Evaluation of Commercial Mass Spectrometers for NASA Applications

(Preliminary Results)

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Overview

- HGDL Backgroud
- Target Specifications
- MS Evaluation Test Operations
- Units Evaluated (DUTs)
- Data Analysis Examples
- Preliminary Evaluation Results
- Conclusions
- Acknowledgments

Hazard & Gas Detection Lab
Kennedy Space Center

- Gas Analysis Instrumentation at KSC
  - Design Equipment for Launch Equipment "Process Control"
  - Provide Gas Analysis Capability in Field
  - Maintain Expertise in Equipment (MS, Pumps, etc)

- Gas Analysis Expertise
  - Provide Troubleshooting Capabilities
  - Methods and Procedures Development

KEY TARGET SPECIFICATIONS NASA-KSC

- Gases of Interest: H_2, He, CH_4, N_2, O_2, Ar
- Mass range:
  - 1- 50 Th Minimum
  - 1-100 Th Standard
  - 1-200 Th Prefered (Good enough H_2 to He separation)
- Resolving Power: 100 or more
- Relative accuracy (10% Max Reading Error)
- 5-orders of dynamic range (~10ppm to 100%) without detector saturation (No Elec Mult in some cases)
- 100% Helium to 100% Nitrogen recovery time <30 sec
- Scan Time (+Analysis Time): ~1 sec
- Access to Raw Data

DESIRED SPECIFICATIONS for MS ANALYZERS

- **COTS (Comercial Of The Shelf)**
- **Size:** Approx. 27,000 cc or less,
- **Weight :** Approx. 6 kg or less
- **Max Power:** ~75 W
- **Detection Limit:** Able to monitor 25 ppm Hydrogen in ~100% Helium
- **Reading Error:** 10% relative error over a dynamic range: 100ppm to 50% v/v
- **Scan Rate:** (1 sec desired, 10 sec acceptable)

- **Filament Protection:** Redundant filament with auto safing
- **Connection:** Interface to a CF 2.75" (metal gaskets)
- **PC connection protocol:** Non-proprietary command and data retrieval interface (such as RS-232with query/response)
- **Standards Compliance:** SL-E002 Book 2 EMI standards
- **Operating environment:** 0 - 40°C, 0 - 95% RH
- **Other:** Able to withstand high vibrations is desirable

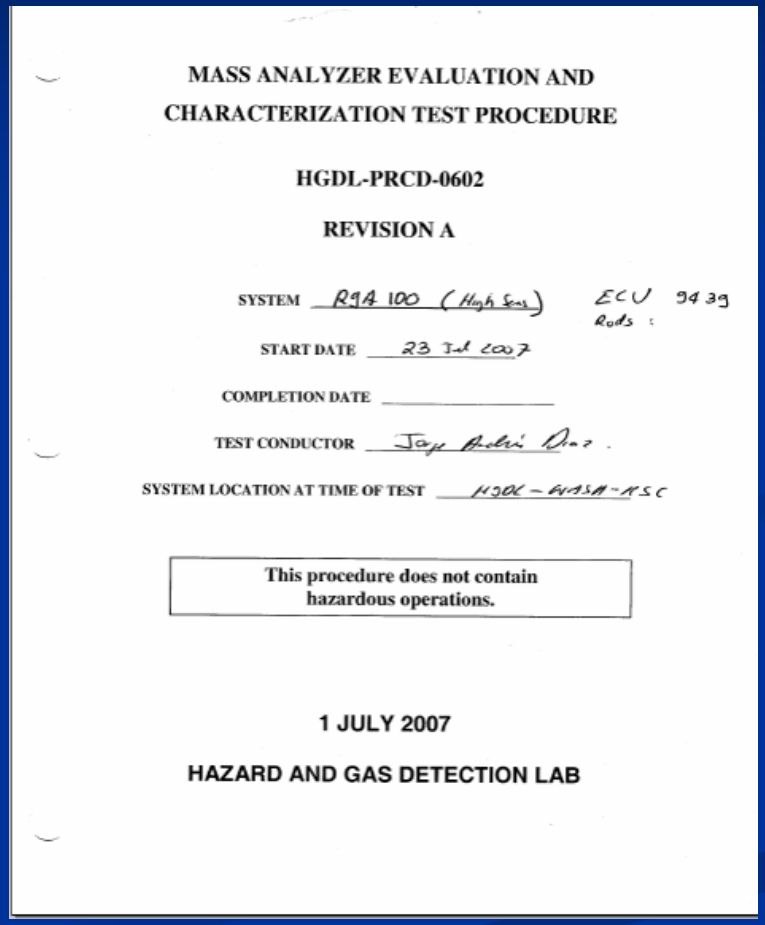
DESIRED SPECIFICATIONS for MS SYSTEMS

- **COTS components** (pumps, analyzer, inlet, valves, heather, etc)
- **Size** 150,000 cc or less
- **Weight:** Less Than 60 kg
- **Max Power:** ~750 W Start-up, < 500 W Steady State
- **Detection Limit:** Able to monitor 25 ppm Hydrogen in ~100% Helium
- **Reading Error:** 10% relative error over a dynamic range of ~100ppm to 50% v/v
- **Scan Rate:** 1 sec desired, 10 sec acceptable
- **Recovery Time:** Helium Clear-out time (switch from 100% He to 100% N2, until He signal less than 100ppm) less than 5 minutes (30s desired)
- **Response Time:** Less than 30 sec

- **Connection:** 1/4" 37° flare fitting (KC) (1/4" swage, NPT, VCR, etc are OK)
- **Filament Protection:** Redundant filament with auto filament shut-down
- **PC connection protocol:** Non-proprietary command and data retrieval interface
- **Standards Compliance:** SL-E002 Book 2 EMI standards
- **Operating environment:** 0 - 40°C, 0 - 95% RH
- **Other:** Ability to withstand high vibrations is desirable

MS EVALUATION PROCEDURE and DOCUMENTATION

- Invitation extended to each potential MS Vendor with target specs.
- Units Evaluated at HGDL-KSC
  - (Jul-Sept 2007) Phase I
  - (Oct-Dec 2007) Phase II
- NASA-KSC Document HGDL-PRCD-0602 used for Evaluation
- Paper traveler generated for each unit
- Internal report to be submitted to NASA for its use in procurements
- Journal Article with main results to be published next year.



MASS ANALYZER EVALUATION AND CHARACTERIZATION TEST PROCEDURE

HGDL-PRCD-0602

REVISION A

SYSTEM RGA 100 (High Sens) ECU 9439 Rods

START DATE 23 Jul 2007

COMPLETION DATE

TEST CONDUCTOR Jaye Andrés Díaz

SYSTEM LOCATION AT TIME OF TEST HGDL – NASA-KSC

This procedure does not contain hazardous operations.

1 JULY 2007

HAZARD AND GAS DETECTION LAB

Units Evaluated

(Phase I)

Focused on SMALL COTS MS

- MS Analyzers
  - HAL 2001-RC (Hiden Analytical)
  - Micro Vision IP (MKS)
  - RGA 100 (SRS)
  - Prisma Plus (Pffifer)
  - XPR3 (INFICON)
- MS Systems
  - HPR20 (Hiden Analytical)
  - QMS 300 (SRS)
  - AV2900 (VTI)
  - Omni Star (Pffifer)

- Phase II
  - XT300 (EXTORR)
  - Multipole (FERRAN/HORIBA)
  - AEROVAC (VTI)
  - CIS-Extorr (ARDARA TECH.)
  - MG3000 (Monitor Instruments)

- Other COTS MS Instruments are welcome !!!

