TOMRA

Ore Sorting
What is ore sorting?

**Ore sorting** is the separation of a target mineralogy, ore or element from waste at an individual particle level.

The ore is sorted to **remove waste** and **improve the efficiency and capacity** of processing plant while increasing the grade.

**Ore sorting is**....

✓ Accurate > high recovery
✓ Fast > upto 5,000 particle per sec = high tonnage
✓ Mature and proven technology
✓ Removes the variability in the plant feed
THE TOMRA GROUP

- Publicly listed on Oslo Stock Exchange (OSEBX:TOM)
- 2,500 employees globally
- Revenues of 800 million $AUD equivalent (2014)
Tomra History

2004
TOMRA acquires TITECH, the world’s leading provider of optical recognition and sorting technology for the waste industry and TOMRA’s transformation journey starts.

2005
TOMRA acquires Orwak Group, a leading provider of compaction solutions for a variety of materials.

2006
TOMRA acquires Commodas—a leading supplier within the field of sensor-based products for mining and metal recycling.

2008
TOMRA acquires Ultrasort—specialists in sensor-based mining technology.

2011
TOMRA acquires Odenberg, rounding out the offering to include food optimization.

2012
TOMRA acquires BEST, leading food sorting machine producer. With the acquisition of BEST TOMRA has by far the widest reach within the food sorting universe.

2012
Through its transformation journey TOMRA has moved from a business of many brands to one brand with many areas of expertise. We are one TOMRA.

FROM: TOMRA
A house of brands

TO: TOMRA
A branded house
Our SORTING Solutions Are Used In Numerous Applications Across Multiple Industries

Recycling
Applicable for:
- E-scrap · CRT Glass · Wood
- Single Stream · Paper
- Packaging · Wire · C&D waste · Car shredder
- Plastics · Organic · MSW · Metals · RDF monitoring

Mining
Applicable for:
- Precious metals · Base metals · Diamonds
- Coal · Ferrous metals
- Copper · Platinum · Slag
- Industrial minerals · Gold Tailings · Gemstones

Food
Applicable for:
- Dried fruit · Fresh cut · Fruit · Nuts · Seeds
- Processed potato · Whole potatoes · Seafood
- Meat/Process Analytics
- Vegetables · Whole products · Peeling solutions
Tomra Australia

- Strong mining heritage and understanding of the demands of mining and ore processing
- Australian operation is the core research and development for mining
- Total of 18 dedicated staff
- Experienced engineers, field service and research team
- 3,600m² modern facility
- Research and development laboratory areas for...
  - Electronics
  - Software development
  - Laser and Optics
  - Rock testing
  - X-Ray and sensor development

- Full scale sorters for bulk test work
Tomra Australia – Electronics Lab
Tomra Australia – Rock Testing Lab
Tomra Australia – Laser & Optics Lab
What we don’t do...

Coal sorting circa 1911

Coal sorting in Vietnam 2015
Sorting Creates Value in Mining!

1. Increase your deposit exploitation and life-of-mine
2. Decrease your mining costs
3. Reliable and efficient sorting
4. Decrease your haulage costs
5. Reclaim old waste dumps
6. Divert your ore types
7. Increase production
8. Reduce energy consumption
9. Reduce the amount of fine tailings
10. Reduce water consumption
11. Sell a coarse product

- Reduce or remove pebbles (scats) from the milling circuit
- Reduce the size of the TSF significantly
Benefits of Ore Sorting

✓ Normally **10% - 90%** of the mass can be rejected in an early stage of the process at the primary, secondary or tertiary crushing stage

✓ Low grade waste rocks don’t need to be transported, crushed, milled or further treated
Liberation...the $64million question?
Liberation...*the $64million question* ?

