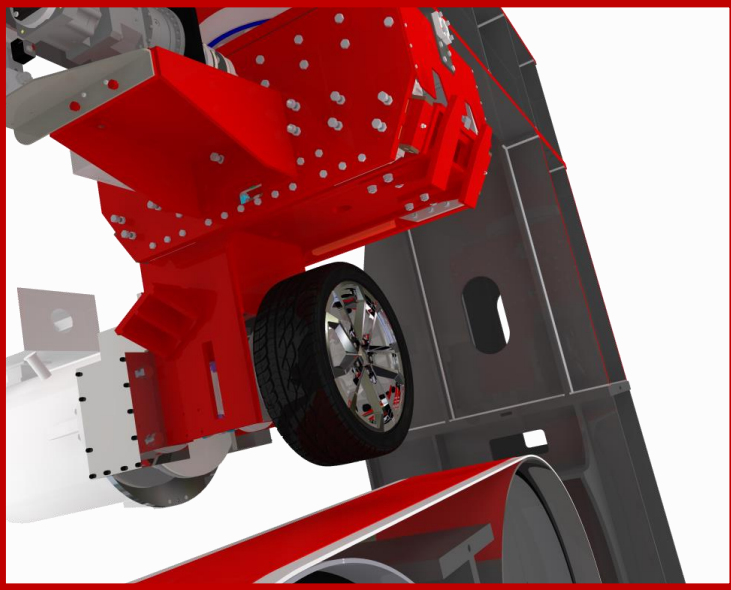




CALSPAN TIRE TESTING



CALSPAN – 70 YEAR HISTORY

1943

Curtiss-Wright
Aircraft Division
Research
Laboratory



Construction of one of the
nation's largest transonic
wind tunnels begins



1946



Cornell
Aeronautical
Laboratory

Operated as C.A.L.
for 26 years

1973

Calspan **TIRF**
opens for
business



The world's first flat-track
tire testing machine

1977

VERIDIAN

Merged with
Veda to form
Veridian



Calspan produces a
research safety vehicle
that incorporates
advanced safety
system concepts.

2003

Acquired by
**General
Dynamics**

GENERAL DYNAMICS
Advanced Information Systems

2005

Calspan
Corporation
privately held



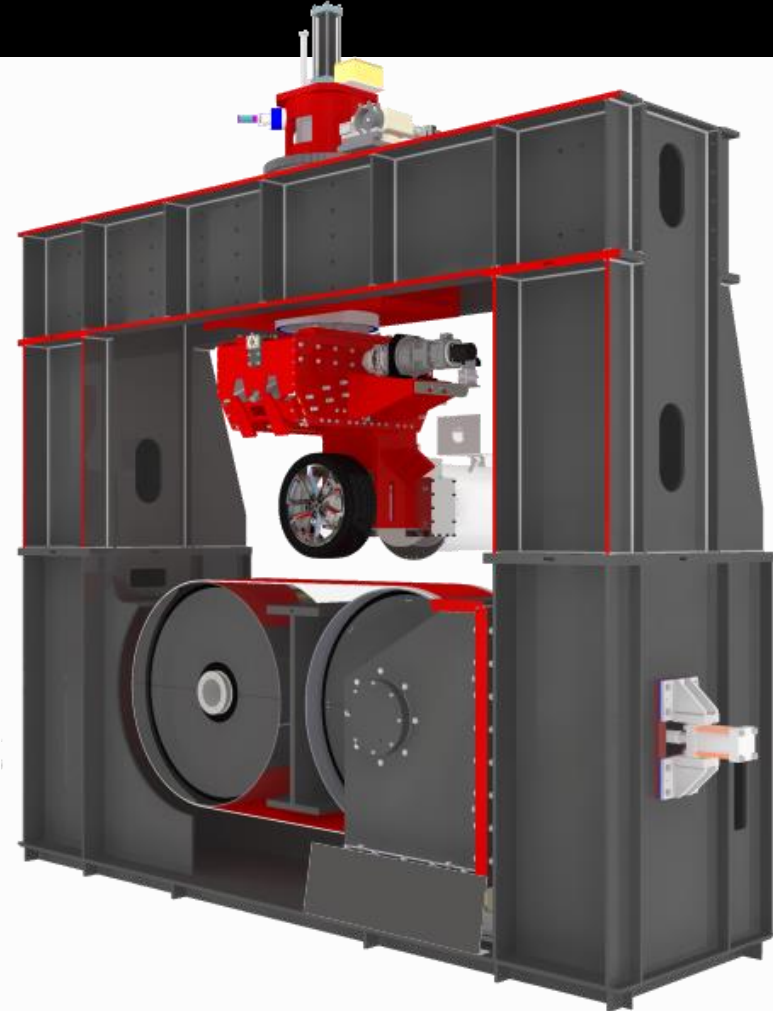
Learjet In-Flight
Simulator is used to
develop automatic
aerial refueling for the
U.S. Air Force.

CALSPAN TIRE TESTING

- MOST POWERFUL TIRE TESTING MACHINE IN THE WORLD
- MOST EXPERIENCED TECHNICAL STAFF IN THE WORLD
- EXCEPTIONAL TESTING CAPABILITIES
- PROVEN MEASUREMENT REPEATABILITY AND ACCURACY
- INDEPENDENT ORGANIZATION
- CUSTOMER CONFIDENTIALITY

