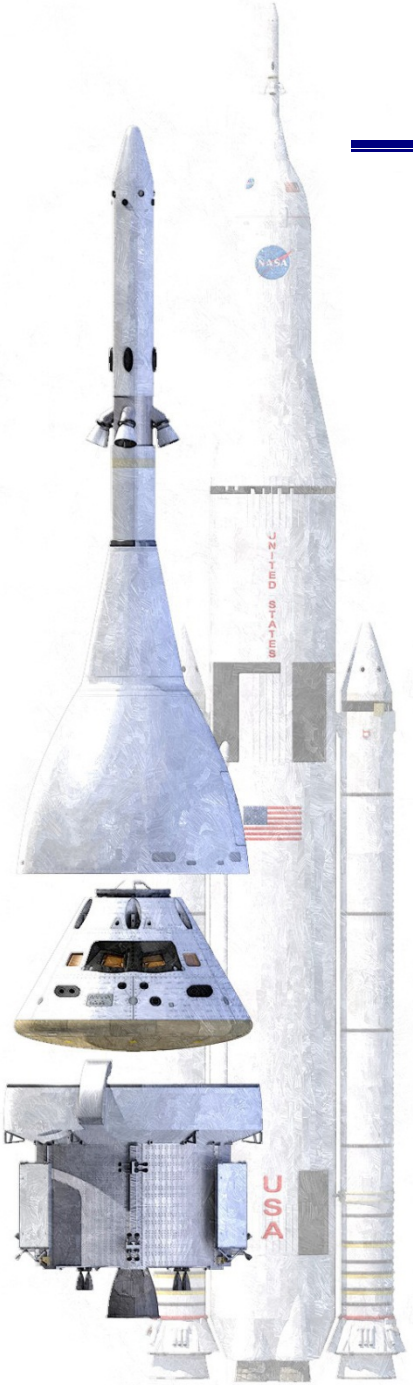


# NASA Orion Spacecraft

# Crew and Service Modules Development and Production Cost Estimate

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# Outline

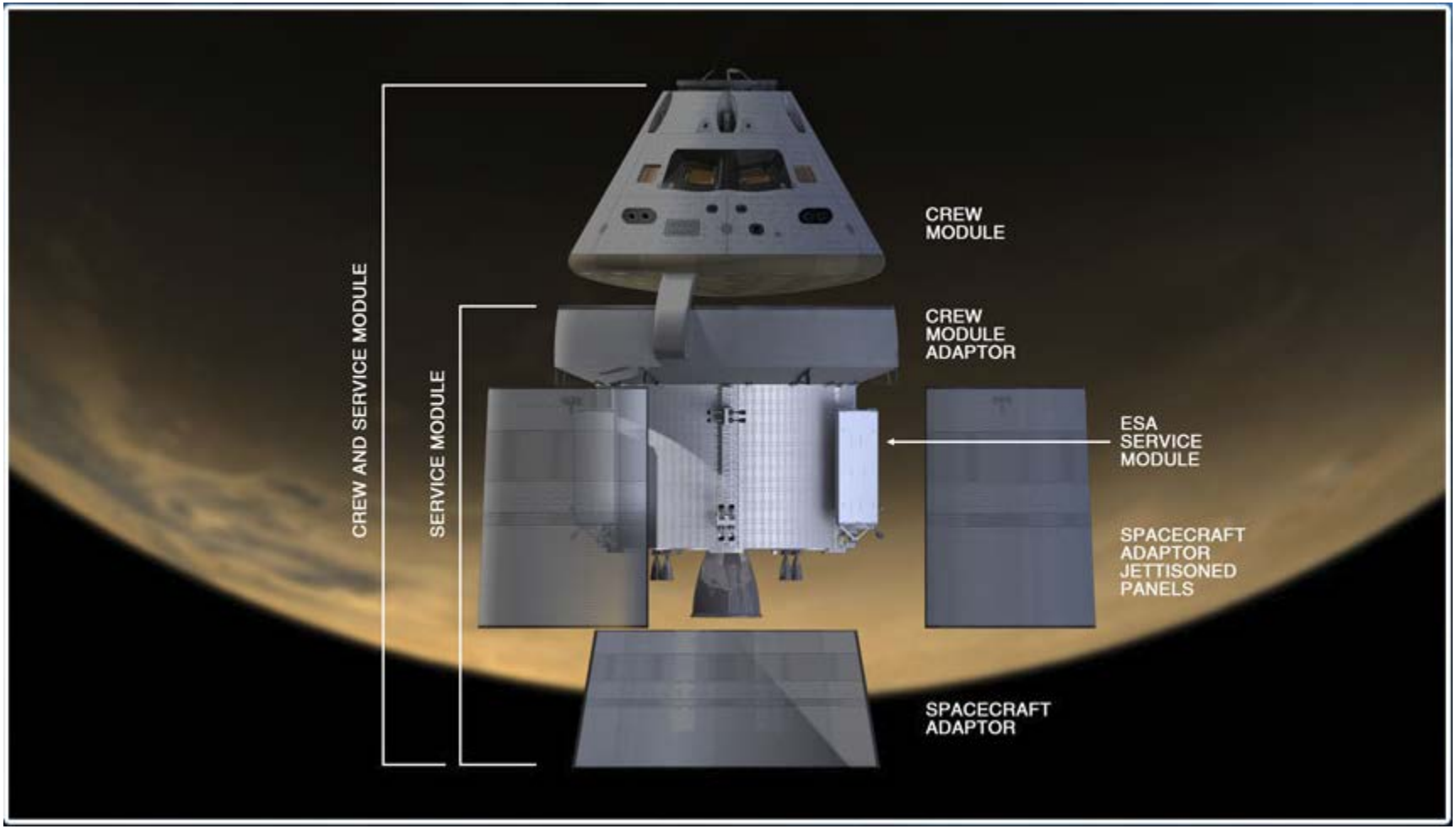
- Orion Spacecraft Overview
- Estimating Ground Rules / Assumptions
- Exploration Flight Test-1 vs Exploration Mission Complexity
- Estimating Methodology
  - Development Phase
  - Production Phase
- Estimate Cross-Check

