# Design and Development Strategies for Main Gear Box Loss of Oil Performance Improvement

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EASA
European Aviation Safety Agency

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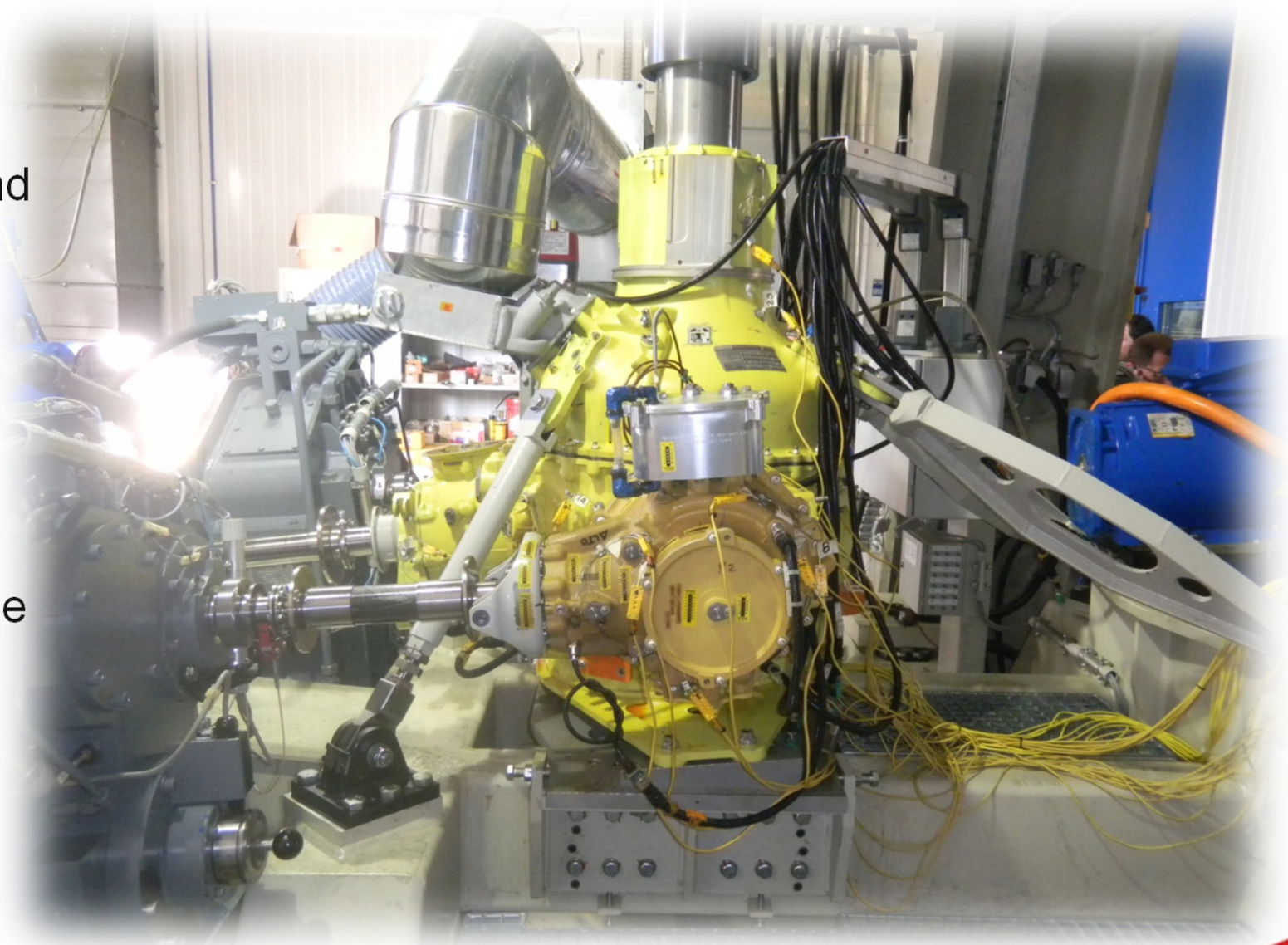
# THE **REQUIREMENT**

- EASA CS29.927(c) says that "***unless such failures are extremely remote, it must be shown by test that any failure which results in loss of lubricant in any normal use lubrication system will not prevent continued safe operation for at least 30 minutes after perception by the flight crew of the lubrication system failure or loss of lubricant***".
- Then, according to basic airworthiness requirements, a loss of lube event should be:
    1. **DETECTABLE**
    2. **NOT PREVENTING SAFE OPERATION (for at least 30 minutes)**
- Other civil or military aviation requirements present similar considerations even if formulated in different ways, or aimed to other purposes (i.e. ballistic damage tolerance).

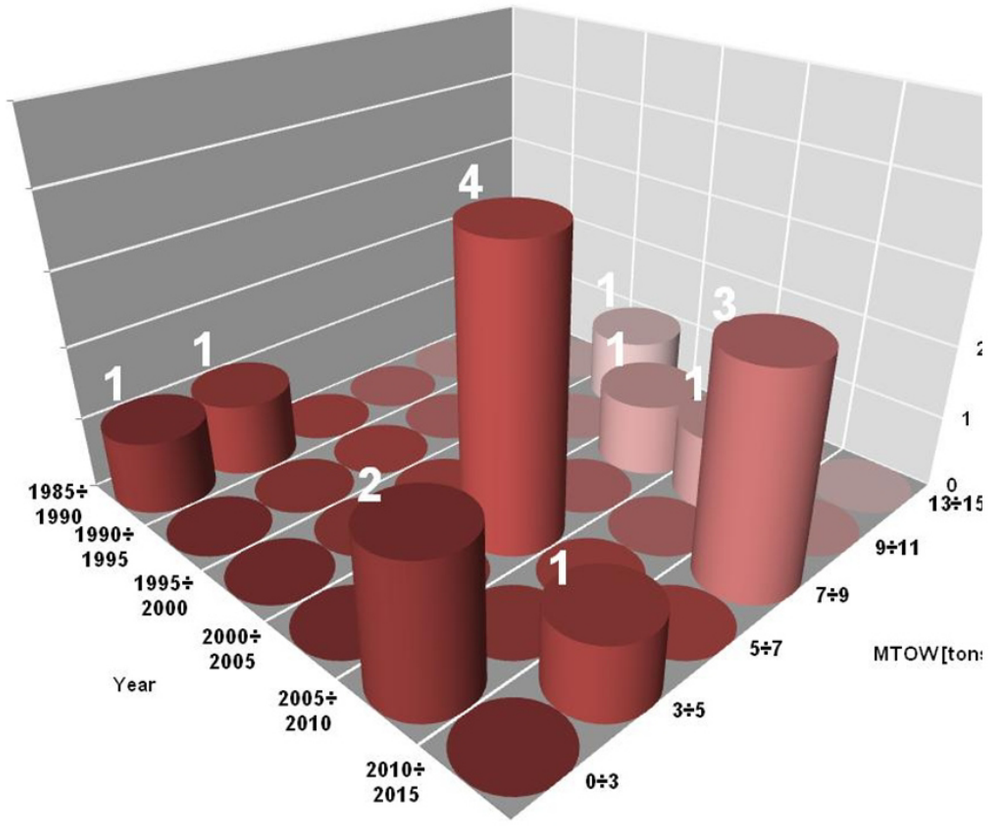
# THREE DECADES OF EXPERIENCE (1/2)

The information and data presented herein are totally derived from AgustaWestland development experience acquired during the last 30 years.

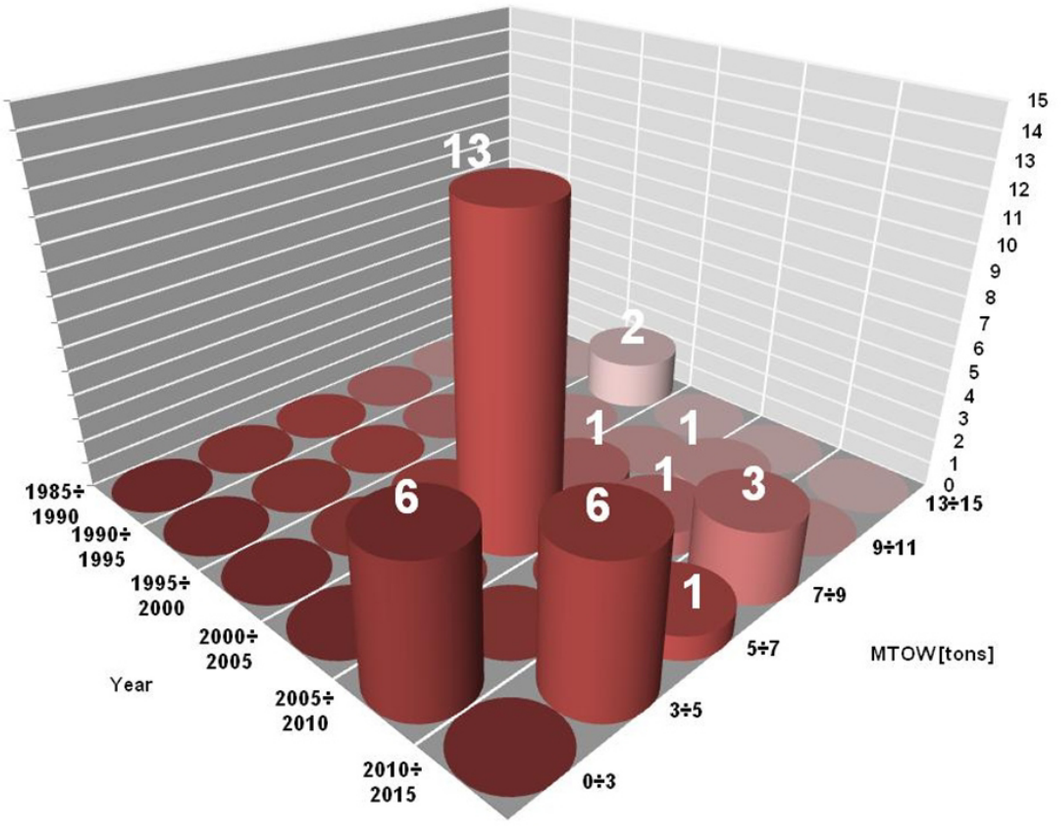


# THREE DECADES OF EXPERIENCE (2/2)

## FULL SCALE TESTING (15)

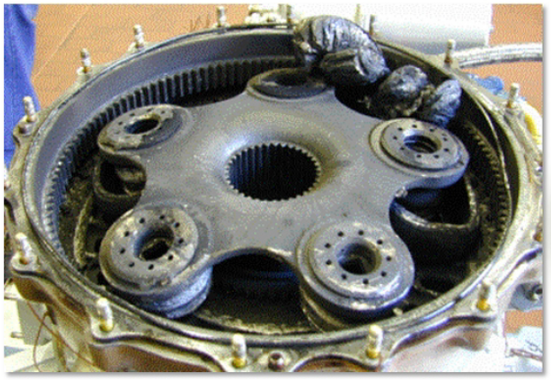


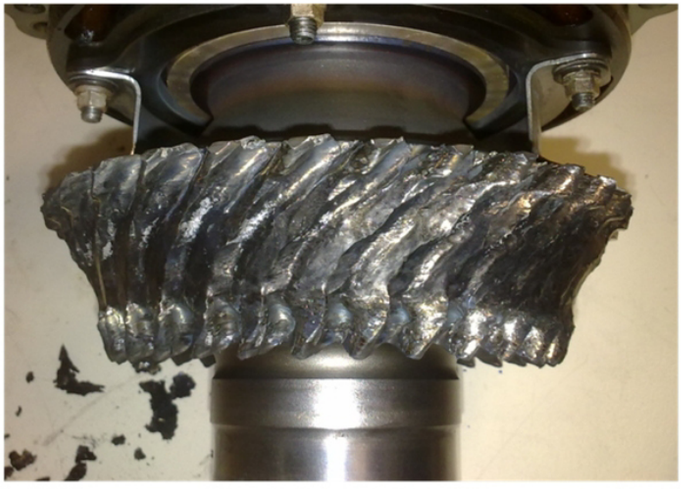

## MODULAR TESTING (34)



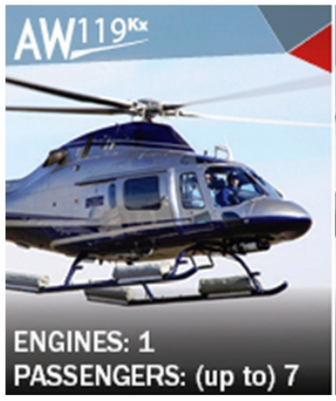

About 15 full scale tests and 34 modular tests have been carried out over the past 30 years for both certification and development purposes. Modular test approach is more widely applied since certification of AW139 helicopter, dated back in 2003.

