Living Inside the UA Space Analog

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Bio-regeneration is one of the main research pillars at the Space Analog for the Moon and Mars (SAM) and key to supporting long-term human habitation of other celestial bodies. In December 2024 I spent three days alone inside the SAM sealed system with the goal of measuring my individual CO2 fingerprint.

This controlled environment habitat can operate in four modes on site at the University of Arizona's Biosphere 2. Mode 0: unpressurized sealed, mode 1: unpressurized, flow-through, mode 2: pressurized, flow-through and mode 3: pressurized sealed. Operating in mode 0 for the entirety of my three day stay, I tried to better understand the amount of CO2 I emit in a 58 hour time period while following a strict diet, exercise, and daily routine.

The SAM habitat has interesting historical significance and now it has been rejuvenated to continue a mission towards supporting human life and exploration throughout the solar system. Built in 1987, the test module (TM) was used as a proving ground for the larger audacious project, Biosphere 2. In 2021 the TM began a new life, registered as an aircraft with the FAA under the n-number N1987B, metaphorically setting its research goals high in the sky and poised to chase after them.

Figure 1 The SAM Test Module made of steel and glass (design wouldn't be used in space), the perpendicular 20ft container engineering/medical bay, then 40ft crew quarter container and air lock to the right

Over the course of three years the TM underwent facility expansion, testing and crewed missions. Including but not limited to the construction of a covered Mars yard sculpted with a geologically accurate eye and is a well thought out representation of Martian landscape, it even has a gravity offset device. After an initial life support scrubber systems test in summer 2021 the Test Module grew an engineering/medical bay (20ft) and a living/crew quarters (40ft) to support a crew of up to 4 persons. With my stay being focused on living and working inside the habitat, no extra vehicular analog spacewalks were performed.

On the morning of December 15th I sealed the large airlock door to the habitat and began my three day mission fully sequestered from the outside atmosphere without any type of co2 scrubbing device. Having completed my pre-launch checklist, the vernier sensor unit and SIMOC live sensor array were humming along without any issues checking pressure, temperature, humidity, and CO2. During the mission I was also wearing a Dexcom Stelo continuous glucose monitor and Oura ring to track my biometrics, specifically heart rate variability, sleep, and exercise. I also tracked morning blood pressure with an automatic cuff unit.

In 2024, Earth's atmosphere was composed of 440 parts per million CO2. I noticed my starting habitat concentration was ~500 ppm at a single sensor in the engineering bay. According to NASA, the CO2 in Earth's atmosphere has remained below 300 ppm for what a human would consider a larger chunk of history, 800,000 years. Albeit just a fraction of Earth's planetary timeline of over 4 billion years. CO2 of course has its benefits and detriments to life depending on exposure and timescale. In the smaller volumes of space habitats, the level of CO2 is required to be monitored for immediate safety. You want enough of it to play its physiological role of regulating the body's pH balance and trigger breathing responses as well as cultivate plant photosynthesis. But not so much of the gas as to cause headaches, nausea, and loss of consciousness.

Human physiology, as you can imagine, has a tremendous impact on space habitat design requirements. On the International Space Station (ISS) there are CO2 standards, even OSHA has exposure standards. These requirements vary depending on time exposed and concentration. For example, OSHA maintains 5,000 ppm exposure average limit over an 8 hour work day. But 30 minutes at 50,000 ppm can cause intoxication, with 70,000 ppm to 100,000 ppm over a few minutes can cause unconsciousness. Everyone's body will respond slightly differently to the elevated levels but exposure to high concentrations across the board can be tragic.

At a standard 440 ppm in Earth's atmosphere, we understand CO2 as still being a trace gas (0.04%). The majority of our atmosphere is made of nitrogen (79%) and oxygen (21%). Depending on space habitat and exploration requirements the pressure and concentrations of oxygen can be curated to fit a mission profile and system technological capabilities. For example, the ISS maintains a standard Earth Atmosphere at 14.7 psi (79% nitrogen, 21% oxygen). The NASA EMU spacesuit maintains an atmosphere of 100% oxygen at 4.3 psi. In both instances human consciousness is maintained by tweaking the balance of pressure and oxygen concentration. However, it takes 4.5 hours for an astronaut to safely decompress and transition from the atmosphere inside the ISS to suit before a spacewalk. But what if you want to plan a faster transition for an EVA on the moon? Or how about if you have a lunar greenhouse and wish to maintain higher levels of CO2? These design considerations are types of questions that get brought up in space exploration frameworks.

