

Dynamic Measurement Group Meeting

# Consolidation of Dynamic Signal Analyzer and Vibration Analyzer

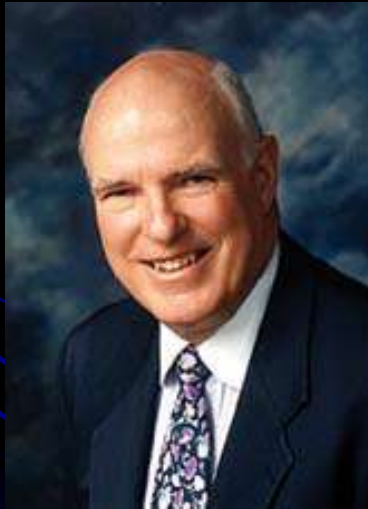
James Zhuge, Ph.D.  
Crystal Instruments Corporation  
Santa Clara, CA  
[www.go-ci.com](http://www.go-ci.com)

May 6<sup>th</sup>, 2009

# Crystal Instruments/Santa Clara

- Located in the Silicon Valley, California
- Co-founders, James Zhuge and Justin Tang
- James also co-founded Dactron in 1996.
- Dedicated to real time control, dynamic signal analysis and vibration data collector

**Many Thanks to John Mitchell and  
Joe Deery for contributing their valuable  
thoughts and materials.**



**John S. Mitchell,  
San Juan Capistrano, California**



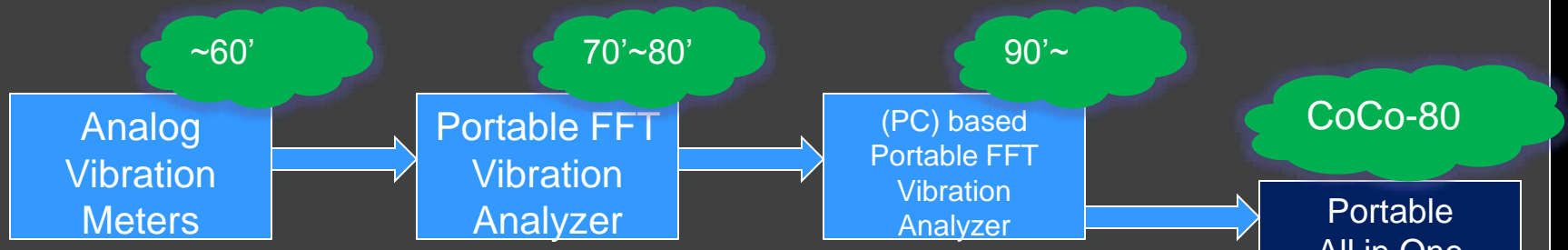
**Joe Deery, AIM & C,  
Newfoundland, New Jersey**

# “DSA” and “VDC”

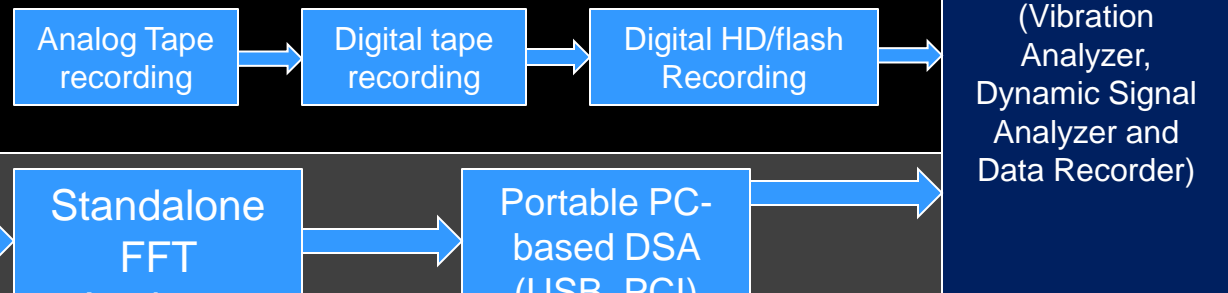
	Dynamic Signal Analyzer and System	Vibration Data Collector (VDC) and Vibration Analyzer
Purpose	Structural Testing for improving the design or solve structural related problems, or non-mechanical applications: geophysics, hydraulic test etc..	Machine monitoring, analysis and predictive maintenance
Players	B&K, LMS, OROS, DP, LDS, IOTech, Muller BBM, Agilent, SRS, NI, CI...	CSI (Emerson), IRD (Rockwell), CommTest, SKF, Bentley (GE), Benstone, Ludera, DLI (Azima), DataStick, CI...
Channel Numbers	Portable applications: 2 to 16 channels Large system: 16~1000 channels	1 or 2 channels most common. 4 channels gets promoted. No more than 4 channels
Functions	Transient capture, auto power spectrum, FRF, octave, sound level meters, order tracking, swept sine, curve fit .....	Route data collection, coast down, run up, balancing
Packaging Form	PC-based, standalone, networked	All are portable and handheld
Sealing	No sealing standard	Most are IP 65
Power	Battery power is not a hard requirement	All battery powered
Dynamic range	24 bits, around 100dB	16 bit is still popular, around 80dB
Customers	R&D engineers for structural testing, “white collar”	Consultants, Plant managers and technicians, “blue collar”
Sensors used	Sensors for test and measurement, such as those from PCB, Dytran or Endevco. More expensive.	Sensors for industrial use, such as those from CTC or Wilcoxon. Less expensive, bigger size.

# Timeline

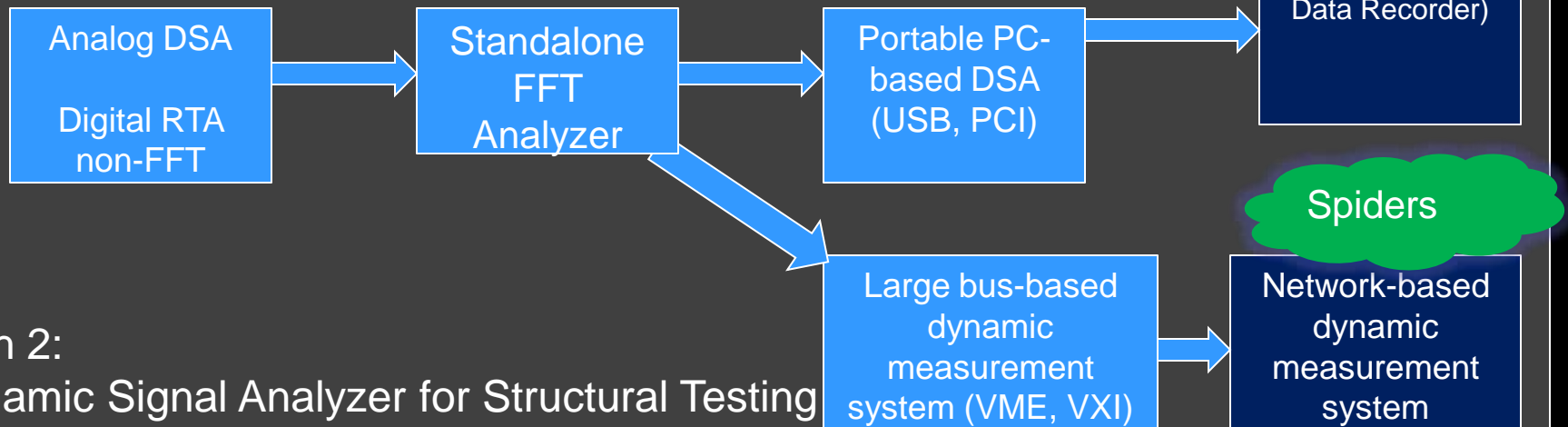
## Path 1: Vibration Analyzer for Machine Maintenance and Analysis



## Path 3: Dynamic Time Recording



## Path 2: Dynamic Signal Analyzer for Structural Testing



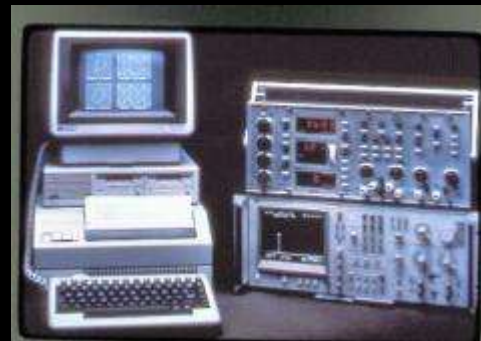
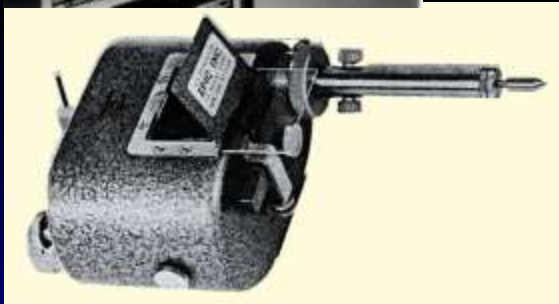
# Path 1: Vibration Analyzers

