GCMS Sensor Characterization

22	laboratory notebooks
3300	written pages of text
2500	data files
260	Megabytes of data
71	pages of notebook index listings
750	hours of instrument operation

3	laboratory notebooks- detector characterization
3	laboratory notebooks- ion source characterization

(notes only)

Ion Source Characterization

After assembly, cleaning, installation on an ultra-high vacuum test stand, and bakeout, new filaments were "burned in" prior to operation:

> Each filament was exposed to slowly increasing current until emission was observed, and then the current was slowly lowered again. Filament current was stepped up at a rate of 50 mA every 7.5 minutes. When emission was observed, emission was increased up to 50 uA at a rate of 10 uA every 7.5 minutes. Rates during current step-down were twice as fast.
>
> During this procedure, the filament bias was 0 V, and all other elements close to the filament were set to +50 V. Emission was measured as the current on these other elements.
>
> Voltage across the filament was measured, as well as filament current, chamber pressure, and filament emission. All of these parameters were compared to expected values during a burn-in in order to ensure proper filament operation.

(notes only)

Then a detailed characterization of the ion source was performed:

> Using various combinations of focussing voltages, lens currents were monitored at a series of emission voltages. These measurements served to identify the particular characteristics of that assembly.
>
> A multiplier assembly was used to monitor the output of the ion source when in this configuration, and the ion beam was quantitatively measured at particular nitrogen pressures to identify those combinations of voltages which maximized sensitivity.
>
> In-house analytical software was used to generate these voltage combinations by computer monitoring of the multiplier current and D/A control of the filament voltages.

All of these focussing lens currents, filament currents, and focussing lens voltage combinations were monitored during ion source operation on the flight sensor.

(notes only)

Ion Source Characterization

Filament burn-in

- Slow filament power-up for stress relief on separate test stand
- Verified overall electron lens distribution and ion source operation

Source characterization

- Verified lens functions
- Verified source sensitivity
- Performed computer-driven optimization of lens potentials

Multiplier Assembly Characterization

After assembly, cleaning, installation on an ultra-high vacuum test stand, and bakeout, new multipliers were slowly turned on by ramping up their high voltage at ~100 V every two minutes.

Then a detailed characterization was taken of the multipliers themselves and of the assembly:

> "Bleeder current" was measured, which is the hot resistance of each multiplier at operating voltage.
>
> "Dark counts" were measured at length, to detect any extraneous multiplier output with the multtipliers at operating voltage and no ion beam present.
>
> Output counts and current for each multiplier were measured at various levels of ion beam input. This allowed calculation of the gain of each multiplier at various input levels.
>
> Each multiplier may be operated as the primary multiplier, depending on which one the incoming ion beam is focussed. The other multiplier acts as the secondary multiplier, sensing some set fraction of the counts that are seen on the primary multiplier. In characterization, output counts and current for each multiplier were measured in every combination of multiplier operation. This allowed the ratio of counts between the primary and secondary multiplier to be characterized.

(notes only)

Pulse height distributions, or PHDs, of each multiplier at various operating voltages and ion beam inputs were taken. The shape of the PHD scan indicates the degree to which the multiplier is reliably producing detectable output for each ion coming into the multiplier.

An extended lifetime test was performed on a pair of multipliers from the lot obtained for the GCMS instrument. After 72 days of ~6 hours a day of 100 pA ion beam dosing, resulting in $5*10^{14}$ ions of dosing on the multipliers, no signifigant deterioration in performance of the multipliers was seen.

Gain, primary-secondary operation ratio, and PHDs for the multipliers were monitored during the course of operation on the flight sensor.

(notes only)

Multiplier Assembly Characterization

Ramping up high voltage at ~100 V every two min.

Measurements taken of:

- "Bleeder current"
- "Dark counts"
- Output counts and current vs. levels of ion beam input
- Calculated gain vs. input levels
- Output counts and current for each multiplier in all multiplier operation modes
- Count ratio between primary and secondary multiplier determined
- Pulse height distributions (PHDs) of each multiplier at various operating voltages and ion beam inputs taken

Extended lifetime test: 72 days of ~6 hours a day of 100 pA ion beam dosing, resulting in $5*10^{14}$ ions. Still satisfied requirements of experiment

Switching Lens Characterization

In-house analytical software was used to generate the optimum set of switching lens voltages for each ion source. This was accomplished by computer monitoring of the multiplier output and on-the-fly D/A control of the switching lens voltages.

The first step of this optimization was an “energy scan.” This energy scan paired certain sets of the switching lenses, holding them in certain relationships, and then these voltages were scanned over a wide range while monitoring the multiplier output. The resulting curve provided a “first cut” voltage set which would result in a reasonable signal level.

