The application of Condition Based Maintenance / Monitoring on railway asset management
狀態檢修及狀態監測技術於現代化鐵路資產管理上的應用

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Key Direction Limited

公司簡介 Intro to Key Direction Limited

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CONSULTANCY TRAINING

成立於2008年，本公司擁有經驗豐富之鐵路系統專家和營運和維護專家，與鐵路相關之重點服務包括：

Formed in 2008 with a pool of experienced experts in rail systems and operations & maintenance with key aspects of railway related service include:

- 鐵路營運與維護規劃Railway Operations and Maintenance Planning and Support
- 鐵路項目投標業務支援Railway Tendering Support
- 鐵路項目成本、項目外加成本和融資方案之獨立評估/審查Independent Railway Project Cost,Project On-cost and Funding Arrangement Assessment / Review
- 獨立鐵路安全評估Independent RailwaySafety Assessment
- 鐵路系統設計與管理Railway System Design and Management
- 鐵路資產狀況評估 Railway Asset Condition Assessment

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簡報大綱 Outline of the Presentation

鐵路資產管理
Railway Asset Management

你會如何做 What do you do when...

➢ 你有價值15億的工廠，重置價值為54億
You have $1.5B worth of installed plant with a replacement value of $5.4B

➢ 資產的平均使用壽命超過40年
Average age of the assets exceeds 40years

➢ 所有的設備在開始使用後需保證功能和可靠性
All equipment are expected to be deployed to be functional and reliable at all time; and

➢ 維護支出將侵蝕收益，而資產置換將不會帶來額外利潤。
Maintenance expenditures would erode earnings and capital replacement would provide for no new revenue

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鐵路資產管理
Railway Asset Management

The Mission

➤ 優化資產投資，同時提高整體系統的可靠性

To optimize the investment in assets while Improving the overall system reliability

The Vision

➤ 在正確的時間進行合理的維護，基於對數據的一致分析，以確保安全、可靠、成本有效的方法

To perform the right maintenance at the right time, based on the consistent analysis of data to ensure a safe, reliable, cost effective approach

鐵路資產管理
Railway Asset Management

什麼是鐵路資產管理？
What is Railway Asset Management?

－在整個鐵路資產生命週期中，積極管理規劃、實施和維護的措施

Proactively manage planning, implementation and maintenance over rail asset lifetime

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鐵路資產管理
Railway Asset Management

-根據ISO 55001：

為了確定組織的方針和策略資產管理計劃，通過該系統和協調的活動和實踐，對其資產和資產系統、與其相關的績效、風險和支出進行最佳和可持續的管理。

Pursuant to ISO 55001: "Systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan".

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鐵路資產管理
Railway Asset Management

以下是資產管理的6個主題:
- 策略和規劃 Strategy and Planning
- 決策 Decision Making
- 生命周期活動 Life cycle Activities
- 資產信息 Asset Information
- 人力資源與組織 People & Organization
- 風險評估 Risk & Review

鐵路資產管理
Railway Asset Management

- 鐵路資產管理的範圍

The scope of Railway Asset Management activities.

鐵路資產管理
Railway Asset Management

為什麼我們需要鐵路資產管理？
Why do we need Asset Management in Railway?

- 迅速在鐵路行業中獲得了影響力
  rapidly gained influence in the rail industry.

- 一組協調活動，可優化資產績效以幫助實現業務目標.
  a group of coordinated activities that optimize asset performance to help deliver a business' objectives.

- 它包括所有的系統，程式和工具 以最大限度地提高資產可用性，從而降低這個生命週期的成本和風險.
  It comprises all systems, procedures and tools to maximize asset availability for a minimum whole-life cost and risk.

- 使用智慧軟件收集和分析有關使用情況的數據，以便進行預測性和預防性維修，而不是進行反應性維修.
  using intelligent software to collect and analyze data about usage so that predictive and preventative maintenance can take place rather than reactive repairs.

- 不僅僅是維修，它還涵蓋了資產的整個生命週期，從設計，施工和運營到更新和處置，以及每項活動的後果.
  not just maintenance, it covers an asset's entire lifecycle, from design, construction and operation through to renewal and disposal and the consequences of each activity.

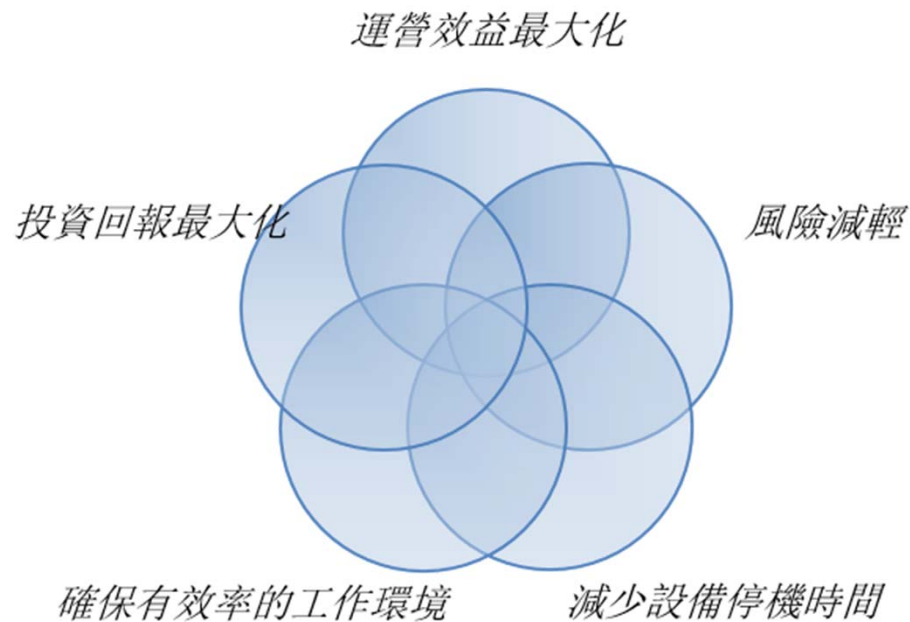CELEBRATING 2008 10 2018 YEARS ANNIVERSARY

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鐵路資產管理
Railway Asset Management

資產管理系統帶來的可量化效益如下：

- 降低維護費用，減少不必要的維護次數；
- 提高有效工作時間10%~20%
- 降低庫存成本10%~25%
- 減少設備停機時間10%~20%
- 增加設備使用效率20%~30%
- 延長設備生命周期超過10%
- 使庫存准確率達到95%以上

運營效益最大化

投資回報最大化

風險減輕

確保有效率的工作環境

減少設備停機時間

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鐵路資產管理
Railway Asset Management

如何運作 How it works?