Path 1: Vibration Analyzer for Machine Maintenance and Analysis

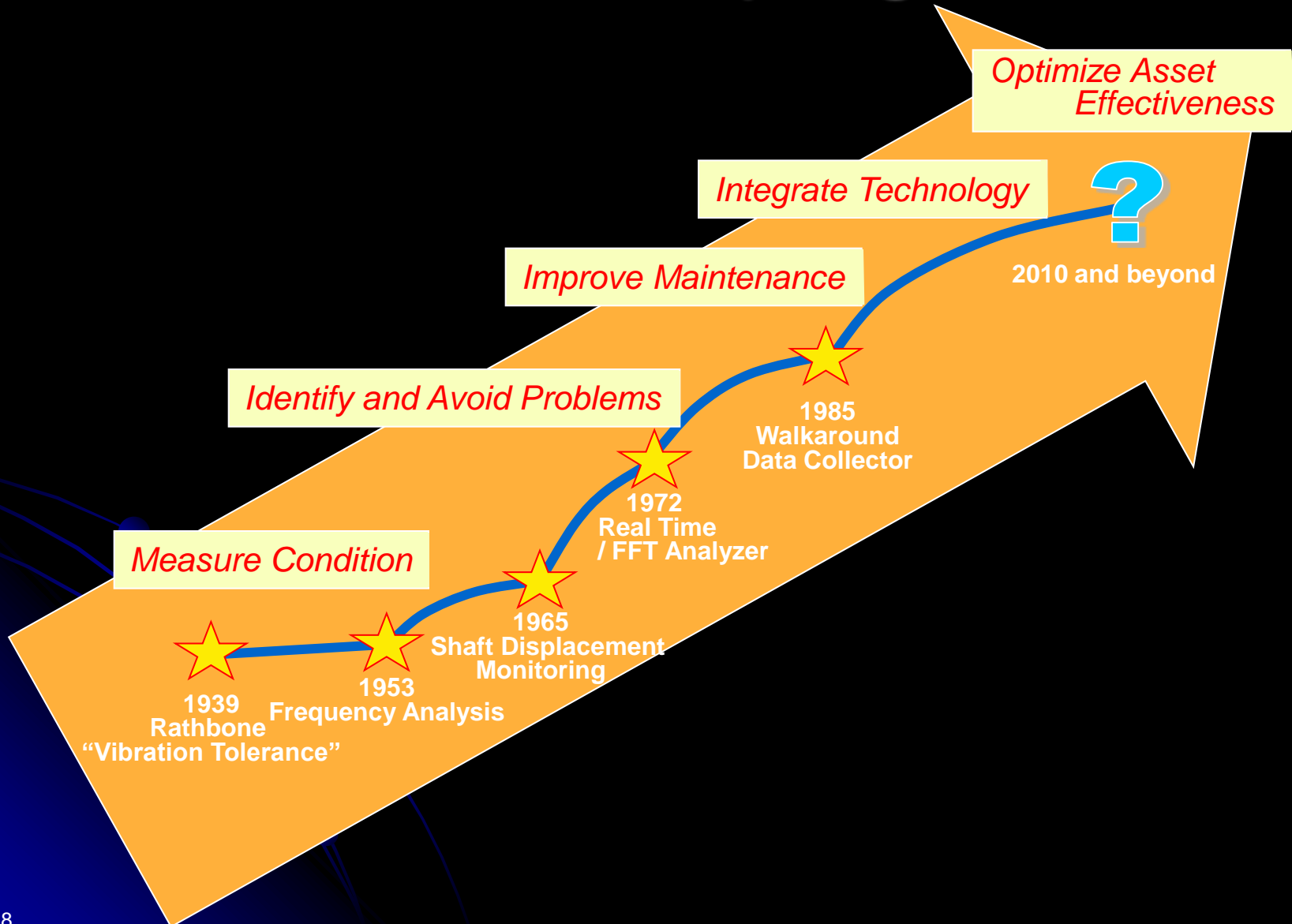




## Path 1: Vibration Analyzer and Data Collector for Machine Conditioning Monitoring and Maintenance

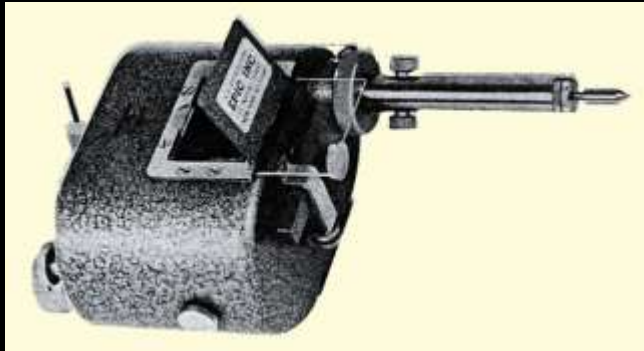


# Continuous progress



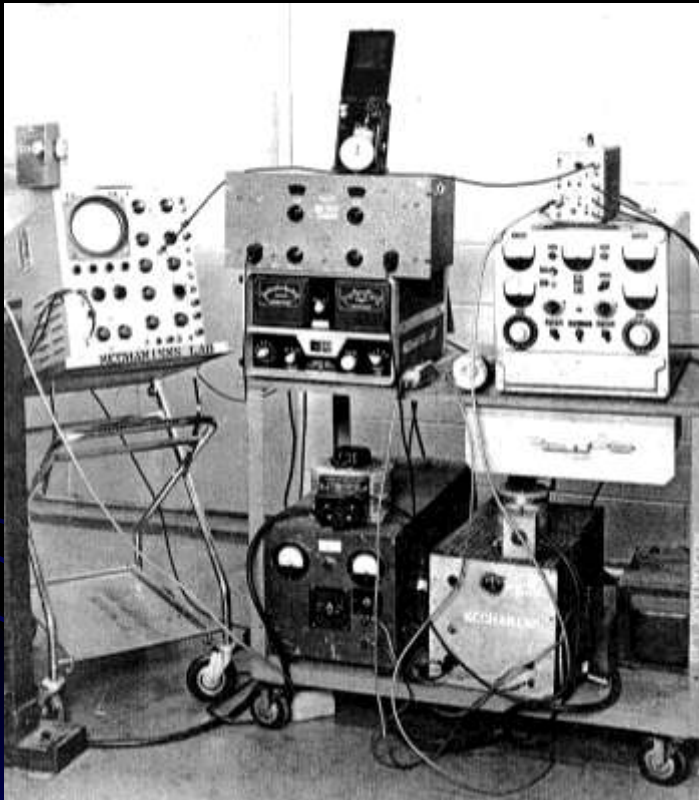


# Early vibration measurement instruments

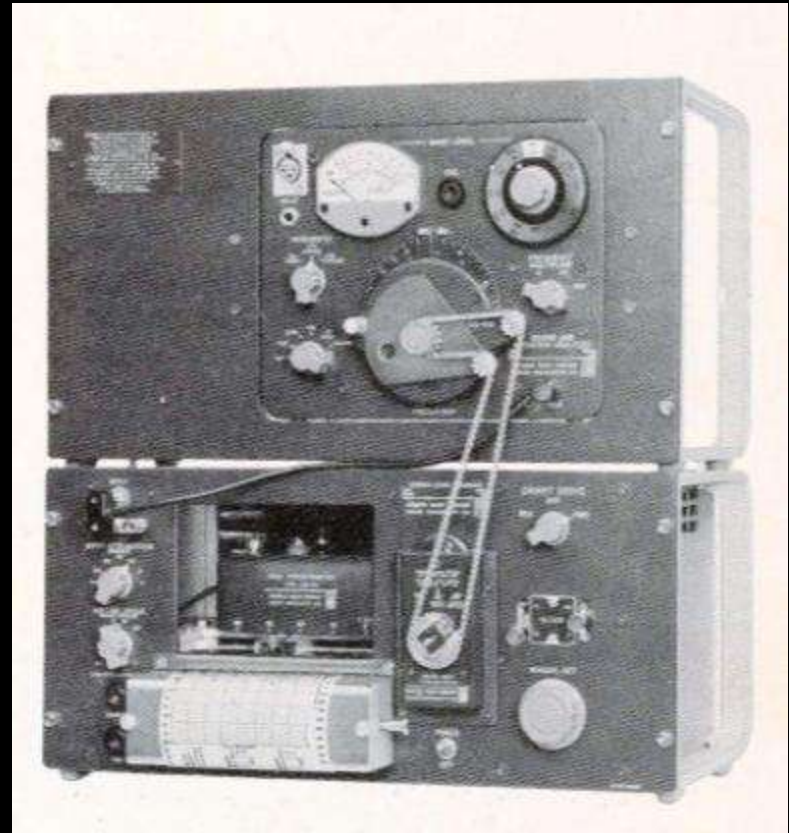


9 Tuned filter vibration meter, 1970

# Early laboratory analysis equipment



*Late 1960s laboratory vibration  
measurement instruments.*



*Courtesy Henry Hall*

# IRD Vibration / Balance





# Advances in vibration monitoring and analysis

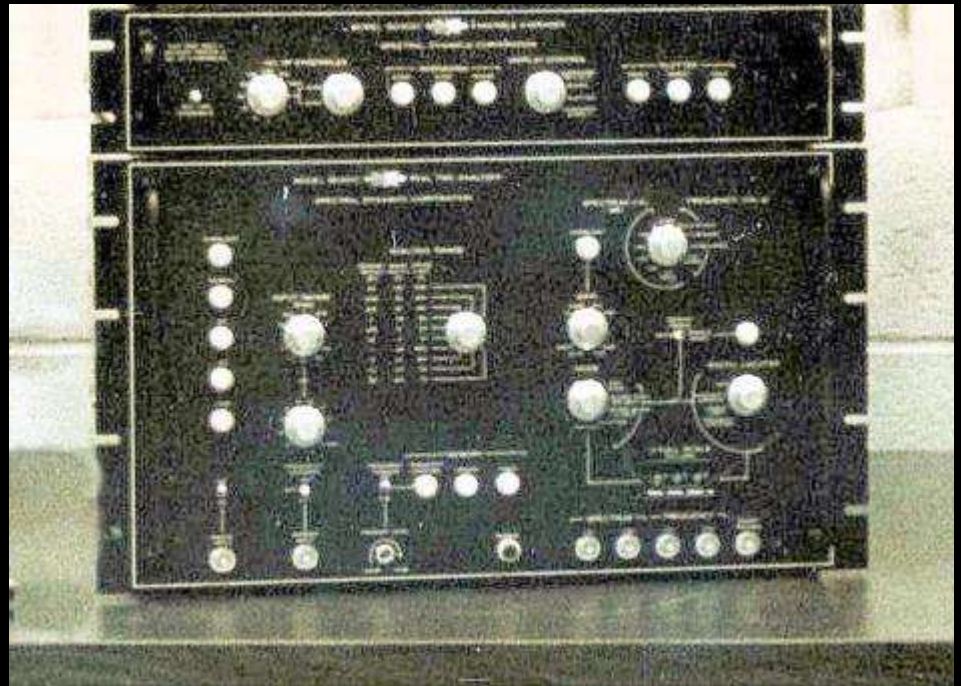
- Manual predictive monitoring: meter and clipboard
- Tape recording, remote analysis
- Accelerometers
- Rolling element bearing condition
  - *Crest Factor; Ralph James, Boeing*
  - *Shock Pulse, Spike Energy, HFD (mechanical resonance)*
  - *Demodulation / envelope detection, Jack Frarey*



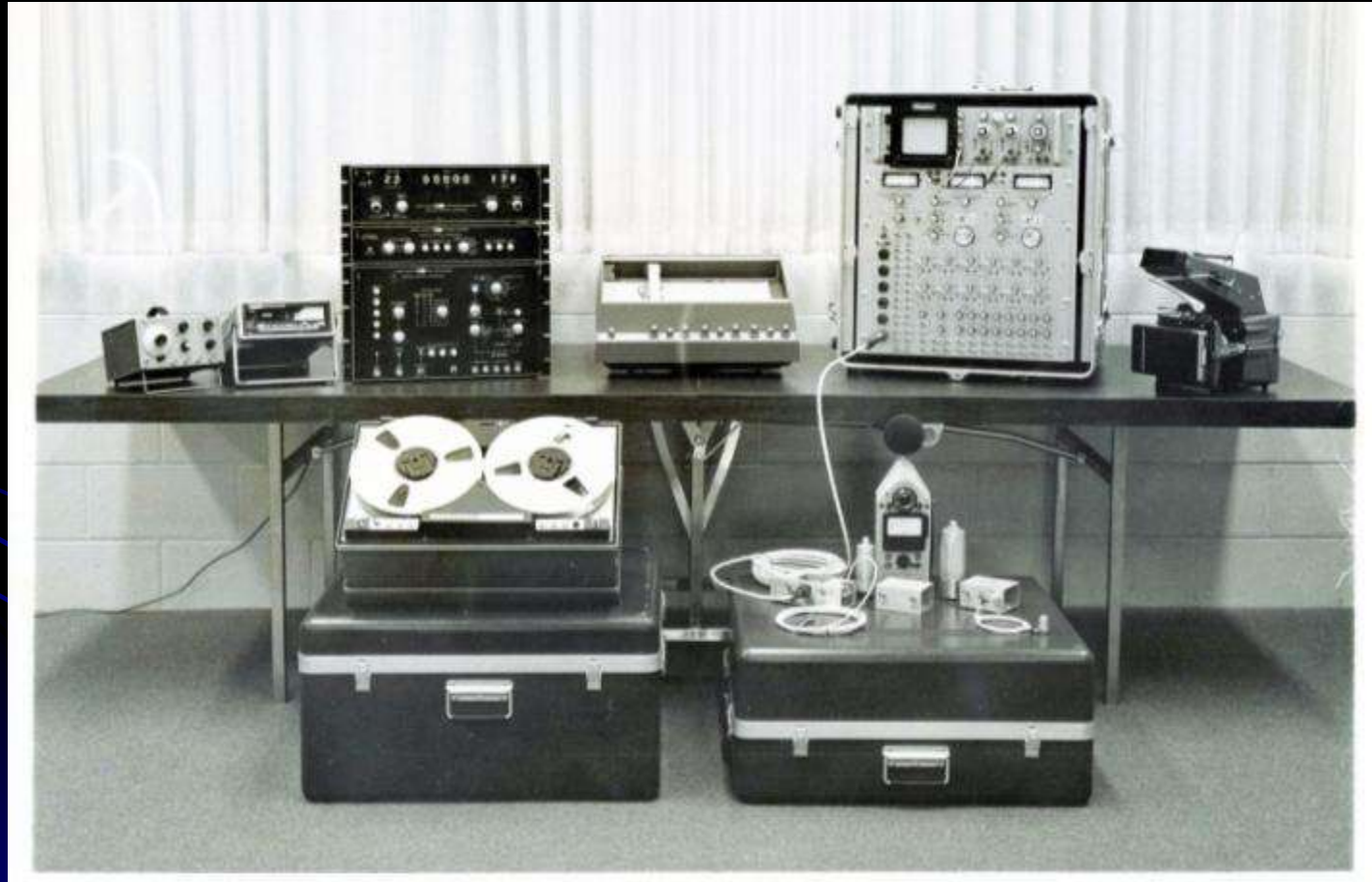
*Nagra two channel magnetic tape recorder used in early predictive maintenance programs (in carrying case).*

# Introduction of the Real Time Analyzer / FFT

- Frequency vs. amplitude spectrum in real time
  - *Time compression RTA initially introduced for structural analysis about 1970*
  - *Opened high frequency acceleration measurements*
  - *One of the initial papers published in 1972 at the first Texas A&M Turbo Machinery Conference*
  - *Followed by the FFT*



# Early 70's "portable" analysis system





# Another 70's "portable" Real Time Analyzer!



# Van mounted monitoring & analysis system



**Assembled by Uri Sela, EXXON  
With real time FFT analyzer and plotter**





# The portable data collector – mid 1980's

- Required 5 – 7 years gestation
  - *Gerry Mueller (Exxon R&E) paper — late 70's*
  - *Tecalamit (UK) AV-1 — about 1981*
    - Octave band, on board memory
  - *Beta Monitors and Controls (Data Trap), Vitek — 1983*
    - Time domain snapshot – no averaging, FFT in host
  - *TEC (Technology for Energy Corp.) — 1983*
    - FFT on board, spectrum display, banded monitoring
  - *IRD — 1985*
    - *Patented route capability*
  - *Palomar Technology — 1985*
    - Full FFT and large display
  - *CSI — 1986*
- Peak vs. rms controversy



