CMS - OWNER PERSPECTIVE

DAVID CLARK

CMS

WIND

WIND TURBINE CONDITION MONITORING AND CONSULTING

THREE WAYS TO OPERATE A WIND TURBINE:

- WAIT FOR A FAILURE

  REACTIVE MAINTENANCE

- MAINTAIN AT A SET INTERVAL

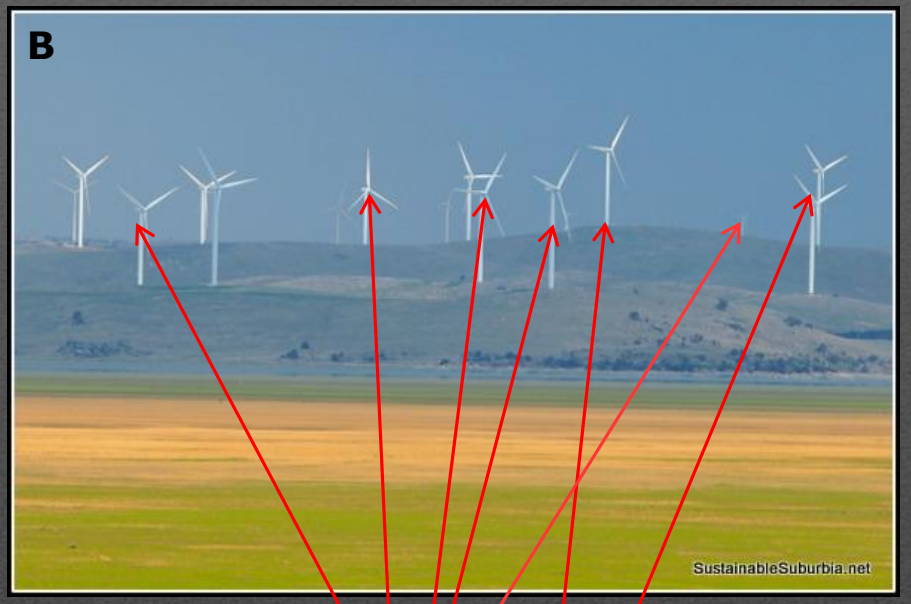
  PREVENTATIVE MAINTENANCE

- PREDICT FAILURE

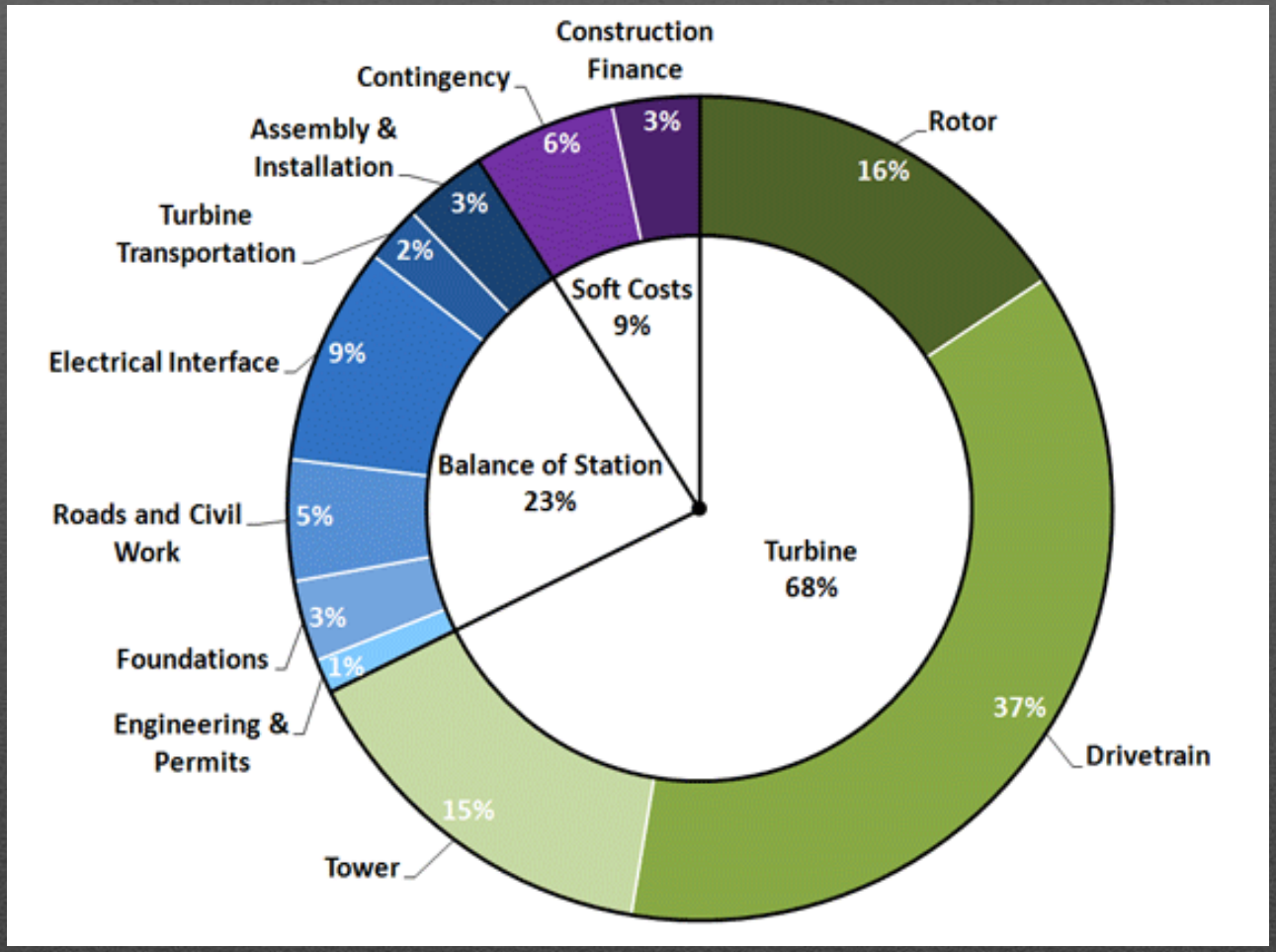
  PREDICTIVE MAINTENANCE

DEVELOP A BUDGET- POST WARRANTY

Labor, purchasing, production, maintenance, availability, due diligence, insurance, financing.

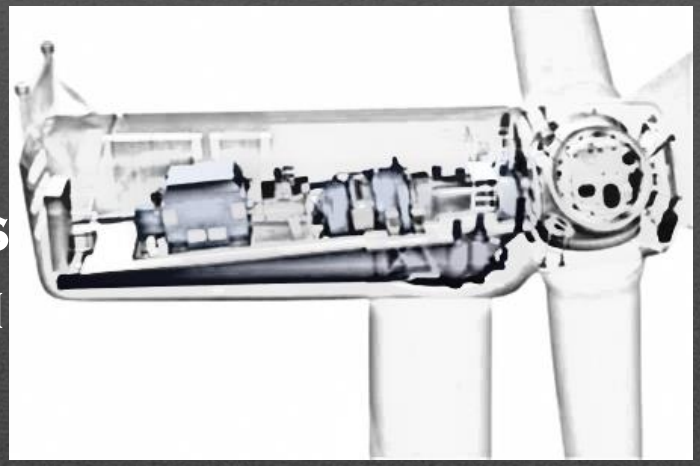


- High speed shaft
- Generator bearing
- Planetary section
- Misalignment at coupling

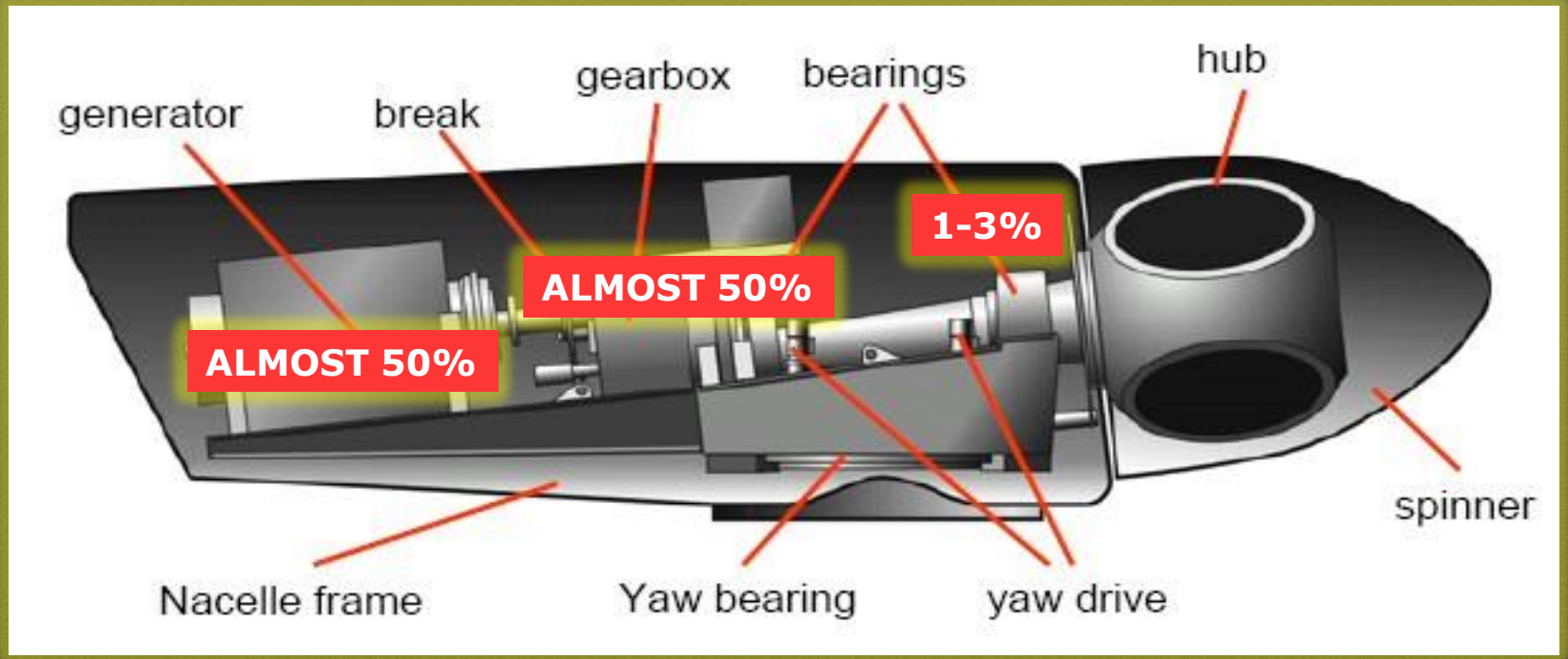

Construction Finance
3%
Contingency
6%
Assembly & Installation
3%
Turbine Transportation
2%
Electrical Interface
9%
Roads and Civil Work
5%
Foundations
3%
Engineering & Permits
1%
Tower
15%
Drivetrain
37%
Rotor
16%
Soft Costs
9%
Balance of Station
23%
Turbine
68%

CONDITION MONITORING TECHNOLOGIES

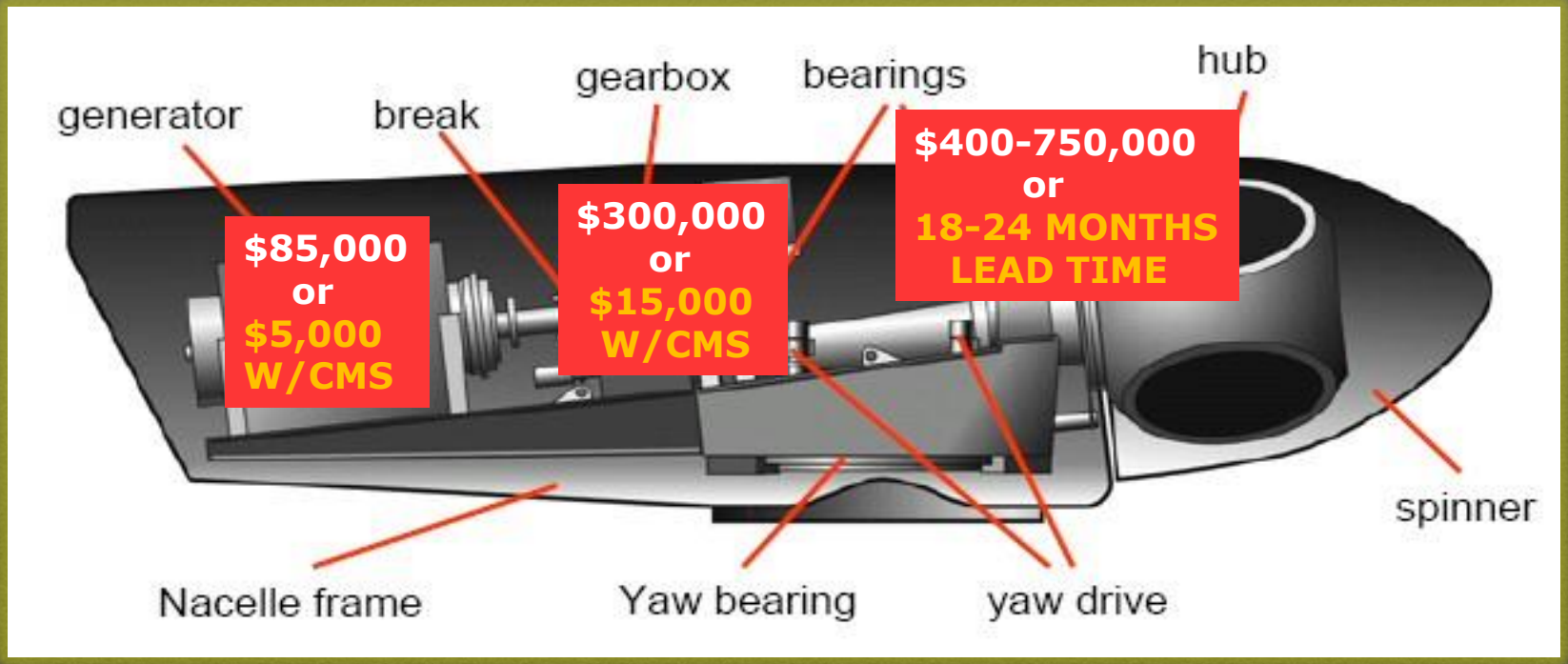
- Lubrication analysis
- Infrared thermography inspection
- Oil particulate sensors
- Laser alignment
- **Vibration analysis**
- Acoustic analysis
- Motor current analys
- Bore scope inspection



