JOINT SMALL ARMS TECHNOLOGY

DEVELOPMENT STRATEGY

FOR

JOINT SERVICE SMALL ARMS SCIENCE AND TECHNOLOGY INVESTMENTS

26 January 2016

JOINT SMALL ARMS TECHNOLOGY DEVELOPMENT STRATEGY

SUBMITTED BY:

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Preface

In 1978, the Office of the Under Secretary of Defense directed the establishment of the Joint Service Small Arms Program (JSSAP) and the JSSAP Management Committee with the Army as the Executive Agent. In 1991 JSSAP transitioned acquisition responsibilities of Army production efforts and Lifecycle support of small arms along with the Soldier Enhancement Program (SEP) to Product Manager Small Arms. PM Small Arms is now known as Project Manager Soldier Weapons (PM SW). The Charter for the Joint Service Small Arms Synchronization Team (JSSAST) was updated and approved by Mr. Claude Bolton (AAE) on 31 August 2004.

The purpose of the Joint Service Small Arms Synchronization Team (JSSAST) is to coordinate and harmonize new Service materiel requirements with potential joint applications and to maintain an awareness of the Services' efforts to improve Small Arms capabilities in order to reduce duplication of ongoing and planned technology, acquisition and sustainment activities.

The JSSAST is comprised of six principal voting members - one representative each from the Army, Air Force, Navy, Marine Corps, Coast Guard and the Special Operations Command. Service representatives will be the interface for the JSSAST with that Service. Each representative will be responsible for maintaining liaison and coordination within his/her Service. The Project Manager Soldier Weapons and the Director, Joint Non-Lethal Weapons Program are permanent, non-voting members.

The JSSAST Charter identifies 5 principal areas of responsibility for the JSSAP Office:

1. Intensive Management of the DoD Small Arms Tech Base
2. Harmonization of Requirements
3. Transition to Project Managers for Engineering and Manufacturing Development
4. Long Range Plans and Strategies
5. Influence of International Small Arms Activities

The JSSAP office executes their mission through a small staff of Department of the Army Civilians who manage the Small Arms Tech Base through the Joint Service Small Arms Requirements Integration (JSSARI) Working Group and the Joint Service Small Arms Program Science and Technology Advisory Council (JSTAC).

The JSSARI assures that the Services' Small Arms Systems Capabilities Developments are coordinated and harmonized at the Service Combat Developers level. The JSSARI Working Group (WG) will review and coordinate all Small Arms Systems related Joint Capabilities Integration and Development System Documents.

The JSTAC promotes a process for the timely exchange of Science & Technology information, Develops and maintains the Joint Service Small Arms Technology Development Strategy (JSATDS), Maintains an awareness of the small arms Science & Technology portfolio, Maintains an awareness of both domestic and foreign

technology and identify areas of possible exploitation and recommends to the JSSAST prioritized plans, programs and strategies semiannually

JSSAP defines Small Arms as man portable and platform mounted, individual and crew-served weapon systems used against protected and unprotected personnel and light armored and unarmored vehicles. Included among these weapons systems are ballistic and non-ballistic systems and associated munitions, aiming, powering, storage and other ancillary items.

This Joint Small Arms Technology Development Strategy (JSATDS) is prepared by the Joint Service Small Arms Program Science and Technology Advisory Council (JSTAC) comprised of representatives from the Army, Navy, Air Force, Marine Corps, Coast Guard and Special Operations Command (SOCOM) joined by the Joint Non-Lethal Weapons Directorate, Project Manager Soldier Weapons, Project Manager Soldier Sensors and Lasers, Project Manager Maneuver Ammunition Systems, Office of Naval Research, The U.S. Army Research Laboratory, The U.S. Army Armament Research, Development and Engineering Center, The Communications-Electronics Research, Development and Engineering Center Night Vision and Electronic Sensors Directorate and Navy Project Manager Small Arms, RDECOM Forward Element Command, Program Executive Office Soldier, Program Executive Office Ammunition, Maneuver Center of Excellence and Army for Acquisition, Logistics, and Technology (ASA(ALT)) Research & Technology Staff Members. The JSATDS is based upon existing and evolving small arms master plans, requirements or strategies of the aforementioned five Services and SOCOM and the approved Top 50 opportunity investments areas as defined by the Joint Service Small Arms Synchronization Team (JSSAST).

The JSATDS summarizes by investment taxonomy and Army Budget Activity what investments are necessary to mitigate the JSSAST Top 50 Opportunity Areas in order to evolve current systems into the next generation of small arms weapons and munitions.

JSATDS section leads were provided from the following agencies and services: ARDEC, ARL, USMC, JSSAP, JNLWD and ONR creating a Joint document from inception. The JSATDS is an excellent example of stakeholder engagement. The process of jointly wiring this document across the services demonstrates stakeholder commitment, buy-in and participation. This document serves as a partnership with shared accountability and responsibility, multiple-way engagement, joint learning and decision making. This document supports the tenets of the chartered mission of the Joint Service Small Arms Program (JSSAP) office.

The goals set forth in this JSATDS makes it clear that a qualitative and quantitative edge in small arms capability will be pursued aggressively though a joint scientific body of stakeholders and that the creation of a dramatically empowered combatant will be the result.

Executive Summary

The JSATDS, endorsed by all the Services and SOCOM, represents an investment strategy aimed at filling user requirements by structuring investments through the lenses of taxonomy and budget activity across the services. The development of the JSATDS, as Science & Technology (S&T) investment roadmap, is a result of direction to the authority chartered to the JSTAC as part of their mission. The JSATDS provides senior Joint Service/DOD decision makers a single document describing the S&T investment strategy for the development of small arms system(s).

The JSATDS, describes the Lean Six Sigma process used to derive the JSSAST approved Top 50 Opportunity Areas based on approved requirement documents and strategies provided by all services. Each budget activity specific section, provides a problem statement, scope and objective, linkage and analysis to the Top 50 Opportunity Areas and Program of Records, defines a Science & Technology Strategy to achieve goals and finally provides a Proposed Investmentto achieve the S&T Goals (in priority order).

The JSTAC recognizes that recent system studies have shown that if the weapon system (ammunition, weapon, and fire control) are designed together in concert with Human Interface effects (recoil, weapon balance, and other metrics that can affect Soldier Aim error), then extremely significant improvements can be achieved. These significant enhancements are achievable because the improvements are synergistic in nature. These synergies among the various weapon system component improvements could result in performances beyond anyone's expectation. For that reason JSATDS section leads had to work together to create, across taxonomy boundaries, a more holistic strategy, synchronized to support a systems approach of weapons development.

The Budget Activity (BA) 6.2 sections of the JSATDS focus on technology investments allowing for simultaneous development of weapon and ammunition subsystems. Each system at a Budget Activity (BA) 6.3 level will have different attributes and therefore different requirements from subsystem to subsystem. For instance, two different ammunition solutions aimed at meeting ambitious lethality requirements may take different BA 6.2 technical approaches to achieve those lethality affects, and therefore will likely have different needs in terms of the weapon and fire control system that fires them. This does not mean that pursuing the development of specific technologies in each subsystem area is the incorrect approach, however it does mean that cognizance of the applicability of the technologies must be maintained throughout development. In terms of enabling 6.2 technology development, this means that a given weapon/fire control/ammunition system may not need all of the weapon system and enabler technologies recommended for development under this strategy, but that all systems will need some of the technologies that are recommended for development. In order to maintain a ready posture for anything that may come down the line, the prudent approach is to pursue development of technologies that have the potential to be needed for a given system level solution.

The resultant Strategy requires a significant increase in budget activity 6.2 and 6.3 funds to support the JSSAST Approved Top 50 Opportunity Areas, Programs of Records, The Soldier Modernization Process, near term product improvements and far term revolutionary improvements.

1. Purpose.

The Small Arms Technology Development Strategy is being prepared in response to the approved Joint Service Small Arms Top 50 Opportunity Area (OAs). The OAs provide an itemized priority list that should guide scientific JSSAP Science and Technology investments and strategies in order to maximize the financial assets appropriated to the Joint Service Small Arms program elements.

2. Opportunity Areas:

The Opportunity Areas were developed through a formalized Standing Operating Procedure (SOP) derived from the Lean Six Sigma Project #1187, "Improved Technical Selection Process for FY16 – FY21 JSSAP Office R&D Projects. Source Documents were requested from the JSSAST Principal Members (Army, Navy, Air Force, Marines, Coast Guard and SOCOM). Source Documents conformed to the following conditions:

A. Source Documents were fully staffed and approved at the Service / Component HQ level

B. Source Documents were able to be related to Science & Technology (S&T) Investments. Examples of this S&T Investment Relation include, but are not limited to:

1) Requirements documentation (JCIDS or other processes) to include, but are not limited to, CBAs, ICDs, CDDs, IPLs, Gap Analyses, AoAs, FNAs, FAAs, and FSAs
2) Service / Component specific Small Arms and associated munitions, fire control and related technology Master Plans, Strategies, and Roadmaps
3) Fully validated UONS/JUONS type documentation
4) PEO and PM Roadmaps and 1-N Lists

The Joint Service Small Arms Requirements Integration Team was provided a draft Prioritized Opportunity Area List to rate, rank, discuss, re-order, and ultimately jointly recommend a final order to the Joint Service Small Arms Synchronization Team for approval. Table 2-1 lists the prioritized JSSAST Approved Opportunity Areas.

Opportunity Area (1-25)		Opportunity Area (26-50)	
1	Engage Threat Personnel in Defilade from 15 to 500m	26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m	27	Breach Existing Entry Points with a Single Shot at 0m
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m	28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m	29	Breach (6' x 4') from Distances Beyond 40 Meters
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m	30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact

6	Positively Identify Friendly Forces	31	Breach Existing Entry Points with a Single Shot up to 50m
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature	32	Signature Reduction System that Minimizes Projectile Muzzle Strike
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments	33	Fire Disabling Fire with Small Arms
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions	34	Collect Target Information
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP	35	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle	36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter	37	Detect, Identify, Classify and Track Surface Contacts Visually
13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life	38	Corrosion Prevention and Control
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance	39	System Accuracy of 5" Mean Radius at 300 Meters and 10" Extreme Spread at 600 Meters Throughout Barrel Life
15	Engage Threats with Small Arms Volume Fire from 51 to 600m	40	Engage Surface Ships With Small Arms Gunfire (Including Precision Fire from Precision Marksman)
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m	41	Barrel Life of 3,600 Rounds When Fired in Accordance with the OMS/MP
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m	42	Determine Range to Target to ±1m from 0 to 1200m
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m	43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m	44	Determine Range to Target to ±1m from 0 to 600m

20	Engage Targets	45	Determine Range to Target to ±1m from 0 to 1000m
21	Conduct Tactical Reconnaissance and Surveillance	46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold Zero
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)	47	Mark or Tag Targets to 1000m
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)	48	Mark or Tag Targets to 2400m
24	Determine Friendly, Enemy, Neutral, and Noncombatant identification	49	Mark or Tag Targets to 3000m
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)	50	Hit Targets from Defilade Position to Standard

Table 2-1 JSSAST Approved Opportunity Areas.

3. Supported Approved Requirement Documents:

The Small Arms Technology Development Strategy is being prepared in response to the approved Joint Service Small Arms Top 50 Opportunity Area (OAs) supported by the approved requirements documents submitted by all service components. These documents can be seen in Table 3-1. Both approved and emerging requirements are recognized in the Technology Development Planning. These documents are synchronized with the Long-Range Investment Requirements Analysis (LIRA), Roadmapping & Soldier Modernization Process.

Reference Capability Document	Reference Capability Document
Initial Capabilities Document (ICD) for Counter-Materiel Joint Non-Lethal Effects	Family of Weapon Sights (FWS) Capability Development Document (CDD)
Initial Capabilities Document (ICD) for Counter-Personnel Joint Non-Lethal Effects	Squad (SQD) Capabilities Based Assessment (CBA)

Reference Capability Document	Reference Capability Document
Small Arms Capability Based Assessment (CBA)	Joint Small Arms Capabilities Assessment (JSACA)
Next Generation Squad Automatic Rifle Draft Capabilities Development Document (CDD)	Individual Carbine (IC) Capability Development Document (CDD)
Maritime Security Response Team (MSRT) Required Operational Capabilities (ROC)	Integrated Base Defense Security System (IBDSS) Capability Development Document (CDD)
Maritime Safety and Security Teams (MSST) Required Operational Capabilities (ROC)	Future Handgun Quick Turn Capabilities Based Assessment (CBA)
Port Security Units Required Operational Capabilities (ROC)	Small Arms Signature Reduction (SASR) Draft Capability Development Document (CDD)

Table 3-1 Service Submitted Requirement Documents

4. Roadmapping.

Each Project Manager and Service Science & Technology Lead was invited to provide and present their Acquisition Roadmaps to the JSSAP Science & Technology Advisory Council (JSTAC). These Technology Roadmaps provide input from Project Managers, demonstrating big picture Program of Record plans, assisting to create linkages from BA 6.2, 6.3 projects to Program of Records and help identity current investment into small arms (BA 6.1-6.7, and SBIRS). Ninety Eight separate technical investments were charted against the JSSAST Top 50 Opportunity Areas to help guide the Small Arms Technology Development Strategy. Table 3, below, provides the results of a cross referenced current FY15 S&T investments (6.2-6.7) referenced against the approved JSSAST Top 50 OAs. We must understand where we have our current investments in order to make recommendations.

Table 3-2 S&T Investments against JSSAST Approved Top 50 OAs

		Number of FY 15 Investments		
	JSSAST OA	BA 6.2-6.3	BA 6.4-6.7, SBIRS	Total Number
1	Engage Threat Personnel in Defilade from 15 to 500m	**4**	**2**	**6**
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m	**9**	**11**	**20**
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m	**12**	**14**	**26**
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m	**12**	**13**	**25**
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m	**12**	**14**	**26**
6	Positively Identify Friendly Forces	**3**	**0**	**3**
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature	**1**	**1**	**2**
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments	**2**	**0**	**2**
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions	**4**	**2**	**6**
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP	**4**	**2**	**6**
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle	**2**	**2**	**4**
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter	**0**	**3**	**3**
13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life	**3**	**6**	**9**
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance	**2**	**4**	**6**
15	Engage Threats with Small Arms Volume Fire from 51 to 600m	**8**	**9**	**17**

		Number of FY 15 Investments		
	JSSAST OA	BA 6.2-6.3	BA 6.4-6.7, SBIRS	Total Number
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m	**10**	**9**	**19**
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m	**9**	**11**	**20**
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m	**10**	**14**	**24**
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m	**7**	**8**	**15**
20	Engage Targets	**12**	**22**	**34**
4	Conduct Tactical Reconnaissance and Surveillance	**3**	**4**	**7**
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)	**2**	**4**	**6**
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)	**2**	**4**	**6**
24	Determine Friendly, Enemy, Neutral, and Noncombatant identification	**3**	**0**	**3**
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)	**1**	**1**	**2**
26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons	**0**	**0**	**0**
27	Breach Existing Entry Points with a Single Shot at 0m	**0**	**2**	**2**
28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation	**0**	**0**	**0**
29	Breach (6' x 4') from Distances Beyond 40 Meters	**0**	**2**	**2**

		Number of FY 15 Investments		
	JSSAST OA	BA 6.2-6.3	BA 6.4-6.7, SBIRS	Total Number
30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact	**2**	**1**	**3**
31	Breach Existing Entry Points with a Single Shot up to 50m	**0**	**3**	**3**
32	Signature Reduction System that Minimizes Projectile Muzzle Strike	**2**	**2**	**4**
33	Fire Disabling Fire with Small Arms	**0**	**0**	**0**
34	Collect Target Information	**0**	**0**	**0**
35	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°	**0**	**2**	**2**
36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges	**0**	**6**	**6**
37	Detect, Identify, Classify and Track Surface Contacts Visually	**0**	**0**	**0**
38	Corrosion Prevention and Control	**3**	**3**	**6**
39	System Accuracy of 5" Mean Radius at 300 Meters and 10" Extreme Spread at 600 Meters Throughout Barrel Life	**0**	**0**	**0**
40	Engage Surface Ships With Small Arms Gunfire (Including Precision Fire from Precision Marksman)	**0**	**0**	**0**
41	Barrel Life of 3,600 Rounds When Fired in Accordance with the OMS/MP	**1**	**2**	**3**
42	Determine Range to Target to ±1m from 0 to 1200m	**1**	**0**	**1**
43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)	**1**	**0**	**1**
44	Determine Range to Target to ±1m from 0 to 600m	**3**	**0**	**3**
45	Determine Range to Target to ±1m from 0 to 1000m	**3**	**0**	**3**

		Number of FY 15 Investments		
	JSSAST OA	BA 6.2-6.3	BA 6.4-6.7, SBIRS	Total Number
46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold Zero	**1**	**0**	**1**
47	Mark or Tag Targets to 1000m	**0**	**0**	**0**
48	Mark or Tag Targets to 2400m	**0**	**0**	**0**
49	Mark or Tag Targets to 3000m	**0**	**0**	**0**
50	Hit Targets from Defilade Position to Standard	**1**	**0**	**1**

Table 3-2 (continued) S&T Investments against JSSAST Approved Top 50 OAs

5. Strategy Formation.

As part of the approved mission of the JSSAP Science & Technology Advisory Council (JSTAC), BA 6.2, 6.3 small arms technology development teams were established across the Stakeholders of the JSSAST and the JSTAC. The JSTAC recognizes that recent system studies have shown that if the weapon system (ammunition, weapon, and fire control) are designed together in concert with Human Interface effects (recoil, weapon balance, and other metrics that can affect Soldier Aim error), then extremely significant improvements can be achieved. These significant enhancements are achievable because the improvements are synergistic in nature. As an example, if a new weapon system can increase the velocity of an existing cartridge (same projectile), the new weapon system extends the range in which the projectile's lethal mechanism can be effective, and it also improves the probability of hit, P(H), as the flatter fire reduces the sensitivity to ranging errors that occur. When implemented with fire control, still greater improvements are possible, as the flatter trajectories can drastically reduce the demands placed upon the fire control to achieve the desired P(H). Therefore the synergies among the various weapon system component improvements could result in performances beyond anyone's expectation. For that reason it was encouraged that these leads work together to create a more holistic product.

The Agency Leads were:

BA/Taxonomy	Agency Lead
6.2 Weapon System/Enablers	The U.S. Army Armament Research, Development and Engineering Center (ARDEC)
6.2 Ammunition	US Army Research Laboratory (ARL)
6.2 Optics & Fire Control	The Office of Naval Research (ONR)
6.2 Scalable Effects	The Joint Non-Lethal Weapons Directorate (JNLWD)
6.2 Training & Human Performance	The United States Marine Corps (USMC)
6.3 System Integration and Demonstration Program	Joint Service Small Arms Program Office (JSSAP)
Deep Future Plans	Joint Service Small Arms Program Office (JSSAP)
International Involvement	Joint Service Small Arms Program Office (JSSAP)

Table 5-1 JSATDS Section Agency Leads

Each section lead was asked to:

A. Assemble a team to represent the Stakeholders associated with the topic

B. Develop a strategy on how their specific small arms taxonomy area could attack the JSSAST approved Top 50.

C. Based on the analysis of the Top 50, current investments, roadmaps and other data, an investment strategy based on Science & technology and/or demonstration (BA 6.2/6.3) could be developed for the near, mid and far term.

D. Specific templates were provided to each agency lead that help define the following problems, scope/objective, Linkage to JSSAST Top 50 Opportunity Areas, Linkage to Program of Records, Science & Technology Strategy to achieve goals, Proposed Schedule to achieve the S&T Goals (in priority order)

The following sections (6-13) are dedicated to developing the Small Arms Technology Development Strategy.

6. Strategy: BA 6.2: Weapon Systems and Enablers

Problem Statement

Today more than ever, small arms systems around the world are constantly benefitting from advances in technology, allowing the adversaries of the United States to realize various improvements in performance as compared to their legacy weapon systems. In order for the United States to achieve and maintain overmatch, we too must continuously advance and develop small arms technologies. Today's fiscal environment dictates that the small arms technical community must be selective in determining which technologies are worthy of developing and advancing. Further, with so many unique customers with both common and unique individual requirements, and as such, both common and unique technology development efforts, the small arms technical community must work to minimize duplication of effort across the Joint Services to the extent possible.

Historically, the Joint Service Small Arms Program (JSSAP) has been successful in synchronizing the Joint Services' small arms strategies through the implementation of the Joint Service Small Arms Requirements Integration (JSSARI) and the Joint Service Small Arms Synchronization Team (JSSAST). While the JSSARI is tasked with the integration of small arms requirements among the Joint Services, the JSSAST is the primary group tasked with the harmonization of long term plans and strategies for the Joint Service small arms community. In particular, the JSSAST makes decisions regarding small arms technology investments, and relies on recommendations from the technical community in order to make decisions on which technologies to invest in. These decisions are made at the JSSAST semi-annual meetings. In order to create a more formalized process to provide recommendations for technology investment to the JSSAST, the JSSAP Science and Technology Advisory Council (JSTAC) was chartered, consisting of six working groups tasked with generating a Technology Development Strategy to guide technology investment. The Armament Research, Development, and Engineering Center (ARDEC) was designated as the lead for the Weapon Systems and Enablers Working Group. As such, ARDEC was tasked with the establishment of the Weapon Systems and Enablers Technology Development Strategy outlined in this document.

Recent trends in ammunition development have leaned towards the development of higher energy, flatter fire, less wind sensitive, and more lethal rounds for the foreseeable future. Therefore, the weapon system and its enabling technologies must evolve to facilitate more accurate and more lethal delivery of these ammunition solutions to increasingly challenging targets. In doing so, weapon and enabler technology development must take into account the increased energy to the system in terms of system accuracy with Soldiers in the loop, weapon operation under higher energy loads, signature suppression, and maintenance and reliability, as well as other indirect implications of increased accuracy and lethality, such as Soldier mobility.

Scope/Objectives

The objective of the Weapon Systems and Enablers Technology Development Strategy is to define a strategy for technology development in small arms weapon systems and enablers to increase the performance of small arms weapon systems in the hands of the Soldier, Marine, Sailor, Airman, or Coast Guardsman. Technology development could apply both to the design and development of specific technologies, as well as the development of assessment methods and tools to measure or assess the performance of such technologies. There are currently many technologies being developed across the Joint Services and in industry that aim at increasing performance, however it is often unclear whether these improvements will have an effect on the overall performance when put in the hands of the user. Thus, it is important to consider the Weapon and the user as a system when developing technologies or assessing the effectiveness of technologies. While there are many technologies currently in development, there are likely many technologies that the community does not yet know about or does not yet understand the relationship to small arms weapon systems. Thus, the Weapon Systems and Enablers Technology Development Strategy must be broad enough that it does not exclude technologies not yet in development, but it must be specific enough that it generates investment in technologies that will have significant effect on the overall performance of small arms weapon systems and enablers.

The JSSAST Top 50 Opportunity Areas List is the primary driver for the Weapon Systems and Enablers Technology Development Strategy. In addition, the Strategy will leverage transition potential from 6.1 and 6.2 science and technology efforts currently underway, as well as transition potential to current or planned 6.3-6.5 efforts, Programs of Record (POR), and future or emerging requirements. Identifying key technology areas with respect to the JSSAST Top 50 as well as these transition opportunities is the basis of the Technology Development Strategy. In order to better understand how a weapon system or enabler can impact the JSSAST Top 50 Opportunity Areas, we must first agree on some basic definitions across all working groups. For the purposes of the Weapon Systems and Enablers Technology Development Strategy, the following definitions are used:

Acquire: To locate a target in a sighting or fire control system.

Aim Error: Defined in ARL-TR-2065 as the ability of the shooter to hold his or her aim on target. Aim error includes components such as stress, fatigue, physical ability, steadiness, experience, and training.

Enabler: Any part of the weapon system or ancillary item that is not part of a fire control component and performs some function beyond that of a fire control component, including those parts of the weapon system that integrate with or are affected by the fire control system.

Engage: To successfully deliver lethal effects to a target through the use of a small arms system.

Identify: To positively recognize whether an acquired target is personnel or material, and whether it is friend or foe.

Target: Any personnel or materiel asset on the battlefield that requires identification by the Infantryman in an effort to determine whether or not to engage that personnel or materiel asset.

Analysis of JSSAST Top 50 Opportunity Areas:

Using the JSSAST Top 50 Opportunity Areas list as a starting point, “performance” of a small caliber weapon system can be broken into several key areas. These areas include target identification and acquisition, target marking and tracking, target ranging, system accuracy (to include the Shooter in field conditions), lethality or terminal effects, signature reduction, and maintenance and reliability. Using the definitions above, it has been determined that technologies in weapon systems and enablers will not address all of these performance areas, and therefore, will not be able to address all of the JSSAST Top 50 Opportunity Areas. An initial analysis of the JSSAST Top 50 List was performed in order to determine which Opportunity Areas can be impacted or improved by weapon systems and enablers. Those Opportunity Areas are highlighted in green in the table below:

Opportunity Areas That Can be Addressed by Weapon Systems and Enablers

Index	Opportunity Area
1	Engage Threat Personnel in Defilade from 15 to 500m
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m
6	Positively Identify Friendly Forces
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter
13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance
15	Engage Threats with Small Arms Volume Fire from 51 to 600m
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m
20	Engage Targets
21	Conduct Tactical Reconnaissance and Surveillance
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)
24	Determine Friendly, Enemy, Neutral, and Non-Combatant identification
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)
26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons
27	Breach Existing Entry Points with a Single Shot at 0m
28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation
29	Breach (6' x 4') from Distances Beyond 40 Meters
30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact
31	Breach Existing Entry Points with a Single Shot up to 50m
32	Signature Reduction System that Minimizes Projectile Muzzle Strike
33	Fire Disabling Fire with Small Arms
34	Collect Target Information
35	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°
36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges
37	Detect, Identify, Classify and Track Surface Contacts Visually
38	Corrosion Prevention and Control
39	System Accuracy of 5" Mean Radius at 300 Meters and 10" Extreme Spread at 600 Meters Throughout Barrel Life
40	Engage Surface Ships With Small Arms Gunfire (Including Precision Fire from Precision Marksman)
41	Barrel Life of 3,600 Rounds When Fired in Accordance with the OMS/MP
42	Determine Range to Target to ±1m from 0 to 1200m
43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)
44	Determine Range to Target to ±1m from 0 to 600m
45	Determine Range to Target to ±1m from 0 to 1000m
46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold Zero
47	Mark or Tag Targets to 1000m
48	Mark or Tag Targets to 2400m
49	Mark or Tag Targets to 3000m
50	Hit Targets from Defilade Position to Standard

Table 6-1 Opportunity Areas that can be addressed Through Weapon Systems and Enablers

The remaining Opportunity Areas from the JSSAST Top 50 list can be grouped in such a way that "bins" of technologies can be identified that in some way address each Opportunity Area. Each area may be addressed by one or more of these technology "bins". The Weapon Systems and Enablers Working Group has identified a list of six (6) *Technology Area Bins* that can address applicable Opportunity Areas in the JSSAST Top 50.

Technology Area Bins:

1. **Accuracy / Controllability (Human Interface)**
   Opportunity Areas (from Table 6-1), 1-5, 15-20, 26, 27, 29, 31, 33, 35, 39, 40, and 50 are directly related to achieving incapacitating effects at various ranges. This can be broken down into the ability to hit the target, and the ability to achieve desired effects on the target. This technology Bin would be those weapon system and enabler Technologies that improve the accuracy and controllability, or the ability of the weapon system to hit the target, with the shooter in the loop. Defilade gaps can be included since there is little difference from a weapon standpoint, in terms of what the weapon needs to do to deliver the projectile.

   Technologies or studies to improve system accuracy, controllability of the weapon system during semi-automatic and automatic fire, speed and accuracy of follow on shots or bursts, effects of weapon system balance or weight on accuracy and controllability, effects of recoil on accuracy and controllability, effects of rate of fire on system accuracy, and reduction of operator aim error should all be considered under this technology area bin.

   Since this is a strategy to develop weapon systems and enablers, this does not include standalone fire control technologies, but includes technologies in the weapon system intended to reduce aim error and increase accuracy. These technologies could either be independent, or could be coupled with fire control systems or technologies.

   It is important to also consider studies that assess the performance of such technologies with Soldiers in the loop. Potential future ammunition solutions, as well as fire control solutions, should be carefully considered when determining which weapon system and enabler technologies to pursue.

2. **Advanced Weapon Operation**
   Similar to Accuracy, Controllability, and Human Interface, the likely application of higher powered ammunition to address Opportunity Areas (from Table 6-1), 1-5, 15-20, 26, 27, 29, 31, 33, 35, 39, 40, and 50 will result in the need for weapon systems themselves to operate under more extreme, and generally different conditions than they currently do (i.e. high pressure, higher temperature, novel projectile materials and shapes, other advanced ammunition principles). Thus, Advanced Weapon Operation includes technologies and studies to assess and facilitate the operation of the weapon system with novel or advanced ammunition concepts required to meet lethality requirements. Included in this area are technologies to facilitate weapon unlocking and cycling under high pressures, tapered bore barrels and operating systems,

advanced ignition weapon cycling, advances in barrel strength, technologies to feed novel shaped ammunition in automatic weapons.

