A Flexible Architecture to Repurpose a Deployed System

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Agenda

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• Johns Hopkins Partnership with Raytheon IDS for MSSE
• Purpose is to assist students in developing the systems engineering knowledge and skills necessary to successfully lead the planning, development and engineering aspects of large, complex systems.

• JHU Program Goals
  — Acquire the knowledge and problem-solving skills required to:
    • Guide the development of modern complex systems
    • Integrate systems and make tradeoffs between performance, cost, and schedule
    • Employ the principles of systems engineering
  — Apply knowledge and skills to solve practical systems engineering problems
    • Exercise skills in analysis, synthesis, and coordination of the various disciplines required to develop, engineer, and produce a complex system to meet a customer's need
    • Think through the entire complex process of system development, from analyzing requirements to deploying systems in the field
Project Background

• Systems Engineering of Deployed Systems course project posed the question: How can an aging deployed system be modified/upgraded for new modern purpose?
  – Scope for this course project was to develop a notional design and sustainment strategy for a hypothetical mission upgrade to the Joint Stand-Off Weapon (JSOW)
  – JSOW architecture was notionally repurposed as a humanitarian aid and disaster relief vehicle, called the Prompt Disaster Relief Vehicle (PDRV)

• Repurposing a deployed system requires a flexible sustainment architecture and focus on integrated logistics

• Principles applied in this academic project are applicable to real-world deployed system
  – Following slides detail the approach proposed by the project
Project Problem Statement & Solution

The following description details the problem statement used to frame the project and summarize the project team’s solution:

• Current vulnerability in the effectiveness and responsiveness of global disaster relief, leading to deaths/illness and economic issues that could have been avoided
  – Recent events like the 2010 Haiti and 2015 Nepal earthquakes highlight the deficiencies in the current humanitarian relief effort

• Separately, certain US Navy JSOW weapons are being removed from the DoD weapon suite based on the undesirable impacts unexploded ordnance (UxO) rate of the sub-munitions it carries.

Opportunity to (fictitiously) re-purpose the JSOW in support of humanitarian response to global disasters
Current Deficiencies

The primary deficiencies driving a needed upgrade are the following:

- The current system delays in providing relief can lead to additional loss of life and injuries.
- The current system is challenged in providing relief to specific location that are in need (remote areas).
- The current system relies mainly on active ports and airports for the majority of the deliveries.

Efficiency & Accuracy must be addressed during humanitarian missions
Key Requirements / Metrics

Technical Performance Measures
- The operational availability of the PDRV system shall be greater than 99%.
- System corrective maintenance shall be less than 25% of all maintenance activities, as a percentage of maintenance downtime.

Operational and System Requirements
- Following aid deployment, the PDRV shall locate a safe zone and terminate flight.

Sustainability and Maintenance Requirements
- The PDRV shall be sustained through a 3-Level maintenance concept consisting of Organizational (O), Intermediate (I), and Depot (D) level maintenance.
- The PDRV shall allow for long-term storage in a Navy sheltered (Ns) environment (per MIL-HDBK-217) of no less than 2 years without degradation of system functionalities or capabilities.

Reliability Centered Maintenance
- RCM will be practiced in accordance with DoD Manual 4151.22-M.

PHS&T Requirements
- The contractor shall coordinate stowage and/or removal of material from assigned storage locations, performing periodic audits and inventories as outlined in NAVSUP/Navy guidance to ensure accurate synchronization between documentation and material with a 100% accuracy.

~50 Top Level System Requirements

Drives RCM plan

Safe & accessible

Cornerstone of maintainability planning

No/minimal margins in supply chain
Assumptions

• The decision of where to provide relief will be determined by the Navy;
• Reuse of Navy equipment aboard vessels carrying the PDRV to the maximum extent possible;
• Scope of PDRV deployment/support extends to all nine Unified Combatant Commands;
• Deployment of PDRV is only via aircraft or PDRV launcher;
• PDRV Payload content is available when needed; and
• Required personnel are available and accessible when needed.

