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FINAL REPORT
TO
THE NATIONAL INSTITUTE OF JUSTICE
ON GRANT NUMBER
2000LTBXKOO4

VARIABLE RANGE LESS-THAN-LETHAL BALLISTIC

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II. PROJECT DESCRIPTION

Project Number 2000LTBXK004 calls for the Phase I design of a variable-range less-than-lethal ballistic. Participants in this project were Law Enforcement Technologies, Inc. (LET), Martin Electronics Incorporated (MEI) and Sandia National Laboratories (SNL). Law Enforcement Technologies Inc. was responsible for overall project management as well as the design of the launch platform. Martin Electronics was responsible for the design of the ballistic as well as selecting the materials to be used in the casing of the ballistic. Sandia National Laboratories was responsible for developing a formulation for the pyrotechnic, or flash/bang, materials to be used in the ballistic.

The project proposal called for the design of a variable-range 37.5mm (for law enforcement) or 40mm (for the military) less-than-lethal ballistic that could be fired at targets ranging in distance of 15 to 120 meters. The ballistic would contain a quantity of energetic materials, which would be detonated at close proximity to a suspect in order to achieve disorientation and/or incapacitation.

The project's Statement of Work called for the following:

Technical Tasks:

LET and its sub-contractors were to develop the less-than-lethal ballistic on four fronts:

a) Develop the pyrotechnic formulation for the flash/bang component (Sandia National Laboratories).
b) Design the packaging for the ballistic, including the flash/bang formulation and means for ignition, as well as the propellant component to launch the ballistic (SNL/Martin Electronics).
c) Design and develop the ranging mechanism to ensure the accurate delivery of the ballistic to the target and means of detonating the ballistic a safe distance from the target (LET).
d) Conduct the research into which chemical agent would provide the maximum disabling effects on the target, while at the same time ensuring that the chemical agent would not be combustible at the time of ballistic detonation (SNL/LET).

Operational Tasks:

The Operational Tasks were to include the following:

(a) The pyrotechnic formulation for the flash/bang component will require:
- That it has sufficient lumens per watt to temporarily reduce the target's vision without permanently damaging the target's eyesight. This task will incorporate data already developed by SNL's Explosive Components Facility along with a review by a licensed optometrist who is part of a medical review panel created by LET. (NO HUMAN TESTING WERE CONDUCTED IN PHASE I OF THIS PROPOSAL.)
- The flash component will have a short flash duration to minimize heat risk to the target.
- The report component will be sufficient to cause temporary ear pain (130dB(A)) and disrupt the balance of the person who is targeted without permanently damaging the target's eardrums. This task will incorporate data already developed by several health organizations, including the National Institute of Health (NIH) and British United Provident Association (BUPA), as well as a study conducted by Paul Cooper of Sandia National Laboratories in 1993.
- The overpressure energetic shock wave will be sufficient to knock down a man of average size and weight. This task will incorporate data already developed by Paul Cooper of Sandia National Laboratories, using test animals, in 1993.

(b) The design and packaging of the ballistic included:
- Two means of ignition, including a multiple-fuze system (developed under the NIJ grant) and a radar-based approach (funded privately by LET) that sends a radio signal to an onboard RF receiver.
- The casing for the ballistic will be constructed of materials that will disintegrate into non-shrapnel fragments upon detonation.
- The propellant component will be designed to launch the less-than-lethal ballistic at a minimum muzzle velocity of 200 fps.
- The propellants will be designed to work within the pressure limits of 37.5mm and 40mm M79 and M203 launch platforms.

- A crush safety switch will be incorporated into the design to incapacitate the ballistic upon impact with an object. The switch will be encased in the nose cone of the ballistic, which will be composed of closed-cell foam.

(c) The ranging mechanism was to include:

- A multiple-fuze system that allows the operator to dial in the correct range (at five-meter intervals) as determined by a conventional range finder. This design allows manual control by the operator and is the most straightforward design available.

(d) Research into the selection of the optimum chemical agent to be used in the less-than-lethal ballistic was to include:

- The combustibility of various chemical agents.
  - The temperatures at which these chemical agents become combustible.
  - The optimum volume of these chemical agents to create the desired debilitating effects on the target.
  - The amount of deterioration on the chemical agents while traveling at distances of two to three meters after dispersal from the ballistic.

Deliverables for the Phase I portion of the project were to include:

- The pyrotechnic formulation for the flash/bang component.
- Packaging (casing) design for the complete ballistic, including flash/bang formulation and various means of ignition.
- Complete research and testing to determine the appropriate chemical agent, which will be used in the less-than-lethal ballistic.
- The propellant formulation, which will launch the ballistic at a minimum muzzle velocity of 200 fps.
- Complete design of the ballistic to ensure optimum flight characteristics.
- Complete design of the multiple-fuze timing system.
- A complete bibliography of past and present research conducted on flash/bang devices.

III. PARTICIPANTS

For Law Enforcement Technologies, Inc.:

Greg MacAleese, Project Manager
Jerry Hausner, Electro Science Technologies, Firing Platform Electronics Package
Valerie Gonnella, Support Staff

For Martin Electronics, Inc.:

Duane Johnson, Lead Designer
David Lloyd, CAD-CAM Design Engineer

For Sandia National Laboratories:

Mark Grubelich, Principal Member of the Technical Staff
Brian Melof, Ph.D., Member of the Technical Staff

IV. ACTIVITIES

The first organizational meeting for the Less-Than-Lethal Ballistic project took place on February 22, 2001 at Sandia National Laboratories' Explosives Components Lab. Present were Greg MacAleese, Charles Baldwin II and Jerry Hausner, representing Law Enforcement Technologies Inc.; Duane Johnson, representing Martin Electronics Inc.; and Mark Grubelich, Brian Melof, Lloyd Bonson and Susan Bender, representing Sandia National Laboratories.

Greg MacAleese distributed copies of the Grant Proposal to all attendees for their review. Discussion followed on the key issues pertaining to the design of the LTL ballistic. Consensus was achieved on the following issues:

1) The ballistic would have to be designed so that the casing was totally frangible. Any objects, such as radio antennas, detonators, or transponders would either have to be materials that would be consumed in the detonation of the ballistic or located in the ballistic so that their forward momentum would be eliminated by the detonation, thus reducing their risk of becoming potentially deadly shrapnel.
2) The ballistic would have to be accurately detonated at a consistent distance from the target to ensure the safety and effectiveness of the ballistics' energetic materials.

3) It was the consensus of the attendees that the best opportunity for accurate detonation existed with the optional radar-based design as opposed to the multiple-fuze design.
4) It was suggested that the barrel of the launch platform be rifled in order to spin the ballistic, thus creating greater accuracy.
5) The launch platform should have a safety mechanism in place to avoid any inadvertent in-chamber detonations.
6) The ballistic would have to be lightweight and launched at low muzzle velocity in order to avoid lethality in the event the ballistic failed to detonate and actually struck the target.
7) Existing ballistic designs and materials should be considered first so that, if possible, development time is shortened to an absolute minimum.

Representatives from SNL requested that the Phase I project deadline be extended from June 15 to August 15, 2001, in order to give them more time to develop and test the flash/bang formulation. They also requested that samples of plastic fuzes and syntactic foam be provided to them for testing. Duane Johnson said he would arrange for those samples to be provided. Duane Johnson also said that he planned to acquire some of the rigid foam material currently being considered for the casing in order to test its strength under simulated launch conditions.

All attendees were in agreement that while there were technical issues that had to be resolved, the development of an effective variable-range less-than-lethal ballistic was very feasible.

Following the initial organizational meeting, Greg MacAleese sent an email to Trent DePersia with the National Institute of Justice requesting that the project deadline date be extended to August 15, 2001. Mr. DePersia granted this extension.

In late March, Duane Johnson obtained a quantity of syntactic foam from General Plastics Manufacturing Company of Spokane, WA. He scheduled a series of stress tests on the 40mm foam bodies at Martin Electronics' test range. These tests were conducted on June 7, 2001. The tests revealed that the syntactic foam bodies would not withstand the stress from being launched from a 40mm platform. At the same time, the stress tests revealed that when the syntactic foam disintegrated, the foam quickly lost speed and combined with its very light weight did not present any apparent shrapnel hazard.

As a result of the failure of the syntactic foam to withstand the stress of launch from a 40mm platform, Mr. Johnson immediately began designing a rubber shock absorber to protect the bottom of the less-than-lethal ballistic. The shock absorber will be about ½ inch thick and 1 ¼ inches in diameter and weigh less than eight grams. The idea would be that the shock absorber would trail the ballistic as it left the barrel, then drop harmlessly to the ground shortly after launch (less than 20 meters from the point of launch), thus avoiding any potential risk to bystanders, other police officers, or the target itself.

A second concern in the development of the less-than-lethal ballistic was the variability in the propellants used to launch the ballistic. Current best technology has determined that there is as much as a 10-meter variation at 100 meters (or about 5% plus or minus variability) in the distance traveled by a M781 40mm training round currently manufactured by Martin Electronics. This variability was not acceptable to the developers of the Variable Range Less-Than-Lethal Ballistic.

As a result, two designs were developed to enhance the accuracy of the ballistic. The first was the Transponder Design, developed by Jerry Hausner of Electro Science Technologies. This has a calculated error rate of 6 inches at 100 meters. The Transponder Design eliminates any effects of the variability in the propellants because a radar system located on the firing platform tracks the transponder located in the ballistic. This information is sent to a microprocessor on the firing platform that continuously calculates the relationship of the ballistic to the target and then sends an electronic detonation signal to the ballistic in order to detonate it at the optimum distance in front of the target.

In another effort to improve the accuracy of a non-electronic ballistic, Duane Johnson designed a ballistic with an innovative two-delay system. In the Two Delay Concept, the distance at which the round is initiated is controlled by the delay composition's burning time accuracy and the internal ballistics. The Two Delay Concept would reduce the variability of the ballistic by another 2%. It would not be as accurate as the Transponder Design but would cost less to manufacture.

Sandia National Laboratories developed the flash/bang payload for the Variable-Range Less-Than-Lethal Ballistic. For the past few years, SNL has been working on improvements to the materials currently used in hand-thrown flash/bang devices that would make them safer and more versatile.

SNL developed a powdered fuel made of aluminum and/or magnesium that auto-ignites when mixed with ambient air. The process is similar to a grain elevator explosion. The powdered fuel is discharged from the ballistic when it is detonated. The fuel cloud created by the detonation is then ignited by a fuel-air combustion reaction.

What makes SNL's powdered fuel so attractive is that it produces a bright flash (measured for this project by SNL personnel at 700 milliWatts per square centimeter at a distance of 12 feet), a sufficiently loud report (175 to 180 dB) without using explosive materials. This reduces any risk of in-muzzle detonations.

At the same time, SNL's formulation produces a longer pressure pulse with a slower rise to peak pressure than other standard flash/bang devices. The desired effects of acoustic and visual disorientation and discomfort are preserved at longer duration with less long-term physical risk to the target.

In addition to selecting the appropriate materials for the flash/bang payload, SNL's role in the development of the Variable-Range Less-Than-Lethal ballistic under this grant was to calculate how much material would be needed to achieve the desired flash/bang effects, and then conduct some limited tests to confirm that these effects would be achieved.

Until this project, there had never been any test data published about the acoustic and visual effects of any existing flash/bang device. SNL's testing for this project represents the first known measurable data. The tests indicated that at a distance of 12 feet from the target, using 20 grams of flake aluminum, the Variable-Range Less-Than-Lethal ballistic creates a fireball of about two meters. The heat of the fireball dissipates so rapidly that within 10 to 40 milliseconds it is reduced to room temperature. In point, this means that even if the ballistic detonates within a foot of the target, there is little or no risk of creating any serious burns to the target. As an illustration, researchers describe the effect of the heat at point of flash to be comparable to rapidly putting one's finger through the flame of a candle.

The acoustic report at point of detonation was 180 dB. The optical output was 700 milliWatts per square centimeter, or 100 times brighter than the sun when viewed from earth for about 60 milliseconds. The anecdotal result of the flash was that one of the SNL researchers was still seeing "a bright ball" about 20 minutes after looking at the fireball. These results were well within the desired effects sought for the Variable-Range Less-Than-Lethal ballistic.

It should be noted that the design of the Variable-Range Less-Than-Lethal ballistic has enough internal capacity to hold up to 40 grams of flake aluminum or magnesium. In view of the test results conducted by SNL, this capacity appears to be not totally required and could be used instead to house a chemical irritant or fluorescent paint to identify participants in riots or other criminal activities.

Lastly, there is one other important consideration about SNL's flash/bang formulations of either aluminum and/or magnesium. Each of these formulations produces less smoke and therefore is more environmentally friendly than any other type of existing flash/bang device.

All participants had their final reports submitted to Project Manager Greg MacAleese by August 10, 2001. Mr. MacAleese then prepared the Final Project Report for submission to NIJ by August 15, 2001.

V. LAUNCH PLATFORM

(Please see Section IX: "Reports/Drawings/Addendums" for the complete final Phase I Report from Jerry Hausner of Electro Science Technologies.)

The launch platform consists of a 40mm launcher with an electronics package that is surface mounted on the launcher. The electronics package consists of an optical rangefinder, 286 microprocessor, LED display, small radar system and a radio transmitter.

The radar system would operate in the 76 to 77 GHz range and have a beam width of 30 degrees. The benefit of operating at 76 to 77 GHz is that most collision-avoidance radars currently being installed in vehicles operate in this frequency range. Since there are a number of these radar systems being built, it would provide cost reduction in manufacturing the radar system for the launch platform because of the ready availability of parts for the unit. In addition, the 30-degree beam width for the radar antenna would allow the system to easily track the transponder in the ballistic without altering the orientation of the firing platform to perform such a task. Operating at 76 to 77 GHz with a 30-degree beam width would reduce the size of the radar antenna on the firing platform to about one inch by one inch, according to calculations by Jerry Hausner of Electro Science Technologies. The total weight of the electronics package will be about 2 ½ pounds. The total weight of the launch platform will be about 10 ½ pounds.

The launch platform is a breakfront, single-shot design with a 24-inch barrel made of blued steel. Unlike the M-79 or M-203, the bore on the variable-range launch platform will be rifled with four grooves, right hand twist, although the aerodynamics of the ballistic might be stable enough to allow the use a smooth-bore barrel. The prototype platform will be designed so that the electronics package can be surface-mounted. The prototype launch platform will use a standard wooden butt-stock. Future production models might have a folding stock to allow easier storage in patrol cars.

Here is how the launch platform is designed to work:

- The operator aims the launch platform at the target.
- The distance to target is determined by the range finder and this information is digitized and sent to the on-board microprocessor (a distance in front or behind the target can be also used if desired).
- The microprocessor calculates the distance to target and the muzzle velocity of the ballistic (250 feet per second) to determine the angle of inclination to set the launch platform. This information is relayed to the operator through an LED display on the launch platform.
- The operator raises the launch platform to the proper angle of inclination and then fires the ballistic.
- The operator then keeps the launch platform trained on the target. This allows the range finder to continue to send digitized range information to the microprocessor to determine if there is any change in the distance to target. Any changes are immediately calculated by the microprocessor and can be used to change the point of initiation of the ballistic.
- As the ballistic leaves the barrel, it passes over a sensor, which then turns on a transponder located near the rear of the ballistic.
- The radar system located on the launch platform tracks the transponder on the ballistic. This information is sent to the microprocessor.
- With information about the location of both the target and the ballistic now stored in the microprocessor, the microprocessor will determine the time necessary to send radio signal energy to an electric match, which then detonates the ballistic.

The elegance of this design is that for all of its electronic complexity, the actual operation of the system requires little or no skill on the part of the operator to deliver an extremely accurate ballistic at a static target. With a modicum of training and practice, the operator should be able to accurately deliver a ballistic that detonates in close proximity to a moving target. In addition, with practice other nuances of the system such as off-setting the detonation in relation to the target to achieve greater surprise and effect should become familiar to the operator.

A complete schematic and parts list for the electronics package is included in "Non-Lethal Munitions Radar Fuse Development – Phase 1 Completion Report" by Jerry Hausner of Electro Science Technologies in Section IX. Mr. Hausner's report also includes a schematic for the transponder to be used in the ballistic.

VI. BALLISTIC DESIGN

(Please see Section IX: "Reports/Drawings/Addendums" for Duane Johnson's complete report and Technical Drawing Package on the Variable-Range Less-Than-Lethal Ballistic.)

