# The On-Orbit Electromagnetic Environment for NASA Spacecraft

**2018 DoD E3 Review**

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**May 9, 2018**

# Agenda



- Background
- STS Environment - 1985
- NASA CR-4776 - 1995
- MIL-STD-464 & -464A Environment
- Space Shuttle Study
- NASA Environment - 2006
- MIL-STD-464C
- Comparisons
- Conclusion

# Background

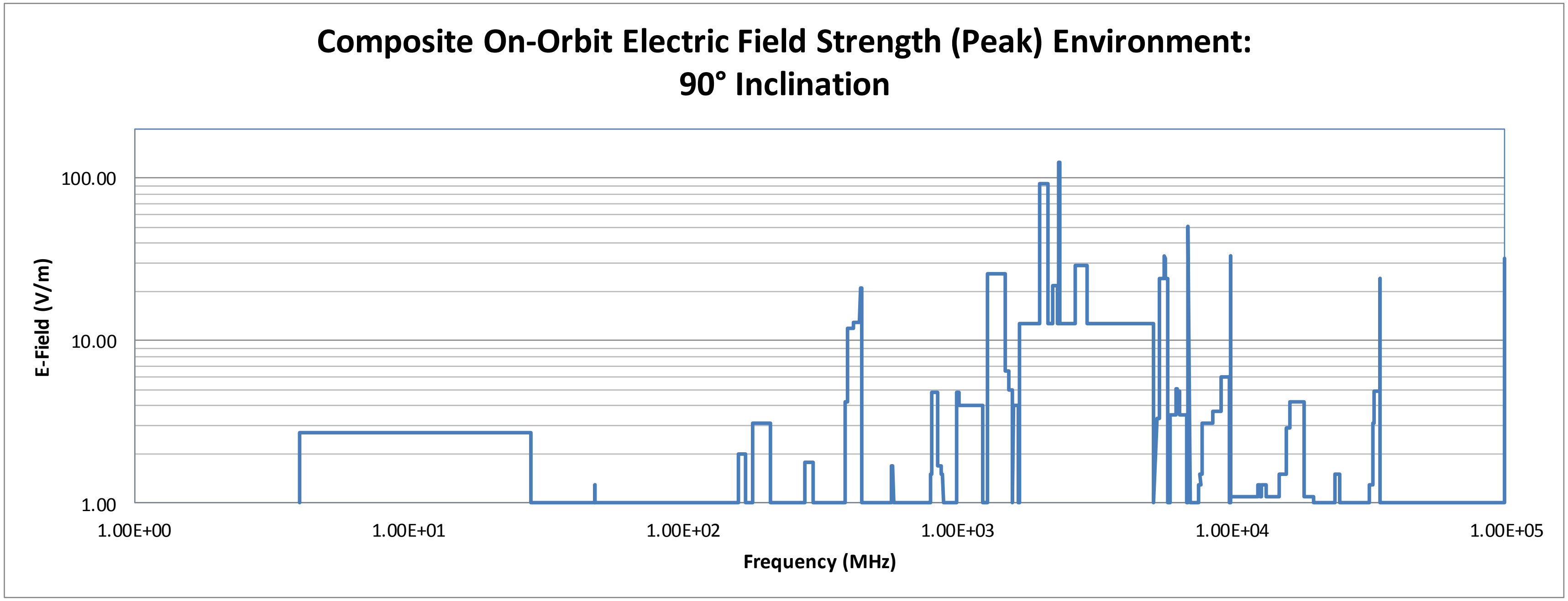


- Prior to the 1997 publication of MIL-STD-464, there was not a defined electromagnetic environment (EME) for space and launch vehicles
- NASA identified a need for an on-orbit EME definition as early as the mid-80s
  - Although each spacecraft-generated EME is unique, an environment due to ground-based emitters is applicable to all spacecraft

