**International Space and Aeronautics Agency (ISAA)**

**Europa Exploration Program (EXP)**

**Wilkes Land Test Facility (WLTF)**

**ANOMALY REPORT**

*Event Date: June 16, 2020*

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| **Executive Summary**  On June 16, 2020 at 3:19 AM Indochina Time (ICT), an anomaly occurred during testing of the Modular Habitat Base Camp (MHBC) at the Wilkes Land Testing Facility (WLTF) in Antarctica. The MHBC temperature dropped below the emergency threshold of 12.7o C. ISAA operators and crew attempted to raise the temperature through Environmental Control and Life Support (ECLS) commanding but were unable to do so. As a result, the ISAA Emergency Response Team (ERT) evacuated the crewmembers at 4:52 AM and testing was suspended.  The ERT and flight surgeons determined that no crewmember injuries resulted from the anomaly. Crewmembers reported no significant symptoms or injuries beyond shivering and discomfort. The final MHBC internal temperature reading was minus 5o C.  A root cause investigation revealed that the probable cause was a failed temperature sensor in the Contingency Heating Assembly (CHA). The sensor telemetry read a constant 20o C throughout the anomaly and evacuation. Engineers were unable to recreate the failure in the spare flight unit, but analysis indicates that the sensor failed due to its proximity to the Allen Logistics Rack (ALR), which contains a high-powered heating element.  Recommended corrective actions include enhanced thermal shielding for the CHA backplate, or relocation of the CHA to the opposite wall of the crew cabin. Engineering also recommends increasing the maximum power of the ECLS heaters (which are inhibited to lower power for test purposes).  This Anomaly Report summarizes the event, including an investigation report and proposed corrective actions. |

**Detailed Report**

1. **Background**

As part of the Europa Exploration Program (EXP), the Modular Habitat Base Camp (MHBC) provides an atmosphere-controlled environment for crewmembers to live in during the planned seven-day ground exploration mission in 2030. The MHBC test site is at Wilkes Land Testing Facility (WLTF), Antarctica, which ISAA selected to mimic the extreme cold temperatures of Europa.

The MHBC design includes an Environmental Control and Life Support (ECLS) heating system intended to provide habitable conditions at Europa’s equator, where the maximum temperature is minus 160o C. A backup system, the Contingency Heating Assembly (CHA), is intended to provide emergency supplemental heating until crewmembers can repair the ECLS heaters or evacuate the MHBC. The MHBC also includes six Extravehicular Activity (EVA) suits which allow brief, two-hour excursions on Europa’s surface. (For the purposes of the test expedition, these suits are not present, and have been replaced with sets of heavy winter clothing consistent with ISAA Antarctic explorers.)

While it is impossible to simulate Europa’s exact extreme temperature conditions on Earth, the WLTF provides the closest equivalent possible, averaging minus 60o C. The heaters are electrically inhibited to 10% of their maximum operating power. The CHA is also inhibited by 15%.

The primary goal of the MHBC test expeditions is to provide ISAA astronauts and operators with a complete, flight-ready environment to practice commanding, daily operations, and emergency scenarios.

1. **Anomaly Description**

The anomaly occurred during the 15th day of the third test expedition of the MHBC in Antarctica, which was originally scheduled to last 21 days. Two ISAA astronauts, Warwick Tannhauser and Tatiana Oleynik, participated in the test. (They are assigned to the EXP Demo Mission 2 backup crew.)

Daily activities concluded at 10:00 PM ICT, and the nominal crew sleep period began, intended to last until 6:00 AM. Per nominal operations, the MHBC ELCS heaters were set to “low.” (This setting was already selected earlier in the day, and was confirmed by Warwick Tannhauser.)

At 1:30 AM, ISAA meteorologists notified WLTF operators that a severe snowstorm is forming and will affect the MHBC test site within one hour. Storms of these severity are common in the Wilkes Land area, and operators are trained to watch telemetry closely for any temperature shifts or structural penetration of the MHBC.

At 1:55 AM, Tatiana Oleynik woke from sleep. WLTF operators contacted the MHBC, and Oleynik stated that she was woken by the sounds of precipitation outside. The snowstorm was still affecting the area, and operators noted the external temperature dropped to minus 80o C. Before returning to sleep, Oleynik noted the interior temperature of 10o C requested an increase to the ECLS heater power. (Standard operating procedures require operators, not crew, to perform ECLS heater adjustments during the sleep period.) After confirmation from the flight surgeon on duty, the operators increased the ECLS heater setting to “moderate.” Oleynik returned to sleep at 2:10 AM.