The Variable-Range Less-Than-Lethal Ballistic proposed under this grant is 37.5mm to 40mm in diameter, between 7.96 inches to 9 inches long and weighs approximately 75 grams. The casing is made of LAST-A-FOAM FR-6714, a rigid foam material that fractures into extremely small low-weight particles under explosive stress. The fragments rapidly undergo deceleration because of their low densities and small size. A rubber shock absorber ½ inch thick and 1 ¼ inches in diameter and weighing less than eight grams will be used to protect the base of the projectile when it is launched. The shock absorber will not be attached to the projectile. It will trail the projectile as it leaves the barrel. Due to the light weight and shape of the rubber shock absorber, it will quickly decelerate and will not travel more than 20 meters from the point of launch.

A M212 Assembly is used to launch the projectile. The M212 Assembly is comprised of a double-based commercial propellant in a closed brass container fabricated from a standard .38-caliber shell and ignited by a standard primer used in conventional .38-caliber shells.

The ignited propellant builds up pressure to a point where the end of the closed brass container opens and the high pressure is released. The pressurized hot combustion produced from the burnt propellant then starts the forward acceleration of the projectile down the rifled barrel. The projectile is ejected from the barrel at a design velocity of 250 feet per second and travels towards the intended target.

With a barrel velocity of 250 feet per second, it is calculated that the projectile will reach twenty (20) meters in 0.263 seconds and one hundred (100) meters in 1.316 seconds.

Current best technology developed by Duane Johnson and engineers at Martin Electronics, Inc. for the M781 40mm practice round indicates that there will be a variation of plus or minus six feet per second for a projectile traveling 250 feet per second. This means a projectile fired at a target 100 meters away and using a barrel elevation of 4.87 degrees off horizontal would actually travel between 95 to 105 meters. A projectile fired at a target 20 meters away using a barrel election of 0.97 degrees off horizontal would actually travel 19 to 21 meters.

The effects of these variations must be reduced in order to deliver an accurate round that consistently detonates at, or near, the same point in front of the target. The two designs (Transponder and Two Delay systems) developed under this grant do significantly reduce these variations.

The first design incorporates a transponder and radar-based tracking system along with an electronic detonation package. The projectile is nine inches long and weighs approximately 75 grams. In this configuration, a transponder is located near the rear of the projectile. When the projectile leaves the barrel of the firing platform, it passes over a sensor that turns on the transponder. The transponder is then tracked by a radar system located on the firing platform. The projectile is then detonated at a predetermined distance from the target. This design means that the variability rate of the ballistic is greatly reduced. The exact reduction will be determined during Phase 2 testing.

One concern that had to be resolved in the transponder design was how to control the electronic components and energy source once the projectile was detonated. The components and energy source are located near the rear of the projectile. In all probability the forward momentum of the electronic components and energy source would be stopped when the Expelling Charge in the Center Tube is ignited. However, as an added safety feature, a small parachute will be attached to the epoxy casting containing the electronic components and energy source. The parachute would automatically deploy when the projectile is detonated. Further tests will be conducted during Phase 2 testing to determine if a parachute is actually needed.

The second projectile design is the two delay concept. The ballistic is 7.96 inches long and weighs approximately 50 grams. In this design, one of two pyrotechnic delays are selected for a target distance of either 20 meters or 100 meters. The delay times are calculated to be 0.263 seconds and 1.316 seconds. The ability of the pyrotechnician to control delay times is typically about plus or minus 6%. This would reduce the variability rate of the ballistic by at least 30 percent (to 1.2 meters longer or shorter at 20 meters and 7 meters longer or shorter at 100 meters). This projectile would be significantly less expensive the manufacture, but would lack the precise accuracy of the transponder-based projectile.

One last consideration about the projectile's design is its aerodynamic capability. The launch platform for the Variable Range Less-Than-Lethal projectile is designed to have a rifled barrel. Rifling obviously imparts a spin to the projectile which aids in the stability of the projectile while it is in flight. The length-to-diameter ratio of both projectiles being designed, however, may not require spinning in order to have stable flight. This will be determined during Phase 2 testing.

VII. FLASH-BANG MATERIALS/FORMULATION

(Please see Section IX: "Reports/Drawings/Addendums" for the complete report written by Mark C. Grubelich and Brian Melof of Sandia National Laboratories on the "Next Generation Diversionary Devices.")

Based on recent research, coupled with the desire for an improvement in safety, a safer and more versatile diversionary device is being developed using the rapid combustion of a fuel delivered by the device with oxygen present in the ambient air. This next generation device ejects a powdered fuel that mixes with ambient air and then auto-ignites. This process is similar to the ignition of propellant gases in guns resulting in "muzzle flash" or a grain elevator explosion. The operation of this device produces a fuel-air combustion reaction. Since the combustion process is more spatially and temporarily diffuse than that of a conventional explosive, a longer pressure pulse (IOO's of milliseconds) with a slower rise to the peak pressure results. This produces a near-field peak overpressure that is several orders of magnitude lower (IO's of psi) than that of a Mk 141 diversionary flash-bang device. The desired far-field effects of acoustic and visual alarm are preserved (nominally 175 to 180 dB at 100 times the duration) with the ability to generate a more intense, longer duration flash, as well as delivering more total impulse (energy) to the adversary.

Initial preliminary testing at SNL with 20 grams of Obron 5413H flake aluminum resulted in a peak optical output of approximately 700 milliWatts per square centimeter at a distance of 12 feet. For purposes of comparison, this is one hundred (100) times brighter than the sun, as viewed from the earth for approximately 60 milliseconds. The resultant fireball diameter was approximately two (2) meters.

There are many advantages of this next-generation diversionary device. Due to the reduced near-field peak overpressure, the possibility of permanent damage to subjects exposed to the near-field pressure wave would be greatly reduced. The acceleration of any near-field objects produced by the overpressure would be less, making serious injury due to secondary high-velocity fragments much less likely.

The non-explosive nature of the powdered-metal fill allows the Variable-Range Less-Than-Lethal ballistic to be considered bore safe and would allow the devices to be stored and shipped with fewer (if any) restrictions. The fuel-air reaction will produce less smoke since the products of combustion would not contain potassium chloride. Therefore, continuous target acquisition is possible. The improved diversionary devices "yield" could be customized in the field. The acoustic and light output could be adjustable by simply increasing or decreasing the fuel charge during each particular operational scenario.

For the next generation diversionary device, both aluminum (Obron 5413H dark flake) and magnesium (Reade RMC-325-325 mesh granular) with colloidal silica (Cabot Chemical TS-720 Cabosil) used as an anti-caking/flow agent have been used as fuels. Fine aluminum particles have high reactivity in air and good combustion efficiency without being pyrophoric. This is accomplished commercially by passivating even sub-micron aluminum particles to produce a thin inert aluminum-oxide layer while still allowing the underlying aluminum to remain active. Commercial –325 mesh flake magnesium has been used with great success providing a brighter flash. Blends of aluminum and magnesium may be used to tailor the output of the device.

Building on the existing prototype hand-thrown fuel-air diversionary device, three preliminary designs have been conceived for the Variable Range Less-Than-Lethal Ballistic. All three designs share the same basic outside geometry. The munition is 152 mm long and 40 mm in diameter, with an internal cavity for the fuel approximately 27 mm in diameter and 100 mm in length. Approximately 20 to 60 grams of aluminum or 20 to 40 grams of magnesium or a blend of the two will be ejected from the device in order to produce a brilliant flash and the desired acoustic output.

The first design is a semi-rigid plastic body with radial discharge holes in the nose of the projectile. At the desired range, a pyrotechnic gas generator is ignited in the base of the projectile which pressurizes the projectile body and then ejects and ignites a cloud of fuel. The plastic body's forward velocity will be retarded by the ejection of the fuel and may be allowed to impact the adversary for an additional diversionary effect.

The second design employs a fully frangible foam body with a central pyrotechnic gas generator/burster. At the desired range, the pyrotechnic gas generator is ignited which pressurizes the projectile body and causes it to flow apart into rubble. This disperses the fuel cloud and subsequently ignites the fuel cloud. In this design, the frangible foam body is reduced to harmless, low velocity pieces.

The third design employs a super-frangible foam nose and frangible foam body. At the desired range, a pyrotechnic gas generator is ignited in the base of the projectile which pressurizes the projectile body, fragmenting the nose of the projectile and projecting the fuel cloud forward while simultaneously igniting the fuel cloud. The frangible foam projectile's forward velocity will be retarded by the ejection of the fuel and will pose little if any adversary impact risk due to the extremely low ballistic coefficient and low velocity.

VIII. CONCLUSION

After six months of studying, designing and testing the components for a Variable-Range Less-Than-Lethal ballistic, the participants in this project have come to the conclusion that such a system is feasible.

It is probable that the ballistic can be delivered accurately at either a static or moving target at distances ranging from 15 to 100 meters. At the point of detonation, the resulting flash-bang effects could be terrifying to an adversary. The target would be confronted with an exceptionally bright fireball at least two meters in width that would appear to totally envelop him. The acoustical report would probably create intense pain in the adversary's ears. The shock wave of 2.5 to 3.0 psi would probably create more terror. And if the ballistic contains a chemical irritant, it would cause the adversary even greater disorientation and discomfort.

Much work remains to be done in order for the Variable-Range Less-Than-Lethal ballistic to become a reality. A prototype of the launch platform must be built to ensure that the system delivers on its promise of accuracy and ease of use. Prototypes of the ballistic have to be manufactured and extensively tested – in stress tests to determine the reliability of the casing, in static tests to measure its flash-bang output and in simulated operational scenarios (without human targets) to verify its efficiency in a variety of field situations.

Lastly, the ballistic would have to undergo actual field testing to determine its suitability as a long-range less-than-lethal ballistic for domestic and international law enforcement and military personnel.

In the meantime, very few tools are available to police officers and soldiers when they are confronted with long-range situations in which less-than-lethal force is a desirable option.

IX. REPORTS/DRAWINGS/ADDENDUMS

ELECTRO SCIENCE TECHNOLOGIES

Non-Lethal Munitions Radar Fuse Development Phase 1 Completion Report

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July 1, 2001

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ELECTRO SCIENCE TECHNOLOGIES

REPORT

Less-Than-Lethal Munition Radar Fuse
for Law Enforcement Technologies, Colorado Springs, CO
PROJECT PHASE COMPLETION
Contract No. EST 01-103

June 28, 2001

The current phase of this project was to provide some continuation of the work performed in 1999 on this program. The task authorized herein were:

1. Review previous work to get back up to speed.
2. Complete the schematics/block diagrams.
3. Generate parts lists and Bill of Material
4. Design physical layout for the brassboard (alpha).
5. Convert design to surface mount technology.
6. Design physical layout using surface mount components.
7. Use physical layout and surface mount parts to determine size and weight.
8. Misc. meetings, correspondence, reports, etc.

The level of effort authorized for this work was 88 hours.

At this point all of the above items have been completed within the alotted budget. This package contains the following documentation for each of the above items.

1. No documentation is applicable.
2. Diagrams of the latest launcher and transponder designs.
3. Bills of material for the alpha and a surface mount configuration are provided.
4. A physical layout of the RF deck for an alpha brassboard unit is shown. The lower deck is not shown as the power supplies and controller circuit boards are placed as dictated on assembly.
5. The design was converted to use surface mount and drop-in parts.
6. A layout of the launcher radar unit for 10 GHz operation is shown using surface mount and drop-in parts.
7. Based on the design shown in item 5 an estimate of the size and weight is provided. This would be for early production units. Later on tooling investments would further reduce the size, weight and cost.
8. Other docmumentation was provided as required.

Figures 1 and 2 show the latest block diagrams with signal levels. These are very similar to the ones done during the previous effort and have only minor changes. New bills of material have been

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generated. This was extended to a vision of the BoM for the beta prototypes being built using surface mount and drop-in construction. Just going from the alpha connectorized prototype to the first beta the BoM cost decreased from $12,578 to $4,118. This is based on very low volume prices with no value engineering applied at this time. The transponder unit decreased from $4,780 to $395 for a similar transition to say a few hundred units. It is recongized that is cost is still an order of magnitude greater than that needed for the product to be marketable. The major cost reduction will come from tooling and a higher level of integration assuming that it is justified by the market. Even though there are economies to be realized, the volume of the launcher will never reach the volume of the transponder.

The weight of the launcher has been estitmated to be less than two pounds, based on surface mount and drop-in construction. Figure 3 shows how the parts will fit into the volume of less than 50 cubic inches. By the same reasoning, the weight of the transponder is estimated to be less than 1.5 ounces. Figure 4 shows how the transponder will fit into a cylinder that is less than 40 mm in diameter and 17.5 mm long.

In addition, the estimate to construct an alpha brassboard was reviewed and the original estimate is deemed to be valid. Thus, should LET decide to proceed with such a prototype, the cost to fabricate it will be approximately $135,000. A layout of the brassboard which will be suitable for proof-of-concept testing and readily modified to evaluate different configurations is shown in Figure 5. For the purpose of such testing the transponder would be built into a case that is about 60 cubic inches to permit the same flexibility. Finally, the currently proposed bills of materials for the brassboard and a surface mount prototype are included.

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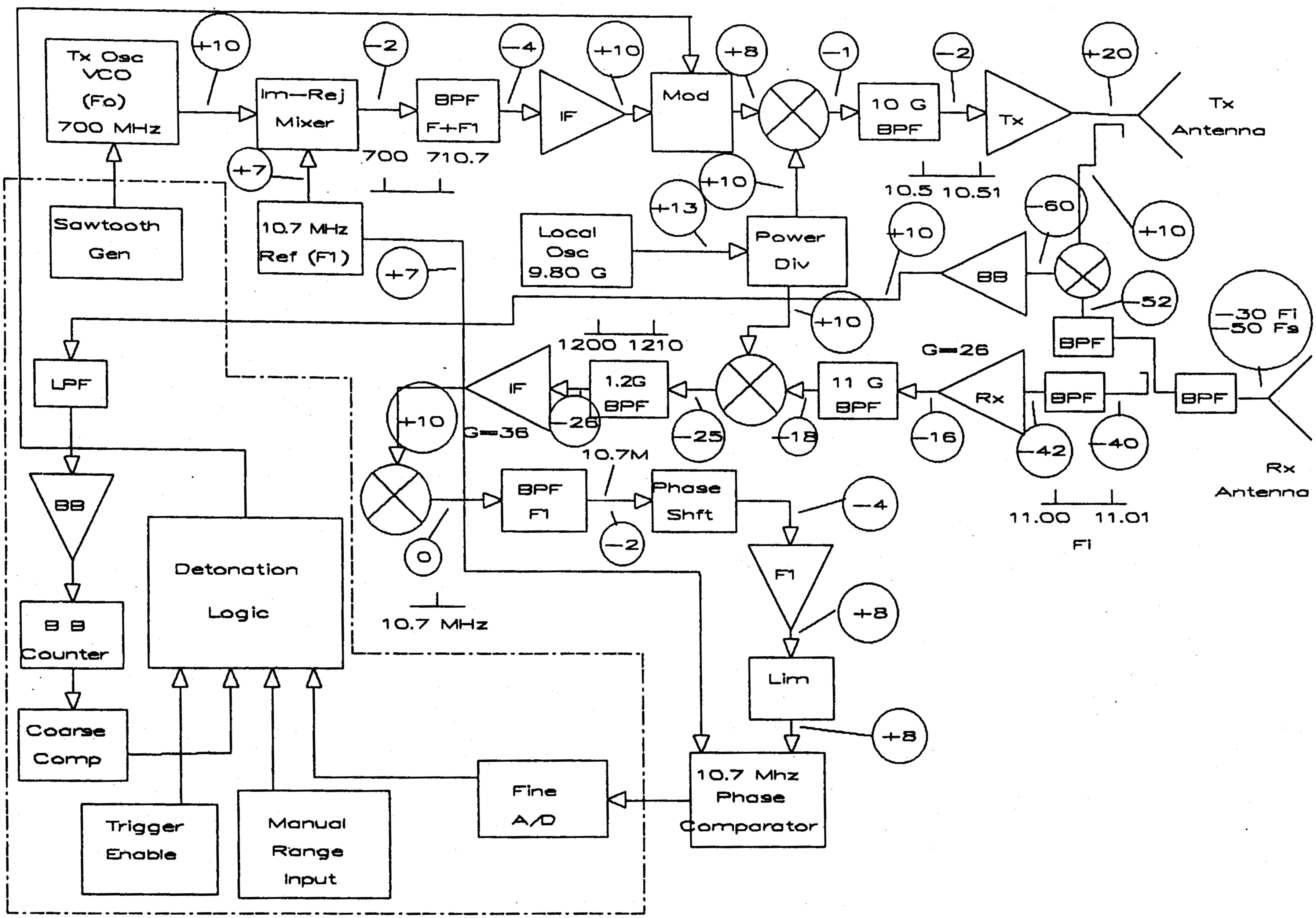

