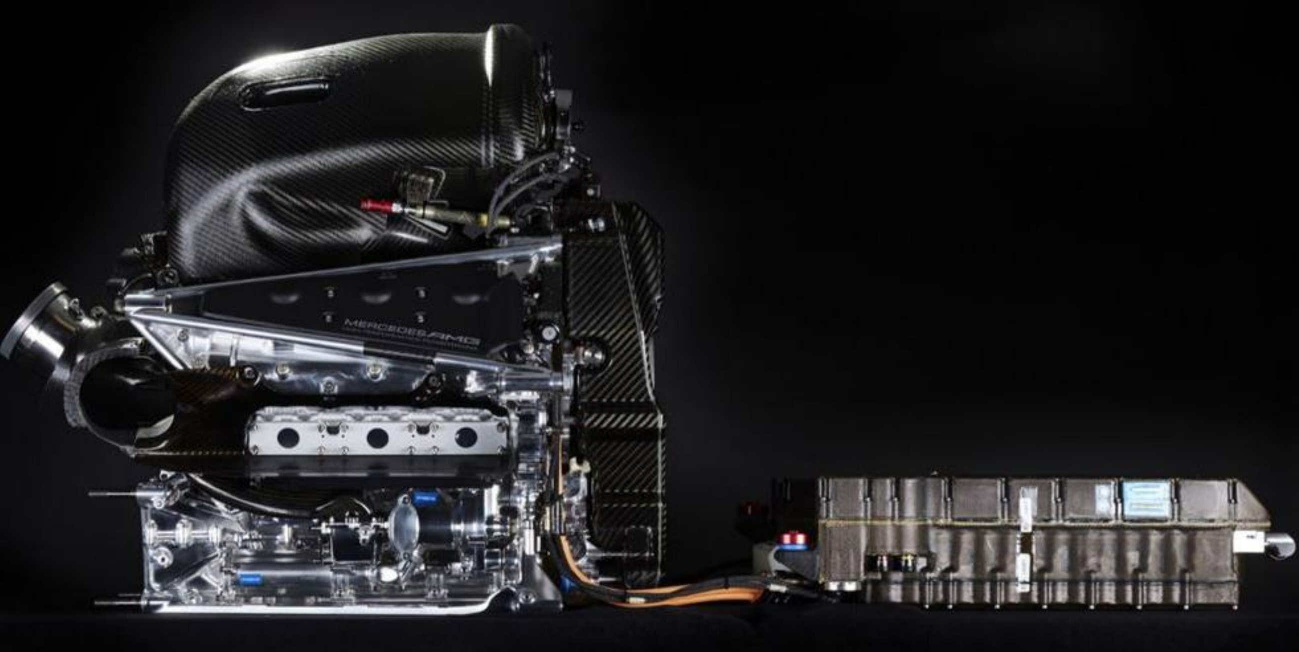


Materials & Processing in Mercedes F1 Power Units

"The Performance is in the Detail!"

Senior Materials Engineer - Stephen Edge MSc Advanced Materials

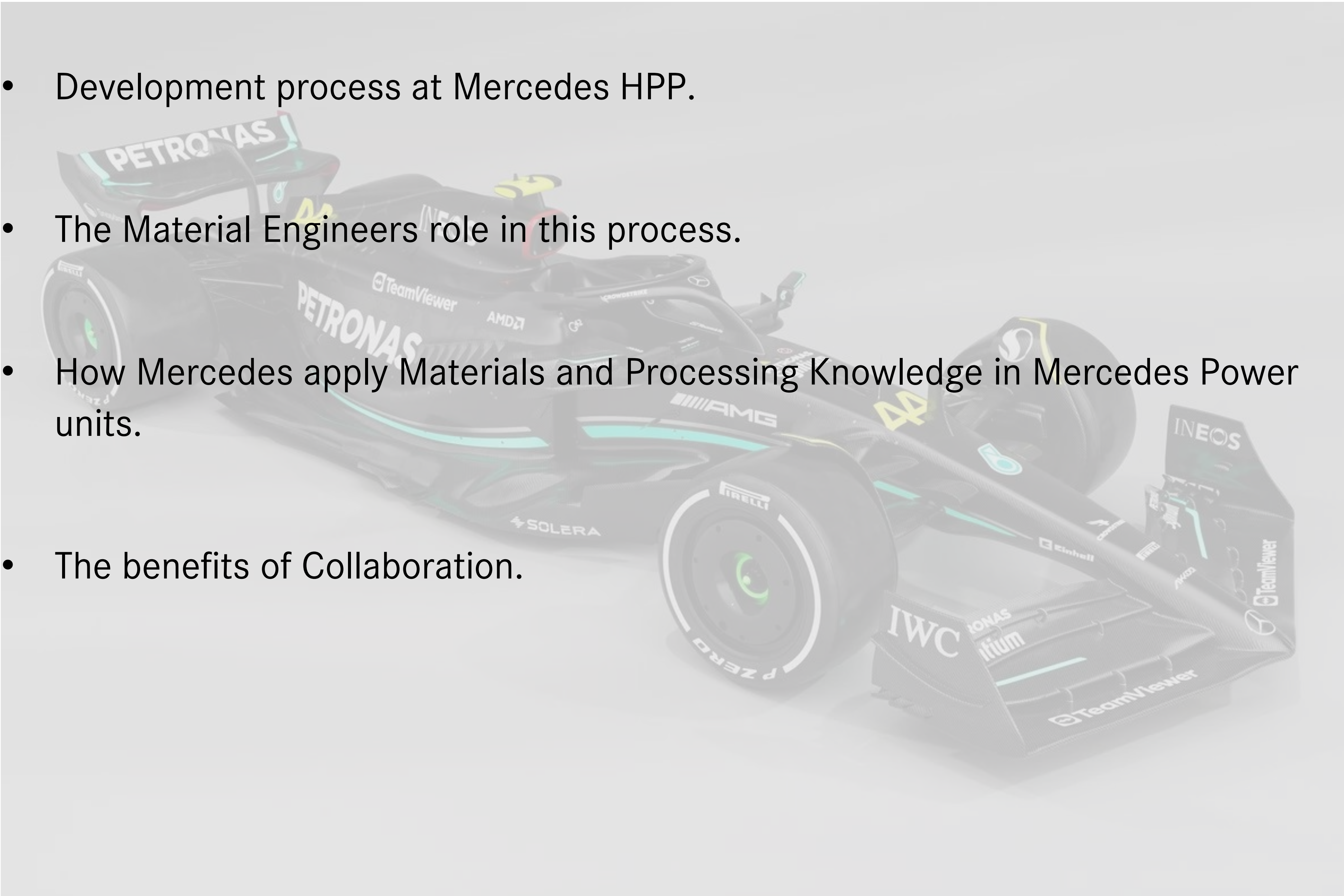
IMechE @ GE Rugby 16th May 2023

MERCEDES AMG
HIGH PERFORMANCE POWERTRAINS

Mercedes-Benz

Introduction to This Evenings Talk!

- Development process at Mercedes HPP.
- The Material Engineers role in this process.
- How Mercedes apply Materials and Processing Knowledge in Mercedes Power units.
- The benefits of Collaboration.



About Me – Stephen Edge

Growing up I had two passions:

Lego and Formula 1 – Fan Since Silverstone 1988 (Ayrton Senna & Nigel Mansell)

Materials and Processing Engineering Based Career.