- Invited but Declined for this Evaluation
  - Dycor (Analyzer & System)
  - Extrel (Analyzer)

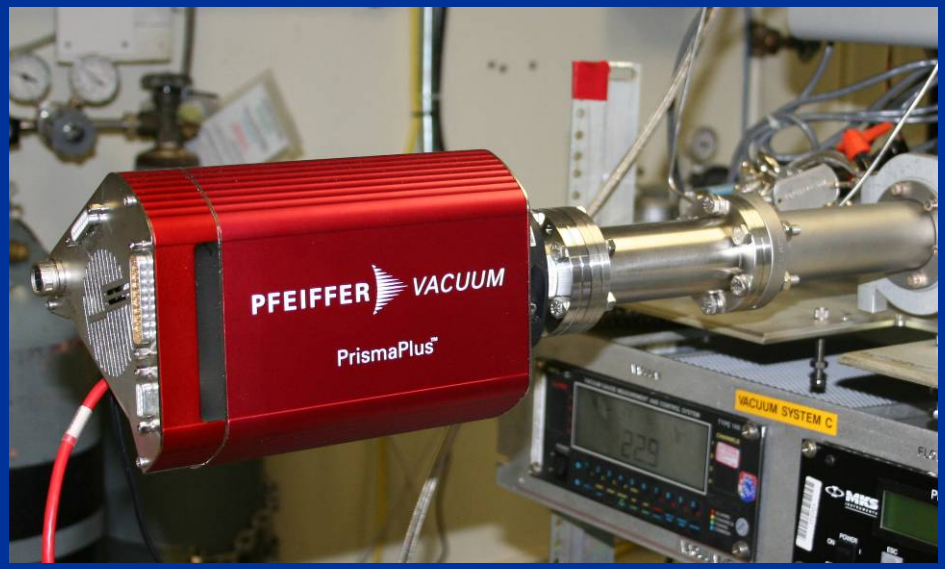
MS Analyzers

RGA-100 (SRS)

XPR-3 (Inficon)

MS Analyzers

Prisma Plus (Pffifer)



HAL 201 RC (Hiden Analytical)

MS Analyzers

Micro Vision IP (MKS)

XT300M (EXTORR)

MS Systems

AV 2900 (VTI)

(Only Analyzer shown)

QMS 300 (SRS)

MS Systems

Omni Star (Pffifer)

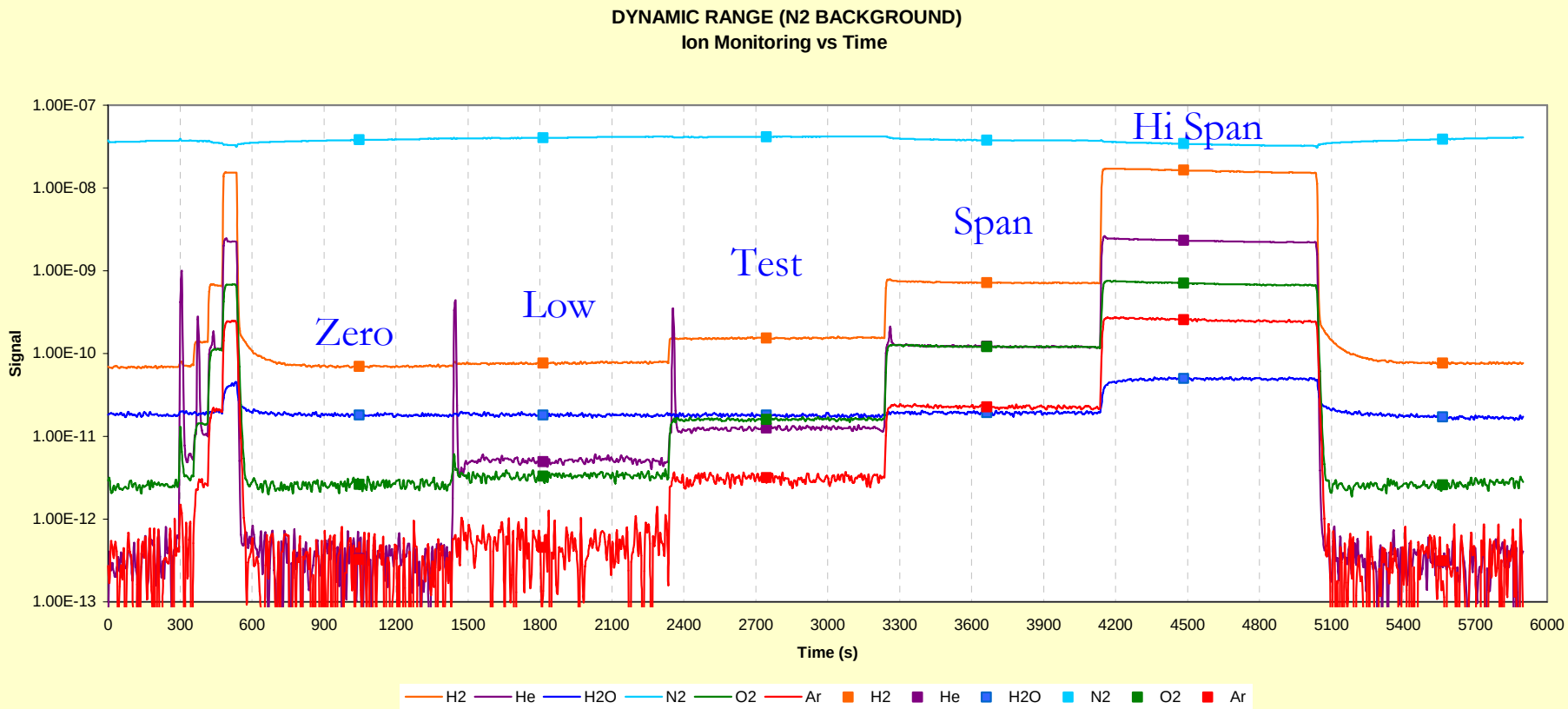
HPR-20 (Hiden Analytical)

TEST OPERATIONS

1. Preparation, Pump Down, & Optimization
2. Accuracy / Dynamic Range (N2 and He Background)
3. Drift (N2 and He Background)
4. Response and Recovery Time (N2 and He Background)
5. High Helium Clear-out time
6. He/H2/ Air interferences