✓採用資產管理和預測資產維護，可以通過收集和分析與歷史、保修和使用相關的鐵路資產資料，以促進從反應性維修到預測維護的範式轉換。

✓Adopting asset management and predictive asset maintenance, rail asset data related to history, warranty and usage can be collected and analyzed to facilitate a paradigm shift from reactive repairs to predictive maintenance.
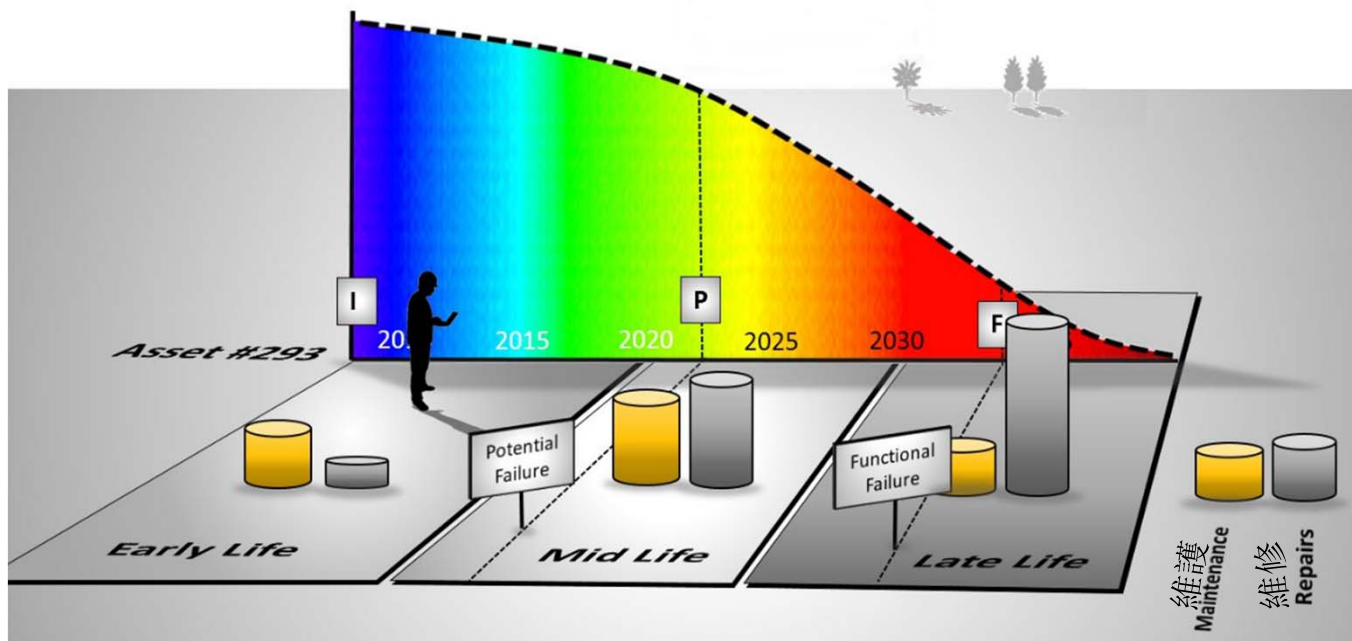
資產壽命可以分爲幾個階段

狀態為本的檢修
Condition Based Maintenance

什麼是狀態檢修？

- **狀態為本的檢修**(CBM)是行業用來積極管理資產的健康狀況的一種維護準則，以便在需要的時候和最合適的時候進行維護。CBM 可以大幅降低運營成本, 提高所需維修的資產的安全性。

- **Condition-Based Maintenance (CBM)**is a maintenance philosophy used by industry to actively manage the health condition of assets in order to perform maintenance only when it is needed and at the most opportune times. CBM can drastically reduce operating costs and increase the safety of assets requiring maintenance