# Orion Spacecraft

- Orion is America's next generation spacecraft that will take astronauts to exciting destinations never explored by humans

- Serves as the exploration vehicle
  - To carry crew to distant planetary bodies
  - Provide emergency abort capability
  - Sustain the crew during space travel
  - Provide safe re-entry from deep space

# Orion Crew and Service Module



# Estimating Ground Rules / Assumptions

## ❖ Development

- Structures
  - Design and verification of all Crew Module (CM) and Service Module (SM) primary and secondary structure
  - Does not include European Space Agency (ESA) provided structures
- Mechanisms
  - Design, verification and pre-delivery testing of all CM, SM and Launch Abort System (LAS) mechanical components
  - Does not include European Space Agency (ESA) provided mechanisms

## ❖ Production

- Structures
  - Work associated with fabrication of structural elements and delivery to Assembly, Test & Launch Operations (ATLO)
  - CM Pressure Vessel (PV) component procurements
  - Welding operations and PV testing
  - SM panel fabrication
  - Secondary structure
- Mechanisms
  - Fabrication and assembly work prior to delivery to ATLO

# EFT-1 vs. EM Complexity

- Exploration Mission (EM) vehicle's structural design scope comparable to Exploration Flight Test-1 (EFT-1) vehicle
  - Leveraging EFT-1 secondary structure work
  - Leveraging EFT-1 testing processes
  - EM primary structure needs to meet higher abort loads
  - Modifying cone assemblies to reduce welds
  - Optimizing mass
- EM vehicle's mechanisms design scope comparable to EFT-1 vehicle
  - Similar number of components
  - Expect some efficiencies/learning gained from EFT-1 experience
  - Expect efficiencies/learning in testing and lab utilization
  - Incorporation of abort loads results in comparable testing scope but need to meet higher thresholds
  - Incorporation of functional hatches adds scope

# Development Estimating Methodology (Part 1)

- Driven by EFT-1 development actuals
  - Used total development phase historical values
  - Considered effort performed by prime contractor and subcontractors
  - Management Level-of-Effort (LOE) included in dataset

- Calculated overall average Hours per Drawing factor for both Structures and Mechanisms
  - Collected final drawing count
  - Drawing revisions taken into consideration

