Status on Boeing's Implementation of CVM and PZT sensors on the 737NG Aft Pressure Bulkhead

SAE / AISC-SHM Committee Meeting, Sept 27-29, 2022

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Implementation of CVM and PZT on the 737NG Aft Pressure Bulkhead

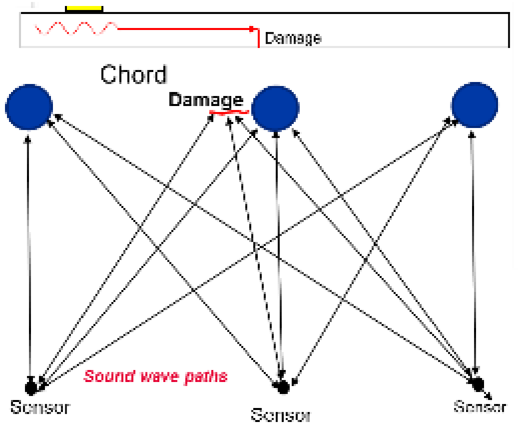
Objective & Agenda

Objective

- Provide visibility of the work Boeing is doing with CVM and PZT sensors to help mature the technology for Structural Health Monitoring (SHM) of airframe structure.

Agenda

- CVM & PZT Sensors
- Selection of SHM Application
- Implementation Approach
- Probability of Detection
- Status of CVM & PZT Project: Challenges / Lessons Learned



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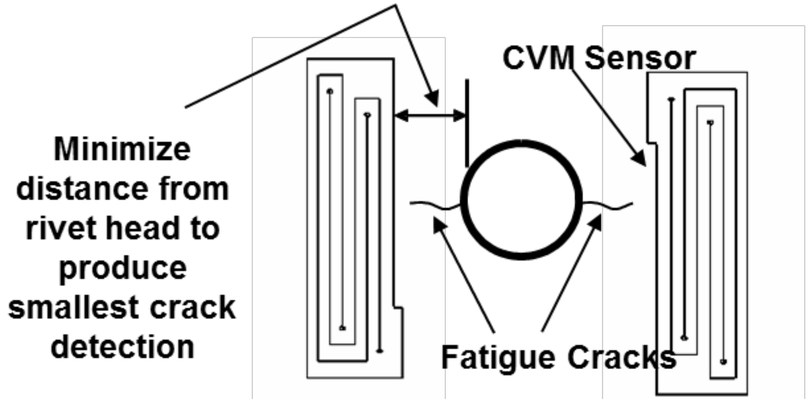
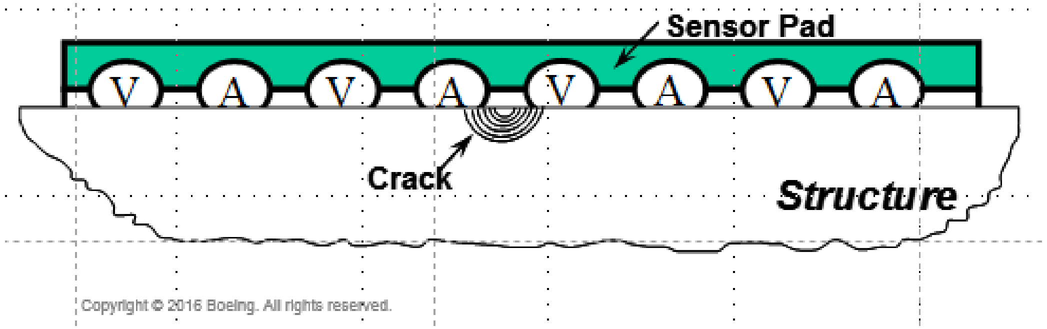
Comparative Vacuum Monitoring (CVM)

CVM Technology

- Sensors contain fine channels – vacuum is applied to embedded galleries
- Leakage path produces a measurable change in the vacuum level





Pros
- Doesn't require electrical excitation
- Simple damage detection scheme
- First certified SHM method for commercial aviation
- Self monitoring for failure

Cons
- Damage detection only limited to surface cracking
- Sensors must be placed on crack paths

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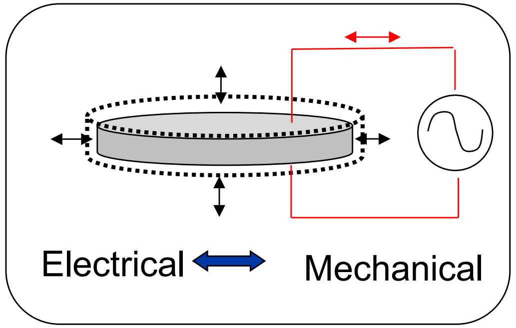
Piezoelectric Transducer (PZT)

