NEVADA NATIONAL NNSS SECURITY SITE
Managed and operated by Mission Support and Test Services

One More Talk About Multiplexing

PDV Workshop
May 15–18, 2018

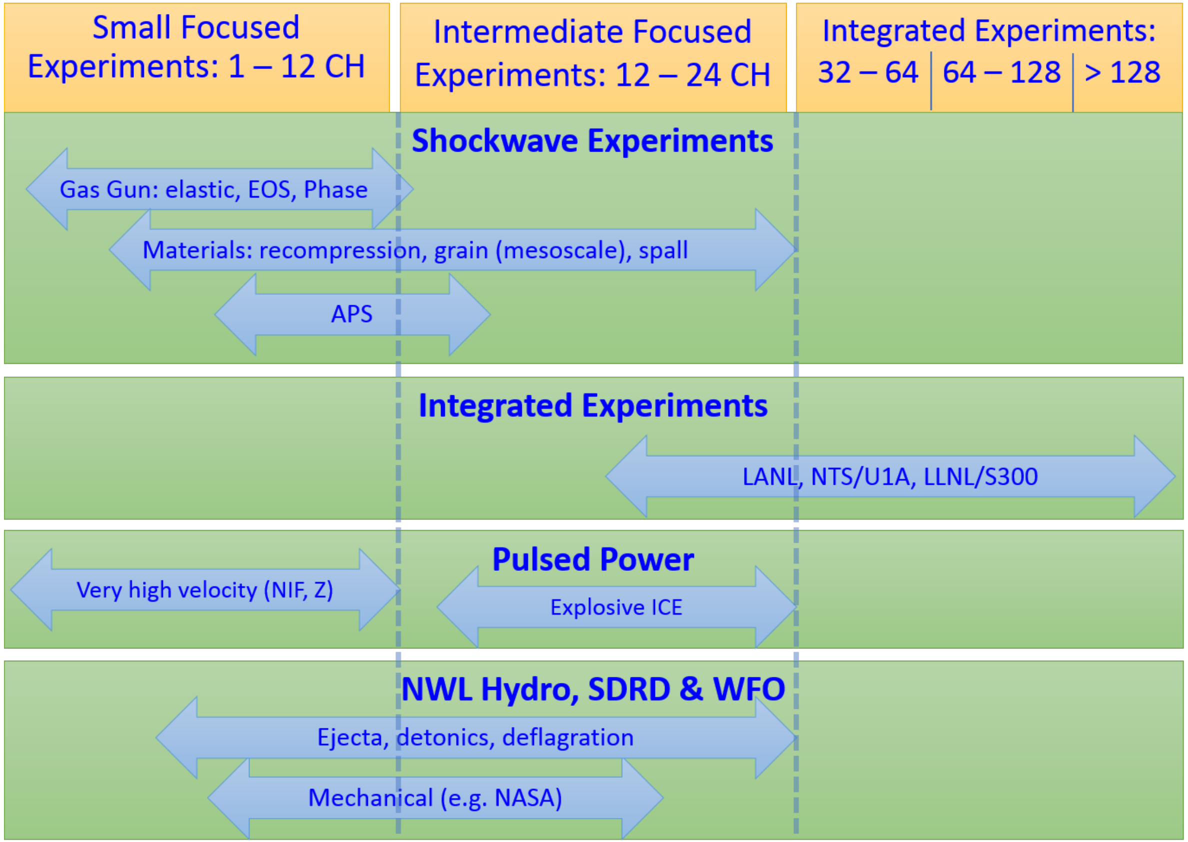
Ed Daykin, Martin Burk, Carlos Perez, Michael Pena

This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy and supported by the Site-Directed Research and Development Program. DOE/NV/03624--0126.

iMPDV for Focused Experiments

- Outline
  - Motivation
  - Design Approach & Capabilities
  - Modularization
  - Performance Analysis
  - Operations
  - Complexity & Cost
  - Summary