Despite the increase in heater power, temperatures in the MHBC continue to drop. At 2:30 AM, operators noted an internal reading of 8.3o C, with an external temperature of minus 85o C. After a brief conference call, testing director Alanna Christoph authorized operators on duty to set the ECLS heater power to “high” for one hour. (Setting the power to “high” removes a level of failure tolerance and requires director approval.)

At 3:19 AM, Level 2 Caution and Warning (C&W) alarms sounded after the internal MHBC temperature dropped to 6.8o C. Per pre-established hazard controls, operators instructed Tannhauser and Oleynik to don available EVA thermal garments. The crew and operators then followed ECLS troubleshooting procedures as established in hazard report MHBC-ECLS-1566 and the MHBC flight manual, ISA-EXP-0044646.

After troubleshooting, operators determined at 4:10 AM that the ECLS heaters are functioning properly, but are still somehow unable to maintain a temperature differential. Additionally, the outdoor temperature has dropped further to minus 89o C, and the indoor temperature has reached 4o C. Director Christoph authorized activation of the Contingency Heating Assembly (CHA) to further heat the MHBC, and instructed the WLTF Emergency Response Team (ERT) to remain on standby.

At 4:15 AM, Operators sent a software command for the CHA to power on, but it failed to respond. Use of backup commanding and the emergency console also failed to initiate the CHA. Following this, the crew attempted to power on the CHA with the Crew Command Panel (CCP), but the CHA did not respond. At 4:35 AM, the internal temperature dropped further 0o C.

At 4:36 AM, Director Christoph ordered an evacuation of the MHBC – however, due to severe weather conditions, an evacuation was deemed unsafe, and the crew were ordered to shelter-in-place. The internal temperature dropped again to minus 5o C.

At 4:52, a break in the weather allowed ERT to evacuate the crew. After successful evacuation, WLTF suspended test operations.

Medical exams following evacuation showed that Tannhauser and Oleynik sustained no injuries or hypothermic symptoms beyond shivering.

1. **Timeline of Anomaly**

*Table 1: Timeline*

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| **Date** | **Time** | **Event Description** |
| 6/15/20 | 10:00 PM | Crew sleep period begins. MHBC ECLS heaters are set to “low.” Internal temperature is at a nominal 20o C. |
| 6/16/20 | 1:30 AM | ISAA meteorologists notify WLTF operators that a severe snowstorm will form over the MHBC test area within the hour. |
| 6/16/20 | 1:55 AM | ISAA astronaut Tatiana Oleynik wakes up and reports loud noises from precipitation outside. |
| 6/16/20 | 1:57 AM | Temperatures outside the MHBC reach minus 78o C. |
| 6/16/20 | 2:00 AM | Citing discomfort, Oleynik requests permission to increase ECLS heater setting. Crew readout shows internal MHBC temperature at 10o C. |
| 6/16/20 | 2:01 AM | Operators set MHBC ELCS heaters to “moderate.” |
| 6/16/20 | 2:10 AM | Oleynik returns to sleep. |
| 6/16/20 | 2:30 AM | Remote telemetry shows MHBC internal temperature at 8.3o C. External temperature reaches minus 85o C. |
| 6/16/20 | 2:35 AM | Operators call the WLTF Testing Director. She authorizes the operators to raise ECLS heater power to “high” for 1 hour. |
| 6/16/20 | 2:45 AM | Operators remotely command MHBC ECLS heaters to “high.” |
| 6/16/20 | 3:19 AM | Level 2 Caution and Warning (C&W) alarms sound and wake the crew. Remote telemetry and MHBC crew command panels show a temperature of 6.8o C. |
| 6/16/20 | 3:20 AM | Operators instruct crew to don thermal garments. |
| 6/16/20 | 3:25 AM | Crew and operators begin to troubleshoot ECLS heater system. |
| 6/16/20 | 4:10 AM | Operators find no errors or faults in the ECLS heater system. |
| 6/16/20 | 4:10 AM | Remote telemetry and crew monitoring reports internal MHBC temperature at 4o C. |
| 6/16/20 | 4:11 AM | Director Alanna Christoph authorizes CHA use. |
| 6/16/20 | 4:15 AM | Operators attempt to power the CHA using standard software commands. CHA fails to respond. |
| 6/16/20 | 4:20 AM | Operators attempt to power the CHA using backup software commanding and the emergency panel. CHA fails to respond. |
| 6/16/20 | 4:35 AM | Crew attempts to power the CHA using CCP. CHA fails to respond. |
| 6/16/20 | 4:35 AM | Remote telemetry and crew monitoring reports internal MHBC temperature at 0o C. |
| 6/16/20 | 4:36 AM | Director Christoph orders an evacuation of the MHBC. |
| 6/16/20 | 4:40 AM | Meteorologists report weather radar shows severe weather will abate briefly in 10 minutes. Operators instruct the crew to shelter-in-place until ERT can reach them. |
| 6/16/20 | 4:45 AM | Remote telemetry and crew monitoring reports internal MHBC temperature at minus 5o C. |
| 6/16/20 | 4:52 AM | ERT evacuates crew from MHBC. |
| 6/16/20 | 4:52 AM | WTSF suspends test operations. |
| 6/16/20 | Unknown | Medical exam of crew reveals no injuries or symptoms. |