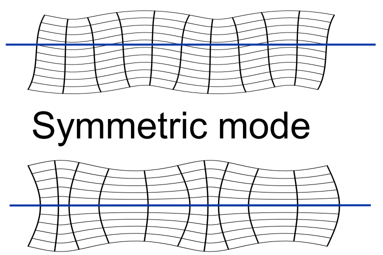
PZT Technology

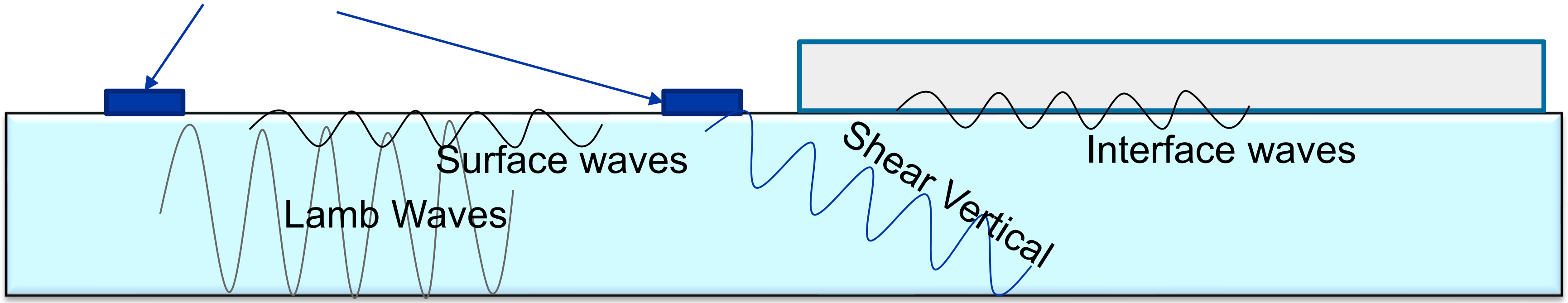
- Guided Waves for Damage Detection
- Pulse Echo & Pitch-Catch Transmissions

- Piezoelectric (PZT) ceramic



- Both transmitters and receivers





Induced Guided Waves	Damage/structure properties
Lamb Waves (LW)	Impact induced delamination, disbonds, cracks, E, EI, G
Surface waves (i.e. Rayleigh waves)	microcracking, surface damage
interface waves (i.e. stoneley waves)	Bondline/interface integrity
shear vertical waves	skewed defects

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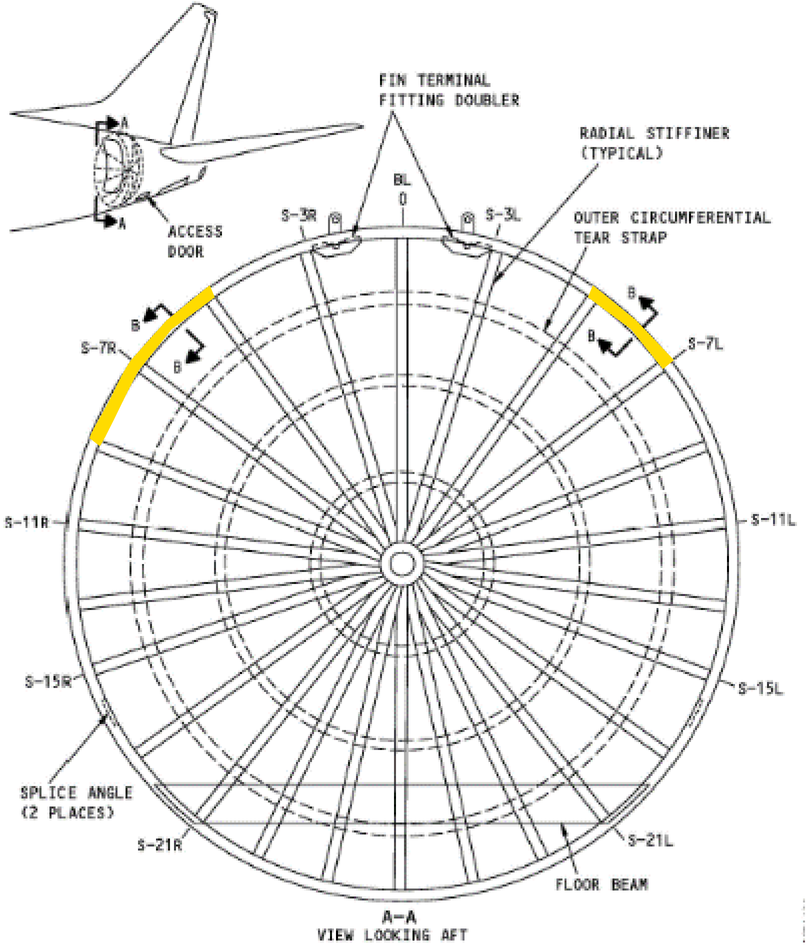
Selection of SHM Application

