Guided UAV Undersea Launch Platform (GUULP)

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645.800 Systems Engineering Project
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• Student Biography
• Introduction
• Needs Analysis
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• Trade Study
• Test and Evaluation Plan

• System Specification
• Risk Management
• Project Management
• Lessons Learned
• Evaluation & Next Steps
• Recommendations
• Questions
**Student Biography**

**Education**

- Hudson Valley Community College (2009-2011)
  - A.S. Engineering Science
- Rensselaer Polytechnic Institute (2011-2014)
  - B.S. Computer and Systems Engineering
- Johns Hopkins University (2015-Present)
  - M.S.E. System Engineering

**Employment**

- Saab Sensis (now Saab Defense) (2013)
  - Systems Engineering Intern
- General Dynamics Mission Systems (2014 - Present)
  - Systems Engineer
• Ohio-class SSGN
  - Four converted SSBN
    - 24 missile tubes
  - Armament
    - Up to 154 BGM-109 Tomahawk (undersea deployable)
    - 4 x Mark 48 Torpedo tubes
  - Mission Capability
    - Deployable Special Operations Forces (SOF)
    - Lock-out chambers
    - 2 x Advanced Seal Delivery System (ASDS)
  - Provides the U.S. a survivable and undetectable conventional firepower platform
Needs Analysis

• **Deficiencies**
  
  ▪ **Resource Limitations**
    ▪ Reliance on external assets
      ▪ Satellite / UAV
      ▪ Ground stations
      ▪ Other naval vessels
  
  ▪ **Autonomy and Support Capability**
    ▪ No SOF support from SSGN post-deployment
    ▪ No assessment of engaged target(s) post-strike
    ▪ Limits SSGN ability to operate autonomously and clandestinely
  
  ▪ **Customer concurrence**
• Guided UAV Undersea Launch Platform (GUULP)

  ▪ Conversion of missile tubes to support UAV deployment
    ▪ Special UAVs with stowed wing capability
    ▪ Both submerged and surfaced launches
    ▪ Supports UAVs of varying sizes
    ▪ Operates independently of legacy Attack Weapons Control System (AWCS)
    ▪ Flexible design and integration to support legacy SSGN payloads (Multiple All-Up-Round Canisters)

  ▪ Mission Operations
    ▪ Post UAV deployment, GUULP provides UAV control, communication, and observational capability
• **Mission Needs Statement**
  - The GUULP will provide the SSGN (Ship, Submersible, Guided, Nuclear) submarine the capability of deploying a UAV (Unmanned Aerial Vehicle) and supporting SSGN mission planning and execution

• **Stakeholders**
  - SSGN Crew (Missile Technicians, Weapons Officer, Ship’s Captain, Mission Commander, SOF Forces)
  - System Maintainers (Shore Operations)
  - Naval Sea Systems Command (NAVSEA) – Owner / Maintainer
  - Strategic Systems Program (SSP) – User organization
  - General Dynamics Mission System (GDMS) - Contractor
• Requirements Research
  ▪ Requirements Elicitation
    ▪ In-person interview with GDMS SSGN Program Manager
    ▪ Email Interview with SSP representative
    ▪ Consultation with SSBN Fire Control System (FCS) Subject Matter Experts (SME)
    ▪ Consultation with SSGN System SMEs
    ▪ Legacy system documentation
  ▪ Documentation
    ▪ SSP Technical Objectives and Guidelines Document (TOG)
    ▪ SSGN Ordnance Documentation (OD)
    ▪ SSGN Coordination Drawings (Coords)
    ▪ MIL-STD
Requirements Analysis

• Operating Environment
  - Submarine
    - Missile Tube
    - Climate controlled compartments
  - External
    - Seawater
    - Air
    - Shock / Vibration
    - Accelerative Force
### Requirements Analysis

#### Key Performance Parameters (KPP)

<table>
<thead>
<tr>
<th>Requirement ID</th>
<th>Description</th>
<th>Source</th>
<th>Class</th>
<th>Verification Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUULP 3.2.1.5</td>
<td>The UAS seals <em>shall</em> prevent water from entering the missile tube below the UAS when the UAS is subjected to a sea pressure specified in TOG 5000</td>
<td>Derived TOG</td>
<td>Performance</td>
<td>Test</td>
</tr>
<tr>
<td>GUULP 3.3.1.5</td>
<td>The GUULP <em>shall</em> transition to the Standby State from the Power On state within the number of minutes described in TOG 5000</td>
<td>Derived TOG</td>
<td>Performance</td>
<td>Test</td>
</tr>
<tr>
<td>GUULP 3.3.1.6</td>
<td>While in the Standby State, the GUULP <em>shall</em> transition on command to the Mission State within the number of minutes described in TOG 5000</td>
<td>Derived TOG</td>
<td>Performance</td>
<td>Test</td>
</tr>
<tr>
<td>GUULP 3.3.4.6</td>
<td>The GUULP ejection capability <em>shall</em> function to a depth defined in TOG 5000</td>
<td>Derived Customer</td>
<td>Performance</td>
<td>Demonstration</td>
</tr>
<tr>
<td>GUULP 3.3.7.1</td>
<td>The GUULP <em>shall</em> provide the capability to load UAVs with a stowed profile between 25 inches and 83 inches (inclusive) in diameter.</td>
<td>Limitation of missile tube diameter (large) and useful UAV size (small)(customer need)</td>
<td>Functional</td>
<td>Analysis</td>
</tr>
<tr>
<td>GUULP 3.8.1.1</td>
<td>The GUULP <em>shall</em> have a Mission Reliability as specified in TOG 5000</td>
<td>Derived TOG</td>
<td>Performance</td>
<td>Analysis</td>
</tr>
<tr>
<td>GUULP 3.8.2.1</td>
<td>The GUULP <em>shall</em> have an Operational Availability as specified in TOG 5000</td>
<td>Derived TOG</td>
<td>Performance</td>
<td>Analysis</td>
</tr>
</tbody>
</table>
• System Operational Scenarios

