Thermal Testing Short Course

Test Implementation

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August 21, 2003

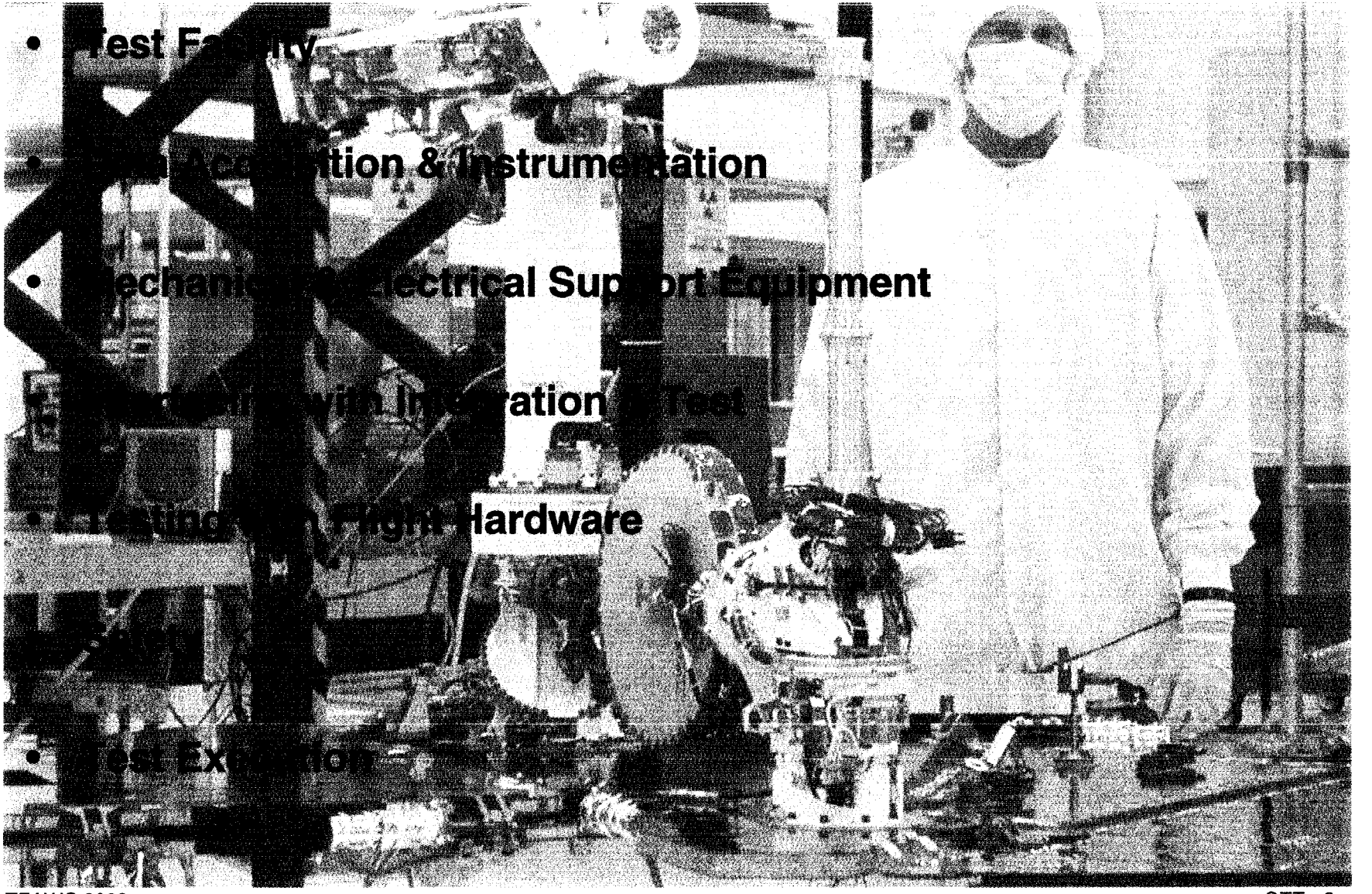
Introduction

- Test planning & implementation are closely intertwined
  - Planning aimed at development of the test approach & plan
  - Implementation focused at factors that will affect your test preparation
- Much of the material will serve as a checklist
  - It will identify the "tall tent poles"
  - It has been culled from my JPL experience with thermal development, qualification/flight acceptance, [illegible] testing

