LAT TECHNICAL NOTE	Document # **LAT-TD-05956-01**	Date 2/28/05
	Author(s) B. Pugh	Supersedes None
	System or Sponsoring Office System Engineering	

Document Title

GLAST LAT Radiator VCHP Reservoir Heater Control Algorithm Description

CHANGE HISTORY LOG [Change history log may be deleted if not used]

Revision	Effective Date	Description of Changes	DCN #
01		Initial Release	LAT-XR-05957-01

Gamma Ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Radiator VCHP Reservoir Heater Control Algorithm Description

TABLE OF CONTENTS

1. Scope and Purpose

This technical note documents the LAT Radiator VCHP Reservoir Heater Control Algorithm developed by Lockheed Martin Corporation (LMC).

2. Applicable Documents

[1] LAT-SS-00399, "LAT Flight Software Specification-Level III"

3. Summary of Requirements Used by LMC to Develop Algorithm

This document supplements the Thermal Flight Software requirements specified in LAT-SS-00399, "LAT Flight Software Specification-Level III."

During normal operations, the LAT Radiator's six software controlled VCHP reservoir heaters are used for two basic purposes:

- Maintaining reservoir temperatures (Tres) above -65°C for antifreeze protection.
- Maintaining radiator interface temperatures (Trit) between -10°C and +17°C during normal operations. However, if Trit - Tres is less than or equal to 6°C, the reservoir heater should remain off regardless of Trit.

Antifreeze protection takes precedence over maintaining the RIT temperature and the Trit - Tres delta temperature is ignored when antifreeze protection is required.

The values for the reservoir antifreeze limit (-65°C), the RIT lower limit (-10°C), the RIT upper limit (15°C), and Trit – Tres (6°C) are subject to change based on design evolution and mission requirements. Per LAT-SS-00399, these limits shall be implemented as parameters that can be changed via software upload.

4. LMC Algorithm to be Implemented by LAT FSW

A logic diagram proposed by LMC that meets these requirements is provided in Figure 1 and its corresponding states and outcomes are shown in Table 1.

The possible operational states shown in Table 1 are a function of the number of control parameters in the algorithm. LMC's VCHP reservoir heater control algorithm utilizes 6 control parameters which are as follows:

- Tres ≤ -65°C
- Tres ≤ -64°C
- Trit < -5°C
- Trit < -4°C
- Trit-Tres>6°C
- Heater Flag = On

Note that LMC chose RIT temperatures between -5°C and -4°C. This choice was arbitrary and, as mentioned above is changeable.

If the above parameters were independent there would be $2^6 = 64$ unique states that the VCHP reservoir heater algorithm could encounter. However, there are three unique dependencies that make some of these theoretical states impossible.

- "Tres ≤ -64°C" can not be false if "Tres ≤ -65°C" is true.
- "Trit < -4°C" can not be false if "Trit < -5°C" is true.
- If Tres is less than -64°C and Trit is greater than -5°C, then "Trit-Tres>6°C" must be true.

When these dependencies are factored in, there are only 28 possible states that the heater control algorithm could encounter. The 28 possible states are identified in Table 1 along with the 34 impossible states (which are highlighted in yellow). Note that a "1" indicates true and "0" indicates false (e.g. if there is a "0" in the "Tres ≤ -65°C" column, it means that actual value of Tres is greater than -65°C).

A summary of how the reservoir heaters should perform under both normal (software controlled) operations and during survival mode is provided in the Appendix.

