

Recent Advances in Portable Mass Spectrometry Systems at Kennedy Space Center



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Overview

- KSC Goals & Applications
- History
- Recent Portable Systems of Interest
- Current & Future Efforts
- Acknowledgements

KSC Goals and Applications

- Leak Location / Detection 10 ppm to 4% H₂
- Purge Processing 10 ppm to 100% He
- Process Monitoring 10 ppm H₂ in He
- System Characterization
- Grab Bottle Analysis
 - ~5 Order Dyn Range
 - ~ 10% Accuracy
 - ~1 sec Sample Rate

History – Apollo

- Several Iterations
- Started with Apollo 4
- Quad & Sector
- Diffusion Pumped
 - LN₂ Trap, Water Cooled
- High Cost
- Low Performance
- Poor Maintainability
- Difficult Operation

History – Shuttle

Primary Task Hydrogen Safety

1978 - 2001	Prime
1985 - 2001	Back/Up
1993 - 2011	HUMS
2001 - 2011	HGDS 2000



History



Vehicle “Saves”

STS-6 18 Dec 1982

STS-35 30 May 1990

6 Sept 1990

18 Sept 1990

STS-38 29 Jun 1990

13 July 1990

25 July 1990

STS-73 28 Sept 1995

STS-93 20 July 1999

STS-113 10 Nov 2002

STS-119 11 Mar 2009

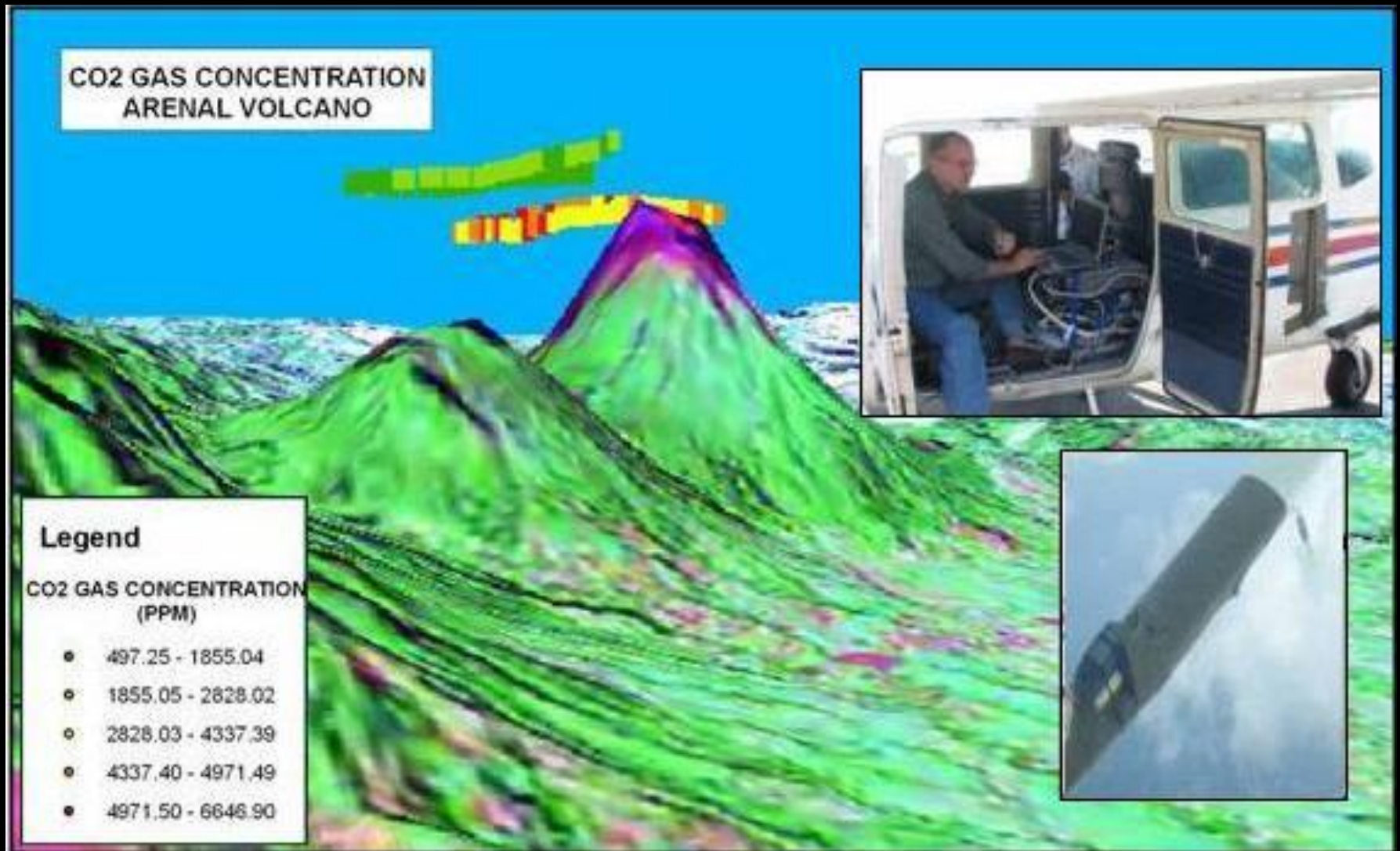
STS-127 13 June 2009

17 June 2009

STS-133 5 Nov 2010



AVEMS



AVEMS – System Description

Designed to Monitor Volcanic Gas Emissions

(He, CO₂, SO₂, H₂S,...)

