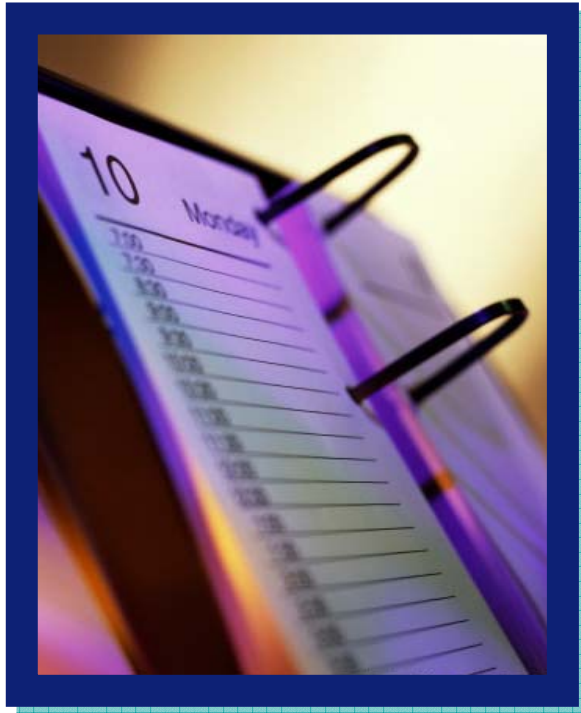




## Overcoming the challenges of aero-engine dynamic testing

Aerospace Testing Expo Europe 5 6 7 April 2005  
Benoit Dierckx, Thomas Vasel

# Outline



- Introducing LMS
- The challenges of dynamic data acquisition
- Solutions for dynamic data acquisition systems
- Examples
- Conclusion

# LMS, 25 years of engineering innovation

## Market leadership in noise & vibration engineering



### A future built on strong fundamentals

- Driven by a compelling vision
- The industry largest R&D commitment to Engineering Innovation
- Talented people, 650 professionals committed to customers' success
- More than 3000 manufacturing companies actively use LMS products and services
- Strong financial track record of double digit profitable growth
- 20 offices worldwide



to 2005



# LMS, delivering a next generation portfolio for functional performance engineering



## LMS Tec.Manager

Test and Simulation  
Data Management

## LMS Engineering

Process Integration &  
Engineering Services



## LMS Test.Lab

Market Leader Physical Test



## LMS Virtual.Lab

Technology Leader Virtual Simulation

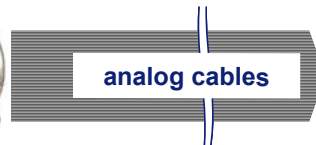
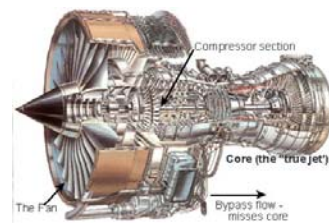
# Outline



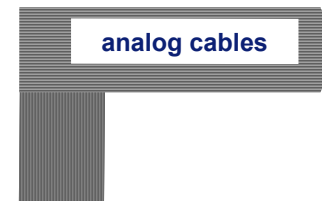
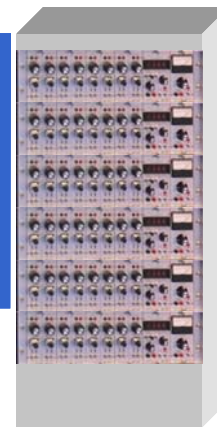
- Introducing LMS
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# A typical aero-engine dynamic data acquisition system

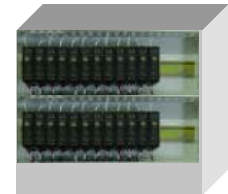
- From 30 to 300+ channels
- Frequency bandwidth between 5 and 80 kHz
- Static and Dynamic strains, pressure, accelometer, microphone, ....
- Short and long test duration
- Real-time scope monitoring
- Dedicated level and order alarming



