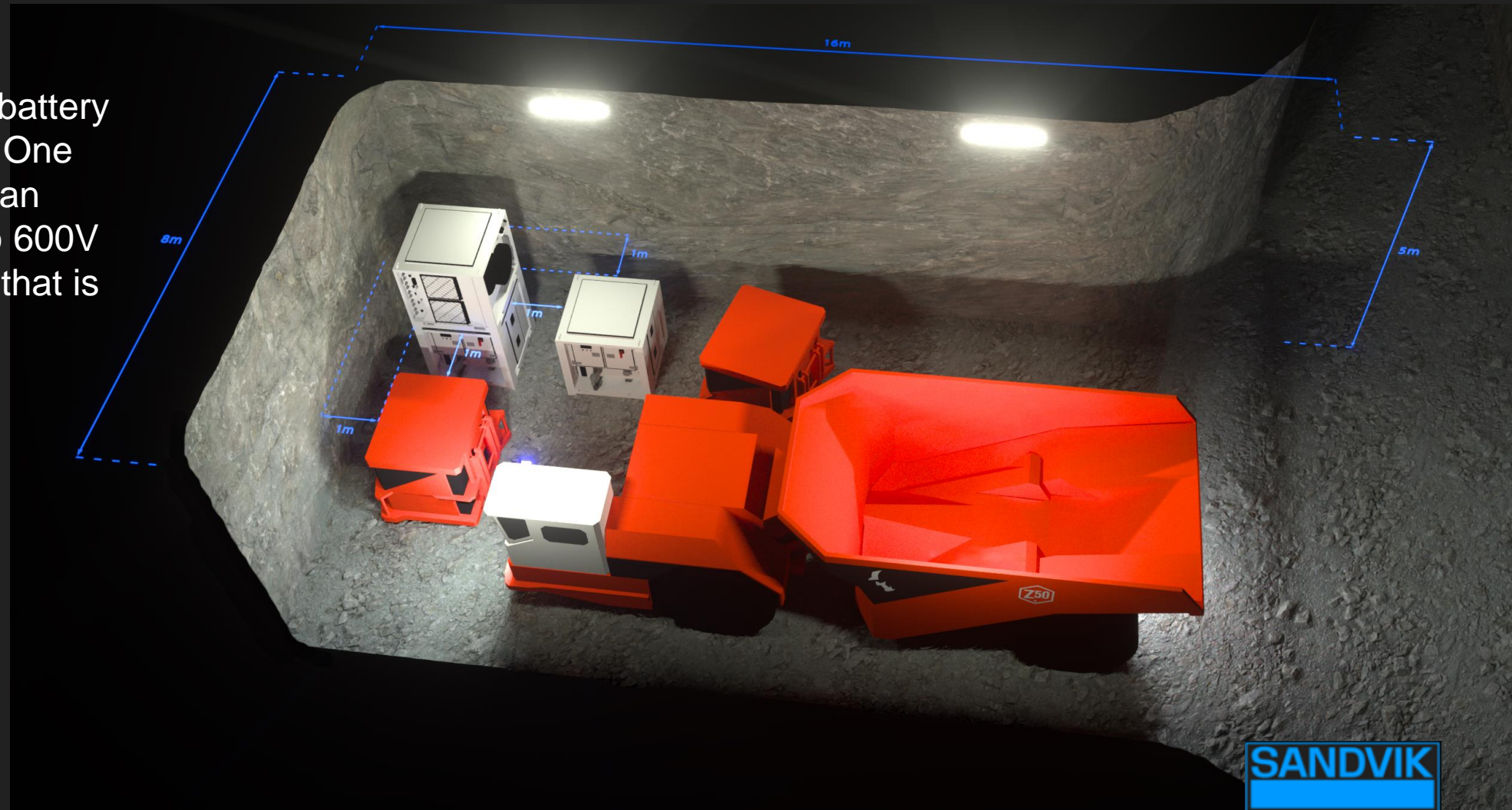
IN	DISCONNECT	DROP	TRAM	PICK UP	CONNECT	OUT	00:00:00:00
:09	1:49	:18	:42	:25	2:41	:26	



# ReThink Battery Swap.

Preparing for your new battery powered Z50 is simple. One charge bay cut out and an electrical panel with two 600V 200A connections is all that is required.

- No overhead cranes
- No additional back height requirements
- No concrete pad needed (graded level ground only)
- No vent duct required (for shallow configurations)



# No Special Facilities.

As the mine develops, moving charge locations is easy

- Carry chargers in loader bucket
- Plug chargers into jumbo plugs
- No extra ventilation required



# Simulation Tool.

## Route Definition

Description	Name	Ramp Segments																						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		21	22
Segment Distances in m	ramp_distances	1,028	478																					m
Segment Grades	ramp_grades	15.0%	3.0%																					grade
Segment Speed Limit - Out	out_speed_limit																							kph
Segment Speed Limit - Back	back_speed_limit																							kph

Total one way distance 1506m

## Mine Variables

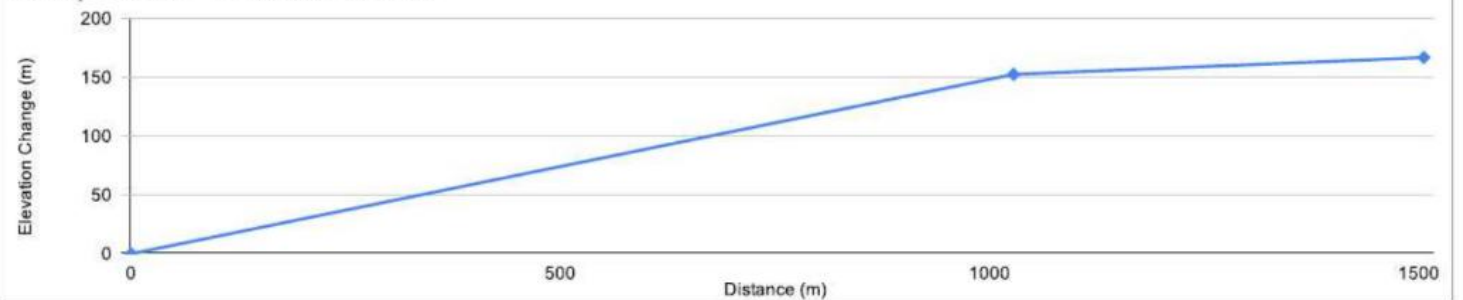
Description	Name	Value	Units
Mine speed limit	speed_limit	15	kph
Effective shift time / seat time	shift_hours	7.14	h
Fixed cycle time for loading, dumping, turning e	idle_time	9	min
Mass of Load in the truck	load	45	tonnes
Shifts per day	shifts_per_day	2	shifts
Hauling target in single shift	shift_goal_tonnes	1896	tonnes
Is the load being carried out or back	hauling_out	<input checked="" type="checkbox"/>	
Availability	availability	85%	
Days per year	working_days_per_year	364	days
Electricity Cost	electricity_cost	\$0.07	\$/kWh



