SHUTTLE LESSONS LEARNED – TOXICOLOGY

Okay. I've been asked to talk about the toxicology and the lessons we've learned from the Shuttle.

My own experience has gone from about 1989 to the present, 2010.

I divided this into four segments.

The first segment is gonna deal with dust in the space vehicle.
and how we've managed
that and learned about it

over the decades or so
that we've studied it.

The next segment will
be archival samples,

that is methods that we
have used and developed
to sample the air during a
flight, bring back the samples

and analyze them after
the mission is over.
This has clear limitations if you're trying to diagnose and troubleshoot a problem to get data that are three or four months old. It's just not very useful. Then I'll go on to talk about real time on-board analyzers that give us a lot of capability in terms of monitoring for combustion products and some of the lead end to being able
to monitor volatile organics on the station

where we've developed a lot

of the techniques improving them on the Shuttle.

And then finally, I'll pick up some bits and pieces

that don't have anything to do with hardware but have to do

with other lessons we've learned about setting limits and dealing
with ground-based issues that pertain to toxicology and so on.

[00:01:20.976] So, let me start off with dust.

[00:01:23.636] If you were to take a sample of dust from the Shuttle, from the vacuum cleaner, it would look something like this.

[00:01:30.516] You'll see in here a lot of fiber particles.

[00:01:34.786] There are clearly some food particles.

[00:01:36.926] If you were to look closer,
there would be a few metal shavings and so on.

And this particular sample was taken in order to determine if rat food bar pellets or pieces were getting out into the cabin.

This was during an experiment when there was a rat habitat onboard.

And we're actually able to discern a few particles
that looked like rat food and pulled them out from the mess I just showed you.

But to look like a rat food bar is not enough.

And what we did was use GC mass spec pyrolysis to identify a spectrum for these particles and for rat food bar material that we knew about.
And we're able to identify with high confidence that in fact the pellets from the rat food bar were getting out. That was no big deal because there weren't that many pellets actually. There was a concern early on in the '80s about the particles in the Shuttle and particularly having to do
with the respirable particles which are those that are less than 5 microns.

Then Lou and some other experts at the University of Minnesota and some monitors here at JSC got a flight together and there were two instruments on that flight.

One was the cascade impactor which would partition
the particles according

to their size and
another one was

This is the instrument that was used

to measure the wall concentrations.

This is the instrument that was used
to measure the wall concentrations

and follow them overtime.

The experiment was very successful
from the very beginning and
gave us two good reassurances

about dust particles.

First of all, the concentration
in the air was not so high

that it would be a threat to
crew health, and in addition,

the concentration

in the respirable size was well
below any standards we would set

for the Shuttle.
Eventually, the large floating particles, they came a nuisance to the crew.

And so in the mid late '90s, something called the orbiter cabin air cleaner was developed.

This was a large unit that fit in the opening between the mid-deck and the flight deck.
It had the advantage that yes indeed it cleaned

out the large particles but it was noisy

and the crew didn't always welcomed its presence,

but it did get rid of the dust such as it was.

Now, I wanna go on and talk a little bit about archival samplers.
These are samplers that are used on orbit by the crew and we bring back samples and analyze them on orbit.

In 1985, the toxicology group patented this device which we call the solid sorbent air sampler.

This was to enable the crew to take up to 7 samples during a mission and they had to turn this dial.
to select which sampler they wanted to load the air sample onto and then 8 was a parking position,

they could use that for a sample.

The way this thing function was this - there was a holder for batteries right here, two B-size cells.

There was a pump here, something like what you might have in an aquarium, and
there were tiny tubings

[00:04:58.896]
that would run the gas around
and deposit the contaminants

[00:05:05.026]
in these long tubes that were
filled with absorbent material.

[00:05:08.136]
This device was brought
back into the lab

[00:05:12.046]
and the hot air was
run through these tubes

[00:05:14.746]
to desorb the pollutants
and they were put

[00:05:17.736]
into a GC mass spectrometer.
Problems with this were primarily concerning the pump.

We measured the flow before and after flight, and oftentimes, the flows didn't match very well.

We, for a while, thought that maybe that was due to obstruction getting into these tubes when we drew air in but we had a very good filter over the end of it.
And eventually, we concluded that the way we were actually doing the measurements in the lab was not sufficiently consistent, and so we worked that over and got this to go very well.

We did fly this for a number of times on the Shuttle-Mir Program. One adaptation we made for Mir was that there were a lot
of floating dust particles in Mir.

And what also would later appear to us to be liquids and food and so on, and often the inlet would get plugged up on Mir.

And so what we devised was actually an inlet with 5 ways in.

If you look at this, there are the 4 ways around.
and then the one on the in.

[00:06:21.336]
This gave us 4 more ways for
air to get into the inlet

[00:06:26.456]
as compared to just one
of these round holes.

[00:06:28.706]
And this never failed.

[00:06:29.786]
We never had a plug-up
problem after that.

[00:06:33.716]
I might point out that this unit
is actually a fairly famous unit

[00:06:40.926]
because it was the one that
Dr. Jerry Linenger used
after the SFOG fire.

And if you could look very closely on this,

he notes where the fire occurred.

We'd had two routine samples before the fire and then he notes here that the fire occurred.

And he used it on a very carefully worked out sequence, not like we've planned,
but very smartly to show

[00:07:02.016]

that pollution actually

cleared from the air

[00:07:03.816]

in about a day and a half.

[00:07:05.506]

So, in a certain sense, this

is a historic solid sorbent

[00:07:08.846]

air sampler.

[00:07:09.676]

(Noise) That was good.

[00:07:15.006]

We thought we would

build something better.

[00:07:17.046]

So, we built a larger version
of this shown in this picture.

[00:07:24.076] This had 16 tubes and
they were longer tubes

[00:07:28.026] and we have them set so
that we could take them

[00:07:29.706] out more carefully and desorb
them better than we could

[00:07:33.456] in the solid sorbent
air sampler.

[00:07:35.576] We also had this set
up with a programmer

[00:07:37.816] so that the whole unit
could be programmed
to automatically take samples once the unit got on orbit.

It turned out it was too large and too cumbersome to actually fly.

Test in the lab indicated it was pretty good, but we learned a couple lessons. One, you can’t fly really big things no matter how much you want.
And we knew that
krypton was important

but this did not have
enough gain in terms

of not using krypton to
actually get it flown.

The other goal of
flying things on orbit is
to get things smaller.

There were thin ground
base testing on a lot
of labs had used something we call the archival

organic sampler.

We flew a cluster of these, and the idea with these things is

that you would not need the pump.

Remember I said the pump in the solid sorbent air sampler was a little bit of a problem.