3. Signature Reduction

Opportunity Areas (from Table 6-1), 7, 11-14, 30, and 32 are directly related to Signature Reduction. In order to address Opportunity Areas related to signature reduction, technologies and studies to assess and reduce a weapon's signature, both firing and non-firing, must be performed. Signature can be broken down into "flash", including visual and non-visual spectrum, and acoustic, including acoustic signature in frequencies both audible and inaudible to the human. Signature Reduction would include technologies intended to study, measure, assess, reduce, control, or mask all types of weapon signature, both firing and non-firing. Since recent work in the ammunition area trends toward higher powered ammunition solutions, and therefore higher overall signature, both flash and acoustic, is likely and this area should strongly consider technologies associated with muzzle devices and other systems that interact with the combustion gasses during muzzle exit in order to decrease flash and sound. Combining or using these technologies to reduce recoil would also be desirable. It is also important that signature reduction technologies do not affect the overall weapon reliability. In addition to assessing and decreasing signature, it is also important to understand and document how to properly measure sound, light and thermal signature and translate those values into detectability limits for both human and machines or electronic systems.

Signature reduction also includes non-firing signature reduction capabilities. Technologies in this area include weapon paints and coatings, and thermal barriers or insulators that mask or decrease the non-firing visual, thermal, geometric, and infrared signature of the weapon, its enablers, fire control components, optics, and pointers.

4. Maintenance and Reliability

Opportunity Areas (from Table 6-1), 8-10, 13, 14, 38, 39, and 41 are directly related to Maintenance and Reliability. The Maintenance and Reliability Technology Area includes technologies and studies to assess and improve weapon system maintainability and reliability. Maintainability is the ability of the system to be maintained. Often maintainability is broken down and measured by corrective maintenance and preventative maintenance. Corrective maintenance is the unscheduled maintenance required to restore a weapon to a specified condition after a failure. Preventative maintenance is scheduled maintenance required to maintain a specified performance. The major concern for this Technology Development Strategy (TDS) is preventative maintenance.

Reliability refers to the ability of the weapon to consistently fire over long periods of time without failure or degradation of performance. Technology development in this area will include studies and technologies associated with improved wear characteristics, reduction of required maintenance, improved coating technology to reduce or eliminate lubrication and improved resistance to corrosion, as well as improved fatigue life of weapons or components

In addition to the weapon operation itself, a large part of weapon maintenance and reliability is directly related to the ability to predict the need for maintenance or repair prior to the weapon system failing. As such, Maintenance and Reliability will include technologies that are aimed at failure prediction, including analyses intended to estimate part life, and weapon shot counters.

5. **Enabling Weapon Technologies**
   Enabling Weapon Technologies include technologies and studies that do not directly address a JSSAST Top 50 Area, but that will need to be considered when addressing the JSSAST Top 50 Areas. Since many performance advances are likely to result in increased weight, this will include studies and technologies intended to reduce weight and improve Soldier mobility, but can also include other technologies that may be indirectly linked to the JSSAST Top 50.

   Enabling Weapon Technologies will also include physical and data interfaces between the weapon and fire control, such as powered rails and wireless communication, as well as other enabling technologies, including integration with Nett Warrior.

6. **Remote Weapon Technologies**
   Remote Weapon Technologies include those technologies that apply specifically to remote weapon systems. Similar to Enabling Weapon Technologies, these technologies do not directly address a JSSAST Top 50 Opportunity Area, but these technologies should be pursued in order to advance the effectiveness and viability of remote weapon systems in the battlefield. While many of the technologies that address other Technology Area Bins will also apply to remote weapon systems, the inclusion of Remote Weapon Technologies as a separate Technology Area Bin is intended in an effort to include those technologies that apply specifically to remote weapons and their platforms.

Potential Linkage Of Weapon Systems and Enablers to Current and Emerging Requirements:

The following emerging and current requirements documents represent the driving needs for Science and Technology investment in the area of weapon systems and enablers. Each requirement is followed by discussion of how the development of technologies in each of the Technology Area Bins will influence or address the emerging or current requirement in order to meet PM and user needs.

1) **Family of Next Generation Squad Weapons (NGSW) Capabilities Development Documents (CDD)** The family of Next Generation Squad Weapons will include a Next Generation Squad Automatic Rifle (NGSAR), a Next Generation Squad Carbine (NGSC), and a Next Generation Squad Designated Marksman (NGSDM). The NGSAR will be the first CDD to come out. The draft CDD outlines a requirement for a new and improved automatic rifle for the Squad, which features increased accuracy and controllability, increased lethality and range, reduced weight, and reduced signature as compared to the current M249 Squad Automatic Weapon. The NGSC and NGSDM are expected to follow, and will follow the same overall approach of

increased performance and reduced weight and signature. The NGSAR, NGSC, and NGSDM will need to incorporate technologies from the first five (5) Technology Area Bins identified in this TDS.

2) **Lightweight Dismounted Automatic Machine Gun (LDAM) CDD** Much like the family of NGSW, the LDAM CDD is expected to feature requirements for increased accuracy, range, and lethality, as well as reduced signature and weight. Thus, the LDAM will need to incorporate technologies from the first five (5) the Technology Area Bins identified in this TDS.

3) **Fire Control CDD** The Fire Control CDD outlines the requirements for improved Fire Control Systems for legacy and future small arms systems. In particular, the Fire Control CDD could include requirements for technologies that decrease Soldier Aim Error (Accuracy/Controllability Technology Bin). While the overall requirements of the CDD will fall under "Fire Control," there is potential for the use of systems that use the fire control to manipulate the weapon system, and thus there would be crossover between "Fire Control" and "Weapon Systems and Enablers." The CDD will include capabilities that improve reporting of far target location and form basis for networked lethality. Thus, it is important to identify the potential for technologies in the area of weapon systems and enablers to combine with fire control systems to meet requirements in the Fire Control CDD.

4) **Small Arms Signature Reduction (SASR) CDDs** The Army and Special Operations Command (SOCOM) both have emerging requirements for Small Arms Signature Reduction. The SASR CDDs outline requirements for improved signature suppression for small arms systems, both legacy and future. Signature reduction in the SASR CDDs is expected to include visual, multi-spectral, thermal, and audible, and will include both firing and non-firing signatures. The Army and SOCOM CDD's will have some differences, but overall, both SASR CDDs will need to incorporate various technologies that fall into the Signature Reduction Technology Bin.

5) **Family of Ammunition (FOA) CDDs** the 5.56mm, 7.62mm, and caliber .50 FOA CDDs will be drivers for technologies needed in current and future small arms systems. The range of performance required by the improved ammunition solutions in the FOA CDDs will directly affect what the weapon systems need to do and how they need to operate in order to reliably fire the required families of ammunition.

6) **Externally Powered Weapon (EPW) CDD** Lightweight, low recoil, reduced sized capability that combines capability of .50 cal/40mm high velocity into a single system.

Science & Technology Strategy to Achieve Goals

Today's battlefield environment is realizing technological advances in all aspects. In particular, there are constant improvements being made around the world to small caliber weapon systems and ammunition, personnel detection and fire control systems, and personal body armor. For the United States to maintain overmatch against our adversaries, we must continue to advance our weapon and ammunition systems so that they are more accurate, more lethal, have greater effective ranges, are less detectable, and are more maintainable with shorter downtime.

It is important to recognize that weapon systems, as a whole, should be designed as a system. Each system will have different attributes and therefore different requirements from subsystem to subsystem. For instance, two different ammunition solutions aimed at meeting ambitious lethality requirements may take different technical approaches to achieving those lethality affects, and therefore will likely have different needs in terms of the weapon and fire control system that fires them. This does not mean that pursuing the development of specific technologies in each subsystem area is the incorrect approach, however it does mean that cognizance of the applicability of the technologies should be maintained throughout development. This cognizance allows informed decisions for risk/reward/cost/durability to enable the desired effect. In terms of weapon system and enabler technology development, this means that a given weapon/fire control/ammunition system may not need all of the weapon system and enabler technologies recommended for development under this strategy, but that all systems will need some of the technologies that are recommended for development. In order to maintain a ready posture for anything that may come down the line, the prudent approach is to pursue development of technologies that have the potential to be needed for a given system level solution. If priorities need to be made however, it is best to review the risk/reward/cost/durability of each technology, and select the technology that provides the biggest reward for the lowest risk/cost that has durability.

The most significant contributor, the largest error, to the error budget in small arms systems is the operator induced aim error, defined above. Aim error includes components such as stress, fatigue, physical ability, steadiness, experience, and training. Traditionally, fire control systems for small arms are intended to increase a shooter's ability to hit a target by providing the necessary information for the shooter to properly aim the weapon. A fire control system by itself would not fall under the umbrella of "Weapon Systems and Enablers," since there is a separate "Fire Control" TDS. However, a fire control system, if coupled with a weapon system component in order to control operation of the weapon in some way, could fall under "Weapon Systems and Enablers." For instance, a fire control system may detect and track targets, as well as interact with the weapon to mechanically keep that weapon pointed at the target or to semi-autonomously fire the weapon when pointed at a particular target. In this case, a system that only detects and tracks targets would fall into the "Fire Control" arena, while a system that interacts with and controls the weapon in order to reduce operator aim error would be a technology that, if viable, should be pursued under "Weapon Systems and Enablers." Investment should be made in technologies in the weapon system that couple with fire control systems to reduce the operator's aim error. These technologies

include weapon stabilization and trigger interrupt technologies that result in the weapon staying on target or only firing when on target.

From an ammunition standpoint, and in order to realize improvement in accuracy, range, and lethality, trends in recent ammunition development have leaned primarily toward ammunition solutions with higher muzzle velocities and muzzle energies. One of the more promising ways to achieve these higher muzzle velocities and muzzle energies is to increase the operating pressure of the system. The "Ammunition" section of this TDS shows that there are multiple ongoing efforts in the area of improving the efficiency and energy of propellants. As such, science and technology should have a heavy focus on technologies that enable these high powered ammunition solutions to safely, reliably, and consistently be fired. To enable these ammunition technologies, the weapon system must include technologies that reduce the muzzle pressure of the ammunition; otherwise the weapon system will not be safe for Soldiers. The technologies that need to be invested in are muzzle pressure mitigation devises, technologies that enable operating group unlocking and cycling after high pressure events, and high strength material application to small arms systems. Additionally, technologies that should be invested, second tear priority, in include high strength barrels or advanced barrel technologies, chrome replacement technologies. These technologies would fall under the category of "Advanced Weapon Operation."

With higher operating pressures and higher muzzle energies often comes higher recoil and reduced weapon controllability. Thus, it is important to consider the overall Shootability and controllability of weapon systems in science and technology development programs. Investment should be made in recoil reduction technologies and assessments, as well as studies to determine the effects of parameters such as weapon weight, weapon balance, and rate of fire on weapon controllability, and technologies to optimize these parameters to increase controllability and follow-on shot speed in an operational environment. The overarching analysis of ongoing efforts shows that few, if any, current efforts seem to address this important by-product of increased ammunition powering and higher pressures. Particularly important will be to gain an understanding of the contributors to weapon controllability under various firing scenarios, including various firing stances and schedules, as well as various firing modes (single, burst, full auto). Understanding these contributors will provide guidance for future technology development. These technologies would fall under the category of "Accuracy and Controllability." Limited controllability studies, focused only on recoil, are planned to be completed in the Small-Arms Ammunition Configuration Study (SAAC Study), however follow-on studies, in FY17-18, to look at the other parameters listed above are necessary to ensure we provide our Soldiers the most accurate system possible.

Another approach that is currently being investigated in order to achieve higher lethality is the use of novel or unique ammunition geometries and principles. One such technology is the use of tapered bore in small arms. This technology involves a projectile that gets squeezed to a smaller diameter in the bore of the weapon, and results in higher velocities with lower operating pressures. There are various technological challenges with making a weapon that fires this type of ammunition

reliably. Among others, these challenges include barrel design, fabrication, and resistance to erosion, and feeding of ammunition with novel shapes. In addition, studies have taken place to investigate the effectiveness of various other ammunition geometries and principles, including case telescoped ammunition, caseless ammunition, folded ammunition, saboted rounds, long rod bullet shapes, and many others. Thus, technology development should include research and development of advanced barrel technologies, as well as ammunition feeding studies with various novel geometries. Much of this technology development should be done in conjunction with ammunition technology development, so that any studies focus on the weapon's interaction with realistic potential ammunition solutions. These technologies would fall under the category of "Advanced Weapon Operation."

Since higher operating pressures and more muzzle energy often come with increased weapon signature, it is important for science and technology to address weapon signature reduction. Again, the driver for technologies in this area, beyond the identification of technology gaps and needs through the JSSAST Top 50 opportunity areas, is the research and development work being done in the area of higher energy propellants and ammunition solutions. First and foremost, there should be investment in areas aimed at quantifying, measuring, and understand weapon signature. This includes visual spectrum signature, non-visual spectrum signature, and acoustic signature, both audible and inaudible to the human ear. Since mechanical and electronic means are increasingly used to detect and locate weapon signature, technologies should not only be focused on reduction of signature that is detectable to humans, but also those signatures which are detectable by machines or electronics.

Signature reduction is often thought of as a trade space, and as such, it will be important to understand which weapon signatures (visual, non-visual, acoustic) will realize the most benefit from reduction. This would require an Army HRED study to outline critical thresholds, and trade-offs between the types of signature that result in detectability from humans (primary concern). This will allow the follow on technology investments to understand the trade-offs/critical thresholds to adjust the increased energy that needs to be dissipated to the environment without increasing or even decreasing the detectability. Technology investment should include traditional suppressor technologies as well as advanced concepts that interact with the exiting muzzle gasses or suppress sound and flash in other ways. Particularly important will be efforts intended to improve the effectiveness of traditional suppressors, as well as ways to reduce the size and weight of traditional suppressors while keeping their same effectiveness. In addition to development of technologies to reduce weapon signature, it is also important to understand how to assess weapon signature, so technologies intended to study, measure, and assess weapon signature and the effects and perception of weapon signature on both the operator as well as individuals located downrange should also be considered. Combining or using these technologies to reduce recoil would also be desirable. It is also important that signature reduction technologies do not affect the overall weapon reliability.

In addition to science and technology investment in reduction of the weapon's firing signature, it is also important to consider the reduction of the weapon's non-firing

signature. Technology development and investment in this area should include materials, coatings, paints, and/or other methods intended to reduce, conceal, or mask the weapon's signature in both the visual and non-visual spectrum, including but not limited to thermal, short wave, and long wave infrared. This will greatly assist in the avoidance of detection on the battlefield.

Weapon maintainability and reliability is another area where science and technology should be pursued in order to give our Warfighters an advantage over our adversaries. When a weapon system operates reliably in all conditions, is insensitive to dirt or environmental conditions, and requires little or no regular maintenance, that advantage can be realized. Investments should be made in coatings and materials that are intended to improve wear characteristics, reduce required maintenance, and improve resistance to corrosion. Often times when a Soldier maintains his weapon using wet lubricants, which is currently the standard, there is a tendency for that lubricant to attract dirt, sand, or dust, which has the potential to degrade performance over time. Further, if maintenance can be reduced such that an operator no longer needs to lubricate the weapon, this eliminates one source of error that could cause weapon malfunctions, and reduces the logistic requirements for the Army. Thus, technology development for reliability and maintainability should include development of coatings and materials that reduce the need for wet lubrication. In addition to the elimination of wet lubricants, technologies that increase a weapon's ability to resist wear and corrosion, and technologies that reduce a weapon system's sensitivity to dirty conditions should also be pursued. This could include advanced materials and coatings, as well as advanced operating systems that are self cleaning or reduce the overall sensitivity to these adverse conditions.

In addition to improving technologies in this area, it is also important to understand system failure modes and be able to either design these failure modes out, or reliably predict when a part will fail so that a failure does not occur when the weapon needs to fire. Thus, science and technology should include studies or technologies to assess or improve fatigue life of weapons or components, including development and application of high strength materials and assessment, or development of methods of assessment of failure modes of weapon parts within the system.

While not specifically addressed in the JSSAST Top 50 Opportunity Areas list, there are many technologies that will need to be developed in order to enable the weapon system to perform at a high level, and to enable the soldier to perform tasks other than simply firing the weapon and hitting the target. These are the technologies identified as "Enabling Weapon Technologies."

Mobility is an important aspect of a Soldier's job. If a Warfighter cannot maneuver himself or his weapon system in such a way as to engage a target, or avoid being engaged by a target, he is rendered ineffective. Further, with the trends in high energy ammunition, and the potential addition of advanced fire control systems, future weapon systems will inherently be heavier, and thus will have to employ weight reduction technologies in order to maintain Soldier mobility on the battlefield. Technology investment should be made in weight reduction technologies including advanced

lightweight materials and material processing, advanced manufacturing techniques. In addition, technology investment should be made in design and analysis of lightweight structural components to reduce weapon receiver and chassis weight. Weight reduction research and development would be considered “Enabling Weapon Technologies.”

With the introduction and development of new and improved fire control systems, integration onto the weapon system, and ergonomics and usability with respect to the operator are important considerations. All systems need to be integrated so that they can be effectively employed, efficiently operated, and if need be, overridden by backup systems. The systems should also be integrated with Nett Warrior and other Intra Soldier Wireless systems. Technologies in this area include weapon mounted power and integration systems, weapon mounts, and ergonomic systems to operate and integrate the Soldier/Weapon/Fire Control System. These technologies also fall under “Enabling Weapon Technologies.”

In addition, with the advancement of electronics and fire control systems, remote operated weapon systems are becoming a viable solution on the battlefield. Small caliber remote weapons have a variety of benefits in comparison to Soldier-carried weapon systems, however they are limited in utility due to their size, weight, mobility, and ease of use on the battlefield. Currently, remote weapon systems are relegated to use as vehicle mounted platforms. In the right scenarios and circumstances, remote weapons could be used to take Soldiers out of harm’s way, and to fire unconventional and higher powered ammunition solutions that currently cannot be fired safely by a handheld weapon system. Thus, investments should be made in technologies that are directly related to remote weapon systems. Investments in this area could include technologies and studies intended to reduce power consumption, increase reliability, reduce system or component weight, improve usability, improve stability, reduce gunner burden, improve target acquisition, and improve accuracy of the remote weapon system. Technologies associated with externally powered weapons that are lightweight, low recoil, reduced size and that combine capability of .50 caliber and 40mm high velocity into a single system should also be pursued.

Proposed Investment to achieve the S&T Goals (in priority order)

Proposed Investment	Investment Description	Summary Linkages to JSSAST Top 50/PORs/ Transition	Proposed Lead Agency/Agencies
1. Accuracy / Controllability	Technologies and studies to assess and improve accuracy and controllability with Soldier in the loop	JSSAST Top 50: 1-5 15-29 31, 33,35,50	ARDEC / ARL(HRED)

2. Advanced Weapon Operation	Technologies and studies to assess and facilitate the operation of the weapon system with novel or advanced ammunition concepts required to meet lethality requirements.	JSSAST Top 50: 1-5 15-29 31, 33,35,50	ARDEC / ARL(WMRD)
3. Signature Reduction	Technologies and studies to assess and improve weapon signature suppression.	JSSAST Top 50: 7 11-14 30, 32	ARDEC/ARL (HRED&WMRD)
4. Maintenance and Reliability	Technologies and studies to assess and improve weapon system maintainability and life.	JSSAST Top 50: 8-10 13-14 38-39 41	ARDEC
5. Enabling Weapon Technology Areas	Technologies and studies that do not directly address a JSSAST Top 50 Area, but that will need to be considered when addressing the JSSAST Top 50 Areas	JSSAST Top 50: All	ARL/ARDEC
6. Remote Weapon Technologies	Technologies and studies in the area of remote weapon systems	JSSAST Top 50: All	ARDEC

Table 6-2 Proposed Investment to achieve the S&T Goals as related to Weapon Systems and Enablers

Lead Shape Watch Analysis:

Each Proposed Investment had a peer reviewed "LEAD", "SHAPE", "WATCH" analysis created to justify the need for the investment. Definitions used in this and the following sections for the analysis are as follows:

Lead:
Maintain in-house technical expertise (knowledge, skills and abilities), infrastructure, equipment, and/or level of investment in support of unique Army needs.

Shape:
Leverage significant industrial, academic and other agency capabilities and resource, shaping them for Army-specific applications and environments, as needed.

Watch:
Attentive monitoring of S&T research, discoveries, and trends in technology areas that do not address unique Army requirements and within which development will occur without dedicated Army S&T involvement.

1. Accuracy / Controllability: **(LEAD)** Accuracy and controllability studies are required by the military in order to understand the contributors to accuracy and controllability to small arms systems, and to understand the technical opportunities and challenges associated with improving the Soldier's ability to control the weapon system during firing and to improve the time that it takes to hit a target, particularly for a follow on shot. With the ongoing Small Arms Ammunition Configuration Study (SAAC), and the Future Advanced Squad Technologies (FAST) Program, the Army LEADs this area, and should continue to LEAD, since higher powered ammunition is likely to require advanced controllability technologies to combat high recoil. Firing this type of ammunition at long ranges, through fully automatic weapon systems, and with the need to quickly take follow on shots is a military-unique requirement set. The Army is currently the LEAD for the design of advanced ammunition technologies that will need to be integrated with controllable and accurate weapon systems, and these systems should be developed concurrently. Industry/Academia are not leading this area because the advanced systems are not currently required or in demand. Military should LEAD this area to include recoil reduction technologies, controllability studies, active stabilization technologies, user interface technologies, advanced barrel technologies to meet more stringent accuracy requirements through a wide range of varying environmental conditions, and any weapon system and enabler technologies that have the ability to reduce Soldier-induced aim error. It can be noted that Industry currently leads in active stabilization, however this is an area where an Army LEAD will permit better integration of the weapon with the active stabilization system.

2) Advanced Weapon Operation: **(LEAD)** Much like accuracy and controllability, Military should LEAD advanced weapon operation, since many of the anticipated ammunition technologies are currently in development by the Military, rather than by Industry or Academia, and due to the unique needs of the Military (in comparison to the civilian world) as far as range, accuracy, and terminal ballistics. The Military should LEAD the development of advanced mechanisms, and the research and application of advanced materials and materials processing that will facilitate weapons to operate with advanced ammunition solutions.

3) Signature Reduction: **(LEAD)** The Military should LEAD the area of signature suppression due to their unique needs, particularly for sound suppression levels, as well as for durability, maintenance, and reliability of the signature suppressors. The Military should LEAD signature reduction by maintaining in house technical expertise, knowledge, skills, and abilities in order to perform in house experimentation and research into the technologies, trade-offs, and performance associated with signature suppressors. The Military currently has a large amount of expertise in the area of signature suppression due to various development and

modeling efforts. In particular, the Army has developed several signature suppressors, muzzle device attachment methods, and has developed tools and methods to model and test signature suppressors, including computational fluid dynamics models, finite element models, and testing techniques that are Military driven, rather than Industry or Academia driven. The Military should also use the understanding of their unique requirements to SHAPE the development of signature suppressors, since there are currently a wide array of commercially available, and commercially developed signature suppressors for small arms systems, as well as numerous commercial designers and manufacturers. These commercial entities presumably have numerous lessons learned from their suppressor design, and have the expertise and infrastructure already in place to develop and manufacture suppressors based on Military requirements. The Military must also LEAD in the area of standardized quick attach/detach interfaces for signature suppression devices, since currently each manufacture has proprietary methods of attaching suppressors to flash hiders or other muzzle devices. This is expected to become more and more important as suppressors proliferate the battlefield, and could potentially benefit from NATO standardization as well.

4) Maintenance and Reliability: **(LEAD and SHAPE)** Industry should LEAD in the area of development of advanced surface treatments due to their existing infrastructure and expertise in this area. The Military should LEAD in the application of advanced surface treatments to small caliber weapon systems due to their unique needs in this area. These technologies fall under JSSAP's Small Arms Material and Process Technology IPT, and include Durable Solid Lubricants (DSL). The Military should also LEAD in the areas of analysis, particularly in failure predictions, since the Army has specific and unique requirements for both the use and the life of weapon parts, which may change over time. The Military must develop and maintain in-house technical expertise in advanced analysis methods, including mathematical and physics based modeling and failure prediction analyses based on operationally and militarily relevant scenarios and environments. The Military should also LEAD in areas of reliability studies, including studies of the reliability of different types of operating and feed systems in operationally and militarily relevant scenarios and environments. The Military should LEAD in the area of barrel life and advanced barrel technologies due to their unique needs in terms of thermal loading, accuracy across a wide temperature range, and overall barrel wear under harsh operational conditions. The Military should SHAPE maintenance and reliability by providing Industry and Academia with the current and anticipated capability gaps associated with maintenance and reliability, including improved wear, reduction of maintenance, improved corrosion resistance, and improved fatigue life to ensure solutions meet Army needs.

5) Enabling Weapon Technology Areas: **(LEAD and SHAPE)** The Military should LEAD the development of other enabling weapon technologies. Primarily, with the exception of fire control which is covered separately, this includes weight reduction (load reduction to the soldier), ergonomics, and communication and integration of fire control components. Specifically in the area of integration and interfaces,

powered rails, and communication, the Military must LEAD this area because the Joint Services must retain control over these interfaces, and NATO currently has a STANAG defining requirements for power and communication interfaces on NATO rails. Industry cannot be the owner of these interfaces. The Military should SHAPE studies that assess the Soldier's mobility, since the Marine Corps and Navy are already leaders in that area. The Military should continue to LEAD in the area of lightweight materials work through the various military labs that are working on R&D in that area, and by leveraging work done by Industry and Academia, since this covers the gamut of not only advanced lightweight materials, but advanced processing and design theory which would be specific to the particular weapon system. The Military is already a LEADER and should continue to LEAD in the area of nano-materials and 3D printers.

6) Remote Weapon Technologies: **(LEAD)** The Military is currently the leader in remote small arms weapon technologies, and should continue to LEAD that area due to its unique needs regarding remote weapons and remote weapon stations on vehicles. The Army and Navy have both done significant work in this area already, and are currently leaders in the area. Integration is of paramount importance, and as such, the Military should LEAD integration of remote weapons onto various platforms, particularly in terms of maintaining full control and ownership over electrical and mechanical interfaces and communication. This may be an area where a NATO Standard would be necessary, and as such would indicate Military LEAD. Industry/Academia does not have the required mix of experts in both weapons and electro-mechanical systems to lead this area, however Industry may lead certain sub-areas if technology is already in place. In this case, the Military would be considered the LEAD for the integration portion, allowing the Joint Services to leverage Industry's expertise in sub-areas while integrating the proper technologies together to achieve systems that can be easily powered, communicate, and mount seamlessly to various vehicle platforms and fire various ammunitions.

7. Strategy: BA 6.2: Ammunition

Problem Statement

A community approved identification/selection on the best Science and Technology programs that can provide the most improved capability to the Soldier is a desired outcome of both the Small Arms Ammunition Configuration (SAAC) Study and JSTAC council. A cohesive community answer on the trades in capability, cost, and serviceability would allow senior leadership the ability to decide the best opportunities for the dollar, and better provide our Soldiers with the most capable solution the US military is willing to procure.

Recent system studies have shown that if the weapon system (ammunition, weapon, and fire control) are designed together in concert with Human Interface effects (recoil, weapon balance, and other metrics that can affect Soldier Aim error), then extremely significant improvements can be achieved. These significant enhancements are achievable because the improvements are synergistic in nature. As an example, if a new weapon system can increase the velocity of an existing cartridge (same projectile), the new weapon system extends the range in which the projectile's lethal mechanism can be effective, and it also improves the probability of hit, P(H), as the flatter fire reduces the sensitivity to ranging errors that occur. When implemented with fire control, still greater improvements are possible, as the flatter trajectories can drastically reduce the demands placed upon the fire control to achieve the desired P(H). Therefore the synergies among the various weapon system component improvements could result in performances beyond anyone's expectation.

Avoiding detection at a distance of 40m from the weapon by reducing acoustic signature at the muzzle is a very challenging task. Investigations into non-traditional systems such as subsonic and captive piston systems may apply to these problems although it is likely that these will be specialty systems and not a solution to an individual weapon. However, these systems will be inherently more sensitive to ranging error, as the velocities will be lower.

Scope/Objectives

The objectives of the group is identical to those listed in the Weapon Systems and Enablers Technology Development Strategy (ref), which may be boiled down to identify research and development areas needed to provide improvements in weapon systems that will provide our Soldiers an "Unfair Advantage" over our adversaries.

