An Overview of the Space Shuttle Orbiter's Aging Aircraft Program

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Abstract:

The Space Shuttle Orbiter has well exceeded its original design life of 10 years or 100 missions. The Orbiter Project Office (OPO) has sponsored several activities to address aging vehicle concerns, including a Corrosion Control Review Board (CCRB), a mid-life certification program, and most recently the formation of the Aging Orbiter Working Group (AOWG). The AOWG was chartered in 2004 as a proactive group which provides the OPO oversight for aging issues such as corrosion, non-destructive inspection, non-metallics, wiring and subsystems. The core team consists of mainly representatives from the Materials and Processes Problem Resolution Team (M&P PRT) and Safety and Mission Assurance (S&MA). Subsystem engineers and subject matter experts are called in as required. The AOWG has functioned by forming issues based sub-teams. Examples of completed sub-teams include adhesives, wiring and wing leading edge metallic materials. Current sub-teams include Composite Over-Wrapped Pressure Vessels (COPV), elastomeric materials and mechanisms.

Introduction:

The Space Shuttle Orbiter has well exceeded its original design life. The original Orbiter fleet was designed to be maintenance free for 10 years or 100 flights. Using the Orbiter well past its design life is complicated by the fact that the vehicles utilize a wide variety of materials used over a wide range of operating temperatures and pressures. Due to its unique design and operational requirements the Orbiter is subjected to some harsh environments. These environments include those introduced by the aggressive fluids systems used by Orbiter sub-systems, the sea-coast exposure seen during launch pad stays and ferry flight and the vacuum of space.

The structural design of the Orbiter is very similar to what is considered normal for airframe design. Examples include minimization of galvanic couples, sealing of faying surfaces, wet installation of fasteners and finish specifications. However, in some cases weight was often more important than corrosion resistance. Specific examples include less than adequate galvanic barriers and lack of corrosion protection in electrical bonding scenarios.

Logistical support has also become an increasing difficult challenge due to the fact that vendors are going out of business or no longer will to support the program due to the extra expense involved because of the unique hardware design.

Addressing the issue:

The Orbiter project office has (OPO) addressed the aging fleet on several occasions. From a Materials and Processes (M&P) perspective this includes the formation of a Corrosion Control Review Board (CCRB), an age life assessment of non-metallic materials used in critical systems and the recent formation of an Aging Orbiter Working Group (AOWG).

Corrosion Control Review Board (CCRB):

In 1993 OPO chartered the CCRB. The board was formed as an advisory panel with the goal of assuring that all Orbiter corrosion issues have been properly addressed and that solutions are recommended.

The CCRB draws its core membership from the M&P discipline and Safety and Mission Assurance (S&MA) Engineers from both NASA and the prime contractors. The CCRB also receives regular support from structures engineering and from specialist from various NASA organizations in fields such as chemistry, materials science and nondestructive evaluation.

The objectives of the CCRB include:

- Assessment of the extent and causes of corrosion
- Providing long term and short term corrective actions
- Generation and maintenance of a historical corrosion database
- Development and implementation of methods for detecting corrosion
- Development and implementation of corrosion training and certification programs

CCRB Products:

The CCRB has published three history reports. A database was created in the mid 1990's and then subsequently updated and improved in 2004. Reviews of inspection, reporting and training requirements have been completed. Numerous fleet wide and select unique corrosion issues have been reviewed and with corrective actions implemented. The CCRB has initiated several proactive measures to prevent corrosion such as galvanic barriers, corrosion preventative compounds (CPCs), design changes, washing of exposed surface and depainting/repainting. Additionally, the CCRB has been involved in the review and disposition of a number of subsystem corrosion issues.

Aging Vehicle Assessment (AVA) Corrosion Program:

Recently, an extensive corrosion program was completed. The program was part of the overall AVA program, discussed later in this paper, and was partnered and directed by CCRB members from The United Space Alliance and Boeing. The AVA program provided a complete review of the Orbiter's corrosion control program and provided the CCRB with an extensive list of products for the remainder of the program.

