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DEVELOPMENT OF THE EUROPEAN SERVICE MODULE PROPULSION SUBSYSTEM FOR THE MULTI-PURPOSE CREW VEHICLE

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Background

- **Orion/MPCV the future of human spaceflight beyond LEO**

- **Major Elements of Orion**
  - ESM (Airbus)
  - CMA (Lockheed)
  - CM (Lockheed)
  - SA (Lockheed)
  - LAS (Lockheed)

- **Major Milestones**
  - May 2011: Study Phase
  - November 2012: Decision for ESM
  - May 2014: System PDR
  - November 2014: PSS PDR
  - February 2016: PSS CDR
  - June 2016: System CDR
  - August 2017: Initiation of PQM Tests
Propulsion Subsystem (PSS) Description

- Pressure-fed, bi-propellant propulsion system
- Uses MMH and NTO (MON-3)
- Usable Propellant: 8,602 kg (18,964 lbm)
- 4 metallic propellant tanks, 2 per propellant type, plumbed serially
- 2 Composite Overwrap Pressure Vessel (COPV) helium bottles, 1 per commodity
- 3 classes of engines, all supplied from common propellant storage
  - 1 Main Engine with Thrust Vector Control (TVC)
  - 8 Auxiliary Engines, one string
  - 24 RCS Engines, 2 redundant strings, 6 pods
PSS Development Approach

• Hardware Heritage
  – Schedule limitations and budget constraints drove the need for extensive use of heritage hardware designs
  – In some cases flight hardware reuse (from Shuttle) was required, and will be delta-qualified for use on Orion (e.g., Orbital Maneuvering System (OMS) Engine, TVC)

• Primary sources of heritage:
  – ATV
  – Shuttle
  – Orion Crew Module (CM) Propulsion Subsystem (PSS)
  – Ariane 5 Hypergolic Upper Stage (EPS)

• Targeted Development Testing
  – Component development testing was performed to address the highest risk areas of heritage design compliance with Orion requirements
  – Assembly level development testing was performed to understand complex assemblies and component interactions
Orbital Maneuvering System Engine (OMS-E)

- **Heritage**
  - Direct re-use of assets from Shuttle Orbiters, all assets have varying flight history

- **Basic Specifications:**
  - Thrust: 6000 lbf
  - Isp (min): 310 sec
  - MR: 1.65
  - Nozzle area ratio: 55:1

- **Orion Use**
  - Used by Orion for major translational maneuvers

- **Design Changes (only as required)**
  - Redundant chamber pressure measurement and 2nd fuel injector temperature sensor
  - Heater kit (on TCA nozzle)
  - New harnesses
Thrust Vector Control (TVC)

• Heritage
  – Direct re-use of assets from Shuttle Orbiters, all assets have varying flight history

• Orion Use
  – Used by Orion to gimbal the main engine during major translational maneuvers

• Development Testing
  – Random vibration on controller box (lead to card retention design mod)

• Design Changes (only as required)
  – Circuit board retention in controller box (single instance from Shuttle flight history)
  – New, longer harnesses
Auxiliary (Aux) Engines

• Basic Specs
  – (8) fixed position engines
  – Thrust: 105 lbf
  – Nozzle area ratio: 164:1

• Orion Use
  – Nominally used for separation maneuvers and mid-course correction maneuvers
  – In contingency scenario (failed main engine), used for major translational maneuvers
    • Drives the need for long continuous duration firing
    • Drives the need for off-pulsing (to steer)
    • Control authority requires 50% duty cycle

• Development Testing
  – Random Vibration (added vibration isolation bracket)
  – Hot fire, duty cycle (changed MR)
Reaction Control System (RCS) Thrusters

- **Basic Specs**
  - (24) engines, two redundant strings of 12 engines each
  - Packaged in 6 pods of 4 engines each

- **Orion Use**
  - Used for attitude control, rendezvous, and proximity operations

- **Development Testing**
  - Hot fire, 5 Hz command frequency (PT thermal issue)
Qualification Testing – Propulsion Qualification Model (PQM)

- System level qualification test to be performed at WSTF in Test Stand 301
  - Sea level test stand for hypergolic system testing
  - Self-pumping diffuser added for OMS-E
- Flight like configuration with some exceptions:
  - Non-flight prop tanks (without PMD’s)
  - Single string of RCS thrusters
  - One string of valves per PCA
  - Partial representation of helium cross feed system
- Will complete PSS design qualification by test. Requirements verification that could not be accomplished at a lower level
- Will provide insight into complex system interactions and will also be used for anchoring of analytical models
Summary and Conclusions

• Major design milestones are complete (PDR, CDR). The ESM design meets Orion requirements and is ready for hardware manufacturing and assembly

• Heavy reliance on heritage hardware designs allowed for an expedited design/development schedule within the available budget

• Targeted component and assembly-level development testing were used to buy down the areas of highest risk
Backup
### Heritage Designs and Development Testing

<table>
<thead>
<tr>
<th>Component</th>
<th>Supplier</th>
<th>Heritage</th>
<th>Dev Testing</th>
<th>Test Focus</th>
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<tr>
<td>OMS-E</td>
<td>Aerojet</td>
<td>Shuttle</td>
<td>No</td>
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