# STS Environment - 1985



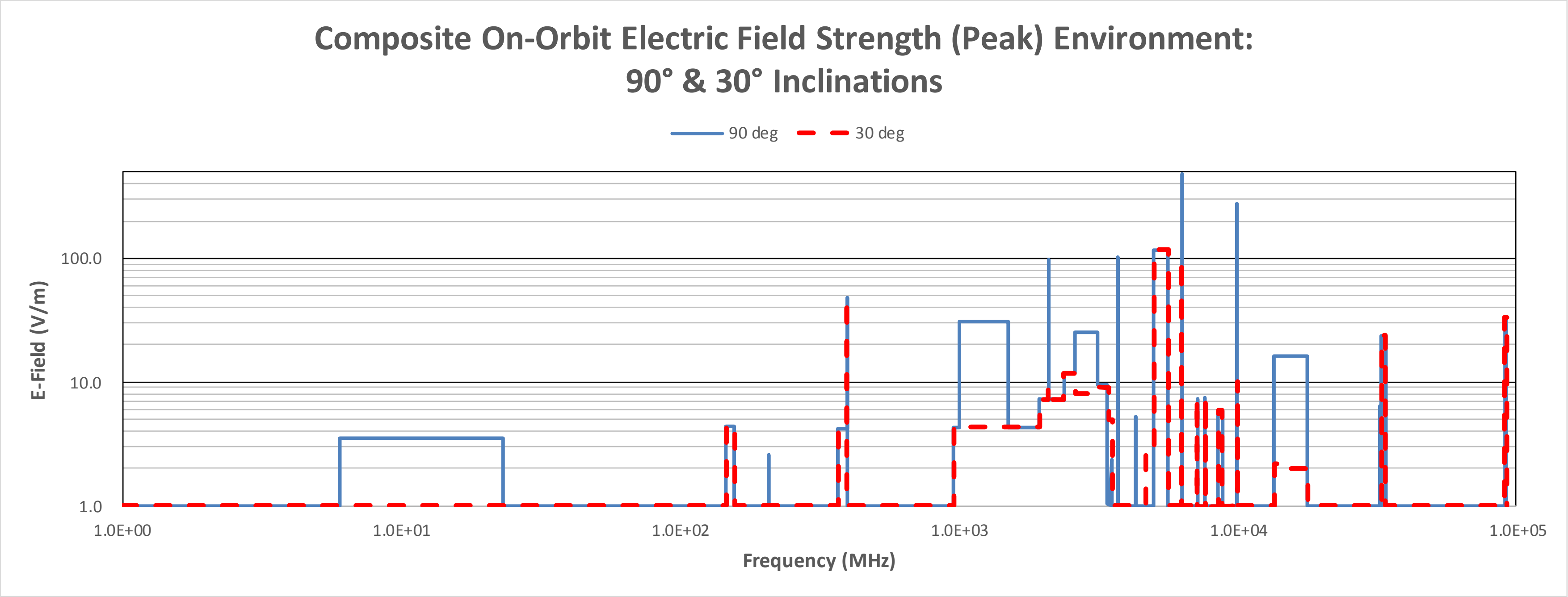
- USAF funded report developed by the EMC Analysis Center to support Space Shuttle operations
  - Data provided peak on-orbit EME for 30°, 60°, & 90° inclination and 100 – 250 nautical mile (nm) altitudes



# NASA CR-4776 - 1995



- NASA CR-4776, Provided on-orbit EME for 30°, 60°, and 90° inclinations and altitudes from 100 nm to 2000 nm
- Effort funded by NASA's Space Environments and Effects Program to provide on-orbit information to aid the International Space Station and other NASA spacecraft programs



