New Frontiers in Spacecraft Charging

Dale C. Ferguson, AFRL/RVBXR

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New Frontiers in Spacecraft Charging

No, not Old Frontiers, New Frontiers!

New Frontiers in Spacecraft Charging

4 New Frontiers

- Non-static Spacecraft Materials Properties
- Non-static Spacecraft Charging Models
- Novel Mitigation Techniques
- New Technologies and Power Requirements

Basic SC Materials Properties

- **Bulk electrical resistivity**
  - charge bleedoff through surface materials
  - highly temperature dependent
- **Surface resistivity**
  - charge bleedoff across surface materials
  - highly dependent on surface morphology and contamination
- **Secondary electron emission**
  - first and second crossover points – positive gain
  - basic to snapover – dielectrics act like conductors
  - highly dependent on surface morphology and contamination
- **Photoemission**
  - charge bleedoff when in sunlight
  - highly dependent on surface conditions

We don't have any measurements of these basic properties for many new spacecraft materials!

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SC Materials Properties Depend On:

- Proper Measurement Techniques – such as charge storage method for bulk resistivity
- Temperature – mat'l property values may vary by orders of magnitude over satellite operating temperature range
- Radiation Flux – Radiation Induced Conductivity (RIC) important
- Electric Field – can not only polarize materials, but change values
- Surface Treatment – smooth, reflective surfaces differ from rough, absorbing surfaces
- Surface Contamination – contaminants often very different from pristine surfaces
- Surface Modification – arcing, atomic oxygen, vacuum conditions, UV, radiation
- Synergistic Effects – for instance UV fixing of contaminants

We need measurement-validated models for all these effects!

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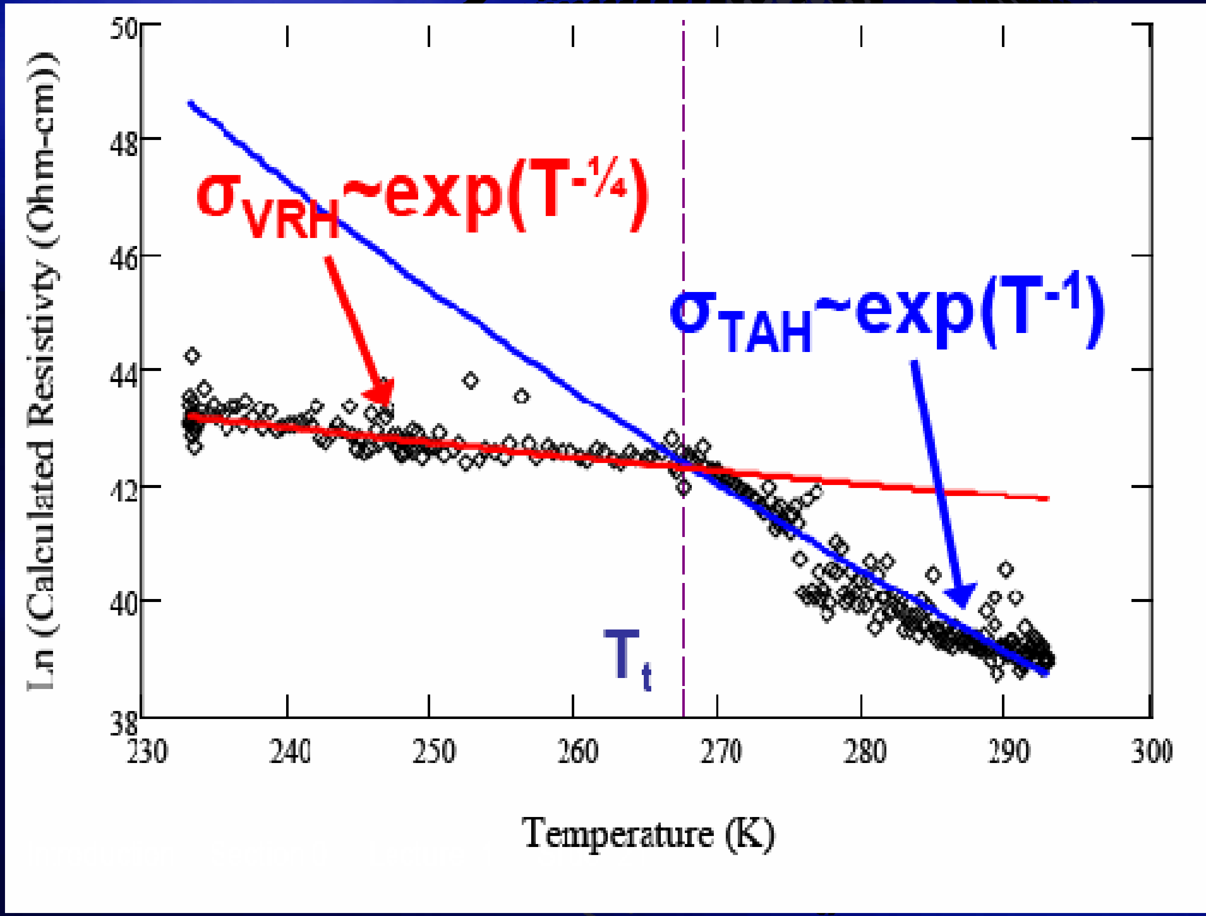
Temperature Dependence of Bulk Resistivity for LDPE (courtesy, J.R. Dennison)