# NOT ALL THE TESTS WERE ALWAYS SUCCESSFUL...





# FINALLY ALL **CERTIFICATION** TESTS PROVED **30 MINUTES CAPABILITY…**









## …AND MORE

Starting from 2012, with the AgustaWestland announce of the **Family and Modularity Program** for a new generation of helicopters, a different approach to the CS29.927(c) requirement lead to extended loss of oil capability for the drive system.

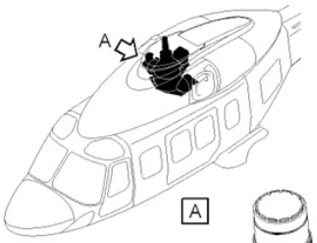
Then, based on its wide experience, AgustaWestland Transmission Department focused on the development of strategies for Main Gear Box Loss of Oil Performance Improvement.

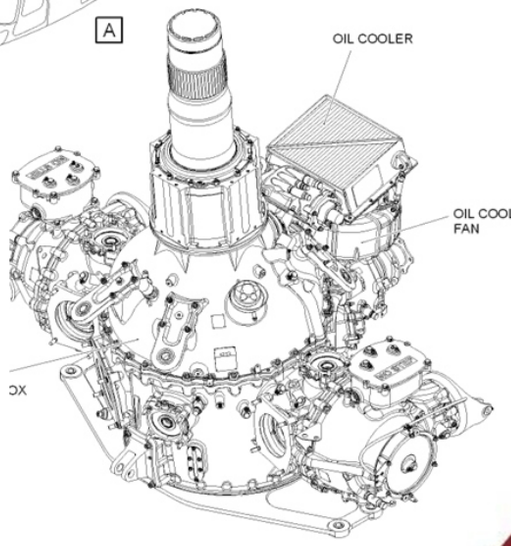
The Target is to achieve the **longest durability** after loss of oil



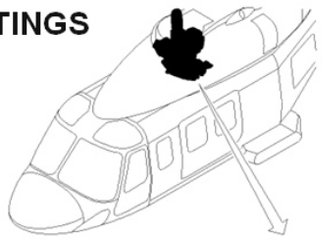
# THE MAIN GEARBOXES OF THE **AW "FAMILY"**

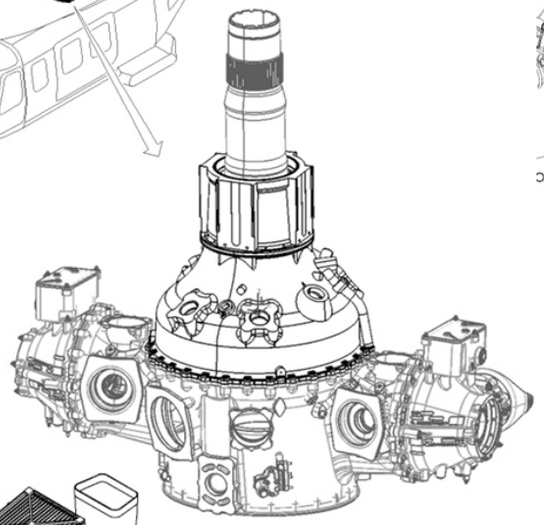
**AW189 DRIVE SYSTEM RATINGS**
**8.6 TONS ROTORCRAFT**



