SHUTTLE LESSONS LEARNED – TOXICOLOGY

[00:00:00.506]

(Silence)

[00:00:05.046]

>> Okay. I've been asked to

talk about the toxicology

[00:00:08.346]

and the lessons we've

learned from the Shuttle.

[00:00:11.816]

My own experience has gone from

about 1989 to the present, 2010.

[00:00:16.976]

I divided this into

four segments.

[00:00:19.166]

The first segment is gonna deal

with dust in the space vehicle

[00:00:22.736]

and how we've managed

that and learned about it

[00:00:24.686]

over the decades or so

that we've studied it.

[00:00:27.616]

The next segment will

be archival samples,

[00:00:30.716]

that is methods that we

have used and developed

[00:00:33.446]

to sample the air during a

flight, bring back the samples

[00:00:36.616]

and analyze them after

the mission is over.

[00:00:39.986]

This has clear limitations

if you're trying to diagnose

[00:00:42.536]

and troubleshoot a

problem to get data

[00:00:46.236]

that are three or

four months old.

[00:00:48.276]

It's just not very useful.

[00:00:50.986]

Then I'll go on to talk about

real time on-board analyzers

[00:00:54.136]

that give us a lot of capability

in terms of monitoring

[00:00:56.626]

for combustion products and some

of the lead end to being able

[00:01:01.266]

to monitor volatile

organics on the station

[00:01:04.446]

where we've developed a lot

[00:01:05.376]

of the techniques improving

them on the Shuttle.

[00:01:08.006]

And then finally, I'll pick

up some bits and pieces

[00:01:10.326]

that don't have anything to do

with hardware but have to do

[00:01:13.356]

with other lessons we've learned

about setting limits and dealing

[00:01:17.046]

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,

[00:01:30.516]

from the vacuum cleaner, it

would look something like this.

[00:01:34.786]

You'll see in here a

lot of fiber particles.

[00:01:36.926]

There are clearly

some food particles.

[00:01:39.106]

If you were to look closer,

[00:01:40.396]

there would be a few

metal shavings and so on.

[00:01:42.856]

And this particular sample was

taken in order to determine

[00:01:46.706]

if rat food bar pellets

[00:01:49.946]

or pieces were getting

out into the cabin.

[00:01:51.926]

This was during an experiment

[00:01:53.136]

when there was a

rat habitat onboard.

[00:01:55.816]

And we're actually able

to discern a few particles

[00:01:58.656]

that looked like rat

food and pulled them

[00:02:02.076]

out from the mess

I just showed you.

[00:02:05.476]

But to look like a rat

food bar is not enough.

[00:02:08.026]

And what we did was use

GC mass spec pyrolysis

[00:02:11.726]

to identify a spectrum

for these particles

[00:02:14.946]

and for rat food bar

material that we knew about.

[00:02:18.806]

And we're able to identify

with high confidence

[00:02:21.466]

that in fact the pellets

[00:02:23.206]

from the rat food

bar were getting out.

[00:02:25.736]

That was no big deal

because there weren't

[00:02:28.126]

that many pellets actually.

[00:02:30.846]

There was a concern early on

in the '80s about the particles

[00:02:35.956]

in the Shuttle and

particularly having to do

[00:02:39.206]

with the respirable

particles which are those

[00:02:41.136]

that are less than 5 microns.

[00:02:45.346]

Then Lou and some other experts

at the University of Minnesota

[00:02:49.126]

and some monitors here at

JSC got a flight together

[00:02:52.946]

and there were two

instruments on that flight.

[00:02:54.486]

One was the cascade impactor

[00:02:56.366]

which would partition

the particles according

[00:02:58.586]

to their size and

another one was

[00:03:00.416]

to measure the wall

concentrations.

[00:03:02.636]

This is the instrument

that was used

[00:03:04.046]

to measure the wall

concentrations

[00:03:06.126]

and follow them overtime.

[00:03:08.036]

The experiment was

very successful

[00:03:09.856]

from the very beginning and

gave us two good reassurances

[00:03:13.976]

about dust particles.

[00:03:15.236]

First of all, the concentration

in the air was not so high

[00:03:18.486]

that it would be a threat to

crew health, and in addition,

[00:03:21.486]

the concentration

[00:03:22.506]

in the respirable size was well

below any standards we would set

[00:03:26.696]

for the Shuttle.

[00:03:28.516]

(Pause)

[00:03:35.246]

>> Eventually, the large

floating particles,

[00:03:38.446]

they came a nuisance

to the crew.

[00:03:40.206]

And so in the mid late '90s,

[00:03:42.566]

something called the orbiter

cabin air cleaner was developed.

[00:03:46.106]

This was a large unit

that fit in the opening

[00:03:48.226]

between the mid-deck

and the flight deck.

[00:03:52.506]

It had the advantage that

yes indeed it cleaned

[00:03:54.796]

out the large particles

but it was noisy

[00:03:58.056]

and the crew didn't always

welcomed its presence,

[00:04:01.206]

but it did get rid of

the dust such as it was.

[00:04:05.486]

Now, I wanna go on

and talk a little bit

[00:04:07.046]

about archival samplers.

[00:04:08.666]

These are samplers that are

used on orbit by the crew

[00:04:12.086]

and we bring back samples

and analyze them on orbit.

[00:04:15.436]

In 1985, the toxicology

group patented this device

[00:04:19.086]

which we call the solid

sorbent air sampler.

[00:04:22.226]

[00:04:26.546]

This was to enable

the crew to take

[00:04:28.176]

up to 7 samples during a mission

and they had to turn this dial

[00:04:33.746]

to select which sampler they

wanted to load the air sample

[00:04:37.736]

onto and then 8 was

a parking position,

[00:04:40.296]

they could use that

for a sample.

[00:04:42.286]

The way this thing function

was this - there was a holder

[00:04:48.616]

for batteries right

here, two B-size cells.

[00:04:53.386]

There was a pump here, something

like what you might have

[00:04:56.096]

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.

[00:05:20.966]

[00:05:22.166]

Problems with this were

primarily concerning the pump.

[00:05:25.616]

We measured the flow before and

after flight, and oftentimes,

[00:05:30.296]

the flows didn't

match very well.

[00:05:33.076]

We, for a while, thought

that maybe that was due

[00:05:36.596]

to obstruction getting into

these tubes when we drew air in

[00:05:39.966]

but we had a very good

filter over the end of it.

[00:05:43.366]

And eventually, we concluded

[00:05:44.786]

that the way we were actually

doing the measurements

[00:05:46.616]

in the lab was not sufficiently

consistent, and so we worked

[00:05:50.246]

that over and got

this to go very well.

[00:05:53.146]

We did fly this for

a number of times

[00:05:55.326]

on the Shuttle-Mir Program.

[00:05:57.266]

One adaptation we made for

Mir was that there were a lot

[00:06:01.546]

of floating dust

particles in Mir.

[00:06:04.296]

And what also would later appear

to us to be liquids and food

[00:06:08.446]

and so on, and often the inlet

would get plugged up on Mir.

[00:06:13.216]

And so what we devised

was actually an inlet

[00:06:15.606]

with 5 ways in.

[00:06:16.956]

If you look at this, there

are the 4 ways around

[00:06:19.786]

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

[00:06:43.596]

after the SFOG fire.

[00:06:45.566]

And if you could look

very closely on this,

[00:06:47.386]

he notes where the

fire occurred.

[00:06:49.336]

We'd had two routine

samples before the fire

[00:06:52.616]

and then he notes here

that the fire occurred.

[00:06:54.756]

And he used it on a very

carefully worked out sequence,

[00:06:58.246]

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

[00:07:40.006]

to automatically take samples

once the unit got on orbit.

[00:07:44.346]

It turned out it was too large

[00:07:45.746]

and too cumbersome

to actually fly.

[00:07:47.906]

Test in the lab indicated

it was pretty good,

[00:07:50.136]

but we learned a couple lessons.

[00:07:52.816]

One, you can't fly really

big things no matter how much

[00:07:56.026]

you want.

[00:07:57.126]

And we knew that

krypton was important

[00:08:01.036]

but this did not have

enough gain in terms

[00:08:03.386]

of not using krypton to

actually get it flown.

[00:08:07.876]

The other goal of

flying things on orbit is

[00:08:11.846]

to get things smaller.