- Correlate to Volcanic Cycles
- Portable: 92,400 cm³; 35 kg
- Power : 350 W steady state
- Rugged: >40,000 ft
- Autonomous Operation
- Single Quadrupole
- 2 Stage Differential Pump



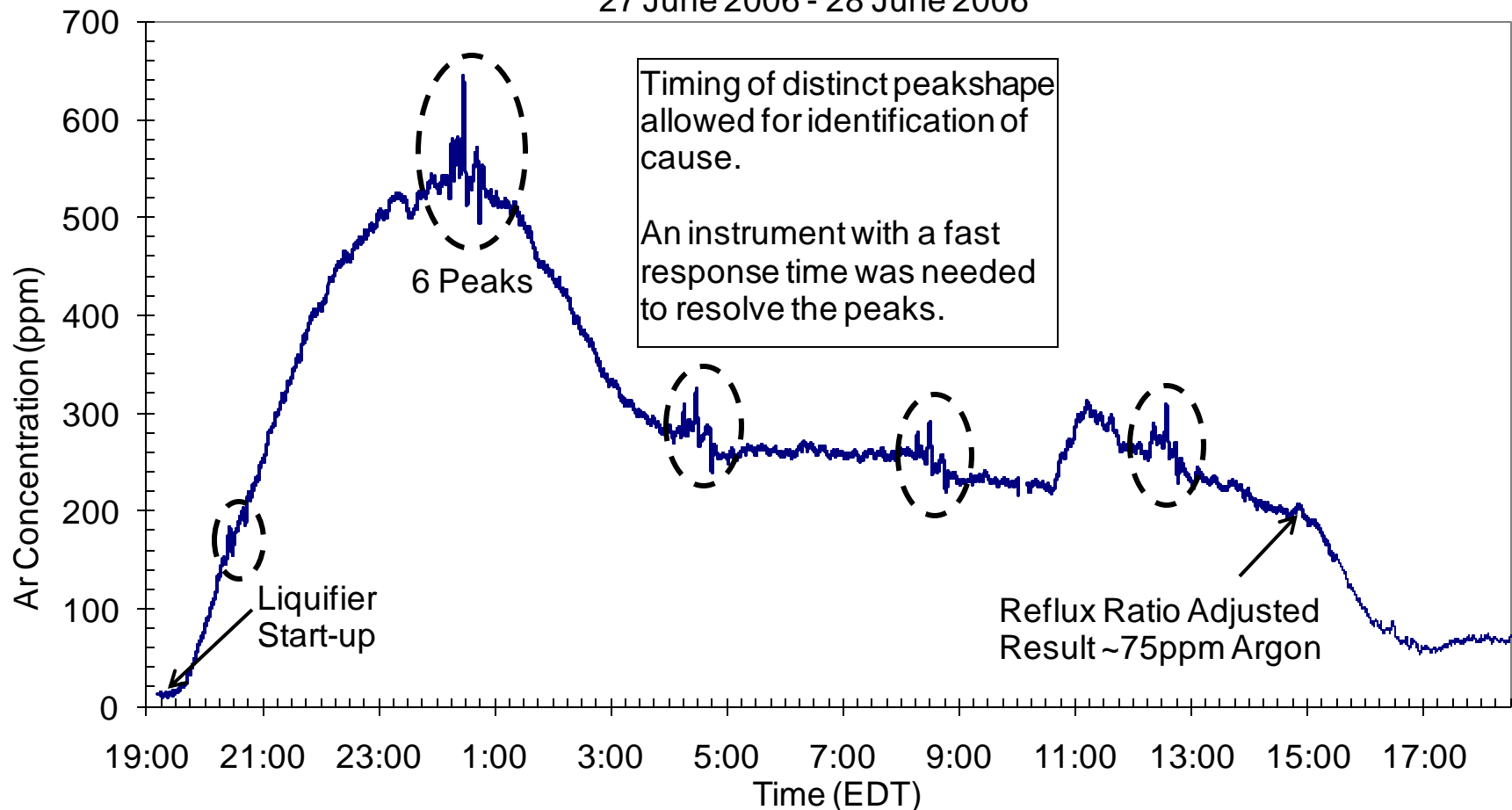
AVEMS – LN₂ / GN₂ Production

- Project
 - Excess Ar in N₂ Purge
 - Monitor Prior to STS-121
 - LO₂ vs. Air
- Success
 - Identified pulse every 4hrs of ~600 ppm (traced to heater valve)
 - Below 75 ppm
 - Quantitative Resolution of MS
- Issues
 - Portability
 - Embedded H/W Issues



