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U.S. Army Research, Development and Engineering Command
Benét Laboratories

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RAREFACTION WAVE GUN TANK MAIN ARMAMENT DEMONSTRATOR

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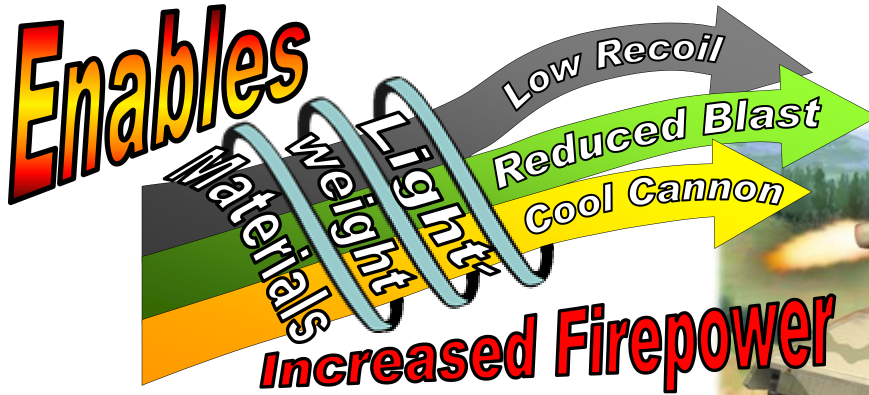
RAVEN RArefaction waVE guN



RAVEN is a hybrid propulsion that achieves:

The ballistic efficiency of orthodox guns.

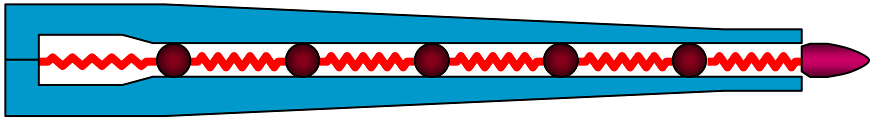
The recoil advantage of prior recoilless rifles.

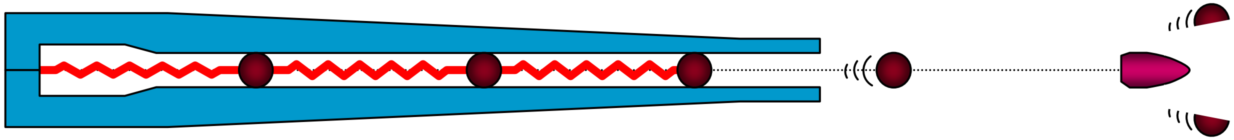
Unprecedented reductions in barrel heating.

Increased accuracy.

- For an orthodox gun, recoil is imparted by both the projectile and propellant.
  - Envision propellant as n “billiard balls” pressurized by massless springs. (This is a “Finite Volume” approximation.)
  - Each “billiard ball” has a mass, mci, equal to the total charge mass divided by n.
  - After shot exit, the propellant gases continue to expand and accelerate out of the cannon.

- For tank gun KE rounds, there is more recoil from the propellant gas than the bullet.