→ ATTRACTS TOP-TIER AUTOMOTIVE COMPANIES

→ MEASURE AND UNDERSTAND



MEASURE AND UNDERSTAND

SIMULATION

PERFORMANCE

DURABILITY

BENCHMARKING

CALSPAN
TIRE TESTING

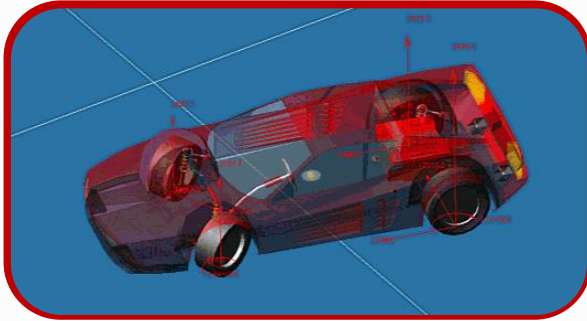
QUALITY

THERMAL

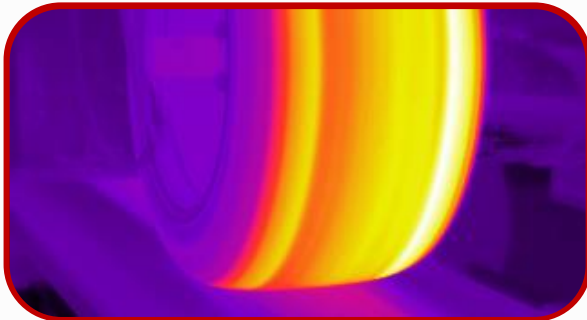
CONSTRUCTION

MATERIALS

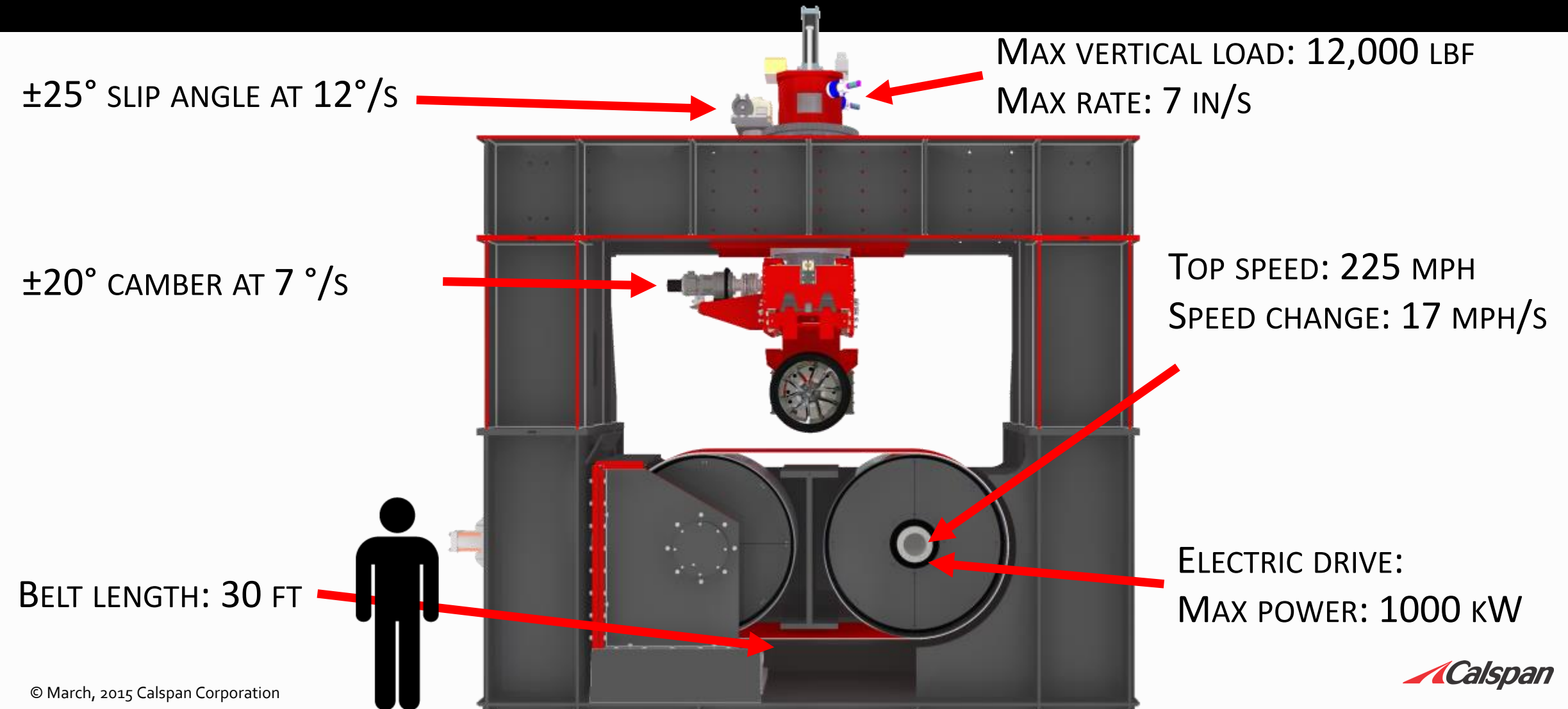
MEASURE AND UNDERSTAND



CALSPAN TIRE TESTING



CALSPAN TIRE TESTING - MECHANICAL

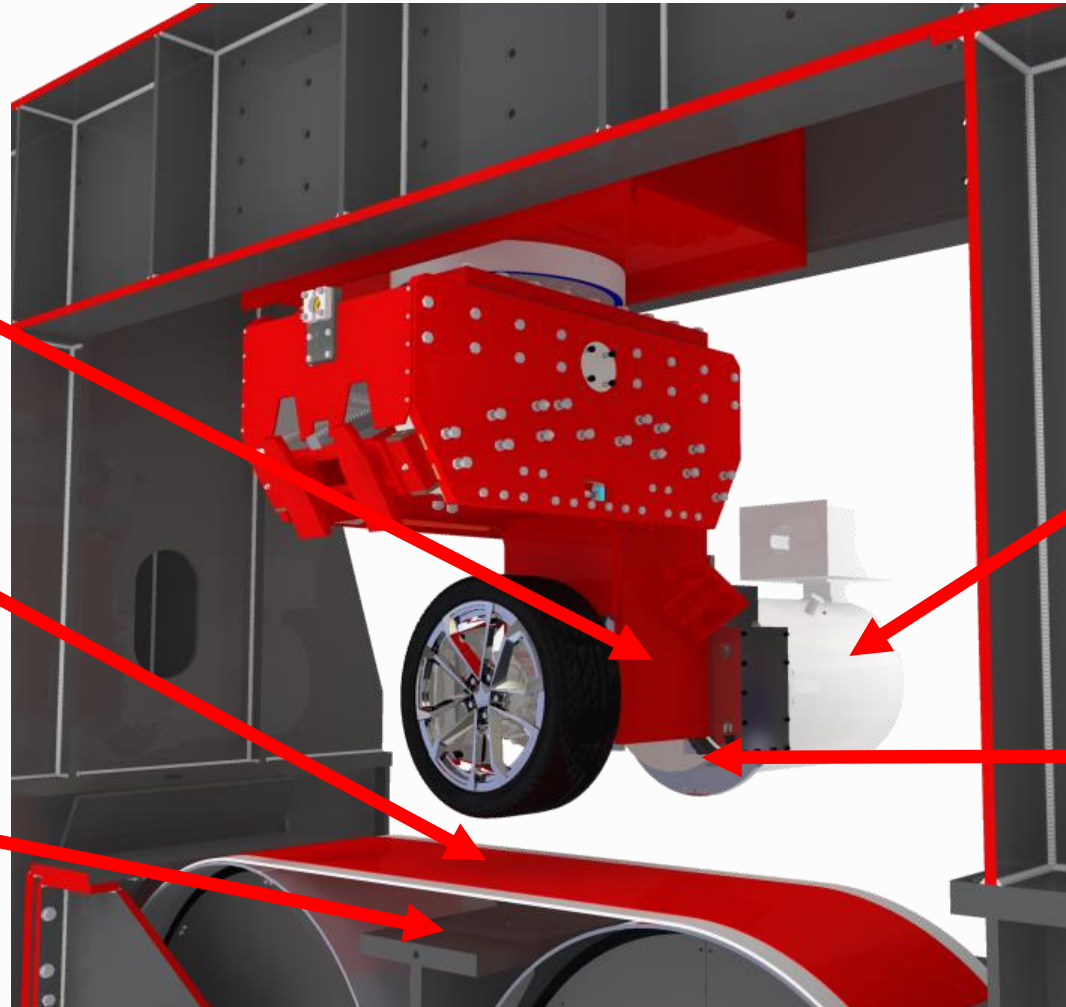


CALSPAN TIRE TESTING – MECHANICAL

BESPOKE BALANCES FOR
F&M MEASUREMENTS.

