National Aeronautics and Space Administration

Evolving Reliability & Maintainability Allocations for NASA Ground Systems

GSDO GROUND SYSTEMS DEVELOPMENT & OPERATIONS

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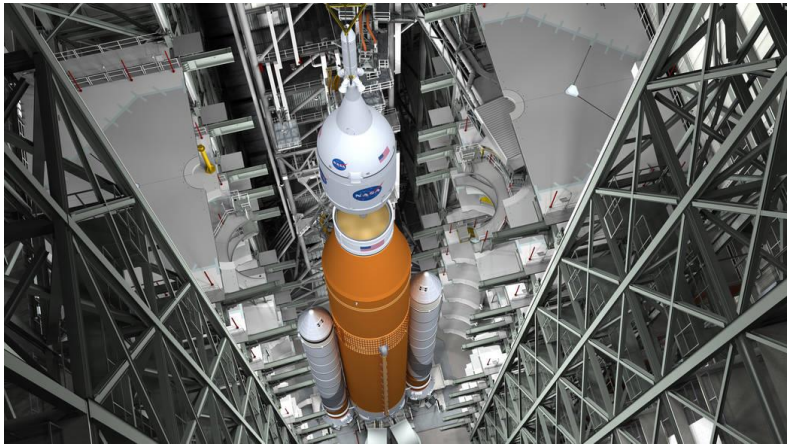
The Journey to Mars

- **Exploration Mission – 1**
- **Launch Complex 39B, Kennedy Space Center (KSC)**
  - Space Launch System (SLS)
  - Orion
  - Ground Systems Development & Operations (GSDO)

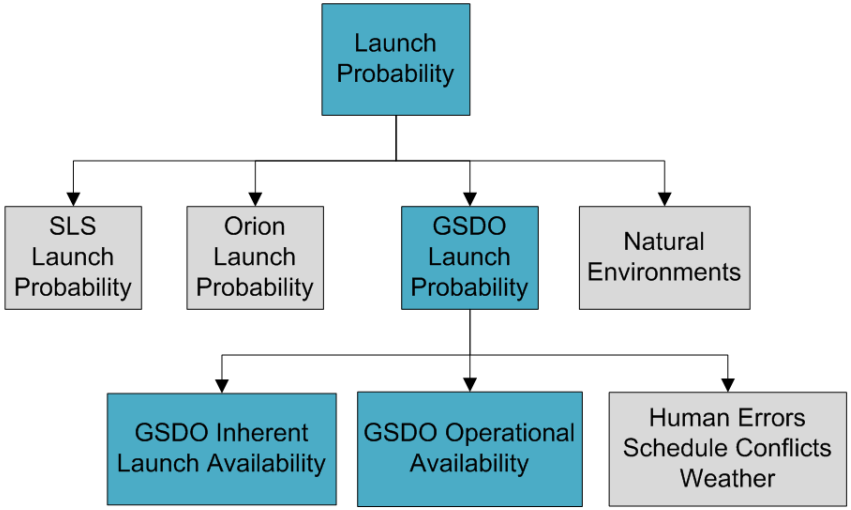


Ground System Development & Operations (GSDO)

- **Evolvable Launch Architecture**
  - Space Launch System (SLS)
- **Upgrades and modifications across KSC**
  - Launch Complex 39B
  - Mobile Launcher
  - Vehicle Assembly Building
  - Umbilicals
- **Critical Design Review – October 2015**

Launch Probability

- **GSDO requires safe and reliable ground systems**
- **Launch Probability is a key Technical Performance Measure**
  - Applicable to SLS, Orion, and GSDO
  - Seeking no less than 90% for each launch attempt
- **GSDO Launch Probability Requirements**
  - Inherent Launch Availability
    - 98% for each launch attempt
    - @ 24 hours
  - Operational Availability
    - 80% between launch attempts
    - @ 360 hours or 14 days

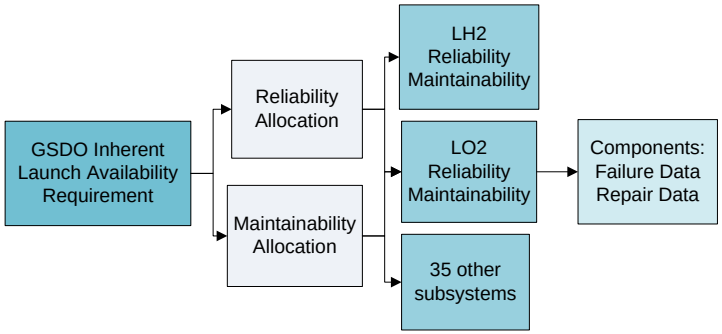


Reliability, Maintainability, Availability (RMA)

- **RMA team analyzes the integrity of hardware chosen for GSDO ground systems**
  - Failure and Repair Data
    - Historical data from previous programs
    - Manufacturer
    - Subject Matter Expertise
    - Ancillary Handbooks
- **RMA analysis verifies GSDO requirements**
- **Integral part of the design review process**
- **Critical reliability analysts interface directly with design and operations engineers**