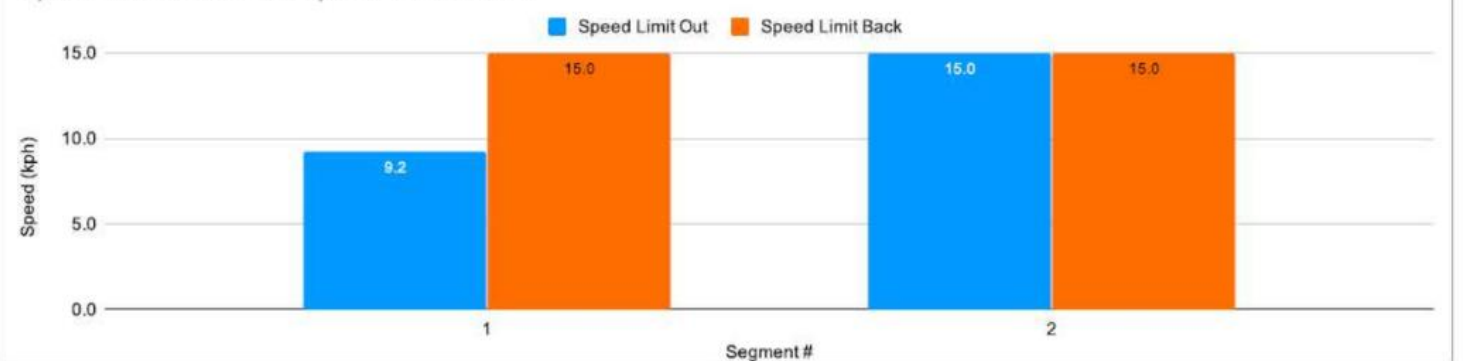
## Vehicle Parameters

Description	Name	Value	Units
Max Machine Speed	speed_max	20	kph
Charge Capacity of the vehicle's battery	battery_energy	353	kWh
Battery usable capacity upper limit	upper_lim	95	%
Battery usable capacity lower limit	lower_lim	30	%
Battery discharge power limit	discharge_lim	480	kW
Battery charge power limit	charge_lim	300	kW
Auxiliary Power Draw	power_aux	9.8	kW
The weight of the vehicle	vehicle_weight	48	tonnes
Time to swap a battery	swap_time	6	min

Ramp Profile - Elevation Meters



Speed Limit Out and Speed Limit Back



# Simulation Tool.

## Calculations & Results - Machine Performance

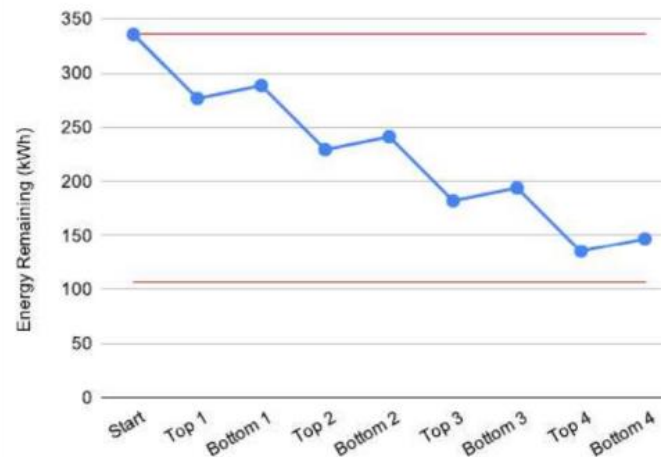
Description	Name	Result	Units
Total ramp distance	ramp_distance	1,506	m
Average grade of all ramp segments	ramp_grade	0.11188	
Average speed out	out_speed	10.5188	kph
Average speed back	back_speed	15	kph
Time to travel outbound on the cycle	out_time	8.59026	min
Time to travel back on the cycle	back_time	6.024	min
Time to make one trip	cycle_time	23.6	min
Tonnes each vehicle hauls in a shift	vehicle_shift_tonnes	765	tonnes
<b>Trucks needed to meet daily goal</b>	<b>vehicles_needed</b>	<b>3</b>	<b>vehicles</b>
<b>Total haul by all vehicles in a shift</b>	<b>shift_tonnes</b>	<b>2295.0</b>	<b>tonnes</b>

## Calculations & Results - Battery Performance

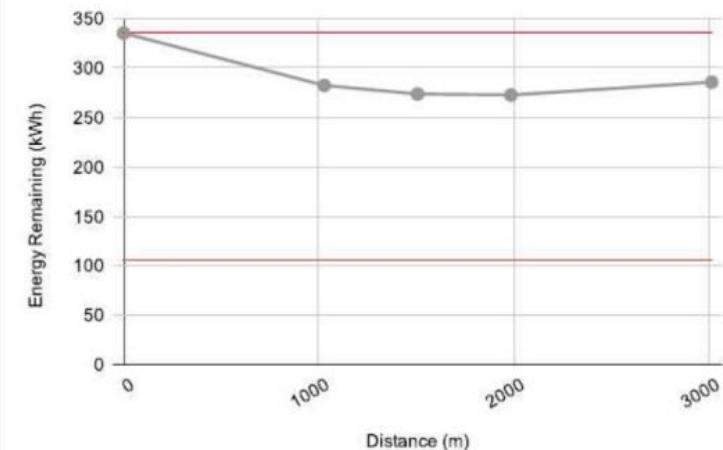
Description	Name	Result	Units
DOD after one trip	DoD	57%	
Total trips possible before swapping	loads_per_charge	4	trips
Battery runtime	battery_runtime	1.6	hr
# of cycles each vehicle can make in a shift	loads_per_shift	17	loads
# of battery swaps per shift	shift_swaps	4	swaps
Fast charge time (350kW)	charge_time_min	32	min
Battery charge cycles per year	charges_per_year	3640	cycles
Expected cycle life to 80% capacity	cycle_life	4562	cycles