Figure 1. Laucher Unit—Signal Levels

jh 5/9/01
Launch3B

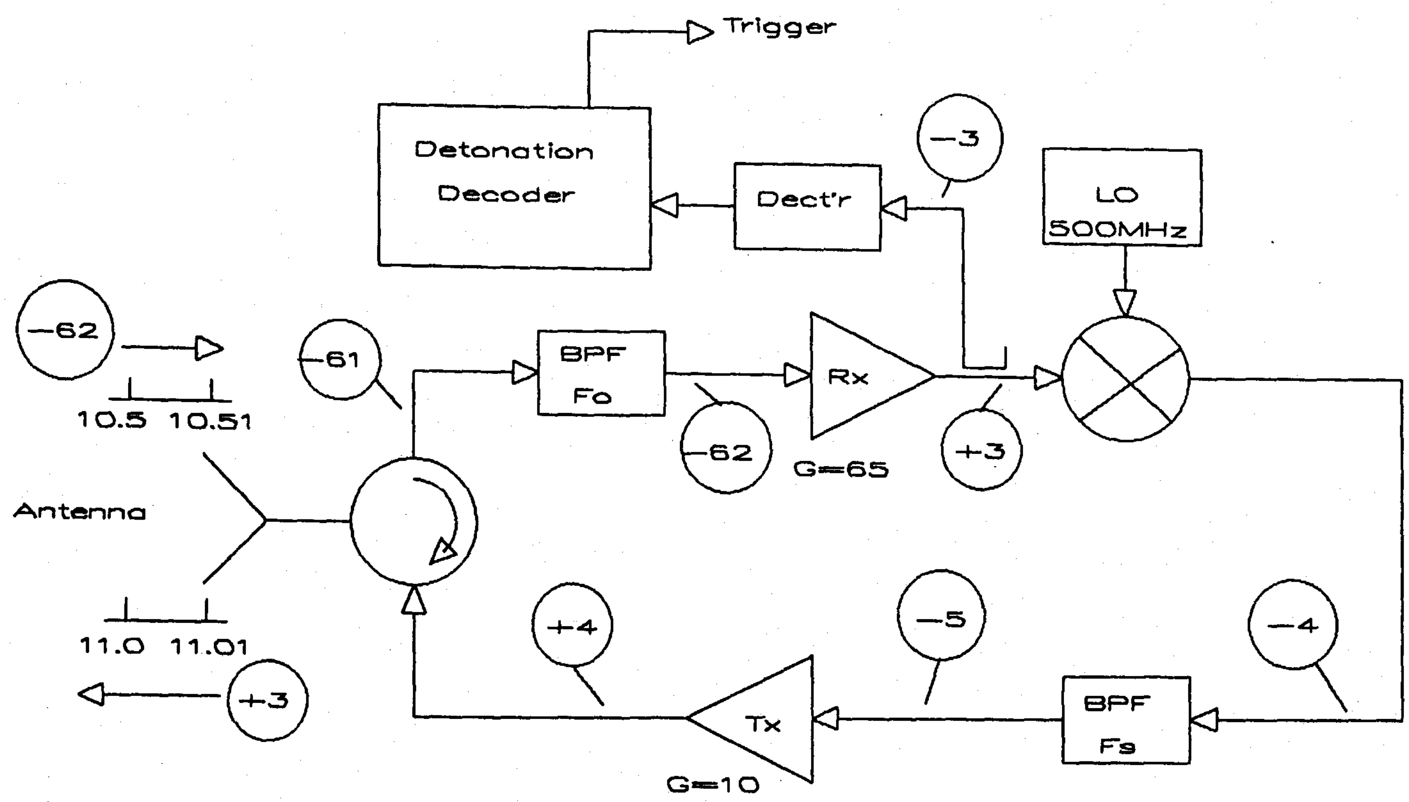

Figure 2. Transponder — Signal Levels

jh 10/19/99
xpsiglev

ELECTRO SCIENCE TECHNOLOGIES

June 26, 2001

TECH NOTE

Launcher Weight Estimate

The launcher unit has been converted to surface mount components from the original design that used connectorized components. The result is that on a first pass the size has been reduced from a 5 1/4 inch full rack width enclosure which occupies 1680 cubic inches to a dedicated enclosure with a volume of 48 cubic inches. Overall, the size of the launcher mounted radar unit can be approximately 8 X 3 1/4 X 2 inches. Greater size reduction is readily feasible with tooling and additional integration.

The weight of the launcher unit is estimated to be about 2 pounds using this type of construction. This is based on an estimate of 2 oz for all the electronic components as most weight only a few grams. The battery is the heaviest component and would likely weigh about 6 oz. The launcher will consist mostly of duriod dielectric material with a density of 2.2 and aluminum which as a specific gravity of about 8. The duriod will have negligible weight while the aluminum will weigh about 16 oz. The total weight then should be less than 2 pounds. Again, this can be reduced by additional product mechanical engineering and higher level circuit integration. This effort will be required to be sure that the design can withstand the shock of the weapon being fired, if weapon mounted, and certainly the rough handling expected in field operations.

A possible means of construction of the launcher electronics is shown in the following figure. This approach uses a three layer design. The top layer contains all the RF components that can be integrated using surface mount construction. The second layer contains the connectorized components and, the third layer contains the analog, digital circuits and the battery. The antenna is external and can mounted on the weapon or the personnel operating the weapon. Production quantities permitting, there is much room for further integration and, in fact, if the design makes use of 76 GHZ automotive radar modules, then the antenna size will be greatly reduced.

The size and weight of the projectile mounted transponder has already been determined to be about 0.35 in^3 and will weight less than 1.5 ounces.

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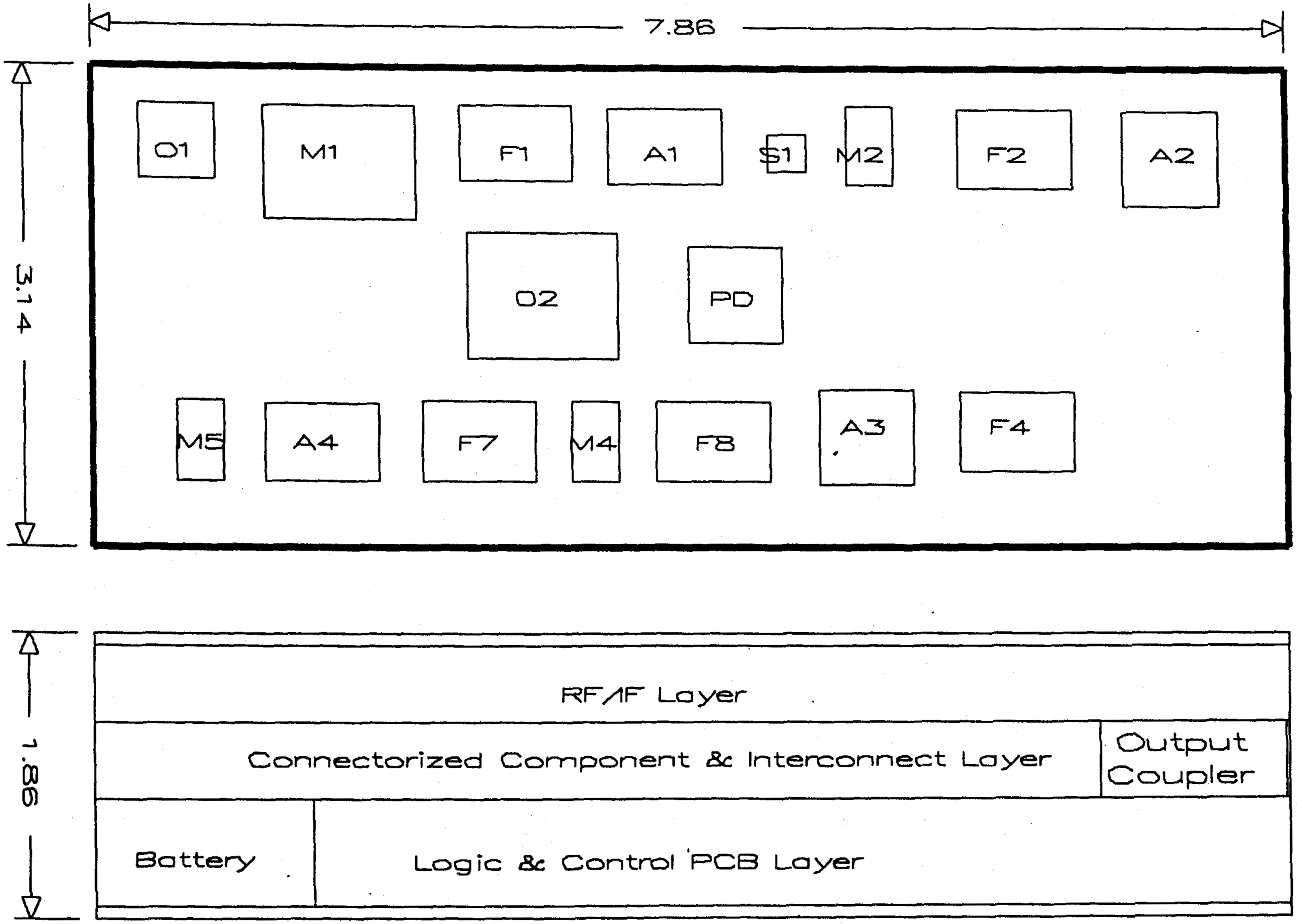