The major products of the AVA program included:

- Baseline
- Prioritization
- Prevention and Detection
- Reaction and Mitigation
- Trending – Reports/Documentation
- Process Definition

The Future of the CCRB:

In 2006, using the tools developed during the AVA program the CCRB has developed a project plan. This plan assumes a Space Shuttle Program end date of the end of fiscal year 2010. The project plan was divided into three categories; near term (approximately one year), mid-term (approximately three years) and continuous (end of program).

The near-term project goals include creating a CCRB website, finalizing recommendations for the implementation of non-chromated primer and performing life cycle testing of CPCs. The Mid-term goals were defined as completing the development of any NDE (e.g. for corrosion under the thermal protection system) and to finalize the recommendation for the development of Laser de-painting. Finally, the continuous goals were defined as documenting lessons learned, maintaining the database, revising the Fair Wear and Tear document, updating the CPC specification, networking and benchmarking.

Aging Vehicle Assessment:

The OPO sponsored a comprehensive Aging Vehicle Assessment (AVA) program. The AVA program was part of a certification assessment and verification for return-to-flight.

The objection of certification verification is to access the integrity of hardware certification relative to actual vehicle operational and processing environments. The goals were to ensure that actual ground processing and operational practices over time have not exceeded the engineering bases of certification or had introduced any unknown risks. The may be referred to as process creep. The certification verification will also assess the adequacy of hardware inspection requirements for critical hardware.

Typical questions considered during this assessment included:

- What are the differences between the Qualification/Certification configuration and the configuration we operate with today?
- Is the equipment still being used within Qualification/Cert parameters?
- Do original design documents accurately specify the conditions/environments in which the equipment is being used?
- Do performance and maintenance histories indicate an issue with the existing design or certification?
- Are existing hardware inspection requirements of critical hardware adequate to maintain hardware integrity through the certified life with consideration to current hardware processing and operations as well as aging vehicle concerns?

The AVA program was organized with a bottoms up approach, Figure 1. The initial assessments were performed by the subsystem Problem Resolution Teams (PRTs). The analysis of each PRT was then feed into a broader Super PRT. Figure 1 illustrates an example for how the Fluids Super PRT would be feed by several subsystem PRTs. All the results from the various Super PRTs were then reviewed by the Horizontal Integration Panel and finally by a Core Management Team.