Figure 1. VCHP Reservoir Heater Algorithm Proposed by LMC

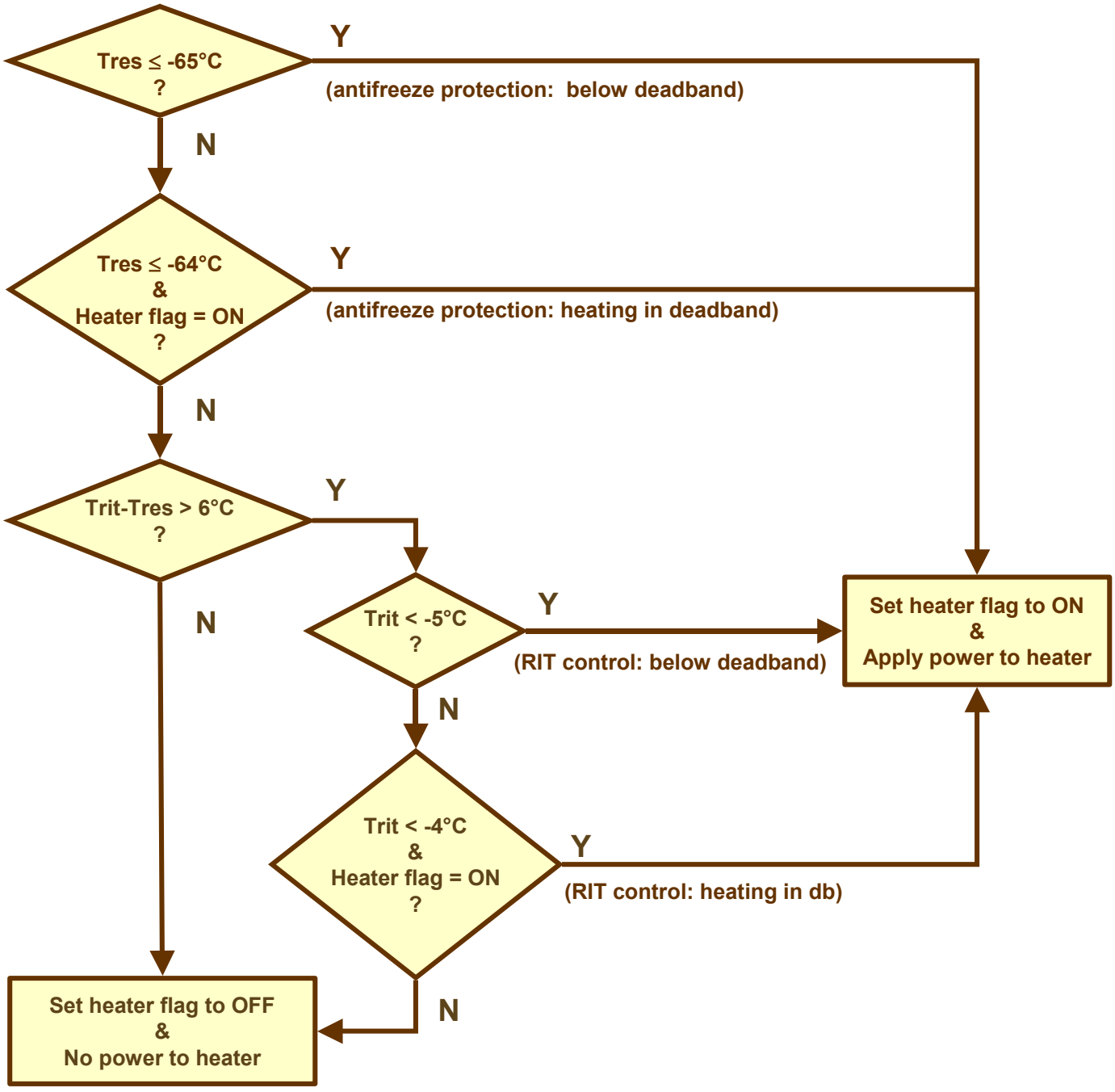
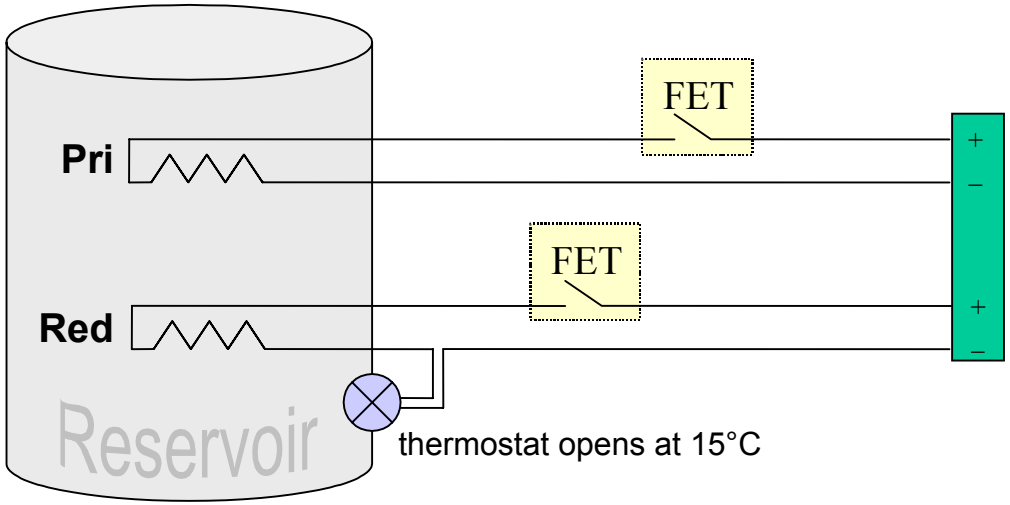