狀態為本的檢修
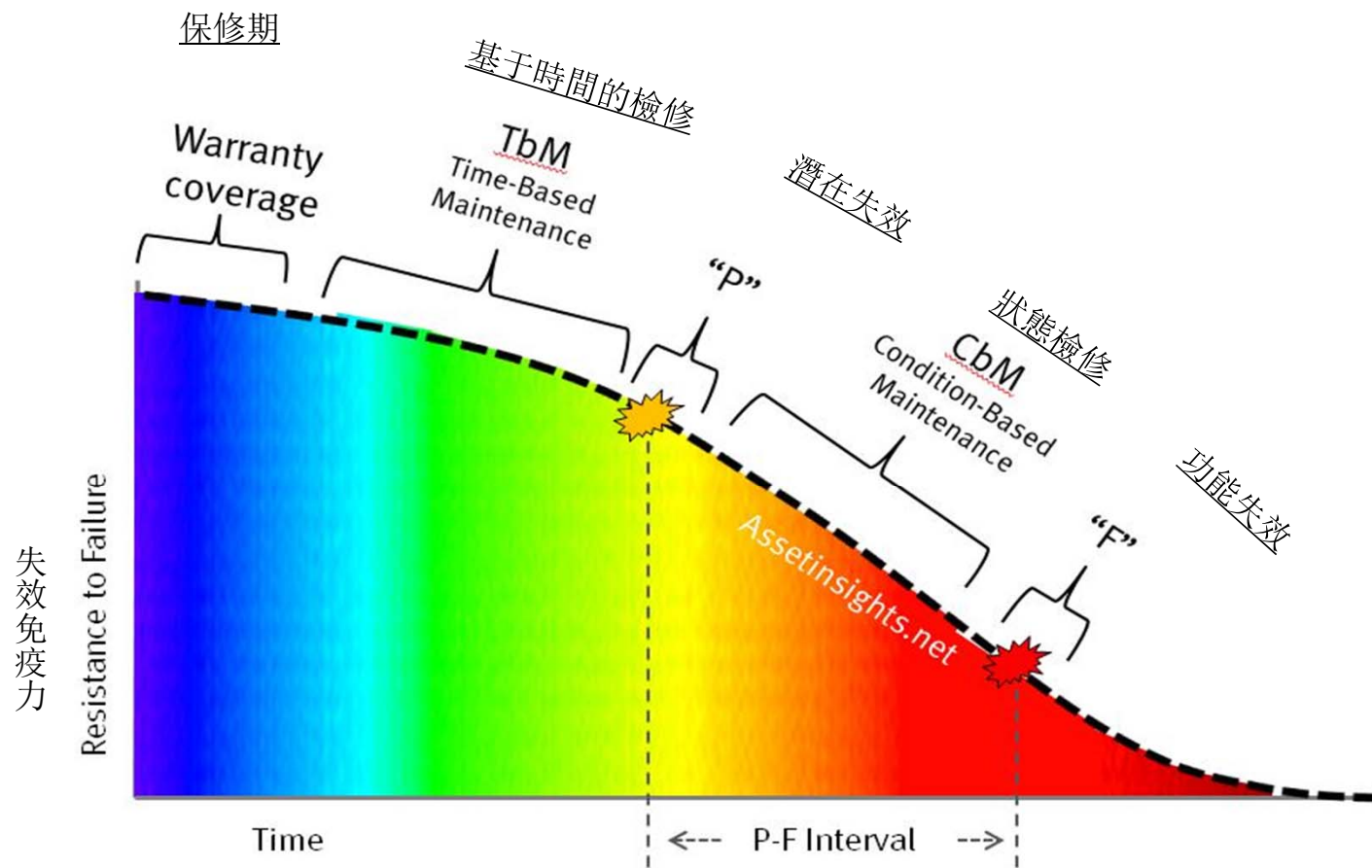## Condition Based Maintenance

狀態為本的檢修定義：

- 歐盟標准EN13306(Maintenance terminology)的定義：根據設備性能和/參數的監測結果及其處理措施進行的預防檢修。

- 其他定義：在設備狀態出現了明顯的劣化後實施的檢修策略，而狀態的劣化是由被監測的機器狀態參數的變化反映出來的。

狀態為本的檢修
Condition Based Maintenance
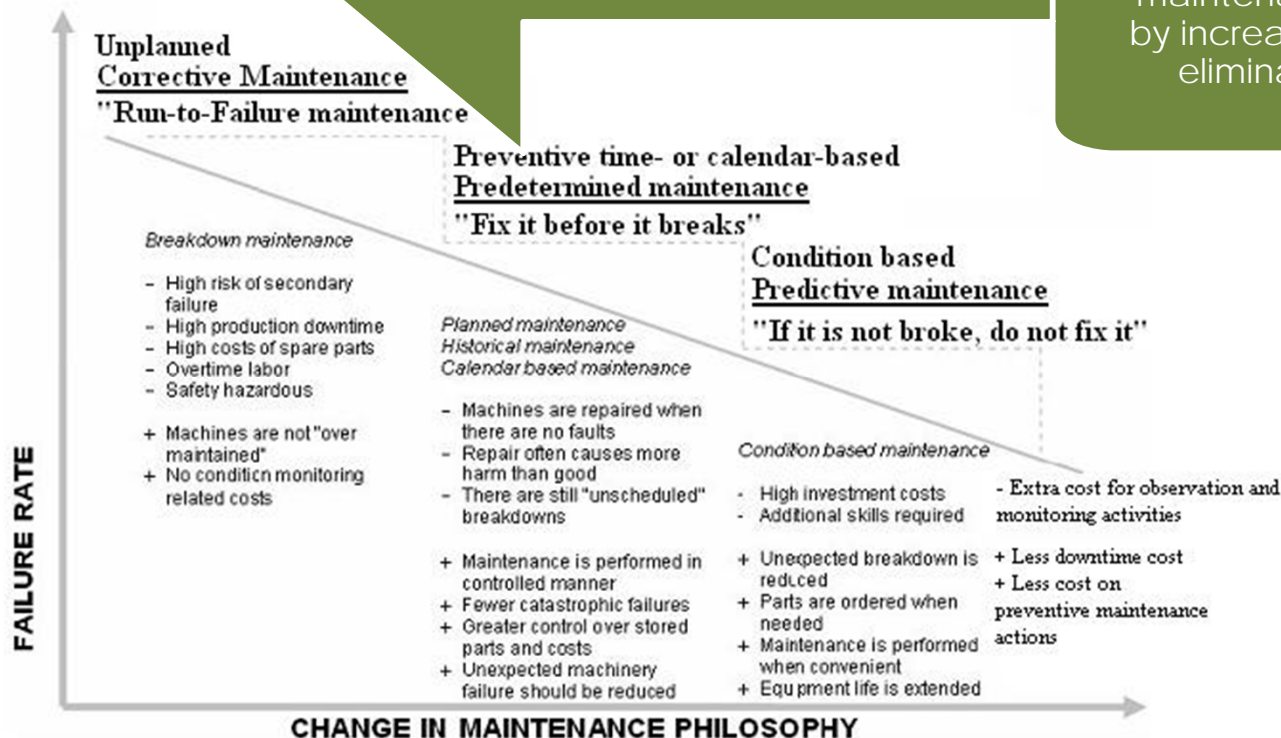

測維護（PdM）技術沿P-F曲線與潛在失效（P）和功能失效（F）的關系

狀態為本的檢修
Condition Based Maintenance

故障檢修/反應性維修可能會增加明顯的績效成本，預防/定時維修會在使用壽命結束前更換部件。

Corrective/reactive maintenance can have severe performance costs, and preventive/ scheduled maintenance replaces parts before the end of their useful life.

CBM 通過提高可用性和可靠性，同時消除不必要的維修活動，優化維修成本與績效成本之間的權衡.