**Mission Operational Scenarios**
- **OS1: Mission Planning**
  - Provide Stowed UAV capability and availability information
- **OS2: Launch Preparations**
  - Prepare Missile Tube and UAV for launch
- **OS3: Launch Operations**
  - Eject UAV and enable UAV flight
- **OS4: Handoff**
  - Enable UAV control and mission execution
- **OS5: Mission Operations**
  - Conduct SSGN mission and UAV flight control

**Non-Mission Operational Scenarios**
- **OS6: Standby**
  - Monitor GUULP and UAV availability
  - Conduct training / maintenance
- **OS7: UAV Onload / Offload and Shore Operations**
  - Load/Unload UAV
  - Maintenance activities
  - Legacy payload switch
GUULP

Functional Context Diagram

External Systems / Environment

Mechanical / Launch Support / Communication

Inputs

Ship (SSGN)

Outputs

UAV (Multiple Variants)

Inputs

Commands (Pres./Vent.)
Voice communication
Visual sensor data
Data upload

Outputs

UAV health / status

Launch status

Launch availability

UAV status (away)

Launch capabilities

Launch direction

Launch trigger signal

Launch sequence reset

Ship’s Captain

Missile Technician

Launch Operations

Inputs

Launch trigger signal
Launch sequence reset

Outputs

Operation feedback
System availability
Launch availability
Launch availability
Launch status

Missile Technician

(Missile Control Center)

Inputs

Commands (Launch)
Commands (Maint.)
Commands (UAV Init.)

Commands (Training)

Casualty procedures

Outputs

Mission status

UAV away

TO THE GUULP

Outputs

FROM THE GUULP

GUULP

Guided UAV Undersea Launch Platform

UAV Control

Inputs

Voice communication
Data upload
Visual data

Outputs

UAV control inputs
Sensor control inputs
Weapon control

Ship / Sea Environment

Inputs

Temperature
Humidity
Seawater

Outputs

Climate control
Sound dampening
Seawater

Mission Operations

Special Operations Forces (SOF)

Inputs

Voice communication
Data upload
Visual data

Outputs

Mission data upload

SOF Commander

Inputs

Voice communication
Voice communication

Outputs

Mission data

UAV Control

Inputs

Voice communication

Outputs

Visual flight information
Sensor information
UAV away

Operating Environment / Regulation

Inputs

Coord. Documents
Ord. Documents

Outputs

Verification Documents
 Coord. Documents

Maintenance Operations

Inputs

Spare parts
UAV Unload / Offload

Outputs

Media offload

Ship’s Captain

Inputs

Tube pressure
Tube temp./humidity

Outputs

Tube status

UAV away

Ship’s Hydraulics
Ship’s Power
Ship’s Communication

Inputs

UAV health / status

Outputs

Climate control

Sound dampening

Seawater

GUULP

Guided UAV Undersea Launch Platform

Functional Context Diagram

Inputs

Temperature
Humidity
Seawater

Outputs

Climate control
Sound dampening
Seawater

Mission Operations

Special Operations Forces (SOF)

Inputs

Voice communication
Data upload
Visual data

Outputs

Mission data upload

SOF Commander

Inputs

Voice communication
Voice communication

Outputs

Mission data

UAV Control

Inputs

Voice communication

Outputs

Visual flight information
Sensor information
UAV away

Operating Environment / Regulation

Inputs

Coord. Documents
Ord. Documents

Outputs

Verification Documents
 Coord. Documents

Maintenance Operations

Inputs

Spare parts
UAV Unload / Offload

Outputs

Media offload

Ship’s Captain

Inputs

Tube pressure
Tube temp./humidity

Outputs

Tube status

UAV away

Ship’s Hydraulics
Ship’s Power
Ship’s Communication

Inputs

UAV health / status

Outputs

Climate control

Sound dampening

Seawater
Functional Analysis

- Top-Level Functions (TLF) / Decomposition
  - Generated from Operational Scenarios (OS1-OS7)
  - Decomposed to sub-functions