Evaluation Results

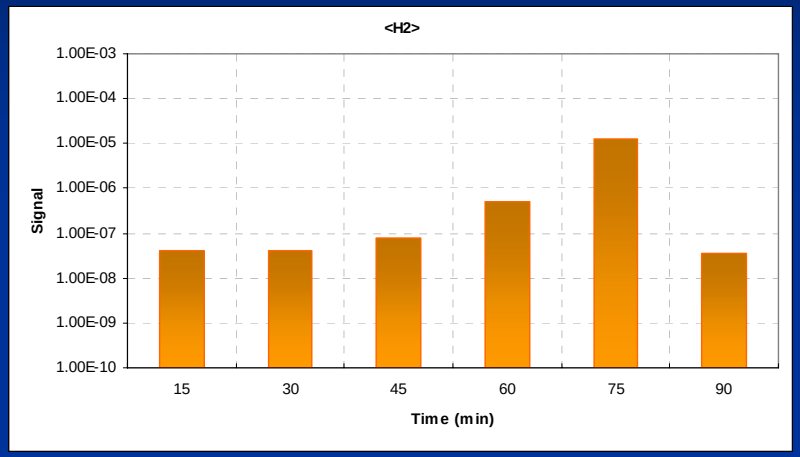
Accuracy / Dynamic Range Example

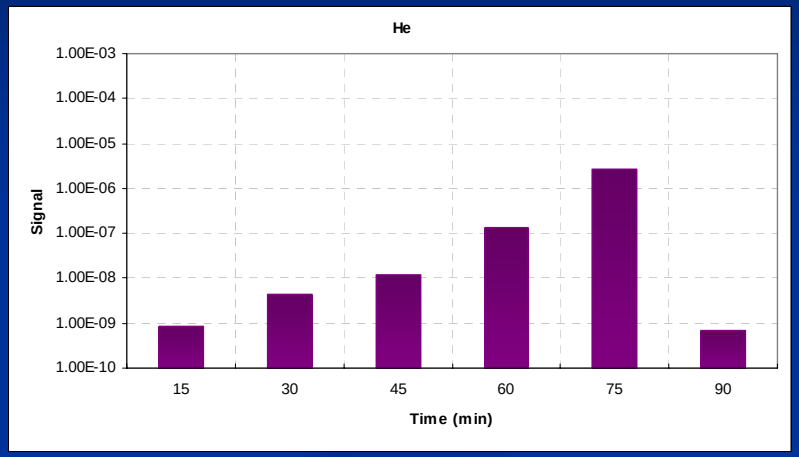


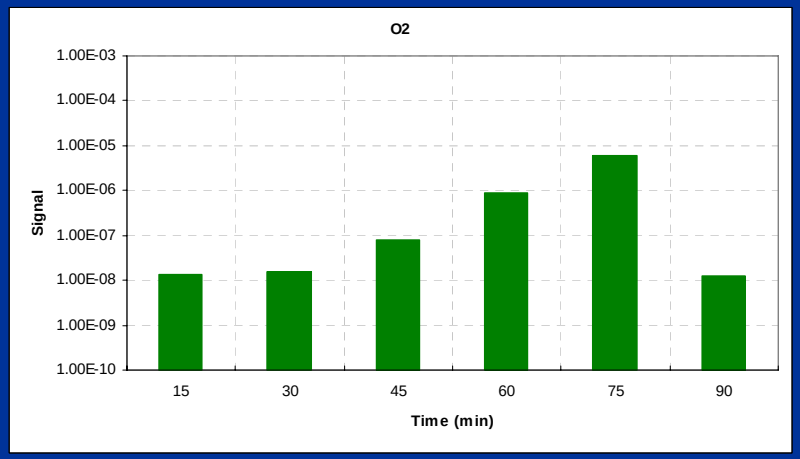
Calibration Gases for N2 Background

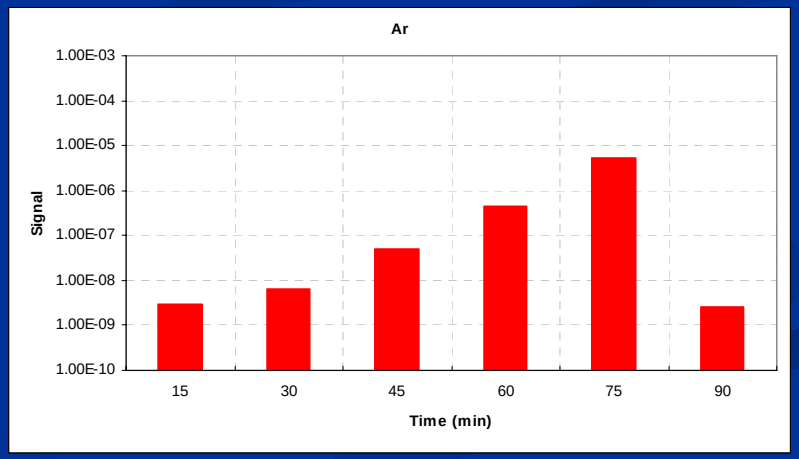
Calibration Data (ppm) N_2 Background Test									
		H_2		He_2		O2		Ar	
Bottle	***Bottle #***	***Nominal***	***Real***	***Nominal***	***Real***	***Nominal***	***Real***	***Nominal***	***Real***
Zero		0	0	0	0	0	0	0	0
Low		25	24.7	0	0	25	25.9	0	0
test		500	499.5	500	507.3	500	502	100	104.1
Span		5000	5102	5000	5022	5000	5075	1000	1035
Hi Span		100000	99930	100000	101050	25000	24980	10000	10020
N2 Zero		999900							