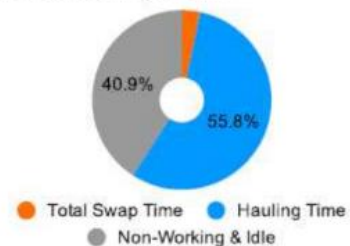
### Battery Charge Cycle



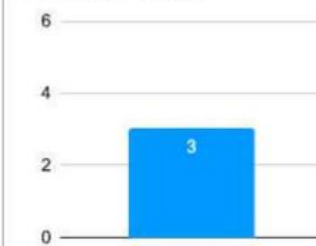
### Single Trip Energy Detail



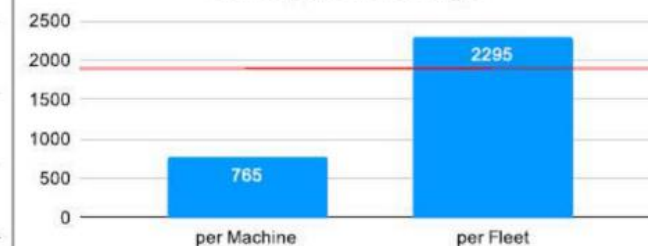
### Time breakdown per shift



### Vehicles Needed



### Tonnes per Shift vs Target





# Vehicle Dashboard.

Date Range Totals:

Distance  
1,144.86

Hours  
220.39

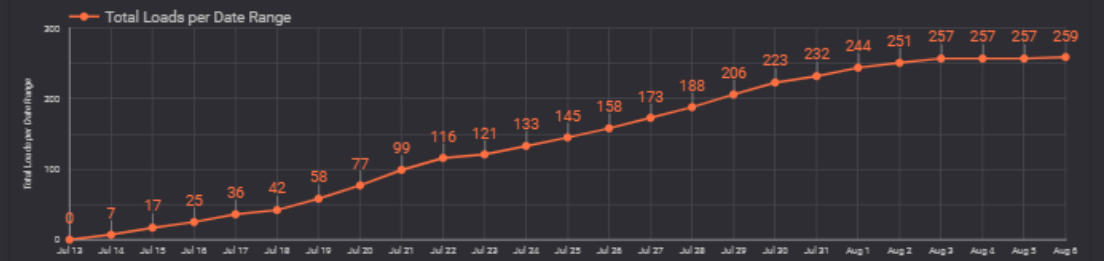
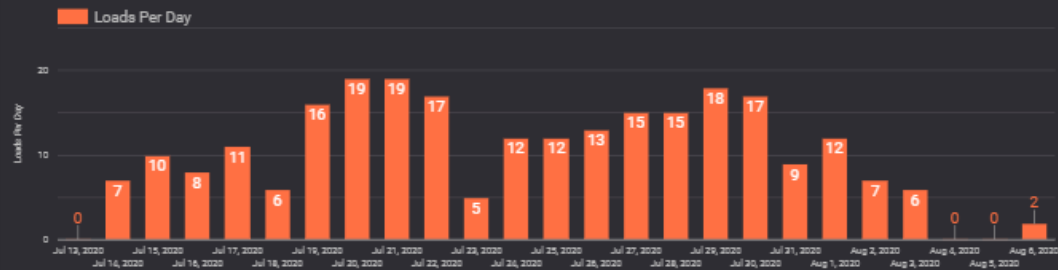
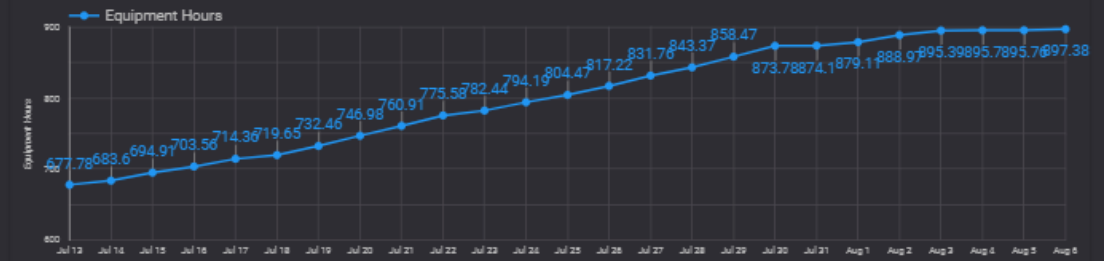
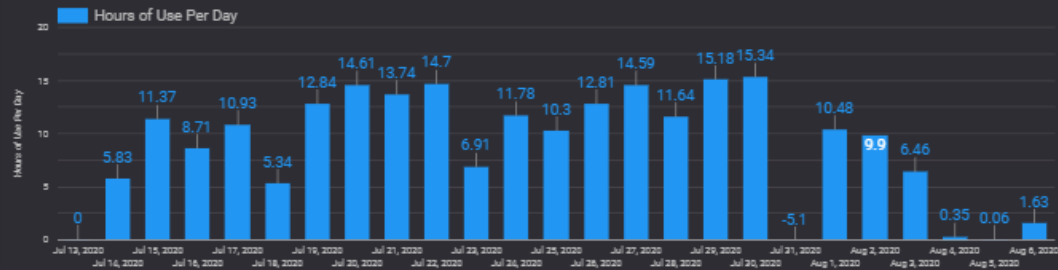
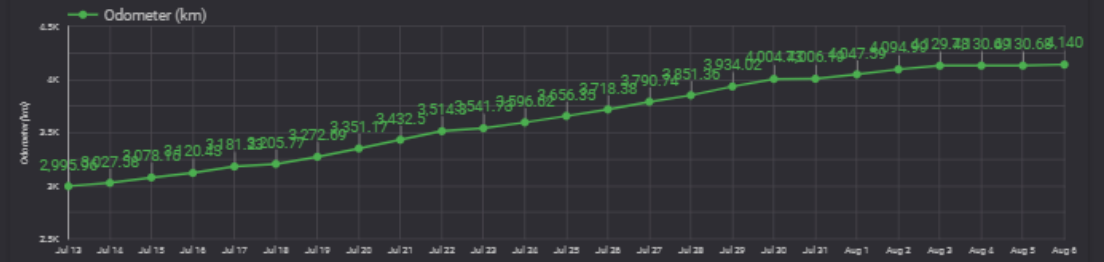
Loads  
256

