AEROSPACE REPORT NO.
TOR-2014-02137

RF Breakdown Prevention in Spacecraft Components Product Overview

May 8, 2014

Timothy Graves
Payload Engineering
Space Based Surveillance Division

Prepared for:

Space and Missile Systems Center
Air Force Space Command
483 N. Aviation Blvd.
El Segundo, CA 90245-2808

Contract No. FA8802-14-C-0001

Authorized by: Space Systems Group

Developed in conjunction with Government and Industry contributions as part of the U.S. Space Program Mission Assurance Improvement Workshop.

AEROSPACE
Assuring Space Mission Success

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **08 MAY 2014**	2. REPORT TYPE **Final**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **RF Breakdown Prevention in Spacecraft Components Product Overview**	5a. CONTRACT NUMBER **FA8802-14-C-0001**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Timothy Graves**	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **The Aerospace Corporation 2310 E. El Segundo Blvd. El Segundo, CA 90245-4609**	8. PERFORMING ORGANIZATION REPORT NUMBER **TOR-2014-02137**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **Space and Missile Systems Center Air Force Space Command 483 N. Aviation Blvd. El Segundo, CA 90245-2808**	10. SPONSOR/MONITOR'S ACRONYM(S) **SMC**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
NA, The original document contains color images.

14. ABSTRACT
NA

15. SUBJECT TERMS
NA

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**35**	

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.

This document was created by multiple authors throughout the government and the aerospace industry. For their content contributions, we thank the following contributing authors for making this collaborative effort possible:

Kevin Campbell, Exelis Incorporated
Will Caven, SSL
James Farrell, The Boeing Company
Robert Frankievich, Lockheed Martin Corporation
Aimee Hubble, PhD, The Aerospace Corporation
Thomas Musselman, The Boeing Company
Preston Partridge, The Aerospace Corporation
Mike Settember, Jet Propulsion Laboratory
Jian Xu, Aeroflex Incorporated

A special thank you for co-leading this team and efforts to ensure completeness and quality of this document goes to Dr. Jeffrey Tate, Raytheon Space and Airborne Systems.

Acknowledgments (Cont)

The authors deeply appreciate the contributions of the subject matter experts who reviewed the document:

Jerry Michaelson, The Aerospace Corporation
Lee Olson, The Aerospace Corporation
Anthony Owens, Raytheon Corporation
Joseph Roubal, Aeroflex, Inc
Paul Tatomir, The Boeing Company
Marty Bieti, The Boeing Company
Luigi Greco, Exelis, Inc.
Douglas Dawson, JPL
Richard Hodges, JPL
Dennis Mlynarski, Lockheed Martin Corporation
Steve Holme, SSL
Larry Arnett, SSL
Ghislain Turgeon, SSL
Rob Singh, SSL
Richard Bennett, Flight Microwave Corporation
Victor Sank, NASA – GFSC
Bruce Flanick, Northrop Grumman
Stefan Vincent, Orbital
Lester Lopez, Harris Corporation