SAM as a platform is an incredible tool to help answer some of these types of questions. Located in Oracle Arizona the habitat uses ambient air to pressurize and seal the system at about 12.78 psi (79% nitrogen, 21% oxygen). If operated in mode 3, pressurized and sealed, you maintain a slight positive pressure over ambient and could study topics such as long-term microbial life growth. Or perhaps maintain a higher CO2 concentration in the TM greenhouse space to understand how to grow plants more efficiently without other gasses leaking to the inside. Of course, in my mission the mode 0 configuration was used in establishing baseline values for individual CO2 footprints.

For volume reference, the entire habitat of SAM is approximately 21,000 cubic feet. Here are approximate values for other stations and habitats for comparison:

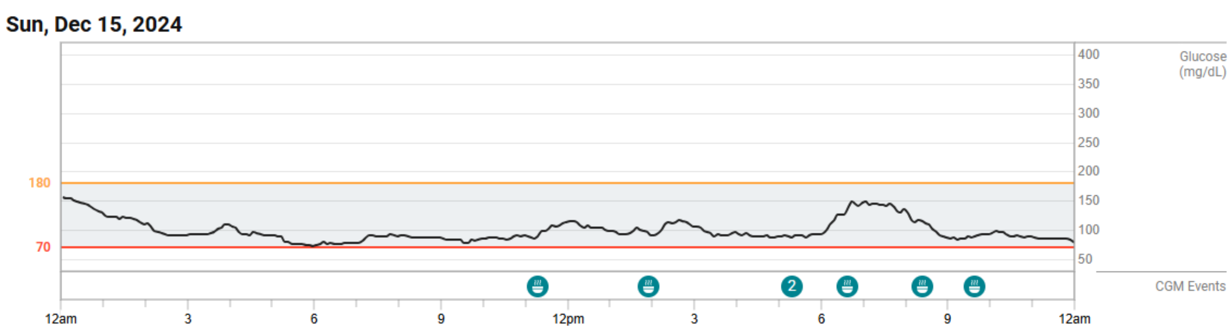
Station/Habitat	Location/anticipated	~Habitable Volume (cubic feet)
Space Analog for the Moon and Mars (SAM)	University of Arizona's Biosphere 2, Oracle AZ	21,000
International Space Station (ISS)	Earth Orbit	13,696
China's Tiangong Station	Earth Orbit	12,000
Space X Starship	Earth Orbit/Lunar Lander/Mars	35,000-40,439
Blue Origin Blue Moon	Lunar Lander	353
Blue Origin Orbital Reef Station	Earth Orbit	15,594-29,311
NASA Apollo LM	Lunar lander	235
VAST Haven 1 Station	Earth Orbit	1,589
Axiom Station	Earth Orbit	unknown

The space available in SAM for a 58 hour stay as a solo individual was more than sufficient. Apollo 11 took 75 hours and 49 minutes to get to and land on the Moon with the command module and LM totaling 450 cu ft. I had 2/3 of a Starship to live and work.

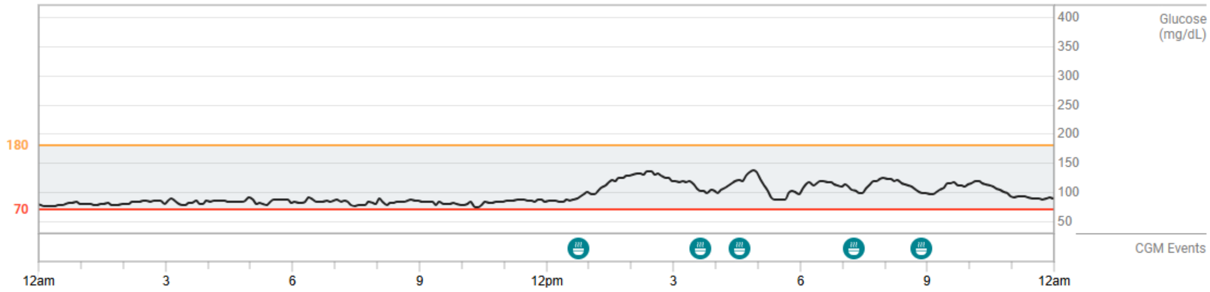
Throughout the mission, my CO2 production was tracked continuously from door closure to egress. This data is currently being processed. In the meantime, I would like to share aspects of my experience including some of my own physiological data which I collected. This raw data, which will also live at the NASA's Open Source Data Repository was collected as a trial run towards my upcoming NASA Exploration Atmosphere mission.