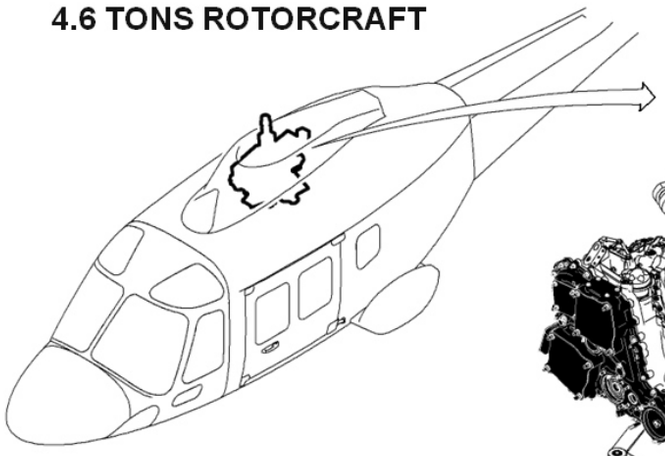



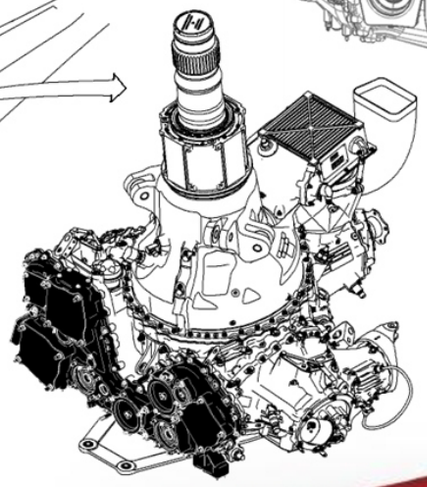

**AW139 DRIVE SYSTEM RATINGS**
**7.0 TONS ROTORCRAFT**



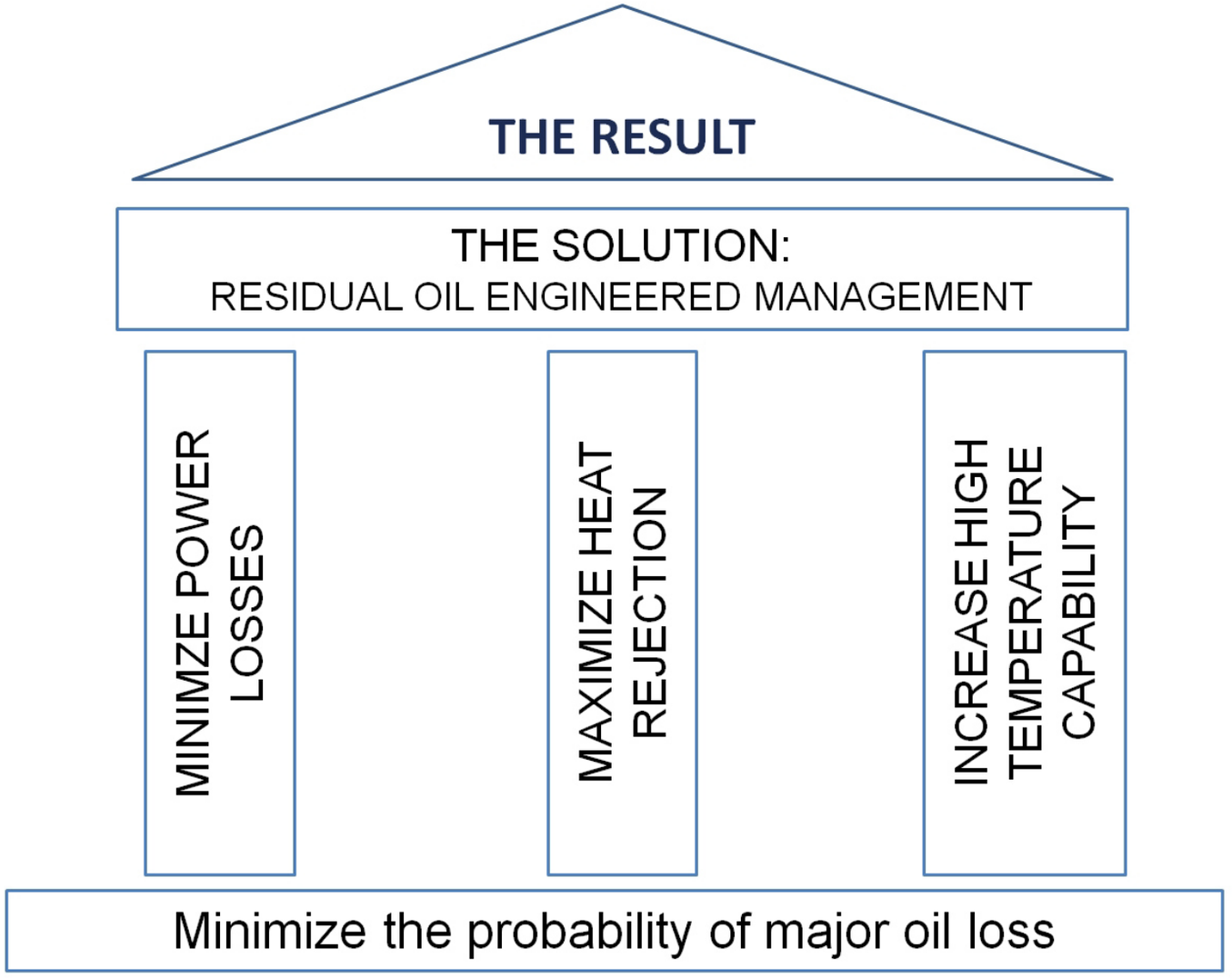


**AW169 DRIVE SYSTEM RATINGS**
**4.6 TONS ROTORCRAFT**





# THE **STRATEGY**
# to improve MGB LoL performance



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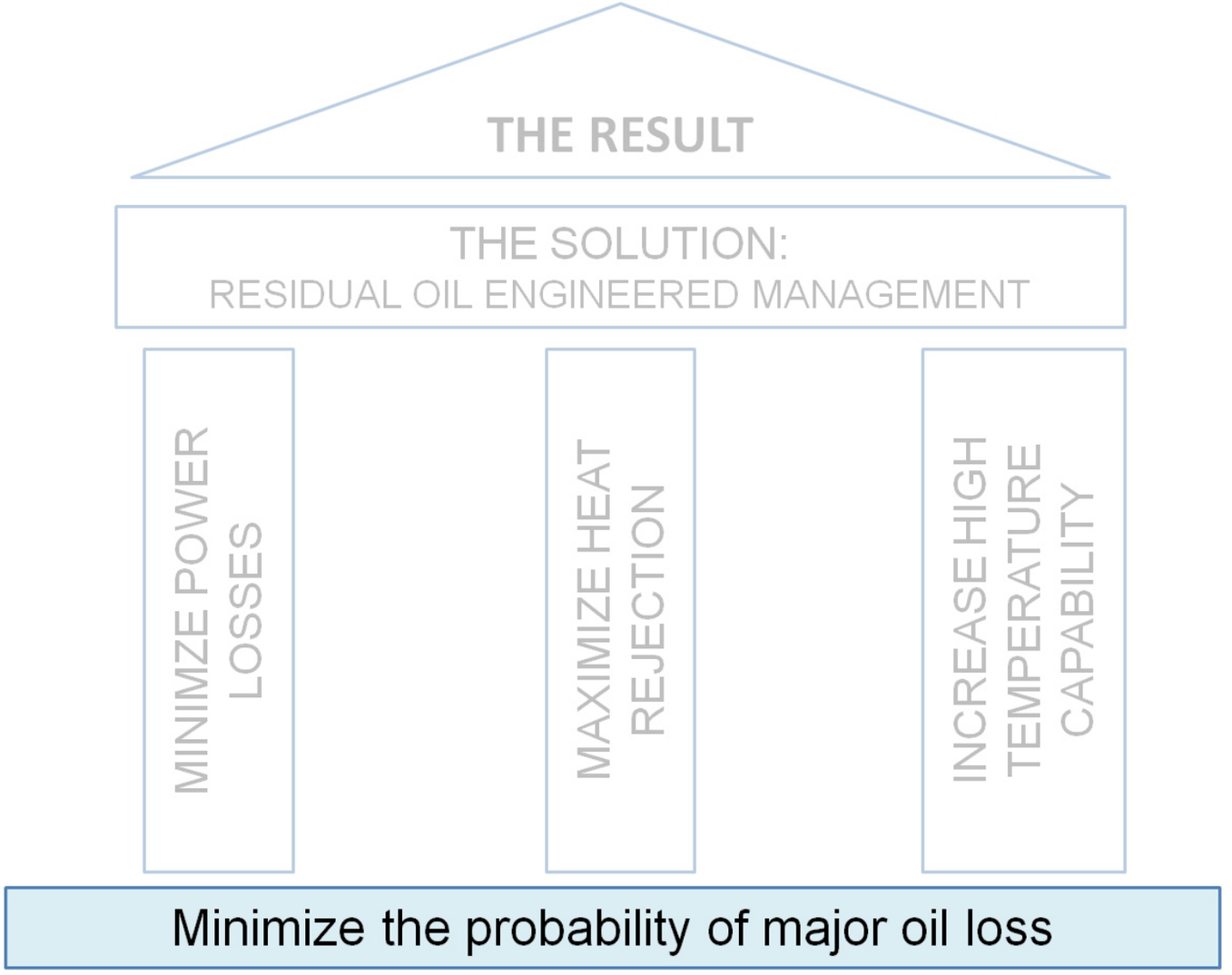
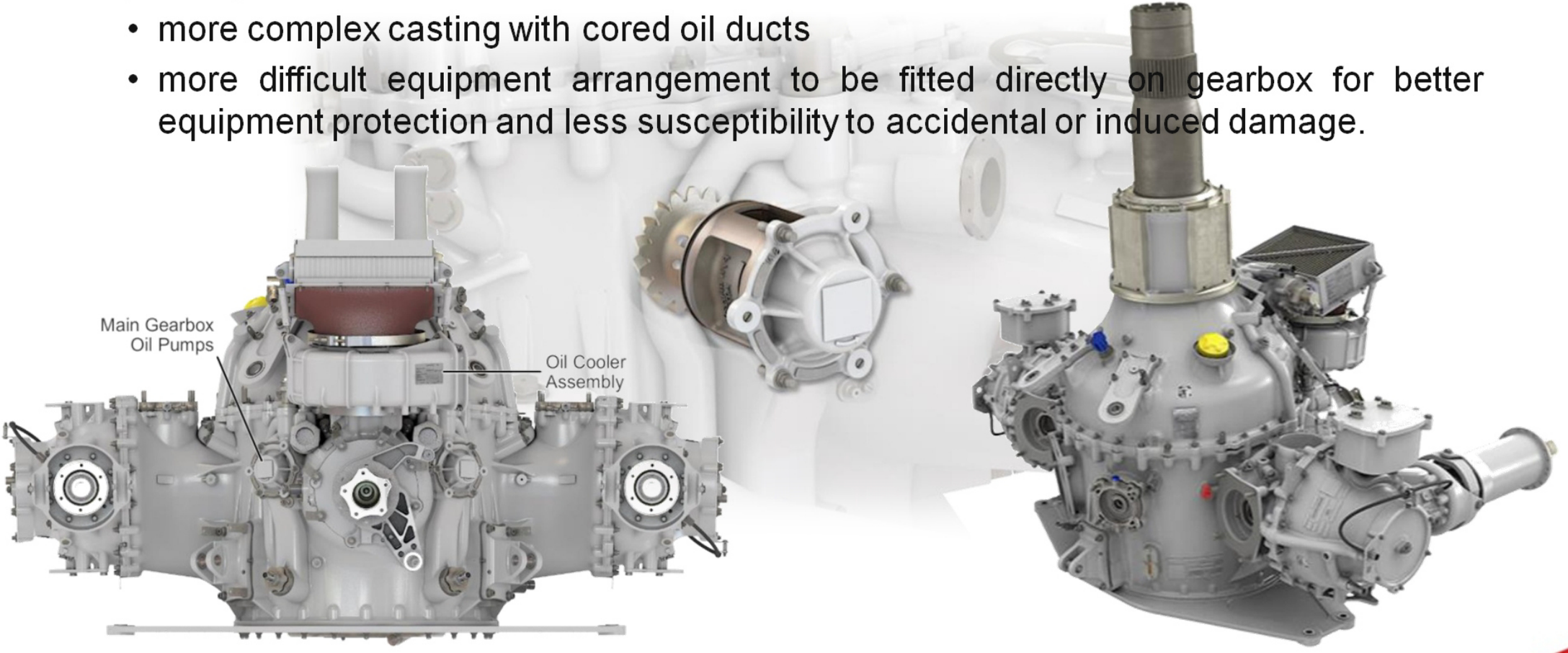


# MINMIZE THE **PROBABILITY OF MAJOR OIL LOSS** (1/2)

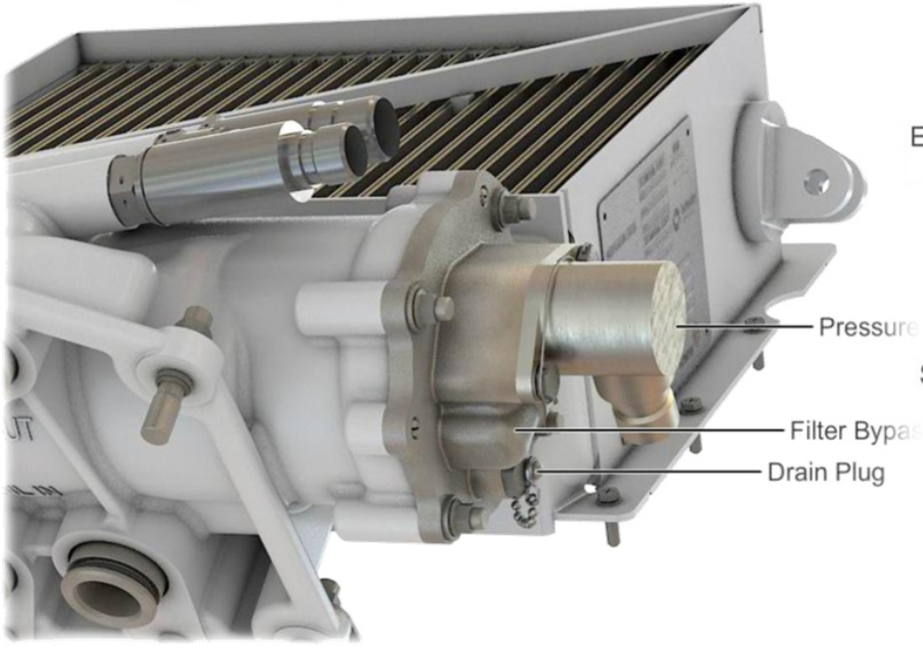
Design measures implemented in typical AW gearboxes are:

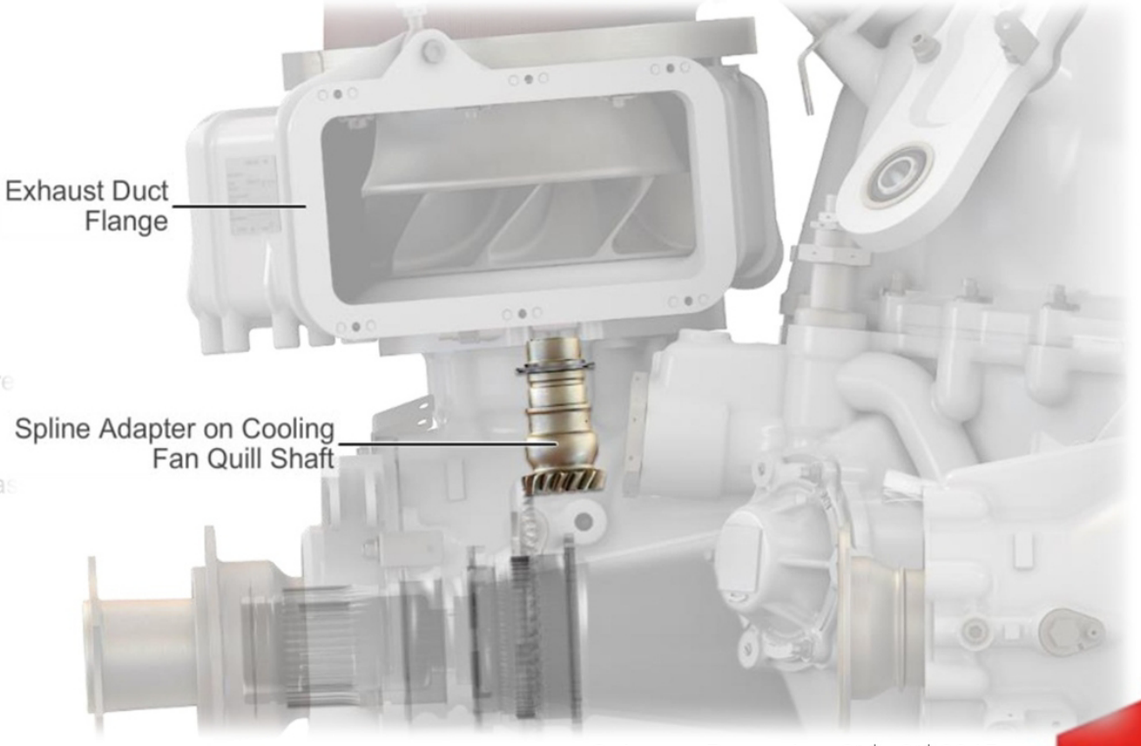
1. To avoid any external oil pipes and fittings by replacing them with **integral cored oil passages**:
   - more complex casting with cored oil ducts
   - more difficult equipment arrangement to be fitted directly on gearbox for better equipment protection and less susceptibility to accidental or induced damage.



# MINMIZE THE **PROBABILITY OF MAJOR OIL LOSS** (1/2)

2. To provide **redundancy on lubrication system supply by means of dual pumps** working in parallel.
3. To provide **fail-safe capability** on pressurized items fittings after having lost one or more fasteners.
4. To provide **independent lubrication** (sealed grease or oil) to all external equipments.
5. To prevent any **assembly error or induced damage** by means of multiple green run testing and system checks.