Figure 3. Surface Mount Construction Launcher Layout

sm-lot
jh 6/25/01

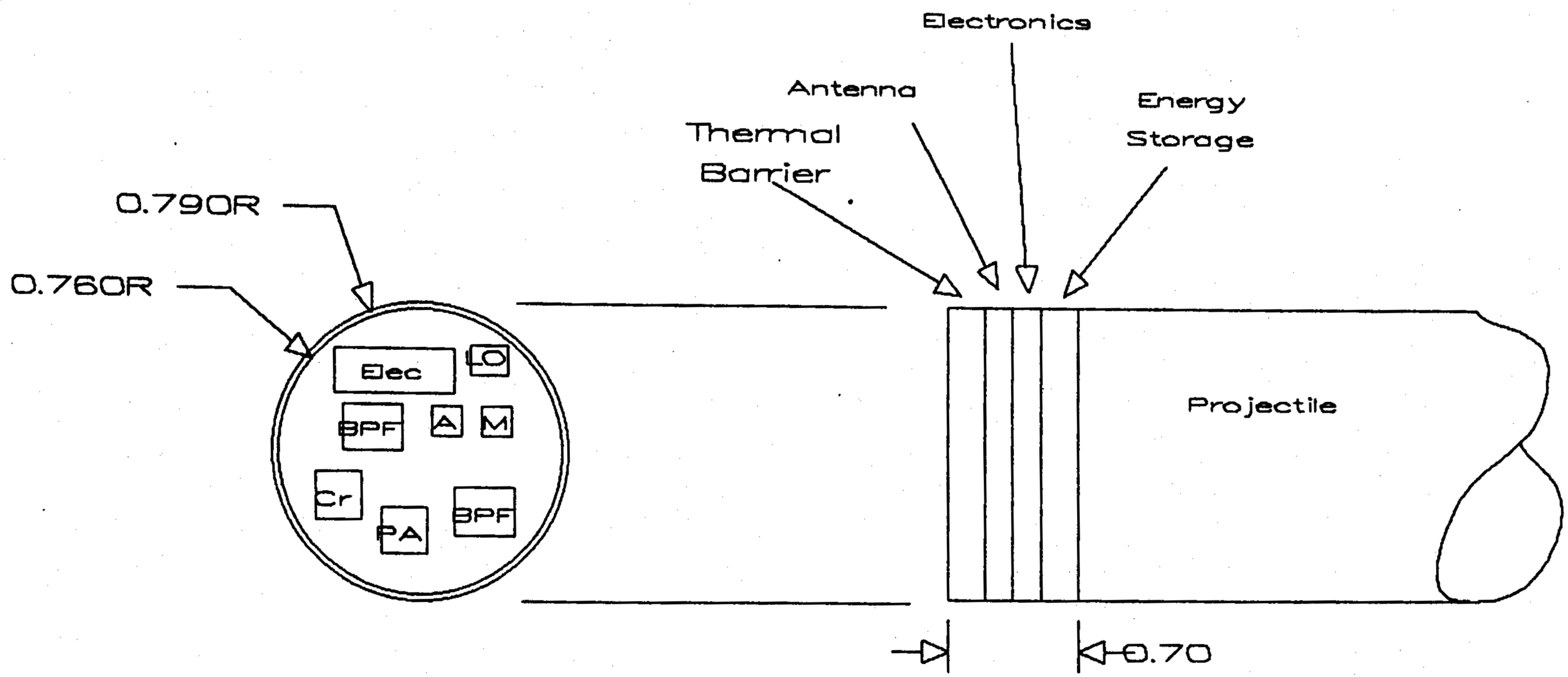

Figure 4. Non-Lethal Munition

Transponder Layout

xpndlayo

jh 3/20/01

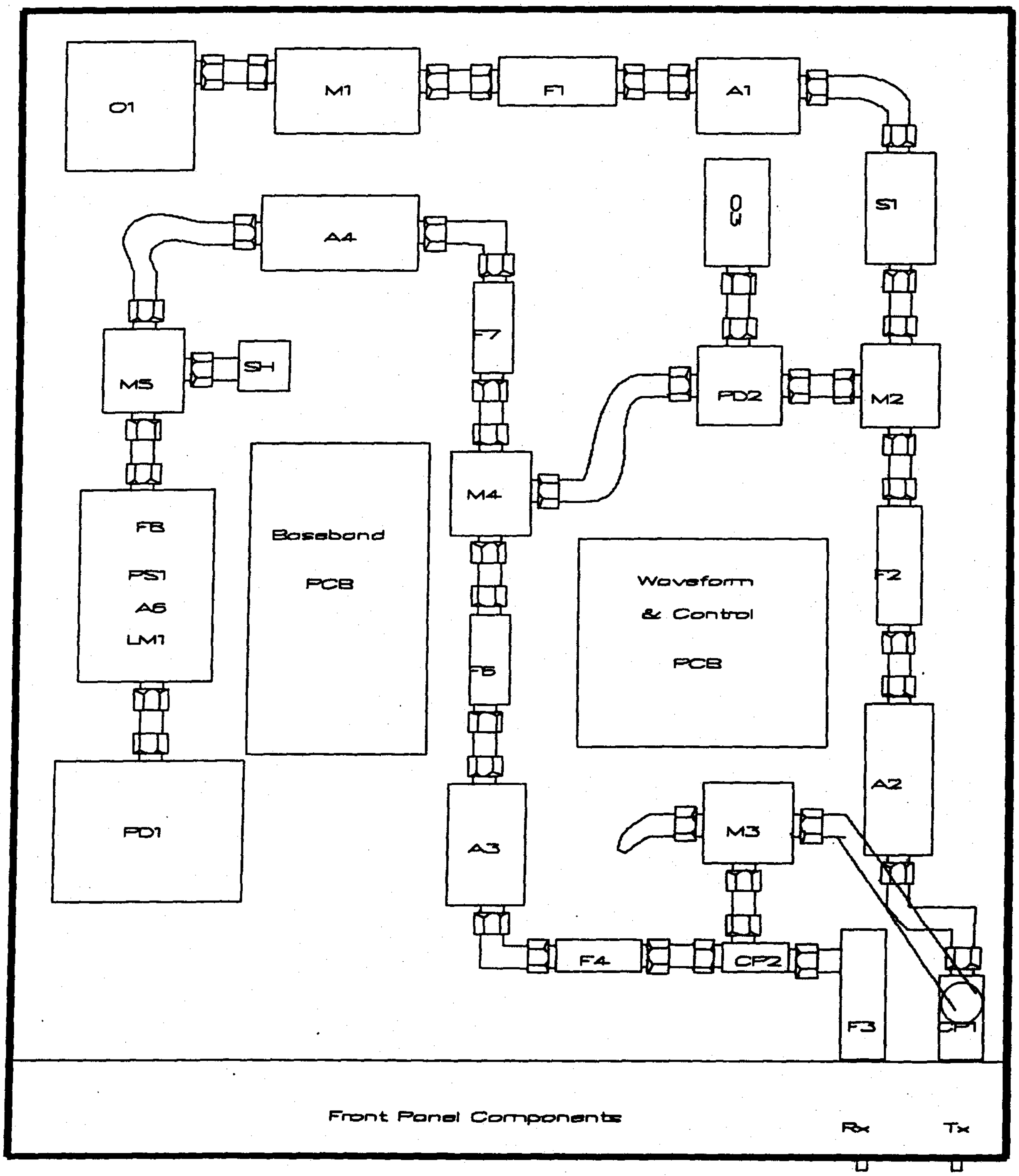

Figure 5. RF Deck Layout

alf-lo-2

ELECTRO SCIENCE APPLICATIONS 5-Jun-2001

NON-LETHAL WEAPONS RADAR FUSING

Breadboard Parts List - Launcher Unit

PART	VENDOR	MODEL	SPEC	CKT DESIG	PRICE
Antennas	Narda	640 & 4601 WG Adapters	8.0 - 12GHz, G=15 dB	AN1, AN2	$1,500.00
Primary Osc	MiniCircuits Labs.	JTOS-1025P	700 MHz VCO, +9 dBm	O1	$100.00
Ref Osc	Vectron	CO-718SB29-L2-10M	10.7 MHz X-tal	O2	$800.00
Oscillator, local	Narda	NSO-XM-10525	DRO, 9.8 GHz, 13 dBm	O3	$1,010.00
Power Divider, 2 way	Narda	4315-2	8-12 GHz	PD1	$250.00
Mixer, Image Reject	MiniCircuits Labs.	Made of the following 3 parts	Output 700 & 710,rej 690Mhz	M1	$60.00
Mixers, Balanced	MiniCircuits Labs.	JMS-2LH	20-1000 MHz/ DC-1GHz		$9.45
Hybrids, 90 deg	MiniCircuits Labs.	LRPQ-700	500-700 MHz		$9.95
Zero deg Pwr Dividers	MiniCircuits Labs.	LRPS-2-1	5-500 MHz		$8.95
Filter, BP	Filtek	BP12/705-X40-4AA	705 MHz, BW=20 MHz	F1	$225.00
Mixer, Balanced	Miteq	DM0812LW2	10 GHz, 700 MHz IF	M2	$300.00
Amplifier, Tx, Pre	MiniCircuits Labs.	MAR-4	700 MHZ, G=14 dB	A1	$20.00
Modulator	MiniCircuits Labs.	ZFSWHA-1-20	700 MHZ	S1	$75.00
Amplifier, Tx	Miteq	AFS3-08001200-40-20P-4	G=20 dB, Po>+20 dBm	A2	$1,200.00
Direx Coupler	Narda	4015C-10	8-12 GHz, 10 dB	CP1,2	$500.00
Filter, Tx	Filtek	BP26/10505-X40-3AA	10.3-10.7 GHz, IL<1.5 dB	F2	$330.00
Filter, BP, Receive	Filtek	BP30/10800-550-4AA	10.3-11.3 GHz, IL<1.5 dB	F3	$310.00
Filter, BP Rx FMCW	Filtek	BP26/10505-X40-3AA	10.3-10.7 GHz, IL<1.5 dB	F5	$330.00
Mixer, Balanced	Miteq	DM0812LW2	10 GHz, DC IF	M3	$300.00
Amplifier, Baseband	Motorola	TBD	G=50 dB, BW=5 MHz	A5	$100.00
Filter, BP Rx Shifted	Filtek	BP26/11005-40-3AA	10.9-11.1 GHz, IL<1.5 dB	F4	$330.00
Amplifier, Rx, LN	Miteq	AFS3-08001200-09-10P-4	8-12 GHz, G=26 dB,NF=1dB	A3	$800.00
Filter, BP, Rx Shifted	Filtek	BP26/11005-40-3AA	10.9-11.1 GHz, IL<1.5 dB	F6	$330.00
Mixer, Balanced	Miteq	DM0812LW2	11 GHz, 700 MHz IF	M4	$350.00
Filter, BP	Filtek	BP12/1205-X40-4AA	1.2 GHz, BP, BW>40 MHz	F7	$225.00
Amplifier, IF, 1200 MHz	MiniCircuits Labs.	MAR-Series	1200 MHz, G=36 dB	A4	$50.00
Mixer, Single diode Unbal	Herotek		1200 MHz to 10 MHz	M5	$250.00
Filter, BP, 10.7 MHz	MiniCircuits Labs.	SBP-10.7	Very Sharp 10.7 MHz	F8	$100.00
Amplifier, Driver, 10 MHz	MiniCircuits Labs.	MAR-3	10 MHz, G=12, P=+8 dBm	A6	$20.00
Sawtooth Generator	EST	Custom	TBS		$100.00
Limiting Amp, 10 MHz	MiniCircuits Labs.	AMP-11-2, 2 stages	10 MHz,G=14, NF=3 dB	A7	$90.00
Phase Shifter	MiniCircuits Labs.	JSPHS-10-X	10 MHz, 360 degrees	PS1	$50.00
Phase Detector, 10 MHz	MiniCircuits Labs.	SYPD-1	0-180 deg, 2 v p-p	PH1	$35.00
Filter, Baseband	EST	Custom	100 KHz	F8	$10.00
Enclosure	Buckeye	DSC-5254-13/MP40565 handles & bail bar		Case	$170.00
Power Supply	Acopian	15EB100	+15 volts @ 1 amp	PS1	$130.00

Power Supply	Acopian	5EB200	+5 volts @ 2 amps	PS2	$130.00
Power Supply	Acopian	12EB70	-12 volts @ 0.7 amp	PS3	$130.00
Terminations	Narda	4377B	50 ohm, DC-8GHz	R1,2,3,4	$340.00
Misc. Hardware	J. Smith	Adapters	SMA parts	35 of	$600.00
Interconnect Cables	KMW Microwave	SMA-SMA	3,6,9,12" lengths	30 of	$400.00
Misc. Parts	Various	TBD			$500.00
	Parts Cost				$12,578.35

ELECTRO SCIENCE TECHNOLOGIES

25-Jun-01

Beta Model - Surface Mount Parts List - Launcher Unit

PART	VENDOR	MODEL	SPEC	CKT DESIG	PRICE
Antennas	Seavey Eng.		8.0 - 12GHz, G=15 dB	AN1, AN2	$20.00
Primary Osc	Maxim		700 MHz VCO, +9 dBm	O1	$15.00
Ref Osc	Maxim		10.7 MHz X-tal	O2	$5.00
Oscillator, local	Narda	NSO-XM-10525	DRO, 9.8 GHz, 13 dBm	O3	$1,010.00
Power Divider, 2 way	Narda	4315-2	8-12 GHz	PD1	$250.00
Mixer, Image Reject	MiniCircuits Labs.	Made of the following 3 parts	Output 700 & 710,rej 690Mhz	M1	$60.00
Mixers, Balanced	MiniCircuits Labs.	JMS-2LH	20-1000 MHz/ DC-1GHz		$9.45
Hybrids, 90 deg	MiniCircuits Labs.	LRPQ-700	500-700 MHz		$9.95
Zero deg Pwr Dividers	MiniCircuits Labs.	LRPS-2-1	5-500 MHz		$8.95
Filter, BP	Integrated	BP12/705-X40-4AA	705 MHz, BW=20 MHz	F1	$5.00
Mixer, Balanced	Miteq	DM0812LW2	10 GHz, 700 MHz IF	M2	$300.00
Amplifier, Tx, Pre	MiniCircuits Labs.	MAR-4	700 MHZ, G=14 dB	A1	$20.00
Modulator	MiniCircuits Labs.	MSW-2-20	700 MHZ	S1	$2.45
Amplifier, Tx	Miteq	AFS3-08001200-40-20P-4	G=20 dB, Po>+20 dBm	A2	$400.00
Direx Coupler	Narda	4015C-10	8-12 GHz, 10 dB	CP1,2	$150.00
Filter, Tx	Filtek	BP26/10505-X40-3AA	10.3-10.7 GHz, IL<1.5 dB	F2	$100.00
Filter, BP, Receive	Filtek	BP30/10800-550-4AA	10.3-11.3 GHz, IL<1.5 dB	F3	$100.00
Filter, BP Rx FMCW	Filtek	BP26/10505-X40-3AA	10.3-10.7 GHz, IL<1.5 dB	F5	$100.00
Mixer, Balanced	Miteq	DM0812LW2	10 GHz, DC IF	M3	$200.00
Amplifier, Baseband	Motorola	TBD	G=50 dB, BW=5 MHz	A5	$10.00
Filter, BP Rx Shifted	Filtek	BP26/11005-40-3AA	10.9-11.1 GHz, IL<1.5 dB	F4	$100.00
Amplifier, Rx, LN	Miteq	AFS3-08001200-09-10P-4	8-12 GHz, G=26 dB,NF=1dB	A3	$400.00
Filter, BP, Rx Shifted	Filtek	BP26/11005-40-3AA	10.9-11.1 GHz, IL<1.5 dB	F6	$100.00
Mixer, Balanced	Miteq	DM0812LW2	11 GHz, 700 MHz IF	M4	$175.00
Filter, BP	Filtek	BP12/1205-X40-4AA	1.2 GHz, BP, BW>40 MHz	F7	$75.00
Amplifier, IF, 1200 MHz	MiniCircuits Labs.	MAR-Series	1200 MHz, G=36 dB	A4	$10.00
Mixer, Single diode Unbal	HP Diode		1200 MHz to 10 MHz	M5	$6.00
Filter, BP, 10.7 MHz	MiniCircuits Labs.	SBP-10.7	Very Sharp 10.7 MHz	F8	$8.00
Amplifier, Driver, 10 MHz	MiniCircuits Labs.	MAR-3	10 MHz, G=12, P=+8 dBm	A6	$6.00
Sawtooth Generator	EST	Custom	TBS		$20.00
Limiting Amp, 10 MHz	MiniCircuits Labs.	AMP-11-2, 2 stages	10 MHz,G=14, NF=3 dB	A7	$50.00
Phase Shifter	MiniCircuits Labs.	JSPHS-10-X	10 MHz, 360 degrees	PS1	$30.00
Phase Detector, 10 MHz	MiniCircuits Labs.	SYPD-1	0-180 deg, 2 v p-p	PH1	$22.00
Filter, Baseband	EST	Custom	100 KHz	F8	$10.00

Enclosure				Case	$25.00
Power Supply	National Semi	15EB100	+15 volts @ 1 amp	PS1	$5.00
Power Supply	National Semi	5EB200	+5 volts @ 2 amps	PS2	$10.00
Power Supply	National Semi	12EB70	-12 volts @ 0.7 amp	PS3	$5.00
Terminations	FMI	4377B	50 ohm, DC-8GHz	R1,2,3,4	$5.00
Misc. Hardware	J. Smith	Adapters	SMA parts	35 of	$50.00
Interconnect Cables	KMW Microwave	SMA-SMA	3,6,9,12" lengths	30 of	$30.00
Misc. Parts	Various	TBD			$200.00
	Parts Cost				$4,117.80

ELECTRO SCIENCE APPLICATIONS 5-Jun-2001

NON-LETHAL WEAPONS RADAR FUSING SYSTEM

Breadboard Parts List - Transponder

PART	VENDOR	MODEL	SPEC	CKT DESIG	PRICE
Antenna	Narda	460 & 4601 Adapter	G=15 dBi @ 10 GHz	AN1P	$725.00
Circulator	UTE Microwave	CT-5158-O	8-12 GHz, SMA, ISOL>18 dB	CQ1P	$200.00
Filter, BP Rx	Filtek	TBD	10.505 GHz, BW < 50 MHz	F1P	$350.00
Amplifier, Rx, LN	Miteq	AFS43-09001100-09-10P-44	9-11 GHz, G=60 dB,NF=1dB	A1P	$1,000.00
Coupler	Narda	4015C-6	8-12 GHz, 6 dB	CP1P	$245.00
Detector	Narda	4503	1-18 GHz	D1P	$350.00
Mixer	Miteq	DM0812LW2	10-11GHz, 500 MHz IF	M1P	$350.00
Filter, BP Tx	Filtek	TBD	11.05 GHz, BW<50 MHz	F2P	$350.00
Amplifier, Tx	Miteq	AFS3-08001200-09-10P-4	8-12 GHz, G=10 dB,NF=1dB	A2P	$400.00
Power Supply	Acopian	15EB100	15V @ 1amp	PS1P	$150.00
Logic Circuit	ESA	Custom	Counter/Contoller	PCB1P	$150.00
Misc Hardware	Various				$500.00
Case	Radio Shack				$10.00
					$4,780.00

ELECTRO SCIENCE TECHNOLOGIES

NON-LETHAL WEAPONS RADAR FUSING SYSTEM

Beta Surface Mount Parts List - Transponder

29-Jun-01

PART	VENDOR	MODEL	SPEC	CKT DESIG	PRICE
Antenna	Tecom	TBD	G=15 dBi @ 10 GHZ Printed	AN1P	$15.00
Circulator	UTE Microwave	CT-5158-O	8-12 GHz, SMA, ISOL>18 dB	CQ1P	$35.00
Filter, BP Rx	Built in	TBD	10.505 GHz, BW < 50 MHz	F1P	$35.00
Amplifier, Rx, LN	TBD	TBD	9-11 GHz, G=60 dB,NF=1dB	A1P	$35.00
Coupler	TBD	Printed	8-12 GHz, 6 dB	CP1P	$15.00
Detector	TBD	diode	1-18 GHz	D1P	$4.00
Local Oscillator	Minicircuits	POS-500	500 MHz	OS1P	$15.00
Mixer	TBD	dropin	10-11GHz, 500 MHz IF	M1P	$50.00
Filter, BP Tx	TBD	TBD	11.05 GHz, BW<50 MHz	F2P	$35.00
Amplifier, Tx	TBD	TBD	11 GHz, BW<50 MHz	A2P	$50.00
Power Supply	Sprague	16,000 uF @ 20 volts		PS1P	$6.00
Logic Circuit	ESA	Custom	Counter/Contoller	PCB1P	$40.00
Misc Hardware	Various				$50.00
Case	Custom				$10.00
	Total				$395.00

Note: TBD Vendor candidate is Infineon, a manufacturer of integrated circuits for 70 GHz radar components.

ELECTRO SCIENCE APPLICATIONS

ADDENDUM TO REPORT
Less-Than-Lethal Munition Radar Fuse
for Law Enforcement Technologies, Colorado Springs, CO
PROJECT PHASE COMPLETION
Contract No. EST 01-103

August 3, 2001

The following information has been gathered as a result of the meeting with the Sandia National Laboratory portion of the team.

The ignition device that will be used for the pyrotechnic material will be an electric match manufactured by DaveyFire, model M28F. There are others available from a variety of suppliers. This match requires a signal energy of 1.6watts for 40 milliseconds (64millijoules). The resistance of the match is about 1.6 ohms. The specified current for *all fire* is 1.0 amps and 0.4 amps for *no fire*. Therefore, the circuitry must provide 1 amp for reliable operation. After application of the current for 30 ms, the light off time is then about 10 ms and the event output would take something less than 100 ms to occur. Dwane Johnson reports that a total time of 40 ms is repeatable.

Adding all this up results in a lead time of 30+10+100=140 ms worst case. If the projectile is traveling at 200 ft/sec, it will cover a distance of 28 feet (8.5 meters) in 140 ms. This means that the ignition signal must be transmitted when the projectile is 8.5 meters in front of the target. Programming of the system to accomplish this is readily accomplished. However, the repeatability of the pyrotechnics is the limiting factor in how accurately the position of the event can be controlled. The travel time for the ignition signal to travel to the target at a range of 100 meters is 333 nanoseconds and the timing jitter in the electronics will be well under a microsecond. This is many orders of magnitude below the repeatability of the pyrotechnics material.

