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RF Breakdown Prevention, Part 2 Product Overview

May 7, 2015

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Acknowledgments

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The other members of the team came from the government and the aerospace industry. For their contributions, we thank the following contributing authors for making this collaborative effort possible:

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Bruce Flanick	Northrop Grumman
Aimee Hubble	The Aerospace Corporation
Thomas Musselman	The Boeing Company
Preston Partridge	The Aerospace Corporation
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Jeffrey Tate	Raytheon Space and Airborne Systems

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Raul Perez	Jet Propulsion Laboratory
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RF Breakdown Prevention, Part 2

Product Overview

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Preston Partridge, The Aerospace Corporation

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Agenda

- Issue definition
- Examples
- Motivation for product
- Team charter
- Product overview
- Workshop results
- Topic follow-on recommendations
- Team membership and recognition

RF Breakdown Remains an Issue

- Ionization breakdown (IB) and multipactor have caused multiple failures in RF components
  - *Increasing satellite powers and bandwidth requirements will continue to increase risk*
  - *Consequence of failure ranges from degraded mission capability to complete loss of satellite*
- Significant ground/on-orbit failures on current government and commercial programs
  - *High power filters, isolators, circulators, antenna feeds, switches, etc.*
- Issues currently handled by a few industry experts (many of whom are on the team) and each organization's general guidelines