CBM optimizes the tradeoff between maintenance costs and performance costs by increasing availability and reliability while eliminating unnecessary maintenance activities

FAILURE RATE

Unplanned
Corrective Maintenance
"Run-to-Failure maintenance"

Breakdown maintenance

- High risk of secondary failure
- High production downtime
- High costs of spare parts
- Overtime labor
- Safety hazardous

+ Machines are not "over maintained"
+ No condition monitoring related costs

Preventive time- or calendar-based
Predetermined maintenance
"Fix it before it breaks"

Planned maintenance
Historical maintenance
Calendar based maintenance

- Machines are repaired when there are no faults
- Repair often causes more harm than good
- There are still "unscheduled" breakdowns

+ Maintenance is performed in controlled manner
+ Fewer catastrophic failures
+ Greater control over stored parts and costs
+ Unexpected machinery failure should be reduced

Condition based
Predictive maintenance
"If it is not broke, do not fix it"

Condition based maintenance

- High investment costs
- Additional skills required

+ Unexpected breakdown is reduced
+ Parts are ordered when needed
+ Maintenance is performed when convenient
+ Equipment life is extended

- Extra cost for observation and monitoring activities

+ Less downtime cost
+ Less cost on preventive maintenance actions

CHANGE IN MAINTENANCE PHILOSOPHY

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狀態為本的檢修
Condition Based Maintenance

維修更加有效率成為推動力
Motivation -Efficiency in maintenance

在適當的**時間**，用適當的**資源**和**備件**執行必要的幹預措施，確保列車的**可用性**和**安全性能**，並且確保執行維護活動的可**跟蹤性**和**數據資料品質**。

Perform the required interventions at the **right time** with **appropriate resources** and **spare parts** ensuring the train **availability** and **safety** performance with **traceability** and **data quality** of the executed maintenance activities
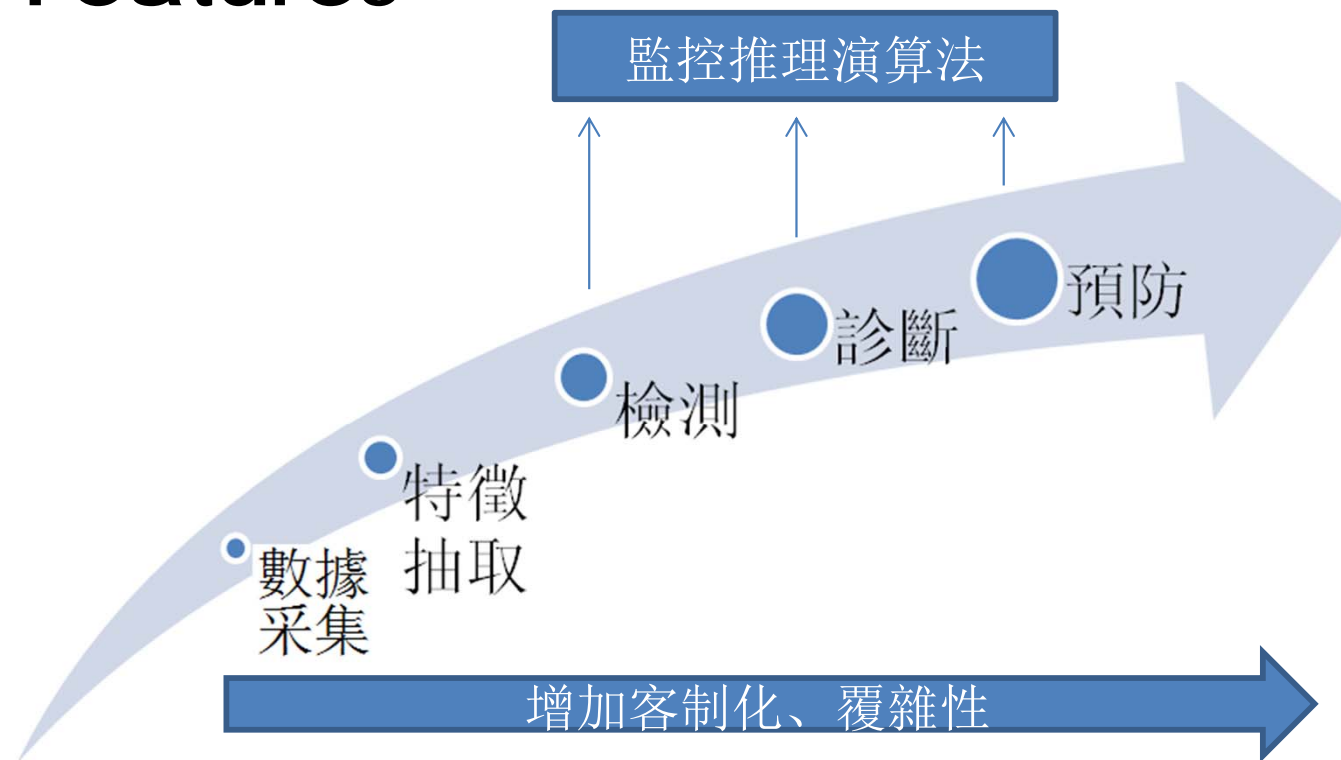
狀態為本的檢修
Condition Based Maintenance

- CBM 的特徵

CBM Features

監控推理演算法

預防

診斷

檢測

特徵
抽取

數據
采集

增加客制化、覆雜性

狀態為本的檢修
Condition Based Maintenance

➢ **數據采集可能涉及各種類型的資訊，包括：**

➢ **Data acquisition** may involve various types of information such as:

- ✓ 震動Vibration
- ✓ 溫度Temperature
- ✓ 壓力Pressure
- ✓ 速度Speed
- ✓ 電壓/電流Voltage/current
- ✓ 壓力/應力/打擊Stress/strain/shock
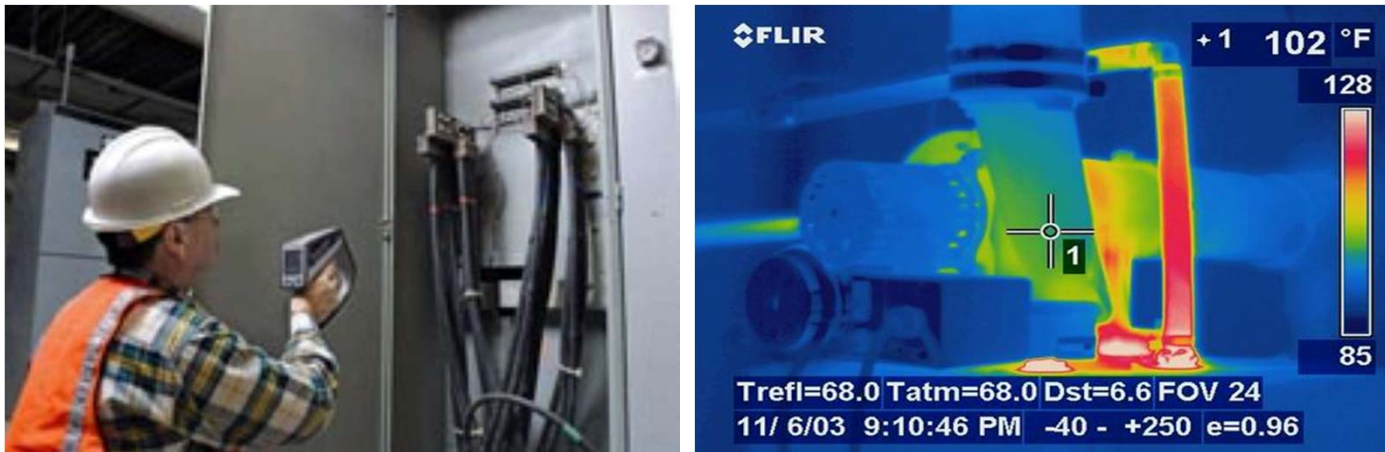- ✓ 位置Position
- ✓ 微粒計數/成分Particulate count/composition