AVEMS – LN₂ / GN₂ Production

Air Liquide GN2 Argon Concentration
27 June 2006 - 28 June 2006



AVEMS – Umbilical Testing

Project

- Characterize New Umbilical Components
- Safety Monitoring (LH₂ Leakage)

Success

- Provided Characterization of Hydrogen / Helium / Nitrogen in 50ppm to 100% range

Issues

- Alternative Calibration Routines (S/W)

AVEMS – Umbilical Testing



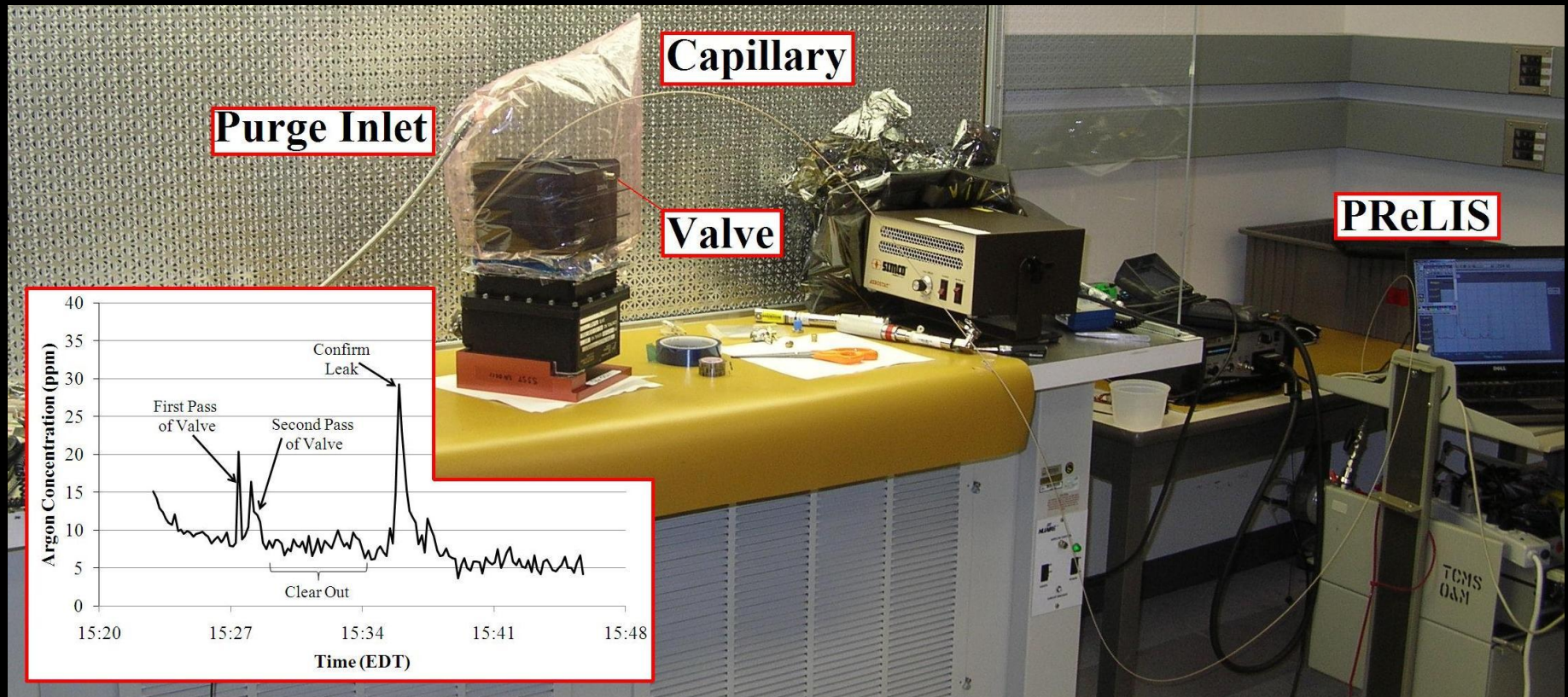
PreLIS – System Description

- Design to be non-helium leak detector (originally Freon)
- Single Quad
- Capillary Inlet (Very Low Flow)
- Capillary Extension (Smpl Xport)