Courtesy of J. Farrell and Boeing

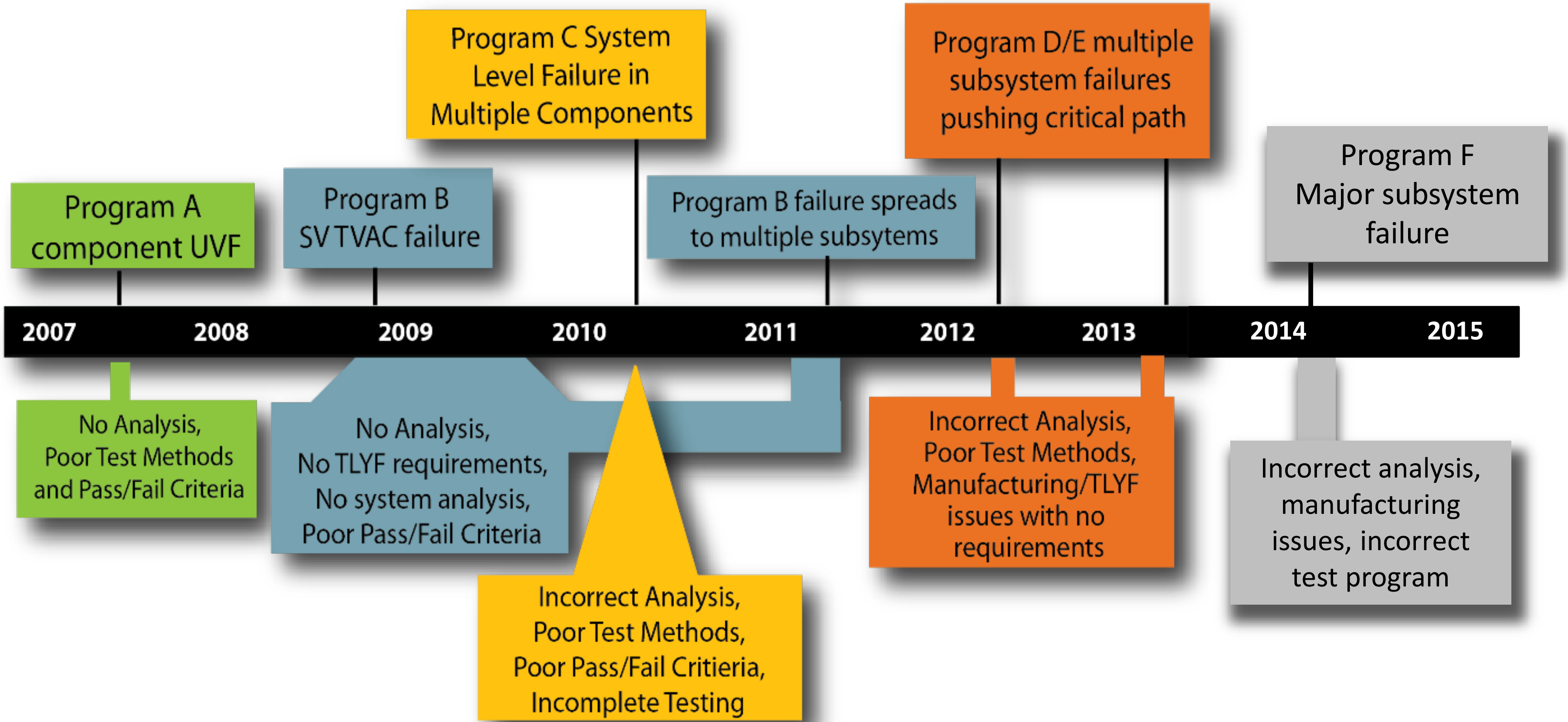
IB plasma discharge in isolator

Courtesy of J. Farrell and Boeing

IB damage in cavity filter from test

Timeline of RF Breakdown Issues

- Recall timeline from Year 1 presentation
- Problems continue to arise, requiring deployment of experts



Major program delays and loss of functionality caused by RF breakdown

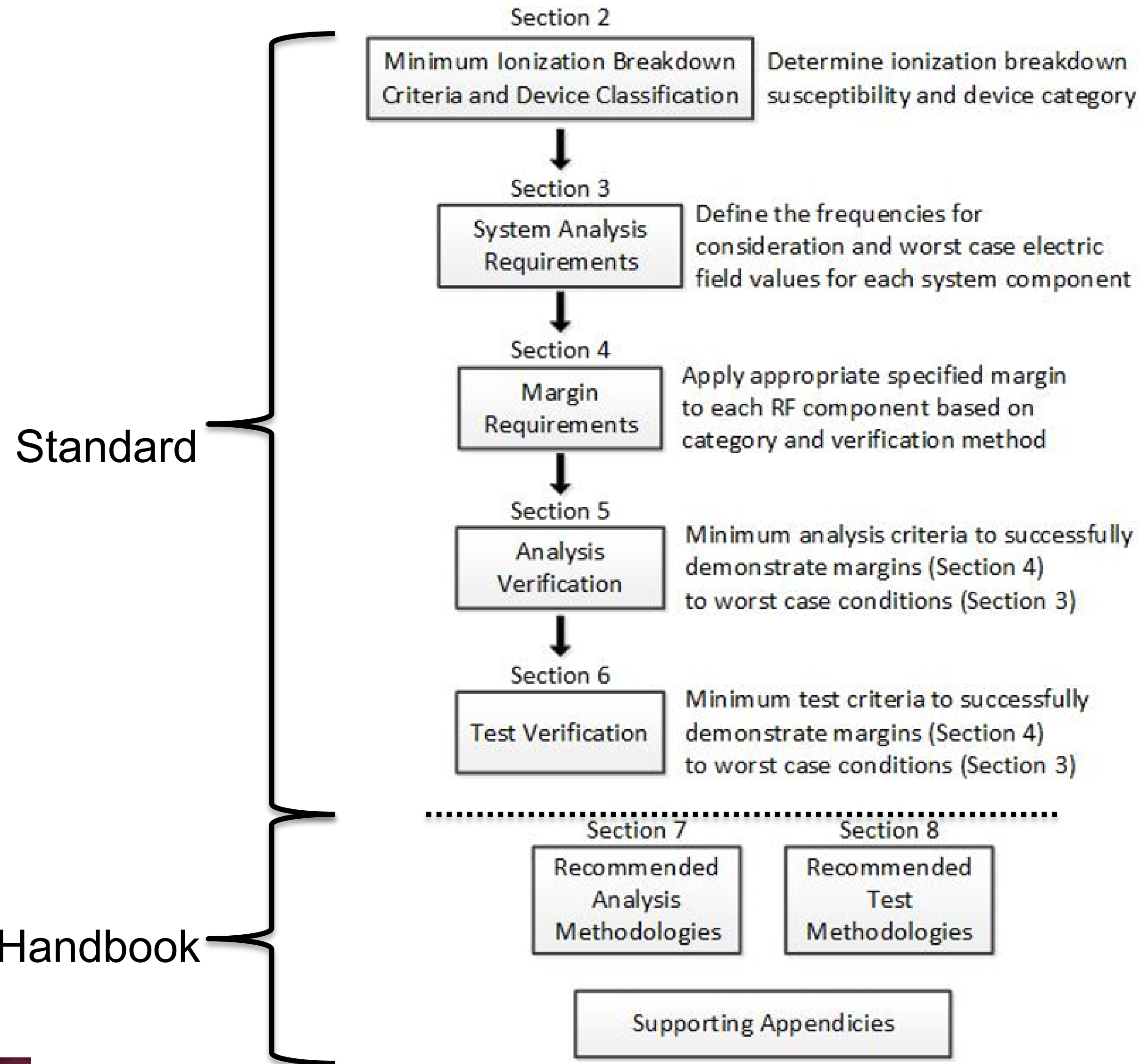
Motivation for RF Breakdown Prevention Standard