Motivation for iMPDV: Focused Experiments



Our Design Approach

- iMPDV is "best of" from lessons learned and MPDV fielding experiences
- Modularize for improved serviceability
  - Standardized electrical and fiber-optic connections
- Minimize "number of moving parts" complexity
- User-friendly operation
  - Minimize learning curve – intuitive operation similar to traditional PDV
- New multiplexing architecture (neither Gen-1, 2 or 3)
  - Mode 1: Time multiplexing (1×6) for optimal photometric sensitivity
  - Mode 2: Frequency multiplexing (4×1) for maximum record length
- Provide built-in capabilities
  - Cross-timing: Internal, "built-in" system that also has external timing marks
  - Self-check mode: Automated optical signal flow verification
  - Health mode: Electrical power, temperature, and communications
  - Shot mode information: OBR values and signal-to-noise ratio (SNR) calculator for each data channel

Innovative!
A new approach for stockpile E-O diagnostics that leverages 3-D printing

Engineering and Fielding Approach

- Serviceable by non-SME (module replacement)
- Cost effective manufacturing ➔ mass production of modules
- Portable ½ rack
- Internal health monitor (temperature, communications, power)
- Provide self-contained cross-timing system
  - Optical cross-timing mark onto each data window
  - Allow for internal and/or external optical cross-timing
- Self-contained system ➔ no external fiber cross-connects
- Autonomous operations via internal FPGA ➔ no PC required
- Laser modes: Class I & Class IV (key control and interlocks included)

Measurement Capabilities

- Two multiplexing modes (frequency × time) are selectable
  - **1×6 time mux'd to maximize SNR** → **24-channel capability**
  - **4×1 frequency mux'd for long data records** → **16-channel capability**
- Time mux window τ = 50, 100, or 200 μs (*configurable*)
- Photometric sensitivity (a.k.a. SNR): P_{min} ≈ PDV or MPDV-3 (≈ –60 dBm)
- One-fiber and two-fiber probes (selectable, able to mix and match)
- Selectable laser power
  - Gated or CW high power, P ≥ 200 mW
  - CW low power, P < 10 mW (eye safe)
- Homodyne- and heterodyne-capable (selectable)
- Built-in cross-timing accounts for variability from fiber delay temperature