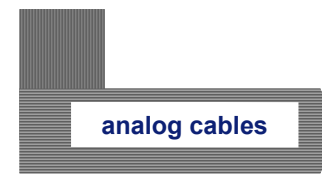
Signal Conditioning



Alarming



Recording



Oscilloscopes  
Data Viewing

Custom made system

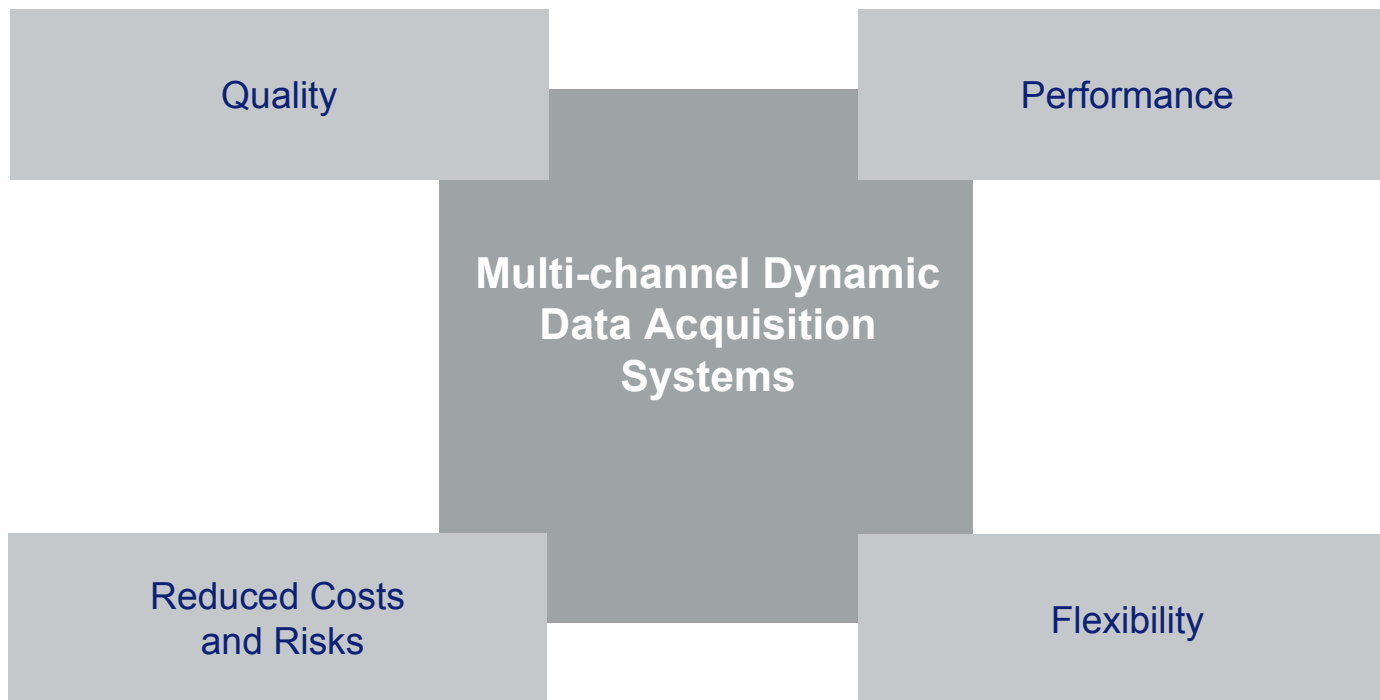
Specialized components

Long and expensive signal cables

Expensive maintenance

Little evolution

# Challenges for the future



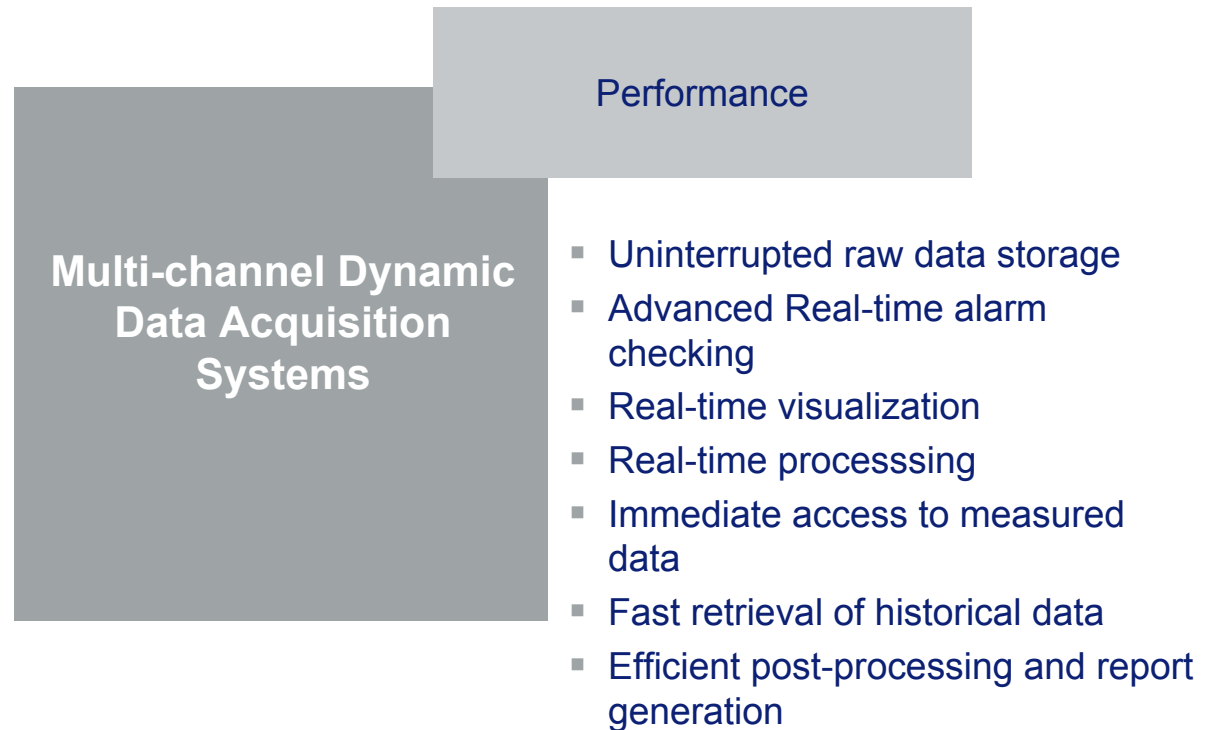
# Challenges for the future

Quality

- All digital – 16/24 bit
- High quality signal conditioning
- Early digitization
- Full synchronization
- Tight hardware and software intergration
- Diagnostics
- Troubleshooting tools

Multi-channel Dynamic  
Data Acquisition  
Systems

# Challenges for the future



# Challenges for the future

## Multi-channel Dynamic Data Acquisition Systems

- Easy Test Preparation
- Easy channel configuration
- Different acquisition bandwidths
- From small transportable to large “super” test
- Flexible online data visualization and processing
- Broad post-processing