- Function to Requirement Trace
  - Traced Operational Requirements to lowest feasible function level
  - Traced to Functional Context Diagram

- Functional Models
  - Created using Vitech CORE
  - Hierarchy Diagrams
  - Functional Flow Block / N2 Diagrams
• **Top-Level Functions (TLF)**
  - TLF1: Support SSGN Mission Planning and Execution
  - TLF2: Maintain UAV and GUULP availability
  - TLF3: Provide Stowed UAV Information
  - TLF4: Prepare UAV and GUULP for Launch Operations
  - TLF5: Deploy UAV
  - TLF6: Provide Deployed UAV Control and Communication
  - TLF7: Support UAV Onload / Offload and Shore Operations
**Functional Analysis**

- **Level 0 Spider Diagram**

- **TLF1 Level 1/2 Functional Hierarchy**

- **TLF1 Level 2/3 Functional Hierarchy**
Functional Analysis

- Level 0 N2 Chart

High Availability UAV Deployment...

Command Decision to Deploy UAV
Launch Preparation Actions
Captain’s Perm to Fire / WEPS Launch Trig...
Radio Communication

Guulp Audit and Maintenance Logs
High Availability UAV Deployment...

Available System Inputs
AVAILABILITY INDICATIONS

- TLF1 Level 1 N2 Chart

TLF - Maintain UAV and GUULP availability

Operator Test, Maintenance, or Training...
Operator Action
Control Algorithms / Manual Action
Status of Stowed UAV
Availability Indications
Ship’s Power

Power Maintenance

Missile Tube Environment and Control
Maintained Missile Tube Equipment
UAV Communication

Distribute Power
Distribute Power
Distribute Power
Distribute Power
Distribute Power
Utilize Ship’s Power
• GUULP Level 0 Functional Flow Block Diagram

• TLF1 Level 1 Functional Flow Block Diagram
GUULP

Physical Block Diagram
Conceptual Design

• Subsystem / Component Decomposition
  ▪ Generated from System Functions and SSGN physical architecture
  ▪ Subsystems decomposed to HWCI and CSCI components

• Subsystem to Function Trace
  ▪ Traced System Functions to lowest feasible component level
  ▪ Traced to Physical Context Diagram

• Physical Models
  ▪ Created using Vitech CORE
  ▪ Level 1/2 Physical Block Diagrams
## Conceptual Design

### GUULP Subsystems
- **S1**: Launch Control Subsystem (LaCS)
- **S2**: Mission and UAV Control Subsystem (MUCS)
- **S3**: UAV Adapter Subsystem (UAS)
- **S4**: Launcher Subsystem (Launcher)
- **S5**: Booster Subsystem (Booster)
- **S6**: Tube Content Switching Subsystem (TuCSS)
- **S7**: LaCS – UAV Interface Subsystem (LUIS)
- **S8**: LaCS – Interface MC Subsystem (LMIS)

### Legacy SSGN Subsystems
- **L1**: Missile Tube
- **L2**: Ship’s Power
- **L3**: Ship’s Communication (CSRR)
- **L4**: Missile and Tube Interface Box (MTIB)
- **L5**: Launch Control Unit (LCU)
- **L6**: Launch tube Network Center (LNC)
- **L7**: Unmanned Aerial Vehicle (UAV)
- **External to the SSGN and GUULP**

### Table: GUULP Subsystems

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsystem</td>
<td>S1</td>
<td>Launch Control Subsystem</td>
<td>See Section 4.1.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(LaCS)</td>
<td></td>
</tr>
<tr>
<td>HW Element</td>
<td>1.1</td>
<td>Launch Control Display 1</td>
<td>Launch status and control monitoring panel</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>Launch Control Display 2</td>
<td>Launch status and control monitoring panel</td>
</tr>
<tr>
<td>HWCI</td>
<td>1.3</td>
<td>Console Desk 1</td>
<td>Desk which houses monitor, internal interface components, and flat space for operator use</td>
</tr>
<tr>
<td>HW Element</td>
<td>1.3.1</td>
<td>Launch Trigger</td>
<td>Part of the Console Desk, this provides the weapons officer with singular point of control for the ejection of the UAV</td>
</tr>
<tr>
<td>HW Element</td>
<td>1.3.2</td>
<td>Pointing Device 1</td>
<td>Operator input</td>
</tr>
<tr>
<td>HWCI</td>
<td>1.3</td>
<td>Hardware Cabinet 1</td>
<td>Houses the electronics and power units for the LaCS</td>
</tr>
<tr>
<td>HW Element</td>
<td>1.3.1</td>
<td>Power Regulator 1</td>
<td>Regulates and distributes the incoming power to the rest of the LaCS units</td>
</tr>
<tr>
<td>HW Element</td>
<td>1.3.2</td>
<td>LaCS CPU Module</td>
<td>LaCS processing unit which hosts the subsystem’s CSCIs</td>
</tr>
<tr>
<td>CSCI</td>
<td>1.1</td>
<td>Network Handler CSCI 1</td>
<td>Handles the network traffic (and all data encapsulated within) between the LaCS, LUIS, and LMIS</td>
</tr>
<tr>
<td>CSCI</td>
<td>1.2</td>
<td>Operating System CSCI 1</td>
<td>Handles the CSCI support software, display drivers, and operator input</td>
</tr>
<tr>
<td>CSCI</td>
<td>1.3</td>
<td>Launch Boolean CSCI</td>
<td>Handles the launch control, countdown, and other SUBSAFE algorithms</td>
</tr>
<tr>
<td>CSCI</td>
<td>1.4</td>
<td>LMIS Interface Handler CSCI</td>
<td>Handles incoming and outgoing LMIS interface data</td>
</tr>
<tr>
<td>HW Element</td>
<td>1.3.3</td>
<td>Discrete I/O Module 1</td>
<td>Module that handles discrete signals with the LCU</td>
</tr>
<tr>
<td>HW Element</td>
<td>1.3.4</td>
<td>Serial I/O Module 1</td>
<td>Module that handles serial signals from the LMIS and network traffic between LaCS, LUIS, and LMIS</td>
</tr>
<tr>
<td>HW Element</td>
<td>1.3.5</td>
<td>Module Backplane 1</td>
<td>Part of the required cabinet stowage requirement for GUULPS interface and computational electronics components. The module backplane provides physical mounting and data/power bus to facilitate inter-module communication. Each module must be seated in the backplane in order to function.</td>
</tr>
</tbody>
</table>

