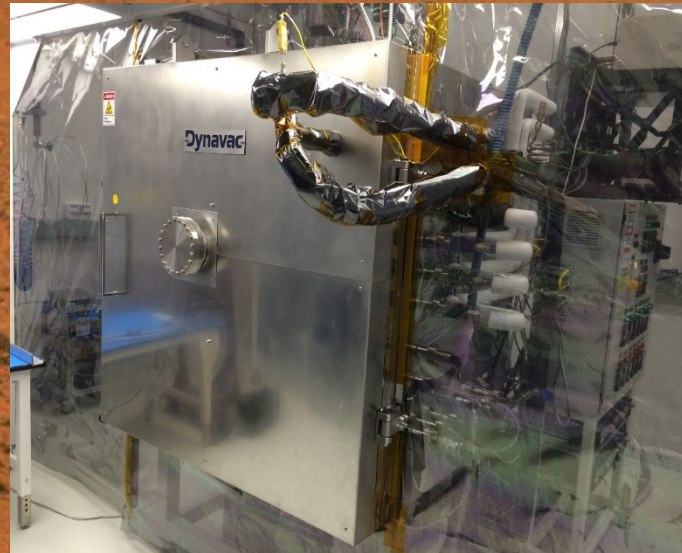
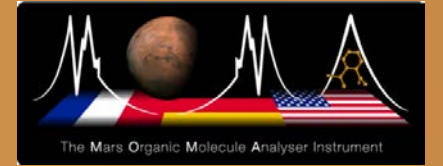




A Low Cost Thermal Control Method for Testing in a Mars Environment

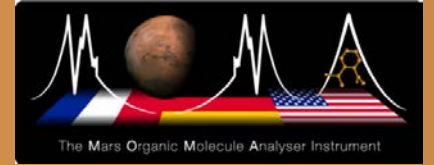
November 5, 2018



David Steinfeld, GSFC Thermal Engineer
Chris Johnson, GSFC Engineering Technician
30TH Space Simulation Conference
Annapolis, MD



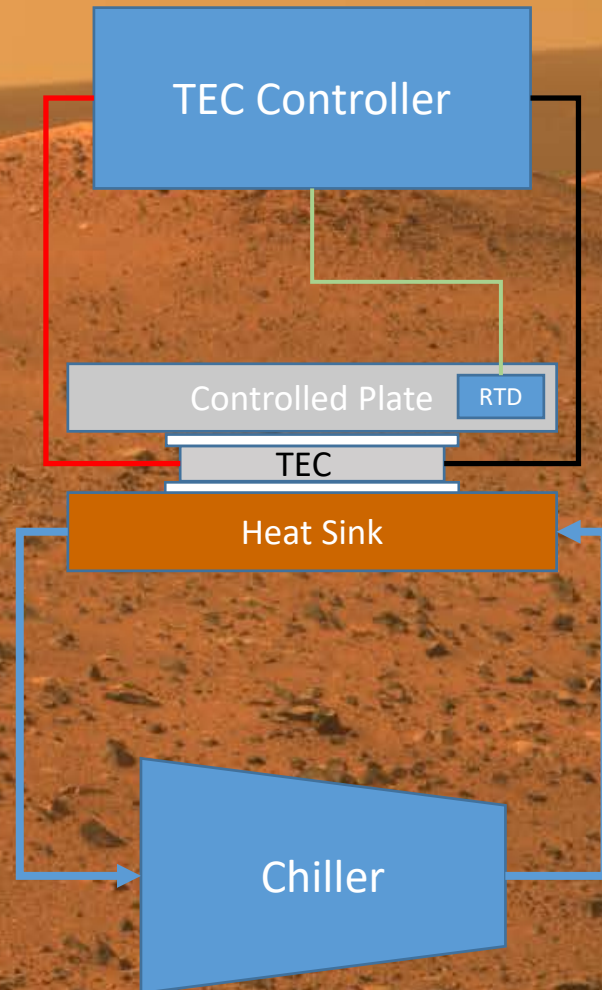
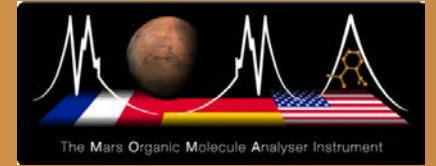
Overview of the Thermal Control System