That these would actually capture sample by diffusion
through a very tiny hole that I think probably is difficult to see that there's a tiny hole right in the middle of this.

And the idea is that pollutants would diffuse across this into a trapping resin below it and then the crew would simply see what back up and we would get it back in lab and analyze the pollutants in the resin.
Two problems with this, one, they weren't sensitive enough to capture the level of pollutants we would see on Shuttle.

And two, things like this right here actually release enough pollutants that it contaminated the trapping resin. And so we tried to use these but they didn't work.
Now, one last sorbent effort was conducted after Columbia.

Shuttle had been one of the main ways we were getting samples down from the station, but when Columbia occurred, the Columbia accident, we had to very quickly get away to bring back samples.

Samples had been coming back in this grab sample canister that I'll talk about in a minute,
but we needed a much smaller way

that we can get back
samples on Soyuz.

So, in a period of about a month
or two, we went from concept
to ready to fly with something
we call the archival released

with just dualsorbent samplers.

We call them dualsorbents
because of instead of like this

with one sorbent material,
we actually had two sorbents in here.

We had a pump that would fly and this would go back and forth

and the crew would pull the ends off of these

and aspirate the sample through

and then you can see the heat marks here.

Once these are brought back, the tubes are heated,
this sample is desorbed
and analyzed in the lab.

[00:10:14.676]
This is very much like
a single component

[00:10:17.276]
of the solid sorbent air sample

[00:10:19.396]
that I showed you
the inside of here.

[00:10:22.336]
We learned a lesson here.

[00:10:26.286]
We really did a crash
program to get these

[00:10:28.816]
on as I said in a month or two.

[00:10:30.146]
And the recoveries from these were very good if the samples were more than about a month old.

But oftentimes on Station, we wouldn't get samples back until they were three or four months old, and a lot of the volatile organic polar compounds declined rapidly. We never did figure out where they went,
we developed correction factors for those pollutants.

But because of that, it made measurements that much more uncertain, and we eventually abandoned this.

It's not sufficiently accurate.

Now, I wanna move on to a new kind of sampler.

These samplers didn't require a sorbent that as
such to capture the sample.

In the 1980s, we were using something we affectionately called the "sausage."

And this would-- we would evacuate the inside of this canister here and the crew member to get a sample would remove the dust cap, most of the time, open this valve, and the sample would be aspirated in here.
We learned a few things.

One is that the crew members like to unscrew this too far,
hence we added this little arm so that that's impossible to do.

The other problem that we never really solved because we have
to have a dust cap here, is that occasionally the crew member would forget
to take the dust cap off and
we could tell very quickly

[00:11:55.256]
that no sample was acquired
because there are pollutants

[00:11:57.996]
on the orbit that are very
characteristic of what you want

[00:12:00.666]
to see from a spacecraft
such as methane.

[00:12:03.066]
If you didn't see any
methane, it was a bad sample.

[00:12:06.436]
[00:12:09.456]
These have an okay volume to
surface area configuration.

[00:12:16.166]
But a sphere actually
gives you better volume to surface area configuration.

And one of the problems with the sausage was that we were afraid some of the pollutants were actually adhering to the walls of the canister and we couldn't see them.

So we started using these brown canisters in the 1990s.
And you could see again, here's the dust cap,

this particular version doesn't have the arm
to prevent this from coming off.

The other issue that this solved was that this--

there's a metal to metal contact in here.

And if any dust does get in here when the sample is acquired,

then when the crew member goes to seek this valve back,
the dust—piece of dust gets trapped in there

and occasionally we will lose a sample that way.

The other thing is the metal to metal valve actually got ruined from time to time because the crew members would over tighten the shut valve.

So now you can see there's a clutch here.
And this is very much like your gas cap if you've got a relatively moderate car.

You can only tighten it so far and then it clicks and you're done.

These still are in service.

We use these on the International Station and we use this on Shuttle now.
to bring back an end-of-mission sample.

We did try for a period of time to heat the walls of these

to dry the can-- some of the pollutants that may have gotten

on the interior walls but that brought in a host

of other problems, and so we eventually abandoned the idea

of heating the walls of these things.
Now, I wanna step back just a second.

This is another sorbent method that came along in the 1990s.

One of the compounds that sticks to the walls of these things that is very difficult to quantify is formaldehyde.

But formaldehyde is an important component of offgassing and is also released in some of the curing processes.
that are used for materials on Shuttle.

[00:14:13.146] So we looked around and found formaldehyde badges.

[00:14:17.206] This is very inexpensive.

[00:14:18.496] They are 20 dollars even now.

[00:14:20.346] And the way this work is the crew member pulls off this tab

[00:14:24.676] to start the process.

[00:14:26.606] And this bisulfide material in here traps formaldehyde

[00:14:31.616]
as it passes by in a flow stream.

[00:14:34.086] After 24 hours, the crew member covers the badge,

[00:14:38.006] and it's brought back for analysis by spectrophotometry in the lab.

[00:14:39.846] Problems with these badges are that they are small

[00:14:42.596] and they sometimes get lost.

[00:14:45.326] They've found these badges that have been opened for weeks
or even months, tucked in somewhere in the station.

They-- we push the limit of detection with these badges also so that we use them in pairs for more accurate readings.

But they still are used on Space Station.

We did use them for a period of time for example in the extended duration orbiter program of the Shuttle
and we found that formaldehyde was not a problem then on Shuttle at least within the limits that we had set then.

We did have an experience with these.

We were using these in a Lunar-Mars Life Support Test on the ground and a lot of formaldehyde was being released as it turned out from some of the acoustic materials and some of the murals that
were put in there

[00:15:36.286]
to keep the crew entertained.

[00:15:38.496]
And these formaldehyde
badges were used--

[00:15:41.156]
being used and were showing that
formaldehyde was increasing.

[00:15:44.006]
And one of the crew members
actually had some problem

[00:15:46.096]
with respiratory irritation,
and so the question came up,

[00:15:49.406]
were these badges
really accurate.
And we used the gold standard method that's--

a wet chemistry method which you could never use in space to show that in fact these badges were given very accurate readings and so we trust them a lot.

Now, I wanna move on from samplers to actual analyzers on orbit.

We experienced a
number of issues

that involved small combustion events

in the late 1980s and early 1990s.

This is a picture from STS-28 which flew in 1989.

If you look carefully, what's happened here is that a wired junction with a sleeve of Teflon has pyrolyzed.

It was actually out in the or--general space in the Shuttle
and the crew was very aware when this happened because it arched, it sparked.

It made a little smoke and it definitely got their attention.