The Sandia team also estimates that the Magnesium cloud will continue to burn for about 80 milliseconds. The cloud material is very susceptible to deceleration by the air, so it will have very little forward velocity. But, it must also be determined empirically as to how much additional lead is needed in the electronic timing circuits to prevent the cloud from actually reaching the target. A possible means to ease this problem is to reduce the muzzle velocity of the round. At a muzzle velocity of 200 ft/sec, the round will have a maximum range of 377 meters and it will take a bit over 4 seconds to reach a target at 100 meters. It the velocity were reduced the range would be reduced accordingly but the distance traveled during any uncertainties is also reduced. A lower velocity and acceleration out of the barrel would also ease some of the mechanical design considerations with regard to the shell casing and forces on the electronics, along with a lower probability of inflicting harm to the target.

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FINAL REPORT FOR PHASE ONE

LESS-THAN-LETHAL BALLISTIC

Submitted By:

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FINAL REPORT - PHASE 1

From Duane Johnson

1. INTERNAL BALLISTICS

The less-than-lethal projectile will be propelled from the launch platform by the M212 Assembly which is comprised of a double-based commercial propellant similar to regular pistol powders. The propellant is contained in a closed brass container fabricated from a standard 38 caliber shell and ignited by a standard primer utilized in conventional 38 caliber shells. The ignited propellant builds up pressure to a point where the end of the closed brass container opens and the high pressure is released to the volume below the obturator of the main projectile. The pressurized hot combustion products from the burnt propellant then starts the forward acceleration of the projectile down the rifled barrel and the projectile is ejected from the barrel at a design velocity of 250 feet per second towards the intended target area.

2. EXTERNAL BALLISTICS

With the barrel at an elevation of approximately 4.87 degrees off horizontal and a barrel exit velocity of 250 feet per second, calculations indicate that the projectile would reach one hundred (100) meters in 1.316 seconds at the same off-ground altitude at which it was fired.

Likewise, with the barrel at an elevation of approximately 0.97 degrees off horizontal and a barrel exit velocity of 250 feet per second, calulations indicate that the projectile would reach twenty (20) meters in 0.263 seconds at the same off-ground altitude at which it was fired.

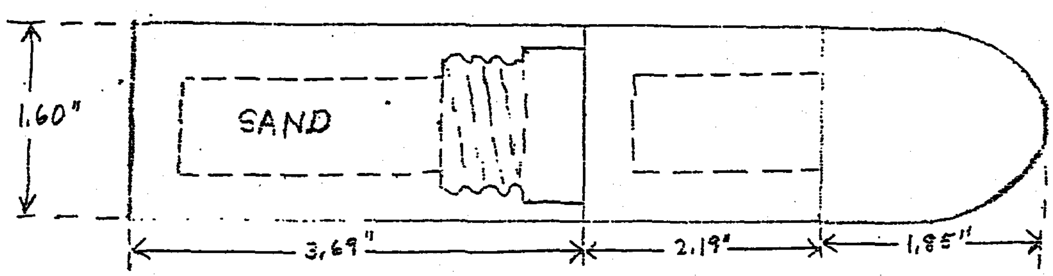
Current best technology, as developed by the author and Martin Electronics, Inc. engineers for the M781 40 MM Practice Round, indicates that the expected range for the target 250 feet per second will be +-6.0 feet per second (95% confidence interval). At the same elevations, i.e. 4.87 and 0.97 degrees, the distance travelled by the projectile would vary from 95 to 105 meters and 19 and 21 meters respectively. The effect of these differences will be discussed in later paragraphs.

3. SHOCK MITIGATION

On June 7, 2001, a shock test was conducted using a projectile fabricated from two LAST-A-FOAM FR-6714 MK141 Diversionary Charge bodies as received from General Plastics Manufacturing Company (Tacoma, WA) with some minor modifications. A rough sketch below illustrates the modifications. Each body was turned down to an outside diameter of 1.60 inches. One body was loaded with 31.6 grams of sand in the body cavity and the plug screwed in place. The second body was cut off at the bottom of the plug cavity and epoxied to the first body as shown in the sketch. An ojive (the so-called windshield from a M781 40 MM Practice Round) was epoxied to the second body. This assembly was then inserted down a M203 barrel firmly against a M212 Cartridge Case Assembly which had a Body and Band inserted into the M212 Cartridge Case Assembly. This was the configuration as tested.

The purpose of the test was to evaluate this foam material for potential application in the Less-Than-Lethal Ballistic design. The test was expected to provide a "go-no-go" piece of information concerning the foam itself.

The round was fired at a barrel exit velocity of approximately 245 feet per second. Upon firing, pieces of the foam projectile were expelled within a distance of about thirty-five feet from the end of the barrel. The pieces that could be found were recovered and reassembled to the degree possible by using Elmer's Glue-All. The reassembled body showed clearly that the damage done was at the baseof the body where the shock loading would have been expected to have been the most severe. From calculations, it is estimated that there was 930-970 g's (average) in this test. From information available, the actual acceleration may have been initially as high as three times the average value calculated.



In the two different conceptual designs, the Transponder Design and the Two Delay Concept (see the Technical Drawing Packages), both have a Shock Absorber at the base of the projectile. The Shock Absorber will be a rubber section, the Hardness (or stiffness) of which will act to absorb the initial shock due to the the high accelerations encountered during the firing of the round. The Shock Absorber should eliminate the undesirable fracturing of the FR-6714 foam. Testing during Phase 2 of this program will define the material specifically.

4. LESS-THAN-LETHAL FEATURES

The LAST-A-FOAM FR-6714 which will be utilized in Phase 2 of this program has been utilized in the MK141 Diversionary Charge because it fractures into extremely small low-weight particles under explosive stress. These small particles (or fragments) rapidly undergo deceleration because of their low densities and small size. This feature is ideal for the two items under development here.

The epoxy casting which will contain the electronic components, antenna and an energy source will probably be one of the heavier masses in the Transponder Design. The Technical Drawing Package (TDP) for this design shows a parachute which will serve to rapidly decelerate the epoxy casting to a velocity that will certainly be less-than-lethal. When the Squib ignites the Expelling Charge in the Center Tube, the forces available from the Expelling Charge may produce a set-back force that slows the epoxy casting to a less-than-lethal velocity without the parachute. This will be be determined during Phase 2 of this program.

The Energetic Material which produces the temporary blinding of the targeted suspect, an acoustic report of approximately 180 dB and an overpressure of 2.5 to 3.0 pounds per square inch is a less-than-lethal combination of characteristcs. While there may seem to be a realistic concern regarding the high temperature of this deflagration, the time for this reaction is so short (estimated to be within 10-40 milliseconds) that no significant transfer of energy by conductive, convective or radiant processes to the targeted suspect could occur that would be life-threatening. The radiant transfer of visible light would cause temporary blinding but there would not be enough infrared energy transferred to burn the targeted suspect. For example, if one passes their finger quickly through a candle flame, no physiological damage is done because of the short contact time with the heat source.

5. PROJECTILE ACCURACY

A. Transponder Design

As discussed in Paragraph 2., there will be variations in the velocity of the rounds. To significantly reduce these variations would be prohibitive if the cost objectives of this program are to be met. However, the advantage of the Transponder Design tends to negate these variations in the rounds velocity due to the transponder's capability to be initiated at a predetermined distance. This means that the 95-105 meter range will be greatly reduced. The exact reduction will be determined during Phase _ testing.

B. Two Delay Concept

The accuracy of the Two Delay Concept would be expected to be as detailed in Paragraph 2, i.e. 95 to 105 meters at the 100 meters and 19 to 21 meters at 20 meters as far as accuracy as determined by the variations inherent in the internal ballistics. In this round, the distance at which the round is initiated is controlled by the delay composition's burning time accuracy and the internal ballistics.

In the Two Delay Concept, one of two pyrotechnic delays will be selected for a target distance of either 20 meters or 100 meters. The times (as estimated from the average velocity and the desired distance) would be 0.263 seconds and 1.316 seconds. Typically, the ability of the pyrotechnician to control delay times will be about +-6%. If one assumes a constant velocity, then the distance where the Energetic Material would be initiated would be approximately 1.2 meters longer or shorter than the desired 20 meters. For the 100 meter distance, this error would amount to approximately 7 meters longer and shorter than desired. When the delay variance is coupled with the velocity variance, the error induced is not the sum of the two variances, i.e. the variance is less than the sum of varinces. The exact variation will be determined during Phase 2 of this program.

6. RIFLING ENGAGEMENT

The M203 barrel is a rifled barrel. Rifling obviously imparts a spin to the projectile which aids in the stabilization of the flight of the projectile. In the M781 40 MM Practice Round, the rifling lands are engaged by a cast zinc Body-and-Band. Since one of the concerns in a less-than-lethal unit is to minimize the use of metallic parts since such a part could obtain higher velocities and provide a potentially lethal projectile, the design philosophy for this program is to minimize or eliminate any significantly heavy, dense parts from the design.

Examination of the proposed TDP for Phase 2 development and testing shows that the Electronics Package in the Transponder Design and the Delay Body in the Two Delay Concept have a protrusion relative to the outer diameters of the other parts in each design. In the Transponder Design, the Electronics Package is fabricated from cast epoxy and, in the Two Delay Concept, the Delay Body is fabricated from hard foam. The purpose of using the two different materials where the rifling lands are engaged is to investigate if these materials will hold up to the shock force seen during engagement with the rifling lands. If one material fails to be strong enough, the other material will be utilized in that design. If both materials fail to perform properly, the protrusion will be eliminated and the projectile's stabilty will be examined without the benefit of spinning being induced by the rifling lands engagement. The length-to-diameter ratio of both the projectiles being designed may not require spinning in order to have stable flight.

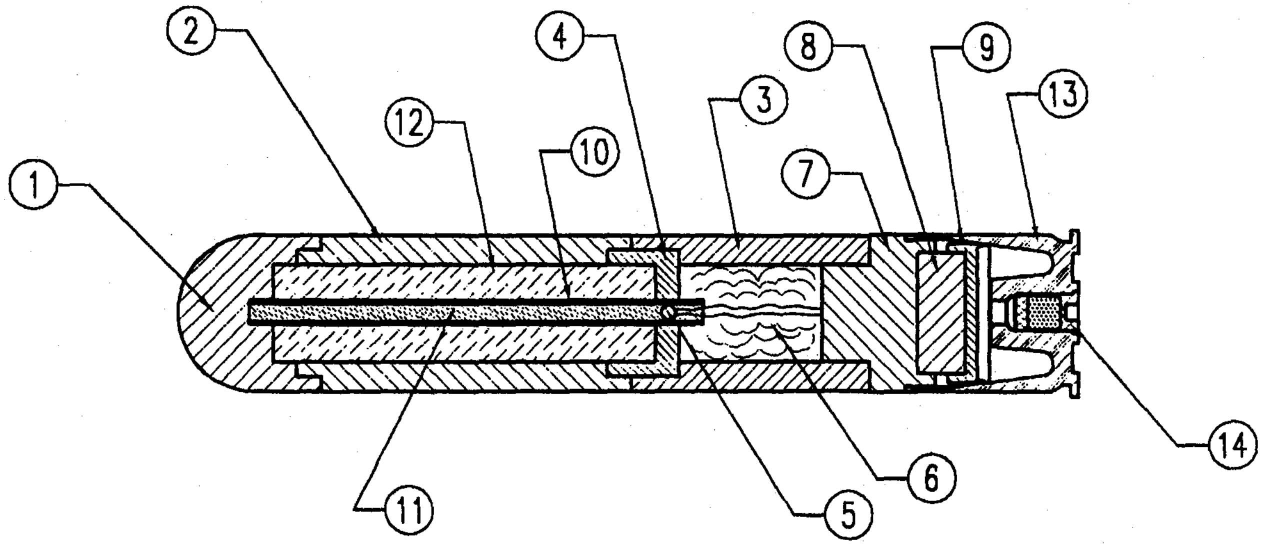
7. TECHNICAL DRAWING PACKAGES

The Technical Drawing Packages will be the starting point for both of the designs. It can be anticipated that changes will be made in these packages as fabrication and testing of the designs take place in Phase 2. At the end of Phase 2, the Technical Drawing Packages will corrected and updated with the inclusion of assembly instructions. Assembly techniques will be determined during the next phase of this program.

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



NOTES:

1. THIS DRAWING NOT COMPLETE WITHOUT SHEET 2 OF 2.

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED)
DECIMAL .XXX= ±.010
.XX= ±.02
FRACTIONS ± 1/16
ANGLES ± 2°

APPROVED	DATE
ENGINEERING	
SAFETY	
DRAWN BY D.L.	08-05-01

CHECKED BY | DATE

MATERIAL

PROJECT

LAW ENFORCEMENT TECHNOLOGIES, INC.

TITLE

TRANSPONDER ASSEMBLY

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	1 OF 2			

NOTES:
1. MAGNESIUM, 325 MESH WITH TS720 CABOSIL (SILICONE TREATED)
2. THIS DRAWING NOT COMPLETE WITHOUT SHEET 1 OF 2.

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

ITEM NO.	QTY. REQD.	DWG. SIZE	PART NO.	DESCRIPTION
14	1			38 CARTRIDGE ASSEMBLY
13	1			M212 CARTRIDGE
12			SEE NOTE 1	ENERGETIC MATERIAL, 20 GRAMS
11			Zr / $KClO_4$	EXPELLING CHARGE, 3 GRAMS
10	1	A		CENTER TUBE
9	1	A		SEAL
8	1	A		SHOCK ABSORBER
7	1	A		ELECTRONIC PACKAGE
6	1			PARACHUTE
5	1			SQUIB, DAVEY FIRE N28F ELECTRIC IGNITER
4	1	A		PUSHER PLATE
3	1	A		PARACHUTE SUPPORT
2	1	A		CHAMBER
1	1	A		OGIVE

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED)
DECIMAL .XXX= ±.010
.XX= ±.02
FRACTIONS ± 1/16
ANGLES ± 2°

APPROVED	DATE
ENGINEERING	
SAFETY	
DRAWN BY D.L.	08-05-01

CHECKED BY | DATE

MATERIAL

PROJECT

LAW ENFORCEMENT TECHNOLOGIES, INC.