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狀態為本的檢修
Condition Based Maintenance

– 診斷工具（**Diagnostic Tools**）

以下是一些用于狀態檢測的客觀診斷技術：

* 磨屑分析 Wear Debris Analysis
* 溫度記錄/熱像圖 Thermography
* 鐵譜分析 Ferrography
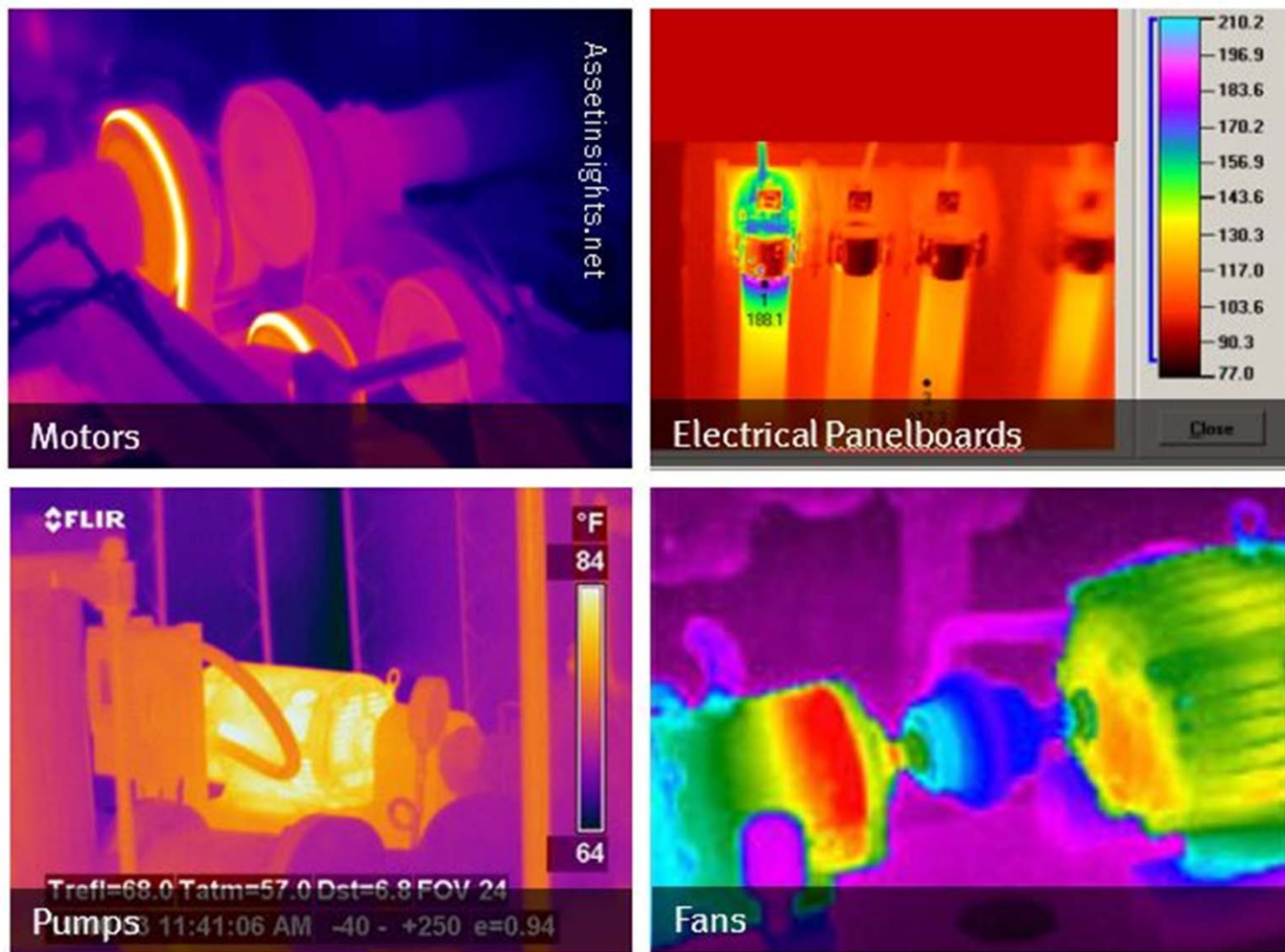* 超聲波 Ultrasonic
* 振動監測 Vibration Monitoring

電子面板的掃描和泵的熱像圖

狀態為本的檢修
Condition Based Maintenance

熱像掃描技術是眾多有助于資產預測維護(PdM)的診斷技術之一

狀態為本的檢修
Condition Based Maintenance

➤ **特徵抽取**計算可能涉及 ：

Feature extraction calculations may involve:

- ✓ 快速傅立葉轉換 Fast Fourier Transform
- ✓ 數據濾波/平整 Data filtering/smoothing
- ✓ 溫度/壓力比 Temperature/pressure ratio
- ✓ 效率 Efficiency
- ✓ 質量流量 Mass flow

狀態為本的檢修
Condition Based Maintenance

➢**檢測演算法**向使用者提示潛在的問題和未知的故障
Detection algorithms alert users to potential problems and otherwise unknown failures.

➢**診斷演算法**將故障隔離到特定的元件或子系統中
Diagnostic algorithms isolate failures to specific components or subsystems.

➢**預測演算法**根據過去和未來的操作概況和失效模型的物理狀況來估計剩餘使用壽命
Prognostic algorithms estimate remaining useful life based on past and future operational profiles and physics of failure models.