Flexibility

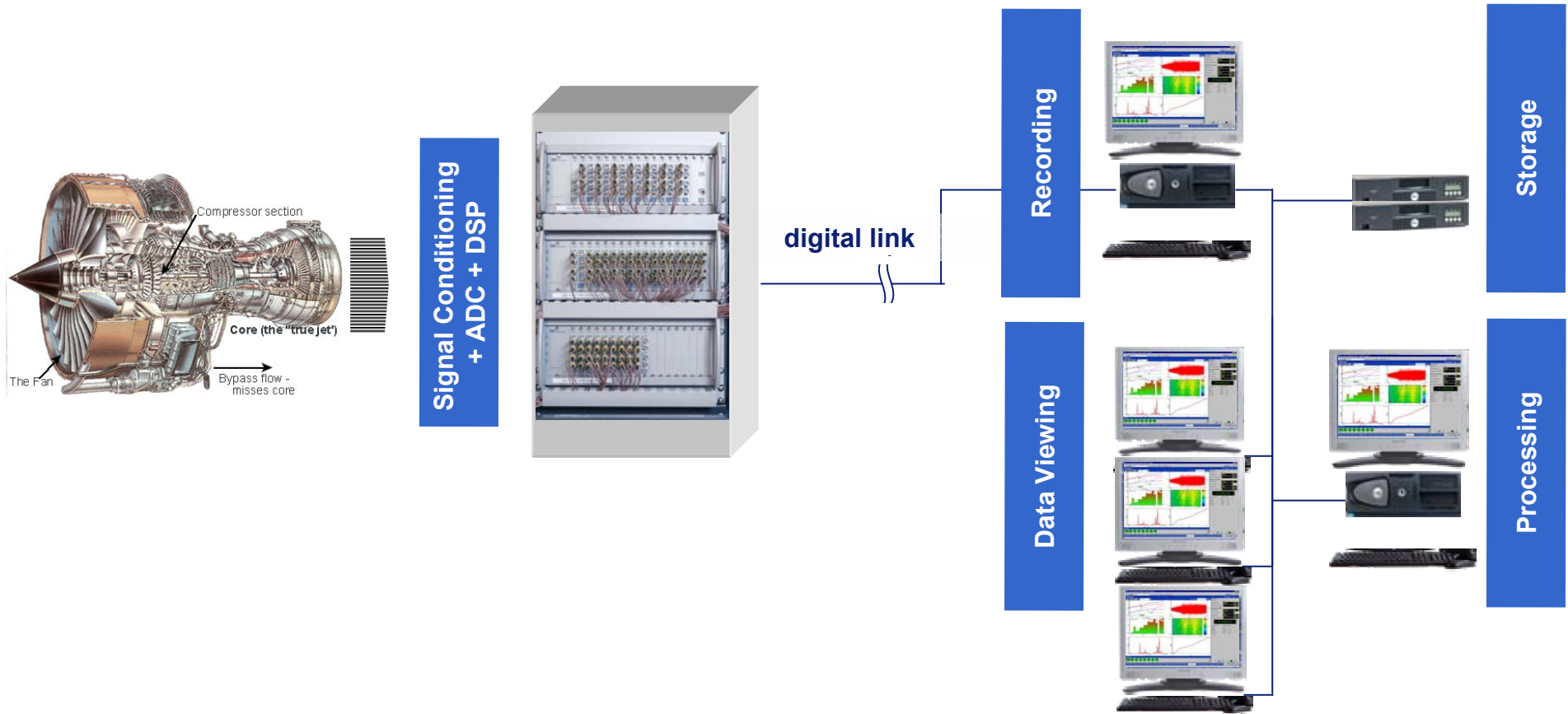
# Challenges for the future

- COTS components
- Benefit of “standard” IT componentes
- Low training costs
- Reliable single source supplier

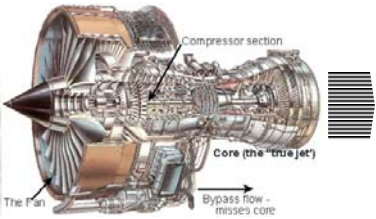
Multi-channel Dynamic  
Data Acquisition  
Systems

Reduced Costs  
and Risks

# The ideal aero-engine dynamic data acquisition system



# The ideal aero-engine dynamic data acquisition system

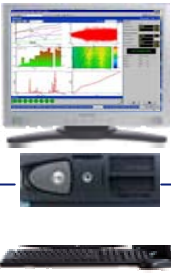


Signal Conditioning  
+ ADC + DSP

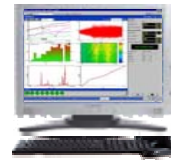


digital link

Recording



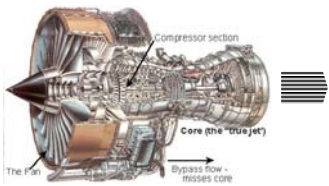
Viewing



Storage



Processing



Signal Conditioning  
+ ADC + DSP

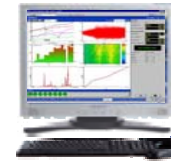


digital link

Recording



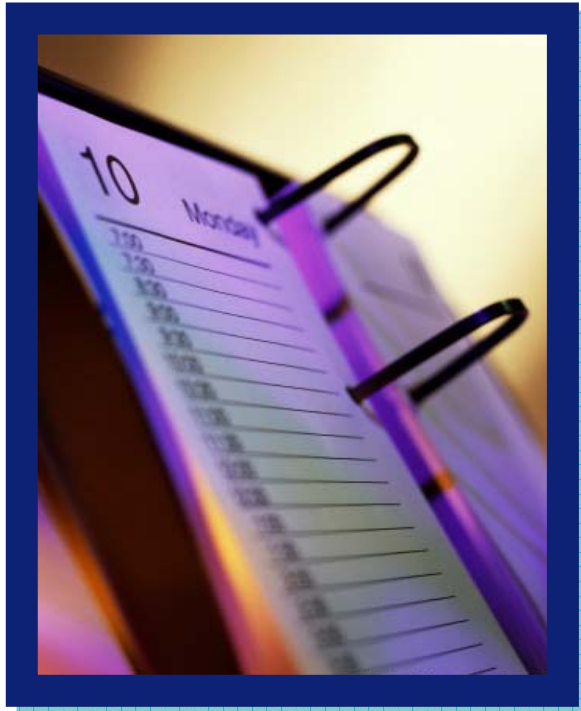
Viewing



Processing



# Outline



- Introducing LMS
- The challenges of dynamic data acquisition
- Solutions for dynamic data acquisition systems
- Examples
- Conclusion