"Sharpen Your Saw"

- You are responsible for overseeing a multitude of tasks & issues covering a wide spectrum of interfaces
  - A process for proactively addressing & attending to each task is essential
    - Prioritized task list that is reviewed daily
    - War charts
    - Daily logbook
- You should know the working style of your team & interfaces
  - Leverage on strengths
  - What is their preferred method of communication?
  - Avoid springing "surprises"
  - Who requires more of your attention & who can be given a "long leash?"
- You should be familiar your institutional and/or project procedures for conducting tests

Prioritized Focus Areas



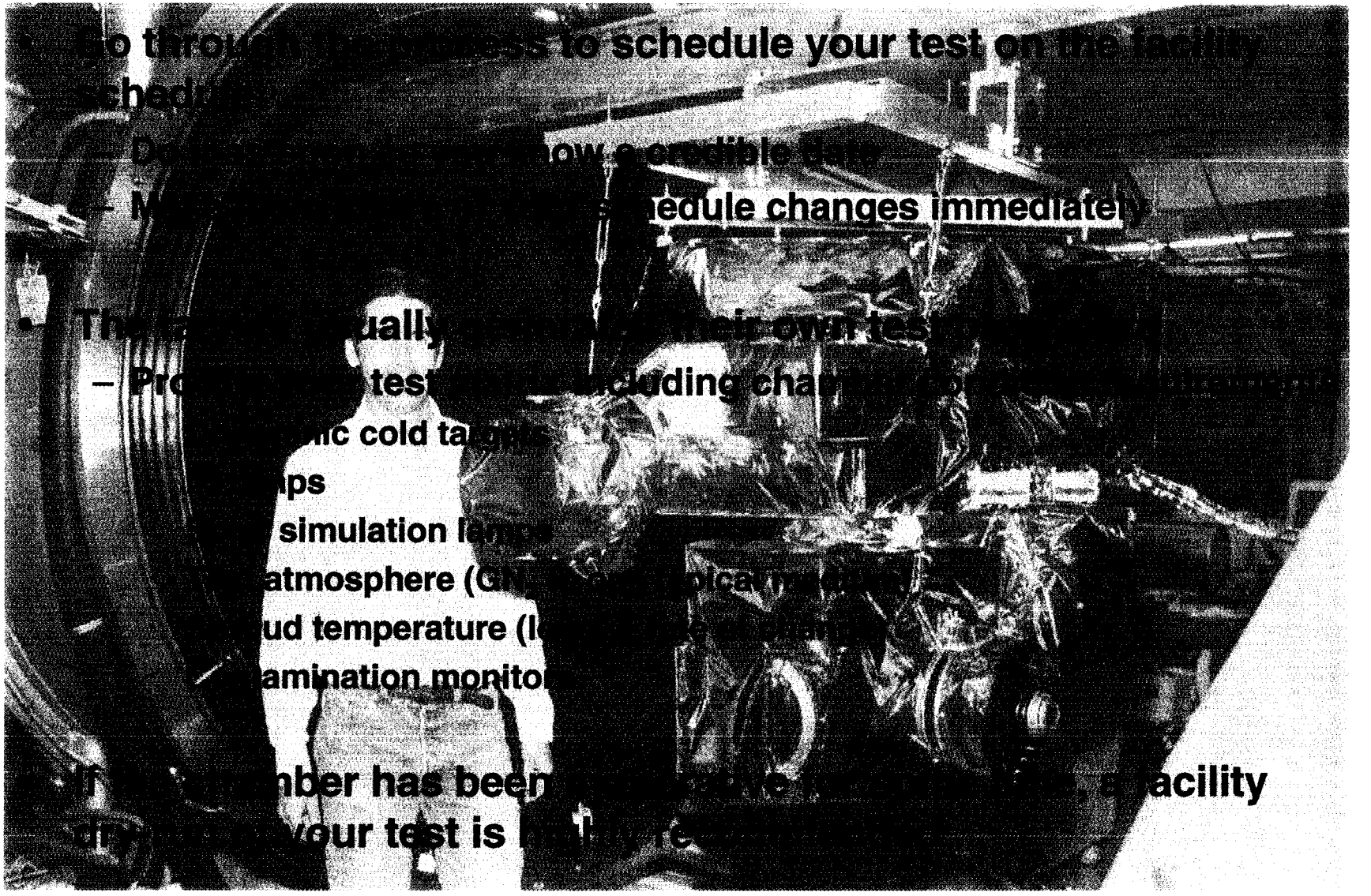
- Test Facility
- Data Acquisition & Instrumentation
- Mechanical & Electrical Support Equipment
- Thermal Vacuum Integration & Test
- Testing on Flight Hardware
- Test Execution

Where Should You Test?

