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RF Breakdown Prevention in Spacecraft Components Product Overview

May 8, 2014

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Acknowledgments

This presentation provides a summary overview of TOR-2014-02198, “RF Breakdown Prevention in Spacecraft Components”, which was produced as part of the Mission Assurance Improvement Workshop.

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RF Breakdown Prevention in Spacecraft Components

Product Overview

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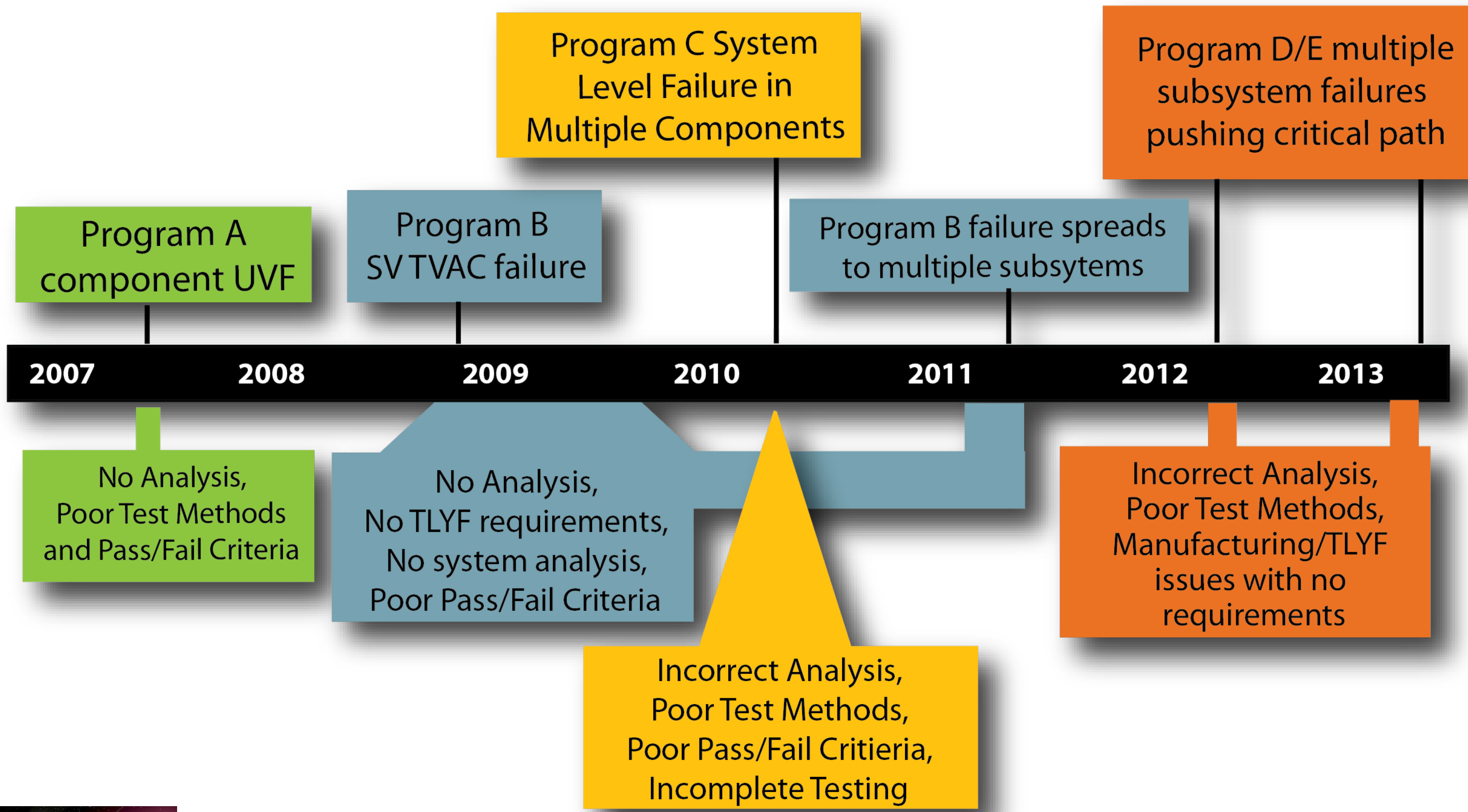
Motivation for RF Breakdown Prevention Standard