MAX Fx: 9,000 LBF
MAX Fy: 9,000 LBF

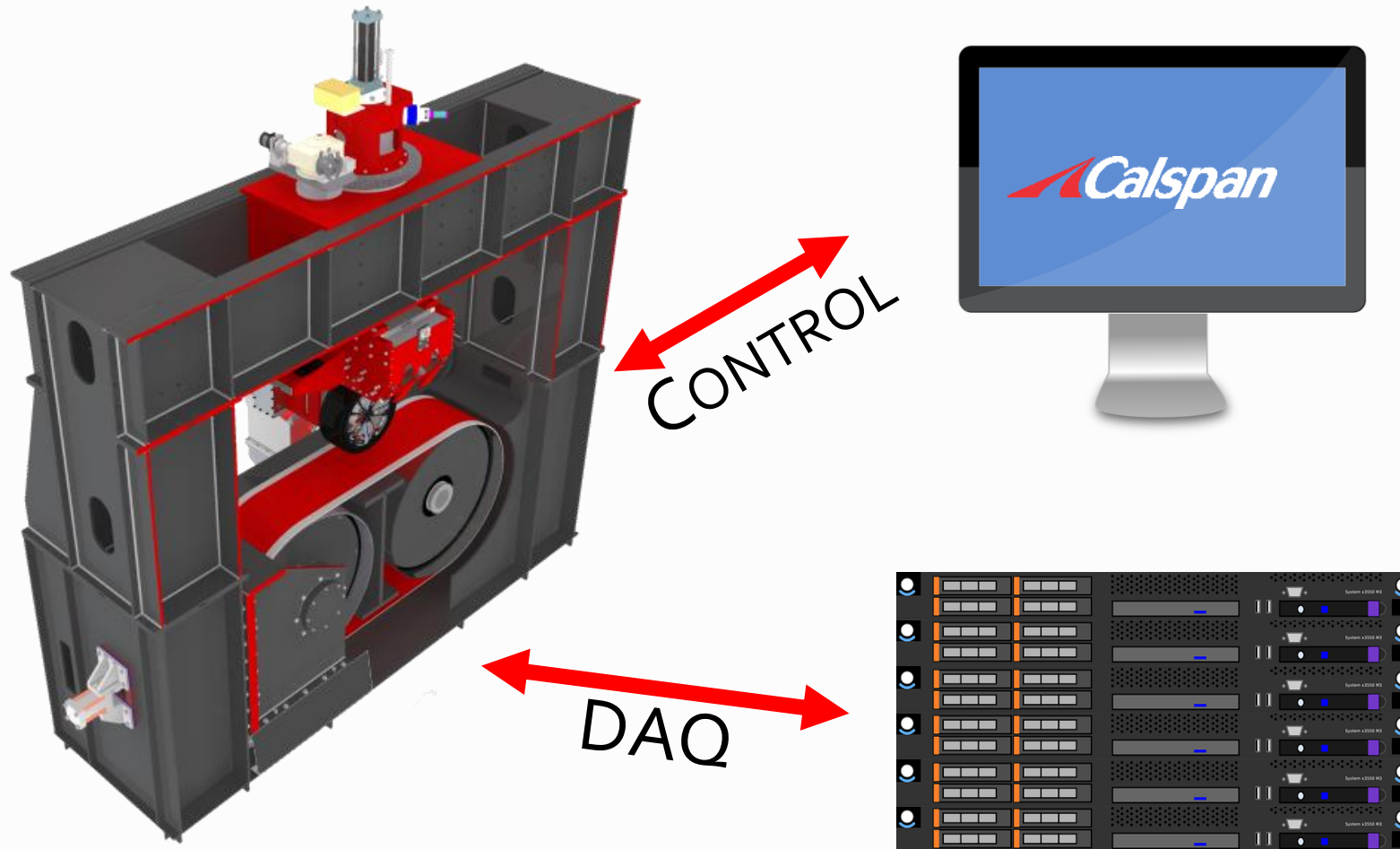
BESPOKE AIR
BEARING DESIGN



ELECTRIC DRIVE:
MAX POWER: 750 kW
MAX TORQUE: 8,000 FT-LB

DISK BRAKE:
MAX TORQUE: 14,000 FT-LB
TORQUE RATE: 15,000 FT-LB/s

CALSPAN TIRE TESTING – ELECTRICAL



- COMPLETE SOURCE CODE
- COMPLETE CONTROL
- SAMPLING UP TO 2 KHZ
- EXTENDABLE
 - ADDITIONAL SENSORS
 - ADDITIONAL DAQs

WHY CALSPAN TIRE TESTING



- MORE QUALITY DATA PER UNIT TIME
- HIGHER DATA RESOLUTION (NONLINEARITIES)
- TIRE DATA REDUCES DESIGN/SETUP ITERATIONS NEEDED
- TESTING PROCEDURES CAN BE DESIGNED TO MIMIC REALITY
- SEVERE TEST CASES CAN SAFELY BE EVALUATED

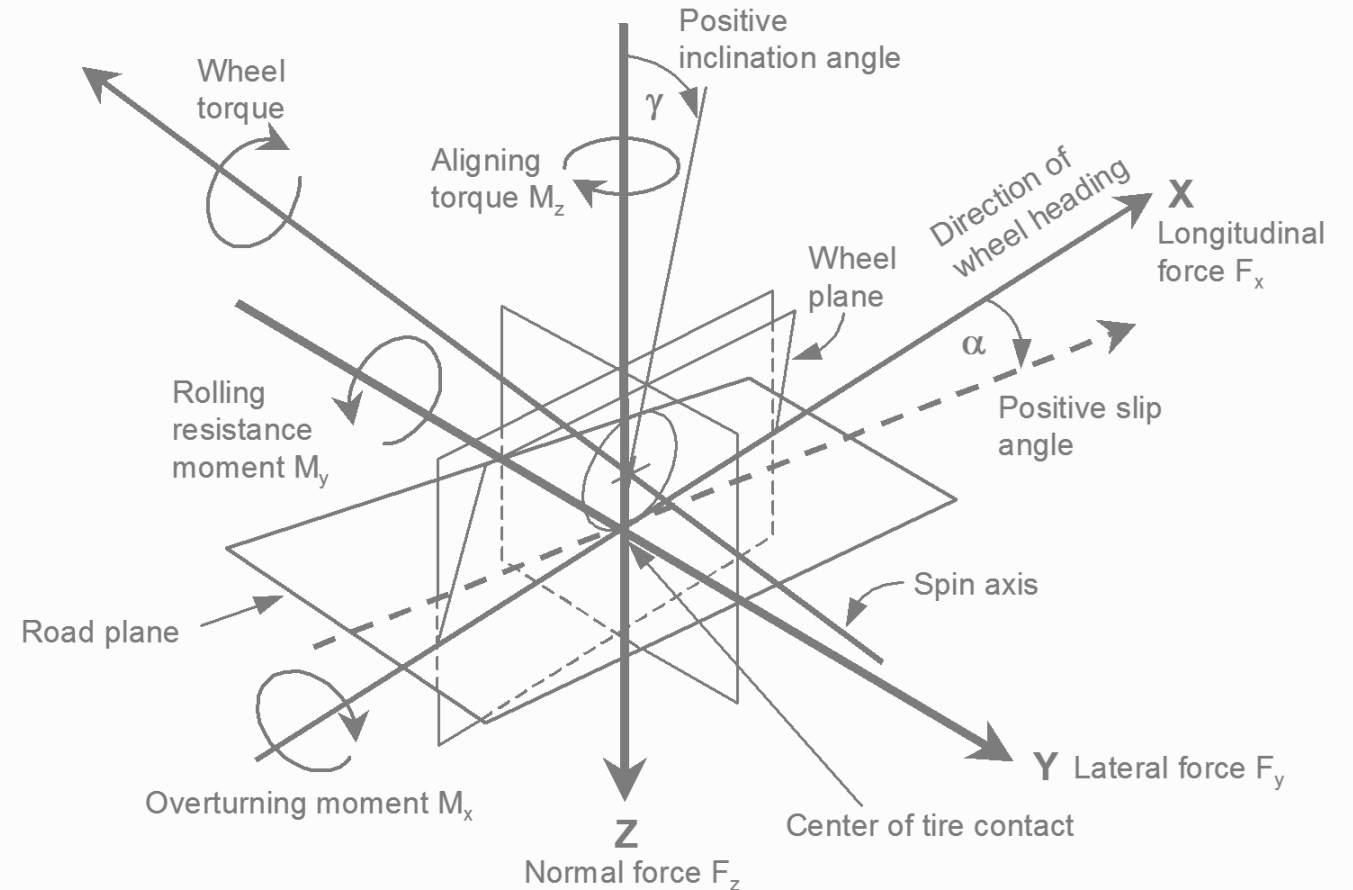
WHY CALSPAN TIRE TESTING?