TITLE

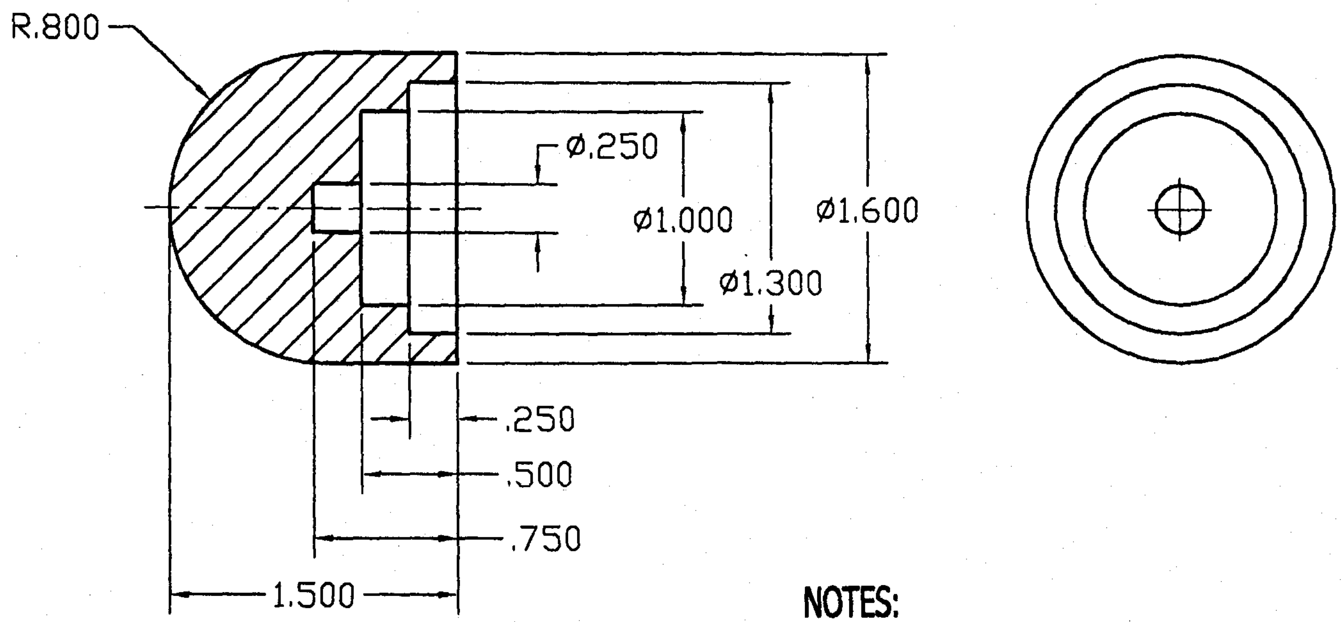
TRANSPONDER ASSEMBLY

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	2 OF 2			

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



NOTES:

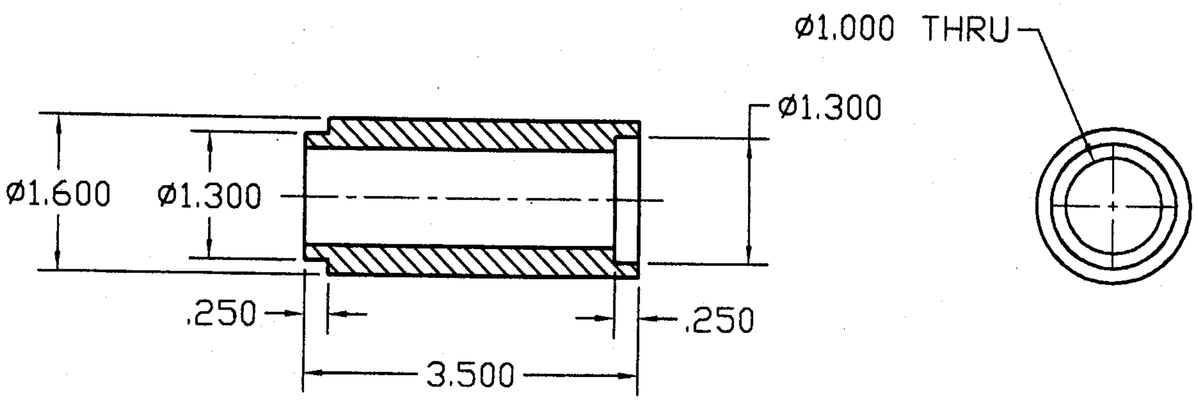
1. MATERIAL: LAST-A-FOAM FR-6714

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE	LAW ENFORCEMENT TECHNOLOGIES, INC.
	ENGINEERING		
	SAFETY		TITLE OGIVE
CHECKED BY / DATE	DRAWN BY D.L.		
MATERIAL	PROJECT		SIZE A · SCALE 1/1 · SHEET 1 OF 1 · CAGE CODE · DRAWING NO. TA-1 · REV

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



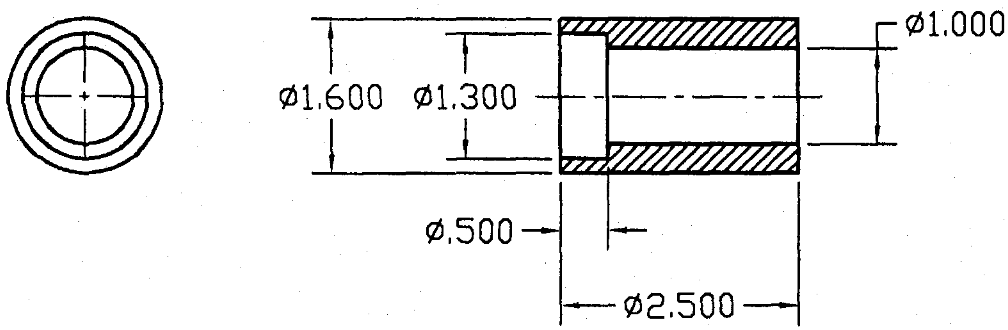
NOTES:
1. MATERIAL: LAST-A-FOAM FR-6714

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED / ENGINEERING / SAFETY	DATE	LAW ENFORCEMENT TECHNOLOGIES, INC.
CHECKED BY / DATE	DRAWN BY D.L.	08-05-01	TITLE CHAMBER
MATERIAL SEE NOTE 1	PROJECT		SIZE A / SCALE 1/2 / SHEET 1 OF 1 / CAGE CODE / DRAWING NO. TA-2 / REV

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



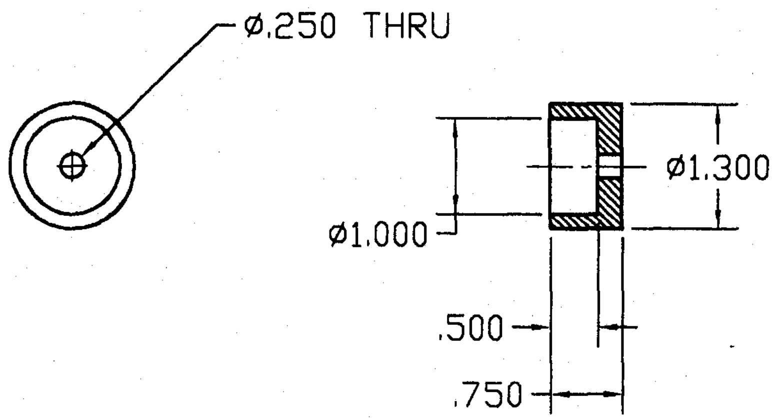
NOTES:
1. MATERIAL: LAST-A-FOAM FR-6714

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE	LAW ENFORCEMENT TECHNOLOGIES, INC.
	ENGINEERING		
	SAFETY		TITLE *PARACHUTE SUPPORT*
CHECKED BY / DATE	DRAWN BY D.L.	08-05-01	
MATERIAL SEE NOTE 1	PROJECT		SIZE: A · SCALE: 1/2 · SHEET: 1 OF 1 · CAGE CODE: · DRAWING NO.: TA-3 · REV:

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



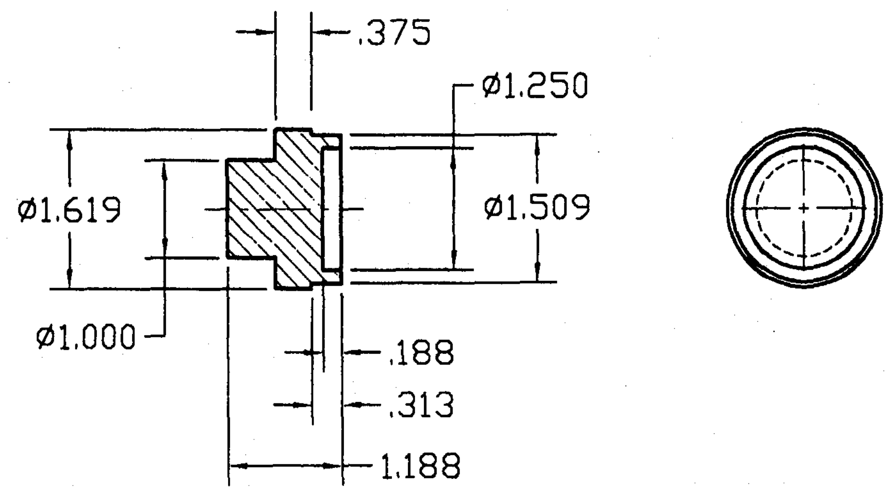
NOTES:
1. MATERIAL: LAST-A-FOAM FR-6714

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE	LAW ENFORCEMENT TECHNOLOGIES, INC.
	ENGINEERING		
	SAFETY		TITLE PUSHER PLATE
CHECKED BY / DATE	DRAWN BY D.L.	08-05-01	
MATERIAL SEE NOTE 1	PROJECT		SIZE A · SCALE 1/2 · SHEET 1 OF 1 · CAGE CODE · DRAWING NO. TA-4 · REV

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



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DECIMAL .XXX= ±.010
.XX= ±.02
FRACTIONS ± 1/16
ANGLES ± 2°

APPROVED	DATE
ENGINEERING	
SAFETY	

CHECKED BY	DATE	DRAWN BY	
		D.L.	08-05-01

MATERIAL: EPOXY-CAST

PROJECT:

LAW ENFORCEMENT TECHNOLOGIES, INC.

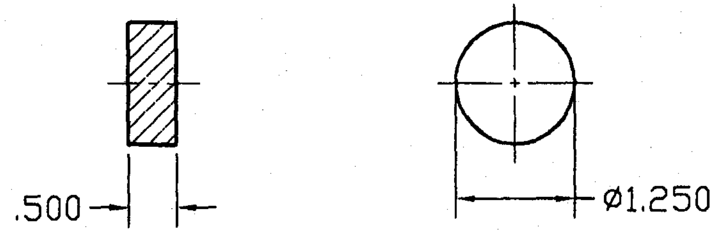
TITLE: *ELECTRONICS PACKAGE*

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	1 OF 1		TA-7	

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

DWG. NO. | SH | REV.



TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE
	ENGINEERING	
	SAFETY	
CHECKED BY / DATE	DRAWN BY D.L.	08-05-01
MATERIAL: RUBBER CYLINDER	PROJECT	

LAW ENFORCEMENT TECHNOLOGIES, INC.

TITLE: *SHOCK ABSORBER*

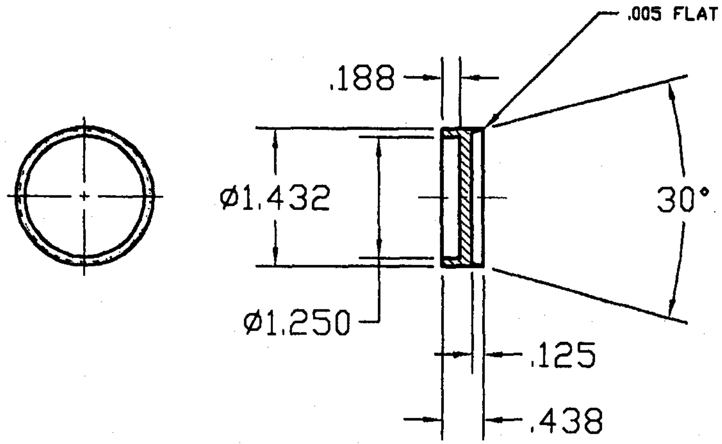
SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	1 OF 1		TA-8	

DWG. NO.	SH	REV.

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED

2

B



B

A

TOLERANCES ON DIMENSIONS
(UNLESS OTHERWISE NOTED)
DECIMAL .XXX= ±.010
.XX= ±.02
FRACTIONS ± 1/16
ANGLES ± 2°

APPROVED	DATE
ENGINEERING	
SAFETY	
DRAWN BY D.L.	08-05-01

CHECKED BY	DATE

MATERIAL
POLY-ETHYLENE

PROJECT

LAW ENFORCEMENT
TECHNOLOGIES, INC.

TITLE
SEAL

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	1 OF 1		TA-9	

A

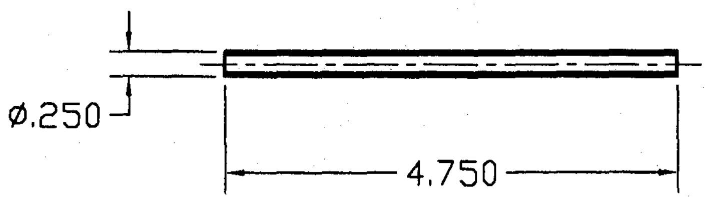
2

1

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



NOTES:
1. MATERIAL: 1/4" OD DRINKING STRAW

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE	LAW ENFORCEMENT TECHNOLOGIES, INC.
	ENGINEERING		
	SAFETY		TITLE *CENTER TUBE*
CHECKED BY / DATE	DRAWN BY D.L.	08-05-01	
MATERIAL SEE NOTE 1	PROJECT		

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
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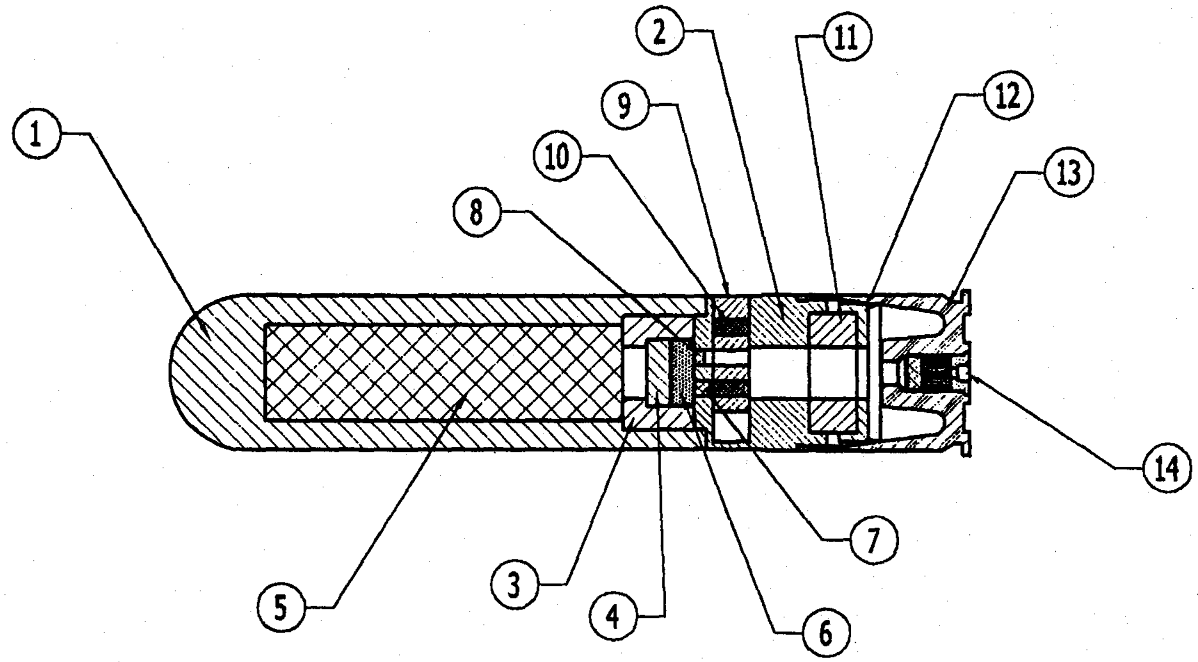
2

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

B



B

NOTES:

1. THIS DRAWING NOT COMPLETE WITHOUT SHEET 2 OF 2.

A

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED)
DECIMAL .XXX= ±.010
.XX= ±.02
FRACTIONS ± 1/16
ANGLES ± 2°

APPROVED	DATE
ENGINEERING	
SAFETY	
DRAWN BY D.L.	08-08-01

CHECKED BY | DATE

MATERIAL

PROJECT

LAW ENFORCEMENT TECHNOLOGIES, INC.

TITLE

TWO DELAY CONCEPT

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	1 OF 2			

A

2 1

NOTES:
1. MAGNESIUM, 325 MESH WITH TS720 CABOSIL (SILICONE TREATED)
2. THIS DRAWING NOT COMPLETE WITHOUT SHEET 1 OF 2.

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

ITEM NO.	QTY. REQD.	DWG. SIZE	PART NO.	DESCRIPTION
14	1			38 CARTRIDGE ASSEMBLY
13	1			M212 CARTRIDGE
12	1	A		SEAL
11	1	A		SHOCK ABSORBER
10	2	A		RUBBER PLUG
9	1	A		DELAY SELECTION SLIDER
8	1			SHORT DELAY, Zr/Ni DELAY COMP
7	1			LONG DELAY, Zr/Ni DELAY COMP
6	1			EXPELLING CHARGE, BLACK POWDER, 3 GRAMS
5	1		SEE NOTE 1	ENERGETIC MATERIAL, 20 GRAMS
4	1	A		CHARGE SEAL
3	1	A		CHARGE BODY
2	1	A		DELAY BODY
1	1	A		CHAMBER SHELL

TOLERANCES ON DIMENSIONS
(UNLESS OTHERWISE NOTED)
DECIMAL .XXX= ±.010
.XX= ±.02
FRACTIONS ± 1/16
ANGLES ± 2°

APPROVED	DATE
ENGINEERING	
SAFETY	

CHECKED BY | DATE

DRAWN BY D.L. | 08-08-01

MATERIAL

PROJECT

LAW ENFORCEMENT TECHNOLOGIES, INC.