- Utilized TEC's (Thermal Electric Coolers) for precise temperature control
- Remove TEC waste heat by a very low temperature chiller cooling loop
 - Galden HT-85 was the final heat transfer fluid selection
 - Key factors in this selection were operating temperature range and personnel and hardware safety
- Do the heavy lifting with the fluid loop and the fine control with the TEC's
- Utilize Commercial Off The Shelf TEC Controllers
 - One Controller per thermal zone
- Vacuum chamber uses Carbon Dioxide (CO₂) atmosphere (4-8 Torr)
 - Highvac capability for vehicle cruise phase simulation
- 6 zone chamber shroud employs cryogenic boil-off nitrogen gas and embedded cartridge heaters for temperature control of the Mars gas environment

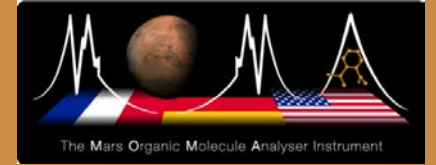


Sample TEC Setup





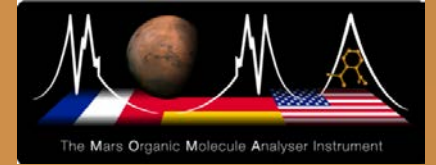
TEC Modules



- Must be wired in series (not in parallel) for thermal control
 - Constant current is required.
 - Variability of current between modules creates thermal instabilities
 - TECs will fight themselves
 - Match TEC impedance for each zone
- In a Mars atmosphere (not high vac) observe $\frac{1}{2}$ " of separation between hot and cold side plates
 - Gas gap conduction/convection will cause too high of a heat leak if not done
- Thermal interface materials must be used on both sides of the TEC
 - Both sides cannot have wet joints.
 - Indium on 1 side, Nusil 2946 on the other
- Adequate, uniform pressure is required. But don't crack the TEC!
 - Maintain compression with Belleville washers