Accuracy/ Dynamic Range Averaging

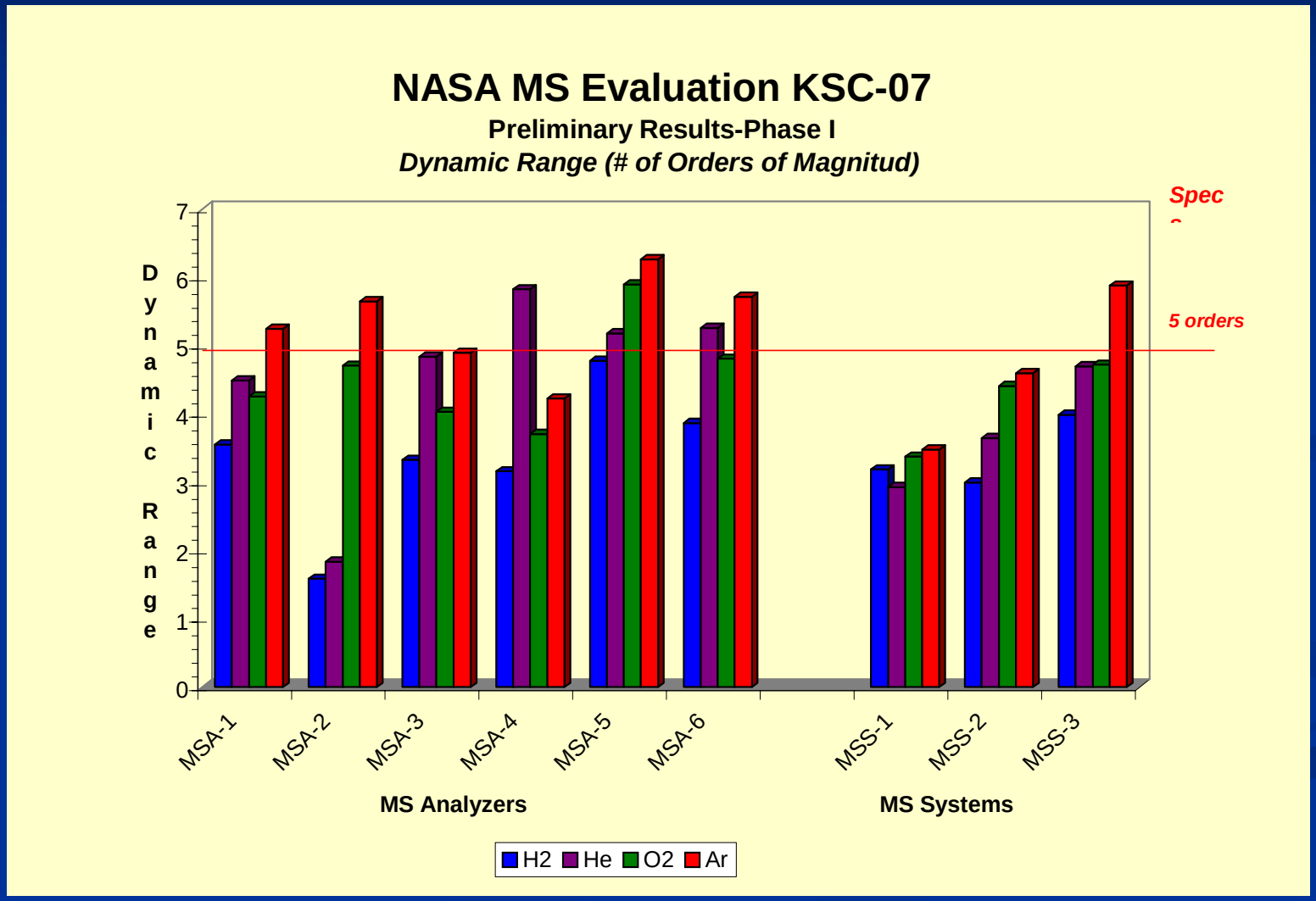




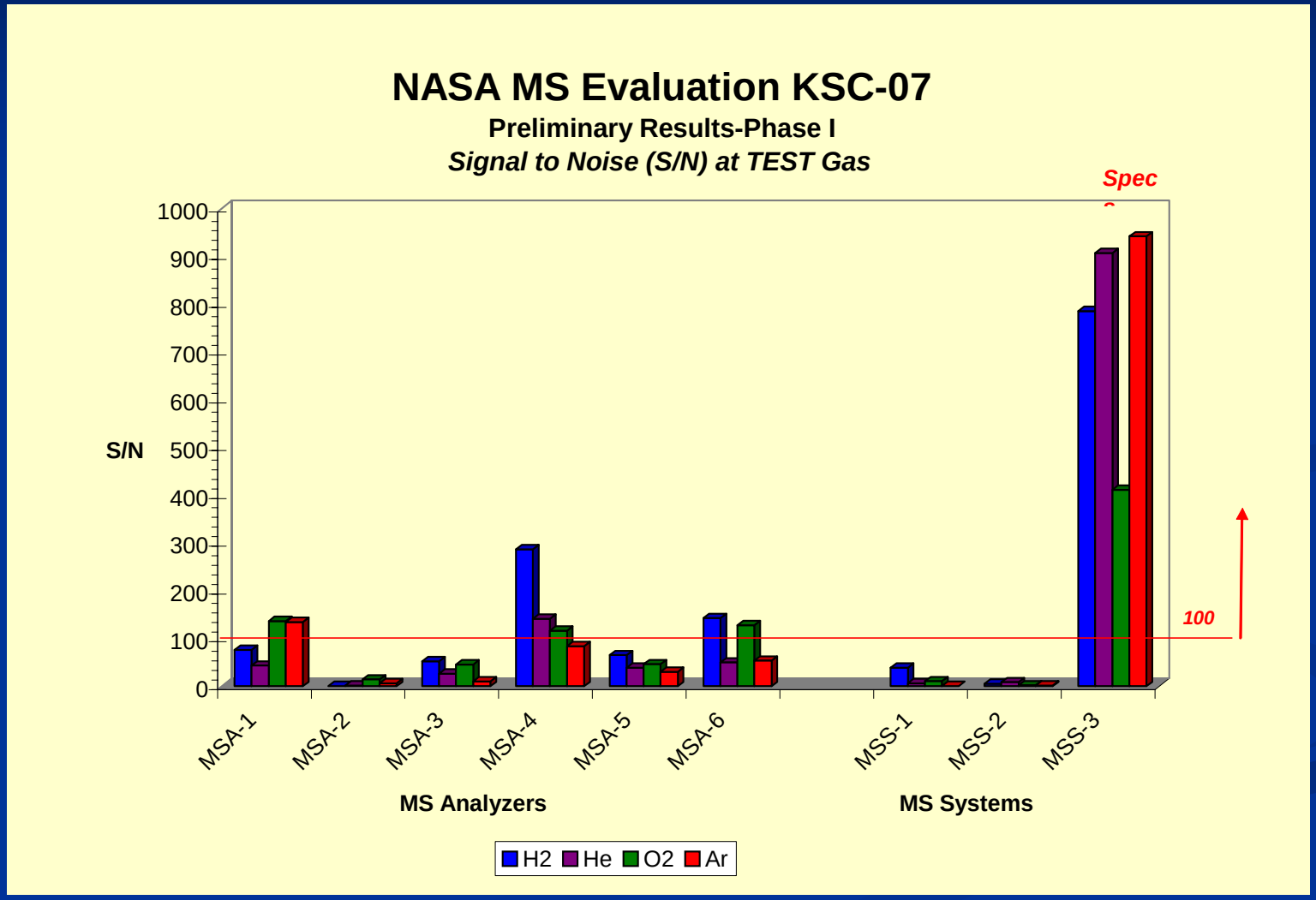




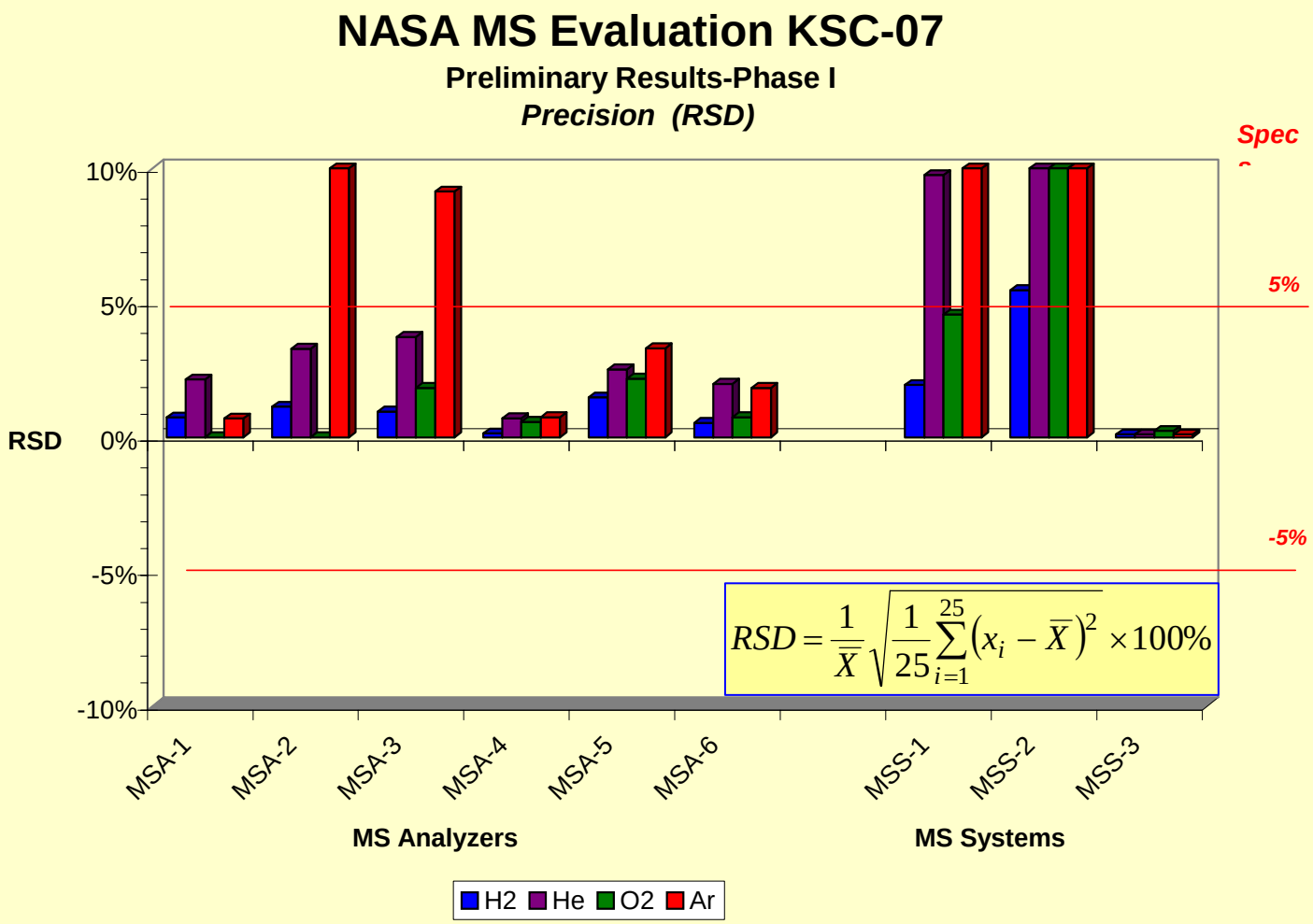
Dynamic Range



Signal to Noise