Lifetime Totals:

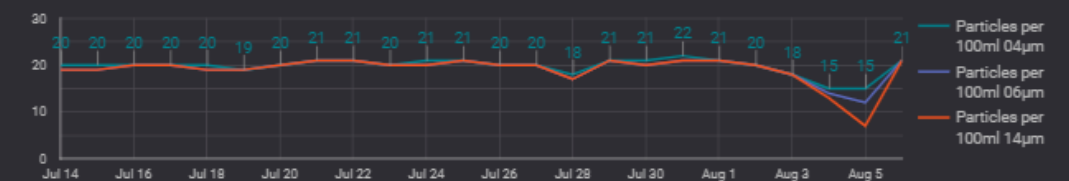
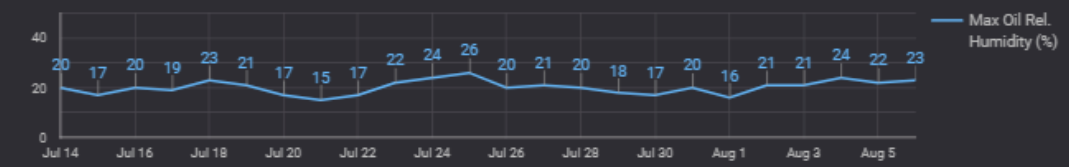
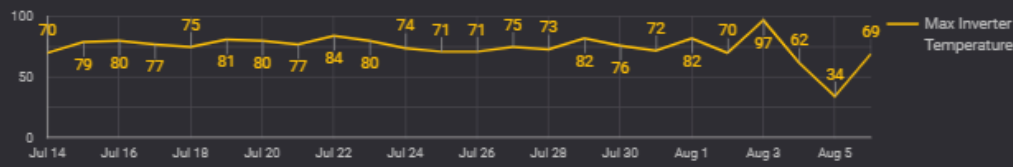
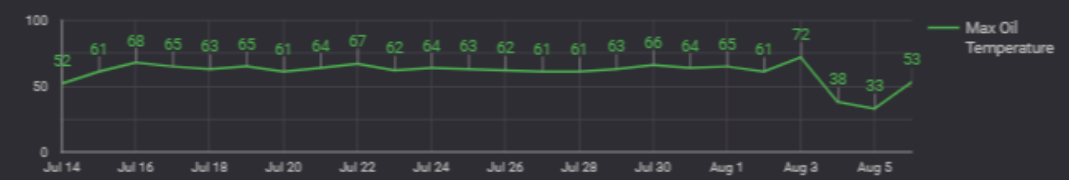
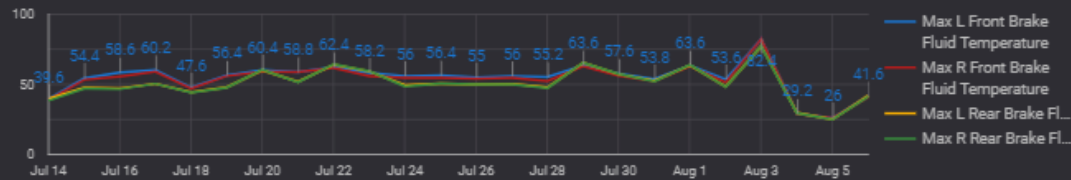
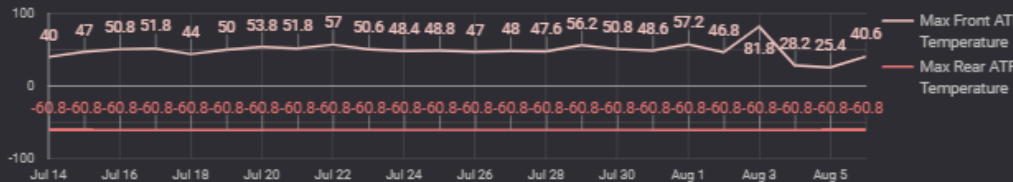
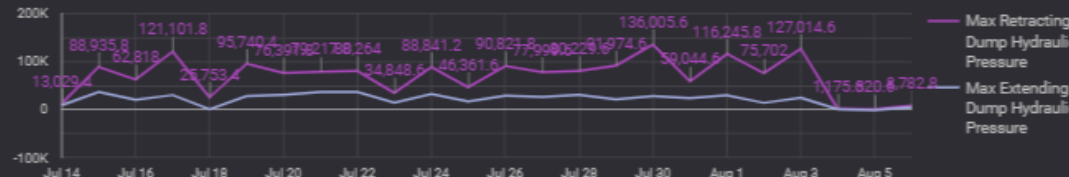
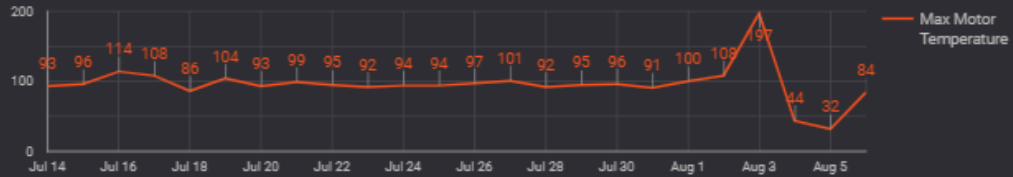
Odometer  
4,130.69