-Not shown for readability purposes: Function Trace
Conceptual Design

- S1: LaCS Component Diagram

- GUULP Level 0 Component Diagram
• GUULP Component Diagram (CSCI)

• S1: LaCS Level 2 Physical Block Diagram
Trade Study

• Trade Study Selection

UAV Status / Availability
- UAV Away (2)
- Power / Data (3)

Movement Inputs
- HDMI (1)
- Software Load
- UAV Status

Input Signals
- Visual (2)
- Trigger Pull
- Module Power (1)
- Trigger Pulse
- HDMI (2)
- Captain's Permission to Fire
- UAV Away (1)
- 270 VDC (1)
- Power / Data (2)

Operating Power
1.1 Launch Control Display
1.2 Launch Control Display
1.3 Console Desk 1
1.3.1 Launch Trigger
1.3.2 Pointing Device 1
1.4 Hardware Cabinet 1
1.4.1 Power Regulator 1
1.4.2 LaCS CPU Module
1.4.3 Discrete I/O Module 1
1.4.4 Serial I/O Module 1
1.4.5 Module Backplane 1

• Trade Study Topics
  ▪ Mission operation computational needs
  ▪ Mission and launch operation human systems console layout
  ▪ Ejection gas generation
  ▪ Booster design
  ▪ Network Switching
Component Selection Trade Study Conducted
- Adhered to formal Trade Study process (JHU MSSE program)
- Trade Study subject selected after discussion with SMEs and consideration of criticality of components
- More information available for Analysis of Alternatives
- Single-Board Computer selected for analysis

Selection Criteria Established
- Determined based on Operational Requirements to subsystem
- Weightings ranked based on SME pair-wise determination

Selection of Alternatives / Trade Study Conduct
- Rationale provided for each alternative
- Analysis performed with sensitivity and cost values considered
- Recommendation provided
Trade Study

1.1.1. Display Ports

Driven by the requisite number of displays required to output all pertinent information to the operators of the LaCS and MUCS, the number and type of display ports is important. The larger the number of display ports means the more displays that can be supported natively without suing expansion slots. Three types of display ports that are available for SBCs are VGA, DVI, and HDMI. Each can support certain video outputs and can provide the necessary output to operators so that GUULP functions are easily visible. Display Ports is measured in Number of Ports and Type of Ports (#/Type of Display Ports).

Related requirements:

<table>
<thead>
<tr>
<th>Requirement ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUULP 3.3.2.4</td>
<td>The GUULP shall provide UAV capability information of all stowed UAVs</td>
</tr>
<tr>
<td>GUULP 3.3.2.5</td>
<td>The GUULP shall display pre-loaded UAV information</td>
</tr>
<tr>
<td>GUULP 3.3.2.6</td>
<td>The GUULP shall display geographic maps for Mission Planning and Operations</td>
</tr>
<tr>
<td>GUULP 3.3.6.4</td>
<td>The GUULP shall display user-selectable video sensor information for all deployed UAVs</td>
</tr>
<tr>
<td>GUULP 3.3.6.5</td>
<td>The GUULP shall display other sensor information for all deployed UAVs</td>
</tr>
<tr>
<td>GUULP 3.3.6.6</td>
<td>The GUULP shall overlay UAV position data onto geographic mission map</td>
</tr>
</tbody>
</table>

Table 1 - Display Ports Related Requirements

1.1.2. USB Ports

One of the functions of the GUULP is to support a SOF audio communication link and operator input into the system. A standard input/output port is the Universal Serial Bus or USB, and can be utilized for many of the functions of the GUULP. These inputs are pointing devices, keyboards, and headsets, and flight input. The number of USB Ports is the main consideration for this criterion (# of USB Ports).