狀態為本的檢修
Condition Based Maintenance

➢ **監控推理**演算法協調相互矛盾的資訊，並提供如下建議：
Supervisory reasoning algorithms reconcile conflicting information and provide recommendations such as:

- ✓ 檢查 Inspections
- ✓ 修理 Repairs
- ✓ 零件訂購 Parts ordering
- ✓ 設備停用 Equipment shutdown

狀態為本的檢修
Condition Based Maintenance

➢ **狀態監測**是狀態為本的檢修策略的核心部分。一個精心編排的狀態監測系統促進了持續的改進，會潛移默化地帶來巨大的改變。

➢ Condition monitoring is a central part of a condition based maintenance strategy. A well-orchestrated condition monitoring system facilitates continuous improvements that could have dramatic impacts.

➢ **狀態監測系統**可以加強

➢ A condition monitoring system enhances:

• 運營安全，保護資產，減少對環境的影響。Safe operation, preserves assets and minimizes environmental impact.

• 一體化運營促成線上線下的全球協作。 Integrated operations enabling global collaboration between off-site and on-site activities.

• 延長設備調查和大修之間之時段，減少計畫外停機、維護和運營成本。 Extension of time between equipment surveys and overhauls, and reducing unplanned downtime, maintenance and operating costs.

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狀態為本的檢修
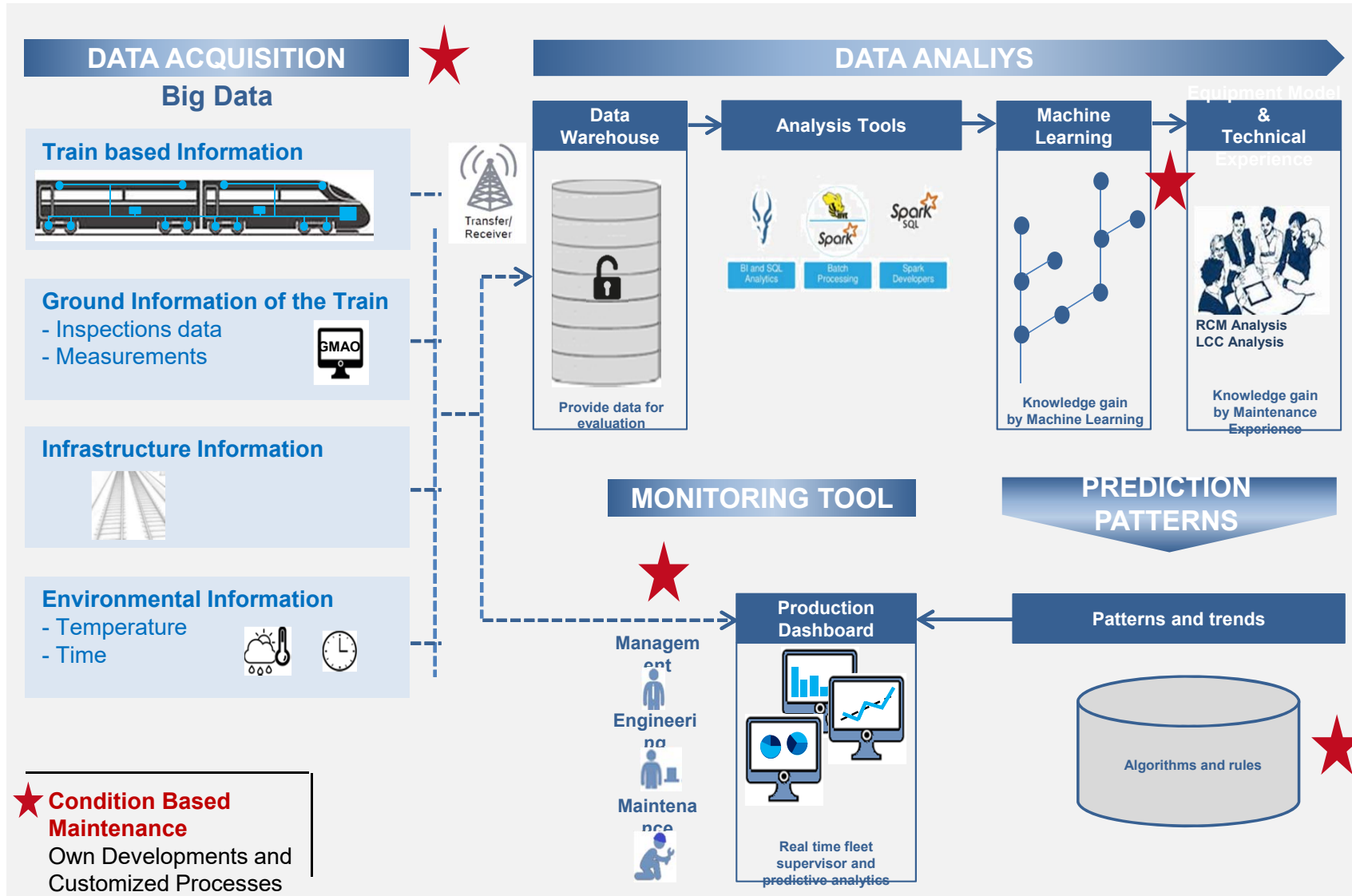## Condition Based Maintenance
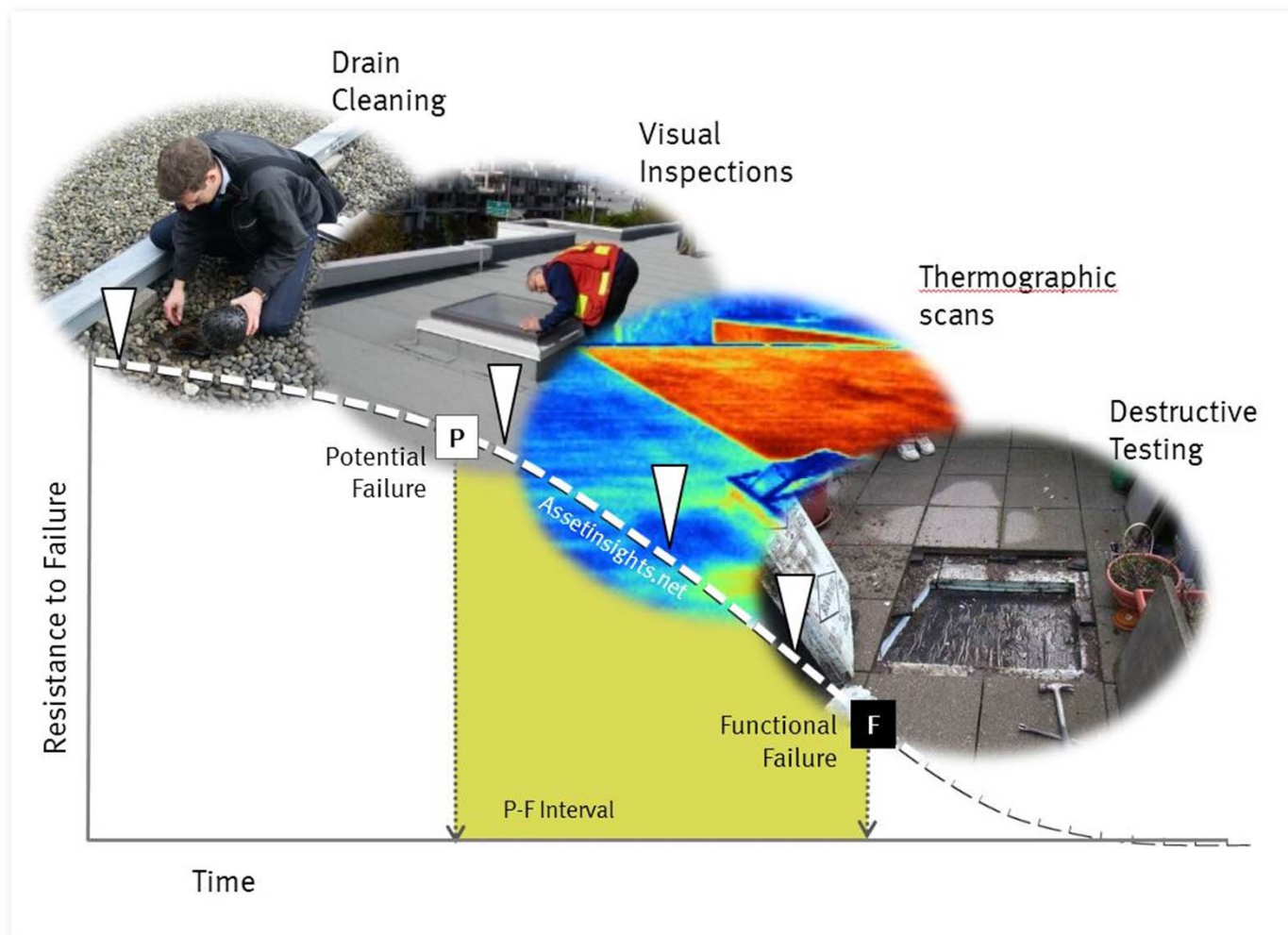
主要維護任務映射到P-F曲線