Hour Meter  
897.38

Loads  
990



# Vehicle Dashboard.



# ReThink Capacity.



**Capacity**

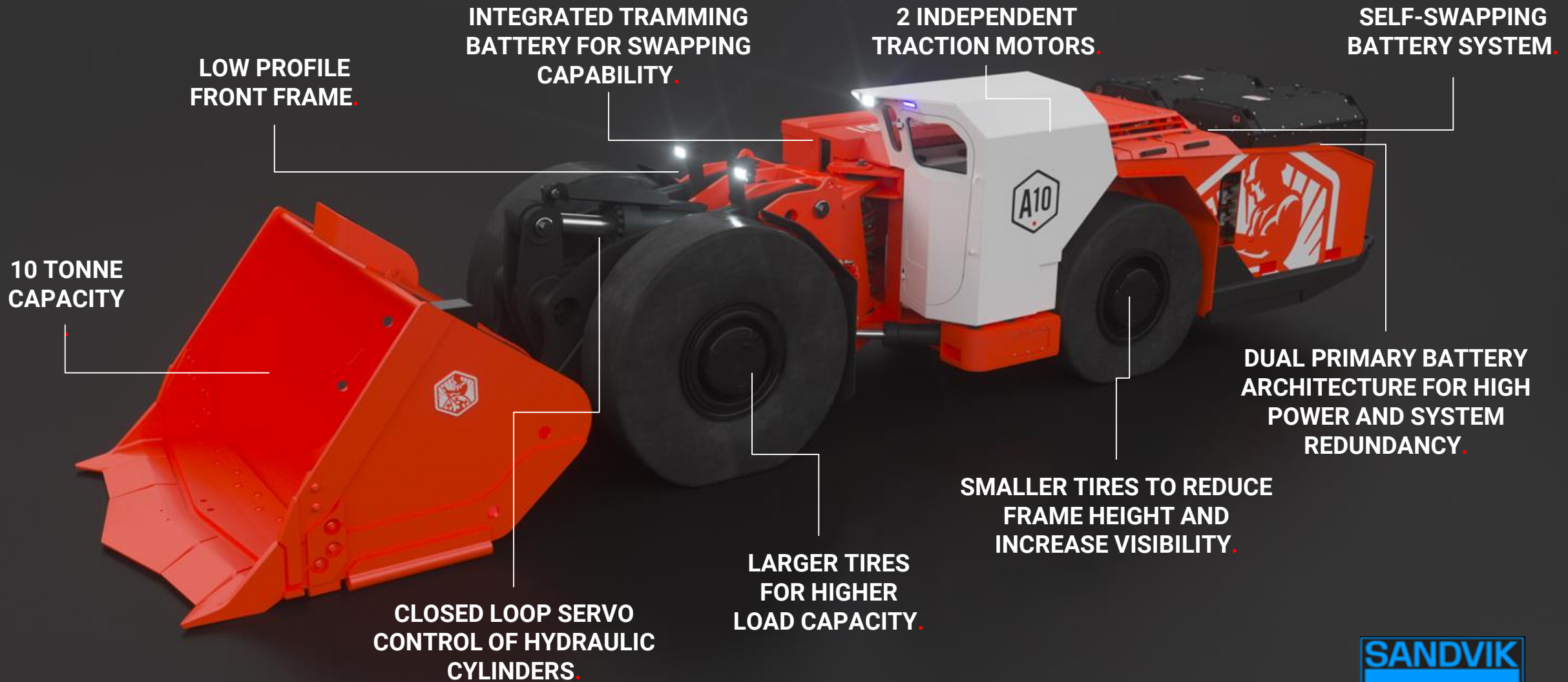
**Size**



**6 Yard (10 tonne)**

**4 Yard (7 tonne)**

# ReThink Loaders.

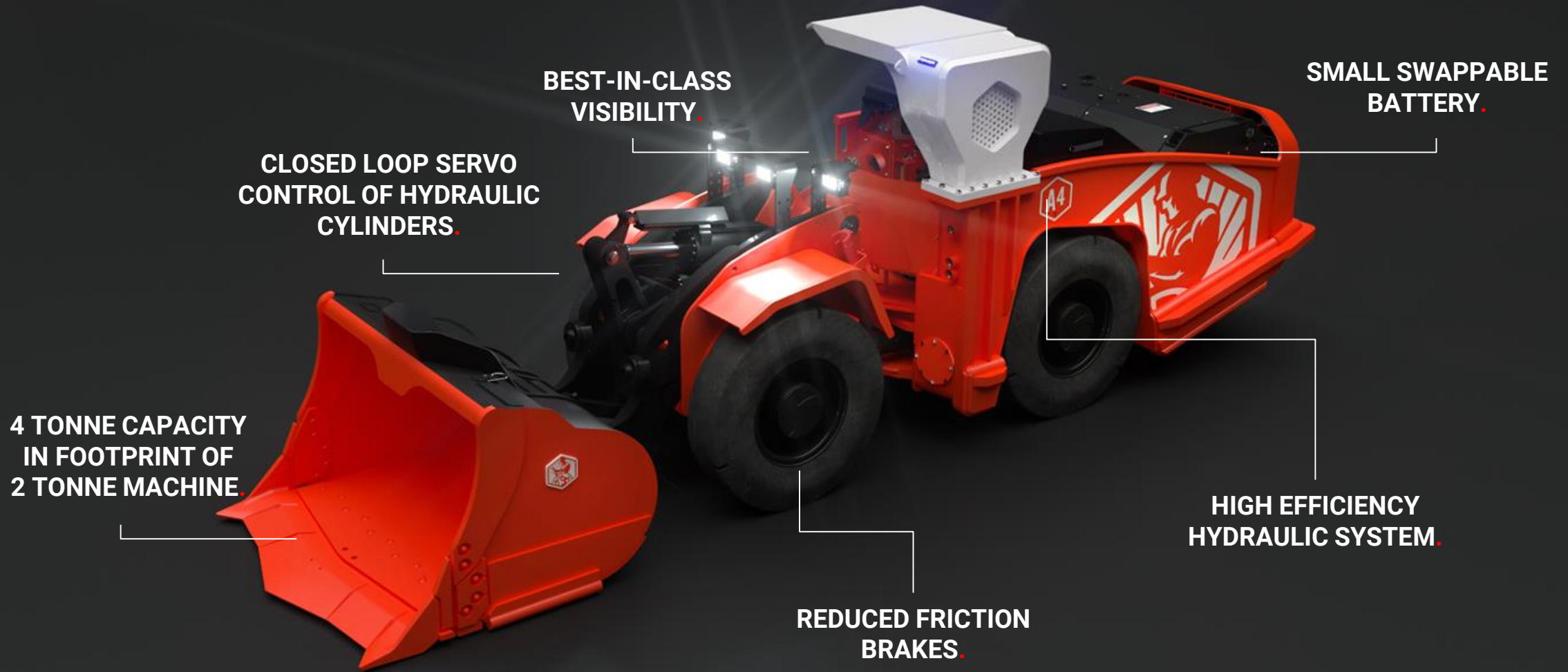


# ReThink Battery Swap.

CONFIDENTIAL • ARTISAN A10 BATTERY SWAP VISUALIZATION DRAFT



# ReThink Small.



**BEST-IN-CLASS  
VISIBILITY.**

**SMALL SWAPPABLE  
BATTERY.**

**CLOSED LOOP SERVO  
CONTROL OF HYDRAULIC  
CYLINDERS.**

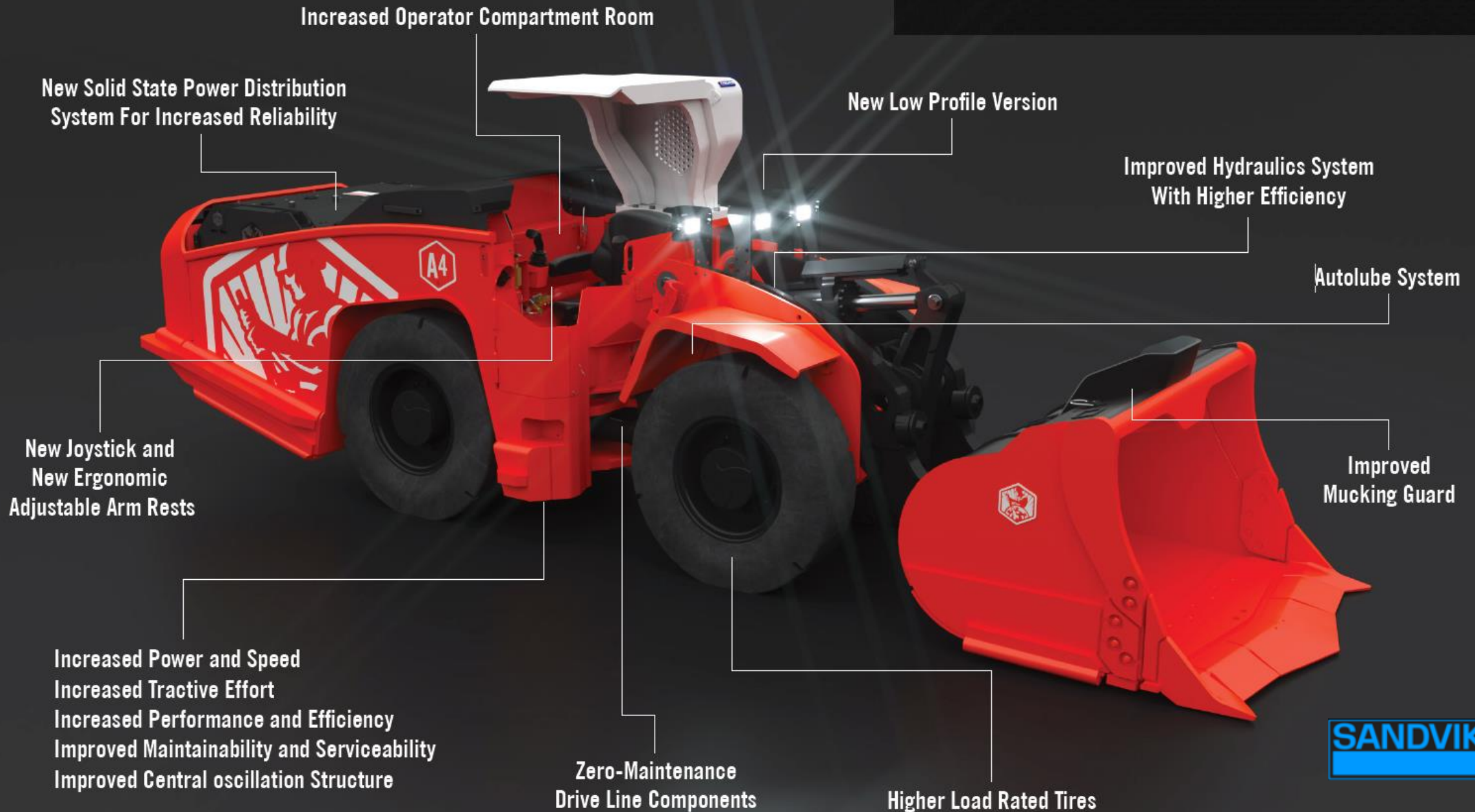
**4 TONNE CAPACITY  
IN FOOTPRINT OF  
2 TONNE MACHINE.**

**HIGH EFFICIENCY  
HYDRAULIC SYSTEM.**

**REDUCED FRICTION  
BRAKES.**

**SANDVIK**

• **A4 2019 FEATURE UPDATES**



# ReThinkSmall.



**SANDVIK**



# The A18 Is Coming.



**Most Capacity for its Size**



# The A18 Is Coming.



**Capacity**

**Size**



**10 Yard (18 tonne)**

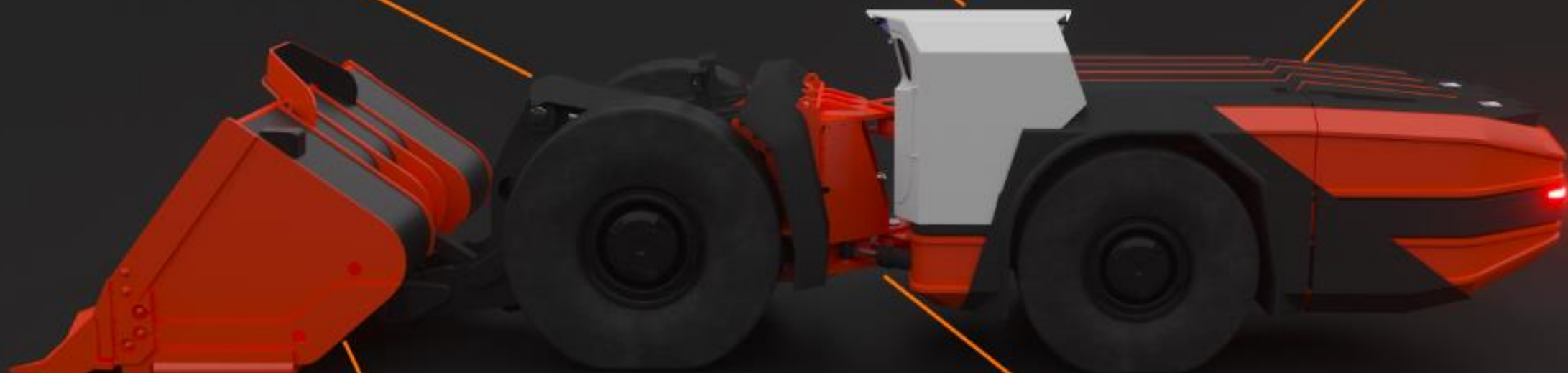
**8 Yard (14 tonne)**

# A18 LHD - Features.

Integrated Sandvik boom design and components

Latest model Sandvik LHD cabin

