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Small Effective Air-to-Surface Munitions for Unmanned Tactical Aircraft Applications

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1.0 SUMMARY

This paper describes two emerging munition technologies beneficial to Unmanned Tactical Aircraft (UTA) and attempts to define a necessary weapon load capability. To determine a weapon/loadout combination that maximized the lethal effectiveness of an UTA while minimizing the payload weight required, a mission level analysis was conducted and concludes that a minimum of 1000-lb (454 kg) of payload provides an UTA a viable air-to-ground combat mission capability. A 2000-lb (908 kg) payload provides an increased effectiveness but must be contrasted with the associated increase in UTA cost, size, weight and propulsion needed to employ the additional payload weight.

2.0 INTRODUCTION

As the name implies, an Unmanned Tactical Aircraft (UTA), has a mission requirement to provide a combat capability as opposed to only a non-combat mission role, such as providing reconnaissance, surveillance, or assessment of battle damage to enemy targets. Currently, to provide a combat capability against fixed-soft, fixed-hardened and stationary ground targets, the UTA must be capable of carriage and deployment of air-to-surface munitions. Unfortunately, a payload capability equivalent to only one 2000 pound (908 kg) class munition may require the UTA design to increase in size beyond what is acceptable with respect to cost and/or logistic goals. Smaller, high precision, autonomous munitions have been envisioned to provide the UTA with a desired level of combat capability. Enabling technologies being developed and demonstrated in US Air Force laboratories are beginning to provide new small weapon systems well suited to an UTA role. It is clear that a selection of munition options for UTA operations is critical to maximizing the utility and mission. Additionally, a system engineering approach is necessary to ensure that the munitions be incorporated into the UTA design early in the development phase especially since the munitions play such a key role in providing the basis for the desired combat capability.

3.0 MUNITIONS

3.1 Low Cost Autonomous Attack System (LOCAAS)

LOCAAS has successfully merged three newly developed technologies into a weapon that could change the nature of air-to-surface anti-materiel warfare. When the compact airframe design is fitted with a state-of-the-art

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sensor/seeker, and an adaptable warhead system the results are a highly capable weapon system that puts all fixed-soft, mobile and relocatable targets at risk. LOCAAS offers numerous benefits to the battle managers. Launch platforms will be held out of harms way due to the standoff capability. Platforms carrying twelve LOCAAS units have the lethal capability of 6 platforms each carrying two 'Maverick' missiles. The increase in sortie effectiveness should increase the tempo of the conflict as well.

LOCAAS houses a Laser Detection and Ranging (LADAR) seeker developed to accurately and autonomously acquire, classify, and track targets during the attack. With this capability, LOCAAS scans the battlefield, finds potential targets, and then switches into a "track" mode to differentiate between tanks, trucks, missile launchers and radar sites. Once the LADAR unit determines a valid target the computer selects the appropriate kill mechanism to maximize the lethal effectiveness. The multi-mode, shaped-charge warhead can selectively fire an armor penetrating 'long-rod' if the target is heavily armored, such as a battle tank. If the target is lightly armored or protected by reactive armor the warhead can select a penetrating 'aero-stable slug'. Finally, if the target is 'soft' or thin-skinned like a surface-to-air missile launcher, radar site, or theater ballistic missile, the warhead can operate in a fragmentation mode to distribute lethal fragments over a large area. This unique warhead achieves the three modes of operation by selectively detonating high explosive behind a copper plate. One mode forms the plate into a long rod. The second mode forms the aero-stable slug and the third mode causes the plate to break into multiple fragments.

The LOCAAS, shown in Figure 1, is 30 inches (76.2 cm) long and weighs approximately 100-lbs (45.4 kg). A miniature turbo-jet engine provides 100 nautical miles (185.2 km) range and the ability to search over large areas. The small size provides the ability to package numerous LOCASS units in current and future delivery platforms.