Continuous Blood Glucose:

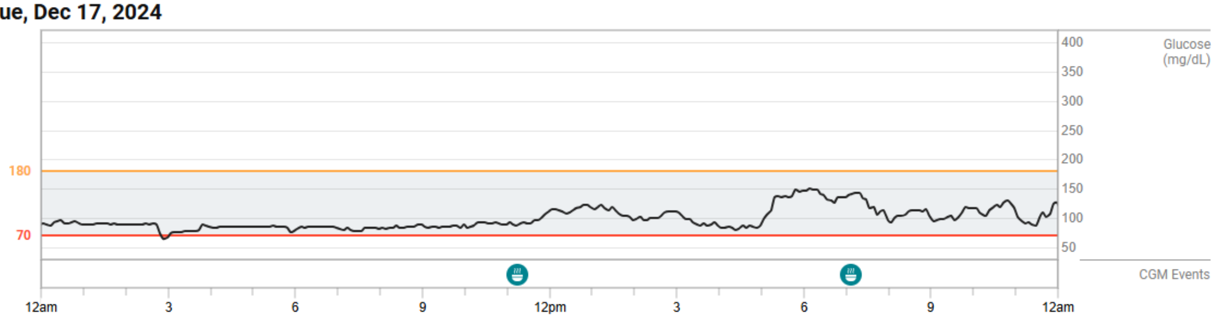
This data was collected using a Dexcom Stello using the iOS app on an iPhone 13 pro. The data was gathered and can be exported in CSV file or graphical charts like shown below. Notate habitat entrance 7:35am on the 15th and exit at 5:35pm on the 17th.



Mon, Dec 16, 2024



Tue, Dec 17, 2024



Food Consumption:

Out of the 24 food options available I mostly stuck to about 10 items. The diet prescribed was vegetarian. My pasta was not weighed separate from sauce as it was premixed. Food stuffs listed to be inside included: bagel, hummus, cheese, trail mix, almonds, cucumbers, red peppers, carrots, onions, tomatoes, apples, bananas, oranges, oats, pasta, pasta sauce, pasta salad, wheat thins, pretzels, peanut butter, honey, popcorn, chocolate, and coffee.

Date	MEAL	Bagel	Almonds	Carrots	Apple	Orange	Pasta	Wheat T.	Pretzels	Peanut B.	Chocolate
12/15/24	breakfast	97.60	-	-	-	-	-	-	-	43.00	-
	snack	-	-	-	-	134.30	-	-	-	-	-
	lunch	-	-	-	-	-	-	-	-	-	-
	snack	-	20.00	-	-	-	208.10	-	-	-	-
	dinner	-	24.20	93.50	-	-	-	-	-	-	21.90
12/16/24	breakfast	101.80	55.50	-	-	-	-	-	-	34.00	-
	snack	-	-	-	-	-	-	50.80	-	-	-
	lunch	-	-	-	-	-	337.50	-	-	-	-
	snack	-	-	-	160.60	-	-	-	25.50	26.80	-
	dinner	-	-	-	-	-	-	-	-	-	-
12/17/24	breakfast	100.00	23.90	-	-	-	-	-	-	23.80	-
	snack	-	-	-	-	-	-	-	-	-	-
	lunch	-	-	-	-	-	322.30	-	-	-	-
	snack	-	-	-	-	-	-	-	-	-	-
		299	124	94	161	134	868	51	26	128	22
				1,905	total food (grams)						

Blood Pressure:

I took my blood pressure every morning around 8am. The quality of blood pressure cuff it to be examined. For this project I used the iHealth Track Blood Pressure Monitor. The manufacturer notates that its pressure accuracy is ±3 mmhg.

Date	Time	Systolic	Diastolic	Resting Heart Rate during blood pressure	Fasting Blood Glucose
12/15/2024	0800	119	81	71	91
12/16/2024	0800	110	70	66	80
12/17/2024	0800	99	64	60	82

Oura ring data:

As I just began using the Oura ring again after a year long hiatus before the mission it's unclear to me how accurate this included data is. I believe that the longer you use the ring the better the sensor algorithms become for your metrics. I do know that NASA Human Health and Performance Labs have used the Oura ring, and I have been asked to track my sleep with it for the Exploration Atmosphere mission. Seems like sleep duration is in seconds, then the scores are a factor percentage of the algorithms. This is an example of the CSV data layout.