Linkage and Analysis to JSSAST Top 50 Approved Opportunity Areas:

The JSSAST Top 50 is a Joint Services prioritized listing of the small-arms deficiencies that the services are requesting S&T to address in any way possible. Of the "Top 50" listing, see Table 8, thirty-three of these can be addressed through ammunition developments, which are highlighted in blue. These same thirty-three items would be better addressed through the joint development of the weapon, ammunition, and fire control. The co-development of the system parts, would allow better decision making on

the individual components, as to where the trades between how much risk/reward can be gained on the overall system, and how the changes in individual components can be used to compensate for deficiencies in other components.

The thirty-three ammo/weapon system items highlighted can be grouped together, as many of the technologies that would improve a single item would also address many other items in the list.

JSSAST Top 50

1	Engage Threat Personnel in Defilade from 15 to 500m
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m
6	Positively Identify Friendly Forces
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter
13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance
15	Engage Threats with Small Arms Volume Fire from 51 to 600m
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m
20	Engage Targets
21	Conduct Tactical Reconnaissance and Surveillance
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)
24	Determine Friendly, Enemy, Neutral, and Non-Combatant identification
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)
26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons
27	Breach Existing Entry Points with a Single Shot at 0m
28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation
29	Breach (6' x 4') from Distances Beyond 40 Meters
30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact
31	Breach Existing Entry Points with a Single Shot up to 50m
32	Signature Reduction System that Minimizes Projectile Muzzle Strike
33	Fire Disabling Fire with Small Arms
34	Collect Target Information
35	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°
36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges
37	Detect, Identify, Classify and Track Surface Contacts Visually
38	Corrosion Prevention and Control
39	System Accuracy of 5" Mean Radius at 300 Meters and 10" Extreme Spread at 600 Meters Throughout Barrel Life
40	Engage Surface Ships With Small Arms Gunfire (Including Precision Fire from Precision Marksman)
41	Barrel Life of 3,600 Rounds When Fired in Accordance with the OMS/MP
42	Determine Range to Target to ±1m from 0 to 1200m
43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)
44	Determine Range to Target to ±1m from 0 to 600m
45	Determine Range to Target to ±1m from 0 to 1000m
46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold Zero
47	Mark or Tag Targets to 1000m
48	Mark or Tag Targets to 2400m
49	Mark or Tag Targets to 3000m
50	Hit Targets from Defilade Position to Standard

Table 7-1 Binned Ammunition Areas against the JSSAST Top 50

Defilade Kill

The first and last item on the Top 50 is the development of a system for defilade kill. This is to be expected, as defilade kill is the hardest problem to attack, since the Soldier does not have the ability to directly see nor shoot the target. This makes just the pointing of the weapon a very challenging problem. Additionally, current weapon systems (for defilade target defeat) are extremely sensitive to ranging errors and are very limited in the maximum ballistic range. The technical challenges that S&T needs to address these limitations includes:

1) Overcoming the limited ballistic range
    a. Recoil constraints
    b. Ballistic constraints – glide/fly round to extended ranges
2) Implementation of GNC technologies that can adjust the trajectory to hit the target
    a. Navigation technologies small enough to implement into manportable system, yet accurate enough to get the desired effects
    b. Navigation technologies that can identify a target while in flight, adjust the desired impact based on tracking the target and guide the munition to the threat target
    c. Miniaturization of actuators and CPUs to Guide Projectile to location identified by the navigation
3) Fusing of warhead
    a. Develop an accurate fuse that can initiate the warhead to maximize the fragmentation of the warhead

Of these current technical challenges, the greatest payoff would come from investing S&T on the navigation portion of the problem. This could theoretically allow for the correction of the largest errors of the weapon system/Soldier. If automatic target acquisition could be implemented into a seeker, then the performance of these systems could completely change the entire battlefield, and provide our Soldier's an "Unfair Advantage".

Engage Threat Personnel with Small-Arms Fire

Opportunity Areas (from Table 7-1) Items 2-5, 15-20, 33 and 39 are all Small-Arms technology challenges. These challenges can be broken down to the Ability to Hit the target and the ability to get the desired response (incapacitate the adversary).

Opportunity Areas (from Table 7-1) Items 2 & 19 deal with engagements in Close Quarters Battle (CQB), ranges less than 50 meters. The primary reason these areas need S&T investments is the difficultly in hitting the target within the time constraints placed upon the Soldier to shoot first. The time constraint causes an error called reflexive Pointing error, and it is not a weapon/ammo problem. However, the emergence of new armors to stop State-Of-The-Art (SOTA) Armour Piercing (AP) rounds, even at muzzle velocity, is clearly a weapon/ammo problem that needs to be addressed.

Opportunity Areas (from Table 7-1) Items 3-5 and 15-18 can all be addressed/drastically improved with the implementation of ballistic technologies and manufacturing technologies that allow three things:

1) Increased Muzzle energy
    a. Technologies that meet safety constraints (noise, muzzle pressure) yet increase velocity/muzzle energies
    b. Exotic Launch mechanisms (sabot, taper bore, etc)
    c. Improved Propellant – higher energy densities, multiperf-deterred, etc
    d. Reduced Bore Resistance Projectiles
2) Implementation of Low-drag Shapes and maintain/improve dispersion
    a. Implementation of lower drag shapes with no sacrifice to or even improved penetration
    b. Provide “Match-like” ammo dispersion with tactical/improved full bore mechanisms
    c. Improved Transitional Ballistic understanding to enable precise sabot-discard projectiles
3) Improved Penetration mechanisms
    a. Reduce the energy to perforate “toughest targets”
    b. Improve behind armor lethality against protected targets to approach lethality against unprotected targets

Detection/Signature

This area of S&T is far less refined than other research areas because the basic understandings of physics of these systems are much less mature than other ballistic areas. However, the importance of these suppressive devices is becoming much more important with the push to higher energy systems in the future. The detection/signature field of research would encompass the items Opportunity Areas (from Table 7-1) 11-14, 30, and 32 from the “Top 50”.

Opportunity Areas (from Table 7-1) Items 11 and 12 relate to avoiding detection caused by weapon signature and can be broken into two distinct categories defined by the mechanism of detection. The basic detection means are visual and acoustic both of which are very different in manifestation and mitigation approach.

Acoustic Detection

Avoiding detection at a distance of 40m from the weapon by reducing acoustic signature at the muzzle is a very challenging task. Typical signature levels of suppressed weapons approach 138-140 dB in relevant small arms systems. The levels required to avoid detection at 40m are on the order of 60-80 dB even with high levels of background noise (Level 1 environments MIL-STD-1474D). Flight noise of supersonic projectiles is approximately 135-140dB, and conventional semi/full automatic weapons have signatures of 120-140 dB purely from the operation of the action even in the absence of ammunition. Investigation in to non-traditional systems such as subsonic and captive

piston systems may apply to these problems although it is likely that these will be specialty systems and not a solution to an individual weapon.

Visual detection

Assessing and mitigating the detection of muzzle flash is a much less understood and refined area when compared to the acoustic signature. Technical challenges exist in the basic understanding and mitigation techniques as well as the operationally relevant metrics by which they should be evaluated. It is important to determine what is important operationally in terms of what ranges are desired to be undetectable as well as what types of environments and background light levels will be most important. Defining time of day (full sun, overcast, dusk/dawn, moonless night, etc.) will be a necessary step as well.

The difficulty in predicting flash computationally stems from the complex chemically reactive and high speed mixing nature of the muzzle flow. Efforts into modeling the chemistry in conjunction with the flow field through devices designed to mitigate both acoustic and visual signature would be beneficial to the underlying understanding of the behaviors of the systems of interest.

Currently there are two main approaches the S&T community has undertaken to address the muzzle flash problem. The first approach is to mechanically modify the flow by using some device. Mechanically disrupting the formation of ignition sources such as mach discs, or other shock wave interactions are how traditional flash hiders have operated in the past and they have been very efficient. However the incorporation of blast mitigation devices makes this a more difficult problem, one approach could be the containment of the flash such that it is not externally visible (making the devices large), while another approach would be the modification of flow, each of these approaches are not without risk.

The second approach is to chemically modify the conditions of the flow such that the flash is reduced or suppressed. Current propellant technology does this by the addition of flash suppressive compounds. There are multiple mechanisms that could be exploited including shifting the spectrum of the burning away from the visible regime, scavenging combustion ingredients, etc. However, more research in these areas may also highlight additional mechanisms in which to chemically modify the flash, and uncovering new mechanisms could have significant reductions in the visual signature.

Opportunity Areas (from Table 7-1) Items 13 and 14 relate to the impact to weapon performance when a mitigation device is incorporated into a weapon system. The first concern applies to the life of the mitigation device. Multiple efforts have demonstrated that by combining design features along with advanced materials, devices can withstand upwards of 15,000 rounds without failure. Material/manufacturing research in terms of advanced materials, and how to process them into relevant geometries for these devices, would help advance the state of the art and allow the life of the device to approach the life of the barrel.

The second weapon system concern is that the device should not degrade current performance. Systems currently exist that do not degrade weapon performance; therefore this becomes a design and engineering effort. However, performance needs to be defined more completely in order to adequately address this task, incorporating performance in lethality or weapon reliability, or some combination of both. Therefore system designs approach that addresses all components of the system simultaneously may be the best way to achieve this.

Breaching

The breaching research area would encompass Opportunity Areas (from Table 8) items 27, 29, 31, and 35 of the "Top 50" listing. ARL is currently researching this area by looking to perforate the toughest targets with large caliber systems. If new mechanisms can be developed to reduce the required energy, and provide standoff for the weapon system, then the research will be shifted to smaller systems to determine if scalability is possible.

Additionally, new energetic materials that can provide 3-10 times the amount of energy, If successful in the next 10 years, then these increases could potentially allow increase blast loads to be used to breach structures.

Training

The new ammunitions and weapon systems currently being fielded or considered, all have more efficient aerodynamic features and improved penetration mechanisms. These improvements are great for combat use, however they do cause concerns in Range Safety. The need to invest S&T into training ammunition that can fly with similar trajectories to the relevant training ranges, yet quickly decelerate and not exceed the containment of current training ranges is apparent. Additionally, the use CQB training facilities with the current crop of higher penetration capable ammunition, especially when combined with future higher energy systems, also raises concerns about the longevity of the training facilities, ricochet, and safety behind the barriers.

Potential Linkage to Current and Emerging Requirements:

The following emerging and current requirements documents represent the driving needs for Science and Technology investment in the area of weapon systems and enablers, ammunition, and optics and fire control. Each requirement is followed by discussion of how the development of technologies in each of the Technology Area Bins will influence or address the emerging or current requirement in order to meet PM and user needs.

1) **Family of Ammunition (FOA) CDDs T**he 5.56mm, 7.62mm, and 0.50 Cal FOA CDDs will be drivers for the ammunition technologies needed in current small arms weapon systems. The performance against the array of targets required by the improved ammunition solutions in the FOA CDDs directs the current 6.2 and 6.3 ammunition research.

2) **Family of Next Generation Squad Weapons (NGSW) Capabilities Development Documents (CDD)** The family of Next Generation Squad Weapons will include a Next Generation Squad Automatic Rifle (NGSAR), a Next Generation Squad Carbine (NGSC), and a Next Generation Squad Designated Marksman (NGSDM). The NGSAR will be the first CDD to come out. The draft CDD outlines a requirement for a new and improved automatic rifle for the Squad, which features increased accuracy and controllability, increased lethality and range, reduced weight, and reduced signature as compared to the current M249 Squad Automatic Weapon. The NGSC and NGSDM are expected to follow, and will follow the same overall approach of increased performance and reduced weight and signature. The NGSAR, NGSC, and NGSDM will need to incorporate technologies that enable higher energy ammunition/weapon systems, improved penetration mechanisms that can be implemented with better aerodynamic shapes, and the implementation of fire control that address Soldier Aim Error, Ranging/elevation correction, wind (at shooter as a minimum) correction, and temperature/elevation (air density, muzzle velocity changes) correction.

3) **Counter Defilade Target Engagement (CDTE) CDD** The new counter defilade solution, the XM25 will provide revolutionary capability. The technologies identified earlier in this document could enable the capabilities outlined in the CDD.

4) **Precision Sniper Rifle CPD** The Sniper community has the desire to increase their ability to hit at extended ranges over the current system (M2010). The Sniper community has recognized that a faster projectile that decays at a slower rate can increase their ability to hit the target by allowing their system to be less sensitive to ranging errors and wind. The CPD allows the purchase of a COTS rifle system, however follow on ammunition CDDs are expected to increase the weapon system's effects.

5) **Lightweight Dismounted Automatic Machine Gun (LDAM) CDD** Much like the family of NGSW, the LDAM CDD is expected to feature requirements for increased accuracy, range, and lethality, as well as reduced signature and weight. Thus, the LDAM will need to incorporate technologies listed in item 2 above.

6) **Fire Control CDD** The Fire Control CDD outlines the requirements for improved Fire Control Systems for legacy and future small arms systems. In particular, the Fire Control CDD could include requirements for technologies that decrease Soldier Aim Error (Accuracy/Controllability Technology Bin). While the overall requirements of the CDD will fall under "Fire Control," the implications of this CDD affect the future ammunition requirements, because if these systems are done properly, the ammunition could work synergistically with the improved fire control to allow the "weapon system", ammunition, weapon, and fire control, to fill the extremely aggressive Capabilities Based Assessment PH objectives. Thus, it is important to identify the potential for technologies in the area of weapon systems and enablers to combine with fire control systems to meet requirements in the Fire Control CDD.

7) **Small Arms Signature Reduction (SASR) CDDs**The Army and Special Operations Command (SOCOM) both have emerging requirements for Small Arms Signature Reduction. The SASR CDDs outline requirements for improved signature suppression for small arms systems, both legacy and future. Signature reduction in the SASR CDDs is expected to include visual, multi-spectral, thermal, and audible, and will include both firing and non-firing signatures. The Army and SOCOM CDD's will have some differences, but overall, both SASR CDDs will need to incorporate various technologies that fall into the Signature Reduction Technology Bin.

Science & Technology Strategy to achieve goals:

1. Many improvements in ammunition technologies in combination with weapon technologies may enable higher energy weapon systems to meet safety constraints. These technologies have demonstrated capabilities that were once thought impossible; however they do place additional demands upon the weapon system. Therefore weapons research to overcome these new demands will be required to help realize the potential payoff of these new ammunition concepts and muzzle pressure technologies.

2. Knowledge is incomplete regarding levels of noise, flash, IR signatures, and what levels of these signatures result in detections. A human study to systematically evaluate these signature types and their subsequent detectability in various combat terrains is necessary to better understand the trades available for propulsion and suppressor technologies. These studies are necessary for both improving performance and reducing detectability.

3. Increases in overall muzzle energy and options with higher energy density propellants could improve the performance of weapon systems and/or provide greatly increases energy from the weapon systems at the same cartridge weight. Additionally, research allowing one to shorten the cartridge case could reduce the overall weapon length and would be advantageous for increasing the lethality of the system.

4. Incorporating GNC into man portable systems is a very tough problem, as the projectile is quite small. However the implementation of GNC into weapon systems with high arching trajectories could have profound effect on the toughest targets to defeat, those that are either completely or mostly covered in defilade. The technologies that need to be researched are: Seeker navigation that allow the munition to adjust while in flight, navigation to increase the rounds accuracy of self-location, and to a lesser extent, the miniaturization of actuators.

5. Significant improvements have been achieved in the area of ammo development that drastically reduces the energy required to perforate the toughest targets. However, still more efficient mechanisms are needed to further extend capabilities against current threat targets, and just as importantly, provide additional improvements against future threat targets. The implementation of new mechanisms into efficient, aerodynamic shapes is a key aspect of efforts looking at future growth of small-arms weapons.

Proposed Investment to achieve the S&T Goals (in priority order)

Man-portable systems performance is extremely interdependent to the entire system, Fire Control, Weapon System, and Ammunition. Therefore outlining the priority for just one portion of the weapon system would be detrimental to leaders' decision making process. Consequently the priority of all three areas will be outlined in this section.

The proposals outlined below assume that suggested studies in the SAAC and FAST studies are completed, thus limited information on recoil effects on Soldier Aim Errors are available.

Proposed Investment	Investment Description	Summary Linkages to JSSAST Top 50/PORs/ Transition	Proposed Lead Agency/Agencies
1. Advanced Weapon Operation	Technologies that enable the advance ammunition concepts required to meet lethality requ to be fired.	JSSAST Top 50: 1-5 15-20 33,36,40	ARDEC
2. Signature Reduction	Human Factors Study to prioritize operational significance of weapon signature, i.e. the weighting of noise, flash, IR, etc.	JSSAST Top 50: 1-5, 7, 11-20, 30, 32, 33,36,40	ARDEC/ARL
3. Propulsion	Technologies to increase muzzle velocity, introduce compact cartridges, and lighten cartridge weight.	JSSAST Top 50: 1-5, 7, 11-20, 30, 32, 33,36,40	ARDEC/ARL
4. GNC for defilade kill	Technologies to improve navigation in man-port systems that are accurate enough to get desired affects	JSSAST Top 50: 1, 50	ARL/ARDEC
5. Improved Projectiles	Technologies to reduce energies required to perforate toughest targets and implement highly efficient aerodynamics	JSSAST Top 50: 1-5 15-20 33,36,40	ARL/ARDEC
6. Reduced Range Training Ammo	Technologies resulting in trajectories similar to the tactical round to relevant training ranges, and rapid deceleration	N/A	ARDEC/ARL

	beyond, to insure safe containment with Range		

Table 7-2 Proposed Investment to achieve the S&T Goals as related to Ammunition

Lead Shape Watch Analysis:

1. Advanced Weapon Operation: **(LEAD)** The Army has the need to increase weapon systems overmatch capability. One approach to do this, the weapon and ammo need to drastically increase the pressure of the system, while not exceeding the safety constraints (noise - hearing damage). These challenges are unique to the US military, where the importance of these systems is paramount for the dismounted Soldier. Unlike Industry, the Army has demonstrated approaches to overcome the largest hurdles for a high energy systems, which are the noise and recoil constraints.

2. Signature Reduction: **(LEAD/SHAPE)** The Army has the need to reduce the weapon system signature so the Soldiers' targets cannot detect them and return fire, this is a constraint that is not a consideration for industry whom is developing for the hunter. Some of the ammunition signature reduction efforts that need to be led by the Joint Services include One Way Luminescence, where the improvement in hit goes up for the follow on shots due to the ability to see the projectiles trajectory, however current technologies identify the Soldiers location. Additionally, the weapon signature for unlimited fire.

3. Propulsion: **(LEAD/SHAPE)** The need for higher energy density propulsion systems are unique to the Joint Services. Current small-arms powders are generically the same technologies that have been around for a century, and the industry continues to repackage through blending to provide incremental changes in the available energy. Research to reduce the weight of the ammunition through higher energy density propulsion is unique to the Joint Services.

4. GNC for defilade kill: **(LEAD/SHAPE)** The Joint Services need research to look at the various options for the navigation of the man-portable for extremely small actuators to increase the sphere of influence for individual Soldiers.

5. Improved Projectiles: **(LEAD/SHAPE)** The Joint Services have unique target sets that require a deep/significant understanding of penetration mechanics against/into of a wide array of targets. Currently the projectiles are becoming more complex for terminal ballistic reasons where the desire is to not just hit the target, but to incapacitate the target. Additionally, the Army is looking to implement more efficient aerodynamic shapes to improve hit, which do cause implications on the terminal response, and the ability to enable these technologies with reducing the terminal is imperative. However, industry does have the ability

to produce quality projectiles, and leveraging their needs to understand how specific bullet features (bore riding lengths, CG placement versus bore riding locations, etc.) on dispersion could allow Industry and the Joint Services the ability to reduce the dispersion of current and future projectiles.

6. Reduced Range Training Ammo: **(LEAD)** The new higher capability weapon systems will have drastically improved capabilities, which is great for the Soldier in combat, however the use of this ammo in training facilities that were developed for technologies developed in the 1960s will be far exceeded. Therefore a new training ammunition that can provide a reasonable training aid, while not destroying the training ranges will be imperative. Understanding how to aeroballistically get something to fly with an extremely similar trajectory at short ranges, stop significantly quicker, and provide comparable recoils to the future ammo systems will require significant research that industry will not tolerate the required investment for a cartridge that will likely only be sold to the Joint Services.

8. Strategy: BA 6.2 Optics & Fire Control

Problem Statement

Effectively focused Applied Research (6.2) will enable follow-on S&T developments that will improve the capabilities of warfighters to use small arms. Soldiers systems need improvements for detection, recognition, and identification of individual combatant targets out to the maximum effective ranges. These technologies implemented with aim augmentation, to enable the ability to hit those targets if the shooter desires, in day, night, total darkness (caves, tunnels), all weather conditions, and through battlefield obscurants; with reduced size, weight, and power and cost (SWaP-C) are very desirable for individual and crew served weapons.

Scope/Objectives

Reiterating, this discussion is limited to small arms; those of .50 caliber and smaller plus low velocity and high 40mm weapons systems.

Joint Publication 1-02 defines Fire Control as "The control of all operations in connection with the application of fire on a target." An amplifying generality is the distinction between (1) tactical fire control, the ability to optimally engage threats with weapons and effects, and (2) technical fire control, the ability to detect, identify, and acquire targets and provide an aiming solution to enable the weapon system's effect on target. Given that distinction, this discussion will address only technical fire control.

Generally accepted definitions having application to small arms are that fire control is the art of offsetting the direction of weapon's fire from the line of sight to a point that results in the projectile hitting the target point in space and time. These definitions apply to projectiles having guidance and controllability as well as to those having no maneuver authority in flight.

The fundamental fire control situation incorporates a myriad of factors such as target visibility (for small arms being the ability to detect, identify, and acquire the target point from the weapon system), corrections for projectile flight path due to environmental conditions, and relative movement between the weapon platform and the target point. The weapon fire control system incorporates the pertinent factors to provide the necessary aiming solution; mechanically, computationally, or otherwise.

Joint Publication 1-02 defines Detection as pertains to small arms as "1. In tactical operations, the perception of an object of possible military interest but unconfirmed by recognition." Recognition is defined as "… 2. In ground combat operations, the determination that an object is similar within a category of something already known; e.g., tank, truck, man."

Joint Publication 1-02 defines Identification as pertains to small arms as "1. The process of determining the friendly or hostile character of an unknown detected contact. In

ground combat operations, discrimination between recognizable objects as being friendly or enemy,"

The optics and fire control function therefore must enable the shooter to:

- Perceive that an object is in view that may be a target,
- Determine if the possible target is within the target category of being a person as is stipulated in this section,
- Distinguish if the individual as an enemy.

In this discussion "optics and fire control" will be considered a single subsystem of the weapon system. The optics portion consists of hardware that may or may not incorporate software, to detect and identify the target point. The optics portion may include sensors operating at frequencies anywhere within the electromagnetic spectrum, and is generally located on or in near proximity to the weapon. This discussion will not include optical devices designed to travel aboard the projectile toward the target.

For perspective, Department of Defense (DoD) Major Force Program (MFP) 6 Research and Development (R&D) Categories and Research, Development, Test, and Evaluation (RDT&E) Appropriations Budget Activities (BA) are categorized in Table 8-1.

MFP 6 R&D Category	RDT&E Appropriations BA	RDT&E Appropriations BA Title
6.1	BA 1	Basic Research
6.2	BA 2	Applied Research
6.3	BA 3	Advanced Technology Development
6.4	BA 4	Demonstration and Validation
6.5	BA 5	Engineering and Manufacturing Development
6.6	BA 6	RDT&E Management Support
--	BA 7	Operational System Development

Table 8-1 Appropriations Budget Activities (BA)

This section, as with other sections, is limited to BA 2, or 6.2, described as "Systematic study to understand the means to meet a recognized and specific need. It is a systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods. It may be oriented, ultimately, toward the design, development, and improvement of prototypes and new processes to meet general mission area requirements. Applied research may translate promising basic research into solutions for broadly defined military needs, short of system development. This type of effort may vary from systematic mission-directed research beyond that in Budget Activity 1 to sophisticated breadboard hardware, study, programming and planning efforts that establish the initial feasibility and practicality of proposed solutions to technological challenges. It includes studies, investigations, and non-system specific technology efforts. The dominant characteristic is that Applied Research is directed

toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters. Applied Research precedes system specific technology investigations or development." (Federal Acquisitions Regulations (FAR) Subchapter F, Special Categories of Contracting, Part 35, Research and Development Contracting).

The overarching objective of 6.2 Optics and Fire Control then is to demonstrate the feasibility of technologies that may enable the small arms shooter to fire within the conditions prescribed by the JSSAST Top 50 Opportunity Areas listed in Table 8-2, I would say this goal should be more aggressive filling the void/requirement outlined in the CBA of 0.5 PH at 500m.". The tenants of more effectiveness may include SWaP-C, affordability, versatility, reliability, accuracy, and responsiveness (simplicity, ease of burden, and function-ability for the operator and system lack of latency). The feasibility of technologies may be used to inform concept and requirements developers of the art of the possible and to provide technology demonstrations using prototype systems.

The JSSAST Approved Top 50 Opportunity Areas (OA) are listed in priority order. Each OA that applies to 6.2 optics and fire control can be considered as a required capability that:

- Is not achievable with current material and non-material solutions,
- Is based on a capabilities assessment or formally stated requirement,
- Requires an S&T investment to solve or overcome,
- Is defined by description of the requirement, not by prescribed developmental solution,
- Is generally aligned with a warfighter capability gap.

As implied above by the Problem Statement for 6.2 Optics and Fire Control, an end state achievable after near, mid, and far term S&T development is the capability of warfighters to use small arms for detection, recognition, and identification of individual combatant targets out to the maximum effective ranges of individual and direct fire crew served weapons, and to hit those targets if the shooter desires, in day, night, total darkness (caves, tunnels), all weather conditions, and through battlefield obscurants. Small size, low weight, low power consumption, and affordability are necessary characteristics. The JSSAST Approved Top 50 OA provide specific capabilities in prioritized order along the path to achieving that end state.

Analysis of JSSAST Top 50 Opportunity Areas (OA)

Table 8-2 indicates those stakeholder 6.2 projects and plans that address the JSSAST OAs.

"JSSAST Approved Top 50" Opportunity Area Index Number	Opportunity Area	Does this apply to 6.2 Optics and Fire Control?	6.2 projects or planned projects that address the Opportunity Areas (by stakeholder)							
			ARL	ARDEC	NVESD	USN	USMC	USAF	SOCOM	USCG
1	Engage Threat Personnel in Defilade from 15 to 500m	Yes								
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m	Yes			X		X			
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m	Yes			X		X			
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m	Yes			X		X			
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m	Yes			X		X			
6	Positively Identify Friendly Forces	Yes					X			
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature	Yes								
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments	Yes					X			
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions	Yes					X			
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP	Yes					X			
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle	No								
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter	No								
13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life	No								
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance	No								
15	Engage Threats with Small Arms Volume Fire from 51 to 600m	Yes			X					
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m	Yes			X		X			
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m	Yes			X		X			
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m	Yes			X		X			
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m	Yes			X		X			
20	Engage Targets	Yes			X		X			

"JSSAST Approved Top 50" Opportunity Area Index Number	Opportunity Area	Does this apply to 6.2 Optics and Fire Control?	6.2 projects or planned projects that address the Opportunity Areas (by stakeholder)							
			ARL	ARDEC	NVESD	USN	USMC	USAF	SOCOM	USCG
21	Conduct Tactical Reconnaissance and Surveillance	Yes					X			
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)	Yes			X		X			
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)	Yes			X		X			
24	Determine Friendly, Enemy, Neutral, and Non-Combatant identification	Yes					X			
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)	Yes					X			
26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons	No								
27	Breach Existing Entry Points with a Single Shot at 0m	No								
28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation	Yes			X		X			
29	Breach (6' x 4') from Distances Beyond 40 Meters	No								
30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact	No								
31	Breach Existing Entry Points with a Single Shot up to 50m	No								
32	Signature Reduction System that Minimizes Projectile Muzzle Strike	No								
33	Fire Disabling Fire with Small Arms	Yes			X		X			
34	Collect Target Information	Yes			X		X			
	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°	No								
36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges	Yes			X		X			
37	Detect, Identify, Classify and Track Surface Contacts Visually	Yes					X			
38	Corrosion Prevention and Control	No								
39	System Accuracy of 5" Mean Radius at 300 Meters and 10" Extreme Spread at 600 Meters Throughout Barrel Life	No								
40	Engage Surface Ships With Small Arms Gunfire (Including Precision Fire from Precision Marksman)	No								
41	Barrel Life of 3,600 Rounds When Fired in Accordance with the OMS/MP	No								
42	Determine Range to Target to ±1m from 0 to 1200m	Yes			X		X			
43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)	Yes			X		X			

"JSSAST Approved Top 50" Opportunity Area Index Number	Opportunity Area	Does this apply to 6.2 Optics and Fire Control?	6.2 projects or planned projects that address the Opportunity Areas (by stakeholder)							
			ARL	ARDEC	NVESD	USN	USMC	USAF	SOCOM	USCG
44	Determine Range to Target to ±1m from 0 to 600m	Yes			X		X			
45	Determine Range to Target to ±1m from 0 to 1000m	Yes			X		X			
46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold Zero	Yes			X					
47	Mark or Tag Targets to 1000m	Yes			X					
48	Mark or Tag Targets to 2400m	Yes			X					
49	Mark or Tag Targets to 3000m	Yes			X					
50	Hit Targets from Defilade Position to Standard	Yes								

Table 8-2 Stakeholder 6.2 projects and plans that address the JSSAST OAs

Technology Area Bins

The capabilities described in the Problem Statement for this section will have been demonstrated to be feasible; that is, the 6.2 end state will be achieved, by applying specific technologies to develop the JSSAST Top 50 OA for 6.2 optics and fire control. Those technologies can be grouped into seven technology area bins.

