



Data Acquisition System Architecture & Capabilities At NASA GRC Plum Brook Station's Space Environment Test Facilities

Richard K. Evans

Gerald M. Hill

27th Space Simulation Conference

November 6th, 2012

Presented by

Richard K. Evans

(NASA Glenn Research Center)

ABSTRACT

Very large space environment test facilities present unique engineering challenges in the design of facility data systems. Data systems of this scale must be versatile enough to meet the wide range of data acquisition and measurement requirements from a diverse set of customers and test programs, but also must minimize design changes to maintain reliability and serviceability. This paper presents an overview of the common architecture and capabilities of the facility data acquisition systems available at two of the world's largest space environment test facilities located at the NASA Glenn Research Center's Plum Brook Station in Sandusky, Ohio; namely, the Space Propulsion Research Facility (commonly known as the B-2 facility) and the Space Power Facility (SPF). The common architecture of the data systems is presented along with details on system scalability and efficient measurement systems analysis and verification. The architecture highlights a modular design, which utilizes fully-remotely managed components, enabling the data systems to be highly configurable and support multiple test locations with a wide-range of measurement types and very large system channel counts.



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Presentation Outline

- **Overview**

- Plum Brook location and facilities
- Summary of recent facility upgrades at Plum Brook

- **Plum Brook Facility DAS Design Drivers**

- Goals
- Challenges
- Measurement Topology
- Architecture
- Specifications and Capabilities of shared assets

- **Overview of Plum Brook Data Systems**

- B-2 Facility DAS
- SPF Vibroacoustic Facilities DAS
- SPF Thermal-Vacuum Chamber DAS

Presentation Outline

■ Overview

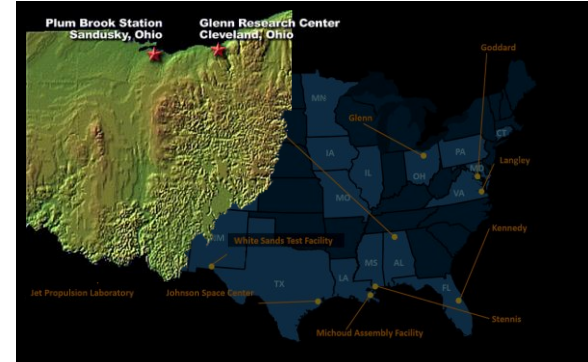
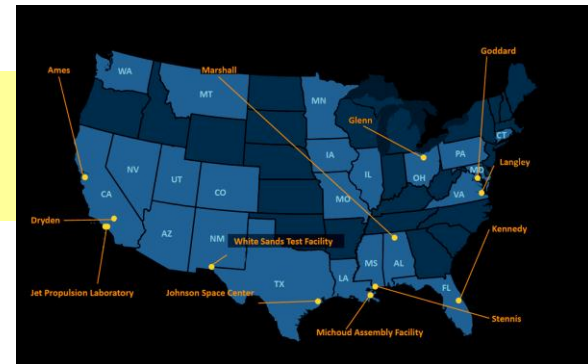
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Overview - NASA Plum Brook Station Test Sites



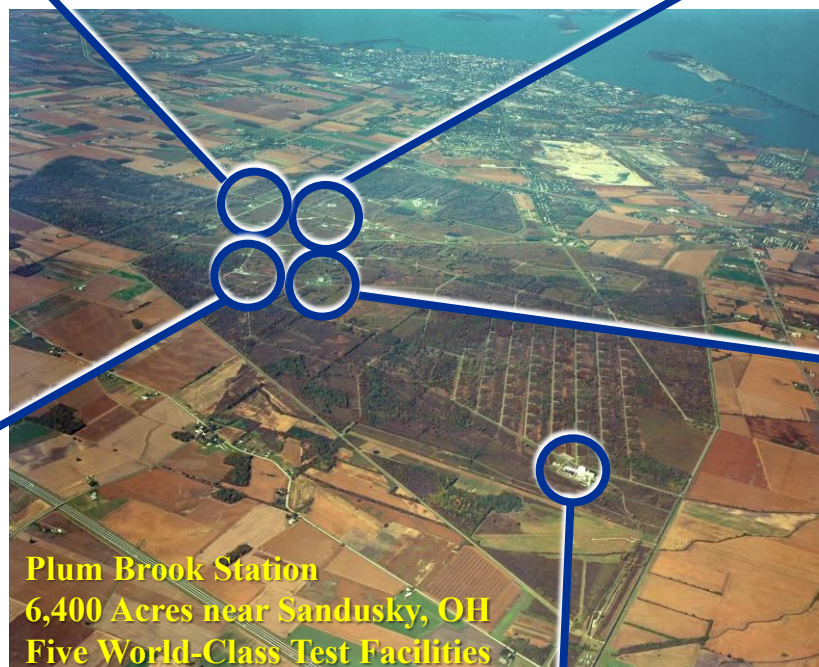
Large-Scale LH₂ Testing



**High-Energy, High Risk
Cryogenics Systems Testing**



**Blow-Down, Non-Vitiated,
Free-Jet Wind Tunnel**



High Altitude Engine Testing



Integrated Space Simulation Facility

- * Thermal Vacuum Chamber
- * Reverberant Acoustic Chamber
- * 3 Axis Sine-Vibration Facility

Overview – Recent Modernization Projects

■ B-2 Restorations (2006..2010)

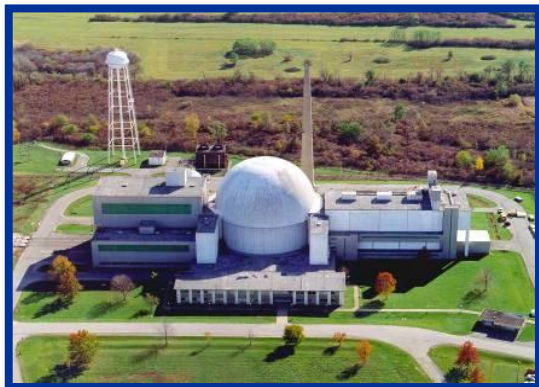


Beginning in 2006, B-2 underwent a systematic, phased refurbishment program to revitalize all major facility subsystems and ancillary infrastructure equipment.

NASA's Space Operations Mission Directorate (SOMD) and Exploration Systems Mission Directorate (ESMD) have funded this activity, under the guidance of the Rocket Propulsion Test Management Board (RPTMB), a NASA Level II office responsible for maintaining the agency's chemical propulsion test capability.

To date this refurbishment includes the chamber and all vacuum systems, propellant and pressurant systems, control and data acquisition systems, and numerous facility support systems.

■ SPF Vibroacoustic upgrade (2007..2011)



In late 2007, NASA began a project to create single location where large-scale space environment testing could be performed. Leveraging the existing thermal-vacuum test chamber at the Space Power Facility (SPF), NASA began the work to add acoustic, vibration, and modal test capabilities at a comparable scale.

The modifications to the facilities were completed in 2011 and included the installation of a dedicated facility data acquisition system to support the new test capabilities as well as a replacement data system for the thermal-vacuum chamber.



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Design Approach for the New Data System

What would the IDEAL DAS solution look like?

- **Commercial Off-The-Shelf (COTS)**
 - Look for mature product lines from industry leading manufacturers
 - Maximize the use of open standards for both hardware and software
- **Modular**
 - Scalability
 - Upgradability
 - Easier to Troubleshoot, Check-out, Verify & Repair
- **Electronically Configurable**
 - Avoid Manual Knobs and Dials
 - Able to automate and back-up “SAVE/RESTORE” functions
 - Configurations included as part of the test record
 - Facilitates “Whole System” automation
- **Highly Integrated Operation**
 - Traceability is “built-in” to a fully integrated modular system
 - Borrowing the merits of the OSI 7-Layer model, Higher-Level Functions in a layered model allows some “transparency” in the system. (such as Ethernet and Fibre Channel) (i.e. – ability for upstream components to control and configure downstream devices)



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~ Our Strategy ~

These characteristics will result in a system that is:

- ✓ Easy to **Operate**
- ✓ Easy to **Maintain**
- ✓ Easy to **Upgrade**
- ✓ Easy to **Verify**

Our goal is to assure :

- ✓ **Highest Quality**
- ✓ **Highest Reliability**



Design Approach for the New Data System

What are some of the challenges in designing a permanent “facility” data system?

- Wide variety of Data Rates and Measurement Bandwidths
- Wide variety of Measurement Types
- Distance Effects and Limitations
- Calibrating the system (and troubleshooting)
- Synchronization and Timing of Data from Multiple Sources
- Future System Growth (Scaling-up when needed)
- SAVE and RESTORE Functions
- Versatility (Every customer wants something different)
- Measurement Fidelity



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Modular Distributed Measurement Topology

**Sensors &
Transducers**

128 – 2,000+ channels

Accelerometers, Mics, Strain, Temperature, etc...

$\mu\text{W/nW}$
(Small Signal Regime)

(Digital Regime)

**Data
Storage**



Modular Distributed Measurement Topology

**Sensors &
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128 – 2,000+ channels

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$\mu\text{W/nW}$

(Small Signal Regime)

$\pm 10\text{V}$

(Strong Signal Regime)

(Digital Regime)

**Data
Storage**



Modular Distributed Measurement Topology

**Sensors &
Transducers**

128 – 2,000+ channels

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$\mu\text{W/nW}$

(Small Signal Regime)

**Signal
Conditioners**

$\pm 10\text{V}$

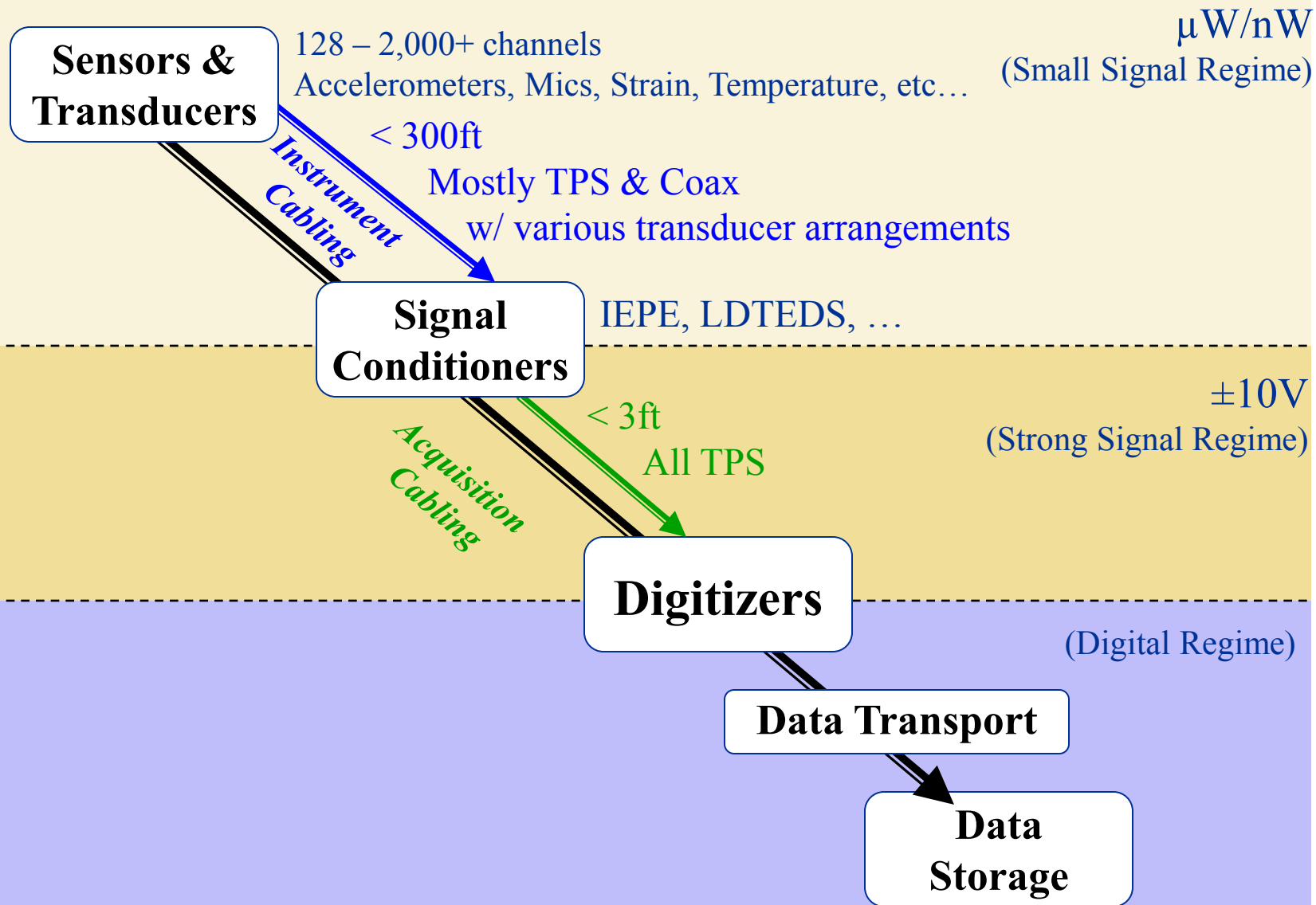
(Strong Signal Regime)

Digitizers

(Digital Regime)