Problem Statement

- Ionization breakdown and multipactor causing multiple failures in RF components
  - Increasing satellite powers and bandwidth requirements will continue to increase risk
- Significant ground/on-orbit failures on current programs
  - High power filters, isolator devices, antenna system components
- Reliance on limited SME support, minimal standardization/TLYF/design criteria



Motivation for RF Breakdown Prevention Standard

System Analysis and Requirements

- Different approach for many programs, suppliers, etc.
- Worst case analysis, risk assessment for system and component susceptibility

Need: Uniform baseline for defining worst-case, bounding requirements

Component Design

- Large margins required due to model uncertainty, no standard process
- Modern analysis tools and mitigation techniques

Need: Better numerical and prediction tool implementation

Ground Test and Integration

- Detection and requirements difficult
- Test diagnostic implementation, test-like-you-fly requirements

Need: More sensitive and standardized diagnostics, test-like-you-fly requirements

MAIW Goals

→ Develop new Standard to directly impact US RF satellite industry

→ Provide guidance for requirement baselines with industry insight

→ Address deficiencies in previous/current processes

→ Outline future directions for research to aid industry

Agenda

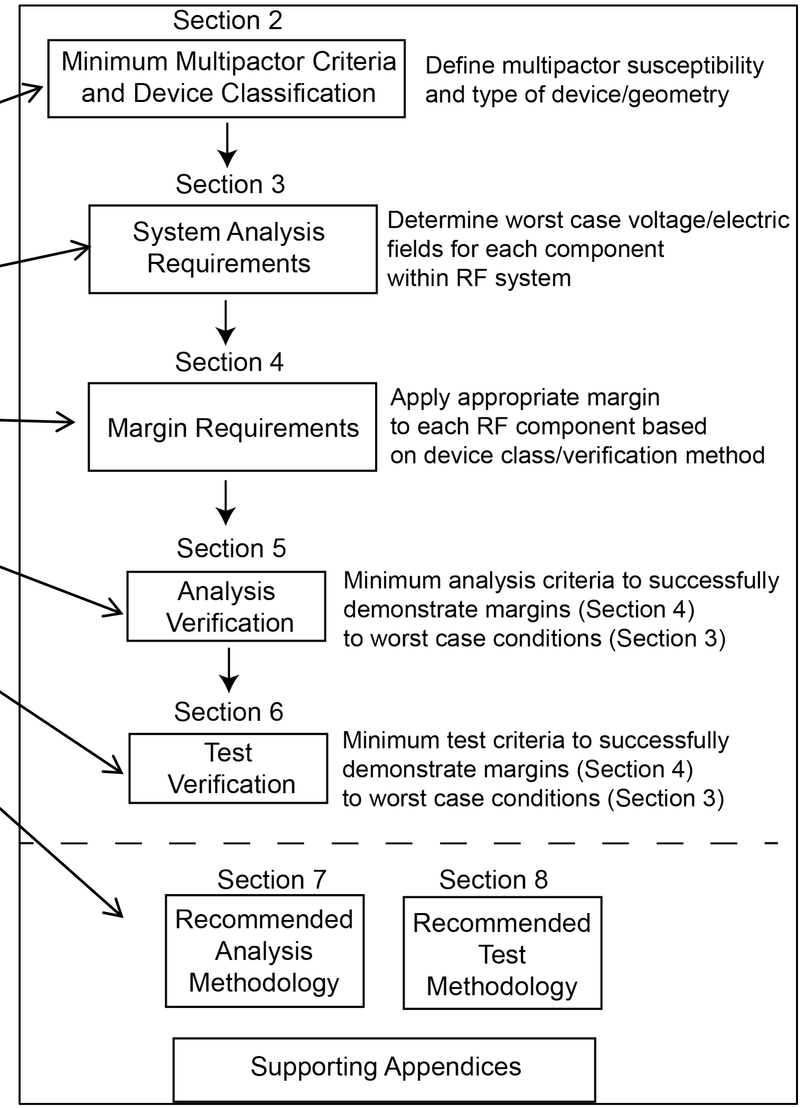
- Product overview of RF breakdown prevention process
  - *Minimum multipactor criteria*
  - *Worst case system analysis*
  - *Margin requirements and verification process requirements*
- SME comments and Workshop products
- Document intended use
  - *Agency adoptions, customer/contractor/supplier implementation*
- Topic Follow-on Recommendations
  - *Future effort to enhance this document and support other classes of RF breakdown*
- Team Membership and Recognition