1. Optics Sensors, Imagers, and Displays. This broad grouping of technologies includes optics, micro-electronics, micro-electromechanical systems (MEMS), thermal, modeling, materials, and manufacturing sciences to develop low SWaP-C sensors integrated across all of or parts of the visual, near-short-mid-long wavelength infrared (Vis-NIR-SWIR-MWIR-LWIR) range of frequencies. Technologies for protecting optics, sensors, and imagers from intentional and non-intentional attack is included. The optics sensors will have variable fields of view and depths of focus, and must be operational over the environmental temperature range specified for small arms. The optics may be direct view, fully electro-optical, or a combination. Identifying pertinent target indicators within images may be accomplished by manually selecting views from among the frequency bands, by automatic hopping between bands, or by automatic multi-image fusion. Probable targets may be highlighted within the operator's viewing device automatically by application of pixel discrimination software. The imaging sensors may be connected with decision logic to the weapon firing sequence to mitigate the wandering aiming error inherent with operator-weapon movement, and ensure the shot is made automatically at a time after the trigger pull when the aim is indeed accurate.

2. Deformable Visible Optics. DVO (direct view optics) have played an indispensable role in the warfighter's ability to sight and engage targets. Current configurations have set magnifications. Technologies within this bin will involve development of new deformable optics materials that will provide the warfighter with a range of

magnifications and focal lengths. These technologies will include new materials (polymer, metamaterials) that will lead to economical manufacturing of deformable DVO.

3. Enhanced Ballistic Computer. Efforts within this bin investigate and develop optics and fire control technologies in order to provide a single ballistic solution to the warfighter. This includes algorithms, technologies, and studies to assess and facilitate the accuracy of the weapon system with new ammunition. Included in this area are solutions to range and elevation under various environmental conditions to include ranges of humidity and temperature.

4. Active Barrel Stabilization. Active barrel stabilization for small arms is a means of mitigating or negating the aiming errors caused by inherent shooter introduced disturbances in his interface with the weapon. The techniques incorporate a decoupling or separation of the traditional rigidity between the barrel and the stock, to enable a sensor-actuator-motor system to control the barrel aiming point though the stock will not be steady. The control system technologies may include piezoelectric crystal, MEMS, and other accelerometer applications, and various control methodologies to compensate for movement and firing shock, impulsive motion signals, vibrations, and automated system drift.

5. Human Tagging, Marking, and Tracking. The ability to mark and keep track of an individual within a crowd is a critical component of confronting and containing threats in urban battlefields. Technologies within this bin will develop new algorithms able to track a target in the midst of many other targets without creating an unacceptable number of false alarms. Technologies include biometrics to track unique human features (facial, gait, etc.) coupled with innovative software solutions.

6. Wind and Environmental Sensing. Environmental effects have a major effect on a bullet's trajectory. Wind sensing has emerged as a critical component in targeting precision. Technologies within this bin include methods to calculate down range wind velocities and incorporate those findings into a ballistic solution for the shooter. Technologies to be developed include means of scintillation mitigation and other novel approaches.

7. Steerable Range Finding. Technologies within this bin include algorithms to actively track targets using piezoelectric approaches that also have ability to actively determine range. A reliably steerable beam is required as well as new and improved tracking algorithms.

8. Ballistic Trajectory Shaping and Off-path Lethality. Though optical devices designed to travel aboard the projectile toward the target are not included within this 6.2 optics and fire control section, other means of providing projectile guidance to alter the ballistic trajectory are included, plus abilities to engage targets in defilade such as by fragmentation effects for enemy located behind retaining walls. Technologies within this bin include laser and electromagnetic spectrum signal steering, aerodynamic control authority, spin-count algorithm, and MEMS fuzing and safety and arming technologies.

Potential Linkage to Current and Emerging Requirements

Successful 6.2 technology transitions for optics and fire control will generally move projects from demonstration of feasibility to demonstration of utility (from 6.2 to 6.3) and then out of the S&T realm where the technologies can be applied to future operational capabilities. Many of the technologies described within the technology area bins have linkages to requirements documents describing those future operational capabilities:

1. **Optics Sensors, Imagers, and Displays:**
   - Small Arms Capabilities Based Assessment (CBA),
   - Joint Small Arms Capabilities Assessment (JSACA), and
   - Squad (SQD) CBA.

2. **Deformable Visible Optics:**
   - Small Arms CBA,
   - JSACA, and
   - SQD CBA.

3. **Enhanced Ballistic Computer:**
   - Small Arms CBA,
   - JSACA, and
   - Next Generation Squad Weapons (NGSW) Draft Capability Development Document (CDD).

4. **Active Barrel Stabilization:**
   - SQD CBA and
   - NGSW Draft CDD.

5. **Human Tagging, Marking, and Tracking:**
   - Squad (SQD) CBA and
   - NGSW Draft CDD.

6. **Wind and Environmental Sensing:**
   - Small Arms CBA,
   - JSACA, and
   - SQD CBA.

7. **Steerable Range Finding:**
   - Small Arms CBA,
   - JSACA, and
   - SQD CBA.

8. **Ballistic Trajectory Shaping and Off-path Lethality:** SQD CBA.

S&T Strategy to Achieve Goals

The strategy to achieve the technology development successes within the scope of 6.2 that will enable follow-on S&T developments to improve the capabilities of warfighters to use small arms for detection, recognition, and identification of individual combatant targets out to the maximum effective ranges of individual and direct fire crew served weapons, and to hit those targets if the shooter desires, in day, night, total darkness (caves, tunnels), all weather conditions, and through battlefield obscurants; with reduced SWaP-C, is built upon transitioning 6.2 technologies for:

- [Priority 1] Individual warfighters in the near- to mid-term,

- [Priority 2] Crew served weapons teams in the near- to mid-term, and

- [Priority 3] Squad as a system in the mid- to far-term.

With that prioritization, transitioning the 6.2 technologies will involve successfully developing their feasibility and practicality generally to inform concepts and requirements developers of the art of the possible and to provide technology demonstrations using prototype systems.

The three part prioritization and the transitioning time-frames are intended to apply to each of the JSSAST Approved Top 50 OA that apply to 6.2 optics and fire control. However the S&T strategy is more systematically approached and achievements measured if the metrics considered are grouped within the eight Technology Area Bins.

Proposed Investment to Achieve the S&T Goals (in priority order)

Proposed Investment (Technology Area Bin)	Investment Description	Summary Linkages to JSSAST Top 50 / PORs / Transition	Proposed Lead Agency
1. Optics Sensors, Imagers, and Displays	Technologies and studies to assess and improve low SWaP-C sensors.	JSSAST Top 50: 1-10, 15-25, 33-34, 36-37, 42-50	NVESD
2. Deformable Visible Optics	Technologies and studies to assess and facilitate economical manufacture of deformable visible optics.	JSSAST Top 50: 1-10, 15-25, 33, 36-37, 43, 46	ARDEC
3. Enhanced Ballistic Computer	Technologies and studies to assess and improve fire control for weapons.	JSSAST Top 50: 1-6, 8-10, 15-25, 33-34, 36-37, 43, 46, 50	ARDEC

Proposed Investment (Technology Area Bin)	Investment Description	Summary Linkages to JSSAST Top 50 / PORs / Transition	Proposed Lead Agency
4. Active Barrel Stabilization	Technologies and studies to assess and reduce aiming errors through barrel stabilization.	JSSAST Top 50: 1-5, 8-10, 15-20, 22-23, 25, 33, 36, 43, 46	ARDEC
5. Human Tagging, Marking, and Tracking	Technologies and studies to assess and facilitate capabilities for tagging marking and tracking.	JSSAST Top 50: 1-6, 8-10, 15-25, 33-34, 36-37, 43, 46-50	NVESD
6. Wind and Environmental Sensing	Technologies and studies to assess and improve ballistic solutions through the addition of wind and environment sensor inputs.	JSSAST Top 50: 1-5, 8-10, 15-20, 22-23, 25, 33-34, 36, 43, 46, 50	ARDEC / NVESD
7. Steerable Range Finding	Technologies and studies to assess and improve reliability of laser beam steering coupled with new and improved tracking algorithms.	JSSAST Top 50: 1-5, 7-10, 15-25, 33-34, 36-37, 42-50	NVESD
8. Ballistic Trajectory Shaping and Off-path Lethality	Technologies and studies to assess and improve ballistic trajectory through projectile guidance.	JSSAST Top 50: 1-5, 7-10, 15-20, 22-23, 25, 33-34, 36, 42-46, 50	ARDEC / NVESD

Table 8-3 Proposed Investment to achieve the S&T Goals as related to Optics & Fire Control

Lead Shape Watch Analysis:

1. Optics Sensors, Imagers, and Displays: **(LEAD)** Current BA 6.2 plans for collaboration through upcoming POM periods have ARDEC and NVESD in Lead roles with USMC in Shape, being monitored by JSSAP. All four stakeholders are fully engaged with and able to leverage industry's multiple, disparate dual use approaches for military and commercial sportsmen markets. Industry efforts are generally seeking spectrum specific breakthroughs and integrated sensors having low SWaP-C which will also shape this technology area bin.

2. Deformable Visible Optics: **(LEAD)** BA 6.2 investments by ARDEC achieve the Lead role for the pertinent technologies, being monitored by JSSAP. ARDEC, NVESD, and USMC S&T out-year pursuits may well insert their influence in future POM periods, dependent to an extent on industry's potential successes in what are currently very few efforts squarely within this bin.

3. Enhanced Ballistic Computer: **(LEAD/SHAPE)** Basic Research Investment and near term plans by ARDEC and NVESD place them in Lead, with USMC focused on likely supervised autonomy remote weapons station applications toward a Shape role, all being monitored by JSSAP. Industry efforts are widespread, generally having eventual dual use development interests, and continue to be monitored by all Government entities.

4. Active Barrel Stabilization: **(LEAD/SHAPE)** Current BA 6.2 investment plans by ARDEC and JSSAP place them in Lead, with USMC focused applications likely for supervised autonomy remote weapons stations toward a Shape role. JSSAP involvement in a coordinating role will remain prudent. Industry's efforts suitable for military applications are generally dependent on Government interests and resourcing.

5. Human Tagging, Marking, and Tracking: **(LEAD/SHAPE)** Through upcoming POM periods, industry Basic Research efforts will likely Lead, with ARDEC and NVESD planned BA 6.2 investments most likely taking a Shape role in developing the algorithms able to effectively track a target in the midst of many other targets, in developing biometrics to track human features such as facial and motion, and in developing novel software solutions.

6. Wind and Environmental Sensing: **(LEAD)** BA 6.2 investments by ARDEC Lead in developing applicable technologies, being monitored by JSSAP. Novel Industry approaches must be categorized as being in a Shape role, generally furthering immature technologies for future dual use applications.

7. Steerable Range Finding: **(LEAD)** NVESD BA 6.2 investments apply to the sensing portion of technologies that apply to this technology area bin. JSSAP is monitoring. Industry involvement within the Basic Research arena is diverse with eventual results of uncertain final outcome.

8. Ballistic Trajectory Shaping and Off-path Lethality: **(LEAD)** JSSAP must lead this BA 6.2 technology area bin; the other Government stakeholders have no near-term POM investment plans. Previous Government and Industry efforts have produced technology demonstrators. Further tangible Government plans to develop innovative laser and electromagnetic spectrum signal steering,

9. Strategy: BA 6.2 Scalable Effects

1. Purpose:

Today, modern small arms for the Joint Force must become increasingly durable, portable, accurate, and precise, yet remain sufficiently agile in the escalation of force continuum to support missions ranging from peacekeeping, support and reconstruction operations, counter-insurgency operations, to full-scale war. The ultimate role of small arms technologists is to invent the next generation of world class weapons to best arm the warrior with practical tools which are both simple to use, and yet sufficiently robust to deliver a decisive advantage over an otherwise superior enemy. The purpose of the Joint Services Small Arms Advisory Panel (JSSAP) Science & Technology (S&T) Advisory Council (JSTAC) is to develop small weapons and ammunition that will best support America's warfighters to effectively operate in an increasingly complex and lethal battlefield of the 21st Century.

2. Objective:

New and disruptive, paradigm changing next-generation technology requires extensive research and development.[1] The objective of the JSTAC is to prioritize investments in small arms S&T to identify, leverage, and deliver innovative small weapons technologies and solutions which will better equip, empower, and enable warfighters for the future. Small arms shall capitalize on the latest technologies to become more durable, low cost, flexible, and that arm the Joint Warfighter with a decisive edge. JSTAC members shall cooperate to synchronize their various S&T investments to design small arms to become lighter, more portable, more agile, and which offer increasingly accurate scalable effects ranging from non-lethal deterrence to decisive lethal force.

3. Linkage and Analyses to the JSSAST Top 50 Approved Opportunity Areas:

The following "Top 50 Approved Opportunity Areas" shall be considered when considering scalability of small arms effects:

Area Index	Opportunity Area
1	Engage Threat Personnel in Defilade from 15 to 500m
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m
6	Positively Identify Friendly Forces
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter

[1] William McRaven, *Spec Ops: Case Studies in Special Operations Warfare: Theory and Practice*, 1995, p. 388.

13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance
15	Engage Threats with Small Arms Volume Fire from 51 to 600m
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m
20	Engage Targets
21	Conduct Tactical Reconnaissance and Surveillance
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)
24	Determine Friendly, Enemy, Neutral, and Noncombatant identification
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)
26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons
27	Breach Existing Entry Points with a Single Shot at 0m
28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation
29	Breach (6' x 4') from Distances Beyond 40 Meters
30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact
31	Breach Existing Entry Points with a Single Shot up to 50m
32	Signature Reduction System that Minimizes Projectile Muzzle Strike
33	Fire Disabling Fire with Small Arms
34	Collect Target Information
35	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°
36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges
37	Detect, Identify, Classify and Track Surface Contacts Visually
38	Corrosion Prevention and Control
39	System Accuracy of 5" Mean Radius at 300 Meters and 10" Extreme Spread at 600 Meters Throughout Barrel Life
40	Engage Surface Ships With Small Arms Gunfire (Including Precision Fire from Precision Marksman)
41	Barrel Life of 3,600 Rounds When Fired in Accordance with the OMS/MP
42	Determine Range to Target to ±1m from 0 to 1200m
43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)
44	Determine Range to Target to ±1m from 0 to 600m
45	Determine Range to Target to ±1m from 0 to 1000m
46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold Zero
47	Mark or Tag Targets to 1000m
48	Mark or Tag Targets to 2400m
49	Mark or Tag Targets to 3000m
50	Hit Targets from Defilade Position to Standard

Table 9-1 Top 50 Approved Opportunity Areas referenced to Scalable Effects

4. Concept of Operations (CONOPS):

"In this new global political environment—distinguished by digital networks and worldwide flows of capital, material, people, and information—the geography of threats and crises grow more complex. While most security challenges remain rooted in a place or region, many will be driven by—and in turn drive—transnational dynamics."[2] Previous conventions of who the combatants are, and what constitutes a battlefield have decidedly shifted beyond conventional norms, so that today military operations are at once having to deal with complex clashes not against countries, but against threats who do not wear uniforms, who hide themselves among civilians to shield themselves from attacks.

[2] *Capstone Concept for Joint Operations* (CCJO*): Joint Force 2020,* 10 September 2012, p. 3.

In this fragile world, extensively connected by the internet and in which sabotage and terrorism yield profound public relations effects, adversaries can more quickly and easily escalate a conflict laterally, including to the U.S. homeland.[3] This unprecedented speed of escalation of combat - and its attendant wide publicity - will make any immediate actions at the **lowest** levels by a military force (*hereafter referred to as a squad (*SQD)) operating within the air, land, sea, space and cyberspace domains even **more critical to the success of military operations.** Furthermore, today's SQDs are also likely to experience a wide spectrum of challenges in the span of a few hours and within the space of a few contiguous city blocks.[4]

5. Small Arms Effects:

A SQD must be able of apply scaled effects through the application of multi-layered, active and passive, lethal and non-lethal measures, within their air, land, sea, space, and cyber-space domains, across a wide range of military operations (ROMO). The SQD must be armed with simple to use yet robust small arms to overmatch their adversaries, and restrict them from employing capabilities that would prevent a SQD from taking decisive action at a time and place of its own choosing.[5] The scope of JSTAC S&T investments shall focus on developing individual personal defense, crew served, and selected mission-specific small arms (i.e., sniper rifles, subcompact weapons, counter-defilade, and shotguns) that deliver scalable effects to warfighters in combat, combat support, and combat service support roles.

5.1. Small Arms:

Small arms are those organic – man-portable, individual, and crew-served weapon systems - used mainly against personnel and lightly armored or unarmored equipment.[6] These organic small arms must be able to deliver "effects" which:

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[3] *CCJO*, p. 3.

[4] Ibid.

[5] *Protection Joint Functional Concept* (PJFC), 30 June 2004, pp. 4-5.

[6] *JP 1-02, Department of Defense Dictionary of Military Terms and Associated Terms*, 23 March 1994, p. 348.

- support a range of both counter-personnel and counter-material missions
- are readily scalable from non-lethal/less-lethal means to lethal force
- deliver their effects further than the enemy's weapons

Moreover, "Small arms system capabilities must complement and be integrated/synchronized with the higher level weapon systems fielded above and adjacent to the SQD level. Additionally, small arms must be capable of being operated in environments that include full daylight though low/no light and open though confined, complex urban terrain. Finally, SQD personnel must be capable of engaging point and area targets at ranges they are able to visually acquire and identify adversaries."[7]

5.2. Effects:

A SQD must have a capability to obtain a desired "effect" on the target populace that leads to achieving an objective. "Force application is the integrated use of maneuver and engagement to create those effects necessary to achieve the assigned mission objectives. Effects are the physical or behavioral changes to a system caused by the application of military force. The Force Application Joint Functional Concept (FAJFC) employs precision lethal and non-lethal means to immediately and continuously pressure enemy forces, gain battle space dominance, and achieve assigned objectives. These actions occur in all domains…Creating a favorable opinion … among the host-nation populous is critical to achieving mission objectives." [8] Scalable small arms effects are to be used by the SQD to either influence or compel a target populace as follows:

5.2.1. Influence - to alter the opinions and attitudes of a host-nation populace through the SQD's presence, and conduct.

Positive influence among the host-nation populace is achieved by applying the least amount of force required to neutralize encountered threats. A SQD should first seek to exploit all non-lethal capabilities as a complement to any compelling effects of a threat of lethal force. "Influence aims to effect behavioral change through non-lethal means. It is more a result of public perception than a measure of operational success. It reflects the ability of forces to operate successfully among the people of the host nation, interacting with them consistently and positively while accomplishing the mission. Here, consistency of actions, words, and deeds is vital. Influence requires legitimacy. Military forces earn the trust and confidence of the people through the constructive capabilities inherent to combat power, not through lethal or coercive means. Positive influence is

[7] *FY 2012-2013 Joint Service Small Arms Program* (JSSAP) *Annual Report*, p. 14.

[8] *Protection Joint Functional Concept*, dated 30 June 04, pp. 21-22.

absolutely necessary to achieve lasting control and compliance. It contributes to success across the lines of effort and engenders support among the people. Once attained, influence is best maintained by consistently exhibiting respect for, and operating within, the cultural and societal norms of the local populace."[9]

5.2.2. Compel - to maintain the threat — or the actual use — of non-lethal means or lethal force to establish control and dominance, effect behavioral change, enforce cessation of hostilities, arrange a truce, or negotiate a peace agreement.[10]

To compel aims to affect perceptions. The use of non-lethal means versus lethal force, and the perceived legitimacy of a SQD are closely interrelated. The SQD's legitimacy is vital to achieving compliance, and thus closely depends on how a host-nation populace perceives the SQD's efforts to limit its use of lethal force, and to avoid collateral damage. "The appropriate and discriminate use of force often forms a central component to success in stability operations; it closely ties to legitimacy. Depending on the circumstances, the threat or use of force can reinforce or complement efforts to stabilize a situation, gain consent, and ensure compliance with mandates and agreements. The misuse of force—or even the perceived threat of the misuse of force—can adversely affect the legitimacy of the mission or the military instrument of national power."[11]

5.3. Scalability:

Innovations must aim to eliminate obstacles that would otherwise complicate the execution of a mission.[12] Small arms innovations shall focus on the invention of future man-portable weapons to remain simple to operate and maintain, yet become more agile so as to provide the SQD with relative superiority to effectively influence or compel their target, despite the efforts of the enemy.[13]

To best provision the SQD with this requisite agility across an escalation of force continuum, the following nine (9) "effects" for designing "scalability" as a criteria into weapons plans:

(1) Escalation of Force (EoF)
(2) Range and Coverage
(3) Precision
(4) Interoperability

[9] *JP 5-0, Joint Operation Planning*, 11 August 2011, pp. III-30 – III-31.
[10] Ibid.
[11] Ibid.

[12] McRaven, p. 13.
[13] Ibid, p. 21.

(5) Adaptability and Reversibility
(6) Resilience
(7) Knowledge Empowered
(8) Expeditionary
(9) Speed and Time

Scalable effects investments for the JSTAC portfolio shall encompass the following areas:

(1) Small arms and ammunition that cover the non-lethal to lethal spectrum
(2) Small arms and ammunition which deliver effects at adjustable ranges and velocities
(3) Small arms and ammunition that offer non-kinetic energy solutions
(4) Small arms and ammunition which deliver limited range, low collateral damage

5.3.1 Escalation of Force (EoF) –

Escalation of Force (EoF) provides a SQD with flexible and scalable options to apply only the minimal force necessary to achieve desired effects, while precluding collateral damage and casualties to noncombatants. EoF scalability seeks to embrace the entire force continuum - from force protection, to controlling the battle space via non-lethal means, then leveraging a limited offensive power, and ultimately to the use of full offense power- to provide flexible and scalable capabilities which will reduce collateral damage, and which will ensure the safety of noncombatants and friendly forces. The focus of EoF is to provide small arms primarily for use in operations constrained by restrictive Rules of Engagement (ROE), and for use in environments complicated by a high ratio of noncombatants to combatants. EoF capabilities are essential in these difficult situations where an enemy is not clearly defined, the use of lethal force is a strategic concern, the threats are unclear, and where collateral damage is detrimental to mission success. But EoF must never inhibit the ability to use lethal force for self-defense, or when otherwise required. EoF should encompass the following spectrum of scalable options:

(a) Force protection – Force protection EoF measures are those actions taken to "mitigate hostile actions against Department of Defense personnel (to include family members), resources, facilities, and critical information."[14] A SQD must be able to employ small arms for effective force protection with a greatly reduced risk of detection, localization, and unnecessary hostile escalation.

(b) Force application – Force application is the integrated use of maneuver and engagement to create the effects necessary to achieve assigned mission objectives. Maneuver is the movement of forces into and through the battle space to a position of advantage in order to generate or enable the generation of effects on the enemy. It is an activity that is fundamental to force application. The ability

[14] *JP-1-02*, p. 126

of our joint forces to move quickly and freely within the battle space not only enables more accurate, rapid and decisive engagements, it can also pose insurmountable dilemmas for enemy forces as we prosecute actions within their decision-making cycle and preclude their ability to react effectively to our mission objectives. Accordingly, lighter and more agile weapon systems are highly desirable. Engagement is the use of kinetic and non-kinetic means in order to generate the desired lethal and non/less-lethal effects. Future capabilities must include not only the familiar kinetic weapons, but they must also effectively incorporate non-kinetic capabilities to create lethal and non/less-lethal effects to provide future joint forces enhanced flexibility in weapon/target matching and allow them to better engage targets constrained by collateral damage concerns."[15] The following shall constitute key EoF criteria:

- **Acquire/Hit** – The individual must be able to acquire and hit the target with a high probability of success - $P_{(s)}$.
- **Probability of Incapacitation** – Given that the individual acquires and hits the target, a high probability of incapacitation of the target (i.e., lethality) is required to successfully achieve scenario resolution - $P_{(i)}$.
- **Reliability/Logistics** – The lethal capability must be readily available and consistently reliable to the SQD, in any environmental condition.

The force application effects will range from non-lethal means to lethal force as follows:

- **Non-lethal means** - Non-lethal command post tasks focus on incapacitating and reversible effects against individuals with the intent of not causing permanent injury.[16] Non-lethal means offer the potential to compel all but the more committed threat individuals to desist. A SQD must be able to employ non-lethal means to reduce a threat's effectiveness without also impacting the Noncombatant populace. Minimizing casualties has become an important aspect to the success of military operations. Scalable effects for small arms will play a significant and strategic role in achieving mission success by avoiding unnecessary civilian casualties or collateral damage. The S&T investments in EoF are intended to develop capabilities to augment, but not replace lethal force. EoF capabilities that warn, deter, dissuade, and temporarily incapacitate non-threat and potential threat individuals with relatively reversible effects are essential characteristics of non-lethal EoF capabilities.[17]

[15] *Force Application Joint Functional Concept,* dated 05 March2004, pp. 10-12.

[16] *www.dtic.mil/ndia/2014armaments/WedCharles.pdf*

- **Lethal force** –The military profession is primarily "distinguished from others in society because of [its] expertise in the justified application of lethal military force."[18] The SQD will possess the small arms capability to destroy or neutralize the adversary and their capabilities, at any time and in any place, while minimizing fratricide and Noncombatant casualties.

5.3.2 Range and Coverage –

A SQD must be able to detect, recognize, acquire, and deliver its weapons effects against an enemy with a range and coverage overmatch advantage relative to an enemy's weapons. SQD capability to engage should extend to the range at which targets can be detected, identified and discriminated as a threat or non-threat.

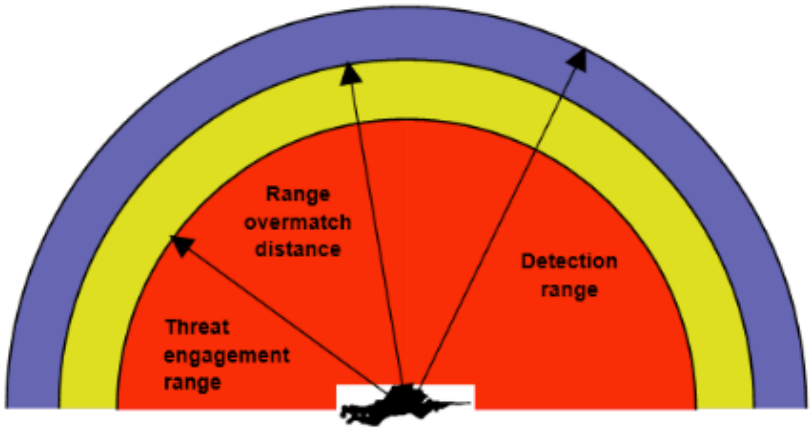

Figure D-1. SQD Range Overmatch.

The small arms target acquisition capabilities must support the engagement of threats at the SQD's maximum effective range. In order to deliver the desired battlefield effect, small arms systems must be able to hit the intended target. Additionally, a SQD must be able to deliver scalable effects at an optimal small unit range (10%–20% range overmatch) against like-sized threat elements (figure D-1). The small arms overmatch buffer provides a standoff range and coverage advantage to neutralize the target outside the enemy's maximum effective weapons range.[19] S&T efforts should strive to push the Range Overmatch Distance out to the maximum range at which targets can be detected, identified and discriminated as a threat or non-threat.

[17] *2012 U.S. Marine Corps S&T Strategic Plan*, 17 January 2012, p.21.

[18] *America's Military – A Profession of Arms White paper*, GEN martin E. Dempsey, CJCS. http://www.jcs.mil/Portals/36/Documents/Publications/aprofessionofarms.pdf.