Operations of the PDRV will be handled by the Armed Forces

Assumptions made early to bound scope and design depth
Leverage existing JSOW CONOPS to ensure maximum compatibility for PDRV upgrade
System / Technical Description

- PDRV System designed to address current deficiencies by rapidly providing humanitarian aid and relief supplies to areas around the world affected by disasters that are inaccessible by regular means.
- PDRV System design consists of 8 internal subsystems and 2 external subsystems.
  - Leverage existing communication and command and control of the US Navy.
- Major upgrades to the legacy system include Payload, Propulsion, & Launcher.

PDRV Provides Rapid Relief Supplies to areas in need utilizing common JSOW design architecture.
# System Pedigree

<table>
<thead>
<tr>
<th>System Component</th>
<th>Source / Prime</th>
<th>Modified Legacy / New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airframe</td>
<td>Raytheon</td>
<td>JSOW-ER Mod</td>
</tr>
<tr>
<td>Propulsion System</td>
<td>Raytheon</td>
<td>JSOW-ER Mod</td>
</tr>
<tr>
<td>Electrical Power and Distribution</td>
<td>Raytheon</td>
<td>JSOW-ER Mod</td>
</tr>
<tr>
<td>GNC System</td>
<td>Raytheon</td>
<td>JSOW Block III and JSOW-ER Mod</td>
</tr>
<tr>
<td>Mission Computer</td>
<td>Raytheon</td>
<td>JSOW-ER Mod</td>
</tr>
<tr>
<td>Communications System</td>
<td>Raytheon</td>
<td>JSOW Block III Mod</td>
</tr>
<tr>
<td>Surveillance System</td>
<td>Raytheon</td>
<td>JSOW Block III Mod</td>
</tr>
<tr>
<td>Payload Delivery</td>
<td>Raytheon</td>
<td>JSOW Block III Mod</td>
</tr>
<tr>
<td>Payload Launcher</td>
<td>Raytheon</td>
<td>New</td>
</tr>
<tr>
<td>Payload Package</td>
<td>Vendor / Depot</td>
<td>New</td>
</tr>
</tbody>
</table>

8 modified subsystems; 2 proposed new subsystems
MTBFs and Reliability Block Diagram

- Developed a notional RBD and predictions for new and existing hardware
  - Need to consider failure rates, failure modes, single point failures, and other vulnerabilities introduced by new elements
- Enables abilities to plan for maintenance, predict spares, and understand nominal system operation/maintenance needs

<table>
<thead>
<tr>
<th>System Component</th>
<th>MTBF (Hours/ Failure)</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fin Assembly</td>
<td>500</td>
<td>0.9900</td>
</tr>
<tr>
<td>Fin Actuator Assembly</td>
<td>500</td>
<td>0.9900</td>
</tr>
<tr>
<td>Carriage System</td>
<td>500</td>
<td>0.9900</td>
</tr>
<tr>
<td>Guidance System</td>
<td>5000</td>
<td>0.9990</td>
</tr>
<tr>
<td>Navigation System</td>
<td>5000</td>
<td>0.9990</td>
</tr>
<tr>
<td>Control System</td>
<td>5000</td>
<td>0.9990</td>
</tr>
<tr>
<td>Battery 1</td>
<td>50</td>
<td>0.9048</td>
</tr>
<tr>
<td>Battery 2</td>
<td>50</td>
<td>0.9048</td>
</tr>
<tr>
<td>Power Distribution</td>
<td>5000</td>
<td>0.9990</td>
</tr>
<tr>
<td>Mission Computer</td>
<td>5000</td>
<td>0.9990</td>
</tr>
<tr>
<td>Surveillance System</td>
<td>5000</td>
<td>0.9990</td>
</tr>
<tr>
<td>GPS</td>
<td>500</td>
<td>0.9900</td>
</tr>
<tr>
<td>Data Link</td>
<td>500</td>
<td>0.9900</td>
</tr>
<tr>
<td>Attaching Connectors Assembly</td>
<td>500</td>
<td>0.9900</td>
</tr>
<tr>
<td>Control Module</td>
<td>500</td>
<td>0.9900</td>
</tr>
<tr>
<td>Mechanical Door Assembly</td>
<td>100</td>
<td>0.9512</td>
</tr>
<tr>
<td>Propulsion Control System</td>
<td>500</td>
<td>0.9900</td>
</tr>
<tr>
<td>Rocket</td>
<td>100</td>
<td>0.9512</td>
</tr>
</tbody>
</table>