Table 1. VCHP Reservoir Heater Algorithm States and Outcomes

Tres ≤ -65°C	Tres ≤ -64°C	Trit-Tres > 6°C	Trit < -5°C	Trit < -4°C	Heater flag = ON	result
0	0	0	0	0	0	0
0	0	0	0	0	1	0
0	0	0	0	1	0	0
0	0	0	0	1	1	0
0	0	0	1	0	0	0
0	0	0	1	0	1	0
0	0	0	1	1	0	0
0	0	0	1	1	1	0
0	0	1	0	0	0	0
0	0	1	0	0	1	0
0	0	1	0	1	0	0
0	0	1	0	1	1	1
0	0	1	1	0	0	1
0	0	1	1	0	1	1
0	0	1	1	1	0	1
0	0	1	1	1	1	1
0	1	0	0	0	0	0
0	1	0	0	0	1	1
0	1	0	0	1	0	0
0	1	0	0	1	1	1
0	1	0	1	0	0	0
0	1	0	1	0	1	1
0	1	0	1	1	0	0
0	1	0	1	1	1	1
0	1	1	0	0	0	0
0	1	1	0	0	1	1
0	1	1	0	1	0	0
0	1	1	0	1	1	1
0	1	1	1	0	0	1
0	1	1	1	0	1	1
0	1	1	1	1	0	1
0	1	1	1	1	1	1
1	0	0	0	0	0	1
1	0	0	0	0	1	1
1	0	0	0	1	0	1
1	0	0	0	1	1	1
1	0	0	1	0	0	1
1	0	0	1	0	1	1
1	0	0	1	1	0	1
1	0	0	1	1	1	1
1	0	1	0	0	0	1
1	0	1	0	0	1	1
1	0	1	0	1	0	1
1	0	1	0	1	1	1
1	0	1	1	0	0	1
1	0	1	1	0	1	1
1	0	1	1	1	0	1
1	0	1	1	1	1	1
1	1	0	0	0	0	1
1	1	0	0	0	1	1
1	1	0	0	1	0	1
1	1	0	0	1	1	1
1	1	0	1	0	0	1
1	1	0	1	0	1	1
1	1	0	1	1	0	1
1	1	0	1	1	1	1
1	1	1	0	0	0	1
1	1	1	0	0	1	1
1	1	1	0	1	0	1
1	1	1	0	1	1	1
1	1	1	1	0	0	1
1	1	1	1	0	1	1
1	1	1	1	1	0	1
1	1	1	1	1	1	1