[00:08:13.936]

There were thin ground

base testing on a lot

[00:08:15.956]

of labs had used something

we call the archival

[00:08:19.026]

organic sampler.

[00:08:20.066]

We flew a cluster of these, and

the idea with these things is

[00:08:25.216]

that you would not

need the pump.

[00:08:26.686]

Remember I said the pump

[00:08:27.986]

in the solid sorbent air sampler

was a little bit of a problem.

[00:08:31.526]

That these would actually

capture sample by diffusion

[00:08:35.996]

through a very tiny hole that

I think probably is difficult

[00:08:38.956]

to see that there's a tiny hole

right in the middle of this.

[00:08:41.926]

And the idea is that pollutants

would diffuse across this

[00:08:44.626]

into a trapping resin below it

[00:08:47.276]

and then the crew would

simply see what back up

[00:08:50.066]

and we would get it back in lab

[00:08:51.426]

and analyze the pollutants

in the resin.

[00:08:53.906]

Two problems with this, one,

they weren't sensitive enough

[00:08:56.616]

to capture the level

[00:08:57.576]

of pollutants we

would see on Shuttle.

[00:08:59.496]

And two, things like this right

here actually release enough

[00:09:02.976]

pollutants that it

contaminated the trapping resin.

[00:09:07.206]

And so we tried to use

these but they didn't work.

[00:09:11.426]

Now, one last sorbent effort

was conducted after Columbia.

[00:09:19.366]

Shuttle had been one of the main

ways we were getting samples

[00:09:21.966]

down from the station, but

when Columbia occurred,

[00:09:26.166]

the Columbia accident, we

had to very quickly get away

[00:09:28.986]

to bring back samples.

[00:09:30.866]

Samples had been coming back

in this grab sample canister

[00:09:34.346]

that I'll talk about

in a minute,

[00:09:35.546]

but we needed a much smaller way

[00:09:37.186]

that we can get back

samples on Soyuz.

[00:09:39.866]

So, in a period of about a month

or two, we went from concept

[00:09:44.066]

to ready to fly with something

we call the archival released

[00:09:49.446]

with just dualsorbent samplers.

[00:09:52.356]

We call them dualsorbents

because of instead of like this

[00:09:55.856]

with one sorbent material,

[00:09:57.006]

we actually had two

sorbents in here.

[00:09:59.426]

We had a pump that would fly

and this would go back and forth

[00:10:02.876]

and the crew would pull

the ends off of these

[00:10:05.326]

and aspirate the sample through

[00:10:07.136]

and then you can see

the heat marks here.

[00:10:08.086]

>> Once these are brought

back, the tubes are heated,

[00:10:11.376]

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

[00:10:32.626]

if the samples were more

than about a month old.

[00:10:35.506]

But oftentimes on Station,

we wouldn't get samples back

[00:10:38.156]

until they were three

or four months old,

[00:10:40.196]

and a lot of the volatile

organic polar compounds

[00:10:43.636]

declined rapidly.

[00:10:44.916]

We never did figure

out where they went,

[00:10:47.446]

we developed correction

factors for those pollutants.

[00:10:51.626]

But because of that,

it made measurements

[00:10:53.696]

that much more uncertain, and

we eventually abandoned this.

[00:10:57.136]

It's not sufficiently accurate.

[00:11:00.706]

[00:11:05.176]

Now, I wanna move on to

a new kind of sampler.

[00:11:07.726]

These samplers didn't

require a sorbent that as

[00:11:12.836]

such to capture the sample.

[00:11:15.376]

In the 1980s, we were using

something we affectionately

[00:11:18.056]

called the "sausage."

[00:11:20.026]

And this would-- we

would evacuate the inside

[00:11:22.816]

of this canister here

and the crew member

[00:11:25.636]

to get a sample would remove

the dust cap, most of the time,

[00:11:31.306]

open this valve, and the sample

would be aspirated in here.

[00:11:36.006]

We learned a few things.

[00:11:37.606]

One is that the crew members

like to unscrew this too far,

[00:11:41.316]

hence we added this little arm

so that that's impossible to do.

[00:11:45.866]

The other problem that we never

really solved because we have

[00:11:48.476]

to have a dust cap here, is

[00:11:50.646]

that occasionally the

crew member would forget

[00:11:52.516]

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

[00:12:18.726]

to surface area configuration.

[00:12:20.816]

And one of the problems

with the sausage was

[00:12:23.816]

that we were afraid some

[00:12:25.946]

of the pollutants were

actually adhering to the walls

[00:12:29.206]

of the canister and

we couldn't see them.

[00:12:31.866]

So we started using these

brown canisters in the 1990s.

[00:12:37.856]

And you could see again,

here's the dust cap,

[00:12:39.706]

this particular version

doesn't have the arm

[00:12:41.756]

to prevent this from coming off.

[00:12:44.256]

The other issue that this

solved was that this--

[00:12:46.816]

there's a metal to

metal contact in here.

[00:12:49.046]

And if any dust does get in here

when the sample is acquired,

[00:12:52.956]

then when the crew member

goes to seek this valve back,

[00:12:56.566]

[00:12:58.886]

the dust-- piece of dust

gets trapped in there

[00:13:02.266]

and occasionally we will

lose a sample that way.

[00:13:05.126]

The other thing is the metal to

metal valve actually got ruined

[00:13:08.046]

from time to time because

the crew members would

[00:13:10.076]

over tighten the shut valve.

[00:13:13.646]

So now you can see

there's a clutch here.

[00:13:15.416]

And this is very much

like your gas cap

[00:13:17.826]

if you've got a relatively

moderate car.

[00:13:19.956]

You can only tighten it so far

[00:13:22.136]

and then it clicks

and you're done.

[00:13:24.496]

These still are in service.

[00:13:25.726]

We use these on the

International Station

[00:13:27.796]

and we use this on Shuttle now

[00:13:29.746]

to bring back an

end-of-mission sample.

[00:13:32.526]

[00:13:36.556]

We did try for a period of

time to heat the walls of these

[00:13:40.416]

to dry the can-- some of the

pollutants that may have gotten

[00:13:43.416]

on the interior walls but

that brought in a host

[00:13:46.506]

of other problems, and so we

eventually abandoned the idea

[00:13:49.446]

of heating the walls

of these things.

[00:13:52.536]

Now, I wanna step

back just a second.

[00:13:54.266]

This is another sorbent method

that came along in the 1990s.

[00:13:58.356]

One of the compounds that sticks

to the walls of these things

[00:14:00.846]

that is very difficult to

quantify is formaldehyde.

[00:14:03.686]

But formaldehyde is an important

component of offgassing

[00:14:06.826]

and is also released in

some of the curing processes

[00:14:10.886]

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

[00:14:39.846]

by spectrophotometry in the lab.

[00:14:42.596]

Problems with these badges

are that they are small

[00:14:45.326]

and they sometimes get lost.

[00:14:46.626]

They've found these badges

that have been opened for weeks

[00:14:50.006]

or even months, tucked in

somewhere in the station.

[00:14:55.206]

They-- we push the limit of

detection with these badges also

[00:14:59.116]

so that we use them in pairs

for more accurate readings.

[00:15:02.336]

But they still are

used on Space Station.

[00:15:04.716]

We did use them for a

period of time for example

[00:15:07.096]

in the extended duration

orbiter program of the Shuttle

[00:15:10.386]

and we found that formaldehyde

was not a problem then

[00:15:12.706]

on Shuttle at least within the

limits that we had set then.

[00:15:20.916]

We did have an experience

with these.

[00:15:22.616]

We were using these in a

Lunar-Mars Life Support Test

[00:15:27.006]

on the ground and a lot of

formaldehyde was being released

[00:15:31.256]

as it turned out from some of

the acoustic materials and some

[00:15:34.586]

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.

[00:15:51.346]

And we used the gold

standard method that's--

[00:15:54.356]

a wet chemistry method which you

could never use in space to show

[00:15:57.906]

that in fact these badges were

given very accurate readings

[00:16:00.896]

and so we trust them a lot.

[00:16:03.016]

[00:16:05.406]

Now, I wanna move

on from samplers

[00:16:08.456]

to actual analyzers on orbit.

[00:16:11.286]

We experienced a

number of issues

[00:16:15.696]

that involved small

combustion events

[00:16:19.376]

in the late 1980s

and early 1990s.