*All values are notional and are not based off real data
Maintenance Concept

**Repair Depot (D-Level Repair)**
- Major repair activities:
  - Major Component Repair & Replacement
  - SW & Firmware updates
  - Complex troubleshooting
  - M&S
  - Repair & Refurbish of reusable parts

**MSC Replenishment Vessels (I – Level Repair)**
- Maintenance activities and Minor Repairs:
  - Component HW Repair & Replacement
  - Diagnostic Test & Analysis
  - **Corrective Maintenance**

**Fwd Deployed Vessels (O – Level Repair)**
- Maintenance activities:
  - Inspection, Diagnostics, Preventative Maintenance

**Testing Equipment and Training Support 3**

Levels of Maintenance
# Maintenance Personnel

<table>
<thead>
<tr>
<th>Location (D, I, O)</th>
<th>Personnel</th>
<th>Level</th>
<th># Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Technician</td>
<td>Master</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>Maintenance Engineer (Raytheon)</td>
<td>E03+</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>Software Engineer (Raytheon)</td>
<td>E03+</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>Lab Technician (Raytheon)</td>
<td>E03+</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>Logistician</td>
<td>E03+</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>Machinist, Civil Service Mariner</td>
<td>Senior</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>USCG Licensed Engineers</td>
<td>3rd Grade</td>
<td>3</td>
</tr>
<tr>
<td>I</td>
<td>Electrician, Civil Service Mariner</td>
<td>Senior</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>Logistician, Civil Service Mariner</td>
<td>Senior</td>
<td>1</td>
</tr>
</tbody>
</table>

No specialized or new personnel needed to maintain the PDRV.
Recommended Course of Actions (FMECA)

- Performed focused FMECA analysis on key areas of upgrade to determine and mitigate any new failure modes introduced into design

- Payload Delivery Subsystem Key to Mission Success
  - Failure to deploy payload = Mission Failure
- FMECA Complete - 2 Major Issues Identified

- Issue: Payload module opens payload doors uncommanded during launch
- Effect: Mechanical interference with launcher platform during launch operations, leading to severe mechanical damage to the PDRV system, unintended delivery of payload, and failure of the PDRV mission (RPN = 400)
- Potential Cause: CCA element failure (e.g., short circuit); Faulty PDRV communications controller interface
- Action Taken: Incorporated fail-safe mechanism into servomotors to prevent doors opening uncommanded in event of a CCA/system failure (New RPN = 40)

- Issue: Payload doors fail to open during mission
- Effect: Payload is not delivered at the intended time, resulting in failure of PDRV mission
- Potential Cause: Multiple (CCA failures; servomotors failure; interface failures; power failures; etc.)
- Action Taken: Addition of heartbeat sensor to PDRV communications to operators; Redefinition of PDRV CONOPS and mission success criteria

Corrective Actions Taken to Mitigate Payload
Logistics Support Planning

- Multifaceted approach through several key logistics analysis efforts performed throughout program development
  - Logistics Support Analysis (LSA)
    - Requirements; Logistics data elements
  - Level of Repair Analysis (LORA)
    - Lowest Replaceable Unit (LRU) identification; Maintenance/site/facilities planning considerations
  - Logistics Management Information (LMI) development
    - Database planning for logistics data elements
  - Spares Analysis
    - Identification of recommended LRU quantities at the various levels & locations of maintenance

Planning performed early in life cycle to integrate logistics considerations and requirements in system design and development.
LSA / LMI Data Elements

- **Part Identification:**
  - Part Number, Cage Code, Lot Code, Batch Code, National Stock Number, Reference Number Category Code, Reference Number Variation Code, Service Agency Designator Code

- **System Identification:**
  - Reference Designation, Indenture Level, Revision, System Quantity

- **Physical Characteristics:**
  - Weight, Weight (Packaged), Height, Height (Packaged), Width, Width (Packaged), Length, Length (Packaged)

- **Handling/Storage Characteristics:**

- **Maintenance Characteristics:**
  - LRU/RPP Identification, Source/Maintenance/Repair Code, Demilitarization Code, Shelf Life