Comminution
# Getting Everything Sorted

<table>
<thead>
<tr>
<th><strong>Industrial Minerals</strong></th>
<th><strong>Gems</strong></th>
<th><strong>Ferrous Metals</strong></th>
<th><strong>Non Ferrous Metals</strong></th>
<th><strong>Fuel</strong></th>
<th><strong>Slag</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>COLOR, XRT, NIR</td>
<td>COLOR, XRT, XRL, NIR</td>
<td>XRT, EM, NIR</td>
<td>COLOR, XRT, NIR</td>
<td>XRT, RM</td>
<td>XRT, EM</td>
</tr>
<tr>
<td>Limestone</td>
<td>Diamonds</td>
<td>Iron</td>
<td>Copper</td>
<td>Coal</td>
<td>Stainless Steel Slag</td>
</tr>
<tr>
<td>Dolomite</td>
<td>Emeralds</td>
<td>Manganese</td>
<td>Zinc</td>
<td>Oil shale</td>
<td>Ferro Silica Slag</td>
</tr>
<tr>
<td>Quartz</td>
<td>Rubies</td>
<td>Chromite</td>
<td>Gold</td>
<td>Uranium</td>
<td>Ferro Chrome Slag</td>
</tr>
<tr>
<td>Rock salt</td>
<td>Saphires</td>
<td></td>
<td>Nickel</td>
<td></td>
<td>Non Ferrous Slag</td>
</tr>
<tr>
<td>Talc</td>
<td>Tanzanite</td>
<td></td>
<td>Tungsten</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcite</td>
<td></td>
<td></td>
<td>Silver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feldspar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Ferrous Metals**: Iron, Manganese, Chromite
- **Non Ferrous Metals**: Copper, Zinc, Gold, Nickel, Tungsten, Silver, Platinum Group Metals
- **Fuel**: Coal, Oil shale, Uranium
- **Slag**: Stainless Steel Slag, Ferro Silica Slag, Non Ferrous Slag
TOMRA Sorters
COM - Belt Sorter

1. Feeding of unsorted material
2. X-ray source
3. X-ray camera
4. Separation chamber
PRO - Chute Sorter
Sensing Systems
## Sensing Systems

<table>
<thead>
<tr>
<th>Sensor/Technology</th>
<th>Material Property</th>
<th>Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RM (Radiometric)</strong></td>
<td>Natural Gamma Radiation</td>
<td>Fuel, Precious Metals</td>
</tr>
<tr>
<td><strong>XRT (X-ray transmission)</strong></td>
<td>Atomic Density</td>
<td>Base Metals, Precious Metals, Industrial Minerals, Fuel, Diamonds</td>
</tr>
<tr>
<td><strong>XRF/XRL</strong></td>
<td>Visible and X-Ray Fluorescence</td>
<td>Diamonds, Base Metals</td>
</tr>
<tr>
<td><strong>COLOR (CCD Color Camera)</strong></td>
<td>Reflection, Absorption, Transmission</td>
<td>Base Metals, Precious Metals, Industrial Minerals, Diamonds</td>
</tr>
<tr>
<td><strong>PM (Photometric)</strong></td>
<td>Monochromatic Reflection/Absorption</td>
<td>Base Metals, Industrial Minerals</td>
</tr>
<tr>
<td><strong>NIR (Near Infrared Spectrometry)</strong></td>
<td>Reflection, Absorption</td>
<td>Base Metals, Industrial Minerals</td>
</tr>
<tr>
<td><strong>IR (Infrared cam)</strong></td>
<td>Heat conductivity, heat dissipation</td>
<td>Base Metals, Industrial Minerals</td>
</tr>
<tr>
<td><strong>EM (Electro-Magnetic sensor)</strong></td>
<td>Conductive Magnetic</td>
<td>Base Metals</td>
</tr>
</tbody>
</table>
Colour Sensing