RF Breakdown Prevention Standard Charter

- Develop industry-wide standard for component, subsystem, and system test with respect to RF breakdown risk mitigation in RF/microwave components
  - *Define system analysis process to determine worst case, bounding conditions for each component*
  - *Define minimum requirement set for analysis and test to ensure proper treatment and consideration*
  - *Reference guides for analysis and test recommended techniques*
  - *Provide standard test geometries for analysis and test facility benchmarking*
  - *Describe areas in need of further research*
  - *Recommend industry adoption (Standard/Handbook adoption)*

RF Breakdown Prevention Standard – Product Traceability

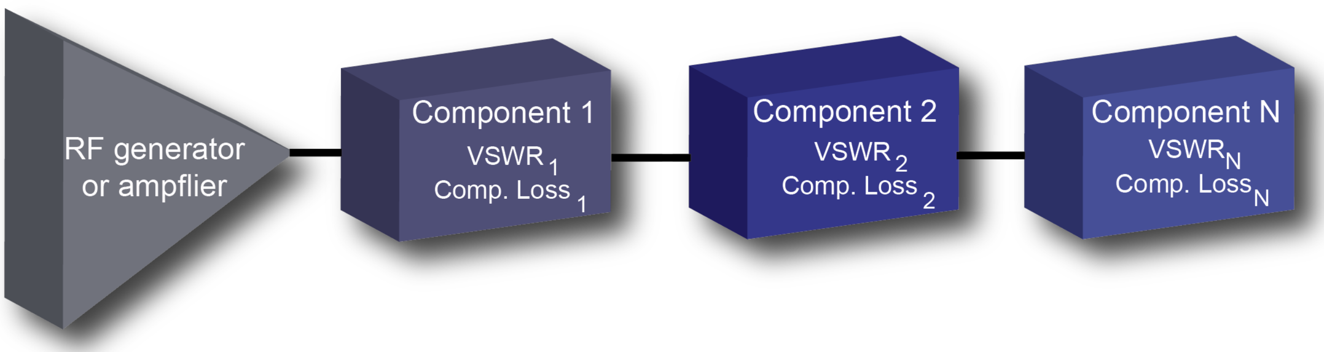
Deliverable Requested
Document applicability, device class/category definitions, process description
Worst case analysis to define system parameters and component power levels
Margin requirements for component types
Analysis minimum requirements
Component test minimum requirements
Reference guides for test and analysis



U.S. Space Program Mission Assurance Improvement Workshop

Product Overview – A New Process Approach

- Standard/Handbook for RF breakdown – multipactor discharge specific
  - *Ionization breakdown/corona to be covered in follow-up year*
- Defining minimum multipactor criteria and device classifications
  - *Allow process tailoring for broad applicability across many system types*
- Full process approach to determine worst case for each component
  - *Improvement over "lumping" excess margin to cover multiple uncertainties*
  - *Define worst case power based on bounding and predictable variables*
  - *Each section of document builds on previous sections*

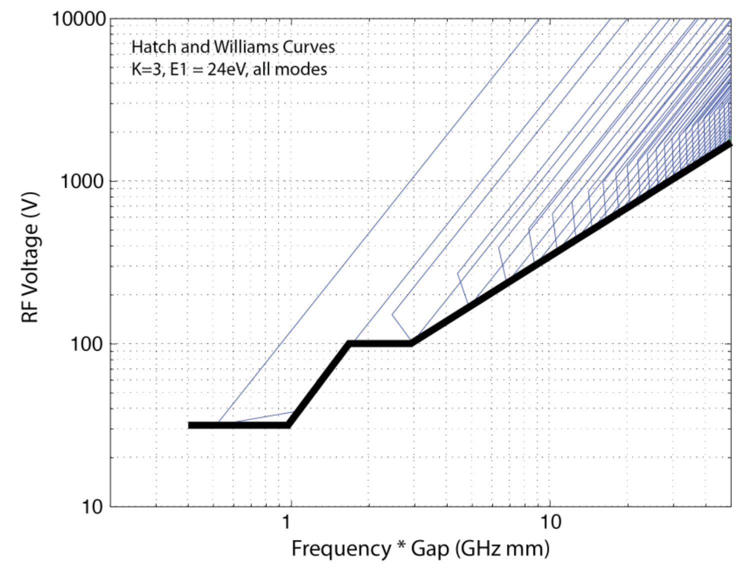


Product Overview – New requirement definitions

- Defining margin requirements
  - *Using worst case system analysis, provide requirements for margins*
- Realistic requirements supported by full process approach