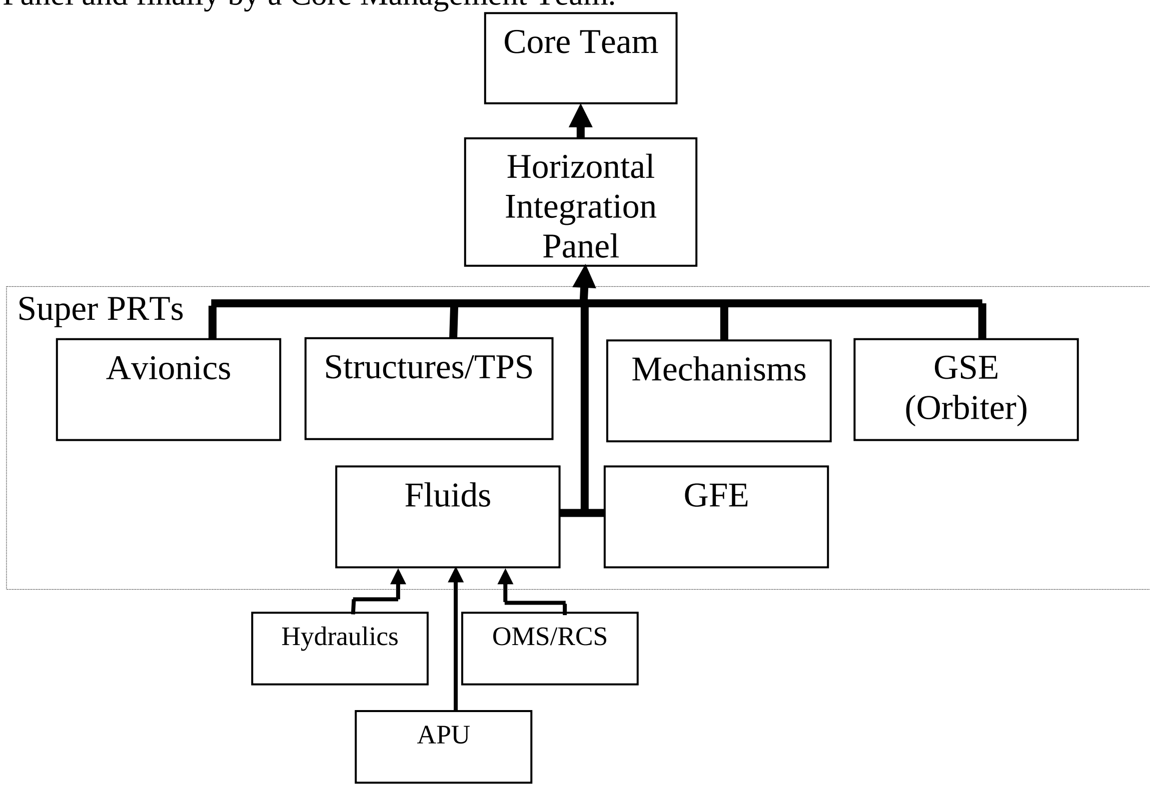

Figure 1 – AVA Organizational Structure

Age Life Assessment of Materials:

To assist the subsystem engineers in their assessments, Boeing M&P Engineering performed an age life assessment for the purpose of age life extension. The goal of this study was to extend material age life from 20 to 40 years. This study included 75 families of materials with approximately 1000 individual materials and covered approximately 500 critical parts.

Age life conclusions were based on independent available data on material performance and on program data on a material's environment and historical performance.

This program found approximately 20% of the materials to be good for 40 years. For approximately 70% for the materials analysis of the data found no reason to suspect the materials were degrading, but not enough data to extend the life out to the end of the program. For each material corrective actions were recommended. For the remaining 10% of materials analysis found the age life to be limited and corrective actions were recommended.

Aging Orbiter Working Group (AOWG):

In 2004 the OPO started the AOWG. The AOWG was designed to provide the OPO oversight for aging vehicle issues such as corrosion, nondestructive evaluation, non-metallics, wiring and subsystems. The AOWG is lead by the OPO's Aging Aircraft Principal Engineer. Team members include mainly members from the M&P PRT. Depending on the issue, ad-hoc members from the various Orbiter subsystems and from the NASA research centers are called upon.

Because the AOWG is an issues based group, the team functions through a variety of issue specific sub-teams. Examples of completed sub-teams included adhesives, wiring (Phase 1) and wing leading edge metallics materials. On-going teams include elastomer, grease and lubricants, mechanisms, composite overwrapped pressure vessels (COPVs) and phase 2 of wiring.

To remain proactive senior engineers from both NASA and the contractor workforce were surveyed and an areas of concern list was assembled. The AOWG is in the process of addressing each item on this list, assessing historical work, defining specific tasks to address the concern and assessing the associated risk. Possible outcomes from this assessment include:

- Item to be worked by the AOWG
- Item requires future investigation
- Item already being addressed by another team or organization
- Item not an aging issue or does not require additional action.