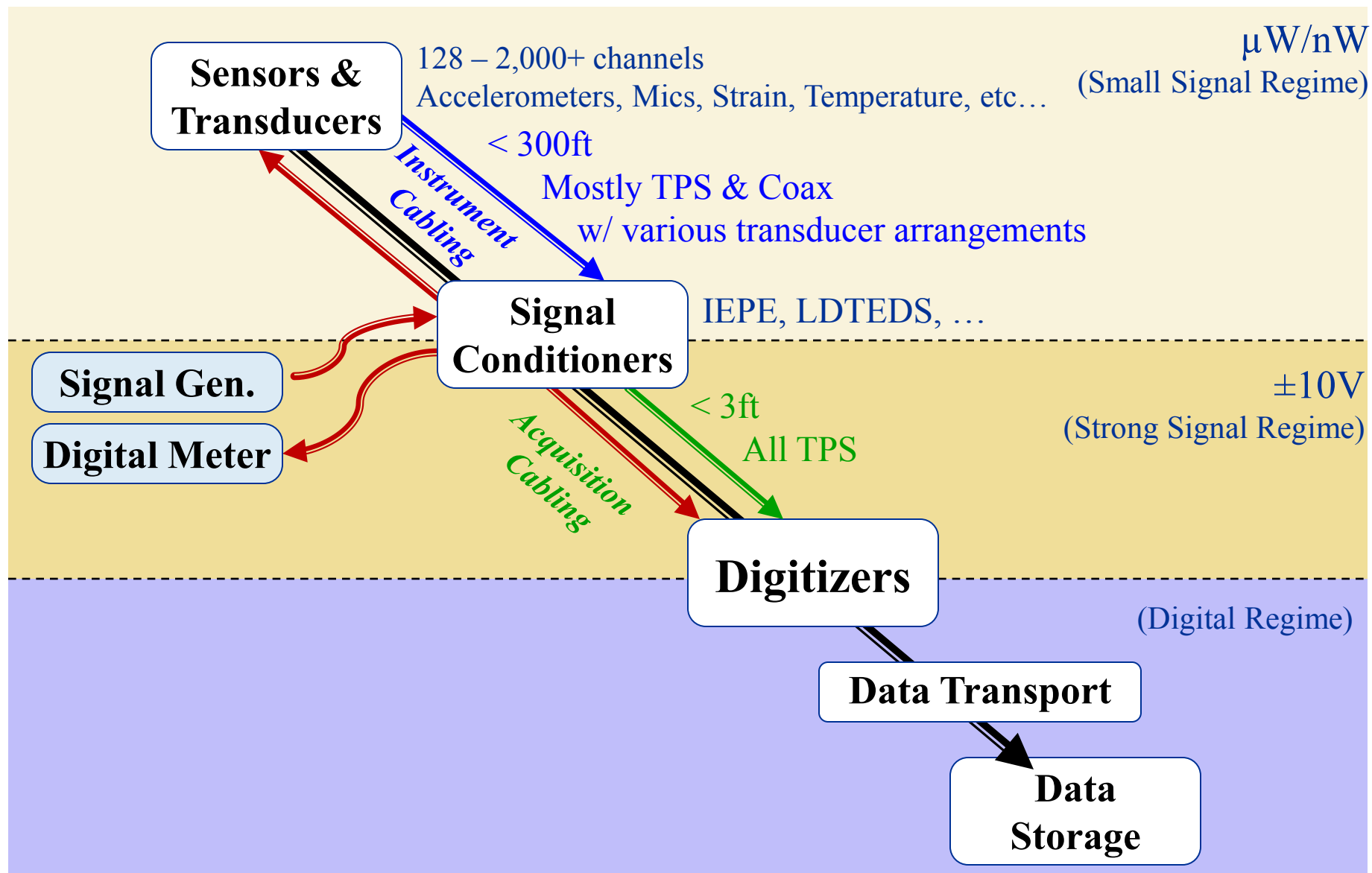
**Data
Storage**

Modular Distributed Measurement Topology

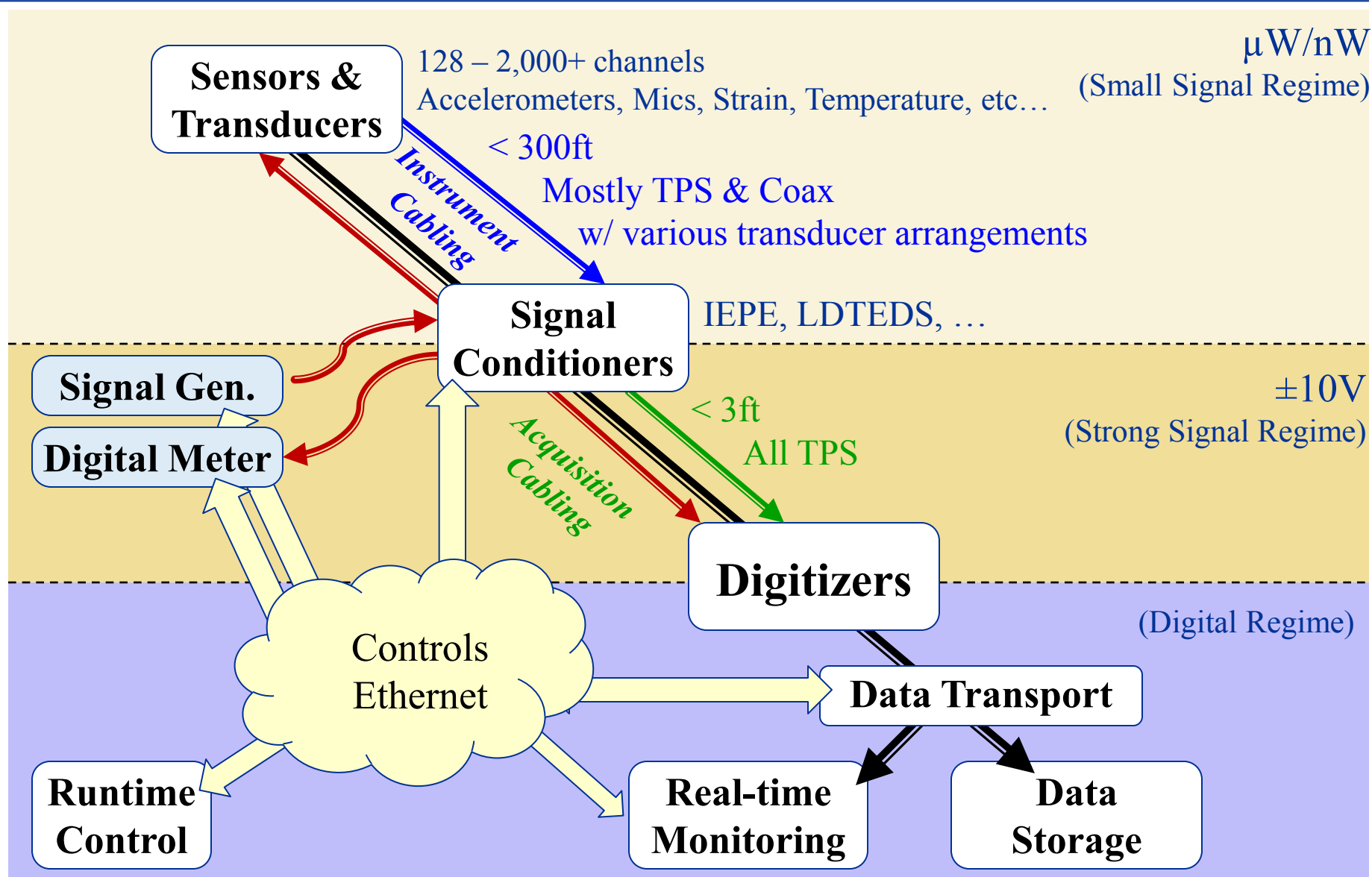




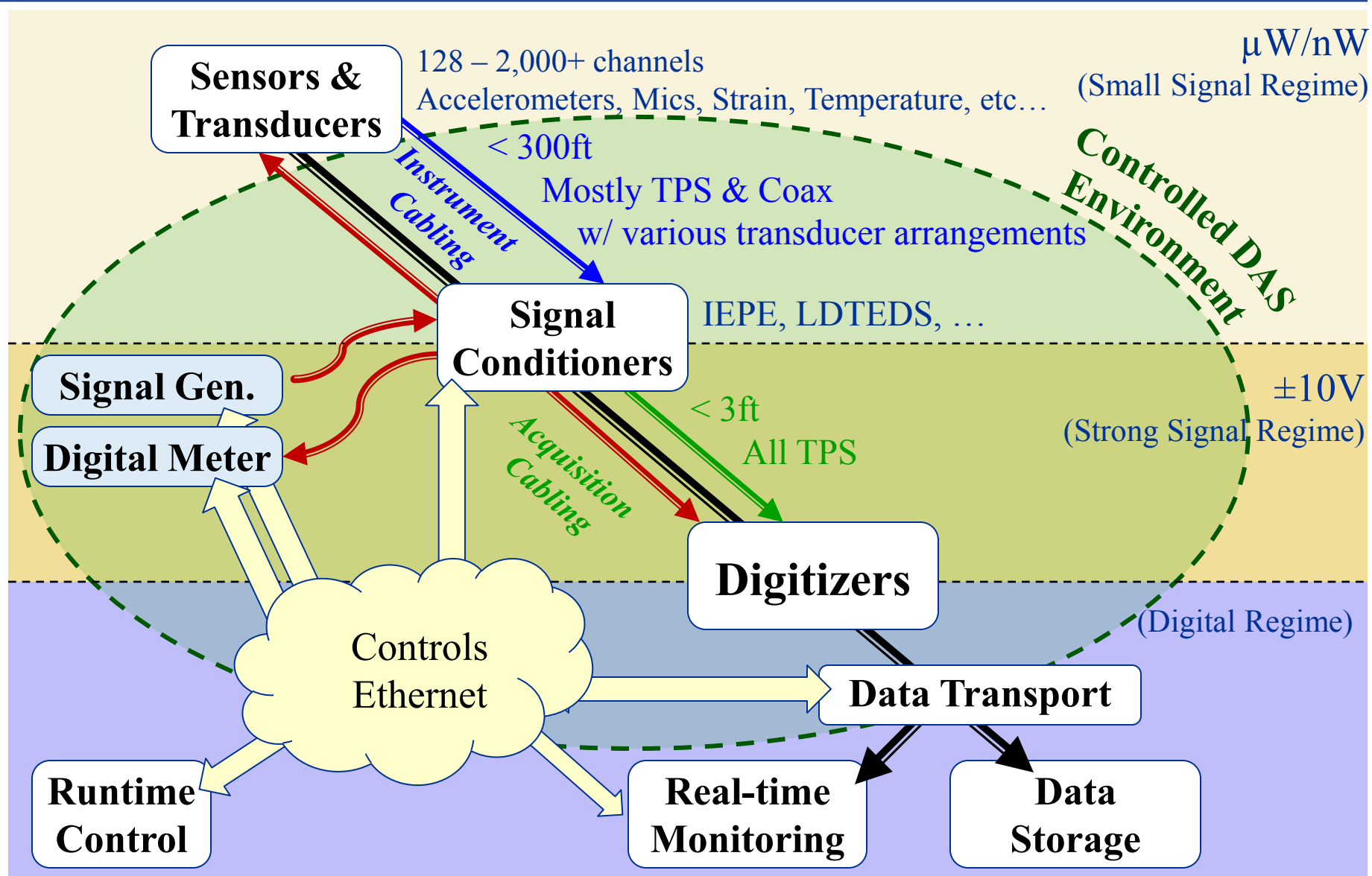
Modular Distributed Measurement Topology



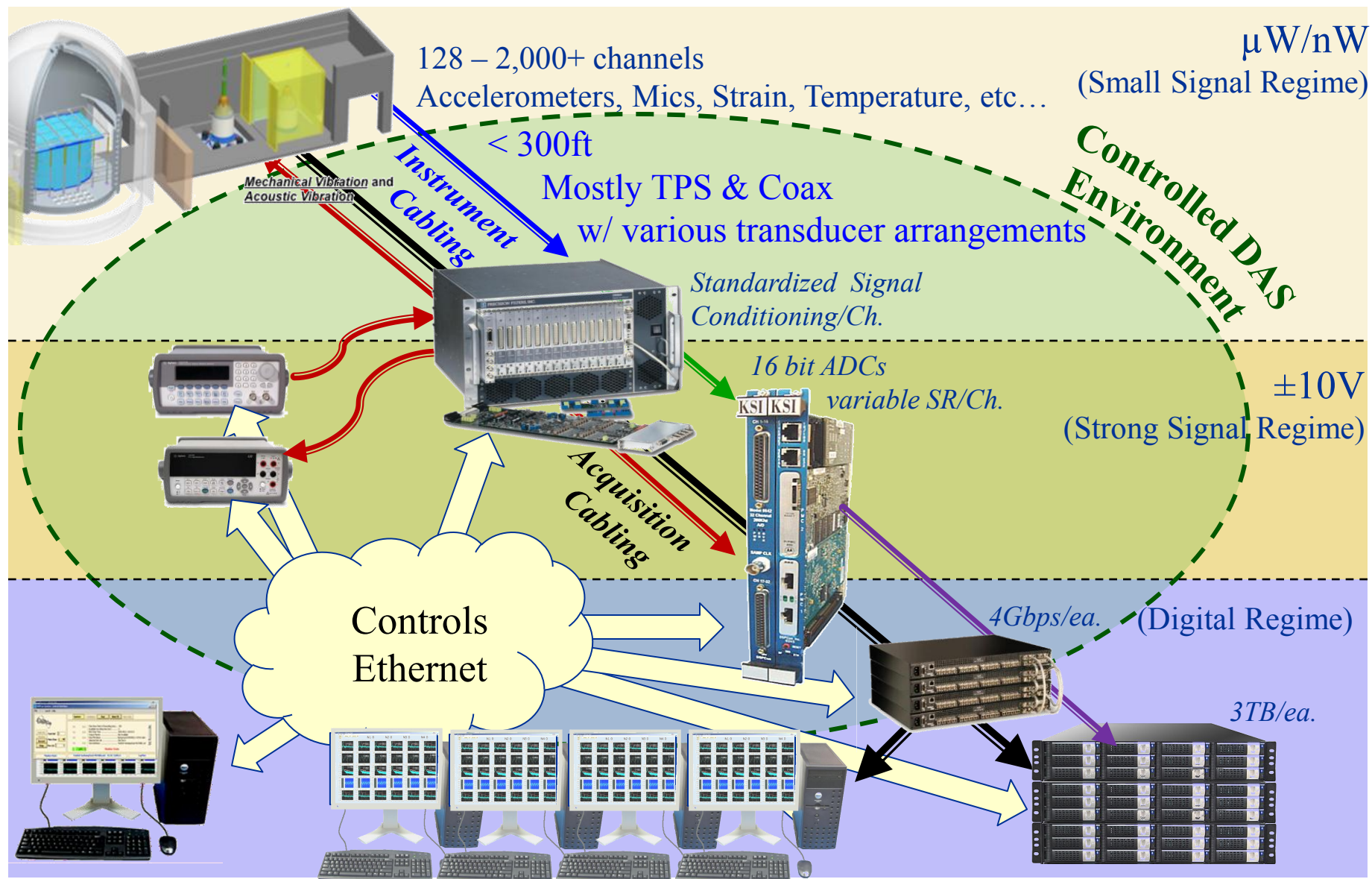
Modular Distributed Measurement Topology



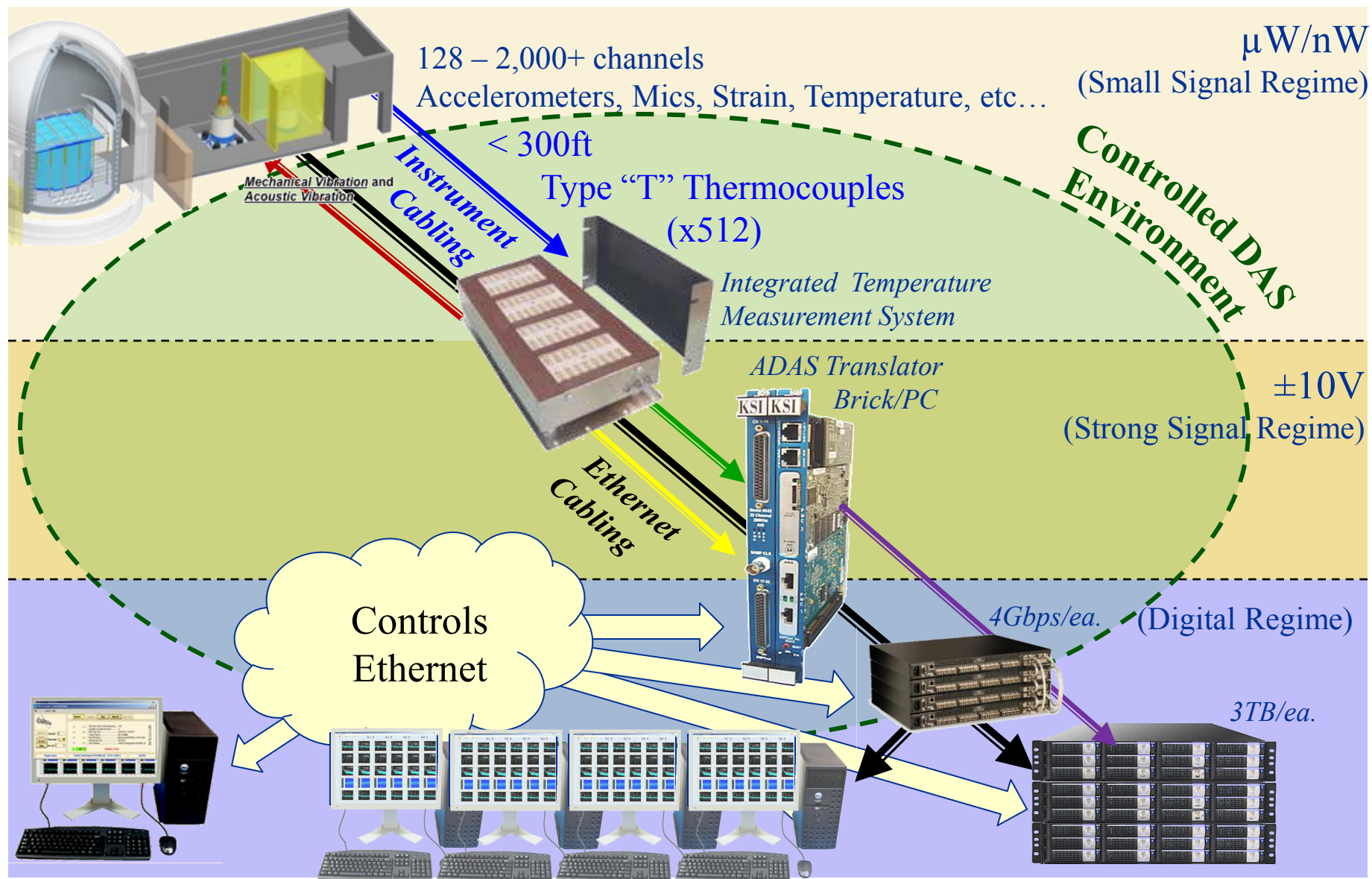
Modular Distributed Measurement Topology



Modular Distributed Measurement Topology

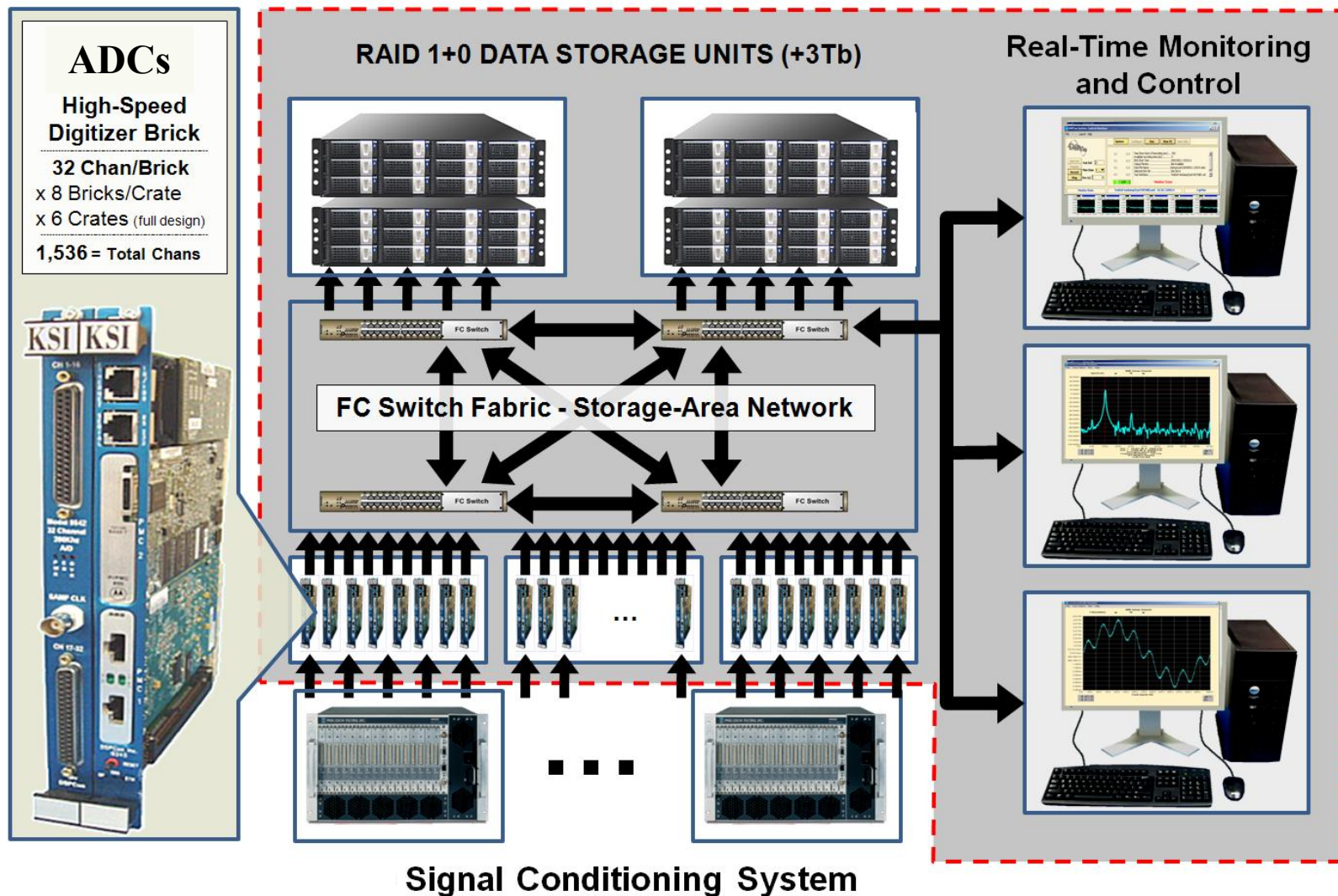


Modular Distributed Measurement Topology



Integrated FC-SAN for Distributed Scalability

The completed system forms a Fibre-Channel Storage Area Network



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DAS - Control and Real-Time Display

