GENERAL DYNAMICS
Armament Systems

Material Movement and Management (M³) Technologies

High Volume Automated Naval Magazines
Objective

To introduce the burdens, compromises and performance interrelationships that govern the design of high volume automated naval magazines
Agenda

- Naval Trends
- Technical Solutions
- Technical Interactions and Relationships
- Conclusions
Emerging Requirements

Requirements
- Volume of Fire
- Lethality
- Cost Effectiveness
- Reduced Manning

Technical Impact
- Large Magazines
- High Rates of Fire
- Multi-Mission Capable
- Electronic Fuzing
- High Accuracy
- Long Range
- Low Mission Cost
- Low Operational Cost
- Integrated System
- Easy repair
- Redundancy
- High Reliability
- Automation

Solutions
Automated Magazine Systems

Balanced within the context of Navy Environment

Shock
EMI
Salt Fog
Ship Motion
Insensitive Munitions

GENERAL DYNAMICS
Armament Systems
Requirement Compromises

- Large systems have unique issues
  - Multiple round types
    - Typically between 2 to 20 different ammunition / propellant variants
    - Common interface is rare
  - Installation complexity
    - Complexity increases proportional to magazine size
    - Munitions hand-offs increase in number

Requirements are also not complementary
Developed Systems

Throughput (Kg / minute)

Rate of Fire (shots / minute)

5000
1000
100
10

500 1000 1500 2000 2500

Gross Mission Effective Weight (Kg / minute)

Indicates System Capacity (tons log scale)

GENERAL DYNAMICS
Armament Systems
Magazine Solutions – Passive Systems

Advantages
- Low power
- Reliable storage
- Low cost
- Easily repairable
- Manually operational
- Accessible

Disadvantages
- Low feed rates
- Storage density versus selectability
- Packaging efficiency
- Mechanism Coordination

Definition:
One munitions set (projectile and propellant) is moved at a time

Note: AGS Phase I, Core developed, Non-competition sensitive AGS design efforts displayed
Magazine Solutions - Active

Definition:
All munitions move simultaneously

Advantages
- Reliable Storage
  - Yet less redundant
- High feed rates
- Simple orchestration
- Flexible configuration
- Selectability

Disadvantages
- Packaging Density
- High Power Demand
- Difficult to maintain
- Cost efficiency

Note: AGS Phase I, Core developed, Non-competition sensitive AGS design efforts displayed
## Magazine Solutions - Hybrids

### Solutions

<table>
<thead>
<tr>
<th>Selectability</th>
<th>Reliability</th>
<th>Power / Rate of Fire</th>
<th>Storage Density</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Selectability Icon" /></td>
<td><img src="image2" alt="Reliability Icon" /></td>
<td><img src="image3" alt="Power Icon" /></td>
<td><img src="image4" alt="Storage Density Icon" /></td>
</tr>
</tbody>
</table>

### A Single Munitions set Moves

- ![Selectability Icon](image1) (Up)
- ![Reliability Icon](image2) (Down)
- ![Power Icon](image3) (Up)
- ![Storage Density Icon](image4) (Up)

### A few Munitions sets Move

- ![Selectability Icon](image1) (Down)
- ![Reliability Icon](image2) (Up)
- ![Power Icon](image3) (Up)
- ![Storage Density Icon](image4) (Down)

### ~half of Munitions sets Move

- ![Selectability Icon](image1) (Up)
- ![Reliability Icon](image2) (Up)
- ![Power Icon](image3) (Down)
- ![Storage Density Icon](image4) (Up)

### More than half Munitions sets Move

- ![Selectability Icon](image1) (Up)
- ![Reliability Icon](image2) (Up)
- ![Power Icon](image3) (Down)
- ![Storage Density Icon](image4) (Down)

### All Munitions sets Moves

- ![Selectability Icon](image1) (Down)
- ![Reliability Icon](image2) (Down)
- ![Power Icon](image3) (Down)
- ![Storage Density Icon](image4) (Up)
Selectability: Size and Packaging

The greater the capacity: The slower a possible round selection

The greater the number of independent storage cells: The faster the round selection
Analysis – Cost vs. Capacity

- Cost efficiency is dependent on magazine technology
  - Passive systems:
    - Small change in cost vs capacity
    - Base price is large
  - Active Systems:
    - Moderate change in cost vs capacity
    - Base price is low
  - Hybrid Systems are a compromise between these two

The cost efficiency of a technology will depend on the capacity required
Analysis – Reliability at capacity

Active and passive hybrids may achieve the same reliability when storage and transfer rates are balanced.

Redundant paths augment a system’s reliability.

Active Hybrid

Passive Hybrid

Unbalanced Passive Hybrid

Horizontal Active Hybrid

Unbalanced Active Hybrid

Active Hybrid

Non-redundant path system

Redundant Path System

Redundant path enabled through use of dual end feed of center row
Storage Efficiency and Magazine Volume

- A linear relationship exists between magazine weight and volume
- Active magazine technologies possess the highest storage efficiency
Conclusion

Magazine designs need to fit the requirements of a system

- Appropriate Technology
- Optimum Packaging
- Acceptable Reliability
- Desired Selectability
- The Right Cost

The Best Solution for the Job