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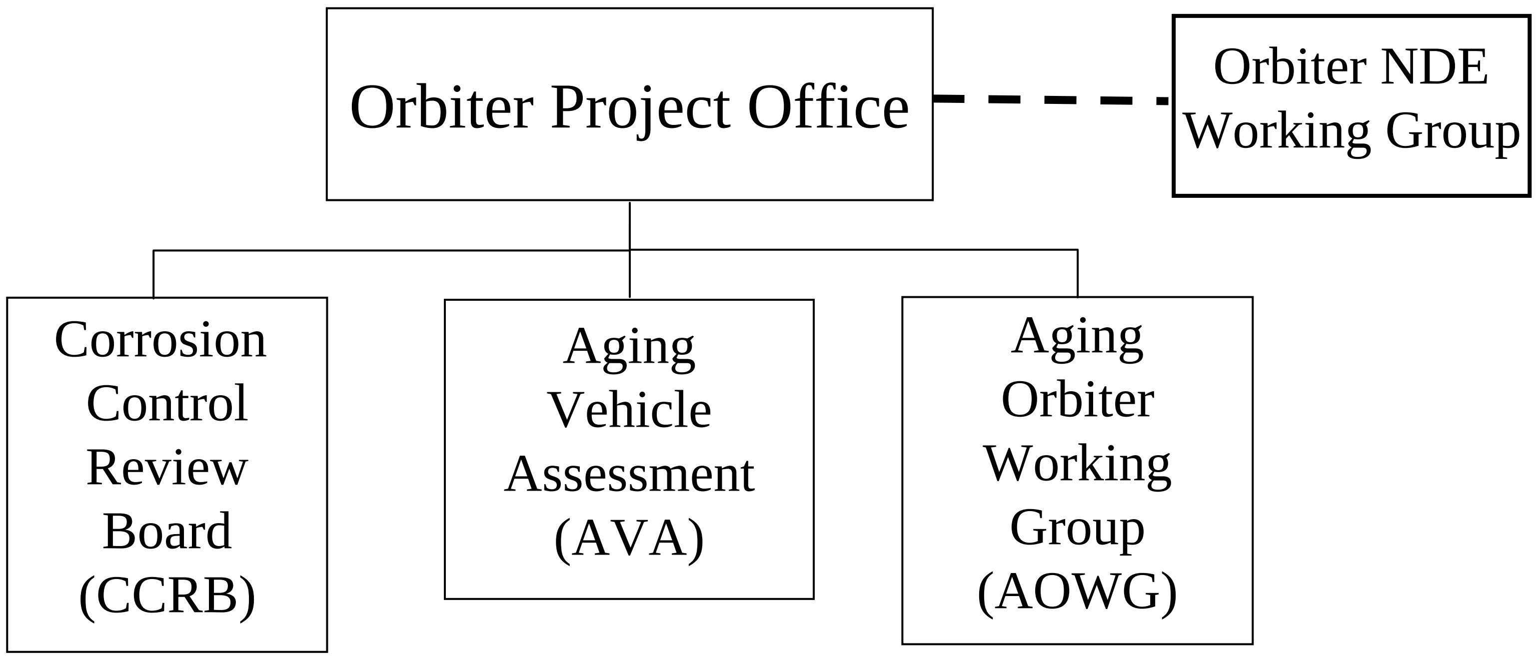
Aging Orbiter Fleet

- The Space Shuttle Orbiter has well exceeded it's original design life of 10 years or 100 missions.
- The Orbiter uses a wide variety of materials over a wide range of operating temperatures and pressures
- The Orbiter is subjected to harsh environments
  - Sea-coast exposure
  - Aggressive Fluid Systems
  - Vacuum
- The Orbiter's structural design is similar to normal airframe design
  - However, weight was often more important that corrosion resistance
- Many Orbiter systems were not designed for inspectability
  - Access
  - Intervals
- Logistics issues becoming more and more an issue
  - Vendors going out of business
  - Extra expenses due to unique hardware design

Orbiter Aging Aircraft Program



Corrosion Control Review Board (CCRB)

- Advisory Panel
- Membership
  - Materials & Processes (M&P)
  - Safety & Mission Assurance (S&MA)
  - Structures
- Objectives
  - Assessment of the extent & cause of corrosion
  - Providing short term and long term corrective actions
  - Generation and maintenance of a historical corrosion database
  - Development and implementation of methods for detecting corrosion
  - Development and implementation of corrosion training and certification programs