- **Sparing Data:**

LMI data forms the backbone of all future logistics, operations, and maintenance activities
Level of Repair Analysis (LORA)

- **O-Level Considerations**
  - Limit maintenance loading
  - Limit spares allocation
    - Space constraints
  - Aligns with personnel skill level
    - Easy R&R (quick connect/disconnect)

- **I-Level Considerations**
  - Take advantage of engineering/mechanical personnel backgrounds
    - Allocated rework to print
  - Take advantage of MSC vessel non-mission based downtime
    - More opportunities to perform maintenance

- **D-Level Considerations**
  - Reserve most difficult / equipment intensive tasks
    - Tools/personnel available
  - Sole source of disposal

*LORA ensures cost and efficiency optimization of maintenance activities at all supported levels*
Supply Support / Sparing

- Performed using reliability predictions and LORA data and several assumptions (listed in report)
- D-Level omitted due to logistics lead time
  - Will procure material as-needed in advance of maintenance activity

*All values are notional and are not based off real data*
Obsolescence Management

• Enacted Obsolescence Management for PDRV program
• Early identification of propulsion control system CCA as obsolescence risk
  – Low cost mass produced CCA that provides control functionality for the PDRV propulsion element
  – Procured from COTS based supplier with rapid deployment of upgrades/updates
    • History of discontinued products and product line support
• Mitigation plan - Lifetime buy
  – Determined annual failures of component against total fielded assets and projected PDRV life span
  – Lifetime buy indicated 20,000 units sufficient to cover lifetime worth of failures
Reliability Centered Maintenance

- RCA analyses concurrent with FMECA generation
- Analysis drove proactive design changes (redundancy) and CONOPS changes (degraded modes)
- RCA drove PM schedules for 5 critical items related to payload
  - Initially once monthly, every other cycle

FMECA/ RCA drove design changes and maintenance CONOPS coincides with NAVY 56
Reliability Centered Maintenance

- The contractor shall implement a reliability centered maintenance plan to be evaluated annually.
- RCM shall be used to ensure effective maintenance processes are implemented.
- RCM shall be used as a logical decision process for determining optimum failure management strategies, including maintenance approaches, and establishing the evidence of need for both reactive and proactive maintenance tasks.
- RCM will be practiced in accordance with DoD Manual 4151.22-M.
- RCM will follow NAVAIR 00-25-403 guidance for NAVY process, metrics, software, training, and certification.

<table>
<thead>
<tr>
<th>Critical Item</th>
<th>Proposed PM Tasking</th>
<th>Initial Interval</th>
<th>Can be performed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latch</td>
<td>Visually inspect fasteners for signs of corrosion or change</td>
<td>1 monthly</td>
<td>Civil Service mariner (machine)</td>
</tr>
<tr>
<td>Connector</td>
<td>Visually inspect connector for signs of corrosion or change</td>
<td>1 monthly</td>
<td>Civil Service mariner (electrical)</td>
</tr>
<tr>
<td>Door</td>
<td>Application of lubricant; Functional test door open and door close on command</td>
<td>1 monthly</td>
<td>Civil Service mariner (machine)</td>
</tr>
<tr>
<td>Door motor</td>
<td>Functional test door open and door close on command Visual inspection servos/motor</td>
<td>1 monthly</td>
<td>Civil Service mariner (electrical)</td>
</tr>
<tr>
<td>Door arms</td>
<td>Functional test door open and door close on command</td>
<td>1 monthly</td>
<td>Civil Service mariner (machine)</td>
</tr>
</tbody>
</table>
PHS&T Methodology

- Utilize existing US Navy and JSOW PHS&T methods when possible
- Configuration 1 includes airframe w/ payload subsystem, pre-packaged
  - Payload Type 1 is long-shelf life items (water purification, electronic goods, non-perishable items)
  - Up to 2 years uninterrupted storage with vehicle
- Configuration 2 airframe & empty payload bay for modular Payload Type 2 for incorporation on aircraft carrier
  - Payload Type 2 - short-shelf life (refrigerated items, medical, etc)
  - Storage and high environmental requirements stored in cold environment