APPENDIX

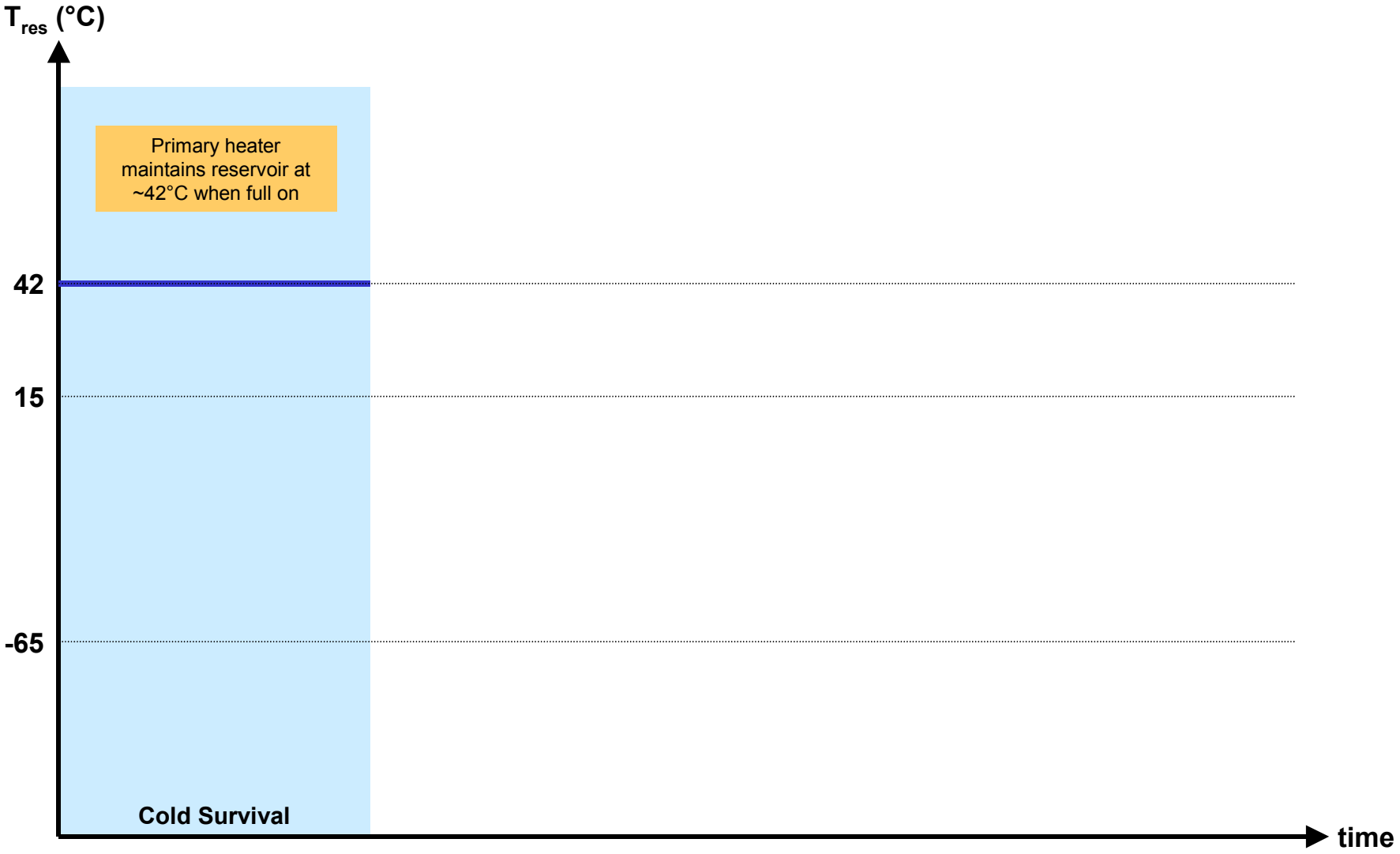
Reservoir Heater Operational Description