# MIL-STD-464 & -464A Environment

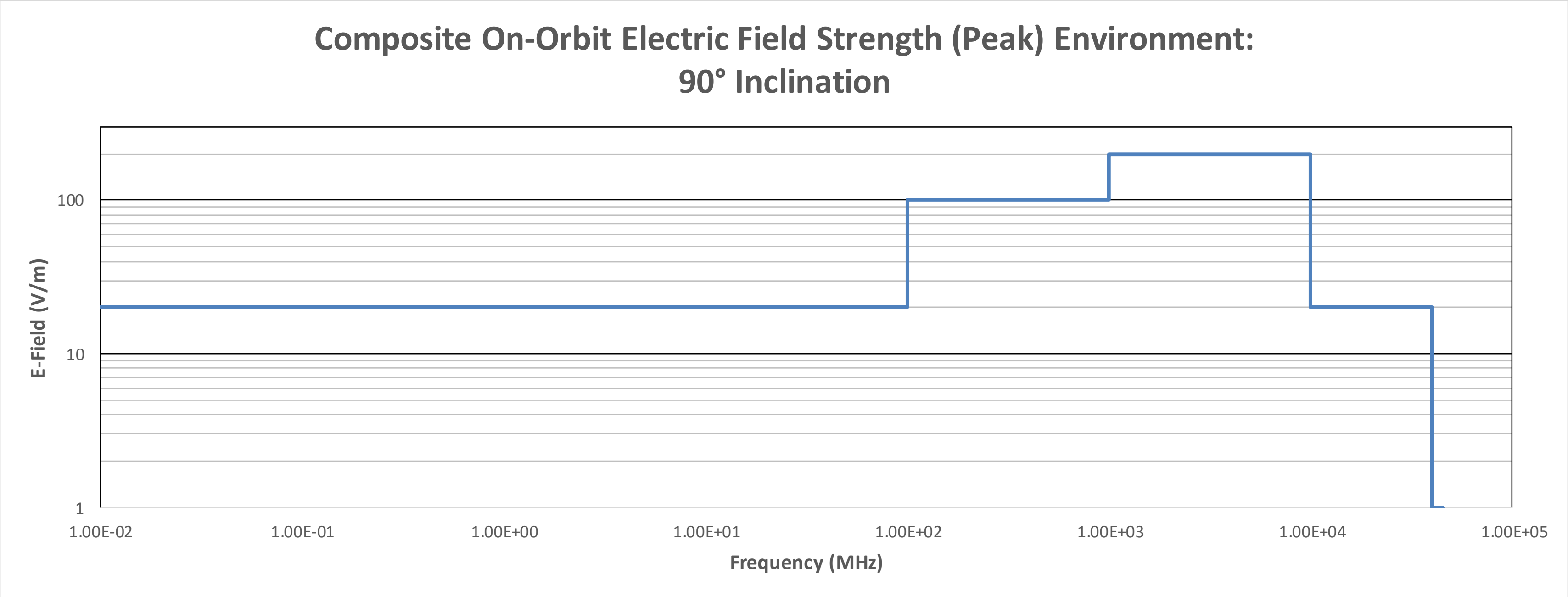


- MIL-STD-464, published in 1997, provided first on-orbit EME for spacecraft and launch vehicles
  - Documents superseded by – 464 provided no spacecraft or launch vehicle specific environment
  - MIL-STD-1541, EMC Requirements for Space Systems, provided no on-orbit EME for spacecraft
- -464 Basic, Appendix A explained environment “derived from an analysis of emitters near launch sites and potential illumination of space vehicles in orbit.”
  - No further information given as to how the environment was derived