- Started career @ ALCAN Research Facility In Banbury UK (precursor to Novellis).
- Diversified Surface Engineering - Developing PVD coatings (TiN, DLC etc).
- Developed Failure Investigation skills -Agusta Westland Military Helicopters.
- Powertrain Applications – Transmissions and Electrification Tech at JaguarLandrover.
- Achieved MSc in Advanced Materials from Cranfield University.
- Mercedes AMG High Performance Powertrains – utilise all these Skills

History Of Mercedes High Performance Powertrains

1984 Ilmor Engineering Ltd. established (Paul Morgan, Mario Illien and funded by Roger Penske)

1993 Ilmor & Mercedes-Benz announce a 5 year joint venture for engine supply.

2005 Joint Venture is subsidery of Daimler with Brixworth HPP site built.

2009 Supply of Engines to Mclaren, Force India & BrawnGP

2010 First Mercedes-Benz works team since 1955, Mercedes-GP

2012 Renamed to Mercedes AMG High Performance Powertrains

Mercedes F1 Powertrains are Designed, Manufactured and Developed by

"Mercedes AMG High Performance Powertrains".

Mercedes HPP is based in Brixworth, Northant's & Employ's Approximately 900 people.

MERCEDES AMG
HIGH PERFORMANCE POWERTRAINS

Developed Mercedes EQXX Battery 1000Km on one Charge.

Mercedes AMG Project one.
2016 F1 Engine for a road car!

Powertrain Supplier

MERCEDES-AMG HIGH PERFORMANCE POWERTRAINS WORLD CHAMPIONS

7 WORLD CHAMPIONS

2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020

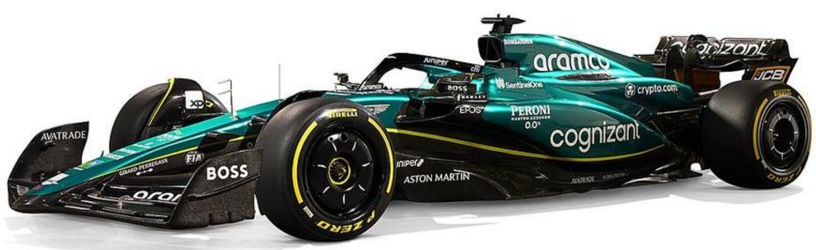
Our Teams

AMG PETRONAS FORMULA ONE TEAM

Customer Teams

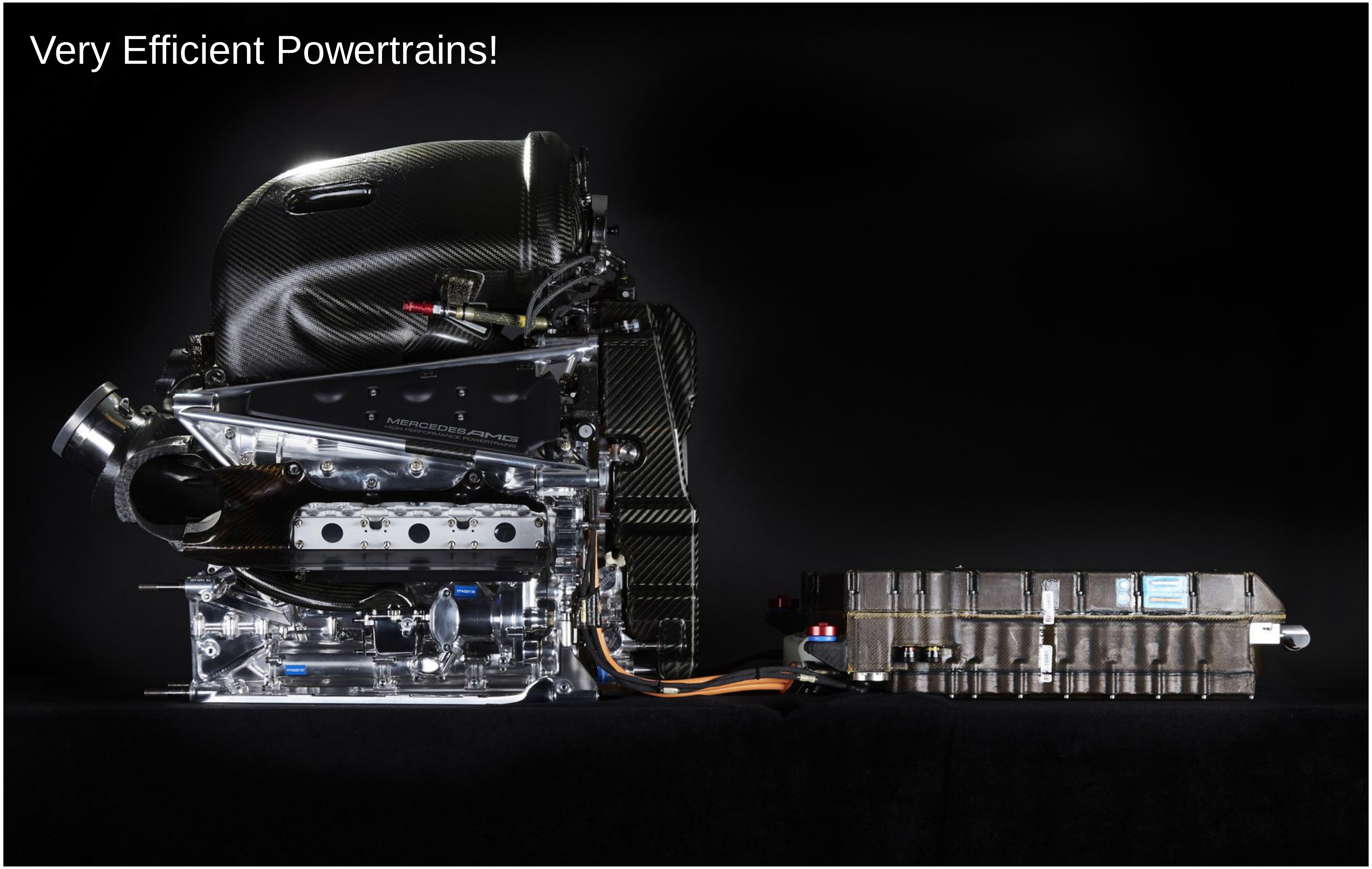
McLaren FORMULA 1 TEAM

ASTON MARTIN FORMULA ONE™ TEAM



WILLIAMS F1 TEAM

So what is it that Mercedes HPP Make?



Mercedes F1 V6 is over 50% thermal efficient

(Best road cars are 35%)