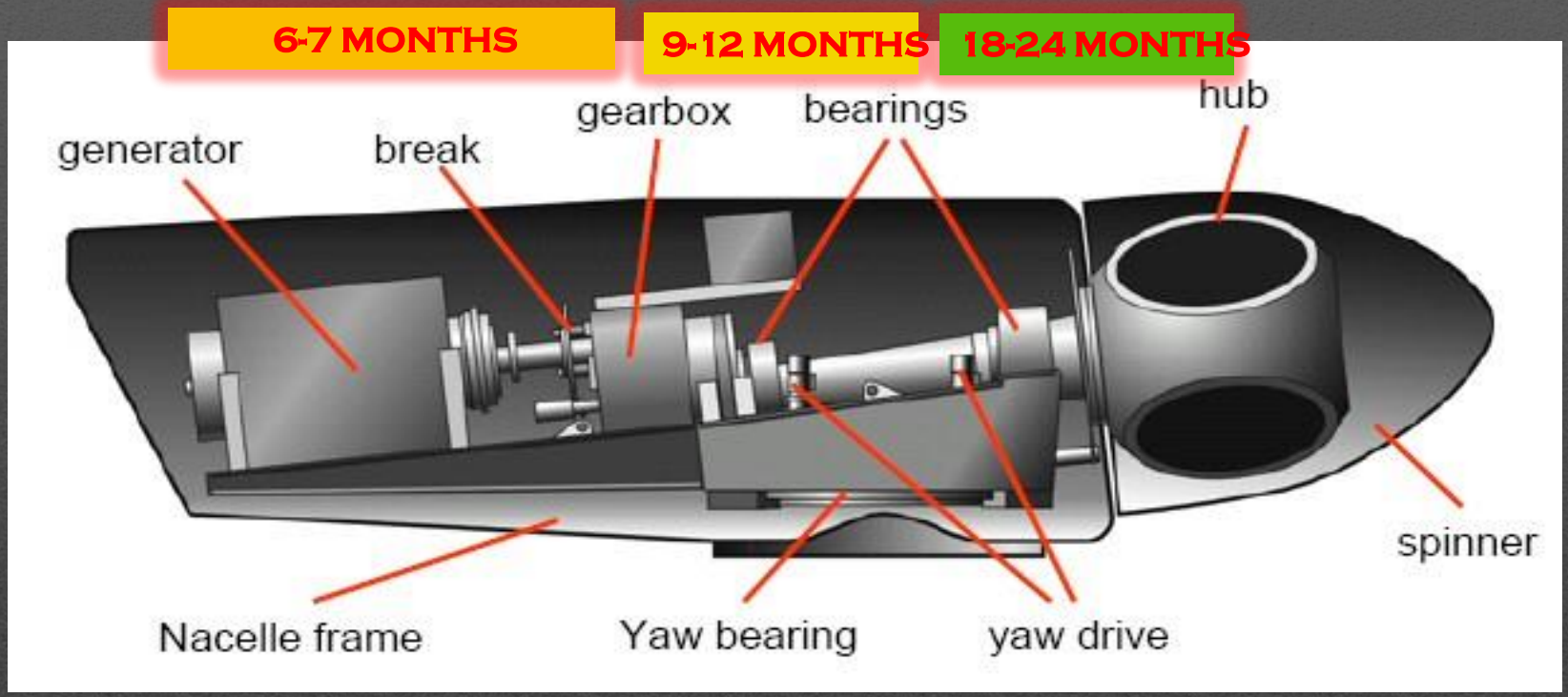
DISTRIBUTION OF FAILURES BASED ON 6 GW



PER EVENT DIFFERENCE WITH CONDITION MONITORING SYSYEM (CMS)

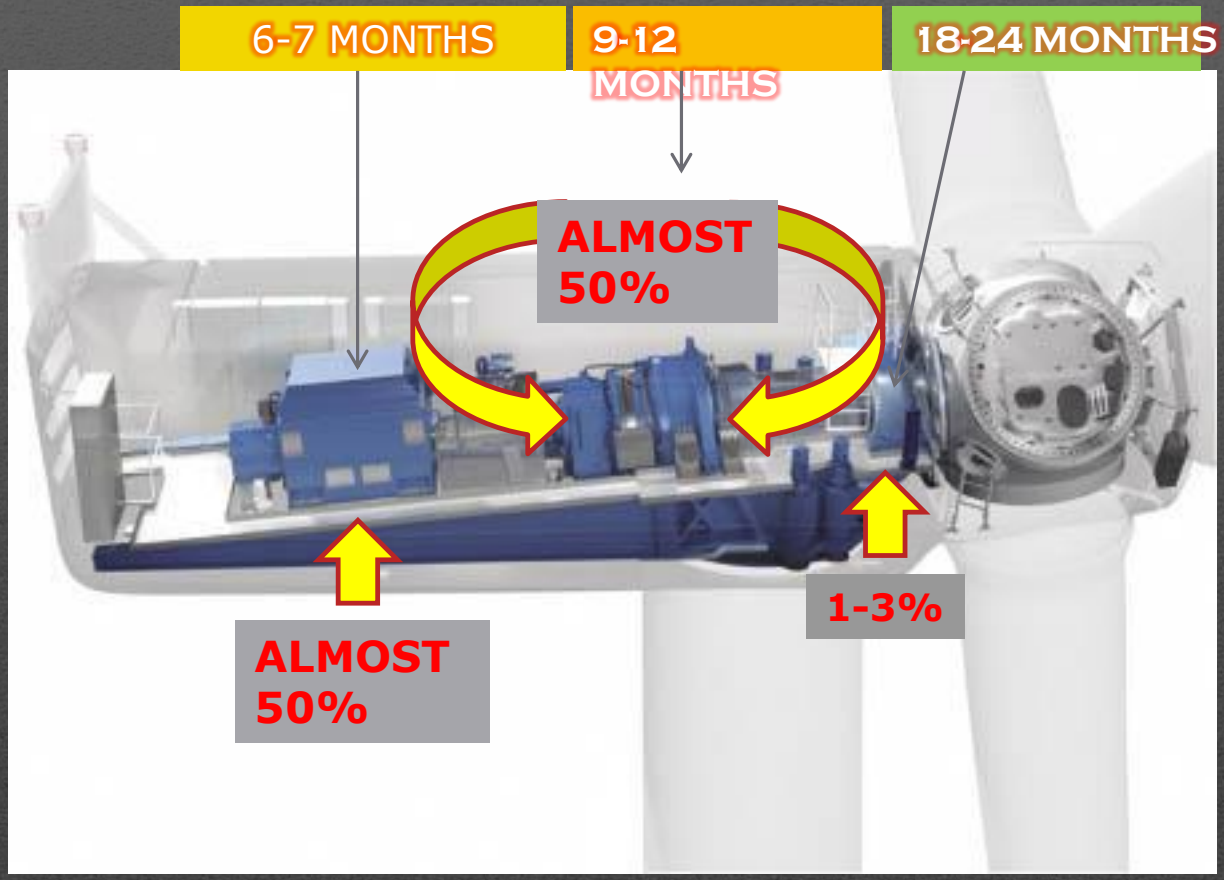


AVERAGE DETECTION LEAD TIME TO FAILURE USING CMS CORRECTLY



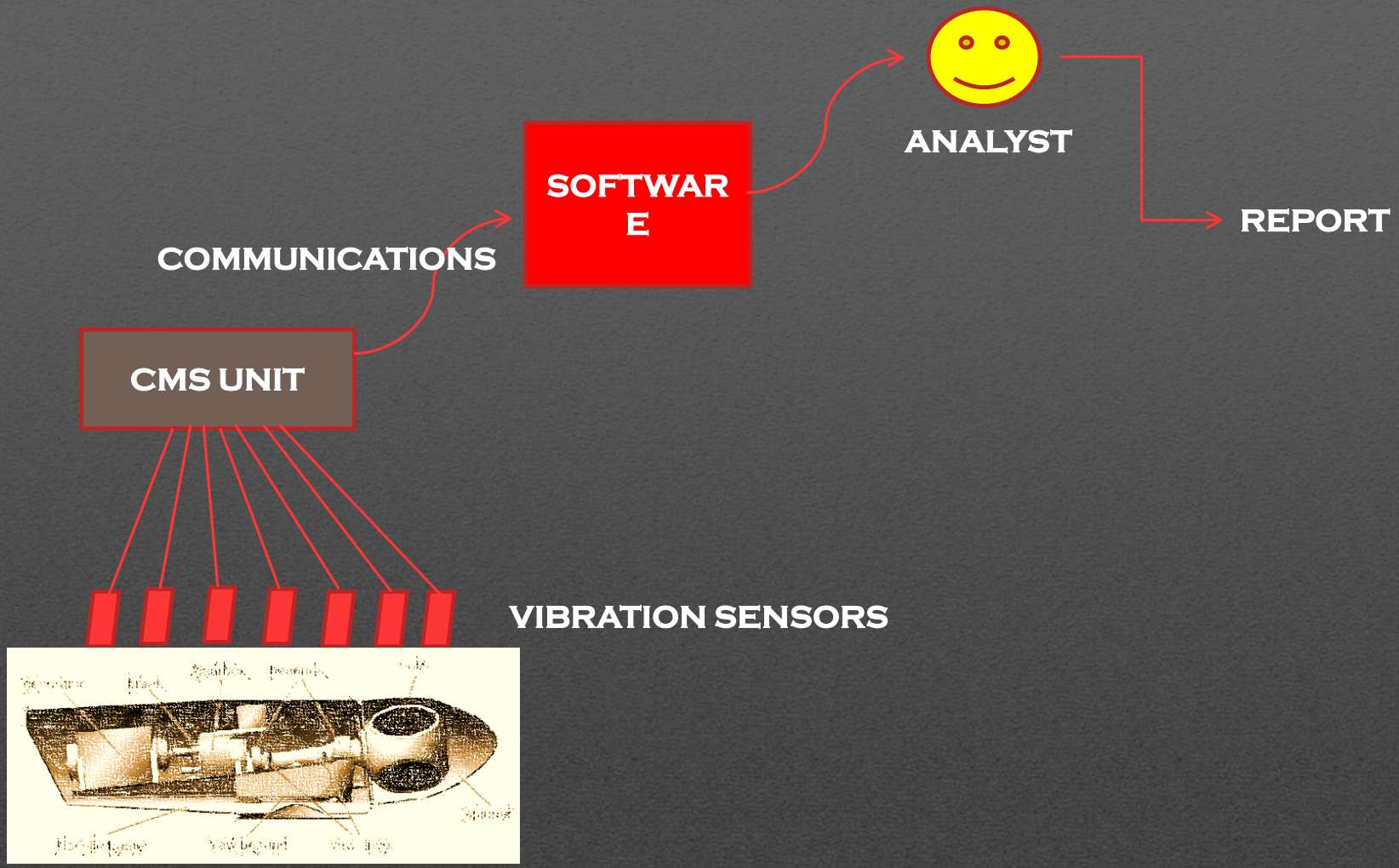
DRIVETRAIN FOCUS WITH CMS

ANNUAL FAILURE RATE OF 11-16% IS COMMON



THREE WAYS TO GET CMS ON WIND TURBINES:

- MANUFACTURER INSTALLED
- RETROFIT
- PORTABLE INSPECTION


ANALYST
SOFTWAR
E
REPORT
COMMUNICATIONS
CMS UNIT
VIBRATION SENSORS

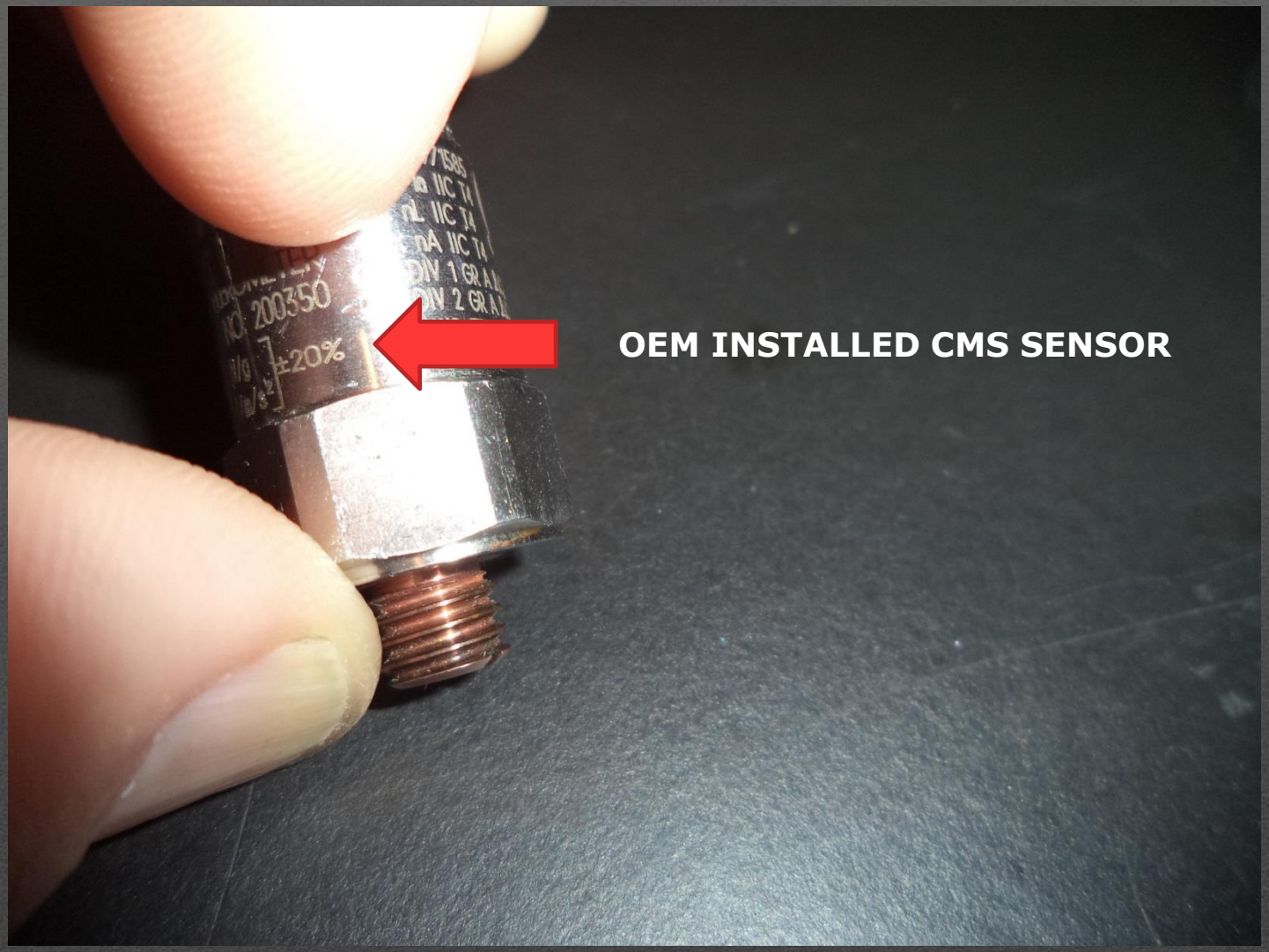
MANUFACTURER AND RETROF

CMS

60 RPM +

12 RPM

+



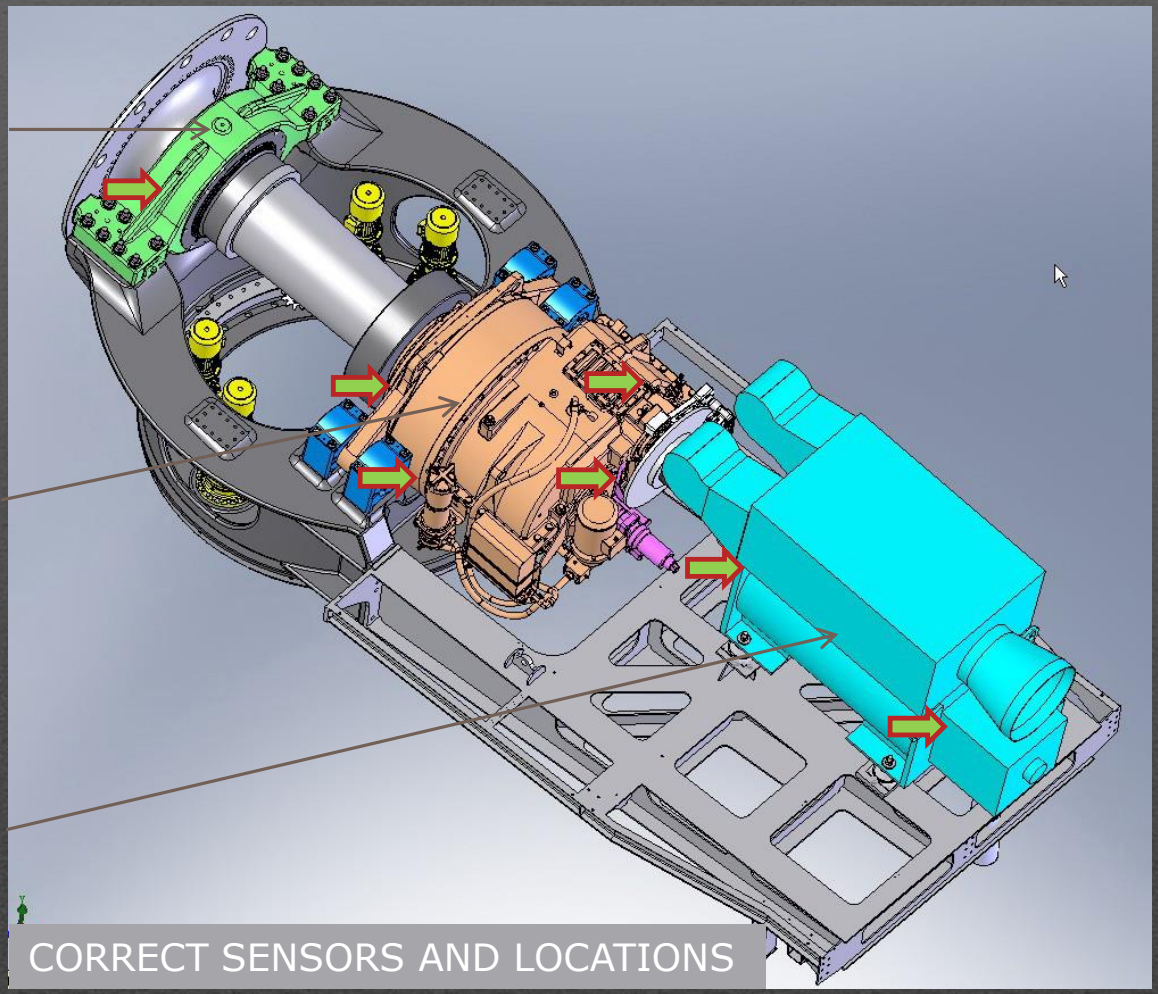
OEM INSTALLED CMS SENSOR

CORRECT APPROACH

MAIN BEARING

GEARBOX

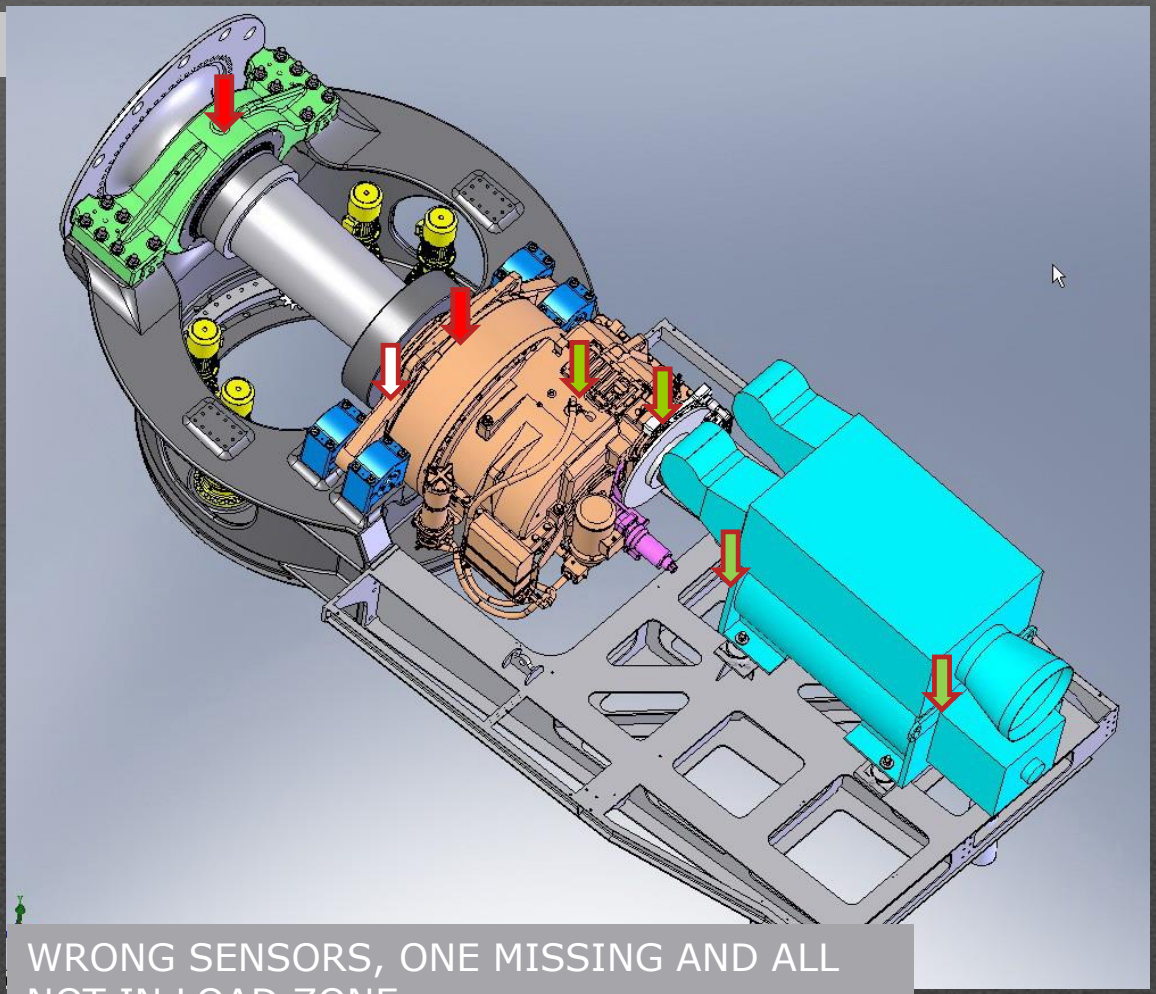
GENERATOR



CORRECT SENSORS AND LOCATIONS

COMPANY “A“ INCORRECT APPROACH

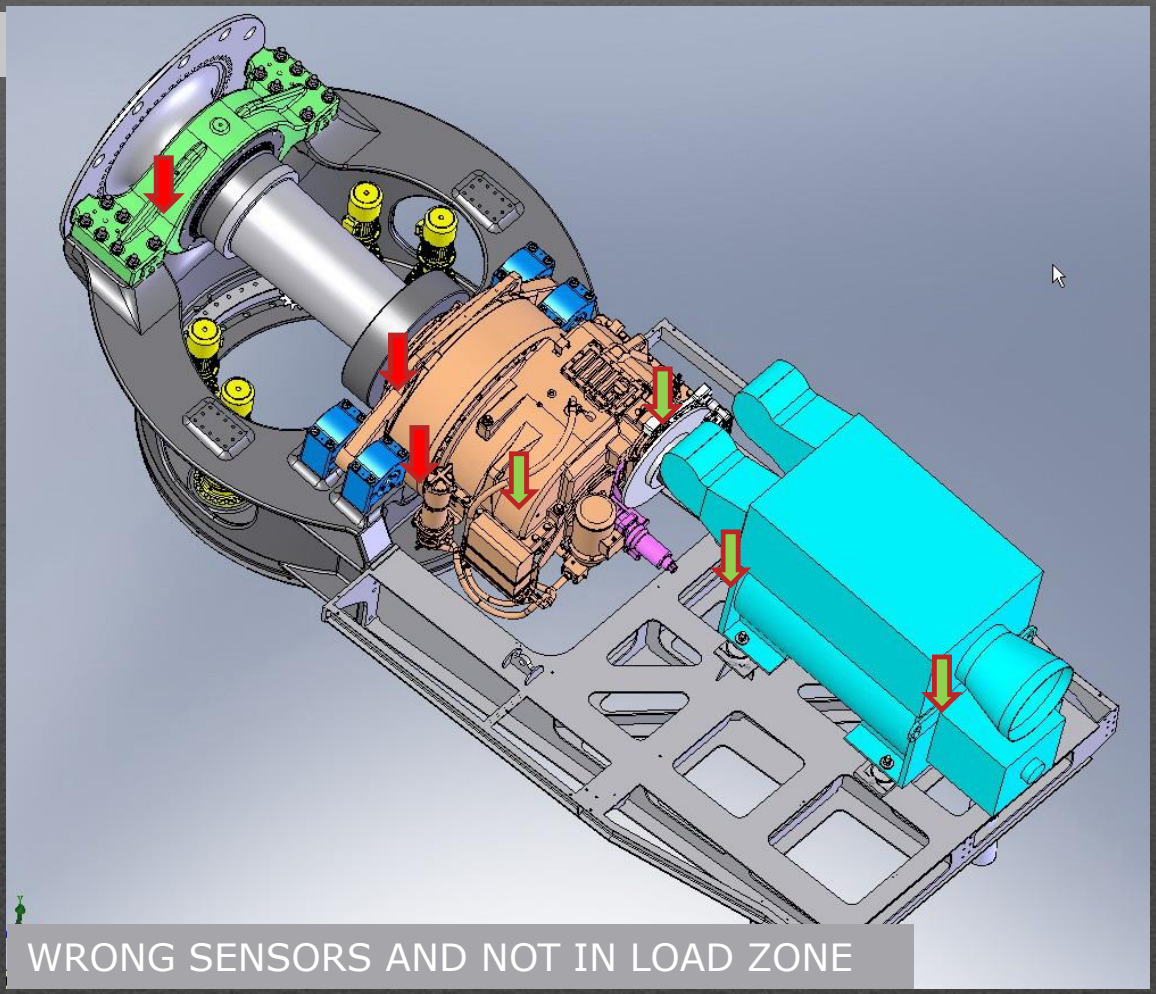
OEM



WRONG SENSORS, ONE MISSING AND ALL NOT IN LOAD ZONE

COMPANY “B“ INCORRECT APPROACH

OEM



WRONG SENSORS AND NOT IN LOAD ZONE

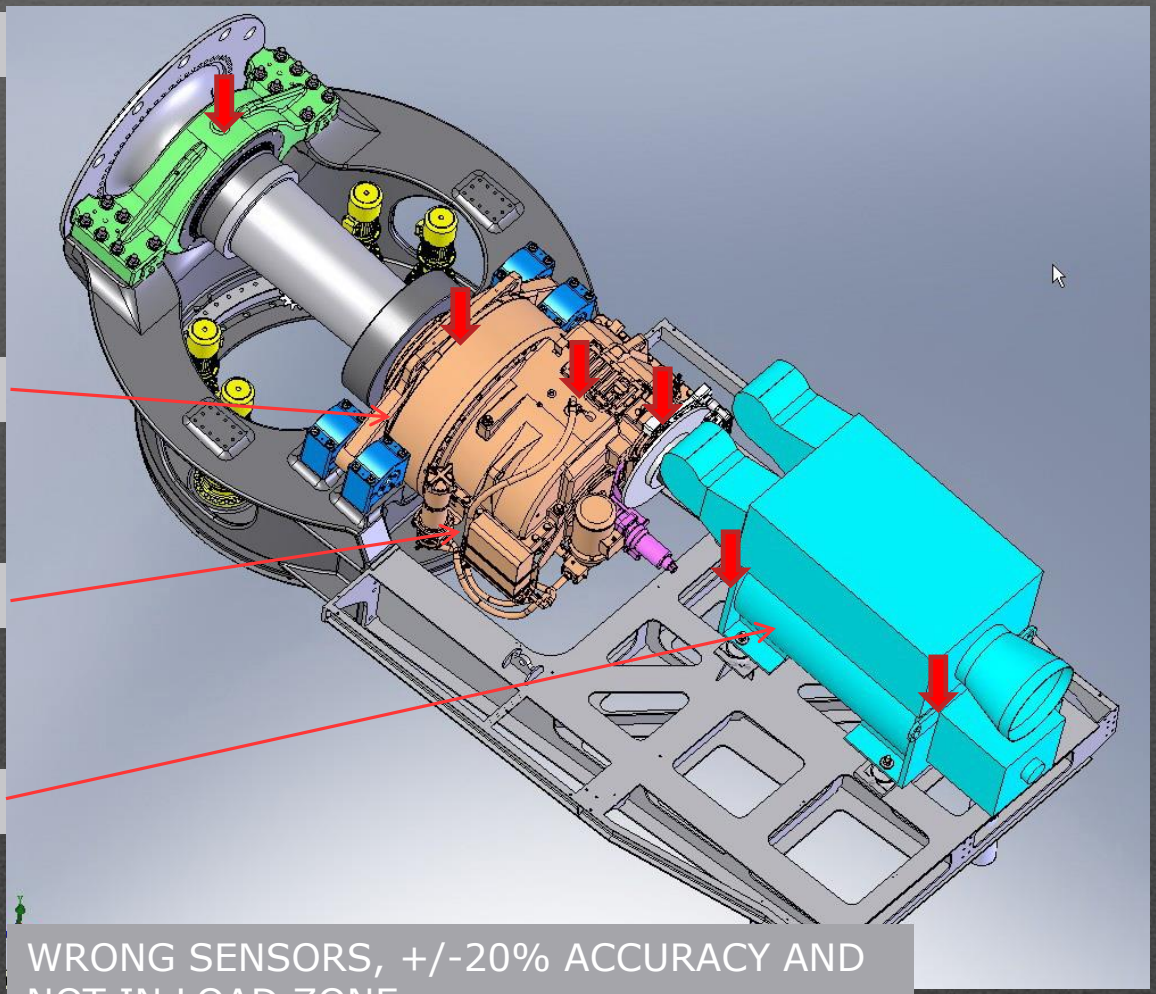
COMPANY “C“ INCORRECT APPROACH

OEM

40% DETECTION

60% DETECTION

80% DETECTION