Self swap battery system



Full range of Sandvik bucket options

Solid state power distribution system



# Battery Design Evolution.

AIR COOLED

INDIVIDUAL CELL BMS SENSORS

RIGID CONNECTOR

PLASTIC CASE CELLS WITH LOW ENERGY DENSITY

COMPLICATED MACHINED MODULE COVER

HIGH NUMBER OF CRIMPED CONTACTS AND WIRES

LIQUID COOLED

NEW ADVANCED BMS

NEW FLEXIBLE CONNECTION SYSTEM

NEW ALUMINUM HOUSED CELLS WITH 30% HIGHER ENERGY

MODULAR INJECTION MOLDED COVER DESIGN

FLEXIBLE CONNECTION ARRAY – NO WIRES / NO CRIMPING



# Battery Build Up.

Cell

Module

Pack

Cage

Machine

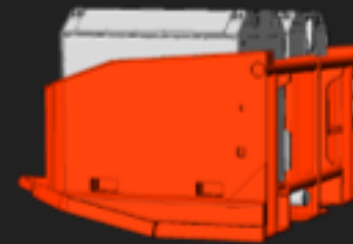
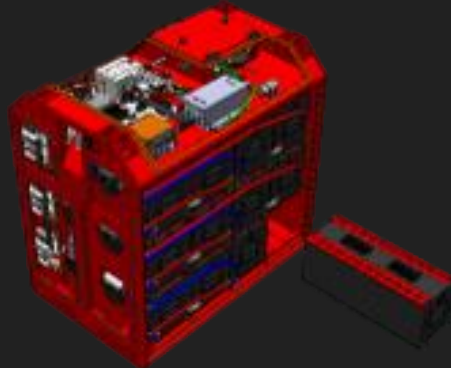
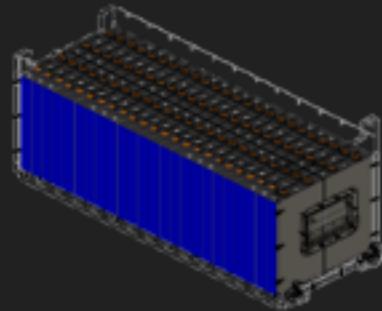
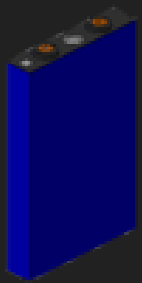
- Smallest unit of the battery assembly

- Cells connected in parallel and then in series

- Group of modules connected in series with cooling, isolation monitoring, fire suppression, and automated connection systems

- Mechanical assembly that carries and protects multiple packs
- This is the assembly that is swapped to “refuel” the machine

- The machine contains all the drive motors and power electronics required for operation
- DC-DC converter
- Auxiliary inverter and motor



**SANDVIK**

# Safe & Proven Battery Technology.

- Advanced LiFePO4 battery systems
- Modular design for optimized uptime and design flexibility
- Safety focused design
- Oil cooled modules
- Scalable module design for application flexibility
- Self contained fire suppression system
- Advanced battery management system
- Designed for arc-flash safety



# Battery Technology.

We use Lithium Iron Phosphate as our battery chemistry because it's a safe option for underground mining.



## LiFePO<sub>4</sub> will withstand:

- Overcharge
- Mechanical shock and vibration
- External short-circuit
- Crushing
- Penetration
- Internal short circuit without starting a fire

## In addition to safety, our LiFePO<sub>4</sub> batteries have:

- Good cycle life
- Good power density
- Good energy density
- Low cost
- No cobalt
- Low environmental impact



