1243 ADT Scraper Tail Validation Project

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Adaptive Corp.
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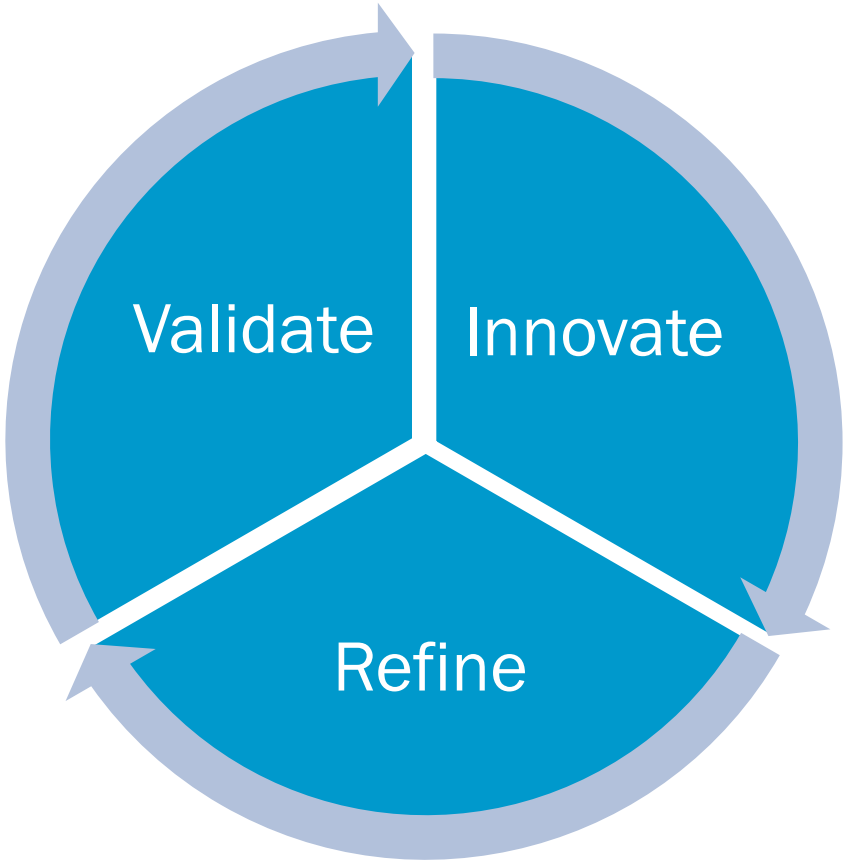
K-Tec History

- K-Tec started in 2000, when Ken Remple built his first pull-type scraper in his barn, due to frustration with lack of quality pull-type scrapers on the market
- Today the manufacture over 100 vehicles per year
- Sizes range from 25 to 63 yard capacity

About Adaptive Corporation



Connecting Virtual Design to the Physical World

Areas of Expertise

Simulation

Wolf Star Technologies

SIMULIA

MSC Software

Endurica
Accelerating Reliable Design

BETA
CAE Systems SA

PLM/CAD

ENOVIA

CATIA

DELMIA

EXALEAD

3DEXPERIENCE

Quality/Metrology

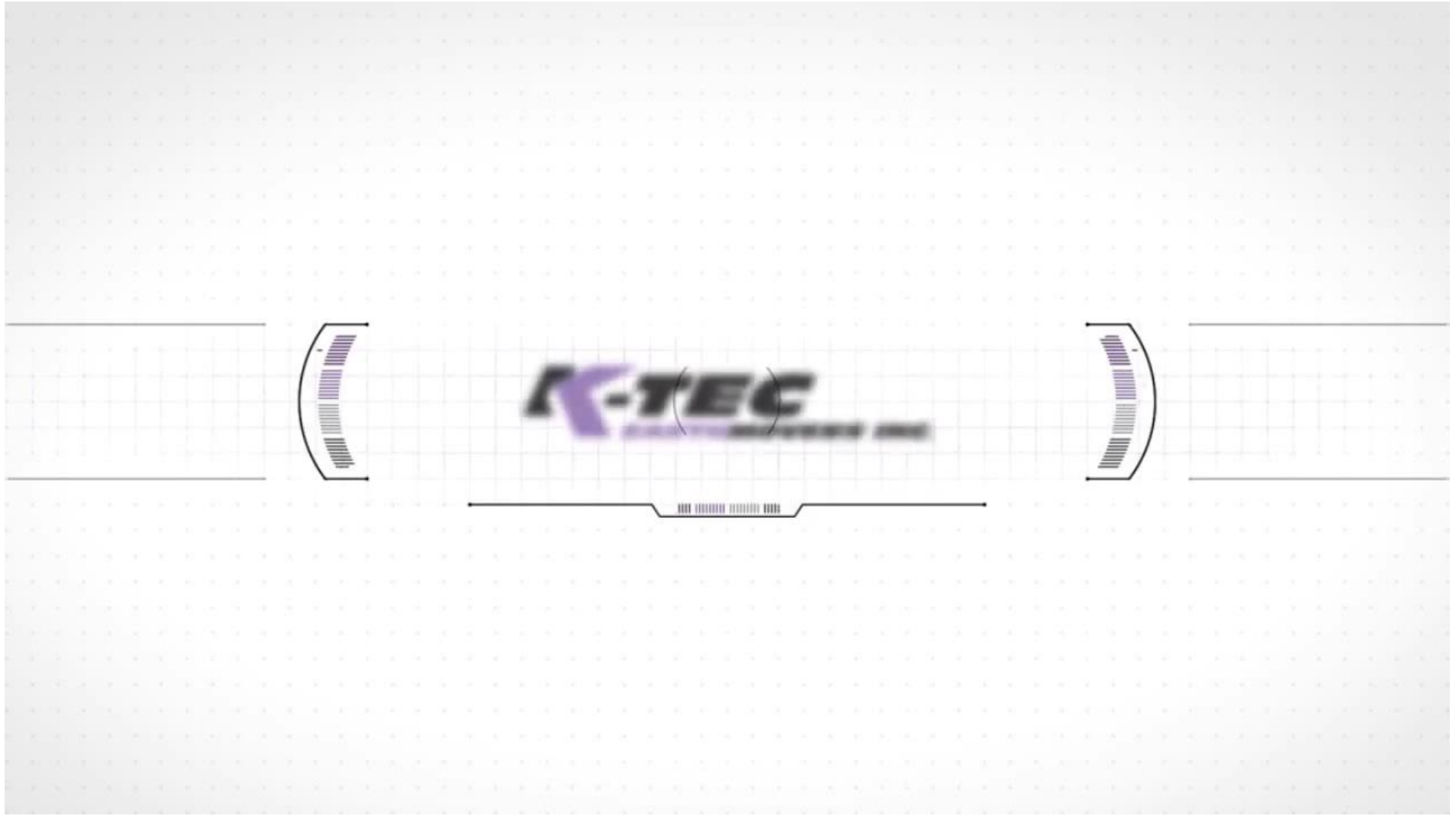
CREAFORM

net-inspect

TRANSMAGIC

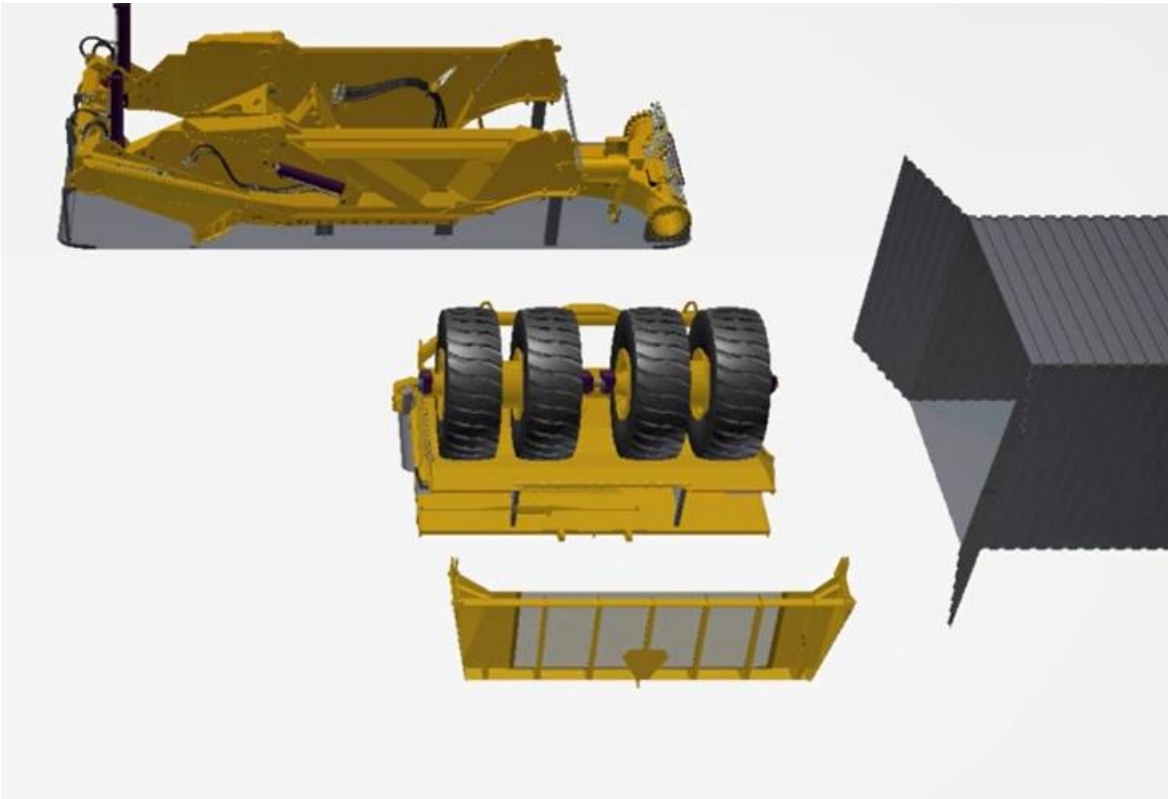
VERISURF

1243 ADT Scraper in Action…



1243 ADT Design

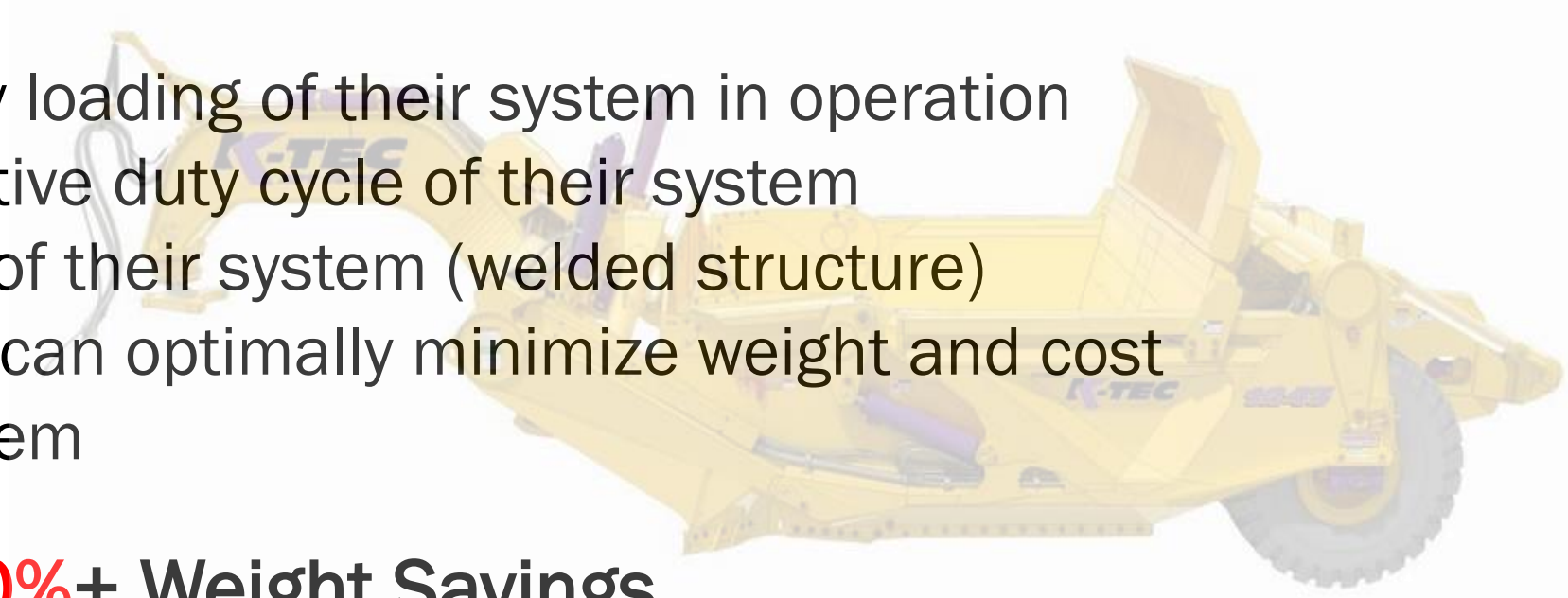
- New Concept to allow large design to assemble into shipping container
- Design sized using max/worst case static loading
- Final design approximately 20% over target weight



1243 ADT Scraper

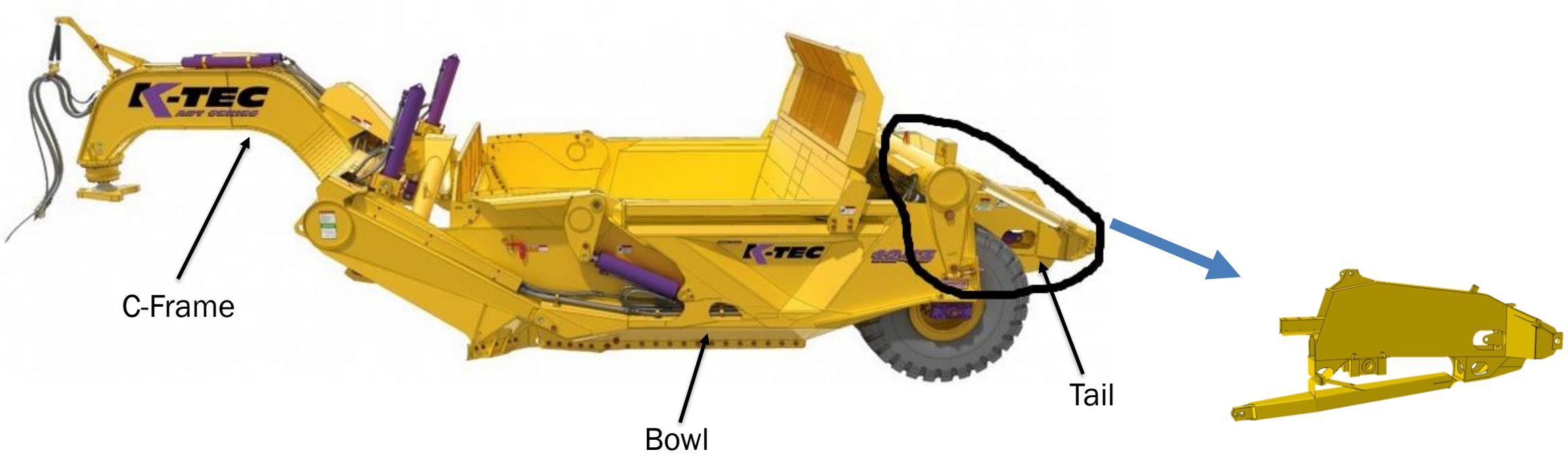
To begin optimizing the vehicle, we need to understand …