# One of the earliest computerized data collectors



# One of the first of the current generation



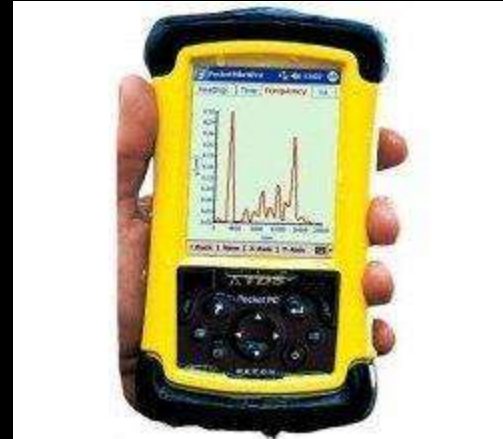
In 1984 Palomar Technology International introduced the first portable data collector with a high resolution internal FFT



# Modern Portable Vibration Analyzer



# PDA or PC based

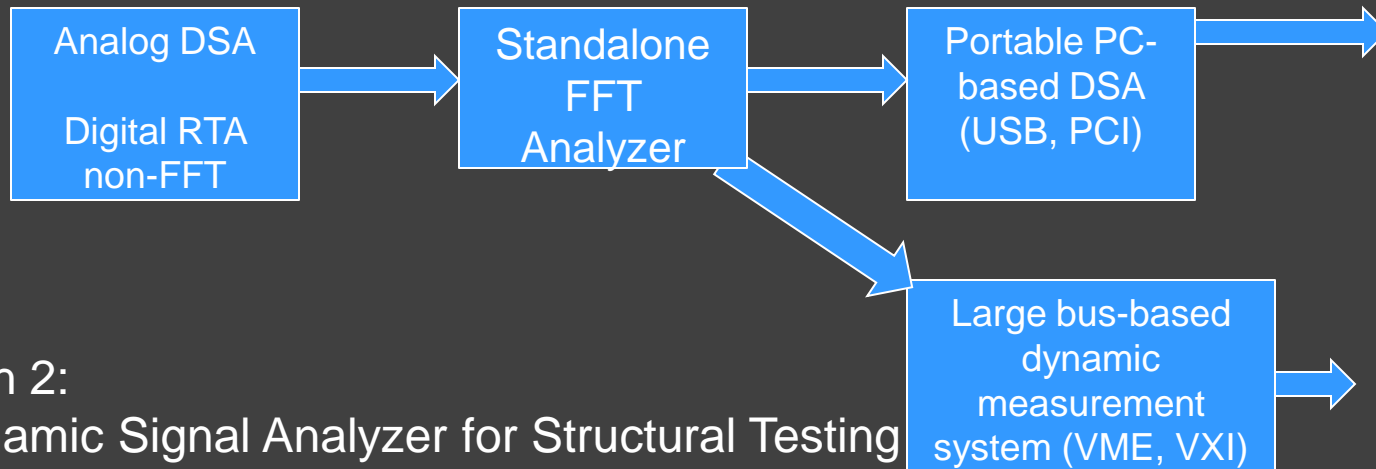


# Path 2: DSA

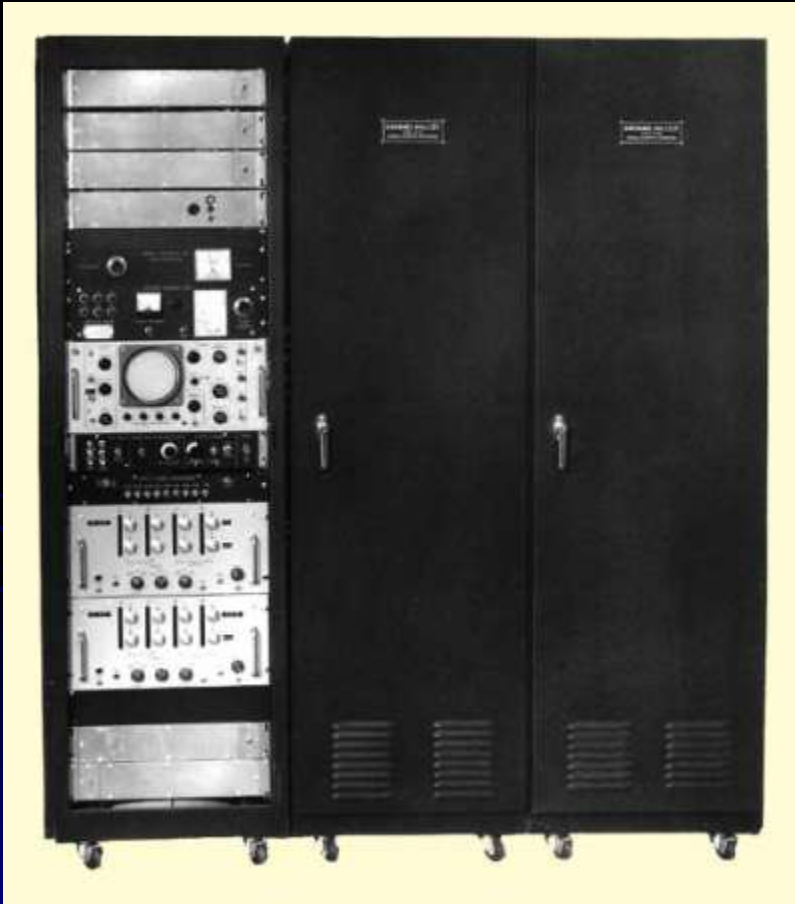
## Path 1: Vibration Analyzer for Machine Maintenance and Analysis



## Path 2: Dynamic Signal Analyzer for Structural Testing



# 50's~60's: Time Compression Technology



1957: *The Simoramic Analyzer*



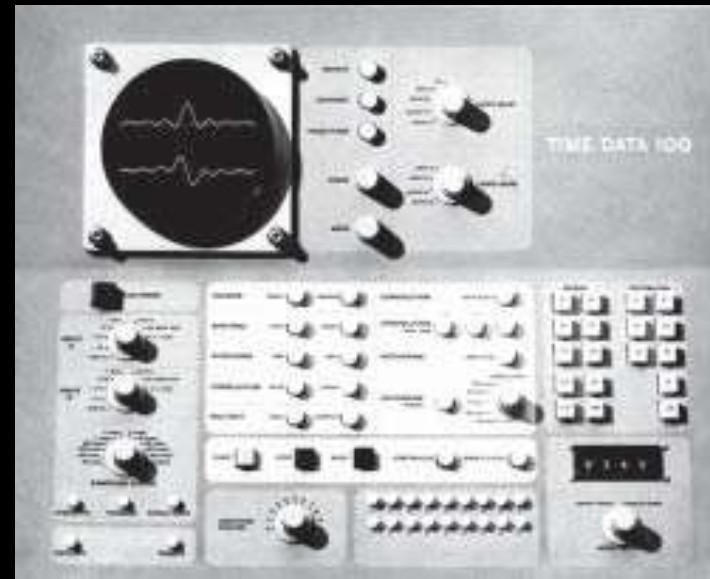
60s: The first commercial RTA from Federal Scientific was the UA-7 Ubiquitous® Spectrum Analyzer.



*Spectral Dynamics SD301.*

# 1967: first FFT Analyzer

In 1965, Cooley and Tukey at Princeton University published their historic paper on the computation of the FFT



*Control panel of Time/Data 100.*

*FFT speed: 1024 points at 1 second*



# 70s: Golden Time of FFT Analyzers



*Nicolet OF-400B Dual-Channel FFT Analyzer.*



*Spectral Dynamics SD 330.*



*HP 5451*



*Nicolet Scientific 440A Mini-Ubiquitous FFT analyzer.*



*B&K 2032.*



*1977: HP 5420A FFT Analyzer.*

80s: HP sold four times more than any other company offering FFT analyzers.