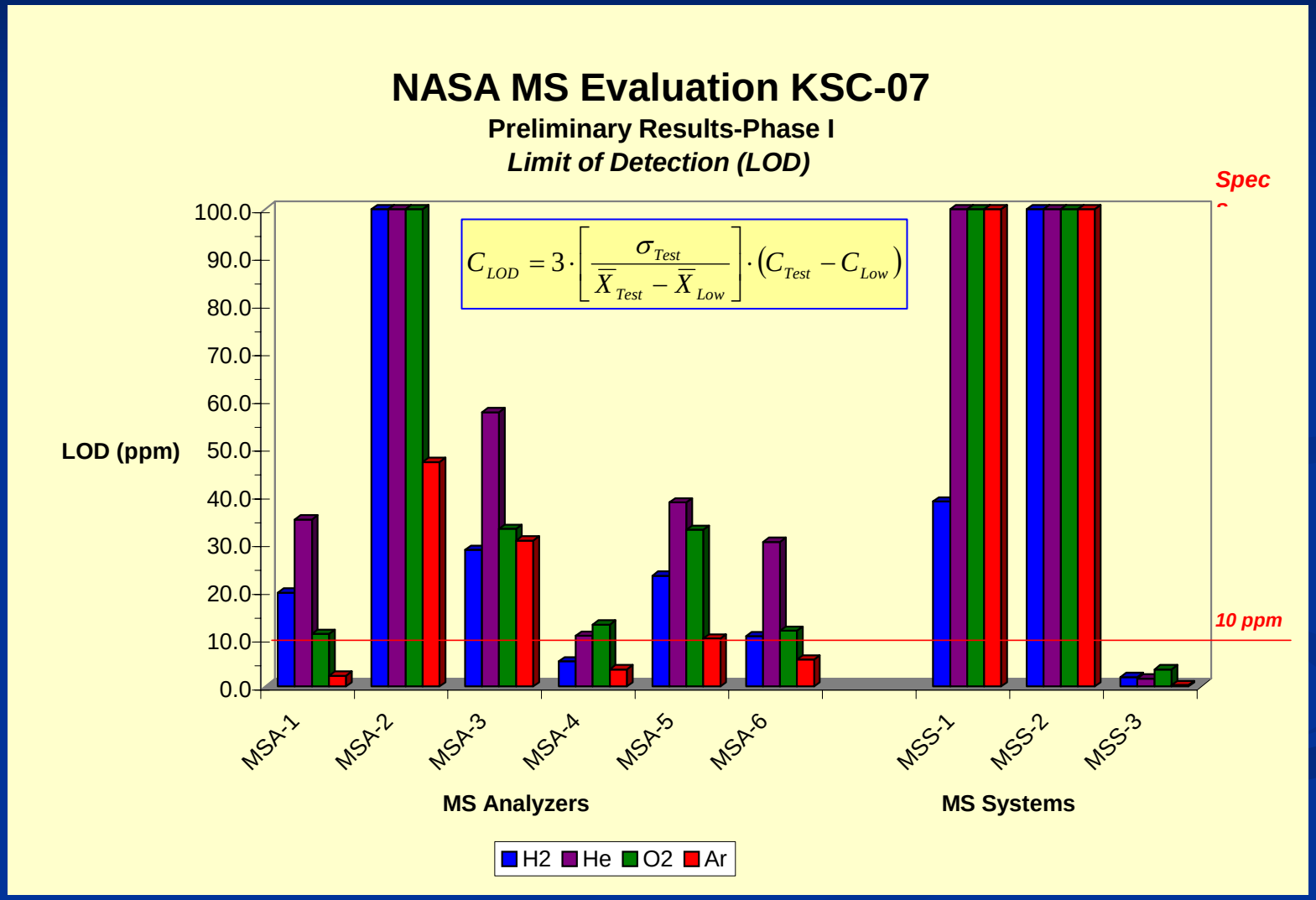


Precision



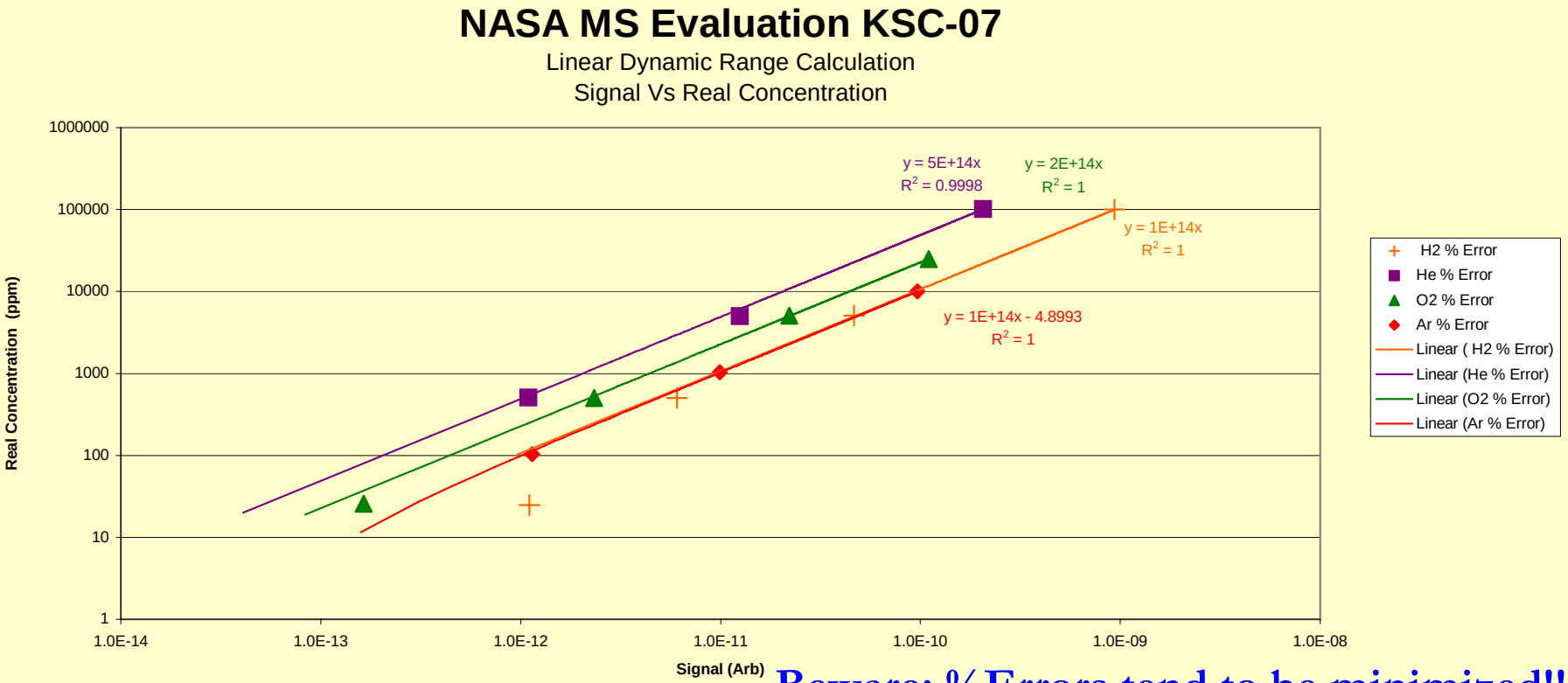
$$RSD = \frac{1}{\bar{X}} \sqrt{\frac{1}{25} \sum_{i=1}^{25} \left(x_i - \bar{X}\right)^2} \times 100\%$$