- ✓Time history loading of their system in operation
- ✓Representative duty cycle of their system
- ✓Fatigue life of their system (welded structure)
- ✓Where they can optimally minimize weight and cost of their system



➢ **Goal of 20%+ Weight Savings**

1243 ADT Scraper Tail

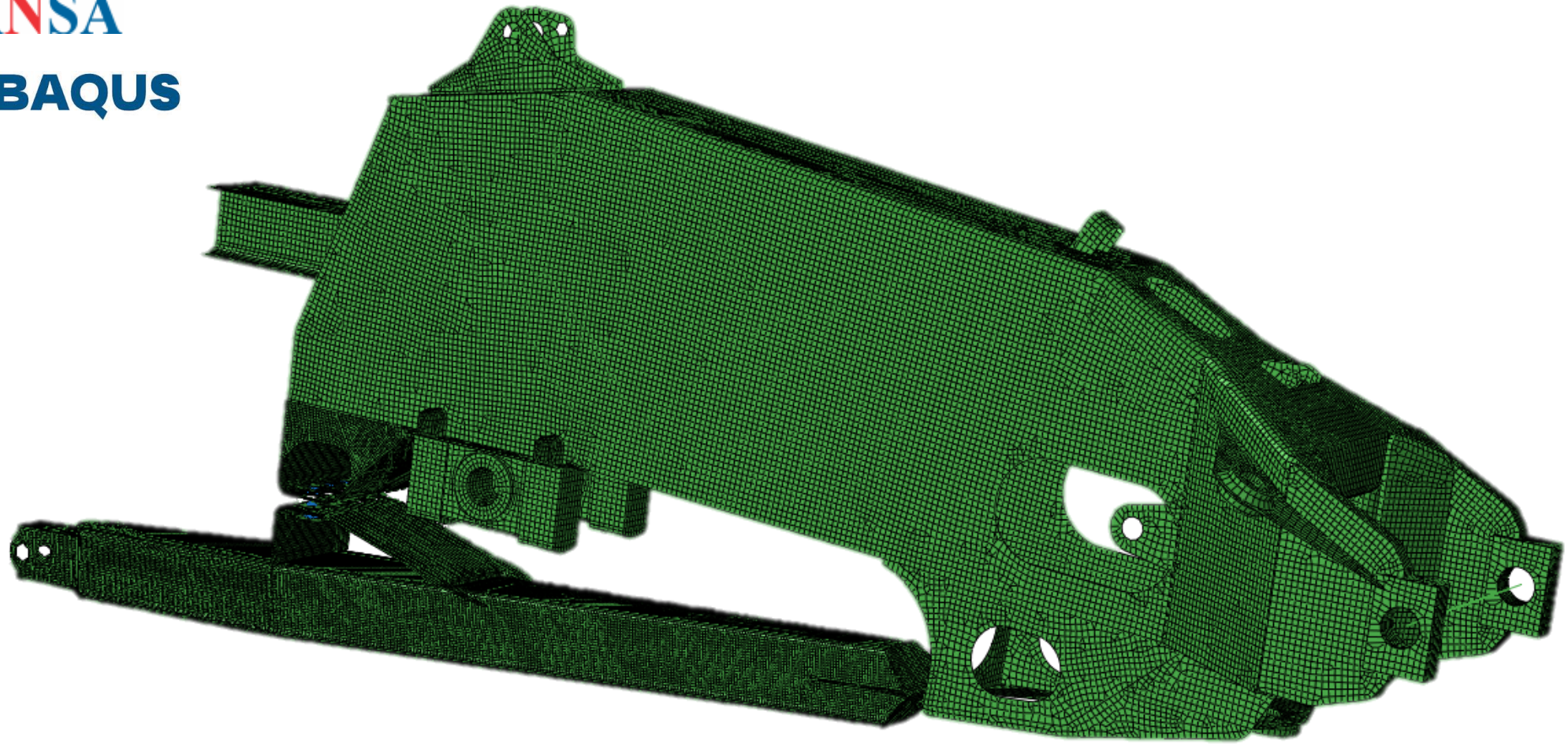


Project Goals:

- Create FEM of Tail System
- Determine Load Time Histories on System via Measured Data
- Develop Duty Cycle from Load Time Histories
- Calculate Fatigue Life based on Duty Cycle/Load Time Histories
- Perform Optimization Based on Load Time Histories

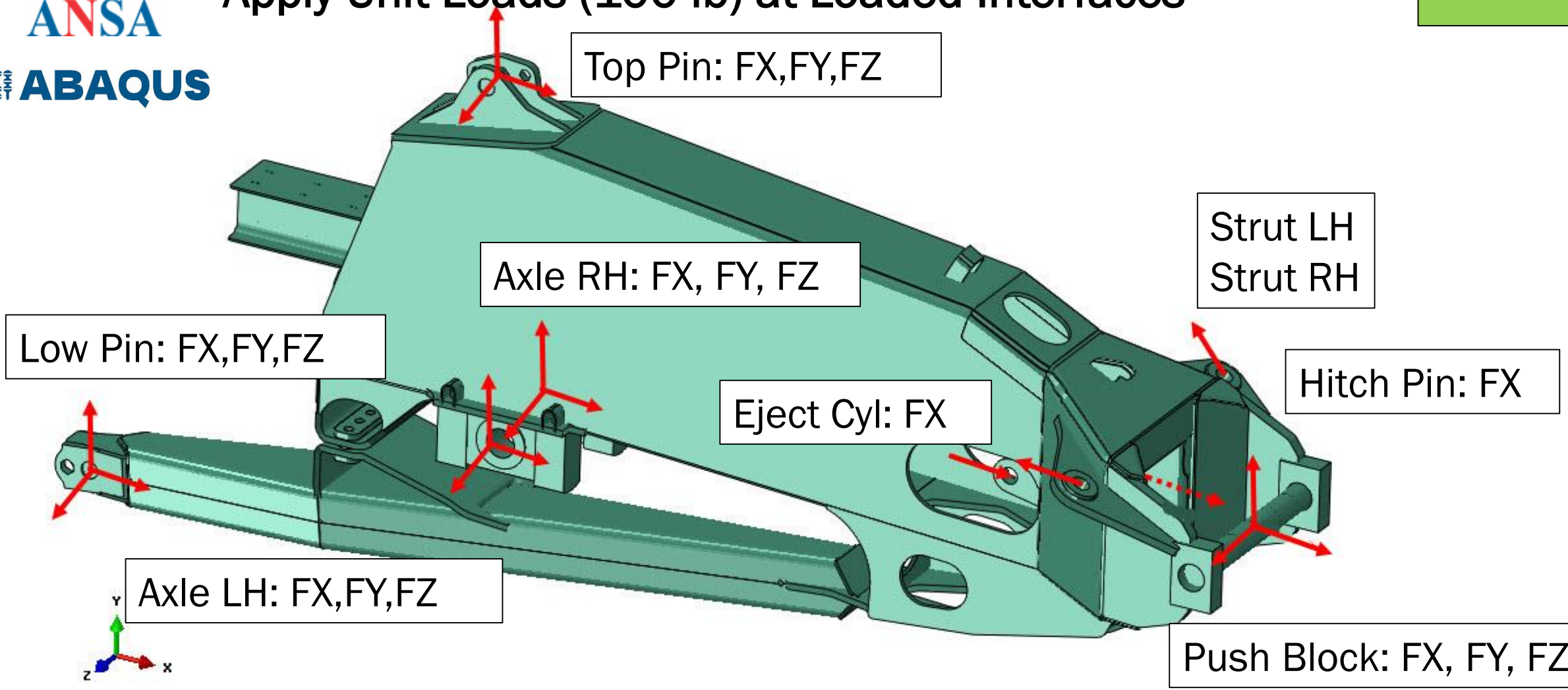
BETA CAE Systems SA
ANSA
ABAQUS
Wolf Star Technologies
True-Load
fe-safe
TOSCA STRUCTURE