Warhead tests have been completed successfully. Seeker testing is ongoing. A short non-powered flight test has demonstrated the autonomous search, acquisition, target-classification and attack modes. All-up flight tests will occur within the next couple of years. Completion of the LOCAAS development will provide the warfighter a very effective munition to defeat advancing mechanized troops as well as perform missions to suppress enemy air defenses during the early phases of a conflict and open the paths for air-to-surface munitions like the small smart bomb described next.

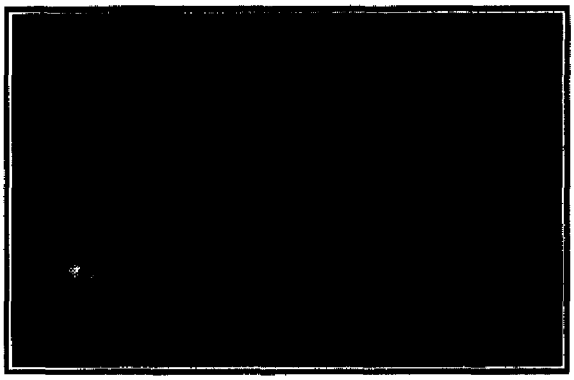

Figure 1. Full Scale Model of LOCAAS

3.2 250-lb (113.5 kg) Penetrator

At the time of this writing, the operational capability of a 250-lb (113.5 kg) Small Smart Bomb (SSB) concept had recently been demonstrated under the Miniaturized Munition Technology Demonstration Program conducted at Wright Laboratory Armament Directorate (WL/MN), Eglin Air Force Base, Florida. The Miniaturized Munition Technology Demonstration (MMTD) program had the objective of developing a 250-lb (113.5 kg) class munition that is effective against many of the fixed soft and hardened targets previously vulnerable to only 2,000-lb (908 kg) class munitions. Figure 2 compares the size of the MMTD test vehicle to a 2000-lb (908 kg) class general-purpose munition.

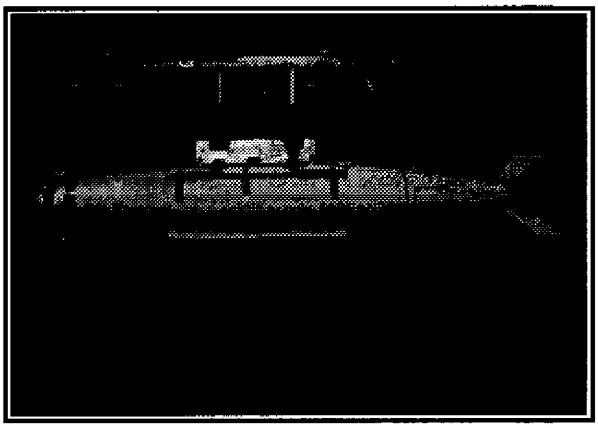

Figure 2. Full Scale Models of MMTD [upper] and 2000-lb (908 kg) [lower]

There are many benefits to smaller bombs, the greatest of which is an increased loadout capability for fighter and bomber aircraft. With each bomb independently targeted and autonomously guided, the number of targets killed by a single fighter or bomber sortie can be tripled or even quadrupled. Besides the capability to increase sortie effectiveness and the number of kills per pass, the smaller volume and weight of 250-lb (113 kg) munitions versus the more typical 2000-lb (908 kg) munition means 3 to 4 times as many bombs can be transported with current airlift capability; allowing a much more rapid deployment of warfighting capability to the region of conflict. Another benefit is that the bomb's accuracy and lower explosive yield will focus the lethality on the target while reducing the potential for collateral damage on friendly forces and noncombatants alike. While these benefits are evolutionary in nature, a truly revolutionary benefit can occur when aircraft designers take advantage of the smaller munitions and reduce the size of aircraft weapons bays, in turn reducing the size and cost of future aircraft like the UTA.