Limit of Detection



Accuracy Determination

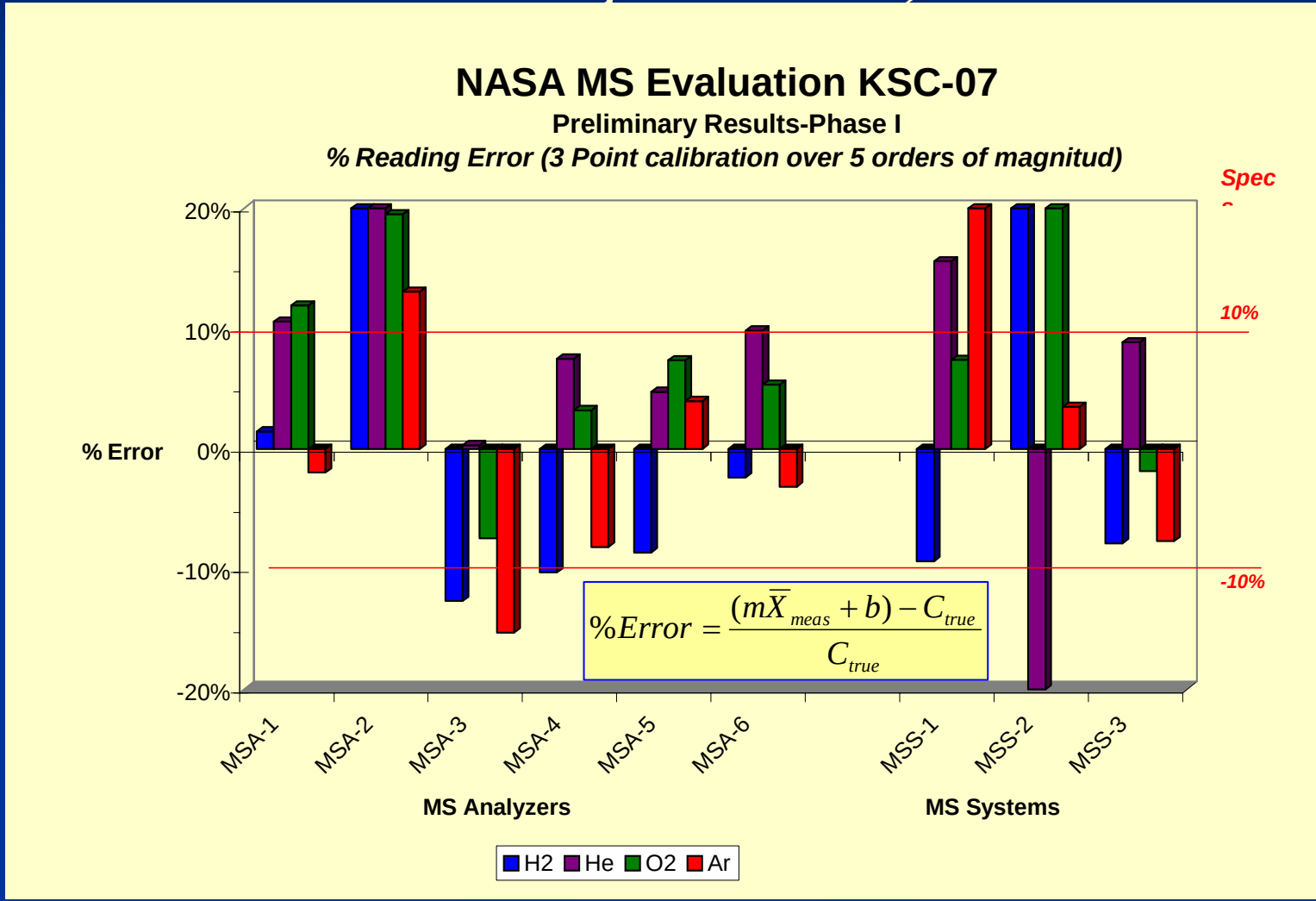
Calibrating over 5 Orders of Magnitude!!!



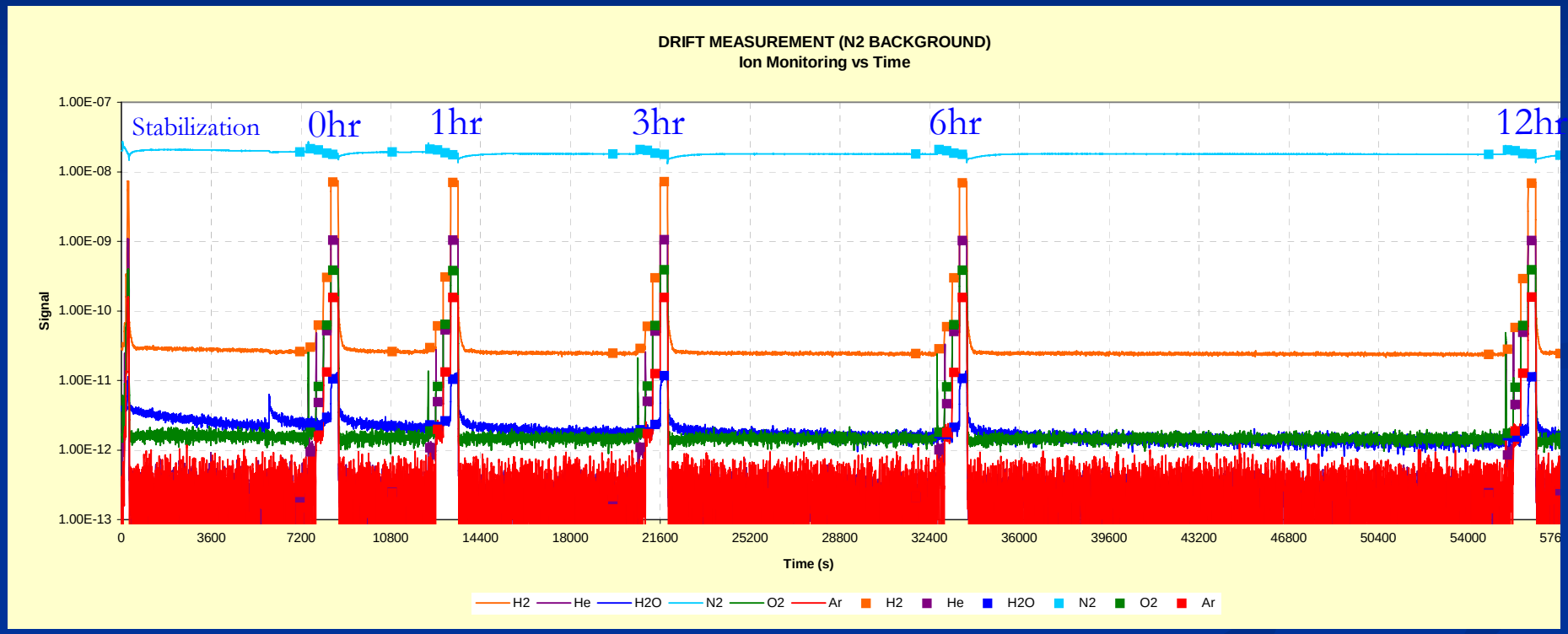
Beware: %Errors tend to be minimized!!

