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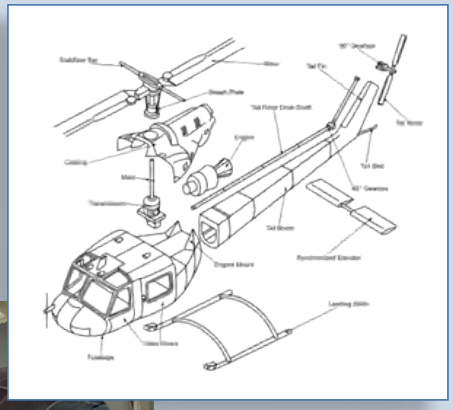
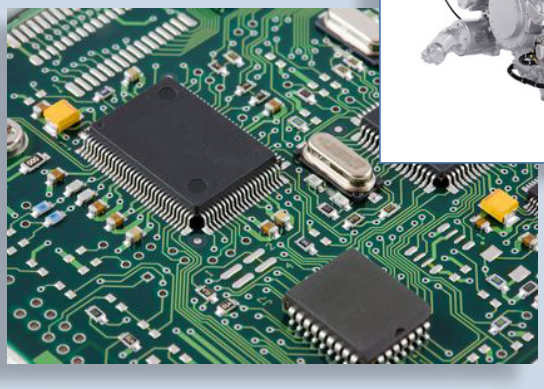




Condition-Based Maintenance (CBM)

CBM processes are applicable to maintenance activities on complex systems.

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.

Corrective/reactive maintenance can have severe performance costs, and preventive/scheduled maintenance replaces parts before the end of their useful life. CBM optimizes the tradeoff between maintenance costs and performance costs by increasing availability and reliability while eliminating unnecessary maintenance activities.

Southwest Research Institute® (SwRI®) develops and implements technologies that enable CBM, including data acquisition systems, management and tracking software, and condition monitoring algorithms.

CBM Components

CBM components are an optimized mix of:

- Maintenance technologies (diagnostics, prognostics)
- Reliability-centered maintenance (RCM)-based processes
- Enablers (total asset visibility)

CBM Features

- Data acquisition may involve various types of information:
  - Vibration
  - Temperature
  - Pressure
  - Speed
  - Voltage/current
  - Stress/strain/shock
  - Position
  - Particulate count/composition
- Feature extraction calculations may involve:
  - Fast Fourier Transform
  - Data filtering/smoothing
  - Temperature/pressure ratio
  - Efficiency
  - Mass flow
- Detection algorithms alert users to potential problems and otherwise unknown failures.
- Diagnostic algorithms isolate failures to specific components or subsystems.
- Prognostic algorithms estimate remaining useful life based on past and future operational profiles and physics of failure models.
- Supervisory reasoning algorithms reconcile conflicting information and provide recommendations such as:
  - Inspections
  - Repairs
  - Parts ordering
  - Equipment shutdown

Applications

The CBM process can be applied to maintain activities in all industries, including:

- DoD weapons systems
- Jet engines
- Wind turbine generators
- Marine diesel engines
- Natural gas compression
- Circuit card manufacturing

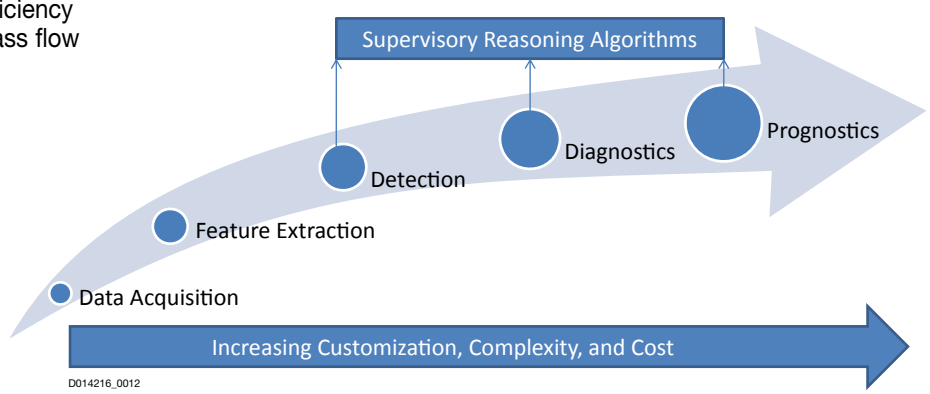
SwRI has developed algorithms for CBM solving the complex problems of:

- Process optimization with complex input/output relationships
- Pattern recognition with incomplete data
- Anomaly detection for earliest indications of adverse performance shifts