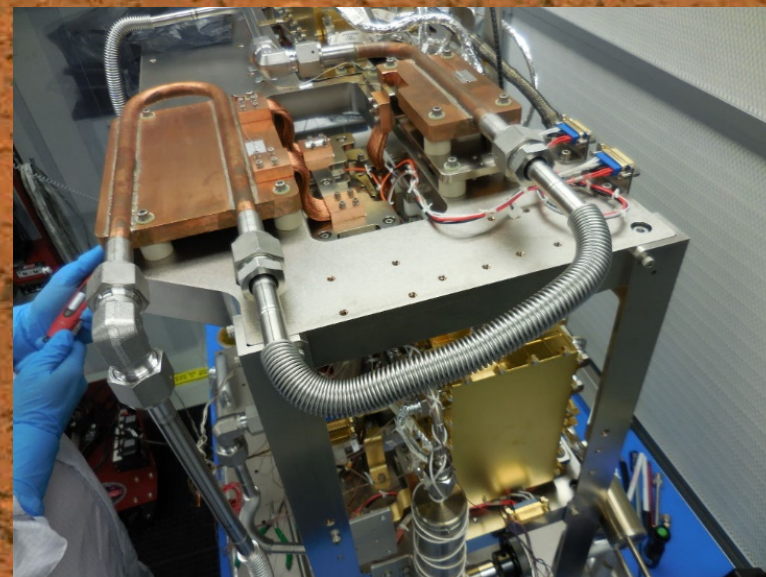
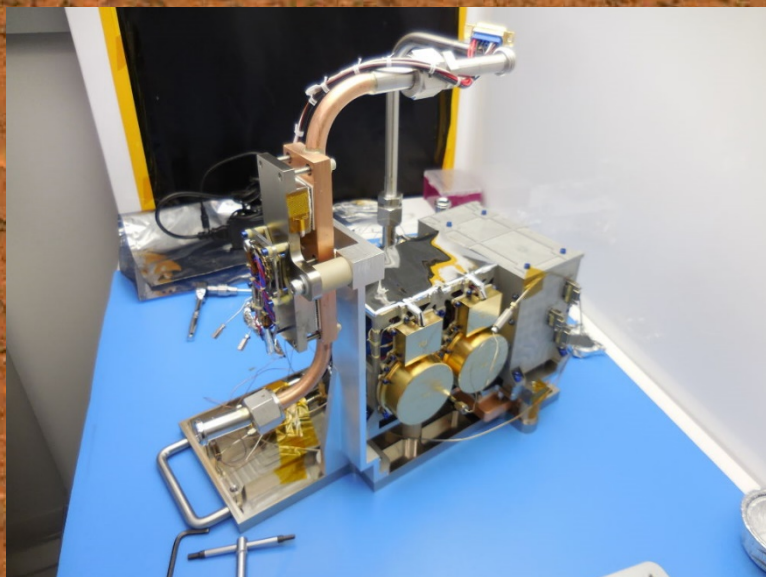
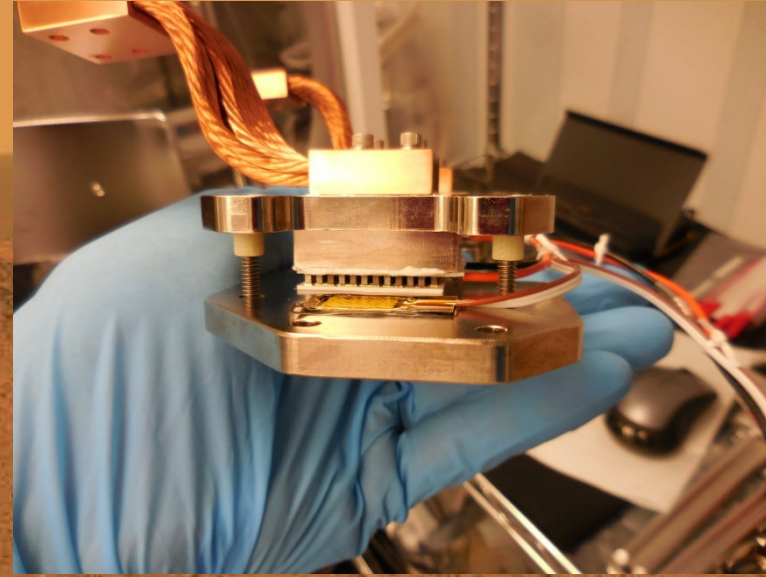
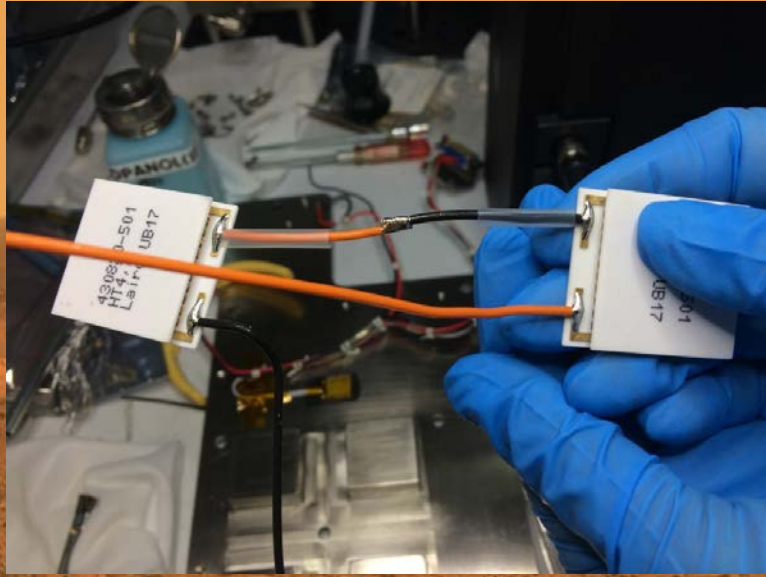
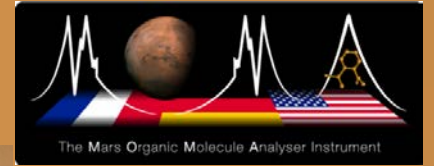
TEC Modules Cont.



- Multiple TEC types were tested in the design phase
- Original selection criteria of Delta T Max and power were replaced by:
 - Heating and Cooling mode performance
 - Precise temperature control
 - Robust vacuum-compatible factory lead attachments
 - Prototype controls experienced solder joint failures where non vacuum compatible factory leads were replaced with Teflon wire.
 - No TEC failures were observed when the Laird ThermalTEC cooler modules were used.

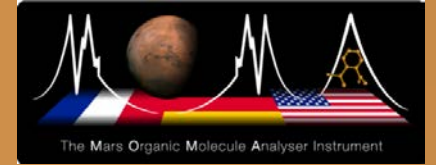


TEC Assemblies





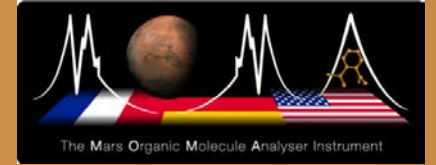
TEC Controller



- DC voltage must be used
- Avoid AC Pulse Width Modulation Controllers
 - High frequencies can cause undue stresses at thermopiles. Lower reliability
- Selected TEC controller should support:
 - Setting max TEC current
 - Setting low and high temperature shutdown limits
 - Controlling temperature ramp rates
 - Automatic detection and shutdown for open control sensor or TEC module failure