Create FEM of Tail System

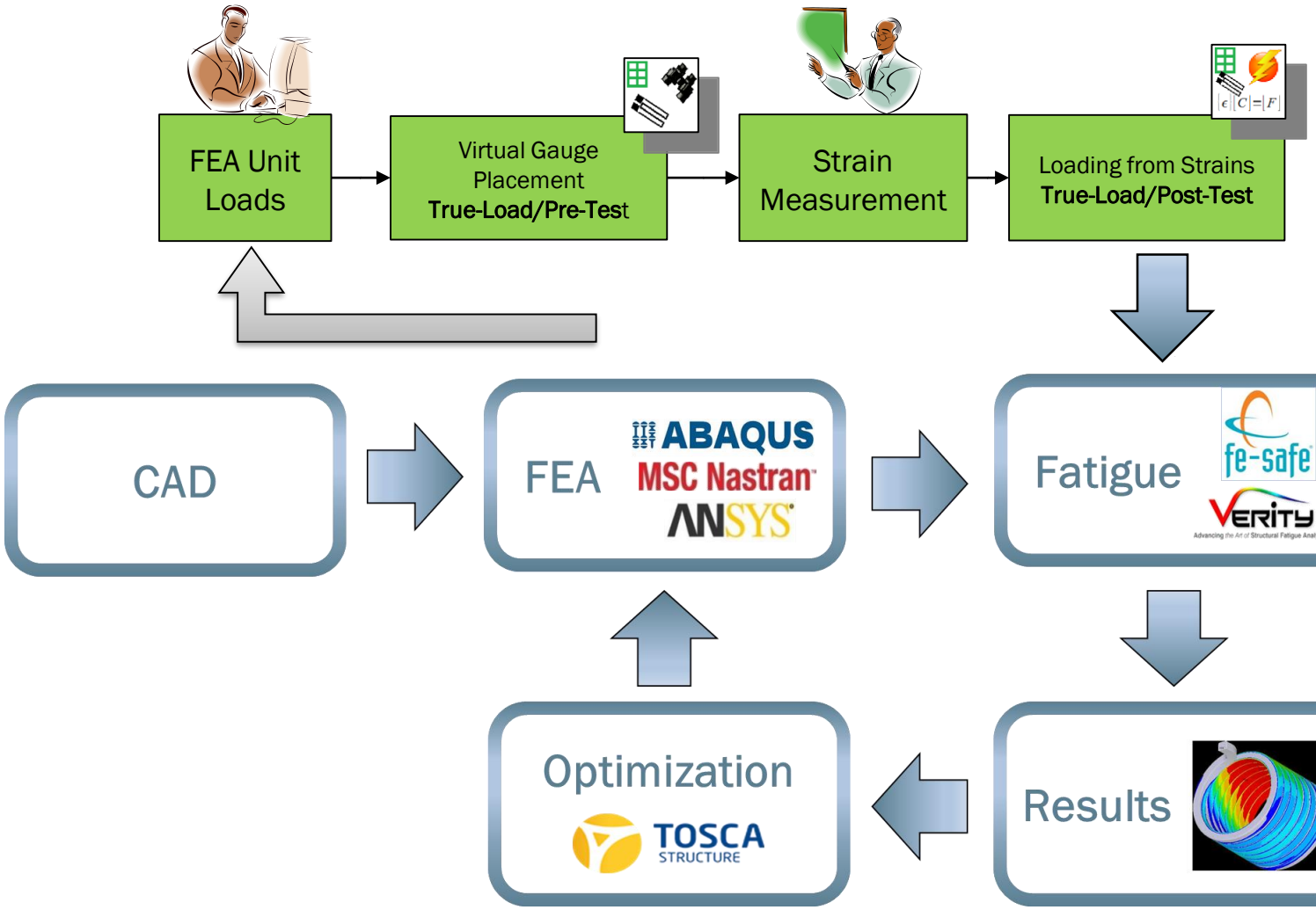


Create FEM of Tail System
Apply Unit Loads (100 lb) at Loaded Interfaces

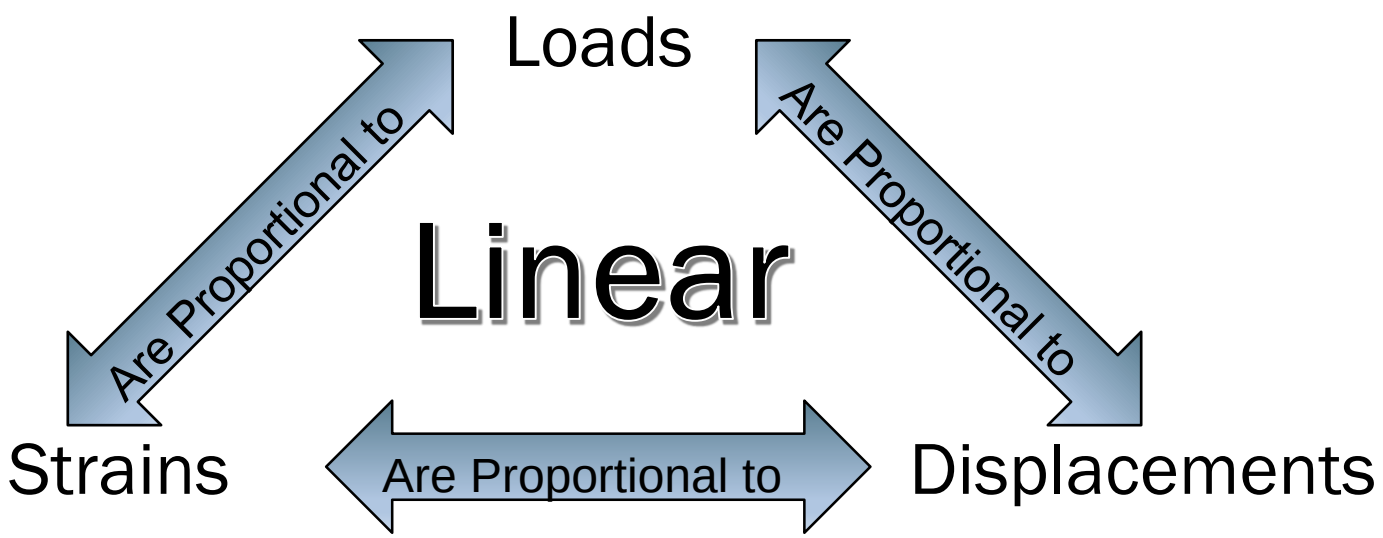
FEA Unit Loads



The True-Load™ Workflow



Linear Systems and Loads



In other words

$$F = Kx$$

and

$$\varepsilon C = F$$

From Test

From FEA

$$F = \varepsilon C$$

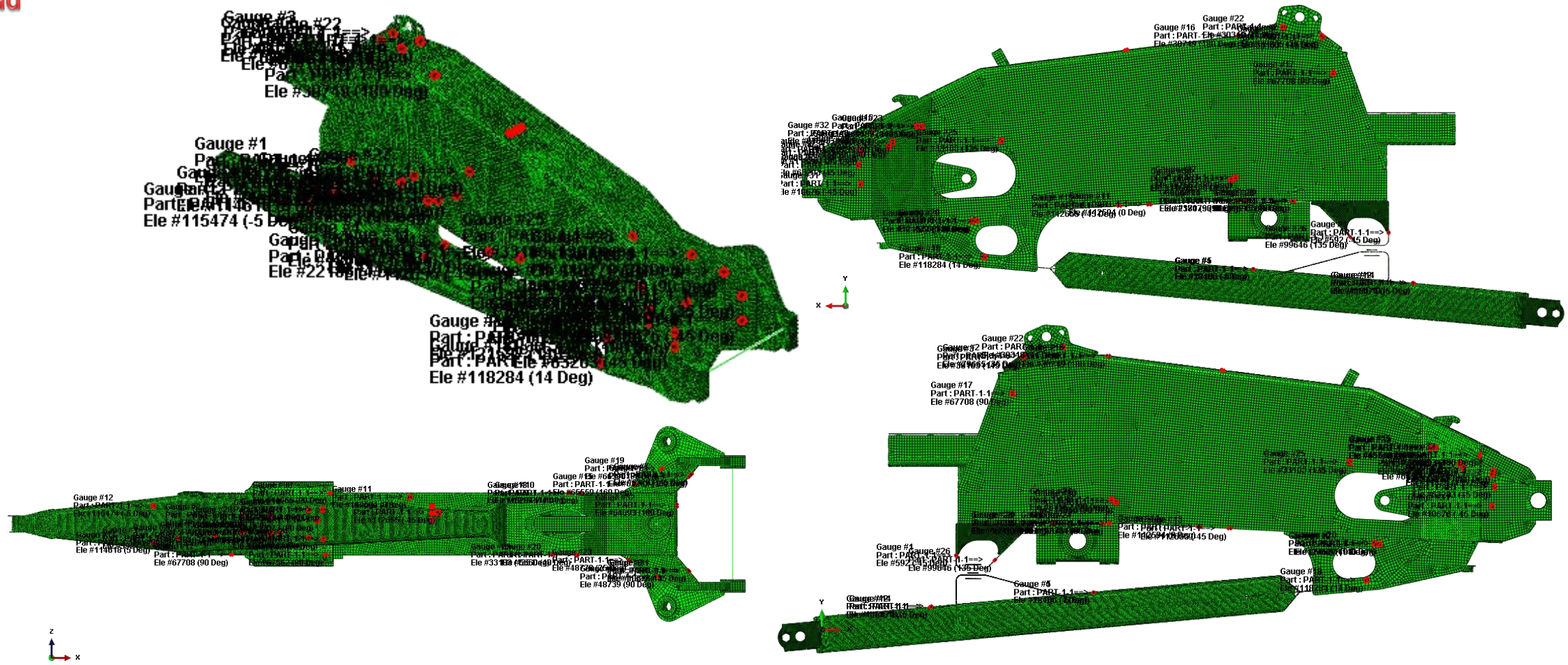
Forces from strains

F, Load vector
K, Stiffness matrix
ϵ, Strain matrix
C, Correlation Matrix

Virtual Gauge Placement
True-Load/Pre-Test

T-L Pre-test

* identify strain gage placement based on FEA Unit Loads



True-Load

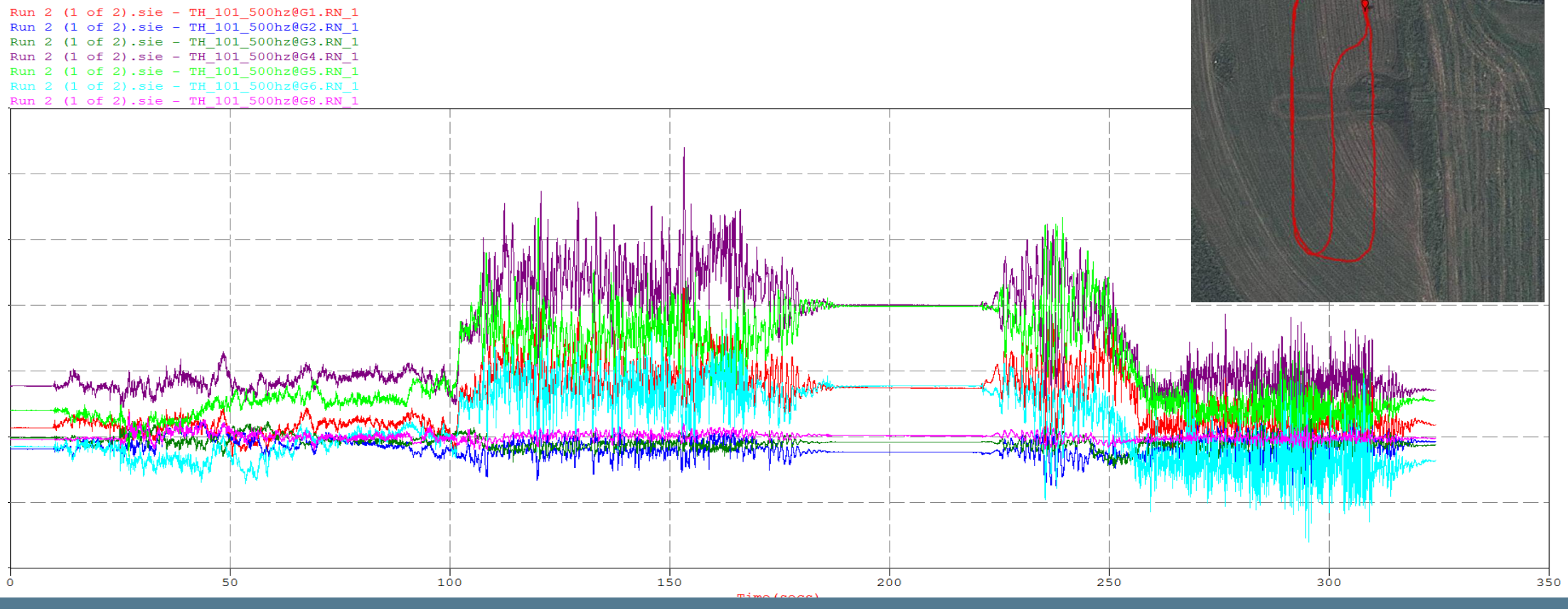
Adaptive Corporation

K-TEC EARTHMOVERS INC.

Strain gage Data Collection…
on various terrains, roads and duty cycles

Strain Measurement

True-Load



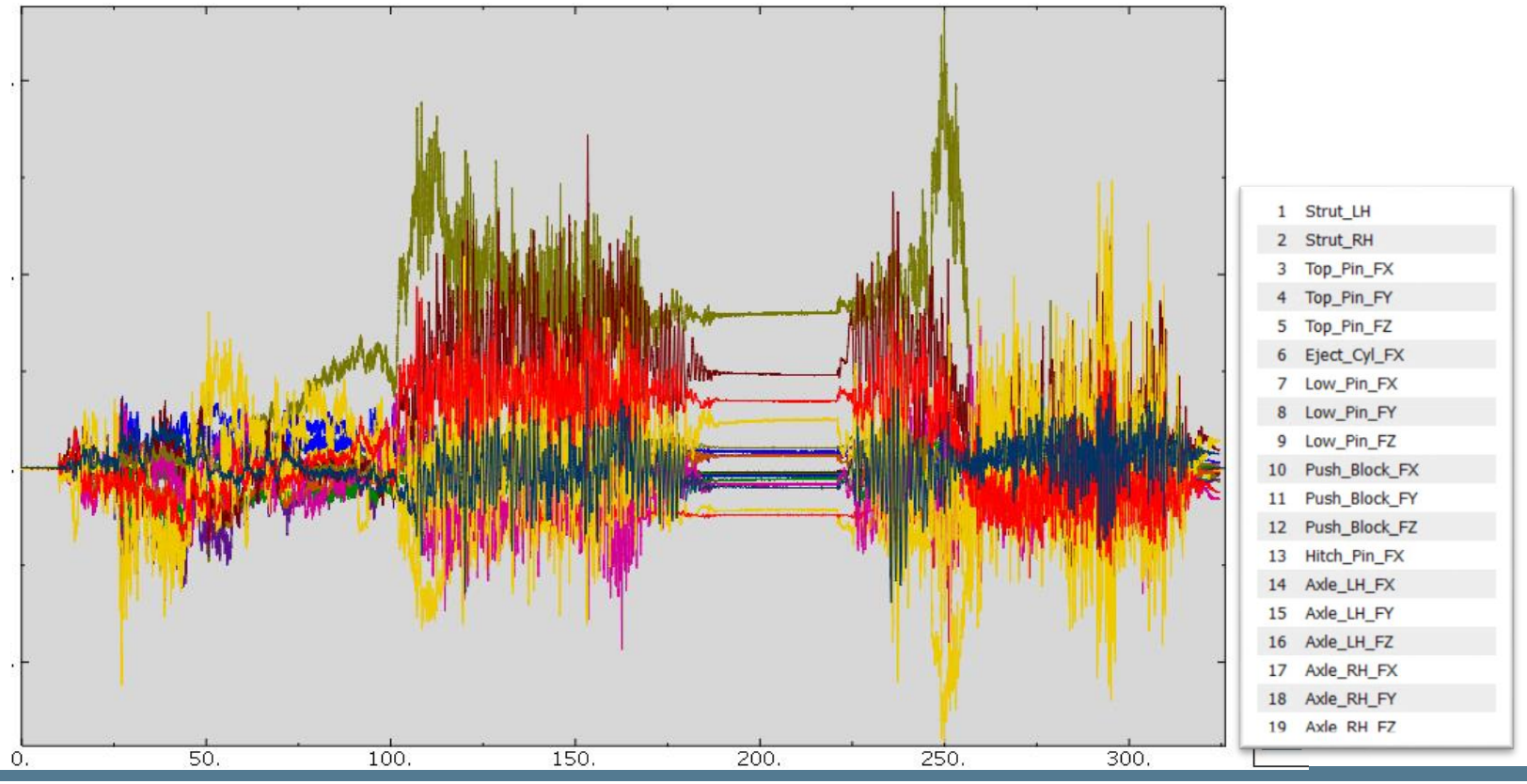
T-L Post-Test:

- Calculate Loads from strain measurement

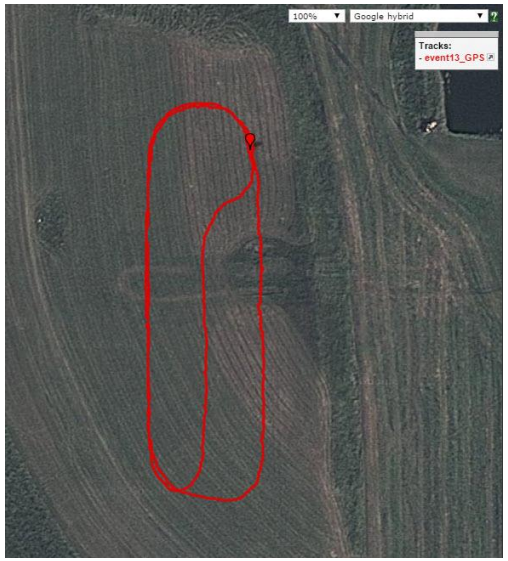
Loading from Strains
True-Load/Post-Test