RF Breakdown Prevention in Spacecraft Components

Product Overview

Jeffrey Tate, Raytheon Company
Timothy Graves, The Aerospace Corporation

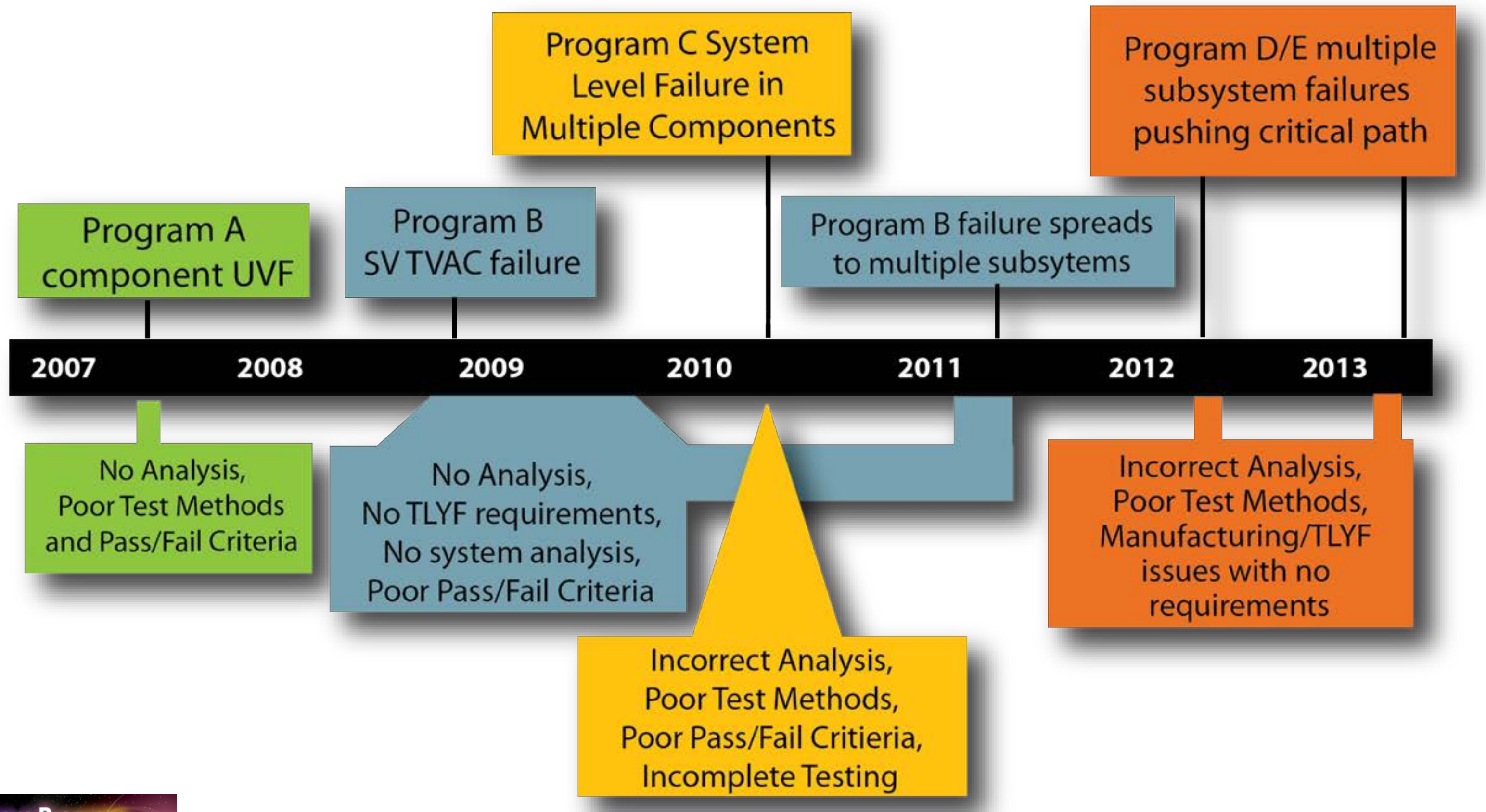
May 8, 2014

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.

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

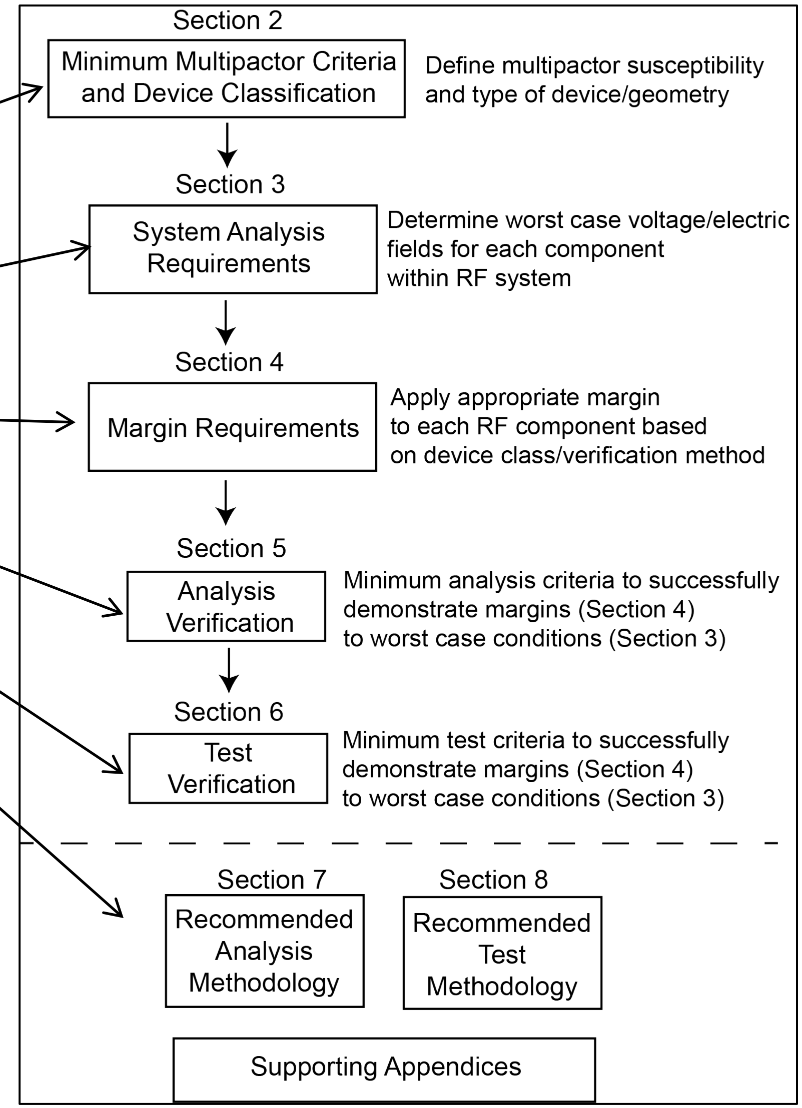
- Product overview of RF breakdown prevention process
  - *Minimum multipactor criteria*
  - *Worst case system analysis*
  - *Margin requirements and verification process requirements*
- SME comments and Workshop products
- Document intended use
  - *Agency adoptions, customer/contractor/supplier implementation*
- 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)*

