



# MSFC Testing Philosophy

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# MSFC Testing Philosophy

- MSFC's only in-house document for thermal testing is MSFC-HDBK-670, "General Environmental Test Guidelines for Protoflight Instruments and Experiments".
  - Scope of protoflight testing of STS instruments and payloads
- Each program determines test program on case-by-case basis, sometimes with vendor specified requirements for contracted programs.
- ISS programs utilize SSP 41172
- Thermal Engineering recommendations to programs are made based on MIL-STD-1540C as a default.
- Typical component at MSFC is protoflight. Test comprises of 8-11 cycles with 1-hr dwell after reaching  $<3\text{C/hr}$  rate of change. Temperatures based on predictions  $\pm$  at least 10C, or 55C minimum sweep, whichever is greater.

# Testing Summary

- Do you perform thermal balance testing before thermal vacuum testing? **Not usually.** Engineering recommends it, but typically, the thermal balance is combined with the thermal vacuum or deleted due to cost/schedule.
- Describe Thermal vacuum test goals: Goal is to drive the test article as a workmanship screen, not to simulate flight environment. "Stimulate, not simulate". Achieve acceptance or protoflight test temperature on all components to extent possible
- Describe Thermal Balance test goals: Goal is to perform a test that provides sufficient data to correlate the thermal math models. For transient-dominated predictions, test environment not necessarily on-orbit simulation.
- Describe Power verification program: Break-out boxes are utilized at lowest level feasible to determine box-level current draw at a known voltage. Extrapolate mission min/max powers by Avionics Department.

# Thermal Vacuum - MSFC's Requirements Summary

## Typical Test Approach for Different Levels of Assembly

<i>Vacuum or Air</i>	<i>Thermal Cycles</i>	<i>Dwell Time at Extremes</i>	<i>Thermal Margins</i>	<i>Assembly Level</i>
$\leq 10^{-5}$ Torr	Four	$\geq 12$ hours	$\pm 10^{\circ}$ C beyond worst-case flight predictions. For heater controlled systems, margin is 80% duty cycle (or 25% margin) instead of temp.	Payload
$\leq 10^{-5}$ Torr	Four	$\geq 12$ hours	$\pm 10^{\circ}$ C beyond worst-case flight predictions. For heater controlled systems, margin is 80% duty cycle (or 25% margin) instead of temp.	Subsystem/ Instrument
$\leq 10^{-5}$ Torr	3 (if combined w/amb. press) 8-11 if vacuum only	$\geq 1$ hours	$\pm 10^{\circ}$ C of flight operational predictions	Component/ Unit
Ambient Pressure	24	$\geq 1$ hours	$\pm 10^{\circ}$ C of flight operational predictions	Component/ Unit

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# Special Cases

- Cryogenic systems require extremely long dwell and precision instrumentation. Dewar boil-off rates are the crucial parameter. Not experienced with cryo-coolers, or active dewar components.
- For avionics which experience small temperature swing due to being coldplate mounted (as in ISS), require 55C minimum sweep (on protoflight) to get workmanship check even though it's not "flight like".
- Components operated in air or Nitrogen environment can skip the thermal vacuum testing and perform ambient pressure thermal cycles only.
- Balloon flight missions utilize a temperature/altitude chamber and the range of pressures/temperatures expected during ascent and "on-station" are bracketed by the chamber. (Environment based on NASA-HDBK-1001)

# Heater Verification Philosophy

- Heater margin: 25% (80% duty cycle) at minimum bus voltage.
- Verification occurs during thermal balance/thermal cycle test program.
- Local thermostat checks for redundant thermostats (that don't actuate nominally) checked in situ w/local cooling/heating as req'd to verify actuation.