True-Load

Event 2 Push Load with D8 Full



Unit Loads



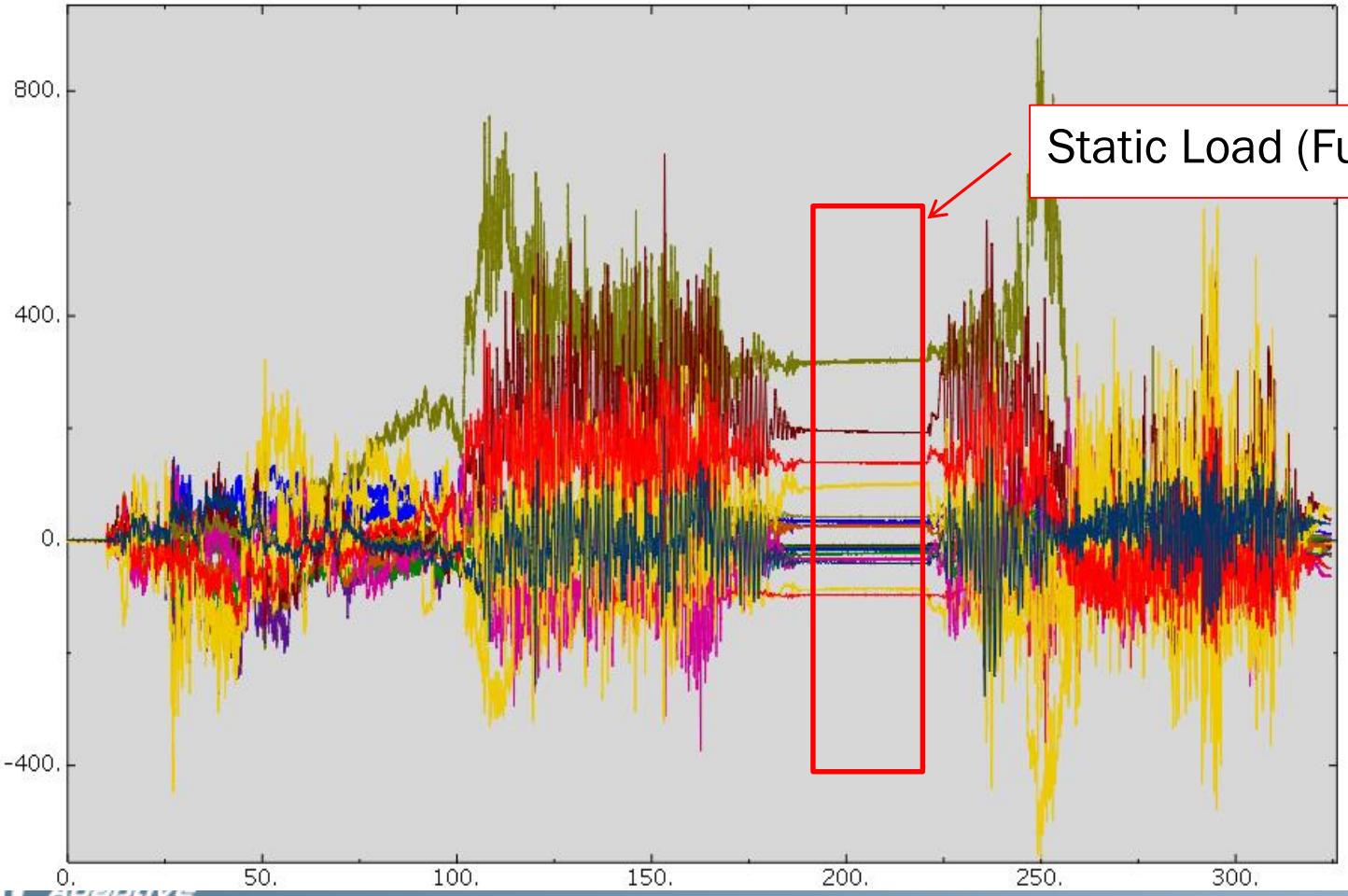
T-L Post-Test:

- Unit Loads of Fully loaded system vs Weight on Rear Axle of Fully loaded system

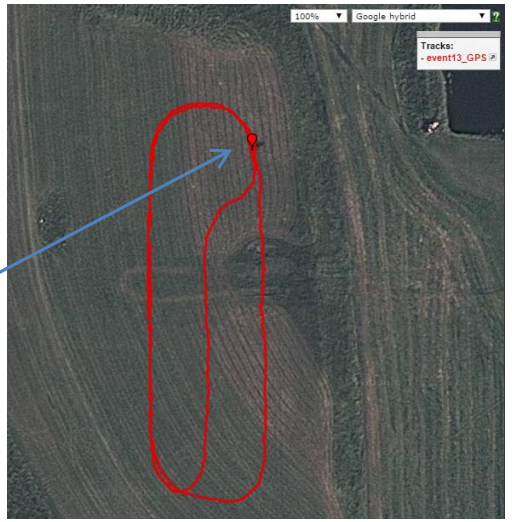
Loading from Strains
True-Load/Post-Test

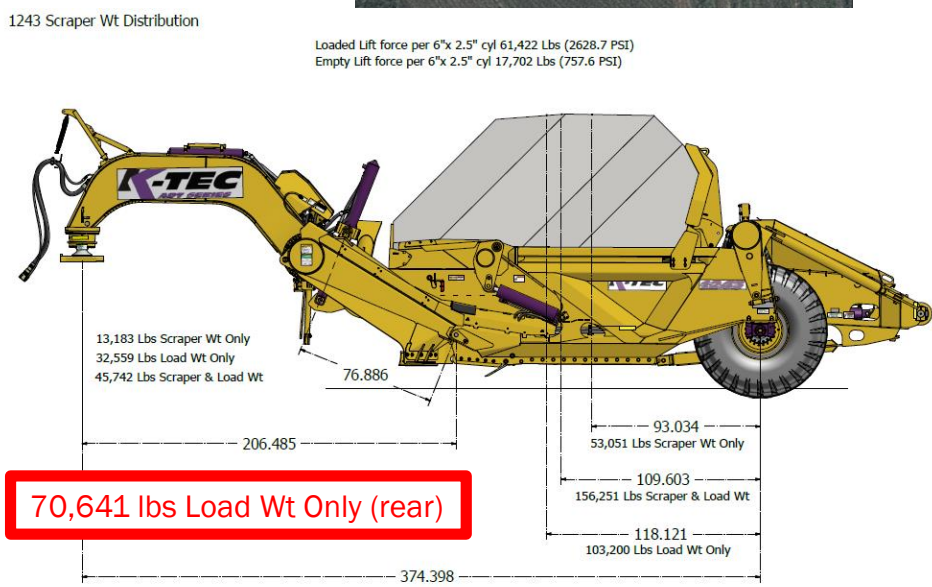
True-Load

Event 2 Push Load with D8 Full



Static Load (Full Pay Load)



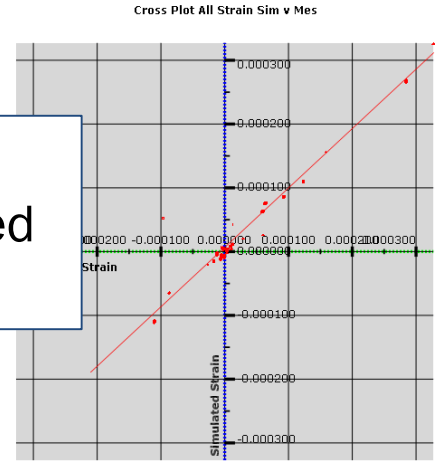


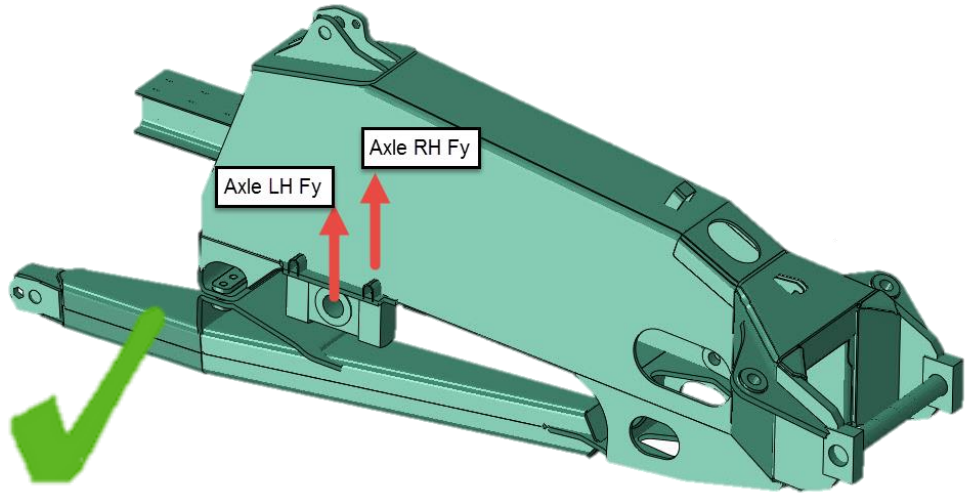
70,641 lbs Load Wt Only (rear)

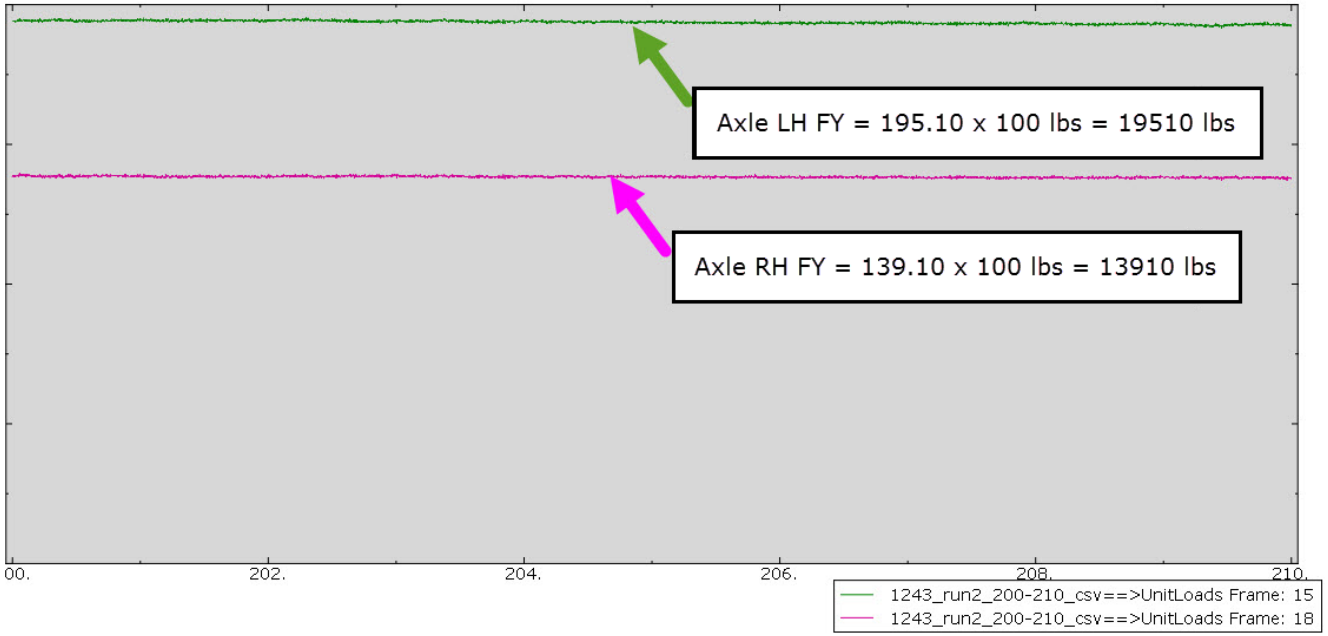
T-L Post-Test

Loading from Strains
True-Load/Post-Test

Strain Gage
Sim vs Measured
Cross-Plot







Total Vertical Load at Axle: 33420 lbs
(~5.3% from Estimate Pay Load value of 35321 lbs)

☆ This also demonstrates that the FEM Unit Load can simulate the Fully Loaded condition

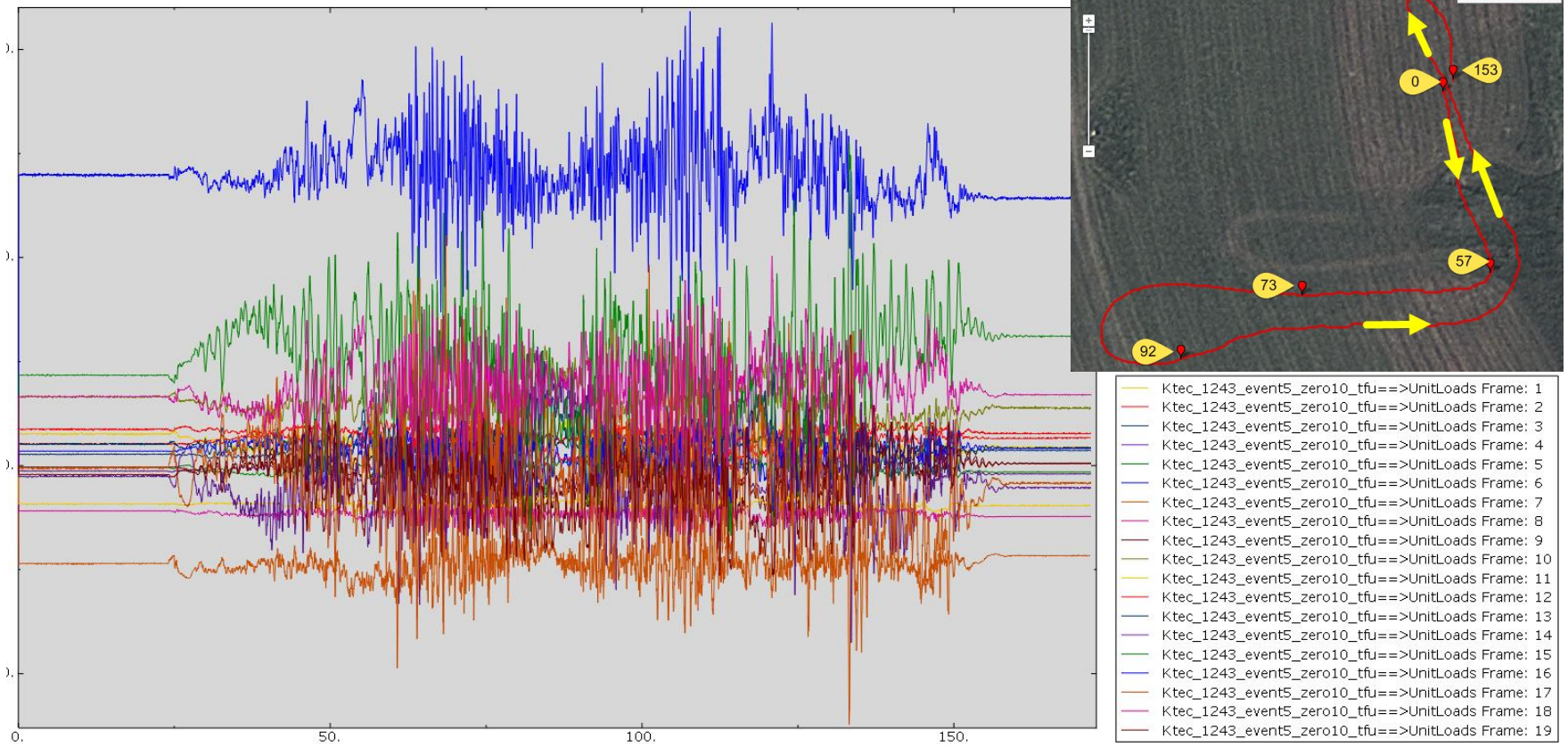
Loading from Strains
True-Load/Post-Test

T-L Post-Test
Load Time History: Event 5: Haul across woops straight

True-Load

K-Tec 1243 strain gauge testing events Sept. 9 '14

1. Self-load as much as possible
2. Push load with D8 full
3. Push load with D8 full around corner
4. Push load deep cut till full
5. Haul across woops straight
6. Haul across alternating woops
7. Haul high speed along dike loaded, record max speed
8. Haul high speed along road loaded, record max speed
9. Haul on rough road with scraper all up to cancel cushion ride.
10. Haul high speed along dike empty, record max speed
11. Haul high speed empty on rough haul road, record speed
12. Haul full load alongside of 4 – 1 slope
13. Haul full load down 4 – 1 slope then make right turn at bottom
14. Empty parked in straight line push on scraper block with D8
15. Empty parked in straight line pull on rear pin with D8
16. Loaded push at 45 deg. On roller push block from right with D8T max pressure (down & up)
17. Loaded push at 45 deg. On roller push block from left with D8T max pressure (down & up)
18. Lift back of scraper up off ground with dozer while loading.