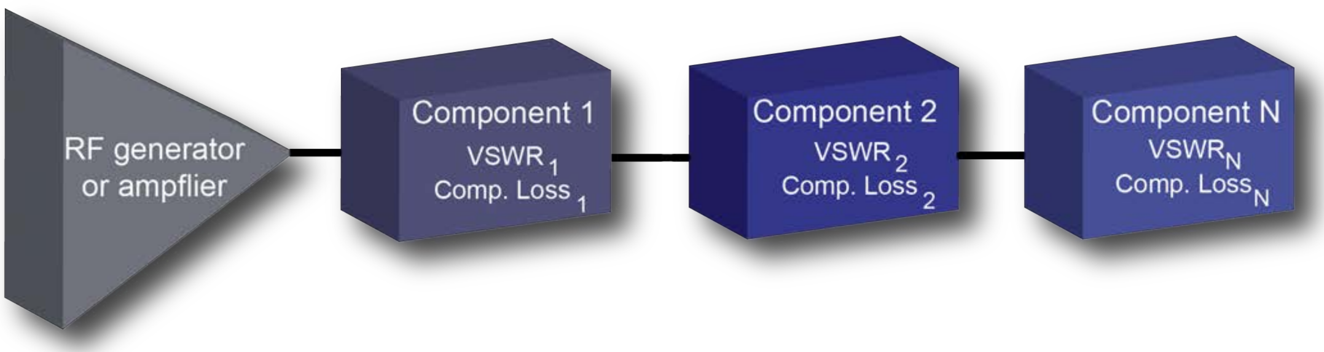
RF Breakdown Prevention Standard – Product Traceability