[00:16:23.836]

This is a picture from

STS-28 which flew in 1989.

[00:16:27.986]

If you look carefully,

what's happened here is

[00:16:32.216]

that a wired junction with a

sleeve of Teflon has pyrolyzed.

[00:16:37.666]

It was actually out in the or--

general space in the Shuttle

[00:16:42.396]

and the crew was very

aware when this happened

[00:16:44.606]

because it arched, it sparked.

[00:16:46.476]

It made a little smoke and it

definitely got their attention.

[00:16:50.006]

This and a few other

events something like this

[00:16:52.306]

but much less sharp-- much

more subtle impelled us to try

[00:16:57.656]

to get some real time onboard

analysis of combustion products.

[00:17:03.366]

Another event that

got our attention was

[00:17:06.106]

when a motor failed in the

orbiter refrigerator freezer.

[00:17:09.506]

This is a picture of that motor.

[00:17:12.366]

[00:17:13.386]

And what happened is that

there was no thermal protect

[00:17:16.416]

on the motor and the sleeve that

this thing was driving that went

[00:17:19.936]

to the fan seized up against its

sleeve and the motor kept trying

[00:17:24.436]

to turn the shaft but could not.

[00:17:26.126]

It got hotter and hotter.

[00:17:27.326]

This is a Delrin case here.

[00:17:30.186]

And one of the best ways in the

world to make formaldehyde is

[00:17:33.466]

for Delrin to be heated.

[00:17:35.586]

And so this thing made copious

amounts of formaldehyde.

[00:17:37.956]

You can see where the plastic

structure is actually destroyed

[00:17:40.516]

here and so the electronics

up here were destroyed.

[00:17:45.216]

This was on STS-40.

[00:17:47.386]

It's my judgment that the

mission would have been cut

[00:17:49.466]

short had the crew not

had a place to go outside

[00:17:52.526]

of the module where

this event occurred

[00:17:55.216]

to escape the bad

smell from this.

[00:17:58.966]

And actually I had this

thing in my lab for a while.

[00:18:02.096]

And it-- even through the bags

that we had in containment,

[00:18:05.096]

there were a lot of clearly

small noxious compounds

[00:18:08.346]

that would get to the bag.

[00:18:10.096]

So, anyway, in the early '90s,

there was a lot of impetus

[00:18:13.206]

to get something up there to

measure combustion products.

[00:18:19.436]

Our first attempt to

that is shown here,

[00:18:22.766]

we call it the combustion

products analyser.

[00:18:25.616]

It did 4 compounds.

[00:18:27.506]

It did hydrogen fluoride,

hydrogen chloride,

[00:18:30.006]

hydrogen cyanide,

and carbon monoxide.

[00:18:33.126]

We looked at the products

of combustion or the kind

[00:18:36.186]

of materials that we

thought might burn on orbit

[00:18:38.526]

that would be primarily

wire insulation

[00:18:41.366]

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

[00:18:48.926]

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

[00:18:59.256]

manager for the Shuttle and

saying hey we've got a problem

[00:19:03.076]

with this combustion

stuff, we've got an analyser

[00:19:05.326]

that we think we can fly.

[00:19:07.826]

His question is how

much money do you need.

[00:19:10.436]

We told him.

[00:19:11.036]

He gave us more than that,

[00:19:13.366]

and we were flying this

thing within a few months.

[00:19:15.616]

No boards, no mess,

no fluff, go do it.

[00:19:20.766]

So we flew this.

[00:19:22.076]

There was a downside,

it turned out.

[00:19:24.626]

We asked. We knew the

carbon monoxide sensor

[00:19:26.936]

on this thing was

sensitive to hydrogen.

[00:19:29.606]

We asked the ECLSS guys,

the Environmental Control

[00:19:32.116]

and Life Support guys, is there

any hydrogen in the Shuttle?

[00:19:35.176]

No, there's no hydrogen

in there, he says.

[00:19:37.836]

Okay, so we're not gonna worry

[00:19:39.656]

about the hydrogen

cross sensitivity.

[00:19:41.336]

So, we flew this baby and

the carbon monoxide sensor,

[00:19:44.436]

which is the electrochemical

sensor

[00:19:45.876]

like all the others gave

us a pretty strong reading

[00:19:48.176]

of carbon monoxide that

gave us some anxiety.

[00:19:51.206]

And when we got back and

looked for hydrogen in this,

[00:19:55.316]

which we had never looked

for before in this canister,

[00:19:57.636]

we discovered that yeah, barely

there is a lot of hydrogen

[00:20:00.416]

in the Shuttle that accumulates

[00:20:01.986]

from human metabolism

and other processes.

[00:20:05.046]

>> So we had to correct

the electrochemical sensor

[00:20:07.156]

in this thing for the hydrogen

cross sensitivity while a

[00:20:10.646]

mission was coming up.

[00:20:11.646]

And we tried to change

the bias voltage

[00:20:14.526]

in the electrochemical sensor

and we thought we had done that.

[00:20:17.046]

We did a very quick

test and it seemed

[00:20:19.836]

like it was gonna work well.

[00:20:22.726]

Unfortunately, we picked the

first flight of that to be one -

[00:20:25.366]

I think it was STS-35 for

two data display units.

[00:20:28.656]

It had a pyrolysis issue.

[00:20:30.466]

And this instrument gave

carbon monoxide readings

[00:20:34.436]

that we will say in

the interesting level.

[00:20:36.716]

And it caused a lot

of the anxiety.

[00:20:38.786]

And we eventually

concluded indirectly

[00:20:42.516]

that it really wasn't

carbon monoxide.

[00:20:44.576]

There wasn't enough

of that in the air

[00:20:45.896]

to set this thing off

but it was hydrogen.

[00:20:48.446]

But a lot of attention

was drawn into this.

[00:20:51.406]

And I would say a lot

of negative publicity.

[00:20:54.456]

If in case I forget

to say it later,

[00:20:56.246]

one of the things we've learned

is if you have an instrument

[00:20:58.956]

that performs 90 percent of the

time and it fails 10 percent

[00:21:02.656]

of the time, they'll

remember the 10 percent.

[00:21:05.016]

And if you build a

subsequent version of it,

[00:21:08.346]

you want to call it

by something else.

[00:21:10.326]

You do not want just

to call it CSACPII.

[00:21:13.226]

Lesson learned, good politics.

[00:21:15.246]

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

[00:21:39.596]

that involved the Trace

Contaminant Control System

[00:21:42.456]

on Mir.

[00:21:44.056]

Basically, a filter that had a

cellulose plate in it was moved

[00:21:47.786]

into a hot stream prematurely

and the cellulose plate burned.

[00:21:52.286]

This caused a little bit

of smoke in the cabin

[00:21:54.036]

but nobody thought

much about it.

[00:21:56.786]

The crew seemed to be fine.

[00:21:58.466]

But later that evening

and the next morning,

[00:22:01.696]

crew members complained

of headache and nausea

[00:22:03.776]

and those symptoms

are consistent

[00:22:05.196]

with carbon monoxide poisoning.

[00:22:06.746]

And it turned out readings

with this instrument

[00:22:09.506]

that was still being flown

[00:22:10.396]

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,

[00:22:27.636]

with appropriate hydrogen

correction give us really

[00:22:29.956]

good readings.

[00:22:32.216]

The lesson there was

not only instrumental

[00:22:34.296]

that is be careful what you

fly, make sure it's as ready

[00:22:37.446]

as it can be, and if

it's an experiment,

[00:22:40.326]

make sure everybody

knows it's an experiment

[00:22:42.816]

and not a ready-to-go hardware.

[00:22:45.816]

There was a lesson there though.

[00:22:47.586]

The Solid Fuel Oxygen Generator

Fire that was associated

[00:22:51.156]

with this was an in-your-face

fourth-of-July type fire.

[00:22:54.136]

It was an obvious fire that

was clearly an immediate threat

[00:22:58.146]

to the entire Mir spacecraft.

[00:23:01.066]

The Trace Contaminant Control

Fire was a much smaller event,

[00:23:05.186]

and we didn't think much of it.

[00:23:06.506]

But toxicologically, it

was much more serious.

[00:23:09.466]

If the carbon monoxide levels

had been twice what they were

[00:23:12.146]

on Mir, it could have

been lethal to the crew.

[00:23:14.546]

That's how high the carbon

monoxide levels were.