CCRB – History

- CCRB established in 1993
- Products include
  - History reports (3)
  - Database
  - Review of inspection and reporting requirements
  - Review of training requirements
  - Review and disposition of fleet wide and select unique corrosion issues
  - Proactive measures to prevent corrosion
    - Galvanic barriers
    - CPCs
    - Design changes
    - Washing exposed surfaces
    - Depainting/repainting
  - Review and disposition of a number of subsystem corrosion issues

CCRB – AVA Program

- Recently completed an extensive AVA Corrosion Program
  - Baseline
  - Prioritization
  - Prevention and Detection
  - Reaction and Mitigation
  - Trending – Reports/Documentation
  - Process Definition
- Provided a “tool box” for the remainder of the program

CCRB Project Plan

- Near- term (approximately 1 year) completion
  - CCRB Website
  - Non chromated primer
  - CPC Life Cycle testing
- Mid-term (approximately 3 year) completion
  - NDE
  - LASER de-paint
- Continuous (end of program)
  - Lessons learned
  - Database
  - Fair Wear and Tear
  - Documentation
  - CPC spec update, include MR database
  - Networking & Benchmarking

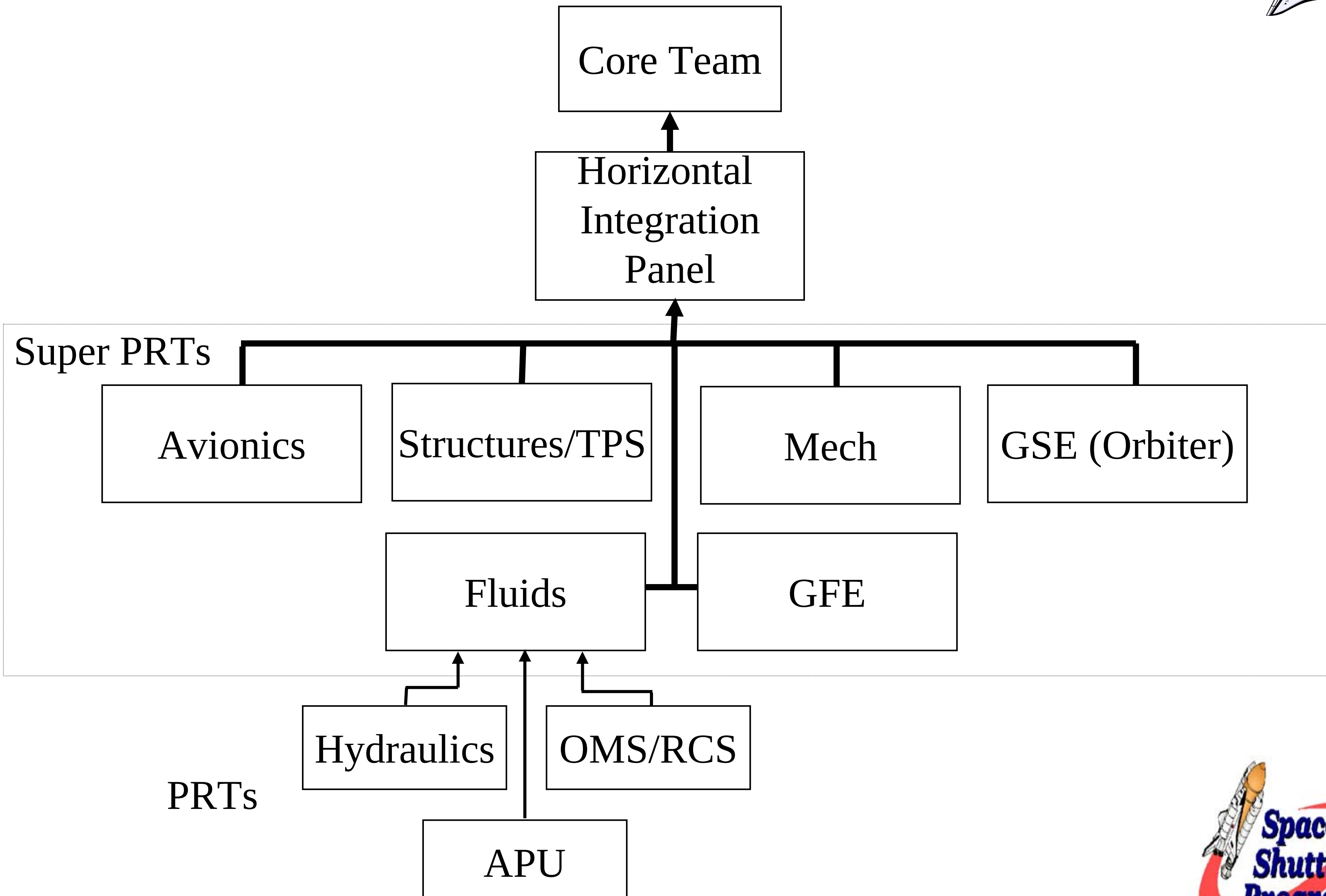
Aging Vehicle Assessment (AVA)