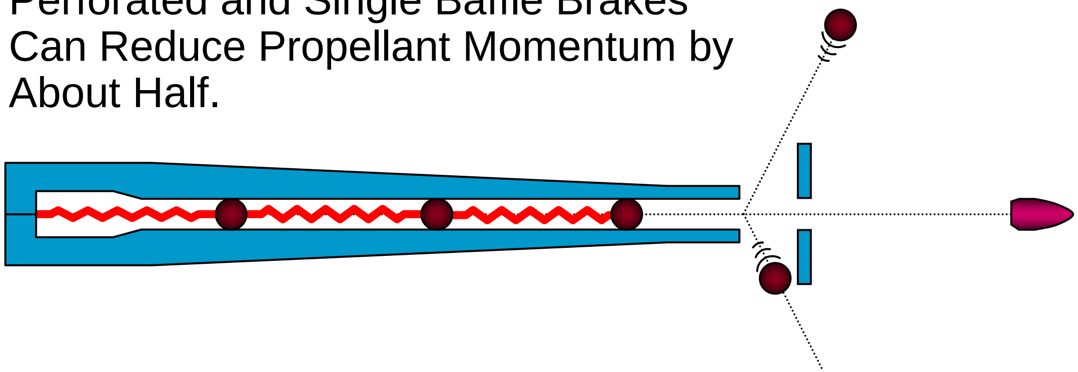




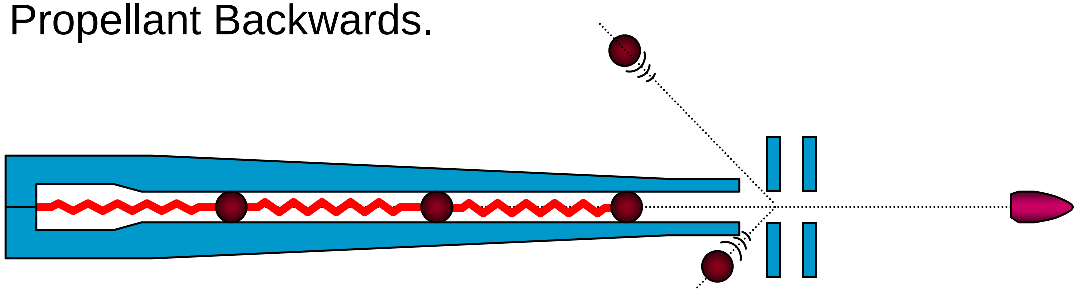
Recoil 101

- Muzzle brakes reduce momentum by redirecting muzzle blast sideways or aft.

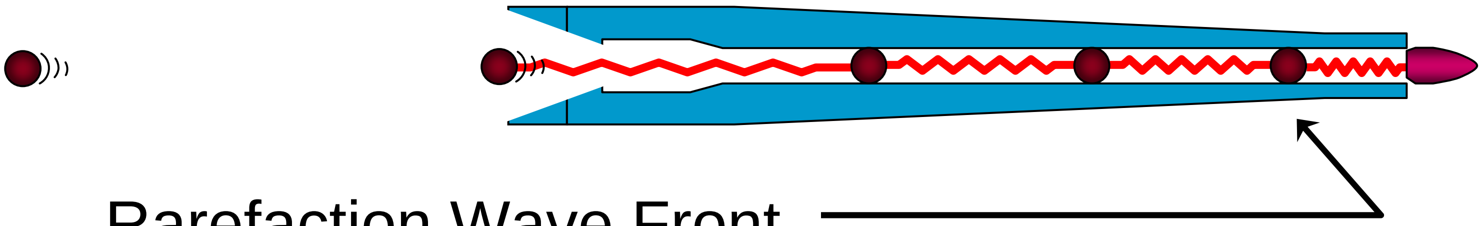
Perforated and Single Baffle Brakes Can Reduce Propellant Momentum by About Half.



Double Baffle Brakes Can Deflect Propellant Backwards.



- RAVEN sends propellant backwards before projectile exit.
  - A delay time occurs between “uncorking” the breech and the forward propagation of the pressure loss through the propellant gas column.



Rarefaction Wave Front

- Between the base of the projectile and here, the conditions are the same as for closed breech firing.
- Pressure, density, and temperature are reduced behind the wave front.

- Heat transfer to the bore of a gun is estimated as (AMCP 706-150 page 3-2):

$$q(x) = \int_0^{t_f} \frac{1}{2} \lambda(x) \left(\frac{\gamma R}{\gamma - 1} \right) \rho(x,t) v(x,t) \left(T_g(x,t) - T_w(x,t) \right) dt$$

- Using representative average values and considering the wall temperature to be small, net heat transfer is essentially proportional to:
  - gas density,
  - gas velocity,
  - gas temperature, and
  - duration of exposure.

$$q(x) \propto \overline{\rho}(x,t) \overline{v}(x,t) \overline{T_g}(x,t) \Delta t$$

- RAVEN Reduces:
  - gas density,
  - gas velocity,
  - gas temperature, and
  - blow-down duration.

- Gun barrel erosion commences in earnest only after reaching the Arrhenius threshold temperature of 1007K for gun steel.
  - Below this temperature, gun steel does not react with propellant gas
  - Above this temperature, gun steel "burns†."
  - RAVEN reduces or eliminates exposure duration above the Arrhenius threshold.

† Chemical reactions with propellant that release heat

- Following the successful trials in 35mm, a large caliber RAVEN was developed using design and hardware assets remaining from the 105mm Multi-Role Armament and Ammunition System (MRAAS) program.