[00:23:17.276]

As we flew this over the yeas

we learned one more lesson I'm

[00:23:21.206]

reminded of here,

this piece of tape

[00:23:22.936]

which is not a very

sophisticated solution

[00:23:25.996]

but worked.

[00:23:27.286]

Sometimes as this

machine was shipped,

[00:23:30.286]

it seemed that people

would either play with this

[00:23:32.496]

or the switch would get moved.

[00:23:35.166]

And so by the time the crew

got it on orbit, it was on

[00:23:38.076]

and the battery was dead.

[00:23:39.736]

So this rather inelegant

but effective solution was

[00:23:43.546]

to put a piece of tape over.

[00:23:45.746]

Simple, cheap makes

you change the drawing.

[00:23:49.016]

That's about it.

[00:23:50.456]

Alright. So, those

were the early days

[00:23:51.746]

of combustion products

monitoring.

[00:23:54.036]

In between there, there was

fear of moving contaminants

[00:23:57.486]

that were outside the

vehicle into the vehicle.

[00:24:00.626]

This was particularly

on Space Station

[00:24:02.796]

but also applied to Shuttle.

[00:24:05.586]

We flew to monitor propellants

particularly hydrazines,

[00:24:10.846]

a derivative of a chemical agent

monitor used by the military.

[00:24:14.156]

This is like a large flashlight.

[00:24:15.906]

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

[00:24:38.046]

to make it respond faster.

[00:24:39.656]

We had changed the

dopant in here

[00:24:42.236]

but the estimate I

think was something

[00:24:43.866]

like a half a million dollars

and the program decided

[00:24:46.366]

that they weren't gonna pay

that much for the modifications.

[00:24:49.466]

So this never flew as

actual flight hardware

[00:24:51.736]

but only as an experiment.

[00:24:53.516]

(Pause)

[00:25:03.646]

>> Years of work with

this gave us some wisdom

[00:25:06.956]

about selecting a new

combustion products analyzer,

[00:25:11.666]

which we did not call a

combustion products analyzer.

[00:25:15.246]

Somewhat awkwardly we called it

the compound-specific analyzer

[00:25:19.316]

for combustion products.

[00:25:21.166]

So that it was not

tarred with the reputation

[00:25:24.706]

that this instrument got,

I think undeservedly.

[00:25:27.446]

We made mistakes

in rushing it on.

[00:25:29.496]

But this was a pretty

good instrument.

[00:25:31.276]

The one failing that

we saw as a chemist was

[00:25:33.906]

that the hydrogen fluoride

sensor never worked right.

[00:25:36.316]

Hydrogen fluoride is

important to monitor

[00:25:38.556]

because it's a key product

from wire insulation burning.

[00:25:42.986]

We struggled to get a

hydrogen fluoride sensor

[00:25:45.086]

that would work and

we never did.

[00:25:47.006]

We went to another instrument

shown here, a good bit smaller

[00:25:51.606]

and much lighter, but there

still is no hydrogen fluoride

[00:25:55.086]

sensor available

for these units.

[00:25:57.476]

Instead, we replaced that

sensor with an oxygen sensor.

[00:26:01.016]

We felt that during a

real fire, a big fire,

[00:26:03.376]

there might be a consumption

of oxygen and that would need

[00:26:05.596]

to be followed by the crew.

[00:26:08.386]

So in this one, we've got a

hydrogen compensated carbon

[00:26:12.796]

monoxide sensor, a

hydrogen cyanide sensor,

[00:26:15.856]

and what we call a

hydrogen chloride sensor,

[00:26:18.626]

but it actually detects all acid

gases such as hydrogen bromide

[00:26:23.096]

and hydrogen fluoride.

[00:26:24.296]

So in a sense, we've

got hydrogen fluoride

[00:26:26.206]

covered indirectly.

[00:26:28.396]

Like the CPA, these are

electrochemical sensors.

[00:26:32.936]

We learned some other

features we wanted.

[00:26:35.546]

One thing we wanted

was a zero filter.

[00:26:39.026]

This goes on a pump head.

[00:26:40.446]

I will show you what

that looks like.

[00:26:44.466]

This pump head fits

right over the unit.

[00:26:48.326]

It should come in like this,

and actually pumps gases

[00:26:53.606]

over these electrochemical

sensors.

[00:26:57.166]

And this particular picture

shows the zero filter in place.

[00:27:01.516]

The zero filter was

necessary to make sure

[00:27:04.986]

that as we were looking at

the atmosphere after a fire,

[00:27:08.376]

we could actually zero

this unit and be sure

[00:27:11.306]

that the carbon monoxide

sensor would re-zero properly.

[00:27:15.306]

And we build this and test

this in our lab even now.

[00:27:19.566]

The other issue with that

device was how to get a sample

[00:27:25.186]

from behind somewhere

where there was a fire.

[00:27:28.076]

This is a wand.

[00:27:29.676]

We hook it to the pump

which hooks to this device.

[00:27:33.296]

And using this attachment, we

can sample in-behind panels

[00:27:37.736]

and so on if that's where we

think the fire is originating.

[00:27:40.626]

To my knowledge, this has

only been used once or twice.

[00:27:43.596]

And it was shown that wherever

the crew thought the carbon

[00:27:47.696]

monoxide was coming from, it

was not coming from there.

[00:27:51.986]

One other issue with this

analyzer was whether it ought

[00:27:56.766]

to alarm, where it

ought to alarm and how.

[00:28:00.126]

There is a caution and warning

system in the Space Station.

[00:28:04.396]

And we asked the question,

[00:28:07.726]

okay is this thing loud

enough to be heard?

[00:28:10.826]

Do we need to plumb it

into caution and warning?

[00:28:13.406]

One thing we've learned is if

you're gonna plumb something

[00:28:16.336]

into a distributive system

like caution and warning,

[00:28:19.436]

you're gonna pay a real price

in dollars and in anguish

[00:28:23.426]

to get it into that system.

[00:28:24.616]

So if you can make a stand-alone

analyzer, it's a good thing.

[00:28:28.046]

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.

[00:29:11.636]

For sometime, this was

actually on all the time.

[00:29:15.916]

It's the first alert monitoring.

[00:29:17.626]

Now it is not.

[00:29:18.666]

These are deployed around the

station and there are 4 of them.

[00:29:21.426]

And I think only one

flies on the Shuttle now.

[00:29:24.226]

For a while, we flew

two of them.

[00:29:28.736]

Okay. That's combustion

products analyzer.

[00:29:31.556]

We are looking for

improvements on this.

[00:29:34.096]

It will be hard to beat this.

[00:29:36.936]

Electrochemical sensors

are a little bit squirrely

[00:29:39.076]

in the sense that they

are not always specific

[00:29:40.776]

for a given compounds.

[00:29:42.366]

And sometimes if you

overdrive them with a huge dose

[00:29:45.136]

of what they're measuring,

they misbehave.

[00:29:49.046]

But right now, there's

good as there is out there.

[00:29:52.186]

[00:29:53.536]

We knew that on Space Station,

[00:29:55.436]

the crew would be there

a long time and we wanted

[00:29:57.516]

to fly an analyzer

for volatile organics.

[00:30:01.176]

[00:30:02.706]

>> The program asked us if

we wanted to fly as part

[00:30:05.456]

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

[00:30:34.686]

by very smart ground

controllers,

[00:30:37.546]

can fix a really

complex instrument.

[00:30:41.596]

This thing has flown now

for 8 years on Station

[00:30:44.076]

and has performed well.

[00:30:46.226]

Two lessons we learned here.

[00:30:47.496]

One, this was a one

of a kind bill

[00:30:49.386]

that cost several million

dollars for each instrument.

[00:30:52.376]

It's very expensive,

extremely complex.

[00:30:56.426]

Safety required us to put

a lot of fuses in here

[00:30:59.216]

and I'm not gonna attack

their wisdom, but it tended

[00:31:01.876]

to be the fuses that failed

and not the instrument itself.

[00:31:05.956]

Complexity is something to

stay away from if you can.

[00:31:10.396]

The other thing we

learned is about crew time.

[00:31:12.986]

This thing could be

programmed from the ground

[00:31:16.796]

and operate independently

of the crew.

[00:31:19.526]

So we got a lot of samples.

[00:31:20.926]

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.