# Data acquisition hardware: the LMS SCADAS III family

Lab / Mobile

Test Bench / Lab



SC316  
SC317S slave unit



SC310(DC)  
SC311S(DC) slave unit



SC305DC  
SC306S slave unit

# The LMS SCADAS III family

## The industry standard dynamic data acquisition system

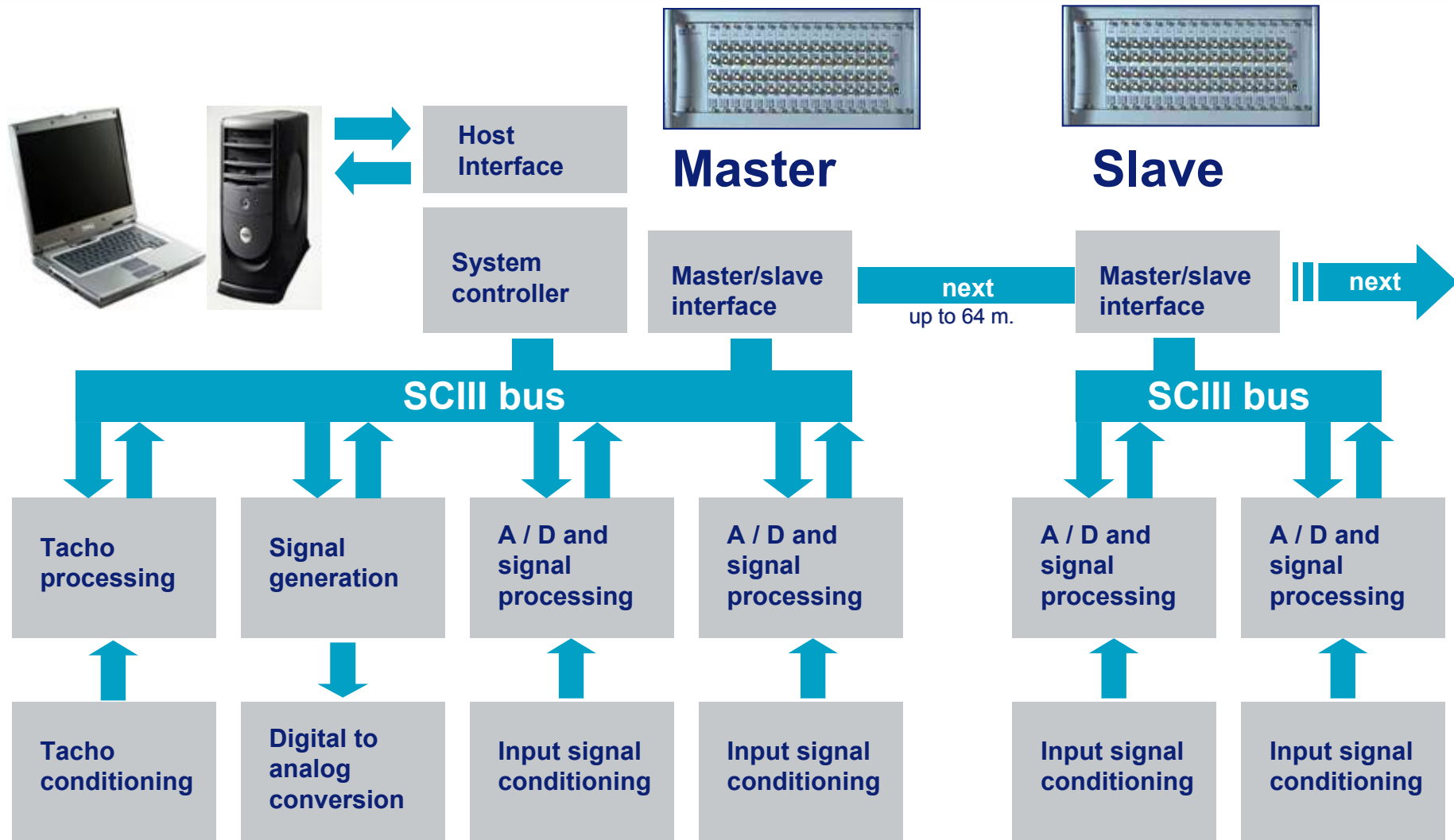


- Size specific mainframes
- 4 to 500+ channels
- 24-bit ADC w/ 116 dB dynamic range
- 6 Hz - 204.8kHz sampling – 92kHz usable bandwidth
- In-stream digital gain and offset calibration
- Up to 6 MSamples/s per frame sustained throughput to host PC
- 2 MSamples FIFO per Channel

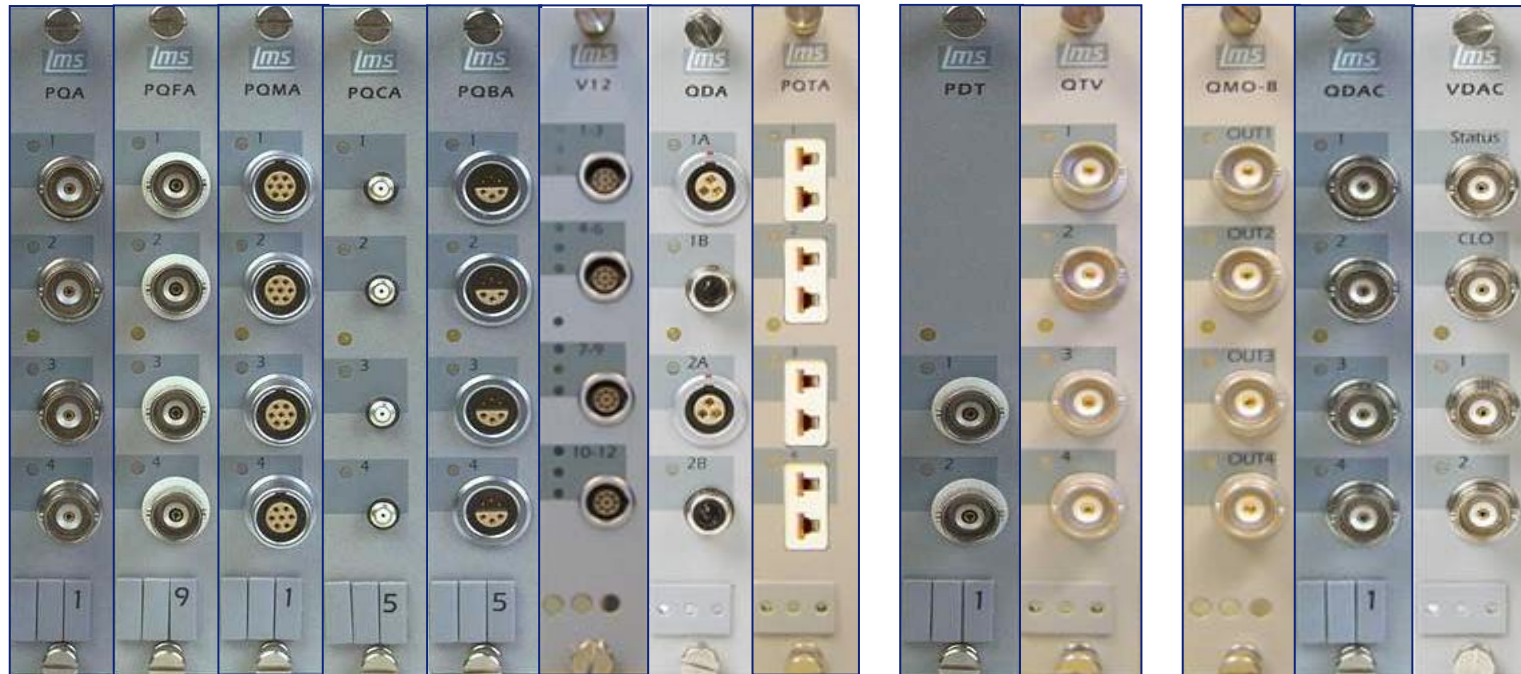


Scalable

# LMS SCADAS III architecture



# LMS SCADAS III: A wide range of signal conditioners

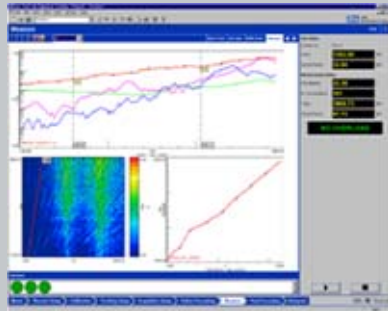


- Input signal conditioning: Voltage, ICP, (differential) charge, (static and dynamic) strain, microphone, temperature ....
- Tacho conditioning – up to 8 tacho signals
- Output conditioning and signal generation

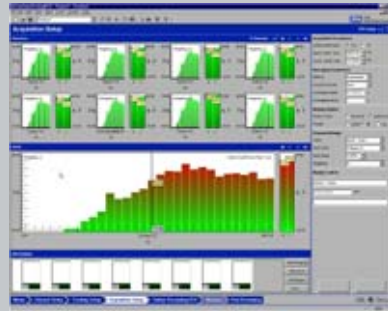
# Introducing LMS Test.Lab software ...