This and a few other events something like this but much less sharp-- much more subtle impelled us to try to get some real time onboard analysis of combustion products.
Another event that
got our attention was

when a motor failed in the
orbiter refrigerator freezer.

This is a picture of that motor.

And what happened is that
there was no thermal protect

on the motor and the sleeve that
this thing was driving that went
to the fan seized up against its
sleeve and the motor kept trying
to turn the shaft but could not.
It got hotter and hotter.

This is a Delrin case here.

And one of the best ways in the world to make formaldehyde is for Delrin to be heated.

And so this thing made copious amounts of formaldehyde.

You can see where the plastic structure is actually destroyed here and so the electronics up here were destroyed.
This was on STS-40.

It's my judgment that the mission would have been cut short had the crew not had a place to go outside of the module where this event occurred to escape the bad smell from this.

And actually I had this thing in my lab for a while.
And it-- even through the bags that we had in containment,

there were a lot of clearly small noxious compounds

that would get to the bag.

So, anyway, in the early '90s, there was a lot of impetus to get something up there to measure combustion products.

Our first attempt to that is shown here, we call it the combustion products analyser.
It did 4 compounds.

It did hydrogen fluoride, hydrogen chloride, hydrogen cyanide, and carbon monoxide.

We looked at the products of combustion or the kind of materials that we thought might burn on orbit that would be primarily wire insulation.
and polymeric materials.

[00:18:43.006]
And that's how we selected those 4 compounds.

[00:18:47.716]
We were under a lot of pressure to get this onboard and that was okay.

[00:18:52.316]
In the early '90s, it was very easy to get things funded.

[00:18:56.046]
I remember going to Clay McCullough who's then the GFE manager for the Shuttle and saying hey we've got a problem
with this combustion stuff, we've got an analyser that we think we can fly.

His question is how much money do you need.

We told him. He gave us more than that, and we were flying this thing within a few months. No boards, no mess, no fluff, go do it.
So we flew this.

There was a downside, it turned out.

We asked. We knew the carbon monoxide sensor on this thing was sensitive to hydrogen.

We asked the ECLSS guys, the Environmental Control and Life Support guys, is there any hydrogen in the Shuttle?

No, there's no hydrogen
in there, he says.

Okay, so we're not gonna worry

about the hydrogen
cross sensitivity.

So, we flew this baby and
the carbon monoxide sensor,

which is the electrochemical
sensor

like all the others gave
us a pretty strong reading

of carbon monoxide that
gave us some anxiety.
And when we got back and looked for hydrogen in this, which we had never looked for before in this canister, we discovered that yeah, barely there is a lot of hydrogen in the Shuttle that accumulates from human metabolism and other processes.

>> So we had to correct the electrochemical sensor in this thing for the hydrogen
cross sensitivity while a

mission was coming up.

And we tried to change
the bias voltage

in the electrochemical sensor
and we thought we had done that.

We did a very quick
test and it seemed

like it was gonna work well.

Unfortunately, we picked the
first flight of that to be one -
I think it was STS-35 for two data display units.

It had a pyrolysis issue.

And this instrument gave carbon monoxide readings that we will say in the interesting level.

And it caused a lot of the anxiety.

And we eventually concluded indirectly that it really wasn't carbon monoxide.
There wasn't enough of that in the air to set this thing off but it was hydrogen.

But a lot of attention was drawn into this.

And I would say a lot of negative publicity.

If in case I forget to say it later,

one of the things we've learned is if you have an instrument
that performs 90 percent of the time and it fails 10 percent of the time, they'll remember the 10 percent.

And if you build a subsequent version of it, you want to call it by something else. You do not want just to call it CSACPII.

Lesson learned, good politics.

This instrument did perform
very well incidentally on Mir.

[00:21:19.866]
Actually, this is one that flew on Mir and I know

[00:21:21.796]
that because it's got all the Russian written

[00:21:24.686]
on the back here.

[00:21:26.456]

[00:21:28.986]
A year after the Solid Fuel Oxygen Generator Fire

[00:21:32.126]
that I told you about in connection with this device,

[00:21:35.406]

[00:21:36.456]
there was a much smaller fire
that involved the Trace Contaminant Control System on Mir. Basically, a filter that had a cellulose plate in it was moved into a hot stream prematurely and the cellulose plate burned. This caused a little bit of smoke in the cabin but nobody thought much about it.
The crew seemed to be fine.

But later that evening and the next morning,

crew members complained of headache and nausea

and those symptoms are consistent

with carbon monoxide poisoning.

And it turned out readings with this instrument

that was still being flown
as an experimental instrument showed carbon monoxide levels

[00:22:14.756]
about 500 ppm.

[00:22:16.776]
And we later confirmed that readings

[00:22:19.126]
of this thing were accurate because one

[00:22:20.626]
of these things was taken during the period of time

[00:22:23.006]
when the carbon monoxide was up.

[00:22:25.666]
So we learned that this instrument really can,
with appropriate hydrogen correction give us really good readings.

The lesson there was not only instrumental that is be careful what you fly, make sure it's as ready as it can be, and if it's an experiment, make sure everybody knows it's an experiment and not a ready-to-go hardware.
There was a lesson there though.

The Solid Fuel Oxygen Generator Fire that was associated with this was an in-your-face fourth-of-July type fire.

It was an obvious fire that was clearly an immediate threat to the entire Mir spacecraft.

The Trace Contaminant Control Fire was a much smaller event, and we didn't think much of it.
But toxicologically, it was much more serious.

If the carbon monoxide levels had been twice what they were on Mir, it could have been lethal to the crew.

That's how high the carbon monoxide levels were.

As we flew this over the yeas we learned one more lesson I'm reminded of here, this piece of tape
which is not a very sophisticated solution

but worked.

Sometimes as this machine was shipped,

it seemed that people would either play with this or the switch would get moved.

And so by the time the crew got it on orbit, it was on and the battery was dead.
So this rather inelegant but effective solution was to put a piece of tape over. Simple, cheap makes you change the drawing. That's about it. Alright. So, those were the early days of combustion products monitoring. In between there, there was fear of moving contaminants.
that were outside the vehicle into the vehicle.

This was particularly on Space Station but also applied to Shuttle.

We flew to monitor propellants particularly hydrazines, a derivative of a chemical agent monitor used by the military.

This is like a large flashlight.

This is the handle that the
human is meant to hold here.

[00:24:22.486]
And the idea was to use
this to scan the EVA suit

[00:24:25.516]
when a crew member came
in if there was a risk

[00:24:27.556]
of hydrazine contamination.

[00:24:29.736]
We flew this couple of times,
it gave negative results.

[00:24:32.186]
That is no hydrazine
was brought in.

[00:24:36.006]
We knew that there had
to be some modifications
to make it respond faster.