[19] http://www.peosoldier.army.mil/docs/PEO_Soldier_Soldier_Battlefield_Effectiveness_White_Paper.pdf

5.3.3. Precision –

A SQD must be able to limit the amount of collateral damage caused, and to maximize the degree of protection achieved for personnel, physical assets, and information. Many non-lethal effects of fire are also accounted for in modeling although these tend to be physical effects. Small arms weapons system physical components that do not include the system operator should therefore be engineered for the highest repeatable mechanical accuracy, and to incorporate the most intuitive human interface that may be achieved within reasonable design, manufacturing, and reliability constraints. The following improvement of those more easily measurable small arms system performance and effects are recommend (organized by small arms capability area):[20]

- **Improved Lethality (Engage) -** pursue materiel improvements which focus on increasing lethal effects at sniper engagement ranges (beyond 1000 m).
- **Improved Accuracy (Engage)** - pursue improvements in small arms accuracy through development and fielding of augmented aiming devices, airburst capability with fire control, guided or steerable munitions, networked weapons, and laser range finders.
- **Improved Optics/Combat ID (Acquire) -** develop fused weapon sights and day/night optics integrated with a combat identification system for identifying targets in day, night, and limited-visibility conditions.
- **Improved Marking/Tagging Capability (Acquire) -** improve ability to mark/tag targets beyond 1000 m through the development of man-portable laser designators; improvements in 40 mm marking rounds; and continued development of non-lethal marking rounds.
- **Improve Signature Reduction (Avoid Detection) -** Pursue improvements in audible and visible signature reduction through the development and fielding of sound suppressors for weapon barrels and flash reduction/suppressive powders.

5.3.4. Interoperability –

The capability of the U.S. to project power across the globe is dependent on Joint interoperability, to include other government agencies and international/coalition partners. Accordingly, small arms system and configuration standardization and commonality should be incorporated to greatly increase interoperability and logistic supportability. Use of Mission, Enemy, Terrain, Troops -Time available, and Civilian considerations (METT-TC) guidelines can also help to identify desired platform characteristics to carefully balance unique user requirements with standardization and commonality among small arms systems.

5.3.5. Adaptability and Reversibility –

Small arms systems must be fully adaptable to produce non/less-lethal effects with either permanent design features such as the compatibility with suitable munitions or

[20] *http://www.peosoldier.army.mil/docs/PEO_Soldier_Soldier_Battlefield_Effectiveness_White_Paper.pdf*

scalable directed energy capability, or modular attachment/detachment of scalable ancillary equipment. These attachments will enable greater flexibility to respond at the appropriate level in the Escalation of Force continuum as the battle space rapidly evolves.

The effects caused by the employment of non/less-lethal systems should not be permanent, rather resulting in levels of injury or damage to property that are relatively reversible and able to return the target to pre-engagement level of functionality. While non/less-lethal capability shall be designed to minimize risk of fatalities, permanent injuries, or permanent damage to materiel, no application of force has a zero probability of producing these effects. Non/less-lethal system materiel development process shall assess the likelihood of achieving the desired effect(s) and identify "Risk of Significant Injury" (RSI) for counter-personnel systems, and collateral RSI to humans from counter-materiel systems. RSI Threshold and Objective performance parameters shall be identified in the materiel development of small arms weapon systems commensurate with warfighting requirements. RSI reference should be noted in DODI 3200.19, Non-Lethal Weapons (NLW) Human Effects Characterization.[21]

5.3.6 Resilience –

Small arms systems must be sufficiently robust and operationally suitable for use in combat environments. Threshold and Objective requirements for Operational Availability shall be identified that can be reasonably achieved within design, manufacturing, and reliability constraints.

5.3.7 Knowledge Empowered –

The *Net-Centric Environment Joint Functional* Concept details how a SQD will have to function in a fully networked environment in the near future.[22] Future small arms systems must therefore be fully compatible with SQD level net-centric equipment, and incorporate modular, scalable, and tailorable design features to accommodate hardware and software upgrades for flexibility, interoperability, and adaptability of the systems to evolving battlefield threats. [23]

5.3.8. Expeditionary –

Small arms systems must be operationally suitable for all Joint force combat environments and conditions. A SQD also requires the ability to detect, recognize, and acquire targets beyond an overmatch range. Since threats are mobile and possibly

[21] DODI 3200.19, Non-Lethal Weapons (NLW) Human Effects Characterization, 17 May 2012

[22] Joint Chiefs of Staff. *Net-Centric Environment Joint Functional Concept*, 7 April 2005.
[23] Ibid.

moving towards the SQD with the intent to engage**,** the range and coverage overmatch must be scalable to be equally effective across the varying terrains

5.3.9. Speed and Time –

Scalable force application technologies increase *engagement range* and *reaction time* to determine intent of potential threats, and provide appropriate response options *graduated to target actions*. Non/less-lethal capability specifically provides for a layered defense, expanding response options available to operational commanders commensurate with perceived threats, preventing unnecessary escalation of force and political consequence. On-scene commanders can and do encounter difficulty determining hostile intent and identifying friend from foe, particularly in current and anticipated "hybrid" combat environments combining aspects of conventional and irregular warfare. If response options are limited to lethal force alone, the potential for Noncombatant casualties is great and could jeopardize mission success. Employing Non/less-lethal capability properly scaled to the threat and/or situation ambiguity significantly increases the time available for proper decision making and potentially deters provocative/aggressive behavior in inflammatory situations. It expands the commander's decision cycle time and engagement options beyond engagement by kinetic means alone, significantly increasing the potential for mission success. Small arms shall be designed and engineered to deliver their desired effects with more speed, so that ultimately the SQD may more appropriately assess its tactical situation, calculate its targeting and acquisition requirements (i.e., aim), and to effectively engage with the appropriate level of force, all in less time than that of the enemy.[24]

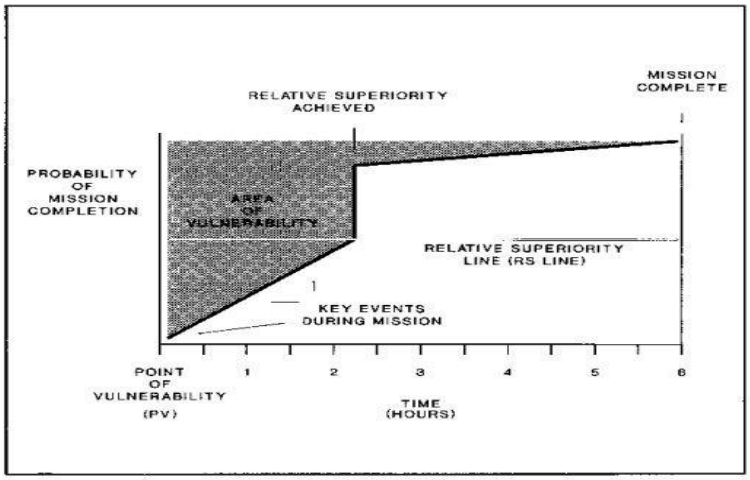

Fig. 1–1. Sample Relative Superiority Graph

Figure D-2 Sample Relative Superiority Graph

[24] McRaven, p. 382

Most importantly, the SQD must be able to employ its weapons quickly enough to defeat the enemy before it is able to target its own weapons against the SQD. "The longer it takes to gain relative superiority, the larger the area of vulnerability. The inherent advantage of technology is that it may help to reduce this area of vulnerability … Overwhelming the enemy does not require numerical superiority, merely innovative tactics or technology." [25] Reversible/adaptable small arms shall deliver their scalable effects to best help the SQD gain valuable time to de-escalate a potentially tense, unpredictable, and rapidly evolving situation, and to instead provide the SQD the needed valuable time to prepare for an operation, allow it to concentrate its force, and to decisively defeat any enemy attack. Small arms shall be engineered to offer more time, and to deliver their desired effects with more speed, so that ultimately the SQD may more appropriately assess its tactical situation, calculate its targeting and acquisition requirements (i.e., aim), and finally, to effectively engage (i.e., fire) its weapons, all in less time than that of the enemy.

S&T Strategy to Achieve Goals

Two limiting technologies have been identified in need of Science & Technology funding through the JSATDS POM Build.

1. Delivery systems for non-lethal weapons and advanced fire control tailored for use with NLW platforms. This includes range, payload capacity, payload flexibility, delivery accuracy, reusability, and specific applicability to allow deployment of a particular non-lethal weapons technology.

2. Sensors and non-lethal weapons. Sensors have a major effect on the conduct of non-lethal warfare, but little has been done to develop sensor/NLW integration to a level comparable with that of the sensor/lethal weapon analogue. Sensor systems should play a role in nearly all aspects of NLW use. They can provide warning, localization, and tracking of potential enemy threats, as well as detecting and identifying adversaries to permit closed-loop tailoring of the desired effect of the NLW. Sensors embedded in the guidance and control systems allow for the precision engagement of hostile targets with NLWs.

Delivery systems for non-lethal weapons continues as an area of research and development. Ideally, the user of a non-lethal weapon system would like the capability to “dial-in” the non-lethal effect as well as use embedded sensors to control the deployment of non-lethal munitions. These are hard problems, and though desirable, are not yet at TRL-3 in any known system.

Unlike conventional weapons systems, the range of effects of non-lethal weapons on the human target is a critical parameter that must be well understood in order to ensure that operationally relevant effects are provided while minimizing the potential for serious

[25] McRaven, pp. 8 & 383.

injury or lethality. Human effects, effectiveness, and risk must be quantified in order to support legal, treaty, and policy reviews and to ensure warfighter confidence in new technologies.

Characterization and quantification of non-lethal human effects is a challenge for developers because effects data is limited in comparison to lethal weapons. Thus, non-lethal human effects characterization has become a focus area for the Joint Non-Lethal Weapons Program's scientific research. The Department of Defense Non-Lethal Weapons Executive Agent, The Commandant of the Marine Corps, has established organizations and processes to facilitate effects research, review, and application.

Proposed Investment to Achieve the S&T Goals (in priority order)

Proposed Investment	Investment Description	Summary Linkages to JSSAST Top 50/PORs/ Transition	Proposed Lead Agency/Agencies
1. Desired operational impact with increased range – multi mission/ multi effects	Technologies that enable range, payload capacity, payload flexibility, delivery accuracy & reusability	JSSAST Top 50: 1-9, 15-29,31, 33-37,39-40, 42-50	JSSAP
2. Miniaturization of Directed Energy Technologies for Small Arms	Technologies that enable the reduction of lasers, particle beams, directed energy	JSSAST Top 50: 1-9, 15-29,31, 33-37,39-40, 42-50	JSSAP
3. Sensors and non-lethal weapons	Sensors embedded in the guidance and control systems allow for the precision engagement of hostile targets with NLWs.	JSSAST Top 50: 1-9, 15-29,31, 33-37,39-40, 42-50	JSSAP

Table 9-2 Proposed Investment to achieve the S&T Goals as related to Scalable Effects

Lead Shape Watch Analysis:

1. Desired operational impact with increased range – multi mission/ multi effects: **(LEAD)** The JSSAP is the key organization to increase the range, accuracy and precision of payload delivery from small arms, regardless of the payload. This is the most technically challenging piece of this overall requirement.

2. Miniaturization of Directed Energy Technologies for Small Arms: **(SHAPE)** DEWs have the potential to meet requirements of the JSSAP. Technical expertise in DEW miniaturization is widely different that kinetic weapons. Other DoD activities are heavily invested (JTO-HEL, JNLWP, etc.) Previous projects worked to package DEW technology into small arms (i.e. Thermal Laser), but recent research has been focused on vehicle- and/or ship-mounted, crew-served weapons.

3. Sensors and non-lethal weapons: **(LEAD)** Sensors allow for the improved targeting and control of impact velocities, increasing the likelihood that the applied force will induce effective and reversible effects. The JNLWD doesn't have the resources or expertise to develop sensor technology unique to the Joint Services.

10. Strategy: BA 6.2 Training & Human Performance

The soldier, sailor, airman or Marine is the primary interface with every small arms weapon system whether operated, semi-autonomous, or autonomous. The weapon system remains a key component of the warfighter as a system and the warfighter as a member of the small unit or squad as a system. The investment in technologies to integrate with the warfighter have to be considered in the early TRL stages. The lessons learned in the past decade has shown that nearly every component of the warfighter as a system has changed or improved with many new capabilities added to squad. New technology in the hands of a user has proven useful at times and has also been a burden. In some cases, the innovative use of a technology in the hands of young warfighters has been used in ways not originally envisioned in the concept of employment. In order for the JSSAST Top 50 Opportunity Areas to be attained, many human performance and training considerations across genders and human systems integration domains must be within the scope of each S&T project from inception to acquisition transition. At the user interface level, the objectives should be simple, reliable and trainable solutions.

Human factors engineering and training directly trade with each other in the development process. Good human factors engineering usually reduces the training burden and training costs. Training is the final step in the employment of any weapon system and must be a key consideration in the investment and development of the Top 50 opportunity areas.

The Manpower and Personnel attributes of the men and women utilizing the transition products of the S&T investment are critical aspects of the development process. The tactical employment of sophisticated and modular small arms weapon systems will require new methods of employment and influence the development of small unit tactics. Consideration should be given to the impact of a technology into the institutional training curriculum for the user community. Anthropometry considerations for both genders will be required in the early S&T stages to include equipped anthropometry specific to weapon systems. Gloved finger manipulation across environmental spectrums, eye relief with protective eye wear and headborne systems, facial and upper torso interfaces with legacy and future warfighting equipment, and utilization of other C4I and power interfaces are examples of key considerations.

Cognitive burden continues to increase as new capabilities and enablers are introduced to the squad. The growing research in measuring of isolated systems cognitive loads and combined system cognitive load impacts will have to be followed in other research communities and considered in the weapon system and fire control TDS efforts. Opportunities for integration of weapon system functionalities into warfighter worn systems such as handheld devices, sensor viewers, and displays will enhance and simplify user interfaces. Concern exists with the cumulative effects of increased enablers and capabilities provided to warfighters influencing the overall training load and cognitive burden.

Training will be a key element of each of the S&T efforts. Reduction of the training burden to the user and simplification towards intuitive use are key design criteria in order to achieve optimal performance. Areas of increasing importance are the ranges and training environments capable of supporting innovations in weapon systems. The focus on the Pacific brings new challenges to units like the 25th Infantry Division and 3rd Marine Division facing limitations in jungle environment training areas or use of host Nation ranges and training areas where dud producing munitions or limited surface danger zones prohibit training. Environmental considerations and range facilities have to remain at the forefront of any S&T project. The employment of weapon systems integrated into the Immersive Infantry Trainers and other new training environments will enhance skill levels for employment at the individual and small unit level. Current and future range management projects and training environments may require an early study to identify the limitations and interface requirements for S&T initiatives. Feedback on user performance in training is essential for improvement of skills. Automated ranges and immersive trainers collect and record various types of data in the training process. Identification of types of data, video and movement tracking requirements, and harmonization of other requirements for successful training events must be considered.

The key to success in this endeavor will be the inclusion and engagement with the warfighter system integrator team for each Service early in the concept development process for each S&T initiative. The best opportunity for integration is in the requirements generation process and will require the requirements and acquisition stakeholders to be included in the S&T process.

Human Performance and Training Considerations in the Top 6 S&T Goals

Accuracy and Controllability - Technologies and studies to assess and improve accuracy and controllability with Soldier in the loop.

Considerations- Linkage of the Weapon Systems and Enablers TDS and the Fire Control TDS is critical in achieving S&T improvements at the whole system level. Weapon system weight and balance will be critical to facilitate weapon handling and engagement techniques for employment. Volume and weight will also impact the warfighter's mobility and ergonomics and must be developed under a systems of systems approach. Bulky fire control systems typically receive poor user acceptance. Implied within this goal is the ability to rapidly bring the weapon system into the engagement process from the carry position to the accurate impact on target. Time to engage is one aspect of controllability and relies upon the functional integration of the warfighter as a system. Past examples of difficult weapon manipulation, sling interferences with other worn components from the carry to employment sequence, and attainment of proper sight picture have plagued previous novel technologies because it was the last consideration in the development process. Corrective eye lens wearers are a significant population group in the Services and must be considered in the S&T process.

Advanced Weapon Operation – Technologies and studies to assess and facilitate the operation of the weapon system with novel or advanced ammunition concepts required to meet lethality requirements.

Considerations – The determination of when a higher powered or unconventional ammunition is used in a weapon system and the transition criteria from handheld to remote based on the users across all the Services population groups may be one of the initial studies to inform this goal. Recoil management, controllability, and sustained fire ability will be factors in trading lethality results with employment criteria. The ability to control and fire a mounted weapon system, whether on a vehicle, on an unmanned system, or on a ground platform, will require C4I interface considerations between the user and the weapon system for employment. The CIED environment and use of jammers can create complex technical problems for remote weapons employment. The safe use and identified hazards of any advanced weapon system will be a critical factor in the approved procurement and fielding process of a new technology.

Signature Reduction – Technologies and studies to assess and improve weapon signature suppression.

Considerations – The positive effects on the warfighter with S&T initiatives in this area are limitless and should be aggressively pursued. Aspects such as reduced noise hazards, increased survivability, and reduced detectability are all positive attributes. Currently, suppressive capabilities typically add length and weight to weapon systems affecting egress and ingress from mobility platforms (ground tactical vehicles, rotary wing transport, and amphibious vehicles), manipulation of the weapon system in confined spaces, and potentially awareness of engagements by other warfighters in the squad. The positive and negative attributes will have to be considered in the pursuit of these S&T initiatives.

Maintenance and Reliability – Technologies and studies to assess and improve weapon system maintainability and life.

Considerations – Simple and reliable are positive traits for any new weapon system. Unique environmental considerations, especially as the jungle and arctic areas increase in importance, must be anchor points in the environmental extremes. Inclusive in this consideration is the reduced time to execute user maintenance, the reduction of tools and consumables to execute the maintenance at the operator level, and the reduction of training to conduct the maintenance. Autonomic logistics attributes to identify usage and predictive failures are a positive attribute for an S&T endeavor in this area.

Other Weapon Technology Areas – Technologies and studies that do not directly address a JSSAST Top 50 Area, but that will need to be considered when addressing the JSSAST top 50 Areas.

Considerations – Manipulation of controls and devices will be a critical factor in user acceptance of new technologies added to any weapon system. Items such as rifle interface controllers, powered rail systems, and centralized power will require interface

control standardizations for use of S&T initiatives across all of the JSSAST Top 50 Areas. These types of modular foundations require additional research and development in order to determine standards and interface control documents to support transition of devices while maintaining weapon zero and accuracy requirements.

Remote Weapon Technologies – Technologies and studies in the area of remote weapon systems.

Considerations – The ability to control remote weapon systems at the small unit level has been demonstrated in OEF. The linkage of UAV's conducting ISR or munitions delivery while being controlled or target designated by a dismounted user have proved to be effective. The digital interoperability of the squad capability is increasing across the Services. The critical problem is the methodology amongst the Services is not identical and the requirements for Joint usage may be expanding. S&T initiatives in this area will have to capture Joint and Service unique requirements to effectively integrate new technologies into this unique area. The awareness of cognitive burden could also be significant and should be considered. Utilization of components a warfighter already has, such as hand held devices, should be utilized in the concept development process.

Human Performance and Training Considerations associated with the measurement of Small Arms Soldier in the loop performance.

The US Army needs an objective system to measure and analyze the performance of the soldier together with his weapon, equipment, ammunition, and training. The current weapons qualification course measures aimed fire from a defensive, Vietnam era firing position and has remained virtually unchanged for 30 years.

In 2009, an OSD-sponsored Joint Assessment Team (JAT) was conducted a thorough review of small arms and ammunition. The JAT concluded the lack of measurable, effects-based standards for some measures of effectiveness impacts DoD's ability to precisely define requirements and evaluate potential solutions for many capability gap areas.

The JAT recommended that the Army pursue the Soldier, Weapon, Equipment, Ammunition and Training (SWEAT) concept. SWEAT is a scientifically derived course that objectively measures the applied lethality of the soldier system to compare products against Military Baselines in a confidential and cost effective manner. JSSAP funded Phase 1 of SWEAT as envisioned by the by the US Infantry School. The issue with the proposed design was it was unaffordable. At a price tag in excess of $30M per SWEAT course the conceived solution married both GOTS and COTS to create a 28 shooting station live fire course requiring a significant instrumentation and a long sustainment tail.

Similar to the idea of skunkworks projects used in the private sector to encourage innovation, the Marine Corps established Gruntworks, also known as the Squad

Integration Facility. Unique within the Department of Defense, Gruntworks analyzes how components of a Marine's equipment influence combat performance in terms of weight, bulk, flexibility and effectiveness. It evaluates planned or fielded capabilities in terms of integration on the Marine and within the squad, enables rapid prototyping of improved designs for those capabilities, and then supports re-evaluation of the improved designs using on site facilities at Gruntworks and combat experienced Marines. An indication of the unique capability and relevance of Gruntworks is the adoption of the concept by the Australians in their creation of "Diggerworks" and the continued interest from international partners such as Canada and the United Kingdom.

Gruntworks designs and refines the Marine Rifle Squad as a system. Gruntworks does not procure equipment; rather, it works with all of the Program Managers within Marine Corps Systems Command to ensure individual items are integrated into an effective combat fighting capability to deliver a balanced squad.

One of the major efforts Gruntworks has undertaken in the last several years is to envision, develop, and implement the Marine Corps Load Effects Assessment Program (MC-LEAP). The MC-LEAP consists of a combination of various obstacles traced to physically demanding infantry tasks that Marines have been encountered in Operation Iraqi Freedom and Operation Enduring Freedom. It provides an assessment and metric for base lining mobility as equipment is added or changed on the Marine in order to determine system level effects on Marines. The mobility baseline can then be used as a point of comparison for improving mobility in new requirements and systems. The Marine Corp developed the Load Effects Assessment Program course—or MCLEAP. Marines maneuver similar obstacles all in the name of improving gear and equipment for the warfighter.

The Army has purchased two LEAP systems. Researchers from the Biomechanics, Human Factors and Anthropometry Teams at the Natick Soldier Research, Development and Engineering Center, or NSRDEC, are conducting a reliability assessment of LEAP.

NSRDEC researchers want to determine if the tool can be adapted to meet Army needs and provide a reliable method to measure the impact of clothing and individual equipment, or CIE, on Soldier performance.

By understanding how CIE affects the warfighter's ability to move and maneuver through the LEAP obstacle course, scientists and engineers will be able to implement modifications to optimize the design and integration of CIE -- thus, improving Soldier-System interface and performance. The reliability assessment is just one in a series of assessments that will be conducted using the LEAP system.

Natick has partnered with PEO Soldier Product Director Soldier Systems Integration; Maneuver Center of Excellence -- Maneuver Battle Lab; and the Army Research Laboratories -- Human Research and Engineering Directorate to share the knowledge learned about using the tool and to develop a standard methodology for product assessment using the tool. This information will also be fed to an international working

group consisting of Australia, Canada, New Zealand, the United Kingdom, and the United States, who hope to be able to use the LEAP tool as a joint data-collection tool."

Based on Marine input, the LEAP tool consists of a series of obstacles and mission-relevant activities to resemble challenges that warfighters face in current combat situations. Soldiers participating in NSRDEC's LEAP assessment navigate stairs, ladders, tunnels, windows, walls and balance beams. They also perform a myriad of mission-related tasks, including load transfers, simulated casualty drags, low crawls, high crawls, back crawls and sprints. The current LEAP course includes one shooting position.

One of the main recommended S&T investments below is a modification to the MCLEAP or LEAP-A course to include 3 shooting configurations instrumented for collections of lethality data based upon the previous work performed on SWEAT. The previous SWEAT work lays out the targets, data collection and instrumentation needed to collect data to asses Soldier in the Loop performance as a Probability of Incapacitation (P(i)) number.

The benefit of modifying the existing LEAP course design is that we can now ascertain Soldier Performance as a System (Soldier Kit and Lethality Output). Changes in body armor, helmets, googles, gloves, ammunition, fire control, optics, weapons can be tested and the output can be correlated to Lethality data. This will be the first time this data will be available and supports the JAT recommendations.

Proposed Investment to achieve the S&T Goals (in priority order)

Proposed Investment	Investment Description	Summary Linkages to JSSAST Top 50/PORs/ Transition	Proposed Lead Agency/Agencies
1.Accuracy / Controllability	Technologies and studies to assess and improve Soldier in the loop performance based on Task, Condition and Standards	JSSAST Top 50: All	ARL-HRED /MCSC/ONR
2.Human Factors	Technologies and studies to improve Soldier in Loop performance ie weapon manipulation, reduction of training for operations, reduction in cognitive burden	JSSAST Top 50: All	ARL-HRED /MCSC/ONR

Table 10-1 Proposed Investment to achieve the S&T Goals as related to Training & Human Performance

11. Strategy: BA 6.3 System Integration and Demonstration Program

Problem Statement

Historically, items are developed in Science and Technology programs by commodity, for example, ammunition, weapons, and fire control. These items may then be demonstrated at a TRL 6 and are suitable for transition, but the opportunity is missed to integrate, mature, and demonstrate these technologies together, which can lead to even greater capability.

Another problem that occurs is that the items transitioned are not adequately mature, and resources are spent in Engineering & Manufacturing Development (EMD) to address issues such as reliability, durability, and manufacturability that could have been done in S&T with less cost.

Scope/Objectives

To provide the strategy to select, integrate, and demonstrate technologies across commodity areas that address multiple capability gaps, and provide mature systems that are truly ready for transition to EMD programs.

Linkage and Analysis to JSSAST Top 50 Approved Opportunity Areas:

Fire Control Top 50 Analysis

Many individual fire control components or technologies exist that solve the JSSAST Top 50 Opportunity Areas. Future efforts would concentrate on selecting and integrating those technologies that solve multiple gaps. Size, Weight, and Power is a real concern with Fire Control

- Current government investments include (but are not limited to): DARPA, JSSAP, ARDEC, SOCOM, NVESD, PM SW PM SSL

Fire Control Top 50 Linkage

1	Engage Threat Personnel in Defilade from 15 to 500m
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m
6	Positively Identify Friendly Forces
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter
13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance
15	Engage Threats with Small Arms Volume Fire from 51 to 600m
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m
20	Engage Targets
21	Conduct Tactical Reconnaissance and Surveillance
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)
24	Determine Friendly, Enemy, Neutral, and Non-Combatant Identification
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)
26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons
27	Breach Existing Entry Points with a Single Shot at 0m
28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation
29	Breach (6' x 4') from Distances Beyond 40 Meters
30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact
31	Breach Existing Entry Points with a Single Shot up to 50m
32	Signature Reduction System that Minimizes Projectile Muzzle Strike
33	Fire Disabling Fire with Small Arms
34	Collect Target Information
35	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°
36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges
37	Detect, Identify, Classify and Track Surface Contacts Visually
38	Corrosion Prevention and Control
39	System Accuracy of 5" Mean Radius at 300 Meters and 10" Extreme Spread at 600 Meters Throughout Barrel Life
40	Engage Surface Ships With Small Arms Gunfire (Including Precision Fire from Precision Marksman)
41	Barrel Life of 3,600 Rounds When Fired in Accordance with the OMS/MP
42	Determine Range to Target to ±1m from 0 to 1200m
43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)
44	Determine Range to Target to ±1m from 0 to 600m
45	Determine Range to Target to ±1m from 0 to 1000m
46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold :
47	Mark or Tag Targets to 1000m
48	Mark or Tag Targets to 2400m
49	Mark or Tag Targets to 3000m
50	Hit Targets from Defilade Position to Standard

Table 11-1 Fire Control Top 50 Linkages

Next Generation Squad Automatic Rifle (Weapon & Ammunition) Top 50 Analysis

Many individual weapon or ammunition technologies exist that have the potential to address the JSSAST Top 50 Opportunity Areas. Future efforts would concentrate on selecting and integrating those technologies that solve multiple gaps. Increases in lethality (and range) must be balanced with increases in weight.

- Current government investments include (but are not limited to): JSSAP, ARDEC, SOCOM, ASA ALT, PM MAS

NGSW/NGAR Top 50 Linkage

1	Engage Threat Personnel in Defilade from 15 to 500m
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m
6	Positively Identify Friendly Forces
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter
13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance
15	Engage Threats with Small Arms Volume Fire from 51 to 600m
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m
20	Engage Targets
21	Conduct Tactical Reconnaissance and Surveillance
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)
24	Determine Friendly, Enemy, Neutral, and Non-Combatant identification
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)
26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons
27	Breach Existing Entry Points with a Single Shot at 0m
28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation
29	Breach (6' x 4') from Distances Beyond 40 Meters
30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact
31	Breach Existing Entry Points with a Single Shot up to 50m
32	Signature Reduction System that Minimizes Projectile Muzzle Strike
33	Fire Disabling Fire with Small Arms
34	Collect Target Information
35	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°
36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges
37	Detect, Identify, Classify and Track Surface Contacts Visually
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42	Determine Range to Target to ±1m from 0 to 1200m
43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)
44	Determine Range to Target to ±1m from 0 to 600m
45	Determine Range to Target to ±1m from 0 to 1000m
46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold Zero
47	Mark or Tag Targets to 1000m
48	Mark or Tag Targets to 2400m
49	Mark or Tag Targets to 3000m
50	Hit Targets from Defilade Position to Standard

Table 11-2 NGSAR (Weapon & Ammunition) Top 50 Linkages

Ammunition Top 50 Analysis

The following programs are being invested in outside the work being done for NGSAR. They have direct linkages to CDDs and PORs.