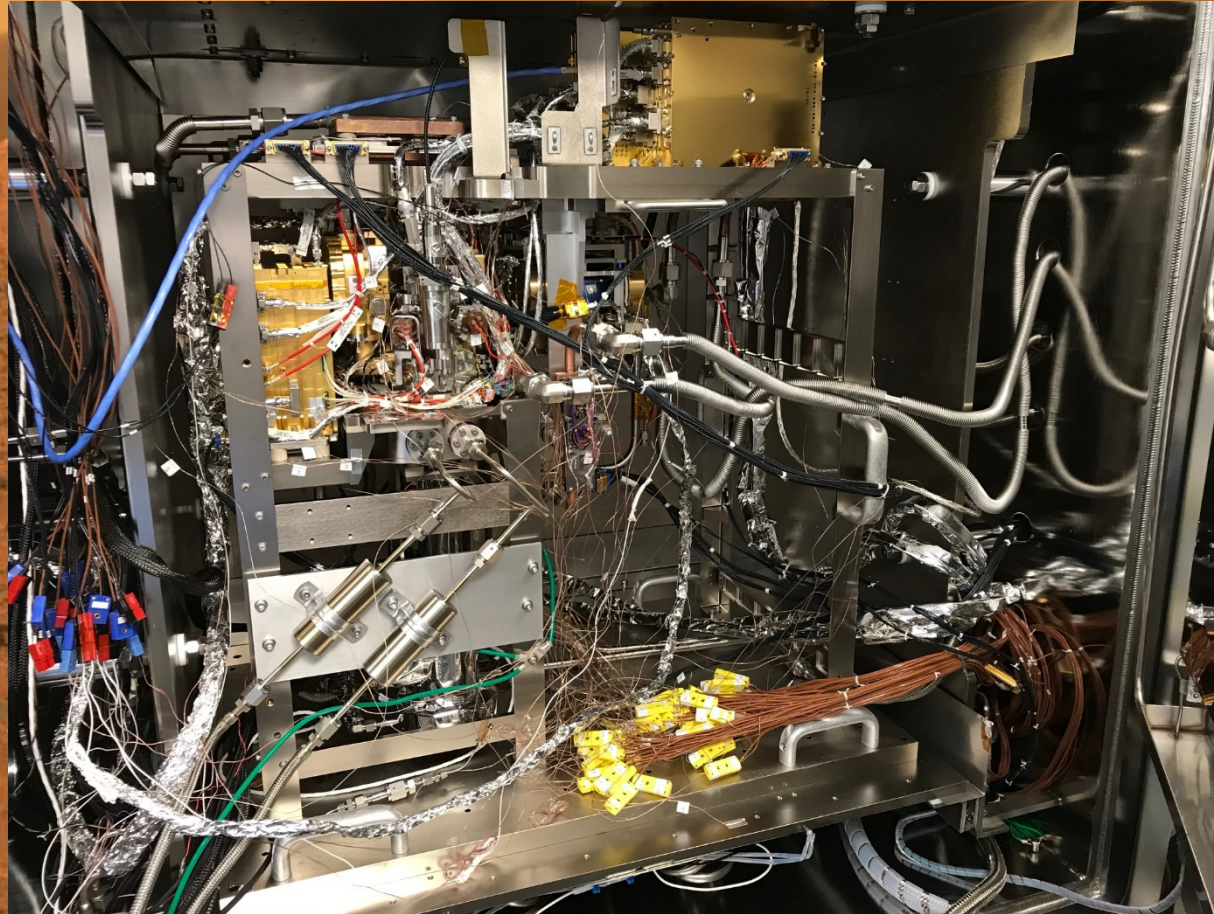
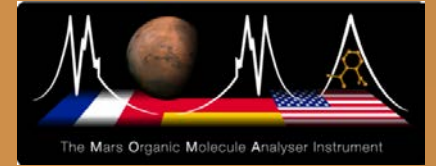
The Chiller



- Correct fluid must be chosen for application.
 - Choose low temperature capability if -60C operation is needed
 - Fluid becomes too viscous if a high temperature fluid is chosen
 - Be cognizant of fluid evaporation at higher temperatures if low temp fluid is chosen
- Put the Chiller on a UPS to prevent power spikes.
 - Newer chillers use LCD displays and micro controllers which cannot tolerate spikes.
- Maintain a dry nitrogen bath purge when operating below the dewpoint