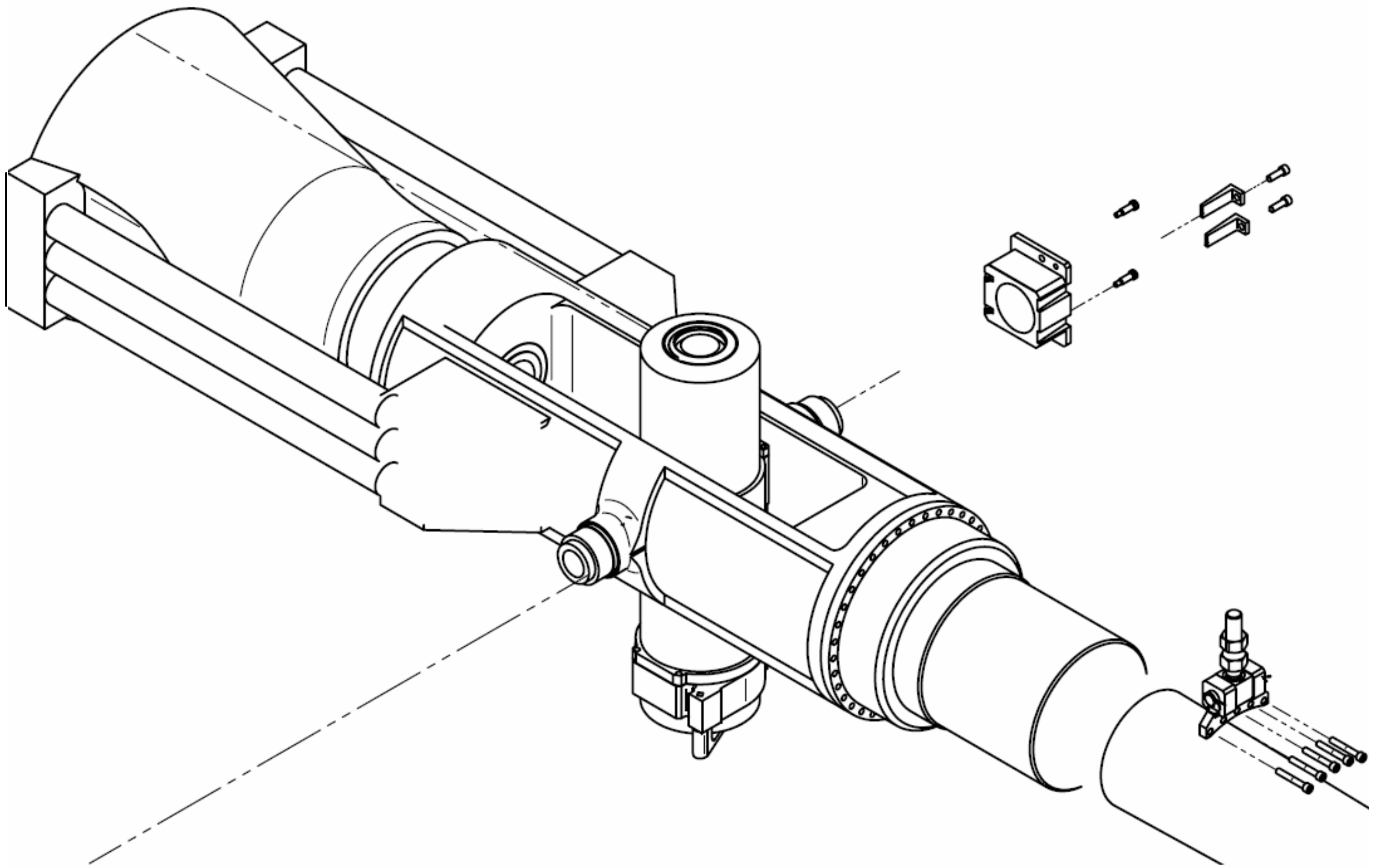
MRAAS incorporated a novel swing chamber.
It was engineered to provide 120mm tank gun lethality from a 105mm bore, and . . .
..to fire beyond line of sight (BLOS) and non line of sight (NLOS) missions.