The MMTD goal was to baseline small bomb technology and demonstrate the operational utility of a 250-lb (113.5 kg) class precision-guided munition. The MMTD munition used a Differential GPS/INS system to achieve a precision guidance accuracy of less than 9.8 feet (3-meters) CEP against a surveyed target. The weapon size requirements [6 inch diameter, 72 inch length, (182.9 cm) and 250-lb (113 kg) total weight] meant that the warhead design space was relatively small. To achieve the reinforced concrete penetration goal of 6 feet (1.8 meters) with a small, lightweight weapon, the warhead was designed with a biconic nose shape. The Armament Directorate-developed Hard Target Smart Fuze (HTSF) has been incorporated into the warhead for determining the optimum detonation point. This fuze has the ability to discriminate between media (concrete, soil, air, etc.) and determine when it has entered a void (room) in a target and then detonates the main explosive charge. The goal of carrying 50-lbs (22.7 kg) of explosive had to be traded off with penetration/survivability goals. The current design allows 42-lbs (19.1 kg) of high-explosive to be packaged in the warhead. The first phase of the MMTD began in September 1995 and was an 18-month effort concluding in March 1997. Ground tests consisted of cannon and sled track testing for penetration performance and arena testing for determining warhead lethality. Five flight tests were conducted culminating in a live drop against a realistic aircraft shelter.

On 25 June 1996, the first penetration and survivability tests of the final warhead design were conducted. The initial test fired the warhead into a 6 foot (1.8 meter) block of concrete reinforced with 1-inch (2.54 cm) rebar. With an impact velocity of approximately 1200 feet per second, (365.8 meters per second) the warhead successfully penetrated the target and exited cleanly on the other side (Figure 4). After recovery and inspection of the warhead, the only noticeable change was that the paint was stripped off. Since that test, the warhead has been shown to penetrate over 6 feet (1.83 meters) of reinforced concrete and still be survivable at impact velocities above 1400 feet per second, (426.8 meters per second) impact angels of 70 degrees, and angles of attack up to 2 degrees. Additional tests in January 1997 successfully demonstrated the end-to-end function of the warhead with a live Hard Target Smart Fuze (HTSF) and live explosive fill against a 6 foot (1.83 meter) reinforced concrete target.

A series of captive flight test were conducted prior to the five free-flight tests, which began 23 December 1997. The first three MMTDs were released from altitudes of 30000 (9.14 km), 25000 (7.62 km), 40000 feet (12.2 km) and at varying distances down-range and cross-range from the reinforced concrete target slabs. The target slabs, measured 20 feet (6.1 m) by 20 feet (6.1 m) and 3 feet (.914 m) thick rested horizontally on the ground. The bombs all impacted within a 9.8 foot (3 meter) radius from the aimpoint. Impact velocities greater than 1100 feet per second (335.4 meters per second) were achieved with impact angles of approximately 83 degrees from the horizontal and less than a 1 degree angle-of-attack. The MMTD penetrated the 3 foot (.914 m) concrete slab and attempts to locate the warhead from the first tests ended after probing 40 feet (12.2 meters) deep in the soil.

The final flight test was conducted to demonstrate the operational utility of the small bomb concept. Two weapons were dropped one second apart on a single pass against two individual targets separated by roughly 300 feet (91.4 meters). Each weapon successfully guided to their intended target after being released from 40000 feet (12.2 km) altitude. The MMTDs were released over 10 nautical miles (18.52 km) down range and off-axis from the target requiring the weapons to maneuver to impact. The warheads entered overcast weather from 30000 feet (9.14 km) to 2000 (0.61 km) feet thereby demonstrating the all weather capability. After release the pilot turned away from the target and although egressing subsonic, was over 20 nautical miles (37 km) from the target location at weapon impact.