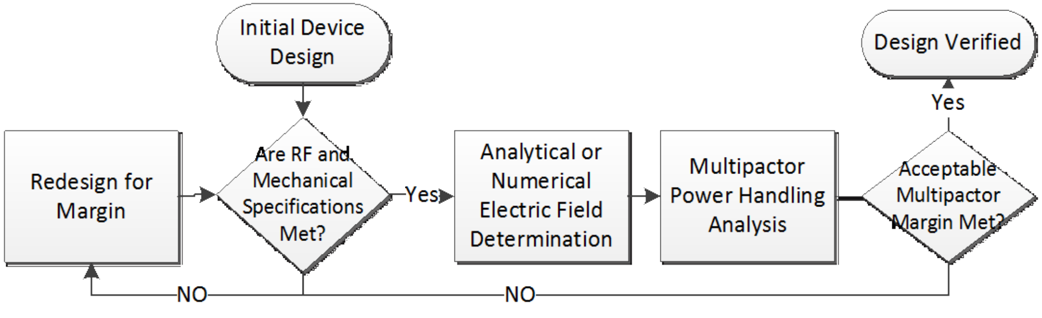
Complexity Level	Analysis Margin (dB)			Test Margin (dB)	Example
	Type 1	Type 2	Type 3	Type 1/Type 2/Type 3	
1	3	3	N/A	3	1-D Transmission Line
2	3	6	N/A	3	Stepped Impedance
3	3	6	N/A	3	Resonant Cavity

- Requirement verification: Minimum criteria
  - *Analysis: Minimum requirements for modern methods and tools*
  - *Test: TLYF implementation for proper screening/detection*

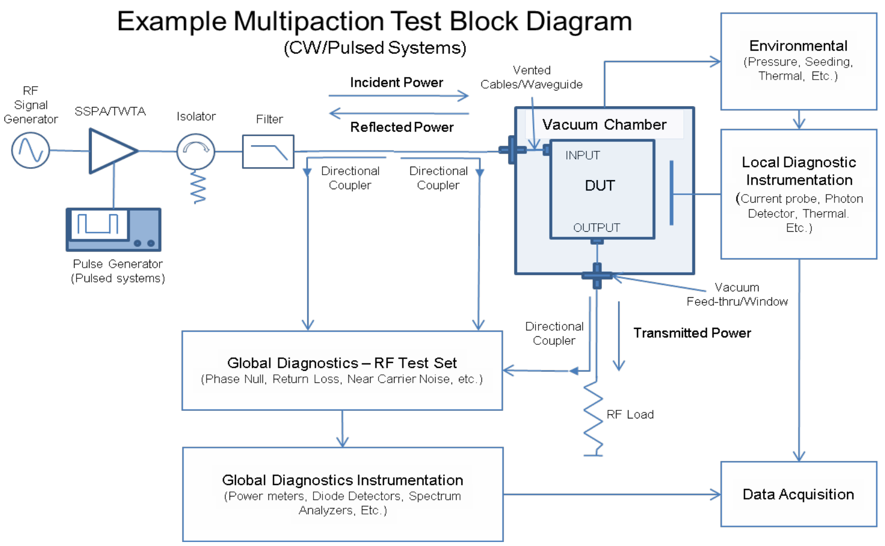


Product Overview – Recommended Methods

- Guidance/Recommendations for analysis and test methods
  - *Provide industry best practices for both analysis and test*
- Analysis techniques: process description and recommendations



- Proper testing: examples and considerations
  - *Data collection*
  - *Recommended diagnostics*
  - *Pass/Fail Criteria*
  - *Test operation*