The second step of this optimization was a “simplex” optimization. The in-house software allows all of the switching lens voltages to be varied in a stepwise fashion while monitoring output. The voltages are then modified on the fly to maximize signal. This method has been shown to reproducibly converge on the best set of switching lens voltages for best signal transmission.

A “single lens scan” set was then taken as the final step in optimization. While monitoring signal levels, each switching lens voltage was scanned over a wide range while holding all of the other switching lenses at their optimum values. The resulting scans were found to be a useful indicator of the degree to which the beam was focussed.

(notes only)

Switching Lens Characterization

In-house analytical software used to generate optimum switching lens voltages

Achieved through computer monitoring of sensor's multiplier output and on-the-fly D/A control of switching lens voltages

- "Energy scan" paired certain sets of switching lenses in certain relationships, sweeping voltages over a wide range while monitoring multiplier output
- Resulting curve provided "first cut" voltage set

- "Simplex" optimization varied each lens voltage while monitoring output
- Voltages then modified on the fly to maximize signal
- Method has been shown to reproducibly converge on the best set of switching lens voltages for best signal transmission

- "Single lens scan" set final step
- While monitoring signal levels, each switching lens voltage scanned over wide range, holding all other switching lenses at optimum values
- Resulting scans useful indicators of beam focussing

Sensor Characterization Performed

Switching Lens Characterization

Leak Characterization

- For each leak, characterized sensor response vs. sample inlet pressure, gas mixture, pumping conditions

GCMS Characterization

- For each column, characterized sensor response vs. sample volume, sample inlet pressure, gas mixture, injection valve squirt time

Gas Mixtures Used in GCMS Sensor Characterization

1. Nitrogen mixture with trace amounts of various light hydrocarbons and other components:
~100 ppm each of--

methane	(CH_4)	ethane	(C_2H_6)
ethene	(C_2H_4)	ethyne	(C_2H_2)
propane	(C_3H_8)	propene	(C_3H_6)
n-butane	(C_4H_{10})	cis-2-butene	(C_4H_8)
1-butene	(C_4H_8)	trans-2-butene	(C_4H_8)
1,3-butadiene	(C_4H_6)	pentane	(C_5H_{12})
carbon dioxide	(CO_2)	carbon monoxide	(CO)

2. Nitrogen mixture with trace amounts of various heavy hydrocarbons:
~100 ppm each of--

2-methylpropane	(C_4H_{10})	2-methyl-butane	(C_5H_{12})
isohexane	(C_6H_{14})	benzene	(C_6H_6)
toluene	(C_7H_8)	o-xylene	(C_8H_{10})
3-methyl,1-butene	(C_5H_{10})	2,2-dimethyl propane	(C_5H_{12})

3. Nitrogen mixture with trace amounts of various noble gases:
~50 ppm each of xenon, krypton, argon
~250 ppm neon ~575 ppm helium

4. Nitrogen with 10% argon

5. Helium with ~1000 ppm CO

6. Helium mixture with trace amounts of various light hydrocarbons:
~150 ppm each of--

methane	(CH_4)	ethane	(C_2H_6)
ethene	(C_2H_4)	2-methylpropane	(C_4H_{10})
1-hexene	(C_6H_{12})	ethyne	(C_2H_2)
propene	(C_3H_6)	propane	(C_3H_8)
benzene	(C_6H_6)		

7. Helium mixture with large amounts of various noble gases:
~5% each of xenon and krypton
~8% argon ~25% neon

8. Pure nitrogen

9. Pure hydrogen

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ethyne	(C_2H_2)	propane	(C_3H_8)	propene	(C_3H_6)
n-butane	(C_4H_{10})	cis-2-butene	(C_4H_8)	1-butene	(C_4H_8)
trans-2-butene	(C_4H_8)	1,3-butadiene	(C_4H_6)	pentane	(C_5H_{12})
carbon dioxide	(CO_2)	carbon monoxide	(CO)		

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GCMS Flight Components Tested Before Installation

Break-off cap

Hydrogen reservoir

Hydrogen regulator

Burst diaphragm

Valves

Pressure transducers

Flow restrictors

Capillary leaks

Columns

Heaters

Ion sources

Multipliers

Getter pumps

Ion pumps

Leaks:

Leak sizes:

Leak 1	$1.8*10^{-4}$ atm*cc/sec for He
Leak 2	$3.0*10^{-7}$ atm*cc/sec for He
Leak 3	$1.3*10^{-3}$ atm*cc/sec for He
Leak 4	$1.7*10^{-6}$ atm*cc/sec for He
VX	$1.2*10^{-3}$ atm*cc/sec for He

Columns:

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IS-3	Glassy carbon column	15 m
IS-4	Packed column	2 m
IS-5	MXT column: MXT-1701	10 m