System Configuration is done using a MS-Excel Spreadsheet

NASA GLENN Example TDF SUBADDRESS 20080401.xls [Compatibility Mode] - Microsoft Excel

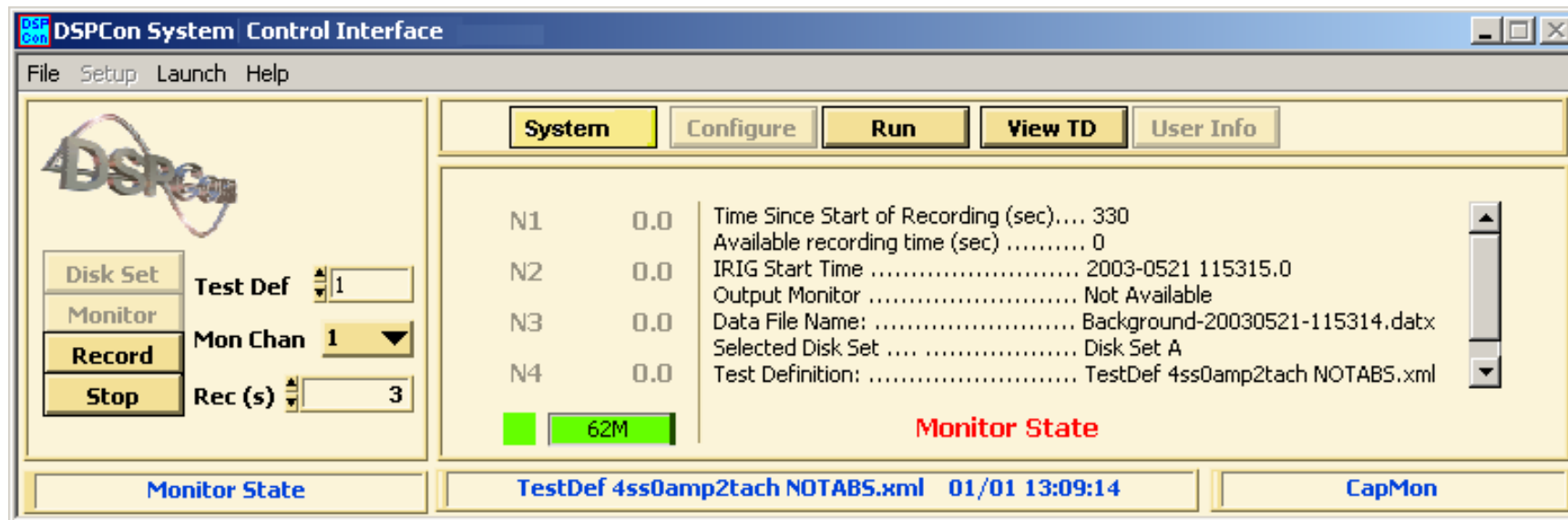
	B	C	D	E	F	G	H	I	J	K	L	M
	Channels				Sensor				ADC & Controls			Channel Type
	Number	Channel Enabled?	Name	Display Scaling	Cal Poly	Sensitivity (volt/EU)	Offset (volt)	Engineering Units	Sample Rate	ADC Gain	ADC Coupling	CSC Card Type
3	1	True	C01	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
4	2	True	C02	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
5	3	True	C03	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
6	4	True	C04	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
7	5	True	C05	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
8	6	True	C06	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
9	7	True	C07	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
10	8	True	C08	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
11	9	True	C09	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
12	10	True	C10	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
13	11	True	C11	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
14	12	True	C12	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
15	13	True	C13	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
16	14	True	C14	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
17	15	True	C15	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
18	16	True	C16	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
19	17	True	C17	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
20	18	True	C18	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
21	19	True	C19	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
22	20	True	C20	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
23	21	True	C21	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
24	22	True	C22	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
25	23	True	C23	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
26	24	True	C24	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
27	25	True	C25	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
28	26	True	C26	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
29	27	True	C27	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)

Channel LowSpeed Channel Dynamic Channel Digital File Header Tachometer Information System Variables Alarm Definition Cal Correction Online Processing DefineChannelMap

Ready Count: 12 131%

DAS - Control and Real-Time Display

System Operation is accomplished using a simple GUI Interface



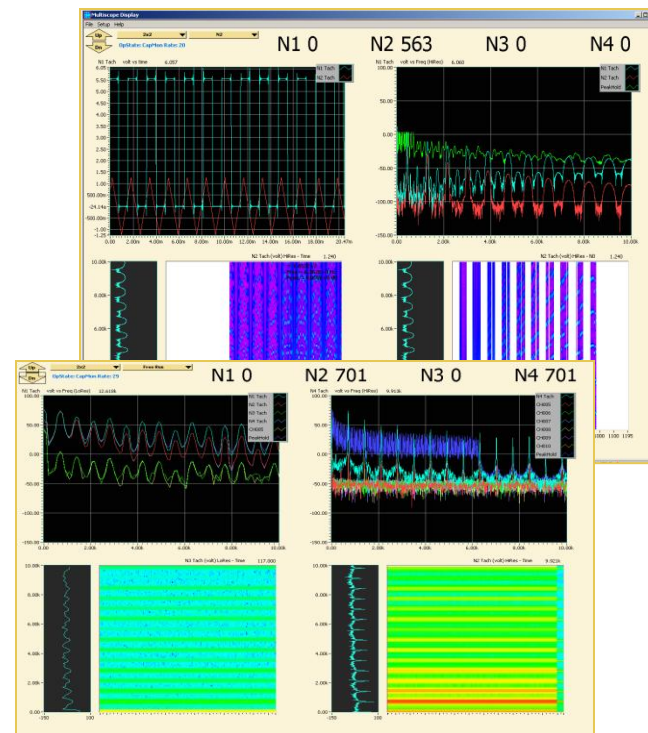
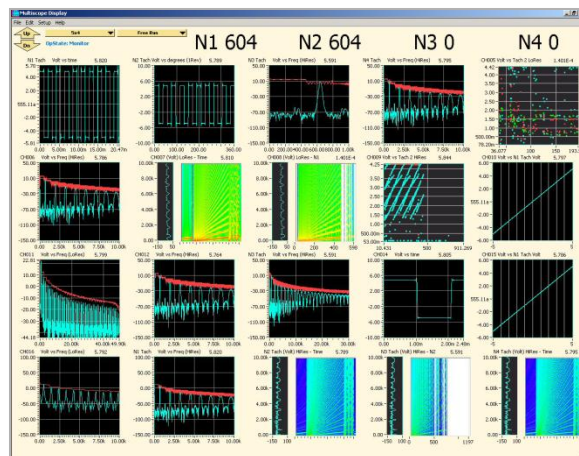
Other Features:

- ✓ Monitor Disk Usage
- ✓ Monitor System Health (Watchdog)
- ✓ Monitor Mode – Ability to Monitor without Acquiring until triggered (Monitor Mode will capture data prior to the event once triggered)

DAS - Control and Real-Time Display

Real-Time Display Capabilities

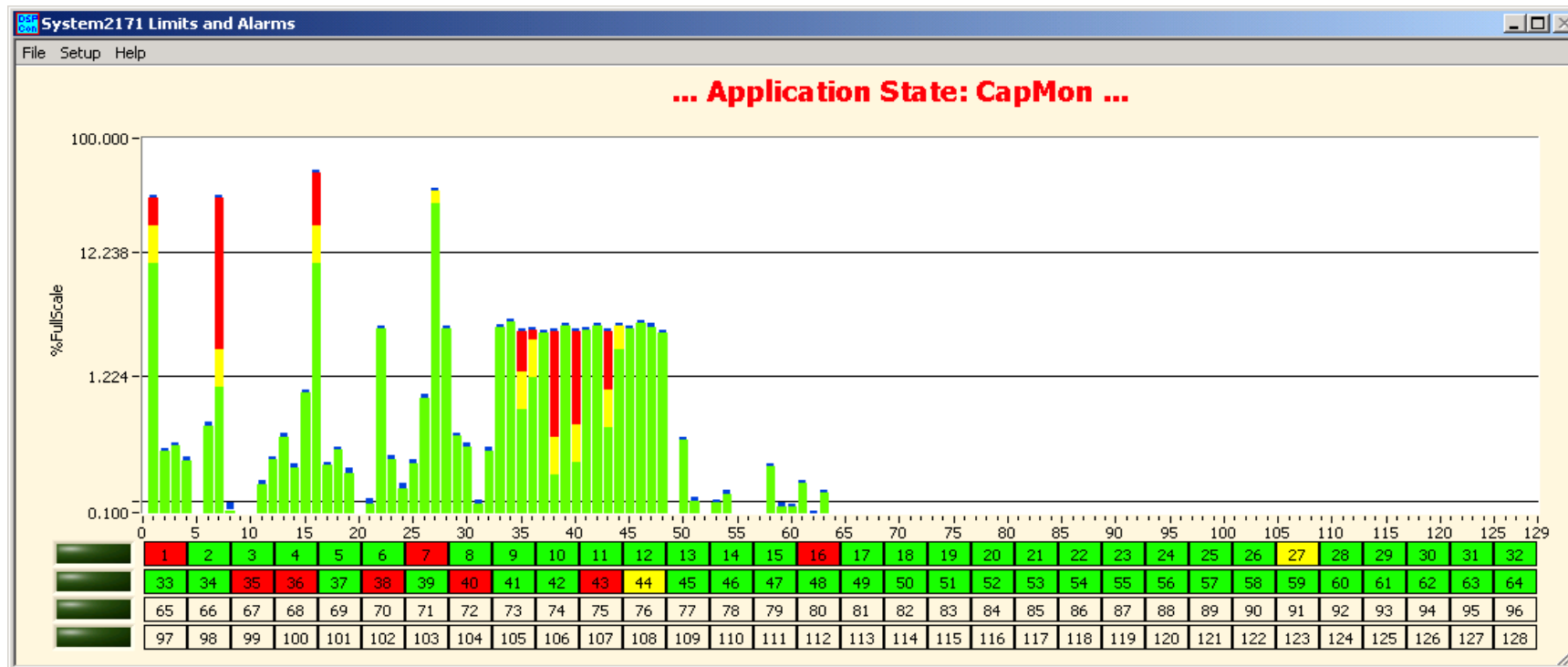
- ✓ Time Plots
 - ✓ Frequency (FFT)
 - ✓ Nth Octave Plots
 - ✓ Signal Transfer Functions
 - ✓ many others
- in many different combinations and arrangements
- ✓ and on multiple “Data Monitoring” PCs



DAS - Control and Real-Time Display

Real-Time Display Types – Limits & Alarms

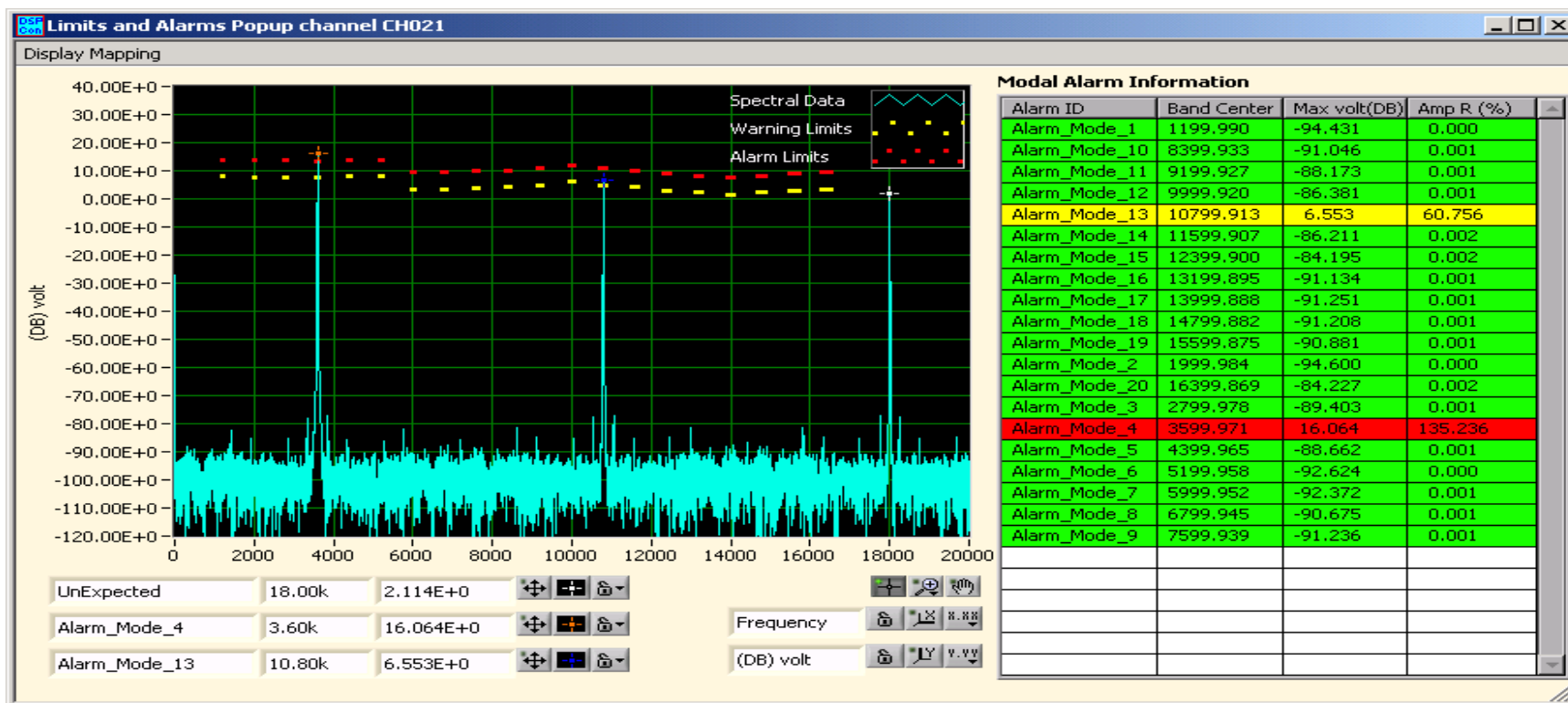
- ✓ Multiscope also allows for Real-time Monitoring of Alarm & Limits Settings for both Peak Amplitude for each Channel **AND** per Frequency/Per Channel



DAS - Control and Real-Time Display

Real-Time Display Types – Limits & Alarms

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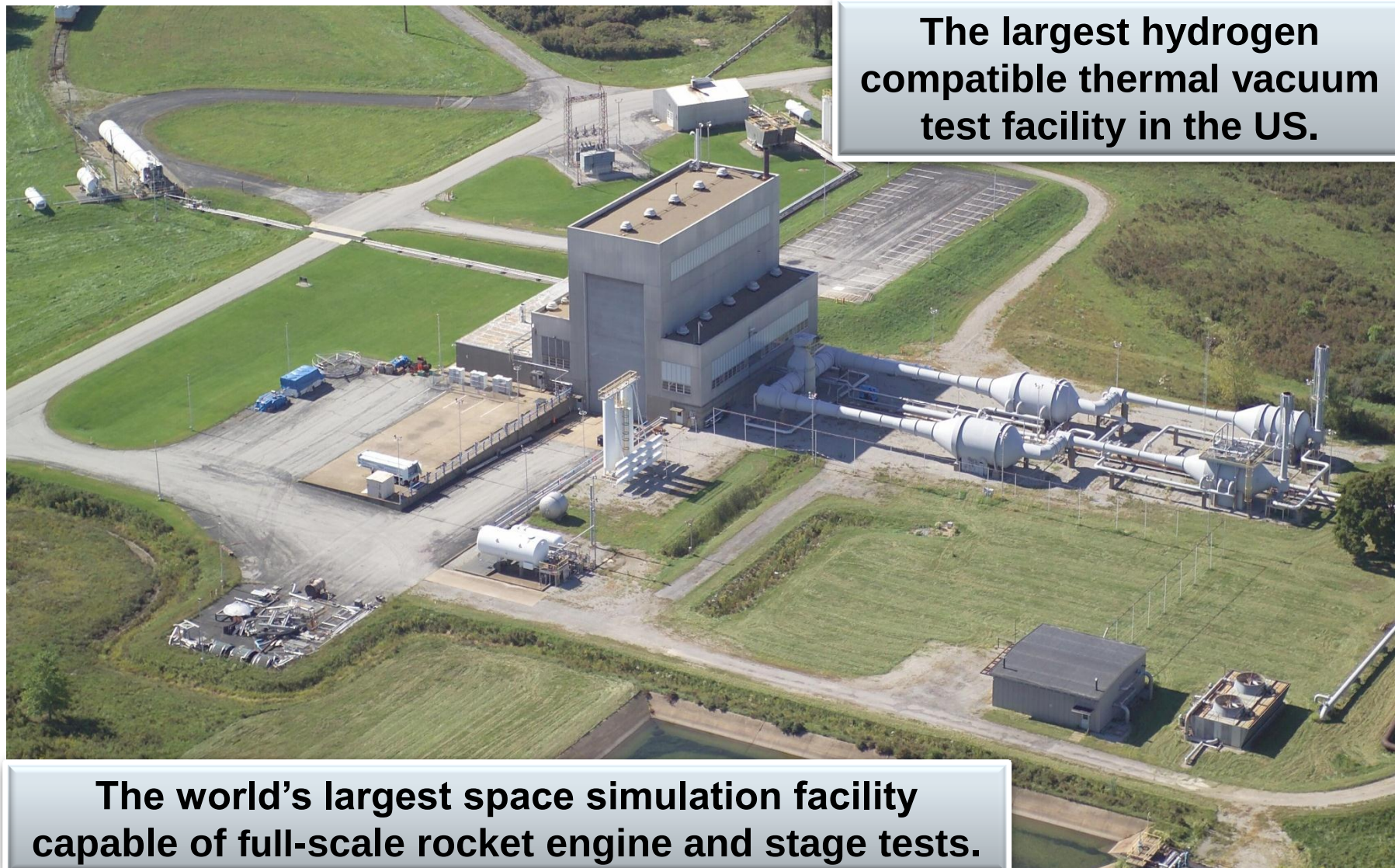
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Ideal for High Altitude Engine Testing



B-2 Facility — Upper-stage Thermal-Vac Chamber (33ft dia. x 55ft high)



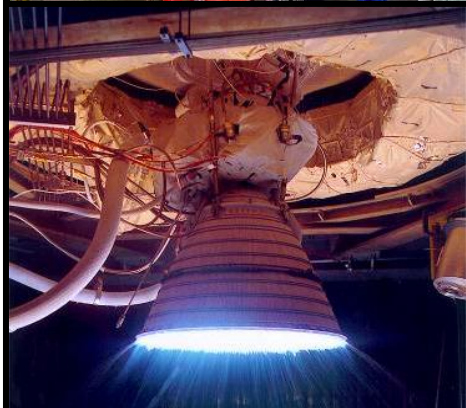
The largest hydrogen compatible thermal vacuum test facility in the US.