狀態為本的檢修的優點
Benefits of employing CBM

- **提高維修效率 Efficiency in maintenance**
  - Equipment's tracking performance.
  - Planning and prioritizing correctives actions.

- **節省維修成本 Savings in maintenance cost**
  - Improvements in performance of components with high failure rate

- **優化備件供應鏈 Spare part supply chain optimization**
  - Supply chain adjusted to accurate forecast

- **提高績效 Performance Improvement**
  - Increase in Availability and Reliability - with less operation related incidents

- **實時監測 Real time monitoring**
  - Status monitoring for all key asset systems / subsystems

- **運營協助 Operational Assistance:**
  - Help operators in real time operation/incident management

案例研究
Case Studies

- CBM架構和流程案例 （An example of the CBM structure and processes)

DATA ACQUISITION
Big Data

Train based Information

Ground Information of the Train
- Inspections data
- Measurements

GMAO

Infrastructure Information

Environmental Information
- Temperature
- Time

Transfer/Receiver

DATA ANALIYS

Data Warehouse

Provide data for evaluation

Analysis Tools

BI and SQL Analytics | Batch Processing | Spark Developers

Machine Learning

Knowledge gain by Machine Learning

Equipment Model & Technical Experience

RCM Analysis
LCC Analysis

Knowledge gain by Maintenance Experience

MONITORING TOOL

Management
Engineering
Maintenance

PREDICTION PATTERNS

Production Dashboard

Real time fleet supervisor and predictive analytics

Patterns and trends

Algorithms and rules

★ Condition Based Maintenance