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



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*

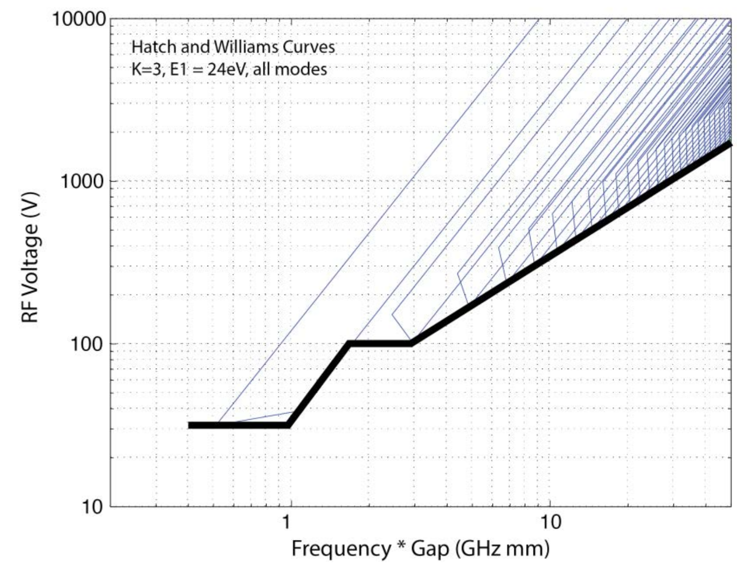


Product Overview – New requirement definitions

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

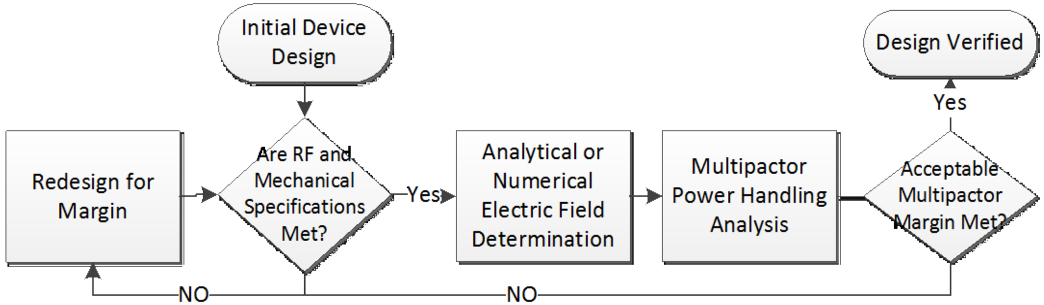
Complexity Level	Analysis Margin (dB)			Test Margin (dB)	Example
	Type 1	Type 2	Type 3	Type 1/Type 2/Type 3	
1	3	3	N/A	3	1-D Transmission Line
2	3	6	N/A	3	Stepped Impedance
3	3	6	N/A	3	Resonant Cavity

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



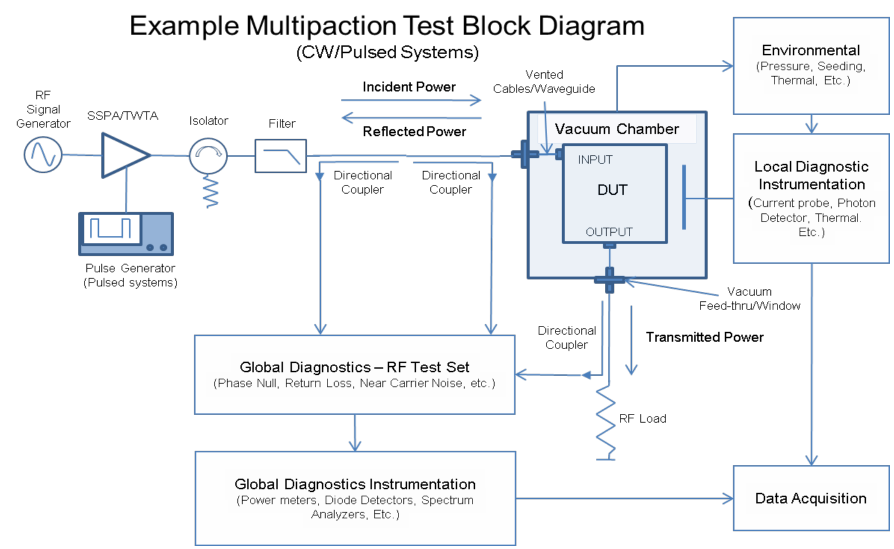
Product Overview – Recommended Methods

- 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

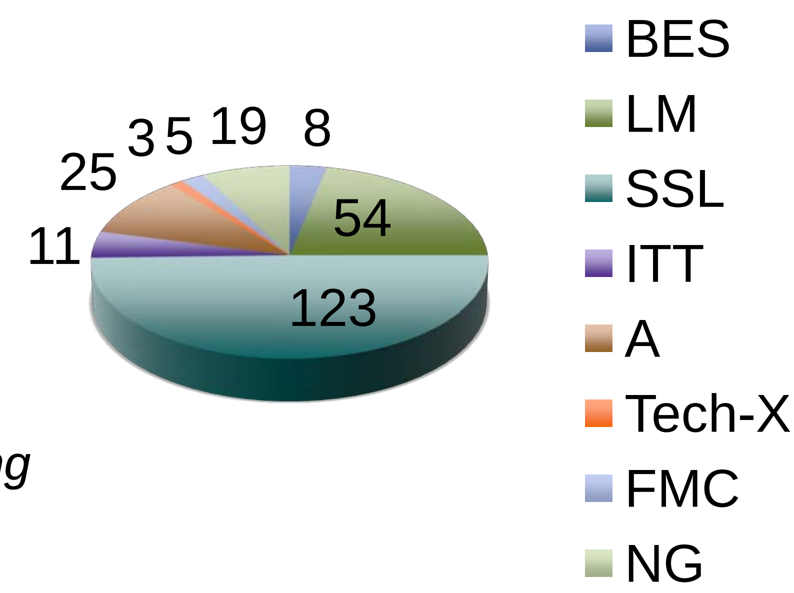
- Incoming objectives of workshop
  - ✓ *Agreement on process elements – worst case, baseline conditions for analysis and test*
  - ✓ *Comparison to other documents and rationale for differences*
  - ✓ *Rationale for minimum verification requirements*
  - ✓ *Document structure including multiple volumes,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

