RAREFACTION WAVE GUN
TANK MAIN ARMAMENT DEMONSTRATOR

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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.
• 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.

\[
q(x) \propto \bar{\rho}(x, t) \bar{v}(x, t) \bar{T}_g(x, t) \Delta t
\]
• 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.
MRAAS Firing Video Showing Load and Fire
• MRAAS rotating chamber gun shown open with integrated blow-back nozzle/bolt.
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.
• 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.
• 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.

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<tbody>
<tr>
<td>$m_p$</td>
<td>8.31</td>
<td>Kg</td>
</tr>
<tr>
<td>$m_c$</td>
<td>6.29</td>
<td>Kg</td>
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<td>$v_m$</td>
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<td>km/s</td>
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<tr>
<td>$I_p$</td>
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<td>kN*s</td>
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<tr>
<td>$I_T$</td>
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<td>kN*s</td>
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## Test Data/Results

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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>17</th>
<th>Date</th>
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<tbody>
<tr>
<td></td>
<td>2/19</td>
<td>4/14</td>
<td>5/1</td>
<td>5/19</td>
<td>8/13</td>
<td>8/27</td>
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### Test Set-up

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<tr>
<td>Distance to Vent</td>
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<td>42</td>
<td>42</td>
<td>50</td>
<td>43</td>
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<td>Projectile Mass</td>
<td>Kg</td>
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<td>Charge Mass</td>
<td>Kg</td>
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<td>Chamber Volume</td>
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### Predicted Results

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<tbody>
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<td>Max Pressure</td>
<td>MPa</td>
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### Experimental Results

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<tbody>
<tr>
<td>Muzzle Velocity</td>
<td>km/s</td>
<td>-</td>
<td>-</td>
<td>1.16</td>
<td>1.34</td>
<td>1.37</td>
<td>1.38</td>
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<tr>
<td>Max Pressure</td>
<td>MPa</td>
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<td>225</td>
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<td>389</td>
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<td>447</td>
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<tr>
<td>Momentum</td>
<td>kN*s</td>
<td>-</td>
<td>-</td>
<td>12.4</td>
<td>12.9</td>
<td>12.7</td>
<td>-</td>
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Impact on Soldier of the Future

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