We had changed the dopant in here

but the estimate I think was something like a half a million dollars and the program decided that they weren't gonna pay that much for the modifications.

So this never flew as actual flight hardware but only as an experiment.
Years of work with this gave us some wisdom about selecting a new combustion products analyzer, which we did not call a combustion products analyzer. Somewhat awkwardly we called it the compound-specific analyzer for combustion products. So that it was not
tarred with the reputation

that this instrument got,
I think undeservedly.

We made mistakes
in rushing it on.

But this was a pretty
good instrument.

The one failing that
we saw as a chemist was

that the hydrogen fluoride
sensor never worked right.

Hydrogen fluoride is
important to monitor
because it's a key product from wire insulation burning.

We struggled to get a hydrogen fluoride sensor that would work and we never did.

We went to another instrument shown here, a good bit smaller and much lighter, but there still is no hydrogen fluoride sensor available for these units.
Instead, we replaced that sensor with an oxygen sensor.

We felt that during a real fire, a big fire, there might be a consumption of oxygen and that would need to be followed by the crew.

So in this one, we've got a hydrogen compensated carbon monoxide sensor, a hydrogen cyanide sensor,
hydrogen chloride sensor,

but it actually detects all acid
gases such as hydrogen bromide

and hydrogen fluoride.

So in a sense, we've
got hydrogen fluoride
covered indirectly.

Like the CPA, these are
electrochemical sensors.

We learned some other
features we wanted.
One thing we wanted was a zero filter.

This goes on a pump head.

I will show you what that looks like.

This pump head fits right over the unit.

It should come in like this, and actually pumps gases over these electrochemical sensors.

And this particular picture shows the zero filter in place.
The zero filter was necessary to make sure that as we were looking at the atmosphere after a fire, we could actually zero this unit and be sure that the carbon monoxide sensor would re-zero properly.

And we build this and test this in our lab even now.

The other issue with that device was how to get a sample
from behind somewhere
where there was a fire.

This is a wand.

We hook it to the pump
which hooks to this device.

And using this attachment, we
can sample in-behind panels

and so on if that's where we
think the fire is originating.

To my knowledge, this has
only been used once or twice.

And it was shown that wherever
the crew thought the carbon monoxide was coming from, it was not coming from there.

One other issue with this analyzer was whether it ought to alarm, where it ought to alarm and how.

There is a caution and warning system in the Space Station.

And we asked the question,
Do we need to plumb it into caution and warning?

One thing we've learned is if you're gonna plumb something into a distributive system like caution and warning, you're gonna pay a real price in dollars and in anguish to get it into that system.

So if you can make a stand-alone analyzer, it's a good thing.

By the way, this slide's
now on Shuttle and Station.

[00:28:32.956]

Its alarm is not loud enough to be heard

[00:28:35.196]

by the crew given the noise in the Shuttle or Station.

[00:28:38.826]

We had thought about flying an alarm-- alarm enhancer.

[00:28:44.326]

That's this thing.

[00:28:45.936]

In case you want to--

[00:28:48.236]

( Beeping )

[00:28:48.303]

>> That is deemed loud
enough to be heard

[00:28:51.806]
on station should it go off.

[00:28:54.606]
The powers that be
decided in their wisdom

[00:28:57.786]
that we really didn't
need an alarm that loud

[00:28:59.956]
with a little instrument
like this

[00:29:02.296]
that the crew would actually be
able to see the visual flashing

[00:29:07.676]
which these things
do when necessary.
For sometime, this was actually on all the time.

It's the first alert monitoring.

Now it is not.

These are deployed around the station and there are 4 of them.

And I think only one flies on the Shuttle now.

For a while, we flew two of them.

Okay. That's combustion products analyzer.
We are looking for improvements on this.

It will be hard to beat this.

Electrochemical sensors are a little bit squirrely in the sense that they are not always specific for a given compounds.

And sometimes if you overdrive them with a huge dose of what they're measuring,
they misbehave.

But right now, there's
good as there is out there.

We knew that on Space Station,
the crew would be there
a long time and we wanted
to fly an analyzer
for volatile organics.

>> The program asked us if
we wanted to fly as part
of risk mitigation experiments
on the Shuttle and we leapt

[00:30:08.586]
at the opportunity, if you will.

[00:30:11.256]
This is the Volatile Organics
Analyzer we eventually flew

[00:30:15.186]
on Station.

[00:30:16.106]
We flew it twice on
Shuttle STS-86 and STS-89.

[00:30:20.536]
The first time it didn't
work at all and we ended

[00:30:22.496]
up just bringing it back.

[00:30:23.386]
The second time we had to
do an in-flight maintenance.

[00:30:26.426]
I think it was several hours.

[00:30:28.576]
It was a complex process.

[00:30:30.896]
We did learn from that that the crew, if properly instructed

by very smart ground controllers,

[00:30:34.686]
can fix a really complex instrument.

[00:30:37.546]
This thing has flown now for 8 years on Station

[00:30:41.596]
and has performed well.

Two lessons we learned here.

One, this was a one of a kind bill that cost several million dollars for each instrument.

It's very expensive, extremely complex.

Safety required us to put a lot of fuses in here and I'm not gonna attack their wisdom, but it tended
to be the fuses that failed
and not the instrument itself.

Complexity is something to
stay away from if you can.

The other thing we
learned is about crew time.

This thing could be
programmed from the ground
and operate independently
of the crew.

So we got a lot of samples.

Other analyzers like this,
for example for water,

[00:31:25.326]

had to be dragged out,

set up and then operated

[00:31:28.916]

over 45 minutes to

an hour of crew time

[00:31:31.366]

and that never happened for

some of those instruments.

[00:31:34.136]

So minimize crew time.

[00:31:36.236]

Another thing to minimize is

how dependent your devices are

[00:31:47.156]

on the resources of

the parent vehicle.
For example the Volatile Organic Analyzer was dependent on nitrogen from one of the ECLSS systems to operate. And we were not aware that ECLSS for example was gonna periodically shut down the nitrogen system to purge it and so on and they didn't know to tell us. And so we had some real hiccups for a few times
when they were maintaining their nitrogen system

and our instrument over here went crazy wondering what happened to its nitrogen supply.

Okay, one last instrument I'd like to show you is a carbon dioxide monitor.

We were asked to put this instrument on by the Environmental
Control and Life Support people

[00:32:32.266] because they felt that
their whole module sensor

[00:32:36.816] on Shuttle was not giving a true
reading of the carbon dioxide

[00:32:41.126] that the crew was
being exposed to.

[00:32:43.806] And so we got this
handheld device.