Team Introductions

Company	Core Team Member	Subject Matter Expert
The Aerospace Corp.	Timothy Graves, Preston Partridge, Aimee Hubble	Jerry Michaelson, Lee Olson
Raytheon Corp.	Jeffrey Tate	Anthony Owens
Aeroflex Inc.	Jian Xu	Joseph Roubal
The Boeing Company	James Farrell, Tom Musselman	Paul Tatomir, Marty Bieti
Exelis Inc.	Kevin Campbell	Luigi Greco
JPL	Mike Settember	Douglas Dawson, Richard Hodges
Lockheed Martin Corp.	Robert Frankievich	Dennis Mlynarski
SSL	Will Caven	Steve Holme, Larry Arnett, Ghislain Turgeon, Rob Singh
Flight Microwave Corp.		Richard Bennett
NASA – GFSC		Victor Sank
Northrop Grumman		Bruce Flanick
Orbital		Stefan Vincent
Harris Corp.		Lester Lopez

AEROSPACE REPORT NO.
TOR-2014-02137

RF Breakdown Prevention in Spacecraft Components Product Overview

Approved Electronically by:

Jacqueline M. Wyrwitzke, PRINC DIRECTOR
MISSION ASSURANCE SUBDIVISION
SYSTEMS ENGINEERING DIVISION
ENGINEERING & TECHNOLOGY GROUP

Jackie M. Webb-Larkin, SECURITY SPECIALIST III
GOVERNMENT SECURITY
SECURITY OPERATIONS
OPERATIONS & SUPPORT GROUP

Russell E. Averill, GENERAL MANAGER
SPACE BASED SURVEILLANCE DIVISION
SPACE PROGRAM OPERATIONS

David J. Gorney, EXECUTIVE VP
SPACE SYSTEMS GROUP

SK0668

AEROSPACE REPORT NO.
TOR-2014-02137

RF Breakdown Prevention in Spacecraft Components Product Overview

Technical Peer Review Performed by:

Jacqueline M. Wyrwitzke, PRINC DIRECTOR
MISSION ASSURANCE SUBDIVISION
SYSTEMS ENGINEERING DIVISION
ENGINEERING & TECHNOLOGY GROUP

SK0668

External Distribution

REPORT TITLE		
RF Breakdown Prevention in Spacecraft Components Product Overview		
REPORT NO. TOR-2014-02137	PUBLICATION DATE May 8, 2014	SECURITY CLASSIFICATION UNCLASSIFIED