Related requirements:

<table>
<thead>
<tr>
<th>Requirement ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUULP 3.3.4.12</td>
<td>The GUULP shall support the operation of 2 deployed UAVs</td>
</tr>
<tr>
<td>GUULP 3.3.5.3</td>
<td>The GUULP shall prevent flight control commands from transmitting to the UAV until the UAV has reached flight velocity</td>
</tr>
<tr>
<td>GUULP 3.3.6.1</td>
<td>The GUULP shall allow for manual flight control of every deployed UAV</td>
</tr>
<tr>
<td>GUULP 3.3.6.7</td>
<td>The GUULP shall enable communication between deployed Special Operations Forces (SOF) and GUULP operators</td>
</tr>
<tr>
<td>GUULP 3.6.1</td>
<td>The GUULP shall be compatible with the availability of personnel as described in TOG 5000</td>
</tr>
</tbody>
</table>

Table 2 - USB Ports Related Requirements
• Alternatives

2.3.1. Curtis Wright VME – 186

2.3.2. Acromag X-VME – 6510

2.3.3. Extreme Engineering Solutions (X-ES) XCalibur4531

2.3.4. Eurotech CPU 71-15
# Trade Study

## Utility Functions

<table>
<thead>
<tr>
<th>CPU Speed</th>
<th>Clock Speed of Each Core</th>
<th>Total CPU Speed</th>
<th>Function (WolframAlpha)</th>
<th>Utility Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtiss Wright</td>
<td>1.5 GHz</td>
<td>12</td>
<td>$0.526316 + 0.0394737 x$</td>
<td>1</td>
</tr>
<tr>
<td>Acromag</td>
<td>2.4 GHz</td>
<td>9.6</td>
<td>$0.333333 + 0.0416667 x$</td>
<td>0.90526352</td>
</tr>
<tr>
<td>X-ES</td>
<td>2.4 GHz</td>
<td>9.6</td>
<td>$0.333333 + 0.0416667 x$</td>
<td>0.90526352</td>
</tr>
<tr>
<td>Eurotech</td>
<td>2.2 GHz</td>
<td>4.4</td>
<td></td>
<td>0.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Memory</th>
<th>Utility Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtiss Wright</td>
<td>4 GB</td>
</tr>
<tr>
<td>Acromag</td>
<td>16 GB</td>
</tr>
<tr>
<td>X-ES</td>
<td>16 GB</td>
</tr>
<tr>
<td>Eurotech</td>
<td>8 GB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Display Type</th>
<th>Display Ports</th>
<th>Utility Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGA</td>
<td>0 native ports</td>
<td>0.125</td>
</tr>
<tr>
<td>DVI</td>
<td>1 native ports</td>
<td>0.25</td>
</tr>
<tr>
<td>HDMI</td>
<td>2 native ports</td>
<td>0.5</td>
</tr>
<tr>
<td>3 native ports</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>4 native ports</td>
<td>1</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>USB Ports</th>
<th>Utility Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 native ports</td>
<td>0.166666667</td>
</tr>
<tr>
<td>1 native ports</td>
<td>0.333333333</td>
</tr>
<tr>
<td>2 native ports</td>
<td>0.5</td>
</tr>
<tr>
<td>3 native ports</td>
<td>0.666666667</td>
</tr>
<tr>
<td>4 native ports</td>
<td>0.833333333</td>
</tr>
<tr>
<td>5 native ports</td>
<td>1</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Discrete I/O</th>
<th>Utility Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 native ports</td>
<td>0.166666667</td>
</tr>
<tr>
<td>1 native ports</td>
<td>0.333333333</td>
</tr>
<tr>
<td>2 native ports</td>
<td>0.5</td>
</tr>
<tr>
<td>3 native ports</td>
<td>0.666666667</td>
</tr>
<tr>
<td>4 native ports</td>
<td>0.833333333</td>
</tr>
<tr>
<td>5+ native ports</td>
<td>1</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Serial I/O</th>
<th>Utility Value</th>
</tr>
</thead>
<tbody>
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<td>0 native ports</td>
<td>0.25</td>
</tr>
<tr>
<td>1 native ports</td>
<td>0.5</td>
</tr>
<tr>
<td>2 native ports</td>
<td>0.75</td>
</tr>
<tr>
<td>3+ native ports</td>
<td>1</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Power Draw</th>
<th>Utility Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtiss Wright</td>
<td>40 W</td>
</tr>
<tr>
<td>Acromag</td>
<td>50 W</td>
</tr>
<tr>
<td>X-ES</td>
<td>(estimated) 50 W</td>
</tr>
<tr>
<td>Eurotech</td>
<td>25 W</td>
</tr>
</tbody>
</table>

---

![CPU Speed](chart1.png)

![Display Ports](chart2.png)

![Discrete I/O](chart3.png)