*1979: HP 3582A with ZOOM!*

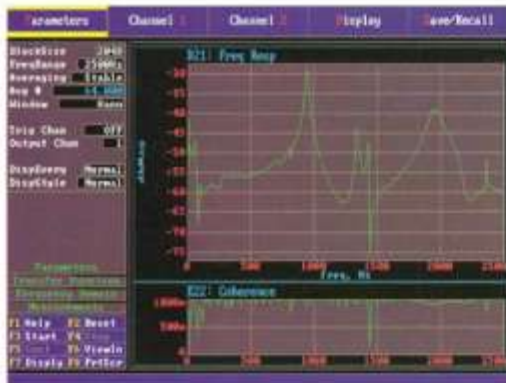


*HP VXI modules*



*Hewlett Packard 3565S Paragon system*

# Turn Your PC-AT into a Precision FFT Analyzer



- ▶ Fast and Accurate
- ▶ High Baseband Resolution
- ▶ Multichannel Excitation
- ▶ Easy to Use Menu System

*Introducing the DP420 FFT Analyzer... a precision FFT workstation at a cost well below comparable instruments*

The dual channel DP420 from Data Physics provides:

- 4000 spectral lines for observing closely spaced resonances
- 20 KHz realtime rate and 75 dB dynamic range for high speed and accuracy — 1024 FFT in 10 milliseconds
- High resolution EGA display with softkey driven menu system becomes the DP420's control panel — no knobs to turn, no programs to write
- Context sensitive on-screen help — never more than a keystroke away
- All common measurement functions in the frequency, time, and amplitude domains
- 40 MHz TMS320C23 digital signal processors perform all input, output, and FFT calculations
- Anti-aliasing filters and programmable input gain
- Dual channel, user programmable excitation sources for application specific testing under real conditions
- Easy connectivity to popular PC analysis software, including most modal analysis programs
- Flexibility you require today and in the future provided by a wide range of user installable options including zoom, swept sine, and SIGNALCALC™ signal analysis library

*Find out how easy it is to add a precision FFT analyzer to your lab or test setup. Call or write Data Physics today.*

PC-AT is a trademark of IBM Corporation



**DATA PHYSICS CORPORATION** SOLUTIONS IN SIGNAL PROCESSING

1210 Bascom Avenue, Suite 224  
San Jose, CA 95128  
Telephone: (408) 977-0800  
FAX: (408) 977-0801  
**Circle 111 on Inquiry Card**

# 1989: Data Physics PC-Based FFT Analyzer



# In 1995, Crystal Instruments created the “smallest signal analyzer”



Type II PCMCIA card (5mm thick), with TMS320C51 DSP, two inputs and two outputs

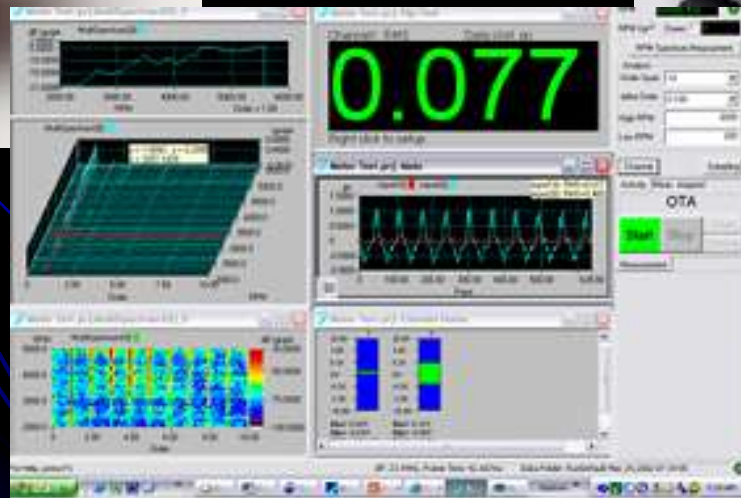
The product is still being sold a few hundred sets a year for machine condition monitoring apps.

# James and Justin led the engineers created a series of dynamic signal analyzers at Dactron

Products owned by LDS



Photon, the first USB based DSA released in 2000





Products owned by LDS



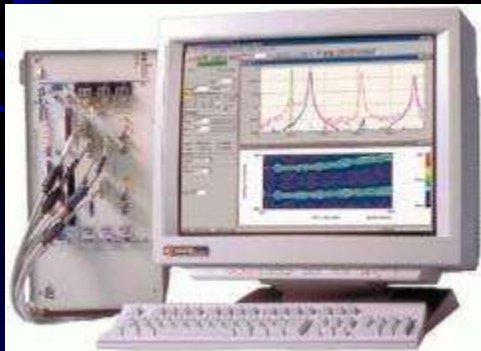
# Bus-Based DSA Systems

VME



LAN +  
IEEE 1588

VXI



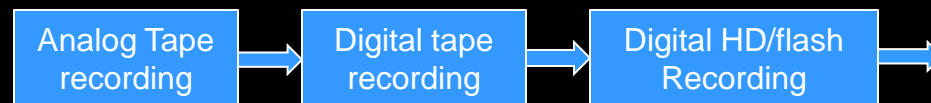
PXI

# Path 3: Dynamic Data Recording

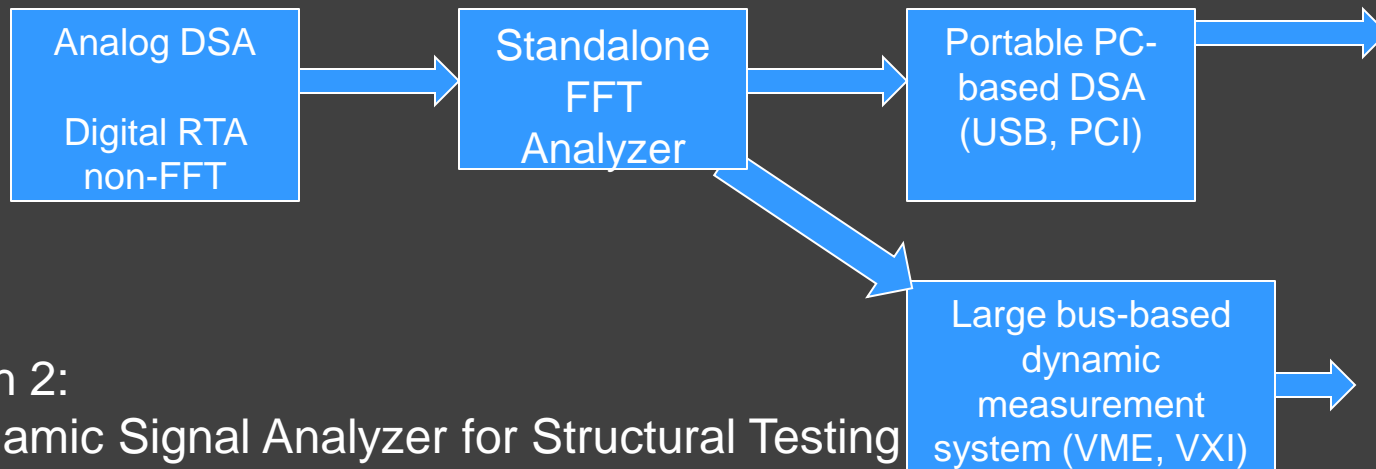
## Path 1: Vibration Analyzer for Machine Maintenance and Analysis



## Path 3: Dynamic Time Recording



## Path 2: Dynamic Signal Analyzer for Structural Testing





# Path 3: Dynamic Data Recording



TEAC A6010 Audio Recorder



The portable, two channel direct (AM) tape recorder manufactured by Kudelski in Switzerland,