LOS Demonstration

BLOS/NLOS Demonstration

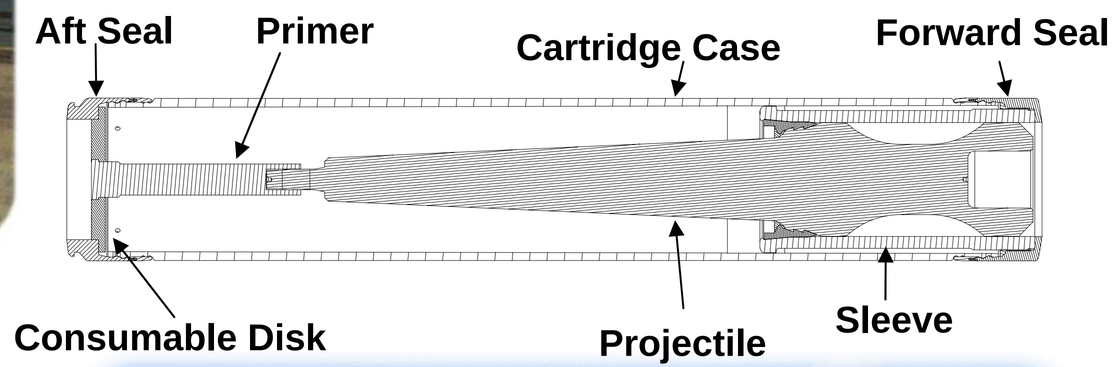
MRAAS Firing Video Showing Load and Fire

- MRAAS rotating chamber gun shown open with integrated blow-back nozzle/bolt.



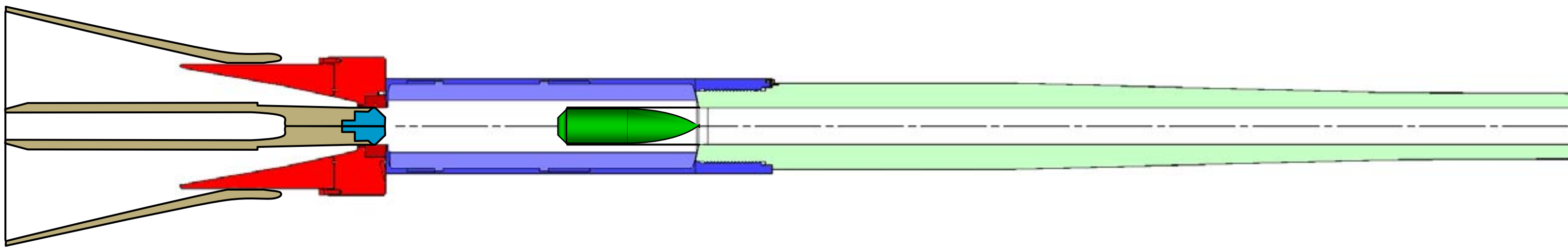
105mm System

- Employs a balanced blow-back bolt with integral expansion nozzle and hydro-pneumatic recoil cylinders.
- The recoilless barrel will substantially reduce muzzle whip, and, thus, increase accuracy.



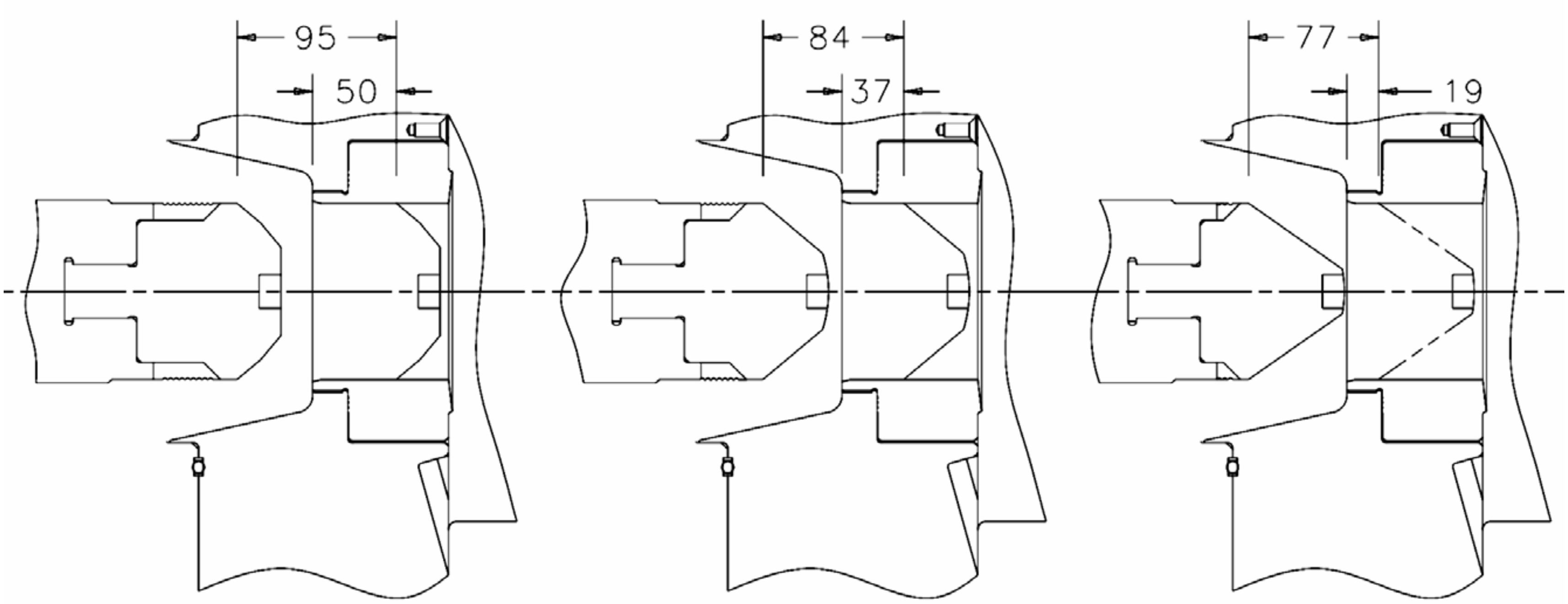
The swing chamber approach affords a straightforward munitions handling method to accommodate RAVEN's rearward facing expansion nozzle.