Operational (Fielding) Capabilities

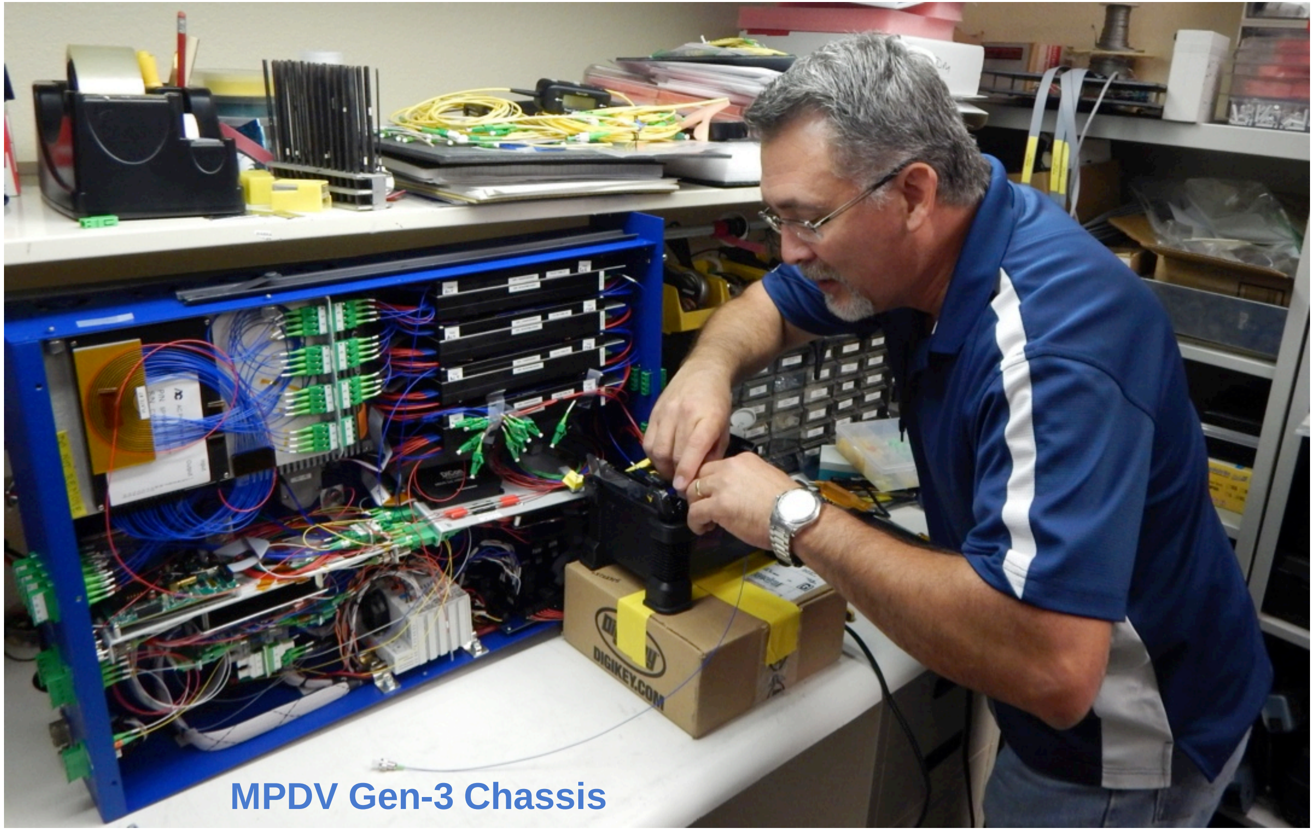
Two Operating Modes

1. Remote operations: LabView VI via e-net
   - Bunker controls, including Run Ready and Fire Ready closures
   - SIS laser safety interlocks
   - Emergency stop
2. Local "manual" operation
   - No PC required
   - Bunker permissive and external delay generator NOT required

- Plug-n-play: No external interconnects, only connections are fiber-optic probes
- Self-check: Mode verifies internal optical signal path
- LUNA (or "blink test") capable
- OBR capable: Measure during operations; sensitivity P_{min} ~ –60 dBm

A Design Requirement: Serviceability

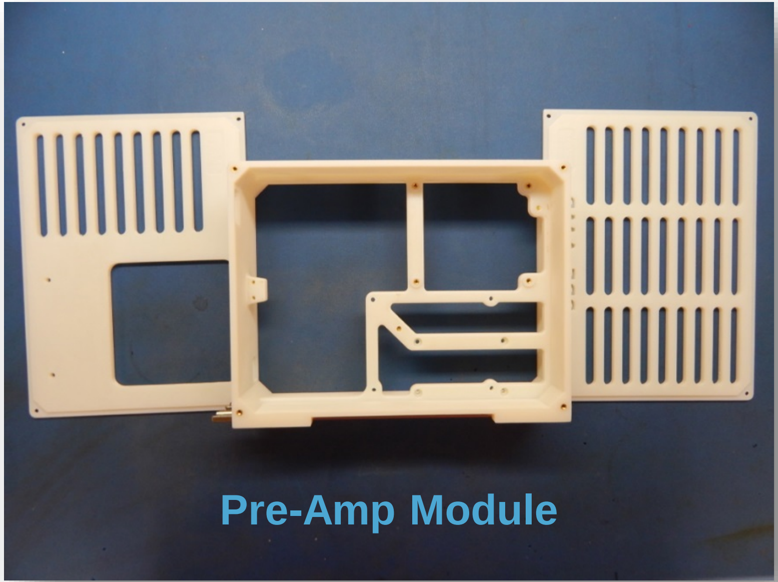
… move away from fully integrated chassis with very complex electro-optic systems that require SME to troubleshoot and/or repair