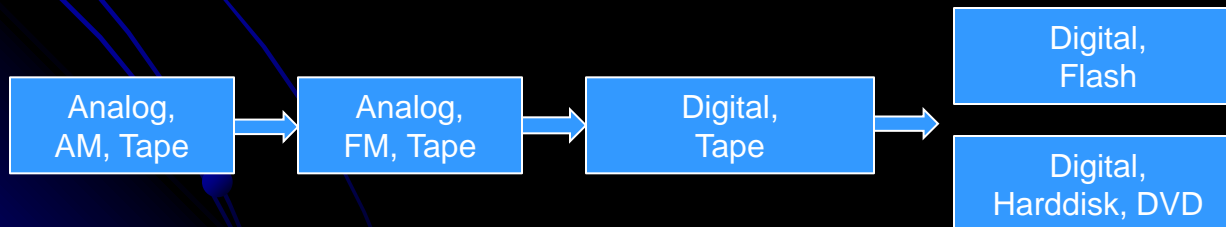


SONY EX



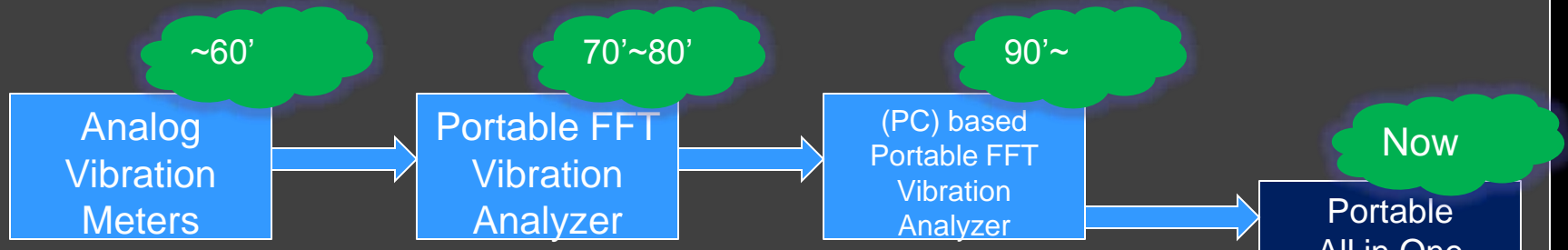
TEAC GX

Technology

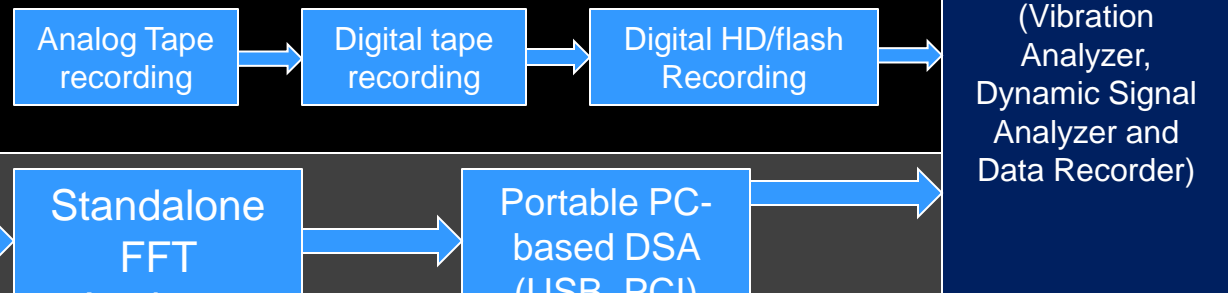


# Consolidation: Happening in 2008 and 2009

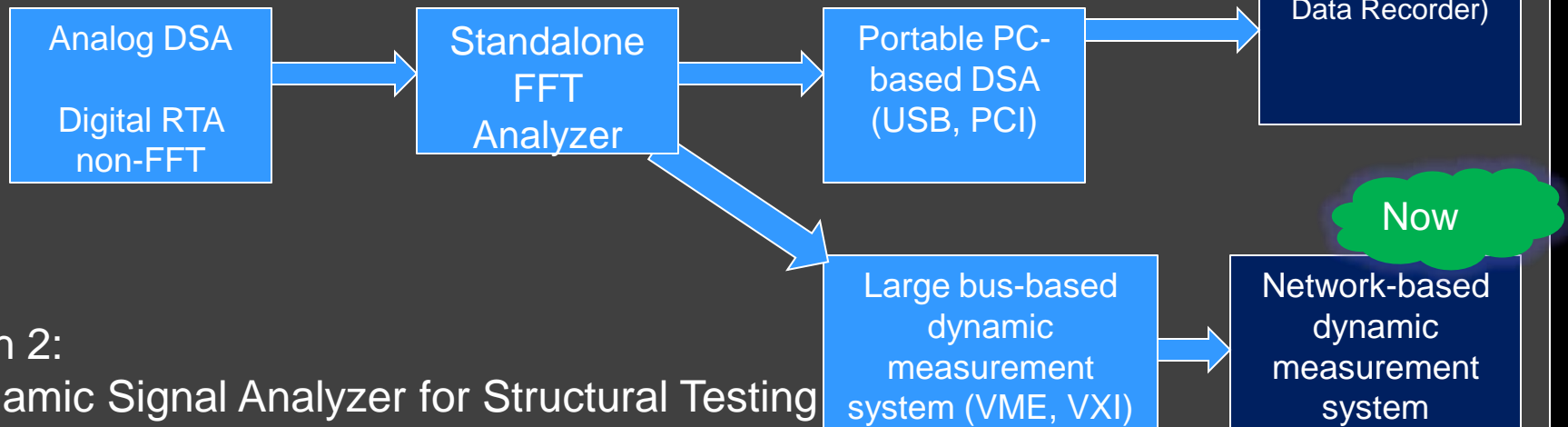
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## Path 3: Dynamic Time Recording

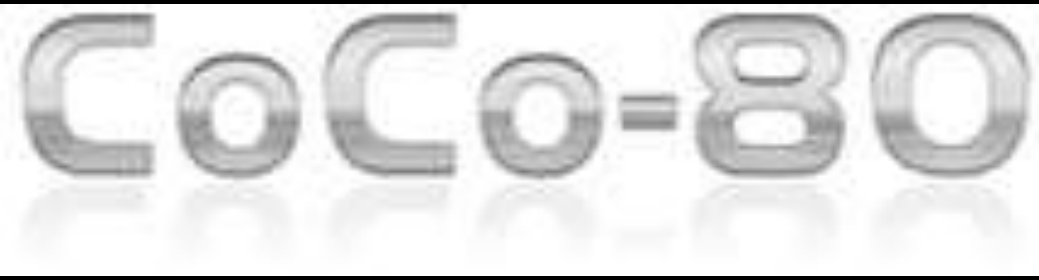


## Path 2: Dynamic Signal Analyzer for Structural Testing



# Driving Factors of Consolidation

- Market need:
  - Products with lower cost and multi-functions
  - Can be used in both lab and field
- Advances of Technology
  - Revolution in consumer electronics
    - Powerful DSP and CPU
    - Large storage: HD and flash
    - Brighter LCD with less power consumption
  - Embedded software programming
  - DSP algorithms
  - Two Unique Technologies from Crystal Instruments
    - Very high dynamic range (130dB~150dB in both time and freq domain)
    - Configurable Signal Analysis (CSA)



Released in later 2007



- Data recorder, signal analyzer and vibration data collector
- 2/4/8/16 input channels and 1 signal source
- Sample all input channels simultaneously up to 102.4 kHz
- 24 bit A/D and D/A
- 130 dB dynamic range
- Continuous recording for all channels at full speed
- FFT sizes up to 64K
- Portable: weighs less than 1.7 kg (3.4lbs)
- Battery life: > 8 hours
- Qualified for rugged operating conditions
- 5.7" color LCD
- Ethernet, USB, SD card and audio interface
- Wide variety of signal analysis functions; including Time, Power Spectra, Frequency Response, Coherence, Phase, RMS, and others
- Multiple data format support; including ASAM-ODS, UFF, BUFF, MATLAB, NI-TDM, ASCII and Excel
- Machine analysis capabilities; NVH, acoustic analysis, vibration analysis, machine condition monitoring, modal analysis, route data collection, balancing

## Advantages over PC-Tethered Instruments

- Reliability: PC tethered instruments use either USB or Ethernet cables for real-time data transfer. Any disruption to the cable, such as shock or vibration, or power surge, may stop or corrupt the data. CoCo-80 integrates the user interface, DSP and storage into one compact instrument. CoCo-80 is designed to be more reliable.
- Portability and User Interface: Field work with a tethered instrument requires the operator to juggle the PC, the instrument and the interconnection cables while the combination is heavier than the CoCo-80. By nature, the PC-tethered instrument is not user-friendly in the field.
- Performance: The performance of PC-tethered instruments depends on many factors such as the processor speed and the operating system of the PC, or the tasks running on the PC. CoCo-80 is under the control of designers and is always deterministic.
- Battery Power: PC-tethered instrument are difficult to operate on batteries. Some use the USB to supply the power to the instrument but the total battery operating time and the number of channels will be limited.

## Lab Performance and Handheld Portability

- None of standalone portable instruments in the market has 8 input channels. They mostly have only 2. Benstone has 4 ch.
- Standalone instruments such as Agilent 35670A and SRS 785 have high performance but are 60 lbs heavier, not battery powered, with old software technology
- LMS, OROS, NI and B&K (PULSE) have high performance but are PC-Tethered
- SKF, Emerson, GE, DLI, Benstone and CommTest are portable but are not full signal analyzer and with lower front-end specs

Performance: number of channels, phase match, dynamic range, real-time bandwidth, varieties of analysis functions





## Battery Powered, No Cooling Fan

- Battery-powered became a necessity for field use or for high reliability lab use
- Battery is actually used as a UPS (Uninterruptible Power Supply) to prevent data loss. To serve this purpose OROS uses battery in their PC-tethered instruments with only a few ten minutes battery life. Many others without battery are struggling for this tough question from the users about how to deal with loss of data when power is interrupted
- CoCo battery life can last 6 hours in normal operation
- The careful thermo design of CoCo removes the cooling fan so it can be used for quiet noise measurement



## Long Waveform Recording

- CoCo can continuously record the time waveform at 102.4kHz, for all 8 channels, with 32 bits floating point format
- Recording size is only limited by the flash memory (4GB configured)
- Advantages over PC-Tethered recording device: **CoCo is more reliable**
- Advantages over SONY-EX or TEAC GX: **CoCo has a display screen and real-time processing capability**
- Just released a data compression function that saves 50% space