[00:31:50.366]

For example the Volatile

Organic Analyzer was dependent

[00:31:53.026]

on nitrogen from one of the

ECLSS systems to operate.

[00:31:58.646]

And we were not aware that ECLSS

[00:32:02.336]

for example was gonna

periodically shut

[00:32:04.236]

down the nitrogen system

to purge it and so on

[00:32:06.646]

and they didn't know to tell us.

[00:32:08.386]

And so we had some real

hiccups for a few times

[00:32:11.206]

when they were maintaining

their nitrogen system

[00:32:14.916]

and our instrument over here

went crazy wondering what

[00:32:17.436]

happened to its nitrogen supply.

[00:32:19.716]

Okay, one last instrument I'd

[00:32:22.486]

like to show you is a

carbon dioxide monitor.

[00:32:25.626]

We were asked to

put this instrument

[00:32:28.376]

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,

[00:32:51.586]

let's say when they're

exercising.

[00:32:53.356]

And this was used to

determine if there were pockets

[00:32:55.656]

of carbon dioxide from

human metabolism and so on.

[00:32:59.676]

It's built by the same

company that builds ugly boxes

[00:33:03.536]

for combustion products.

[00:33:05.046]

As you can see, this is a very

different technology though.

[00:33:08.156]

This is infrared spectrometry.

[00:33:11.686]

This is an exceptionally

good instrument.

[00:33:14.386]

I could throw this across

the room, pick it up

[00:33:16.206]

and it'd still be calibrated.

[00:33:17.976]

We brought these things

back and even 4 or 500 days

[00:33:20.796]

after they were calibrated,

flown and brought back,

[00:33:23.476]

they still operate very well.

[00:33:25.866]

The one thing that's needed is

a little filter to remove water

[00:33:32.476]

so that the tiny infrared

cell in here gives a--

[00:33:37.846]

is not confused by the

water being present.

[00:33:40.536]

And this thing is

fun to play with.

[00:33:41.746]

Not only can you blow into it

[00:33:43.116]

and make carbon dioxide

jack it up.

[00:33:46.766]

This thing is kind of cute too.

[00:33:48.706]

Okay. Now, you can cut

that out if you want.

[00:33:52.866]

Now I want to go on to

non-hardware lessons.

[00:33:59.776]

I guess I might capture

the hardware lessons here

[00:34:02.636]

in summary just about briefly.

[00:34:05.426]

Don't let them push you to fly

hardware before it's ready.

[00:34:11.856]

Keep it simple.

[00:34:13.846]

Don't depend on other people's

systems to drive your hardware

[00:34:19.866]

and don't use crew time

if you can help it.

[00:34:24.466]

Make it small, make it reliable,

and don't over promise.

[00:34:29.396]

And they will always

remember the failures.

[00:34:34.386]

Okay, non-hardware lessons.

[00:34:37.756]

Going into Shuttle in the early

'90s, we realized that a lot

[00:34:41.936]

of chemicals were

flying in the vehicle

[00:34:45.646]

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

[00:35:05.936]

to escape and determine how

toxic they were and sort

[00:35:09.036]

of figure out what to do.

[00:35:11.596]

That evolved during

the Shuttle era

[00:35:13.966]

into a hazard material

summary database.

[00:35:17.276]

It's computerized.

[00:35:18.696]

It's available to the crew

on Shuttle and on station.

[00:35:22.456]

It's available to the Flight

Surgeons, the BMEs and a number

[00:35:25.456]

of other people that use it.

[00:35:26.616]

Very quickly if something

leaks, the crew

[00:35:29.556]

or others can determine

what it is that is leaking

[00:35:32.256]

and what the hazard level is.

[00:35:34.516]

And we are in the process of

getting decals on all the pieces

[00:35:37.586]

of hardware up there at least

on the US side of the Station

[00:35:41.556]

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,

[00:36:06.626]

we found that the PI might

change their mind right before

[00:36:09.906]

flight and slip something in

on us that was never intended

[00:36:13.696]

to be part of that experiment

or we didn't know about.

[00:36:16.446]

So actually now what

we've got is a two-tiered

[00:36:18.416]

verification process.

[00:36:20.256]

When a principal investigator

proposes to fly a payload

[00:36:23.456]

with chemicals in it,

we ask them what group

[00:36:27.366]

of chemicals they are gonna

fly and give us a list

[00:36:29.326]

of their proposed chemicals,

knowing that not all will fly.

[00:36:32.846]

We do an assessment

of those and then

[00:36:35.656]

when the experiment

is packed for flight

[00:36:38.086]

that may be a few months before

flight or it may be on the day

[00:36:40.926]

of launch we ask

[00:36:42.716]

for verification of

exactly what flew.

[00:36:45.376]

So that when the database

is put together for the crew

[00:36:47.756]

and for the Flight Surgeons

and so on, it is accurate

[00:36:51.066]

as we could possibly make it.

[00:36:53.746]

We also learned during

the Shuttle era

[00:36:55.496]

that we needed to be on call.

[00:36:57.946]

And since those days and always

there's been a NASA toxicologist

[00:37:01.936]

on call, there has been a

contractor mission specialist,

[00:37:05.566]

that is a contractor

toxicologist

[00:37:07.856]

who knows the details of the

experiments that are flying

[00:37:10.776]

and knows about the toxic

chemicals that are in there.

[00:37:13.516]

And we also have a

contractor hardware specialist,

[00:37:16.386]

always on call to deal

with whichever one

[00:37:19.126]

of these things might be flying.

[00:37:21.126]

And those people are the people

[00:37:23.146]

that calibrate the

instruments in the lab.

[00:37:24.916]

They know how they behave.

[00:37:25.936]

They know their idiosyncrasies

and so on.

[00:37:28.266]

And they can be very valuable

[00:37:29.836]

when an issue comes

up on the orbit.

[00:37:33.826]

There were a number of ground

based issues that pertain

[00:37:36.926]

to toxicology during

the early 1990s.

[00:37:40.656]

One involved the application

of dimethyl-ethoxysilane

[00:37:45.066]

to the orbiter thermal tiles

[00:37:47.776]

that coat the underneath

side of the orbiter.

[00:37:51.236]

What was happening was

some of the workers

[00:37:53.966]

down at KSC were getting sick

[00:37:55.476]

when they were injecting

the tiles.

[00:37:57.916]

And so there was a

big angst over that

[00:37:59.526]

and the industrial hygenist

down there called this

[00:38:01.916]

and asked us to get involved.

[00:38:04.126]

It turned out that no one

had done a credible tox study

[00:38:06.976]

on dimethyl-ethoxysilane

so we proposed to do

[00:38:10.336]

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.

[00:38:26.596]

But because of the

monitoring of the humans and so

[00:38:30.766]

on at Kennedy Space Center and

the frequency of the events,

[00:38:34.616]

there was a fairly low level

set by the American Conference

[00:38:38.506]

of Governmental Industrial

Hygenists.

[00:38:40.686]

We actually went to that

group and proposed a TLV

[00:38:44.036]

for BMES and got it approved.

[00:38:46.476]

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

[00:39:06.246]

on Shuttle, how soon will

the crew have to come back?

[00:39:09.356]

Because we knew that this fire

extinguisher was not scrubbed

[00:39:12.986]

well and the answer

was we don't know

[00:39:15.806]

because we don't know how

toxic it is to humans.

[00:39:18.426]

So there's actually a human

experiment done in the late '80s

[00:39:21.846]

where humans were exposed,

I think it was 8 humans

[00:39:24.456]

for 24 hours to this

material and it was very clear

[00:39:28.206]

that Halon 1301 was a good

choice from the point of view

[00:39:31.646]

of not being toxic to

humans at reasonable levels.

[00:39:35.176]

And so the flight rules were

modified to reduce the risk

[00:39:38.526]

of going to a primary

landing site

[00:39:40.616]

or an emergency landing site.

[00:39:42.656]

Both of those events to my

knowledge have never taken place

[00:39:46.616]

but I'm told they're very risky.

[00:39:49.266]

And you don't want to go to

those unless you really have to.

[00:39:52.276]

And so, we had a

really good flight rule

[00:39:54.356]

for Halon discharge

if it were to occur.

[00:39:59.046]

>> The last thing I want to

mention is that over the years

[00:40:01.956]

of Shuttle, say from about

1990 until 2008 we worked

[00:40:05.986]

with the National Research

Council Committee on Toxicology

[00:40:09.066]

to get improved limits for the

Shuttle and for Space Station.