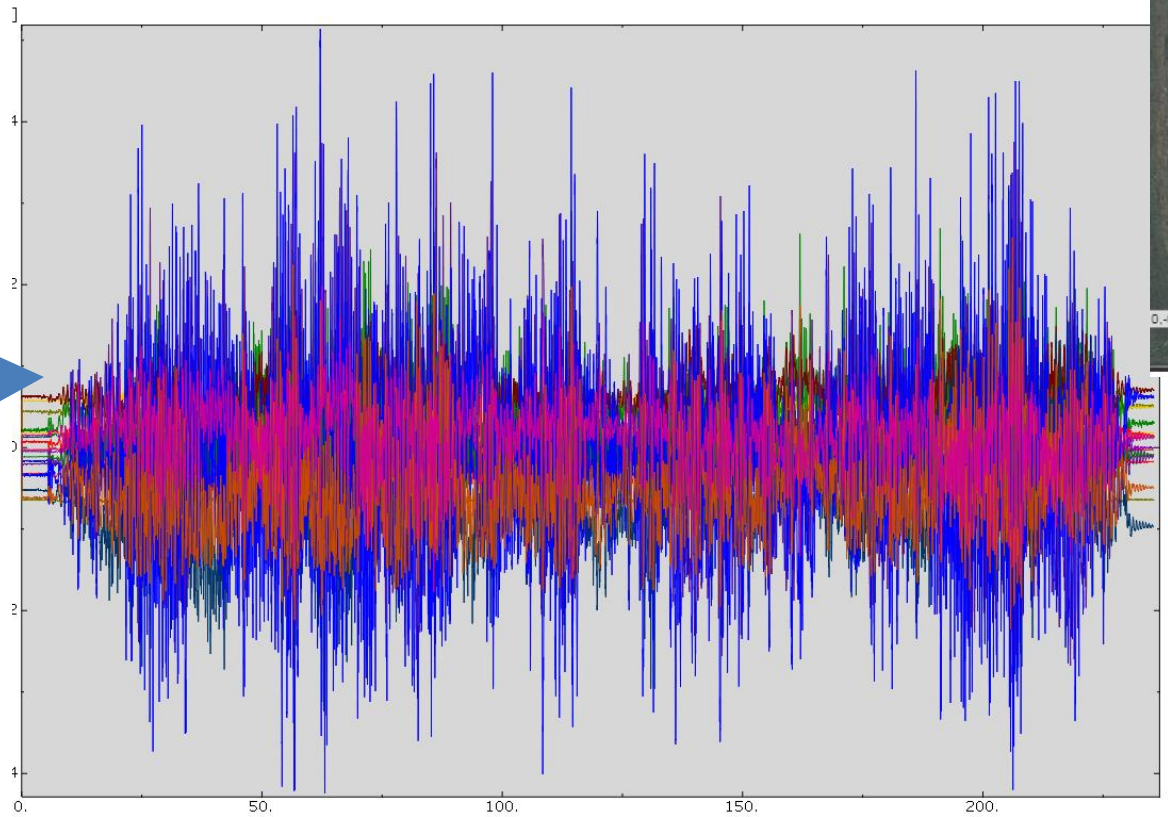
Loading from Strains
True-Load/Post-Test

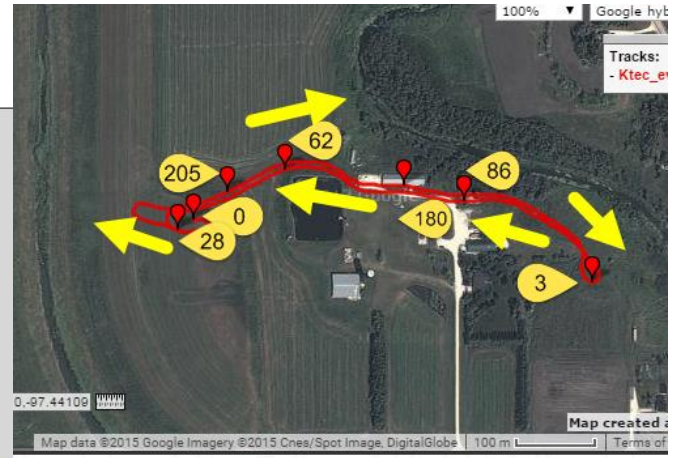
T-L Post-Test
Load Time History: Event 11: Haul High Speed Empty on Rough Haul Road

True-Load

K-Tec 1243 strain gauge testing events Sept. 9 '14

1. Self-load as much as possible
2. Push load with D8 full
3. Push load with D8 full around corner
4. Push load deep cut till full
5. Haul across woops straight
6. Haul across alternating woops
7. Haul high speed along dike loaded, record max speed
8. Haul high speed along road loaded, record max speed
9. Haul on rough road with scraper all up to cancel cushion ride.
10. Haul high speed along dike empty, record max speed
11. Haul high speed empty on rough haul road, record speed
12. Haul full load alongside of 4 – 1 slope
13. Haul full load down 4 – 1 slope then make right turn at bottom
14. Empty parked in straight line push on scraper block with D8
15. Empty parked in straight line pull on rear pin with D8
16. Loaded push at 45 deg. On roller push block from right with D8T max pressure (down & up)
17. Loaded push at 45 deg. On roller push block from left with D8T max pressure (down & up)
18. Lift back of scraper up off ground with dozer while loading.





Ktec_1243_event11r2_zero10_tfu==>UnitLoads Frame: 1
Ktec_1243_event11r2_zero10_tfu==>UnitLoads Frame: 2
Ktec_1243_event11r2_zero10_tfu==>UnitLoads Frame: 3
Ktec_1243_event11r2_zero10_tfu==>UnitLoads Frame: 4
Ktec_1243_event11r2_zero10_tfu==>UnitLoads Frame: 5
Ktec_1243_event11r2_zero10_tfu==>UnitLoads Frame: 6
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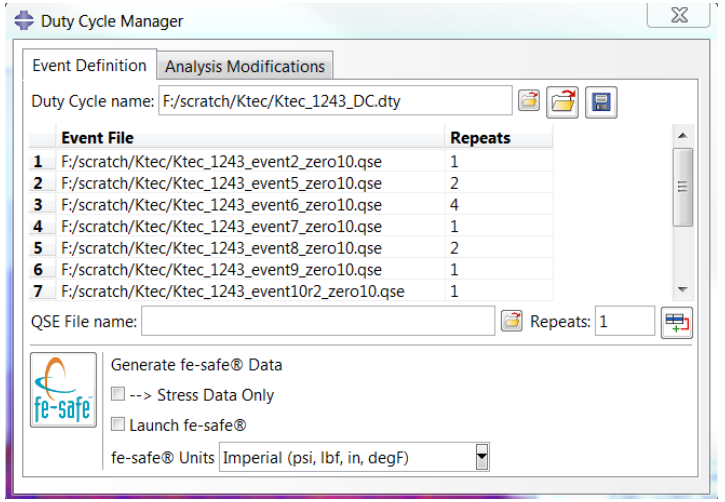
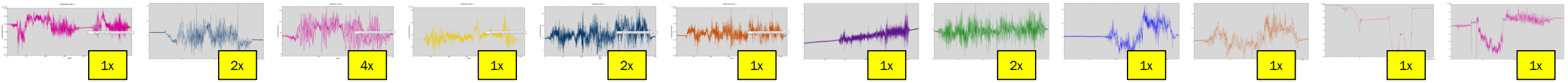
Duty Cycle Development



- Based on input from customer
- 1 duty cycle = 1.07 hours of operation
- Direct fe-safe interface

Event #	Event Name	#repeats	time min (absolute)
2	F	1.00	5.41
5	H	2.00	5.73
6	H	4.00	8.00
7	H	1.00	5.17
8	H	2.00	10.00
9	H c	1.00	5.27
10	H	1.00	9.17
11	H s	2.00	7.87
12	H	1.00	3.70
13	H t	1.00	2.09
16	L v	1.00	2.00
18	L loading	1.00	1.00
	Total		65.40

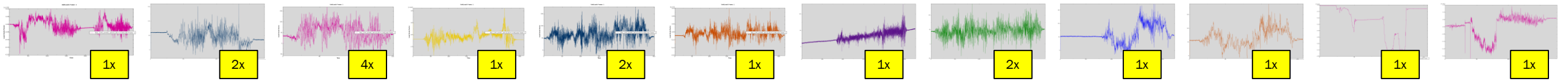


Fatigue Life Calculations

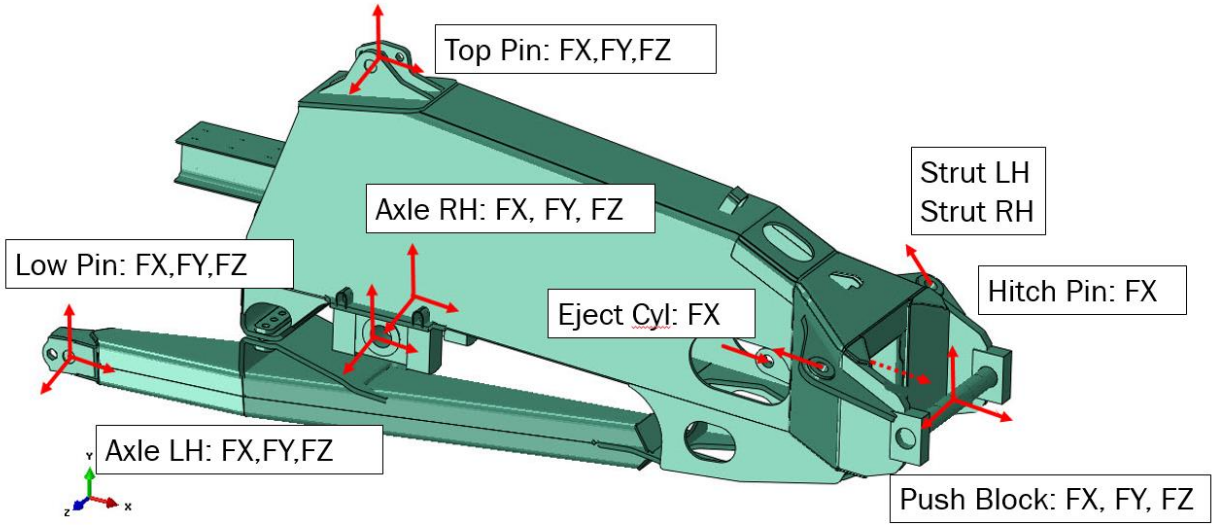
Datasets = Unit Load ABAQUS Results file (*.odb)

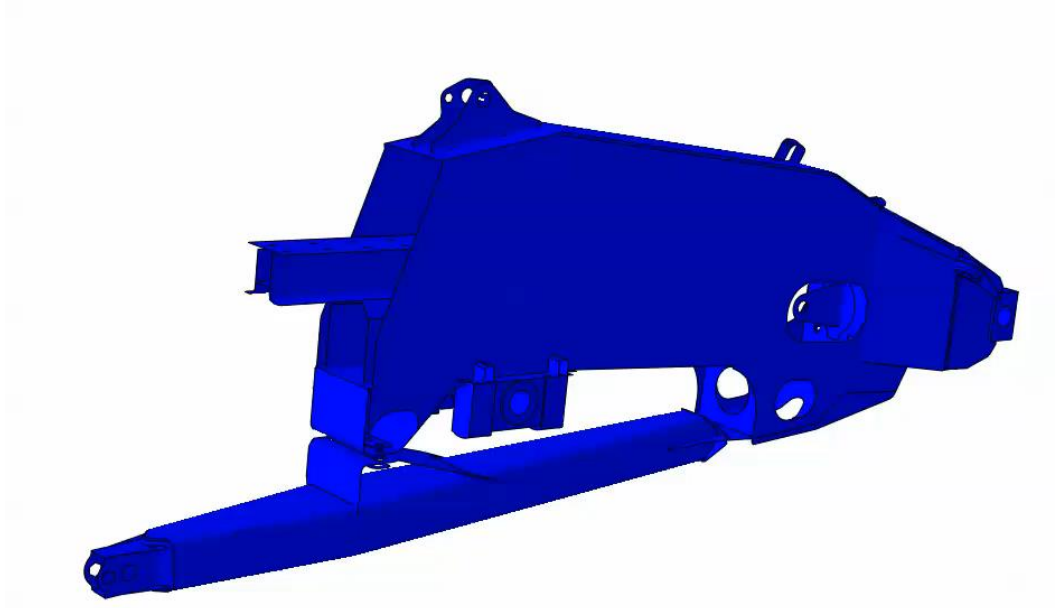
Fatigue Loading = Repeats of Events in Duty Cycle (*.ldf)

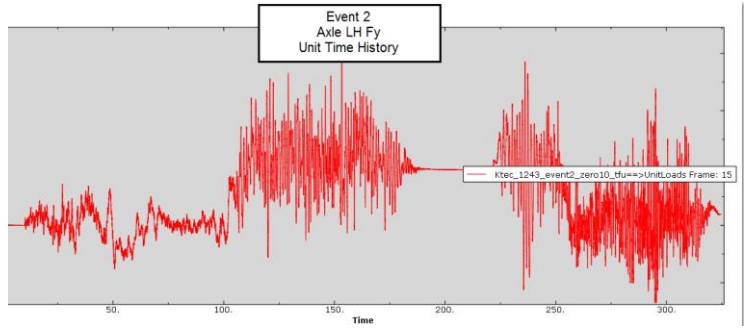
- 1 Elastic block per road event (there are 12)
- Duty Cycle:
  - Each elastic block/road event is repeated accordingly to create Duty Cycle
  - Each block includes datasets (unit loads) from 19 unit loads
  - Each block Datasets (unit loads*) are scaled according to T-L
    - *Unit Time Histories
  - Entire Duty Cycle= 1.1 hours of operation