105mm Operating Principle



- Intentional rupture of cartridge case.
  - Compatible with modular artillery charge and modified cartridge case technology.
- Breech travel governed by same propellant pressure that drives the projectile.
- Recoil stroke to vent port and recoil mass determine vent time.
- Robust, reliable, and weaponizable . . .
  - Prior 35mm tests verified 1% standard deviation in occasion to occasion blow-back bolt vent timing.

Variation in Vent Timing



- Vent timing hastened by progressively increasing sharpness of bolt faces from blunt nosed to conical.
  - Recoil stroke to commence venting varies from 19mm to 50mm as shown above.
  - The upper displacement approximates recoil stroke to un-choked flow.

Shot 3 Experimental Results.

m_p	8.31	Kg
m_c	6.29	Kg
v_m	1.16	km/s
I_p	9.6	kN*s
I_T	12.4	kN*s

Test Data/Results

Shot number			1	2	3	4	5	6	17
Date			2/19	4/14	5/1	5/19	8/13	8/27	TBD
Test Set-up	Distance to Vent	mm	50	42	42	50	43	37	Closed
	Projectile Mass	Kg	8.31	8.31	8.31	8.31	8.31	8.31	8.31
	Charge Mass	Kg	4.97	5.65	6.29	6.78	6.75	7.05	6.98
	Chamber Volume	L	7.71	7.71	7.71	7.71	7.78	7.84	-
Predicted Results	Muzzle Velocity	km/s	1.12	1.26	1.40	1.50	1.49	1.55	1.57
	Max Pressure	MPa	217	306	454	563	551	643	669
	Momentum	kN*s	9.6	10.7	12.6	14.7	14.0	14.4	24.2
Experimental Results	Muzzle Velocity	km/s	-	-	1.16	1.34	1.37	1.38	-
	Max Pressure	MPa	167	225	-	389	-	447	-
	Momentum	kN*s	-	-	12.4	12.9	12.7	-	-

- **Reduce Recoil Severity Imposed on Combat Vehicles.**
  - **Facilitates large-gun / small-vehicle integration.**
  - **Eases burdens of fire on the move integration.**
- **Increased Thermal Performance.**
  - **Enables use of hotter propellants to achieve higher velocities.**
  - **Nearly doubles sustained firing rate.**
  - **Nearly doubles number of burst fire rounds.**
- **Enables lightweight cannon.**
  - **Recoil energy is inversely proportional to recoil mass.**
  - **Burst fire thermal capacity is proportional to thermal mass.**
  - **Facilitates large-gun / small-vehicle integration.**
- **Reduces and redirects blast.**
  - **Will enable "hatches open" operation while meeting requirements of MIL-STD 1474D.**