The world's largest space simulation facility capable of full-scale rocket engine and stage tests.

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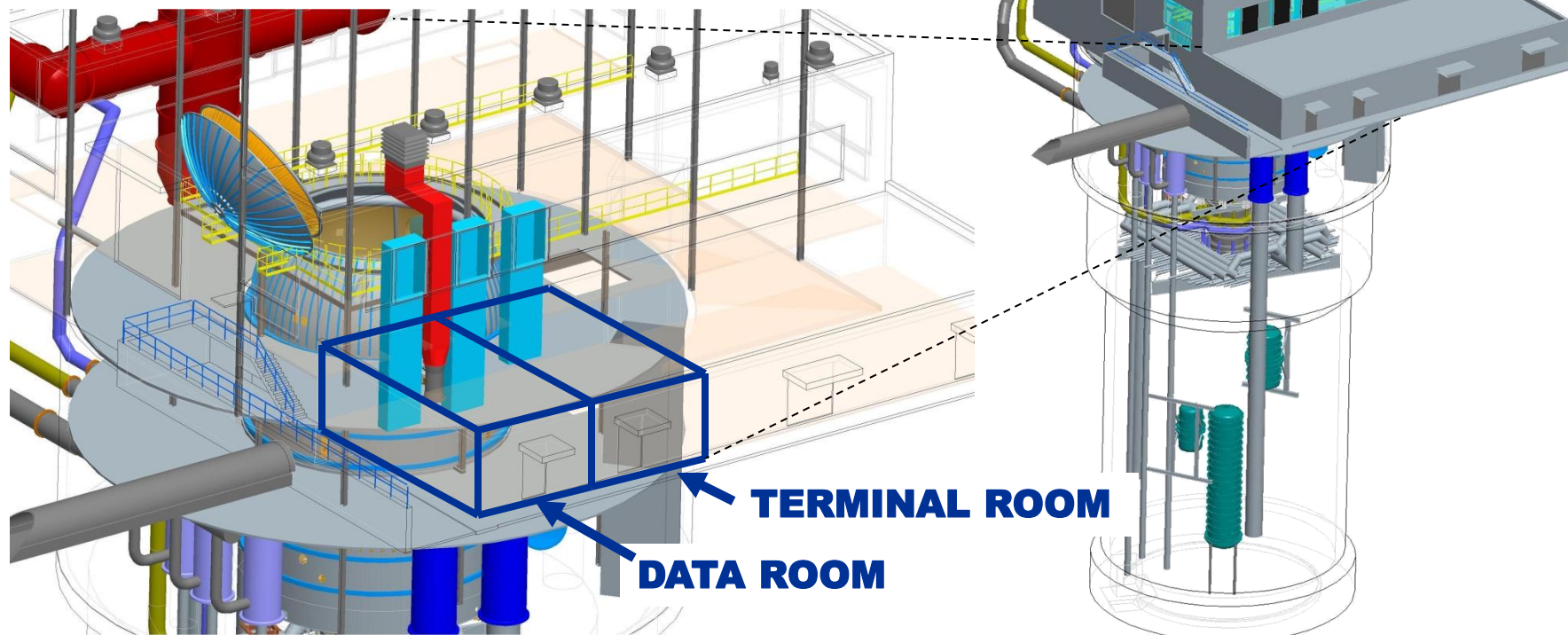


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B-2 Facility

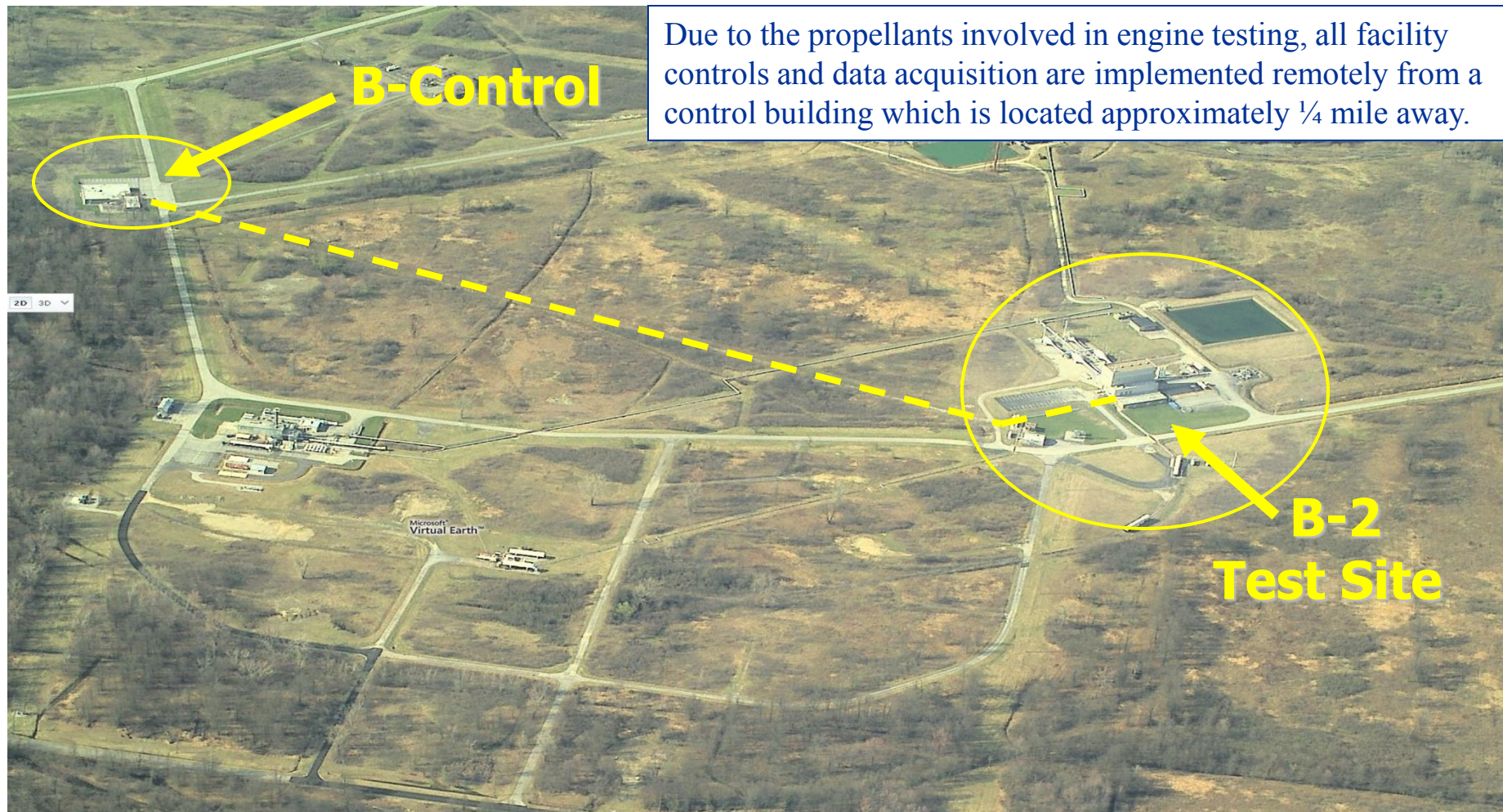
Unique DAS Challenges at B-2

The data acquisition and control systems of B-2 are designed such that all of the field instrumentation signals and data acquisition hardware is consolidated into a set of Class I Div 2 Group B support rooms, one of which is dedicated for the Data Acquisition System.



B-2 Facility

Unique DAS Challenges at B-2



B-2 Facility

DAS Signal Flow

B-2 Test Facility

Test Chamber

Ramp Level
Data DAS Cabinets

Diffusion Pump Level
Data DAS Cabinets

Aux. Signal
Conditioning

B-2 Data Room

Signal Conditioning and Digitizers
and Fiber Network Racks

Interconnects &
Signal Conditioning

Fiber &
Networking

Interconnects &
Signal Conditioning

Digitizers

B-2 Control

Data Recording Units and
DAS Process Control



Data System Operations in the
Control Room at B-Control

B-2 Facility – Dedicated Data Room



B-2 Facility DAS – Summary



**Spacecraft Propulsion
Research Facility**

Designed for High Altitude Engine Testing



Instrument Cabling to Test Chamber		Quantities
1	Single Pair, Twisted-Pair Shielded	>1,700 Ch. 1PR TPS
2	Four-Wire, Twisted-Pair Shielded	312 Ch. of 4C / Ch.
3	Impedance Matched Coaxial	~64 Ch.
Signal Conditioning Equipment		
4	Constant-Voltage Bridge Conditioners	76 Ch.
5	Constant-Current Bridge Conditioners	32 Ch.
6	ICP/IEPE Conditioners	48 Ch.
7	Charge-Type Amplifiers	
8	Filter/Amplifier Signal Conditioners	160 Ch.
9	Frequency-to-Voltage	28 Ch.
10	Direct Voltage Inputs	600+ (see ADCs)
11	UTR Thermocouple Conditioners	<tb>
Digitizing Equipment (ADCs)		
12	High-Speed Digitizers (110 kHz MBW/Ch.)	32 Ch.
13	Low-Speed Digitizers (1 kHz MBW/Ch.)	576 Ch.
14	Discrete Channel Acquisition	32 Ch.
Data Storage		
15	RAID 1+0 redundant fail-over storage	2.5 – 3 Terabytes
Control, Monitoring and Post-Processing		
16	Dedicated Control Computers	2
17	Dedicated Monitoring Computers	4
18	Dedicated Post-Processing Computer	1
Other Notable System Elements		
19	IRIG-B Distribution	All
20	LTO-3 Tape Archival System	All

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Designed for High Altitude Engine Testing



Space Power Facility (SPF)

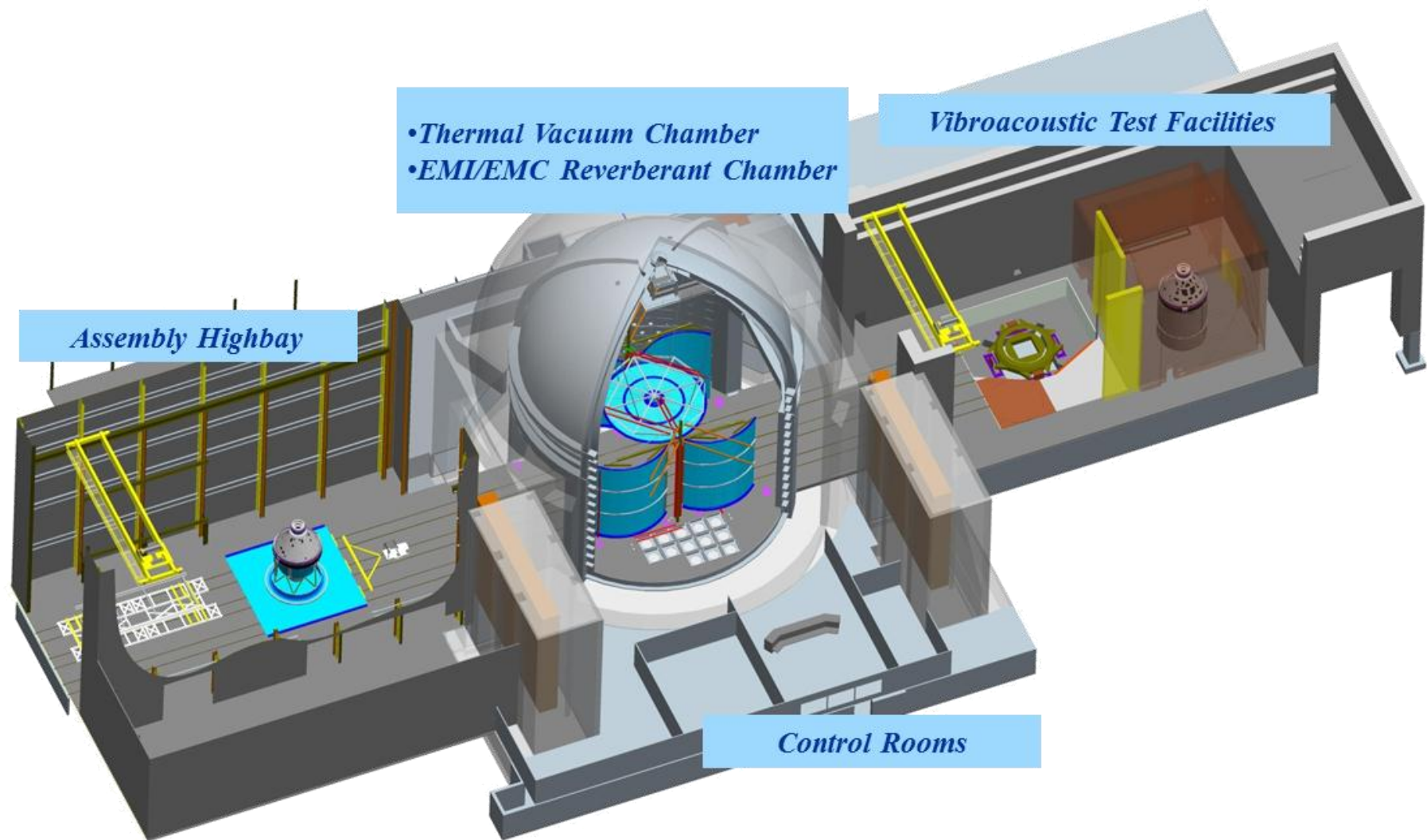
Space Environment Testing under one roof

- Thermal-Vacuum
- EMI/EMC
- Acoustic
- Vibration



The World's largest space environment simulation chamber

Space Power Facility (SPF)

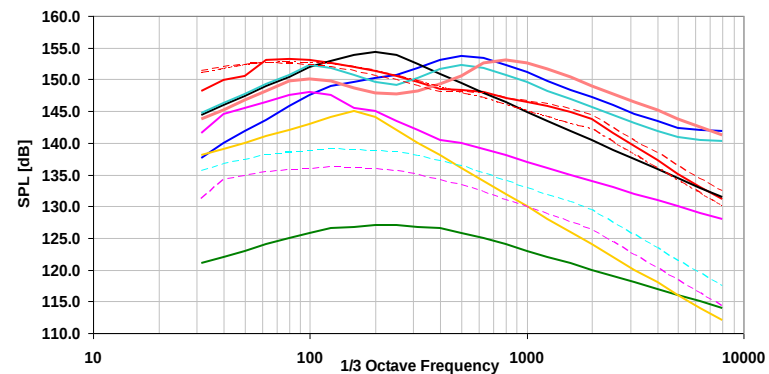


Space Power Facility – Acoustic Facility

SPF – Reverberant Acoustic Test Facility



- ~101,000 ft³ chamber volume
- ~ 37ft (w) x 47ft (d) x 57ft (h)
- ~ 163dB OASPL (Overall Sound Pressure Level)
- 20k Hz Measurement Bandwidth



DAS Measurements Channels to RATF

- 800 - IEPE accels and/or microphones
- 40 - IEPE/charge conditioners
- 184 - 4-arm strain gauge conditioners

Space Power Facility – Vibration Facility

SPF - Mechanical Vibration Facility (MVF)

- 3-axis servo-hydraulic shaker
- Annulus design ~18ft dia.
- Sized for 75,000 lb test articles
- ~4 million lb seismic mass
- 5 -150 Hz Sine Vib.
 - 1.25 g Vert.
 - 1.0 g Lateral

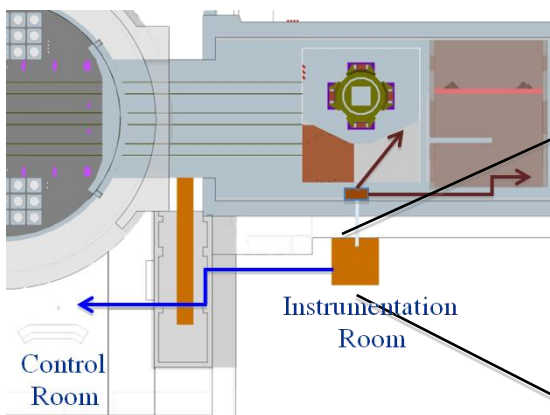
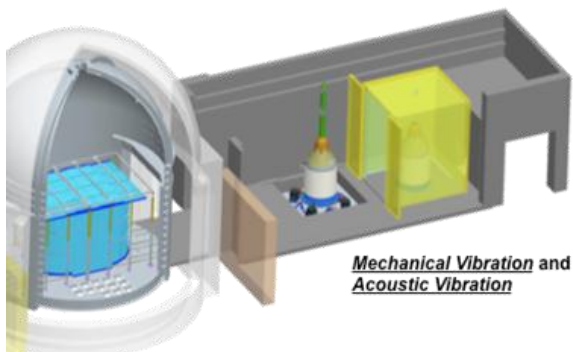
Data System

Measurements Channels to MVF

- 800 - IEPE Accel. conditioners
- 40 - IEPE/Charge conditioners
- 184 - 4-arm Strain gauges



SPF - FDAS - Instrument (Data) Room

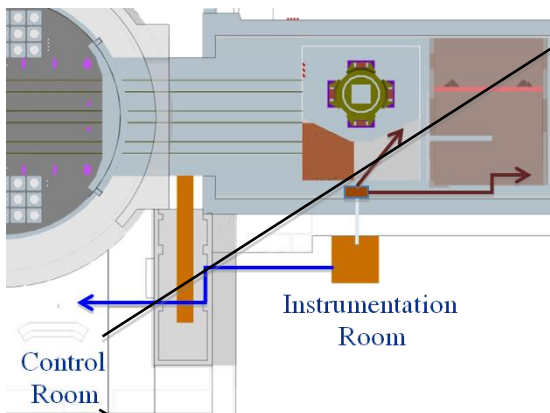
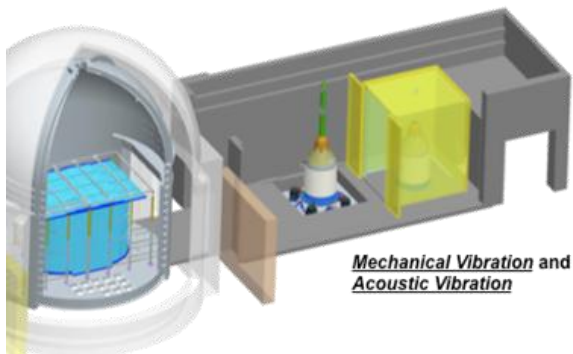


The 1,024 (1,536) Measurement Channels of the HSDAS can be “switched” between the three test locations within a 24 hours period at the “Interface Panel” in the VTC High-bay.