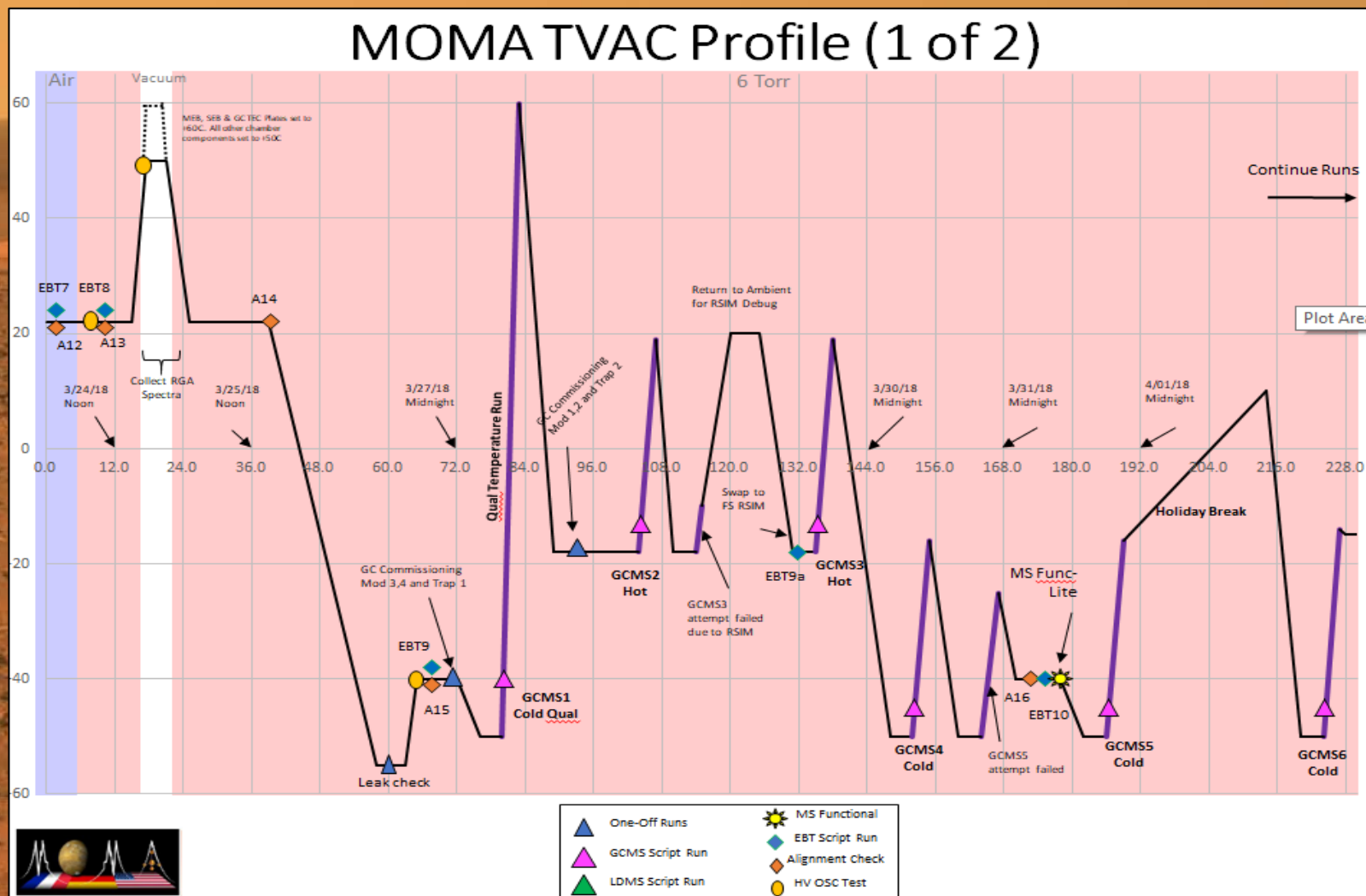
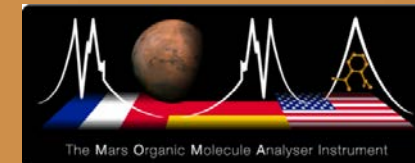