[00:40:14.276]

Before this, an individual in

our group was setting limits

[00:40:18.256]

and while I had no doubt that

he did a good incredible job,

[00:40:21.226]

the pedigree of those

limits was not very clear.

[00:40:24.206]

So we really wanted to get the

endorsement of an outside group

[00:40:27.396]

that involved cognizant experts.

[00:40:30.116]

And so in front of

a panel of about 12

[00:40:32.506]

to 15 expert toxicologists

we developed our limits

[00:40:36.606]

and they are published

in a series of volumes.

[00:40:38.566]

The air limits look like

this and the water limits are

[00:40:42.736]

in a different colored booklet.

[00:40:44.876]

But these are all fully

documented and approved

[00:40:47.516]

by the National Research

Council Committee on toxicology

[00:40:51.356]

and published by the

Academy of Sciences.

[00:40:53.926]

And that has proven to

be a worthwhile thing

[00:40:56.206]

to do while not cheap and not

without its required effort.

[00:41:00.206]

There was a need to stand up so

to speak to some Russian limits

[00:41:03.956]

that were a bit irrational

in our opinion and because

[00:41:06.576]

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.

[00:41:32.046]

And when an emergency comes up

there needs to be a tier system

[00:41:37.356]

where if I'm called I can call

somebody that really knows

[00:41:39.846]

about hardware which I don't.

[00:41:43.416]

If you're going to set

limits for people living

[00:41:45.946]

in space vehicles you must

do it in a very competent way

[00:41:50.436]

and in a way that

others can understand

[00:41:53.116]

that these are good limits and

not just something you cooked

[00:41:57.166]

up in a few minutes

on your desk.

[00:42:00.566]

And I'll leave it at that.

[00:42:02.356]

Questions?

[00:42:03.516]

(Pause)

[00:42:08.056]

>> I've been asked

to talk a little bit

[00:42:09.966]

about how toxicology came to

matter for the space program.

[00:42:15.676]

From the very earliest days,

that would be the early 60s,

[00:42:18.986]

when we decided we were

going to put humans

[00:42:20.966]

in space there was

a lot of concern

[00:42:23.096]

about off gassing the materials

that would go into the capsule.

[00:42:27.116]

And there are old memos from

'64-'65 where there were a lot

[00:42:33.266]

of questions and concerns about

the off gassing of hardware.

[00:42:36.276]

And NASA actually engaged the

[00:42:39.426]

in those days to set

limits for the compounds

[00:42:42.116]

that we thought might come off

of materials that would off gas.

[00:42:47.736]

Sampling in those days

consisted of this.

[00:42:51.046]

Taking the charcoal

filters that were used

[00:42:53.106]

to clean the air during the

Mercury or Gemini flight

[00:42:57.016]

and bring them back to the

lab actually where it is now

[00:43:00.176]

and analyze the charcoal.

[00:43:03.656]

They sort the material off of

there and analyzed the charcoal

[00:43:06.846]

to get an idea of

what was it one time

[00:43:09.486]

and the air had been removed.

[00:43:12.056]

There were some old

reports that show a list

[00:43:15.706]

of probably a hundred compounds

with a table that shows yes,

[00:43:20.556]

they were there or no, they

weren't, but no quantification.

[00:43:24.706]

[00:43:27.356]

The limits that were given to

us by the Academy of Sciences

[00:43:30.806]

in those days were,

pick a number.

[00:43:34.986]

They were based on very little

documentation and were more

[00:43:39.436]

or less promulgated by the

fact that they were set

[00:43:43.626]

by a presumably credible body

and that that body didn't have

[00:43:47.726]

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]

[00:44:05.316]

Sampling evolved to the point

[00:44:07.826]

where some solid sorbent

samplers were used

[00:44:10.866]

in a crude form on

Skylab I believe.

[00:44:14.596]

There was a mass spectrometer on

Skylab but it was not designed

[00:44:17.676]

to quantify air quality.

[00:44:20.686]

And then the Shuttle

came along and that's

[00:44:24.326]

when we got perhaps more serious

about monitoring air quality.

[00:44:31.466]

The drivers of that

were first of all,

[00:44:34.606]

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.

[00:44:54.446]

And then there were

other events,

[00:44:55.896]

the teleprinter cable burned.

[00:44:57.946]

There were two burns of the

data display unit on STS-35

[00:45:02.736]

and it was actually

strong enough and smelled

[00:45:06.076]

that it woke up the crew.

[00:45:08.376]

And that drives a lot of need

[00:45:09.946]

for combustion product

monitoring.

[00:45:12.026]

We saw a lot of volatile

organics in the air of Shuttle

[00:45:15.956]

and it was clear that if we were

gonna fly vehicles for a long,

[00:45:21.236]

long time for example, the

Space Station or something

[00:45:24.336]

that monitoring the volatile

organics would be important.

[00:45:27.436]

Now where do these

things come from?

[00:45:29.086]

They come from off

gassing as I said,

[00:45:30.746]

and that can be controlled.

[00:45:32.326]

If they come from

payloads that leak,

[00:45:34.416]

they come from utility

chemicals that are used.

[00:45:36.776]

Anywhere from deodorants,

hair processing materials,

[00:45:42.686]

body washes, sodding

experiments.

[00:45:46.116]

There are just any

numbers of sources

[00:45:48.716]

and there are things

we see in the air,

[00:45:50.526]

the origin of which

we simply don't know.

[00:45:53.336]

Occasionally we see a spike

of ethanol and the source

[00:45:56.436]

of that can be speculated on.

[00:45:58.816]

But the Space Station

era's quite a Pandora's Box

[00:46:03.306]

of chemical pollution,

usually at very low levels.

[00:46:08.886]

We also wanted to deal with

incidences where things

[00:46:11.496]

that weren't exactly a

pyrolysis product escaped.

[00:46:15.026]

That's why we've gone to

volatile organic analyzers

[00:46:17.886]

to characterize the air

in situations like that.

[00:46:22.316]

What we've actually seen

with a modern analyzer

[00:46:25.166]

that I don't have here is we

can actually follow the opening

[00:46:28.026]

of a new module.

[00:46:29.266]

These tend to have a

build up of pollutants

[00:46:31.296]

because they don't have

an air cleaner in them.

[00:46:33.666]

So when the hatch

is opened on Station

[00:46:36.986]

so that the crew could

enter these modules

[00:46:39.516]

and they have been sealed up for

30 days or 45 days there's a lot

[00:46:43.246]

of pollution in there.

[00:46:44.226]

And we can actually see that

pollution come across Station

[00:46:46.686]

and reach our analyzers that

are typically in the lab

[00:46:50.086]

and increase the values there.

[00:46:53.456]

So that's kind of the story of

where the pollutants come from

[00:46:58.336]

and why we monitor them.

[00:47:00.476]

Clearly if we're going to go to

a distant destination for a year

[00:47:04.486]

and a half we're gonna have

[00:47:05.576]

to have very small

reliable analyzers

[00:47:08.526]

that don't require a lot

of crew time to manipulate.

[00:47:13.796]

Next question.

[00:47:14.516]

>> So why don't you just use the

same kind of analyzers on orbit

[00:47:17.566]

that we've used on the ground?

[00:47:22.396]

>> Well, okay let's

take an example.

[00:47:25.666]

The instrument we use

to analyze these things

[00:47:27.996]

with covers the desktop.

[00:47:31.876]

And we have four

instruments in my lab.

[00:47:36.096]

In a good day, a

good day is when two

[00:47:39.246]

of those are working very well.

[00:47:40.986]

GC Mass Spectrometers

tend to be very fickle.

[00:47:46.706]

They're very complex.

[00:47:49.706]

So you need to fly

something else

[00:47:54.126]

and I won't elaborate on that.

[00:47:56.546]

There are simpler concept--

conceptually simpler analyzers

[00:47:59.876]

that are perhaps not as powerful

[00:48:01.686]

as the GC mass spec. Right now

we're flying a differential

[00:48:08.186]

mobility spectrometer and I

won't go into what that is

[00:48:11.526]

but it's a rather

robust detector

[00:48:13.696]

to put behind the

gas chromatograph.

[00:48:16.156]

And that instrument has proven

very effective on Station.