PRO Secondary COLOR Sorter

True Color Image

Classified Image

Particle feature table

<table>
<thead>
<tr>
<th>Obj No.</th>
<th>Material</th>
<th>Flache</th>
<th>black [%]</th>
<th>satellite [%]</th>
<th>bright [%]</th>
<th>mV [%]</th>
<th>mY [%]</th>
<th>Fleat [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Satellite</td>
<td>3447</td>
<td>0.00</td>
<td>60.88</td>
<td>13.72</td>
<td>0.12</td>
<td>0.25</td>
<td>4.99</td>
</tr>
<tr>
<td>8</td>
<td>Satellite</td>
<td>4613</td>
<td>0.00</td>
<td>63.00</td>
<td>13.46</td>
<td>0.04</td>
<td>1.11</td>
<td>2.30</td>
</tr>
<tr>
<td>7</td>
<td>Satellite</td>
<td>4304</td>
<td>0.14</td>
<td>79.61</td>
<td>9.06</td>
<td>0.11</td>
<td>2.62</td>
<td>0.46</td>
</tr>
<tr>
<td>6</td>
<td>Satellite</td>
<td>17351</td>
<td>0.22</td>
<td>86.58</td>
<td>7.06</td>
<td>0.01</td>
<td>2.75</td>
<td>3.37</td>
</tr>
<tr>
<td>5</td>
<td>Satellite</td>
<td>8063</td>
<td>0.02</td>
<td>78.15</td>
<td>11.15</td>
<td>0.07</td>
<td>8.31</td>
<td>2.29</td>
</tr>
<tr>
<td>4</td>
<td>Satellite</td>
<td>9113</td>
<td>0.01</td>
<td>51.10</td>
<td>5.96</td>
<td>0.00</td>
<td>1.06</td>
<td>1.87</td>
</tr>
<tr>
<td>3</td>
<td>Satellite</td>
<td>8338</td>
<td>4.74</td>
<td>60.09</td>
<td>12.60</td>
<td>1.48</td>
<td>6.39</td>
<td>14.70</td>
</tr>
<tr>
<td>2</td>
<td>Satellite</td>
<td>8072</td>
<td>0.01</td>
<td>82.92</td>
<td>11.57</td>
<td>0.14</td>
<td>3.73</td>
<td>1.64</td>
</tr>
</tbody>
</table>
EM - Electromagnetic Sensing

- The electromagnetic sensors each detect conductivity and magnetic permeability of a particle from 15–80 mm in diameter.
- Direct correlation between grade and conductivity or magnetic permeability

Massive Nickel Sulphide
X-Ray Sensors

COM XRT 1200 Sorter

Raw XRT Image

Classified Image

Particle feature table
XRT - Density

3.2 g/cm³
XRT - Tungsten Ore Application
NIR Sensing

PRO Secondary Colour / NIR Sorter

VIS spectroscopy       NIR spectroscopy

UV  VIS  NIR
Invisible    Visible colour    Invisible

Intensity vs. Wavelength

Quartz  Calcite  Talc
Sorting Applications
Nickel Ore Sorting

EM Sorting Results from Mine in Australia

<table>
<thead>
<tr>
<th></th>
<th>June</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore Sorter Feed (t)</td>
<td>10,835</td>
<td>11,084</td>
</tr>
<tr>
<td>Feed Grade (Ni%)</td>
<td>1.94</td>
<td>1.44</td>
</tr>
<tr>
<td>Accepts (t)</td>
<td>2,305</td>
<td>2,283</td>
</tr>
<tr>
<td>Accepts Grade (Ni%)</td>
<td>8.37</td>
<td>6.53</td>
</tr>
<tr>
<td>Rejects (t)</td>
<td>8,530</td>
<td>8,800</td>
</tr>
<tr>
<td>Rejects Grade (Ni%)</td>
<td>0.20</td>
<td>0.11</td>
</tr>
<tr>
<td>Ni Recovery (%)</td>
<td>91.9</td>
<td>93.7</td>
</tr>
</tbody>
</table>
# Uranium Ore Sorting

![ROM Secondary RM Sorter](image)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorting Task</td>
<td>Pre-concentration</td>
</tr>
<tr>
<td>Feed rate</td>
<td>70 t/h</td>
</tr>
<tr>
<td>Size range</td>
<td>25..80mm</td>
</tr>
<tr>
<td>Reject Rate</td>
<td>30..50%</td>
</tr>
</tbody>
</table>
Calcium Carbonate Sorting - Omya

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorting Task</td>
<td>Contaminant removal</td>
</tr>
<tr>
<td>Feed rate</td>
<td>Up to 110 t/h</td>
</tr>
<tr>
<td>Size range</td>
<td>20..80mm</td>
</tr>
<tr>
<td>Reject Rate</td>
<td>10..20%</td>
</tr>
<tr>
<td>Efficiency (reject)</td>
<td>98..99%</td>
</tr>
</tbody>
</table>