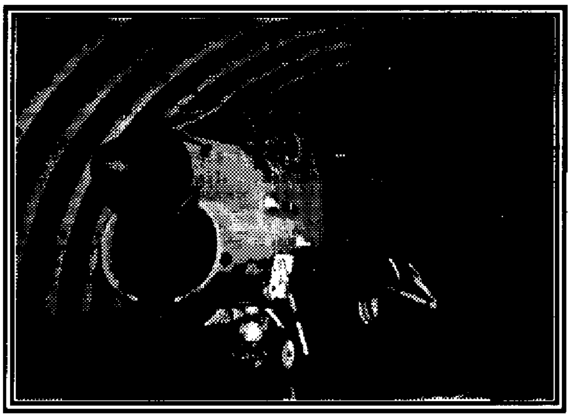

Figure 3a. Pre Test Results

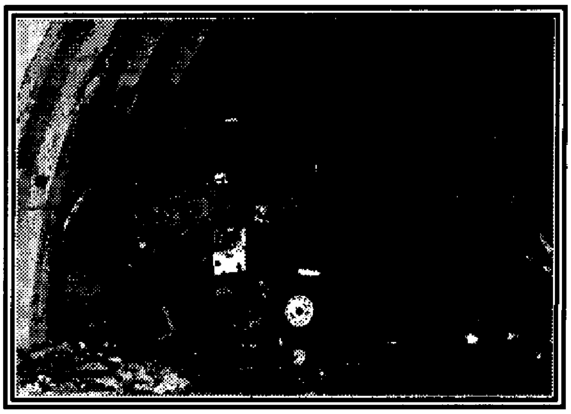

Figure 3b. Post Test Results

One inert weapon demonstrated the folding fin mechanism and successfully guided to its target, which was a dummy aircraft shelter. The second weapon carried 42-lbs (19.1 kg) of tritonal and a live fuze. The aircraft shelter target for this second weapon was covered by roughly 6 feet (1.8 meter) of soil and a layer of concrete. Additionally, a retired A-7 aircraft was parked inside the shelter and the shelter doors were left open for camera coverage of the test. The live warhead guided to the target, penetrated the shelter and detonated at the desired location determined by the hard target smart fuze. Figure 3 reveals the catastrophic damage to the aircraft from the MMTD detonation.

The success of the MMTD program has demonstrated that the technology necessary to develop a small smart bomb is currently available and that the weapon concept can provide a multiple kills-per-pass capability. A second phase of MMTD tests is planned for FY99-02 and may include the integration of a terminal seeker, wing-kit for increased standoff, and anti-jam GPS technology into the baseline weapon. Additional future opportunities to demonstrate the capability of the small smart bomb could include integration of the munition on an uninhabited aerial vehicle (UAV) in the newly formed UAV battle lab at Eglin AFB.

4.0 ANALYSIS

4.1 Munitions

Although small autonomous munitions for both fixed and mobile targets are being developed at Eglin that are applicable for an UTA role this analysis involved only munitions for fixed and relocatable targets. The decision was based on the fact that munitions for fixed targets require greater payload capacity therefore they would drive the UTA weapon carriage requirements. An UTA with a fixed target capability would then also have the ability to carry smaller mobile target munitions, i.e. LOCAAS, described in this report. Three fixed and relocatable target weapons were used in this study, a 1000-lb (454 kg) general purpose, 1000-lb (454 kg) penetrator and a 250-lb (113 kg) penetrator. All munition effectiveness numbers were based on 26 foot (8 meter) and 10 foot (3 meter) Circular Error Probable (CEP) accuracy estimates. The 26 foot (8 meter) accuracy is obtained from an Inertial Navigation System / Global Positioning System (INS/GPS) guidance scheme. A terminal seeker is assumed be required to achieve the 10 foot (3 meter) accuracy.

4.2 Target List

It is important here to define the terminology that will be used to describe targets in this report. Target types include fixed soft, fixed hard, stationary and mobile. Fixed targets include buildings, underground bunkers, aircraft shelters, etc. Each of these fixed targets could be "soft" or "hard". The distinction although somewhat subjective, in this paper refers to whether construction methods are employed specifically to protect the target from damage due to blast, fragment and/or penetration. A stationary target is understood to represent a target that can be moved, but which requires time and dismantling prior to transportation. As an example, a Transporter, Erector, Launcher (TEL) would be considered a stationary target since the launcher requires dismantling and stowage before it can be moved. Mobile targets include trucks, battle-tanks, armored personnel carriers, etc.