TITLE

TWO DELAY CONCEPT

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	2 OF 2			

2

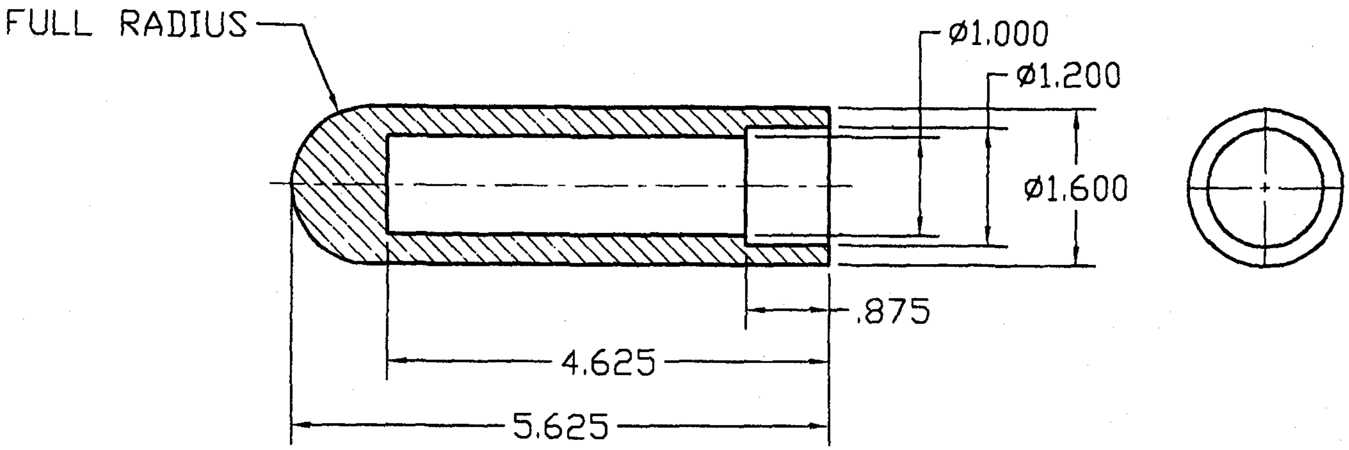
DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

NOTES:
1. MATERIAL: LAST-A-FOAM FR-6714.

B



B

A

TOLERANCES ON DIMENSIONS
(UNLESS OTHERWISE NOTED)
DECIMAL .XXX= ±.010
.XX= ±.02
FRACTIONS ± 1/16
ANGLES ± 2°

APPROVED	DATE
ENGINEERING	
SAFETY	
DRAWN BY D.L.	08-08-01

CHECKED BY	DATE

MATERIAL

PROJECT

LAW ENFORCEMENT
TECHNOLOGIES, INC.

TITLE

CHAMBER SHELL

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	1 OF 1		TDC-1	

A

2 1

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

NOTES:
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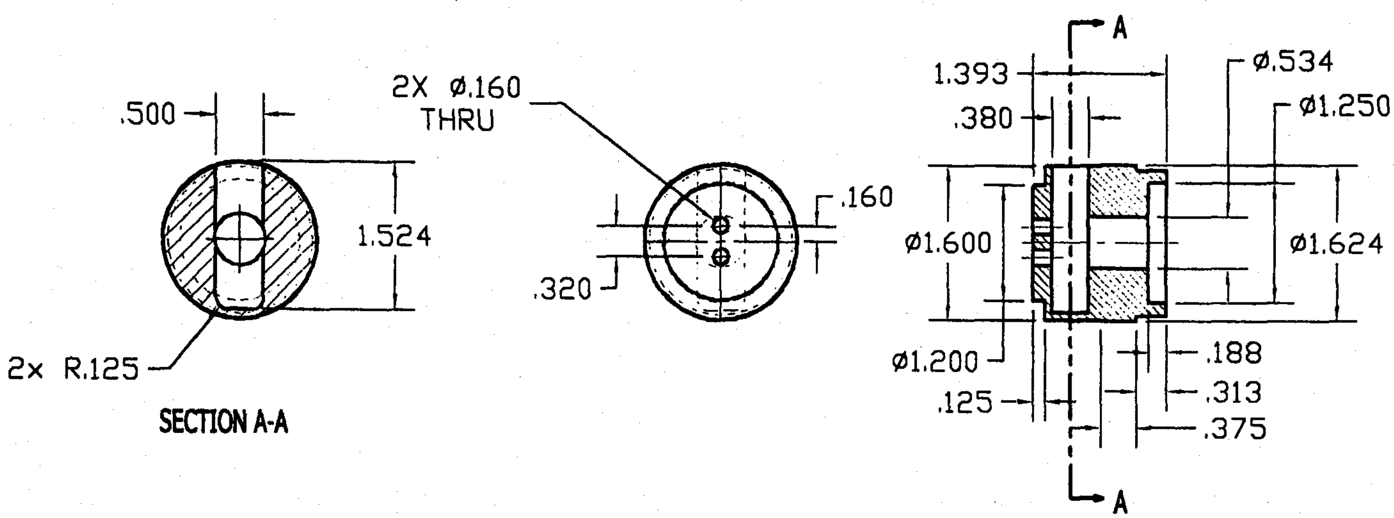


TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE
	ENGINEERING	
	SAFETY	
CHECKED BY / DATE	DRAWN BY D.L.	08-08-01
MATERIAL SEE NOTE 1	PROJECT	

LAW ENFORCEMENT TECHNOLOGIES, INC.

TITLE
DELAY BODY

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	1 OF 1		TDC-2	

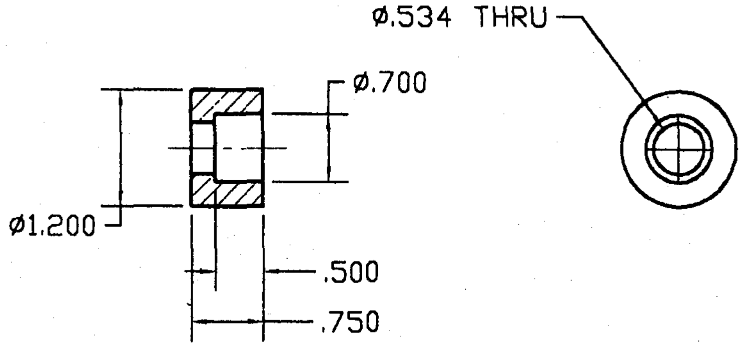
DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

NOTES:

1. MATERIAL: LAST-A-FOAM FR-6714.



TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE	LAW ENFORCEMENT TECHNOLOGIES, INC.
	ENGINEERING		
	SAFETY		TITLE *CHARGE BODY*
CHECKED BY / DATE	DRAWN BY D.L.	08-08-01	
MATERIAL SEE NOTE 1	PROJECT		

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/2	1 OF 1		TDC-3	

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

NOTES:
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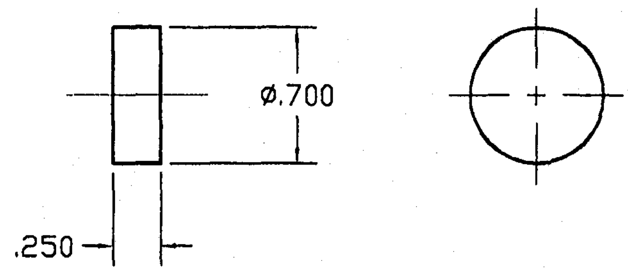

TOLERANCES ON DIMENSIONS
(UNLESS OTHERWISE NOTED)
DECIMAL .XXX= ±.010
.XX= ±.02
FRACTIONS ± 1/16
ANGLES ± 2°

APPROVED	DATE
ENGINEERING	
SAFETY	
DRAWN BY D.L.	08-08-01

CHECKED BY	DATE

MATERIAL: SEE NOTE 1

PROJECT:

LAW ENFORCEMENT TECHNOLOGIES, INC.

TITLE: *CHARGE SEAL*

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/1	1 OF 1		TDC-4	

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED

NOTES:

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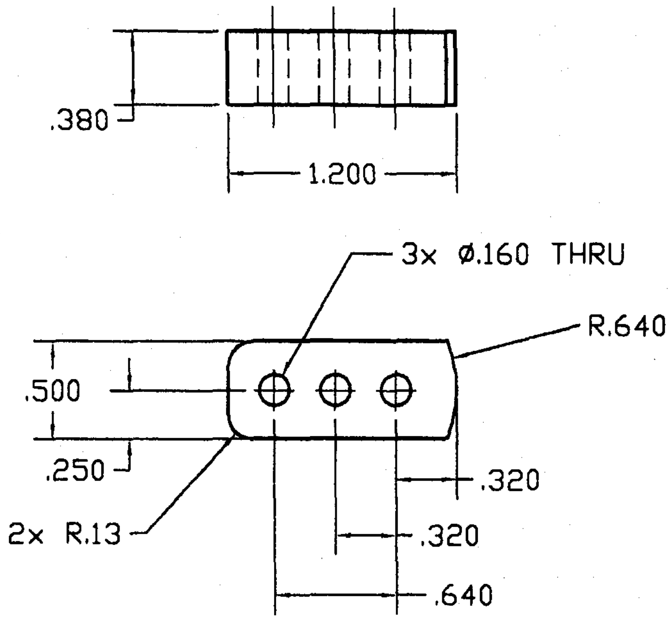


TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE
	ENGINEERING	
	SAFETY	
CHECKED BY / DATE	DRAWN BY D.L.	08-08-01
MATERIAL: SEE NOTE 1	PROJECT	

LAW ENFORCEMENT TECHNOLOGIES, INC.

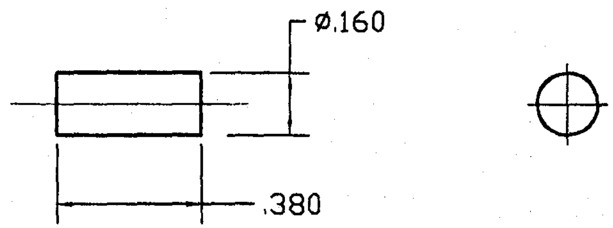
TITLE: ***DELAY SELECTION SLIDER***

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/1	1 OF 1		TDC-9	

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



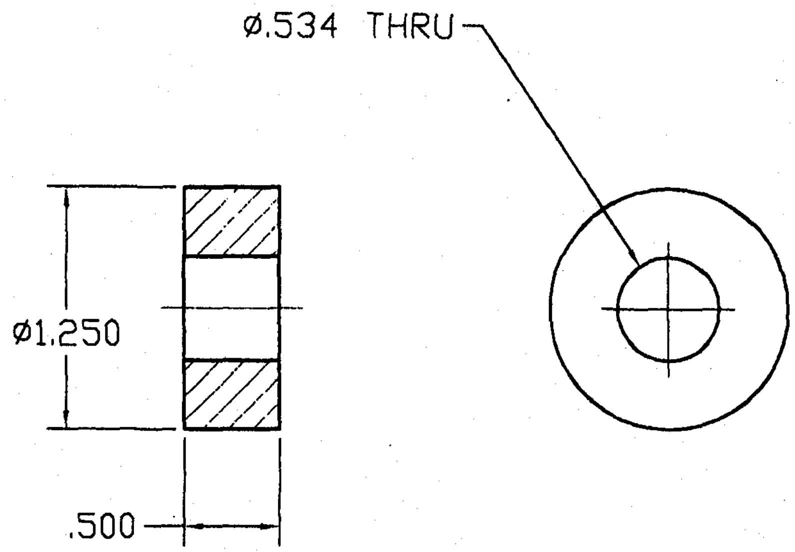
TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE	LAW ENFORCEMENT TECHNOLOGIES, INC.
	ENGINEERING		
	SAFETY		TITLE
CHECKED BY / DATE	DRAWN BY D.L.	08-08-01	RUBBER PLUG
MATERIAL RUBBER	PROJECT		

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	2/1	1 OF 1		TDC-10	

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



LAW ENFORCEMENT TECHNOLOGIES, INC.

TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE
	ENGINEERING	
	SAFETY	
CHECKED BY / DATE	DRAWN BY D.L.	08-08-01
MATERIAL RUBBER	PROJECT	

TITLE

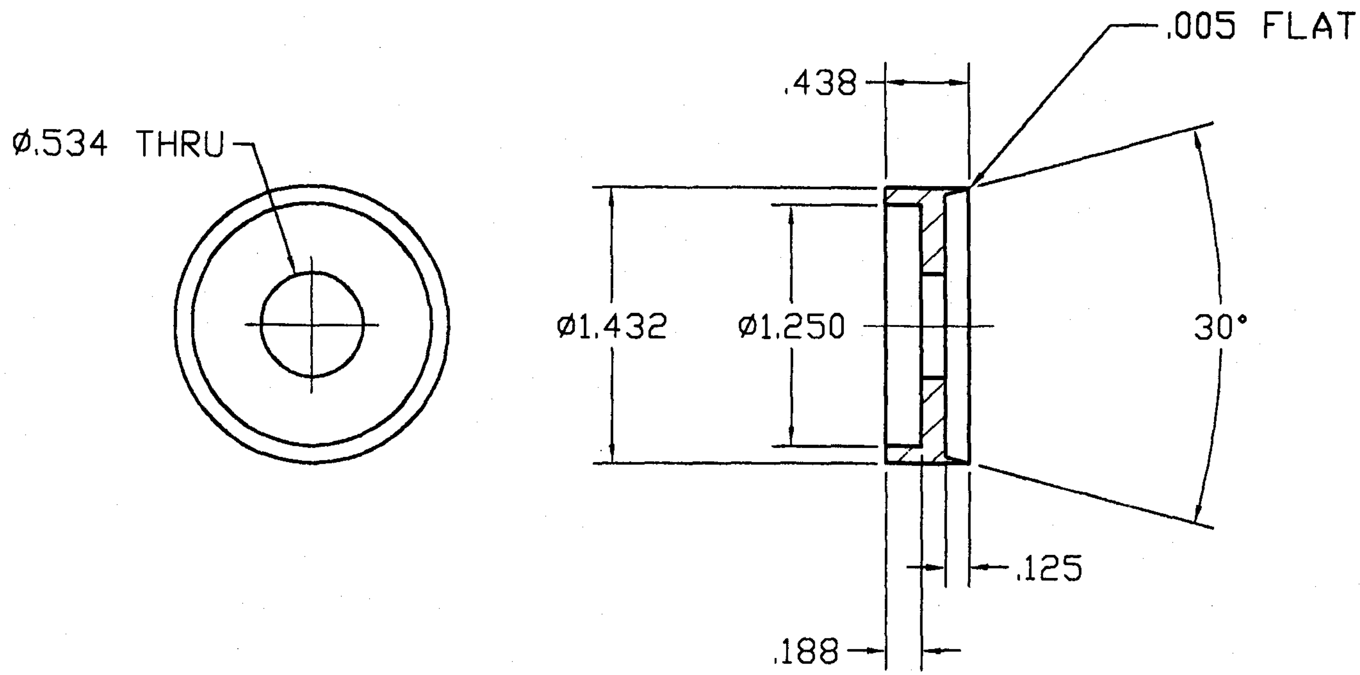
SHOCK ABSORBER

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/1	1 OF 1		TDC-11	

DWG. NO.	SH	REV.

REVISIONS

REV	DESCRIPTION	DATE	APPROVED



TOLERANCES ON DIMENSIONS (UNLESS OTHERWISE NOTED) DECIMAL .XXX= ±.010 .XX= ±.02 FRACTIONS ± 1/16 ANGLES ± 2°	APPROVED	DATE
	ENGINEERING	
	SAFETY	
CHECKED BY / DATE	DRAWN BY D.L.	08-08-01
MATERIAL POLY-ETHYLENE	PROJECT	

LAW ENFORCEMENT TECHNOLOGIES, INC.

TITLE

SEAL

SIZE	SCALE	SHEET	CAGE CODE	DRAWING NO.	REV
A	1/1	1 OF 1		TDC-12	

Next-Generation Diversionary Devices

Mark C. Grubelich and Brian Melof
mcgrube@sandia.gov

Sandia National Laboratories
P .0. Box 5800
Albuquerque, NM 87185-1454

INTRODUCTION

Diversionary devices are used in a wide variety of military and law-enforcement operations. They function to distract and/or incapacitate adversaries in scenarios ranging from hostage rescue to covert strategic paralysis operations. There are a number of disadvantages associated with currently available diversionary devices. Personnel safety is of paramount importance as serious injuries and fatalities have resulted from their use both operationally and in training.