- AVAILABLE 12 MONTHS PER YEAR
- CONTROLLED ENVIRONMENTAL CONDITIONS
- EXTREMELY REPEATABLE (0.5% CORNERING STIFFNESS CHANGE OVER 3 YEARS)
- MACHINE CAPABILITIES OFTEN EXCEED TEST REQUIREMENTS
→ HIGHER QUALITY AND MORE REPEATABLE DATA
- HIGH LEVEL OF CORRELATION TO CUSTOMERS' FIELD TESTS



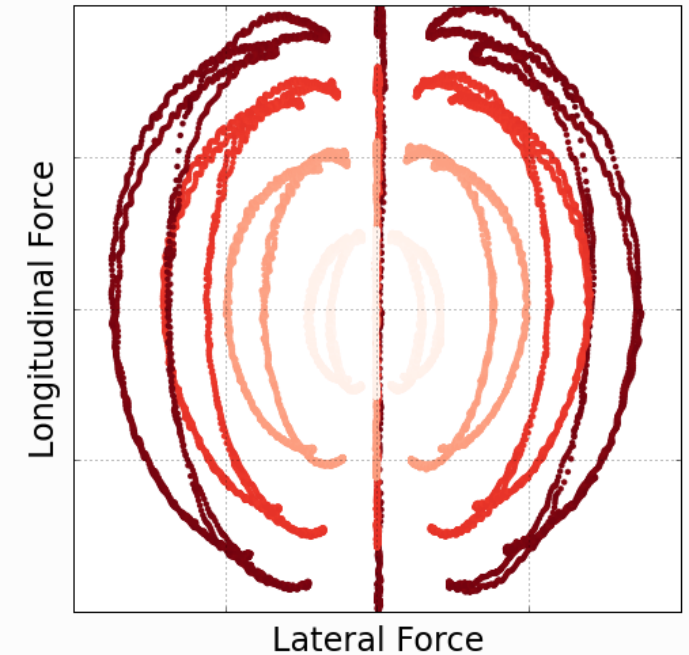
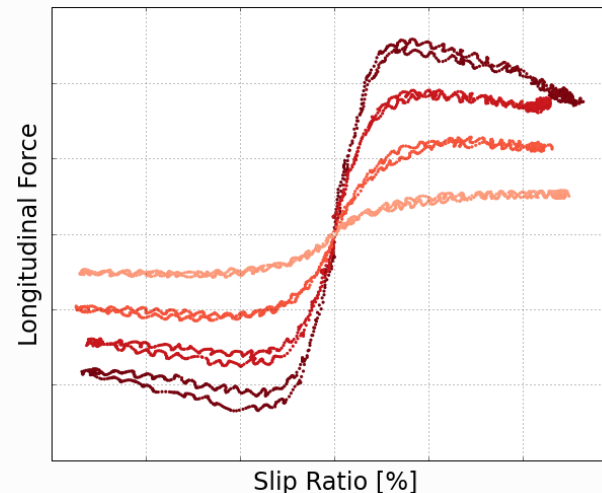
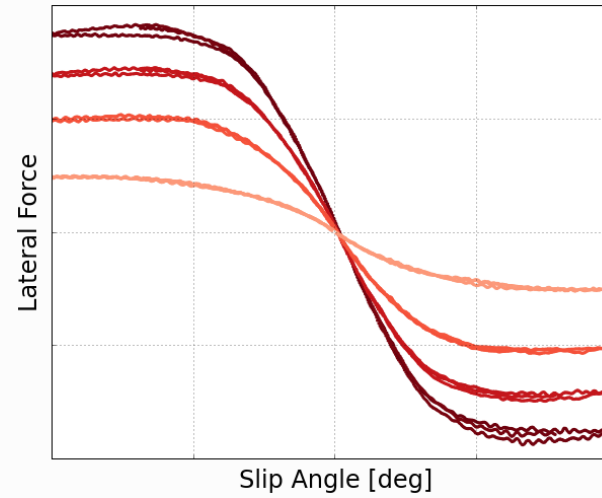
MEASUREMENTS

- FORCES AND MOMENTS
 - $F_x, F_y, F_z, M_x, M_y, M_z$
- POSITIONS/VELOCITIES
 - SA, IA, RL, RE, N, SR, V
- TEMPERATURES
 - SURFACE, SIDEWALL, ROAD, AMBIENT
- WEAR

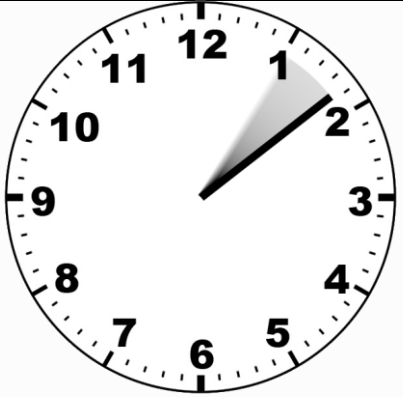


COMMON TEST TYPES

- THE PURPOSE OF THE TESTING DETERMINES TEST PROCEDURES
- THE TEST PROCEDURE AFFECTS THE DATA
- COMMON TESTS
 - FREE-ROLLING CORNERING
 - SPEED CHARACTERIZATION
 - BRAKE-DRIVING
 - BRAKE-DRIVING WHILE CORNERING
 - STATIC TESTS
 - RELAXATION LENGTH



