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**International Space and Aeronautics Agency (ISAA)**
**Europa Exploration Program (EXP)**
**Wilkes Land Test Facility (WLTF)**

# ANOMALY REPORT

Anomaly Date: January 16, 2020

Location: WLTF, Modular Habitat Base Camp (MHBC) Test Expedition

## Executive Summary

On January 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 7° C. ISAA operators and crew attempted to raise the temperature by engaging the Contingency Heating Assembly (CHA), but it was unresponsive. As a result, the ISAA Emergency Response Team (ERT) evacuated the crewmembers at 4:52 AM, and testing was suspended.

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 5° C.

A preliminary root cause investigation revealed that the probable cause was **a failed temperature sensor in the CHA.** Engineers tested the sensor and found that it failed "stuck" at 30° C. Initial analysis indicates that the sensor failed due to its proximity to the Allen Logistics Rack (ALR), which can reach temperatures of 35° C depending on its contents.

Permanent corrective options include:

1) Redesign of the temperature sensor
2) Enhanced thermal shielding for the CHA backplate
3) **Recommended: Relocation of the CHA to the opposite wall of the crew cabin.**

This Anomaly Report includes a background, timeline of events, and findings from the preliminary root cause investigation.

# Table of Contents



# Background

As part of the Europa Exploration Program (EXP), the Modular Habitat Base Camp (MHBC) provides an atmosphere-controlled living quarters for crewmembers to use during EXP Demo Mission 2, which will be ISAA's first human exploration of Jupiter's moon, Europa. The MHBC test site is at Wilkes Land Testing Facility (WLTF), Antarctica, which ISAA selected due to its extremely cold ambient temperatures year-round.

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 ambient temperature is minus 160° C. A backup system, the Contingency Heating Assembly (CHA), is intended to provide supplemental heating.

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

ISAA Life Sciences set an emergency temperature threshold of 7° C for the MHBC test expedition. This temperature was selected because it allows crewmembers adequate time to troubleshoot issues or evacuate the site before experiencing hypothermic symptoms. The emergency threshold for the official EXP missions is still to-be-determined (TBD) pending additional analysis.

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.

# Description of Anomaly

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. The MHBC ELCS heaters were set to “low.”

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 this 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 stated that she was woken by the sounds of wind and snowfall outside. WLTF operators noted the external temperature dropped to minus 80° C. Oleynik noted the interior temperature of 10° C and 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, WLTF operators increased the ECLS heater setting to “moderate.”

Despite the increase in heater power, temperatures in the MHBC continue to drop. At 2:30 AM, operators noted an internal reading of 8.3° C, with an external temperature of minus 85° C. After a brief conference call, testing director Alanna Christoph authorized operators 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 6.8° C. Operators instructed Tannhauser and Oleynik to don all available 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 were functioning properly, but they were still somehow unable to maintain a temperature differential. Additionally, the outdoor temperature dropped further to minus 92° C, and the indoor temperature reached 4° C. Director Christoph authorized activation of the Contingency Heating Assembly (CHA) to further heat the MHBC, and he 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 MHBC Crew Command Panel (CCP), but the CHA did not respond. At 4:35 AM, the internal temperature dropped further to 0° 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 was ordered to shelter-in-place. The internal temperature dropped again to minus 5° C.

At 4:52 AM, a break in the weather allowed ERT to evacuate the crew. Following this, WLTF suspended test operations.

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

**See Attachment B for a detailed timeline of the anomaly.**

## 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.

CHA commanding was attempted using the following methods:

1) WLTF Operators toggled the Emergency Mode switch on the ECLS control panel, sent the “CHA_EMER_START” software command, and waited the required two minutes.

2) Operators sent a backup command, “CHA_EMER_RESTART_PRIORITY”

3) Operators sent the “CHA_EMER_START” command from a reserve laptop (belonging to Director Christoph)

4) Crew members attempted to power the CHA using the CCP and waited two minutes for a response.

Ultimately, CHA initialization failed, and the crew was forced to evacuate.

## Preliminary Root Cause Investigation Results

(Note: full test and analysis results can be found in Root Cause Analysis Report MARCA-0923.)

The MHBC test site was packed and transported to Tereshkova Research Center (TRC) on February 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.

During CHA disassembly and reintegration testing, engineers determined that the ambient temperature sensor had failed "stuck" to a constant 30° C. Because the CHA firmware inhibits operations above 10°C, engineers have concluded that all CHA software commands during the test expedition failed because of this inaccurate sensor.