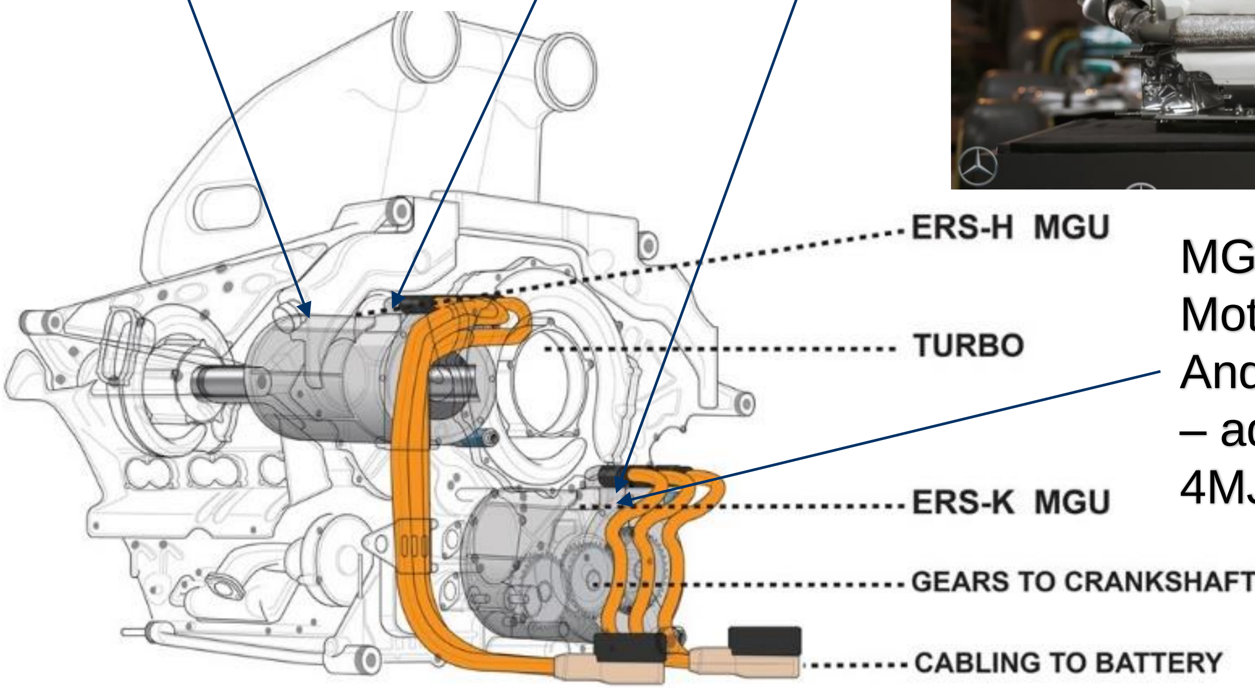
Mercedes F1 Power Unit

ICE - Internal Combustion Engine
1.6 L, 24v V6
Max 15000rpm

Two powerful
Motor generators
MGUH and MGUK

Energy Storage
Powerful & Responsive
Li ion Battery Pack

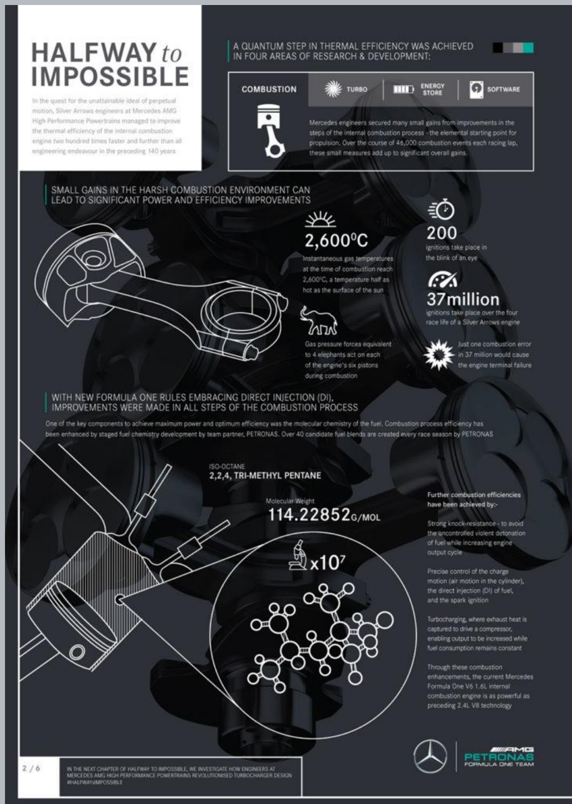
MGUH converts Exhaust
gases to energy.
Also spins the turbo.



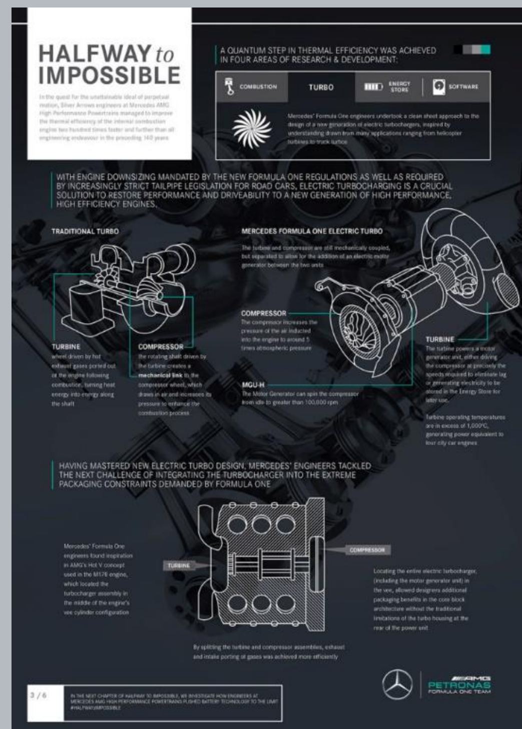
MGUK Converts Kinetic
Motion into Energy.
And provides 120kW 160bhp
– additional electric drive,
4MJ, 33.3s per lap

MERCEDES AMG
HIGH PERFORMANCE POWERTRAINS

Mercedes F1 Power Unit



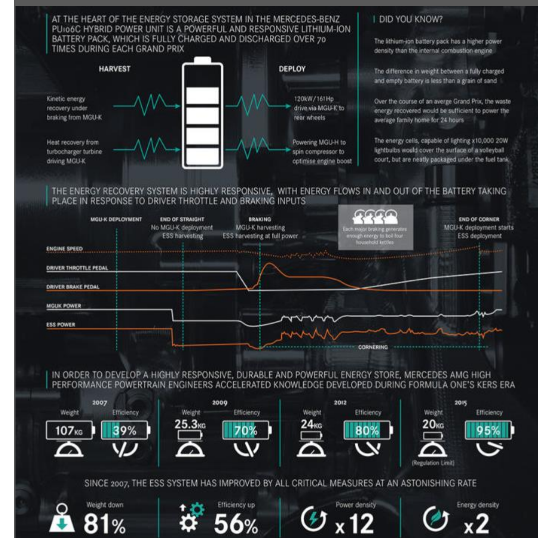
MGUH electric turbo charger -
Increase power
Reduced fuel consumption



Direct injection –
better combustion control.

Current 1.6L V6 ICE is as powerful as 2.4L V8

Energy Storage



F1 Battery
Charges and Discharges
Once a lap!

Upto 70 times a
GrandPrix!

Mercedes HPP Material Engineering – Add Detail.

- Material and process selection
- using “Detailed” engineers requirements.
- “Detailed” Material Characterisation.
- “Detailed” Material and Process specifications.
-

Mercedes HPP Material Engineers - Constraints

Motorsport Constraints:

Low Volume manufacture –

- Restricted to what's available from other industries.

FIA Technical Regulations –

- Commercially available to all Manufacturers – No bespoke materials or processes.
- Article 5.16 to 5.20 Restricted Materials "Power Unit Materials and Construction"

Time –

The Red lights go out if your ready or not…

At Mercedes HPP - Time constraints drive the way we work.