ROM Secondary PM Sorter
Gold Ore Sorting – Central Norseman Gold

- Sorting quartz gold bearing ore from waste dumps
- Feed size +30 / -100mm at 70 tph
- TOMRA PRO Secondary Colour
Gold Ore Sorting – Exterra, Linden Deposit

- Sorting quartz gold bearing ore from waste dumps
- Feed size +30 / -100mm at 70 tph
- TOMRA PRO Secondary Colour / NIR
- Upto x 5 upgrade
Copper Ore Sorting – Glencore CSA, Cobar

- Upgrading copper ore mill feed from underground
- Feed size +20 / -60mm at 70 tph
- TOMRA COM XRT 1200
Aggregate Sorting – Boral Quarries

- Upgrading aggregate for use in concrete, road and rail ballast
- Feed size +20 / -75mm at 70 tph
- TOMRA PRO Secondary Colour / Colour
Iron Ore Sorting – FMG Pilot Plant, Newman

- Upgrading iron ore by removing alumina, silica and manganese
- TOMRA COM Secondary XRT 1200  +20 / -75mm  75 tph
Talc Ore Sorting – Imerys, Three Springs

- Upgrading talc by removing calcites, quartz and basalt
- TOMRA PRO Primary Colour / NIR: +60 / -170mm, 124 t/hour
- TOMRA PRO Secondary Colour / NIR: +25 / -60mm, 70 t/hour
Manganese Ore Sorting – Consolidated Minerals, Woodie Woodie

- Upgrading manganese ore by removing alumina, silica and iron
- TOMRA COM EM Secondary +18 / -75mm 75 tph
- TOMRA PRO Tertiary Colour / NIR +6 / -18mm 14 tph

Mn Feed 46% > 56%  Fe Feed 7.7% > 1%
Antimony Ore Sorting – Hillgrove Mines

- Upgrading antimony + gold ore mill feed from underground
- Feed size +8 / -50mm at 50 tph
- TOMRA COM XRT 1200

ROM head grade 1.5g/t > 6 g/t Sb+Au equivalent
Magnesite Ore Sorting – Sibelco, Kunwarara

- Oldest sorter in Australia 20 years of operation
- Two sorters in parallel operation
- Feed size +12 / -40mm and +40 / -65mm at 60 tonnes per hour
- TOMRA ROM Colour Laser
Magnesite Ore Sorting – Sibelco, Kunwarara

- Pilot plant on trial for new plant design and expansion
- Feed size +10/-65mm upto 60 tonnes per hour
- TOMRA COM XRT 1200
Tin Ore Sorting – Bluestone, Tasmania

- Two COM XRT 1200 sorters in parallel operation
- Feed size +10/-25mm and +25/-60mm
- Test work demonstrated >25% mass rejection with >97% Sn retained
- Rapid project payback <12 months for entire plant
- Increased Sn production by 15-20% or 7,100 t of Sn from current...
Case Study - Tin
Case Study - Tungsten
Case Study - Lithium
Case Study – Graphite
Case Study – Cobalt
Lucara - Update

Second largest diamond ever found at 1,111 carats found with TOMRA’s XRT sorters

The tenth largest diamond ever found soon followed at 813 carats a week later....

Soon after another stone at 374 carats...
Sorter Options and Configurations
Modular Approach – Containerised Sorter
Modular Approach – Containerised Sorter
Containerised Solutions – i2 Mine, Sweden
Testwork
Test work to Production

Rock-by-rock Testwork
- 100-300 rock samples
- Test on all sensors in laboratory
- Report generated with recommendations for subsequent test program

Bulk Testwork
- >1 tonne of sample per ore body
- Sorted by full scale sorter with sensor as prescribed by laboratory testwork
- Full scale upgrade potential established

Pilot Sorter
- Free standing simple pilot plant
- Onsite full scale bulk sorting
- Independent of production plant

Production Sorter
- Full scale integrated production plant

The cost of test work completed is credited against the purchase price of a sorter
Test work reports
Test work reports
Some of our Clients/References
Questions?