![Power Draw](chart4.png)
## Trade Study

### Cost / Sensitivity Analysis and Recommendation

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Units</th>
<th>Weights</th>
<th>Raw Value</th>
<th>Utility Value</th>
<th>Weighted Score</th>
<th>Raw Value</th>
<th>Utility Value</th>
<th>Weighted Score</th>
<th>Raw Value</th>
<th>Utility Value</th>
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<th>Raw Value</th>
<th>Utility Value</th>
<th>Weighted Score</th>
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<tbody>
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<td>CPU Speed</td>
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<td>12</td>
<td>0.15927406</td>
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<td>Memory</td>
<td>GB</td>
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<td>4</td>
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<tr>
<td>Display Ports</td>
<td># / Type</td>
<td>0.067052981</td>
<td>0 DVI</td>
<td>0.25</td>
<td>0.016763245</td>
<td>1 DVI / 1 VGA</td>
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<td>0.016763245</td>
<td>2 HDMI</td>
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<td>USB Ports</td>
<td>#</td>
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<td>Serial I/O</td>
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<td>Power Draw</td>
<td>Watts</td>
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<td>0.091345776</td>
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</table>

**Weighted Sum**

- **Curtiss Wright**: 5.13
- **Acromag**: 0.787444
- **X-ES**: 4.70526
- **Eurotech**: 0.664716

### Alternatives

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Curtiss Wright</th>
<th>Acromag</th>
<th>X-ES</th>
<th>Eurotech</th>
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<tr>
<td>Price ($)</td>
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<td>11395</td>
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<td>Cost Effectiveness</td>
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<td>9.633568131</td>
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</table>

### Recommendation:

- **Curtiss Wright VME-186**
  - Closely aligned with system needs
  - Proven performance in Legacy applications
  - Greatest number of interface ports
Developed Test Methodology

- Utilized the Vee Model in 3 phase approach to establish test events / environments
- Integration testing from component through subsystem / system
- Verification of system functions, operational / system requirements
- System Validation testing
Test and Evaluation

- **ETS Layout**
  - Established ETS Layout for integration and system testing
  - Identified lab equipment required
  - Identified personnel required
• **Test Requirements**
  - Identified subsystem allocated requirements for verification activity
  - Established acceptance criteria
  - Established metrics to be collected for verification

<table>
<thead>
<tr>
<th>Requirement ID</th>
<th>GUULP Operational Requirements Document</th>
<th>Verification Method</th>
<th>Acceptance Criteria</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3 System Operation</td>
<td>3.3.1. General</td>
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<td></td>
<td></td>
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<tr>
<td>GUULP 3.3.1.1</td>
<td>The GUULP shall transition between its operational states</td>
<td>Demonstration</td>
<td>The operator is capable of transitioning the LACS between all of the possible system states</td>
<td>Visible indication of system state, and logged event data indicating SW transitions to correct state</td>
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<tr>
<td>GUULP 3.3.1.2</td>
<td>The GUULP shall pull its software loads from the SSGN Launch tube Network Center (LNC) during initialization.</td>
<td>Analysis</td>
<td>The LACS loads its software</td>
<td>Sniffed network traffic verifying boot requests and software loads from AWCS simulator</td>
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<tr>
<td>GUULP 3.3.1.3</td>
<td>The GUULP shall be capable of a safe, orderly shutdown</td>
<td>Test</td>
<td>The operator is capable of transitioning to the Power Off state and power the system back on</td>
<td>Inspection of system in Power Off state and ‘Green Board’ when powered on.</td>
</tr>
<tr>
<td>GUULP 3.3.1.4</td>
<td>The GUULP shall allow for power isolation through hardware mechanisms</td>
<td>Inspection</td>
<td>Inspection of hardware switches and that they can isolate power to the cabinet</td>
<td>Power check on cabinet components</td>
</tr>
<tr>
<td>GUULP 3.3.1.5</td>
<td>The GUULP shall transition to the Standby State from the Power On state within the number of minutes described in TOG 5000</td>
<td>Test</td>
<td>The operator is capable of transitioning to the Standby state</td>
<td>Visible indication of system state, and logged event data indicating SW transitions to correct state</td>
</tr>
<tr>
<td>GUULP 3.3.1.6</td>
<td>While in the Standby State, the GUULP shall transition on command to the Mission State within the number of minutes described in TOG 5000</td>
<td>Test</td>
<td>The operator is capable of transitioning to the Mission state</td>
<td>Visible indication of system state, and logged event data indicating SW transitions to correct state</td>
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<tr>
<td>GUULP 3.3.1.7</td>
<td>The GUULP shall transition to the Power Off state via a</td>
<td>Test</td>
<td>The operator is capable of</td>
<td>Inspection of system in Power Off state</td>
</tr>
</tbody>
</table>
### System Specification

**System Requirements Generated**
- Based off of Operational Requirements
- Added additional subsystem-specific requirements
- Provided context information and other support requirements/documents
- Completed traces to requirement source, MNS, OS, Type, Class, and Verification Method