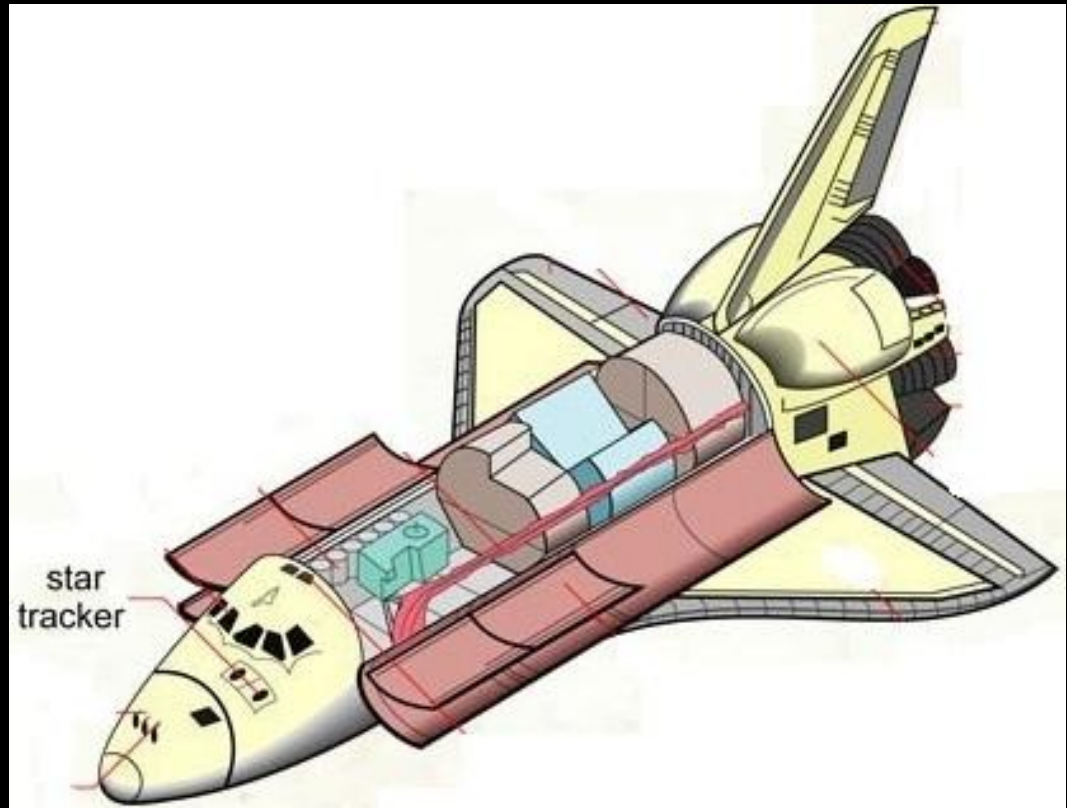
PreLIS – Star Tracker

- Identify Leak Source
- Semi-Quantitative Validation of Fix



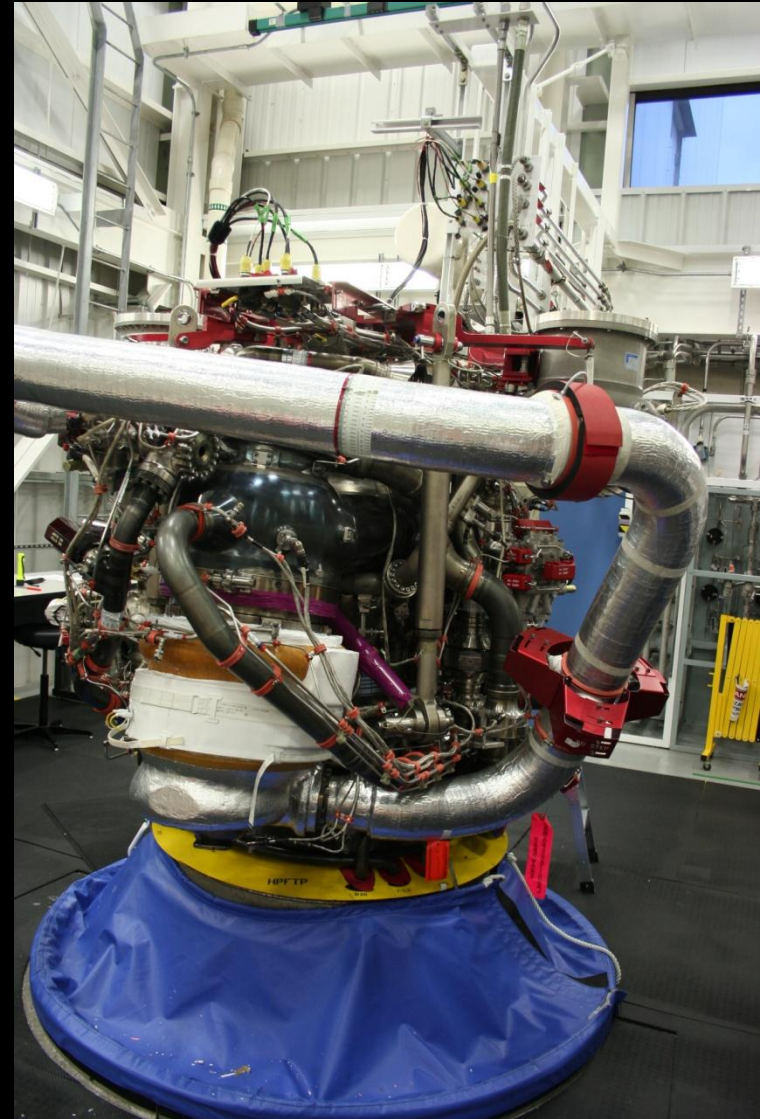
PreLIS – Star Tracker

- Success
 - Both Goals Met
- Issues
 - Poor Response Time
 - Manual Rastering
 - ? Quantitation ?