Date	Total Sleep Duration	Light Sleep Duration	Deep Sleep Score	REM Sleep Score	Average Resting Heart Rate	Activity Burn	Respiratory Rate	Average HRV
12/15/2024	23910	11640	97	96	62.05	247	14.875	41
12/16/2024	36240	22260	77	100	55.24	185	14.625	62
12/17/2024	25470	13920	71	97	59.66	223	14.375	47

Schedule/time allocation:

Most of my time during the day was spent on the computer working interspersed with phone calls. Some time was used for entertainment as well as exercise. On both the 15th and 16th I rowed on a stationary machine for an hour which worked out well in the given space. Rowing seemed to provide me with a quality full body workout. Sleep is important to me, and I made sure to get enough. The schedule outlined below are in order from top to bottom: December 15th, 16th and 17th.

As this was a CO_2 baseline project, no operational tasks were given. It can be anticipated that in a mission longer in duration and scope my activity would be dispersed among many other tasks.

Time	Compute	Calls	Work in TM	Eat	Clean/Org	Exercise	Entertain	Bath	Sleep	Sum
07:35 AM	-	-	-	-	0.50	-	-	-	-	0.50
08:00 AM	1.00	-	-	-	-	-	-	-	-	1.00
09:00 AM	1.00	-	-	-	-	-	-	-	-	1.00
10:00 AM	1.00	-	-	-	-	-	-	-	-	1.00
11:00 AM	0.75	-	-	0.25	-	-	-	-	-	1.00
12:00 PM	-	-	-	-	-	-	1.00	-	-	1.00
01:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
02:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
03:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
04:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
05:00 PM	0.25	-	-	0.25	-	0.50	-	-	-	1.00
06:00 PM	-	-	-	-	-	0.50	0.50	-	-	1.00
07:00 PM	-	-	-	-	-	-	1.00	-	-	1.00
08:00 PM	-	-	-	-	-	-	1.00	-	-	1.00
09:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
10:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
11:00 PM	-	-	-	-	-	-	-	-	1.00	1.00
12:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
01:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
02:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
03:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
04:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
05:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
	6.00	4.00	0.00	0.50	0.50	1.00	3.50	0.00	7.00	**22.50**
06:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
07:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
08:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
09:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
10:00 AM	0.75	-	-	0.25	-	-	-	-	-	1.00
11:00 AM	-	1.00	-	-	-	-	-	-	-	1.00
12:00 PM	0.50	0.25	-	0.25	-	-	-	-	-	1.00
01:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
02:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
03:00 PM	-	0.25	-	0.25	-	-	0.50	-	-	1.00
04:00 PM	0.50	-	-	-	-	-	0.50	-	-	1.00
05:00 PM	-	-	-	-	-	1.00	-	-	-	1.00
06:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
07:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
08:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
09:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
10:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
11:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
12:00 AM	-	-	-	-	-	-	1.00	-	-	1.00
01:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
02:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
03:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
04:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
05:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
	6.75	4.50	0.00	0.75	0.00	1.00	2.00	0.00	9.00	**24.00**
06:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
07:00 AM	-	-	-	-	-	-	-	-	1.00	1.00
08:00 AM	1.00	-	-	-	-	-	-	-	-	1.00
09:00 AM	-	1.00	-	-	-	-	-	-	-	1.00
10:00 AM	-	1.00	-	-	-	-	-	-	-	1.00
11:00 AM	0.75	-	-	0.25	-	-	-	-	-	1.00
12:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
01:00 PM	1.00	-	-	-	-	-	-	-	-	1.00
02:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
03:00 PM	-	1.00	-	-	-	-	-	-	-	1.00
04:00 PM	-	0.50	-	-	-	-	-	-	-	0.50
05:00 PM	0.50	-		-	0.50	-	-	-	-	1.00
05:35PM	-	-	-	-		-	-	-	-	0.00
	4.25	4.50	0.00	0.25	0.50	0.00	0.00	0.00	2.00	**11.50**
	17.00	13.00	0.00	1.50	1.00	2.00	5.50	0.00	18.00	58.00

Further notes:

As mentioned the volume of space available in SAM was ample for a single individual. I felt completely safe and comfortable with the integrated fire suppression system, radio connection to the 24 hour on site staff, and co2 levels that were well within OSHA and NASA standards despite being completely sealed inside without outside airflow. I knew at any point in time in an emergency I could open any of the three air lock doors and leave if necessary.