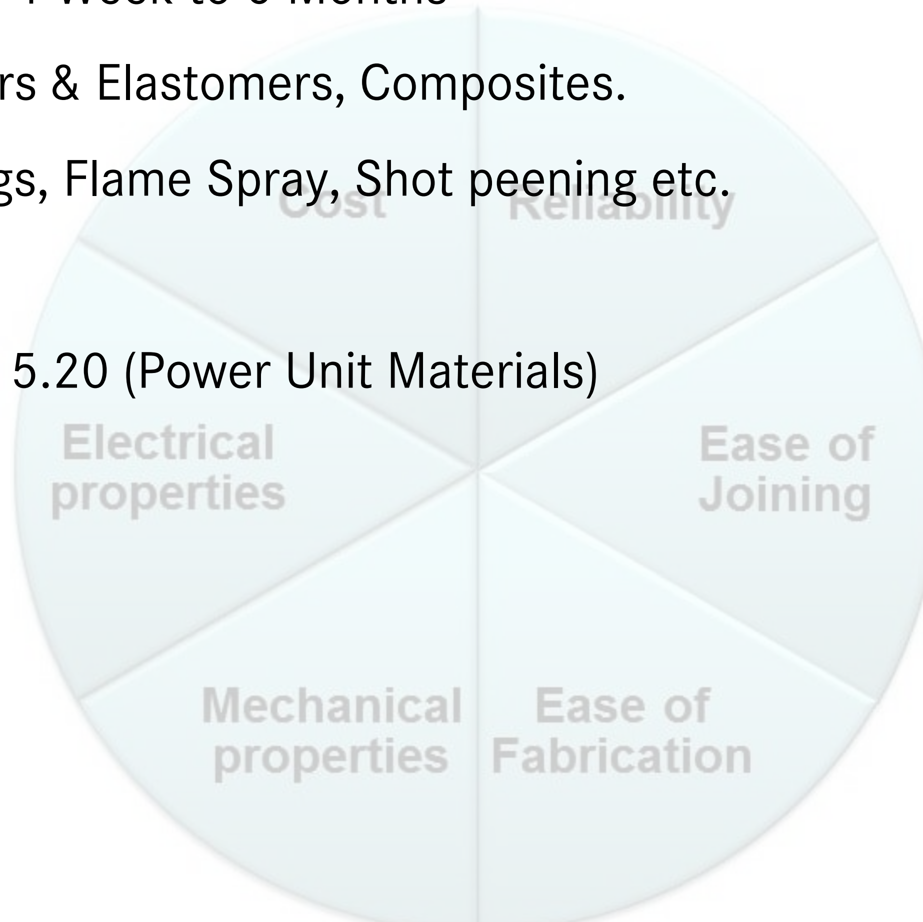
- Application and Process Development Fast Tracked - Robustly.
- Bespoke testing - Innovative methods to obtain data quickly.
- Concise Communication, Flexible.

1 –Application Development - Detailed Development

Engineers define the concept! – We provide Material and Process Selection.

Time for Application Development Varies – 1 Week to 6 Months

- Aerospace Alloys, Performance Polymers & Elastomers, Composites.
- Processes – ALM, PVD and DLC coatings, Flame Spray, Shot peening etc.



FIA Material Restrictions – Articles 5.16 to 5.20 (Power Unit Materials)

5.17 Materials and construction – General

5.17.1 Unless explicitly permitted for a specific application, the following materials may not be used on the power unit:

a. Magnesium based alloys.

b. Metal Matrix Composites (MMC's) containing more than 2.0% volume/volume of other ceramic, metallic, carbon or intermetallic phase which is not soluble in the liquid phase at 100°C above the melting point of the metallic matrix.

c. Intermetallic materials.

d. Alloys containing more than 5% by weight of Platinum, Ruthenium, Iridium or Rhenium.

e. Copper based alloys containing more than 2.75% Beryllium.

f. Any other alloy class containing more than 0.25% Beryllium.

g. Tungsten base alloys.

h. Ceramics and ceramic matrix composites.

i. Aluminium based alloys containing more than 2.5 weight % Lithium.

j. Materials containing nanomaterials.

k. Thermal insulation containing unbound nanomaterials.

2 - Material Characterisation – Detailed Analysis

F1 Components have Low Factors of Safety for Performance.

- Engineers require accurate material properties for analysis! But where from?

  Try googling fatigue properties of Ni alloys at 800°C! and would you trust it?

- Mercedes developed methodologies that our Engineers can trust.
- Evaluating the effect of Manufacturing Processes: Surface finish/Shot peening etc
- Bespoke tests due to constraints of time or material.

Detailed Material Characterisation gives Engineers confidence.

3 - Materials and Processing Controls – Detailed Control

Detailed Specifications – Give Consistent Properties.

- Suppliers are developed – An extension of our team.
- Detailed internal documentation captures the process envelope.
- Detailed traceability is essential for development feedback loop.

All team members and suppliers understand consequences of a change to process.

- i.e Surface finish, Residual stresses or Micro-Structure then the properties are not as measured .

Material & Process Development

Example : Additve Layer Manufacture (ALM) - Metallic Component Manufacture.

Materials Engineers Role – Application Development

- Select Supplier, Material and Heat treatments

Characterisation

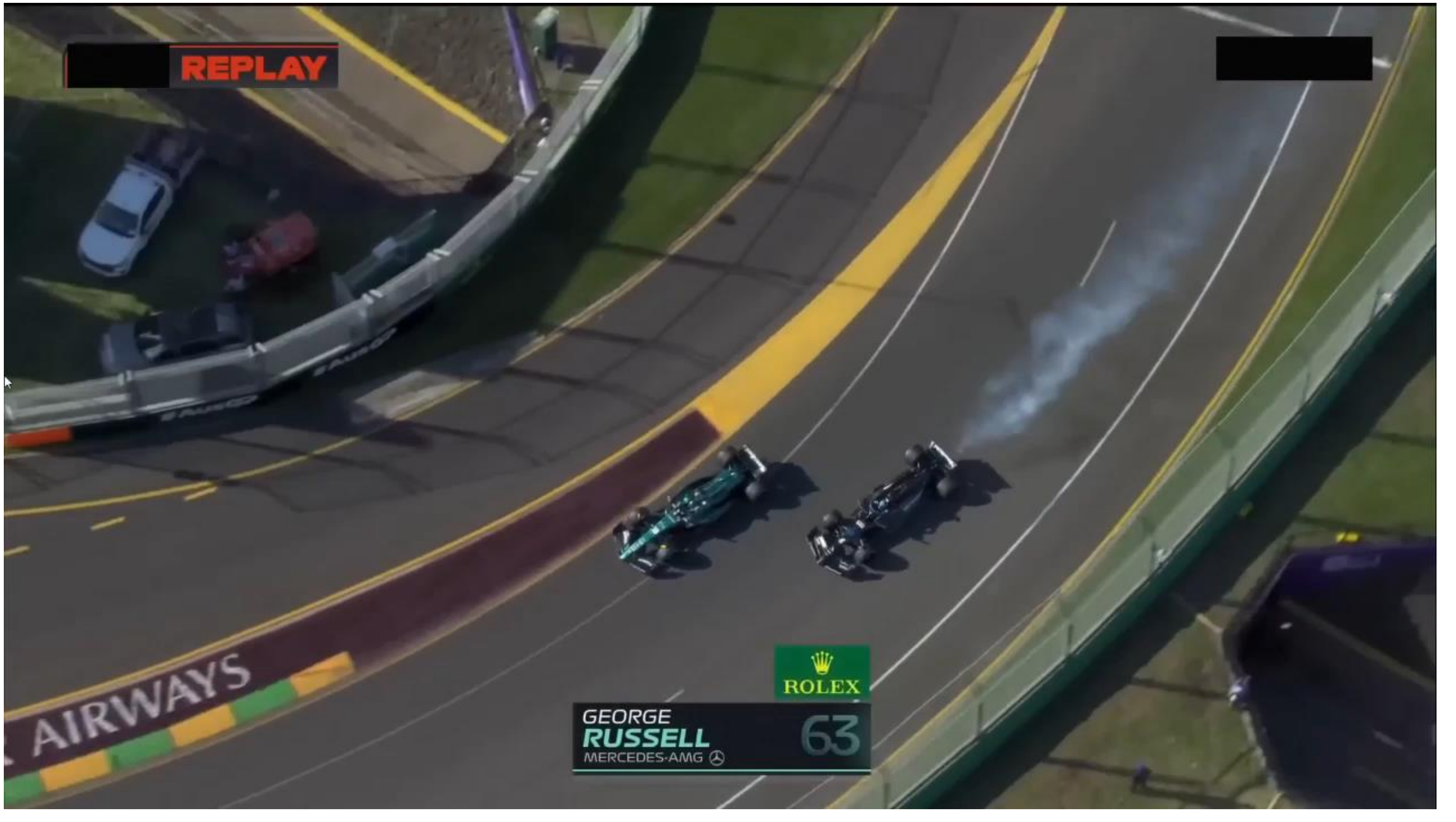
- Measure mechanical properties representative of finished part (Fatigue, Tensile, Thermal etc) for FEA.