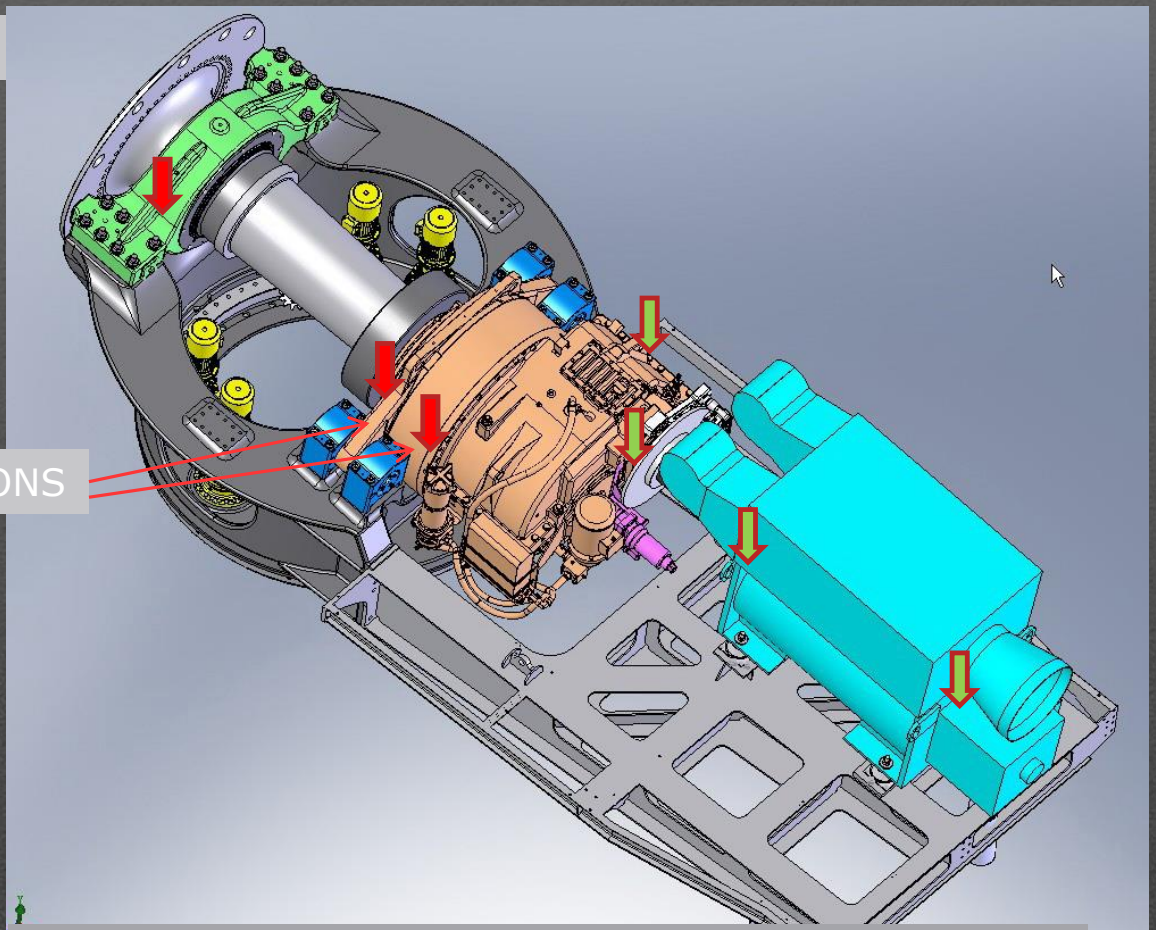


WRONG SENSORS, +/-20% ACCURACY AND NOT IN LOAD ZONE

COMPANY “D“ INCORRECT APPROACH

OEM

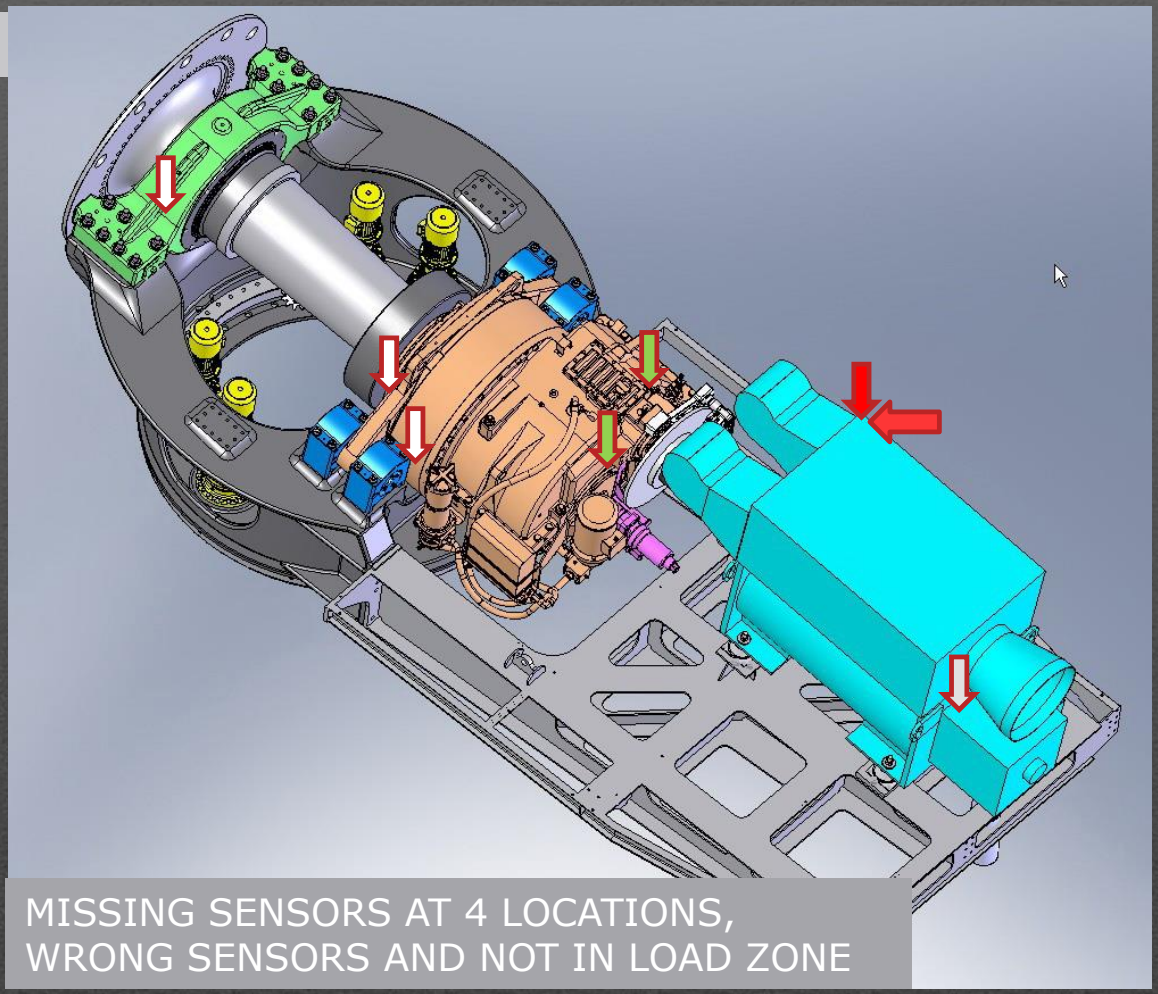
MISSED DETECTIONS



WRONG SENSORS AND TREND FOR 9-12 MONTHS

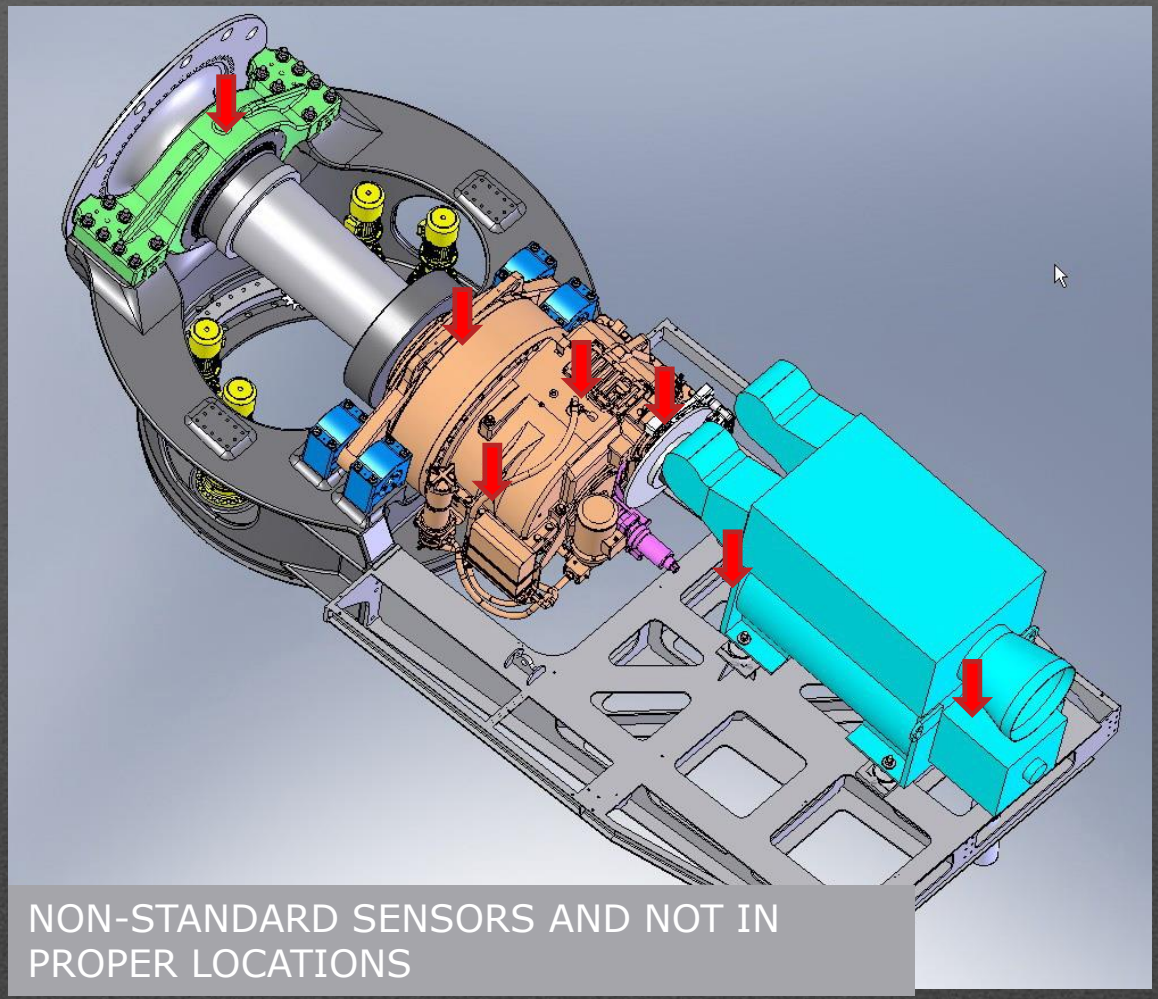
COMPANY “E“ INCORRECT APPROACH

OEM



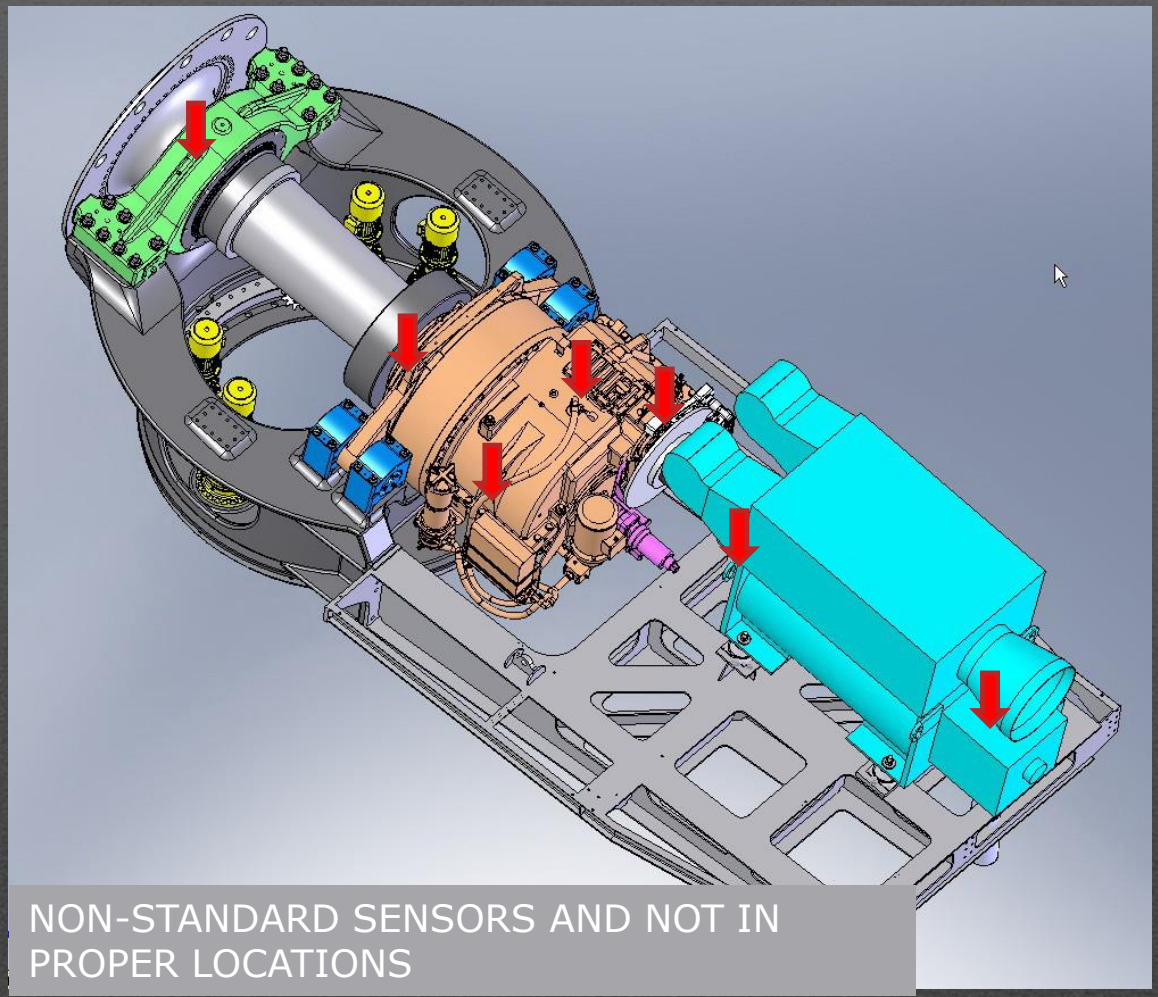
MISSING SENSORS AT 4 LOCATIONS,
WRONG SENSORS AND NOT IN LOAD ZONE

COMPANY “F“ INCORRECT APPROACH



NON-STANDARD SENSORS AND NOT IN PROPER LOCATIONS

COMPANY “G“ INCORRECT APPROACH

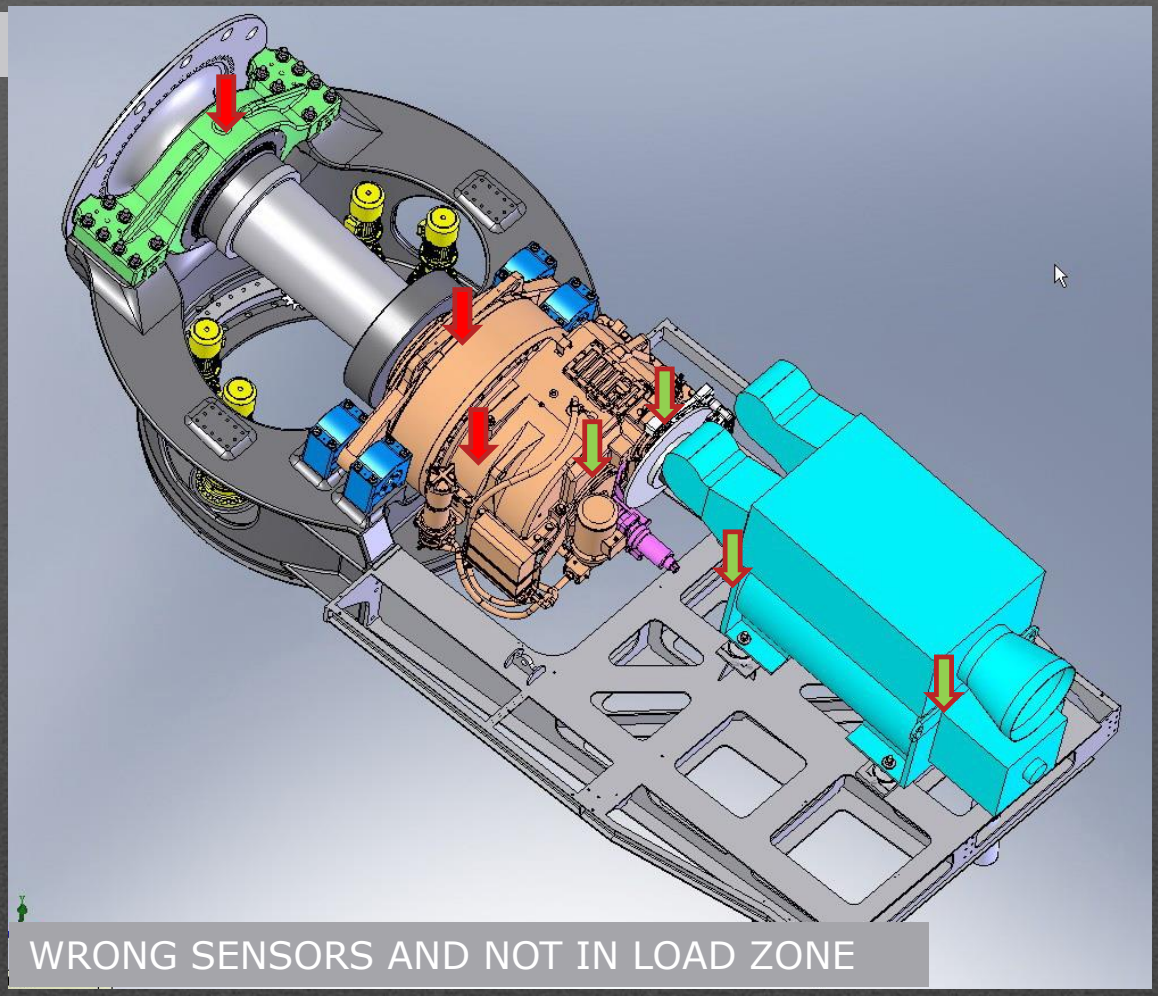


NON-STANDARD SENSORS AND NOT IN PROPER LOCATIONS

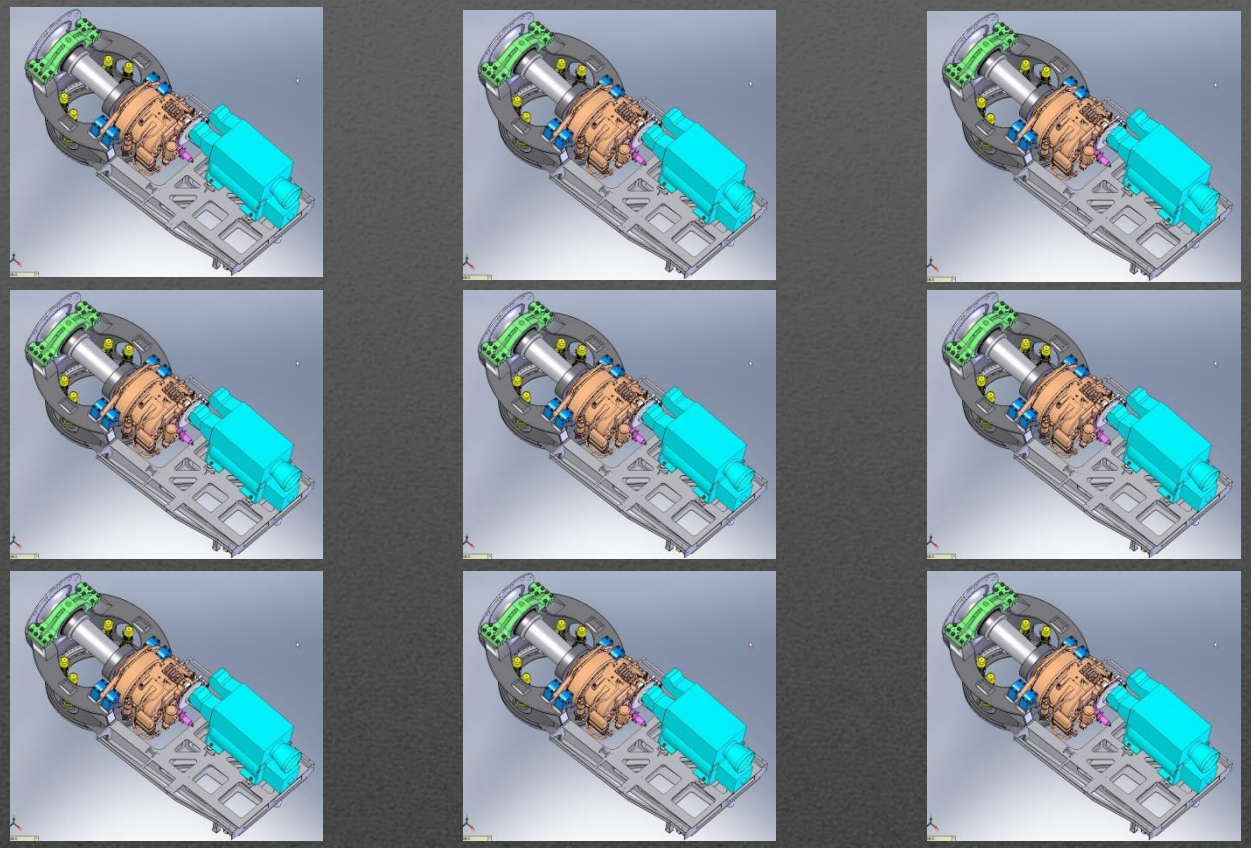
COMPANY “H“ INCORRECT

APPROACH

OEM



WRONG SENSORS AND NOT IN LOAD ZONE