A target "type" also can consist of unitary or multiple elements. A unitary target type would be a single building, for example, while a multiple element target type could be a Petroleum, Oils, and Lubrication (POL) field containing numerous POL storage tanks. Thus, a POL target with 10 POL tanks would be a single target "type" with 10 target "elements". A kill of this POL target would result in up to10 target elements killed. A theater can contain many target types and multiples of each type with each type having one or more elements.

The targets selected for this analysis contained 61 different target types resulting in 3720 total targets and 34930 total elements. Table 1 gives a breakdown of these targets by type and quantity. No personnel or mobile targets were included in this target set.

Target Type	Number of Types	Total Number of Elements
Hard, Fixed	22	1458
Soft, Fixed	32	19828
Relocatable	7	522

Table 1. Target List by Type and Quantity

4.3 Loadout

Various loadout configurations were used with each of the appropriate weapons in this study. Loadouts of 1 and 2 were used for the 1000-lb (454 kg) munition while a for the SSB the loadouts were varied between 2, 4, and 8. By varying the loadout options it was possible to investigate the effect of loadout and to determine an optimum loadout quantity. 2000-lb (908 kg) munitions were not used.

4.4 Methodology

Analysis was accomplished using accepted procedures as defined by the Joint Technical Coordinating Group for Munitions Effectiveness (Air-to-Surface). Standard Joint Munitions Effectiveness Manuals and the "Open-End Methods" (Reference 2) were used throughout.

5.0 RESULTS

Prior to reviewing the results of the analysis it is important to understand the figure of merit used to draw conclusions. The term Expected Kills per Sortie (EKS) represents the ability of a delivery platform to defeat multiple targets on a single sortie and is indicative of the number of weapons that can be carried and deployed by that platform. The average EKS is simply the total number of elements in the target set divided by the total number of sorties needed to kill all the elements in that same target set. It should be remembered that some munitions will be more efficient at defeating some target type/elements, and much less efficient at others. Computing an average will result in a loss of this fidelity, however an average is an indication of the pervasiveness of a munition's effectiveness across all targets

The following figures will provide insight as to the UTA loadouts necessary to achieve a desired level of effectiveness against the complete target set.

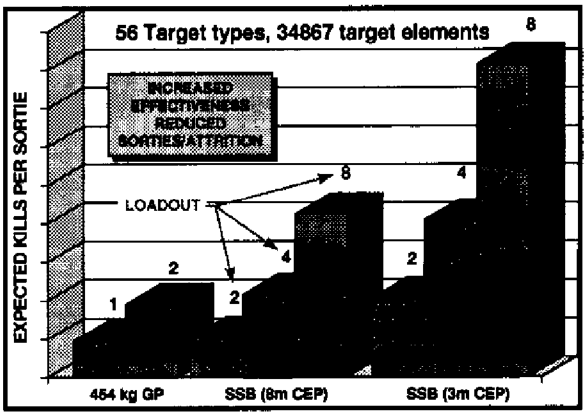

Figure 4. Expected Kills/Sortie for UTA

From Figure 4, we see that to achieve the effectiveness of two 454 kg GP munitions would require a minimum of four SSBs with an 8-meter CEP accuracy or two SSBs with 3-meter accuracy