In-house or Out-of-house?

- Appropriate chamber available in-house?
- Can you live with in-house chamber capability?
- What are the transportation risk to your hardware?
- Will your test use a lot of support equipment?
- Will your test use a lot of support equipment and/or personnel?

Chamber Facility's Role



- Go through the process to schedule your test on the facility schedule
  - Do [illegible] now a credible date
  - M[illegible] schedule changes immediately
- The [illegible] usually [illegible] their own test [illegible]
  - Pro[illegible] test [illegible] including chamber [illegible]
    - [illegible]ic cold targets
    - [illegible]ps
    - [illegible] simulation lamps
    - [illegible] atmosphere (GN[illegible] optical [illegible])
    - [illegible]ud temperature (l[illegible]
    - [illegible]amination monitor[illegible]
- If [illegible] chamber has been [illegible] facility dry [illegible] your test is [illegible]

Data Acquisition & Instrumentation (1/6)

- Data acquisition system
  - Does it have enough capacity?
    - Temperature channels & power supply telemetry
  - Does it meet your data sampling needs?
    - One entire scan every minutes is usually sufficient
  - Can it perform computations with raw test data?
  - Can it display you data in digital (time-slice) & analog (plot) form?
  - Does it have telemetry alarms (red & yellow)?
  - Provide the data acquisition support group a comprehensive list:
    - Temperature sensors (total number, type, location, alarm limits)
    - Heaters (total number, power, resistance, location, alarm limits)
    - Computed data (formulae)
    - Data display preference (grouping of telemetry for digital or analog display)

Data Acquisition & Instrumentation (2/6)

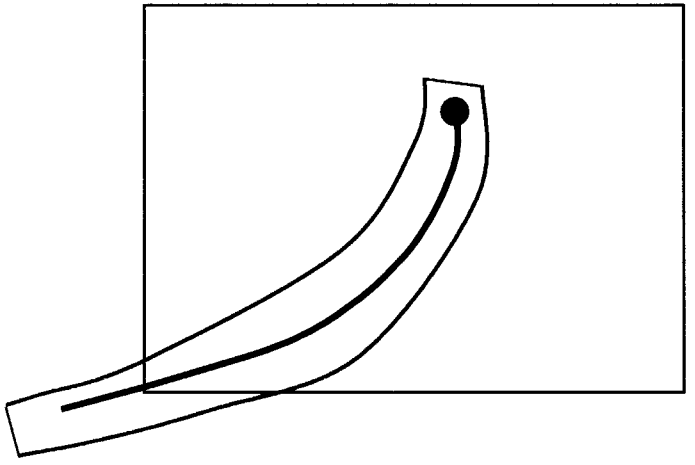
- **Temperature instrumentation**
  - **Thermocouple type: Type E, 26 AWG**
    - **Chromel/Constantan recommend to minimize parasitic heat leak**
    - **Smaller gauge wire may be needed for very low thermal balance cases**
      - These thermocouples are more susceptible to breakage
  - **Consider redundant thermocouples in critical situations**
    - **Avoid the need for a chamber break in an event of a failure**
  - **Provide sufficient lead time for the installation of thermocouples that are buried inside hardware assemblies**
    - **May result in "clip & fly" approach; may need to consider shielding or grounding open thermocouple**
  - **Place a test thermocouple on every test heater & have its telemetry visible**
  - **For external surface thermocouples, use tape to match actual surface emittance**

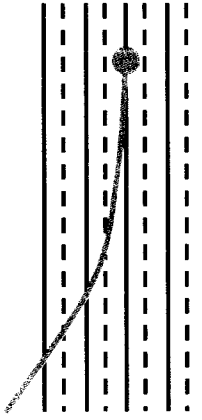
Data Acquisition & Instrumentation (3/6)