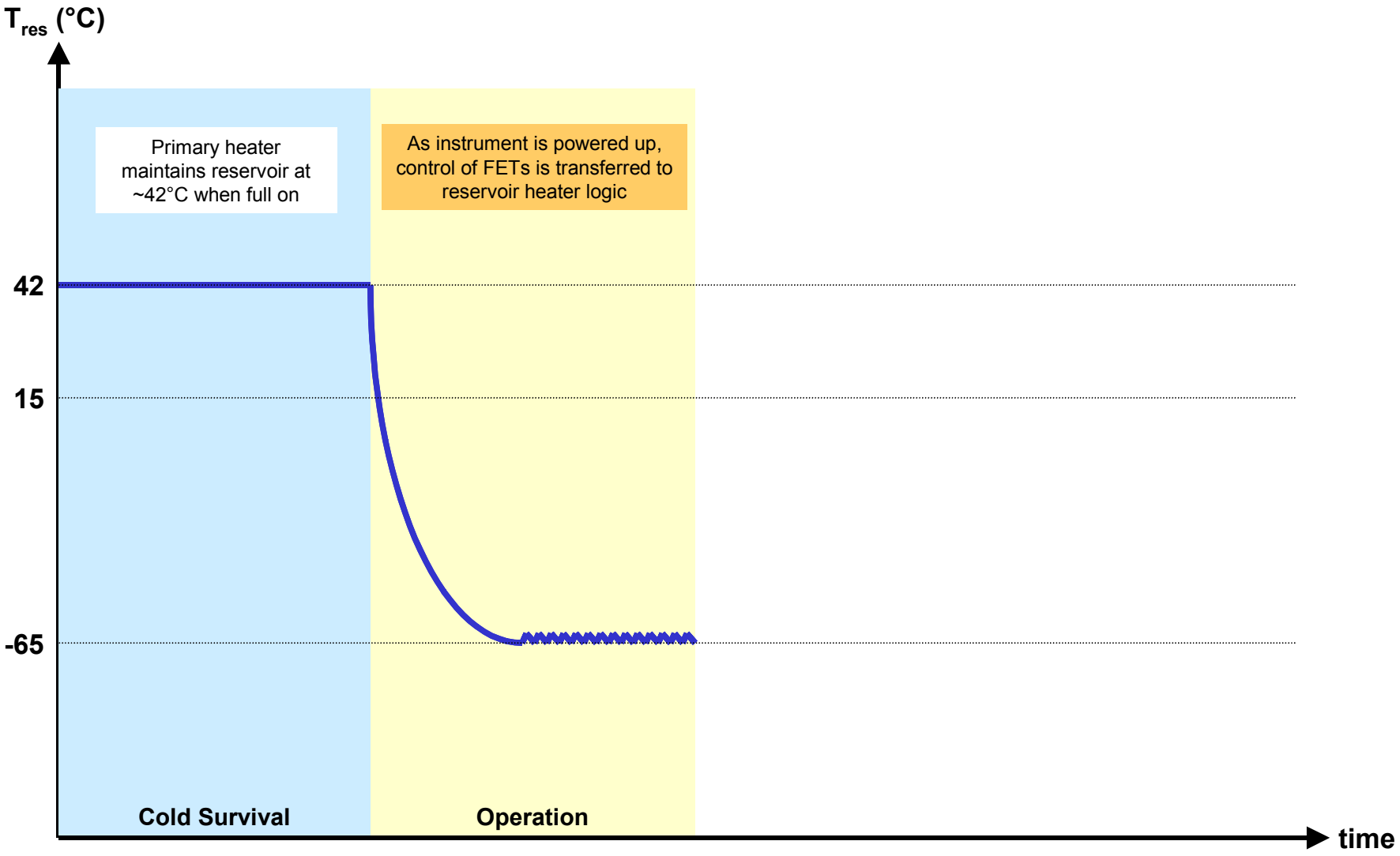


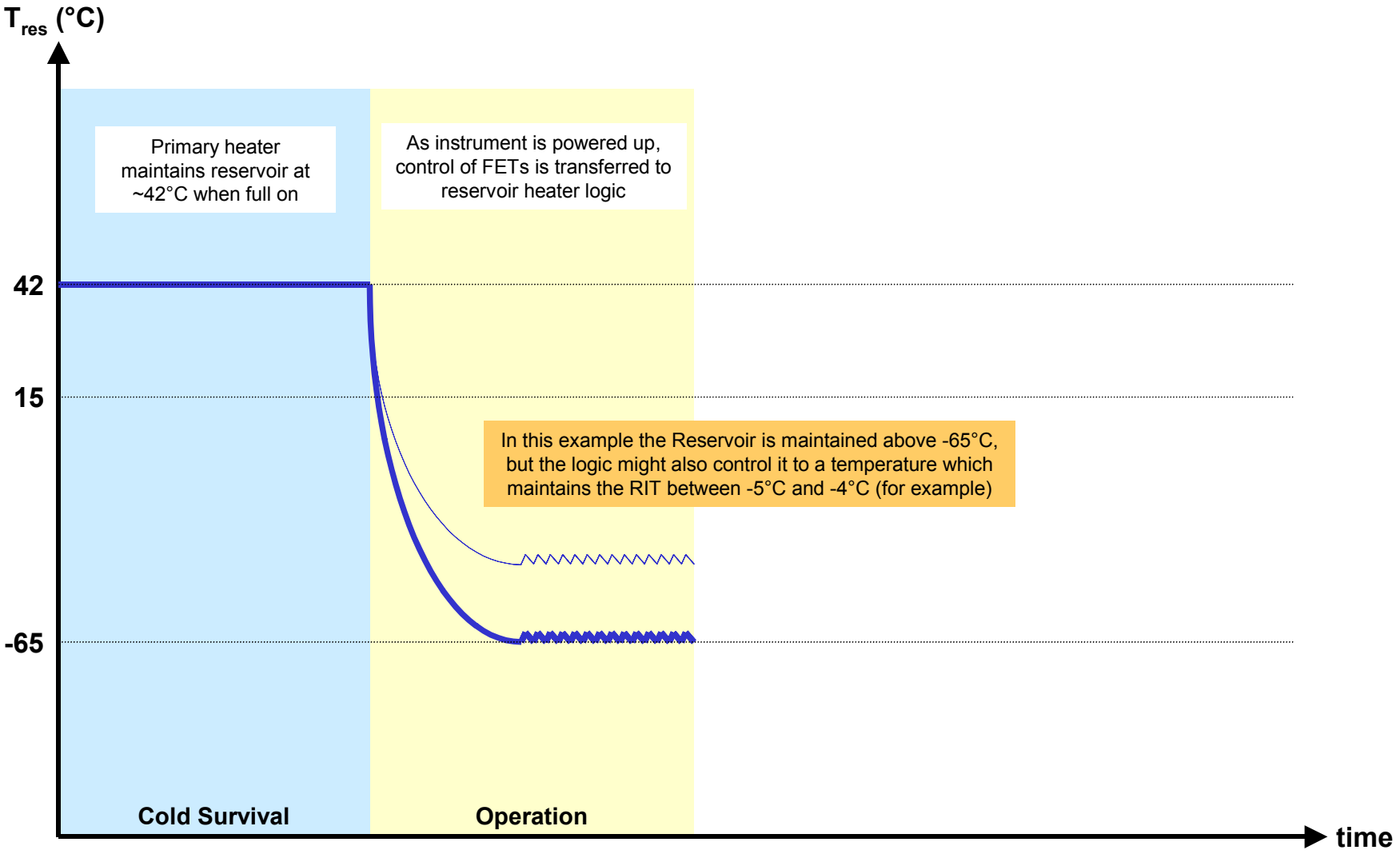
Power is provided by bus and is always on