PreLIS – SSME

- Project
 - Determine Leak Components in Static Purge
- Success
 - Components Identified
 - Not LO₂ as concern
 - ** Pseudo non-destructive
- Issues
 - N/A, not in-situ



PDP-MS – System Description

- Designed as Portable Purge Monitor
- Single Quad
- Single Stage Diff. Pumping
- Integrated Sample Transport System
 - 0.2 – 5 sLpm (100-1,000 Torr)
- Dew Point Monitoring
 - -100 to +70°F (-70 to +20 °C)
- H₂, He, CH₂, N₂, O₂, Ar, CO₂, etc.
 - 25 ppm – 100%
- On-board Calibrants
- 45 min. Back-up Power

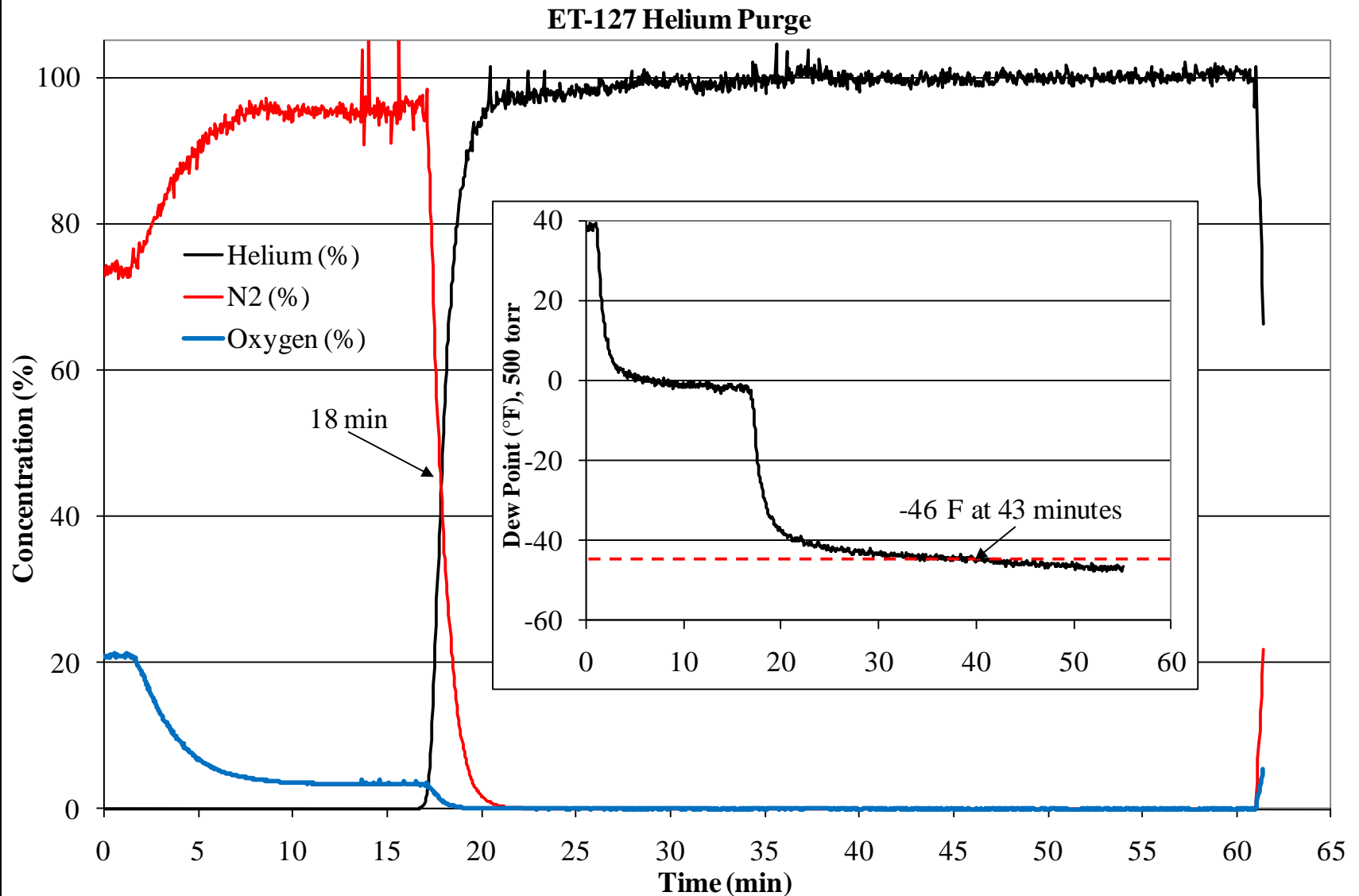


PDP-MS – External Tank

- Project
 - Reduce Helium
 - Characterize Process
 - In-Situ Data
- Success
 - Reduce Time by ~20%
 - Demonstrated In-Situ
- Issues
 - Software