## One single user environment - for any Noise and Vibration job

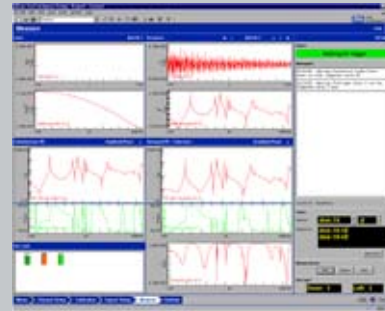
Rotating Machinery



Acoustics



Structural



Environmental & Durability

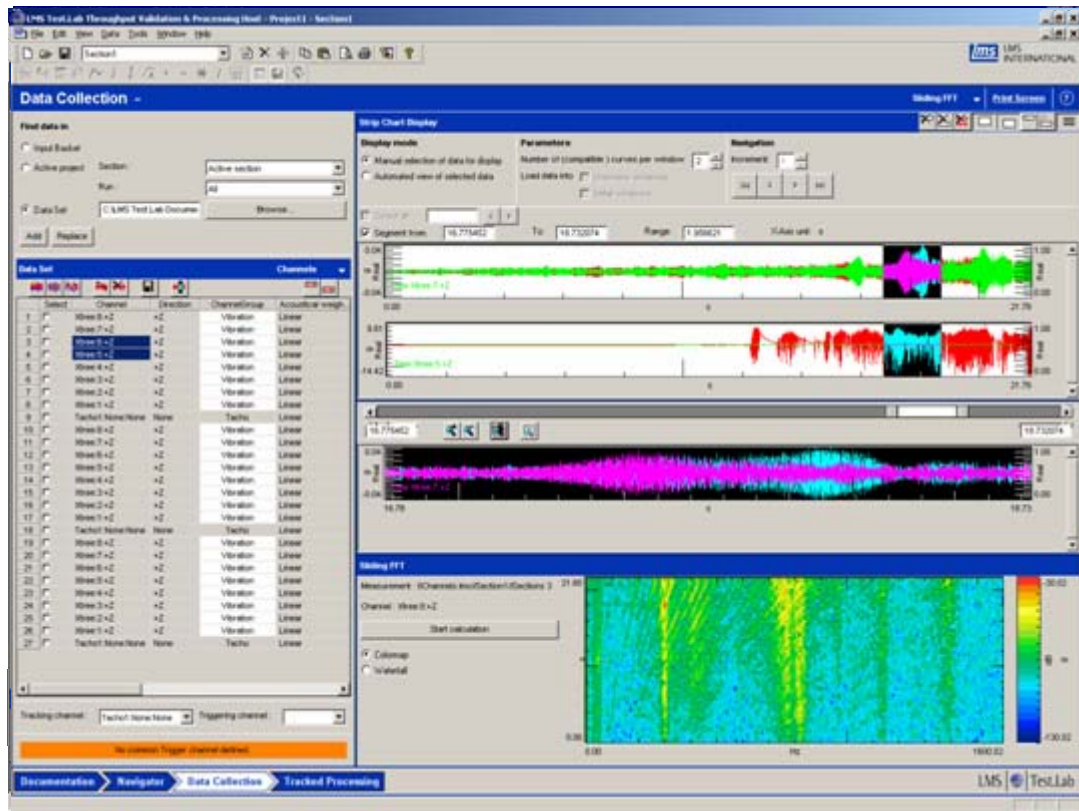


Reporting  
Data Sharing  
Advanced  
Analysis



# Test laboratory concept

## Embedded workflow provides sequencing of tasks



### Embedded Workflow ...

- Sequence to follow guided through major and minor task workflow
- Consistency in execution delivers quality in results
- Operational within half a day through suggested workflow in the workbooks
- Ease-of-Use for:
  - Occasional User
  - Operator
  - Expert

**Report**



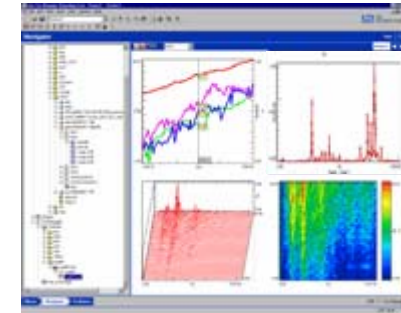
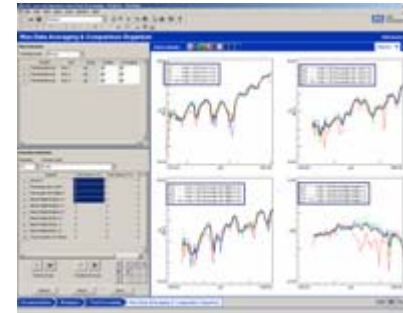
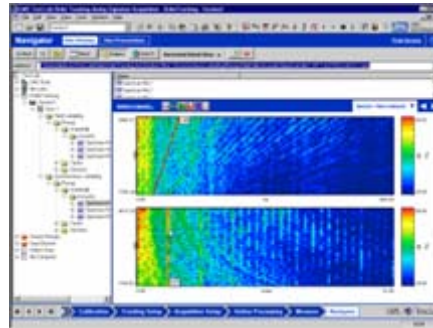
# A complete solution for rotating machinery testing

Measurement Setup

Test Execution

Test Validation  
Post processing

Reporting



Throughput Data Recording  
Spectral Analysis  
Order Analysis  
Octave Analysis

Compare Measurements  
Sign. Data Post processing  
Throughput Validation  
Throughput Processing  
Operational Deflection Shapes

Desktop  
Batch Printing

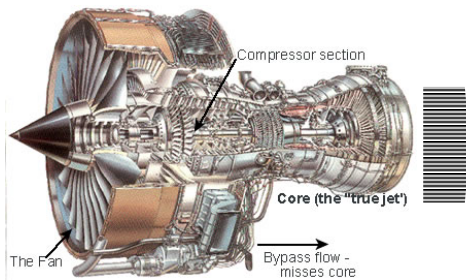
Audio Replay & Filtering

Psycho acoustic Sound  
Diagnosis

# The LMS Solution for aero-engine dynamic testing

## Basic configuration

**Stand-alone**  
**Transportable**  
**Flexible**  
**Easy to Use**



**Signal Conditioning  
 + ADC + DSP**



**digital link**

**Recording  
 or  
 Processing**



**Data Viewing**



- **Recording Station**
  - LMS Test.Lab
  - High Speed Time Data Recording Workbook
  - Acquisition Control
  - 60 channel @ 40 kHz BW – 8 hours gapless
- Data Storage: Internal / External RAID / SAIT 1 (500 GB/tape)