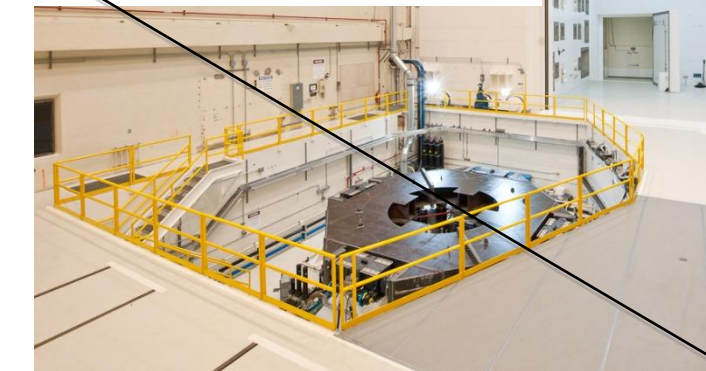


From the Interface Panel in the VTC High-Bay area, all 1,024 (1,536) Channels are routed through the wall and into the HSDAS Instrument Room. The Instrument Room houses all of the Signal Conditioning and Digitizing Hardware

SPF - FDAS – Integrated Control Room



The 1,024 (1,536) Measurement Channels of the HSDAS can be “switched” between the three test locations within a 24 hours period at the “Interface Panel” in the VTC High-bay.



SPF Vibroacoustic FDAS – Summary



Designed for Large-Scale Environment Testing



Instrument Cabling to the MVF table and RATF chambers		Num. of Channels
1	Single Pair, Twisted-Pair Shielded	>1,700 Ch. TPS
2	Impedance Matched Coaxial to/from ACS	64 Ch.
3	Impedance Matched Coaxial to/from VCS	64 Ch.
Signal Conditioning Equipment		
4	ICP/IEPE Conditioners	800 Ch.
5	Constant-Voltage Bridge Conditioners	160 Ch.
6	Direct Voltage Inputs from ACS/VCS	64 Ch.
7	Buffered Voltage Outputs to ACS/VCS	64 Ch.
Digitizing Equipment (ADCs)		
8	High-Speed Digitizers (20 kHz MBW/50 kHz SR)	1024 Ch.
Data Storage		
9	RAID 1+0 redundant fail-over storage	3 Terabytes total
Control, Monitoring and Post-Processing		
10	Dedicated Control Computers	1
11	Dedicated Monitoring Computers	3
12	Dedicated Post-Processing Computer	1
Other Notable System Elements		
13	IRIG-B Distribution	All
14	LTO-3 Tape Archive	All

Presentation Outline

■ Overview

- Plum Brook location and facilities
- Summary of recent facility upgrades at Plum Brook

■ Plum Brook Facility DAS Design Drivers

- Goals
- Challenges
- Measurement Topology
- Architecture
- Specifications and Capabilities of shared assets

■ Overview of Plum Brook Data Systems

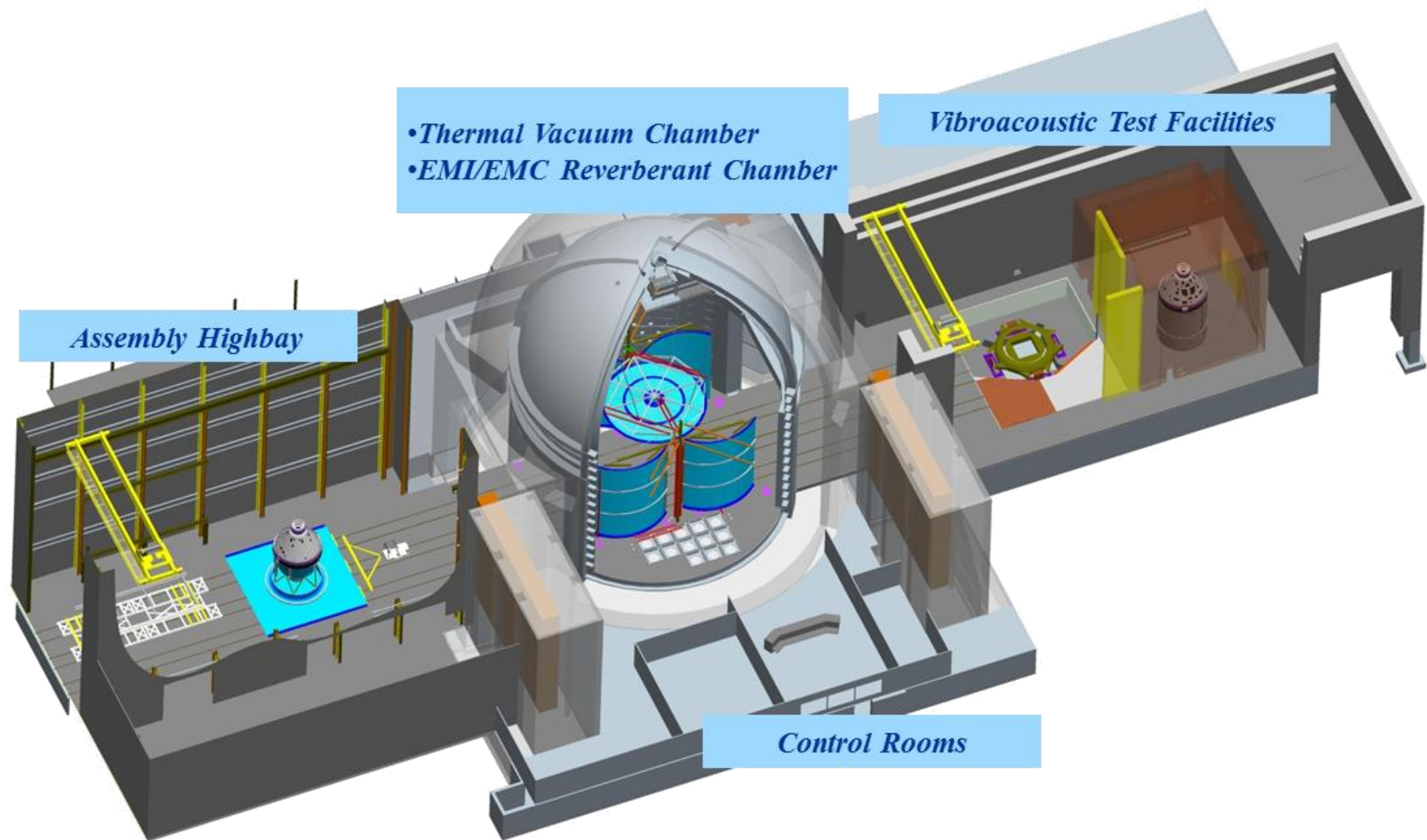
- B-2 Facility DAS
- SPF Vibroacoustic Facilities DAS
- SPF Thermal-Vacuum Chamber DAS



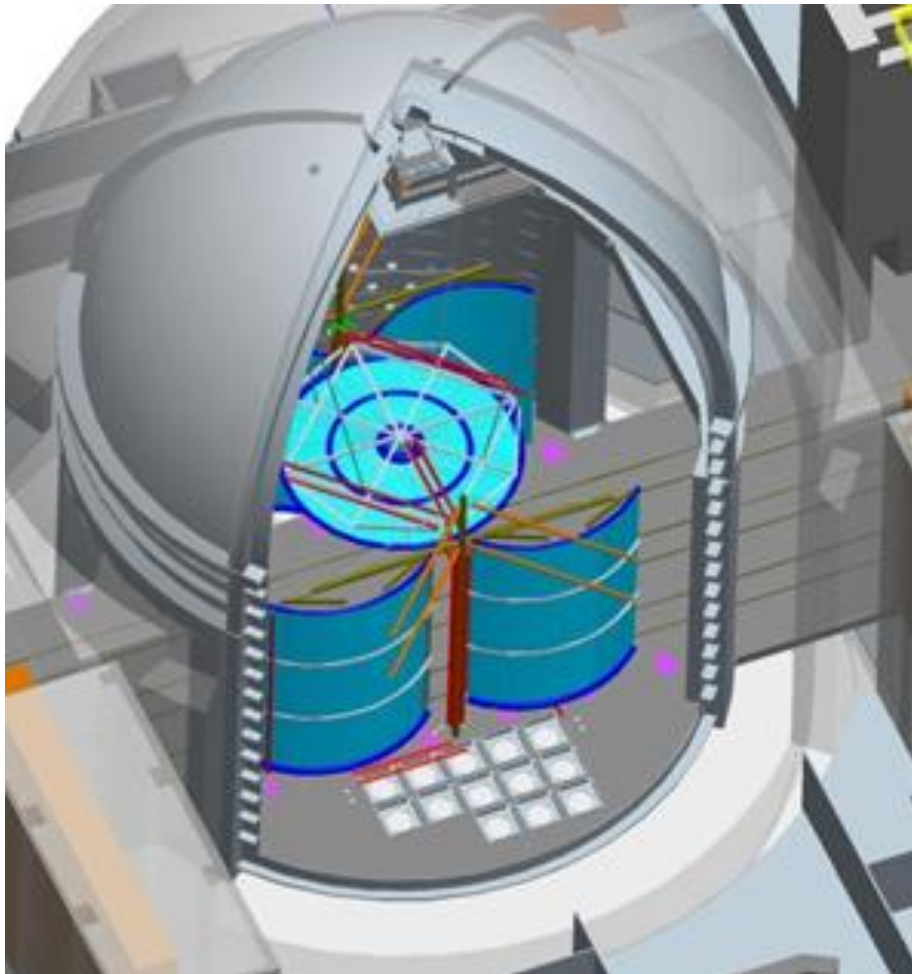
Designed for Large-Scale Environment Testing



Space Power Facility (SPF)



SPF Thermal-Vacuum – Chamber Description



**Thermal-Vacuum Tests
Require “Low-Speed” DAS**

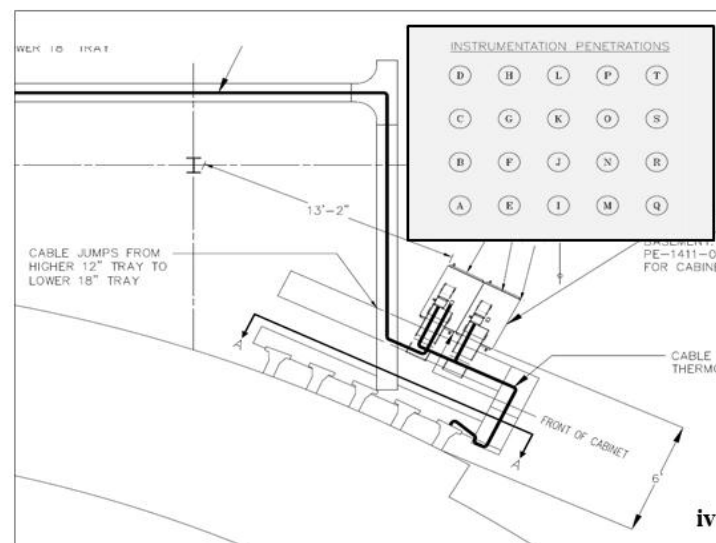
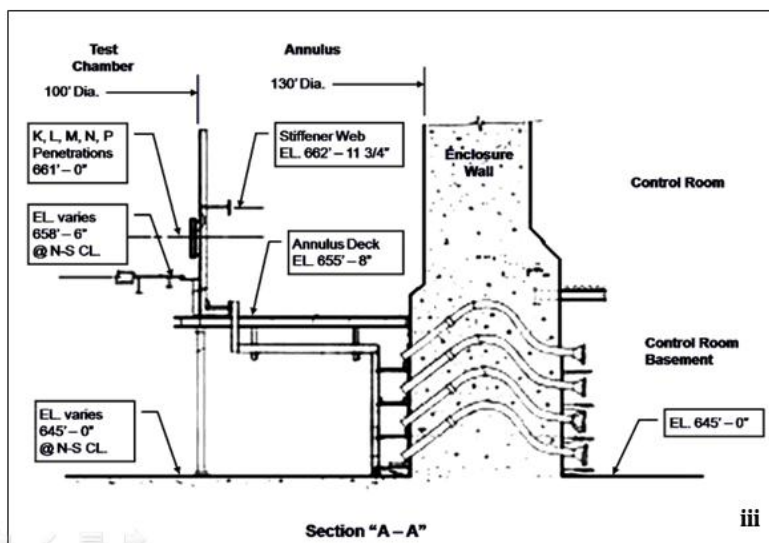
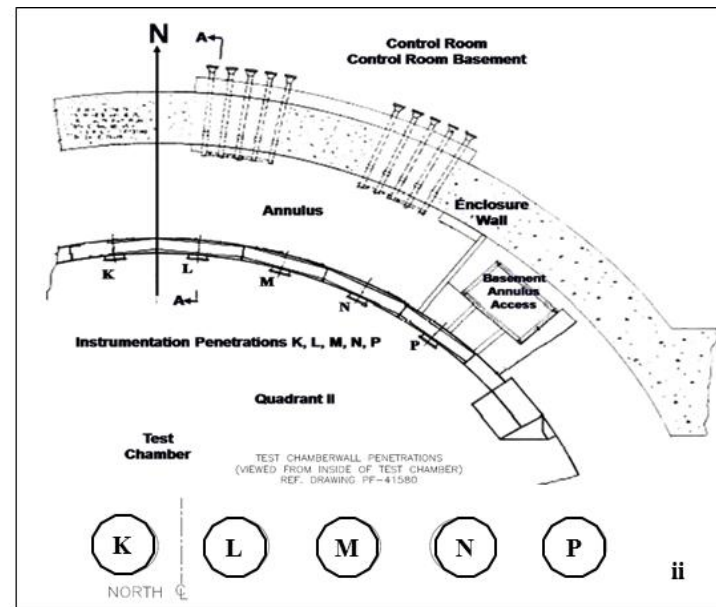
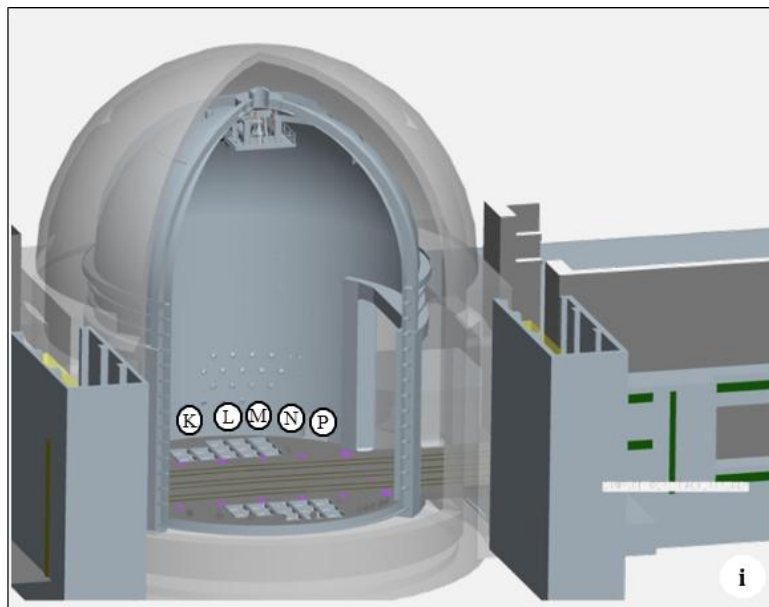