# Battery Safety.

**Abuse Tolerance Improvement**

E. Peter Roth  
Sandia National Laboratories  
Albuquerque, NM

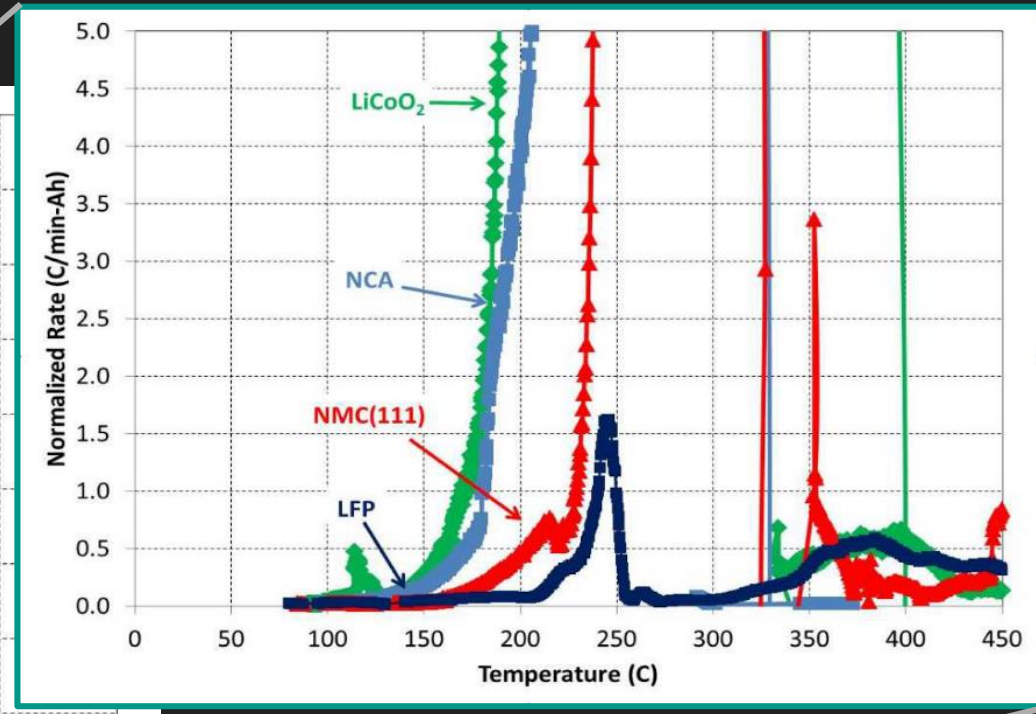
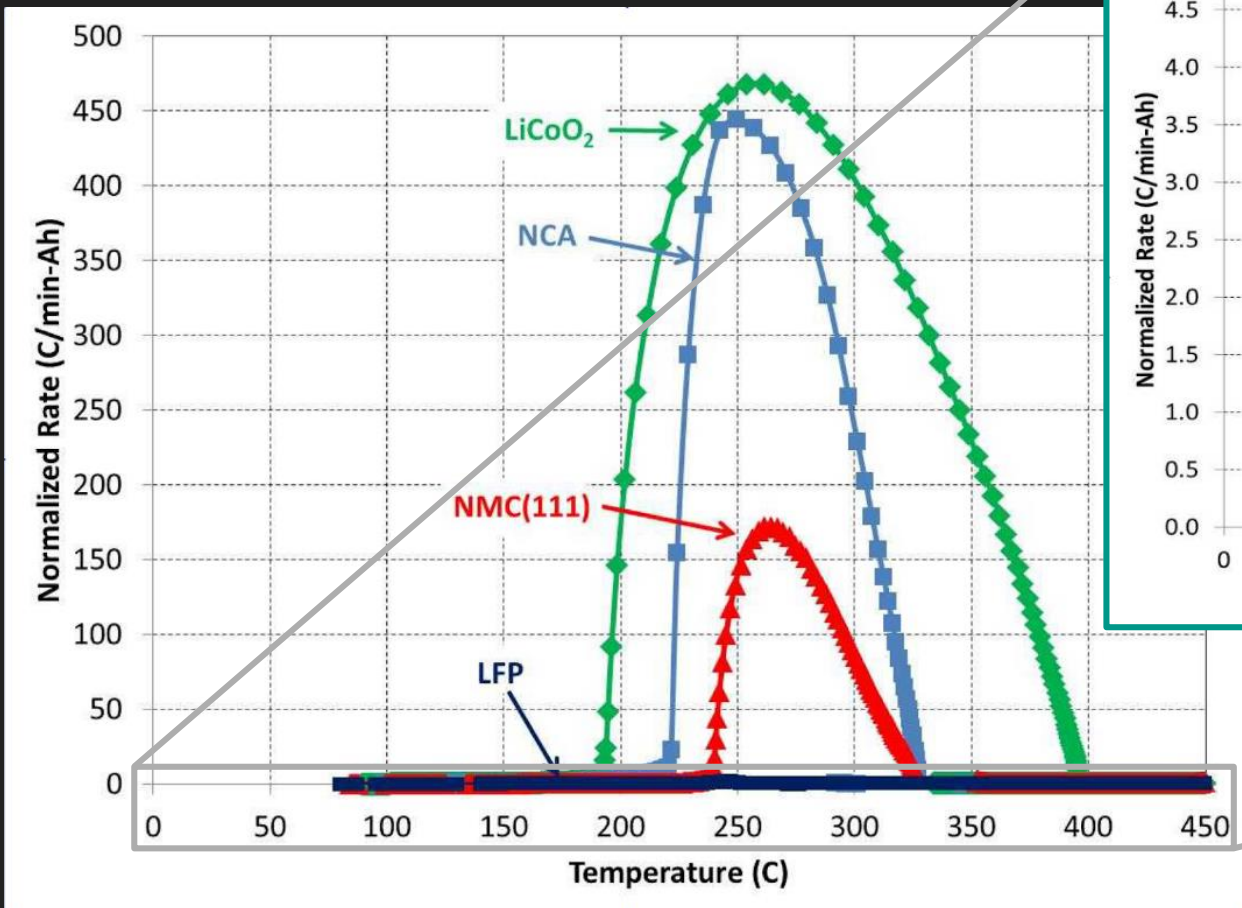
DOE Vehicle Technologies Peer Review  
Gaithersburg, MD  
Feb. 26, 2008

FreedomCAR  
Fuel Partnership

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NASA Sandia National Laboratories





# Battery Safety.



[www.soltaro.com.au](http://www.soltaro.com.au)



# BEV Training.

High level overview of the training efforts currently in place in USA, Canada and Australia:

- Factory technician training
- Operator training videos – online
- Technician training videos - online
- Sales Area champions: key to success
- Weekly engagements with applications team
- Technical support training – USA/Canada/Australia visits in 2019
- Australia:
  - > Risk Assessments carried out
  - > Engagement with Queensland and Kalgoorlie TAFE – industry training
  - > Early engagement for Victoria & Western Australian BEV's

# Thank You.



**SANDVIK**