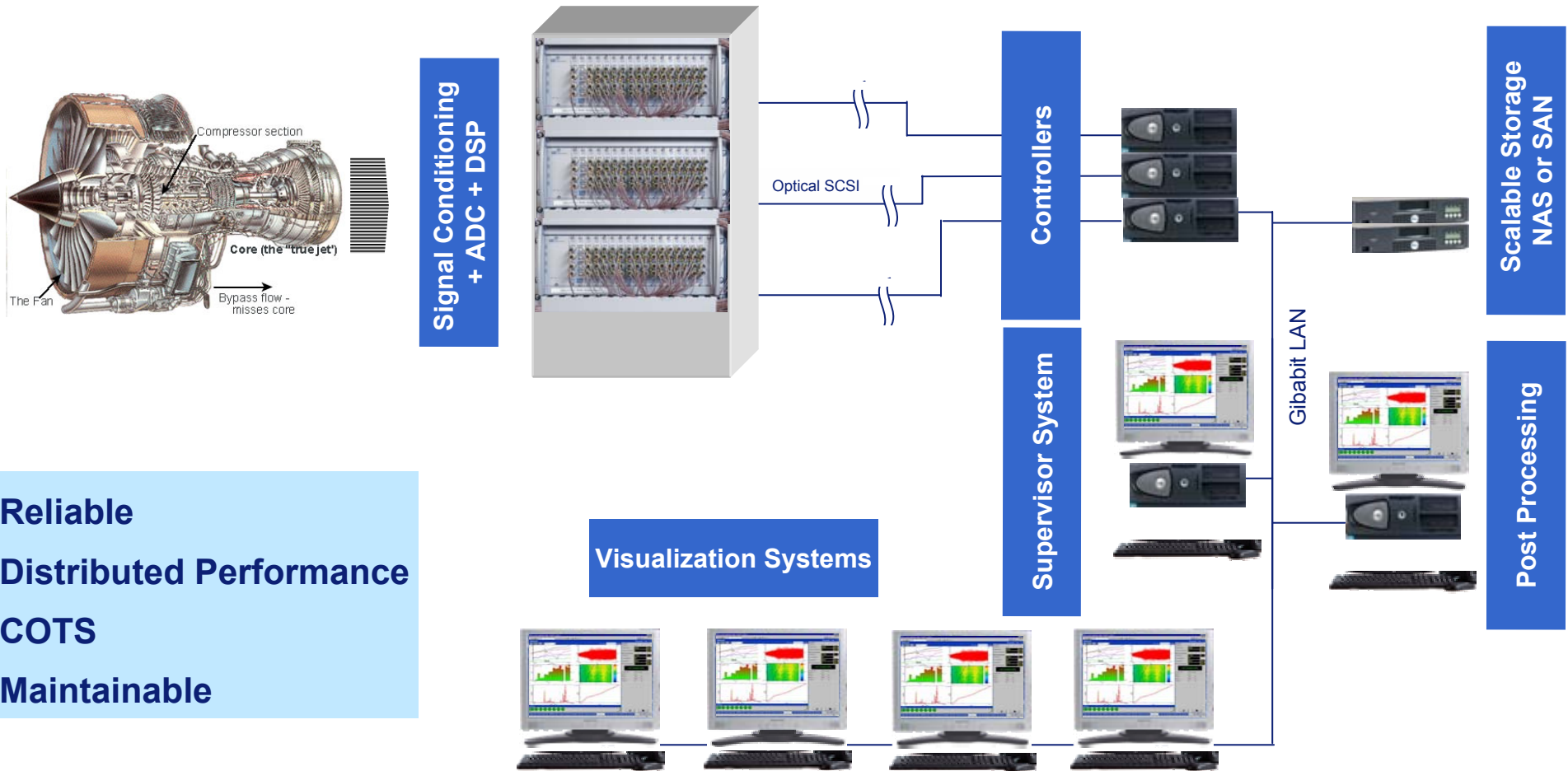
- **Channel Data Acquisition Front- end**

- SCADAS 316
- Clock Synchronization
- Trigger Synchronization
- SP92D Digital Signal Processor Units
- 1 Tacho module
- 15 PQx - 4 channel Conditioning
- IRIG-B acquisition

- **Visualization Station**

- LMS Test.Lab High Speed Monitoring Workbook
- Single or Multiple display / Mouse and Keyboard
- Flexible Visualisation with added value
- Time/Order/Octave/Frequency data
- Warning / Alarm Levels

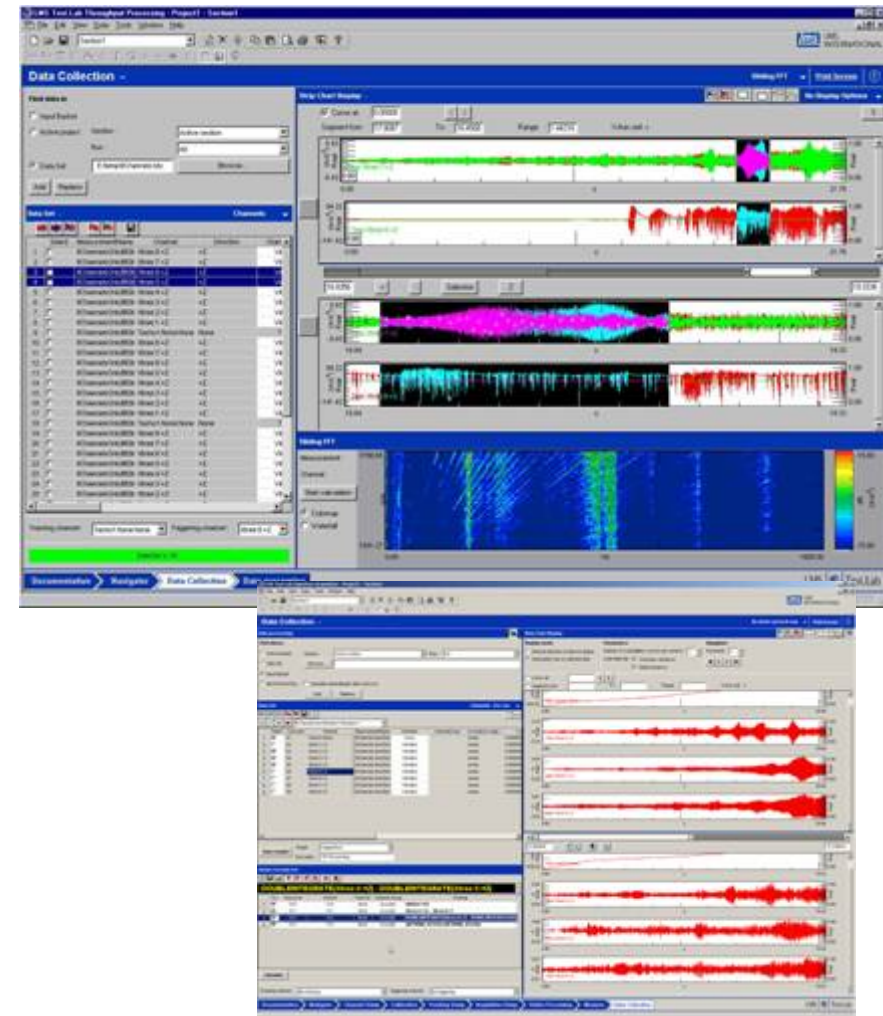
# Flexibility and Expandability using Industry Standard Components