Accuracy

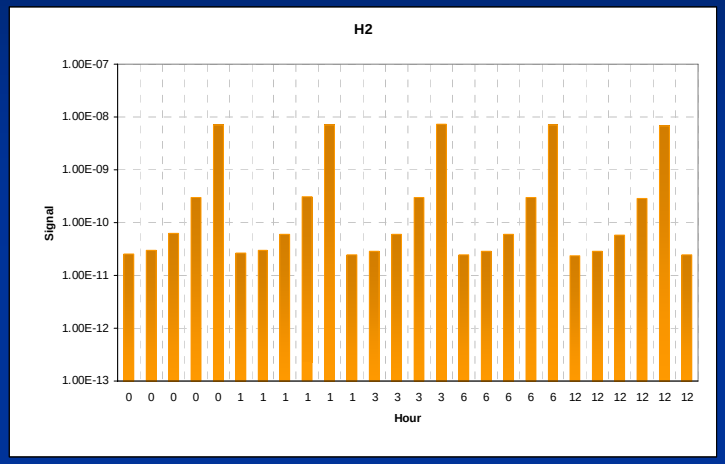
(For this particular set of condition and test parameters!!!)

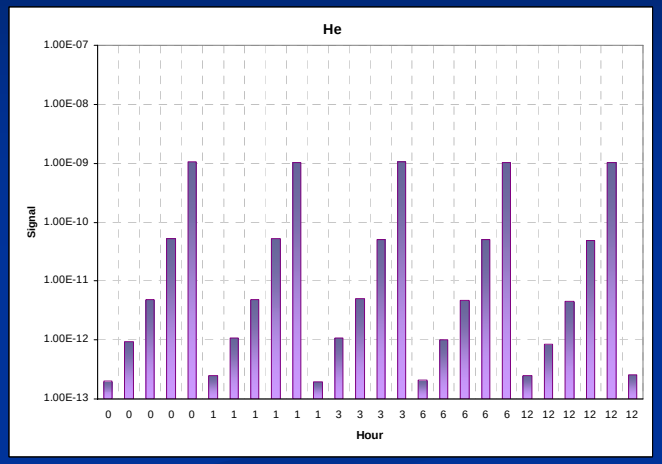


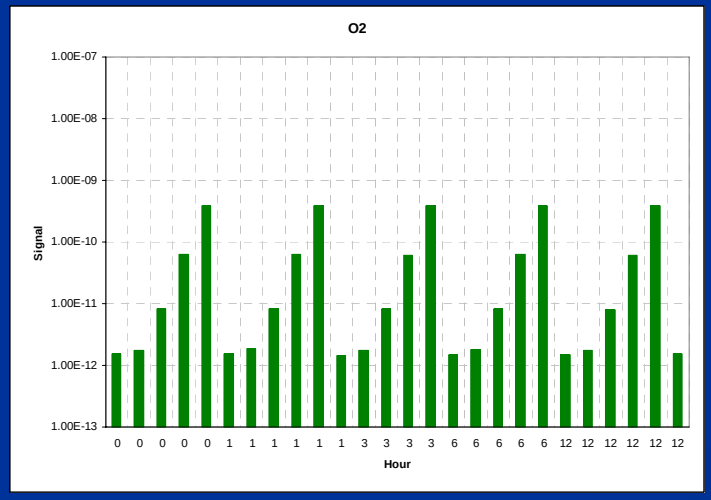
Drift Test Example

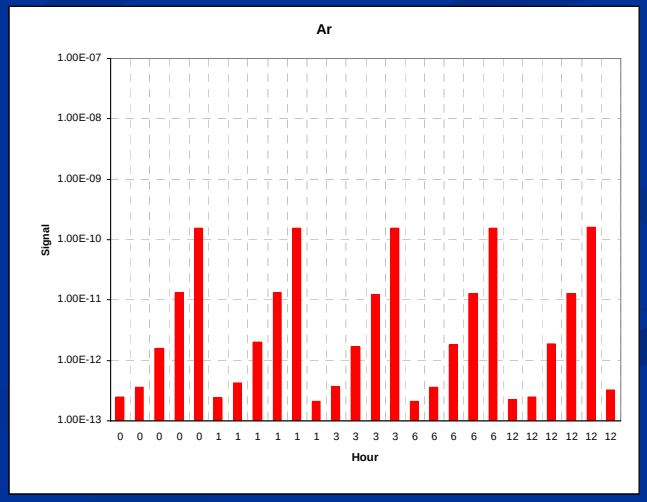


Drift Test Averaging

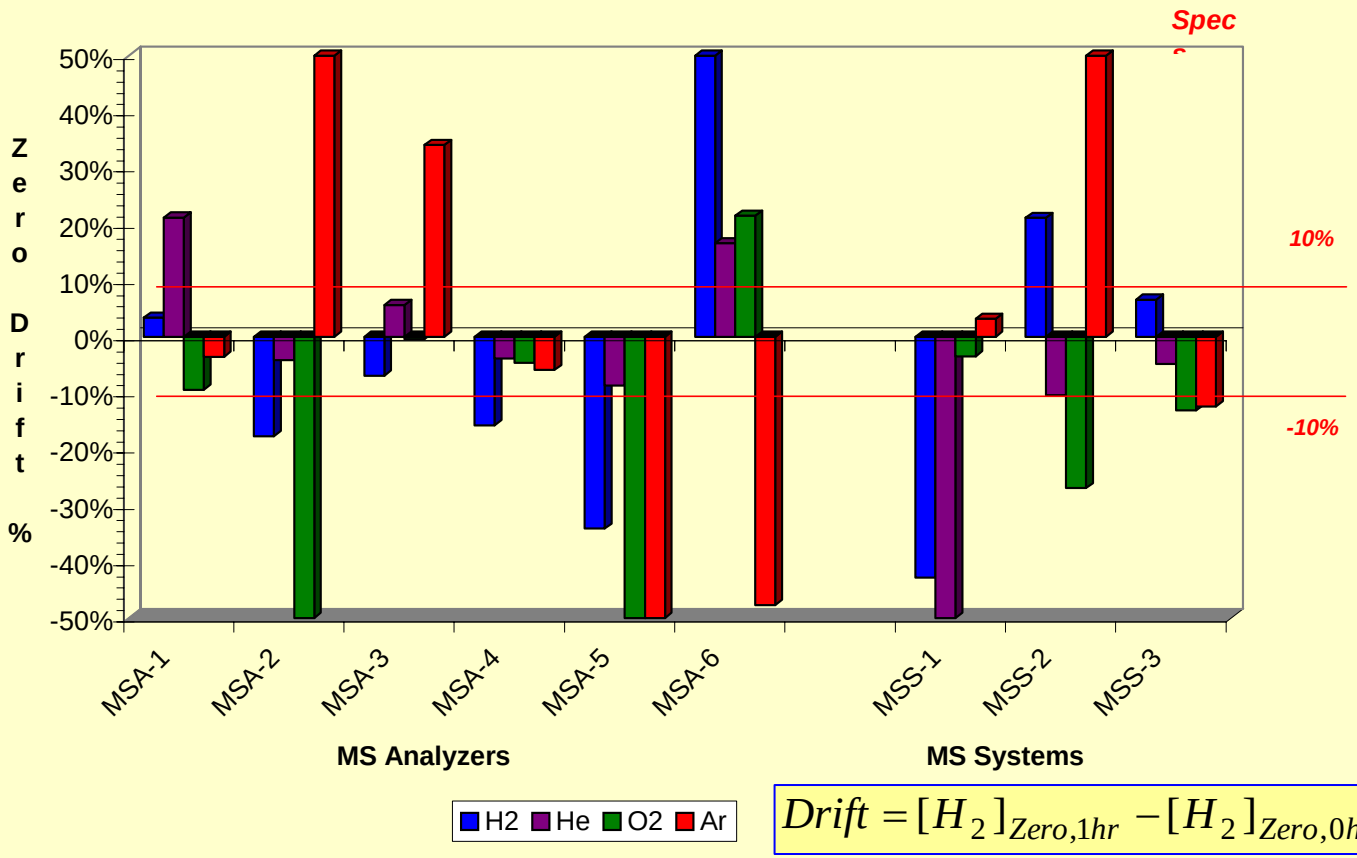






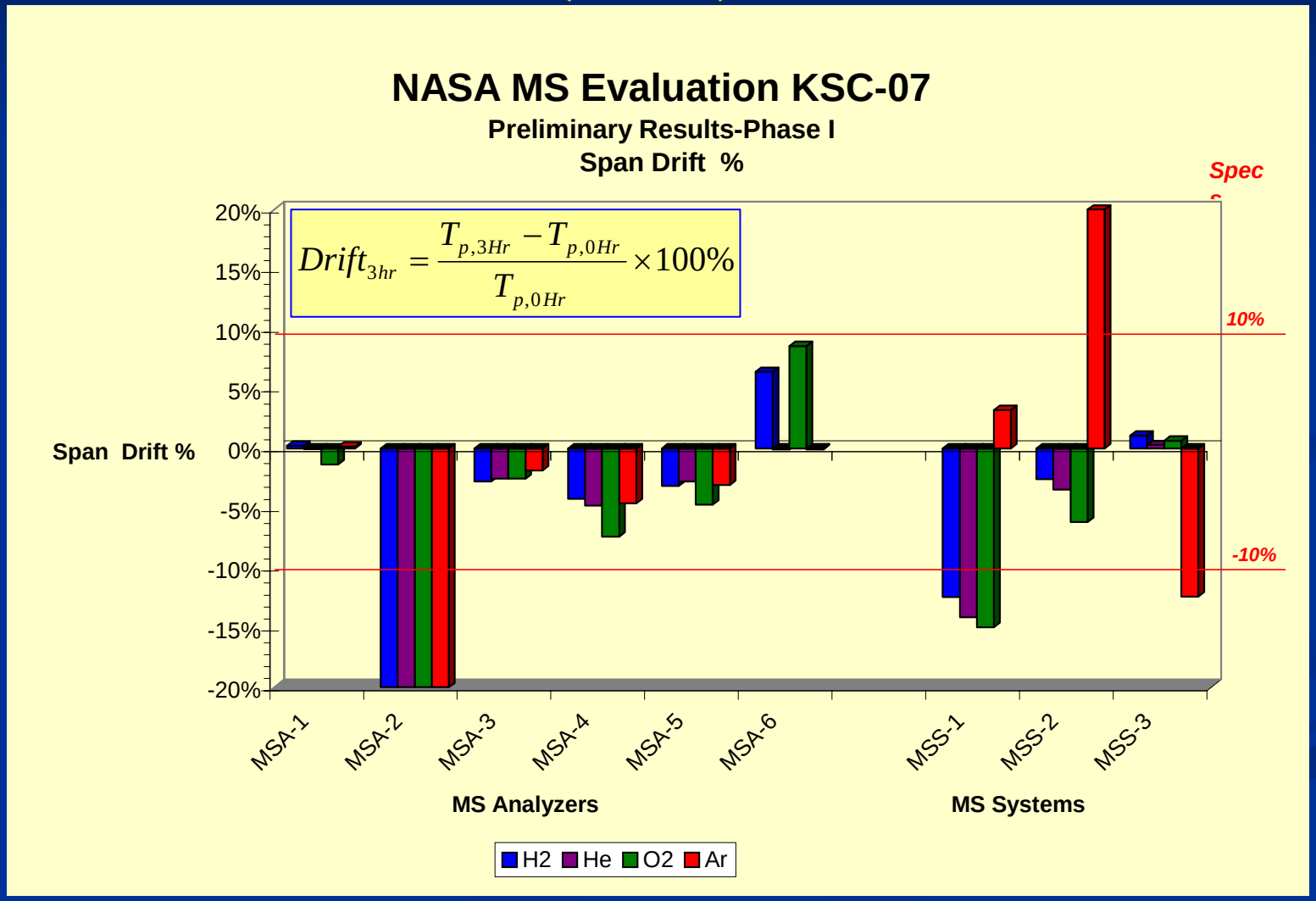


Zero Drift
(12hr)



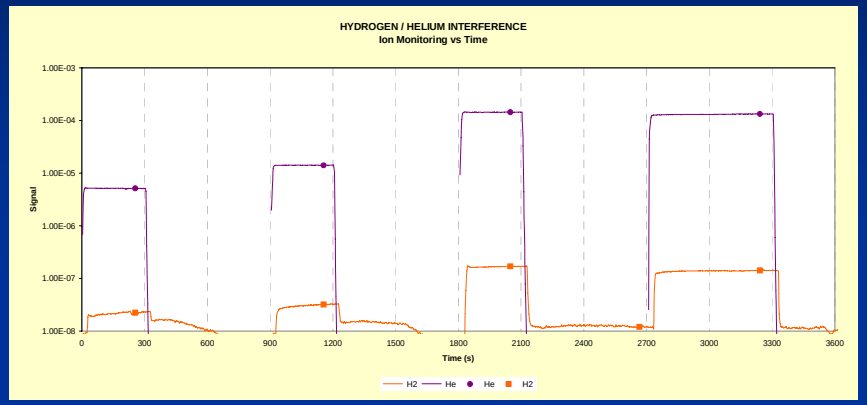
$$Drift = [H_2]_{Zero,1hr} - [H_2]_{Zero,0hr}$$

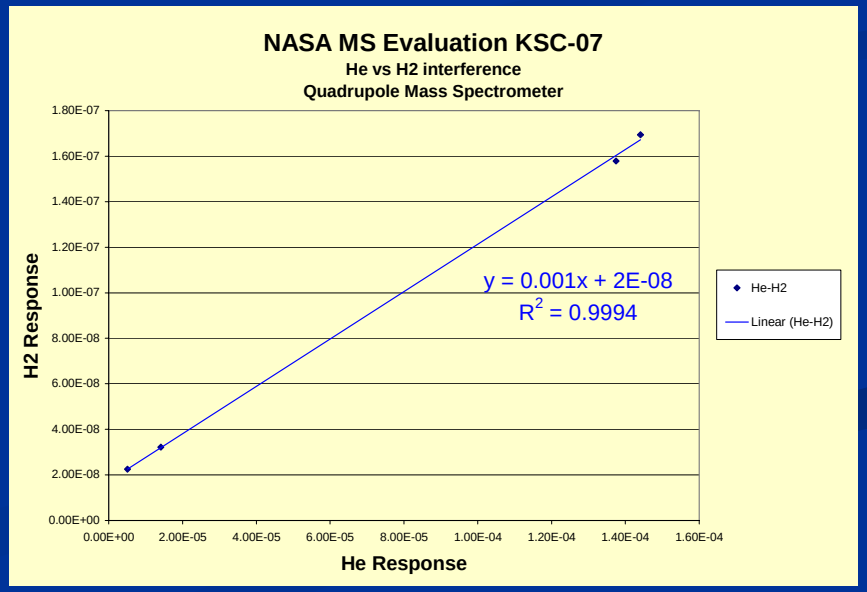
Span Drift
(12 hr)



Other Tests

- Same set of test was repeated for He Background calibration Bottles
- Working on Data from:
  - Response and Recovery time tests
  - High He clear out time
- High He interference on H2 signal found in most units (0.1% of signal)





Conclusions

- Small Commertial MS Analyzers and Systems Evaluated
  - 10 products tested (some still under testing)
  - Most Systems Meet Target Specification
  - Better results on some DUT than previous small-prototype-like MS systems evaluated
- Areas That Need Improvement
  - Response & Time Recovery Time
  - Fater Scan Rate from ppm to 100% levels for FC detector
  - System Volume & Weight
- Future Work
  - Complete testing (Phase II)
  - Generate internal report to NASA-KSC
  - Evaluate Magnetic Sector Analyzers for H_2/He applications
  - Publish result in academic journal (AVS, JASMS)

Acknowledgements

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  - Chad Wilson. Pascal Technologies
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