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Non-Static Spacecraft Charging Models:

- Old-style spacecraft charging models used a steady-state approach
  - Equilibrium determined through numerical iteration - most charging situations not treatable analytically.
- Worst charging events happen when equilibrium has not yet been established
  - GEO, ISS, LEO Polar satellites all have rapidly changing conditions, materials properties when coming out of eclipse
  - Thruster firings and substorms can change conditions rapidly
  - LEO-GEO transfer orbits mean orbital conditions vary greatly
  - Antennas must incorporate high frequency effects

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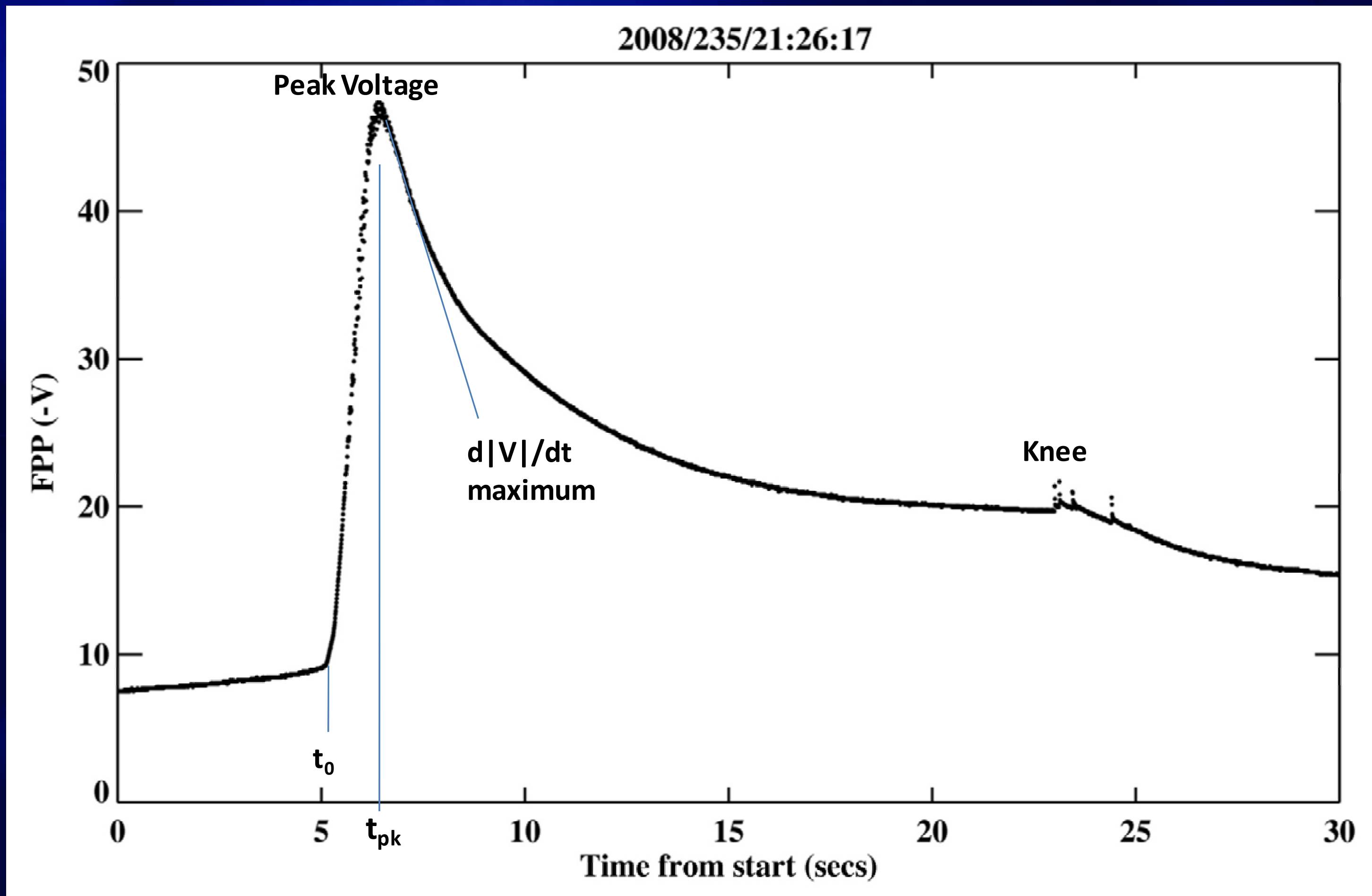

Rapid Charging Event on ISS at Eclipse Exit

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Non-Static Spacecraft Charging Models:

- New spacecraft charging models must use new techniques to calculate charging effects of space and time variations in:
  - fields
  - particle fluxes and spectra
  - temperature
  - changing materials properties
  - changing orbits
  - plumes and thrusters
  - antennas and other local field generators (plasma contactors, etc.