Standards and Requirements

- Create processing requirements and specification for repeatable parts.
- Ensure inspection Inspection Criteria is repeatable and results are verified.- (NDT/CT Hardness Tensile specimens) Ensure Quality.

What do Material Engineers do?

4 - Failure investigation



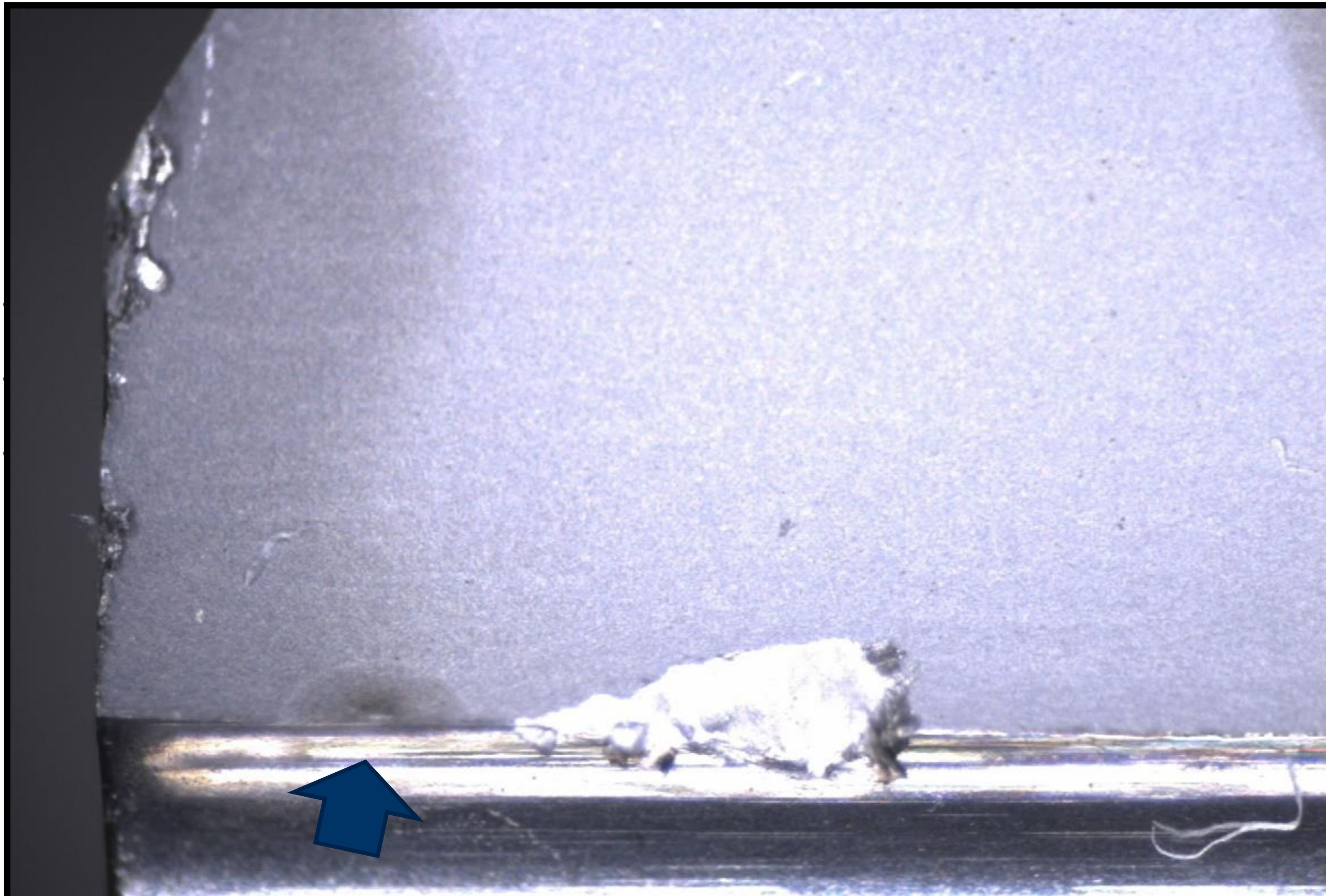
When it all goes WRONG!

4 - Failure Investigation

3 Questions that the engineers need to know.

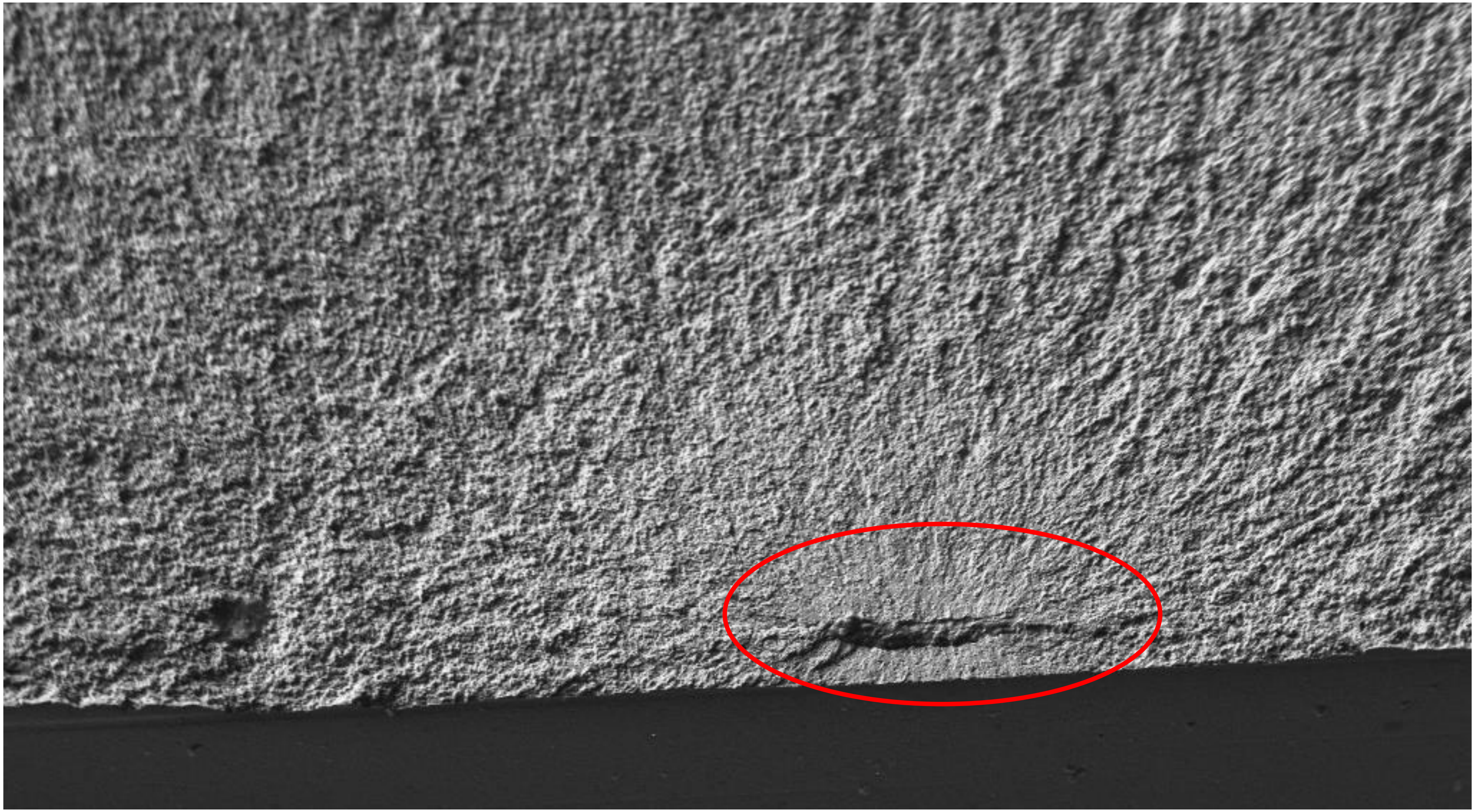
- Failure mechanism and location?
- Manufacturing, Design or Material Defects?
- Does the Material Comply with Requirements?