Workshop Objectives and Accomplishments

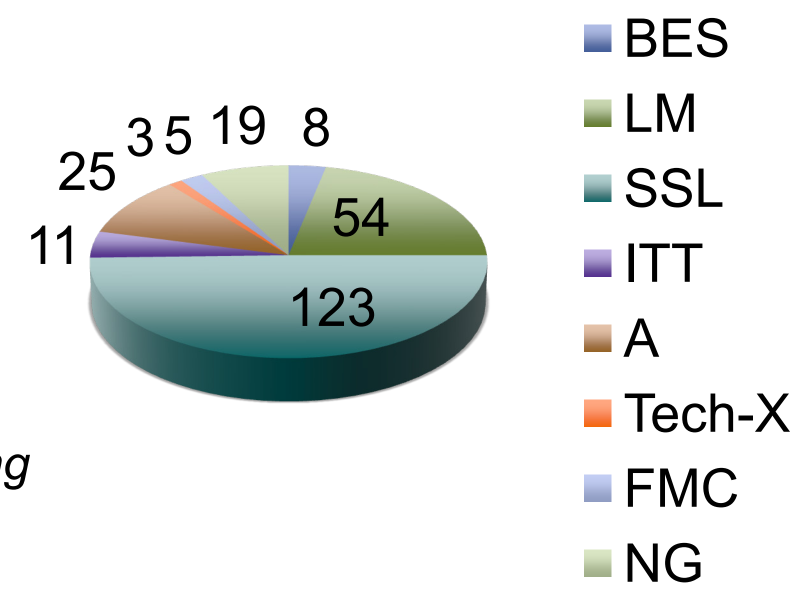
- Incoming objectives of workshop
  - ✓ *Agreement on process elements – worst case, baseline conditions for analysis and test*
  - ✓ *Comparison to other documents and rationale for differences*
  - ✓ *Rationale for minimum verification requirements*
  - ✓ *Document structure including multiple volumes, handbook versus standard*

- Workshop Accomplishments
  - ✓ *Dispositioned all SME comments*
  - ✓ *No major or technical actions, only remaining to refine document language*
  - ✓ *Action ECD May 14, 2014*
  - ✓ *Discussed proposed follow-on activities*

Disposition of Comments

- Over 250 comments from SMEs, currently dispositioning in small committee meetings
  – *Comments coming in from vendors, contractors, and customer communities*
  – *99% have been discussed and implemented*

- Common themes with comments
  ✓ *Formatting for standard adoption (refining to shall statements)*
  ✓ *Comparison to previous (ESA) methods*
  ✓ *Use of different materials in the analysis margin determination*
  ✓ *Applying system analysis to any system*
  ✓ *Thermal requirements for multipactor testing*
  ✓ *Defining pass fail criteria*
  ✓ *Multicarrier power definition – not covered in FY14 effort*



Intended Product Use (1 of 2)

- Improved "front-end" guidance for multipactor risk mitigation for RF/microwave spacecraft components
  - *Applicability for all parties within the component life cycle*
    - Customer: Requirement definition
    - Contractor: System engineering requirement flow-down to suppliers
    - Supplier: Minimum requirement set for analysis and test
  - *Product will be updated with future improvements in analysis and test methods*
  - *Margin requirements can be updated based on new/updated data*
- Implementation for any spacecraft system
  - *Applicable for government, civil, and commercial systems*
- Customer benefit to incorporating Standard
  - *Developed cooperatively by industry, uses modern-day tools, provides end-to-end risk mitigation process*

Intended Product Use (2 of 2)

- Long term goal: document in contract language from program initiation
  - *Current programs still experiencing issues, document features already in use*
- Creation of "official" Standard and agency adoption
  - *Determine potential adopting agencies via DoD, IEEE, AIAA, etc.*
  - *Technical communication/vetting through conferences, international collaboration*
    - Slated for 2015 Workshop in RF Breakdown, International Microwave Symposium
- Standard will drive future research for improved scientific understanding and engineering techniques
  - *Multicarrier, surface treatments, advanced diagnostics require support for development*
  - *Current Multidisciplinary University Research Initiative (MURI) effort under investigation*
    - RF breakdown is inherently multi-disciplinary: RF engineering, plasma physics, surface science
    - Need for new innovation and industrial expert base – foster through university research

Topic Follow-on Recommendations

- Standard Adoption (Agency, Formatting, Multi-volume document)
- Multicarrier power definition
  - *Research currently underway at Aerospace with initial green light from industry*
  - *Further work to refine method and apply to different complex systems*
- Ionization breakdown requirements and minimum verification requirements
  - *No existing document in any forum, domestic or international*
  - *Research necessary to refine requirements*
  - *Potential for new volume within existing document – many general principals, diagnostics are similar*
- MURI investigation for future RF breakdown research

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