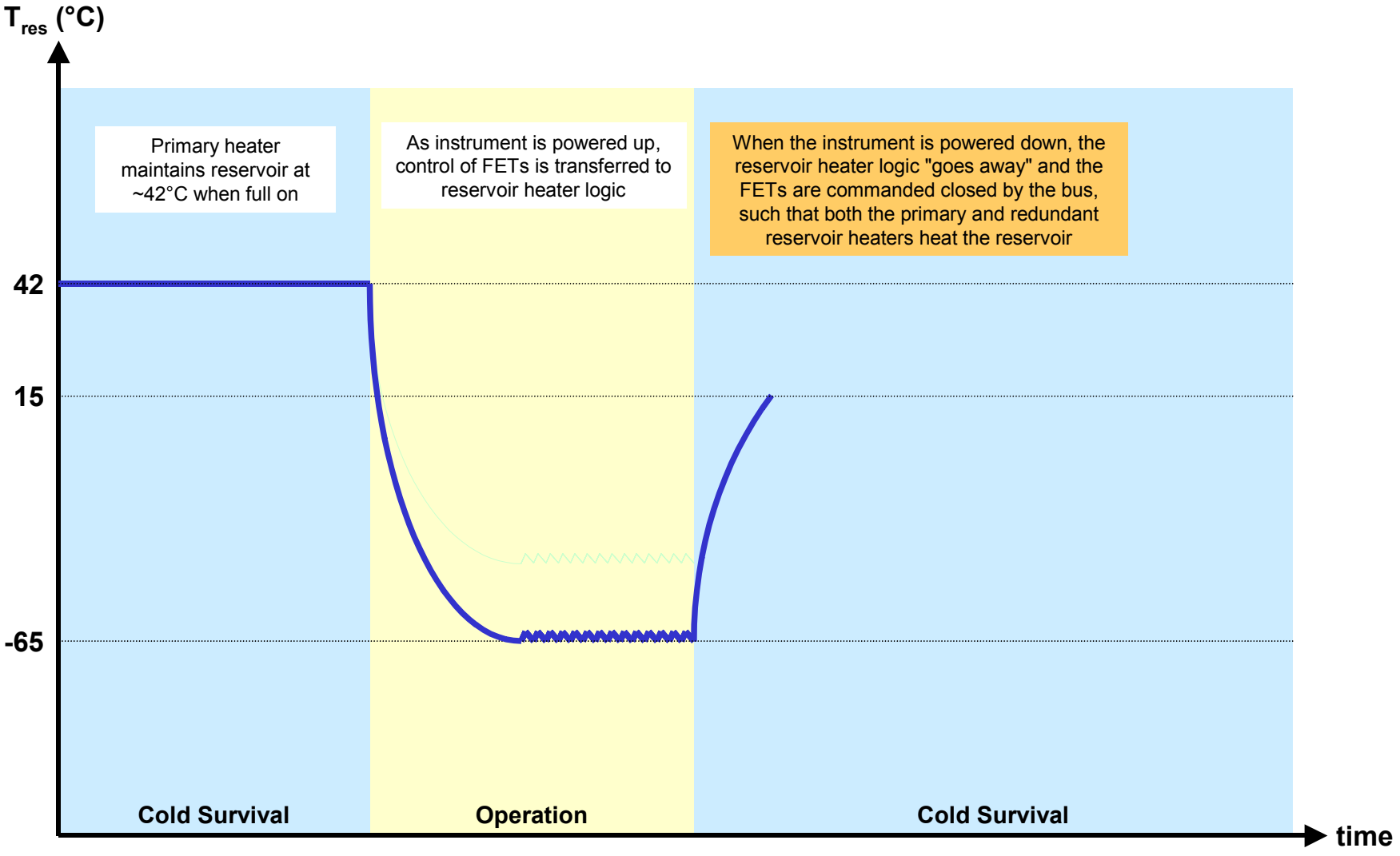
During survival mode:
- FETs are commanded closed by the bus
- Thermostat in redundant heater circuit opens at 15°C (FET stays closed)
- Primary heater maintains reservoir at ~42°C