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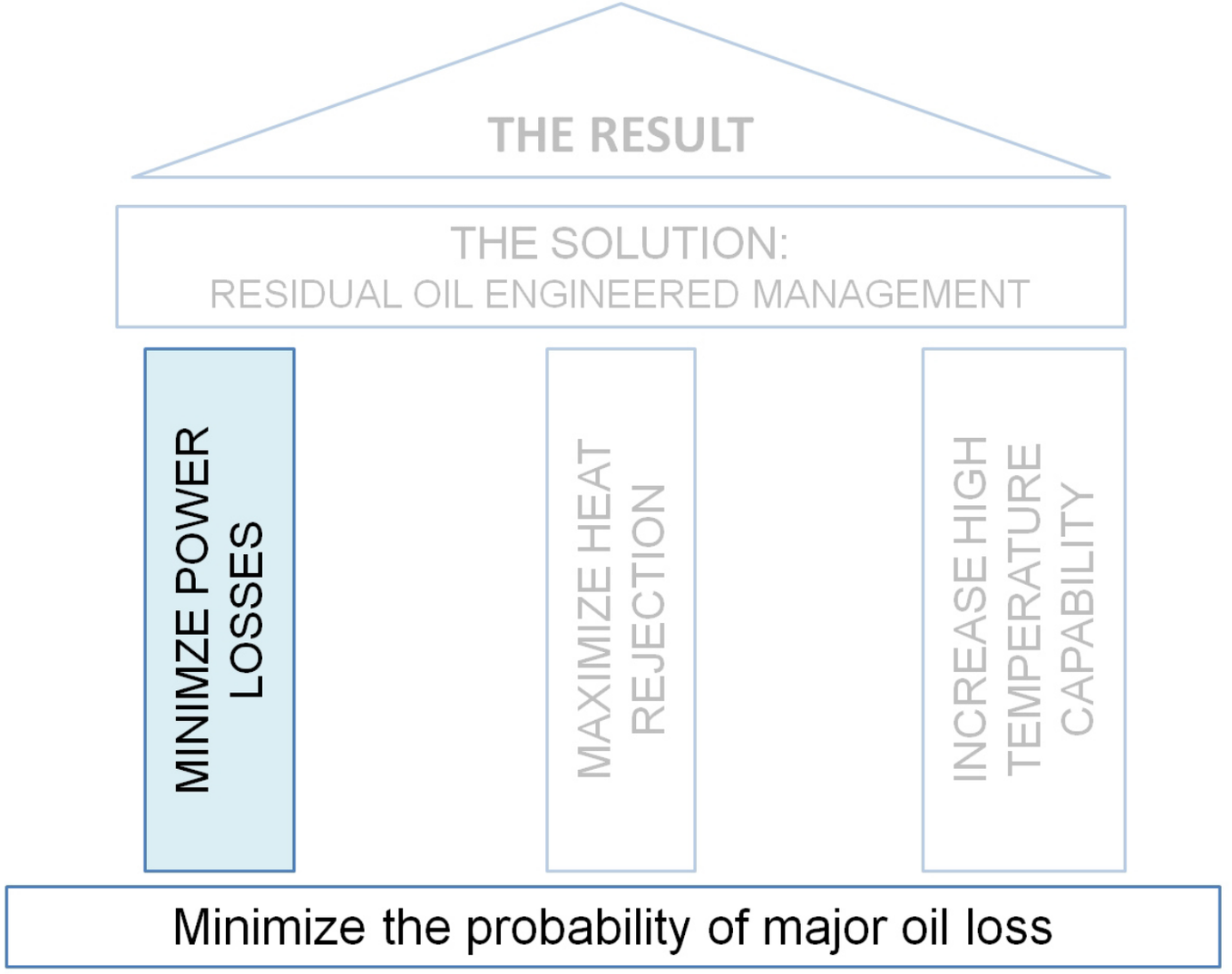
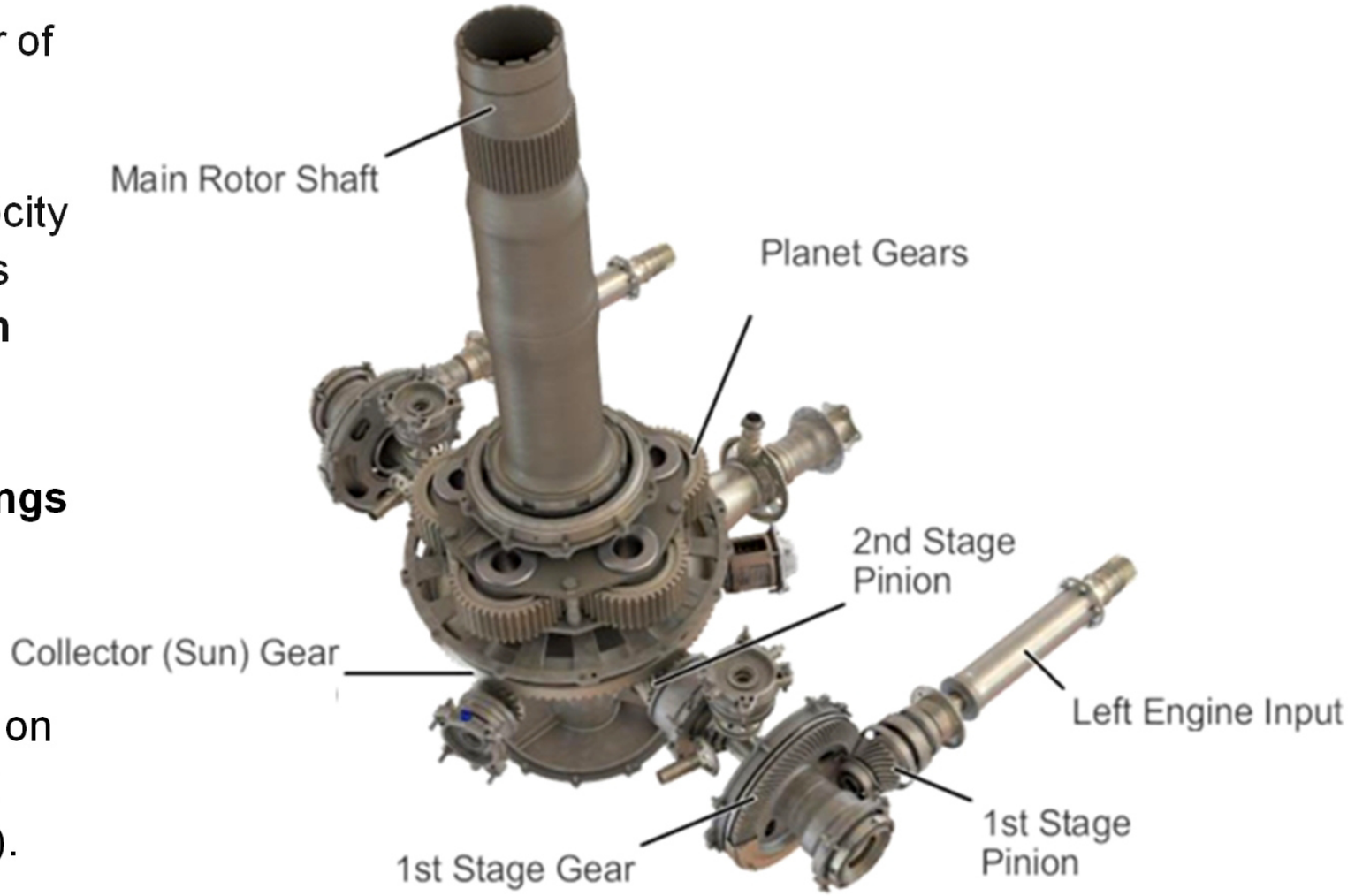


# MINIMIZING **POWER LOSSES** (1/3)

1. To reduce the number of **reduction stages**.
2. To reduce sliding velocity at the loaded contacts by adopting **fine pitch gears**.
3. To prefer **roller bearings** to ball bearings.
4. To use ball bearings **without any preload** on main power load path (only accessory drive).

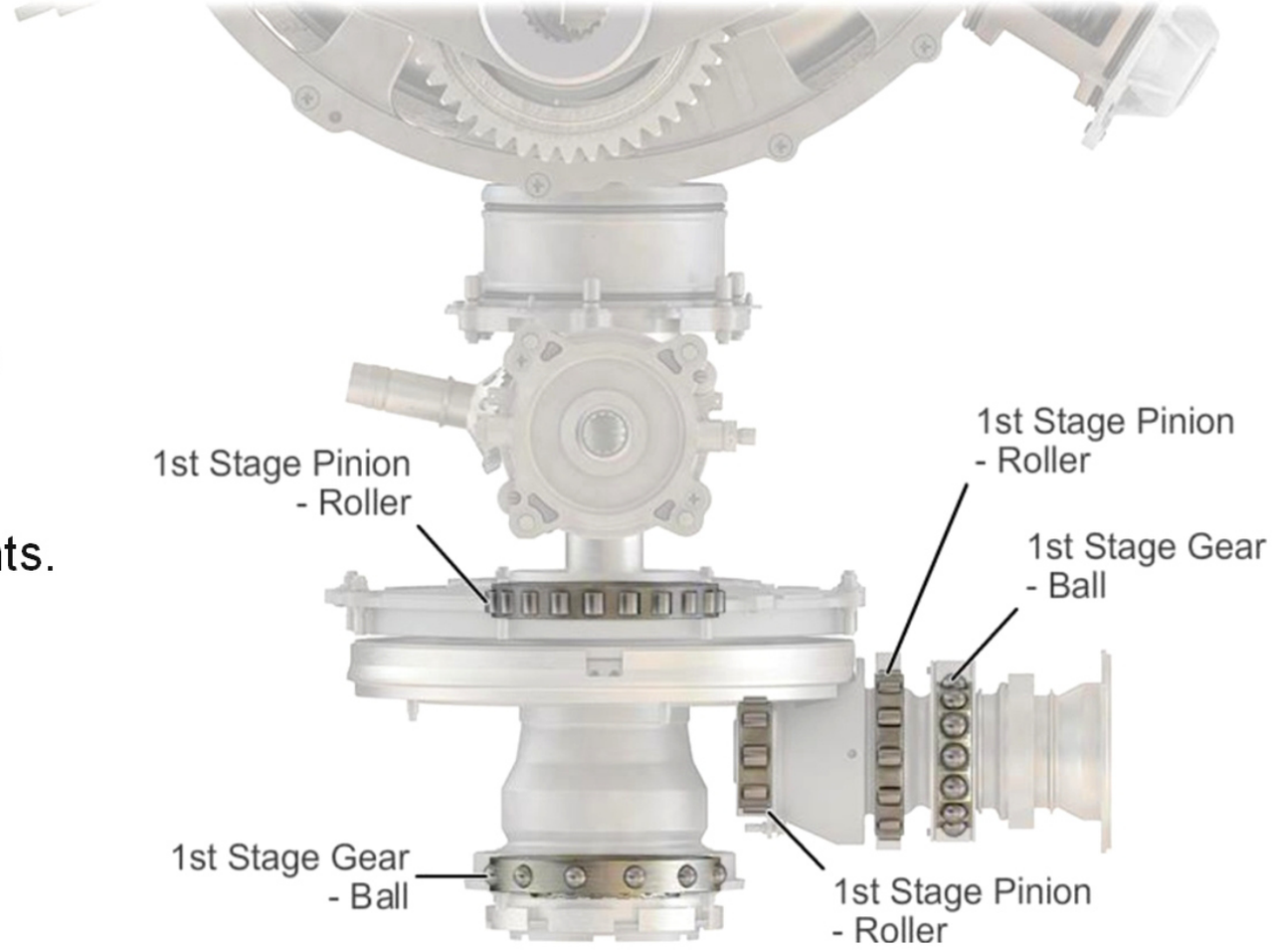


# MINIMIZING **POWER LOSSES** (2/3)

5. To avoid **journal bearings**.

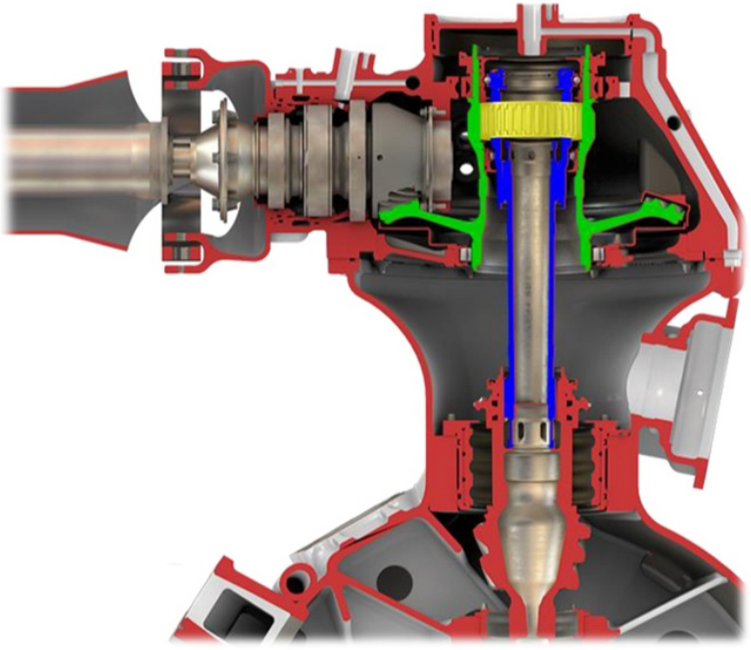
6. To avoid **tapered roller bearings** on high/moderate speed shafts.