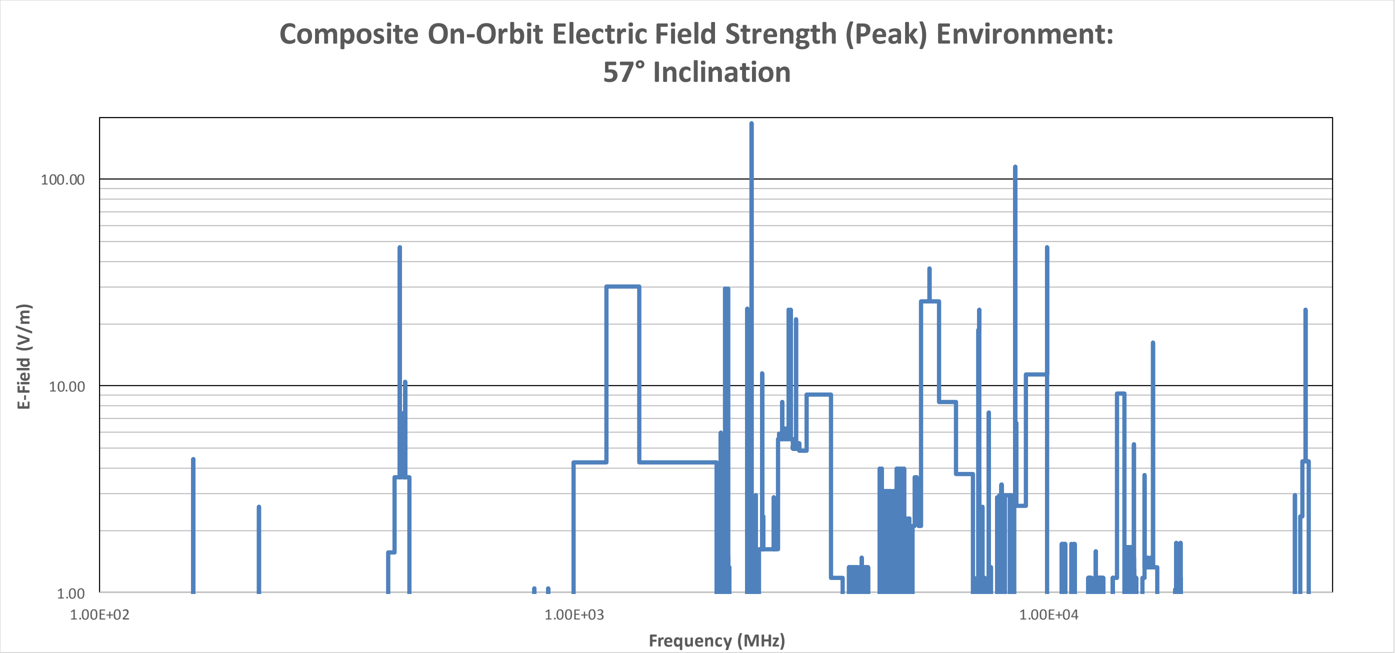
# MIL-STD-464 & -464A Environment



- MIL-STD-464A contained the same spacecraft and launch vehicle EME as -464 basic
  - -464A environment based on information from NASA CR-4776 (200 nm altitude, 90° inclination) and launch site environments (Eastern and Western Test Ranges)



- In 2000, the Joint Spectrum Center delivered JSC-CR-009, *Radio-Frequency Environments for Space Shuttle Launch, Landing, and On-Orbit Scenarios*, to the Johnson Space Center to support Space Shuttle operations
- Study evaluated environment for Kennedy Space Center's LC-39 launch site, on orbit operations (100 nm and 57° inclination), as well as Shuttle nominal and abort landing sites (not shown)