- Part of certification assessment and verification for Return-to-Flight (RTF)
- Objective of Certification Verification is to access the integrity of hardware certification relative vehicle operational & processing environments
  - Ensure ground processing and operational practices over time have not exceeded the engineering basis of certification or introduced unknown risks (a.k.a. process creep)
  - Assess the adequacy of criticality hardware inspection requirements

Aging Vehicle Assessment (AVA)

- Typical questions considered during AVA:
  - What are the differences between the Qual/Cert configuration and the configuration we operate with today?
  - Is the equipment still being used within Qual/Cert parameters?
  - Do original design documents accurately specify the conditions/environments in which the equipment is being used?
  - Do performance and maintenance histories indicate an issue with the existing design or certification?
  - Are existing hardware inspection requirements of critical hardware adequate to maintain hardware integrity through the certified life with consideration to current hardware processing and operations as well as aging vehicle concerns?

AVA Organizational Structure



Age Life Assessment of Materials

- Boeing M&P Engineering is performing Age Life Extension
- Goal of study is to extend material age life from 20 to 40 years
  - ~ 75 material families with 1000 individual materials
  - ~500 criticality 1/1 parts
- Age Life Conclusions based on:
  - Independent <u>available</u> data on material performance
  - Program data on material's environment & historical performance
- Conclusions to date
  - ~20% Green – Good for 40 years
  - ~70% Yellow – No degradation data located to date, but lack of data to extend out to end of program
    - Corrective actions recommended
  - ~10% Red – Age Life Limited
    - Corrective actions recommended

Aging Orbiter Working Group (AOWG)

- Aging Orbiter Working Group
  - New effort began in June 2004
  - Provides OPO oversight for aging issues such as corrosion, NDE, Non-metallics, Wiring and Subsystems
  - Sub-teams - Complete
    - Adhesives
    - Wiring (Phase 1)
    - Wing Leading Edge Metallic
  - Sub-teams – On-going
    - Elastomers, Grease & Lubricants
    - Mechanisms
    - COPVs
    - Wiring (Phase 2)

AOWG Future – Areas of Concern List

- To continue a proactive approach senior engineers from both NASA and contractor workforce were surveyed and an areas of concern list was assembled
- The AOWG is in the process of addressing each issue, assessing historical work, defining specific tasks to address the concern and assessing the risks
  – Each item being addressed with appropriate systems engineering team
- Possible outcomes:
  – Item to be worked by AOWG
  – Item requires future investigation
  – Item already being addressed by another team or organization
  – Item not an aging issue or does not require additional action

Questions?