7. Use **ceramic** rolling elements.



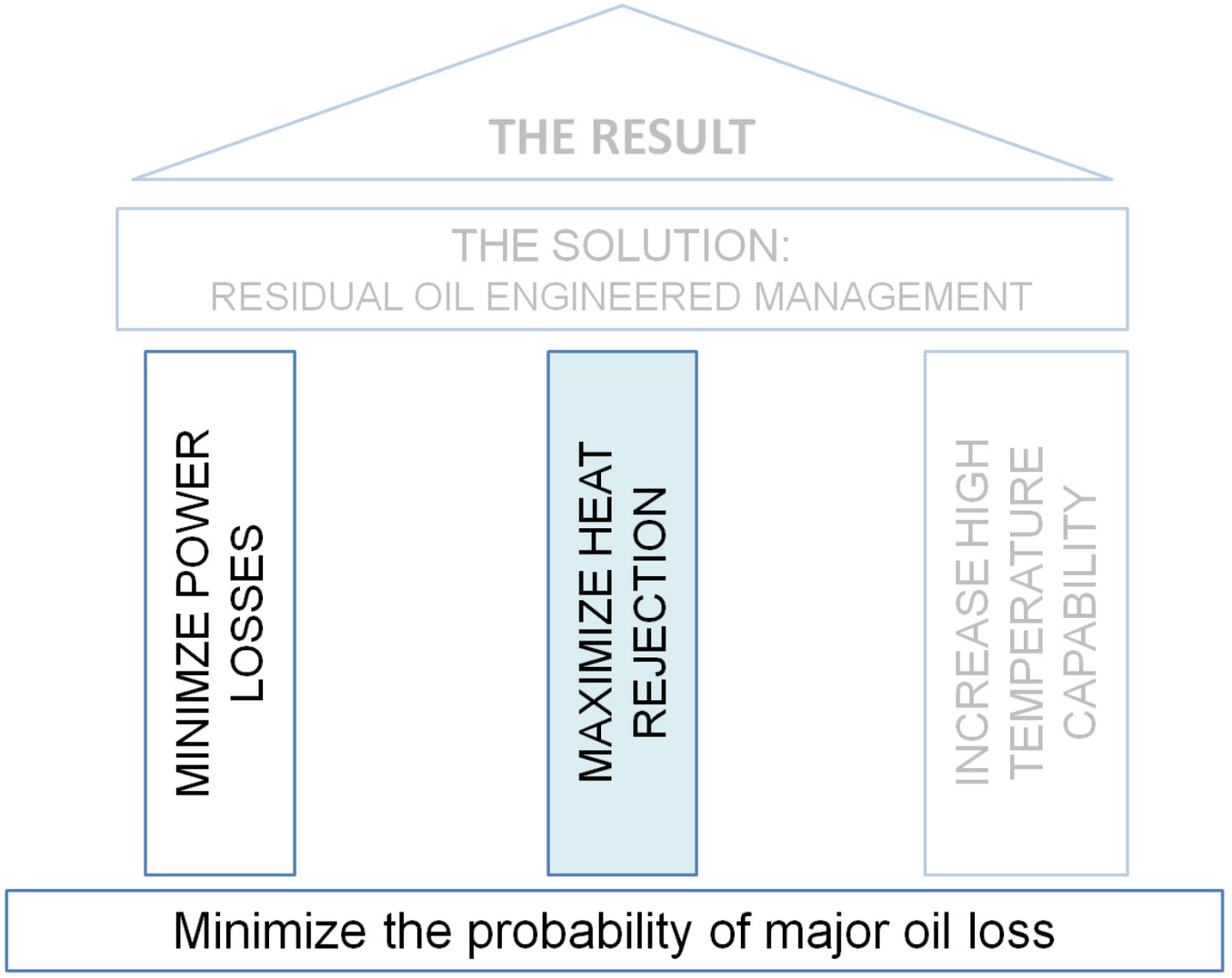
# MINIMIZING **POWER LOSSES** (3/3)

8. Improve surface finishing of gear tooth and integral bearing raceways by **fine grinding** or **super-finishing**.
9. Use **low friction coatings** on ball bearing and seal races (i.e. DLC, tungsten carbides).
10. Use shrouds on first reduction stage gear tooth to reduce **windage losses**;



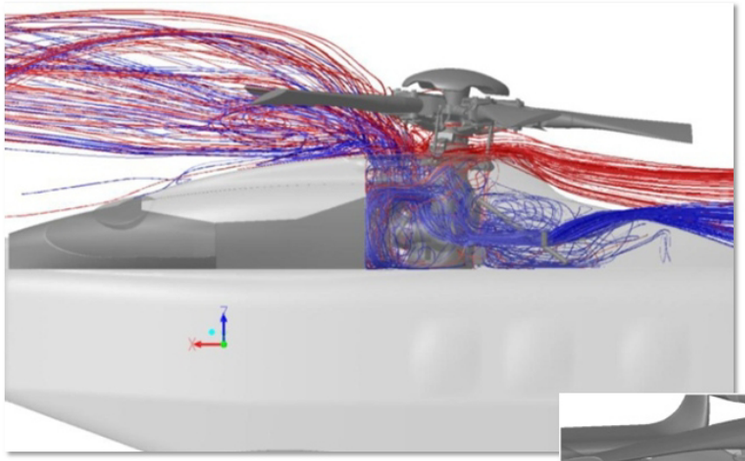
Application of all these design features allowed the AW189 MGB to achieve an overall transmission efficiency up to **96.5%** at min cruise power (LoL test condition).

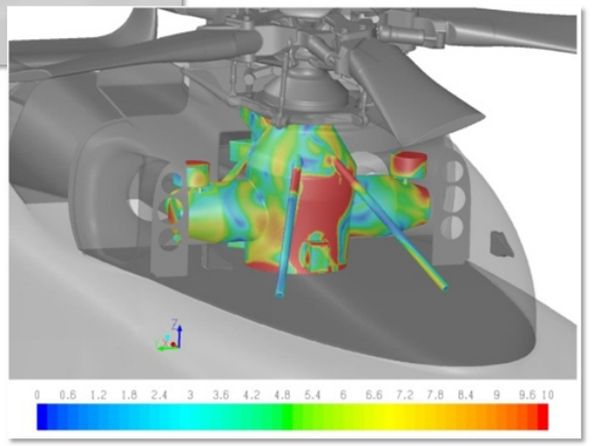
# THE **STRATEGY**
# to improve MGB LoL performance



# MAXIMIZING **HEAT REJECTION**

1. By improving **ventilation** in the transmission bay to increase also convective heat rejection when the oil flow through the heat exchanger is lost (10% of produced heat is normally rejected by convective exchange)

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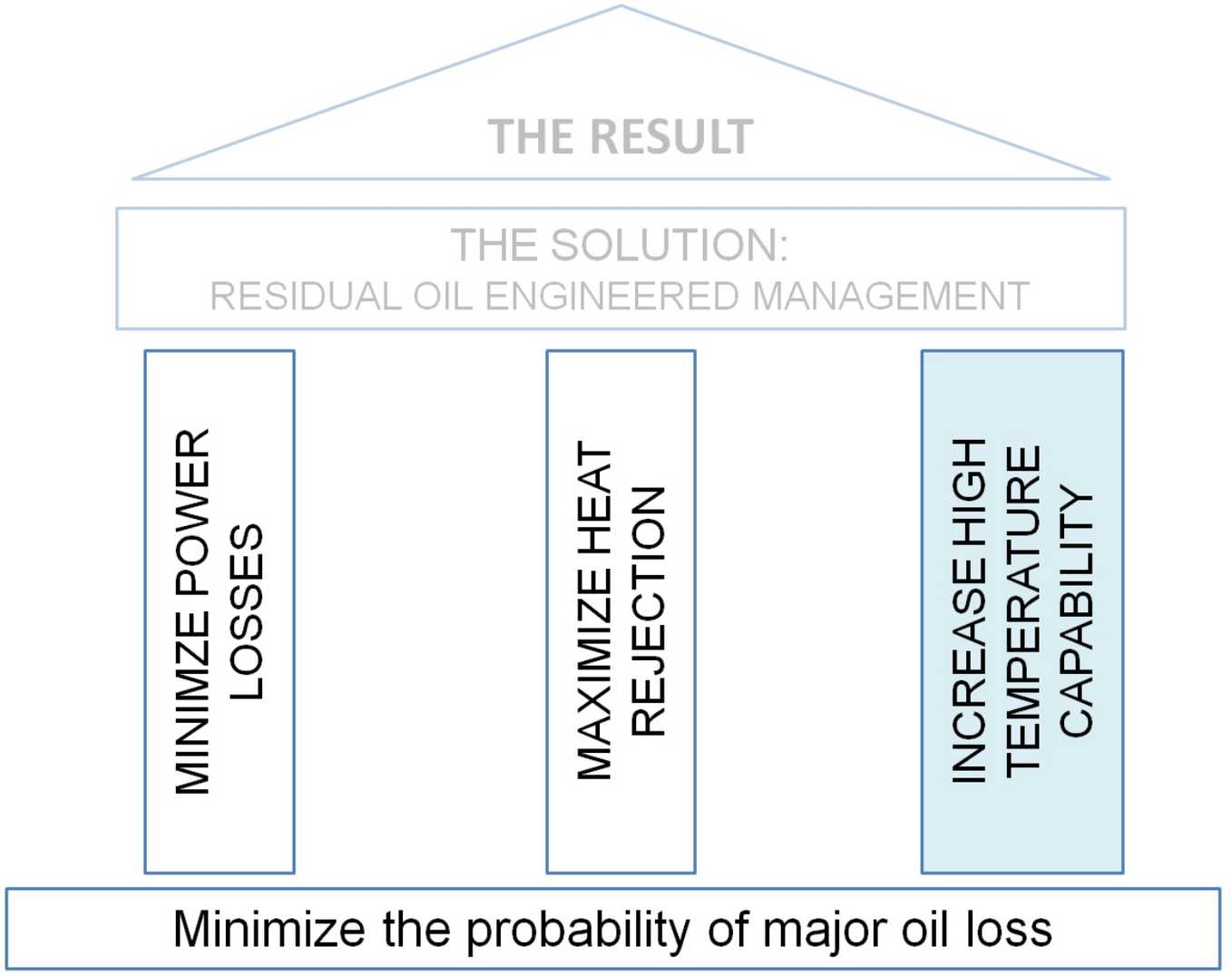


# INCREASE **HIGH TEMPERATURE CAPABILITY** (1/2)

1. **Maintaining clearances, plays and backlashes throughout the highest expected temperatures** is another design measure to increase the operating endurance after loss of oil.