- Current government investments include (but are not limited to): JSSAP, ARDEC, PM MAS, ARL

Ammunition Top 50 Linkage	
1	Engage Threat Personnel in Defilade from 15 to 500m
2	Engage Threat Personnel with Small Arms Fire from 0 to 50m
3	Engage Threats with Small Arms Volume Fire from 601 to 1200m
4	Engage Threat Personnel with Small Arms Fire from 51 to 200m
5	Engage Threats with Small Arms Volume Fire from 1201 to 2400m
6	Positively Identify Friendly Forces
7	Avoid Detection Caused by Weapon Signature by Reducing Nonfiring Weapon Profile Signature
8	Operate in Climate Extremes Ranging from Cold Weather to Tropical to Desert Environments
9	Operate and Maintain Weapons at an Operational Availability of 98% through the Range of Specific Conditions
10	Weapon System reliability ≥.94 Probability of No Class I or II Failures and ≥.97 Probability of No Class III Failures per OMS/MP
11	Avoid Detection Caused by Weapon Signature by Reducing Weapon Flash Signatures by 50% at Muzzle
12	Avoid Detection Caused By Weapon Signature When Firing via Reduction in Acoustic Signature at 40m from the Shooter
13	Signature Reduction System with Longevity Equivalent to the Weapon Barrel Life
14	Signature Reduction System that does Not Degrade Current Level of Weapon Performance
15	Engage Threats with Small Arms Volume Fire from 51 to 600m
16	Engage Threat Personnel with Precise Small Arms Fire from 51 to 600m
17	Engage Threat Personnel with Precise Small Arms Fire from 51 to 1000m
18	Engage Threat Personnel with Small Arms Fire from 201 to 500m
19	Engage Threat Personnel with Precise Small Arms Fire from 0 to 50m
20	Engage Targets
21	Conduct Tactical Reconnaissance and Surveillance
22	Acquire Personnel and Vehicle Targets from 0 to 1000m (day) and 0 to 800m (darkness and limited visibility)
23	Acquire Personnel and Vehicle Targets from 0 to 1200m (day) and 0 to 960m (darkness and limited visibility)
24	Determine Friendly, Enemy, Neutral, and Non-Combatant identification
25	Acquire Personnel and Vehicle Targets from 0 to 2400m (day) and 0 to 1920m (darkness and limited visibility)
26	Attack Enemy Ships, Aircraft, Submarines, and Facilities with Standoff Weapons
27	Breach Existing Entry Points with a Single Shot at 0m
28	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via One-Handed Operation
29	Breach (6' x 4') from Distances Beyond 40 Meters
30	Signature Reduction System that Maintains a Projectile Predictable Shift of Impact
31	Breach Existing Entry Points with a Single Shot up to 50m
32	Signature Reduction System that Minimizes Projectile Muzzle Strike
33	Fire Disabling Fire with Small Arms
34	Collect Target Information
35	Breach Existing Entry Points from 0 to 50m at Angle of Engagement of 0° to 60°
36	Employ Lethal and Non-Lethal Capabilities Coupled with Sensors to Effectively Engage Targets at Extended Ranges
37	Detect, Identify, Classify and Track Surface Contacts Visually
38	Corrosion Prevention and Control
39	System Accuracy of 5" Mean Radius at 300 Meters and 10" Extreme Spread at 600 Meters Throughout Barrel Life
40	Engage Surface Ships With Small Arms Gunfire (Including Precision Fire from Precision Marksman)
41	Barrel Life of 3,600 Rounds When Fired in Accordance with the OMS/MP
42	Determine Range to Target to ±1m from 0 to 1200m
43	Acquire Personnel and Vehicle Targets from 0 to 600m (day) and 0 to 480m (darkness and limited visibility)
44	Determine Range to Target to ±1m from 0 to 600m
45	Determine Range to Target to ±1m from 0 to 1000m
46	Ability to Acquire Targets in all Environmental Conditions, Including Day or Night/Low Visibility for All Engagements from 0 to 50 meters via Night Aiming/ Lighting/Target Designator that will Hold Zero
47	Mark or Tag Targets to 1000m
48	Mark or Tag Targets to 2400m
49	Mark or Tag Targets to 3000m
50	Hit Targets from Defilade Position to Standard

Table 11-3 Ammunition Top 50 Linkages

Linkage to Program of Records:

1) Next Generation Squad Automatic Rifle (NGSAR) CDD

2) Lightweight Dismounted Automatic Machinegun (LDAM) CDD

3) Fire Control CDD

4) Family of Ammunition CDDs (5.56mm, 7.62mm, .50 cal, and Precision)

Linkage to Transitions from 6.2:

1) Fire Control and Optics – two distinct types of fire control are envisioned, with the main difference as follows. The first type of fire control to come out of 6.2 and 6.3 improves the soldier's ability to detect, track, and engage targets out to 800 m (for

individual weapons) and 2400 m (for crew served, mounted, or stationary weapons). This type of fire control is designed to reduce the errors caused by shooter in the loop, such as aim error and range estimation. The second type of fire control is being developed to steer guided munitions. Although some work has already been done in this area in 6.1 and early 6.2, the majority of the 6.2 effort would need to be performed in FY19-FY22 for a transition into 6.3 in FY23.

2) Weapons and Enablers – this general category includes such things as improvements in accuracy and controllability, advanced weapon operation, signature reduction, and maintenance/reliability improvements. The vision is to incorporate subcomponent and weapon system level technologies into full system integration 6.3 efforts to support NGSAR and LDAM.

3) Ammunition – Improvements in ammunition from 6.2 fall into two categories: those that would be included (or at least evaluated) under NGSAR and LDAM type 6.3 efforts, such as improvements in lethality, range, and dispersion; and ammunition that has a unique capability, such as reduced range training ammunition, precision (for sniper applications), and handgun ammunition.

4) Training & Human Performance - It is critical to maintain the warfighter in the loop aspect of all technologies developed in S&T, and even more so in the 6.3 Integration and Demonstration, where system level decisions are made that balance technological improvements with usability, training, and mobility. The use of a system such as LEAP (described in the Training & Human Performance Section) would be of great assistance in making these types of decisions.

5) Scalable Effects (and Directed Energy) – include small arms and ammunition that cover the non-lethal to lethal spectrum, deliver effects at adjustable ranges and velocities, offer non-kinetic energy solutions, and/or which deliver limited range, low collateral damage. These may be part of or an addition to an existing small arms system, such as non-lethal ammunition, or a purpose built scalable system.

Linkage to Transitions from 6.3 to 6.4/EMD:

The successful transition from 6.2 to 6.3 to a Program of Record in 6.4/EMD is dependent on many factors, including budget, technical feasibility, timing, and even political will. Every attempt will be made to build the 6.3 program to support new or emerging Programs of Record that support User requirements.
The first two 6.3 efforts to transition to a 6.4/EMD program will be the Next Generation Squad Automatic Rifle (NGSAR) and the Fire Control. The transition from 6.3 to 6.4 for these two items is envisioned as the following:

1) Next Generation Squad Automatic Rifle (NGSAR): This will be a weapon and ammunition system developed and demonstrated to meet the KPPs and KSAs established in the NGSAR CDD. The complete weapon and ammunition system will be demonstrated at a minimum TRL of 6, with a desired TRL of 7. Along with a

Technical Data Package (where applicable) and set of test data, a quantity of weapons and ammunition will be delivered to avoid delays during the transition process.

2) The transition for the Fire Control effort will include prototype fire control units demonstrated to meet the KPPs and KSAs established in the Fire Control CDD. These will be demonstrated at a minimum TRL of 6, with a desired TRL of 7. These units will include input devices (cameras, laser range finders, gyroscopes, and sensors), software and algorithms, and output devices (eyepieces, displays, etc.). The Technical Data Package (where applicable) and test data will also be delivered.

3) Ammunition: Multiple ammunition Family of Ammunition CDDs are in staffing (or approved). Many of these have future efforts built in which require additional development in S&T. Each of these efforts will be transitioned from 6.3 to EMD once they have reached the required level of maturity needed for Milestone B.

Science & Technology Strategy to achieve goals:

Investments in the 6.3 area are different than 6.1 and 6.2, in that the main scientific focus has already been investigated and is considered feasible. The emphasis of the 6.3 projects, therefore, should be to mature these technologies, integrate them onto applicable platforms, and demonstrate them in relevant environments. For soldier systems, the ultimate goal is a user in the loop assessment with realistic scenarios and missions. For this to happen, safety and environmental testing must be performed, and safety releases must be issued to support the assessments.

To enter a 6.3 project, technologies must be at least a TRL 4, and their correlation to the JSSAP Top 50 should already be established. The technologies may come from existing JSSAP 6.2 efforts, from other agencies, other nations, or from industry where appropriate.

In order to increase the likelihood of a successful transition, the 6.3 projects must be aligned with User requirements, PM programs (where possible), and have a Technology Transition Agreements signed within 1 year of the anticipated transition date.

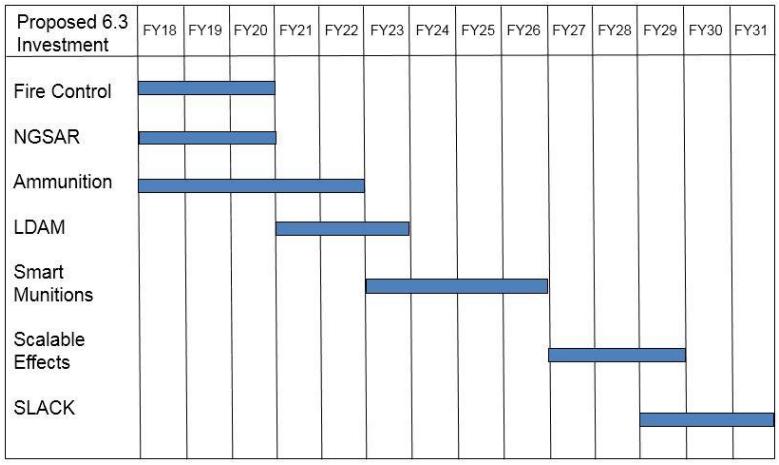

Chart 11-4 Proposed Time Schedule achieve 6.3 S&T Goals Integration and

Demonstration Program

Proposed Investment to achieve the S&T Goals (in chronological order)

Proposed Investment	Investment Description	Summary Linkages to JSSAST Top 50/PORs/ Transition	Proposed Lead Agency/Agencies
1. Fire Control	Integration and demonstration of multiple fire control technologies developed across DoD and private industry to close capability gaps for detection and engagement across the range of interest	JSSAST Top 50: 1-6, 15-25, 28, 34, 37, 42-46 Fire Control CDD	ARDEC
2. Weapon & Ammunition for NGSAR	Integration and demonstration of technologies to support NGSAR requirements. Focus is on increasing lethality, reducing weight, and decreasing detection.	JSSAST Top 50: 2-4, 7-16, 18-20, 30, 32, 33, 38, 39, 41 NGAR CDD	ARDEC
3. Ammunition	Integration and demonstration of ammunition technologies that fall outside NGSW. For example: .50 cal, Precision, Reduced Range Training Ammunition, and Modular Handgun Ammunition	JSSAST Top 50: 2-5, 8, 10,11, 15-20, 33, 39 5.56mm FoA, 7.62mm FoA, and .50 cal FoA CDD, Precision FoA CDD, and MHS CARDS	ARDEC
4. Lightweight Dismounted Machine Gun	Integration and demonstration of technologies to support LDAM requirements. Focus is on increasing lethality, reducing weight, increasing range, and decreasing detection.	JSSAST Top 50: 2-5, 7-15, 18, 20, 30, 32, 33, 38-40, 41 LDAM CDD, Lethality Deep Dive	ARDEC
5. Smart Munitions	Integration and demonstration of smart munition systems for volume and/or precision effects. Capability progression from precision guided to steerable, and from man in the loop to fully autonomous to remote	JSSAST Top 50: 1-5, 11-12, 16-20, 22-23, 25, 28, 34, 36, 42-46, 50 Lethality Deep Dive, LIRA	ARDEC/ AMRDEC
6. Scalable Effects	Integration and demonstration of scalable, tailorable	JSSAST Top 50: 1,2, 4, 18, 20, 26,	JNLWD/ARDEC

	weapons with lethal and non-lethal effects	27, 29, 31, 35, 36, 39, 47, 48	
7. Squad Level Active Collaborating Knowledge (SLACK)	Integration and demonstration of weapon fire control system that deconflicts and prioritizes threats across the squad, assists in directing firepower and maneuver		ARDEC/CERDEC

Table 11-5 Proposed Investment to achieve the S&T Goals as related to System Integration and Demonstration Program

Lead Shape Watch Analysis:

1. Fire Control: **(LEAD)** Fire Control efforts will require Subject Matter Experts from within the Government and industry, but due to the unique needs of the military in this area, will also require an investment in infrastructure and equipment. Close partnering between Government and industry at this stage of development is key to transitioning a mature product that is ready for a Milestone B decision.

2. Weapon & Ammunition for NGSAR: **(LEAD)** In order to meet the requirements for this system, the weapons and ammunition being developed to support NGSAR will be highly specialized and uniquely developed for the military. This will require Subject Matter Experts from within the Government and industry, and will also require an investment in infrastructure and manufacturing equipment. Close partnering between Government and industry at this stage of development is key to transitioning a mature product that is ready for a Milestone B decision.

3. Ammunition: **(LEAD/SHAPE)** Due to the specific and demanding military requirements for small caliber ammunition, many of the ammunition efforts will require that the Army invest in unique technologies not found in industry. Others may be leveraged from industry, and may only require a moderate amount of shaping to meet the military requirements. Close partnering between Government and industry at this stage of development is key to transitioning a suitably mature product that is ready for a Milestone B decision.

4. Lightweight Dismounted Machine Gun: **(LEAD)** In order to meet the requirements for this system, the weapon system and ammunition being developed to support LDAM will be highly specialized and uniquely developed for the military. The LDAM may be the first system to take advantage of the technologies being developed under the 6.2 effort Future Integral Target Engagement System (FITES), which will develop fire control technologies that are integral to the weapon system itself, which will maximize hit probability. This integral effort will require Subject Matter Experts from within the Government and industry, and will also require an investment in infrastructure and manufacturing equipment. Close

partnering between Government and industry at this stage of development is key to transitioning a mature product that is ready for a Milestone B decision.

12. Strategy: Deep Future Plans

As part of revolutionary investments, a portion of BA 6.2 needs to invest funding in the underlying scientific components that will help shape the Deep Future.

In the past few years JSSAP and ASA ALT have held a series of Futures conferences. The issue we had is: how do we translate the material developed from these Futures into "Acquisition" opportunities. When we hold these Futures Conferences we are attempting to stimulate Radical Innovation (RI) versus Incremental Innovation (II). Radical innovators must constantly search for the unarticulated "market" needs through experimentation and bold thinking to identify RI opportunities and engage in it successfully. These conferences are part of that identification process.

We struggle with the II and RI concepts from a requirement and resourcing perspective in the Department of the Army (DA). Army typically funds articulated approved requirements with clear linkages to top priorities or Programs of Records (PORs); User communities can only state the "known" based upon requirements, yet the S&T Community are asked to deliver Radical Innovations. This is an incongruous concept and methodology. The DA innovation process for Incremental Innovation is very standardized as evidenced by the Acronym labeled programs of ATOs, ICDs, CDDs, PORs, AWEs, etc... We know that RI occurs from exploratory investments and that it integrates diverse knowledge/technologies in flexible unexpected ways.

Published literature into RI links it into four main topical headings: 1) RI emerges from unexpected new interactions between technology, application and market trends; 2) identifying unarticulated market needs given the new application functionality forms the primary source of most RIs; 3) successful radical innovators find ways to solicit unarticulated, unmet market needs by probing the technological ecosystem; and 4) they constantly build versatile capabilities to fill the gaps between current technology and the application functionality and market needs through experimentation driven by passion.

We have struggled in the articulation of the answer “We are spending a Billion dollars in Kinetic Energy Weapons per year, what is left to innovate and why?” because of the simplicity of the question. When was the last time you saw a Technology S-Curve from a pure small arms perspective? Where are we on the curve and how do we represent the performance of the not just of the KE weapon but the Solider as a System?

A business would analyze the S-Curve and would modify it with the injection of disruptive technologies to continue their market share or to extend the technology. We in the DoD are not concerned with market share but are very concerned with market competition. The US Warfighter must have an ever increasing Overmatch Capability to counter other nations rise in capabilities. Many people state that “Better is the enemy of good enough” but conversely better on a technology S-Curve doesn’t meet the requirement, because requirements are not plotted on S-Curves. The DoD has been investing KE weapons since the 1800s, but the technology has been around since the 12th century. Do we start the S-curve in 1800?

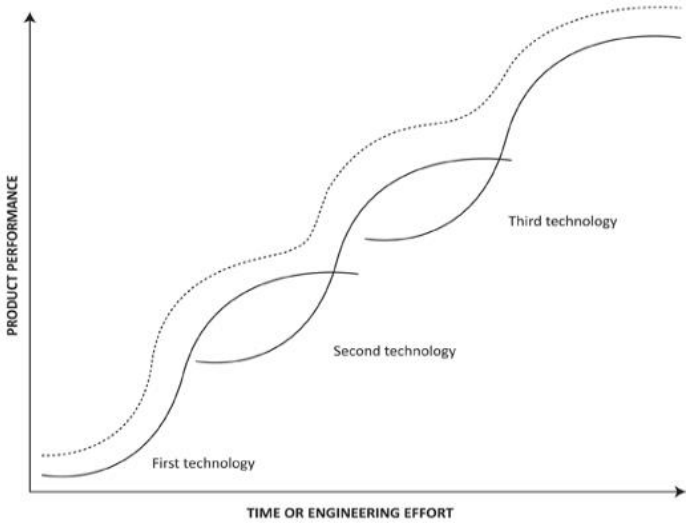

Figure 12-1 Technology S- Curve

The answer is No. Michael Zoltoski, Chief of the Army Research Lab's Lethality Division stated recently that Game-changer armament technologies come just once in a blue moon. The first blue moon moment came during the 1950s, with the development of tactical nuclear weapons, he said. The second was during the mid-1980s, with the introduction of stealth, precision-guided munitions and armaments linked to enhanced intelligence, surveillance and reconnaissance. The third blue moon moment has now arrived, at least developmentally, he said. The opportunity to create the third blue moon or Radical Innovation Period has arrived.

For this section of the JSATDS, The JSSAP Office contracted with Battelle Memorial Institute to conduct an in depth analysis and create a Technology Investment roadmap for the JSSAP Office based on “Future Studies”. The below sections are extracted from their final deliverables. For the full report please contact the JSSAP Office.

For nearly 30 years the Joint Services Small Arms Program (JSSAP) has been conducting Futures meetings. The purpose of these meetings is to:

> “…provide a forum conductive to free thinking in order to capture the thoughts and ideas imaginative and creative people not necessarily prejudiced with current or past weapons development.” (Guess, 1986).

Overall, the objective of these Futures meetings is to identify:

> “...alternative candidate futuristic weapons systems that would offer high-performance payoff.” (Lerner, 2008)

The JSSAP Futures meetings are ideation exercises that ask participants to generate ideas and science and technology (S&T) concepts without regard to means of implementation, cost, manufacturability, and even the laws of physics.

This study picks up where the Futures ideation exercises end. The purpose of this study is to examine and expand upon the S&T concepts captured in previous JSSAP Futures Meeting Reports, and perform engineering assessments of these concepts to ascertain the feasibility of fielding these ideas. The engineering assessment for each concept included

- Key performance envelopes
- Related assumptions
- Potential new hazards
- Life cycle costs
- Concept of operations (CONOPS)
- Multiple concept synergies.

This effort was broken into two distinct phases. **Phase I** of this effort focused on S&T concepts from the most recent JSSAP Futures (SAAL-ZT) Report entitled *Envisioning the Deep Future of Small Arms 2022–2042* released in 2013. **Phase II** of this effort looked at concepts outlined in previous JSSAP Futures reports dating back to 1986.

During this effort Battelle worked with the JSSAP and Subject Matter Experts (SMEs) to better understand how the identified S&T concepts should perform in the field. To this end, input from the SMEs was used to develop performance requirements for each concept and to rate each concept with respect to the concept's utility in the field and the concepts usefulness in possible future warfare scenarios.

Two types of SMEs were employed during the writing of this report. The first type of SME was called a "Technical SME." Technical SMEs were scientists and engineers with backgrounds in small arms and/or technology areas related to the concept(s) they were reviewing. The second type of SME employed of this effort was called an "End User SME." The End User SME group was composed of officers and soldiers with years of hands-on experience, and in most cases the End User SMEs had multiple deployments.

A stated goal of this effort was to generate a ranked list of concepts based on the quantifiable attributes of each concept to the maximum extent possible. To achieve this goal the S&T concepts were rated and ranked with respect to:

- The utility of each S&T concept to the soldier
- The applicability of each S&T concept to a number of possible engagement scenarios
- The perceived impact to Tactics, Techniques, and Procedures (Impact on TTP).

The ranking system used for this report was based on criteria originally defined in the 2013 Deep JSSAP Futures report entitled *Envisioning the Deep Future of Small Arms 2022–2042*. (August 2013). For this effort the ranking system was further clarified and reduced to a standardized questionnaire. The questionnaire consisted of a series of questions that were posed to guide the establishment of consistent ranking values. SMEs were asked to rank and comment on the concepts; however, the End User SMEs

were not asked to evaluate the concepts with respect to technological risks and technological maturity. Similarly, the technical SMEs were not directly asked to evaluate a concept's impact on Tactics, Techniques, and Procedures (TTP). Because of these differences, the ranking results for the two sets of SMEs are presented separately.

The first portion of the ranking questionnaire asked the SMEs to rank the concepts based on "Utility." For Technical SMEs "Utility" was defined as the combination of anticipated risk, anticipated reward, ripple effect (impact on how the Army operates), and payoff to other technology domains. For the End User SMEs the "Utility" score was based on improvements to their ability to Shoot, Move, Communicate, Survive, and Sustain (FM 3-21.8, The Infantry Rifle Platoon and Squad, 2007). Utility results are shown in Figures 12-2 and 12-3 below for Technical SMEs and End User SMEs, respectively.

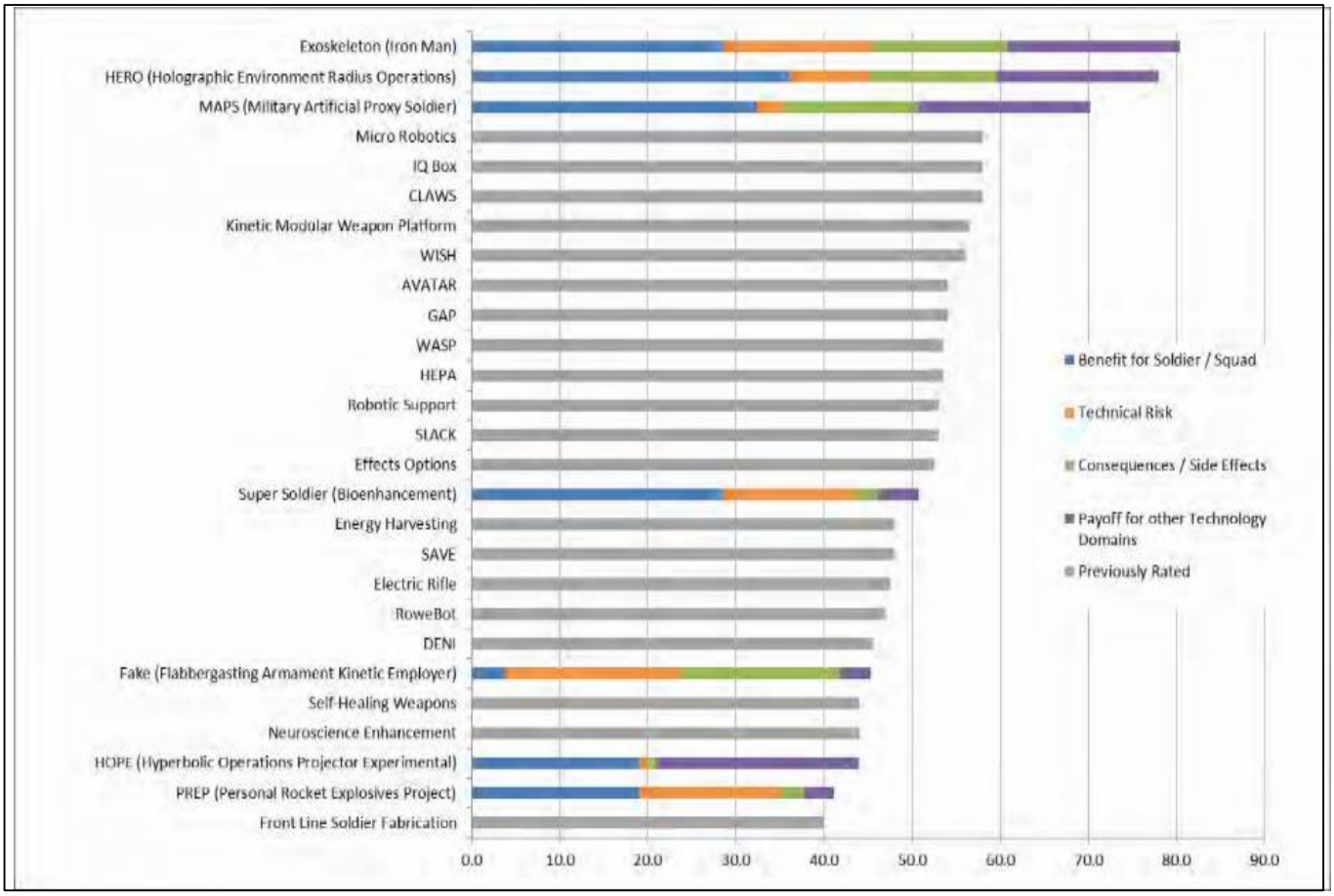

Figure 12-2. Phase I Utility Results for Technical SMEs (Concepts Listed on the Left)

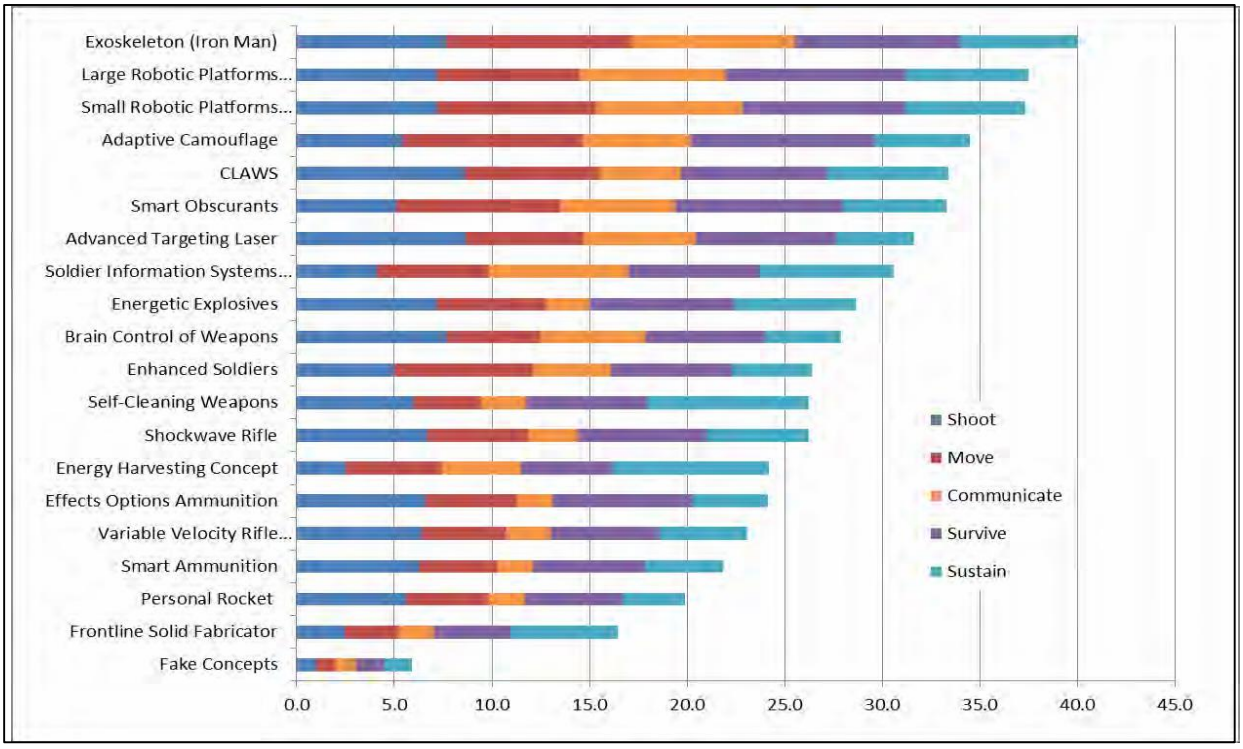

Figure 12-3. Phase I Utility Results for End User SMEs (Concepts Listed on the Left)

Unlike Phase I, Phase II Concepts were only ranked by technical SMEs. This decision was made due to the fact that many of the concepts were abstract; in the words of one of the SMEs, “Many of the Phase II concepts have more to do with Science-Fiction than science.” Figure 12-4 shows the Utility Ranking results for the Phase II concepts

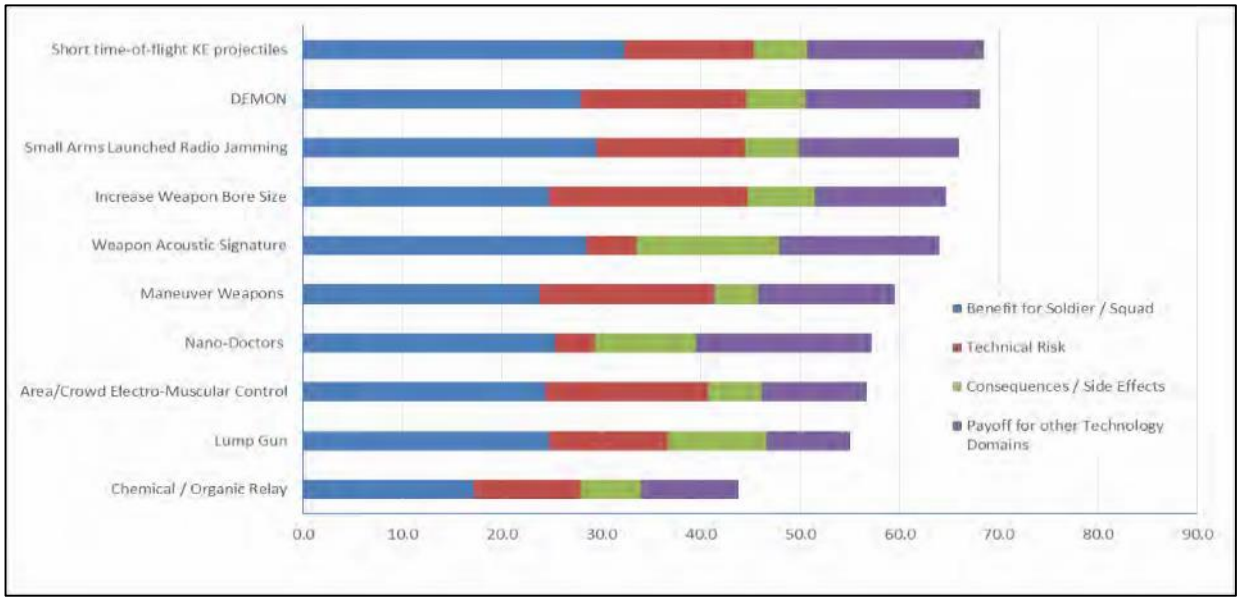

Figure 12-4. Phase II Utility Results for Technical SMEs (Concepts Listed on the Left)

The second portion of the ranking questionnaire asked the SMEs to rank the concepts based on "Applicability." The "Applicability" score is based on four alternate futures described in *Envisioning the Deep Future of Small Arms 2022–2042*. These four alternate futures are:

- **Cold War II:** The United States is locked in a geopolitical standoff with China and a resurgent Russia.
- **Global Footprint:** The United States is engaged in a continuous string of low-intensity conflicts and relief operations.
- **Turning Inward:** Constrained by an unstable economy and beset by domestic security challenges, the United States has pulled back from the global military engagement that characterized the early decades of the 21st century.
- **Standing in a Tinderbox:** The world has become a dangerous and unstable place. Regional wars rage over access to clean water and other vital resources, while the United States, Russia, and China spar over the Arctic. Chemical, biological, and radiological weapons have been used on battlefields in Korea and the Middle East.