1. **Corrective Actions Attempted During Anomaly**

WLTF operators followed hazard report MHBC-ECLS-1566 and flight manual ISA-EXP-0044646 to diagnose the problem. Hazard Cause 2 of MHBC-ECLS-1566, “Inadequate Heating,” listed a series of diagnostic checks which operators and crew followed. The flight manual also listed instructions on how to verify ECLS heater output. After this real-time investigation, operators and crew found no errors or faults in ECLS that would cause inadequate heating.

Operators and crew also attempted to initialize the CHA. Operators toggled the Emegency Mode switch on the ECLS control panel, and sent the “CHA\_EMER\_START” software command, but CHA did not respond after the standard waiting period of two minutes. Operators then sent a backup command, “CHA\_EMER\_RESTART\_PRIORITY” but CHA did not respond. Lastly, operators sent “CHA\_EMER\_START” from a reserve laptop, but there was no response.

Crew members also attempted to power the CHA using the CCP, but it didn’t respond. After waiting the standard two minutes, the crew pressed the button again, but the CHA still didn’t respond.

Because the hazard controls, flight operations, and other mitigation steps were unable to restore proper heating, the crew were forced to evacuate. All attempted corrective actions were unsuccessful.

1. **Root Cause Investigation Results**

The MHBC test site was packed and transported to Tereshkova Research Center (TRC) on July 6, 2020. Miranda Aerospace, the contracting company responsible for the MHBC, performed a full tear-down of the flight unit to determine the source of the failure.

This section summarizes the testing and analysis performed by Miranda Aerospace engineers. Further details can be found in Root Cause Analysis Report MARCA-0923.

*Table 2: Test/Inspection Report Summary*

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| **Component** | **Test Name** | **Pass/Fail** | **Comments** |
| CBCS Software | Code Review | Pass |  |
| CCP | Software Commanding Test | Pass | CCP successfully commanded the ECLS heaters and CHA to power on and off. |
| CHA | Software Log Review | Fail | See Note 1 |
| CHA | Visual Inspection | Pass | No visual damage noted. Compared flight unit with design drawings. |
| CHA (with MHBC) | Thermal Stress Test | Fail | See Note 2 |
| CHA (without MHBC) | Thermal Stress Test | Pass | See Note 3 |
| CHA Temperature Sensor | Sensor Test | Pass | See Note 4 |
| ECLS Heaters | Visual Inspection | Pass | No visual damage noted. Compared flight unit with design drawings. |
| ECLS Heaters (with MHBC) | Thermal Stress Test | Fail | See Note 5 |
| ECLS Heaters (without MHBC) | Thermal Stress Test | Fail | See Note 6 |
| MHBC Thermal Shielding | Visual Inspection | Pass | Minor wear on external softgoods. |
| MHBC Windows | Leak Test | Pass | Windows passed standard pressurized stress test. |
| MHBC Windows | Visual Inspection | Pass | No visual damage noted. |

**Testing Notes:**

1. Review of the internal CHA software logs revealed that the temperature sensor read a steady 20o C throughout the expedition, indicating a failure in the sensor. (See note 4.)
2. The CHA was tested in the Europa Extreme Temperature Room (EETR) while installed in the MHBC. The testing parameters were set to match the maximum outdoor temperature experienced during the expedition (minus 89o C), and the operators were instructed to wait one hour to attempt CHA initialization. The CHA failed to respond to operator or crew commands, and the test was terminated. The internal CHA software logs were reviewed and the temperature sensor read 20oC throughout the
3. The CHA was tested in the EETR individually (without the MHBC) using the same parameters as the integrated CHA/MHBC test (in note 1). The CHA responded to operator commands and maintained 12.7o C or higher for 2 hours. (This is considered a passing test per program requirements.)
4. The CHA temperature sensor was removed from the assembly and individually tested. It passed all testing, despite the expedition software logs indicating failure (see note 1).
5. The ECLS heaters were tested in the EETR while installed in the MHBC. The test parameters were set to match the maximum outdoor temperature experienced during the expedition (minus 89o C), with a time limit of three hours. The heaters failed to maintain the minimum required 10o C, and dropped below the alarm criteria (7o C) after 1 hour, 16 minutes.
6. **Root Cause Analysis Conclusions**While the

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**ATTACHMENT 1: LIST OF ACRONYMS**

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| **Acronym** | **Definition** |
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