4 - Failure Investigation – Detailed Examination



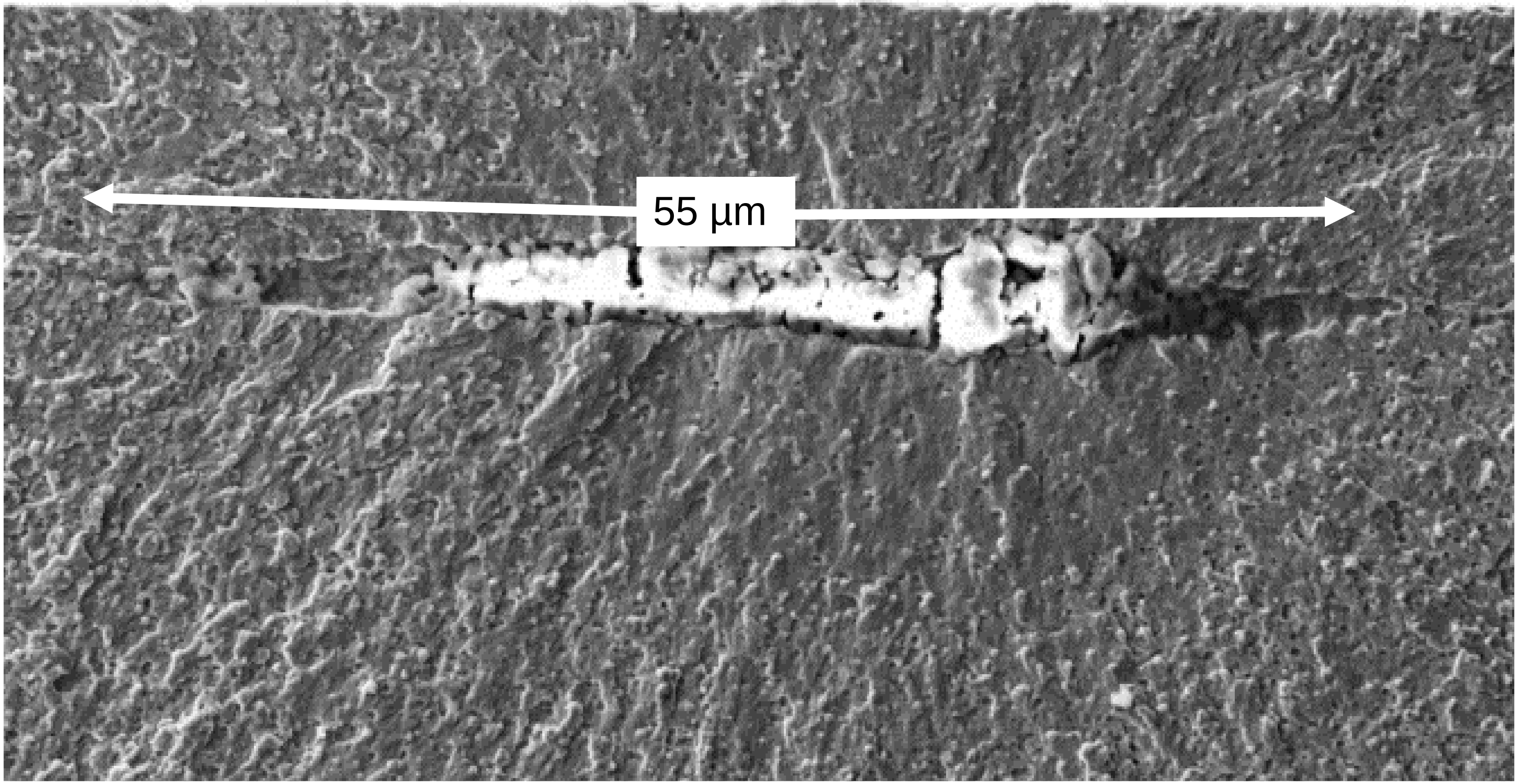
ails)

4 - Failure Investigation – SEM Examination



- SEM – Identifed Subsurface Initiation from NMI.

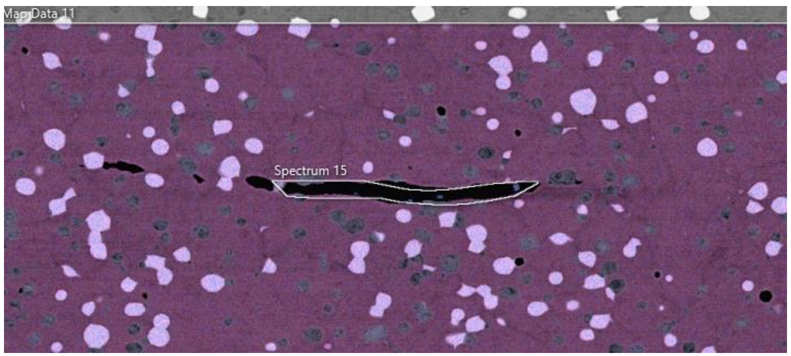
4 - Failure Investigation – Initiation Identification

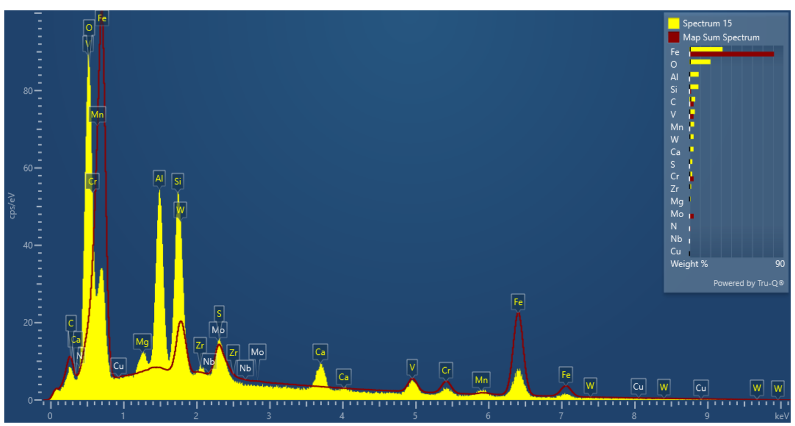


- Chemical Composition can Identify the source of the contamination.