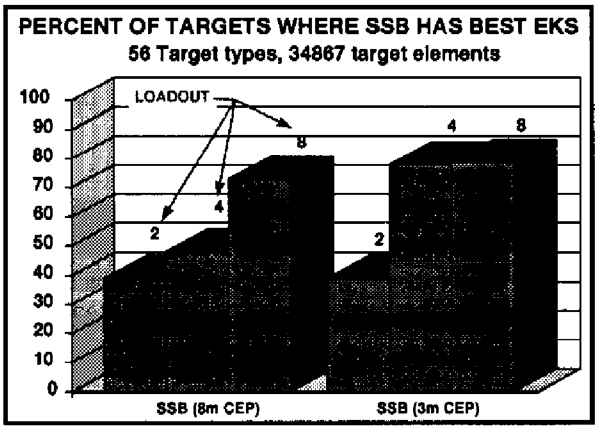

Figure 5. Percent of Target Set Where SSB has the Best EKS

Figure 5 shows the percentage of the 34867 targets where the SSB expected-kill-per-sortie value is higher than the loadout of two 454 kg munitions. We see that a loadout of four SSBs and 8-meter accuracy achieves a best EKS value for slightly less than 50% of the target set. The two 454kg munitions achieve the best EKS for the remaining 50% of the targets. However, a loadout of four SSBs with 3-meter accuracy provides the best effectiveness for almost 80 percent of the targets. By the time a loadout of 8 SSBs is reached, the SSB is the most effective weapon for 75 % of all the targets at either the 8 or 3-meter accuracy. We can make a couple of statements from this observation: 1) There are some targets that are best attacked with 454 kg class munitions, thus a UTA should be able to carry at least a 454 kg class GP bomb, 2) Somewhere between 4 and 8 SSBs with 8-meter accuracy there is a significant number of additional targets where SSB obtains the best EKS. Up to now there has been no indication how much better the EKS value is for the SSB than the 454 kg munition. Figure 6 helps answer this question since the target set is restricted to those targets where the SSB has been shown to have the best EKS. Recall that this restricted set still represents over 75% of the total original set used in this study. For this set of targets we see that even a loadout of two SSBs is as effective as two 454 kg munitions and that four SSBs and 3-meter accuracy provide an average of two targets killed per sortie. When 4 SSBs, which represents 1000-lb (454 kg) in total weight, is compared to a single 454 kg munition of equal weight we can see that on average, the four SSBs (8 meter accuracy) have over 3 times the EKS as the 454 kg weapon. At 3-meter accuracy 4 SSBs have almost 9 times the EKS and has the equivalent weight of a single 454 kg munition.

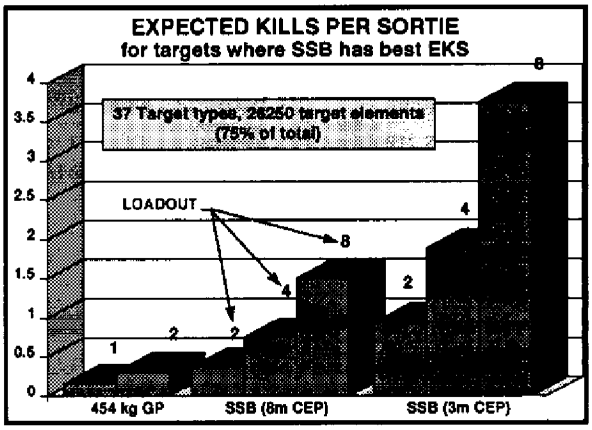

Figure 6. Expected Kills Per Sortie (Targets where SSB has the Best EKS)

This would allow the required number of sorties to be reduced by 300% for an 8-meter SSB and by almost an order of magnitude for a 3-meter accuracy munition. In addition to increasing the conflict tempo, by attacking multiple targets per sortie, a reduction in the total number of sorties required would also reduce attrition, sortie cost, and possibly conflict duration. If these advantages could be realized the additional cost of a terminal seeker to provide a 3-meter accuracy might certainly be justified.

Reviewing figures 4 to 6 with an UTA perspective, a conclusion can be drawn pertinent for the UTA developers. The conclusion is that significant mission flexibility occurs with a minimum payload of 1000 pounds (454 kg). This would allow carriage and deployment of one 1000-lb (454 kg) munitions, two 500-lb (227 kg) munitions, or 4 SSB's. This mix of munitions covers all but the very hardest fixed ground targets. Maximum mission flexibility would occur with a 2000 pound (908 kg) payload capability allowing the loadouts described above to double and provides additional lethal effectiveness.