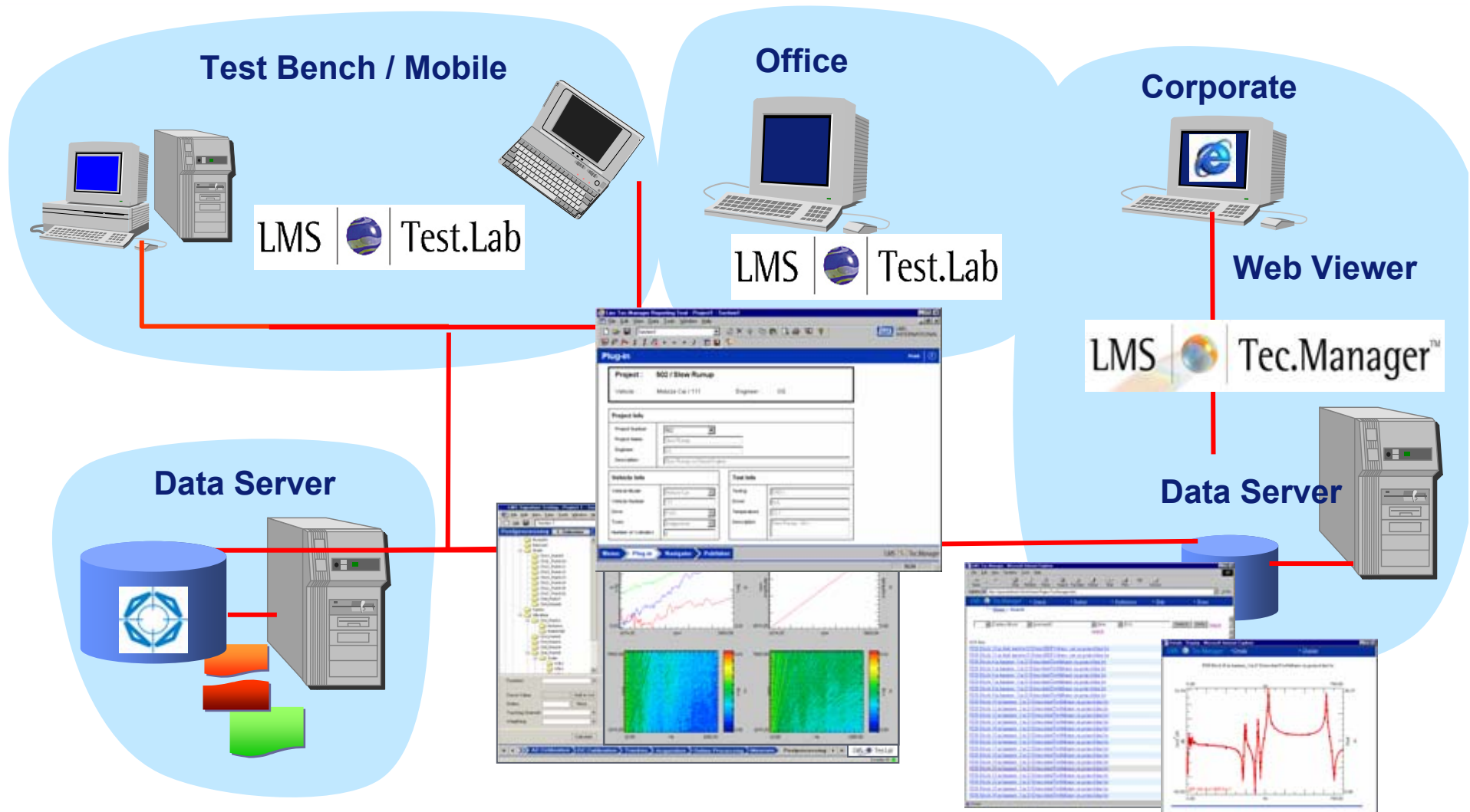
**Reliable**  
**Distributed Performance**  
**COTS**  
**Maintainable**

# Post-Processing

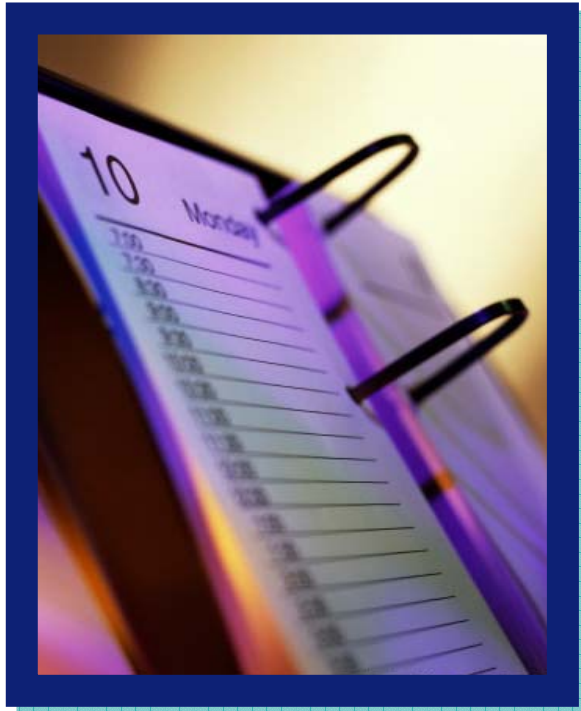
- General Analysis
  - Data Reduction
  - Time/Frequency/Order/Octave analysis
  - Statistics
  - Specific monitoring of events
  - Visualisation of curves
  - Deformation shapes
  - Using Absolute IRIG-B coding
- Specific analysis
  - Transient Analysis
  - Coherence / Correlation analysis
  - Source Identification
  - Operational Deflection Shape analysis
  - Operational Modal Analysis
  - Time-data Animation
- Automation of analysis
  - Automatic Post-processing in batch



# Data organization and retrieval



# Outline



- Introducing LMS
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# Example 1: Recording and Alarm system

## 128 channel recording system

- Up to 8 tacho input channels
- 128 dynamic channels (SP92D)
- IRIG for accurate absolute time annotation
- 1 recording station for control of the data acquisition
- 1 analysis station for post test analysis and data storage
- Data immediately available for visualization and post processing
- Supports two measurement types
  - Performance: up to 128 channels gapless continuous during 1.30 hours
  - Endurance: up to 35 channels continuous with circular buffer on analysis PC of more than 40 hours of data