TEST TYPES

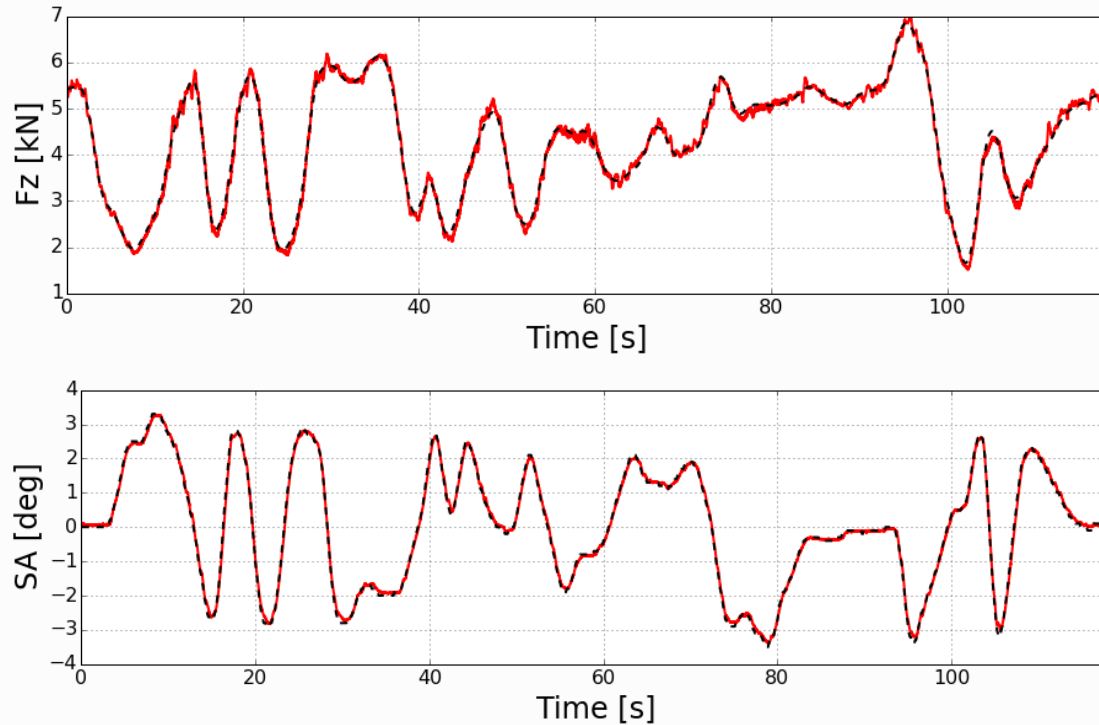


Document	DOD Enterprise Architecture Products (IAW DODAF) (see Note 5)																	Data Service Exposure Sheets	IA Compliance	GTG Compliance
	Supportability Compliance																			
	AV-1	AV-2	OV-1	OV-2	OV-3	OV-4	OV-5	OV-6C	OV-7	SV-1	SV-2	SV-4	SV-5	SV-6	SV-11	TV-1	TV-2			
ICD			X																	
CDD	X	3	X	X	X	X	X	X			X	X	X	X		2	2	1	X	X
CPD	X	3	X	X	X	X	X	X	1		X	X	X	X	1	2	2	1	X	X
ISP	X	3	X	X	X	X	X	X	4		X	X	X	X	4	2	2	1	X	X
TISP	X	3	X		X		X	X		X			X	X		2	2	1	X	X
ISP Annex (SVcs/AVcs)	X	3	X				X				X	X	X	X		2	2	1	X	X

- DATA REPLAY
- THERMAL TESTING
- HIGH CAMBER TIRE TESTING
- SPECIAL INVESTIGATIONS
- INTELLIGENT TESTING

DATA REPLAY

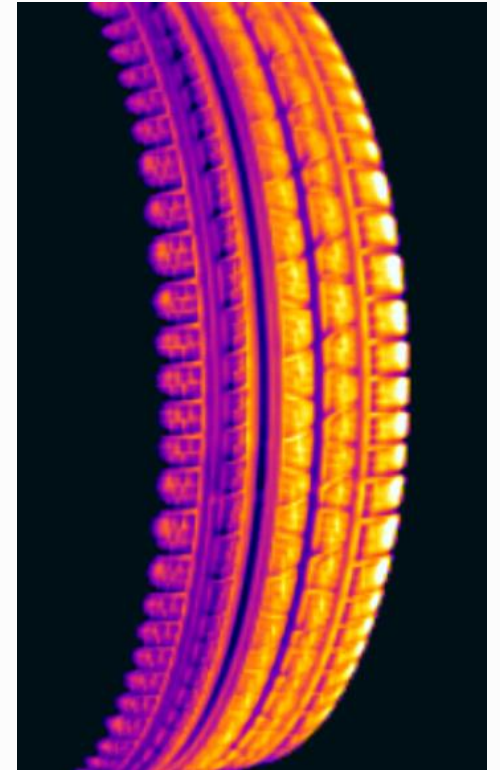
- REPLAY DATA COLLECTED FROM ON-VEHICLE TESTING.
- EVALUATE TIRES IN THE SAME CONDITIONS AS SEEN ON-VEHICLE
- SAFELY UNDERSTAND THE EFFECTS OF PRESSURE AND WEAR
- EARLY WARNING SIGNS OF TIRE FAILURE CAN BE IDENTIFIED