MOMA Instrument in the Mars Chamber



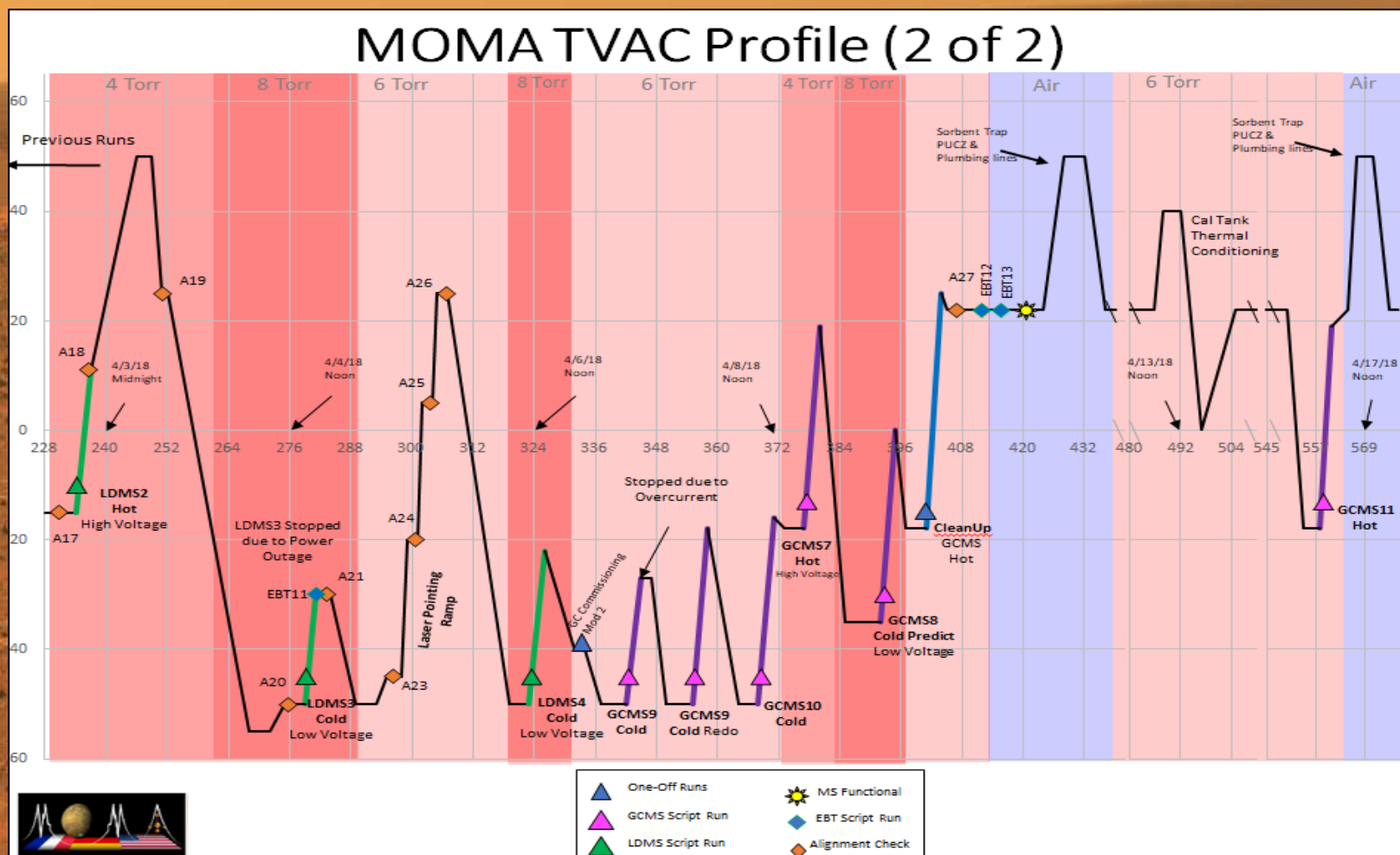
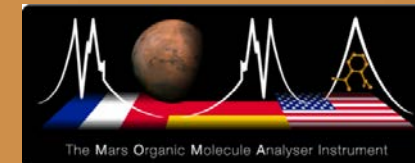