- Yellow & Red Alarms
  - As a rule of thumb, flight hardware must be maintained within any previous test experience
    - PF/QUAL/FA levels apply
    - Not applicable to PF/QUAL testing OR non-flight thermal control models or mock-ups
  - Yellow alarms are generally established as a "warning"
    - Approaching a "hard" limit & intervention by the thermal test engineer may be required to avoid exceedance
    - Particularly useful for thermally isolated & low mass items
  - Red alarms are generally defined as "never-to-exceed"
    - FA test level usually apply to flight hardware undergoing system test

Data Acquisition & Instrumentation (4/6)

- **Thermocouples locally disturb flight-like thermal balance**
  - **Complicates accurate measurement for low heat flow situation (e.g., thermal blankets)**
  - **Minimize non-flight features to the maximum extent practical**





If mounted on an exterior surface, thermally sink thermocouple wire to exterior surface & match exterior surface emittance

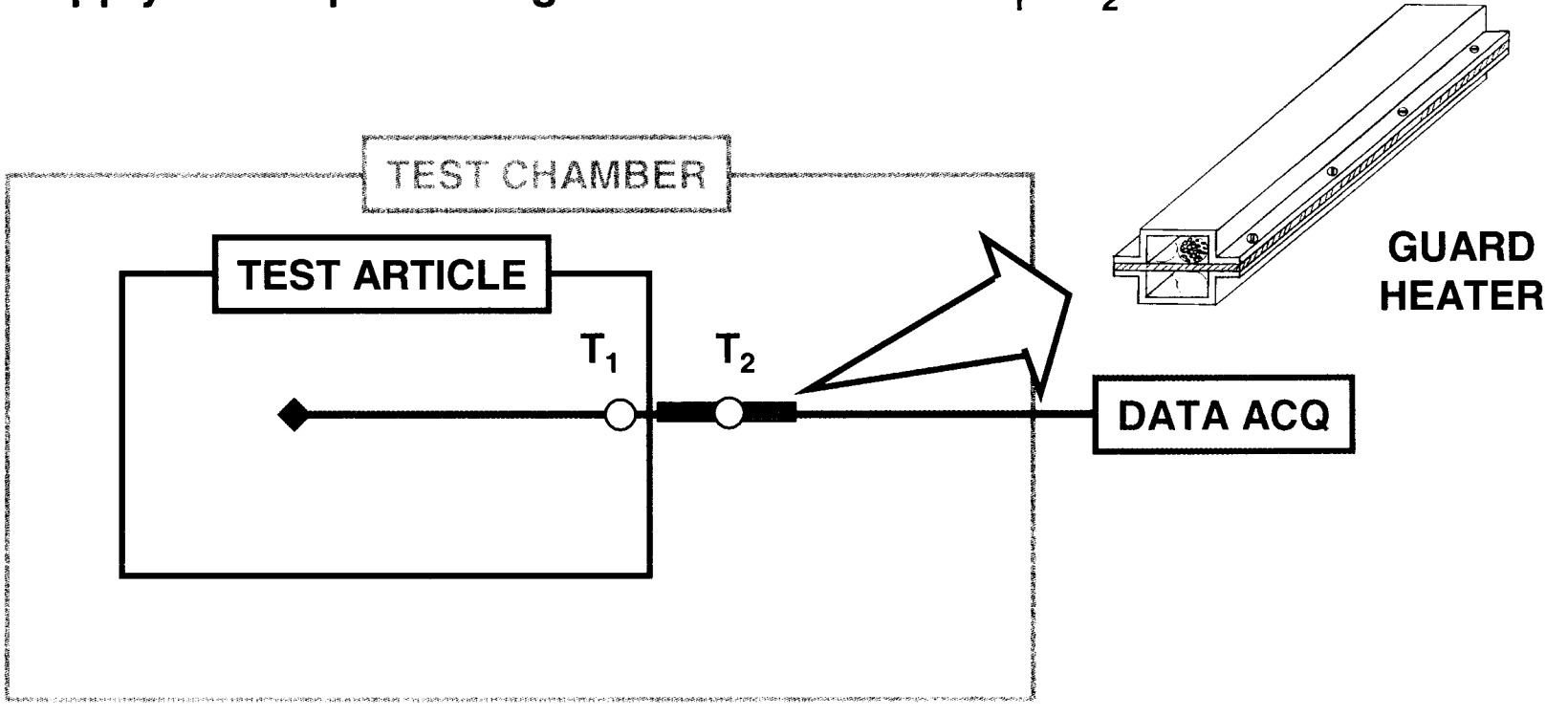
If the blanket is non-flight, attach thermocouple to 2nd or 3rd inner layer & route maximum length of wire inside blanket

Data Acquisition & Instrumentation (5/6)

- Heater instrumentation
  - Use a 4.0 watt/in^2 guideline for maximum heater power density without special heat sinking provisions
    - This is a recommended maximum value when installing test heaters on flight hardware
  - Use test safety or acceleration heaters
  - Heater lead wire should accommodate worst-case current draw
  - Ensure current and/or voltage limit every power supply regardless of soft crow-bar
    - Avoid reliance upon soft crow-bars
  - Do you need guard heaters for instrumentation cabling?