APPROACHES TO CMS SENSORS AND LOCATIONS

CONDITION MONITORING MYTHS

. Need volumes of data, lots of measurements

. Need a vibration baseline, history

. Too difficult to understand the data

. Planetary is difficult to detect

. Not cost justified

END OF WARRANTY

CMS

END OF WARRANTY CONSIDERATIONS

- WIND IS REQUIRED
- ENOUGH TIME TO GATHER DATA AND BUILD A CASE
- KINEMATIC DATA IS HELPFUL BUT NOT ESSENTIAL

TURBINE GEARBOX COMMON INSPECTION TECHNIQUES

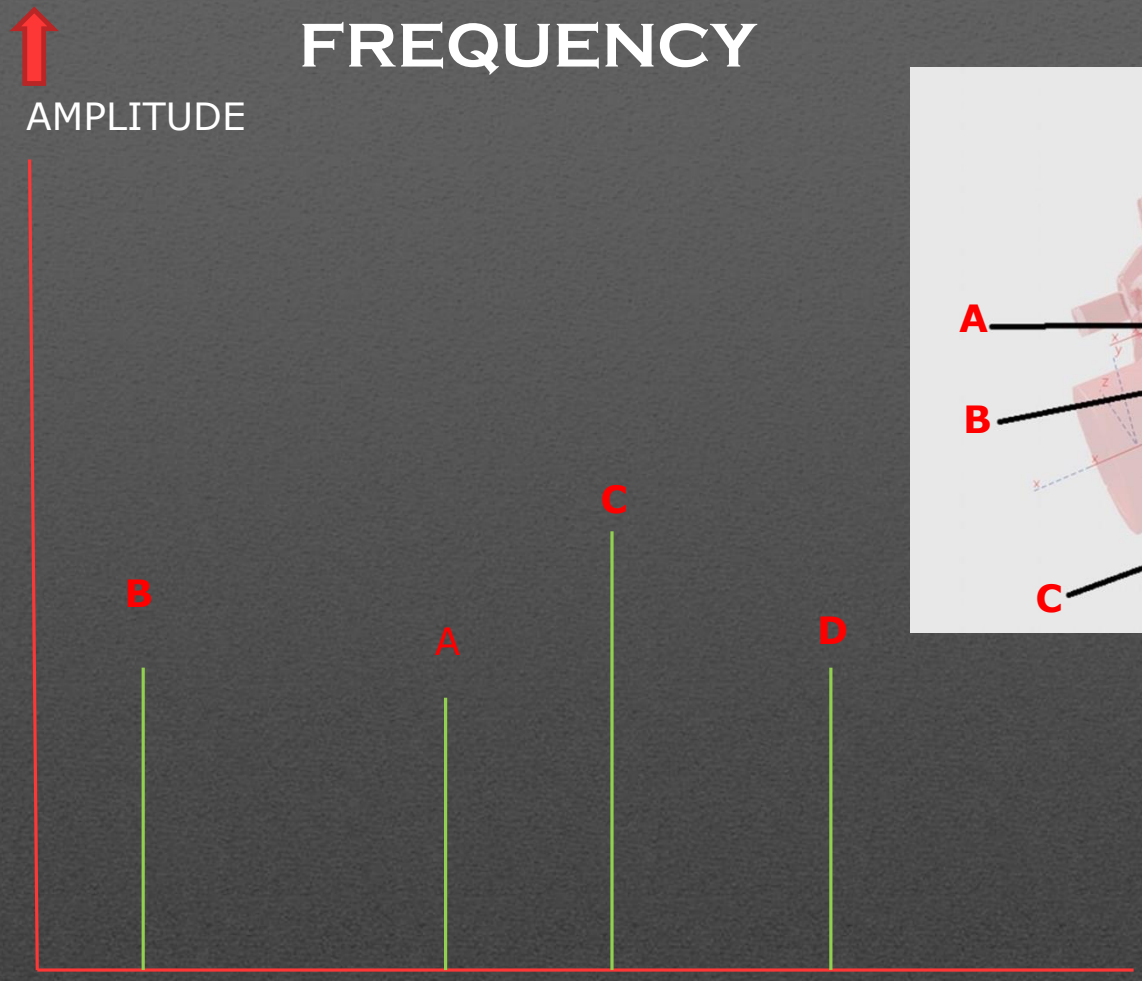
Component detection percentages on a typical gearbox

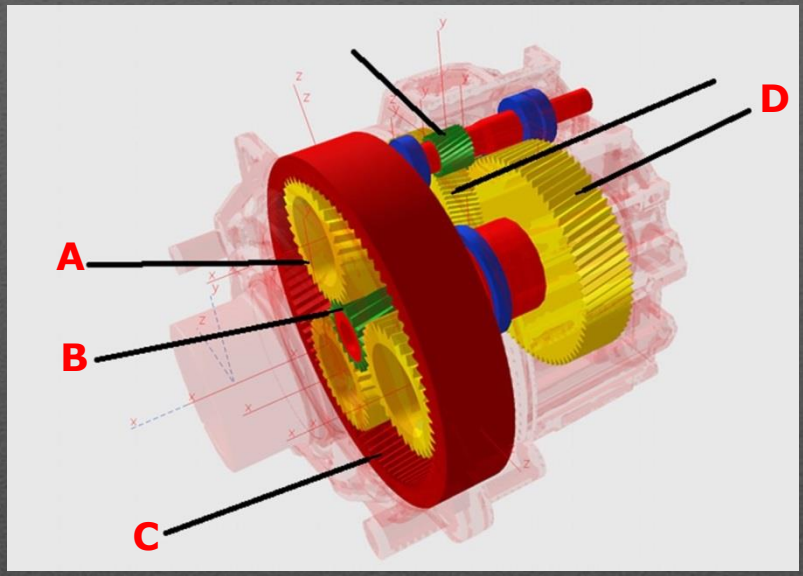
	VISUAL INSPECTION	BORESCOPE	VIBRATION ANALYSIS
High Speed Pinion	50%	50%	100%
Intermediate Wheel & Pinion	100%	N/A†	100%