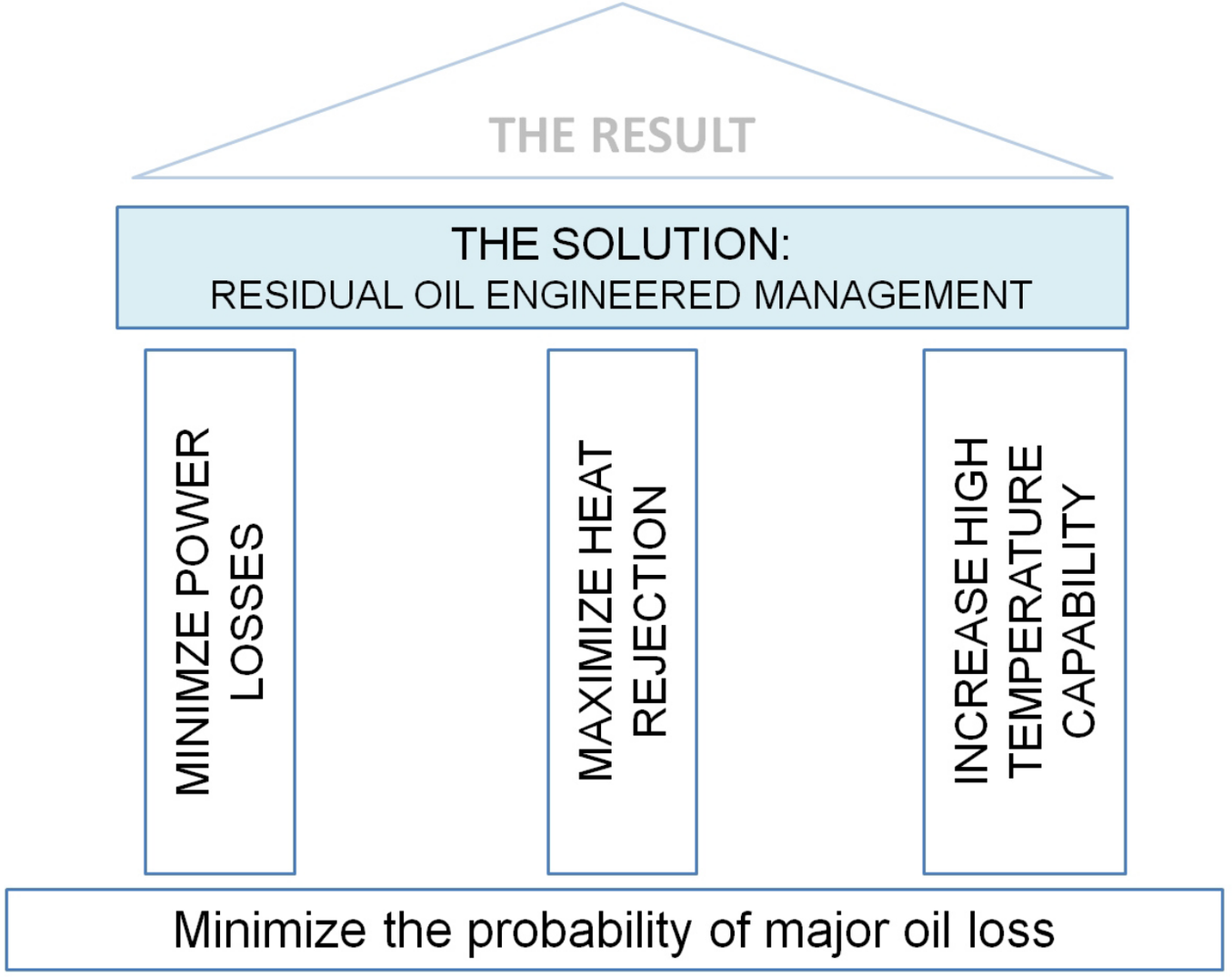
2. Loss of clearance on gear tooth and bearings is likely to generate unwanted tightness causing uncontrolled increase of contact forces (even with moderate axial loading).

# INCREASE **HIGH TEMPERATURE CAPABILITY** (2/2)

3. **Adoption of high hot hardness ($H^3$) materials for gear and bearings** such that they maintain original size, shape and roughness up to the highest temperature is another key factor for stable operating condition. Bearings made in M50/M50-NIL and gears made in Pyrowear steel (EX53), Vasco Jet or nitriding steel are able to withstand operating temperatures up to 350°C without dramatically losing their hardness.

4. **Optimization of bearing cages** which otherwise may loss mechanical properties resulting in a catastrophic failure (loss of drive). Heat tolerant silver plated steel cages must be preferred on main load drive path.

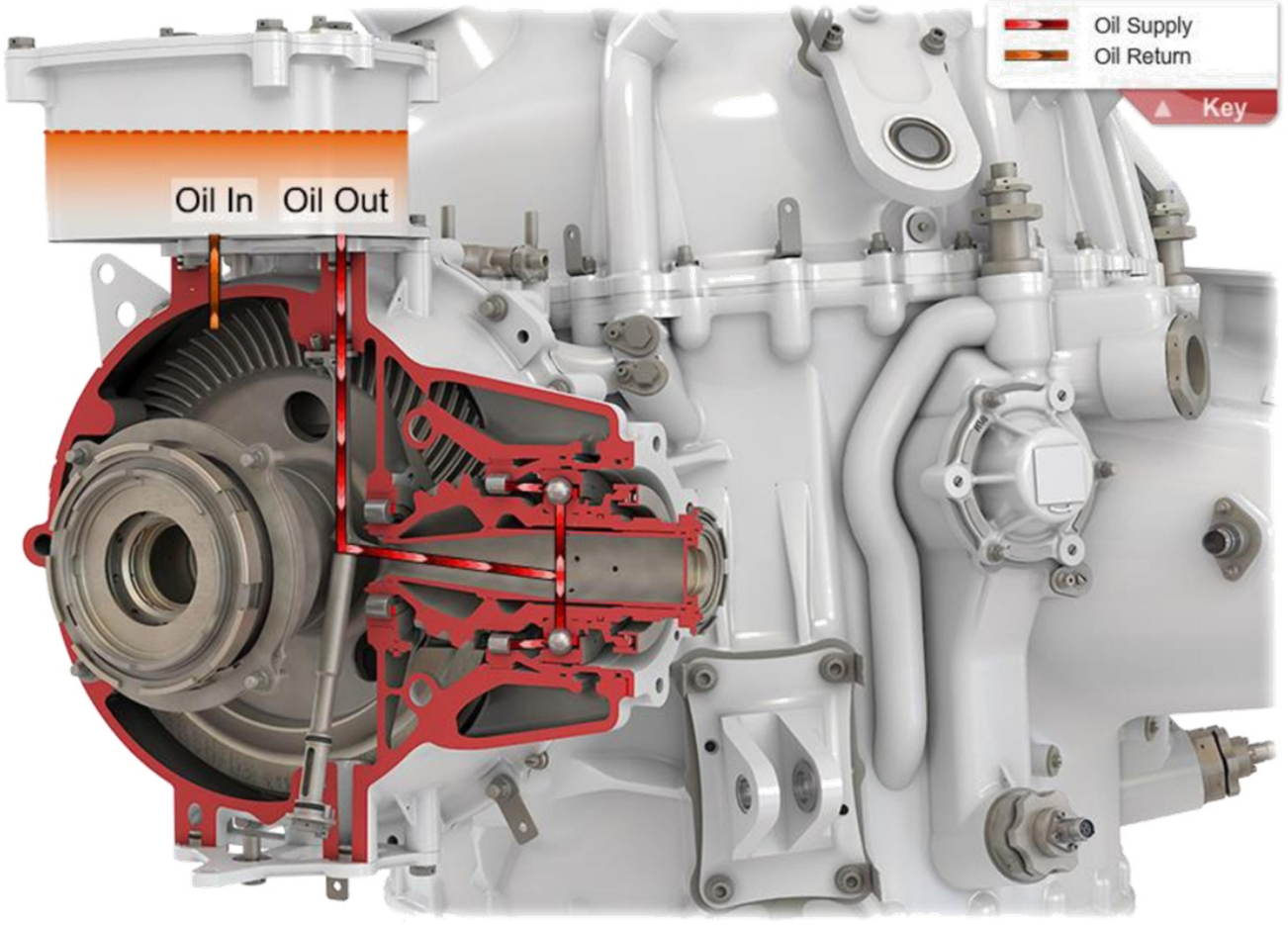
# THE **STRATEGY**
# to improve MGB LoL performance



# THE SOLUTION:

# RESIDUAL OIL ENGINEERED MANAGEMENT

- **Reduced Failure Probability**
- **Transmission System Intrinsic Capability**
- **Residual Oil Quantity**
- **Optimized Dripping Rate**
- **Passive Oil Dripping**



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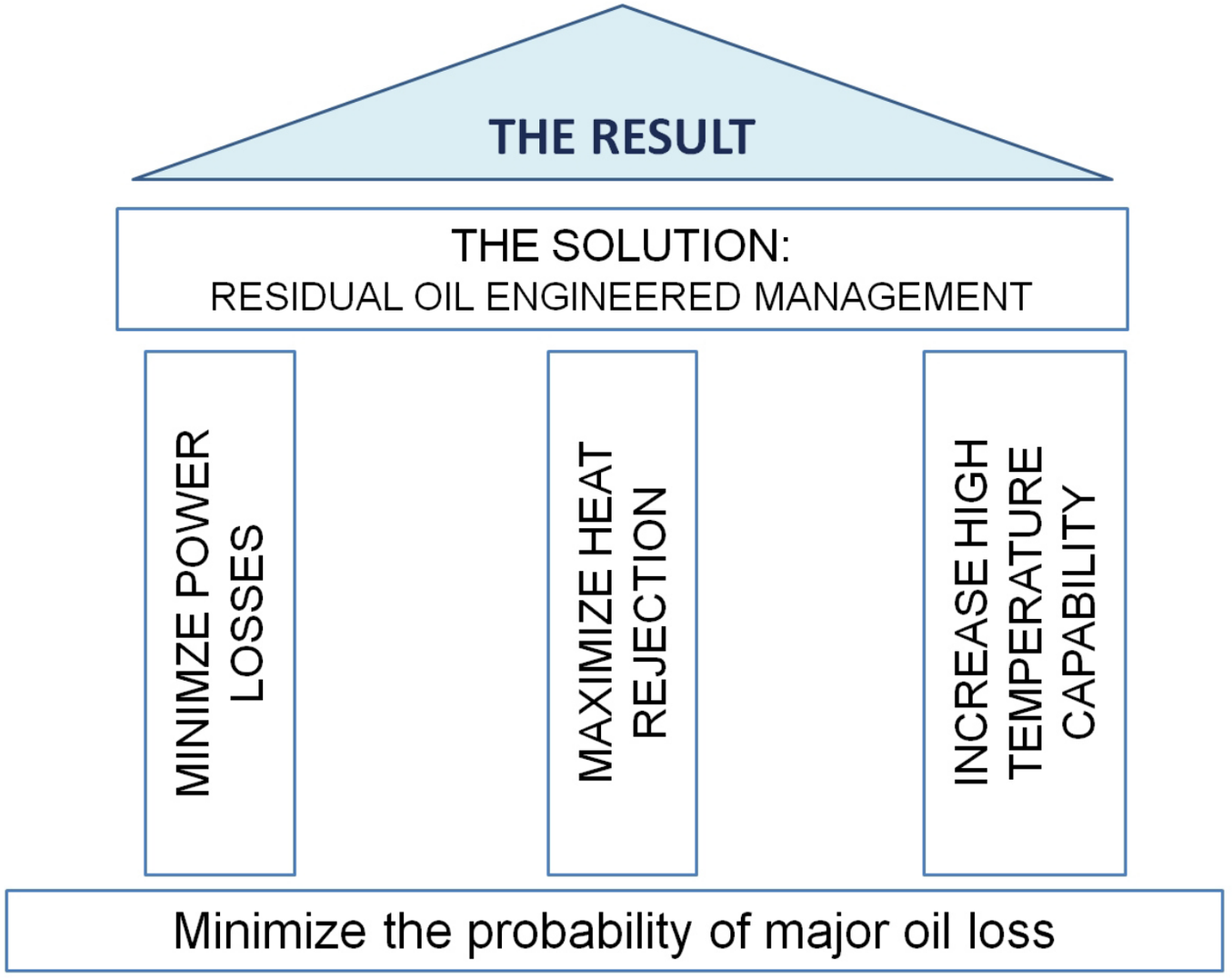
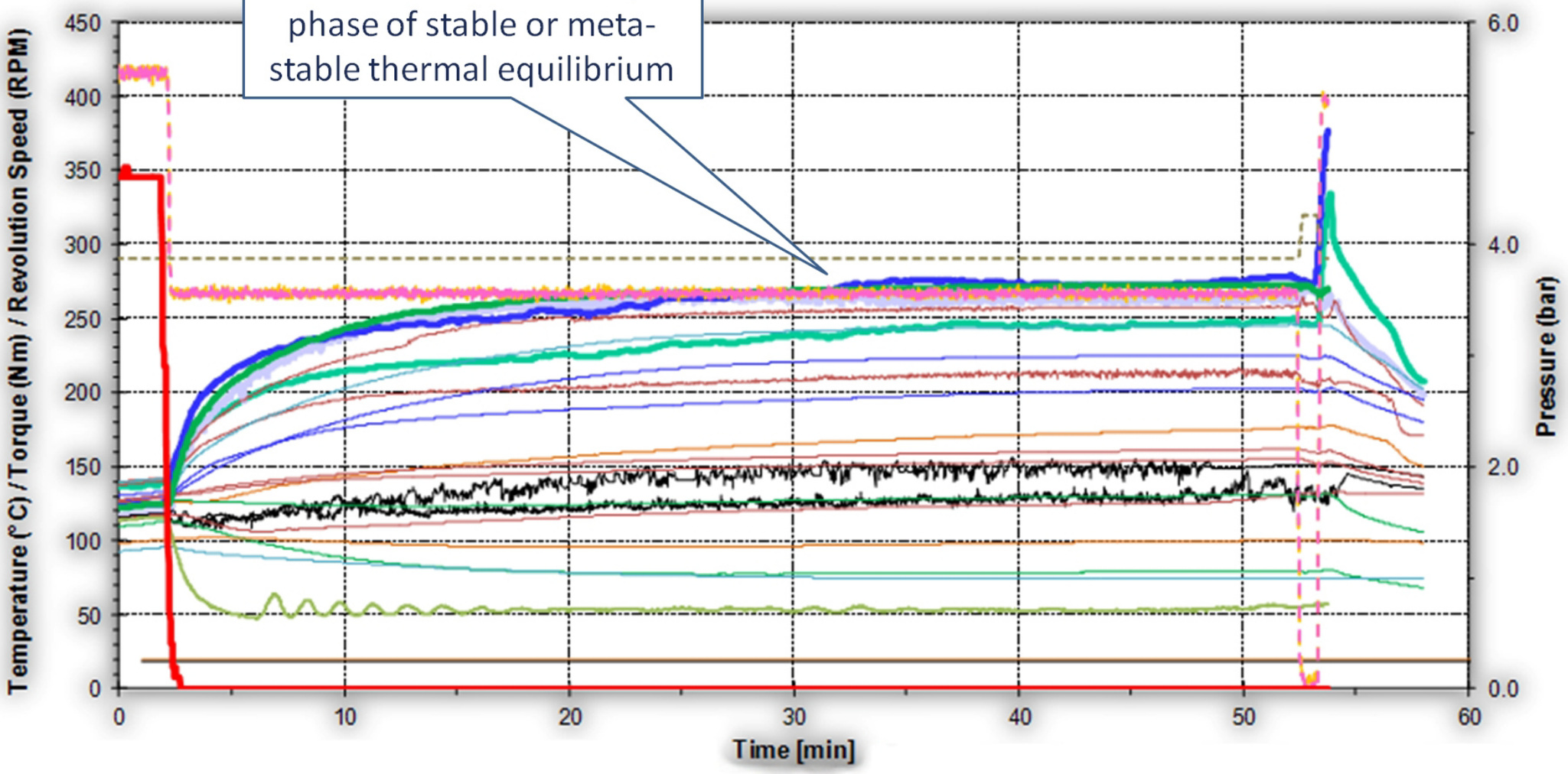
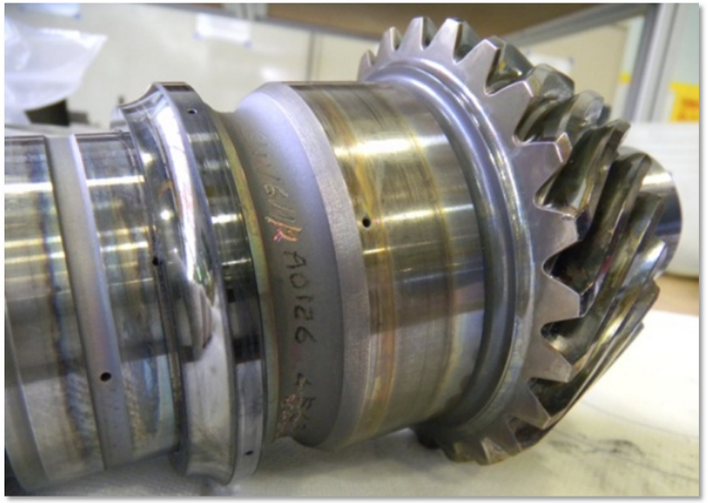