Charles Abernethy
Aerojet
charles.abernethy@aerojet.com

David Adcock
Orbital
adcock.david@orbital.com

Aaron Apruzzese
ATK
aaron.apruzzese@atk.com

Carlo Abesamis
NASA
abesamis@jpl.nasa.gov

Robert Adkisson
Boeing
robert.w.adkisson@boeing.com

Chic Arey
NRO
areyc@nro.mil

Andrew Adams
Boeing
andrew.c.adams@boeing.com

Scott Anderson
Seaker
scott.anderson@seaker.com

Brent Armand
Orbital
Armand.Brent@orbital.com

Larry Arnett
Loral
arnett.larry@ssd.loral.com

Glenn Barney
Comdev-USA
glenn.barney@comdex-use.com

Robert Bodemuller
Ball
rbodemuller@ball.com

Ken Baier
Lockheed Martin
ken.b.baier@lmco.com

David Beckwith
NRO
beckwith@nro.mil

Silvia Bouchard
Northrop Grumman
silver.bouchard@ngc.com

Dean Baker
NRO
bakerdea@nro.mil

Theresa Beech
Metispace
tbeech@metispace.com

Wayne Brown
ULA Launch
wayne.brown@ulalaunch.com

Mark Baldwin
Raytheon
Mark.L.Baldwin@raytheon.com

Barry Birdsong
MDA
barry.birdsong@mda.mil

Christopher Brust
DCMA
Christopher.Brust@dcma.mil

Lisa Barboza
General Dynamics
Lisa.Barboza@gd-ais.com

Ruth Bishop
Northrop Grumman
ruth.bishop@ngc.com

Alexis Burkevics
Rocket
Alexis.Burkevics@rocket.com

Thomas Burns
NOAA
thomas.burns@noaa.gov

Will Caven
Loral
caven.will@ssd.loral.com

Jerald Cogen
FREQELEC
Jerald.Cogen@FreqElec.com

Edward Bush
Northrop Grumman
Edward.Bush@ngs.com

Shawn Cheadle
Lockheed Martin
shawn.cheadle@lmco.com

Bernie Collins
DNI
bernie.f.collins@dni.gov

Tim Cahill
Lockheed Martin
tim.cahil@lmco.com

Janica Cheney
ATK
janica.cheney@atk.com

Jeff Conyers
Ball
jconyers@ball.com

Kevin Campbell
Exelis Inc
kevin.campbell@exelisinc.com

Brian Class
Orbital
class.brian@orbital.com

Kevin Crackel
Aerojet
kevin.crackel@aerojet.com

Larry Capots
Lockheed Martin
larry.capots@lmco.com

Brad Clevenger
EMCORE
brad_clevenger@emcore.com

James Creiman
Northrup Grumman
James.Creiman@ngc.com

Stephen Cross
ULA Launch
stephen.d.cross@ulalaunch.com

Shawn Cullen
JDSU
shawn.cullen@jdsu.com

Louis D'Angelo
Lockheed Martin
louis.a.d'angelo@lmco.com

David Davis
SMC
David.Davis.3@us.af.mil

Douglas Dawson
NASA
douglas.e.dawson@jpl.nasa.gov

Jaclyn Decker
Orbital
decker.jaclun@orbital.com

Larry DeFillipo
Orbital
defillipo.aryy@orbital.com

Ken Dodson
SSL MDA
ken.dodson@sslmda.com

Tom Donehue
ATK
tom.donehue@atk.com

Mary D'Ordine
Ball
mdordine@ball.com

Susanne Dubois
Northrop Grumman
susanne.dubois@ngc.com

David Eckhardt
BAE Systems
david.g.eckhardt@baesystems.com

Robert Ellsworth
Boeing
robert.h.ellsworth@boeing.com

Matt Fahl
Harris Corporation
mfahl@harris.com

James Farrell
Boeing
james.t.farrell@boeing.com

Tracy Fiedler
Raytheon
tracy.m.fiedler@raytheon.com

Mike Floyd
General Dynamics
Mike.Floyd@gdc4s.com

Matteo Genna
SSL
matteo.genna@sslmda.com

Brad Fields
Orbital
fields.brad@orbital.com

David Ford
Flextronics
david.ford@flextronics.com

Helen Gjerde
Lockheed Martin
helen.gjerde@lmco.con

Sherri Fike
Ball
sfike@ball.com

Robert Frankievich
Lockheed Martin
robert.h.frankievich@lmco.com

Ricardo Gonzalez
BAE Systems
ricardo.gonzalez@baesystems.com

Richard Fink
NRO
richard.fink@nro.mil

Bill Frazier
Ball
wfrazier@ball.com

Dale Gordon
Rocket
dale.gordon@rocket.com

Bruce Flanick
Northrop Grumman
bruce.flanick@ngc.com

Jace Gardner
Ball
jgardner@ball.com

Chuck Gray
Fescorp
Chuckg@fescorp.com

Luigi Greco
Exelis Inc
luigi.greco@exelisinc.com

Bob Harr
Seaker
bob.harr@seaker.com

Paul Hopkins
Lockheed Martin
paul.c.hopkins@lmco.com

Gregory Hafner
Orbital