6.0 CONCLUSIONS

The conclusion of this study is that a small munition concept like the SSB, currently being demonstrated at WL/MN provides excellent effectiveness for all aircraft platforms including an UTA concept. The previous trend for USAF munitions was to increase size, weight, and explosive load, but the corresponding reduction in loadout using a large, heavy munition can reduced the overall effectiveness of each sortie. The high loadouts furnished by the SSB and LOCAAS concepts have increased the sortie effectiveness substantially. Even though multiple SSBs may need to be used against a target, the SSB loadouts possible more than make up for this deficit. Additionally, the increased numbers of munitions "on-target" can provide an increased statistical probability of destroying a critical node of the target over a single large munition. The SSB, in its current configuration, is an effective and viable UTA munition. The small size and weight provides the UTA platform a desirable combat capability for a large number of targets. The study suggests that an UTA with 2000-lb (908 kg) of payload is optimum for a combat capability. With 2000-lb (908 kg) of payload the UTA could carry two 1000-lb (454 kg), 8 SSBs, or 16 LOCAAS. With this flexibility all but the hardest targets are at risk. The soft targets are best defeated with LOCAAS. Large area targets, are most susceptible to large blast/frag, general purpose munitions like the 1000-lb (454 kg). The UTA could carry the 1000-lb (454 kg) munitions side-by-side or 4 SSBs on each side of centerline. The next best payload for the UTA is 1000-lb (454 kg) and results in a single 1000-lb (454 kg), 4 SSBs or 8 LOCAAS. While this is less effective than 2000-lbs (908 kg) of payload, it does allow a smaller UTA design and reduce the propulsion requirements. This payload allows a centerline weapons bay instead of the side-by-side bay mentioned earlier. From figures 4 to 6 it is seen that a drop in UTA payload to 500-lbs (227 kg) only allows two SSBs to be carried with the drastic reduction in effectiveness. With only a 500-lb (227 kg) loadout, more sorties would need to be conducted putting the UTA at risk and increasing cost and conflict duration. *In short, the UTA should maintain a 1000-lb (454 kg) minimum payload if it is to be significantly effective against the target set of interest.*

Not addressed in this study are the aircraft integration and weapon interface issues pertinent to high loadout munitions like the SSB. For current manned aircraft the Mil-Std-1760 capability is required since data must be passed to each munition. In addition to having 1760 capability, the aircraft Operational Flight Profile (OFP) software would need to be developed to correctly initialize, arm, sequence, etc. the multiple munitions. For UTA utilization, similar integration issues are found. While the concept of operations for the SSB would likely provide for loading the GPS target coordinates via mission planning cockpit data cartridge and 1760 interface prior to flight, future real-time targeting would require the capability to pass this information from platform to SSB during flight. The OFP software for an UTA may be even more complex than for a manned aircraft since a large amount of data that is currently handled by a pilot, may need to be passed from onboard sensors to a manned ground-station support facility. For an UTA combat mission where a target needs to be identified and classified prior to authorizing weapon release, the data may be even more critical especially if the UTA is used in a close-air-support role. Finally, early UTA design criteria should include the requirement for a munition dispenser to maintain the ability to package and release multiple munitions. Dispenser technology is critical to achieve high loadouts in a small volume like an UTA. The dispenser technology must provide the capability to release unitary munitions or multiple munitions on a target to provide the most effective sortie. Most current dispensers that have been demonstrated are dropped as a unit and the dispensing of submunitions occur later. Since the SSBs and LOCAAS need to be dropped as unitary or multiples to achieve the best effectiveness, the dispenser would most likely be a captive dispenser. It would seem prudent to develop dispenser technology that would be adaptable to both manned aircraft and UTA concepts, but this dispenser concept would obviously impact the UTA design and should be integrated early in the design phase.

7.0 REFERENCES

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