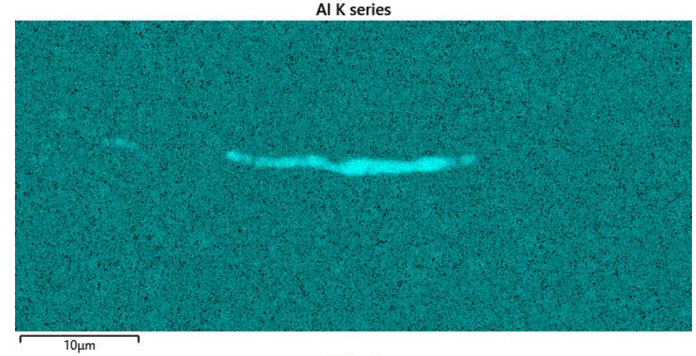
4 - Failure Investigation –EDX Analysis

Chemical composition of NMI measured.

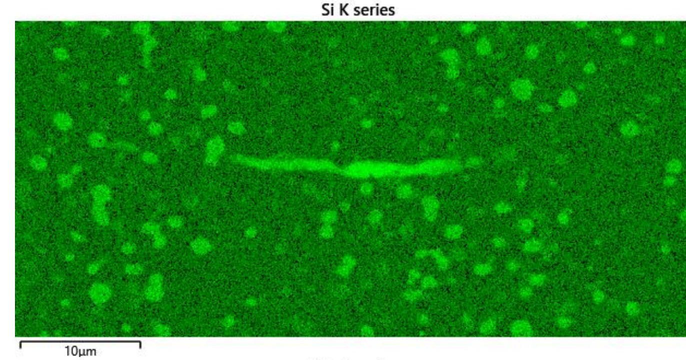




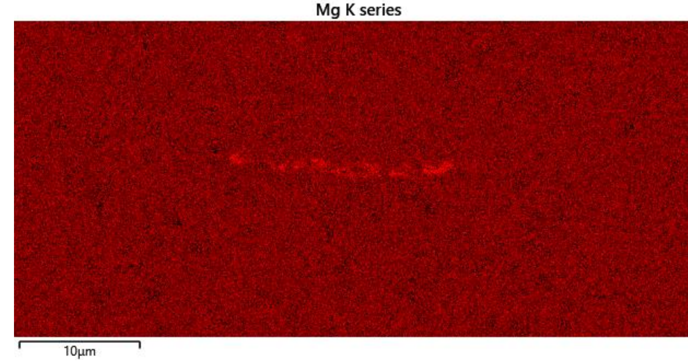
Al K series



Si K series

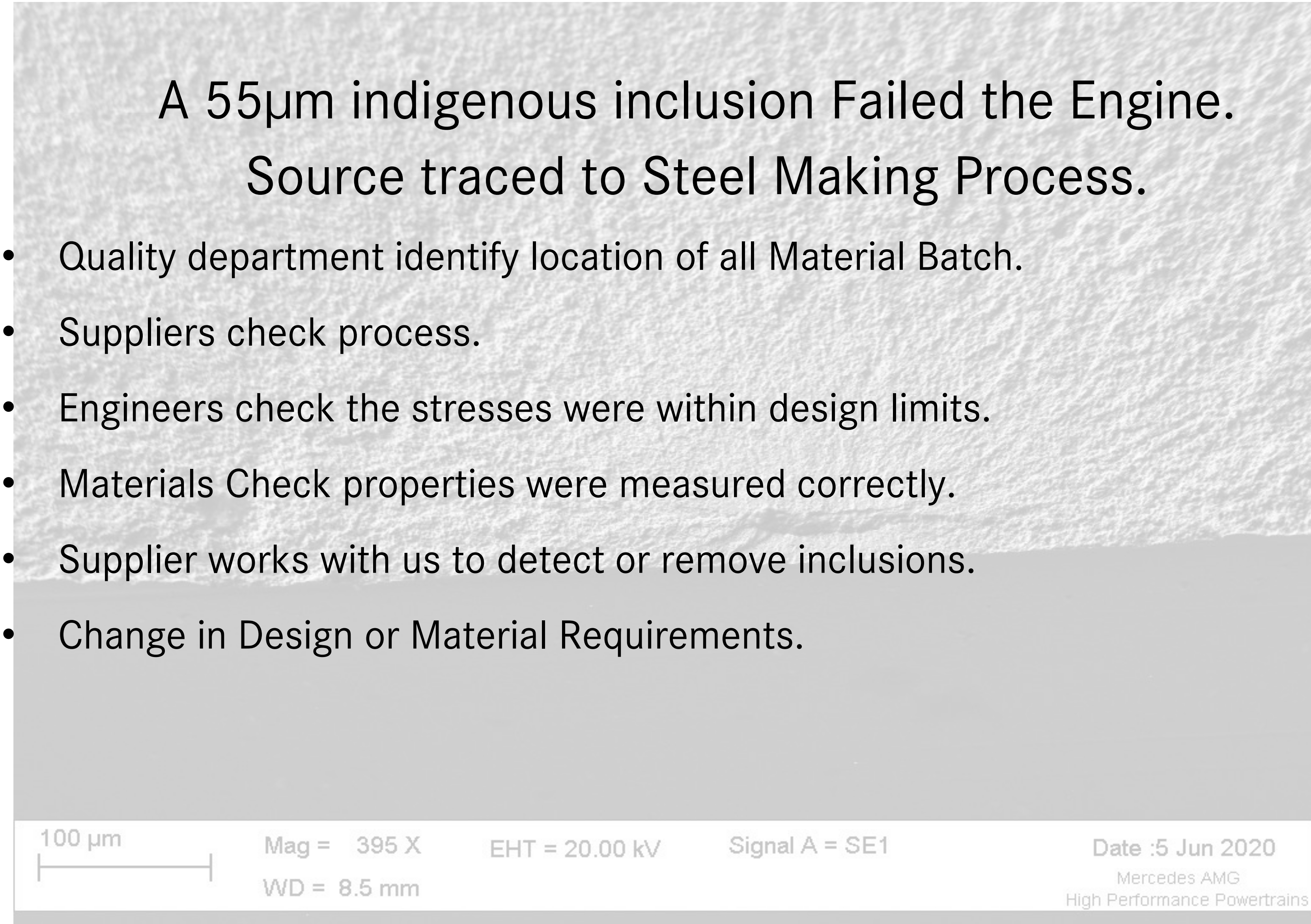


Mg K series



Indigenous Non-Metallic Inclusion of Al, Si, Mg & O

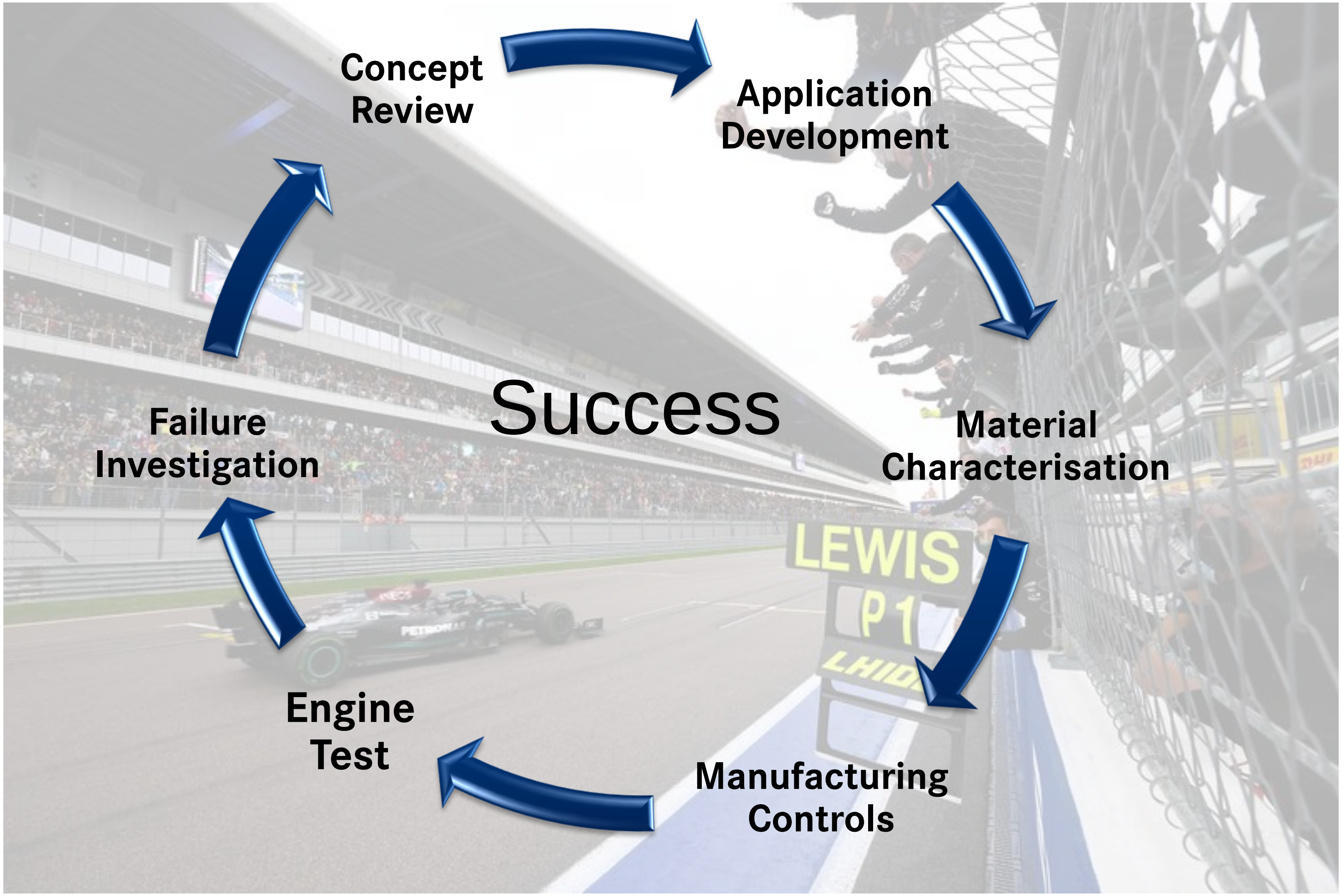
4 – Failure Investigation – Detail Leads to Root Cause.



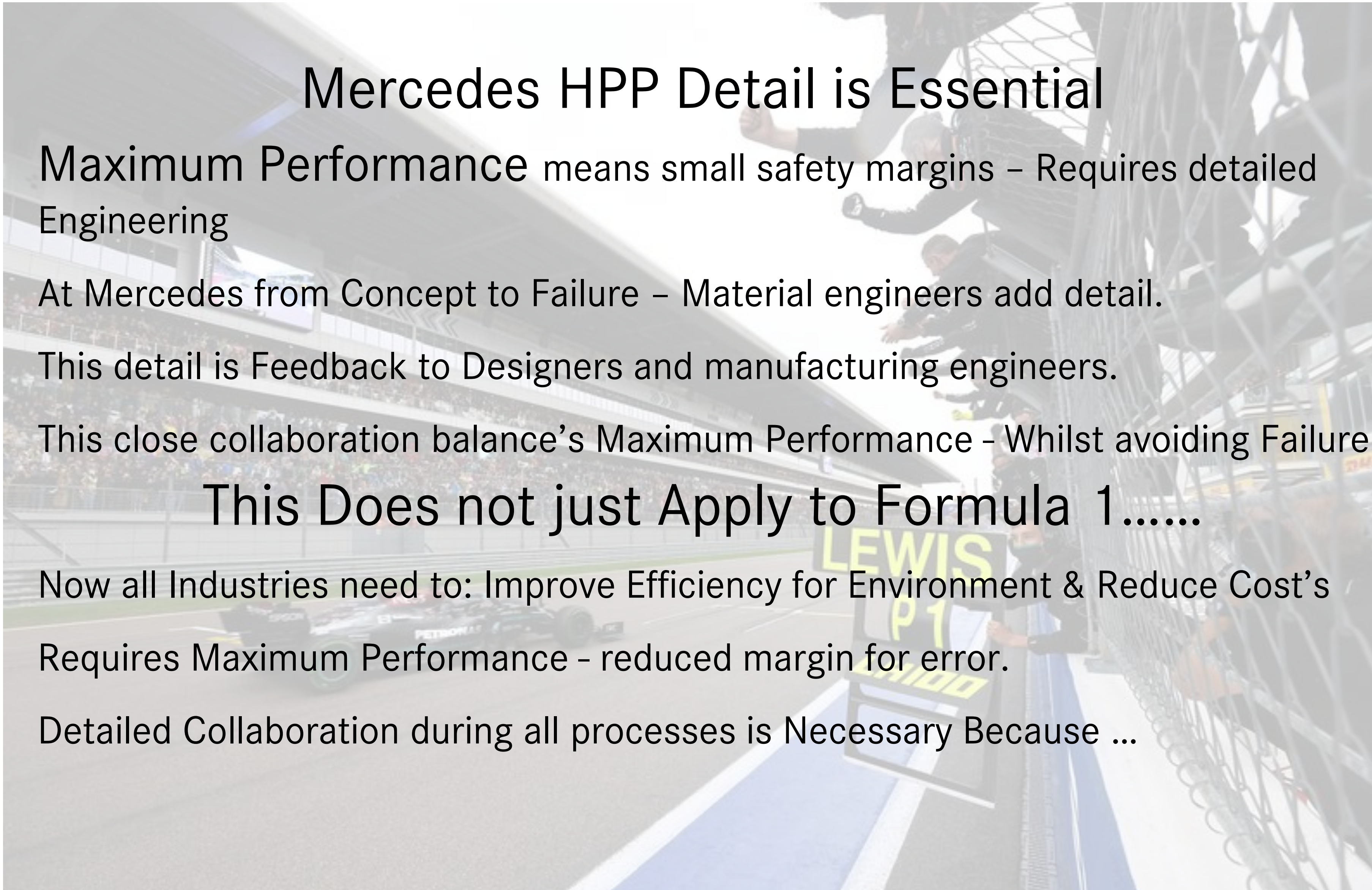
A 55µm indigenous inclusion Failed the Engine.
Source traced to Steel Making Process.

- Quality department identify location of all Material Batch.
- Suppliers check process.
- Engineers check the stresses were within design limits.
- Materials Check properties were measured correctly.
- Supplier works with us to detect or remove inclusions.
- Change in Design or Material Requirements.

Materials Engineers Add Detail to Development Feedback Loop.



Summary



Mercedes HPP Detail is Essential

- **Maximum Performance** means small safety margins – Requires detailed Engineering
- At Mercedes from Concept to Failure – Material engineers add detail.
- This detail is Feedback to Designers and manufacturing engineers.
- This close collaboration balance’s Maximum Performance - Whilst avoiding Failure.

This Does not just Apply to Formula 1……

- Now all Industries need to: Improve Efficiency for Environment & Reduce Cost’s
- Requires Maximum Performance - reduced margin for error.
- Detailed Collaboration during all processes is Necessary Because …

Summary

The Performance is in the Details!

Thank you for your attention!

Any Questions?