Red: On-vehicle data, Black: Calspan test

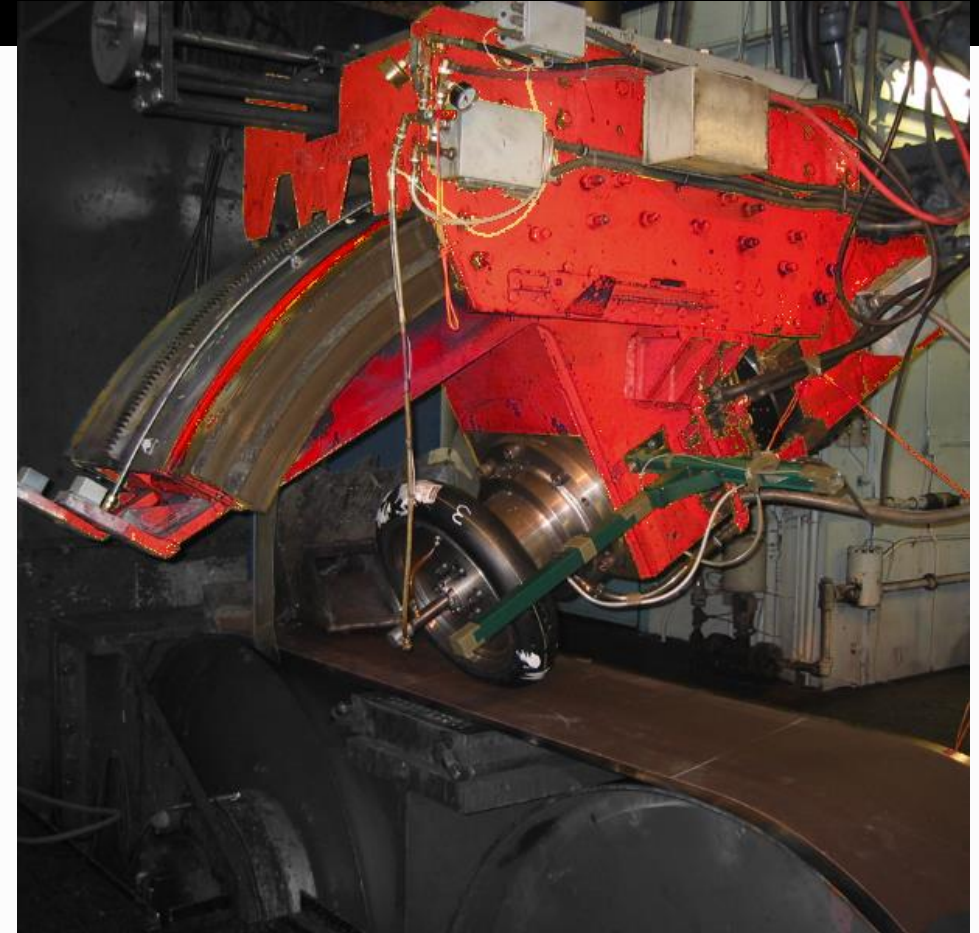
THERMAL TESTING

- CALSPAN'S THERMAL IMAGING IS INTEGRATED TO THE TEST SYSTEM.
- PROVIDES DETAILED INSIGHT INTO CONTACT PATCH BEHAVIOR
- VERY POWERFUL WHEN EVALUATING TIRE CONSTRUCTION DESIGNS.



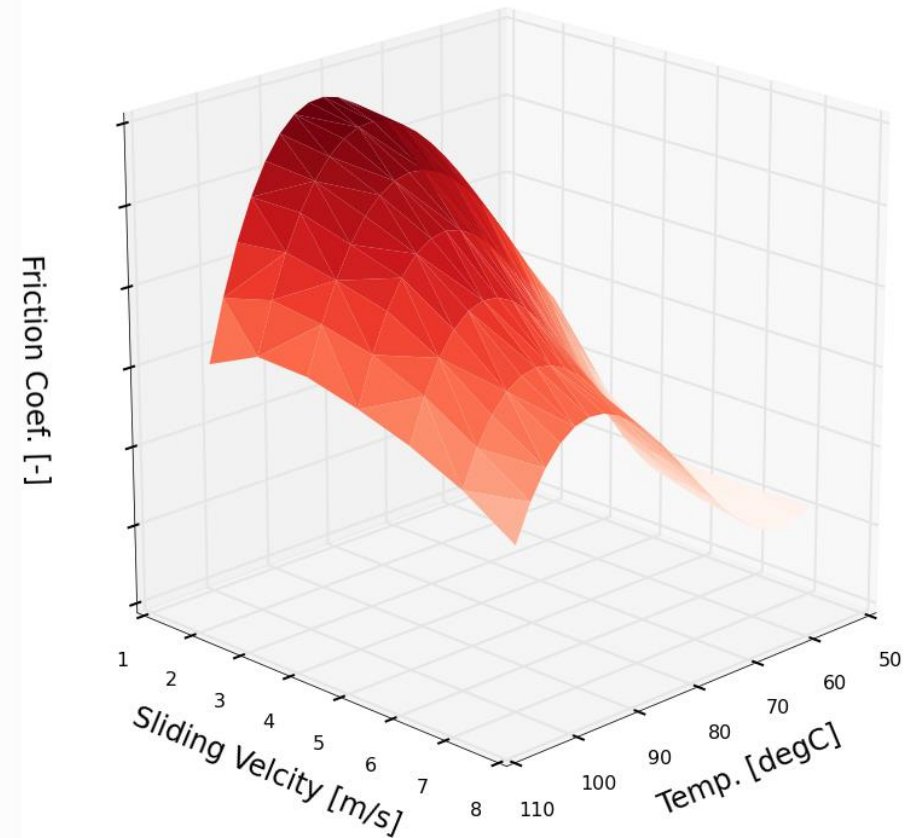
HIGH CAMBER TIRE TESTING

- TEST UP TO ± 25 DEG OF CAMBER TO EVALUATE TIRE BEHAVIOR IN ROLL-OVER SITUATIONS
 - WITH FULL STEER AND TORQUE CAPABILITIES
- VALIDATE TIRE MODELS FOR SEVERE HANDLING CONDITIONS