SONY EX

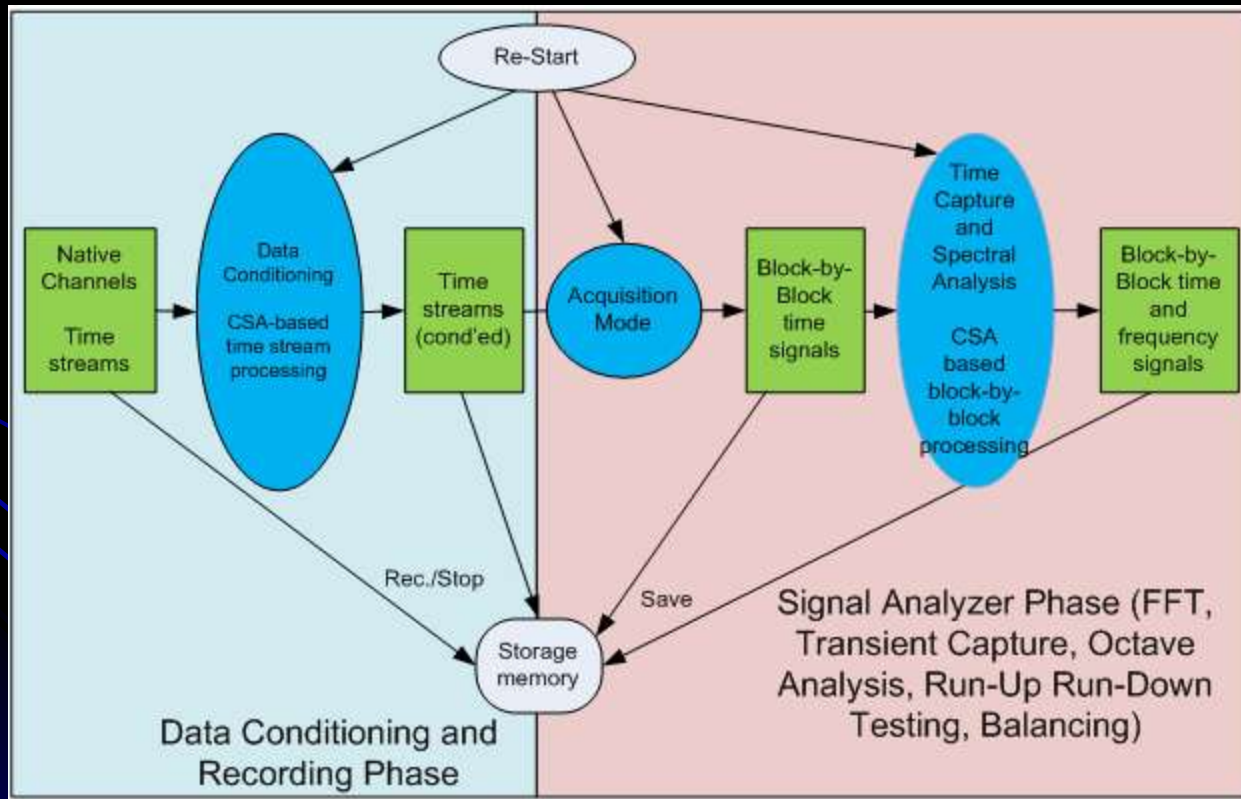


TEAC GX



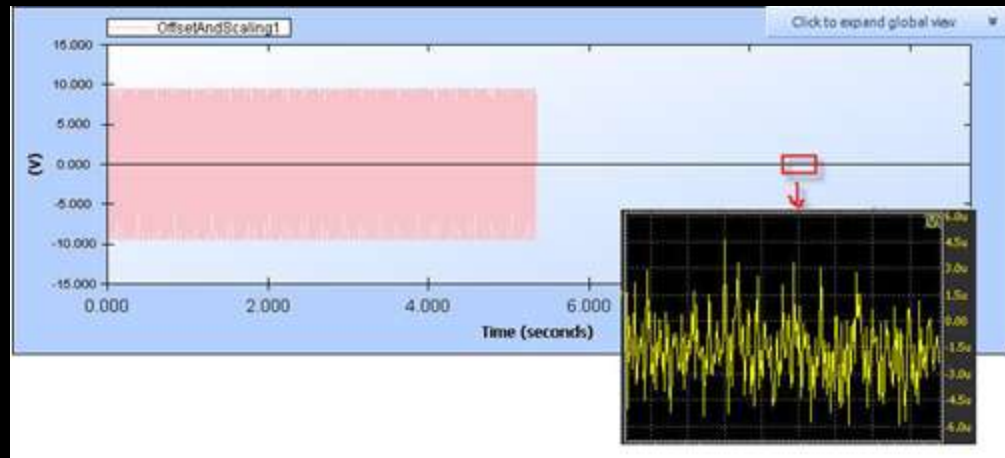
# Simultaneous Recording and Real-Time Analysis

Math functions and digital filters can be applied to data streams in real-time, any data streams can be recorded or used as trigger event



# 130 dB Dynamic Range (with US Patent)

We claim 130dB dynamic range. If we define it in the way of B&K, we can claim it as 150dB! With one range, CoCo does not need to set the input gains.



Time domain dynamic range (10V = Full Scale)

Sampling Rate	102.4 kHz	51.2 kHz	12.8 kHz	1 kHz	100 Hz
dBFS	120.44 dB	130.12 dB	129.08dB	134.85 dB	145.37 dB
Noise RMS	9.50 $\mu$ V	3.12 $\mu$ V	3.51 $\mu$ V	1.81 $\mu$ V	0.54 $\mu$ V

# Modern Hardware Interface

- Ethernet
- USB Host
- USB Slave
- SD Card
- Headphone and speaker
- Microphone and MIC jack

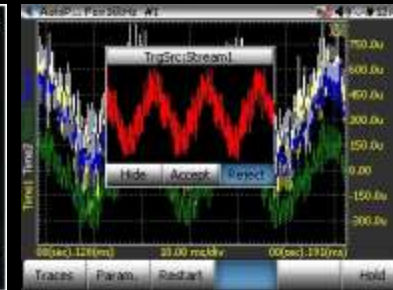
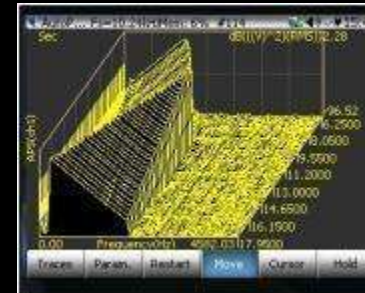


- Fully integrated hardware interface has many advantages. For example, it would be very difficult to listen to the measurement channel signal with headphone on a PC-tethered instrument.
- Products of Benstone, Commtest, Emerson, GE, SKF do not have Ethernet and SD card. With CoCo's Ethernet, multiple units can be managed remotely.



# Complete Suite of Dynamic Signal Analyzer Functions

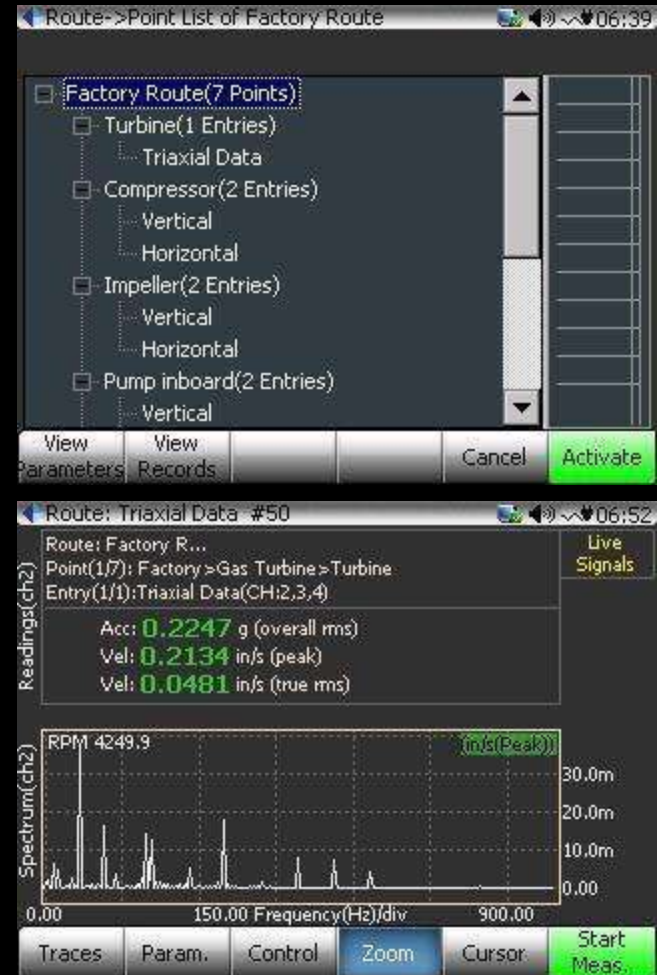
- Long waveform recording with scope display
- Transient capture with Accept/Reject
- Auto and cross spectra, Coherence and FRF
- Histogram and statistics
- 1/1, 1/3, 1/6 and 1/12 Octave Filters and sound level meter
- Order tracking
- Tacho, phase and orbit
- Real-time digital filters
- Real time math operations
- Swept sine test
- Automated limiting test, with scheduling, testing log, alarm check
- Arbitrary waveform output
- Sensor calibration
- System front-end calibration (software included free of charge)