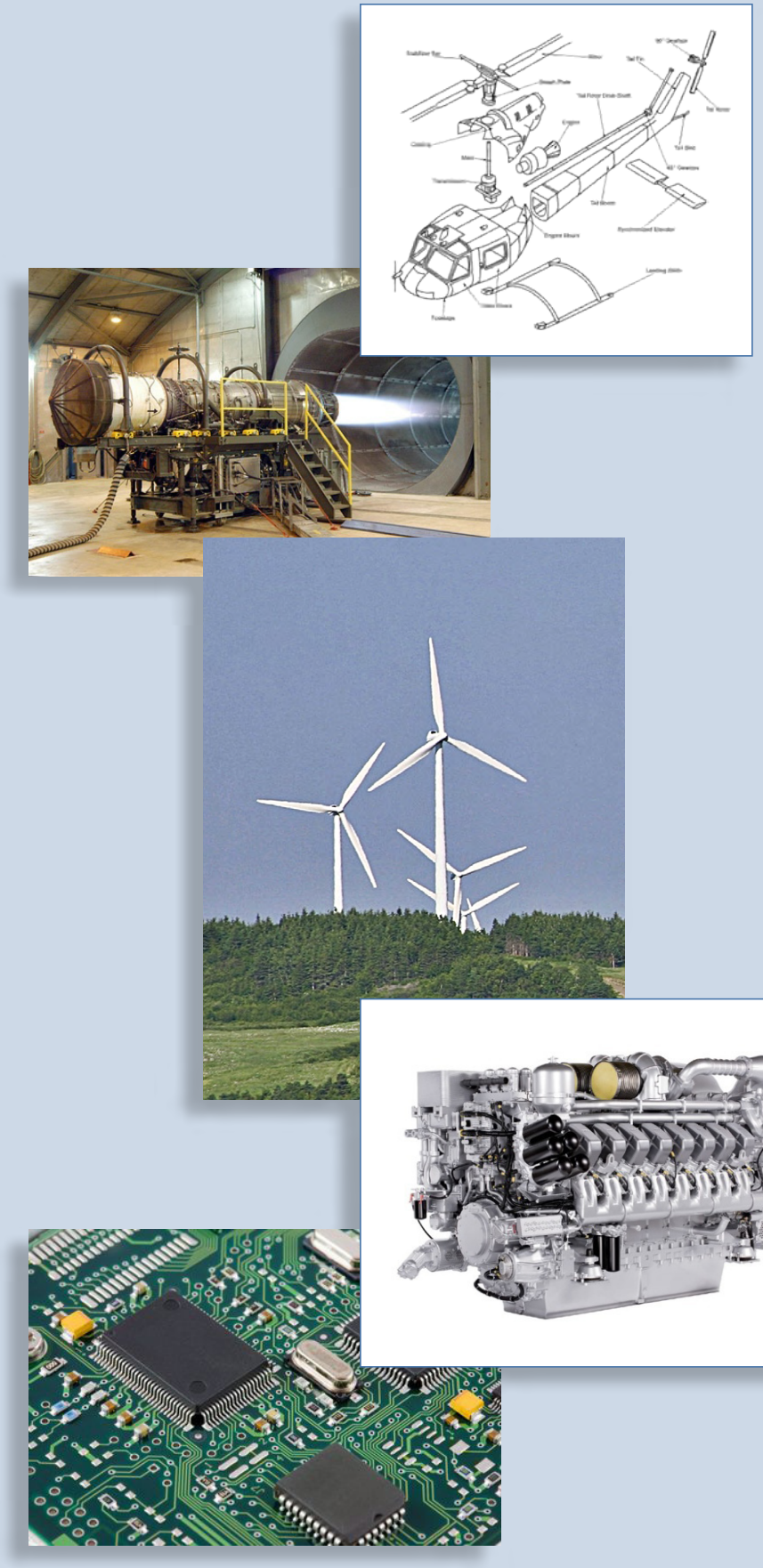
Benefits

The benefits of implementing CBM include:

- Increased system availability
- Increased system reliability
- Reduced maintenance costs
- Reduced inventories



The Detection, Diagnostics and Prognostics (DD&P) process is divided into procedures tailored to the needs of a system.



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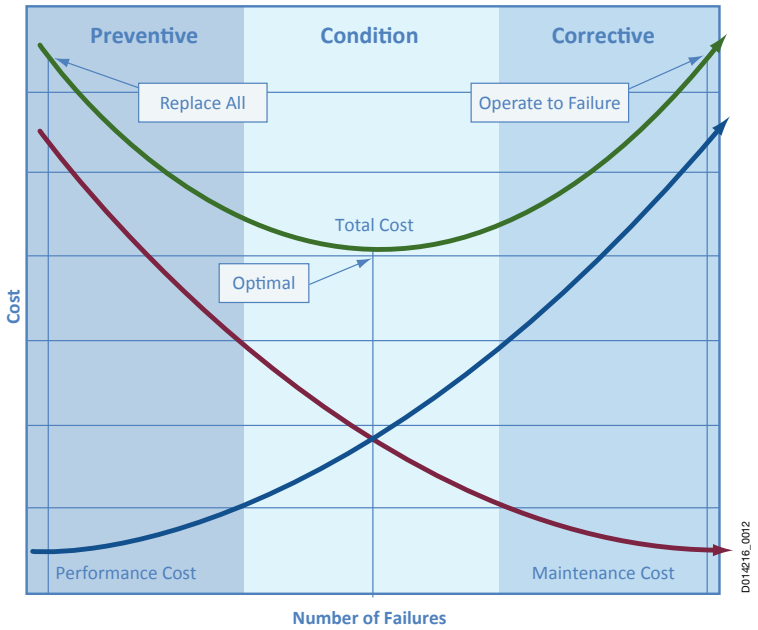

CBM optimizes costs between preventive and corrective maintenance.

From Larry Toms, *Machinery Oil Analysis: Methods, Automation and Benefits*, 1995.

Related Capabilities

SwRI has developed CBM-related capabilities to include hardware, algorithms and tools:

- Sensor suites
- Data acquisition software and systems
- Data manipulation, repository and interface applications
- Automated condition monitoring and state detection algorithms
- Diagnostic algorithms
- Enhanced prognostic techniques
- Advisory tools and systems
- Business process analysis and automation
- Asset management and tracking systems
- Troubleshooting and maintenance aids
- Interactive and hands-on training

Southwest Research Institute is an independent, nonprofit, applied engineering and physical sciences research and development organization using multidisciplinary approaches to problem solving. The Institute occupies 1,200 acres in San Antonio, Texas, and provides more than 2 million square feet of laboratories, test facilities, workshops and offices for more than 3,200 employees who perform contract work for industry and government clients.

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