[00:32:45.576] And actually in space the crew
members can actually hook it

[00:32:48.696] into a vest or something if you
want to measure carbon dioxide,
let's say when they're exercising.

And this was used to determine if there were pockets of carbon dioxide from human metabolism and so on.

It's built by the same company that builds ugly boxes for combustion products.

As you can see, this is a very different technology though.
This is infrared spectrometry.

This is an exceptionally good instrument.

I could throw this across the room, pick it up and it'd still be calibrated.

We brought these things back and even 4 or 500 days after they were calibrated, flown and brought back, they still operate very well.
The one thing that's needed is a little filter to remove water

so that the tiny infrared cell in here gives a--

is not confused by the water being present.

And this thing is fun to play with.

Not only can you blow into it and make carbon dioxide jack it up.

This thing is kind of cute too.
Okay. Now, you can cut that out if you want.

Now I want to go on to non-hardware lessons.

I guess I might capture the hardware lessons here in summary just about briefly.

Don't let them push you to fly hardware before it's ready.

Keep it simple.

Don't depend on other people’s systems to drive your hardware
and don't use crew time
if you can help it.

Make it small, make it reliable,
and don't over promise.

And they will always
remember the failures.

Okay, non-hardware lessons.

Going into Shuttle in the early
'90s, we realized that a lot

of chemicals were
flying in the vehicle
that the crew didn't
know how to deal with it.

[00:34:47.396]
They were to escape either from
a system or from a payload.

[00:34:50.836]
So we developed what
we called the Bluebook.

[00:34:52.606]
It was about this size.

[00:34:55.316]
And for each mission, we'd make
one of this like a pamphlet

[00:34:58.766]
and give it to the BME so they
can have it at the console then.

[00:35:02.286]
And they could look up certain
chemicals in there if they were
to escape and determine how toxic they were and sort of figure out what to do.

That evolved during the Shuttle era into a hazard material summary database.

It's computerized. It's available to the crew on Shuttle and on station. It's available to the Flight
Surgeons, the BMEs and a number

of other people that use it.

Very quickly if something

leaks, the crew

or others can determine

what it is that is leaking

and what the hazard level is.

And we are in the process of

getting decals on all the pieces

of hardware up there at least

on the US side of the Station
and also on the Shuttle

[00:35:42.776] that indicate the
crew's immediate response

[00:35:47.476] if something is leaking.

[00:35:49.586]
[00:35:54.746]
One thing we learned about
building that database is

[00:35:57.616] that we always had to verify
what we thought was gonna fly

[00:36:00.126] with the PI that
was gonna fly it.

[00:36:03.816] We found before we were
doing a verification process,
we found that the PI might change their mind right before flight and slip something in on us that was never intended to be part of that experiment or we didn't know about.

So actually now what we've got is a two-tiered verification process.

When a principal investigator proposes to fly a payload
with chemicals in it, we ask them what group

of chemicals they are gonna fly and give us a list

of their proposed chemicals, knowing that not all will fly.

We do an assessment of those and then

when the experiment is packed for flight

that may be a few months before flight or it may be on the day

of launch we ask
for verification of
exactly what flew.

So that when the database
is put together for the crew
and for the Flight Surgeons
and so on, it is accurate

as we could possibly make it.

We also learned during
the Shuttle era

that we needed to be on call.

And since those days and always
there's been a NASA toxicologist

on call, there has been a
contractor mission specialist,

that is a contractor
toxicologist

who knows the details of the
experiments that are flying

and knows about the toxic
chemicals that are in there.

And we also have a
contractor hardware specialist,

always on call to deal
with whichever one
of these things might be flying.

And those people are the people that calibrate the instruments in the lab.

They know how they behave.

They know their idiosyncrasies and so on.

And they can be very valuable when an issue comes up on the orbit.
There were a number of ground based issues that pertain to toxicology during the early 1990s.

One involved the application of dimethyl-ethoxysilane to the orbiter thermal tiles that coat the underneath side of the orbiter.

What was happening was some of the workers down at KSC were getting sick
when they were injecting the tiles.

And so there was a big angst over that.

and the industrial hygenist down there called this and asked us to get involved.

It turned out that no one had done a credible tox study on dimethyl-ethoxysilane so we proposed to do
that to the Shuttle
programs in the tune

[00:38:11.976]
of about a million bucks

[00:38:14.066]
and after they swallowed
a little bit--

[00:38:17.056]
and we assured them that that's
the only way they were gonna get

[00:38:19.166]
a limit, they came up with
the million bucks for us.

[00:38:22.566]
We contracted out
a study and found

[00:38:24.256]
that it was not that toxic.
But because of the monitoring of the humans and so

on at Kennedy Space Center and the frequency of the events,

there was a fairly low level set by the American Conference of Governmental Industrial Hygenists.

We actually went to that group and proposed a TLV for BMES and got it approved.

And that has governed
the operations

[00:38:48.476]

at Kennedy Space Center since.

[00:38:51.816]

There was another issue

[00:38:52.996]

in the late '80s involving

the toxicity of Halon 1301.

[00:38:57.446]

That's the fire extinguisher

that's used

[00:38:59.326]

in the Shuttle and even now.

[00:39:01.946]

The question was

[00:39:03.036]

if inadvertently a fire

extinguisher were released
on Shuttle, how soon will
the crew have to come back?

Because we knew that this fire
extinguisher was not scrubbed

well and the answer
was we don't know

because we don't know how
toxic it is to humans.

So there's actually a human
experiment done in the late '80s

where humans were exposed,
I think it was 8 humans
for 24 hours to this material and it was very clear

that Halon 1301 was a good choice from the point of view of not being toxic to humans at reasonable levels.

And so the flight rules were modified to reduce the risk of going to a primary landing site or an emergency landing site.

Both of those events to my
knowledge have never taken place

but I'm told they're very risky.

And you don't want to go to those unless you really have to.

And so, we had a really good flight rule for Halon discharge if it were to occur.

>> The last thing I want to mention is that over the years of Shuttle, say from about 1990 until 2008 we worked
with the National Research Council Committee on Toxicology to get improved limits for the Shuttle and for Space Station.

Before this, an individual in our group was setting limits and while I had no doubt that he did a good incredible job, the pedigree of those limits was not very clear.

So we really wanted to get the endorsement of an outside group
that involved cognizant experts.

And so in front of
a panel of about 12

to 15 expert toxicologists
we developed our limits

and they are published
in a series of volumes.

The air limits look like
this and the water limits are

in a different colored booklet.

But these are all fully
documented and approved
by the National Research Council Committee on toxicology

and published by the Academy of Sciences.

And that has proven to be a worthwhile thing to do while not cheap and not without its required effort.