Thermal Vacuum Test Profile



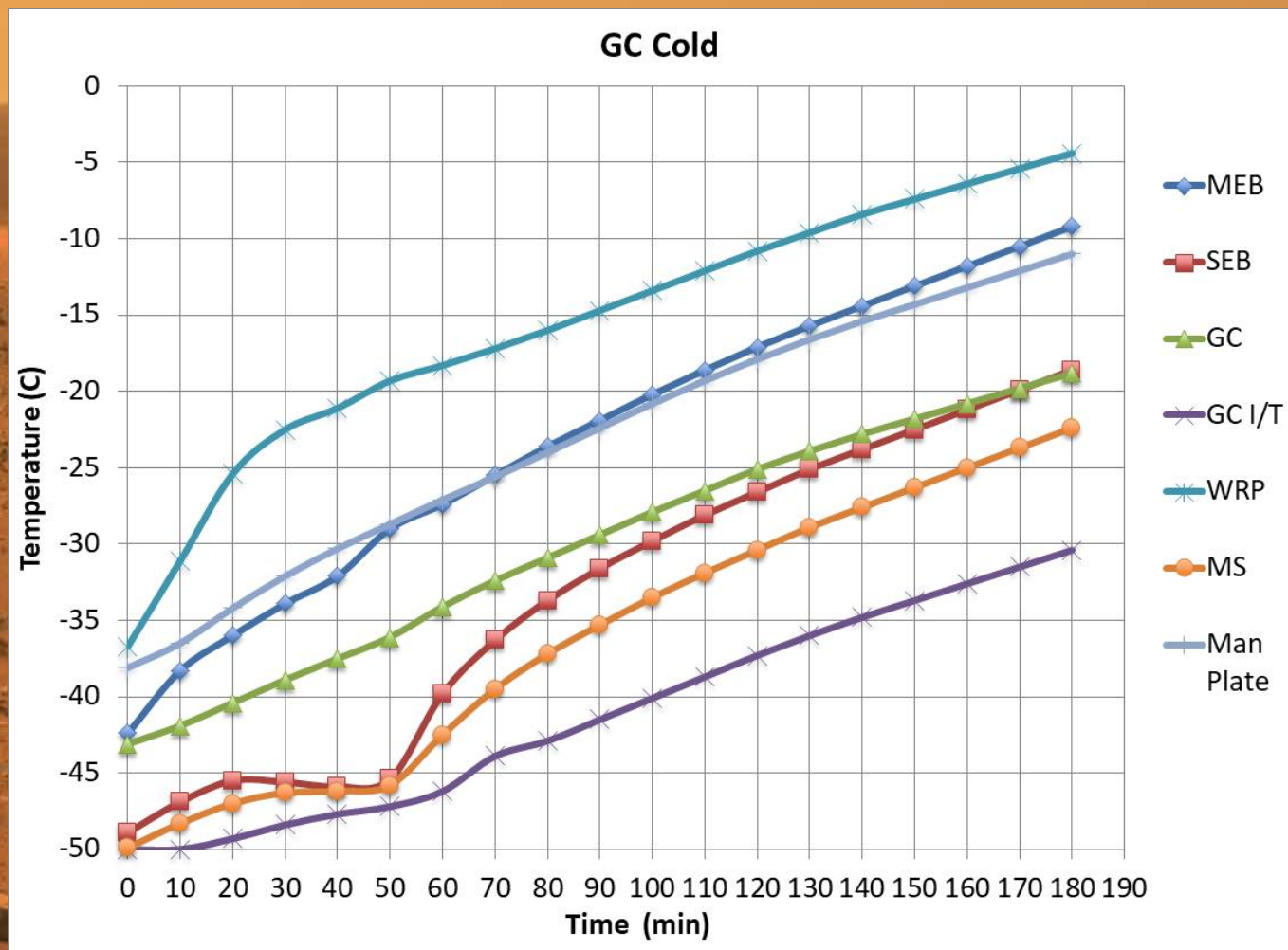
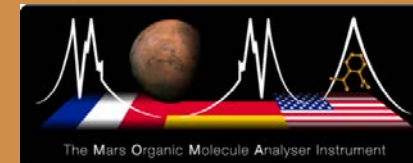


Thermal Vacuum Test Profile Cont.