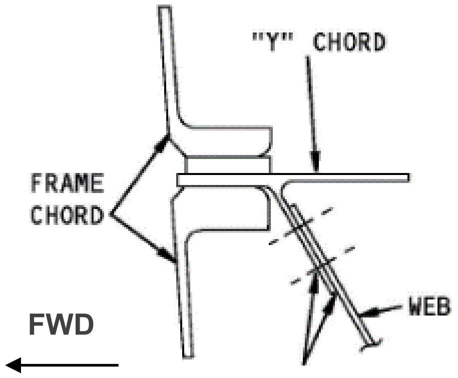
Ideal application: Locations with known cracking, difficult access, and inconvenient inspections intervals.

Service Bulletin 737-53A1248 (AD 2005-21-06 & 2016-18-15) requires inspection of web at "Y" chord at S-5L to S-7L and S-5R to S-9R which is outside of regular maintenance schedule.

Option 1:
LFEC and detailed inspection (aft side) every 1,200 flight cycles

Option 2:
HFEC and detailed inspection (fwd side) every 3,800 flight cycles





Reduce inspection time from 24 hours to 15 minutes. Inspection access through overhead panel.

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Implementation Approach

FAA generic Issue Paper for a Method of Compliance:
Qualification of SHM System for Detection of Damage in Structure

1. Performance and Capability

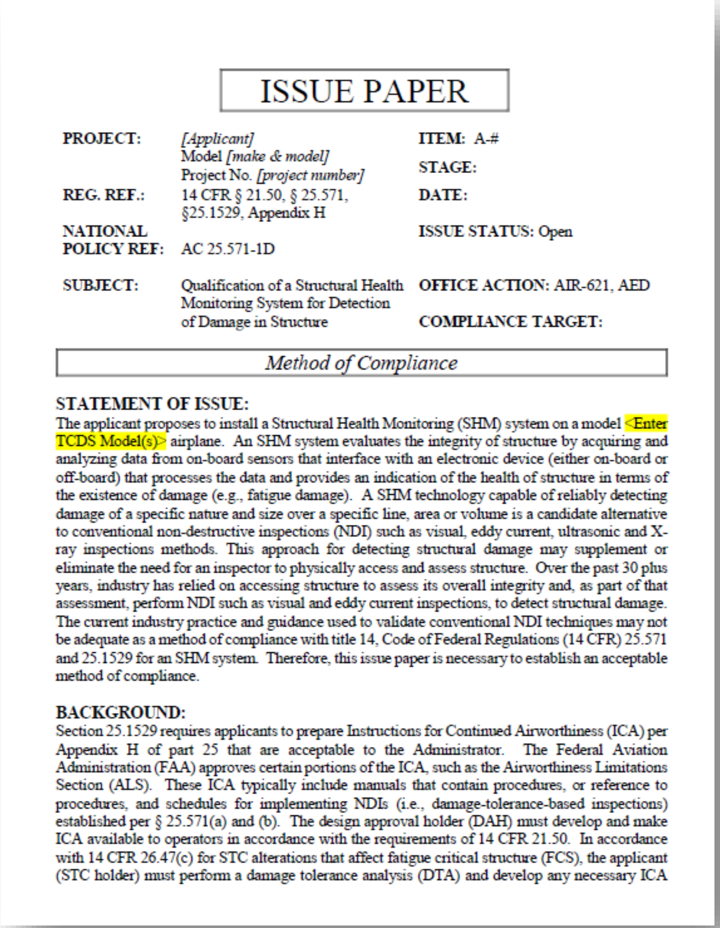
- Testing to establish probability of detection
- Validate SHM equivalent to existing LFEC inspection (1200 FC)

2. Reliability and Durability

- Leverage in-service exposure or test simulated exposure (if needed)
- Utilize existing SHM data and conduct 'gap' environmental tests
- Address system reliability (ie good signal-to-noise ratio)

3. Continued Airworthiness

- Address the impact of other inspections in the area
- Create new economic Service Bulletin for installation of SHM sensors
- Revise alert Service Bulletin 737-53A1248 to add SHM as alternative inspection