# Development Estimating Methodology (Part 2)

- Assessed mix of development effort across 3 types of engineering work
  - Categories
    - A — Non-drawing design and development work; model and prep work performed prior to CAD work
    - B — True CAD drawing release effort
    - C — Test, Assembly and Verification
  - Weightings based on NASA Subject Matter Experts (SME) experience and observation during EFT-1 timeframe
  - Weightings extensively cross-checked against historical NASA programs and validated
  - Subjectively derived mix of categories different to reflect subtleties between Structures and Mechanisms

| | Structures | Mechanisms |
|---|---|---|
| A | 35% | 50% |
| B | 15% | 20% |
| C | 50% | 30% |

- Adjusted Hours per Drawing factor to reflect any learning or change in complexity relative to EFT-1

Retention and Release Mechanism Example: Reducing # of CM to SM Attachment Points

(0.80 x 50%) + (0.80 x 20%) + (1.20 x 30%) = 0.92 Hrs/Dwg Factor Adjustment

# Development Estimating Methodology (Part 3)

- Applied Hours per Drawing factor adjustment to forecasted number of drawings for each system

- Defense Contract Management Agency (DCMA) approved labor rates applied to projected development hours to obtain development labor cost

- Development material costs estimated using wrap factor derived from historical EFT-1 actuals

# Development Estimating Methodology (Part 4)

- Total development cost estimates phased using latest Integrated Master Schedule (IMS)
  - Phasing reflected SME anticipated mixture of development work for each vehicle build
    1. EM-1 (un-crewed mission)
    2. Structural Test Article (STA)
    3. Ascent Abort-2 (AA-2)
    4. EM-2 (crewed mission)
  - Phasing considers some parallel effort but primarily exhibited maturing development work over time

# Production Estimating Methodology

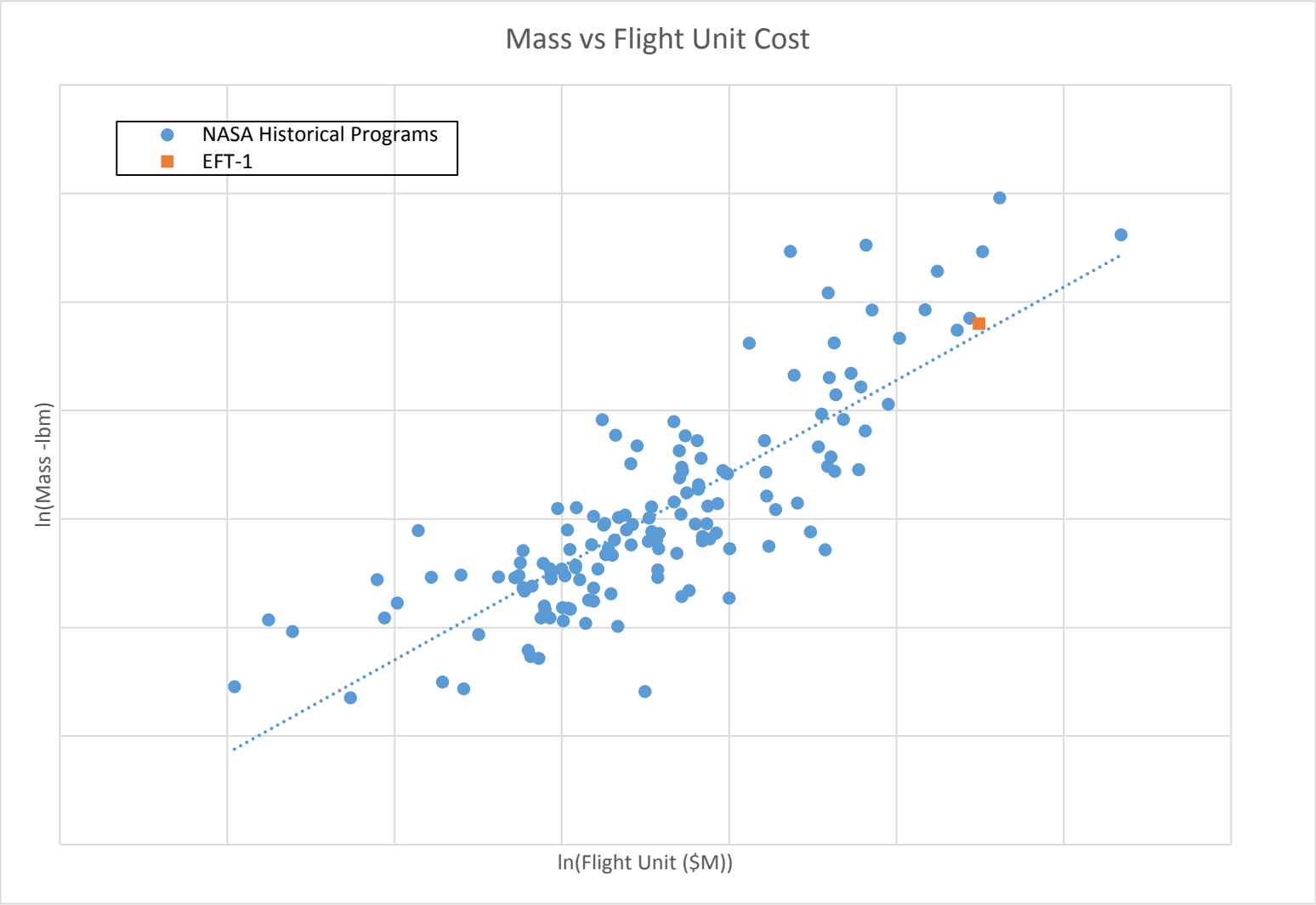
- Production estimate utilized parametric estimating techniques
  - Final EFT-1 Master Equipment List (MEL) used to determine mass allocations for each system
  - EFT-1 historical total production cost and mass data used to derive a separate cost per mass Cost Estimating Relationship (CER) for Structures and Mechanisms
  - Production material costs embedded in CER