Low-Speed Wheel	100%	N/A†	100%
Sun Gear	No	30%§	100%
Planetary Gears (3)	10%	30%§	100%
Ring Gear	20%	30%	100%
High Speed Bearings (3)	No	100%	100%
Intermediate Bearings (2-3)	No	50%‡	100%
Low Speed Bearings (2)	No	50%‡	100%
Planetary Carrier Bearings (2)	No	30%§	100%
Planetary Gear Bearings (6 drCRB)	No	30%§	100%

† Clearly visible during visual inspection by removal of inspection cover
‡ Depends upon gearbox make/model, oil level and bearing configuration
§ Requires several rotations of rotor and to inspect 100%, adding several hours to inspection

By Don Roberts and David Clark

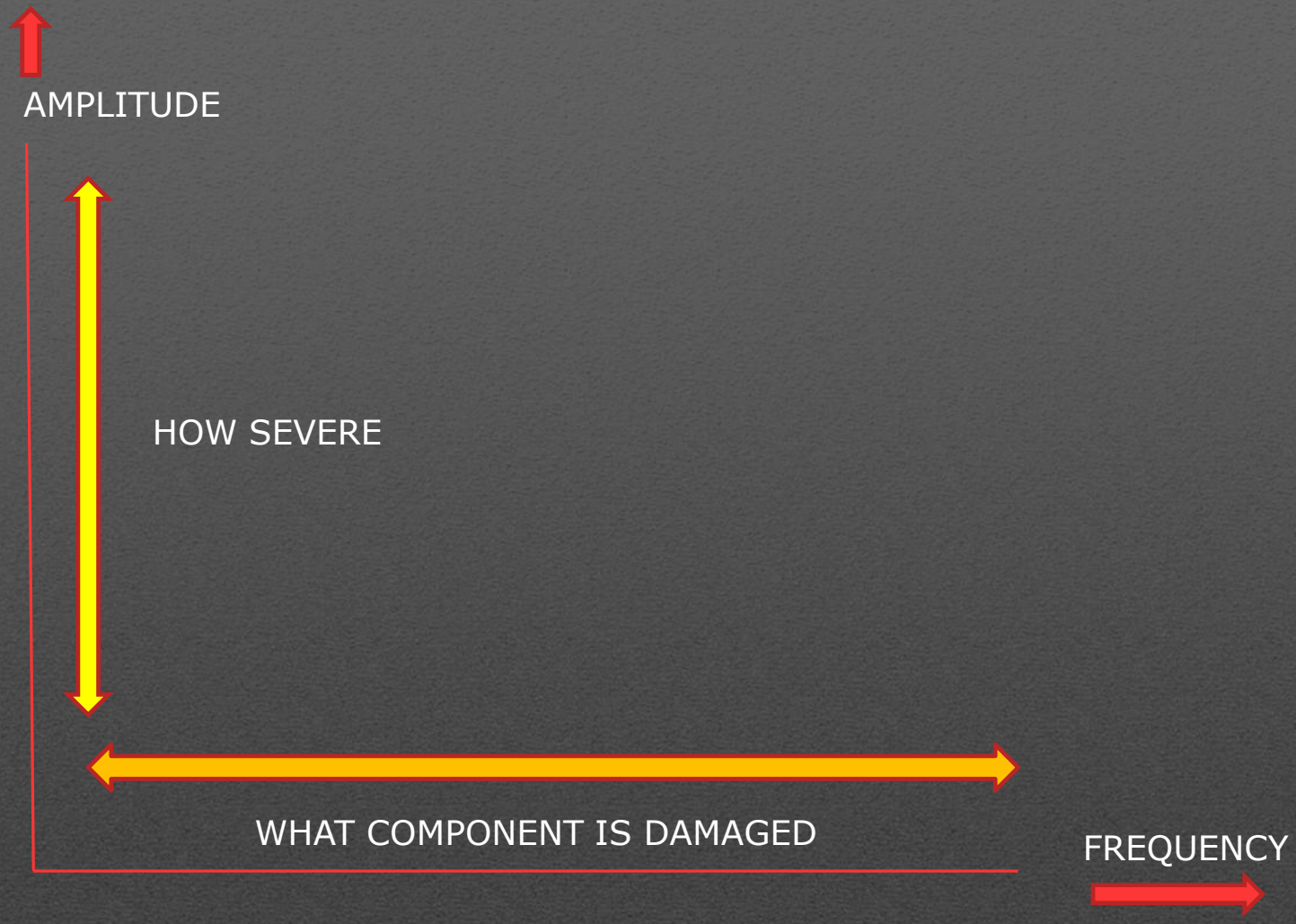
EACH GEAR HAS A FREQUENCY





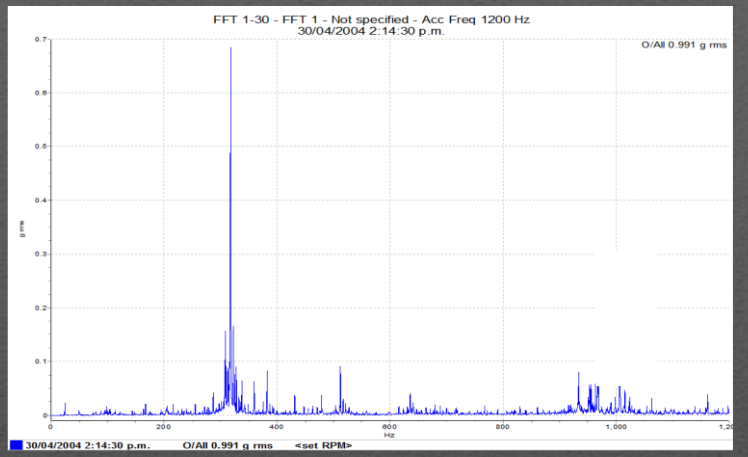
NUMBER OF TEETH X RPM = GEAR'S MESHING FREQUENCY (GMF)