**Altitude Performance Tests
Require “High-Speed” DAS**

SPF Thermal-Vacuum – Chamber Connections



SPF Thermal-Vacuum – Annulus Feedthroughs



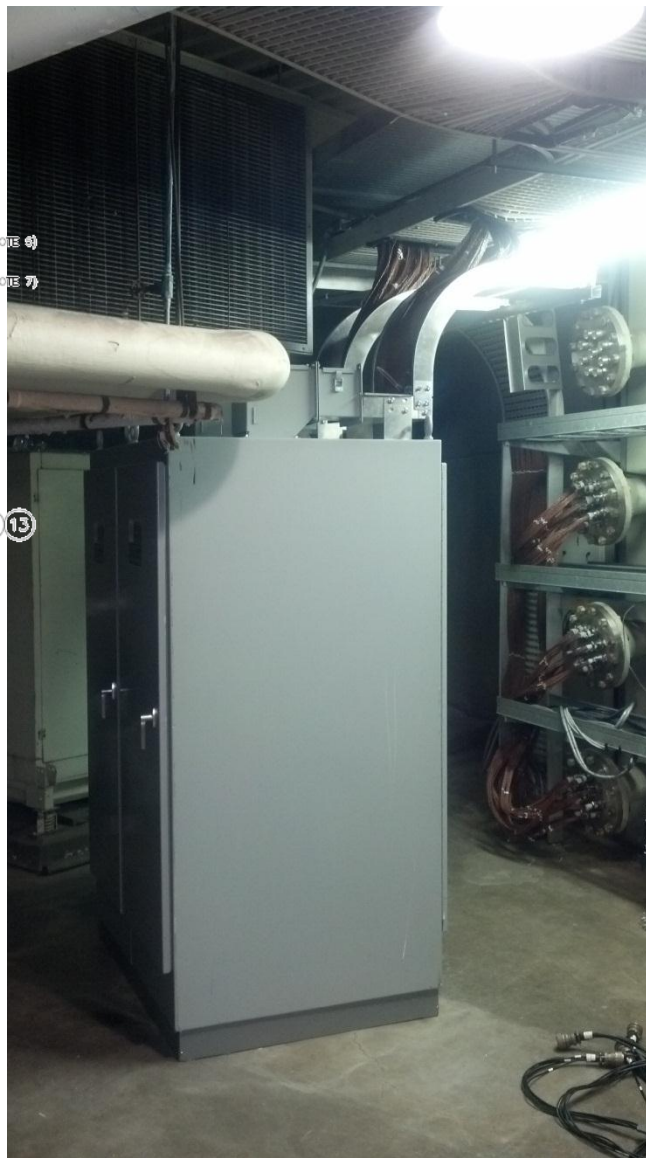
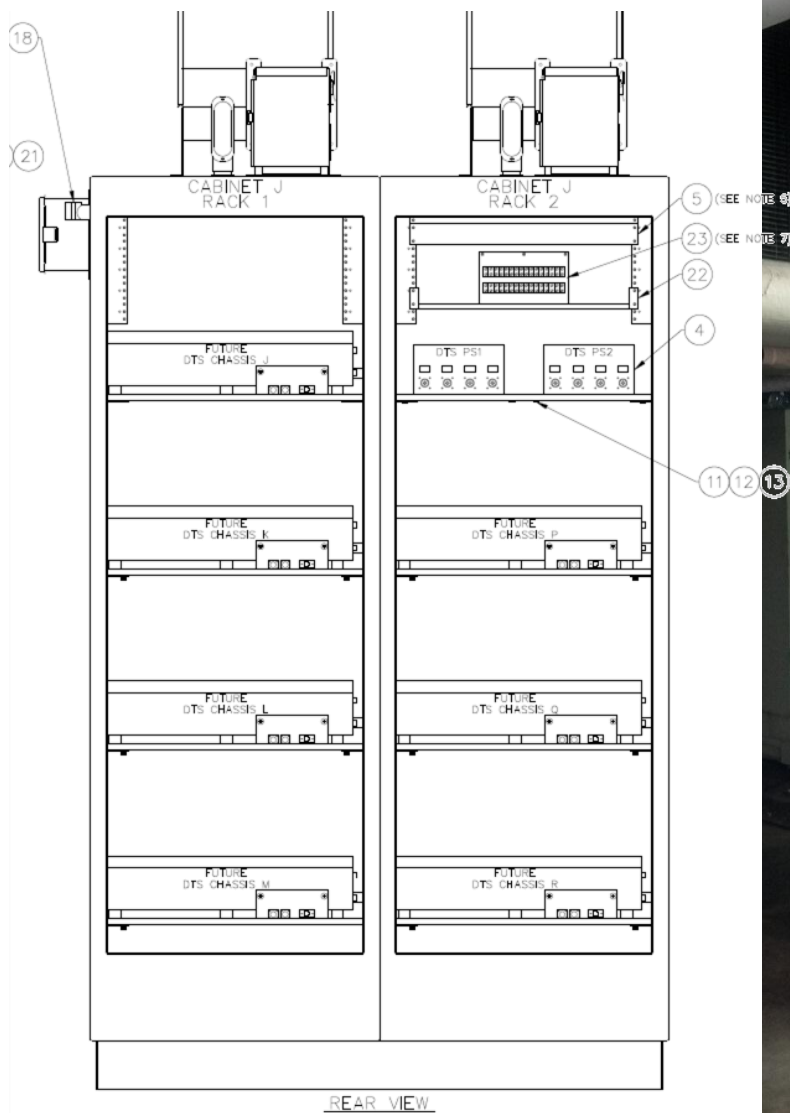
SPF Thermal-Vacuum – Outside Connections



SPF Thermal-Vacuum – Outside Connections

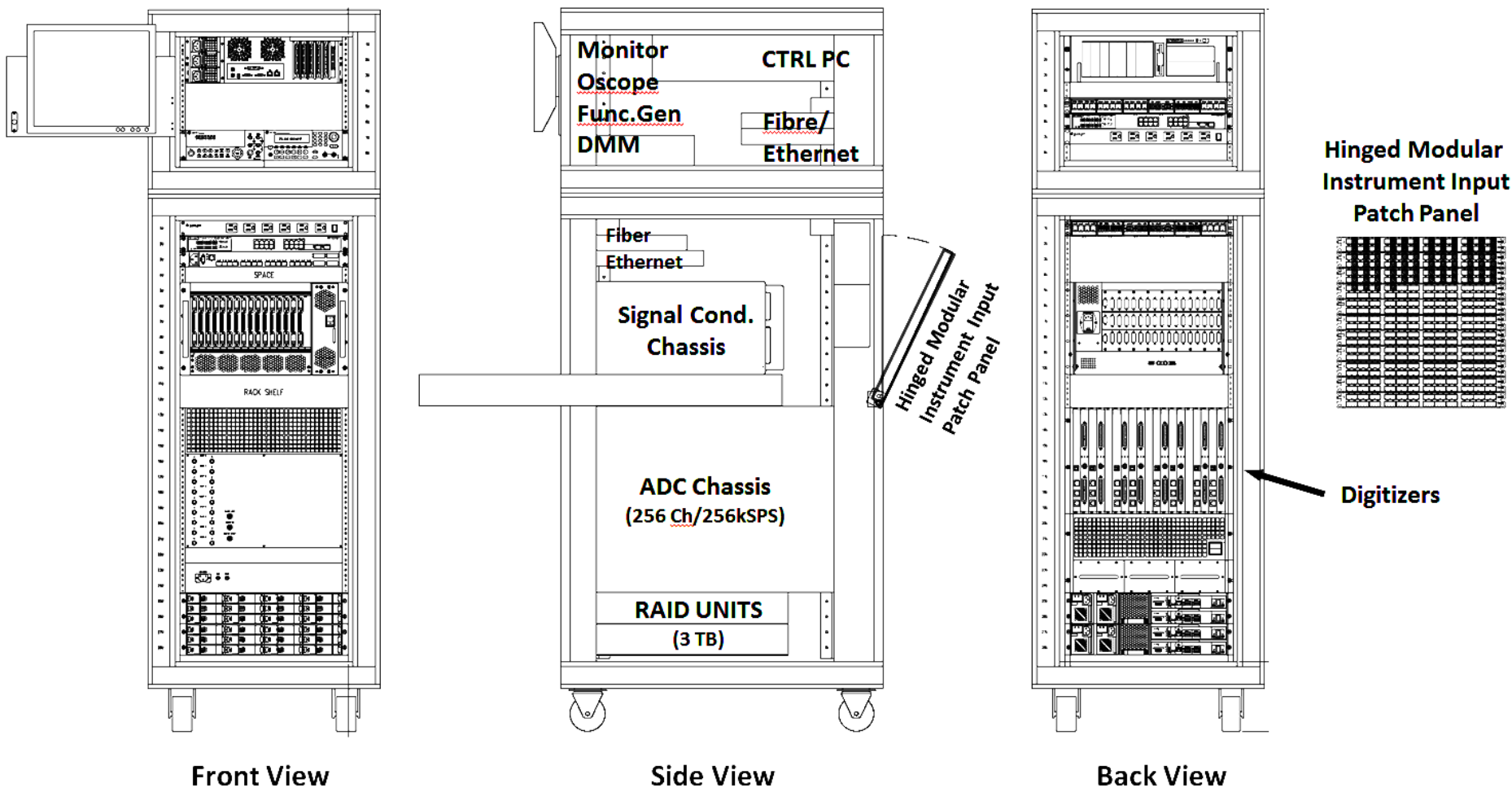


SPF Thermal-Vacuum Temperature DAS Racks



SPF Thermal-Vacuum – Mobile DAS Layout

(High-Speed/Dynamic, 256 Channels)



SPF Thermal-Vacuum MDAS – Front View



SPF Thermal-Vacuum MDAS – Rear View



SPF Thermal-Vacuum MDAS – Control



SPF Thermal-Vacuum MDAS – Summary



Designed for Large-Scale Environment Testing



Instrument Cabling in the Vacuum Chamber Annulus		Num. of Channels
1	Single Pair, Twisted-Pair Shielded	324 Ch. 1PR TPS
2	Four-Wire, Twisted-Pair Shielded	288 Ch. 4C/Ch.
3	Impedance Matched Coaxial	126 Ch. BNC
4	Type-T Thermocouple Instrumentation Wire	512 Ch.
Signal Conditioning Equipment		
5	ICP/IEPE Conditioners	64 Ch. *
6	Constant-Voltage Bridge Conditioners	48 Ch. †
7	Charge-Type Conditioners	24 Ch. †
8	Direct Voltage Inputs	120 Ch.
9	Buffered Voltage Follower Outputs	As needed †
10	Thermocouple Signal Conditioning	
Digitizing Equipment (ADCs)		
11	High-Speed Digitizers (100 kHz MBW/256 kHz SR)	256 Ch.*
11a	Low-Speed Digitizers/Data-Translators (10Hz SR)	512 Ch.
Data Storage		
12	RAID 1+0 redundant fail-over storage	3 Terabytes total
Control, Monitoring and Post-Processing		
13	Dedicated Control Computers	1
14	Dedicated Monitoring Computers	4*
15	Dedicated Post-Processing Computer	1*
Other Notable System Elements		
16	IRIG-B Distribution	All
17	LTO-3 Tape Archive	All*



Thank you.



Backup Charts

A Modular, COTS, Fully Remote-Controllable Signal Conditioning Platform has been selected. This system supports all major transducer types and provides unprecedented remote control and monitoring capabilities.

- Multiple “Card-Cage” Chassis for Signal Conditioning
 (“n” crates x 16 cards/crate @ 4, 8, and 16 Ch/Card = 512 – 1,536 Channels)



DAS - Signal Conditioning

A Modular, COTS, Fully Remote-Controllable Signal Conditioning Platform has been selected. This system supports all major transducer types and provides unprecedented remote control and monitoring capabilities.

Current Signal Conditioning System:

- Multiple “Card-Cage” Chassis for Signal Conditioning
(“n” crates x 16 cards/crate @ 4, 8, and 16 Ch/Card = 512 – 1,536 Channels)



Current Signal Conditioning System supports the following measurement types:

- Voltage Bridge Conditioners
(42 cards @ 4 ch/card = 168 channels)
- Constant Current Conditioners
(12 cards @ 4 ch/card = 48 channels)
- Voltage Amplifier/Filter
(25 cards @ 8 ch/card = 200 channels)
- IEPE/ICP Accels/Microphones
(50 cards @ 16 ch/card = 800 channels)
- Charge/Voltage Accelerometers
(6 cards @ 4 ch/card = 24 channels)
- Frequency to Voltage Converters
(8 cards @ 4 ch/card = 32 channels)

DAS – ADCs (Digitizers)

VME-based Digitizer Modules (“Bricks”)

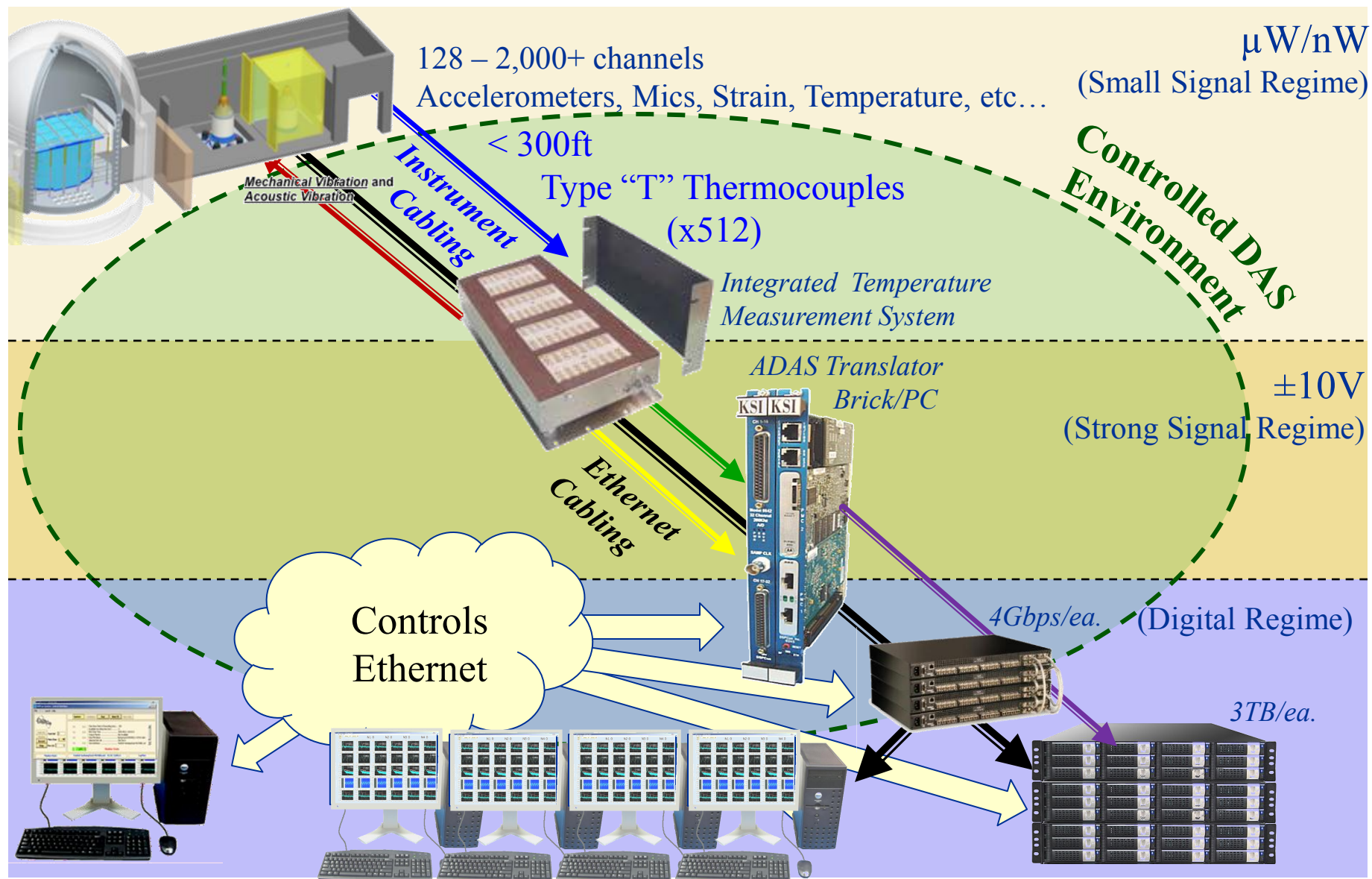
High-Speed and
Low-Speed ADCs

6 x Low-Speed Bricks
32 x High-Speed Bricks and
1 x Discrete Inputs Brick

- Low-Speed Bricks → 96 Channels/Board
- High-Speed Brick (and Discrete) → 32 Channels/Board
- 6 Low-Speed Bricks → 576 channels @ 100 Hz-5kHz SR
- 32 High-Speed Bricks → 1,024 channels @ 5kHz - 256 kHz SR
- 1 Discrete Brick → 32 channels @ 5kHz - 256 kHz SR
- Auxiliary Data Translator for accepting external data sources.
- Simultaneous sampling on all channels
- 16-bit resolution with ~90 dB signal-to-noise
- Integrated linear-phase, anti-alias filters (>100dB Alias rejection)
- Differential inputs (+/- 10V)
- Programmable gains of 1, 10, 100 & 1,000
- On-board DSP and FPGA

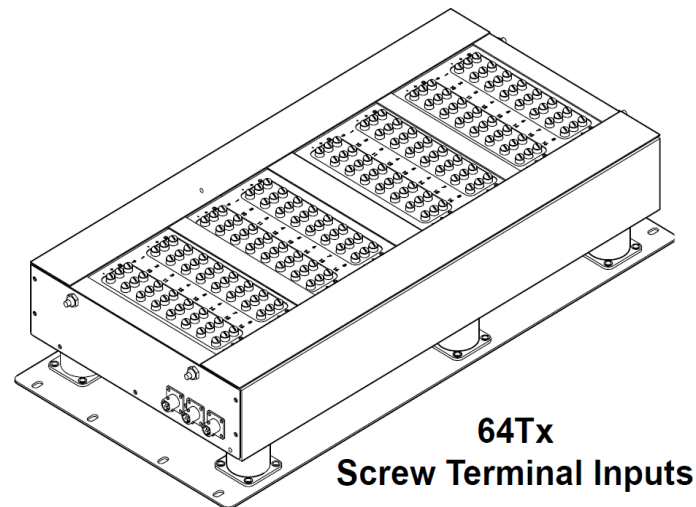
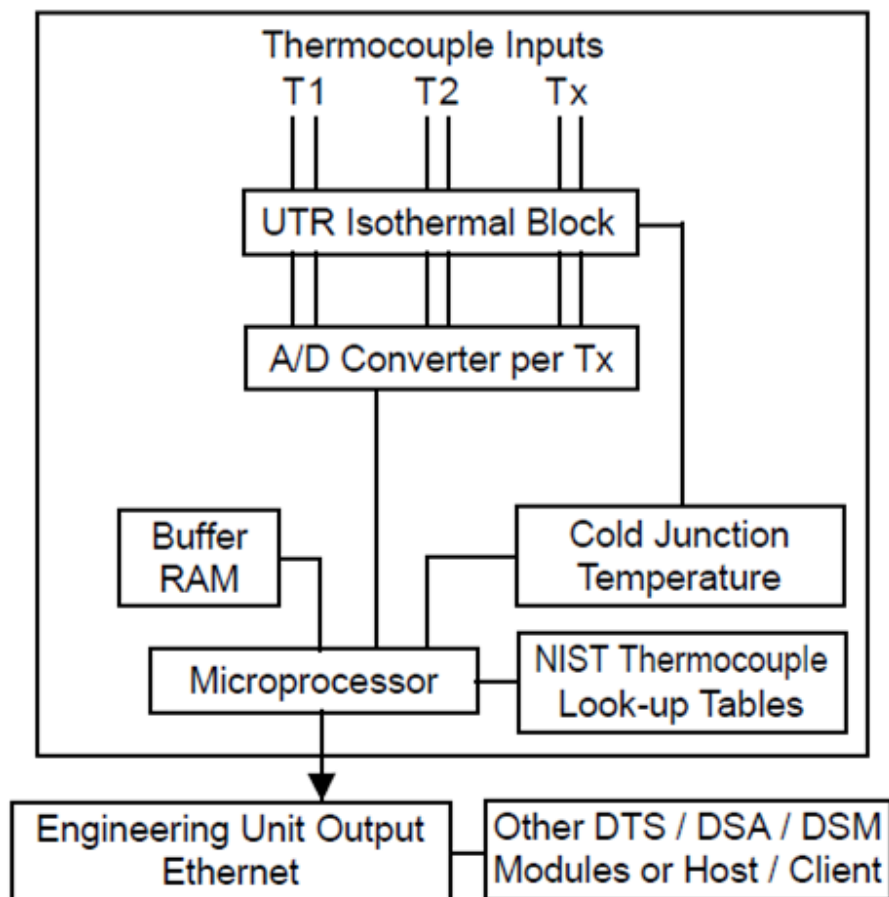