#### Key Performance Parameters Summary

<table>
<thead>
<tr>
<th>Requirement Analysis Report</th>
<th>Total Requirements</th>
<th>Functional</th>
<th>Functional / Total</th>
<th>Performance</th>
<th>Performance / Total</th>
<th>Interface</th>
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<td>77.1</td>
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<td>10.3</td>
<td>20</td>
<td>12.1</td>
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<td>124</td>
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<td>Test Plan</td>
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<table>
<thead>
<tr>
<th>Requirement Analysis Report</th>
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<th>Inspection*</th>
<th>Analysis*</th>
<th>Demonstration*</th>
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<td>104</td>
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<tr>
<td>Test Plan</td>
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<th>Analysis*</th>
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<td>Requirement Analysis Report</td>
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<td>163</td>
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<td>Conceptual Design</td>
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<td>Trade Study</td>
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<td>56</td>
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<td><strong>System Specification Report</strong></td>
<td><strong>245</strong></td>
<td><strong>141</strong></td>
<td><strong>74</strong></td>
<td><strong>124</strong></td>
<td><strong>31</strong></td>
</tr>
</tbody>
</table>
Risk Management

• Identified and Documented Risk
  ▪ Technical and programmatic
  ▪ Established initial risk assessment along with mitigation strategy
  ▪ Revisited risks after each design phase to assess risk posture
  ▪ Followed risk cube matrix representation

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Risk Title</th>
<th>Risk Description</th>
<th>Initial Risk Mitigation Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 (T)</td>
<td>GUULP/SSGN Integration</td>
<td>The GUULP must continue to support current missile tube operational requirements. GUULP design which doesn't take into account is at risk of not being approved by the Navy.</td>
<td>Gives each one of the key architecture factors of the GUULP, this risk is at a low likelihood of occurring, but high consequences. The GUULP architecture will undergo design analysis to evaluate and actively minimize the impact on existing SSGNs/purchased launch support subsystems. Communication with Navy representatives will be frequent to ensure customer concurrence on integration impacts.</td>
</tr>
<tr>
<td>R2 (T)</td>
<td>Operating environment</td>
<td>The GUULP will operate in a typical submarine and sea environment. There are significant Navy requirements for all systems that will be operating onboard the ships. If the GUULP does not meet these requirements, there is a risk of non-acceptance by the Navy, and ultimately loss of contract.</td>
<td>The stringent operating environment requirements are well defined and known from the onset of GUULP development. This risk lies more with verification of those requirements which explains a lower likelihood of occurrence but also of high consequence. The GUULP system requirements and design will track back all applicable Navy safety and operating environment requirements. Hardware selection will incorporate use of vendors that have done business with the Navy in the past and meet the stringent requirements and all components/subsystems will undergo environmental testing at a lab where feasible.</td>
</tr>
<tr>
<td>R3 (T)</td>
<td>Ejection of UAV</td>
<td>Given the nature of the vertical launch platform, the GUULP must be capable of fully ejecting the UVM from the missile tube and water during launch. Should not enough ejector energy be generated, the UVM may not fully clear the tube or water and could result in loss of UVM and degraded mission capability.</td>
<td>This risk is part of any underwater launch platform and is well known and has been realized as an integration in the past with different payloads thus the likelihood is high while the consequences are high as this involves loss of UVM. This mitigation strategy involves ensuring that the GUULP design is capable of fully ejecting the UVM from the missile tube and water and yielding a successful mission.</td>
</tr>
<tr>
<td>R4 (T)</td>
<td>Loss of communication</td>
<td>In the event the GUULP loses its communication link with a deployed UVM, there is a risk of degraded mission capability due to loss of situational awareness for the SOE commander. Also, the GUULP-GUULP communication is what links the UVM pilot with the UVM. Should this link be severed, there is a risk of loss of UVM.</td>
<td>Another risk likely realized is loss of communication with the UVM after launch. Because communication between the ship and UVM provides both the control and sensor data, loss of it would result in significant mission capability degradation and is of high consequence. As with any communication method subject to the electromagnetic spectrum, the likelihood of degradation in loss of signal is high. Mitigation of this risk will be done by performing analysis on the onboard communication methods of the GUULP deployed UVM and outlining performance characteristics / acceptable reliability numbers. This includes frequent discussions with Navy representatives to ensure acceptance and any help decrease requirements on loss of communication for the UVM contractor (autonomous / fail safe characteristics).</td>
</tr>
<tr>
<td>R5 (P)</td>
<td>Late stakeholder inputs</td>
<td>The GUULP project relies on input from subject matter experts for both technical and external component readiness of deliverables. If these inputs are not received on time, late, lower quality deliverables could result.</td>
<td>Any comments from the subject matter experts will be solicited early in the development of each deliverable and less formally throughout the project timeline. Timely incorporation of comments after receipt will help ensure meaningful impact of decisions.</td>
</tr>
<tr>
<td>R6 (T)</td>
<td>Subsystem interface design</td>
<td>The GUULP project relies on two subsystems for integrating all other subsystems and enabling operator control of the system, the LaCS and MUCS. As the primary information subsystem, the LaCS and MUCS will be required to meet the stringent requirements and all components/subsystems will undergo environmental testing at a lab where feasible.</td>
<td>Subsystem design has reduced the risk identified by delegating two critical mission functions (Launch Operations, Mission Operations) between two subsystems (LaCS and MUCS). This reduces the processing and operational input load required from a</td>
</tr>
</tbody>
</table>
### Risk Management