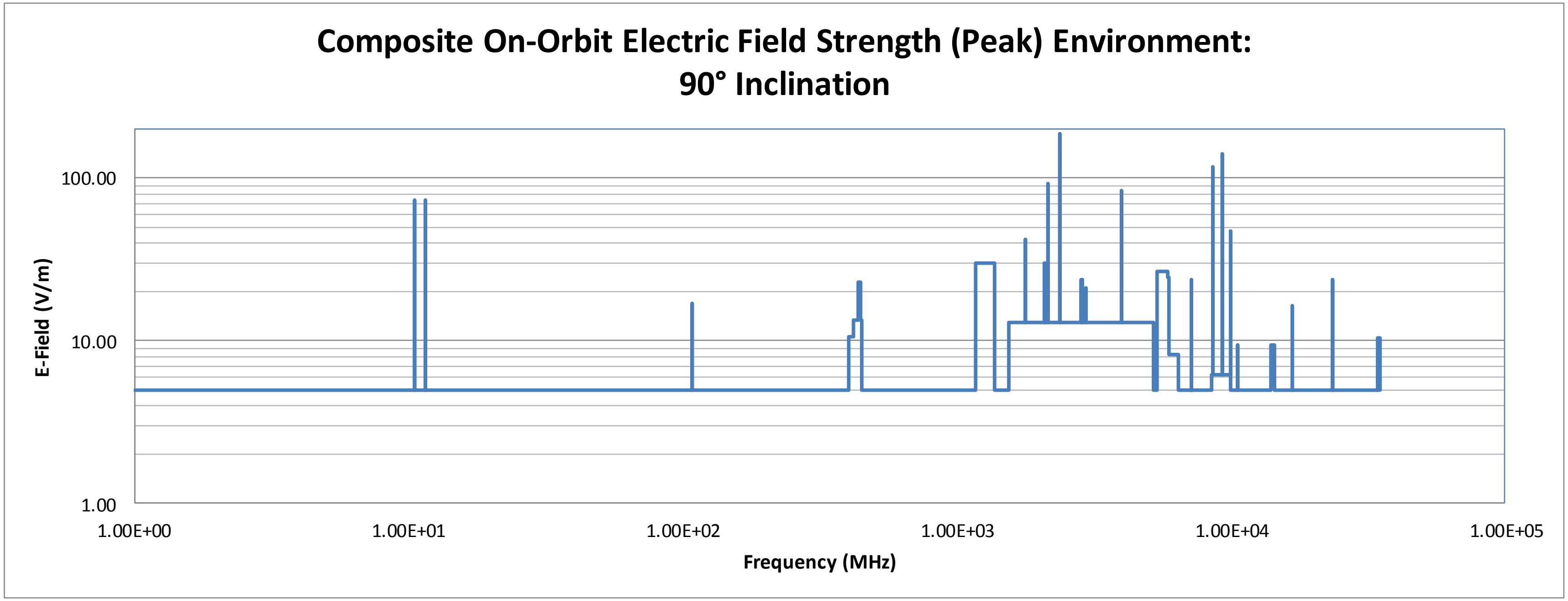
# NASA Environment - 2006



- Marshall Space Flight Center (MSFC) requested that the Joint Spectrum Center evaluate the radio frequency (RF) launch and on-orbit environments for the Crew Launch Vehicle
- Evaluation used a modified version of the approach used in the 2000 Shuttle Study
- Evaluation looked at emitters capable of generating 5 V/m at 100 nm at 57° and 90° inclinations
  - Documented in JSC-CR-06-041 and JSC-CR-06-070
- Data later used to support development of Space Launch System and Orion spacecraft