[00:48:20.116]

It doesn't have the

analytical power

[00:48:21.666]

of the mass spectrometer,

I would say that.

[00:48:24.776]

But it is much smaller and

it's much more reliable.

[00:48:27.626]

We could bet on being

operating 6 months to a year

[00:48:30.586]

from when we would fly it,

[00:48:32.066]

whereas mass spectrometers

tend to be very fragile.

[00:48:36.226]

Instruments of flight should

draw very little power that's

[00:48:41.076]

for obvious reasons.

[00:48:42.036]

You only have so much

power in any vehicle

[00:48:44.256]

and it gets distributed

and shared

[00:48:46.406]

and you only get

your portion of it.

[00:48:49.256]

And as I said earlier you want

[00:48:50.636]

to be independent

of any resources.

[00:48:52.896]

For example the mass

spectrometer,

[00:48:56.756]

this being flown now has to

have helium as a carrier gas

[00:48:59.996]

and they have to

bring their own gas.

[00:49:03.956]

We got burned with the

DOA because we depended

[00:49:07.956]

on Space Station nitrogen

[00:49:10.096]

and that was not a reliable

source all the time.

[00:49:15.326]

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

[00:49:38.096]

like let's say in

the 70s and 80s.

[00:49:41.156]

A man named Elliot Harris was

actually chief for sometime.

[00:49:47.996]

This would have been in the late

Apollo era lead up to Shuttle.

[00:49:52.466]

He was Branch Chief of

the toxicology branch

[00:49:57.046]

at Johnson Space Center.

[00:49:59.366]

For reasons I don't know he left

[00:50:01.966]

and the toxicology branch

disappeared and became a goob.

[00:50:05.056]

>> In those days, their main

task was not to set limits

[00:50:11.576]

in a lot of the things

we do, it was to deal

[00:50:14.376]

with offgassing issues and a

number of other issues that had

[00:50:18.586]

to do with developing a space

vehicle like the Shuttle.

[00:50:23.196]

That kind of involvement has

kind of taken two directions.

[00:50:27.006]

One direction is toward

developing really credible

[00:50:33.796]

ironclad limits that have

a really strong pedigree

[00:50:37.796]

and aren't set by an individual.

[00:50:40.116]

The other is to more involvement

[00:50:42.116]

on a real-time basis

with the missions.

[00:50:44.986]

That really makes it fun

to be a toxicologist here.

[00:50:48.496]

Right now, we're

probably working three

[00:50:50.686]

or four relatively

important issues related

[00:50:53.636]

to Space Station right now.

[00:50:56.196]

And we get called into meetings

and our expertise gets dissected

[00:51:01.156]

and we have to communicate

[00:51:02.556]

to engineers what often is

rather fuzzy and uncertain data

[00:51:06.606]

in a way that they believe it.

[00:51:09.506]

One incident that

comes to mind is

[00:51:12.436]

when this little motor

burned up on STS-40.

[00:51:18.466]

As I said before, it wasn't

[00:51:19.926]

in the orbiter refrigerator

freezer.

[00:51:23.616]

We really were way off

track during flight

[00:51:26.386]

as to what caused that.

[00:51:28.586]

The crew said this thing

reeked and we can't stand it.

[00:51:31.726]

Eventually, we gave the crew

permission to turn the thing off

[00:51:35.486]

and put duct tape over all

the openings and that began

[00:51:38.426]

to control the odor

a little bit.

[00:51:41.046]

We thought at that time it might

have been offgassing so to speak

[00:51:44.796]

from urine that was spilled

inside the refrigerator.

[00:51:47.166]

And when we got the unit back

and examined it, it was clear

[00:51:51.116]

that we were way off base.

[00:51:52.336]

That it was actually

a pyrolysis event.

[00:51:54.506]

The motor had burned up.

[00:51:56.826]

During the mission, a colleague

of mine, Dr. Chiu-Wing Lam

[00:52:01.056]

and I were called in

to deal with this issue

[00:52:04.396]

and I can remember

it was a Saturday.

[00:52:06.666]

And for whatever reason we both

had charge of our little kids.

[00:52:11.326]

I don't remember

where our wives were

[00:52:13.146]

but we brought our

little kids in here.

[00:52:15.466]

And so there were four bored

little kids while we sat

[00:52:18.976]

and tried to deliberate

with the other people

[00:52:21.336]

about what was going on with the

orbiter refrigerator freezer.

[00:52:25.906]

But it was fun and I don't

suppose it killed the kids.

[00:52:29.036]

But as I said, we

were at that time,

[00:52:31.776]

because we didn't have the tools

we needed, we were far off base

[00:52:35.466]

in terms of understanding

what happened.

[00:52:38.136]

[00:52:40.586]

>> So, tell us-- think back over

the years, followed scenarios,

[00:52:46.076]

just tell us another

shuttle story

[00:52:50.146]

and what might be your most

memorable Shuttle memory

[00:52:55.046]

regarding toxicology?

[00:52:57.796]

[00:52:59.296]

>> Well, I guess that

could be good or bad.

[00:53:01.706]

[00:53:04.886]

I remember when we had

gotten the CPA modified

[00:53:08.376]

so that we thought it wasn't

sensitive to hydrogen.

[00:53:11.876]

And then we had the problem with

the data display units burning.

[00:53:19.176]

I was called over to Mission

Control to help sort out things,

[00:53:22.576]

and the flight sergeant

was John Schultz.

[00:53:24.996]

And Sam Pool was

the Division Chief.

[00:53:26.996]

Sam didn't buy tools and

so, we were over there

[00:53:31.666]

and we were going over whether

the increased carbon monoxide

[00:53:35.496]

readings were true.

[00:53:39.716]

And they were high enough

that if they were true,

[00:53:42.506]

it might affect crew

performance,

[00:53:45.306]

including the pilot.

[00:53:46.506]

He was gonna have

to land the Shuttle.

[00:53:48.056]

And there was a lot of

debate going back and forth

[00:53:54.006]

about the levels of carbon

monoxide, the capabilities

[00:53:56.916]

of the pilot, should it be on

his a visor and so on and so on.

[00:54:00.876]

How long would it take to

wash the carbon monoxide

[00:54:03.026]

out if-- were in there?

[00:54:06.406]

Eventually, I was really

impressed with Sam.

[00:54:09.366]

He listened to me, he

listened to the surgeons,

[00:54:12.016]

he listened to the other people

then he decided we were not

[00:54:15.956]

gonna trust the instrument.

[00:54:17.306]

We were gonna go and land

as we were gonna land

[00:54:20.446]

in the first place, and we did.

[00:54:22.726]

And he was right.

[00:54:25.306]

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

[00:54:51.856]

in the toxicology group

[00:54:53.026]

in the 21 years I've

been associated with it.

[00:54:56.406]

[00:54:58.226]

I'm impressed in many ways

[00:55:02.126]

but let me highlight

at least two of them.

[00:55:04.546]

One is the ability

of the chemists

[00:55:09.436]

and the contractor team,

to not only analyze samples

[00:55:14.816]

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

[00:55:45.966]

with that group has

been in many cases

[00:55:48.526]

because of those excellent

analytical chemists

[00:55:53.496]

that stay abreast of current

technology and know how

[00:55:57.396]

to adapt something

for space flight.

[00:56:00.056]

The other thing I wanna

highlight is the expertise

[00:56:02.846]

that resides in a

toxicologist that works

[00:56:05.346]

at Johnson Space Center.

[00:56:06.926]

This would be on both sides the

contractor and the NASA side.

[00:56:12.166]

Probably one of the hardest

things to do is to stand

[00:56:16.926]

up in front of a panel of

experts, perhaps a dozen or so,

[00:56:21.176]

selected by the National

Research Council

[00:56:23.996]

to scrutinize what you're going

to tell them the limit ought

[00:56:26.836]

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

[00:57:08.856]

because of this involvement

[00:57:10.866]

but I've also gained a hearty

respect for the ability

[00:57:14.606]

of my colleagues to go do this.

[00:57:17.346]

In terms of mission support,

[00:57:19.076]

it's probably declined a little

bit over the past few years.

[00:57:22.176]

We've actually tried to

put more tools in the hands

[00:57:24.446]

of the BME insurgent than

we had, let's say in the 90s

[00:57:27.556]

with the Shuttle program

and that's worked okay.