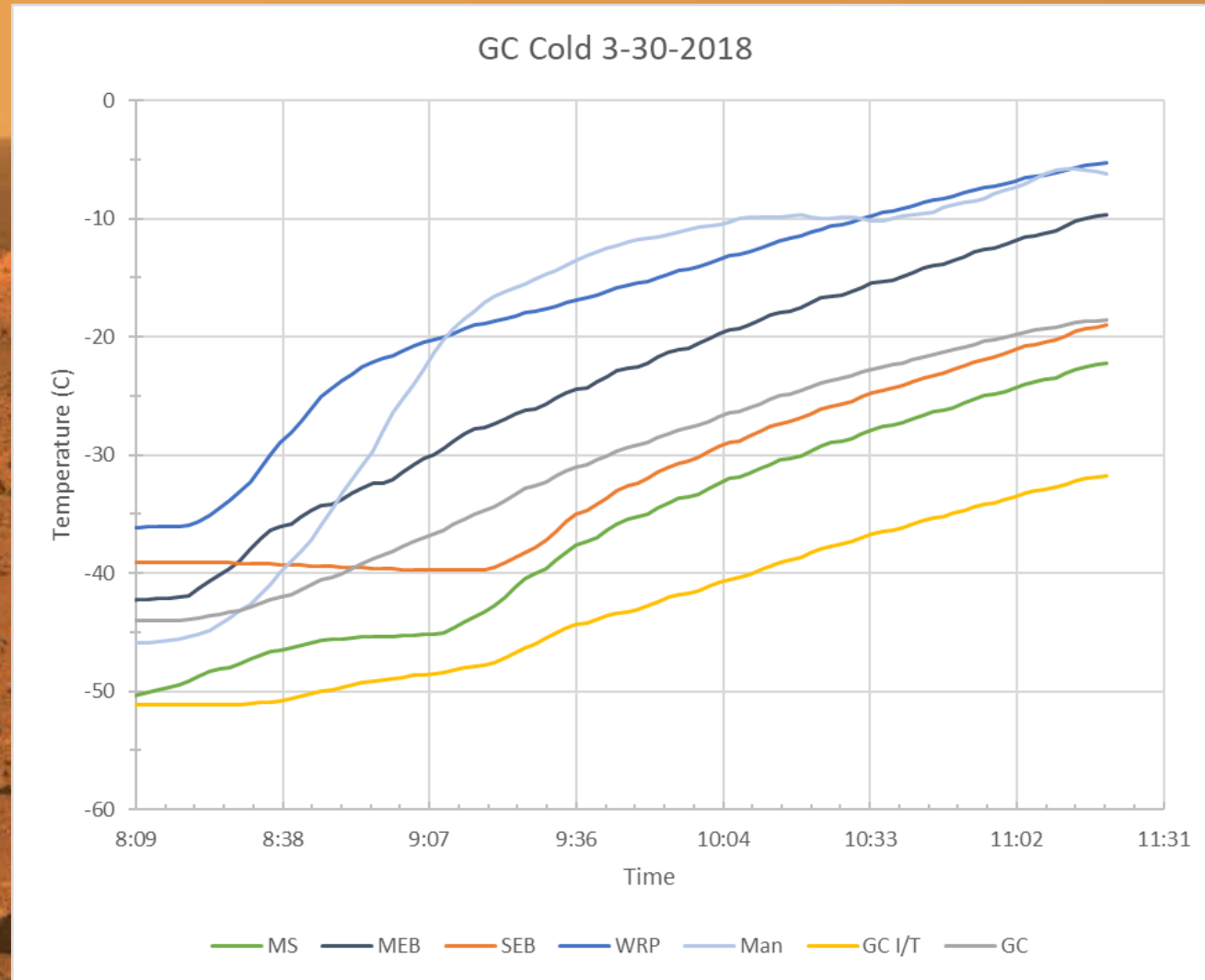
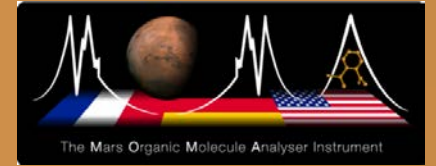


Sample MOMA Temperature cycle



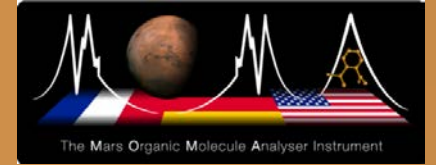


Actual MOMA Temperature cycle





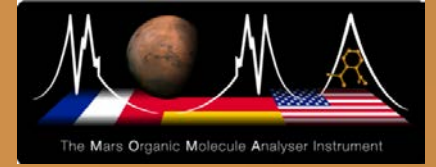
Conclusions and Recommendations



- Substantial planning and testing were required to achieve the required performance objectives
- TEC zones provide better control authority in a Mars environment utilizing conduction while minimizing thermal mass
- Testing in 8 mBar of CO₂ constrains the cooling methods to temperatures above -125C to prevent dry ice formation – No LN₂ allowed
- Significant cost and equipment space savings were realized by utilizing only 2 fluid chillers and 8 commercial TEC controllers instead of multiple thermal conditioning units which go for around \$250K each.



Conclusions and Recommendations Cont.



- Be aware that TEC specifications are assuming an ideal heat sink and no thermal load being transported
- Constrain the total TEC energy applied to the heat rejection limits of the chiller at the coldest fluid operating temperature
- Expect significantly lower thermal conductivity of fluorinated heat transfer fluids to clamp the total TEC energy
- Utilize vacuum brazed copper cold plates with a flatness machining performed after brazing
- Bond control RTD as close practical to the TEC module
- Thank you