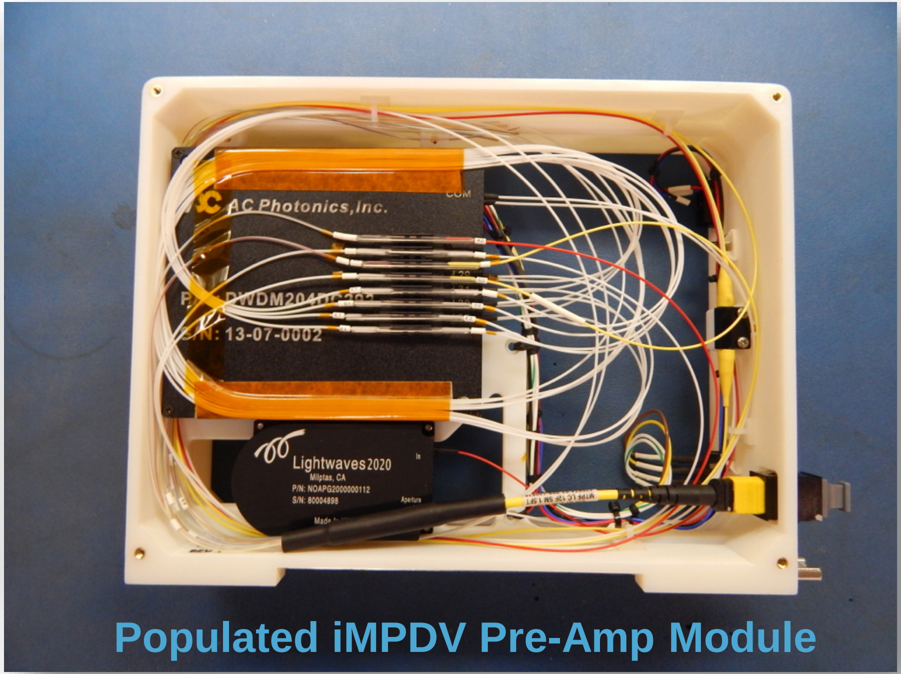
MPDV Gen-3 Chassis

Modular Approach Leverages 3-D Printing

A 3-D printed pre-amp module. Design is specific to components and fiber-optic routing requirements.



Pre-Amp Module



Populated iMPDV Pre-Amp Module

NEVADA NATIONAL NNSS SECURITY SITE

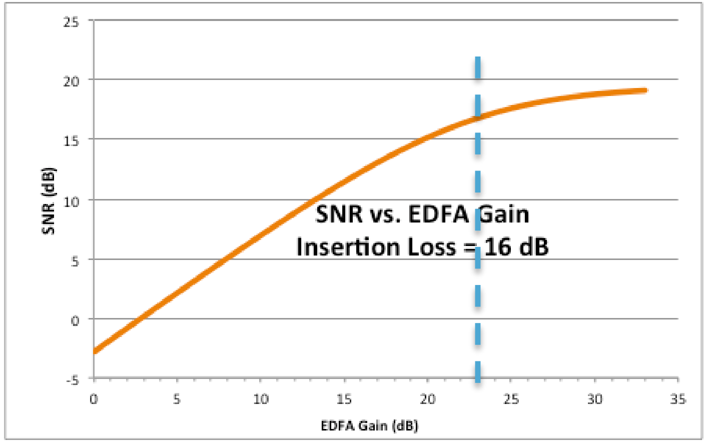
Managed and operated by Mission Support and Test Services

Performance Analysis: SNR Modeling

First, choose optical amplifiers appropriate to insertion losses (IL) inherent to time multiplexing

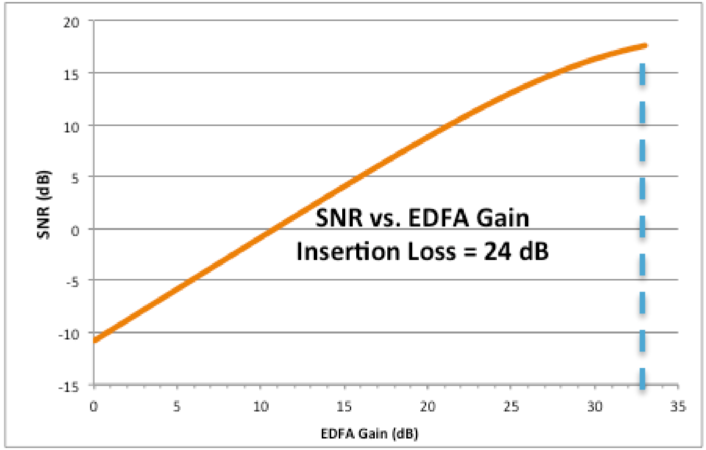
Channels 1 – 16
Estimated Insertion Loss = 16 ±3 dB

➔ Choose EDFA with Gain ≅ 23 dB (Lightwave 2020)