Hafner.Gregory@orbital.com

Frederick Hawthorne
Lockheed Martin
frederick.d.hawthorne@lmco.com

Kevin Horgan
NASA
kevin.horgan@nasa.gov

Joe Haman
Ball
jhaman@ball.com

Ben Hoang
Orbital
Hoang.Ben@orbital.com

Eugene Jaramillo
Raytheon
eugenejaramillo@raytheon.com

Lilian Hanna
Boeing
lilian.hanna@boeing.com

Rosemary Hobart
Hobart Machined
rosemary@hobartmachined.com

Dan Jarmel
Northrop Grumman
dan.jarmel@ngc.com

Harold Harder
Boeing
harold.m.harder@boeing.com

Richard Hodges
NASA
richard.e.hodges@jpl.nasa.gov

Robert Jennings
Raytheon
rjennings@raytheon.com

Mike Jensen
ULA Launch
mike.jensen@ulalaunch.com

Amanda Johnson
Orbital
johnson.amanda@orbital.com

Edward Jopson
Northrop Grumman
edward.jopson@ngc.com

Jim Judd
orbital
judd.jim@orbital.com

Geoffrey Kaczynski
NEA Electronics
gkazynik@neaelectonics.com

Mike Kahler
Ball
mkahler@ball.com

Yehwan Kim
Moog
ykim@moog.com

Jeff Kincaid
Power
Jeffrey.Kincaid@pwr.utc.com

Mark King
Micopac
markking@micropac.com

Andrew King
Boeing
andrew.m.king@boeing.com

Byron Knight
NRO
knightby@nro.mil

Hans Koenigsmann
SpaceX
hans.koenigsmann@spacex.com

James Koory
Rocket
james.koory@rocket.com

Brian Kosinski
SSL
Kosinski.Brian@ssd.loral.com

John Kowalchik
Lockheed Martin
john.j.kowalchik@lmco.com

Rick Krause
Ball
rkrause@ball.com

Steve Krein
ATK
steve.krein@atk.com

Steve Kuritz
Northrop Grumman
steve.kuritz@ngc.com

Louise Ladow
Seaker
louise.ladow@seaker.com

C J Land
Harris
cland@harris.com

Chris Larocca
EMCORE
clarocca@emcore.com

Robert Lasky
Orbital
lasky.robert@orbital.com

Eric Lau
SSL
lau.eric@ssd.loral.com

Marvin LeBlanc
NOAA
Marvin.LeBlanc@noaa.gov

Scott Lee
Northrop Grumman
Scott.lee@ngc.com

Don LeRoy
Barden Bearings
dleroy@bardenbearings.com

Scot Lichty
Lockheed Martin
scot.r.lichty@lmco.com

Sultan Ali Lilani
Integra - Tech
sultan.lilani@integra-tech.com

Josh Lindley
MDA
joshua.lindley@mda.mil

Henry Livingston
BAE Systems
henry.c.livingson@baesystems.com

Art Lofton
Northrop Grumman
Art.Lofton@ngc.com

Joan Lum
Boeing
joan.l.lum@boeing.com

John Mc Bride
Orbital
Mcbride.John@orbital.com

James Loman
SSL
james.loman@sslmda.com

Brian Mack
Orbital
mack.brian@orbital.com

Ian McDonald
BAE Systems
ian.a.mcdonald@baesystems.com

Jim Loman
SSL
loman.james@ssd.loral.com

Julio Malaga
Orbital
malaga.julio@orbital.com

Kurt Meister
Honeywell
kurt.meister@honeywell.com

Lester Lopez
Harris
llopez04@harris.com

Kevin Mallon
1-3 Com
Kevin.P.Mallon@1-3com.com

Jeff Mendenhall
MIT
mendenhall@ll.mit.edu

Frank Lucca
1-3 Com
frank.l.lucca@1-3com.com

Miroslav Maramica
Area 51
miroslav@area51esq.com

Jo Merritt
AVTEC
jmerritt@avtec.com

Charles Mills
Lockheed Martin
charles.a.mills@lmco.com

Edmond Mitchell
APL
edmond.mitchell@jhuapl.edu

Dennis Mlynarski
Lockheed Martin
dennis.mlynarski@lmco.com

George Mock
NYE Lubricants
gbm3@nyelubricants.com

Nancy Murray
Safety Batteries
Nancy.murray@saftbatteries.com

Deanna Musil
SSL
deanna.musil@sslmda.com

Thomas Musselman
Boeing
thomas.e.musselman@boeing.com

John Nelson
Lockheed Martin
john.d.nelson@lmco.com

Dave Novotney
EBA
dbnovotney@eba-d.com

Ron Nowlin
EaglePicher
ron.nowlin@eaglepicher.com

Mike Numberger
Navy
nurnberger@nrl.navy.mil

Michael O'Brien
Exelis Inc
michael.obrien@exelisinc.com

Michael Ogneovski
Exelis Inc
michael.ognenovski@exelisinc.com

Debra Olejniczak
Northrop Grumman
Debra.Olejniczak@ngc.com

Larry Ostendorf
psemc
Lostendorf@psemc.com

Anthony Owens
Raytheon