#### Risk Waterfall

**Risk ID: R1**  
**Risk Name: GUULP/SSGN Integration**


<table>
<thead>
<tr>
<th>Date</th>
<th>Risk Severity</th>
<th>Mitigation Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>September</td>
<td>High</td>
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</tr>
<tr>
<td>October</td>
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</tr>
<tr>
<td>November</td>
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<td></td>
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<tr>
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#### Risk ID: R2**  
**Risk Name: Operating Environment**


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<tr>
<th>Date</th>
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<th>Mitigation Effort</th>
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<tr>
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</tr>
<tr>
<td>December</td>
<td>Low</td>
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#### Risk ID: R3**  
**Risk Name: Ejection of UAV**


<table>
<thead>
<tr>
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<th>Risk Severity</th>
<th>Mitigation Effort</th>
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</thead>
<tbody>
<tr>
<td>September</td>
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<td></td>
</tr>
<tr>
<td>October</td>
<td>Medium</td>
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<tr>
<td>November</td>
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<tr>
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#### Risk ID: R4**  
**Risk Name: Loss of communication**


<table>
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<tr>
<th>Date</th>
<th>Risk Severity</th>
<th>Mitigation Effort</th>
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</thead>
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#### Risk ID: R5**  
**Risk Name: Late stakeholder inputs**


<table>
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<th>Mitigation Effort</th>
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#### Risk ID: R6**  
**Risk Name: Late stakeholder inputs**


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</thead>
<tbody>
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<tr>
<td>October</td>
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<td>Low</td>
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</tr>
<tr>
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</table>
### Project Management

#### Project Effort and Schedule

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Estimated Time</th>
<th>Actual Hours</th>
<th>Difference (in %)</th>
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<td>250 hours</td>
<td>229 hours</td>
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</tbody>
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- **Detailed Breakdown of Tasks:***
  - Task 1: Project Initiation
  - Task 2: Project Planning
  - Task 3: Project Execution
  - Task 4: Project Closure

- **Projected Timeline:***
  - Week 1: Preparation
  - Week 2: Task 1 Initiation
  - Week 3: Task 2 Planning
  - Week 4: Task 3 Execution
  - Week 5: Task 4 Closure

- **Key Milestones:***
  - Milestone A: Project Kickoff
  - Milestone B: Task 1 Completion
  - Milestone C: Task 2 Completion
  - Milestone D: Task 3 Completion
  - Milestone E: Project Closure

- **Potential Risks:***
  - Resource Allocation
  - Scope Creep
  - External Factors

- **Mitigation Strategies:***
  - Prioritization of Tasks
  - Resource Reallocation
  - Contingency Planning

- **Weekly Reviews:***
  - Weekly Progress Updates
  - Risk Management Meetings
  - Task Completion Reviews

- **Technical Support:***
  - Access to Experts
  - Training Programs
  - Software Licenses

- **Vendor Management:***
  - Vendor Selection
  - Contract Negotiation
  - Quality Assurance

- **Data Management:***
  - Data Collection
  - Data Analysis
  - Data Visualization

- **Communication Plan:***
  - Team Meetings
  - Status Reports
  - Stakeholder Communications

- **Project Governance:***
  - Project Sponsorship
  - Steering Committee
  - Project Manager Authority
Lessons Learned

• Proposal / General Observations
  ▪ Schedule slippage
  ▪ Microsoft Word
  ▪ Propagating changes throughout documents
  ▪ When to get started
  ▪ What to focus on

• RAR / CONOPS
  ▪ Customer involvement
  ▪ Operational specifications
  ▪ Requirement titles
  ▪ Graphics

• Functional Analysis Report
  ▪ Vitech CORE

• Conceptual Design Report
  ▪ Interfaces
  ▪ Subsystems

Trade Study
  ▪ Trade study topic
  ▪ Customer input
  ▪ Miscellaneous

• System Specification Report
  ▪ Requirement updates
Evaluation and Next Steps

• Evaluation of the Course
  ▪ Time consuming course
  ▪ Enjoyable
  ▪ Accomplishment
  ▪ Good terminal assignment

• Potential Next Steps
  ▪ Additional detail/analysis in areas that need it
  ▪ SME peer reviewed artifacts
  ▪ Decompose the system more
  ▪ Potential business case / pitch to customer
  ▪ Personal involvement in project implementation
Recommendations

• **Course Structure**
  - Two course structure
  - Part 1: Introduction and develop Proposal
  - Part 2: Currently implemented course

• **Vitech CORE**
  - More official instruction as part of Capstone
  - Possible topic for course part 1

• **Deliverable Comments**
  - Comments received were helpful
  - Expected more comments from more than mentor
Questions?