- **Ionization breakdown failures on programs affecting mission success**
- Lack of ionization breakdown prevention standard in industry
  - *Best practices for ionization breakdown issues vary widely across the industry*
  - *Standardization of testing, analysis, and requirements development methods needed*
  - *No standard currently exists at the domestic or international levels*
- Existing multicarrier multipactor best practices held by each prime contractor
  - *No scientific consensus on best practices*
  - *However, several widely used methods require clear explanation and documentation in multipactor standard*
- Need to establish forum for ongoing updates and reviews of document after MAIW
  - *Creation of AIAA committee for RF spacecraft components and adoption of TORs into AIAA standards*

RF Breakdown Part 2 Team Charter

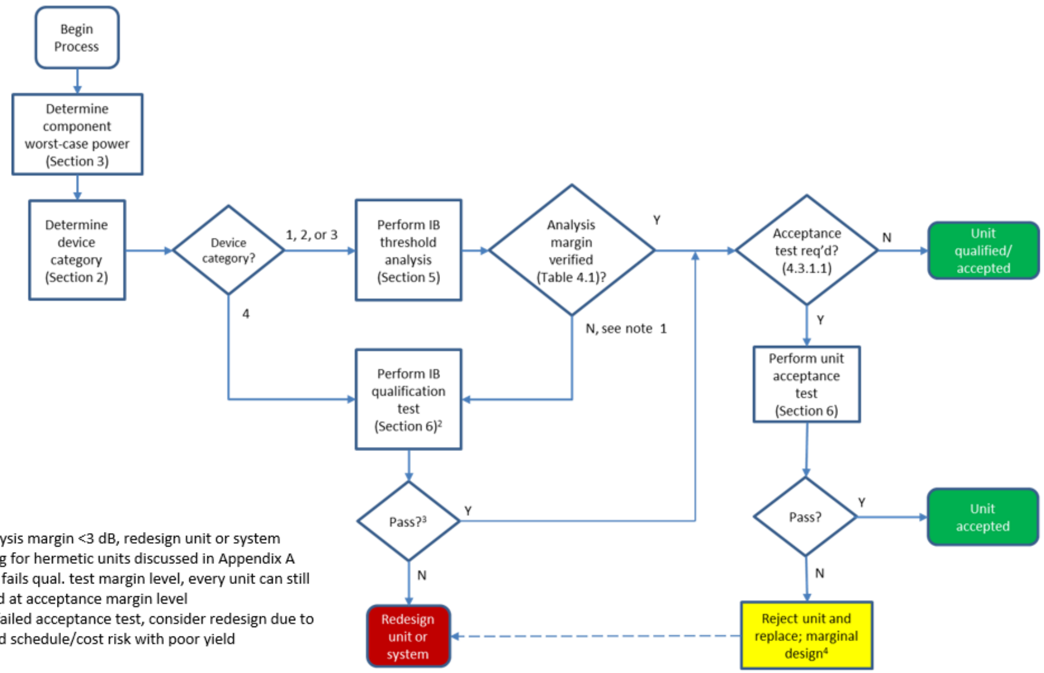
- Create draft standard for ionization breakdown prevention
  - *Follow format of Year 1 multipactor document*
  - *Provide analysis and test minimum requirements and guidelines*
- Address multicarrier multipactor by documenting current industry best practices
  - *Provide summary of survey in a TOR*
- Work with AIAA to create RF breakdown committee
  - *Stand up RF spacecraft components committee for enduring maintenance of documents*
  - *Committee to be made up of MAIW team members with additional members form government and academia*

Ionizing Breakdown (IB) Document Overview



IB Device Verification Flow Chart

- Flow charts used for demonstration of processes to qualify/accept a device for ionization breakdown
- References to sections in document in each box



1. If analysis margin <3 dB, redesign unit or system
2. Testing for hermetic units discussed in Appendix A
3. If unit fails qual. test margin level, every unit can still be tested at acceptance margin level
4. With failed acceptance test, consider redesign due to increased schedule/cost risk with poor yield

Figure 2.2: Flow chart for margin determination and verification process

IB Device Categories and Margins

- Different methods presented for analyzing different device categories
- Margins to qualification by analysis, qualification by test, and acceptance provided