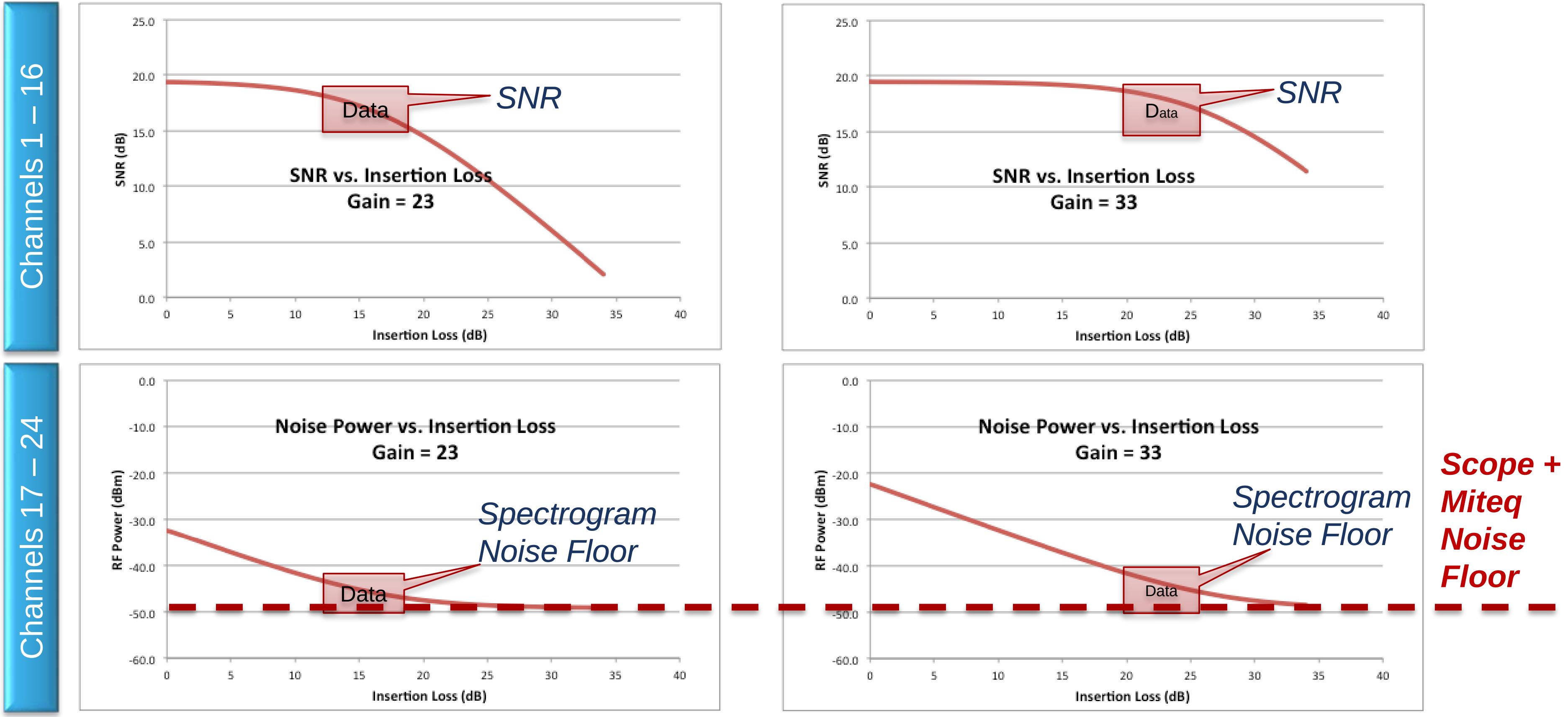
Channels 17 – 24
Estimated Insertion Loss = 22 to 24 dB

Choose EDFA with Gain ≅ 33 dB (OptiLab)