Data Acquisition & Instrumentation (6/6)

- **Cabling guard heater implementation**
  - The objective is to reduce loss from cabling to chamber
  - This is accomplished by controlling the local heat flow where cabling egresses from test article
  - Apply heater power to guard heater so that $T_1 \approx T_2$



Mechanical & Electrical Support Equipment

- Inevitably, non-flight hardware will be introduced into the test setup
- Either mechanical or electrical equipment, you will need to take specific precautions
  - Any support equipment that directly interfaces with flight hardware will require formal certification
  - The support hardware materials must be vacuum compatible
    - You must inventory down to the last fastener
    - Typical problems include cadmium plated fasteners
  - Thermal vacuum bake-outs are required for cabling & thermal blankets if flight hardware is involved
    - Strongly recommend for developmental testing

Interfacing with Integration & Test

- The I&T team plays are critical role for thermal testing involving flight hardware
  - They dri hardware is available for testing
  - They can also help by providing better skilled resources to bear
  - Regular coordination with I&T must take place well before the start of testing
- Important issues prior to the test:
  - ation of test the uples & heaters
  - al test cases
  - and/or electrical support equipment
  - ation of the test hardware into the an

Testing with Flight Hardware

- **Use of flight hardware in any test must be accompanied with a heightened awareness**
  - **Your primary focus is the safeguarding of the hardware**
    - **Whether working on it OR not!**
  - **You should invoke an end-to-end review of the risks that the hardware will be exposed to prior to, during, and after the test**
    - **You must receive buy-in from the cognizant hardware engineer that these risks are reasonable & acceptable**
    - **Lack of budget & schedule are poor reasons to incur risk**
  - **You must become familiar & practice procedures for handling flight hardware**
    - **Cleanroom garb**
    - **Electrostatic discharge avoidance**
    - **Contamination avoidance including planetary protection**
  - **Follow approved procedures & ensure presence of Quality Assurance personnel when working on flight hardware**

Safety First!

- Your other primary focus must be the safety of everyone involved with your test
  - Is the test facility certified?
    - Consider support equipment such as cranes or other hoisting devices
  - Is your test staffing adequately trained to perform their functions?
    - "Buddy" system usage
    - Entry into confined spaces
    - Entry into spaces where GN_2 or LN_2 was used
  - Has test plan/procedure been survey & approved by Safety?
    - Emergency evacuation procedures
    - Emergency contact information
    - Loss of facility power procedures
    - Loss of data acquisition procedure
    - Loss of facility vacuum procedure

Considerations For Executing the Test (1/2)

- Use an optimal test matrix strategy
  - Rule of Thumb: First test case should be coldest environment & then subsequent case are incrementally warmer
  - Rule of Thumb for critical events: Avoid scheduling critical events during the graveyard shift
  - Use a system engineering approach to all functional verification or validation aspects of the thermal design
  - Seek out input from hardware cognizant engineer or I&T engineers for recommendations for special tests
- Balanced monitoring workforce to prevent mistakes
  - Rule of Thumb for around-the-clock testing: 3 shifts with 2 test monitors for a 9-hour duration with an overlap of 1 hour between shifts for a hand-over briefing
  - Provide monitoring relief after 5 consecutive days
- Ensure your monitoring staff has adequate data acquisition training

Considerations For Executing the Test (2/2)

- Insist on a voice net to quickly communicate with critical test personnel (e.g., Facility and I&T personnel)
  - Voice net protocol training
- Use of a logbook
  - Insist on timely archiving of standard (listings & plots) & special data
- Bring a sufficient amount of office supplies
- Use physical barriers to limit foot traffic nearby test chamber

References

- Siebes, G. "System Thermal Testing Standard," Internal JPL Document D-22011, March 15, 2002.

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