ISSUE PAPER

PROJECT:	*[Applicant]* Model *[make & model]* Project No. *[project number]*	**ITEM:** A-# **STAGE:**
REG. REF.:	14 CFR § 21.50, § 25.571, §25.1529, Appendix H	**DATE:**
NATIONAL POLICY REF:	AC 25.571-1D	**ISSUE STATUS:** Open
SUBJECT:	Qualification of a Structural Health Monitoring System for Detection of Damage in Structure	**OFFICE ACTION:** AIR-621, AED **COMPLIANCE TARGET:**

Method of Compliance

STATEMENT OF ISSUE:
The applicant proposes to install a Structural Health Monitoring (SHM) system on a model <Enter TCDS Model(s)> airplane. An SHM system evaluates the integrity of structure by acquiring and analyzing data from on-board sensors that interface with an electronic device (either on-board or off-board) that processes the data and provides an indication of the health of structure in terms of the existence of damage (e.g., fatigue damage). A SHM technology capable of reliably detecting damage of a specific nature and size over a specific line, area or volume is a candidate alternative to conventional non-destructive inspections (NDI) such as visual, eddy current, ultrasonic and X-ray inspections methods. This approach for detecting structural damage may supplement or eliminate the need for an inspector to physically access and assess structure. Over the past 30 plus years, industry has relied on accessing structure to assess its overall integrity and, as part of that assessment, perform NDI such as visual and eddy current inspections, to detect structural damage. The current industry practice and guidance used to validate conventional NDI techniques may not be adequate as a method of compliance with title 14, Code of Federal Regulations (14 CFR) 25.571 and 25.1529 for an SHM system. Therefore, this issue paper is necessary to establish an acceptable method of compliance.

BACKGROUND:
Section 25.1529 requires applicants to prepare Instructions for Continued Airworthiness (ICA) per Appendix H of part 25 that are acceptable to the Administrator. The Federal Aviation Administration (FAA) approves certain portions of the ICA, such as the Airworthiness Limitations Section (ALS). These ICA typically include manuals that contain procedures, or reference to procedures, and schedules for implementing NDIs (i.e., damage-tolerance-based inspections) established per § 25.571(a) and (b). The design approval holder (DAH) must develop and make ICA available to operators in accordance with the requirements of 14 CFR 21.50. In accordance with 14 CFR 26.47(c) for STC alterations that affect fatigue critical structure (FCS), the applicant (STC holder) must perform a damage tolerance analysis (DTA) and develop any necessary ICA

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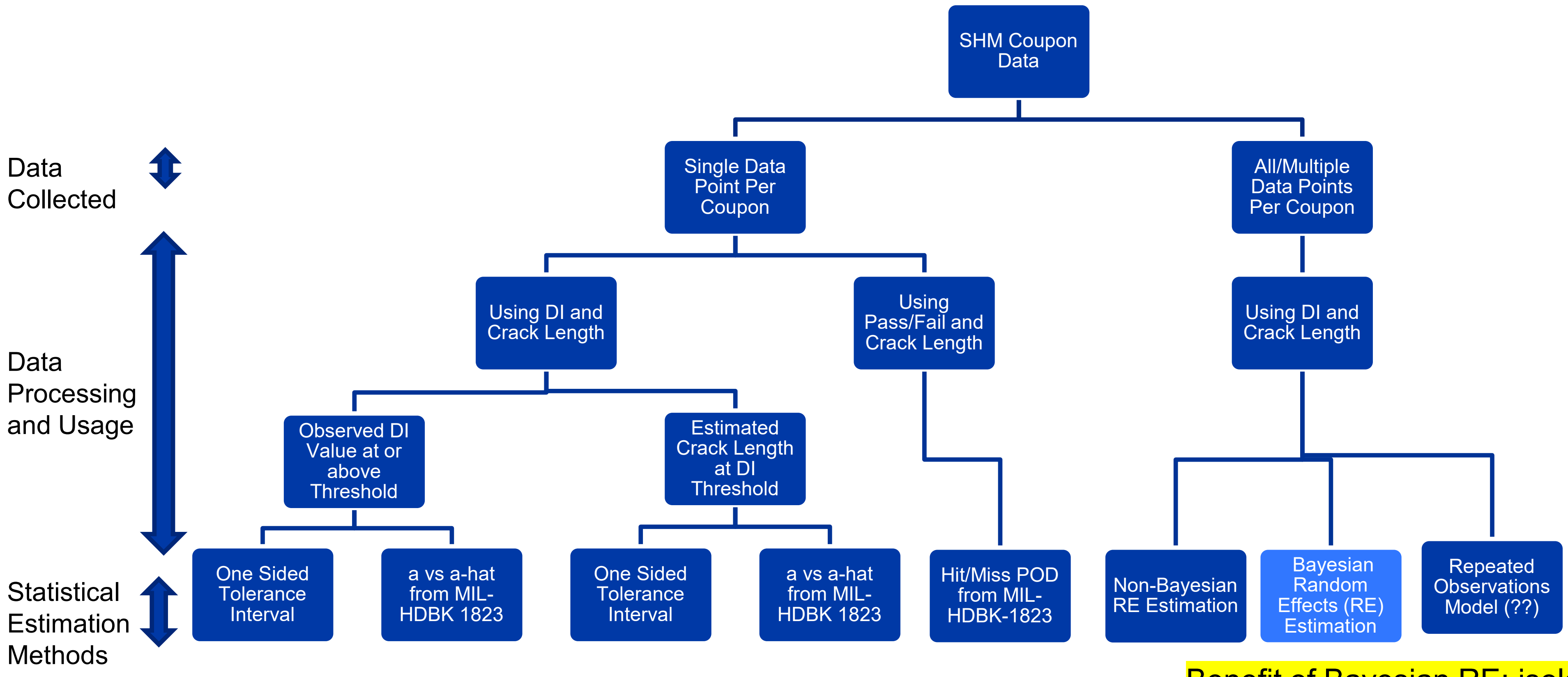
Probability of Detection