[00:57:30.896]

But every once in a while we

catch the BMEs maybe making a

[00:57:33.896]

decision that they should have

called us about but we worked

[00:57:38.446]

that as the case by case goes.

[00:57:40.936]

So, it's really been an honor

to work with these people.

[00:57:44.916]

>> Lets look at this real

quickly or briefly in the future

[00:57:49.416]

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

[00:58:08.406]

go-- are you gonna

fire me or something?

[00:58:11.996]

(Laughter)

[00:58:12.063]

>> You will know

everything I know pretty soon

[00:58:13.786]

and then now you

wouldn't even need me.

[00:58:15.516]

(Laughter)

[00:58:20.516]

>> That's a very good question.

[00:58:22.326]

Of course, the vision of where

we're going is not exactly

[00:58:25.796]

focused but if we are to go

to either a near-Earth object

[00:58:31.776]

or another distant object, let's

say Mars or even a moon of Mars.

[00:58:38.986]

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.

[00:59:14.536]

You're not gonna be bringing

samples like this back.

[00:59:16.836]

It isn't gonna happen.

[00:59:18.106]

You're not gonna bring

back formaldehyde badges.

[00:59:20.316]

You're gonna have to have a way

to do that where the habitat is

[00:59:23.906]

and where the crew is living.

[00:59:25.756]

And that is going to

be a real challenge,

[00:59:27.546]

making exceptionally

good, reliable,

[00:59:31.596]

low-powered analytical

instruments

[00:59:33.796]

that will withstand

the mission of two

[00:59:35.336]

or three years is not easy.

[00:59:38.086]

Nobody does that yet, nobody.

[00:59:40.936]

I think in the next five to 10

years, we will be able to do

[00:59:45.106]

that with a lot of confidence.

[00:59:47.816]

Miniaturization 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

[01:00:26.936]

in the air.

[01:00:27.716]

And the risk is below

some threshold or above.

[01:00:30.796]

Or here's the risk that you

might have too many simple

[01:00:36.846]

nervous system depressants like

alcohols and so on in the air.

[01:00:41.116]

If you're experiencing

some of these symptoms,

[01:00:43.746]

you might wanna look at

your analyzer and see

[01:00:45.726]

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

[01:01:08.076]

that they're constantly

devising new ways

[01:01:11.246]

to set presumably better

limits and of course,

[01:01:14.026]

new data are coming along all

the time with the compounds

[01:01:17.456]

that we're interested in.

[01:01:18.666]

So probably, every 5 to 10

years, we need to read these

[01:01:22.186]

at the limits we've

got already and see

[01:01:23.826]

if they need to be refined.

[01:01:25.816]

And in fact, I'm planning in

2012 to restart the effort

[01:01:29.426]

that we stopped a few years ago

[01:01:31.286]

with the National

Research Council.

[01:01:33.066]

Although we may use a different

body but limits have to be kept

[01:01:37.086]

up to date, limits that are

10 years older are too old.

[01:01:40.276]

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

will probably in--

[01:02:04.436]

ISS ends which is either 2020

[01:02:07.466]

or 2028 we could keep it

functioning that long.

[01:02:13.486]

So, there is the vision.

[01:02:14.806]

>> So, what are some of

the promising technologies

[01:02:17.406]

that you have out there at the--

[01:02:21.296]

>> Okay.

[01:02:22.246]

(Inaudible Remark)

[01:02:26.116]

>> There's-- some of my

colleagues would argue

[01:02:30.246]

that there are optical

techniques

[01:02:32.226]

that will do a better job of

monitoring combustions product

[01:02:35.066]

than electrochemical sensors.

[01:02:36.816]

And as I said, electrochemical

sensors have their

[01:02:39.256]

idiosyncrasies and

sometimes it even matters

[01:02:42.696]

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

[01:03:00.456]

to do one or two compounds.

[01:03:02.156]

That's gonna be too big.

[01:03:03.056]

They're gonna have to shrink.

[01:03:03.996]

And as for combustion products,

we are gonna have a panel

[01:03:07.546]

in a few months to go

over all the technologies

[01:03:09.526]

with outside experts and

see what we've missed

[01:03:11.956]

and see what's most promising.

[01:03:13.136]

In terms of volatile organics,

[01:03:16.296]

[01:03:17.516]

we do fly a gas comatograph

a differential mobility

[01:03:21.136]

spectrometer that I think

shows a lot of promise.

[01:03:24.876]

It could miniaturized

even further.

[01:03:26.876]

I've seen a handheld instrument.

[01:03:28.606]

Well, the one we fly now

is maybe about as big

[01:03:30.476]

as this thing-- are

going to fly,

[01:03:33.036]

its government furnished

equipment.

[01:03:34.806]

It's gonna have a little screen

on it that will communicate

[01:03:37.736]

to the crew if any

of the pollutants are

[01:03:39.006]

out of line and so on.

[01:03:40.716]

But I've seen one that the

company is building that's a

[01:03:47.076]

fifth maybe an eighth

of that size,

[01:03:49.936]

a really handheld

volatile organics analyzer.

[01:03:54.056]

Will these be reliable enough?

[01:03:56.426]

I don't know, experience

will tell us.

[01:03:59.026]

GC mass spectrometry,

[01:04:00.996]

very powerful technique although

the thing people forget is

[01:04:06.246]

that it's sometimes blind

to important compounds.

[01:04:11.446]

GC mass spectrometers

are not the see all

[01:04:14.796]

and end all of everything.

[01:04:16.436]

They are complex,

they are fickle

[01:04:18.626]

and they can be a

challenge I think to make

[01:04:22.106]

in a reliable and

dependable way.

[01:04:25.316]

[01:04:27.496]

There are other techniques

that might be useful.

[01:04:34.996]

Some people have

built a membrane inlet

[01:04:37.906]

mass spectrometer.

[01:04:39.446]

Now, these mass spectrometers

tend to be simpler

[01:04:42.746]

than the more complex ones

[01:04:44.106]

that are behind a gas

comatograph column

[01:04:49.006]

and they show some promise.

[01:04:51.896]

The issue is what the membrane

will let in and what it won't

[01:04:56.436]

and what happens to the

membrane if it gets a high dose

[01:04:58.906]

of some compound action

will in the membrane

[01:05:01.816]

and then the mass spectrometer

fails because it gets overdosed

[01:05:05.636]

on a compound that was

not meant for that.

[01:05:11.236]

There is an optical technique

called Fourier Transform

[01:05:15.346]

Infrared Spectrometry that

has been used by the Europeans

[01:05:20.506]

to fly a rather large

instrument on Station.

[01:05:24.056]

[01:05:25.086]

It gets the spectrum of

everything in the air

[01:05:29.906]

that exhibits an FTI or spectrum

and then deconvolutes those.

[01:05:34.876]

I think it was moderately

successful

[01:05:37.076]

when it flew on Station.

[01:05:39.036]

There were some surprises to the

group but they were able to fair

[01:05:42.456]

out those surprises and figure

out for example that one

[01:05:45.076]

of the compounds that they were

seeing was a compound that leaks

[01:05:49.016]

from the Russian Service

Module air conditioning system.

[01:05:53.926]

I suppose you could argue there

is a bit of witchcraft there.

[01:05:59.026]

To my knowledge, there are

maybe one or two individuals

[01:06:01.556]

in the world that can

deconvolute the spectra

[01:06:05.116]

and make sense of them.

[01:06:06.906]

That's not good.

[01:06:08.946]

That in fact, that's always

an issue with ground-based

[01:06:13.946]

or instruments that are gonna

fly on-- in near-earth orbit.

[01:06:17.646]

Do you have the people

on the ground

[01:06:19.556]

to sustain those

instruments and deal

[01:06:22.546]

with whatever analysis

they produce?

[01:06:25.666]

And that can be a question, if

you have a company build it.

[01:06:29.676]

If the company fails,

you're sunk.

[01:06:32.586]

If you have an exotic team at

some high-level lab build it,

[01:06:37.476]

is that team gonna exist

three years from now

[01:06:39.636]

when your instruments

are giving you fits.

[01:06:43.616]

There are a lot of

questions with how

[01:06:44.826]

to sustain these things.

[01:06:47.146]

So anyway, that's kind

[01:06:48.536]

of a toxicologist

survey of techniques.

[01:06:52.816]

[01:06:54.830]

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