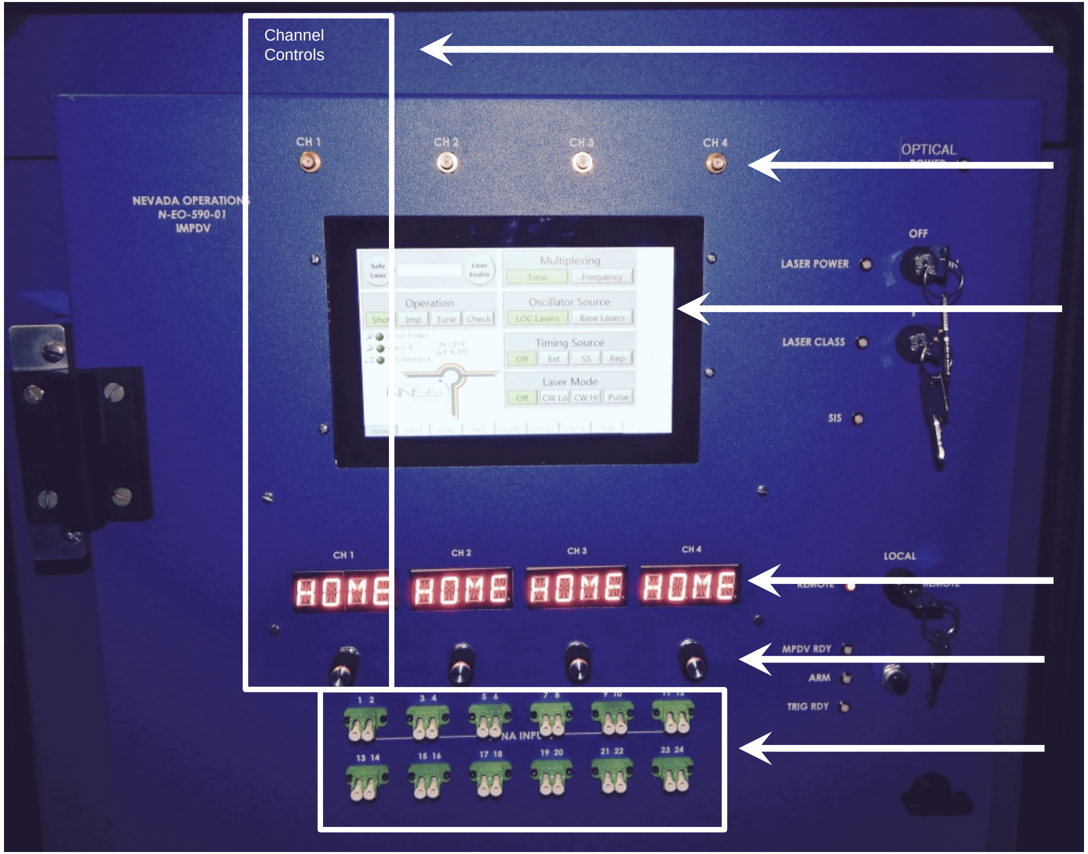
Model parameters: P(sig) = –40 dBm, P(LocOsc @ PD) = –4 dBm

SNR Modeling: Calculate SNR = f(IL)



Model parameters: P(sig) = –40 dBm, P(LocOsc @ PD) = –4 dBm

Operations Part 1a: User Controls



Manual control and readout for each channel

RF outputs

Touch panel system controls

- Home
- Event
- Tune
- NKT lasers
- System health
- Delay times
- Self check
- Help

Readout: Power [dBm] & VOA control

Adjust – Control knob

LUNA inputs, each channel

Operations Part 1b: User Controls

Laser key controls

Laser class select: I or IV

SIS indicator

Local/remote operation select

Arm

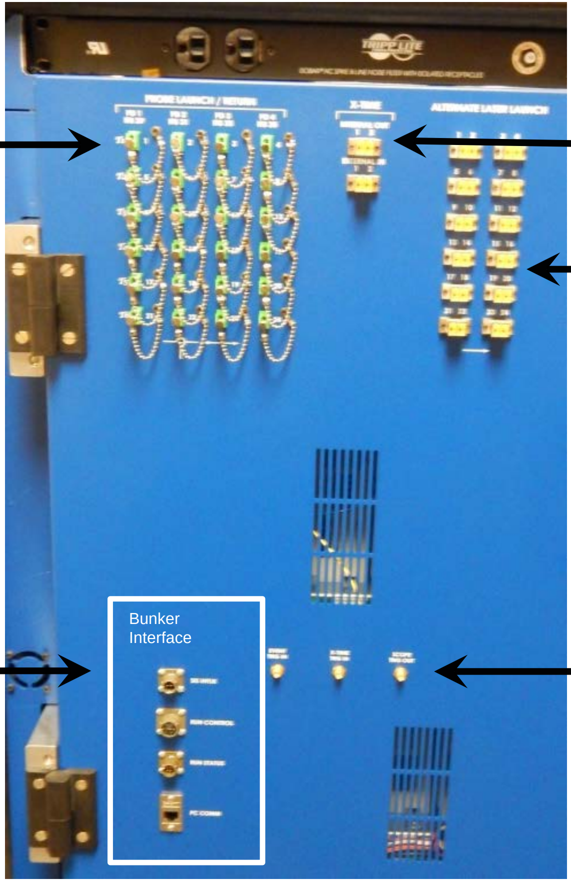
Status indicators:
MPDV ready
Arm
Trigger ready