## Vibration Monitoring System

- 24 dynamic input channels
- Up to 8 tacho input channels
- 8 x 8 low frequency output channels to alarm system
- Tracking of 64 values
  - 1<sup>st</sup> Order Amplitude versus any tacho
  - 1<sup>st</sup> order phase versus any tacho
  - Bandlimited RMS
  - Broadband RMS
  - Integration (1 or 2x)
- Visualization of processed data
  - Predefined 1, 2x2 or 4x4 display with user selectable channel

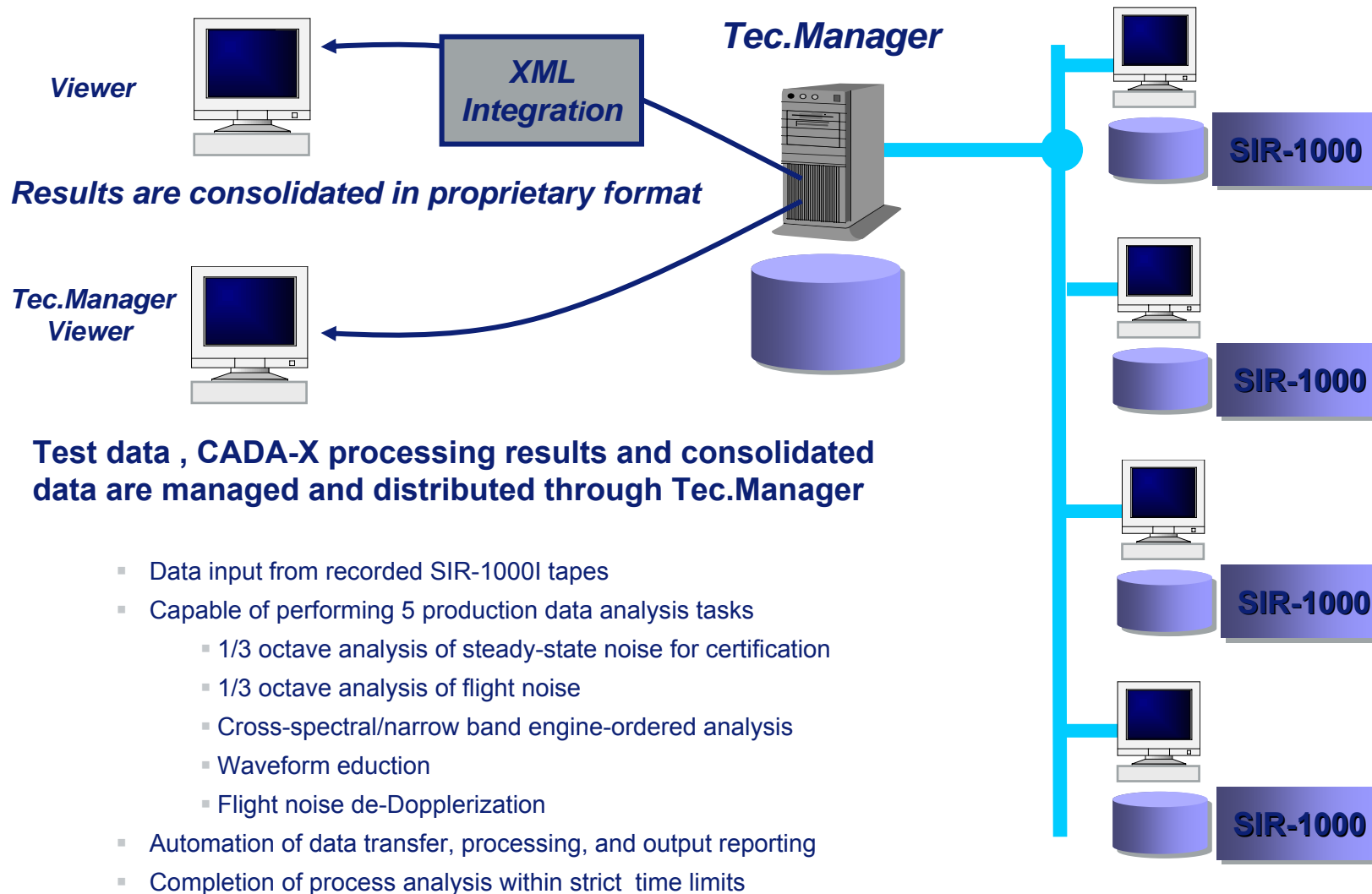
## Example 2:

### 200 channel recording with online visualization and alarming

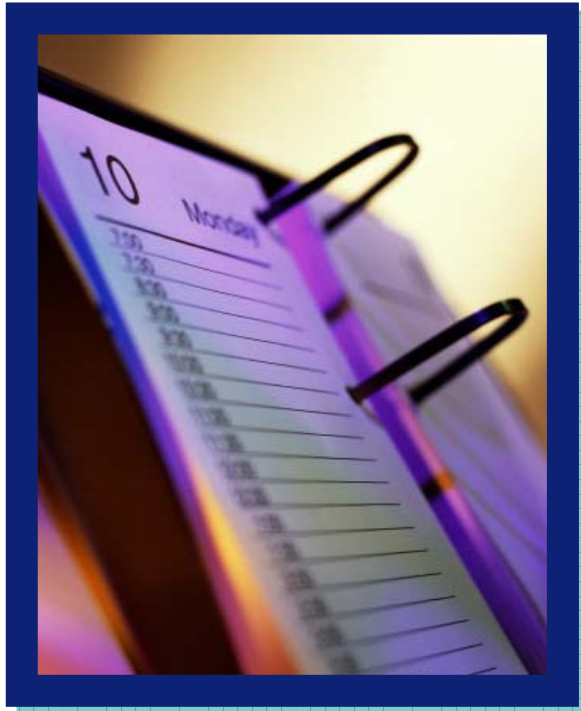
- **200 channel data recording system**
  - 40 kHz bandwidth / channel
  - 5 hour continuous recording
  - Real-time visualization of 64 channels simultaneously
  - Peak and RMS alarm level monitoring of all channels
  - Data on tape within ½ hour after test
  - Integrated signal conditioning and ADC close to test bench
  - 150 m digital data transfer to control room



# Example 3: High-volume data post-processing from aero-engine test cells



# Outline



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# Conclusion

- Flexible, Modular Operation
  - Small / Large Channel Count
  - Stand-alone / Integrated
- Performant Data-acquisition
  - Time / Frequency / Order / Octave
  - High Throughput Rate
- Visualization with Added-Value
  - Time data, Frequency Data, Order data
  - Level w.r.t. Warning/Alarm level
- Maintainable
  - Maximal use of Standard Software & Hardware
  - Interchangeable Hardware components
- Safe operation
  - Data Integrity
  - Data Storage / Archiving
- Process-centric
  - Centralized and User-friendly Acquisition Set-up, Control and Monitoring
  - De-centralized visualization
- Cost-effective





**Thank you**

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