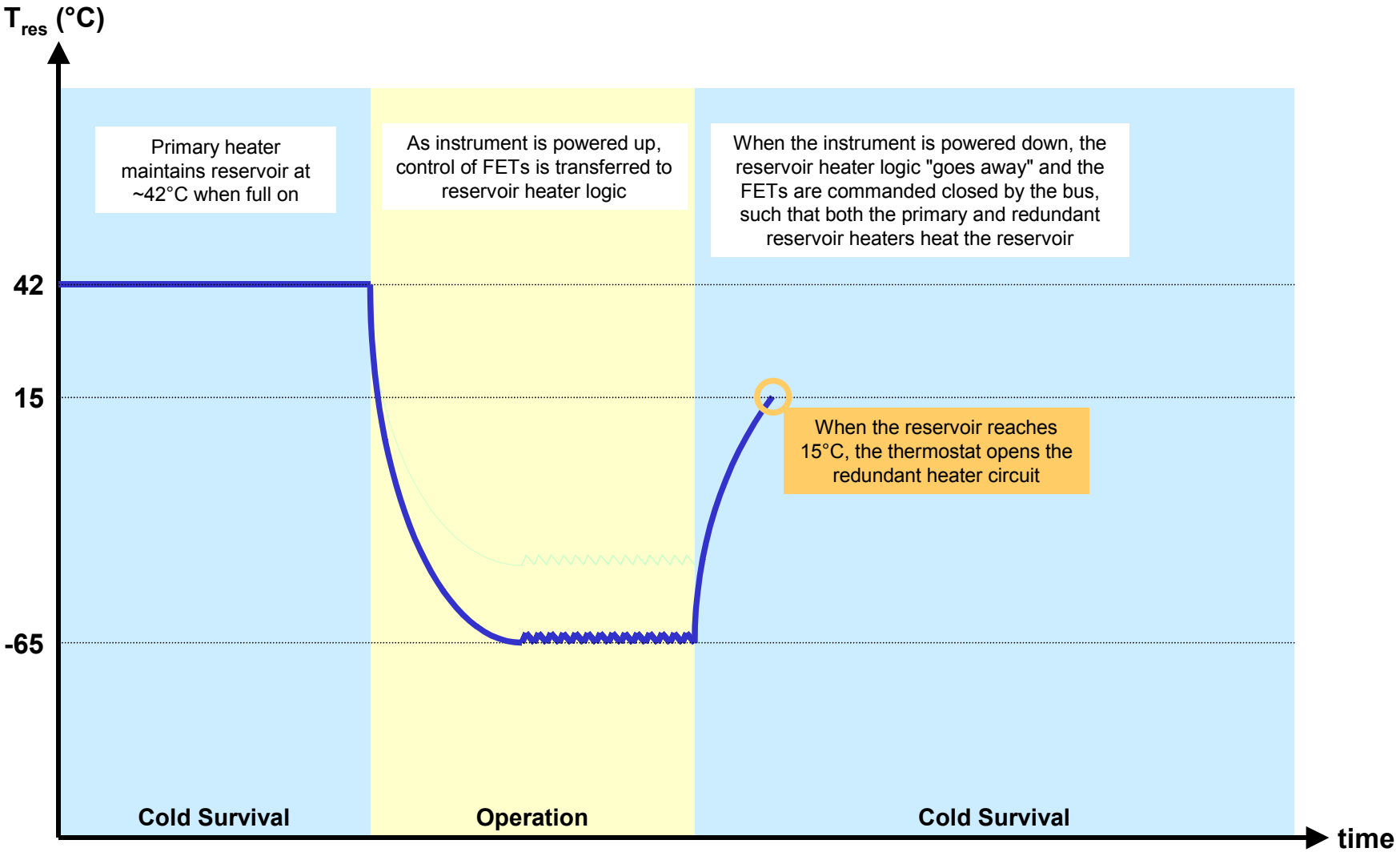
During normal operation:
- Primary heater FET is commanded open or closed by the reservoir heater logic
- Redundant heater FET stays open
- If Primary heater circuit fails for any reason, logic commands Redundant heater FET
- There is no circumstance in which the thermostat is in conflict with the logic:
  - Maximum RIT temperature is 15°C, to prevent LAT overtemp
  - Logic will not close FET if Trit-Tres < 6°C
  - Therefore highest Reservoir temperature at which logic would cl ose FET is 9°C
  - This is below thermostat open temp, so there is no conflict




T res (°C)
Primary heater maintains reservoir at ~42°C when full on
As instrument is powered up, control of FETs is transferred to reservoir heater logic
42
15
-65
Cold Survival
Operation
time


T res (°C)
Primary heater maintains reservoir at ~42°C when full on
As instrument is powered up, control of FETs is transferred to reservoir heater logic
42
15
-65
In this example the Reservoir is maintained above -65°C, but the logic might also control it to a temperature which maintains the RIT between -5°C and -4°C (for example)
Cold Survival
Operation
time


T_{res} (°C)
Primary heater maintains reservoir at ~42°C when full on
As instrument is powered up, control of FETs is transferred to reservoir heater logic
When the instrument is powered down, the reservoir heater logic "goes away" and the FETs are commanded closed by the bus, such that both the primary and redundant reservoir heaters heat the reservoir
42
15
-65
Cold Survival
Operation
Cold Survival
time


T_{res} (°C)
Primary heater maintains reservoir at ~42°C when full on
As instrument is powered up, control of FETs is transferred to reservoir heater logic
When the instrument is powered down, the reservoir heater logic "goes away" and the FETs are commanded closed by the bus, such that both the primary and redundant reservoir heaters heat the reservoir
42
15
-65
When the reservoir reaches 15°C, the thermostat opens the redundant heater circuit
Cold Survival
Operation
Cold Survival
time