Operations Part 2: Fiber-Optic Connections

One-Fiber Probe Patch-Panel

Cross-timing
External Input
Internal Output

Two-Fiber Probe Patch-Panel

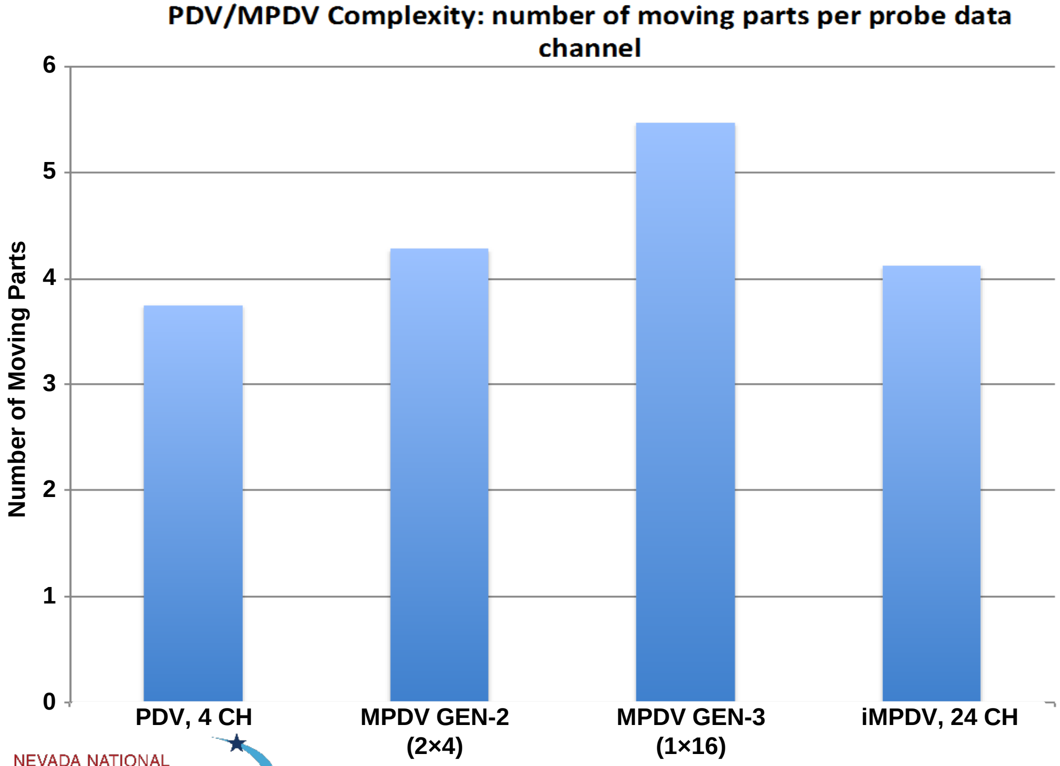


SIS Interlock
Run Control
Run Status

PC Comm

Event Trig In (system trigger)
X-Time Trig In
Scope Trig Out

System Complexity & Cost



M & S Cost

- $450k ➔ $19k per data channel

Number of Modules

MPDV	6
Pre-Amp EDFA	6
High-Power EDFA	3
MEMS Switching	1
Nano Switching	5
Front End	1
Optical Cross-Connect	2
Polarization Control	1
Cross-timing	1

Labor Estimate ~1¼ FTE

Summary

We’ve designed and built a multi-functional, robust, self-contained, portable, 24-channel MPDV system for focused experiments

- Optimized (shot noise limited) SNR performance
- Time or frequency multiplexed
- Heterodyne or homodyne operation
- Class I or Class IV operations
- Single-fiber or two-fiber probes
- Manual control (including touch panel) or remote control (LabView)
- Modular architecture for robustness
- Built-in cross-timing (each data window)
- Built-in self-check mode
- Cost per channel comparable to PDV

NOTE: This page of the template is to be used as a section divider.