The most likely cause of the temperature sensor's failure is its proximity to the Allen Logistics Rack (ALR), which also operated at 30° C during the expedition. Engineers also cannot rule out a defective temperature sensor. Additional information from the sensor vendor is pending.

Additional ECLS and CHA testing is planned for July 2020.

## Recommendations and Conclusions

While the root cause investigation is still ongoing, Miranda Aerospace engineers, in coordination with ISAA EXP, have determined that the probable cause of the CHA failure was a failed ambient temperature sensor, either from a manufacturing defect, or excessive heat from the adjacent ALR.

Permanent corrective options include:

1) Redesign of the temperature sensor and CHA to prevent failure from contact with nearby heat sources (such as the ALR).

2) Enhanced thermal shielding for the CHA backplate. This would prevent interference from nearby heat sources, but it could affect the effectivity and weight of the CHA.

3) **Recommended:** Relocation of the CHA to the opposite wall of the crew cabin. A "tabletop analysis" and visual inspection determined that swapping the locations of the CHA and Portable Computer System (PCS) would be feasible. Furthermore, the PCS is hardened against thermal extremes, which should prevent any issues with its proximity to the ALR.

*Prepared by:*
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# ATTACHMENT A: List of Acronyms

| | |
|---|---|
| **ALR** | Allen Logistics Rack |
| **C&W** | Caution and Warning |
| **CCP** | Crew Command Panel (MHBC) |
| **CHA** | Contingency Heating Assembly |
| **ECLS** | Environmental Control and Life Support |
| **ERT** | Emergency Response Team |
| **EXP** | Europa Exploration Program |
| **ICT** | Indochina Time (UTC+7) |
| **ISAA** | International Space and Aeronautics Agency |
| **MHBC** | Modular Habitat Base Camp |
| **PCS** | Portable Computer System |
| **TBD** | To-be-determined |
| **WLTF** | Wilkes Land Testing Facility |

# ATTACHMENT B: Detailed Timeline of Anomaly

| Date | Time | Event Description |
|---|---|---|
| 1/15/20 | 10:00 PM | Crew sleep period begins. MHBC ECLS heaters are set to “low.” Internal temperature is at a nominal 20° C. |
| 1/16/20 | 1:30 AM | ISAA meteorologists notify WLTF operators that a severe snowstorm will form over the MHBC test area within the hour. |
| 1/16/20 | 1:55 AM | ISAA astronaut Tatiana Oleynik wakes up and reports loud noises from precipitation outside. |
| 1/16/20 | 1:57 AM | Temperatures outside the MHBC reach minus 78° C. |
| 1/16/20 | 2:00 AM | Citing discomfort, Oleynik requests permission to increase ECLS heater setting. Crew readout shows internal MHBC temperature at 10° C. |
| 1/16/20 | 2:01 AM | Operators set MHBC ELCS heaters to “moderate.” |
| 1/16/20 | 2:30 AM | Remote telemetry shows MHBC internal temperature at 8.3° C. External temperature reaches minus 85° C. |
| 1/16/20 | 2:35 AM | Operators call the WLTF Testing Director. She authorizes the operators to raise ECLS heater power to “high” for 1 hour. |
| 1/16/20 | 2:45 AM | Operators remotely command MHBC ECLS heaters to “high.” |
| 1/16/20 | 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 6.8° C. |
| 1/16/20 | 3:20 AM | Operators instruct crew to don thermal garments. |
| 1/16/20 | 3:25 AM | Crew and operators begin to troubleshoot ECLS heater system. |
| 1/16/20 | 4:10 AM | Operators find no errors or faults in the ECLS heater system. |
| 1/16/20 | 4:10 AM | Remote telemetry and crew monitoring reports internal MHBC temperature at 4° C. |
| 1/16/20 | 4:15 AM | Operators attempt to power the CHA using standard software commands. CHA fails to respond. |
| 1/16/20 | 4:20 AM | Operators attempt to power the CHA using backup software commanding and the emergency panel. CHA fails to respond. |
| 1/16/20 | 4:35 AM | Crew attempts to power the CHA using CCP. CHA fails to respond. |
| 1/16/20 | 4:35 AM | Remote telemetry and crew monitoring reports internal MHBC temperature at 0° C. |
| 1/16/20 | 4:36 AM | Director Christoph orders an evacuation of the MHBC. |
| 1/16/20 | 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. |
| 1/16/20 | 4:45 AM | Remote telemetry and crew monitoring reports internal MHBC temperature at minus 5° C. |
| 1/16/20 | 4:52 AM | ERT evacuates crew from MHBC. |
| 1/16/20 | 4:52 AM | WTSF suspends test operations. |