Inside I did experience a feeling of disconnection. Disconnection with the outside world, but connection within the hab. Being secluded from the normal ecosystem while directly experiencing a rise of internal CO2 was exciting. I felt a part of a project that will directly impact human space exploration of our solar system.

I felt that the food I was eating was not a normal diet or amount for myself. I believe this is something to be explored into the future with the SAM team. I did not experience any detrimental impacts of said vegetarian diet. I noticed my spikes in blood glucose when consuming pasta. Food selections for space travel are something I would like to explore more, especially in relation to exercise and schedule. The CGM was useful but I do question its accuracy as I took traditional finger prick tests later in the month and my CGM was up to 20 points off. This is to be explored more.

This experience was my second time sealed inside of SAM. Back in June of 2021 I was a member of the first crew in 30 years. 5 persons sealed inside for 4 hours while testing our CO2 scrubber operations. Data on this experiment can be found on the SAM website here.

The first 4 hour test was similar to the 2024 experience in the sense that I felt removed from Earth's atmosphere but it was not enough time to fully experience the impact of living inside a space.

Conclusion:

I had an incredibly exciting time inside of SAM for 58 hours. Though my daily tasks were nominal I felt like I was doing my small part in moving the needle of human space exploration and habitation. I look forward to being a research subject on future missions to come.

From my time inside I did not experience any abnormalities to my sleep or fitness regime. Blood glucose was mostly kept between 70 mg/dl and 140 mg/dl however I ate less than normal and more pasta. All data will need to continuously be checked against a larger data set but there were no obvious abnormalities that I identified.

SAM as a tool for space research really shines when it comes to closed ecosystem work. From CO2 accumulation studies and life support system testing to plant ecology and crew dynamics. It is my understanding that NASA is looking to expand its analog capabilities as they are no longer participating in SIRUS missions. In this case we may see SAM join the research ranks of other high-fidelity habitats such as the NASA funded HERA, CHAPEA as early as 2025.

Photos from inside the SAM habitat:

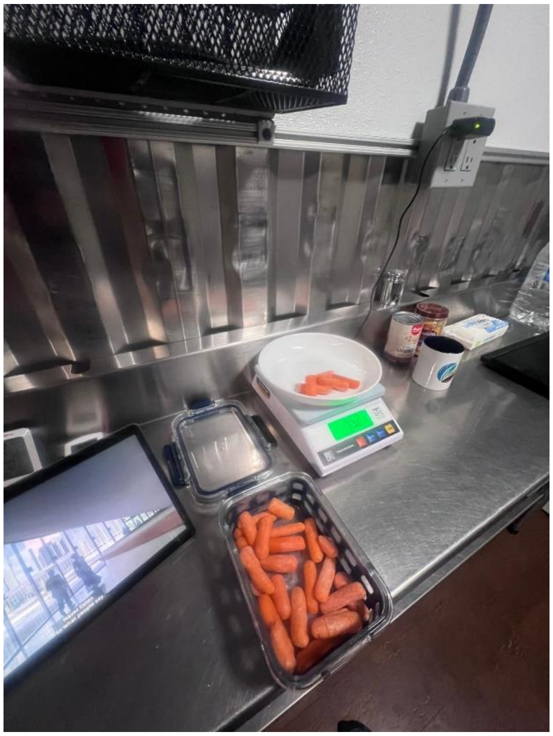


Figure 2 All food was weighed before consumption

Figure 3 This is a photo from inside the test module where I rowed.

Figure 4 Photo of my crew quarters, kitchen/bedroom and bathroom behind me. A single sleeping pad was comfortable for me.

Figure 5 The Engineering and medical bay which connects the crew quarters to the Test Module, this is where the SIMOC live computer was set up and a single vernier sensor

Figure 6 Midday at my work desk in the TM.