# NASA Environment - 2006

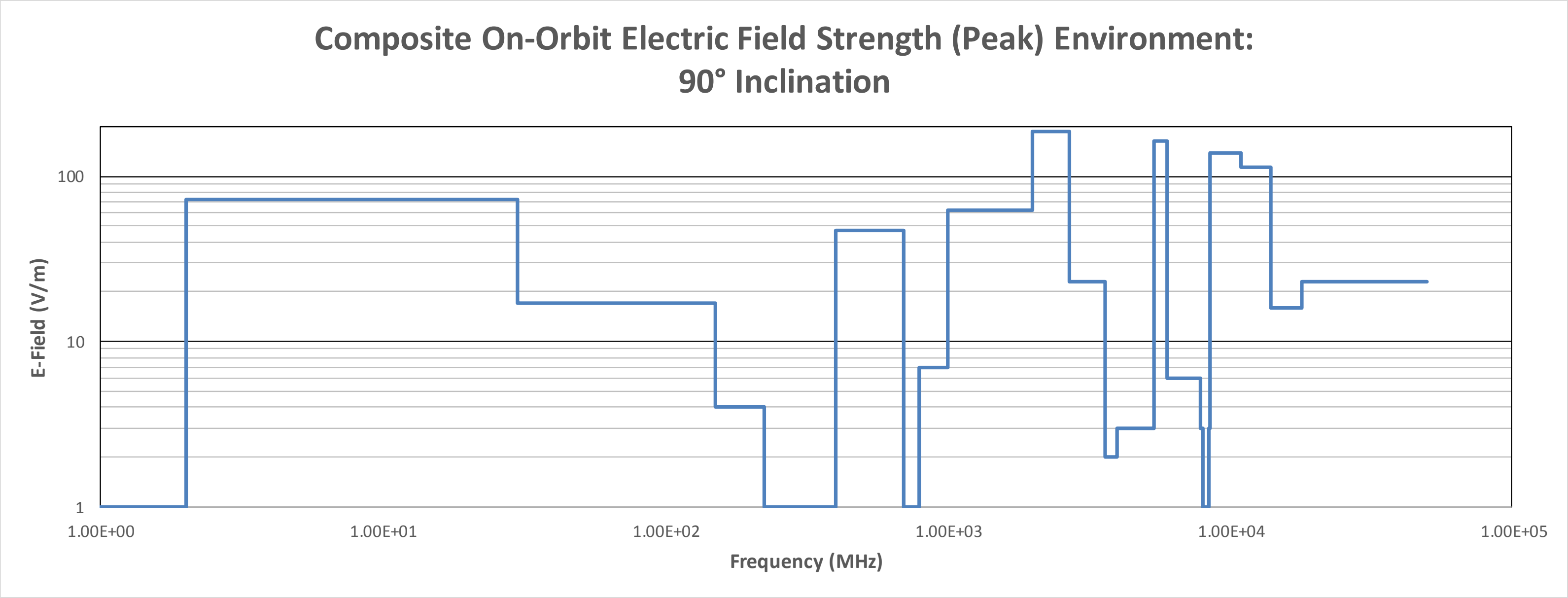




# MIL-STD-464C



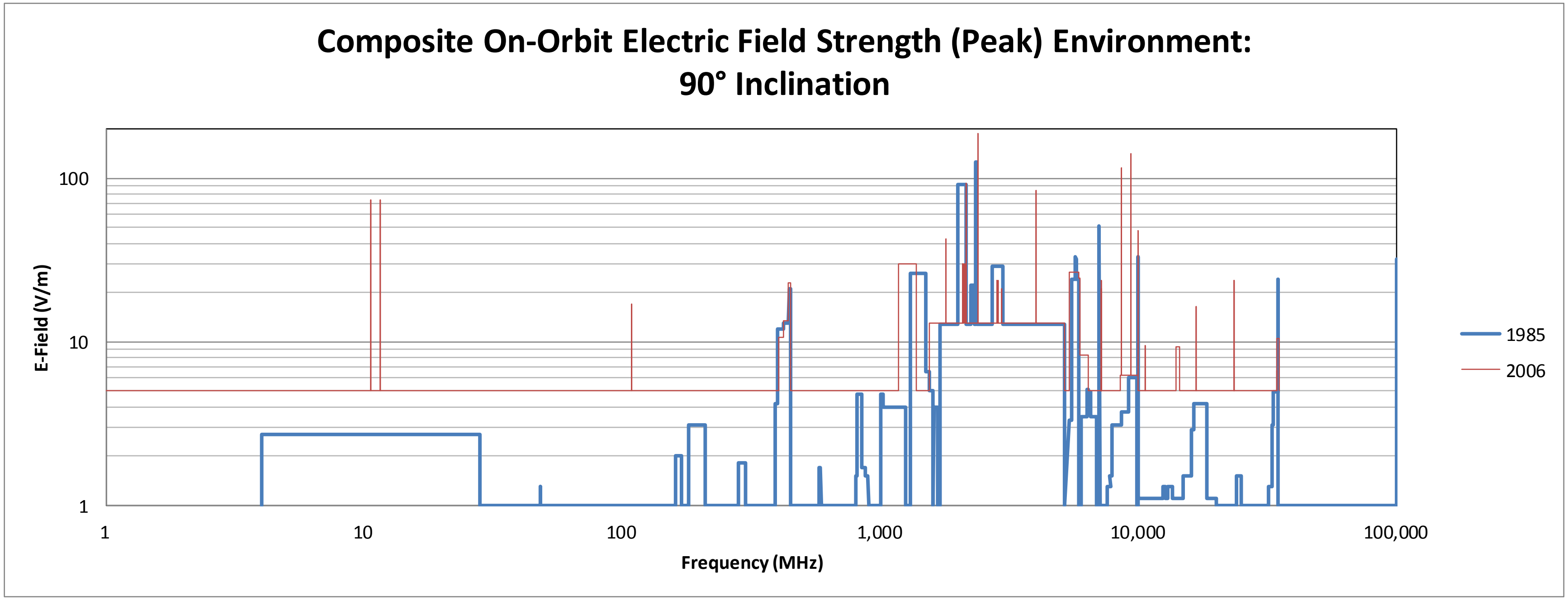
- MIL-STD-464C updated -464A a spacecraft and launch vehicle EME
  - Update provided both peak and average E-field levels
- Appendix A states the levels are derived from the EME levels for space systems in a 100 nm orbit and the composite EME levels 1 km above various launch and recovery sites
  - No orbital inclinations are provided
- Appendix A points the reader to the classified MIL-HDBK-235-3