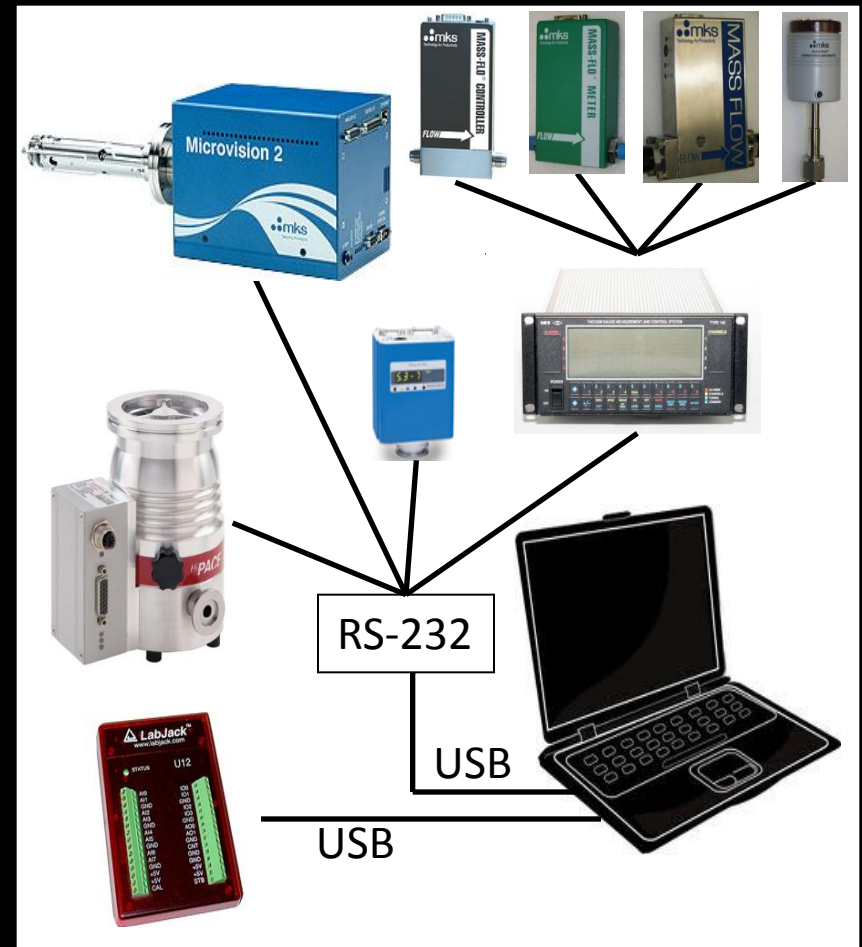
PDP-MS – External Tank



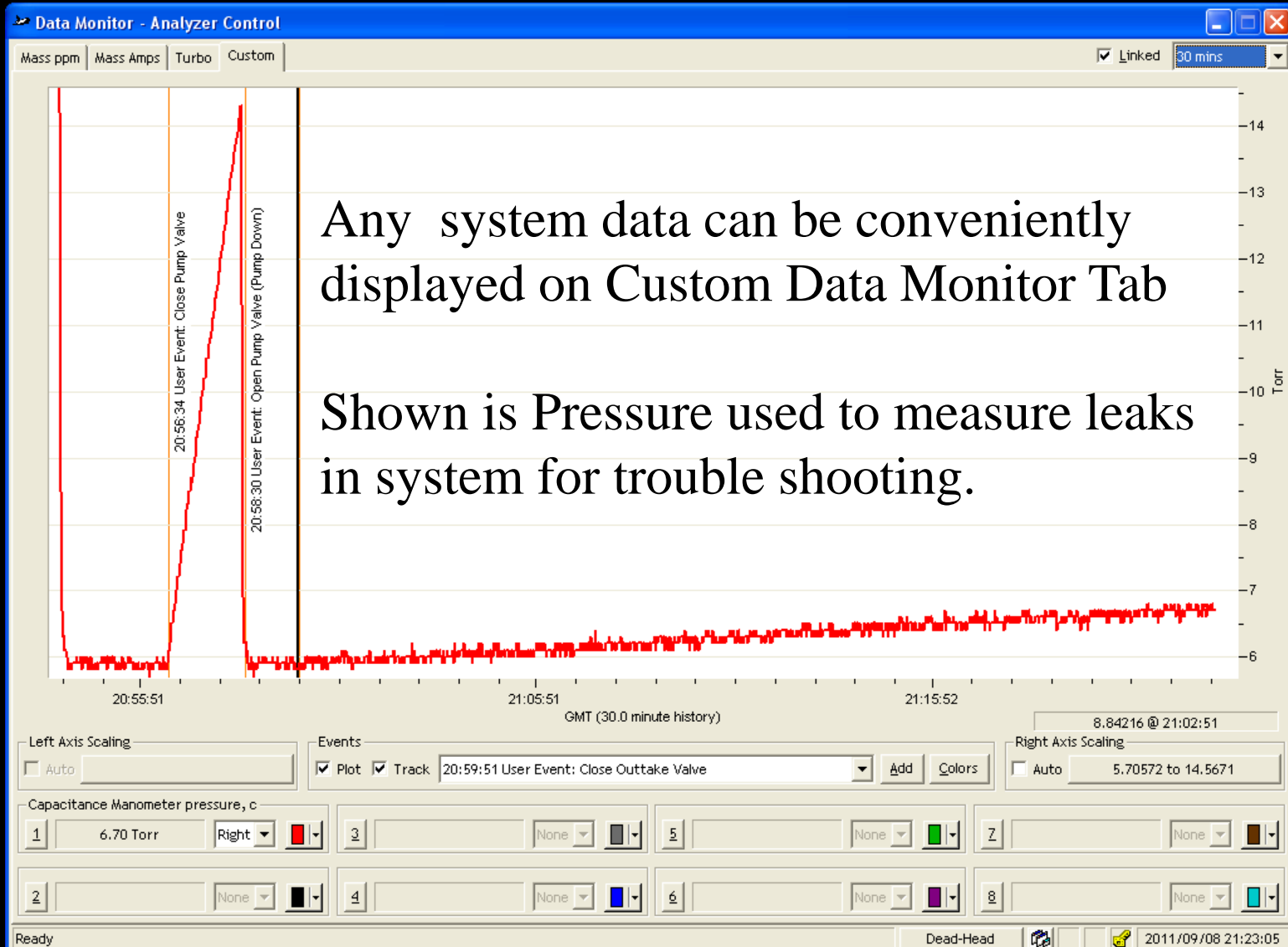
Current & Future Efforts – Software

Too much development time spent on software development and data analysis!

- Common User Interface
- Ease of Calibration
- Ease of Data Analysis
- Synchronize Multiple Components
- Scripting
- Common Data Archival
- PC-based



Process Monitor



Calibration and Validation

Calibration - Analyzer Control

Helium

Nitrogen

Last Calibration: 2011/09/08 17:10:09

	H ₂	He	N ₂	O ₂	Ar	NH ₃	H ₂ O	CO ₂
Low Readings	0.0000e+000 A	0.0000e+000 A		3.2271e-013 A	1.3461e-013 A			
Test Readings	4.4402e-012 A	2.9238e-011 A		2.4572e-012 A	7.9287e-013 A			
High Test Readings								
Span Readings	3.2441e-011 A	3.1853e-011 A		2.2397e-011 A	7.0419e-012 A			
Sensitivity	1.56416e+014	4.47022e+014		2.25885e+014	1.44754e+014			
Calculated Test	651.3 ppm	12995.3 ppm		540.1 ppm	107.7 ppm			
Rel. Error	8.32%	7.53%		-10.61%	-11.33%			
Std. Dev.								
Rel. Std. Dev.								
Limits of Detection								

Configuration