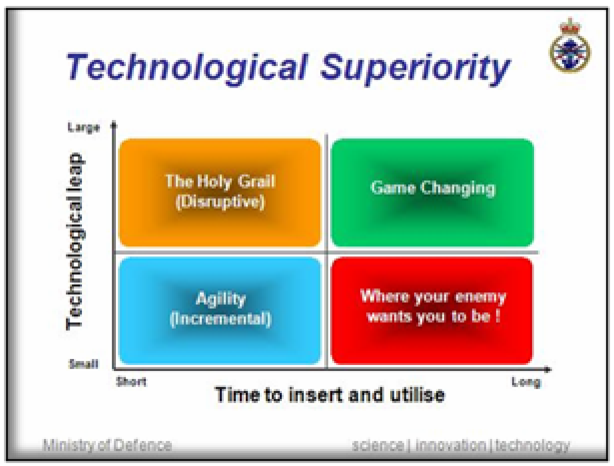
XM360 LOS/BLOS

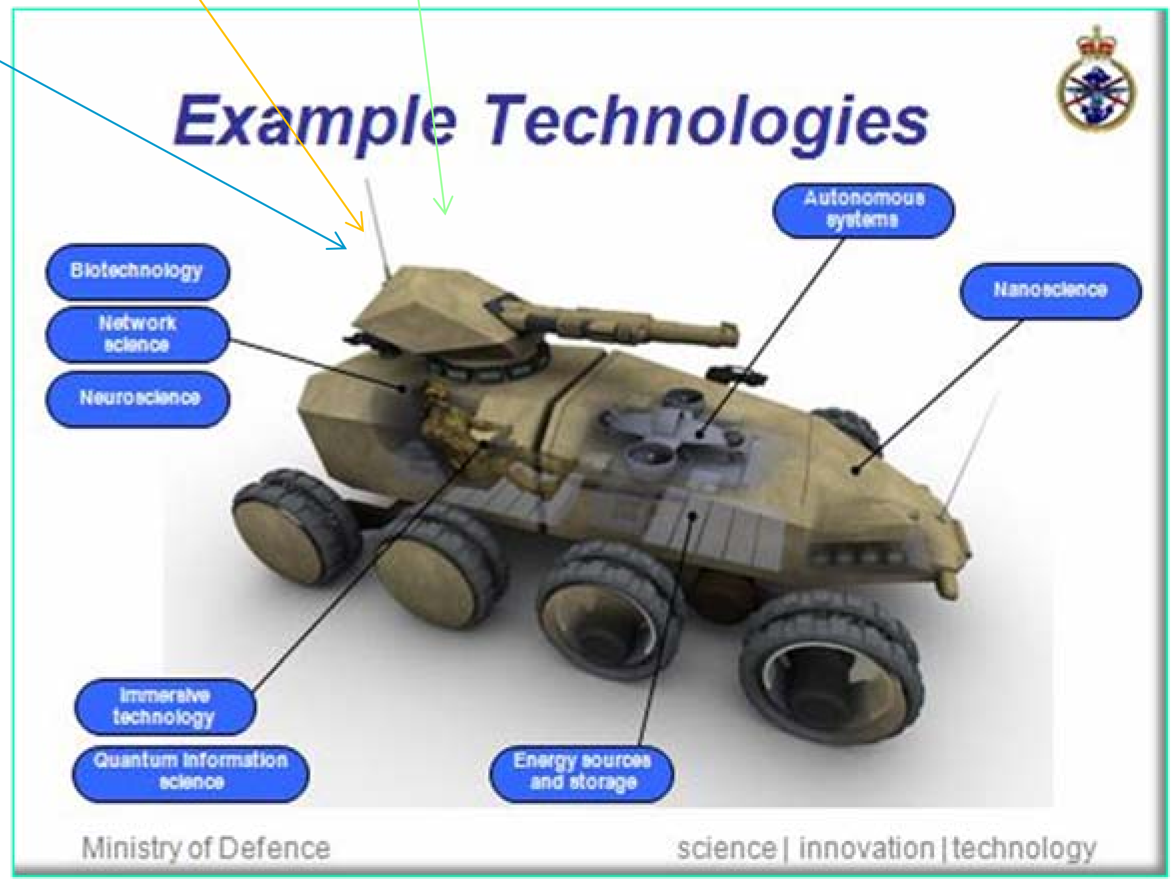
XM324 NLOS-C

XM325 NLOS-M

RAVEN

RAILGUN





Concept Vehicle courtesty of:
Professor Phil Sutton, Director General Science &Technology Strategy, UK MOD

Conclusions

- A truly large caliber rarefaction wave gun has been designed, fabricated, and is currently undergoing test and validation.
  - Results from this brassboard demonstrator support the fundamental precept of RAVEN that venting a large caliber gun during the ballistic cycle does not slow the bullet.
- RAVEN has been successfully integrated with a novel swing-chamber munitions handling interface.
  - This interface affords straightforward combat system integration of this armament technology.