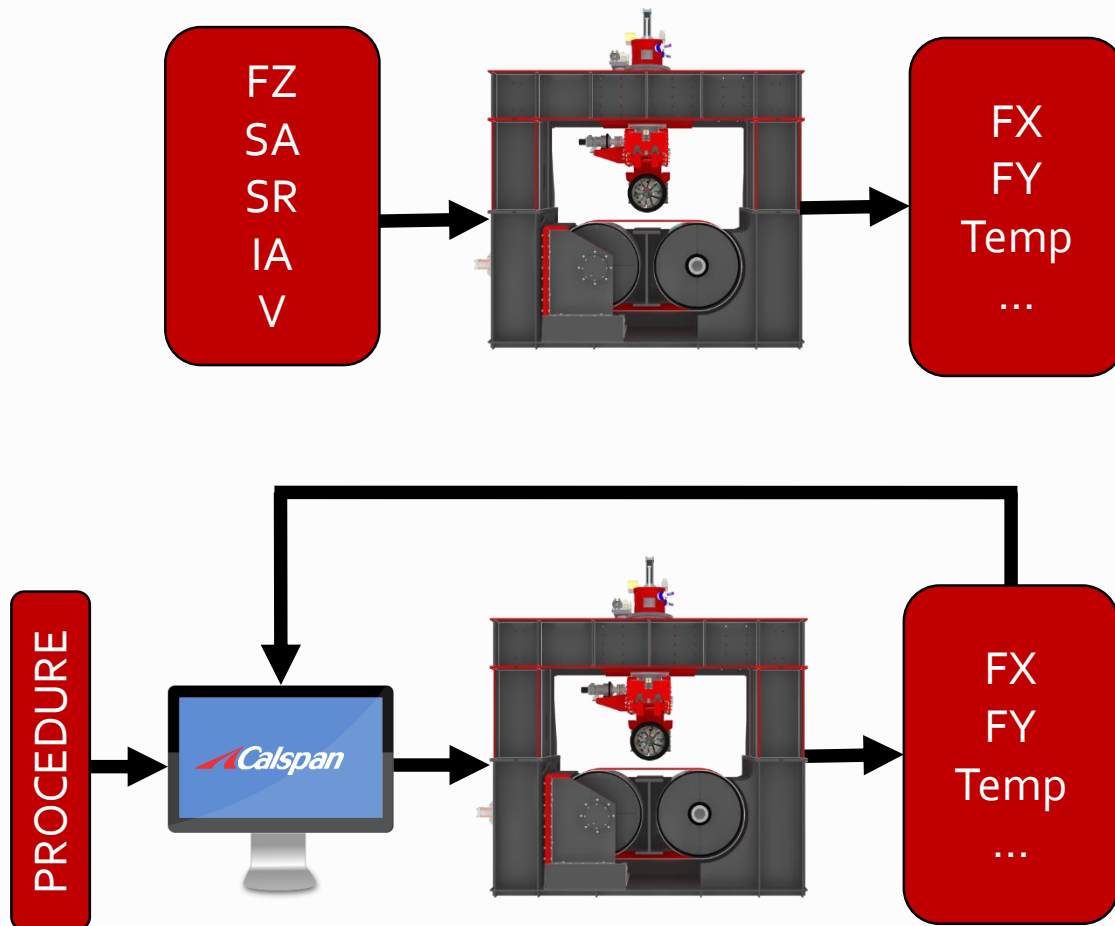


SPECIAL INVESTIGATIONS

- CALSPAN CAN HELP DESIGN TESTS TO CAPTURE SPECIFIC DATA TO SOLVE SPECIFIC PROBLEMS.
- EXAMPLES:
 - IDENTIFY TIRE FAILURE MODES
 - IDENTIFY TIRE WEAR BEHAVIOR
 - IDENTIFY COMPOUND CHARACTERISTICS
 - EVALUATE INTERNAL TIRE SENSORS



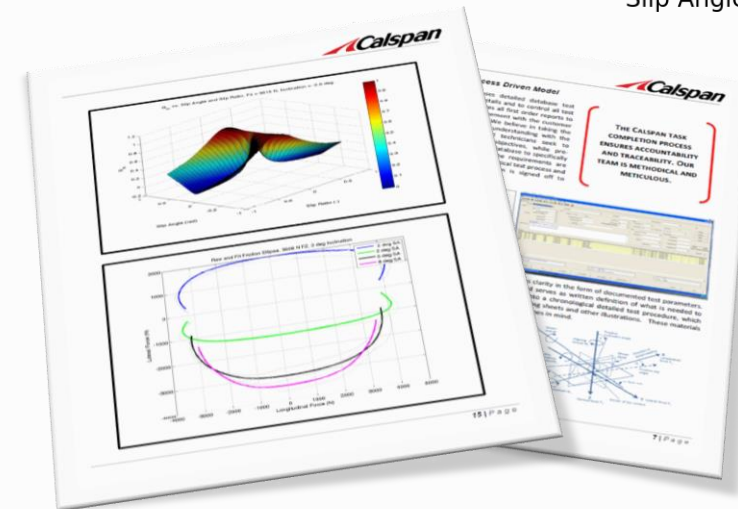
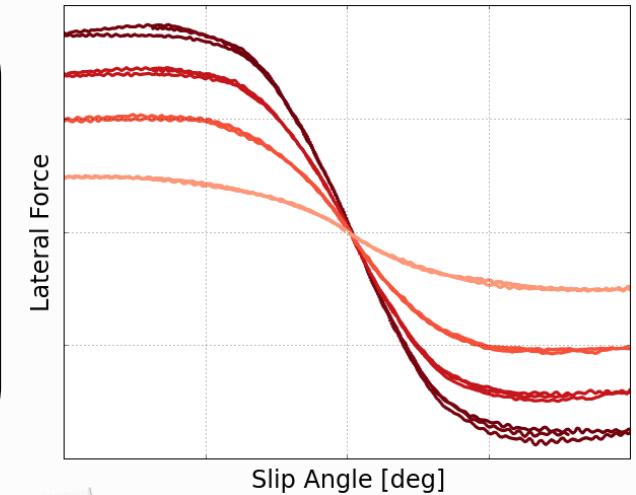
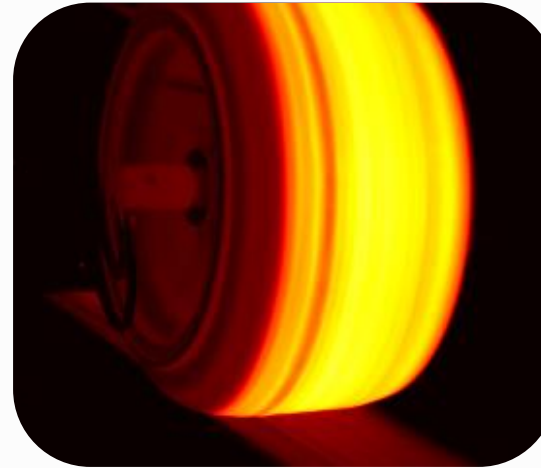
INTELLIGENT TESTING



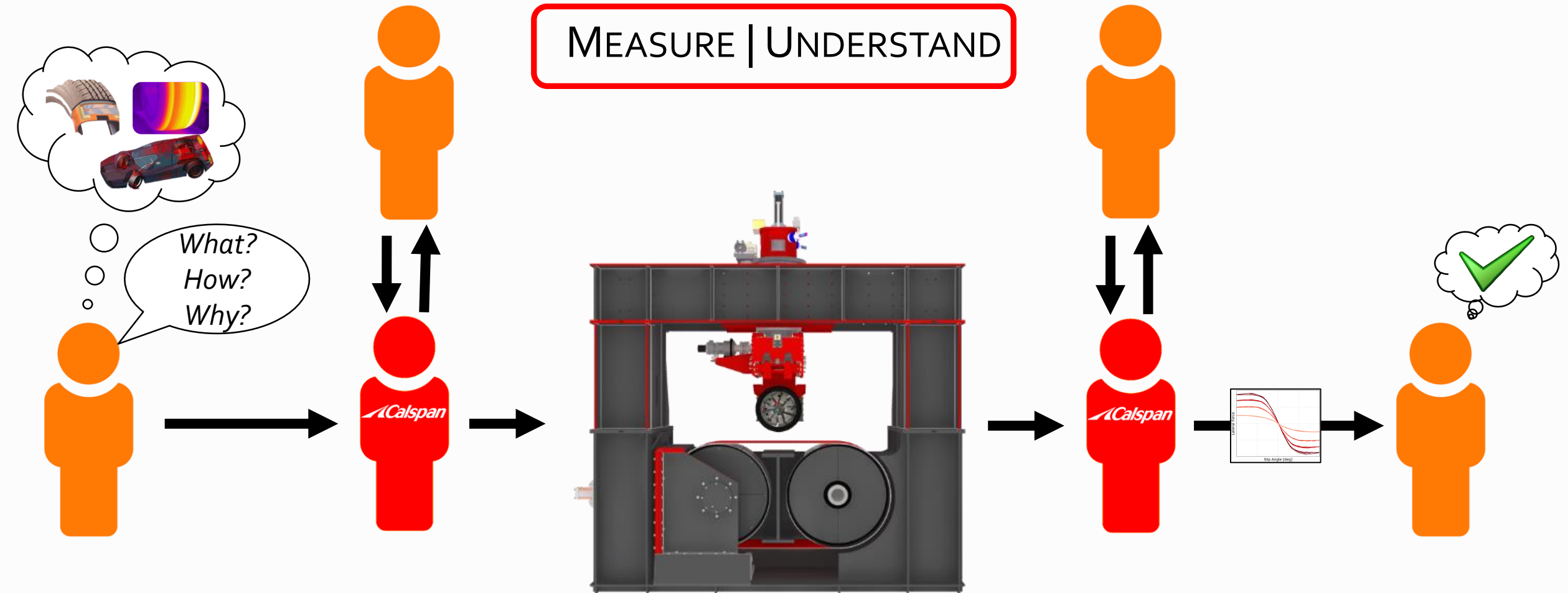
- BASED ON CUSTOMER FEEDBACK, CALSPAN HAS DEVELOPED *INTELLIGENT TESTING*
- TRADITIONALLY, TIRE TEST PROCEDURES SPECIFY THE INPUTS TO THE TIRE:
 - SLIP ANGLE, SLIP RATIO, LOAD, ETC.
- WITH INTELLIGENT TESTING A TEST CAN BE RUN BASED ON THE OUTPUT OF THE TIRE.