Method: 3 Point; Delay: 30 sec; Points: 30; Low: N2_Zero; Test: N2_Test; Span: N2_Span
Mass Analyzer: SRS RGA
SRS RGA configuration: EE 70 eV; FL 0.9976 mA; IE High; VF 90 V; HV 0 V; NF 2; RI -8.6658; DI 121; RS 1058.79; DS -0.18

Setup

Method

3 Point

Low Line

N2_Zero

Test Line

N2_Test

High Test Line

Span Line

N2_Span

Points

30

Delay Time

30 sec

Calibrate

Current Line

N2_Zero

H ₂	He	N ₂	O ₂	Ar	NH ₃	H ₂ O	CO ₂
369.6 ppm	904.0 ppm		1159.3 ppm	143.1 ppm			

Unit

☒ ppm
☐ %
☐ A

Ready

N2_Zero

2011/09/08 17:10:49

Scripting and Automation

Scripting - Analyzer Control

Repository

Location: C:\ACS\Scripts Browse

Available Scripts

Name	Date	Size
Find.MKS.Port.lua	2011/08/30 14:26:27	1009 bytes
Lab.Jack_Poll.lua	2011/09/08 13:17:36	1.3 KB
Lab.Jack_Set.and.Read.lua	2011/09/02 13:40:28	2.2 KB
Lab.Jack_Set.and.Serial.Number.lua	2011/09/02 14:17:23	759 bytes
Load_Cal_Consts_Aug2011.lua	2011/08/31 14:39:17	4.1 KB
Load_Nominal_Cal_Consts.lua	2011/08/26 15:18:44	4.0 KB
MKS.on.Port_3.lua	2011/08/30 14:14:16	594 bytes