Desired improvements to these devices include protection against inadvertent initiation, lower smoke production, the elimination of the possible production of high-velocity fragments, increased light output, and reduced near-field overpressure (ie. blast). We have been developing a next-generation diversionary flash-bang device that would provide increased safety, lower smoke production, no secondary high-velocity fragments, higher light output, and the potential for customized output.

BACKGROUND

In the United States, the first diversionary devices used were M116A1 hand-grenade simulators. The M116A1 used a pull-wire fuze lighter and a length of time-delay blasting fuze that provided a delay of 15 to 30 seconds. This device contained 35 grams of a photoflash mix.

The FBI Hostage Rescue Team modified the M116A1. An M201 fuze assembly, used in smoke grenades, was employed to provide a shorter (two-to-four-second) delay. This was accomplished by removing the pull-wire fuze lighter and time-delay fuze. The M201 fuze was installed in the cardboard body of the M116A1 and a potting compound was used to seal the assembly. Problems associated with these devices included occasional flash-through in the fuze assembly (leading to "instantaneous" functioning), fuze function failures, the ejection of the fuze at potentially lethal velocities (ranging from 80 fps to 180 fps), fires as a result of smoldering cardboard body fragments, and excessive smoke production.

As a result of the US military's requirement for an improved operational device, Sandia National Laboratories were asked to design a device addressing these problems. The new device designed was the Mk141 mod 0 contains 17.5 grams of flash powder composed of flake aluminum and potassium perchlorate. Less smoke is produced due to the decreased charge mass and better combustion efficiency. The design had a molded plastic fuze assembly, which eliminated flash-through problems. It was ejected at a low velocity (-20 fps) prior to the ignition of the flash powder. This was accomplished by igniting a small pyrotechnic charge, which separated the fuze assembly from the Mk141's main body. A short delay column, integral to the main body, subsequently ignited the flash-powder charge, which functioned within approximately one foot of where it was thrown. The body was made of fire-retardant urethane foam to eliminate any high-velocity high-density fragments and to reduce the probability of secondary fires. The body was colored black for covert operations.

PERFORMANCE OF THE Mk141

The Mk141 produces an internal pressure of about 27 kpsi with a rapid rise to the peak pressure. This produces a 185 dB pressure pulse (short duration) at 5 feet. This overpressure, combined with intense light output *(which has* never been characterized), temporarily distracts adversaries. Unfortunately, the contact and very near-field effects of the Mk141 are of sufficient magnitude to cause permanent injuries and/or fatalities due to the overpressure. The degree of injury depends on peak pressure and duration of the overpressure wave. This information is well documented (G. Bowen, E. R. Fletcher, D. R. Richmond, *Estimate of Man's Tolerance to the Direct Effects of Air Blast*, Defense Atomic Support Agency Report DASA 2113, Lovelace Foundation for Medical Education and Research, Albuquerque, NM, October 1968.). Survival threshold lung-damage and ear-damage curves have been compiled for a number of conditions. The near-field overpressure produced by conventional diversionary devices employing flash powder is the result of the rapid "explosive" reaction of the energetic material contained in the device.

Additional safety concerns also exist. The Mk 141 utilizes a flash powder mixture of potassium perchlorate and aluminum, which is a class 1.1 explosive. This material is sensitive to shock, thermal, electrostatic, and mechanical ignition stimuli. These devices are also susceptible to sympathetic initiation and initiation by bullet impact. Furthermore, the Mk141 device must be handled as a destructive device during storage and shipping and is essentially a *small* bomb.

NEXT-GENERATION FLASH-BANG DIVERSIONARY DEVICE

General Description

Based on recent research, coupled with the desire for an improvement in safety, a safer and more versatile diversionary device was developed using the rapid combustion of a fuel delivered by the device with the oxygen present in the ambient air. This next generation device ejects a powdered fuel that mixes with ambient air and then auto-ignites. This process is similar to the ignition of propellant gases in guns resulting in a "muzzle flash" or grain elevator explosion. The operation of this device produces a fuel-air combustion reaction. Since the combustion process is more spatially and temporally diffuse than that of a conventional explosive, a longer pressure pulse (lOO's of milliseconds) with a slower rise to the peak pressure results. This produces a near-field peak overpressure that is several orders of magnitude lower (IO's of psi) than that of the Mk 141. The desired far-field effects of acoustic and visual alarm are preserved (nominally 175 to 180 dB at 100 times the duration.) with the ability to generate a more intense, longer duration flash, as well as delivering more total impulse (energy) to the adversary.

Initial preliminary testing with 20 grams of Obron 5413H flake aluminum resulted in a peak optical output of approximately 700 milliWatts per square centimeter at a distance of 12 feet. For purposes of comparison, this is one hundred times brighter than the sun, as viewed from the earth for approximately 60 milliseconds. The resultant fireball diameter was approximately two meters.

There are many advantages of this next-generation diversionary device. Due to the reduced near-field peak overpressure, the possibility of permanent damage to subjects exposed to the near-field pressure wave would be greatly reduced. The acceleration of any near-field objects produced by the overpressure would be less, making serious injury due to secondary high-velocity fragments much less likely.

The non-explosive nature of the powdered-metal fill would allow the devices to be stored and shipped with fewer (if any) restrictions. The fuel-air reaction will produce less smoke since the products of combustion would not contain potassium chloride. Therefore, continuous target acquisition is possible. The improved diversionary devices "yield" could be customized in the field. The acoustic and light output could be adjustable by increase or decrease of the fuel charge during each particular operational scenario.

Metal Powder Fuels

For the next-generation diversionary device both aluminum (Obron 5413H dark flake) and magnesium (Reade RMC-325 –325 mesh granular) with colloidal silica (Cabot Chemical TS-720 Cabosil) used as an anti-caking/flow agent have been used as fuels. Fine aluminum particles have high reactivity in air and good combustion efficiency without being pyrophoric. This is accomplished commercially by passivating even sub-micron aluminum particles to produce a thin inert aluminum-oxide layer while still allowing the underlying aluminum to remain active. Commercial -325 mesh flake magnesium has been used with great success providing a brighter flash. Blends of aluminum and magnesium may be used to tailor the output of the device.

PRELIMINARY DESIGN

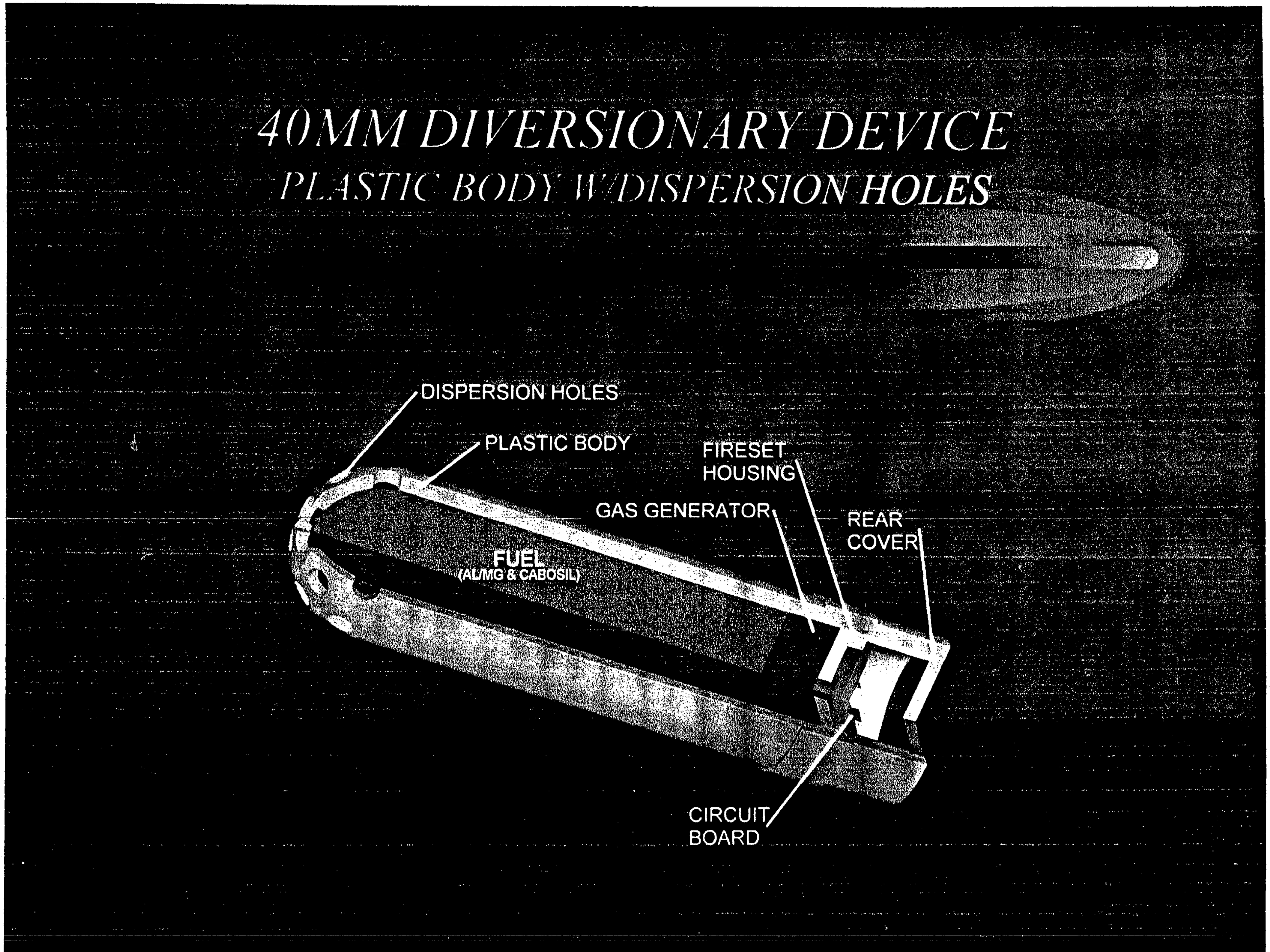
Building on the existing prototype hand thrown fuel-air diversionary device, three preliminary designs have been conceived. All three designs share the same basic outside geometry. The munition is 152 mm long and 40 mm in diameter, with an internal cavity for the fuel approximately 27 mm in diameter and 100 mm long. Approximately 20 – 60 grams of aluminum or 20 – 40 grams of magnesium or a blend of the two will be ejected from the device in order to produce a brilliant flash and the desired acoustic output. The first design is a semi-rigid plastic body with radial discharge holes in the nose of the projectile. At the desired range, a pyrotechnic gas generator is ignited in the base of the projectile which pressurizes the projectile body and then ejects and ignites a cloud of fuel. The plastic body's forward velocity will be retarded by the ejection of the fuel and may be allowed to impact the adversary for additional diversionary effect.

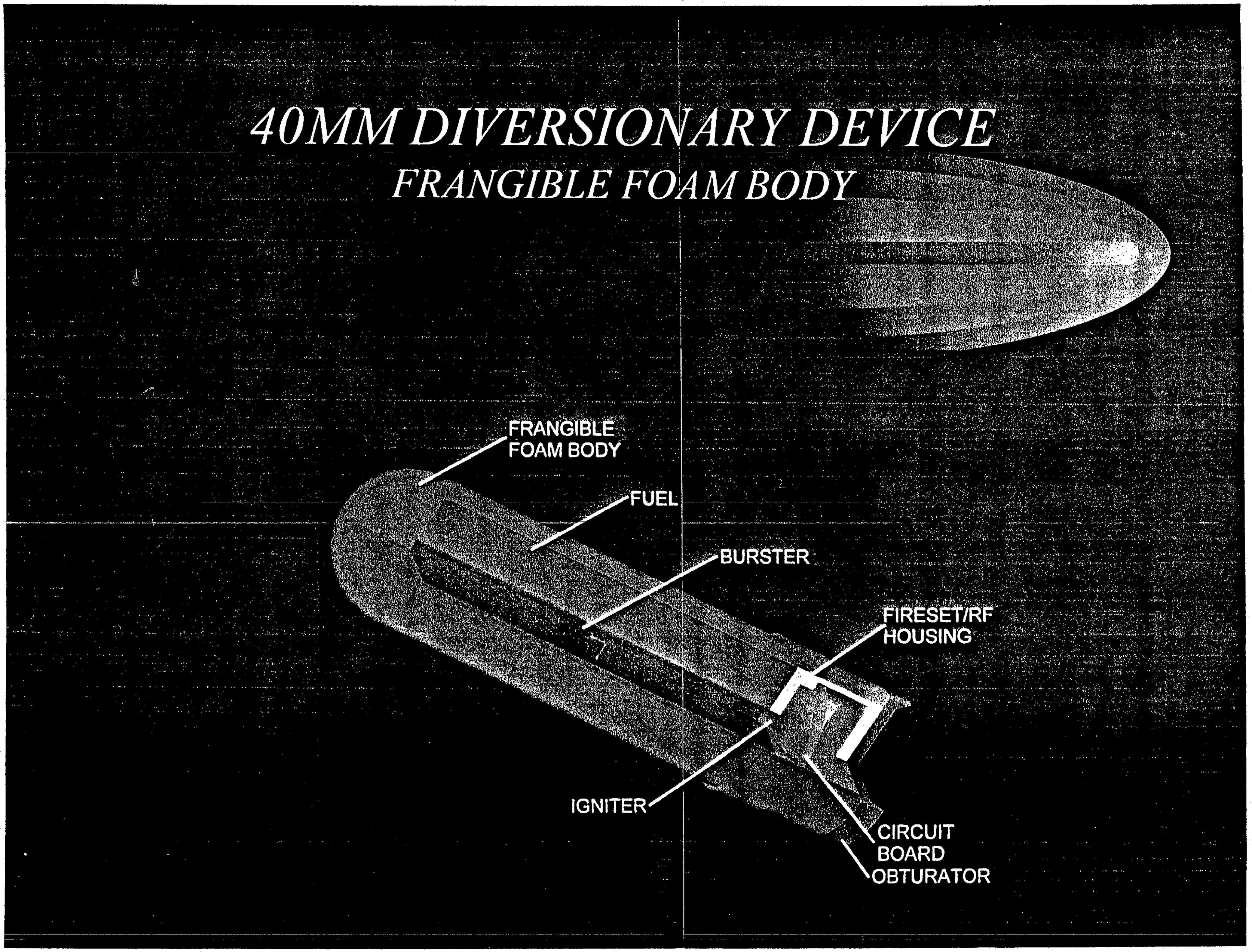
The second design employs a fully frangible foam body with a central pyrotechnic gas generator/burster. At the desired range, the pyrotechnic gas generator is ignited which pressurizes the projectile body rubbleizing it, dispersing the fuel cloud, and subsequently igniting the fuel cloud. In this design the frangible foam body is reduced to harmless, low velocity pieces.

The third design employs a super-frangible foam nose and frangible foam body. At the desired range, a pyrotechnic gas generator is ignited in the base of the projectile which pressurizes the projectile body fragmenting the nose of the projectile and projecting the fuel cloud forward while simultaneously igniting the fuel cloud. The frangible foam projectile body's forward velocity will be retarded by the ejection of the fuel and pose little if any adversary impact risk, due to the extremely low ballistic coefficient and low velocity.

CONCLUSION

We have demonstrated proof-of-concept of a next-generation diversionary device. This new design has many advantages over existing diversionary devices, including less potential for serious injury and fatalities, increased safety from inadvertent initiation, fewer storage and transportation restrictions, lower smoke production, and field-adjustable output. Furthermore, since no explosive is employed in this 40 mm munition, the munition can be considered bore-safe. In other words, if conventional diversionary device technology was employed, ie. flash powder, premature functioning of the munition either in the bore, or upon muzzle exit, would pose a serious threat to the operator. Elimination of flash powder and replacement with fuel-air technology results in reduced operator risk and lower risk of unintended injury to the adversary.


40MM DIVERSIONARY DEVICE
PLASTIC BODY W/DISPERSION HOLES
DISPERSION HOLES
PLASTIC BODY
FIRESET
HOUSING
GAS GENERATOR
REAR
COVER
FUEL
(AL/MG & CABOSIL)
CIRCUIT
BOARD


40MM DIVERSIONARY DEVICE
FRANGIBLE FOAM BODY
FRANGIBLE FOAM BODY
FUEL
BURSTER
FIRESET/RF HOUSING
IGNITER
CIRCUIT BOARD
OBTURATOR