Modular Distributed Measurement Topology



SPF Thermal-Vacuum – Temperature Data

(Low-Speed, 512 Channels)



Features

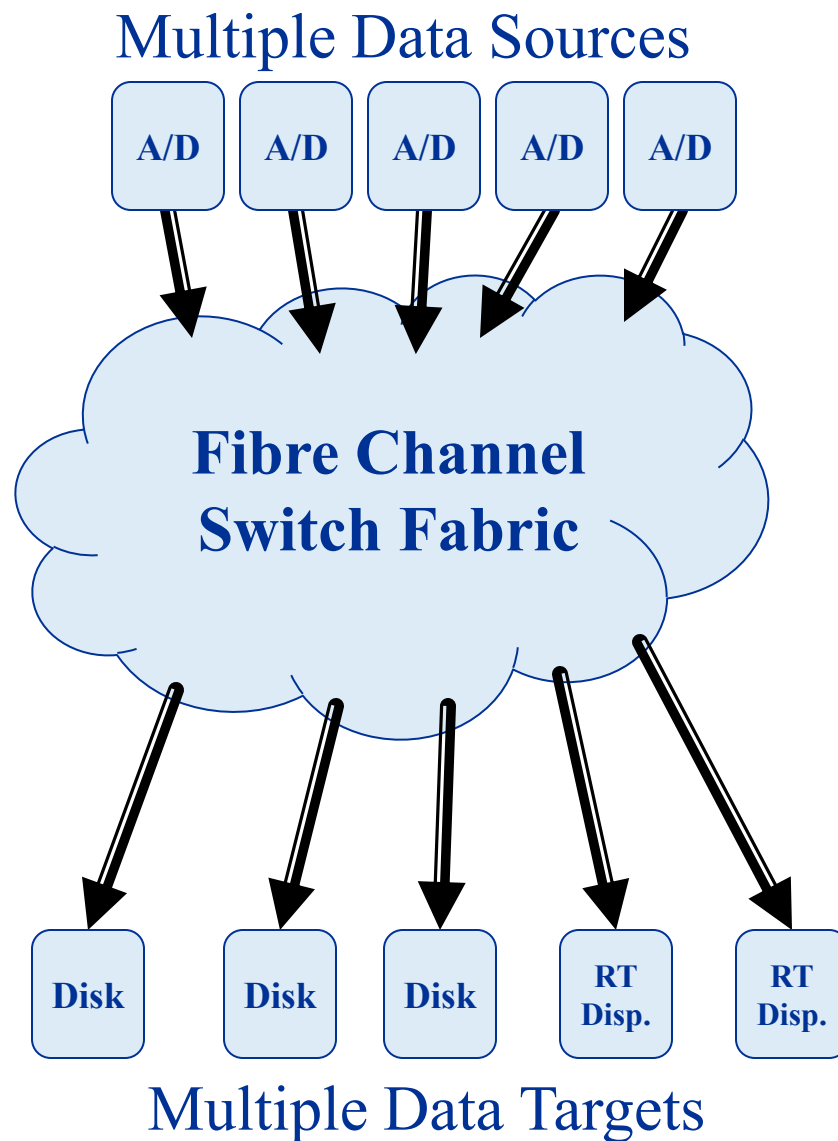
- Accepts type E, J, K, N, R, S, T, and B
- Engineering Unit output, °C, °F, °R, or K
- Ethernet TCP/IP protocol "network ready"
- 10 samples/channel/second
- 50 - 60 Hz noise rejection
- Open thermocouple test
- 1000 Vdc input isolation
- LabView® driver and OPC server
- 16, 32, and 64 channel

DAS - Data Transport using an FC-Switch Fabric



Benefits of a Fibre-Channel Switch Fabric

- Performance to over 4 Gbits/second.
- Delivers sustained Transfer Bandwidth of ≈ 97 Mbytes/Sec for file transfers.
- Support for long distances up to 10 Km.
- Support for multiple simultaneous protocols.
- Allows for shared storage.
- Provides a scalable network.
- Robust data integrity and reliability
- Fast data access and backup.



DAS - Data Storage

> 3TB of RAID 1+0 are provided for the Data System to record to

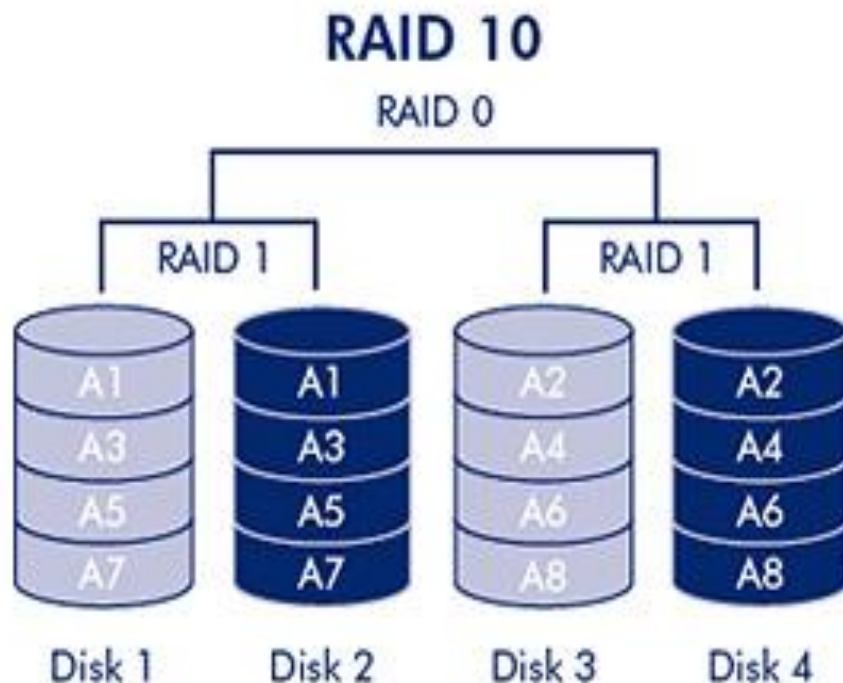
Total Storage Size =

$$\begin{aligned} & \{ \text{Aggregate Data Rate} \} \\ & \times \{ \text{required test duration} \} \end{aligned}$$

> 3 Terabytes $\approx$

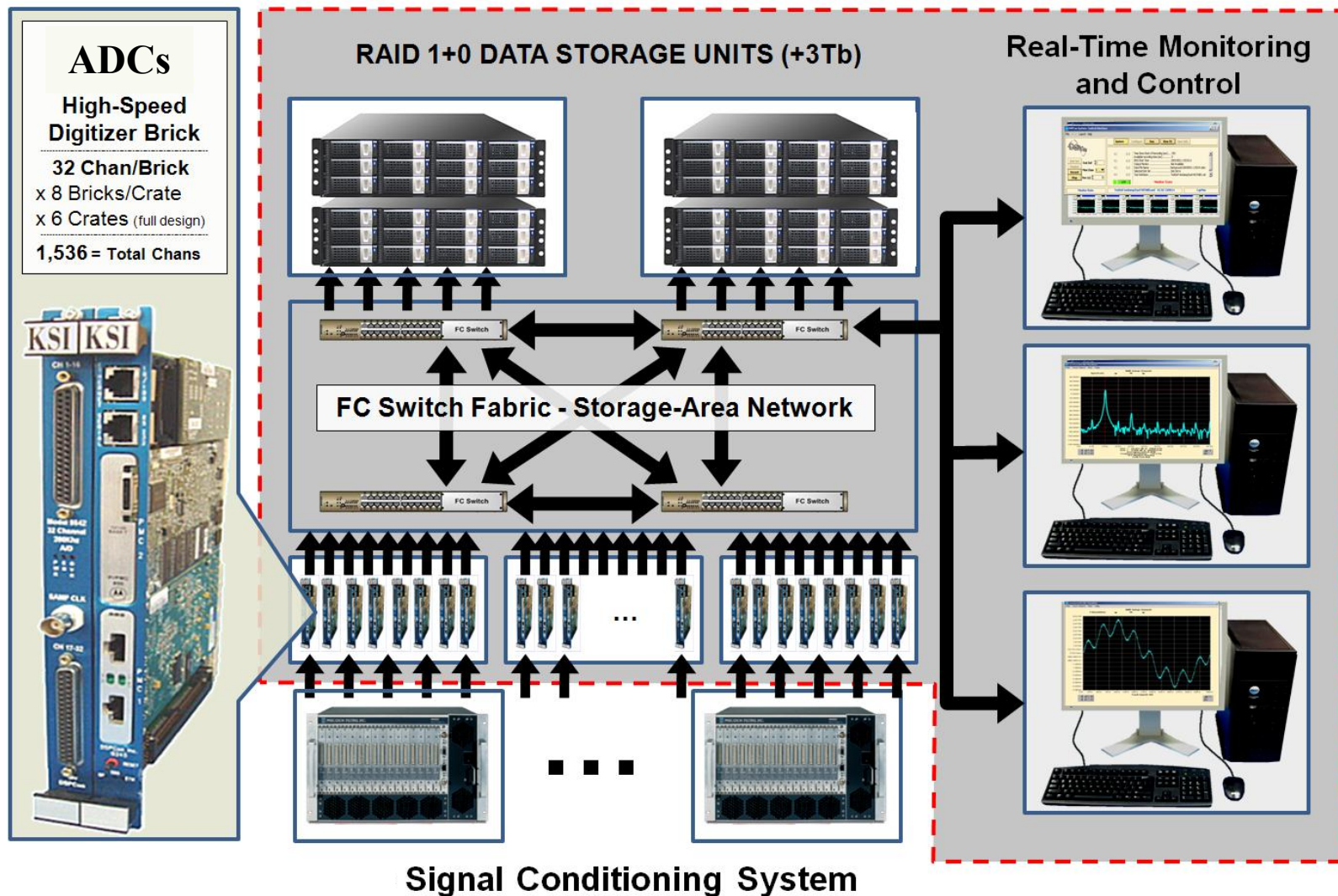
$$\begin{aligned} & \{ 153.6 \text{ Mbytes/sec} \} \\ & \times \{ 8 \text{ hours} \times 3,600 \text{ seconds/hour} \} \end{aligned}$$

RAID 1+0 provides the best combination of data-recording bandwidth and disk-failure protection.



Integrated FC-SAN for Distributed Scalability

The completed system forms a Fibre-Channel Storage Area Network





DAS - Control and Real-Time Display

System Configuration is done using a MS-Excel Spreadsheet

NASA GLENN Example TDF SUBADDRESS 20080401.xls [Compatibility Mode] - Microsoft Excel

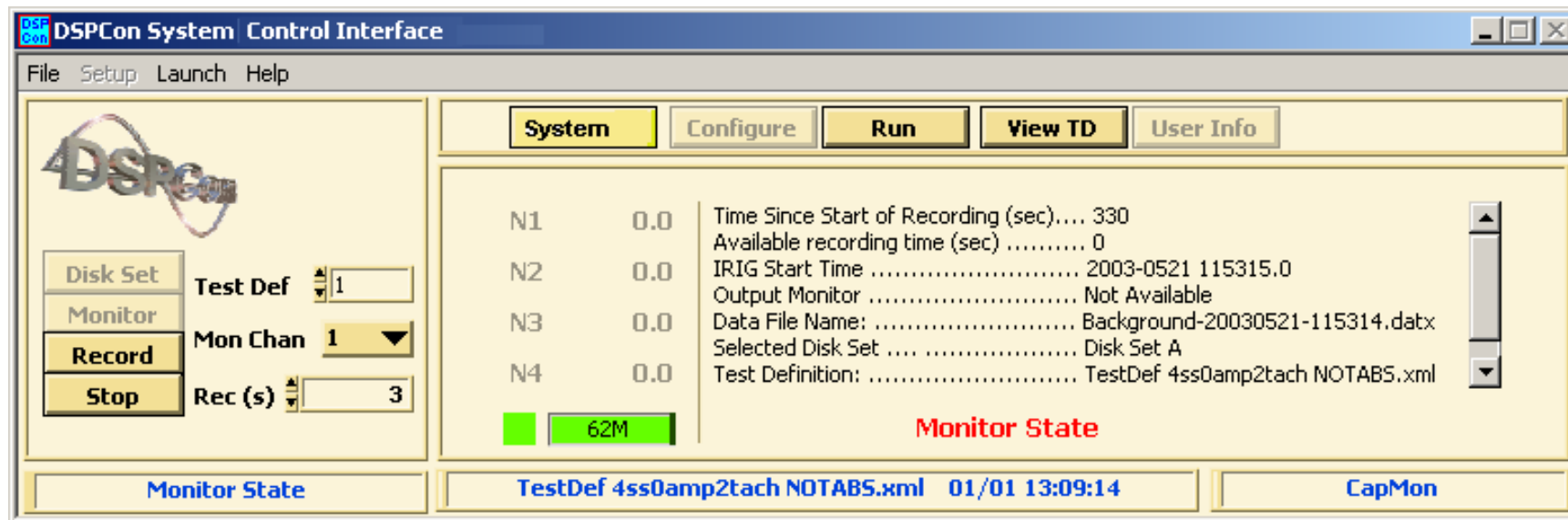
	B	C	D	E	F	G	H	I	J	K	L	M
	Channels				Sensor				ADC & Controls			Channel Type
	Number	Channel Enabled?	Name	Display Scaling	Cal Poly	Sensitivity (volt/EU)	Offset (volt)	Engineering Units	Sample Rate	ADC Gain	ADC Coupling	CSC Card Type
3	1	True	C01	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
4	2	True	C02	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
5	3	True	C03	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
6	4	True	C04	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
7	5	True	C05	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
8	6	True	C06	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
9	7	True	C07	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
10	8	True	C08	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
11	9	True	C09	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
12	10	True	C10	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
13	11	True	C11	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
14	12	True	C12	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
15	13	True	C13	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
16	14	True	C14	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
17	15	True	C15	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
18	16	True	C16	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
19	17	True	C17	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
20	18	True	C18	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
21	19	True	C19	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
22	20	True	C20	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
23	21	True	C21	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
24	22	True	C22	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
25	23	True	C23	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
26	24	True	C24	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
27	25	True	C25	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
28	26	True	C26	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)
29	27	True	C27	Peak	None (linear)	1.000E+00	0.000E+00	volt	4000	1	DC	None (Direct Voltage Input)

Channel LowSpeed Channel Dynamic Channel Digital File Header Tachometer Information System Variables Alarm Definition Cal Correction Online Processing DefineChannelMap

Ready Count: 12 131%

DAS - Control and Real-Time Display

System Operation is accomplished using a simple GUI Interface

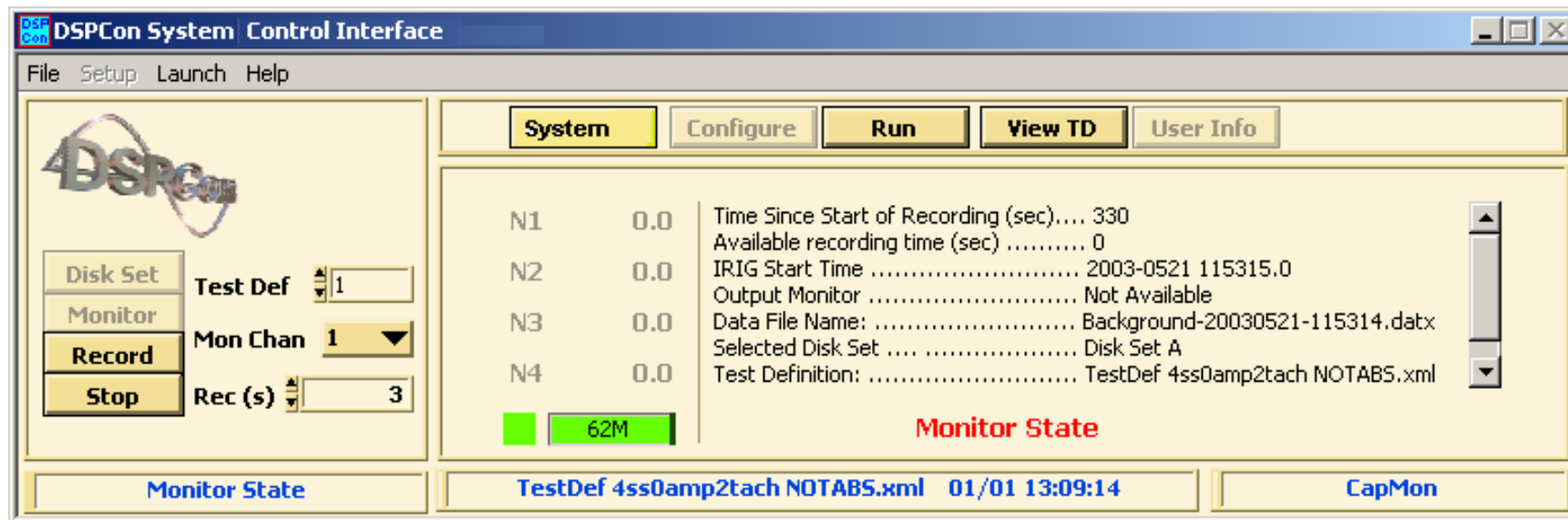


Other Features:

- ✓ Monitor Disk Usage
- ✓ Monitor System Health (Watchdog)
- ✓ Monitor Mode – Ability to Monitor without Acquiring until triggered (Monitor Mode will capture data prior to the event once triggered)

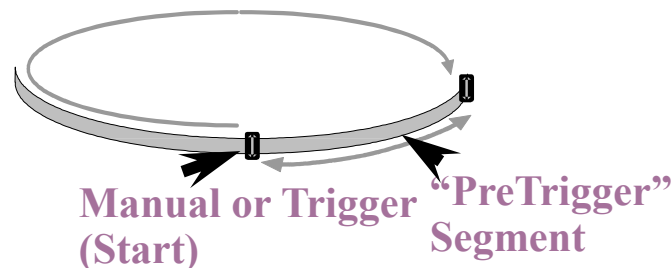
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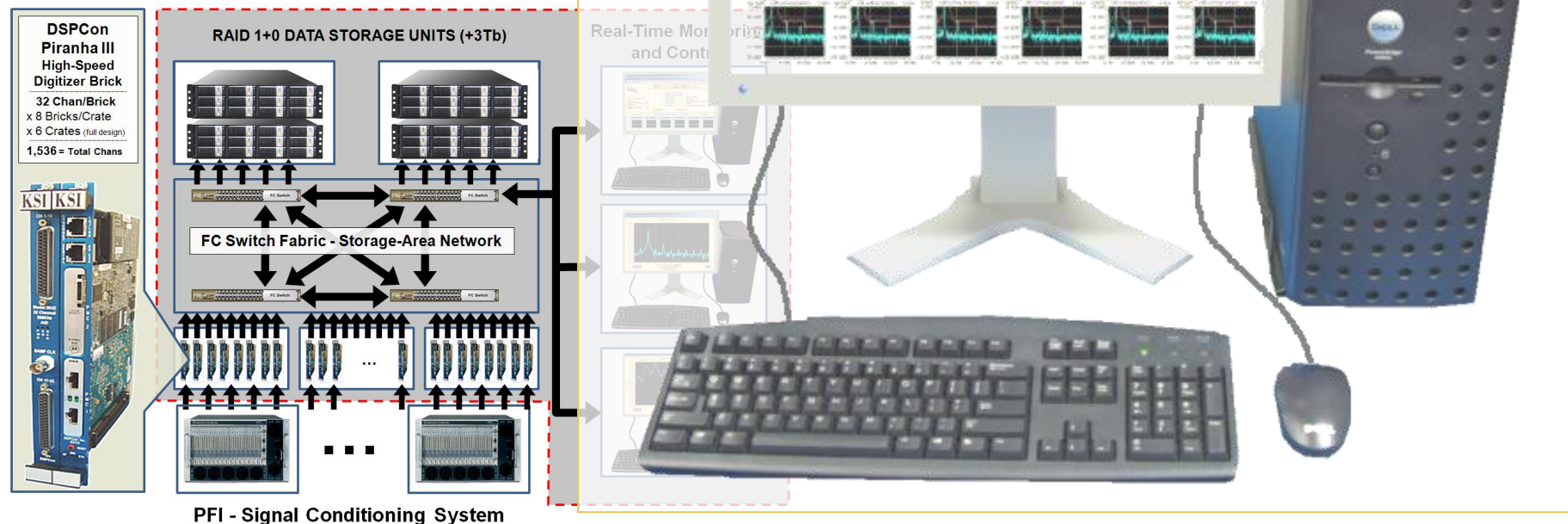
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DAS - Control and Real-Time Display

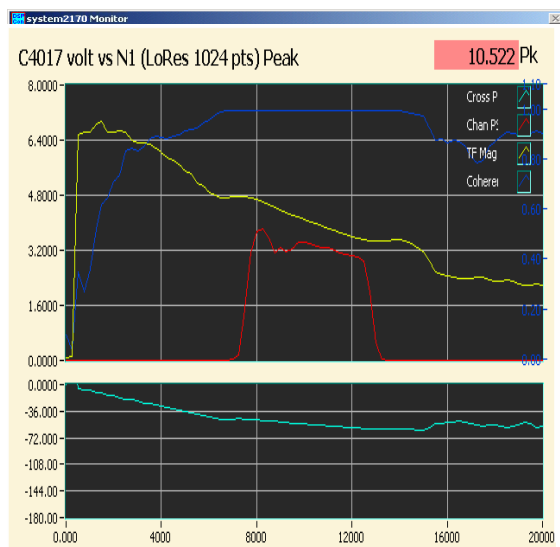
(Pseudo) Real-Time (< 1 sec.) Data Display is provided by the Data System using the fully-integrated software from DSPCon called “Multiscope”



DAS - Control and Real-Time Display

Real-Time Display Types

- ✓ Time Plots
- ✓ Frequency (FFT)
- ✓ Nth Octave Plots
- ✓ Signal Transfer Functions
- ✓ many others...

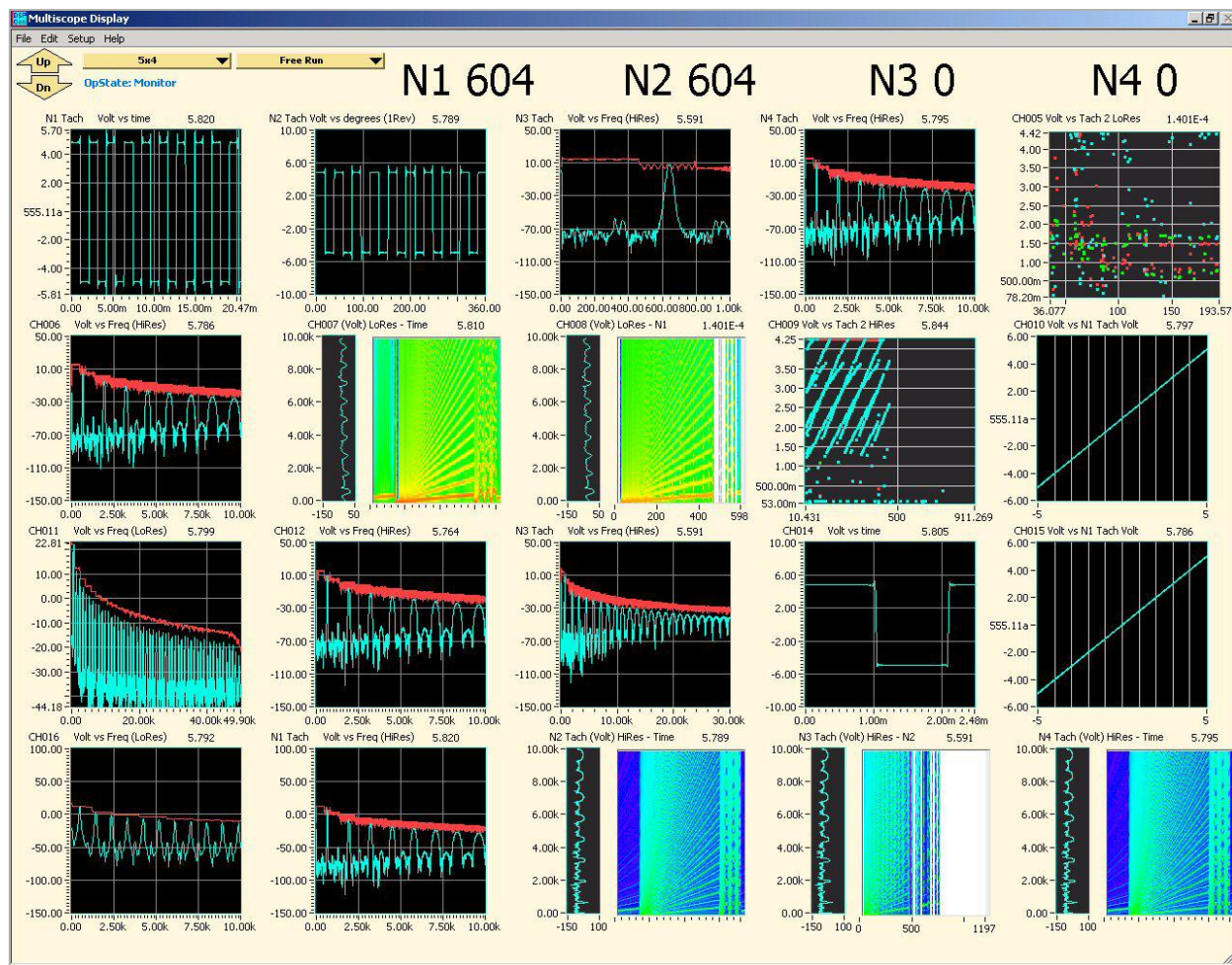


Plot Types	Description
Time Plots	Amplitude Versus Time
Spectral Plots	Amplitude Versus Frequency (Low and High Resolution)
Nth Octave Plots	Amplitude versus Log Frequency
Track Order Plots	Track order plots display spectral responses with a fixed or variable bandwidth that are harmonic orders of shaft speed. Display RMS, minimum, or maximum spectral values.
ZMod Plots	ZMod plots show the user how spectral values change over time as shaft speed changes.
Lissajous	Lissajous shows the time domain correlation between two signals. The reference signal values are plotted on the x axis. The second signal is plotted on the y axis.
Bode Plots	Bode plots show the spectral amplitude and phase response at the shaft speed's fundamental harmonic.
1 Revolution	1 Revolution plots show the time response that spans a single shaft revolution (for rotating machinery applications).
Campbell	Display types: 1. Shaft speed - Campbell Shaft speed shows an icon that is proportional to spectral amplitude centered at the spectral frequency (y axis) and shaft speed (x axis). 2. Time - Campbell Time shows an icon that is proportional to spectral amplitude centered at the spectral frequency (y axis) and time (x axis). 3. Reference channel - Campbell Reference Channel shows an icon that is proportional to spectral amplitude centered at the spectral frequency (y axis) and rms value of the reference channel.
Strip Chart Plots	Strip chart (RMS, Min, Max) show an envelope of the channel response over time; updates are every 2048 samples. Strip Charts can be plotted to show the shaft speed over time; updates are every processed frame.
Waterfall Plots	Waterfall plots allow users to see how x and y values (representing frequency response) change as a function of time or shaft speed.
Transfer Function	This scope renders the transfer function, coherence, and/or cross spectral magnitude and phase response of a channel against a reference channel.

DAS - Control and Real-Time Display

Real-Time Display Capabilities

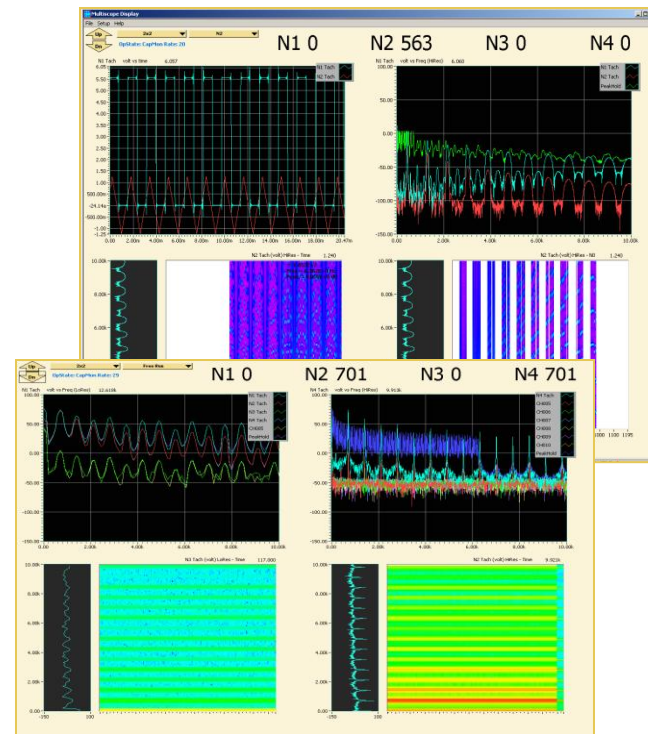
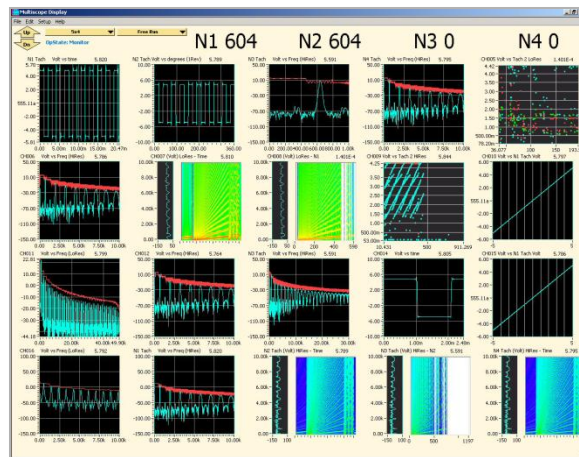
- ✓ Time Plots
- ✓ Frequency (FFT)
- ✓ N^{th} Octave Plots
- ✓ Signal Transfer Functions
- ✓ many others
in many different
combinations and
arrangements
- ✓ and on multiple
“Data Monitoring”
PCs



DAS - Control and Real-Time Display

Real-Time Display Capabilities

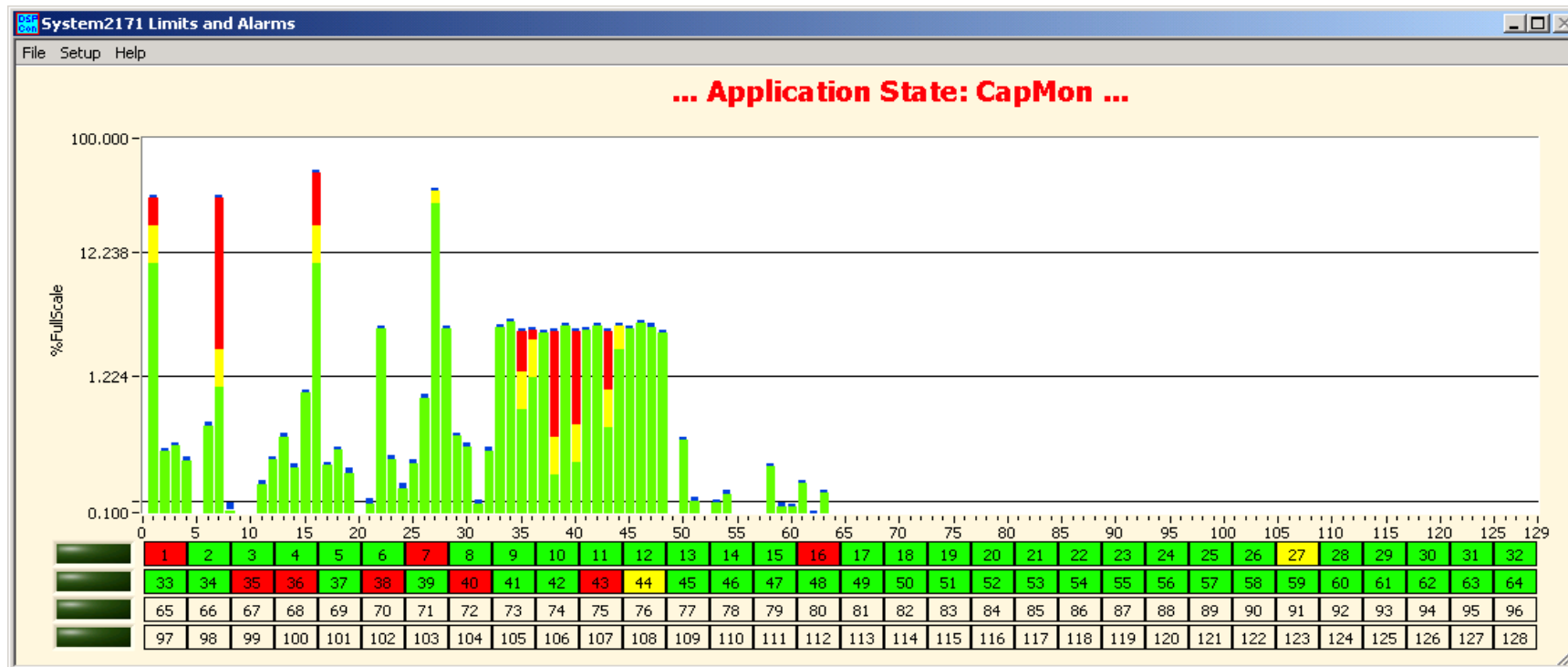
- ✓ Time Plots
 - ✓ Frequency (FFT)
 - ✓ Nth Octave Plots
 - ✓ Signal Transfer Functions
 - ✓ many others
- in many different combinations and arrangements
- ✓ and on multiple “Data Monitoring” PCs



DAS - Control and Real-Time Display

Real-Time Display Types – Limits & Alarms

- ✓ Multiscope also allows for Real-time Monitoring of Alarm & Limits Settings for both Peak Amplitude for each Channel **AND** per Frequency/Per Channel



DAS - Control and Real-Time Display

Real-Time Display Types – Limits & Alarms

- ✓ Multiscope also allows for Real-time Monitoring of Alarm & Limits Settings for both Peak Amplitude for each Channel **AND per Frequency/Per Channel**