Technical SMEs and End User SMEs were both asked to evaluate the concepts with respect to applicability, with both groups receiving the instructions. Applicability was rated on a seven- point scale that ranged from "very applicable" to "not applicable." Applicability results are shown in Figure 12-5 and Figure 12-6 below for Technical SMEs and End User SMEs, respectively.

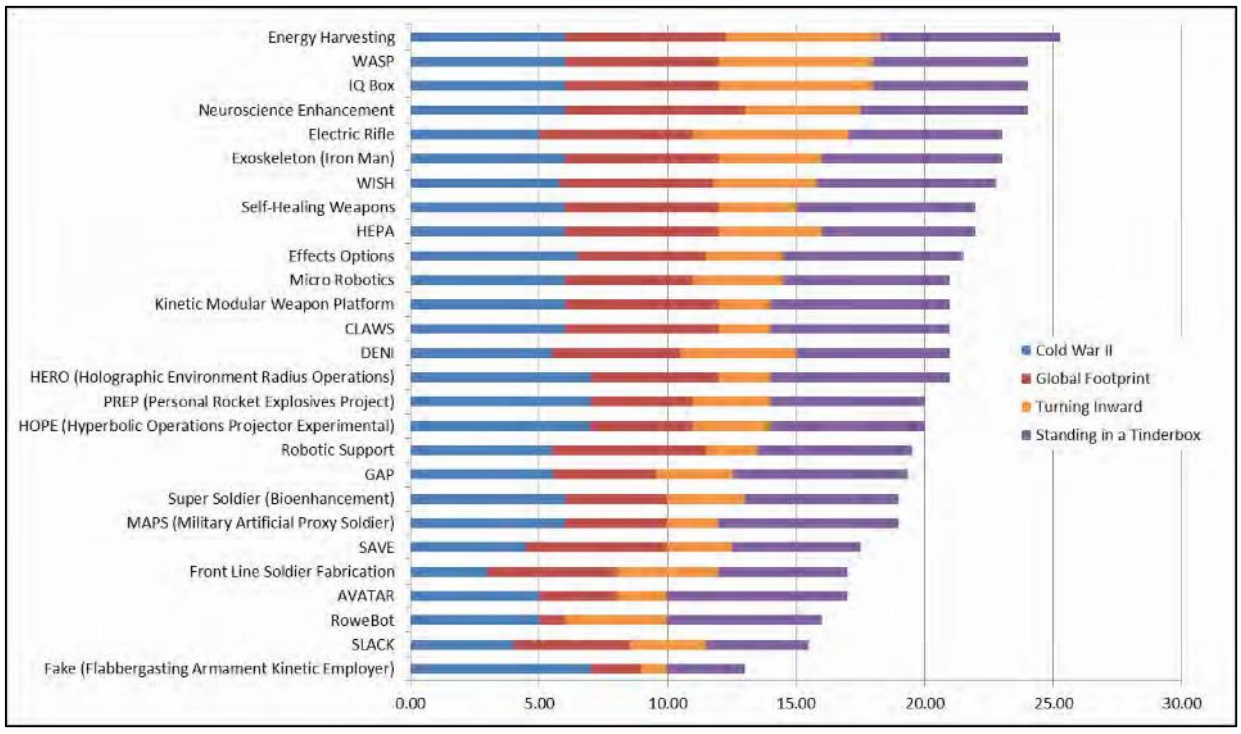

Figure 12-5. Phase I Applicability Results for Technical SMEs (Concepts Listed on the Left)

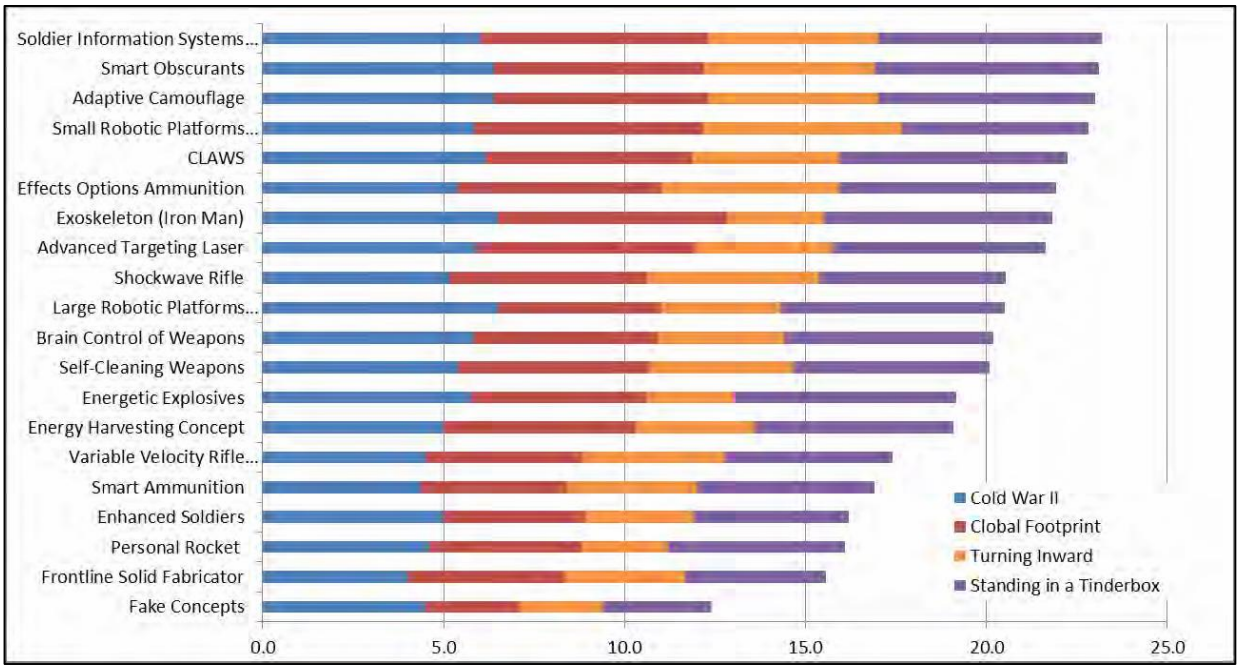

Figure 12-6. Phase I Applicability Results for End User SMEs (Concepts Listed on the Left)

As mentioned above, Phase II Concepts were ranked only by technical SMEs. Figure 12-7 shows the applicability ranking results for the Phase II concepts.

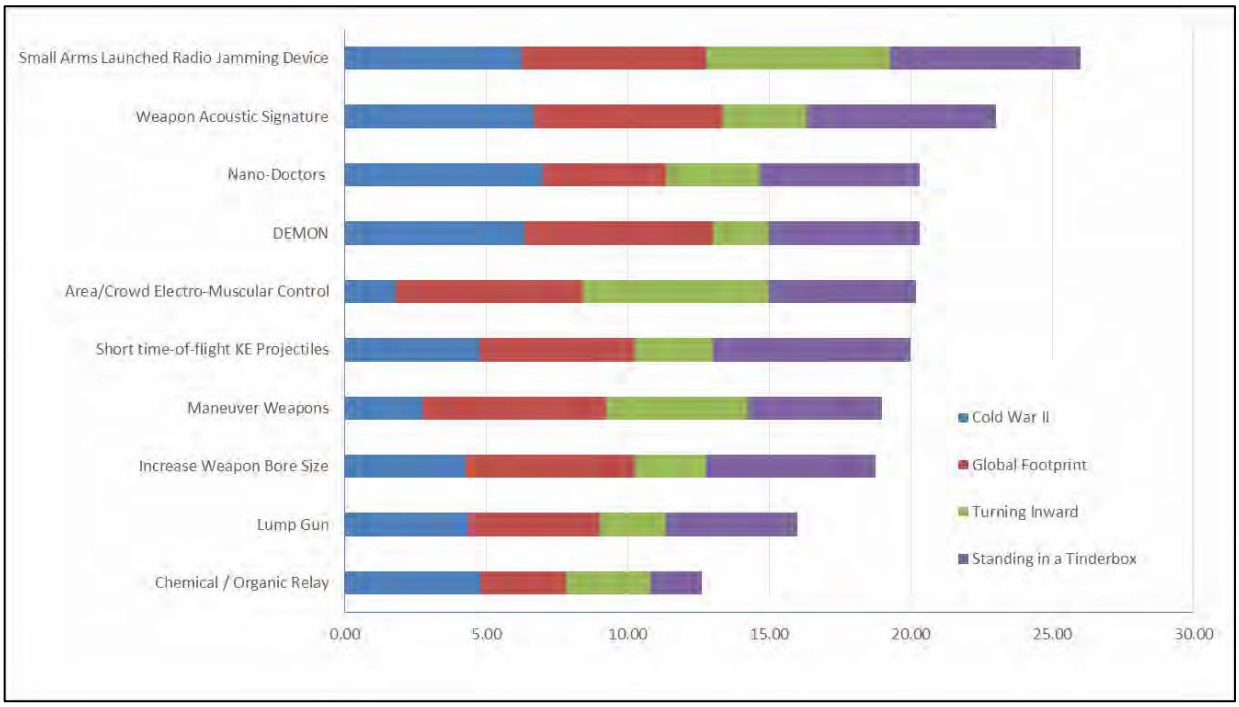

Figure 12-7. Phase II Applicability Results for Technical SMEs (Concepts Listed on the Left)

In the final part of the questionnaire, the End User SMEs were asked to rank the impact that each concept would have on their Tactics, Techniques, and Procedures (TTP) on a scale of one to ten. A score of one indicates that there would be no impact on their TTP, a score of ten indicates that there would be a significant shift in their TTP. Figure 12-8 below shows the results for Impact on TTP as perceived by End User SMEs.

Ultimately, the value of an S&T concept to JSSAP is not just the utility and applicability scores that were generated based on the 2013 JSSAP Deep Future Report methodology. Those scores do not take into account whether or not the ranked concept is related to small arms, or the type and number of small arms technologies related to the concept. The final ranking of the concepts combines the ranking system with the number of associated small arms technologies.

The top ranking **Phase I** concepts are shown in Table 12-9. This table presents the concepts that were primarily related to small arms and were ranked in the top 10 with respect to average utility and/or applicability. In addition to the eight small arms concepts, this table includes two concepts that are not directly related to small arms. These concepts were included because, in addition to having high scores for utility and applicability, they encompassed a number of technologies related to small arms.

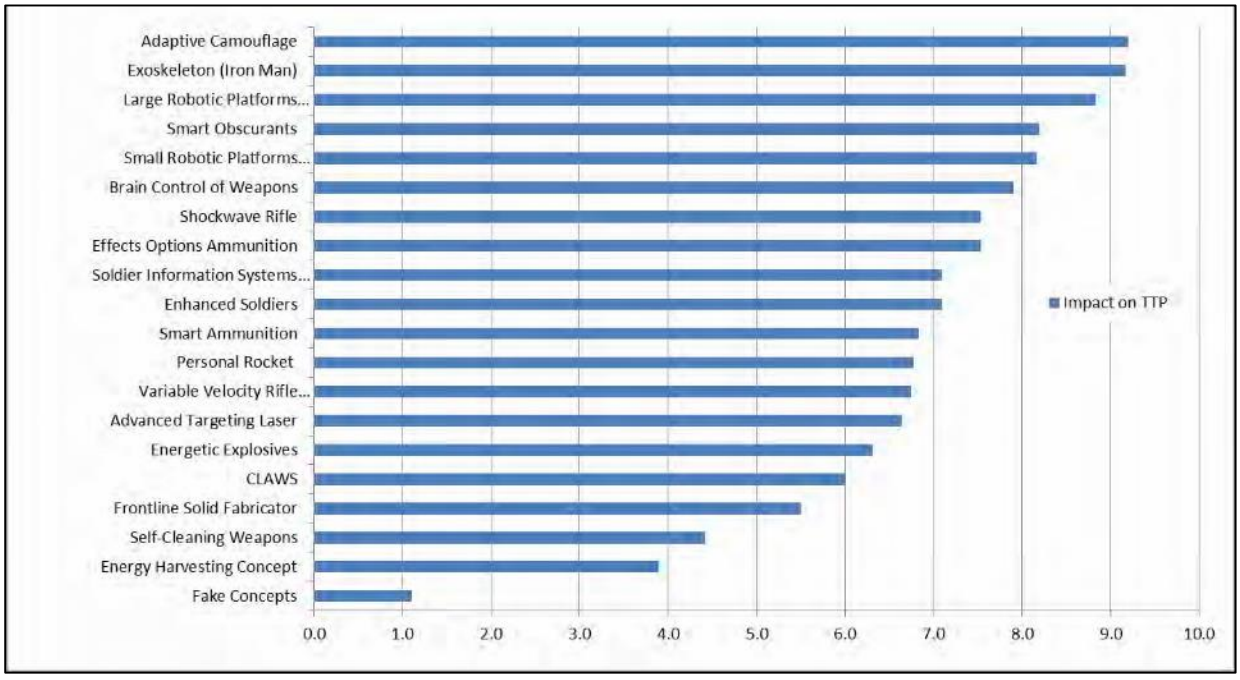

Figure 12-8. Impact on TTP Results for End User SMEs (Concepts Listed on the Left)

Concept	Final Rank	Average Utility Rank	Average Applicability Rank	Small Arms Concept	Associated Small Arms Technologies
WASP (Weaponized Assault Surveillance Platform)	1	5.5	3	No	2
CLAWS (Combat Lightweight Automatic Weapon System)	2	4.5	6	Yes	4
SAVE (Soldier Asymmetric Vision Equipment)	3	8.5	6.5	Yes	1
Electric Rifle	4	14	3	Yes	5
HEPA (Hyper Energy and Power Ammunition)	5	8.5	8.5	Yes	4
DENI (Directed Energy Negation and Integration)	6	10.5	7.5	Yes	3
Effects Options	7	12.5	6	Yes	6
Energy Harvesting	8	12.5	7	Yes	4
Kinetic Modular Weapon Platform	9	10.5	10.5	Yes	3
Exoskeleton (Iron Man)	10	1	5	No	4

Table 12-9. Phase I Top Ranked Concepts

Phase II focused on a total of ten technologies, presented in Table 12-10. The highest rated concepts included a small arms launched radio jamming device, a shoulder fired laser device that targets rotating wing aircraft (DEMON), and a device that completely masks a weapons acoustic signature.

Concept	Final Rank	Utility Rank	Applicability Rank	Small Arms Concept	Associated Small Arms Technologies
Small Arms Launched Radio Jamming Device	1	3.0	1.0	Yes	2
DEMON	2	2.0	3.0	Yes	4
Weapon Acoustic Signature	3	5.0	2.0	Yes	1
Short time-of-flight KE projectiles, low mass tubular or ramjet	4	1.0	6.0	Yes	5
Internal First Aid (Nano-Doctors) / Nano-Doctors in Reverse	5	7.0	4.0	No	4
Increase Weapon Bore Size	6	4.0	8.0	Yes	3
Area/Crowd Electro-muscular Control	7	8.0	5.0	Yes	6

Concept	Final Rank	Utility Rank	Applicability Rank	Small Arms Concept	Associated Small Arms Technologies
Maneuver Weapons Designed for Confined Spaces – Buildings, Caves, Tunnels, etc.	8	6.0	7.0	Yes	4
Lump Gun	9	9.0	9.0	Yes	3
Chemical / Organic Relay	10	10.0	10.0	No	4

Table 12-10. Phase II Top Ranked Concepts

The final portion of this study was to conduct an engineering assessment on each of the selected S&T concepts. An engineering assessment was conducted for all twenty seven (27) of the S&T concepts documented in the 2013 report entitled *Envisioning the Deep Future of Small Arms 2022–2042*. An additional 171 S&T concepts were identified in previous JSSAP Futures reports, dating back to 1986. Of those S&T concepts, ten (10) were selected for engineering assessment.

Associated Technologies Results

Part of the engineering assessment was to identify technologies that are central to the success of the concepts. The technologies listed below are the top technologies that apply to multiple concepts. Note that not all of the concepts presented in the JSSAP Futures reports were directly related to small arms. Some of the concepts presented in these reports were focused on technologies that enhance soldier capability but were not small arms weapon systems or components (i.e., concepts in areas such as survivability and communications). In Table 12-11, the listing is a sort for the 20 most common technologies associated with all the concepts. In Table 12-12, the list is a sort for the 20 most common technologies that were directly related to small arms concepts. The count for occurrence in all concepts and in small arms concepts is provided in both tables.

Technology	Occurrences	
	All Concepts	Small Arms Concepts
Battery Technology – High Density	15	3
Battery Technology – Light Weight	14	3
Battery Technology – Fast Charging	10	1
Target Identification and Tracking / IFF	10	1
Encrypted Wireless Communications / Secure Communications	9	0
Robotics Mobility	9	0

Power Generation / Micro Power Generation	7	1
Advanced Propellants / Liquid Propellants	6	6
Artificial Joints and Limbs	6	0
HUD / Helmet Mounted HUD	6	0
Advanced Fire Control System	5	3
Electromagnetic Launch	5	5
Advanced Energetics / Nano-Energetics	4	4
Neuromuscular Interference / Human Electro-Muscular Incapacitation (HEMI)	4	3
Millimeter Wave / Microwave Weapons	4	3
3D Printing of Metals	3	2
Electromagnetic Pulse (EMP) Weapons	3	2
Cloud Based Computing	3	0
Radio Frequency Identification (RFID)	3	0
Light Weight Ammunition (Caseless and Polymer Cased)	3	3

Table 12-11. Top Technologies Sorted for All Concepts

Technology	Occurrences	
	All Concepts	Small Arms Concepts
Advanced Propellants / Liquid Propellants	6	6
Electromagnetic Launch	5	5
Advanced Energetics / Nano-Energetics	4	4
Advanced Fire Control System	5	3
Battery Tech – High Density	15	3
Battery Tech – Light Weight	14	3
Neuromuscular Interference / Human Electro-Muscular Incapacitation (HEMI)	4	3
Millimeter wave / Microwave Weapons	4	3
Light Weight Ammunition (Caseless and Polymer Cased)	3	3
3D Printing of Metals	3	2
Advanced Fuzing	2	2
Electromagnetic Pulse (EMP) Weapons	3	2
Light Weight Small Arms / Light Weight Materials	2	2
Munition Guidance	2	2
Pain Beams	2	2
Barrel Coatings	1	1
Sensors (Fire Rate / Barrel Wear)	1	1
Sensors (Non-Lethal Weapons)	1	1

Technology	Occurrences	
	All Concepts	Small Arms Concepts
Enhanced Warhead Design	2	1
Electronics/Circuitry Miniaturization	1	1

Table 12-12. Top Technologies Sorted for Small Arms Concepts

Science & Technology Strategy to Achieve Goals

Ultimately the above section recommends technology investments into the top 4 areas as related to small arms of 1) Advanced Propulsion (Propellants / Liquid Propellants) 2) Electromagnetic Launch, 3) Advanced Energetics / Nano-Energetics and 4) Advanced Fire Control System. Investments into these areas will lay the ground work for future success, but these four investments fall short of creating a holistic strategy.

Section 11 of this JSATDS creates the Strategy: BA 6.3 System Integration and Demonstration Program. Along with Section 11 the Soldier Modernization Process Deep Dives have specifically listed the following Technical efforts:

1) Soldier Asymmetric Vision Equipment (SAVE)
2) Squad Level Active Collaborating Knowledge (SLACK)
3) Self Healing Weapons

An analysis of these programs have been performed by Battelle. Quad charts are included below summarizing their findings. For their analysis a pacing technology was defined as a technology that is likely to evolve over time without the support of JSSAP. For example, batteries and battery-related technologies have evolved greatly over the past decade, and the advancement of battery-related technologies is expected to continue into the foreseeable future. Additionally, batteries and battery-related technologies have seen heavy investment from both the government and private industry. This makes batteries a “pacing technology.” Many of the S&T concepts the Deep Future bucket are “paced” by battery technology. This means that these concepts will mature as batteries (or other lightweight power sources) mature, and additional funding by JSSAP could expedite the maturation process.

For this effort a limiting technology was defined as a technology that was mature. These technologies are not expected to evolve in the absence of a scientific breakthrough. A good example of a limiting technology is passive steel armor. Modest gains have been made over the past few decades, but core technology remains unchanged. With respect to the S&T concepts, a limiting technology is seen a large hurdle to the maturation process, a hurdle that may never be overcome. These pacing and limiting designations are important caveats as a strategy and program plan are being assembled as an outgrowth of this JSATDS.

Self Healing Weapons

Original Concept Statement

- **Original**: This concept was presented to the "Envisioning the Deep Future of Small Arms 2022 – 2042"users group as Weapon self-cleans / identifies / mitigates / notifies weapon wear. Optimizes accuracy to environment
- **Presented to user**: A Weapon that self-cleans / identifies / mitigates / notifies weapon wear. Optimizes accuracy to environment

Assumptions

- Surface coatings and propellant formulations and additives can prevent or greatly reduce the adherence of powder fouling and copper jacket build up on the barrel (CFE 223)
- Wear will result in measurable changes in the frequency spectrum of the weapon during operation
- Controlling the cyclic rate can prevent over heating of the barrel and rapid erosion of the throat
- Monitoring cyclic rate can be used to predict maintenance intervals and/or component life remaining.

Associated Technologies

Technology	Technology Category
Vapor Deposition	Pacing
Gas Generating Energetics	Limiting
Sensors	Pacing
Sensors and Software	Pacing
Lubrication	Pacing
Thermal Control	Limiting
Materials	Limiting
Stereo lithography	Limiting

Forecast

Surface coatings can improve gun barrel wear by making the gun barrel surface harder and smoother then the donor in the abrasion and metal removal of the projectile going through the gun barrel will only be the projectile.

Propellant formulations and additives can prevent or greatly reduce the adherence of powder fouling and copper jacket build up on the barrel

Wear will result in measurable changes in the frequency spectrum of the weapon during operation

Chart 12-13. Self Healing Weapons Quad Chart

Soldier Asymmetric Vision Equipment (SAVE)

- **Original Concept Statement:** Soldier deployed spectrally tunable obscurants with commensurate sensors, optics, and optics that allow users to see one another while non-users are denied vision. Can also create localized communications baffling for targets, denying radio/phone contact.
- **Original**: **Presented to user**: Smart Obscurants

Assumptions

- Power requirements can be met by host vehicle
- The entire system is lightweight and easily deployable.

Associated Technologies

Technology	Technology Category
Spectrum and Wavelength Operating in the Visible spectrum 0.4 – 0.7 um	limiting
Spectrum and Wavelength Operating in the Near Infrared 0.7 – 1.2 um	pacing
Spectrum and Wavelength Operating in the Short Wave Infrared 1.5 – 2 um	pacing
Spectrum and Wavelength Operating in the Mid Infrared 3.0 – 5.0 um	pacing
Spectrum and Wavelength Operating in the Far Infrared 8 – 12 um	pacing
Gold and silver nano structures	pacing
Peak wavelengths, peak widths, absorption/scattering ratios	limiting
Operating across multiple bandwidths	pacing
Negative Index Material - Building Blocks	pacing

Forecast

- Future technologies aim towards large scale applications; however the majority of technologies remain in the small-scale range. At this stage of development, researchers are focusing on successful small-scale demonstrations with future goals of scaling the technology to real world applications.
- Several of the technologies related to the concept have the potential to expand into the communication realm as either communication disruptors or enablers.
- Cloaking technologies remain in small-scale development. If active cloaking technologies scale to real-world applications, there will be additional equipment associated with the technologies.
- It is foreseeable to merge the passive and active technologies to create a solution. The object cloaking discussion may focus toward the question of preference, solutions with metamaterials or those reliant on sensor arrays.

Chart 12-14. Soldier Asymmetric Vision Equipment (SAVE) Quad Chart

Squad Level Active Collaborating Knowledge (SLACK)

- **Original Concept Statement:** A small unit networked fire control unit that integrates member/weapon location with threat locations to allow commander to maximize firing effect from a squad, de-conflict targets, prioritizing threats, direct firepower and collective maneuvering of the small unit.
- **Original**: **Presented to user**: Soldier Information Systems (Part Of)

Assumptions

- The SLACK system needs to integrate with various inputs including weapon systems, gunners, topography data, target data, target coordinates and other battlefield information.
- The system needs to communicate with the various sources of information and as part of this information exchange, communication security becomes an issue.
- The SLACK system integrates localized data from a small unit and if this were to be taken to a higher level, the data from the SLACK unit could be further integrated with multiple units and support groups. This type of data integration is referenced as a Weapon Informatics Soldier-Human or WISH system.

Associated Technologies

Technology	Technology Category
Secure Communications	Pacing
Sensors (Weapon System Status)	Pacing
Sensors and RFID (Soldier born)	Pacing
Sensors and RFID (Ammunition)	Pacing
Communications	Pacing

Forecast

- Battlefield data from various sources can be incorporated into a real time usable information that can meet the needs of the soldier and weapons system(s).
- Real time information could include combatant location, building/structure, combatant weapons, combatant auxiliary support and other battlefield variables.
- This concept could be developed into a soldier information center via visual displays that could be weapon or helmet mounted. The soldier could easily access images from other soldiers or sources on combatant details.
- Many additions can be supported by the SLACK system that directly benefits the soldier in terms the soldier's health and/or engagement scenario
- The SLACK system can support and/or the weapon readiness status, ammunition use, fire control and targeting, adjustments for topography and weather conditions and other function characteristics.
- The SLACK system is envisioned as a progressively improving system that would be improvised based on the engagement type and conditions.