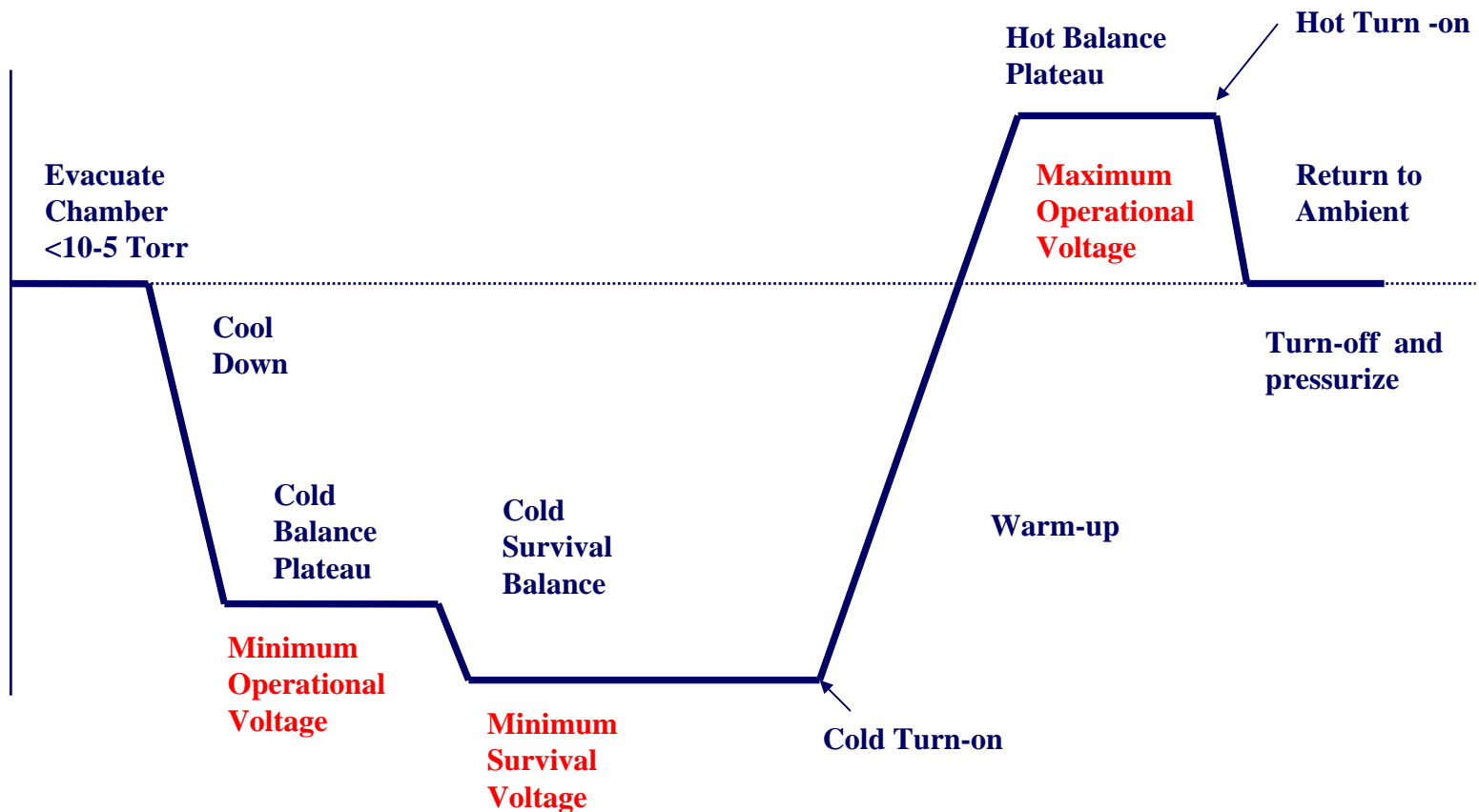
# Soak Criteria, Transition Rates, and Thermal Stability

- Temperature soaks criteria: Temperature soak for component testing begins AFTER reaching achieving the temperature target +/- 2C AND the stability criteria of 3C/hr and is minimum of 1-hr. Long duration dwells are required for massive components with low power dissipation such as batteries. Much longer dwell for system and especially thermal balance testing is required. At LEAST 12 hrs.
- The rate of transition during warming or cooling: 1-5 C/minute. T/V cycles sometimes cannot achieve the 1C/min.
- Consideration of Contamination effects: Pre-bake chamber and all hardware cables/connectors, etc. Utilize scavenger coldplate held at LN2 temperature. RGA, TQCM and OWS monitoring as required. End test on hot half-cycle.
- Stabilization criteria: 3C/hr on cycles, usually baseplate is control T/C. At discretion of thermal engineer for thermal balance. Ensure  $dT/dt$  is negative for hot dwell and vice versa for cold dwell for thermal balance criteria.