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Novel Charging Mitigation Techniques:

1) Surface materials that easily emit electrons are being contemplated and even developed
   - These may promise passive charge control wherever they are placed
2) New small passive devices that emit electrons as fast as they are collected (usually through some type of field emission) have been patented (or have patents applied for)
   - May make realtime charging mitigation cheaply and reliably achievable for the first time

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Novel Mitigation Techniques (Solar Array Designs):

Novel solar cell configurations and coverglass materials

- IMM cells with “Mesa” architecture
  - Grout cell edges with coverglass adhesive
- Very thin cells may make coverglasses obsolete
  - A thin coverslide material may stop low energy protons but let high energy protons pass right through both coverslide and cell
- Conductive coverslide materials (carbon nanotubes?) may prevent e-fields, arcing
- Solar concentrators and high efficiency cells
  - Make grouting cell edges more attractive with less cell edge area to grout

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Lightweight Concentrator Array (courtesy, H. Brandhorst)

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Novel Mitigation Techniques :

Superconducting Power Distribution Cables

- No high voltages needed to carry high power
- All spacecraft components and surfaces may be at nearly the same potential – ergo no arcing
- Need development of new room temperature superconductors

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The Final Frontier – New Technologies and Power Requirements

- Lightweight materials
  - Composites may not be as conductive as old materials, may allow EMI into electronics
  - Smaller chips may make for more SEUs due to smaller component spacing
- High efficiency cells
  - Primary ESDs at cell edges may damage multijunction cells
  - Must either prevent all ESDs or encapsulate all cell edges!

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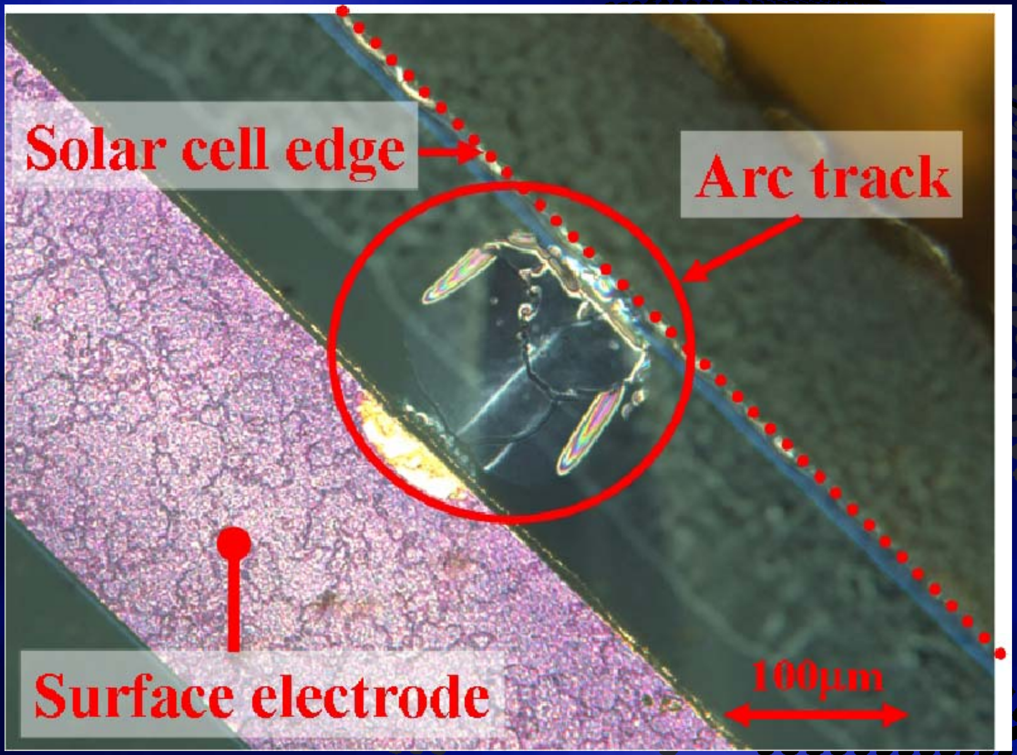

Primary ESD on Solar Cell Edge (courtesy, M. Cho)

The Final Frontier – New Technologies and Power Requirements

- **Increasing Power Requirements**
  - **Longer cables – require higher voltages or superconductors**
  - **If superconductors, high power implies high currents, implies strong magnetic fields**
  - **Spacecraft control and stability may be compromised, loss of superconductivity may lead to explosive events**

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As always, we must extend the boundaries of science and technology to be able to handle the new difficulties and situations that science and technology bring.