Chart 12-15. Squad Level Active Collaborating Knowledge (SLACK) Quad Chart

Clearly from the Pacing and limiting the SLACK concept is far more mature and ready for investments from a 6.2 perspective. The SLACK concept exceeds the Technical Fire Control effects currently programmed and crosses into the Tactical Fire Control arena. It also supports the future Weapon Informatics Soldier-Human or WISH system. The SLACK program is forecasted for 6.3 integration in FY27. The 6.2 Optics and Fire Control JSATDS strategy covers the necessary financial investments at this time for the SLACK program.

From a limiting perspective, both the SAVE and the Self-Healing Weapons quads require additional analysis.

The SAVE package is intended to be deployed by the soldier to render an object or individual invisible from non-users. This is accomplished through the use of sensors, optic devices, and associated electronics. The intent is that the sensor array is capable of disrupting communication related to targets or radio contact. The new technology would enable spectral segment defeat, ranging from ultraviolet (UV), visible, Infrared (IR), radar, and radio and any combinations thereof. Ideally the system is deployable by any three scenarios, individual, crew and vehicle born with attainable power requirements assumed.

Future technologies aim towards large scale applications; however the majority of technologies remain in the small-scale range. At this stage of development, researchers are focusing on successful small-scale demonstrations with future goals of scaling the technology to real world applications. Researchers enabling metamaterials based cloaking believe it is possible to manufacture new materials to larger scales, especially as the art of manufacturing complex materials continues to develop and grow as seen in the last decade.

Cloaking technologies remain in small-scale development. If active cloaking technologies scale to real-world applications, there will be additional equipment associated with the technologies. Additional equipment may be worn by an individual or applied to a piece of equipment. If the technology advances to wide perimeter areas, the technology may be deployed over a wide area.

All options require sensor procurement, transportation, application and monitoring. Incorporating a cloaking system to the soldier adds an additional system that the soldier must monitor and track. At this time, it is difficult to predict which technology is likely to advance to full-scale applications. Likely the advancement is dependent on multiple factors, such as funding levels and manufacturing advancements in some cases. The Army's Small Business Technology Transfer (via A13A-T016) has requested the same or similar technology areas. JSSAP at this point should monitor the progress of the STTR efforts for future integration.

The Self-Healing Weapons concept is a weapons monitoring and stabilization method that optimizes the weapons usage variables. The subject matter experts and end users have indicated that in order to be useful to the solider the Self-Healing Weapons concept must perform as described below:

- Powder residue and copper jacket material do not adhere to weapon
- Minimum time (or rounds) between cleaning TBD
- Weapon indicates required maintenance, i.e. cleaning, lubrication, parts replacement

The subject matter experts and end users have indicated that if the following features could be added to the weapon systems, then the objective of a clean and uniform performing weapon could be achieved;

- Mechanical action of weapon prevents firing residues from building up in weapon
- Sensors monitor the frequency of vibrations of the weapon during operation and measure wear to predict maintenance needs
- Temperature sensors slow cyclic rate to prevent rapid erosion of rifling due to high rates of continuous fire (could be as simple as a bimetallic spring)
- Fire control integrates environmental factors (range, temperature, atmospheric pressure, etc.) and makes correction to reticule.
- Data logger tracks number of rounds fired, rate of fire, temperature of wear prone components during firing.

From a technical perspective, as referenced in Chart 12-12, the limiting technologies include:

1) Propellant formulations and additives can prevent or greatly reduce the adherence of powder fouling and copper jacket build up on the barrel (CFE 223). There are continuous investigations in formulating cleaner burning propellants but due to the nature of the product, combustion of nitrocellulose and additional energetic materials is required to create the gas generation properties needed for the projectile propulsion. Propellant investments are covered in BA 6.2 Ammunition and by ARL.

2) Deep Cryogenics. Another futuristic concept of a Self-Healing weapon is to the ability to control and adjust the Gun Barrel diameter such that each shot from the first to the last shot of the gun barrel's usage life has a controlled gun barrel Internal Diameter (ID). In having the ability to control the gun barrel diameter at all times including, through various environmental exposures, varying gun barrel operating temperatures, after multiple projectile firings and accounting for all of the debris and frictional forces that cause wear and tear on the gun barrel can have a benefit of optimizing the gun barrel performance and it will be able to deliver the projectiles more uniformly. Effectively, a "smart" gun barrel system can be create via the control of gun barrel temperatures. JSSAP should invest in gun barrel development under the BA 6.2 Weapon Systems/Enablers.

3) Metallic Glass. A novel research effort is currently taking place that the development of strong and lightweight materials and could prove to be stronger than our current materials such as steels and tool steels. "Material scientists in California have made a special metallic glass with a strength and toughness greater than any known material, using a recipe that could yield a new method

for materials fabrication. The concept is in its infancy and needs further development to be used as a raw material for any application in gun barrels. JSSAP should monitor this effort.

4) 3D Printing of Metals. A novel approach to replacing worn material with new technologies is 3-D printing. This method is a concept of adding material in layers via using a thermal source (heat source, laser or any other reaction to solidify a material at a controlled point. Using three dimensional points, solidification of material can be made. Repeating this solidification process on multiple point on a plane and then raising the plane level to solidify more material, 3-D or three dimensional parts can be created in various materials including, plastics and metals. Using this concept of material build up or additive material deposition on gun barrels may have an application if the concept can be improvised to do additive material application on the bore of a gun barrel. JSSAP should invest in gun barrel development under the BA 6.2 Weapon Systems/Enablers.

Science & Technology Recommendations:

As part of JSSAP's mission for responsibility of "Long Range Plans and Strategies" the organization has held numerous Deep Dives with Scientists, Science Fiction Writers, Subject Matter Experts from the Government, Subject Matter Experts from just Industry, combinations of both categories. JSSAP has held mini challenges and specifically placed futurist requirements on their Request for Proposals (RFPs) from Industry. It is recommended that these efforts continue. JSSAP has a large internal and external Stakeholder network that they can draw upon. The JSTAC creation of S&T Chiefs provides an opportunity for other portals of participants. The bottom line is that Future Casting must be regularly programmed.

As part of this recommendation JSSAP should allocate 10% of their 6.2 POM requests in each BA category specifically towards awarding future related technology efforts. The identified technical issues are covered by JSSAP's specific taxonomy BA 6.2 requests and should be kept in those taxonomy bins. These award of these future efforts can be targeted at both Industry and Government Organizations. It is recommended that this practice be formalized through internal and external contracting methods.

It is also recognized in the JSATDS and by JSSAP that the "Research Labs" such as ARL, NRL and AFRL and also DARPA play a significant role in the Deep Futures investments. ARL publishes each year their program plans.

Their plan states that they are focusing on addressing "Empower Individual Soldier's with Full spectrum capability" and "Create the Next Generation Lethal Systems". Additionally, the area is focused on providing technologies that can help address "Provide Non-lethal Effects from 0-1000m against Individual and Groups of human targets". ARL's program titles all start with "Low Cost". Affordability is a driver for them.

From a strategy perceptive, the JSATDS needs to remain focused in BA 6.2/6.3 and continue their relationship ARLs allowing them to maintain their mission of the Deep Futures Basic Science 6.1 investments. The JSTAC needs to develop relationships with NRL and AFRL and also continue their relationship with DARPA and RDECOM RFEC to maximize transitions in the Deep Futures area.

13. International Involvement

Today's small arms development (weapons/enablers, ammunition and optics and fire control) can leverage development and resources through Information Exchange Agreements, Cooperative Research Project Agreements, Cooperative Research Project Agreements, Foreign Comparative Testing. Listed below is a compilation of known resources in the international area:

Country	Title/TPO	US TPO
Canada	Small Caliber Weapons and Ammunition	ARDEC
Israel	Infantry Weapons	ARDEC
Japan	Small Arms Technology	ARDEC
Singapore	Weapons & Ammunition	ARDEC
Korea	Conventional Firearms, Recoilless Rifles, Mortar and Artillery Weapons	ARDEC
Poland	Weapons and Munitions	ARDEC
Sweden	Small Arms Technologies	ARDEC

Table 13-1. Current IEAs/DEAs as related to Small Arms

Country	Establishment	Project Title
Taiwan	Chung-Cheng Inst of Tech (CCIT), National Defense University (NDU)	Design a LtWt 5.56mm rifle barrel made of Carbon/Carbon Composite
Sweden	SAAB Bofors Dynamics	Lightweight M3A1 Recoilless Rifle
Singapore	ST Engineering	40mm Counter Defilade Grenade and Fire Control Systems; Airburst Low Velocity Sighting System for Air Burst Round

Table 13-2. Current Foreign Comparative Testing (FCT) Projects as related to Small

Arms

Though listed above as known resources, the IEAs and DEAs fall short of creating a strategy that the small arms community can fully rely on. To maximize international resources for the small arms community a three pronged approach has been undertaken.

Strategy One: RDECOM RFEC- Atlantic

The first strategy is the utilization of the U.S. Army RDECOM Forward Element Command – Atlantic (RDECOM RFEC- Atlantic). The RDECOM Forward Element Command (RFEC) Supports U.S. Army International Armaments Cooperation and Standardization mission. Promote multinational force capability. Under the RFEC-Atlantic there are three International Technology Centers (ITC). The ITCs promote Science and Technology collaboration between U.S. Army and international researchers to advance science and engineering knowledge relevant to the U.S. Army mission. RFEC- Atlantic has undertaken the mission of answering the following key questions:

1) What research is being conducted by Foreign Academia/Industry that applies to the JSATDS Taxonomy?
2) What government projects as related to Small arms and the JSATDS Taxonomy should we be aware of to leverage?
3) What other pieces of information can RDECOM RFEC – Atlantic provide back to the JSTAC that will enable us to better capture the larger picture for Small Arms development?

Strategy Two: New Project Agreements

The second strategy is the creation of international project agreements. These proposed international Project Agreements have been recommended by the NATO Land Capability Group Dismounted Soldier System - Weapon and Sensor Group Chairman. The NATO chairman based on 5 years involvement in the LCG DSS and after reviewing numerous presentations from the 28 NATO member countries, Partners for Peace and Contact Countries recommends the following partnerships.

1) **Australia:** Project Land 125 Ph3C. The objective of the Australian project is to provide Enhanced Lethality to the F88 rifle (EF88). Australia is in Phase #3. The Scope of Land 125C is to provide a: Systems Approach (integrated weapon design), Modular/future-proofed rail mounts, 4 basic variants (commander, marksman, grenadier & standard), Electronic architecture, Enhanced GLA for grenadier. This project focuses on a “lethality” result similar the Probability of Incapacitation. The US should partner with Australia to gather lessons learned from their testing data and Human Factors development. The United States needs to monitor or approach Australia to get lessons learned of this product in an effort to offset investments for the Next Generation of Weapon Systems.

2) **Canada**. Canada has developed a “New Smart Gun”. Canada states through public news reports that “More firepower, improved accuracy and smart integrated accessories that connect to command and control networks are the headline features of the new integrated assault rifle concept that Defence Research and Development Canada. (DRDC) and Colt Canada have developed for the Canadian Armed Forces (CAF).

The prototype, in development since 2009 through the Soldier Integrated Precision Effects Systems (SIPES) project, includes a firing mechanism to shoot lightweight cased telescoped ammunition, a secondary effects module for increased firepower and a NATO standard power and data rail to integrate accessories like electro-optical sights and position sensors.

Canadian Scientists studied how to increase the rifle’s accuracy using technology that can automatically detect targets and assist with engaging them. Questions related to the sensors needed to accurately geo-locate targets for target data sharing were also investigated.

How the soldier interacts with the weapon was also the subject of numerous human factor trials. Ergonomic and weapon prototype handling tests were performed by Human Systems Inc., under the supervision of DRDC scientists, with CAF soldiers from military bases in Petawawa and Edmonton. The testing was crucial to developing optimal design criteria to meet the CAF’s needs for the Small Arms Modernization project.

The SIPES projects utilizes Case Telescope 5.56mm ammunition (ammunition developed under the JSSAP LSAT Program) with an electronic trigger and target tracking algorithms similar to the ones developed by the JSSAP Small Arms Weapons & Fire Control Program.

Additionally The US should monitor the Soldiers Weapon Observer Reconnaissance Devices (SWORD) being developed through the Canadian Government and Colt Canada Advanced System. The below slides were presented at the NATO LCG DSS W&S meeting in 2015.

3) **Netherlands:** The Netherlands are developing Special Ammunition: (Supercavitating ammunition (MEA) and subsonic ammunition.) The Supercavitating ammunitions supports their (OTB) capability. This is an area of interest as articulated by SOCOM.

4) **The United Kingdom**: The UK has briefed two significant projects recently at the NATO LCG DSS Meetings. The first is their Small Arms Power & Data Integration project. The second is the UK’s DDE Weapon as a Platform (WAAP).Both these projects minimize the risk of the future integrated Power Rail for the United States by having access to human factors lessons learned from an integration and Soldier cognitive ability assessment.

6) **Italy:** Italy is developing the new Barrett ARX 160 with a powered rail on it. This is the third nation to go forward with the NATO Approved STANAG 4740 design of the Power Rail. Again the United States needs to monitor or approach Italy to get lessons learned of this product in an effort to offset investments for the Next Generation of Weapon Systems.

7) **Poland:** Poland is the fourth country developing a new Weapon system with a power rail.

Strategy Three: NATO LCG DSS Involvement and leveraging of Teams of Experts

LAND CAPABILITY GROUP ON DISMOUNTED SOLDIER SYSTEMS (LCGDSS)

LCGDSS is the joint North Atlantic Treaty Organization (NATO) group responsible for the system aspects and all equipment for the dismounted operations of Soldiers, Sailors, Airmen, Marines and Special Forces operators. The Dismounted Soldier is defined as those items and equipment that are worn, carried or consumed by the soldier and those items carried for individual or small team use. They:

- Facilitate information exchange among national soldier system programs. The information covers relevant emerging technologies and lessons learned from operations, as well as national and Alliance requirements, concepts, research & development and acquisition programs relating to dismounted soldier systems and equipment, in order to harmonize requirements, establish common concepts and identify areas suitable for cooperative development. Identify implications, requirements, and ways forward for the needs of soldier systems in various ground and air vehicles that might be shared in coalition operations.

- Develop and maintain NATO Standardization Agreements (STANAGs), requirements, white papers and reports related to national dismounted soldier systems, including hardware, weapons, ammunition, Battlefield Combat Identification (BCID), software and training. STANAGs are related to the interoperability of national soldier systems in the critical areas of Power, C4I, Combat Clothing, Individual Equipment, Protection, Head Borne Systems, Systems Architecture, Weapon Systems and Ammunition. STANAGS are developed as LCGDSS identifies and establishes areas of standardization that will enable collaborative development and provide increased capability on dismounted coalition operations.

- Execute the NATO Army Armaments Group (NAAG)-approved program of work as directed via the Land Armaments Management Plan (LAMP) and advise the NAAG on systems and equipment aspects of dismounted operations. Support the objectives of NATO armaments cooperation by identifying and pursuing cooperative programs for the development and procurement of dismounted soldier systems using existing mechanisms such as Phased Armaments Programming System (PAPS); recommend to the NAAG proposals for bilateral or multilateral cooperation.

•Cooperate fully and maintain close liaison with the separate bodies of NAAG, the Conference of National Armaments Directors (CNAD), the NATO Military Authority and other bodies, especially NATO Industrial Advisory Group (NIAG), Research and Technology Organization (RTO) and Joint Analysis and Lessons Learned Centre (JALLC) that have related interests in dismounted soldier systems and equipment so that resources are complementary and duplication of effort is avoided.

Work Groups that fall under the construct of the This Joint Small Arms Technology Development Strategy (JSATDS) include:

Sub Group on Small Arms Ammunition Interchangeability (SG1): responsible for the standardization of all technical aspects of Small and Cannon Caliber Ammunition (up to and including 40 mm and the ancillary items such as links, clips, magazines, bandoliers, boxes, etc.).

Sub Group on Non-Lethal Capabilities (NLC): responsible for NLC across the full spectrum of military operations and operating environments. Has a joint and 3-service focus within Nations and CNAD. SG NLC promotes and improves NATO NLC through information exchange, standardization of NLC materiel, support to NLC-related doctrine development and identification/ promotion of multilateral cooperative activities.

Weapons & Sensors (WS) Group: responsible for issues related to soldier's weapon systems, grenades and shoulder launched and guided anti-tank weapons, as well as dedicated sensors including day and night sights, laser designators, tactical lights and fire control systems. Weapon system includes the weapon itself, different types of ammunition and the dedicated accessories. Responsible for the interface of weapons and sensors with the various other parts of the soldier system and relevant Combat ID related Standards.

Soldier Capability Analysis Group (SCAG): responsible for assessing the operational needs of coalition tactical dismounted forces and guides and makes recommendations to the plenary work of the subordinate groups. Provides the operational basis and rationale for the work of LCG DSS. Work is conducted using a combination of expert military judgment, research and analysis to provide advice and guidance

The United States currently provides the Chairman for the NATO Land Capability Group Dismounted Soldier System (LCG DSS), the Chairman for the Weapons & Sensors (WS) Group, the Chairman for the Sub Group on Non-Lethal Capabilities (NLC), the Vice Chairman for the Sub Group on Small Arms Ammunition Interchangeability (SG1), The Superintendent for the North American Regional Testing Center (NARTC) and the Vice Chairman for the SCAG in addition to Heads of Delegations for all seven sub groups and various subject matter experts to support the ongoing information exchanges and Teams of Experts.

The Weapons & Sensors (WS) subgroup under the LCG DSS currently has five Teams of Experts (ToEs) that must be supported to provide interoperability and compatibility with NATO Partners and also these ToEs offset the financial investments that JSSAP

and stakeholders of the JSTAC would normally incur to develop components, weapons, and test methodologies. Listed below, Table 13-3, are the active Teams of Experts that the LCG DSS W&S group is supporting.

Team of Expert Title	Purpose	Status
Suppressor Team of Experts - Acoustic	Develop a Suppressor Testing Protocol on Acoustic Signature Measurement of Small Arms Suppressors	Test Methodology submitted to the NATO Standardization Agency with the Support of JSSAP, ARDEC, PM SW, USMC, NSWC Crane
Suppressor Team of Experts - Flash	Develop Standardized test methodologies for Flash, Visual, Thermal measurement for the weapon System	ToE kicked off Feb 2015. Support being provided by JSSAP, ARDEC, ARL, HRED, PM SW, USMC, NSWC Crane
D/14	Develop Evaluation procedures for future NATO Small Arms Weapon Systems	Team of experts Formed Oct 2012. Support being provided by JSSAP, ARDEC, PM SW, USMC, NSWC Crane
STANAG 4512	Develop Common definition for Dismounted Personnel Targets	ToE formed in Feb 2015 led by Sweden. Canada, UK and USA (PM SW, PM SSL) will participate. Transition of SET-209 into updated STANAG. (Exploitation of Human Signatures for Threat Determination)
G/3 Cone	Develop a replacement G/3 cone foe the M/3 Tripod. M3 Tripod is a weapon mount used on the M2HB Browning .50 Cal MG	ToE formed in Oct 2014 led by Norway. USA (JSSAP and PM SW) has provide support with original (1950 era) drawings.

Table 13-3. Current NATO LCG DSS W&S Teams of Experts

14. Maintenance and Updating of the JSATDS Document

The JSSAST Opportunity Areas were developed through a formalized Standing Operating Procedure (SOP) derived from the Lean Six Sigma Project #1187, "Improved Technical Selection Process for FY16 – FY21 JSSAP Office R&D Projects. Source Documents were requested from the JSSAST Principal Members (Army, Navy, Air Force, Marines, Coast Guard and SOCOM).

The agreed upon Implementation and Control plan established detailed timelines for yearly review of the Opportunity Areas. Figure 14-1 provides the flow diagram of the overarching process. Figure 14-2 provides a timeline for each step to be accomplished.

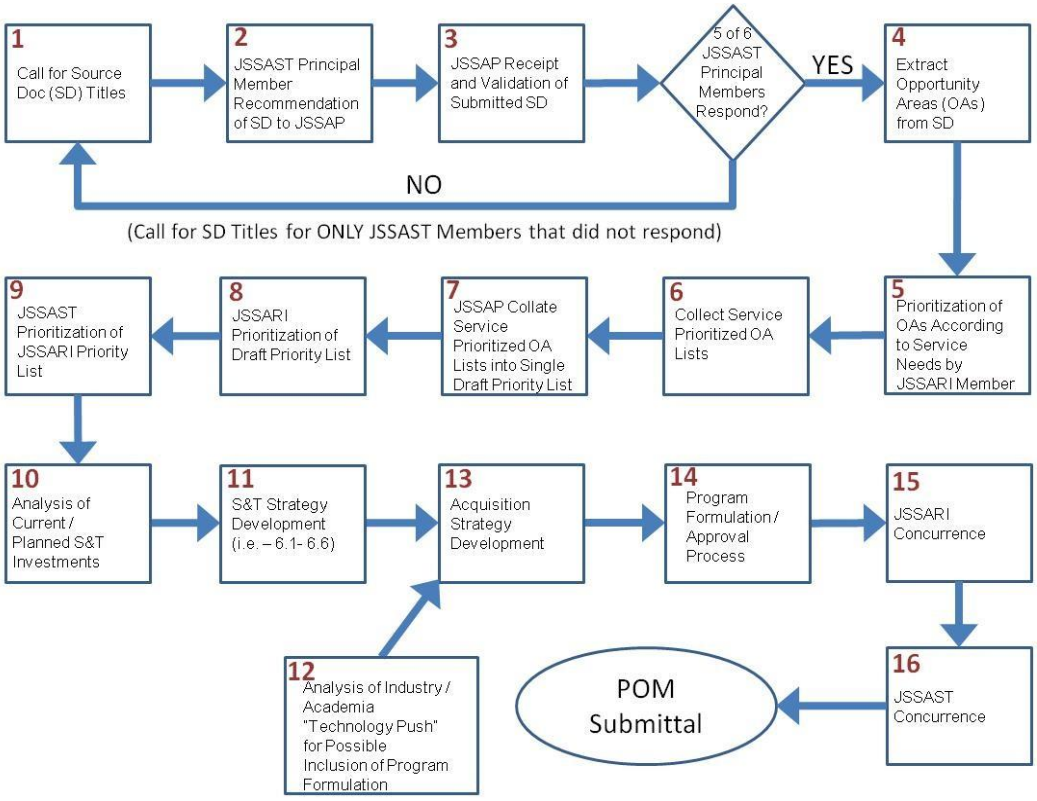

Figure 14-1. Standard Flow for Updating Opportunity Areas

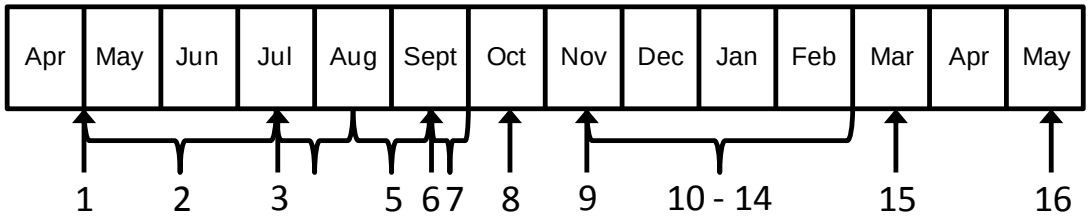

Figure 14-2. Timeline for Conducting the Annual Update

After the approved JSSAST Approved Opportunity Area list is returned to the JSSAP Office in Nov of each year, the JSTAC must analyze the Approved Opportunity Area list and compare it with current and planned Science and Technology Investments across the DOD and DOE, to ensure that duplication of efforts do not occur.

Utilizing the above Science and Technology Investment analysis, the JSTAC shall re-develop, as necessary, the Joint Small Arms Technology Development Strategy (JSATDS) to address the greatest number of Opportunity Areas that are not currently receiving or have limited funding.

Following the Joint Small Arms Technology Development Strategy (JSATDS) re-development, the JSTAC shall re-develop the Acquisition Strategy, as necessary, to fulfill the Science and Technology Strategy. In this process, a re-analysis of Industry and Academia "Technology Push" shall be performed for possible inclusion of "Technology Push" efforts in the Program Formulation.

The Joint Small Arms Technology Development Strategy (JSATDS) is a living document and current agencies are envisioned to retain their roles in the updating process of this strategy.

15. Summary and Final Thoughts and Comments

This Technology Development Strategy has been prepared under the auspices of the Joint Service Small Arms Program through the Joint Service Small Arms Program Science and Technology Advisory Council (JSTAC). This strategy represents the projected direction of the current and future small arms needs of the Armed Services. It accounts for specific documented requirements of the Services and SOCOM through the use of the JSSAST approved prioritized Opportunity Areas while synchronizing Science & Technology investments to support the Soldier Modernization Process.

The JSATDS is provided at a pivotal time in the context of advancing small arms and the transformation of the small arms enterprise. This Strategy describes the structure for how our Science & Technology must be invested in order to align the JSSAP POM submission with service priorities to deliver value through an integrated approach while supporting the JSSAP Mission and Charter. The JSATDS answer a very difficult question. “Why are we spending a Billion dollars in Kinetic Energy Weapons per year and what is left to innovate and why?” A simple question yet a very complex answer.

Anyone who has spent time in the DoD market recognizes the cyclical nature of budgets and the rise and fall of S&T versus production dollars based on real world conflicts. We are in a draw down scenario where budgets are shifting from production to larger investments into budget activity 6.2, (BA 2) Applied Research. The focus is now on Leap Ahead technologies versus incremental improvements. The JSATDS shifts our investments to core technologies for a near, mid and future focus on unfulfilled operational needs based on current and future threat assessments. We previously were in a period of heavy linkage to PORs that measure S&T success as transitions.

Right or wrong, this is the cycle that we are in. Our impetus to innovate remains constant with the Soldier in mind and strong linkages to the JSSAST approved Top 50 Opportunity Areas and the Soldier Modernization Process. Our risk aversion is decreasing with the notion that the magnitude of the technological change that we can construct is based on an inclusive investment strategy for small arms and ancillary devices. We (the global we) look at technology as a means to fulfill an increase in the Probability of Incapacitation when a Soldier fires his/her weapon. The community at large has embarked on a Small Arms Configuration study to come up with options that demonstrate potential dramatic increases in P (i) and P(H). This study will help shape requirements, but it will not provide the answer for Science & Technology investments.

In the past few years JSSAP and ASA ALT have held a series of Futures conferences. The issue we had is: how do we translate the material developed from these Futures into "Acquisition" opportunities. When we hold these Futures Conferences we are attempting to stimulate Radical Innovation (RI) versus Incremental Innovation (II). Radical innovators must constantly search for the unarticulated "market" needs through experimentation and bold thinking to identify RI opportunities and engage in it successfully. These conferences are part of that identification process and now part of the JSATDS. Critical Investments are identified in the JSATDS that will allow us to position technologies to support future concepts. .

Through the writing of the JSATDS we can finally answer the question of "Why are we spending a Billion dollars in Kinetic Energy Weapons per year and what is left to innovate and why?" - Because we need to develop the necessary technologies to posture the Armed Services to provide the right materiel solutions to meet the requirements at the right time.

The resultant Joint Small Arms Technology Development Strategy portrays a synergistic investment plan that accounts for near, mid and farm term Science & Technology investments in order to maintain and achieve overmatch for the Warfighter. The final requires a significant increase in budget activity funds 6.2 to support the JSSAST Approved Top 50 Opportunity Areas, Programs of Records, The Soldier Modernization Process, near term product improvements and far term revolutionary improvements.

Finally the Joint Small Arms Technology Development Strategy (JSATDS) document could not have been written without dedication a professionalism of the Joint Service Small Arms Program Science and Technology Advisory Council (JSTAC) comprised of representatives from the Army, Navy, Air Force, Marine Corps, Coast Guard and Special Operations Command (SOCOM) joined by the Joint Non-Lethal Weapons Directorate, Project Manager Soldier Weapons, Project Manager Soldier Sensors and Lasers, Project Manager Maneuver Ammunition Systems, Office of Naval Research, The U.S. Army Research Laboratory, The U.S. Army Armament Research, Development and Engineering Center, The Communications-Electronics Research, Development and Engineering Center Night Vision and Electronic Sensors Directorate and Navy Project Manager Small Arms, RDECOM Forward Element Command, Program Executive Office Soldier, Program Executive Office Ammunition, Maneuver Center of Excellence and Army for Acquisition, Logistics, and Technology (ASA(ALT)) Research & Technology Staff Members.

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