# Thermal Balance Test Profile

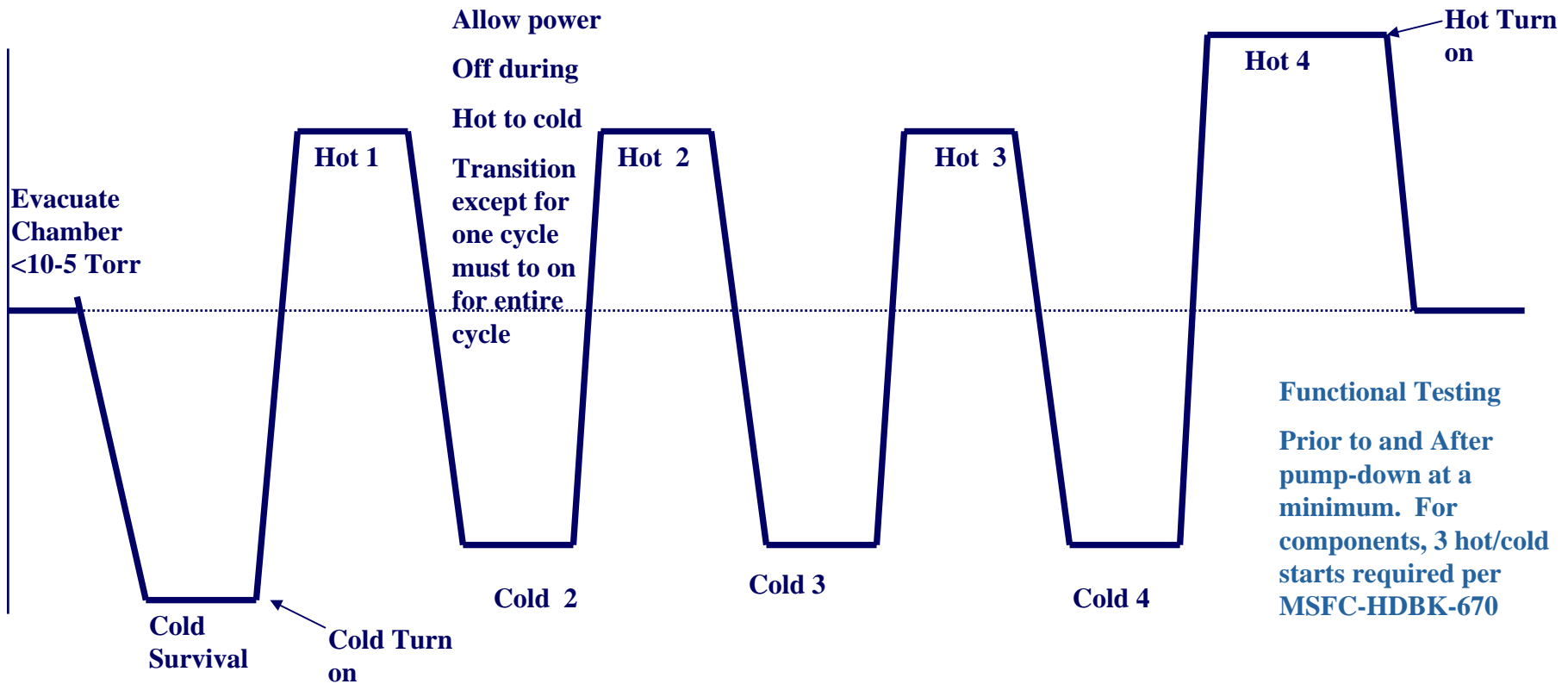
## Thermal Balance Test Profile





# Thermal Vacuum Test Profile

## Representative System-Level Thermal Cycle Test Profile for MSFC



# Example of how a box would get tested at MSFC

## ● Example Test Case

- An externally mounted power distribution box (PDB) dissipating 36 watts (nominally) is predicted to swing between -5C and 34C for a low-earth orbit 5-year mission (EOL optical properties and dissipation).
- In safemode, the unit only operates at 8 watts and requires heaters to control the unit to -15C, which are controlled via bi-metallic thermostats between -15 to -5C on survival bus operating between 24V and 32V. The designer-supplied operational limits are -20C to 45C and survival limits are -20C to 50C.
- Describe the thermal test approach for this box on a typical program at your organization from component to system-level qualification/acceptance.

# Example of how a box would get tested at MSFC

## ● Component Testing (assuming Proto-flight):

- PDB is cycled 8 thermal/vacuum cycles between -18C and 44C.
  - -18C lower limit based on being below heater controlled min. of -15C, but not exceeding designer's hard limit of -20C (considering +/-2C tolerance) for non-operational cycle. Remaining 7 cycles between -15C and 44C.
  - Unit operational during one full cycle (functionality monitored constantly), then turned off for remaining hot-to-cold transitions with cold start after each cold dwell and remaining powered during cold-to-hot.
  - Hot starts on cycles 1, 4 and 8.
  - Control thermocouples bonded with Tra-Con adhesive to baseplate (or representative mass/heat dissipation location). Unit driven with chamber Liquid Nitrogen cold-wall and infra-red lamps (or black anodized heater shroud) since externally mounted. If the example had been coldplate-mounted (or heat dissipation through baseplate design), test would be driven by cold/hot plate in testing.