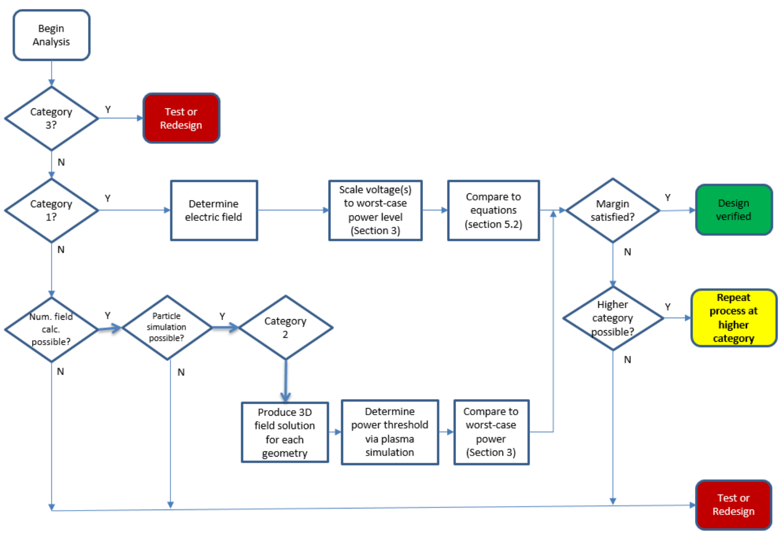
Category	Definition	Device Features or Examples	Analytical RF Breakdown Level Determination (Section 5)
1	Simple geometries. Bounding diffusion length can be determined	Resonator Cavity, Transmission Lines	Require Analytical Curve (Section 5)
2	Diffusion length cannot be directly determined	Impedance transitions, filters, multiplexers, isolators	Require appropriate numerical multidimensional plasma breakdown simulator
3	Uncontrolled geometries or workmanship variability	Potted device, tuning screws in critical areas	N/A

Test (dB)		Analysis (dB)
Qualification	Acceptance	Qualification
6	3	10*

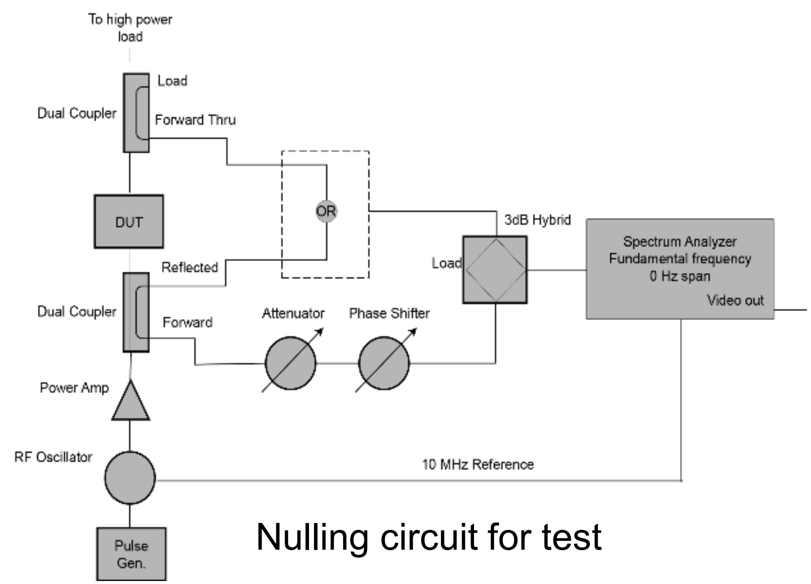
*Category 3 cannot be qualified by analysis

IB Recommended Methods

- Provide industry best practices in guidance sections (7 and 8) of document for analysis and test