There was a need to stand up so to speak to some Russian limits that were a bit irrational in our opinion and because
of the pedigree of our limits we were at least able to get them

[00:41:09.136]
and the requirements for a Space Station.

[00:41:12.236]
And we hoped to return to that effort in a few years.

[00:41:16.216]
So in summary, there's a lot of things to pay attention

[00:41:22.656]
to in terms of toxicology in the Shuttle era.

[00:41:27.326]
You need to be available if you're a toxicologist

[00:41:30.026]
to support the people on flight.
And when an emergency comes up
there needs to be a tier system

where if I'm called I can call
somebody that really knows

about hardware which I don't.

If you're going to set
limits for people living
in space vehicles you must
do it in a very competent way

and in a way that
others can understand
that these are good limits and not just something you cooked up in a few minutes on your desk.

[00:41:57.166]

And I'll leave it at that.

[00:42:00.566]

Questions?

[00:42:02.356]

( Pause )

[00:42:08.056]

>> I've been asked to talk a little bit about how toxicology came to matter for the space program.

[00:42:03.516]

[00:42:09.966]

[00:42:15.676]
From the very earliest days, that would be the early 60s,

when we decided we were going to put humans

in space there was a lot of concern

about off gassing the materials that would go into the capsule.

And there are old memos from '64-'65 where there were a lot

of questions and concerns about the off gassing of hardware.

And NASA actually engaged the
in those days to set limits for the compounds that we thought might come off of materials that would off gas.

Sampling in those days consisted of this. Taking the charcoal filters that were used to clean the air during the Mercury or Gemini flight and bring them back to the lab actually where it is now.
and analyze the charcoal.

They sort the material off of there and analyzed the charcoal to get an idea of what was it one time and the air had been removed.

There were some old reports that show a list of probably a hundred compounds with a table that shows yes, they were there or no, they
weren't, but no quantification.

The limits that were given to us by the Academy of Sciences in those days were, pick a number.

They were based on very little documentation and were more or less promulgated by the fact that they were set by a presumably credible body and that that body didn't have to subject itself
to documentation

[00:43:50.836] of how they actually set the limits.

[00:43:53.076] I believe it was by the early 70s.

[00:43:57.036] We were actually beginning to think about going to Mars.

[00:43:59.876] And some of those limits were extended out to a thousand days.

[00:44:03.896] Sampling evolved to the point

[00:44:05.316] where some solid sorbent samplers were used
in a crude form on
Skylab I believe.

There was a mass spectrometer on
Skylab but it was not designed
to quantify air quality.

And then the Shuttle
came along and that's
when we got perhaps more serious
about monitoring air quality.

The drivers of that
were first of all,
there were small burn instance.

[00:44:36.326]
I believe it was STS-6,
some of the electronics

[00:44:41.066]
that were driving the
humidification system

[00:44:43.416]
or the dehumidifier pyrolyzed.

[00:44:47.036]
And if you can imagine
being in a small space

[00:44:49.776]
with something burning
and have no way out,

[00:44:52.176]
that's really not
where you want to be.
And then there were other events,

the teleprinter cable burned.

There were two burns of the data display unit on STS-35 and it was actually strong enough and smelled that it woke up the crew.

And that drives a lot of need for combustion product monitoring.
We saw a lot of volatile organics in the air of Shuttle and it was clear that if we were gonna fly vehicles for a long, long time for example, the Space Station or something, that monitoring the volatile organics would be important.

Now where do these things come from?

They come from off gassing as I said,
and that can be controlled.

If they come from payloads that leak,

they come from utility chemicals that are used.

Anywhere from deodorants, hair processing materials, body washes, sodding experiments.

There are just any numbers of sources and there are things we see in the air,
the origin of which we simply don't know.

Occasionally we see a spike of ethanol and the source of that can be speculated on.

But the Space Station era's quite a Pandora's Box of chemical pollution, usually at very low levels.

We also wanted to deal with incidences where things
that weren't exactly a pyrolysis product escaped.

That's why we've gone to volatile organic analyzers to characterize the air in situations like that.

What we've actually seen with a modern analyzer that I don't have here is we can actually follow the opening of a new module.

These tend to have a build up of pollutants
because they don't have an air cleaner in them.

So when the hatch is opened on Station...

so that the crew could enter these modules and they have been sealed up for 30 days or 45 days there's a lot of pollution in there.

And we can actually see that pollution come across Station...
and reach our analyzers that are typically in the lab and increase the values there.

So that's kind of the story of where the pollutants come from and why we monitor them. Clearly if we're going to go to a distant destination for a year and a half we're gonna have to have very small reliable analyzers.
that don't require a lot of crew time to manipulate.

Next question.

>> So why don't you just use the same kind of analyzers on orbit that we've used on the ground?

>> Well, okay let's take an example.

The instrument we use to analyze these things with covers the desktop.
And we have four instruments in my lab.

In a good day, a good day is when two of those are working very well.

GC Mass Spectrometers tend to be very fickle.

They're very complex.

So you need to fly something else and I won't elaborate on that.
There are simpler concept--
conceptually simpler analyzers

that are perhaps not as powerful

as the GC mass spec. Right now
we're flying a differential

mobility spectrometer and I
won't go into what that is

but it's a rather
robust detector

to put behind the
gas chromatograph.

And that instrument has proven
very effective on Station.
It doesn't have the analytical power of the mass spectrometer, I would say that.

But it is much smaller and it's much more reliable.

We could bet on being operating 6 months to a year from when we would fly it, whereas mass spectrometers tend to be very fragile.
Instruments of flight should draw very little power that's for obvious reasons.

You only have so much power in any vehicle and it gets distributed and shared and you only get your portion of it.

And as I said earlier you want to be independent of any resources.
For example the mass spectrometer, this being flown now has to have helium as a carrier gas and they have to bring their own gas.

We got burned with the DOA because we depended on Space Station nitrogen and that was not a reliable source all the time.

So I think that's a reasonably
long answer to your question.

[00:49:18.896]

>> So how has the role of
the toxicologist changed

[00:49:22.296]
in the early days
of space flight

[00:49:25.146]
to the Shuttle era in terms of--

[00:49:27.446]

>> Okay.

[00:49:27.996]

>> What your role is and
how you're gonna arrive

[00:49:29.946]
to this (inaudible)?

[00:49:32.126]

[00:49:34.406]
I have some knowledge of what toxicology was like let's say in the 70s and 80s.

A man named Elliot Harris was actually chief for sometime.

This would have been in the late Apollo era lead up to Shuttle.

He was Branch Chief of the toxicology branch at Johnson Space Center.

For reasons I don't know he left
and the toxicology branch disappeared and became a goob.