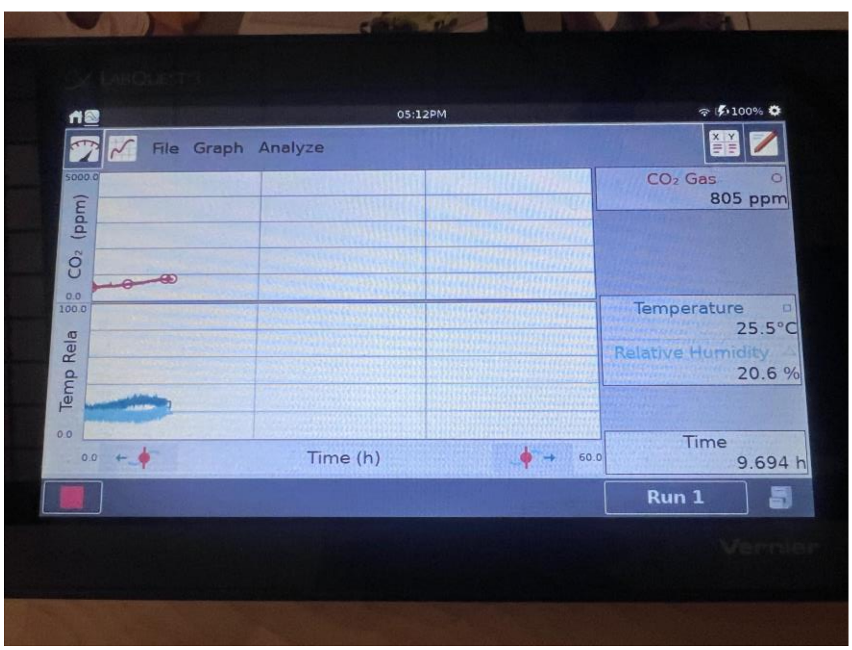


Figure 7 An example view of the vernier data capture screen

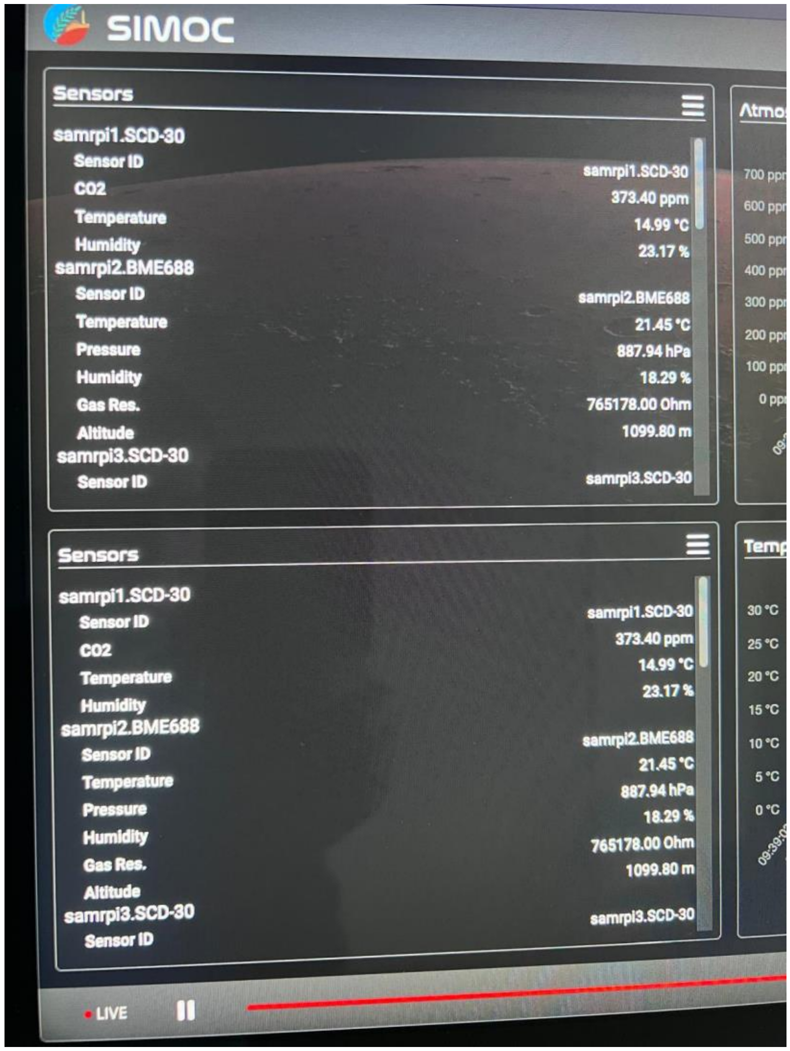


Figure 8 Example of the SIMOC live data capture screen on a desktop monitor