ANALYZING RESULTS AND CONCLUSIONS

- DATA PROCESSING:
 - METRICS
 - VISUALIZATIONS
 - MODELS
 - UNDERSTAND AND MAKE DECISIONS
- TESTING OFTEN LEADS TO :
 - NEW QUESTIONS
 - NEW PATHS IN THE TEST AND ANALYSIS PROCESS
 - NEW/FUTURE WORK
- TESTING OFTEN REVEALS UNKNOWNs
 - NEW UNDERSTANDING AND IMPROVEMENTS



PLANNING A SUCCESSFUL TIRE TEST



CUSTOMER SUCCESS – MEASURE & UNDERSTAND



- A TEST IS NOT SUCCESSFUL WHEN WE DELIVER DATA.
- A TEST IS SUCCESSFUL WHEN OUR CUSTOMER ACHIEVES THEIR GOAL.
- OUR CUSTOMERS ARE BUSINESS PARTNERS.
- CALSPAN GOES ABOVE AND BEYOND TO ASSURE YOU REALIZE THE MAXIMUM BENEFIT FROM YOUR PARTNERSHIP WITH CALSPAN.

NEXT STEPS



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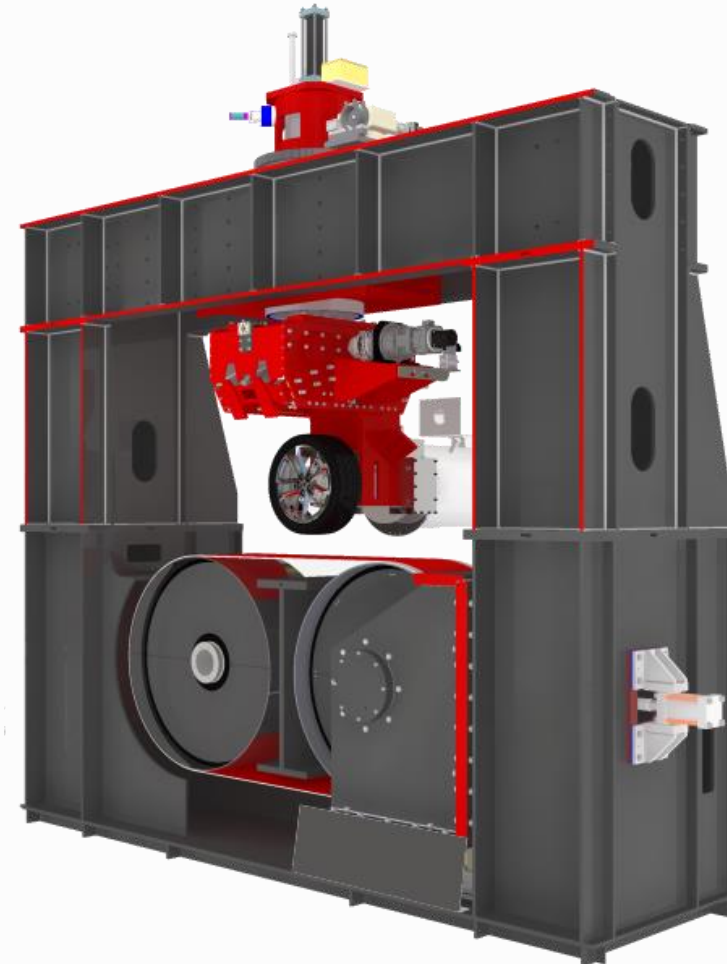
HENNING OLSSON

DIRECTOR, RESEARCH & DEVELOPMENT

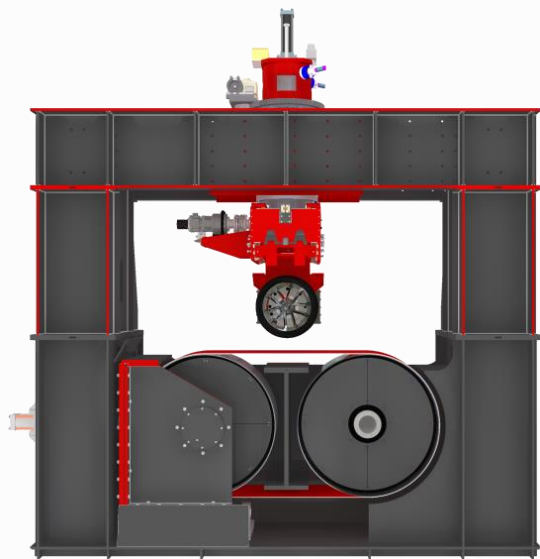
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CALSPAN TIRE TESTING SPECIFICATIONS



Description	Units		Units	
Minimum Loaded Radius	mm	196	in	7.8
Maximum Loaded Radius	mm	610	in	24
Maximum Loaded Displacement Rate	mm/s	178	in/s	7
Smallest Rim Diameter	mm	254	in	10
Maximum Tire Width	mm	605	in	23.8
Maximum Vertical Load	kN	53	lb	12,000
Lateral Force Capability	kN	±40	lb	8992
Longitudinal Force Capability	kN	±40	lb	8992
Slip Angle Range	deg	±30	deg	±30
Maximum Slip Angle Rate	deg/s	12	deg/s	12
Inclination Angle Range	deg	±25	deg	±25
Inclination Angle Range (Motorcycle)	deg	50 / -10	deg	50 / -10
Inclination Angle Rate	deg/s	7	deg/s	7
Spindle Speed	rpm	±3,600	rpm	±3,600
Spindle Torque at 850 rpm	kNm	10.8	lb-ft	8000
Spindle Torque at 1400 rpm	kNm	10.8	lb-ft	8000
Spindle Torque at 2200 rpm	kNm	6.9	lb-ft	5110
Spindle Torque at 3000rpm	kNm	4.0	lb-ft	2900
Spindle Torque at 3600rpm	kNm	2	lb-ft	1440
Spindle Torque Rate	kNm/s	19	lb-ft/s	14,000
Disk Brake Torque	kNm	20	lb-ft	14,000
Roadway Speed (2nd gear / 1st gear)	kph	±360/160	mph	224 / 100
Roadway Maximum Drag Force (2nd gear / 1st gear)	kN	±28/64	lb	6295 / 14,500
Maximum Lateral Belt Travel	mm	±5	in	0.2
Bearing Temperature Control [Surface]	deg C	10 -38	deg F	50 - 100
Tire Inflation Max	kPa	2,400	psi	350