Data and Estimation Methods for SHM



Benefit of Bayesian RE: isolate and simulate multiple parameters (ie temperature)

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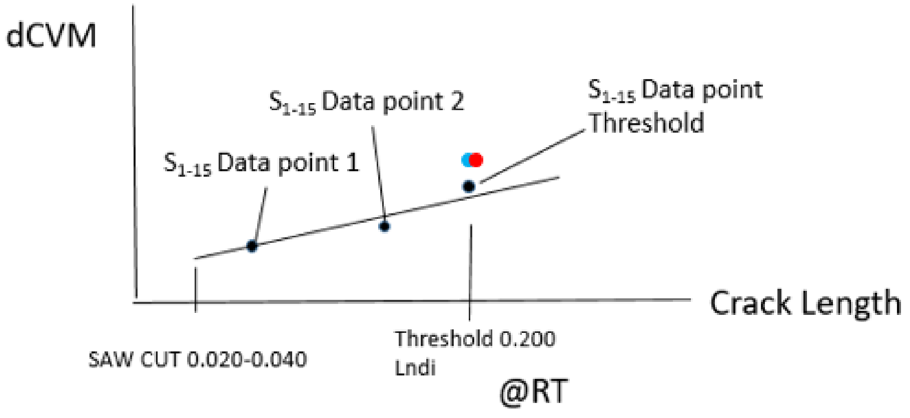
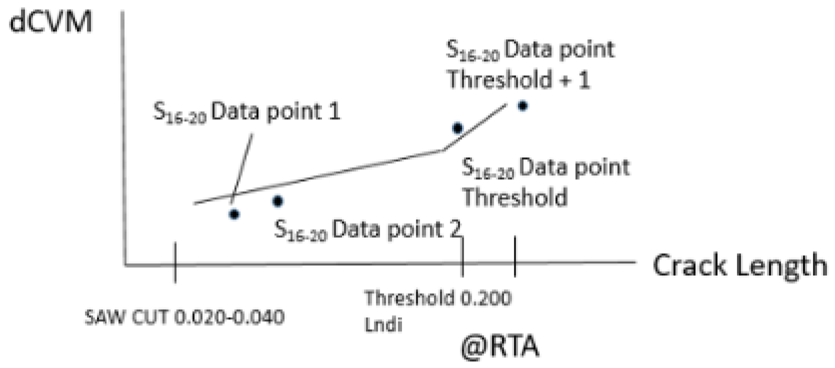
Challenges / Lessons Learned

- Test requirements – Selection of applicable structural design requirements versus standard test requirements.
- Test requirements – Discussion of compression thin membrane structure (design loads versus manufacturing preload).
- Test article design – Design of a test article that is representative to the point design (curved lap joint).
- Test article design – Design of a common test article design for both CVM & PZT. Ended up with different designs.
- Testing – Difficult to get consistent successful tests. Ran a multitude of alternate test article design options.
- Testing – Difficult to initiate cracks at desired location and avoid multi-cracks at a fastener.
- Testing – Difficult to get 2 data points prior to threshold (used for Probability of Detection).
- Service Bulletin – Existing inspection criteria included a concurrent visual inspection which had to be addressed.
- Service Bulletin – Installation and inspection. Decided to put SHM installation as a separate Service Bulletin.





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Thank You

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Questions?

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