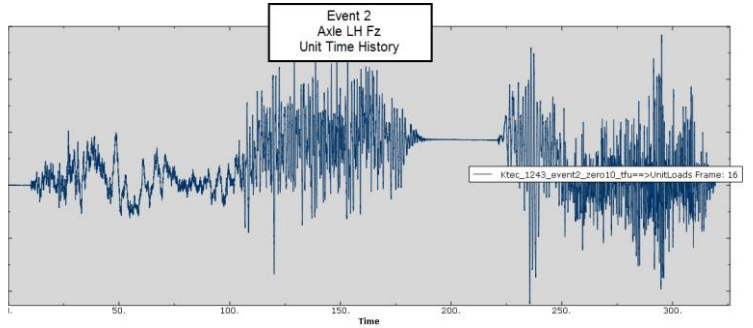


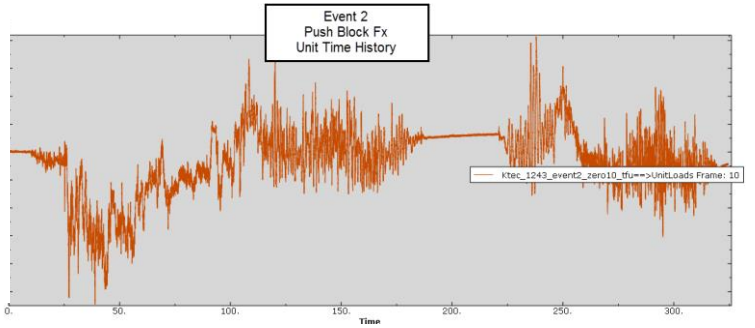
1	Strut_LH
2	Strut_RH
3	Top_Pin_FX
4	Top_Pin_FY
5	Top_Pin_FZ
6	Eject_Cyl_FX
7	Low_Pin_FX
8	Low_Pin_FY
9	Low_Pin_FZ
10	Push_Block_FX
11	Push_Block_FY
12	Push_Block_FZ
13	Hitch_Pin_FX
14	Axle_LH_FX
15	Axle_LH_FY
16	Axle_LH_FZ
17	Axle_RH_FX
18	Axle_RH_FY
19	Axle_RH_FZ









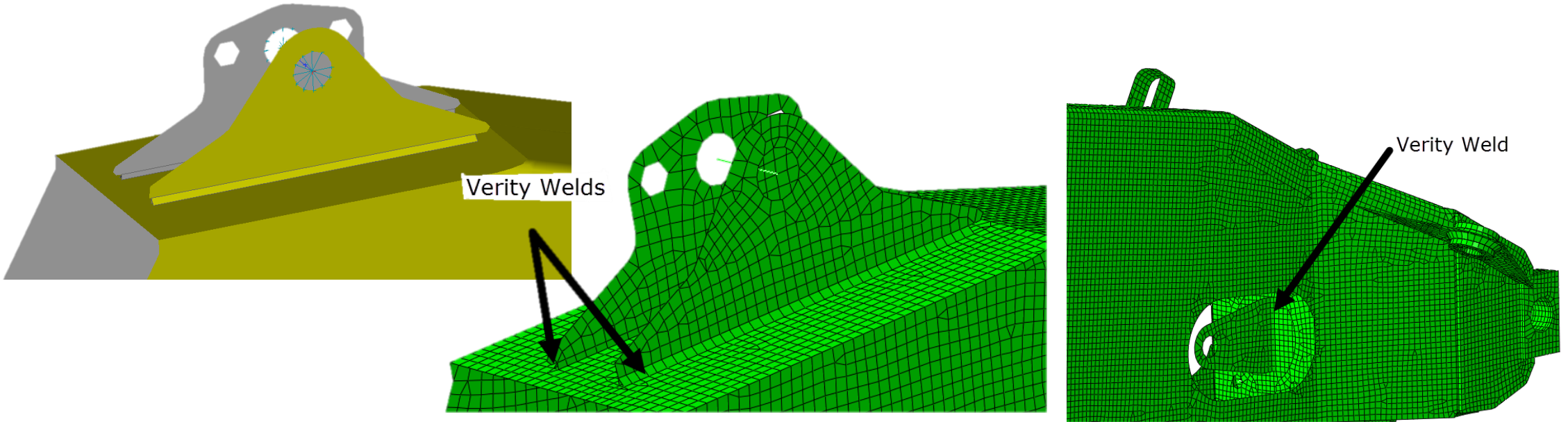


Step: Derived Step, F:/scratch/Ktec/Ktec_1243_event2_zero10.qse
Time 0.0
Primary Var: S, Mises
Deformed Var: U Deformation Scale Factor: +2.000e+01

Fatigue Life Calculations

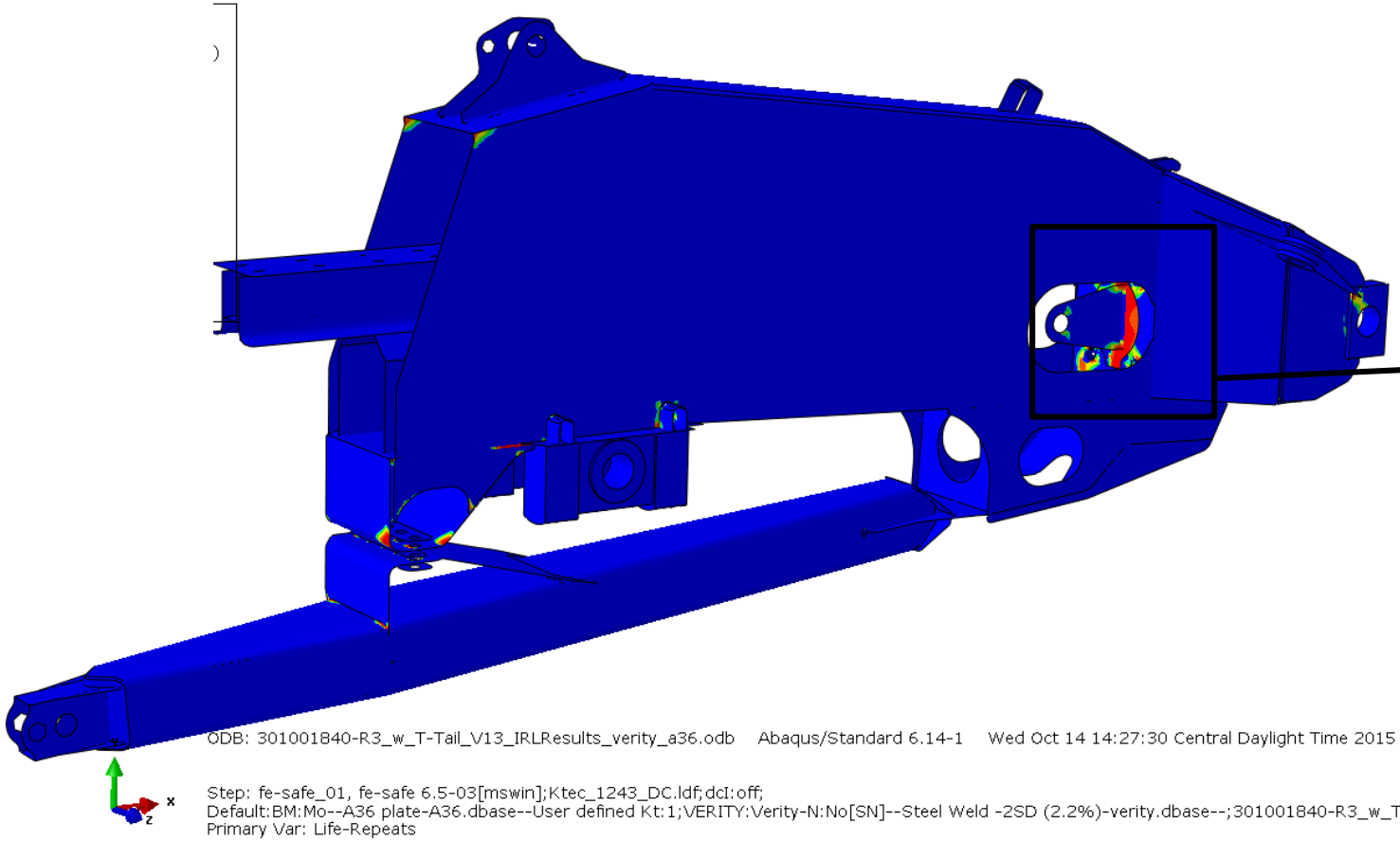
Verity and A36 Parent Material

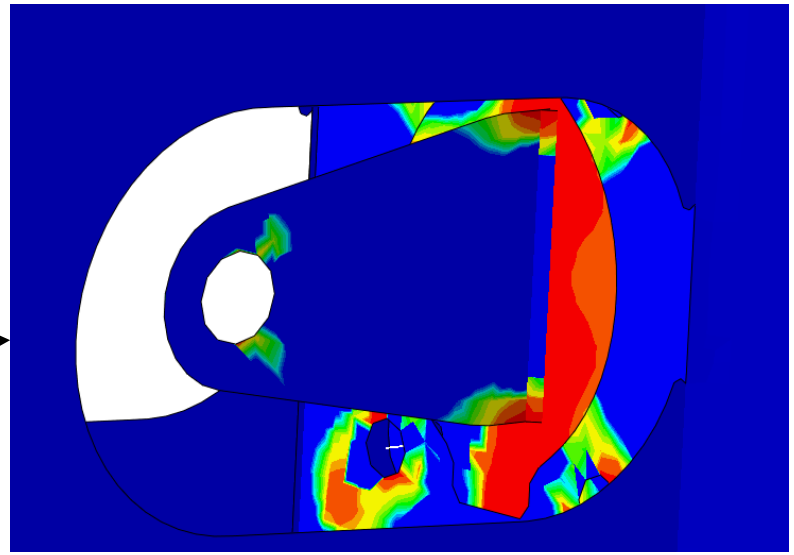
- Weld geometry was defined in FEM at critical locations
- Verity welds defined within fe-safe for fatigue calculations



- Remaining structure defined with A36 fatigue properties

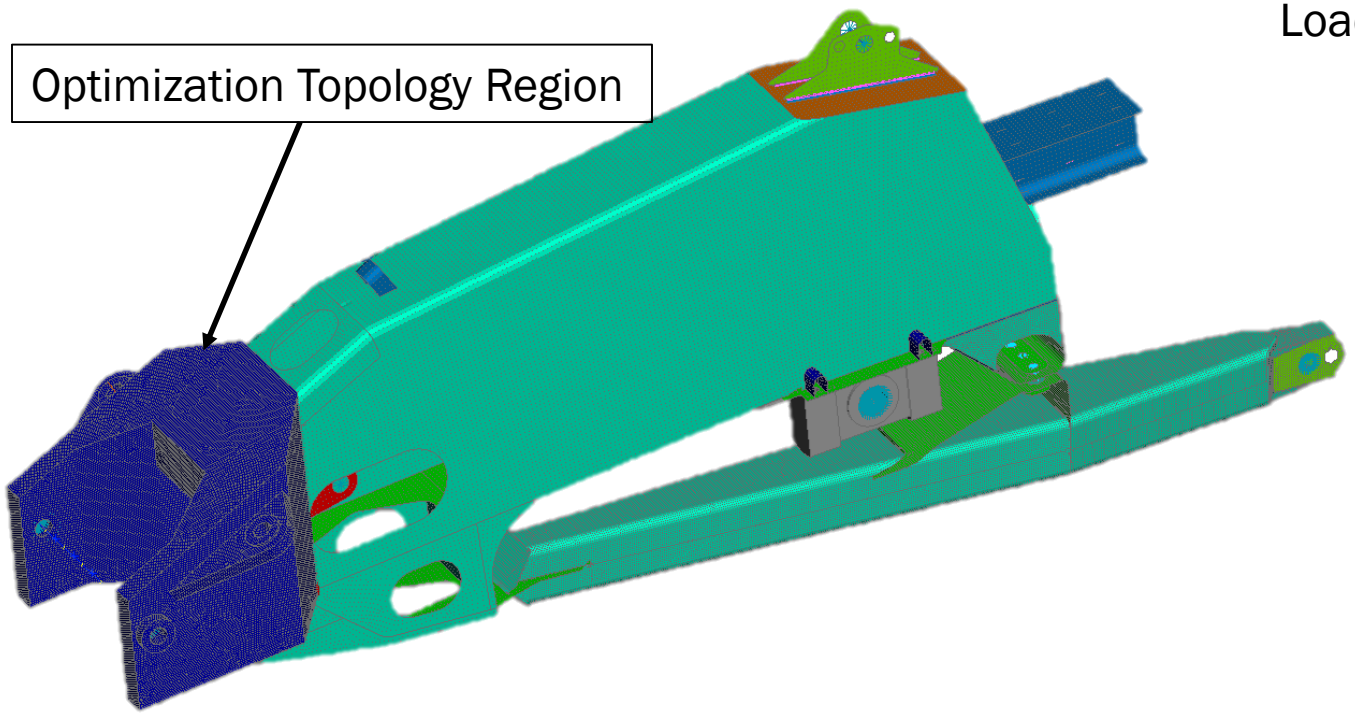
Fatigue Life Calculations





Identify Low Life Welds

Next Step...Optimization



Load Cases:

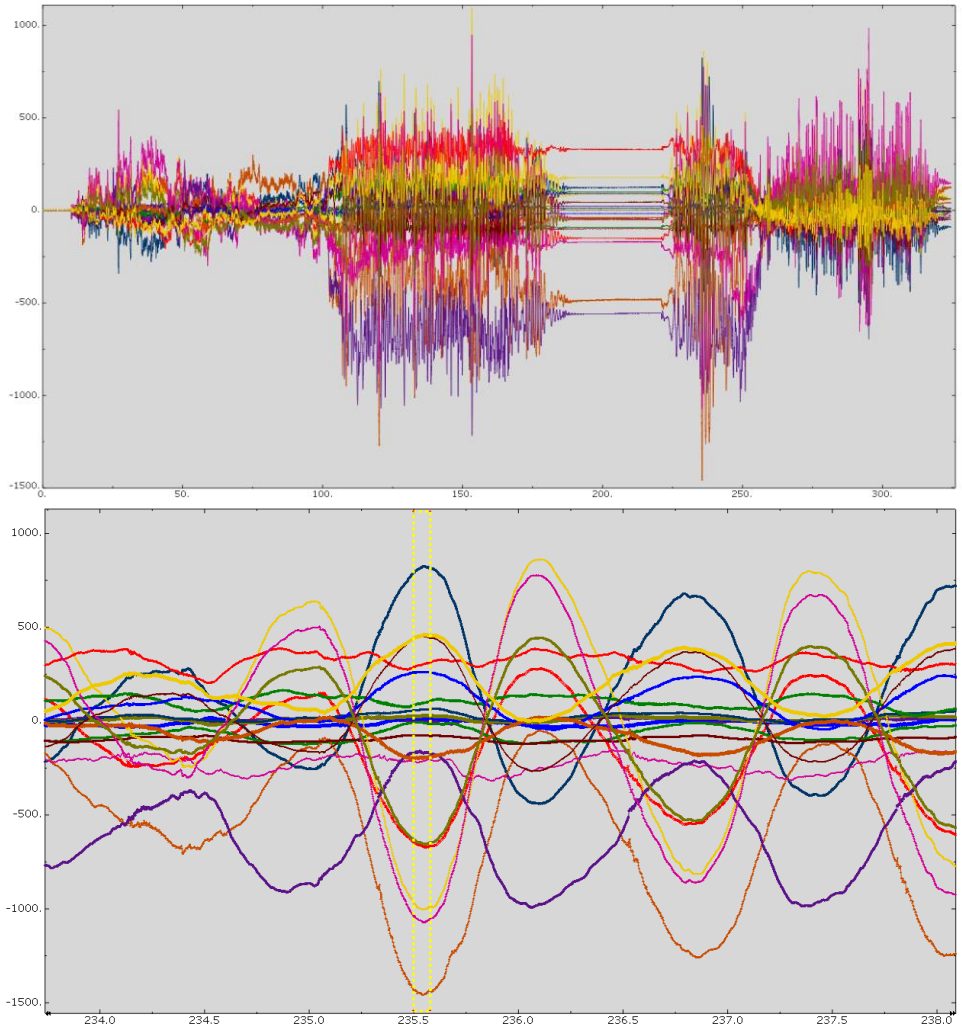
- Highest strain amplitudes in rear of structure
- Unit loads (static points) – snapshots in time history

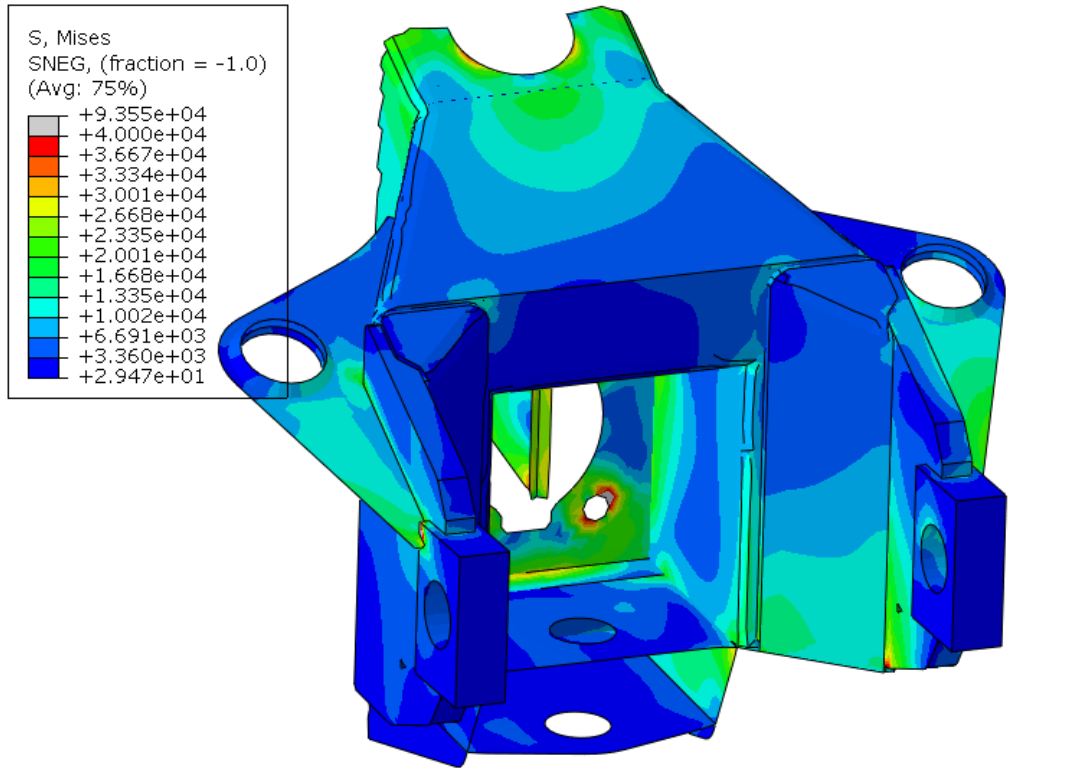
Event #	Event Name	static time
2	Push load with D8 full	108.38
5	Haul across woops straight	114.20
6	Haul across alternating woops	82.78
8	Haul high speed along road loaded, record max speed	141.78
9	Haul on rough road with scraper all up to cancel cushion ride	166.43
12	Haul full load alongside of 4-1 slope	134.878
13	Haul full load alongside of 4-1 slope then make right turn at bottom	36.234
16	Load push at 45 deg. On roller push block from right with D8T max pressure	97.002
18	Lift back of scraper up off ground with dozer while loading	142.58
	Total	

Optimization Loads

Event 2: Push Load with D8 Full, t=235.52s

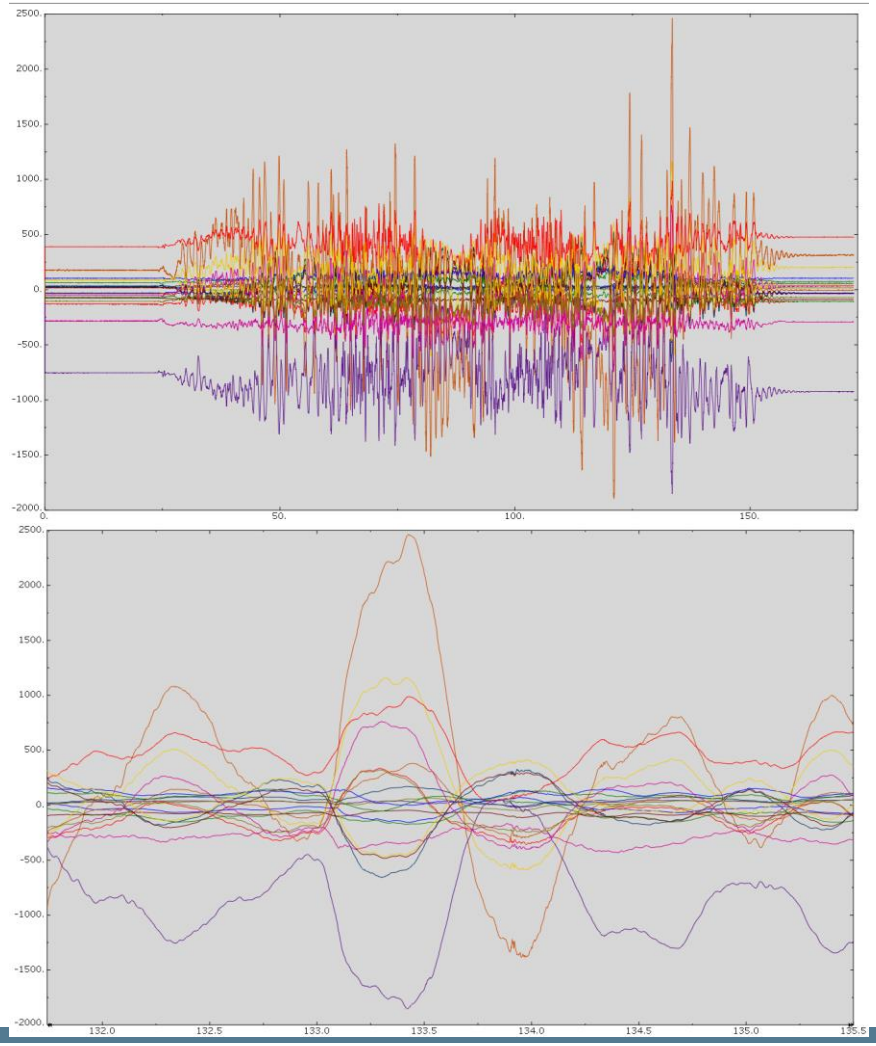
Load x 100 (lbs)