anthony_owens@raytheon.com

Mark Pazder
Moog
mpazder@moog.com

Kay Rand
Northrop Grumman
kay.rand@ngc.com

Joseph Packard
Exelis Inc
Joseph.packard@exelisinc.com

Steven Pereira
APL
Steven.Pereira@jhuapl.edu

David Rea
BAE Systems
david.a.rea@baesystems.com

Peter Pallin
SSL
peter.pallin@sslmda.com

Richard Pfisterer
APL
Richard.Pfisterer@jhuapl.edu

Forrest Reed
EaglePicher
forrest.reed@eaglepicher.com

Richard Patrican
Raytheon
Richard.A.Patrican@raytheon.com

Angela Phillips
Raytheon
amphillips@raytheon.com

Thomas Reinsel
Raytheon
thomas_j_reinsel@raytheon.com

Paulette Megan
Orbital
paulette.megan@orbital.com

Dave Pinkley
Ball
dpinkley@ball.com

Bob Ricco
Northrop Grumman
bob.ricco@ngc.com

Mike Rice
RT Logic
mrice@rtlogic.com

Sally Richardson
Orbital
richardson.sally@orbital.com

Troy Rodriquez
Sierra Microwave
troy_rodriquez@sierramicrowave.com

Ralph Roe
NASA
ralph.r.roe@nasa.gov

Mike Roller
UTAS
mike.roller@utas.utc.com

John Rotondo
Boeing
john.l.rotondo@boeing.com

William Rozea
Rocket
william.rozea@rocket.com

Dennis Rubien
Northrop Grumman
dennis.rubien@ngc.com

Larry Rubin
SSL
Rubin.larry@ssd.loral.com

Lane Saechao
Rocket
lane.saechao@rocket.com

Michael Sampson
NASA
michael.j.sampson@nasa.gov

Victor Sank
NASA
victor.j.sank@nasa.gov

Don Sawyer
AVNET
don.sawyer@avnet.com

Fred Schipp
MDA - Navy
frederick.schipp@navy.mil

Jim Schultz
Boeing
james.w.schultz@boeing.com

Gerald Schumann
NASA
gerald.d.schumann@nasa.gov

Andrew Shroyer
Ball
ashroyer@ball.com

Jerry Sobetski
Lockheed Martin
jerome.f.sobetski@lmco.com

Annie Sennet
Safety Batteries
Annie.Sennet@saftbarries.com

Fredic Silverman
HSTC
fsilverman@hstc.com

LaKeisha Souter
Northrop Grumman
lakeisha.souter@ngc.com

Michael Settember
NASA
michael.a.settember@jpl.nasa.gov

Rob Singh
SSL
rob.singh@sslmda.com

Jerry Spindler
Execlis Inc
Jerry.Spindler@exelisinc.com

Tom Sharpe
SMT Corp
tsharpe@smtcorp.com

Kevin Sink
TTINC
kevin.sink@ttinc.com

Peter Stoltz
TX Corp
pstoltz@txcorp.com

Jonathan Sheffield
SSL
jonathan.sheffield@sslmda.com

Melanie Sloane
Lockheed Martin
melanie.sloane@lmco.com

Thomas Stout
Northrop Grumman
thomas.stout@ngc.com

George Styk
Exelis Inc
george.styk@exelisinc.com

Ghislain Turgeon
SSL
ghislain.turgeon@sslmda.com

Michael Verzuh
Ball
mverzuh@ball.com

David Swanson
Orbital
swanson.david@orbital.com

Deborah Valley
MIT
deborah.valley@ll.mit.edu

John Vilja
Power UTC
jussi.vilja@pwr.utc.com

Mauricio Tapia
Oribital
tapia.mauricio@orbital.com

Fred Van Milligen
JDSU
fvanmilligen@jdsu.com

Vinvent Stefan
Orbital
vincent.stefan@orbital.com

Jeffrey Tate
Raytheon
jeffery_tate@raytheon.com

Marvin VanderWeg
SpaceX
marvin.vanderwag@spacex.com

James Wade
Raytheon
james.w.wade@raytheon.com

Bill Toth
Northrop Grumman
william.toth@ngc.com

Gerrit VanOmmering
SSL
gerrit.vanommering@sslmda.com

John Walker
SSL
JohnF.Walker@sslmda.com

Brian Weir
Booz Allen Hamilton
weir_brian@bah.com

Charlie Whitmeyer
Orbital
whitmeyer.charlie@orbtial.com

George Young
Raytheon
gyoung@raytheon.com

Arthur Weiss
Power UTC
arthur.weiss@pwr.utc.com

Michael Woo
Raytheon
michael.woo@raytheon.com

Craig Wesser
Norhtrop Grumman
craig.wesser@ngc.com

Larry Wray
SSL
wray.larry@ssd.loral.com

Dan White
Comdex-USA
dan.white@comdev-usa.com

Mark Wroth
Northrop Grumman
mark.wroth@ngc.com

Thomas Whitmeyer
NASA
tom.whitmeyer@nasa.gov

Jian Xu
Aeroflex
jian.xu@aeroflex.com

APPROVED BY (AF OFFICE) Jaime Rodriguez DATE June 30, 2014