# THE RESULT (1/2)

**AW189 MGB**
Official LoL Test
Cascina Costa, October 2012



# THE RESULT (2/2)



# NEXT STEPS

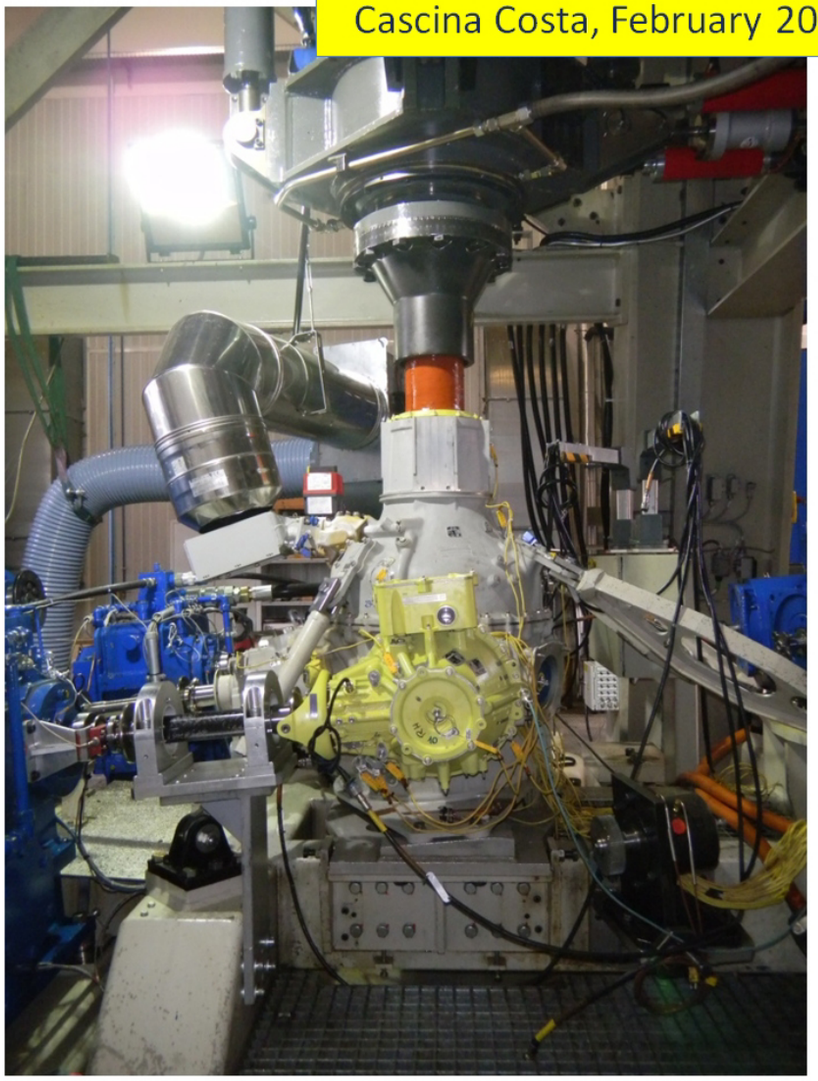
1. AW139+

**AgustaWestland Sets New Safety Benchmark for Helicopter Gearboxes with a 60+ Minutes "Run Dry" Capability**

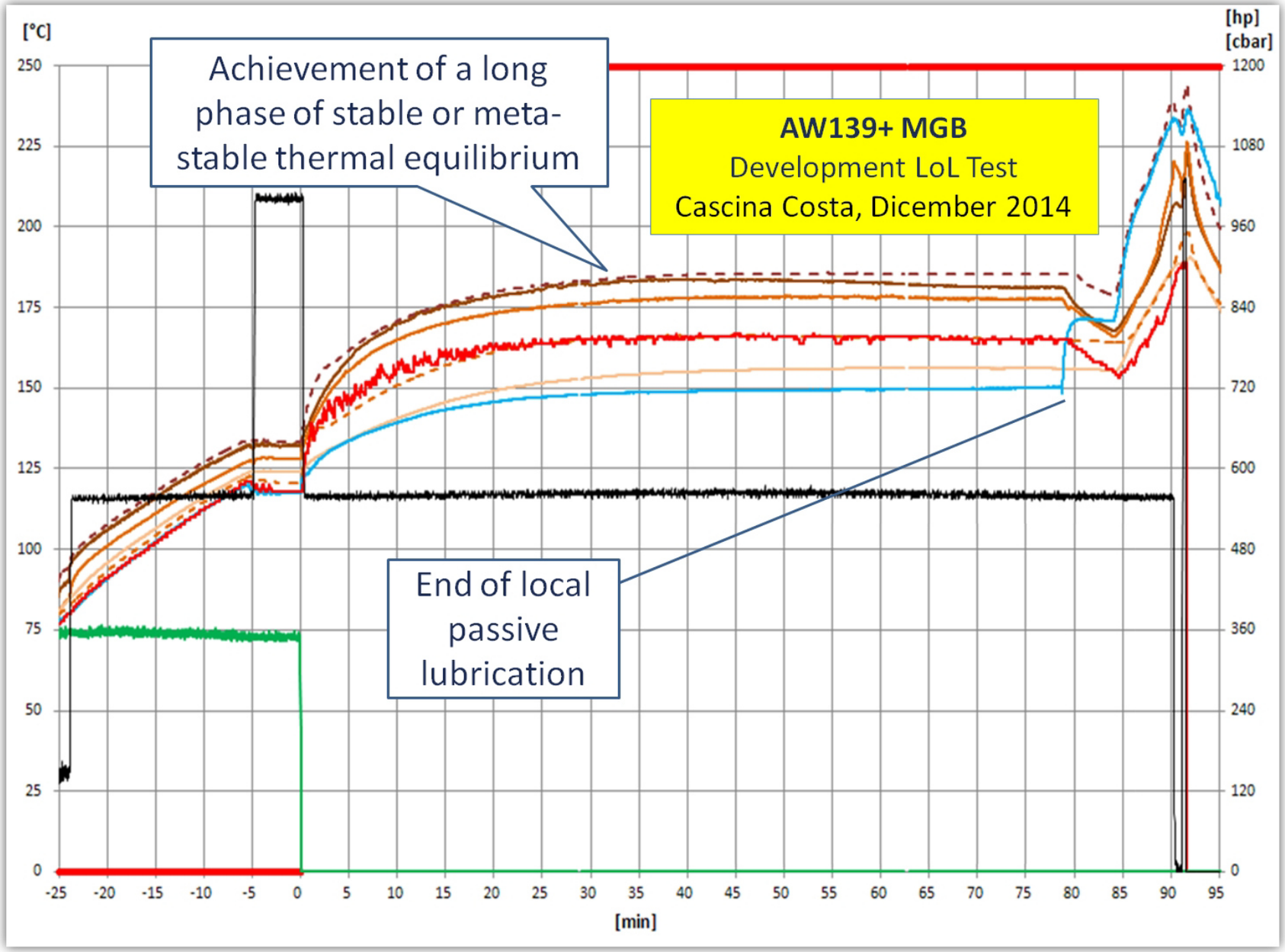
**AW139 will be the first helicopter ever to enter service with such a capability**

- Delivers improved safety for offshore operations
- 30 minutes more than any other currently certified competing helicopter.
- Leveraging Family concept and AW189 design to enhance the existing main MGB

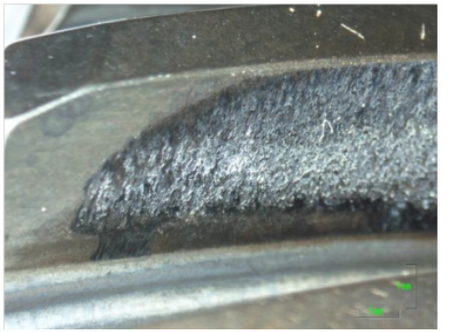
**AW139+ MGB**
Official LoL Test
Cascina Costa, February 2015

