Long Term Life Testing of Satellite Parts and Materials

Chuck Powers
Materials Engineering Branch
NASA Goddard Space Flight Center

10/21/98
Why Conduct Long Term Life Testing?

• To assure that life sensitive components will meet mission lifetime requirements
• To demonstrate mission survivability
• To determine useful lifetime
• To determine long term behavior
• To determine cause of in-flight failures
• To develop screening procedures for flight parts
History of Long Term Life Testing in the Materials Engineering Branch

- The MEB has been involved in operational life testing for over 18 years
- The MEB has life tested
  - GOES VISSR encoder lamps
  - GOES VAS encoder light emitting diodes
  - EOS-AM MODIS calibration lamps
  - NOAA AMSU-A2 support bearings and
  - MAP HEMT amplifiers
History (continued)

• The MEB is currently developing a life test for gold contact slip rings and for a new scanning mechanism for the NOAA AVHRR instrument

• The MEB has also developed a thermal cycling facility to simulate the thermal environment that is seen in Low Earth Orbit (LEO), including a high-speed apparatus that was used to simulate the failure of the HST thermal blankets and to qualify EOS-AM Solar Array diodes
GOES VISSR Encoder Lamp Life Test

• 4 of 4 encoder lamps failed after 1 to 18 months of operation on GOES 2 & 3 which resulted in the loss of Earth images
• Previous accelerated life tests predicted that the lamps should have last 7 years
• MEB life test at actual operating voltages determined true lifetime and failure mechanism
GOES VISSR Encoder Lamp Life Test (continued)

- Lamp failures were caused by tungsten filament evaporation in the accelerated life test.
- Lamp failures were caused by tungsten grain growth when tested at actual flight operating voltages.
- Accurate lifetime predictions made for GOES 5 & 6 from the flight-like life test of 12 lamps (± 1 month of actual lamp failures).
Lessons Learned from GOES VISSR Encoder Lamp Life Test

- Use accelerated life testing cautiously because failure modes can change between accelerated and actual operating conditions
- Characterize parts in detail prior to life testing (this determined that the number of turns in a filament has a strong influence on lamp lifetime)
- Use automation for monitoring a life test and take lots of data (this allowed us to identify the failure mechanism in the lamps)
Lamp lifetime vs. number of turns

![Graph showing the relationship between number of turns and time to burn-out in days.](image-url)
Encoder Lamp Life Cycle

- Burn-in phase
- Grain-growth phase
- Reweld phase

Lamp current vs. Time
EOS-AM MODIS Calibration Lamp Life Test

• Life test were initiated to determine the lifetime of Halogen calibration lamps under flight conditions (constant current or constant radiance)

• Manufacturer reported average lifetime as 1000 hours at constant 5 volts DC

• 10 lamps were tested at constant current (2 amperes, initially similar to 5 volts)
MODIS Calibration Lamp Life Test (continued)

• Lamp parameters were measured once an hour (voltage, current, light output, temperature)
• Periodically, lamp filaments were digitally photographed & time-lapse movies were made near the end-of-life
• Life test determined that useful lamp lifetimes ranged from 500 to 3500 hours
• Life test also identified a screening method to select longer lived lamps
Useful lamp lifetime vs. change in resistance after 50 hours of operation
MODIS Calibration Lamp Life Test also identified failure mechanisms (open or shorting due to evaporation)
NOAA AMSU-A2 Bearing Life Test

- Antenna support bearings were identified as a limited life single point failure
- The scanning mechanism (including the bearings) completed one revolution every 8 seconds with 32 stop-starts per revolution
- Bearings were lubricated with Apiezon C with 5% Lead Naphthenate (LbNp)
- Bearings were operating in the boundary lubrication regime, so acceleration was not possible
- 4 sets of bearings tested for 4.5 to 6.5 years
Results of the NOAA AMSU-A2 Bearing Life Test

- All 4 sets of bearings successfully completed the life test
- Bearing torque during the life test had periodic rises and falls (indicating a possible build up of debris or material, followed by break away)
- The film build up theory was confirmed by post life test analysis (A LbNp film and debris were found in the bearings)
NOAA AMSU-A2 Bearing
Life Test Post Analysis

PbNp Film

PbNp Flakes
Lessons learned for conducting a long term life test

• Avoid accelerated testing if you can
• If acceleration is your only choice, make sure you understand the failure mechanisms of your part or material
• Thoroughly characterize your part prior to life testing (dimensions, defects, IV curves, etc.)
• You can conduct a meaningful life test with a small quantity of well characterized parts
Lessons learned (continued)

• Instrument as much as you can during the life test
• Take lots of data during the life test, especially in the beginning
• Automate the data taking and monitoring of the life test
• Instrumentation and high data rates can provide an understanding of part behavior and can lead to effective screening techniques
• Perform a thorough post life test analysis of parts and materials
Acronyms

- AMSU-A2 Advanced Microwave Sounding Unit, Antenna-2
- AVHRR Advanced Very High Resolution Radiometer
- EOS-AM Earth Observing System AM
- GOES Geostationary Operational Environmental Satellite
- HEMT High Electron Mobility Transistor
- HST Hubble Space Telescope
- LEO Low Earth Orbit
- MAP Microwave Anisotropy Probe
- MEB Materials Engineering Branch
- MODIS Moderate Resolution Imaging Spectrometer
- NOAA National Oceanic and Atmospheric Administration
- VAS VISSR Atmospheric Sounder
- VISSR Visible Infrared Spin-Scan Radiometer