Overview

- US Navy P-8A program has experienced 8 engine (CFM56-7B27) removals due to VSV system damage and binding
  - Failed VSV pull-check performed by field team drove removal of 2 engines (24 Nov 14)
  - Fractured VSV lever arm (15 Apr 15)
  - Bent VSV lever arm (26 Aug 16)
  - Multiple bent/disengaged lever arms (7 Nov 17)
  - Distorted actuation ring and partially disengaged lever arms (8 Mar 18)
  - 1 Broken and 10 disengaging lever arms (6 Apr 18)
  - Multiple bent/disengaged lever arms (30 Aug 18)

- Lever arm disengagement and failures due to stator vane seizure in HPC case
  - Potential for engine stall
  - Vane seizure can progress to HPC rotor failure (Non-Recoverable In-Flight Shutdown)

- Root Cause
  - HPC VSV borehole corrosion

- Unique P-8A low level marine operation results in increased salt and moisture exposure
  - Commercial world spends very little time at low altitude
  - Much higher utilization rate per aircraft
  - Not stationed along coast
Event Findings - External

- **Engineering Investigation**
  - EI conducted on 4 of the engines at CFM shop.
  - Multiple examples of damage and disengagement observed along the VSV system

- Disengaged lever arm
- Fractured lever arm and missing actuation ring bushing
- Bent/Distorted lever arm
- Fractured 2nd Stage VSV actuation ring

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Event Findings - Internal

- **Engineering Investigation**
  - Severe corrosion build up in VSV borehole of the HPC Case found on all four engines
    - Particularly stage 2

![External View of HPC Case](image1)

![Internal View of HPC Case](image2)
The Variable Stator Vane system positions the HPC stator vanes to the appropriate angle to optimize efficiency and improve stall margin.

The VSV actuators provide an output force and motion to the VSV system.

This force is transferred to the vane actuation rings via the bellcrank assembly.

The actuation ring halves rotate circumferentially about the horizontal axis of the compressor.

Movement of the rings is transmitted to the individual vanes, through vane actuating levers.
VSV System Operation – Cont.

LEVER ARMS

VANES

BELLCRANK ASSEMBLIES

ACTUATION RINGS

VARIABLE STATOR VANE ACTUATOR
Failure Mode

- Severe corrosion build up in VSV borehole leads to interference fit of VSVs and increased force required to actuate system.
  - As corrosion builds, vane stem clearance is reduced
  - Over time, required force to open vanes increases
  - Can lead to damage of VSV system lever arms and actuation ring
## Failure History Summary

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Failure History Summary - Metrics

TSN (EFH)

CSN

Calendar Time to VSV Failure
Failure Distribution

![Graph showing engine cycles vs. failures]
Mitigation History

- Original 500 FH recurring hot water engine wash interval reduced to 100 FH with revised dry out procedure in May 2015
  - Core engine wash to remove salt deposits and inhibit corrosion growth

- General visual inspection of VSV hardware added to maintenance requirement at wash interval
  - Inspect for broken, bent, or disengaged lever arms and actuation rings

- Age Exploration Bulletin released Aug 2015 to evaluate effectiveness of these updated maintenance procedures
  - Detailed inspections on six aircraft performed pre and post-wash to determine effectiveness of implemented changes
  - Wash and inspection interval relaxed to every A-check (every 90 days) for AEB aircraft in September 2016
  - 100 FH interval relaxed to align with A-checks fleet wide based off AEB results in July 2017
Current Maintenance Requirements

- At every A-Check:
  - Hot water engine wash
  - General visual inspection of VSV hardware

- Any missing actuation ring bushings can be repaired on-wing and do not drive an engine removal
  - 3 missing bushings: No action required
  - 4 missing bushings: Replace bushings within 200 cycles
  - 5 or more missing: Replace bushings immediately
  - Evaluating further actions if >10 bushings found missing

- Any broken, bent, or disengaged lever arm or actuation ring results in engine removal
  - 5 engines to date removed as a result of inspection findings
- **Implementation of SermeTel corrosion inhibiting coating**
  - Design solution to eliminate VSV seizure failure mode

- **Production cut-in and depot incorporation**
  - Currently applying SermeTel coating to HPC forward stator cases at depot shop visit regardless of reason for removal
    - All USN engines that have been through depot to date have received SermeTel coating
  - Production cut-in for all CFM56-7B27AE began Nov 2017
  - P-8A aircraft began delivery with SermeTel coated engines May 2018
SermeTel – Forced Retrofit

- Forced Retrofit during Aircraft Depot Visits
  - Early lot engines are being forced retrofit with SermeTel
    - Sub-population selected due to time in fleet prior to washing being incorporated.
    - The retrofit aligns with scheduled airframe depot schedule to avoid aircraft down time
SermeTel Concurrent with Aircraft Depot Inductions

A/C MRO to remove, ship engine(s) to Engine MRO, and reinstall

Engine MRO accept, retrofits and ships engine back to A/C MRO
- ~ 60 days turn-around times per RFP
  - Expect ~30 with rotatable case pool
Why SermeTel

- SermeTel corrosion inhibiting coating
  - Aluminum-ceramic coating that can resist the heat of operation while retaining its ability to provide sacrificial corrosion protection
  - Positive field experience on Naval based aircraft and marine engines
    - Used in similar application on F414 engines
  - Meets Mil-Specs
Questions?