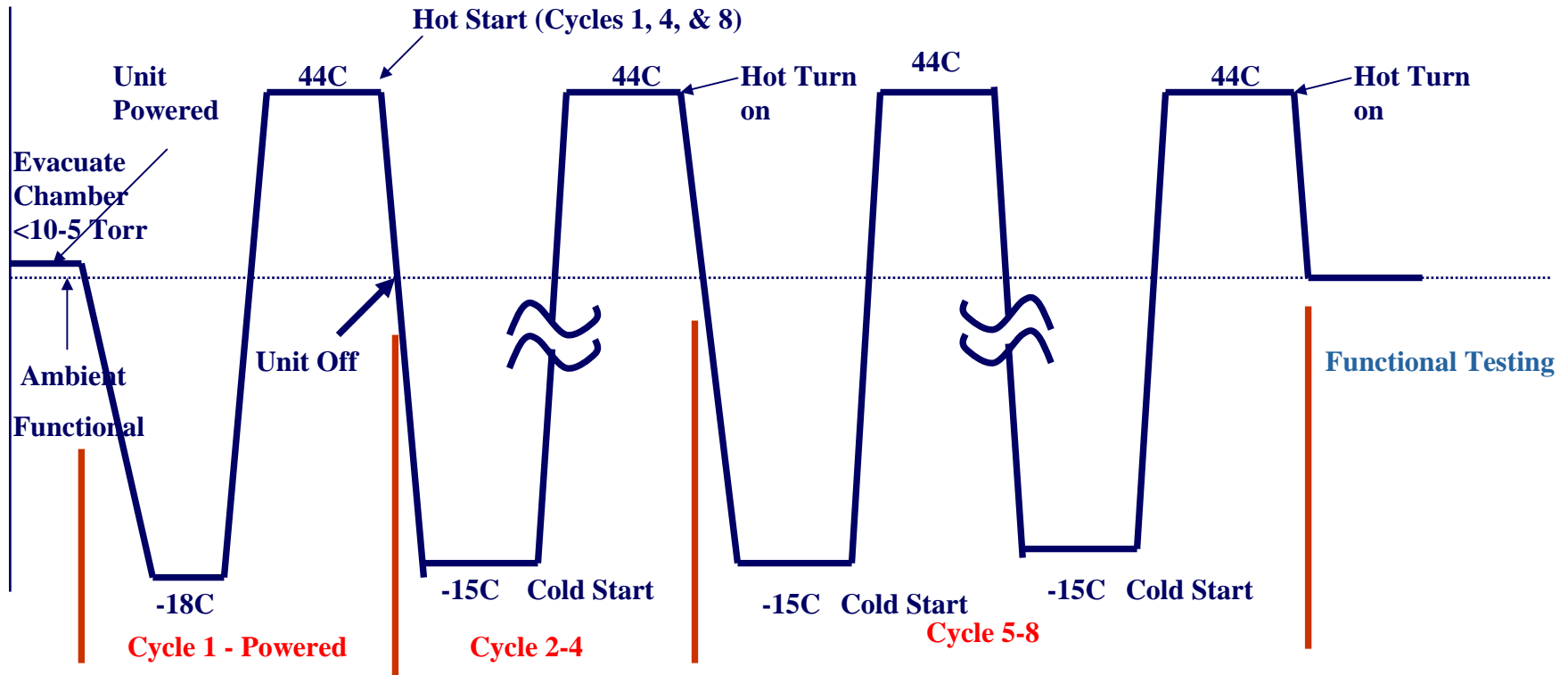
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## ● Component Testing (assuming Proto-flight):

- Continued:
  - A 1-hour dwell is maintained after achieving the 3C/hr stability at each temperature extreme. (Internal temps monitored to verify stable if available)
  - Break-out box used to record current draw on a strip-chart during all operational phases (including safemode configuration)
  - External GSE used to provide flight-like interface for simulating power dissipation, voltage and signal outputs for functional testing.

# Example of how a box would get tested at MSFC

## ● Component Testing (assuming Proto-flight):



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## ● System-Level Testing (assuming Proto-flight):

- PDB is cycled for 4 system-level thermal/vacuum cycles with a hot and cold thermal balance setpoint during the 1st cycle.
  - Go cold survival first. Dwell sufficiently (>12 hrs) to transition to cold thermal balance (+dT/dt) test point and verify heater/thermostat operation between -15C and 5C and  $\leq 80\%$  duty cycle at 24 volts.
  - Liquid Nitrogen cold shroud with internal heater plates for temp. control
  - Increased instrumentation as req'd for post-test model correlation
  - Dwell is many hours, determined real-time based on thermal response of the system (not driven by PDB)
  - Hot Start on final cycle.
  - Break-out boxes used to record current draws on a strip-chart during all operational phases (including safemode configuration)
  - External GSE used to provide flight-like interface for simulating power dissipation, voltage and signal outputs for functional testing of PDB.
  - Post-test correlation based on test environment predictions.