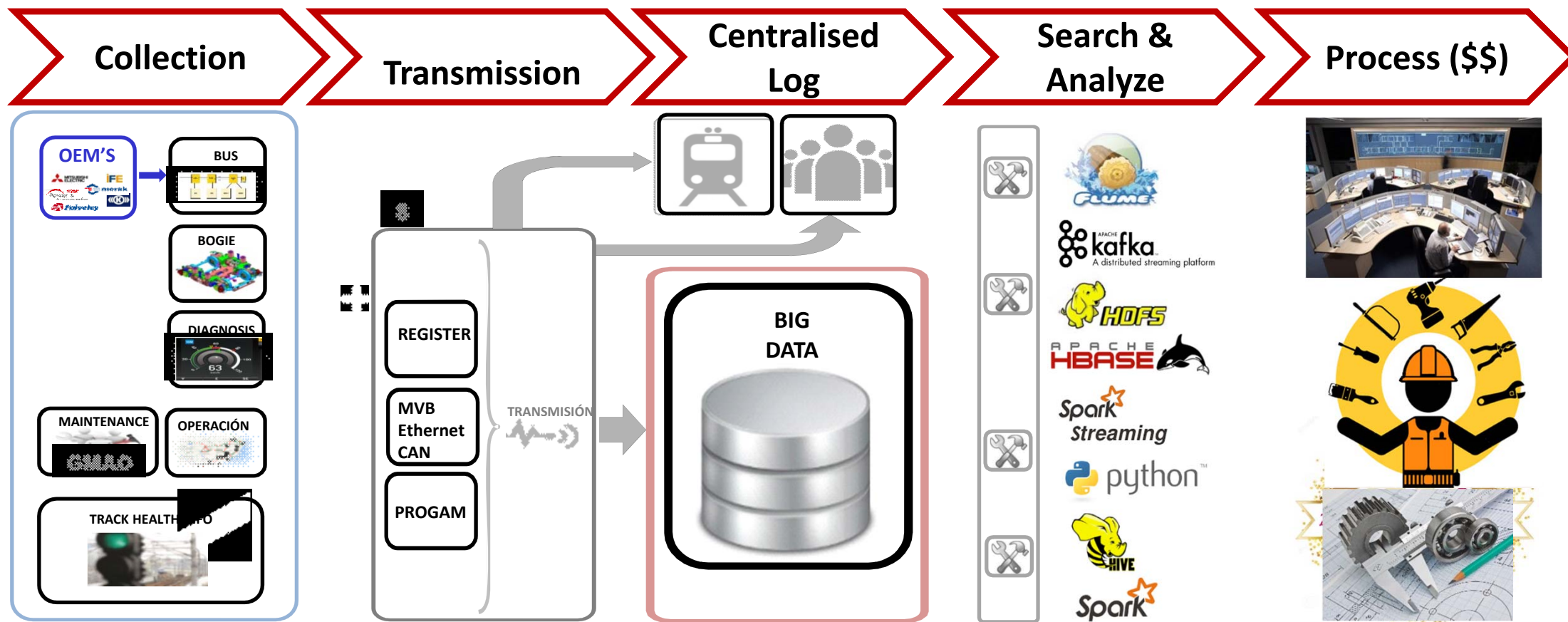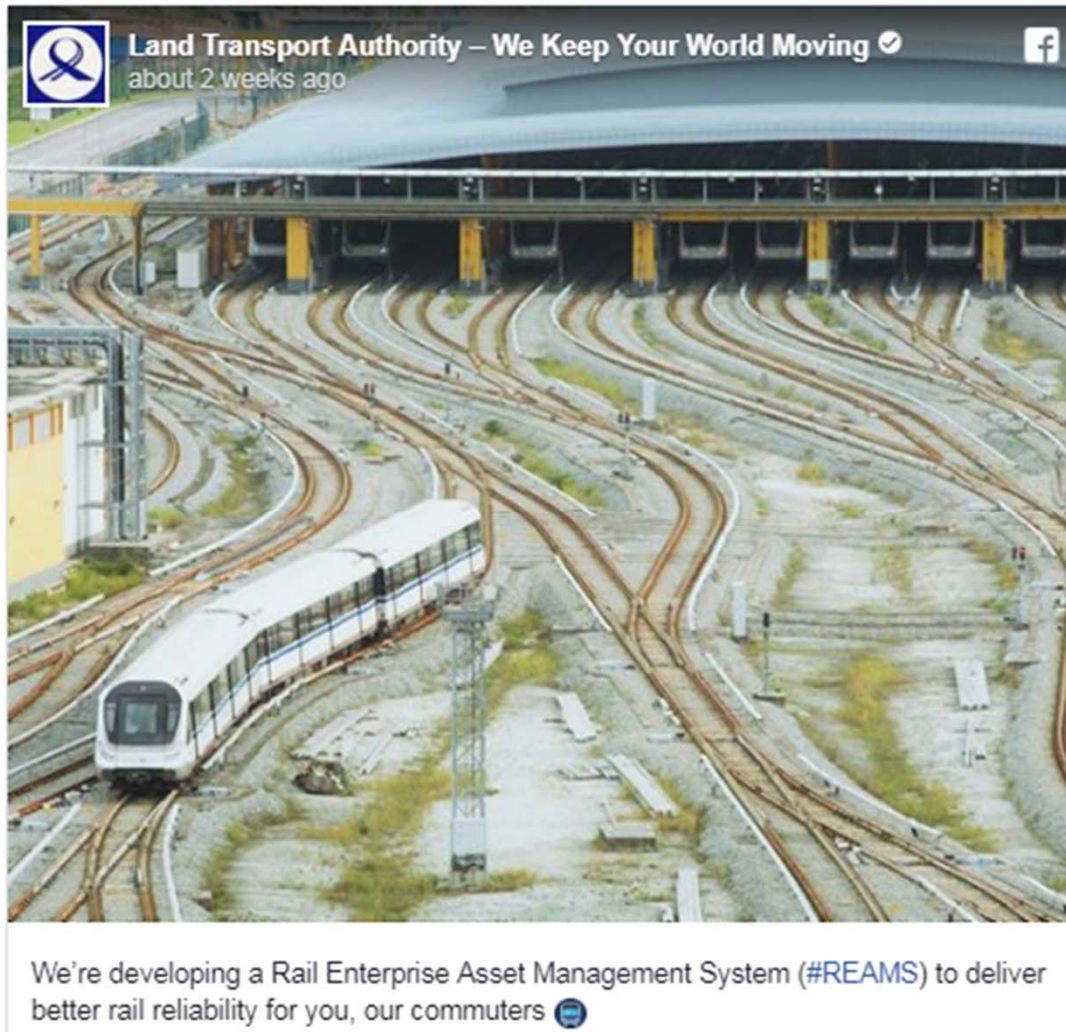Own Developments and Customized Processes

案例研究
Case Studies

- CBM工作平臺和流程案例（An example of the CBM platform and processes)

案例研究
Case Studies

新加坡陸路運輸局
Singapore LTA

案例研究
Case Studies

- 新加坡LTA採購了188萬美元的鐵路企業資產管理系統
- SINGAPORE LTA procured a $18.8 million Rail Enterprise Asset Management System (a software based system) that will integrate asset information across all MRT lines

- LTA表示，"鐵路企業資產管理系統將使工程師能夠更好地監控各個鐵路運營資產在各自生命週期中的健康狀況
- The Land Transport Authority (LTA) stated "the Rail Enterprise Asset Management System (Reams) will enable engineers to better monitor the health of various rail operating assets over their respective life cycles."

https://www.straitstimes.com/singapore/transport/lta-awards-188-million-contract-to-develop-integrated-rail-asset-management

結論
Conclusion

與預防性維護相比，CBM 增加了維護維修之間的時間間隔，因為維護是在基於所需。

它帶來的好處將涵蓋從操作到工程、規劃、保護、維護和資產管理

CBM的實施將提高系統的可用性和可靠性，並降低維護成本和庫存

發展路向
Way Forward

維護方案的演變（**Evolution of maintenance practices**)

曾經　現時　　未來

Past　　Present　Future

- 基於時間間隔的維修 Interval based
  - Time based
  - Counter based (operational parameters)

- 狀態為本的檢修 Condition based (including real time conditions)

- 資產管理未來趨勢 Future Trend on Asset Management
  - 高效率決策 Effective decision making
  - 組織變革 Organizational changes
  - 數據挖掘, 共享 Data mining / sharing
  - 預測性數據分析 Predictive data analytics
  - 標準化 Standardization

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謝謝 Thank you

請賜教
Q&A

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