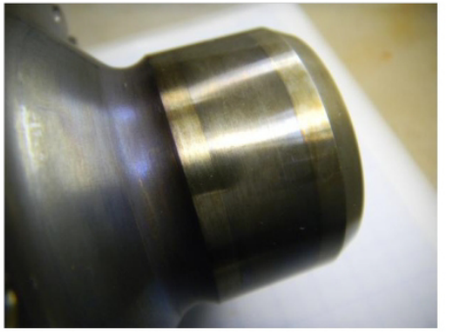


# AW139+ Preliminary Modular Test



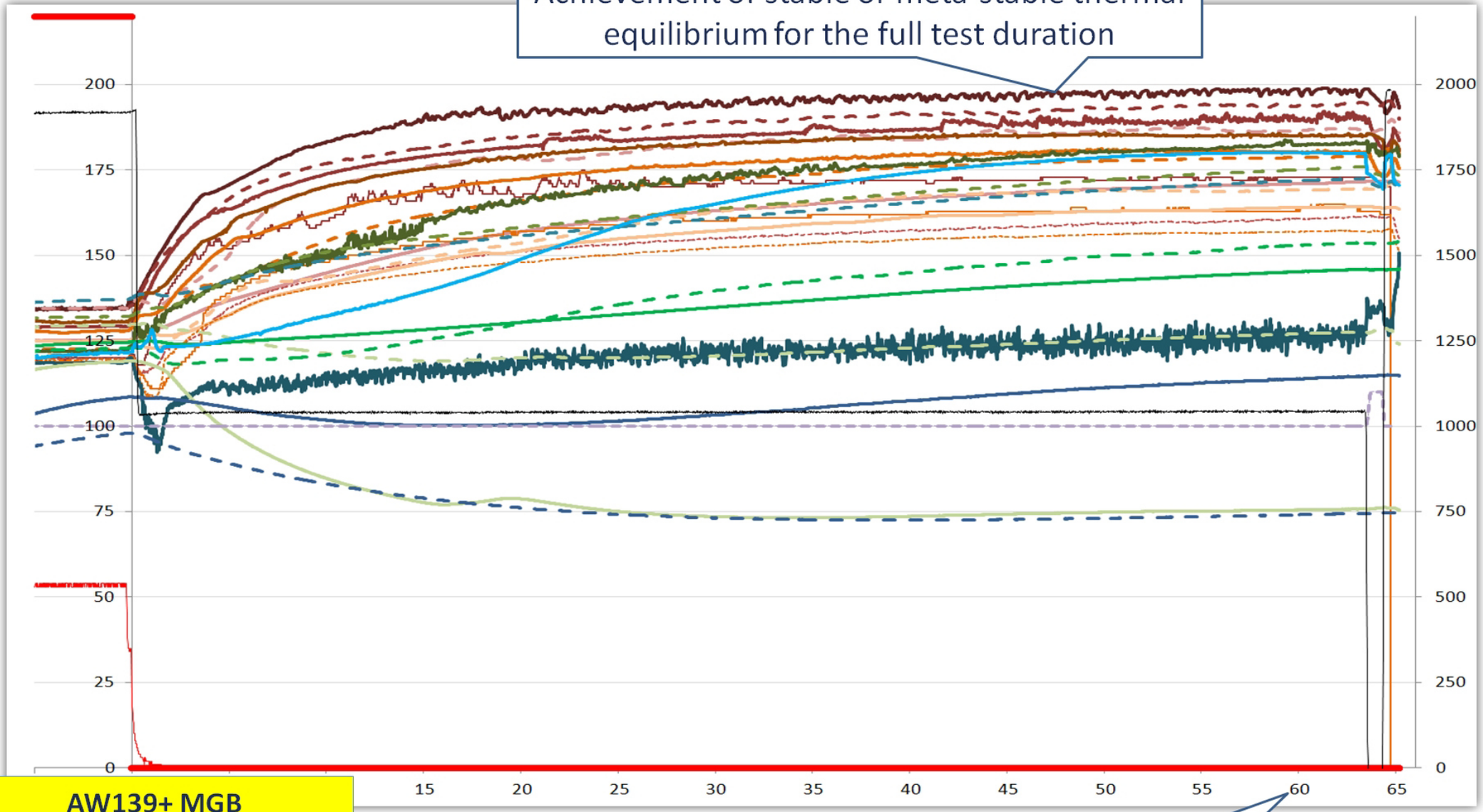

AW139+ parts showing overheating marks





AgustaWestland

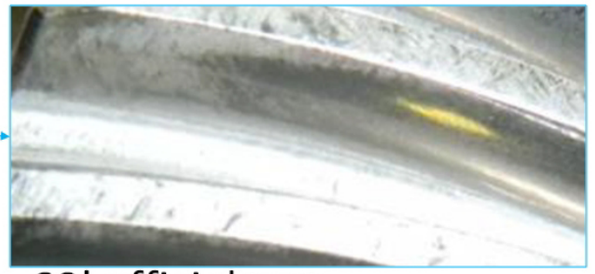
# AW139+ Certification Full MGB Test



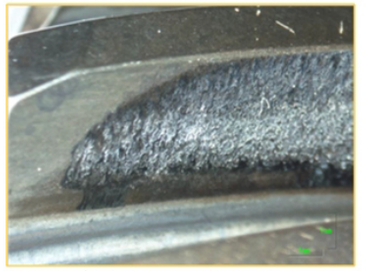

**AW139+ MGB**
Official LoL Test
Cascina Costa, February 2015

# AW139+ Certification Full MGB Test results

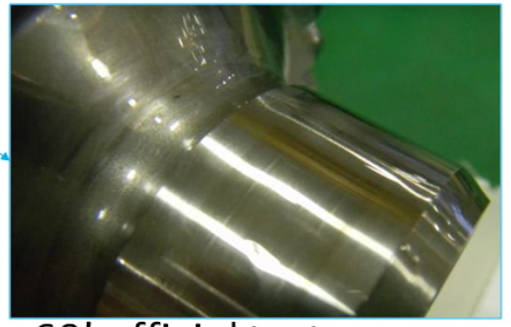
## High speed Gears



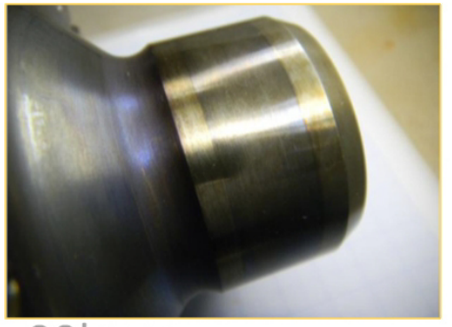
60’ official test



90’ test

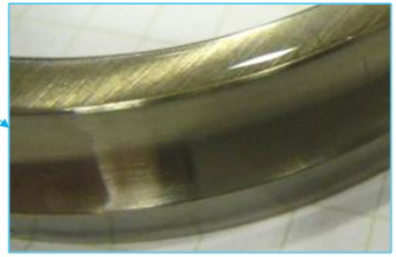


60’ official test



90’ test

## High speed Bearings

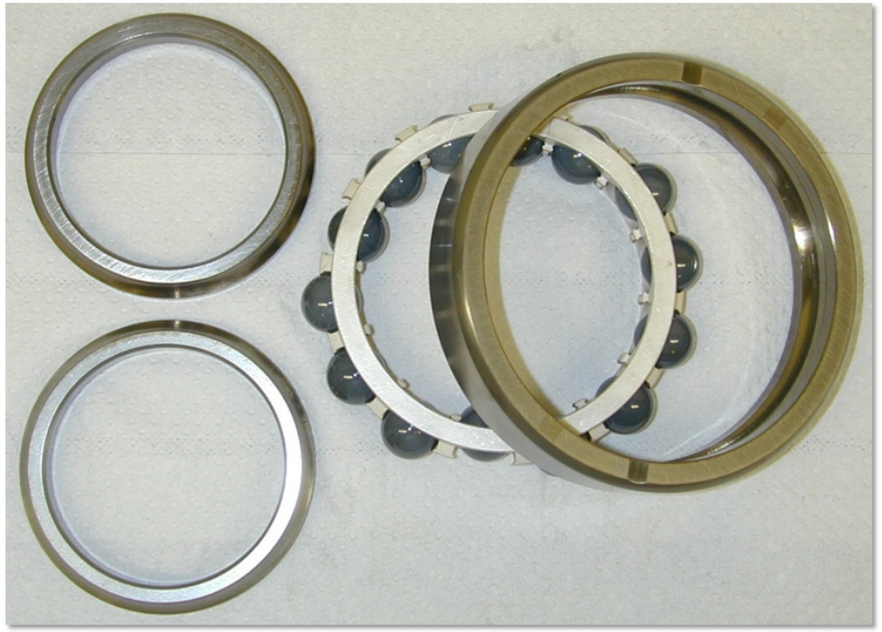


60’ official test

90’ test

# NEXT STEPS

2. Adopting **"Ultra Hybrid" bearing** solution (involving combination of ceramic rolling elements with low friction coating of the raceways) is a further improvement for dry-run capabilities. This kind of solution must be however validated by airworthiness authorities for wide use also on civil applications.

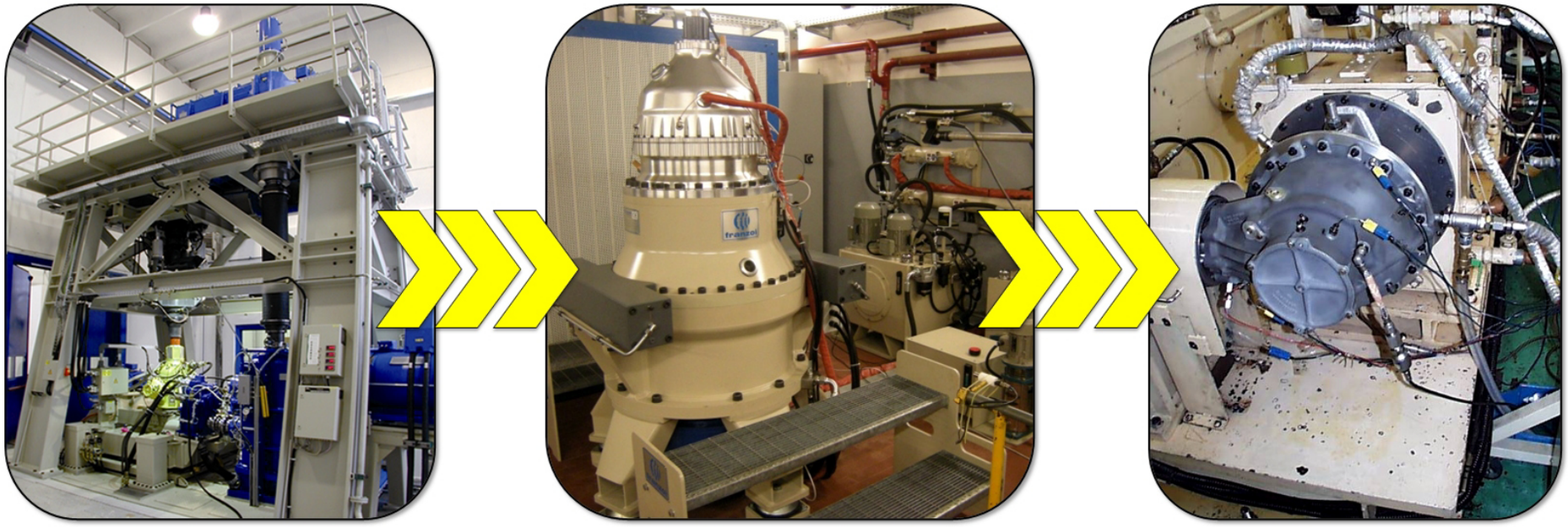


*NH90 MGB first reduction stage – ball bearing*

*AW169 MGB planetary stage – roller bearing*
*Patent Pending*

# NEXT STEPS

3. **Modular testing** can be a wise and efficient way to perform loss of oil testing:
   - during the preliminary phases prior to official certification test to compare different design solutions;
   - when full scale testing or simulation has already evidenced the “weak link” on which the attention must be focused only on most critical items.
   - when it is necessary to reduce the scatter by means of multiple testing with limited effort.



# DESIGN AND DEVELOPMENT STRATEGIES FOR MAIN GEAR BOX LOSS OF OIL PERFORMANCE IMPROVEMENT

**Giuseppe Gasparini**
**Marco Tamborini**

AgustaWestland
A Finmeccanica Company
Transmission Systems Design & Development


THANK **YOU** FOR YOUR ATTENTION