VIBRATION SPECTRUM

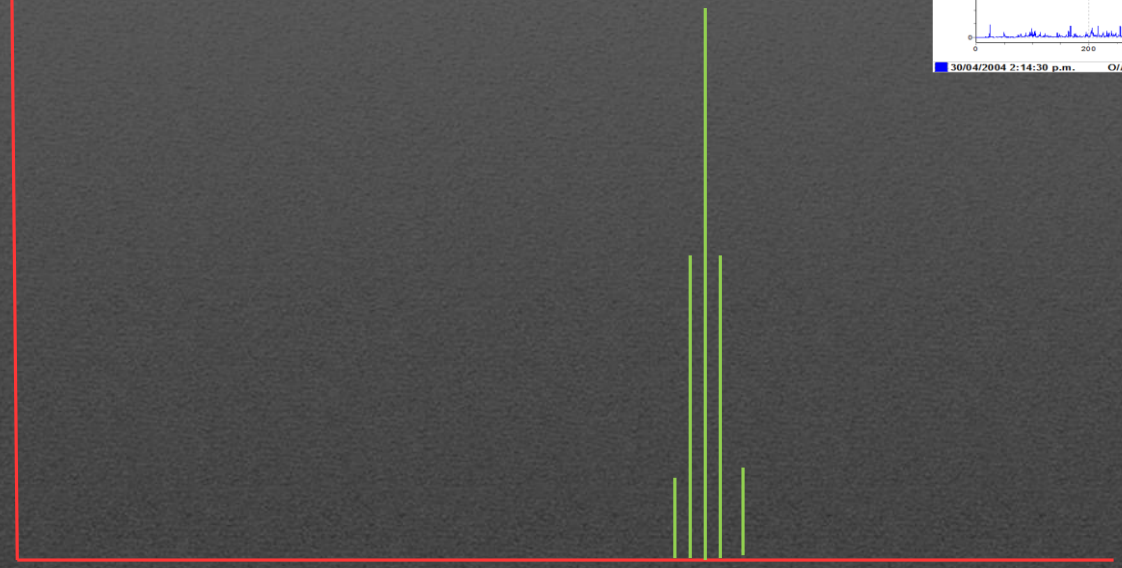


GEAR EXAMPLE

AMPLITUDE



EXAMPLE

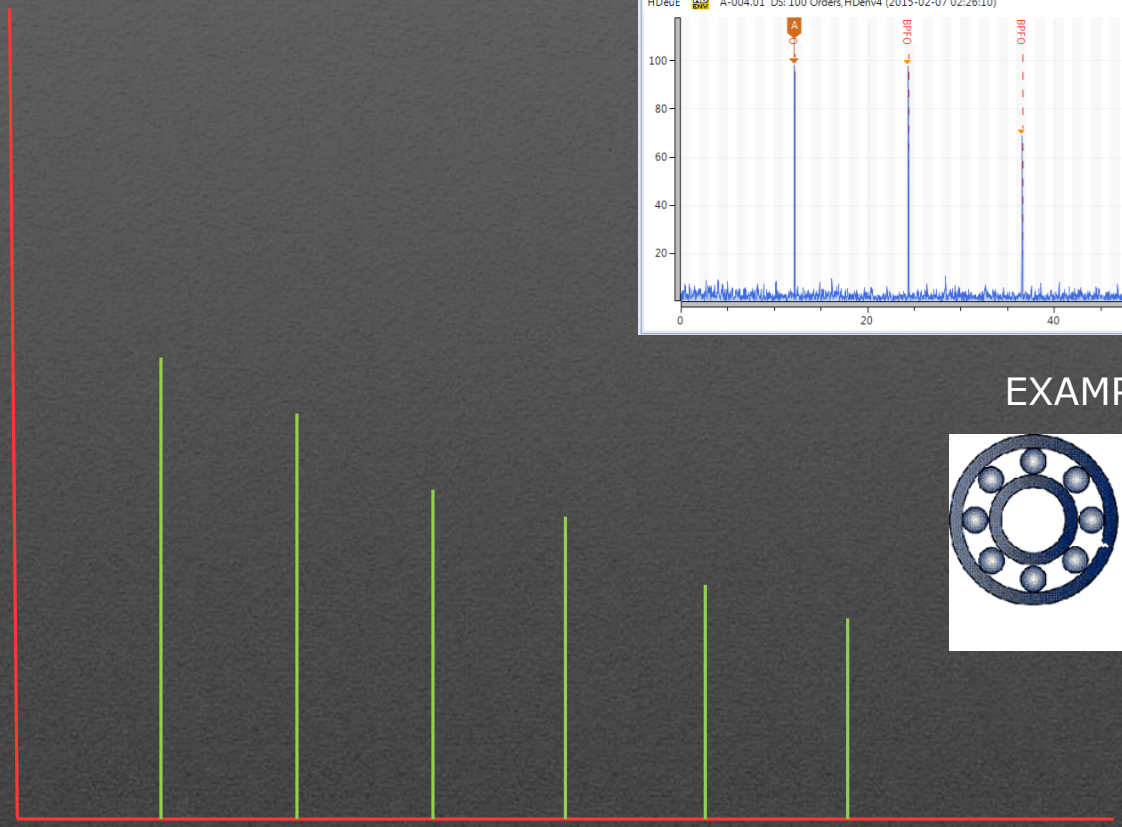


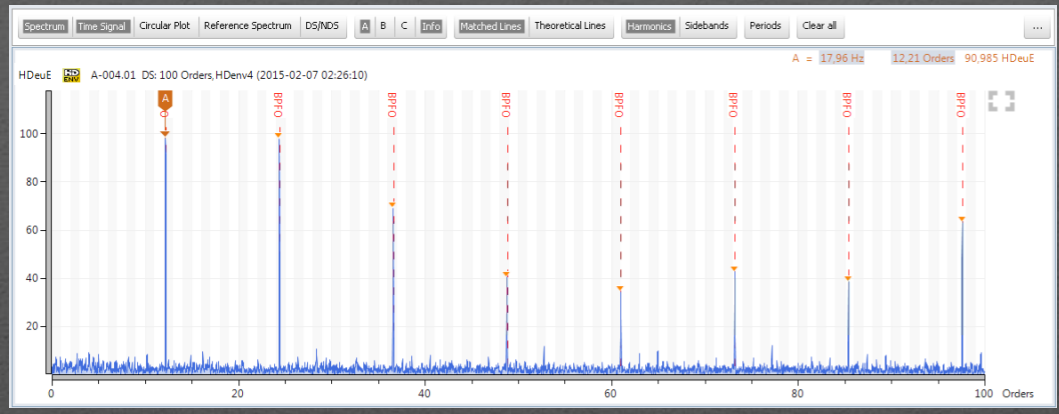
FREQUENCY

NUMBER OF TEETH X RPM = GEAR'S MESHING FREQUENCY (GMF)