>> In those days, their main task was not to set limits in a lot of the things we do, it was to deal with offgassing issues and a number of other issues that had to do with developing a space vehicle like the Shuttle.

That kind of involvement has kind of taken two directions.
One direction is toward developing really credible ironclad limits that have a really strong pedigree and aren't set by an individual.

The other is to more involvement on a real-time basis with the missions. That really makes it fun to be a toxicologist here.

Right now, we're probably working three
or four relatively important issues related to Space Station right now.

And we get called into meetings and our expertise gets dissected and we have to communicate to engineers what often is rather fuzzy and uncertain data in a way that they believe it.

One incident that comes to mind is
when this little motor burned up on STS-40.

As I said before, it wasn't in the orbiter refrigerator freezer.

We really were way off track during flight as to what caused that.

The crew said this thing reeked and we can't stand it.

Eventually, we gave the crew permission to turn the thing off
and put duct tape over all
the openings and that began
to control the odor
a little bit.

We thought at that time it might
have been offgassing so to speak
from urine that was spilled
inside the refrigerator.

And when we got the unit back
and examined it, it was clear
that we were way off base.
That it was actually
a pyrolysis event.

The motor had burned up.

During the mission, a colleague
of mine, Dr. Chiu-Wing Lam

and I were called in
to deal with this issue

and I can remember
it was a Saturday.

And for whatever reason we both
had charge of our little kids.

I don’t remember
where our wives were
but we brought our little kids in here.

And so there were four bored little kids while we sat and tried to deliberate with the other people about what was going on with the orbiter refrigerator freezer.

But it was fun and I don't suppose it killed the kids.
because we didn't have the tools we needed, we were far off base

in terms of understanding what happened.

>> So, tell us-- think back over the years, followed scenarios, just tell us another shuttle story

and what might be your most memorable Shuttle memory regarding toxicology?
Well, I guess that could be good or bad.

I remember when we had gotten the CPA modified so that we thought it wasn't sensitive to hydrogen.

And then we had the problem with the data display units burning.

I was called over to Mission Control to help sort out things, and the flight sergeant was John Schultz.
And Sam Pool was the Division Chief.

Sam didn't buy tools and so, we were over there

and we were going over whether the increased carbon monoxide readings were true.

And they were high enough that if they were true, it might affect crew performance, including the pilot.
He was gonna have
to land the Shuttle.

And there was a lot of
debate going back and forth

about the levels of carbon
monoxide, the capabilities
of the pilot, should it be on
his a visor and so on and so on.

How long would it take to
wash the carbon monoxide
out if-- were in there?
Eventually, I was really impressed with Sam.

He listened to me, he listened to the surgeons,

he listened to the other people then he decided we were not
gonna trust the instrument.

We were gonna go and land as we were gonna land in the first place, and we did.

And he was right.
The message there I think is you get all the information you have

[00:54:29.856]
and you make your best decision.

[00:54:30.996]
All the information
may not be very good

[00:54:36.246]
but when it's the best you're gonna get, you gotta go with it.

[00:54:40.216]
And he made a good call in that case.

[00:54:42.396]
And we learned that you don't fly it until it's ready to fly.

[00:54:49.186]
A lot of really great things have happened
in the toxicology group

in the 21 years I've been associated with it.

I'm impressed in many ways

but let me highlight at least two of them.

One is the ability of the chemists

and the contractor team, to not only analyze samples
and device clever sampling
techniques but also to identify

[00:55:22.556]
and very carefully
scrutinize instruments

[00:55:26.216]
that we might fly onboard,

[00:55:27.626]
either the Shuttle
or the Space Station.

[00:55:30.496]
[00:55:32.126]
It takes a sense of
vision and intelligence

[00:55:36.296]
and a knowledge that's
rare in many places.

[00:55:41.376]
It has not been rare in my group
and my good fortune to work with that group has been in many cases because of those excellent analytical chemists that stay abreast of current technology and know how to adapt something for space flight.

The other thing I wanna highlight is the expertise that resides in a toxicologist that works
at Johnson Space Center.

This would be on both sides the contractor and the NASA side.

Probably one of the hardest things to do is to stand up in front of a panel of experts, perhaps a dozen or so, selected by the National Research Council to scrutinize what you're going to tell them the limit ought
to be for benzene

or carbon monoxide

[00:56:30.906]

or carbon dioxide

for that matter.

[00:56:34.656]

Survey the literature and

defend what you've concluded.

[00:56:38.076]

And I can tell you that over

the years I've gotten a lot

[00:56:40.186]

of respect for my colleagues

for being willing to do that,

[00:56:43.916]

to not be battered down if

you will by multiple spears

[00:56:49.866]

that come from experts and
to weather the storm and come

[00:56:54.526]
out on the other
end and have limits

[00:56:56.966]
that I think we can
be fully proud of.

[00:56:59.726]
And those limits
have been developed

[00:57:01.036]
for air and water both.

[00:57:03.726]
We've made some great
relationships

[00:57:06.236]
with really world
class toxicologists
because of this involvement

but I've also gained a hearty
respect for the ability

of my colleagues to go do this.

In terms of mission support,

it's probably declined a little
bit over the past few years.

We've actually tried to
put more tools in the hands

of the BME insurgent than
we had, let's say in the 90s
with the Shuttle program
and that's worked okay.

But every once in a while we
catch the BMEs maybe making a
decision that they should have
called us about but we worked

that as the case by case goes.

So, it's really been an honor
to work with these people.

>> Lets look at this real
quickly or briefly in the future

and what do you think the future
might be for toxicology and kind

[00:57:54.356] of help you out a little bit in order

[00:58:00.076] [00:58:02.896] to meet your challenges (inaudible)?

[00:58:06.736] >> You're gonna pick my whole brain (laughter) alright you go-- are you gonna fire me or something?

[00:58:11.996] [00:58:08.406] ( Laughter )

[00:58:11.996] [00:58:11.996] You will know everything I know pretty soon
and then now you
wouldn't even need me.

( Laughter )

>> That's a very good question.

Of course, the vision of where
we're going is not exactly
focused but if we are to go
to either a near-Earth object
or another distant object, let's
say Mars or even a moon of Mars.

We're gonna have to deal
with the environment there

[00:58:40.786]

and that's something unique

that we haven't had to deal

[00:58:43.036]

with in toxicology because the--

[00:58:45.536]

we bring the pollutants

with us in these vehicles.

[00:58:47.936]

But when we get to the

surface of Mars or the Moon

[00:58:51.816]

or an asteroid we're

gonna encounter dust

[00:58:55.506]

of a very unusual nature there.