Description

----- Nitrogen Zero Bottle -----

```
acs.Command(acs.ID_SDS_LINE_CO1_BGD, 1) -- Define bottle as N
acs.Command(acs.ID_CAL_CO1_MASS_1_PPM, 0)
acs.Command(acs.ID_CAL_CO1_MASS_2_PPM, 0)
-- skip Mass 03, since it is Background
acs.Command(acs.ID_CAL_CO1_MASS_4_PPM, 0)
acs.Command(acs.ID_CAL_CO1_MASS_5_PPM, 0)
```

Execution Status

"Lab.Jack_Poll.lua" is paused at line 12

Line	Code
1	-- Analyzer Lua Script
2	-- Analyzer Control System
3	-----
4	-----
5	--
6	-- This script sends the LabJack data to the system in
7	--
8	-----
9	-----
10	
11	
12	acs.Delay(15)
13	
14	acs.SystemMessage(acs.CriticalityInfo, format("AIn 0 is
15	
16	acs.SystemMessage(acs.CriticalityInfo, format("AIn 1 is

Execution Control

Editing

Execute Resume Terminate Edit New Delete Rename

Ready N2_Zero 2011/09/08 17:18:14

Traceability

Recording - Analyzer Control

Setup

Base Directory: C:\ACS\Recorded Data Browse

Activity: This_is_FileName_Prefix ▼

Options

☒ Measurements Create new file(s) every

☒ System Messages 1 Hours

Control

Record New File(s)

Status

Disk Space Available 109.99 GB

Time Until File Change 01:00:00

Measurements To Record (11 items)

Description	Identifier	Type	Units
Mass 1 reading	ID_SRSRGA_MASS_1_READING	F64	Ion current
Mass 1 reading (ppm)	ID_SRSRGA_MASS_1_PPM	F64	Parts per million
Mass 2 reading	ID_SRSRGA_MASS_2_READING	F64	Ion current
Mass 2 reading (ppm)	ID_SRSRGA_MASS_2_PPM	F64	Parts per million
Mass 4 reading	ID_SRSRGA_MASS_4_READING	F64	Ion current
Mass 4 reading (ppm)	ID_SRSRGA_MASS_4_PPM	F64	Parts per million
Mass 5 reading	ID_SRSRGA_MASS_5_READING	F64	Ion current
Mass 5 reading (ppm)	ID_SRSRGA_MASS_5_PPM	F64	Parts per million
Line select	ID_SDS_LINE_SELECT	UI32	Line
Electron emission	ID_SRSRGA_FL	F64	mA
Electrometer noise floor	ID_SRSRGA_NF	UI32	Count

Add Items Load Group Save As Group Erase All Erase Invert

N2_Zero 2011/09/08 16:58:46

	A	B	C	D	E	F	G	H	Q	R
1	System	Analyzer Version Analyzer Control System 2.4								
2	Connected to	localhost								
3	Created on host	HGDL-DEV1								
4	Start time	9/8/2011 16:58								
5	Stop time	9/8/2011 17:11								
6	Mass_1	Mass_1	Mass_1_PPM	Mass_1_PPM	Mass_2	Mass_2	Mass_2_PPM	Mass_2_PPM	LINE_SELECT	LINE_SELECT
7	9/8/2011 16:58	1.35E-12	9/8/2011 16:58	1.32E+04	9/8/2011 16:58	1.99E-12	9/8/2011 17:10	1.42E+04	9/8/2011 16:59	16
8	9/8/2011 16:58	1.40E-12	9/8/2011 16:58	1.30E+04	9/8/2011 16:58	1.94E-12	9/8/2011 17:10	1.41E+04	9/8/2011 16:59	0
9	9/8/2011 16:58	1.35E-12	9/8/2011 16:58	1.32E+04	9/8/2011 16:58	1.95E-12	9/8/2011 17:10	1.42E+04	9/8/2011 17:00	16
10	9/8/2011 16:58	1.35E-12	9/8/2011 16:58	1.32E+04	9/8/2011 16:58	0.00E+00	9/8/2011 17:10	1.42E+04	9/8/2011 17:05	1
11	9/8/2011 16:59	0.00E+00	9/8/2011 16:59	1.95E+04	9/8/2011 16:59	0.00E+00	9/8/2011 17:10	1.41E+04	9/8/2011 17:07	16
12	9/8/2011 16:59	0.00E+00	9/8/2011 16:59	1.95E+04	9/8/2011 16:59	0.00E+00	9/8/2011 17:10	1.39E+04	9/8/2011 17:08	2
13	9/8/2011 16:59	0.00E+00	9/8/2011 16:59	1.95E+04	9/8/2011 16:59	0.00E+00	9/8/2011 17:10	1.34E+04	9/8/2011 17:10	16
14	9/8/2011 16:59	0.00E+00	9/8/2011 16:59	1.95E+04	9/8/2011 16:59	0.00E+00	9/8/2011 17:10	1.37E+04	9/8/2011 17:10	0
15	9/8/2011 16:59	0.00E+00	9/8/2011 16:59	1.95E+04	9/8/2011 16:59	0.00E+00	9/8/2011 17:10	1.38E+04	9/8/2011 17:10	0

Acknowledgements

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