- Applied SME-provided scaling factors to take credit for EFT-1 experience or projected manufacturing process improvements and change in complexity

- Latest EM forecasted system-level mass dataset applied to product of CER and scaling factors to obtain production costs

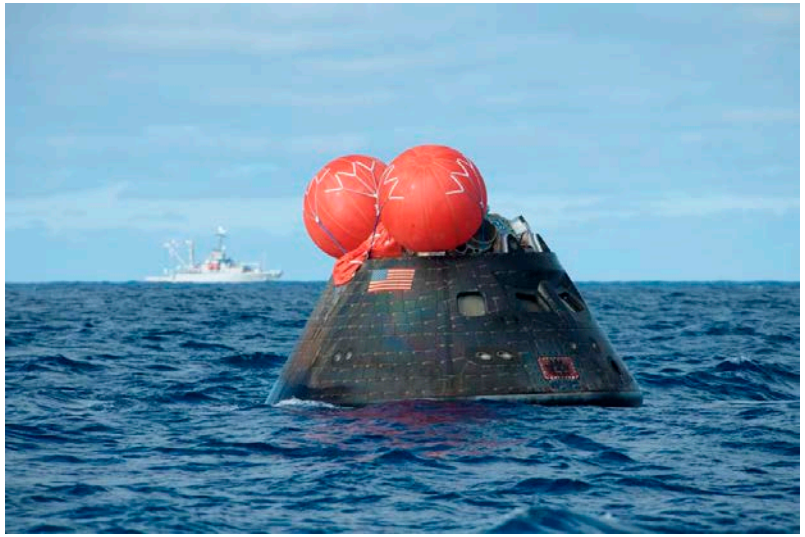
- Total production cost estimates phased using latest IMS

# EFT-1 vs. NASA History



# Estimate Cross-Check

- Independent NASA cost estimator provided cross-check
- Parametric model generated to validate estimates
  - Utilized SEER-H cost estimating software
  - Reflected same development and production scope
  - Used same MEL / mass dataset
  - Applied same labor rates
- Independent cross-check results within 15% of estimate

# Summary

- EFT-1 historical data suitable foundation for building EM cost estimate
- Hours per Drawing factor adjusted to reflect actual mix of Orion development work as well as changes in complexity to calculate development cost
- Validated production CERs adjusted to reflect learning and complexity from previous build to calculate production cost
- Cross-check parametric model results show reasonable delta