Analysis process flow chart



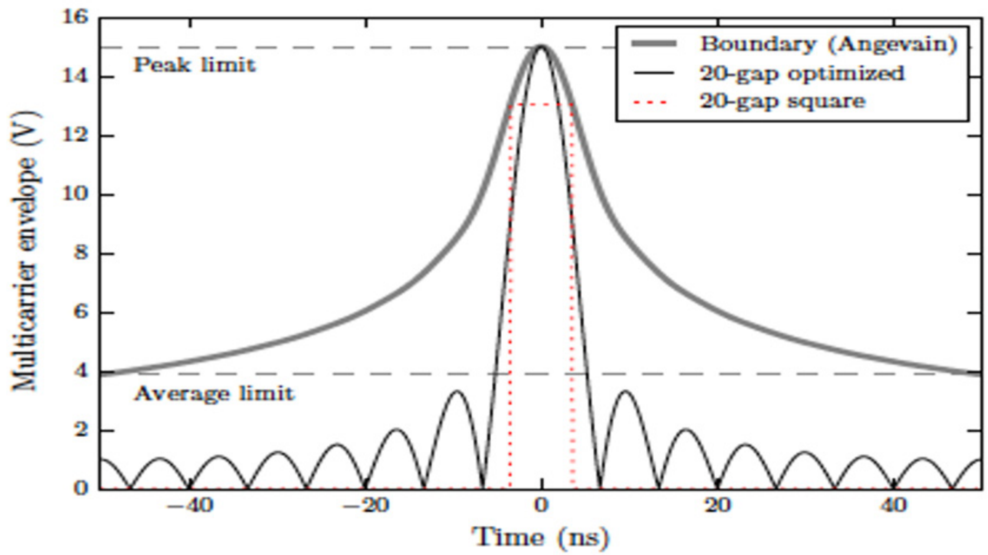
Nulling circuit for test

Multicarrier Multipactor Outline

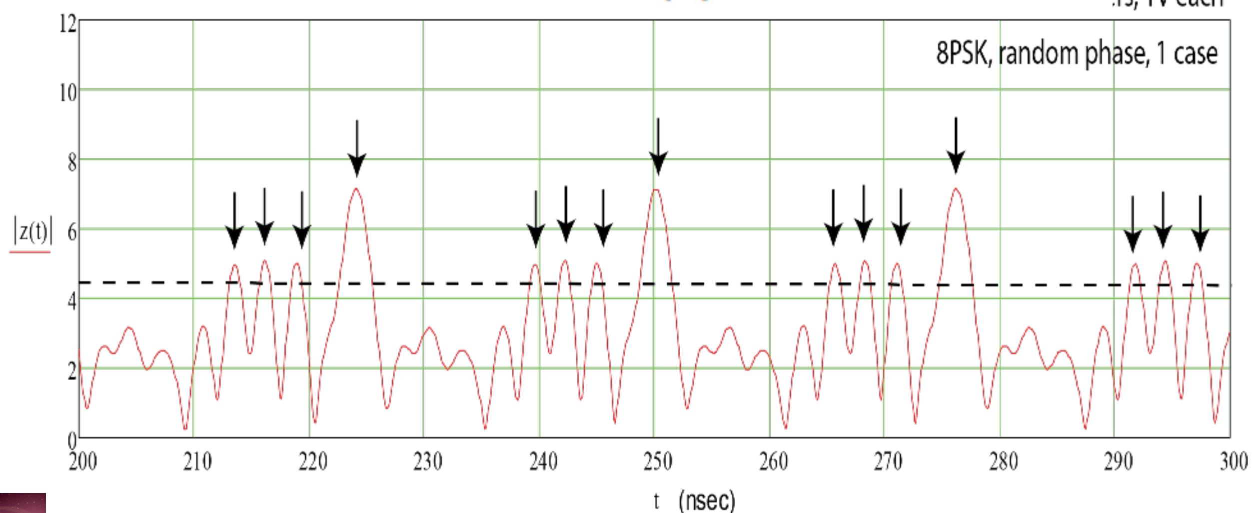
- Detailed explanation of industry best practices used by different organizations
  - *How to calculate*
  - *Applicability and limitations of each*
- Methods discussed
  - *n^2P (square of number of carriers times power of each carrier)*
  - *Gap crossing rules (i.e., P20)*
  - *Total average power*
  - *Statistical methods*

Multicarrier Multipactor Example Charts

P20 method



Statistical method



Intended Product Use

- Ionization breakdown document
  - *Use by prime contractors, suppliers, commercial satellite operators, government agencies*
    - Standard set of requirements for IB test and analysis verification
    - Provide guidance for test and analysis methods
  - *Deliver to new AIAA committee for conversion to formal standard*
  - *Share with ESA to attempt for unified international standard*
- Multicarrier TOR
  - *Use by prime contractors, suppliers, commercial satellite operators, government agencies as a reference document for existing methods*

Leveraging Expertise to Meet Future Challenges

- *Supporting funded efforts by researchers with relevant high-power expertise*
  - MAIW Year 1 released TOR in use
  - Year 2 AFOSR MURI: Transformational Electromagnetics
    - *Lead PI: University of New Mexico*
  - Serving on the Industrial Advisory Board (Tate)
  - Graduate student teleseminars
  - 2014+ year-end reviews
  - MURI Year 3 and 4 recommendations
- *Supporting future AFOSR MURI BAA development*
- *Upcoming discussions with other customer and government communities*

RF Breakdown Prevention, Part 2 Team Membership

Core Team

First Name	Last Name	Organization
Preston	**Partridge**	**The Aerospace Corporation**
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Bold – co-leads

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Bold – attended workshop

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