GSDO RMA Allocations

- **Allocation is an iterative process**
- **Allocation Issues:**
  - Change in the number of subsystems under analysis
  - Increase in the number of components per subsystem
  - Original allocations derived from preliminary designs
    - Eighteen subsystems were not meeting requirements
- **Literature suggests reallocation**
  - Models that include both reliability and maintainability parameters absent from the literature
  - Maintainability allocation methods not applicable to GSDO



Methodology

- **Software**
  - PTC Windchill Quality Solutions
  - Reliability Prediction and Reliability Block Diagrams (RBD) modules
  - Assumes exponential distribution for failure and repair rates
  - MIL-HDBK-217F Parts Count Calculation Model
  - Monte-Carlo Simulations at 1,000,000 iterations

Methodology

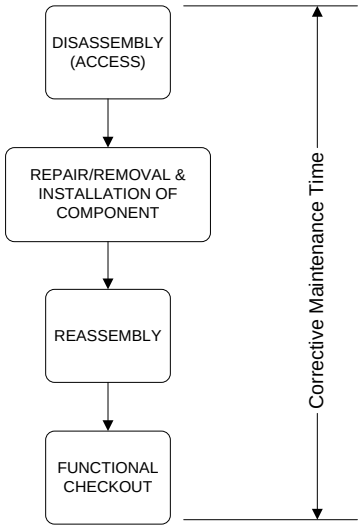
- **Reliability**
  - The probability that a system (or component) will fail at or after a predetermined time *t*
  - Failures rate sources
    - Manufacturer
    - Historical Data
    - Ancillary handbooks – Non-electronic Parts Reliability Database (NPRD) 2016, Electronic Parts Reliability Database (EPRD) 2014
  - Mean Time Between Failures (MTBF)

    - $R(t) = e^{-\lambda t}$, where $\lambda = \frac{1}{MTBF}$, $t = 24$ hours
    - λ is the subsystem or component failure rate

Methodology

- **Maintainability**
  - The ability of a subsystem to be restored or repaired to an operational state within a given time period
  - Values are estimated using subject matter experts (i.e., operations engineers)
  - Mean Time to Repair (MTTR)
    - Corrective Maintenance

- $M(t) = 1 - e^{-\mu t}$
- $\mu = \frac{1}{MTTR}$
- μ is the constant repair rate
- $MTTR_{SS} = \frac{\Sigma(\lambda_i * MTTR_i)}{\Sigma\lambda_i}$



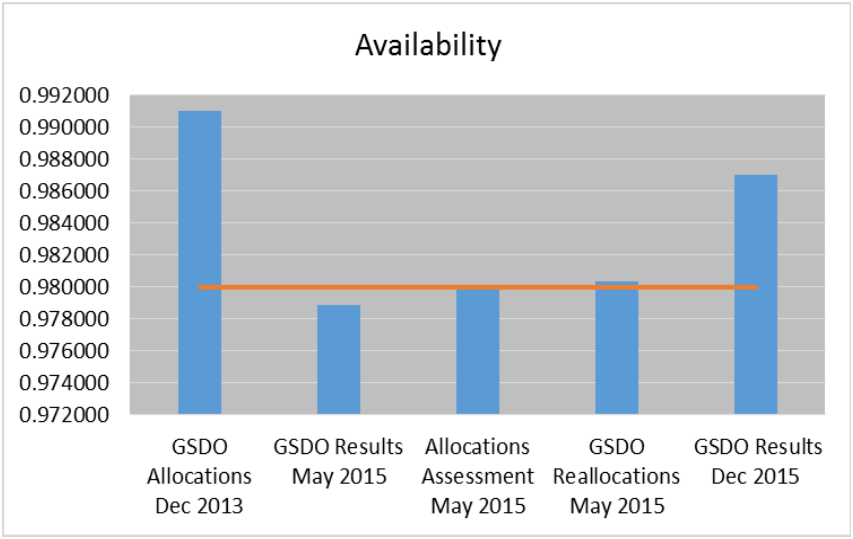
Methodology

- **Availability**
  - Function of reliability and maintainability
  - The probability that a repairable subsystem will operate satisfactorily at a given point in time during the period of analysis
  - Point Availability analysis
    - Excludes logistic and administrative delays

$$A(t) = \frac{\mu}{\lambda+\mu} + \frac{\lambda}{\lambda+\mu} e^{-(\lambda+\mu)t}$$

Reallocation Results

- Reallocations were based on changes to the launch architecture
- Initial Allocations did not reflect current designs
- Verify analysis is correct for current designs



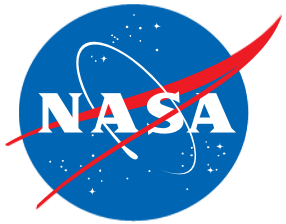
Recommendations

Consider reallocation for:

- Any increase in the number of components without a change in the design strategy (e.g., added redundancy, quality of hardware)
- Subsystems that contain a mix of upgraded and legacy components with historically high failure rates and considered single points of failure
- Significant changes to the launch architecture

Summary & Next Steps

- **GSDO is creating a robust ground systems architecture**
- **GSDO requirements incorporate safety and reliability for successful launch activities**
- **RMA Analysts interface directly with and provide recommendations to design teams to ensure verification of requirements**
  - Continuously perform RMA analyses through subsystem verification and validation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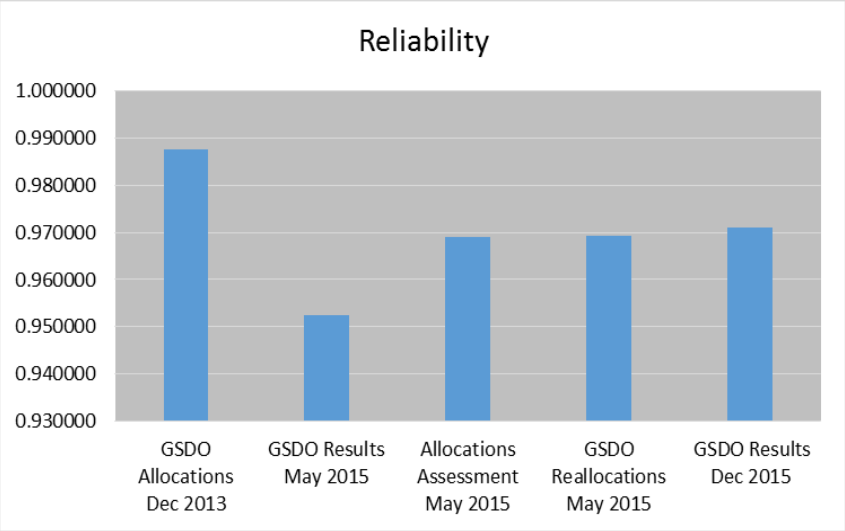
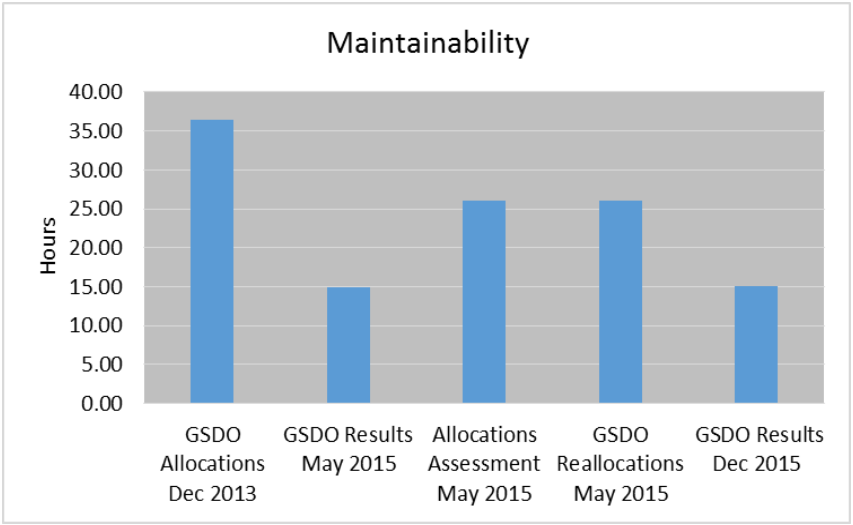
Reallocations - Reliability

- $R(t) = e^{-\lambda t}$
- $\lambda = \frac{1}{MTBF}$
- *t = 24 hours*
- $R_{GSDO} = \prod_{i=1}^{n} R_i(t) = R_1 * R_2 * \cdots R_n$
- *Reliability is a lower-bound measure*
- *Cause for reallocation*
  - *Change in the launch architecture*
    - *Number of subsystems & components*



Reallocations - Maintainability

- $M(t) = 1 - e^{-\mu t}$
- $\mu = \frac{1}{MTTR}$
- *t = 24 hours*
- $MTTR_{GSDO} = \frac{\Sigma(\lambda_{SS} * MTTR_{SS})}{\Sigma\lambda_{SS}}$
- *Maintainability is an upper-bound measure*
- *Cause for reallocation*
  - *Adjustment factor not applicable for all subsystems*



Reallocations - Availability

- $A(t) = \frac{\mu}{\lambda+\mu} + \frac{\lambda}{\lambda+\mu} e^{-(\lambda+\mu)t}$
- $\lambda = \frac{1}{MTBF}$
- $\mu = \frac{1}{MTTR}$
- *t = 24 hours*
- *Availability is a lower-bound measure*
- *Increase in Availability Estimates*
  - *Reallocations of reliability and maintainability*
  - *Change in the number of subsystems under analysis*