End-Of-Life Indicators for NIMA’s High Performance Cesium Frequency Standards

C. Brock, ARL:UT
B. W. Tolman, ARL:UT
R. E. Taylor, NIMA
NIMA Monitor Station Network

- National Imagery and Mapping Agency (NIMA) GPS Monitor Station Network
  - Worldwide, continuous operation
  - Unmanned and automated
  - Geodetic quality data
  - NIMA GPS precise ephemeris production
NIMA Monitor Station Network (MSN)
NIMA Core Monitor Station

- Automated and unmanned since 1995
  - Local Point of Contact (POC) provides occasional assistance
- Unclassified when keyed
- Controlled remotely from the MSNCC
- Redundancy
- 95% design availability
- Equipment
  - Two Ashtech Z(Y)-12 PPS GPS Receivers
  - Two Agilent (HP) 5071A Cesium frequency standards
  - Temperature, pressure, and relative humidity sensors
  - UPS with 14 hour backup batteries
  - Choke ring antenna
NIMA Augmentation Stations

- Automated and unmanned (’98-’00)
  - Local Point of Contact (POC) provides occasional assistance
- Unclassified when keyed
- Controlled remotely from the MSNCC
- Less redundancy than Core stations
- 92% design availability
- Equipment
  - One Ashtech Z(Y)-12 PPS GPS Receiver
  - One Agilent 5071A Cesium frequency standard
  - Temperature, pressure, and relative humidity sensors
  - UPS with 18 hour backup batteries
  - Choke ring antenna
Goals & Purpose

• 11 out of 22 Cesium Frequency Standards (CFSs) have reached end-of-life since 1995.

• When a CFS fails or reaches end-of-life:
  - At Core Stations, backup CFS drives both receivers.
  - At Augmentation Stations, no backup clock available.
  - Replacement CFS shipped to station, transit times 1 to 2 months.
  - Impact on GPS precise production

• Predicting end-of-life of Cesium Beam Tube (CBT)
  - Allows for shipping of replacement CFS prior to end-of-life
  - Reduces time station has no redundant clock or no clock
Prediction Approach

- Analyze CFS parameters
- Analyze the relative clock phase and frequency
  - Used double difference carrier phase estimation program in a zero-baseline configuration
    - Data from Core Station used
    - Program could be used over longer baselines
Available CFS Data

- Each station generates 15 minute CFS event records
  - Event records displayed on status screen at the Monitor Station Network Control Center (MSNCC)
  - Archived in daily transmission packets

- ION Pump Current
- CBT Oven Voltage
- Oscillator Oven Voltage
- C Field Current
- Electron Multiplier Voltage
- Loop Signal Gain
- CFS Internal Temperature
- RF Amplifier 1 Gain
- RF Amplifier 2 Gain
- Operation Status of CFS
Electron Multiplier Voltage (EMV)

- EMV was chosen as parameter to gauge CBT end-of-life.
  - 2 aging components of CBT: Electron Multiplier and Cesium Supply
  - Design lifespan for Electron Multiplier is 25 years
  - Cesium supply design lifespan 7.5 years
  - As Cesium supply is diminished, the EMV is increased to maintain 100 nAmp beam current
EMV Analysis

- Determine at what point end-of-life occurs.
- Determine mean lifespan of NIMA’s CBTs
- Plot EMV for the 11 CBTs that reached end-of-life
- Looked for indications of end-of-life in EMV plots
NIMA’s CFS Mean Lifespan

- **Mean Lifespan**
  - 6.56 years
  - standard deviation of 0.57 years

- **Sample 13 CFSs**
  - 11 at end-of-life
  - 2 still running
Cesium 1, St. Louis
S/N 3249A00659
Cesium 2, Ecuador
S/N 3249A00702
Cesium 1, UK
S/N 3249A00576
Cesium 1 & 2, Australia
S/N 3249A00646 & S/N 3249A00710
Conclusions

- Mean lifespan of NIMA CFS is 6.56 years with a standard deviation of 0.57 years.

- CBT end-of-life defined as time when EMV rapidly increases to 2553V

- Detected jump in Electron Multiplier Voltage 19 to 50 days prior to CBT end-of-life for 10 out of 11 CFSs.

- Using carrier phase as an indicator of CBT end-of-life does not appear promising.
Future Work

- Continue the analysis on remaining NIMA CFSs.

- Develop detection algorithm.

- Develop software to detect and warn network control center.

- Continue using carrier phase estimation program.
  - Look at longer baselines to support single CFS stations.
  - Determine frequency stability of CBT as it approaches end-of-life.
Questions?