# Comparisons



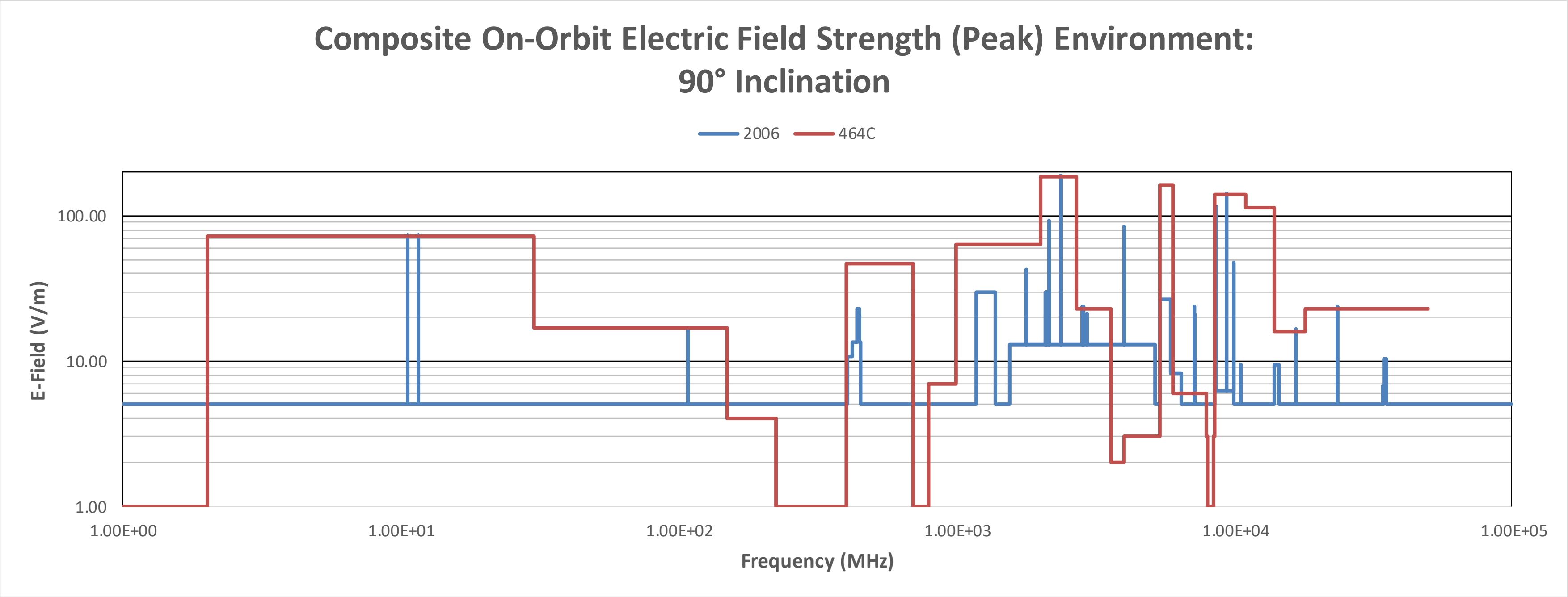
- The on-orbit EME is changing, both amplitude and number of peaks, particularly above 1 GHz



# Comparisons



- The -464C EME envelopes much more of the spectrum than the 2006 NASA environment



# Conclusion



- On-orbit environment levels are increasing, with more of the peak levels moving to frequencies higher than 1 GHz
- MIL-STD-464C defines a much harsher environment than the 2006 NASA environment
  - -464C does not differentiate between the on-orbit environment that a spacecraft must survive from the launch vehicle environment
  - Assumptions used to define -464C environment are contained in classified document

# Conclusion (continued)



- The -464 environments could be improved by:
  - Separating on-orbit environments from launch site environments and
  - Parsing on-orbit environments by inclination angle
- The benefit is potentially reducing cost of spacecraft development by not having to demonstrate compatibility with on-orbit environments it is unlikely to encounter