<table>
<thead>
<tr>
<th>Direction of Supplies</th>
<th>Supply list</th>
<th>PHS&amp;T considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier to Depot/OEM</td>
<td>PDRV Vehicle, Launcher Platform, Payload Supply Type 1, Payload Supply Type 2</td>
<td>Commercial shipping, Navy Depot Storage, standard form factor packaging</td>
</tr>
<tr>
<td>Shipyard Warehouse storage to MSC Vessels</td>
<td>PDRV Vehicle, Launcher Platform, Payload Supply 1</td>
<td>Modular supply containers, utilize shipping crates, crane equipment, forklift</td>
</tr>
<tr>
<td>Medical Navy Vessel to Aircraft Carrier</td>
<td>Payload Supply Type 2</td>
<td>Modular supply containers, underway replenishment</td>
</tr>
<tr>
<td>MSC Vessel to Aircraft Carrier</td>
<td>PDRV Vehicles (Unloaded and loaded types), Payload Supply Type 1, Launcher Platform</td>
<td>Underway replenishment, Vertical replenishment</td>
</tr>
</tbody>
</table>
PDRV Supply Chain

- Efficient supply chain enabled by a two-configured approach.

Inset: US NAVY

Established JSOW Supply Chain

Config 1 (durable) supply chain

Config 2 (perishable) supply chain
### Manufacturing / Production Considerations

<table>
<thead>
<tr>
<th>Potential Manufacturing / Production Issues and Considerations</th>
<th>Action/Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-use of drawings for design and integration</td>
<td>Provide a JSOW test asset for the design, integration and manufacturing teams.</td>
</tr>
<tr>
<td>Standing up a new manufacturing team/line</td>
<td>JSOW-ER production line about to stand up and there is potentially an opportunity to share resources.</td>
</tr>
<tr>
<td>New subcontractors may be used for new subsystems</td>
<td>Continued rigorous screening of any COTS items to ensure only materials on the ‘allowed’ list are used.</td>
</tr>
<tr>
<td>Payload securing for potentially dangerous medical supplies</td>
<td>Extra emphasis will need to be placed on sealing the Payload Delivery system.</td>
</tr>
</tbody>
</table>

Taking advantage of current JSOW manufacturing techniques and resources will help alleviate most of the risk associated with the PDRV.
Training

- Training consists of instructor led and web-training as needed at each repair level and for Operators.
  - Occurs during active duty training, or weekend reserve training activities
- Proposed training specifies additional training for the PDRV upgrades, the Launcher device, and the Payload delivery system in addition to existing Navy required training.

<table>
<thead>
<tr>
<th>Training Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-Level Maintenance Training</td>
<td>PDRV payload delivery disassembly, diagnostic testing, HW repair, SW updates, re-use of recoverable parts, disposal</td>
</tr>
<tr>
<td>I-Level Maintenance Training</td>
<td>PDRV payload delivery disassembly, diagnostic testing and HW repair</td>
</tr>
<tr>
<td>O-Level Maintenance Training</td>
<td>Inspection of PDRV payload delivery system (airworthiness), replacement of LRUs, automatic diagnostic testing</td>
</tr>
</tbody>
</table>
Life Cycle Cost Analysis (LCCA)

• Desire to stress importance of ensuring safe PDRV deployment and cost savings for life cycle of program
  – Developed launcher platform in order to address these concerns
• Research figures indicated F/A-18 aircraft incurred and average $17.2k cost for a single deployment during Operation: Desert Storm
• Cost simulation was ran using an exponential distribution of projected number of manned sorties over an estimated program lifespan of 20 years
• Compared design, production, O&M, and return, et launcher simulation

Life Cycle Cost Analysis (LCCA)

Trade off upfront costs in order to realize safety risk mitigation and cost savings over life of the program

*All values are notional and are not based off real data
Conclusion

• Integrated logistics supports fictional solution that addresses the humanitarian aid and disaster relief mission
  – Focus on leveraging existing US Navy Logistics plan, JSOW architecture and support, equipment, personnel and maintenance processes
  – Realized several opportunities to decrease overall life cycles costs and improve supportability compared to other available options

• Principles applied in this academic project are applicable to real-world deployed systems
  – Reflects best practices to be taken when hardware is upgraded

Flexible sustainment architecture and focus on integrated logistics can be applied to real world deployed systems
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