[00:58:57.026]
And we're gonna have
to understand how

[00:58:58.396]
that dust affects not only
human health because unvariably,

[00:59:01.606]
some of it is gonna get
back in the habitat,

[00:59:04.006]
but also how it affects
hardware.

[00:59:05.476]
That's one of the challenges.

[00:59:07.976]
If you're gonna go even to
the Moon and stay a while,

[00:59:10.616]
you're going to have in
situ-analytical capabilities.
You're not gonna be bringing samples like this back.

It isn't gonna happen.

You're not gonna bring back formaldehyde badges.

You're gonna have to have a way to do that where the habitat is and where the crew is living.

And that is going to be a real challenge,
good, reliable,

low-powered analytical instruments

that will withstand the mission of two

or three years is not easy.

Nobody does that yet, nobody.

I think in the next five to 10 years, we will be able to do

that with a lot of confidence.

Miniaturation is
happening all the time

[00:59:49.866]
with analytical instruments.

[00:59:51.786]
And there are some
promising devices out there

[00:59:54.926]
that have a lot of capability.

[00:59:57.066]
The other thing we have to work

[00:59:58.306]
on is how the data are
presented to the crew.

[01:00:01.646]
>> They're not gonna go
around reading spectrograms

[01:00:04.846]
or complex panels
and tables of data.

[01:00:08.396]
We're gonna have to present this to them

[01:00:09.906]
in a very straightforward way.

[01:00:12.856]
And one thing I've imagined, and I think we could do it,

[01:00:16.196]
is to present the crew-- let's say data on volatile organics

[01:00:20.406]
that would say, okay, here's the risk, that you might have eye

[01:00:23.546]
and nose irritation because of the pollutants we see
in the air.

And the risk is below some threshold or above.

Or here's the risk that you might have too many simple nervous system depressants like alcohols and so on in the air.

If you're experiencing some of these symptoms, you might wanna look at your analyzer and see if it's telling you
that there's too many

[01:00:47.326]

of these compounds in the air.

[01:00:49.156]

But it needs to be
presented in a very simple way

[01:00:51.476]

that the crew can
understand and use

[01:00:54.116]

to diagnose what's
going on in the vehicle.

[01:00:57.796]

And so, there are
plenty of challenges

[01:00:59.536]

in terms of setting limits.

[01:01:04.366]
There are so many toxicologists around you could argue that they're constantly devising new ways to set presumably better limits and of course, new data are coming along all the time with the compounds that we're interested in. So probably, every 5 to 10 years, we need to read these at the limits we've got already and see
if they need to be refined.

And in fact, I'm planning in 2012 to restart the effort that we stopped a few years ago with the National Research Council.

Although we may use a different body but limits have to be kept up to date, limits that are 10 years older are too old.

There're too many
things changing.

[01:01:42.786]
So, it's-- what's going to
go away is archival sampling.

[01:01:50.696]
You know, one day we're gonna
be on the Moon or we're gonna be

[01:01:52.776]
on an asteroid somewhere

[01:01:53.996]
and there's not gonna be huge
GC mass spectrometers back

[01:01:58.386]
in the lab to do samples.

[01:01:59.836]
We won't be doing it that way.

[01:02:01.446]
And now, we guess that
ISS ends which is either 2020 or 2028 we could keep it functioning that long.

So, there is the vision.

>> So, what are some of the promising technologies that you have out there at the--

>> Okay.

( Inaudible Remark )
There's-- some of my colleagues would argue that there are optical techniques that will do a better job of monitoring combustions product than electrochemical sensors.

And as I said, electrochemical sensors have their idiosyncrasies and sometimes it even matters who is building the
back the company.

[01:02:44.386]
If there-- there's a bit of
what I call the witchcraft

[01:02:46.926]
to building those things.

[01:02:48.016]
And it's-- if the craftsman
changes, the sensors change.

[01:02:53.396]
Optical techniques are
a little more robust.

[01:02:55.846]
Unfortunately, the optical
monitors I've seen are

[01:02:58.526]
about four or five
times as big as this
to do one or two compounds.

That's gonna be too big.

They're gonna have to shrink.

And as for combustion products,
we are gonna have a panel
in a few months to go
over all the technologies
with outside experts and
see what we've missed
and see what's most promising.
In terms of volatile organics,

we do fly a gas comatograph

a differential mobility

spectrometer that I think

shows a lot of promise.

It could miniaturized

even further.

I've seen a handheld instrument.

Well, the one we fly now

is maybe about as big

as this thing-- are

going to fly,
its government furnished equipment.

It's gonna have a little screen on it that will communicate to the crew if any of the pollutants are out of line and so on.

But I've seen one that the company is building that's a fifth maybe an eighth of that size,
a really handheld volatile organics analyzer.

Will these be reliable enough?

I don't know, experience will tell us.

GC mass spectrometry, very powerful technique although the thing people forget is that it's sometimes blind to important compounds.

GC mass spectrometers are not the see all
and end all of everything.

They are complex, they are fickle and they can be a challenge I think to make in a reliable and dependable way.

There are other techniques that might be useful. Some people have built a membrane inlet
mass spectrometer.

Now, these mass spectrometers tend to be simpler than the more complex ones that are behind a gas chromatograph column and they show some promise.

The issue is what the membrane will let in and what it won't and what happens to the membrane if it gets a high dose.
of some compound action will in the membrane

and then the mass spectrometer fails because it gets overdosed

on a compound that was not meant for that.

There is an optical technique called Fourier Transform Infrared Spectrometry that has been used by the Europeans to fly a rather large instrument on Station.
It gets the spectrum of everything in the air that exhibits an FTI or spectrum and then deconvolutes those.

I think it was moderately successful when it flew on Station.

There were some surprises to the group but they were able to figure out those surprises and figure out for example that one of the compounds that they were seeing was a compound that leaks.
from the Russian Service

Module air conditioning system.

I suppose you could argue there
is a bit of witchcraft there.

To my knowledge, there are
maybe one or two individuals

in the world that can
deconvolute the spectra

and make sense of them.

That's not good.

That in fact, that's always
an issue with ground-based

or instruments that are gonna fly on-- in near-earth orbit.

Do you have the people on the ground to sustain those instruments and deal with whatever analysis they produce?

And that can be a question, if you have a company build it.

If the company fails, you're sunk.
If you have an exotic team at some high-level lab build it,
is that team gonna exist three years from now when your instruments are giving you fits.
There are a lot of questions with how to sustain these things.
So anyway, that's kind of a toxicologist
survey of techniques.
The video is currently secured in the following temporary area for ease of viewing, but will be moved eventually.

http://sd.jsc.nasa.gov/doclib/sa/sf/Educational_Series/SF_Discipline_Videos/Shuttle_Exp_Space_Toxicology.wmv