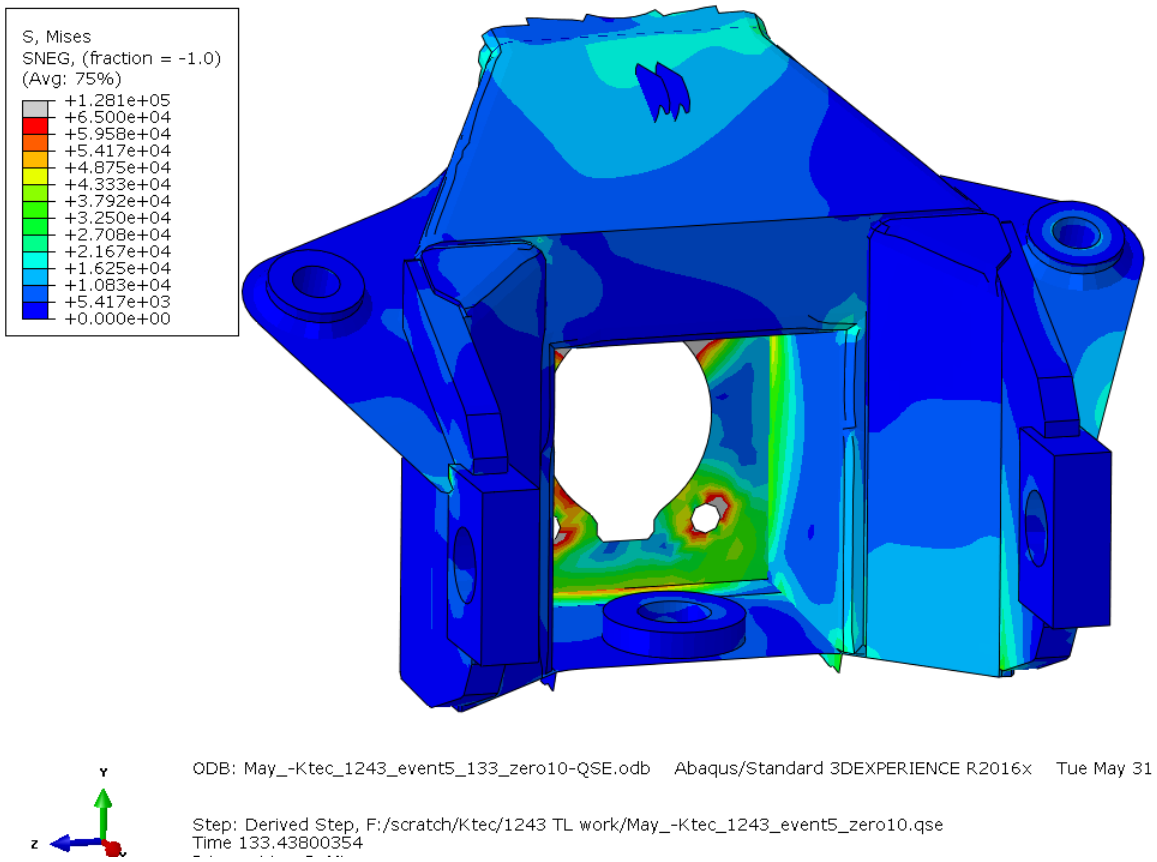




Optimization Loads

Event 5: Haul Across Woops Straight, t=133.438s

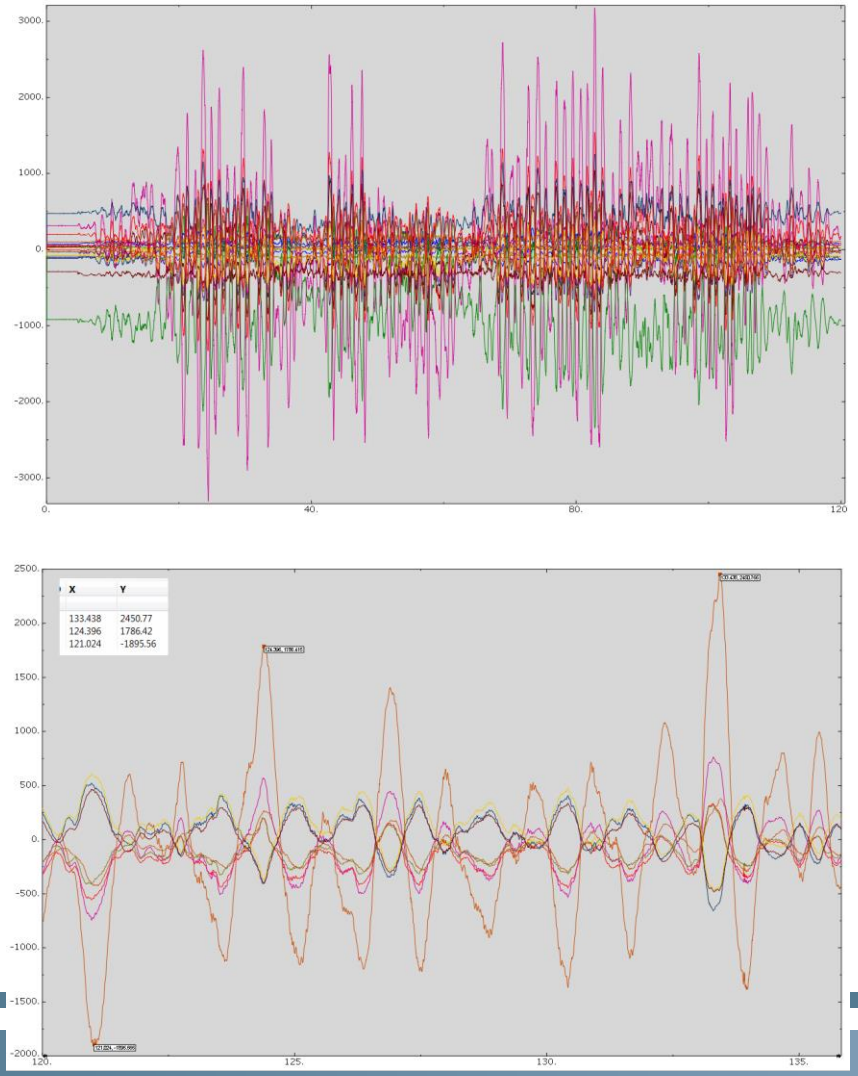


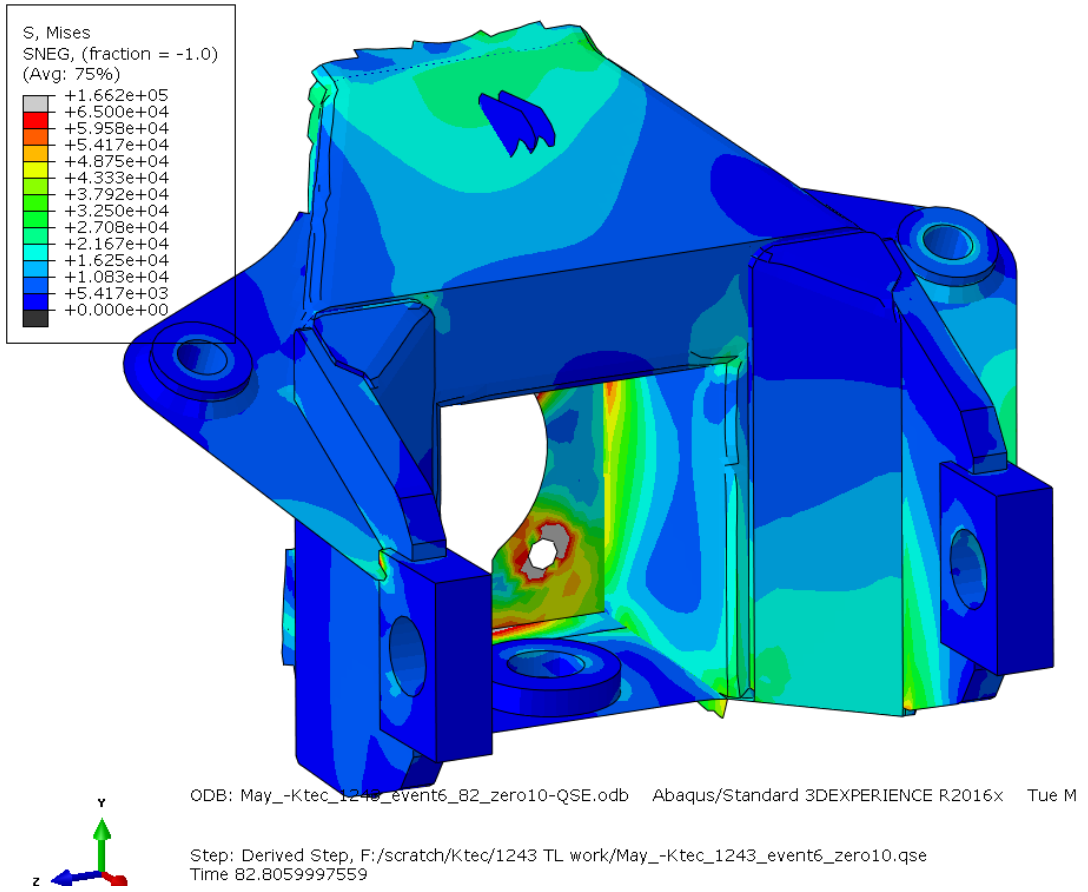


Optimization Loads

Event 6: Haul Across Alternating Woops, t=82.794

Load x 100 (lbs)

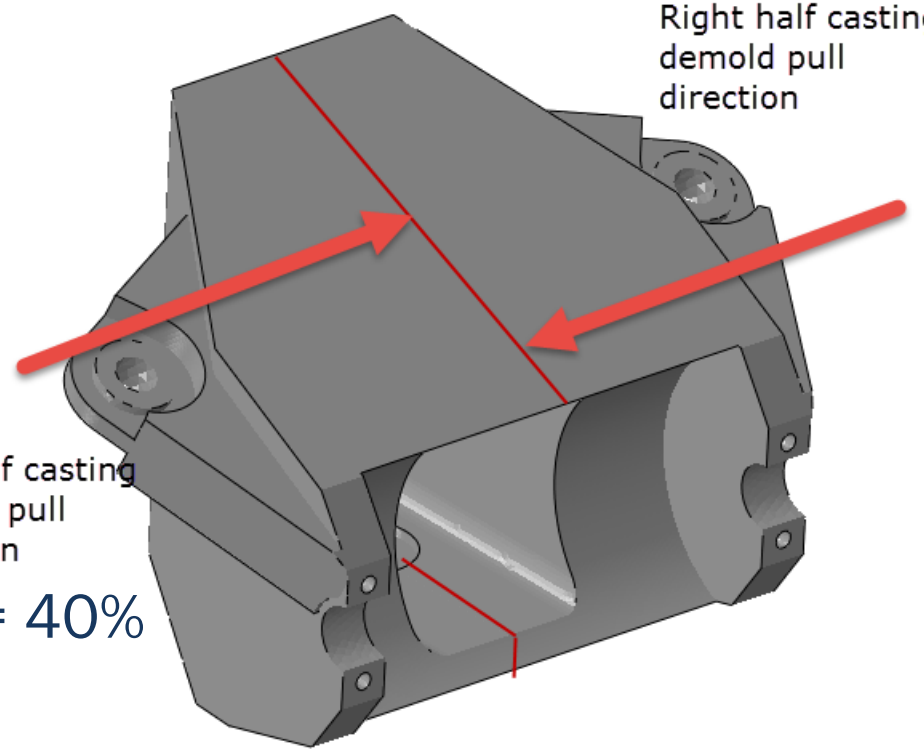




Adaptive Corporation

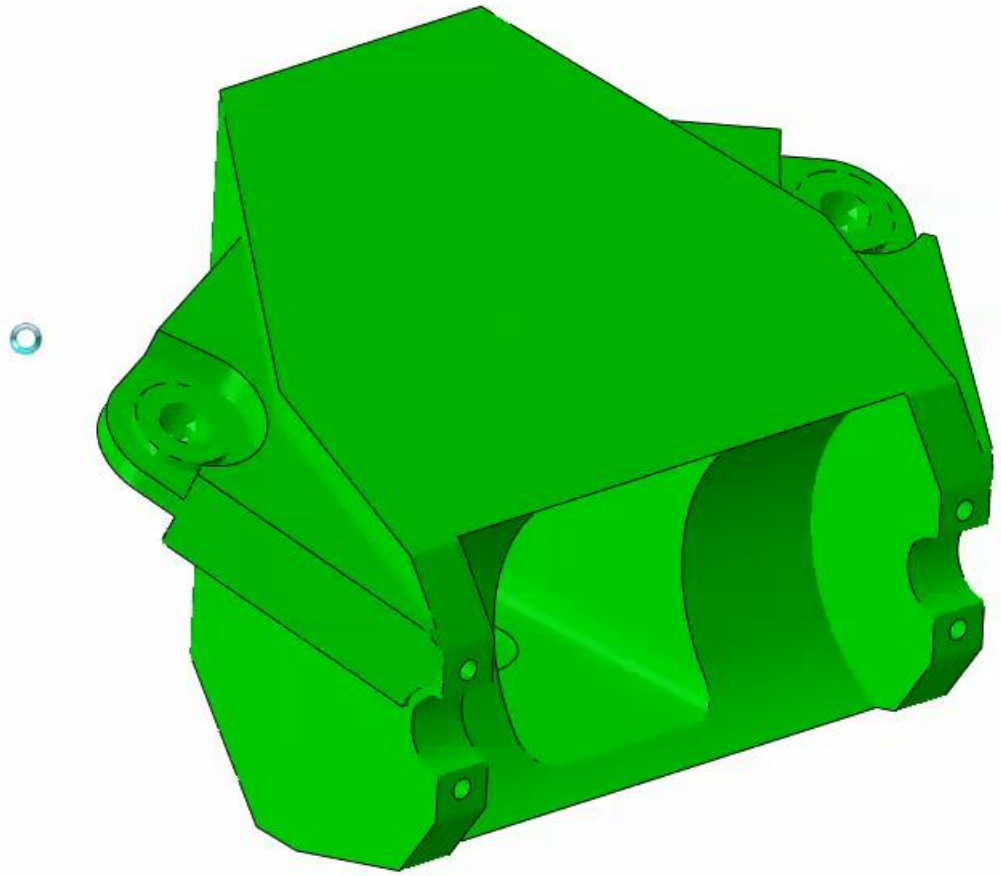
K-TEC EARTHMOVERS INC.

Optimization Criteria

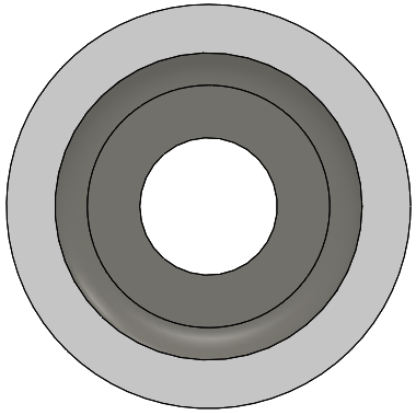


- Design Envelope created
  - Interface to applied load must remain
  - Interface to rest of Tail structure must remain
- Objective – maximize stiffness
- Constraints – design region volume remaining <= 40%
- Geometry conditions
  - left/right planar symmetry
  - 2 halves with casting pull direction pull away from middle (prevent vertical wall in middle of structure)

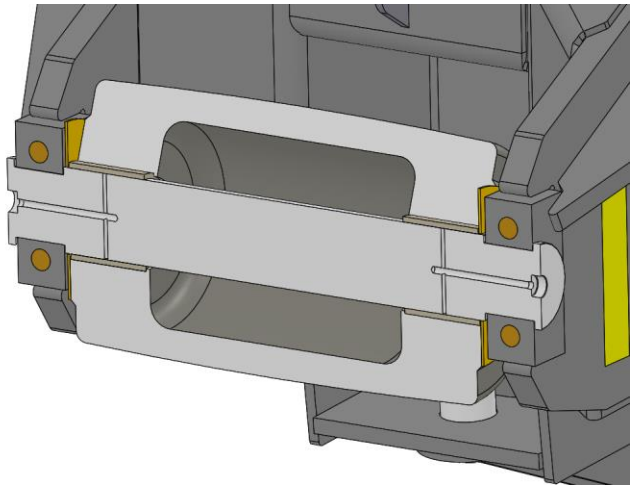
Optimization Results

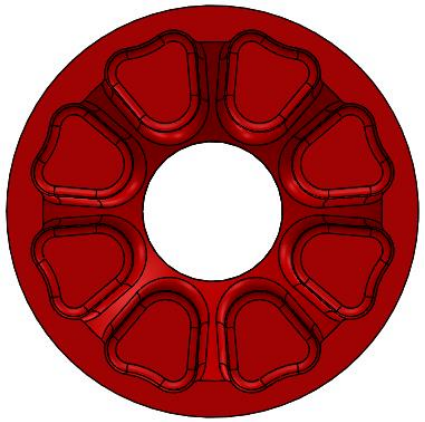


Roller Optimization

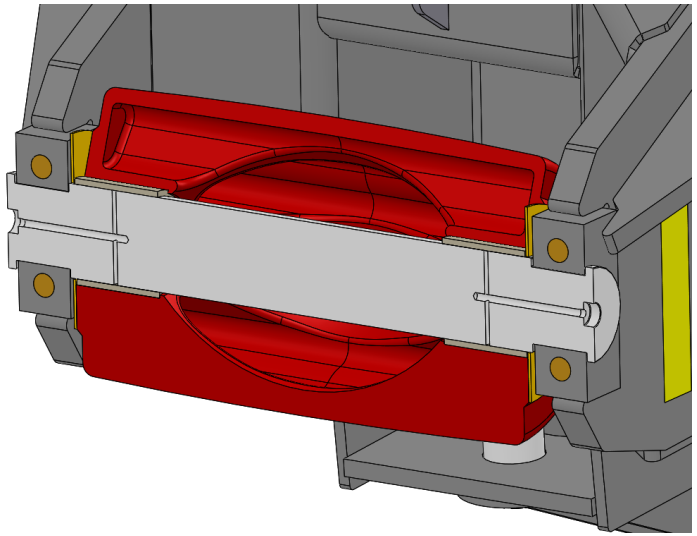


CAD weight: 428 lbs

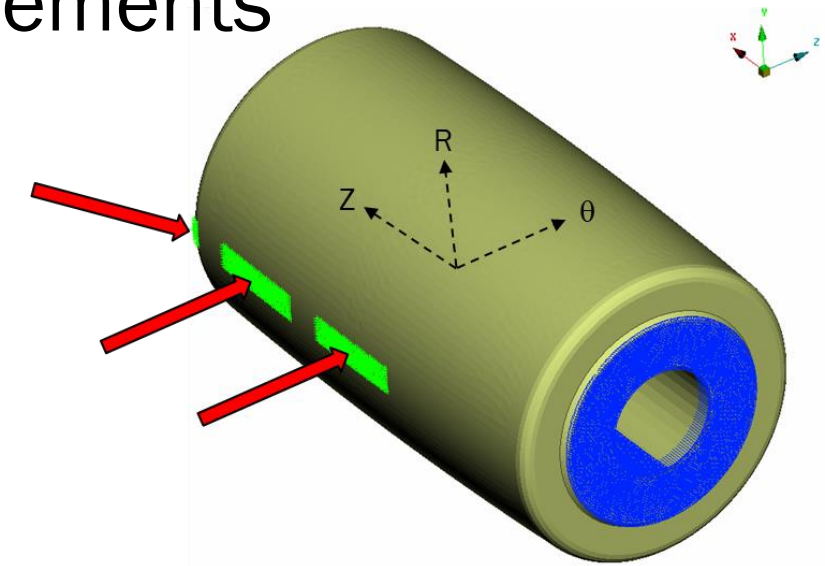




CAD weight: 272 lbs



- 36% Weight Reduction in rear roller
- Confidence in optimization due to accurate load measurements



Questions?