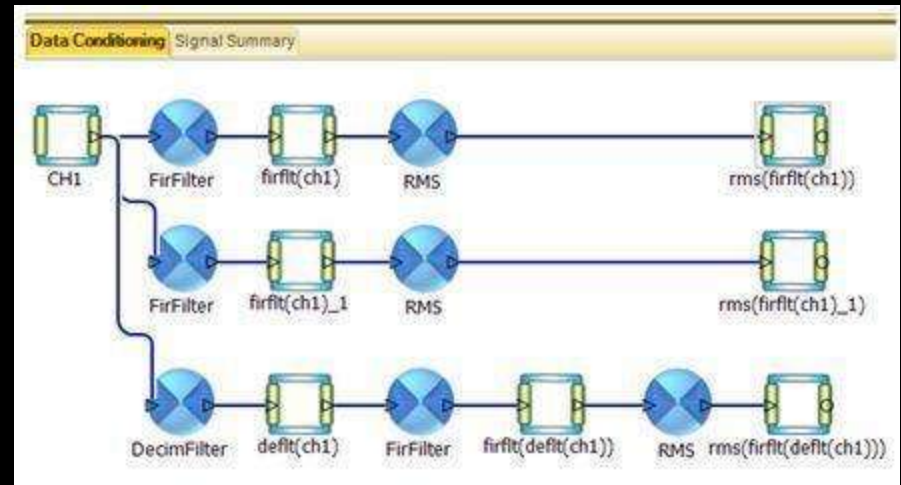
## Dedicated Vibration Data Collection Mode

- Route collection
- Trending and alarm
- Spectrum and waveform
- Demodulation spectrum
- Coast down and run up
- Acceleration, velocity, displacement
- Tacho for RPM
- RMS, overall, peak level
- Balancing
- Database management
- Easy synchronization with PC



# Configurable Signal Analysis

- Using graphic tool quickly create data processing script on PC
- Validate and prove the CSA script on PC
- Upload the CSA script to CoCo
- Run the script on CoCo



## Two major advantages:

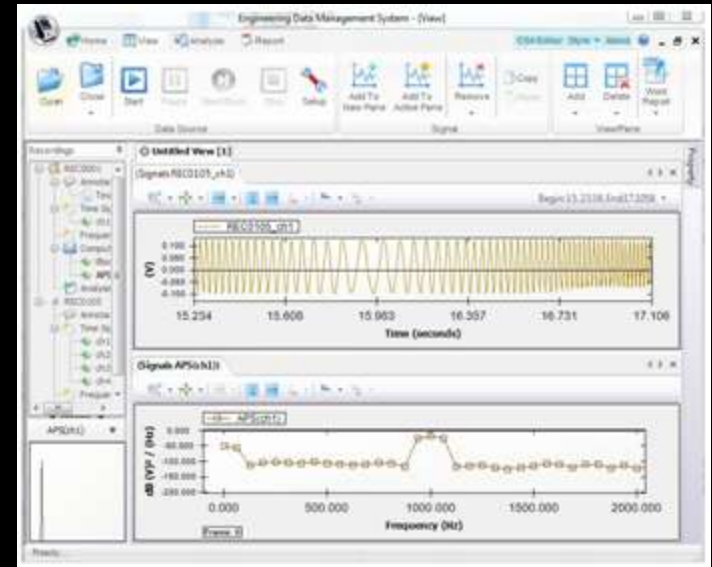
- It makes the user interface of each test function extremely simple
- Flexibility: the variety of the functions are unlimited

Nobody has offered anything similar on a handheld instrument. Closest competition is NI's LabView running on PC

# Powerful Post Processing Software

## Engineering Data Management (EDM)

- Manages communications with CoCo
- View data in both time or freq domain
- Quickly view the large files (gigabytes)
- Search and sort data files
- Cursors, markers, annotation
- Print or generate report with user defined template, into PDF, Word, HTML etc..
- Editing and manage CSA
- Route database management
- FFT, octave, order tracking, filters
- Convert acceleration to velocity, displacement



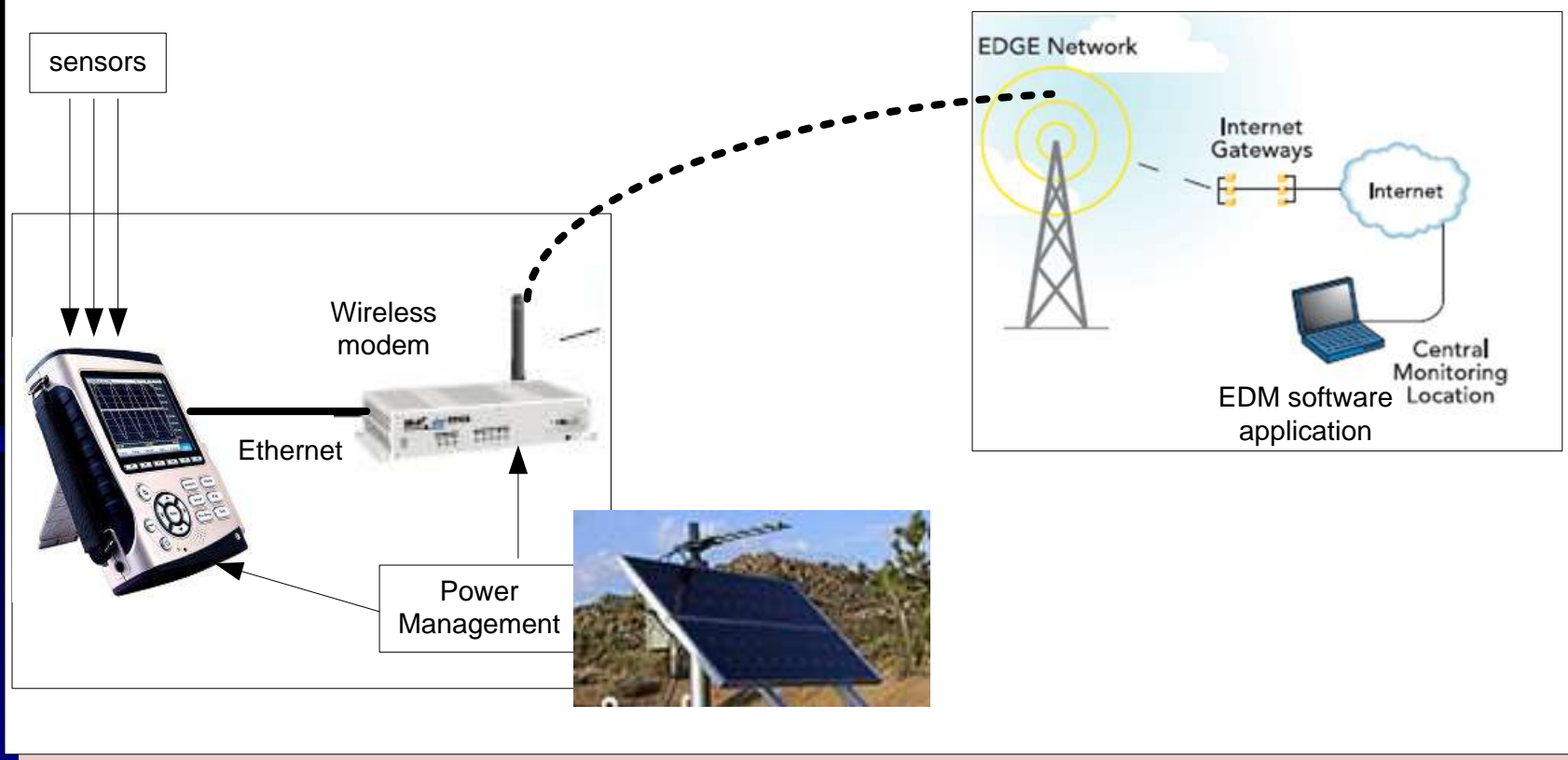
## Other Advantages

- 5 Input Modes: IEPE, AC differential, DC differential, AC Single End, DC Single End
- Build-in integration and double integration (measure the displacement or velocity using accelerometers)
- Signal Source: This is the only handheld analyzer having signal source
- Online Update: Just connect to the Internet and push one button, the software will be updated, Have you seen others doing this?
- Very Reliable: Passed strict environmental test. Very few hardware failures
- Competitive Price



# Wireless Remote Monitoring

Access, monitor and control the CoCo thousand miles away using GPRS wireless



# CSA --- Configurable Signal Analysis demo