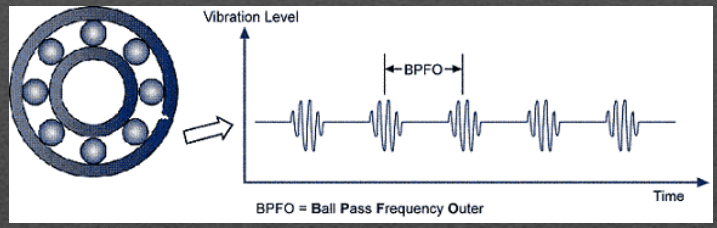
BEARING EXAMPLE

AMPLITUDE





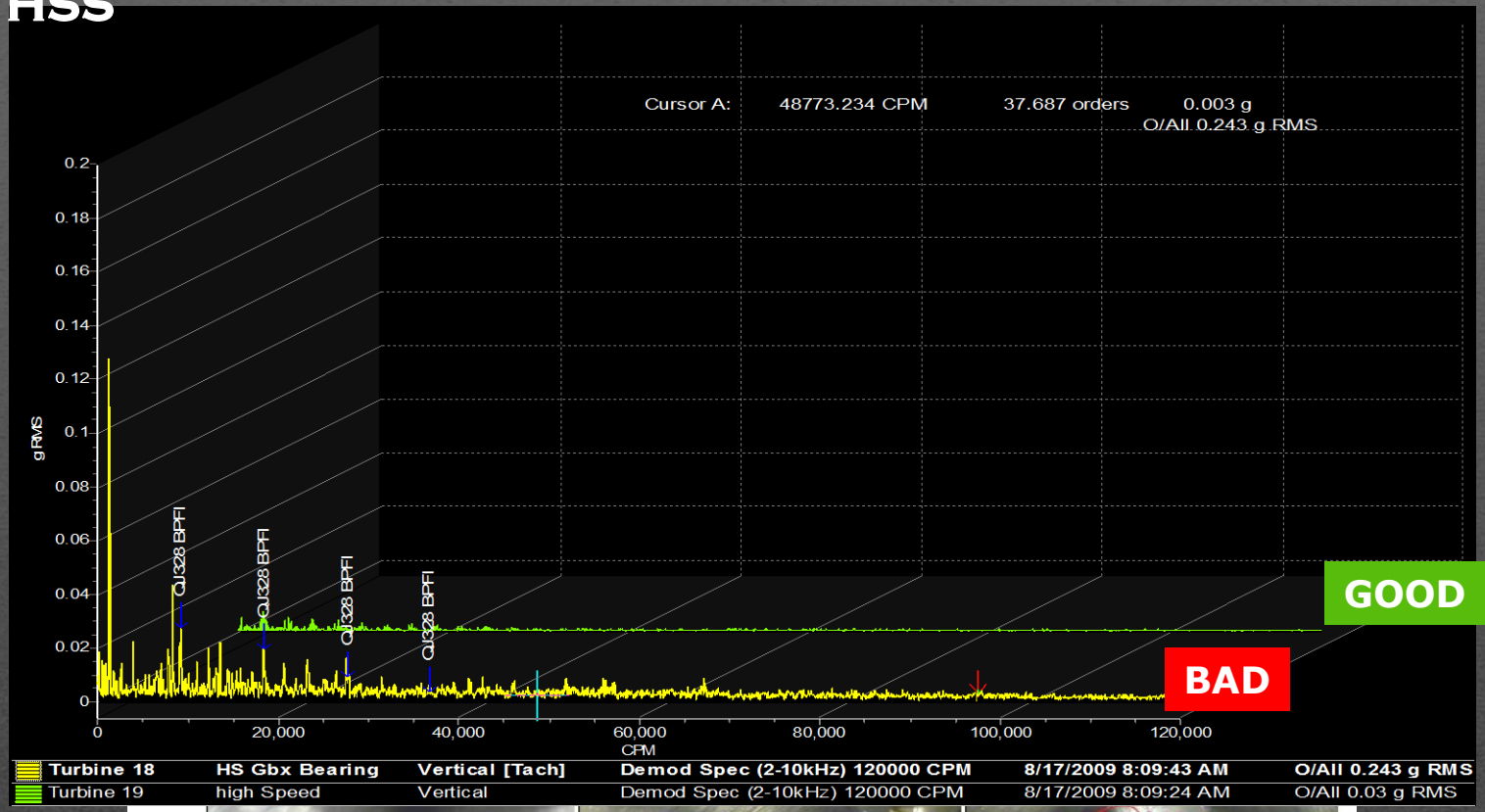
EXAMPLE



FREQUENCY

David Clark Mobius Animations.exe

COMPARISON GOOD VS. BAD HSS

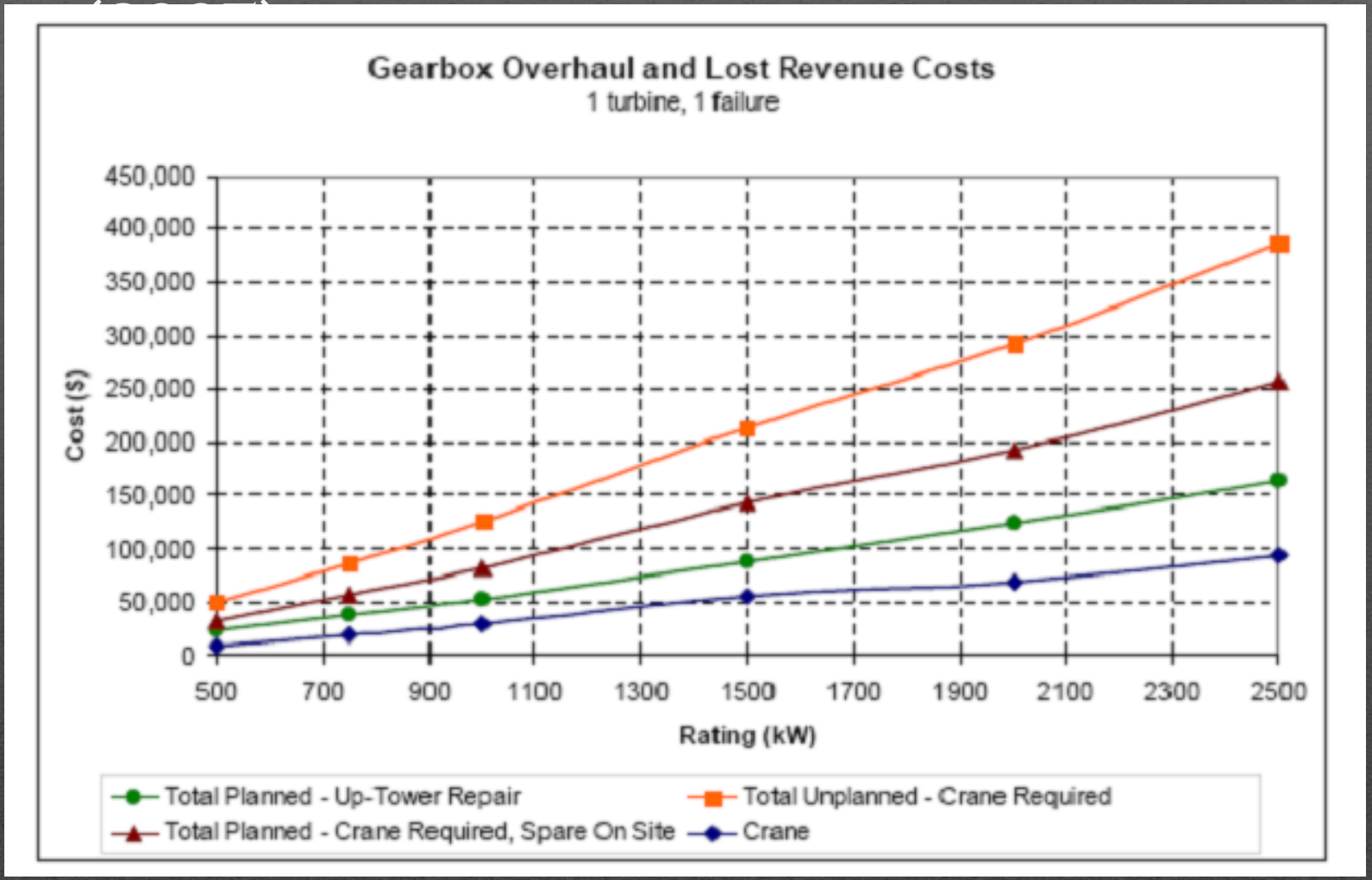


1. Rotor side High Speed 2. Rotor side High Speed 3. Rotor side High Speed

CMS

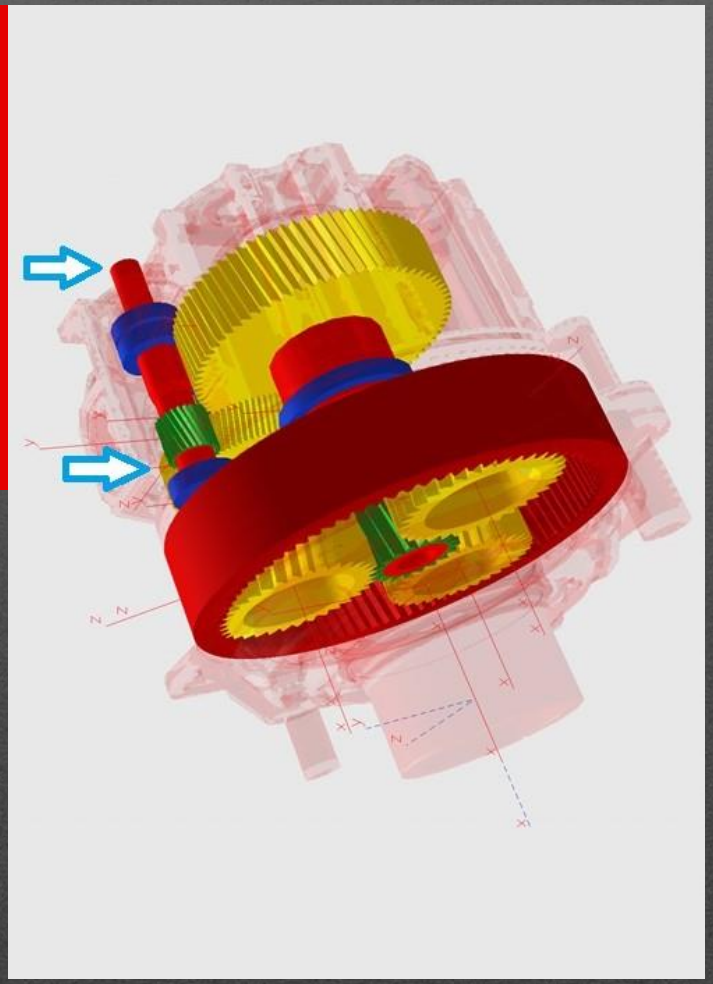
COST JUSTIFICATION

COST JUSTIFICATION, EPRI REPORT



GEARBOX, SINGLE EVENT

BACK HALF OF TYPICAL GEARBOX IS REPAIRABLE UP-TOWER



UPTOWER REPAIRS ARE TYPICALLY $12-$15,000 FOR HSS

CRANE REPAIRS EXCEED $300,000

SAVINGS OF $285,000+ PER EVENT

COST JUSTIFICATION, GEARBOX EXAMPLE

IN ONE YEAR THEY HAD 26 HIGH SPEED SHAFT FAILURES CATASTROPHICALLY

THE COST AVOIDANCE PER EVENT IS $300K+ WITH AN UP-TOWER REPAIR OF
$15,000. PER EVENT, THIS IS A SAVINGS OF ABOUT $300K.

26 X $300K = $7,800,000 IN AVOIDABLE O&M COSTS IN A SINGLE YEAR

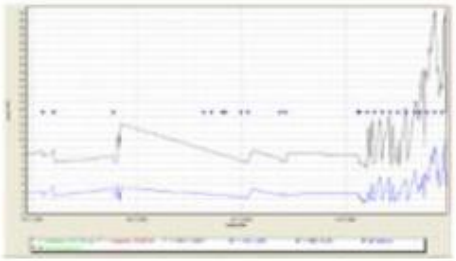
DIFFERENCE OF O&M APPROACHES IS $390,000 FOR PREDICTIVE, $7.8M FOR REACTIVE…***$7.4M DIFFERENCE***

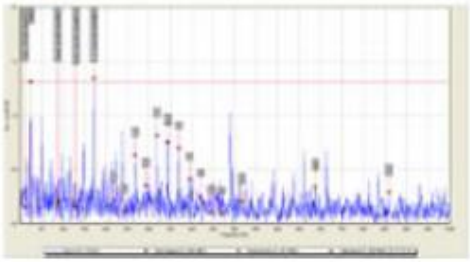
CMS PERMANENTLY INSTALLED IS $2.25-$3.5M…ONCE ON 350 WIND TURBINES

GENERATOR ROI, SINGLE EVENT EXAMPLE

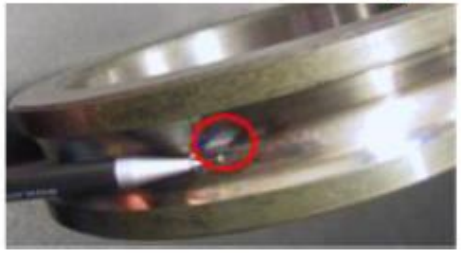
Condition Monitoring
Date : 21.12.2006
Turbine Type : 1.5 MW
Component : Generator
Damage : Bearing Drive End. Side

1. CMS Data : Trend & Spectrum





2. Photo Inner Ring



3. Costs Approach :

With CMS	
Actions conducted	Bearing changed
Real Costs	2 900 €
Real Downtime	11 hours
Without CMS	
Damages generated	Generator destroyed
Costs of the Damages (Parts & Labors)	133 000 €
Downtime	480 hours
Economy performed with CMS	
Reduction Parts & Labors	130 100 €
Reduction of Downtime	469 hours

COST JUSTIFICATION, GENERATOR EXAMPLE

EXAMPLE: TEXAS 350 WIND TURBINES

- IN ONE YEAR THEY HAD 48 GENERATOR FAILURES, *MOST* CATASTROPHICALLY
- THE COST AVOIDANCE PER EVENT IS $92K+ WITH AN UP-TOWER REPAIR OF **$6000** PER EVENT
- THIS IS A SAVINGS OF NEARLY **$86K** PER EVENT
- **48 X $86K = $4,214,000 IN AVOIDABLE O&M COSTS AND LOST PRODUCTION IN A SINGLE YEAR**
- CMS PERMANENTLY INSTALLED IS $2.25-$3.5M

COST JUSTIFICATION, SINGLE WINDFARM EXAMPLE

FACTOR w/CMS	IMPROVEMENT
- DOWNTIME (30 DAYS GBX)	50-75% REDUCTION
- REPAIR COST	30-80% REDUCTION
- CRANE GROUPINGS/ LOGISTICS CONSOLIDATION	$15,000/TOWER REDUCTION
- FREQUENCY/ # OF FAILURES	AVERAGE IS 11-16% ANNUALLY
- PPA/PTC COST PER MW/HR	ACTUAL RATE

- ON THIS SAMPLE 80 TOWER SITE, THE CMS REDUCTION EQUATED TO A YEAR ONE COST REDUCTION OF $1.8M
- $1.3M FORECASTED IN EACH YEAR THEREAFTER

70 TOWERS OVER 6 YEARS

Without CMS			With CMS					
Consequence	**COST - T€**	**Hours lost**	**Action**	**COST - T€**	**Hours needed**	**SAVINGS T€**	**Hours saved**	
Destroy Gene	60	400	Change bearings	5	12	55	388	
Destroy Gene	60	24	Change Gene	60	12	0	12	
Destroy Gearbox	180	600	Change Gearbox	90	60	90	540	
						0	0	
						0	0	
Destroy Gearbox	180	600	Change Gearbox	90	60	90	540	
						0	0	
Destroy Gearbox	180	600	Change Gearbox	90	60	90	540	
						0	0	
Destroy Gene	65	400	Change bearings	5	12	60	388	
Destroy Gene	65	400	Change bearings	5	12	60	388	
Destroy Gearbox	180	600	Change LSS Shaft	30	24	150	576	
Destroy Gearbox	180	600	Change LSS Shaft	30	24	150	576	
Destroy Gearbox	180	600	Change HSS Bearing	8	24	172	576	
Destroy Gearbox	180	600	Change IMS Bearing	6	20	174	580	
						0	0	
Destroy Gearbox	180	600	Change HSS Bearing	4	12	176	588	
Destroy Gearbox	180	600	Change IMS Bearing	6	20	174	580	
Destroy Gearbox	180	600	Change IMS Bearing	6	20	174	580	
Destroy Gearbox	180	600	Change IMS Bearing	6	20	174	580	
Destroy Gearbox	180	600	Change IMS Bearing	6	20	174	580	
Destroy Gearbox	180	600	Change HSS Bearing	4	12	176	588	
Power loss	?	?	Adjust Pitching		12			
						0	0	
						0	0	
Power loss	?	?	?					
Destroy Gearbox	180	600	Change IMS Bearing	6	20	174	580	
						0	0	
						0	0	
						2313	9180	TOTAL HOURS 981120
						2,313	MI	
			TURN OVER			103	MI	(0,07 C|kWh) Price/kWh

Total CMS reduction Spare & Labor

Total CMS reduction hours

Increase availability : 1%

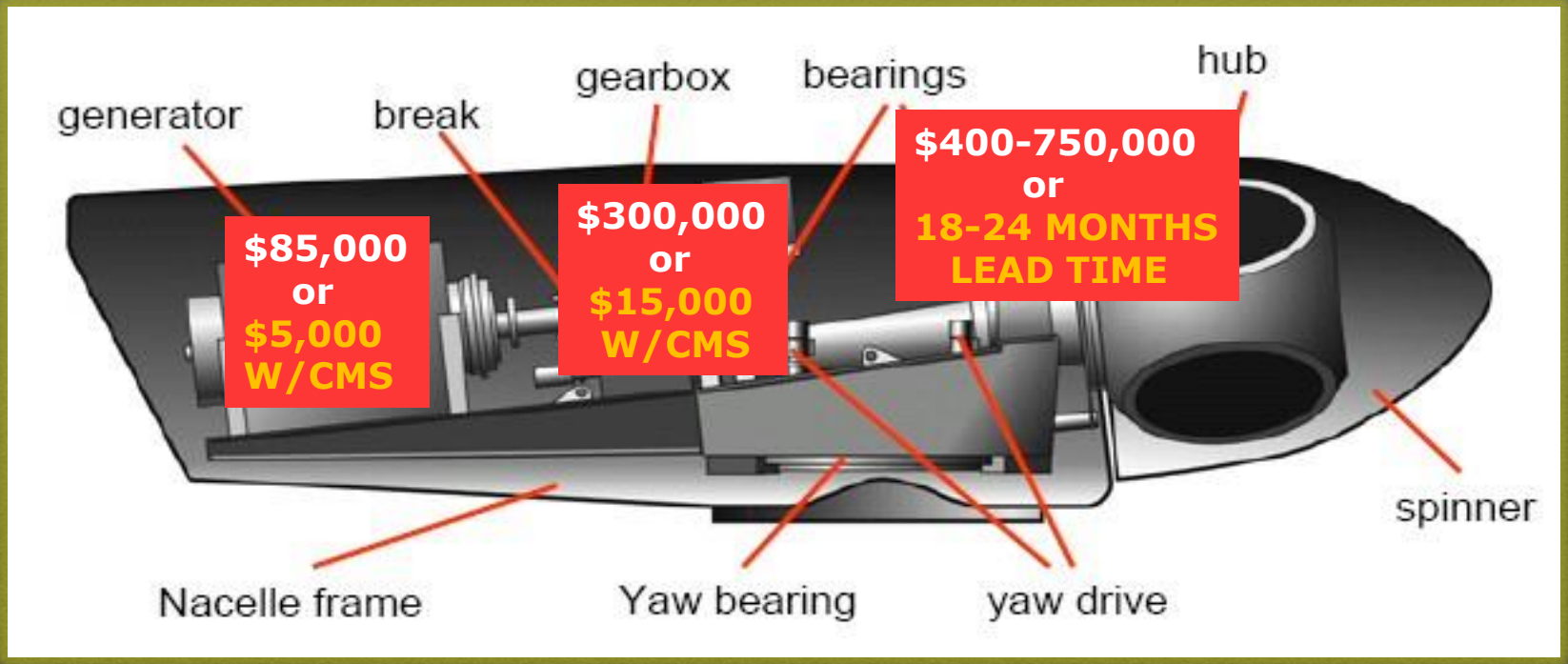
Reduce O&M costs : 2 %

Turn Over
Of the Turbines on
The Period

Total hours
Of Production of the Turbines
On the period

ON A 50 TOWER WIND FARM, ONE GEARBOX AND ONE GENERATOR SAVE DURING THE LIFE OF THE PROJECT…PAYS FOR CONDITION MONITORING

PER EVENT DIFFERENCE WITH CONDITION MONITORING SYSYEM (CMS)



THE CMS DIFFERENCES BETWEEN OTHER INDUSTRIES AND WIND

- THEY TYPICALLY DO NOT USE OEM CMS
- THEY USE SYSTEMS THAT ARE MADE FOR MULTIPLE INDUSTRIES
  FROM INDEPENDANT AND ESTABLISHED SUPPLIERS
- THOSE SUPPLIERS HAVE CORE COMPETENCY IN CMS
- EDUCATION/CERTIFICATION IS WELL SUPPORTED
- CULTURE OF PREDICTIVE MAINTENANCE IS DECADES OLD

CONDITION MONITORING CONSIDERATIONS WIND FARM OWNER

- COMMUNICATIONS UP-TOWER

- UNDERSTAND YOUR FULL SOFTWARE, MONITORING AND ON-GOING COSTS

- QUALITY OF CMS PRODUCT

- UNDERSTAND YOUR ACCESS POST FSA/POST WARRANTY

- NOT ALL CONDITION MONITORING IS THE SAME

- RFQ's RFP's MUST BE WRITTEN CAREFULLY

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QUESTIONS

CMS WIND

WIND TURBINE CONDITION MONITORING AND CONSULTING