THE APPLICATION OF XRT IN THE DE BEERS GROUP OF COMPANIES

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PRESENTATION OVERVIEW

• Introduction

• XRT fundamentals

• History of XRT in the De Beers Group

• Application areas

• Conclusions
X-RAY TRANSMISSION FUNDAMENTALS
XRT FUNDAMENTALS

Click image to run this animated DEM simulation
XRT FUNDAMENTALS

• XRT sorting machines employ the x-ray transmission (XRT) technique to recover diamonds from feed material.

• XRT is similar to medical x-ray radiography or x-ray baggage scanning

• It is sensitive to a number of material characteristics of a particle.
  - Atomic number
  - Thickness
  - Density

• A “Dual Energy”-XRT system allows these material characteristics to be measured to accurately discriminate between diamond and non-diamond particles.
XRT FUNDAMENTALS

X-ray source
XRT FUNDAMENTALS

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THE HISTORY OF XRT IN DE BEERS
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• First XRT system in De Beers?
  - 1990 – De Beers Exploration analyses microdiamonds using XRT – this device is still in service today for +75um stones.

• First XRT system for diamond detection on a De Beers mine?

• First De Beers research into XRT for sensor-based ore sorting?
  - 1990’s for the DWIK project – detecting Diamonds WithIn Kimberlite. Patent registered for Dual Energy XRT.
HISTORY - THE ADVANTAGES THAT XRT PROMISED

Why XRT?

- High diamond selectivity for all diamond types
- Insensitive to feed moisture content and dust
- Low yield for most gravel types
- Potentially more economical than existing processes
- Suitable to high throughput applications
- Applicable in several application areas
HISTORY - THE CHALLENGES THAT XRT FACED

<table>
<thead>
<tr>
<th>Why not XRT?</th>
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<tr>
<td>Achievable throughputs were low</td>
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<td>Performance benchmarks were non-existent</td>
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<tr>
<td>Technology immaturity</td>
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<tr>
<td>Trust was low</td>
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<tr>
<td>High development costs with available technology</td>
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<td>Application areas were not clearly defined</td>
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APPLICATION AREAS IN THE PROCESS FLOW SHEET

- Large diamond recovery early in the flow sheet.
- DMS replacement (Coarse)
- Post DMS reconcentration
- Recovery plant sorting machines
- Sort house reconcentration and auditing
XRT TIMELINE IN DE BEERS

- '90: Microdiamond analysis for Exploration
- '93: Scannex full body x-ray scanner
- '97: First Dual-source high throughput prototype
- '06: XRT Recovery sorter prototype
- '08: XRT Coarse Concentrator (-75+6) Pilot Plant (Namdeb)
- '09: First XRT Recovery Sort Reconcentrator (-32+1) deployment
- '11: Post DMS recombination plant construction (Venetia)
- '13: XRT technology not yet mature enough for sorting
- '14: XRT Researched for DWIK application
- '15: Lab prototype testing commences
- '16: Large diamond plant construction commences (Jwaneng LDPP)
- '17: XRT Simulator enables detailed desktop studies
- '18: XRT Recovery Audit MTU deployed at sea
- '19: XRT Commercial Audit deployed
XRT APPLICATION EXAMPLES IN DE BEERS
LARGE DIAMOND RECOVERY

• The high throughput and low yielding performance of XRT allows it to target large liberated diamonds above the conventional top cut-off size.

• This unlocks revenue early in the flow sheet and reduces the chance of diamond damage.

• Large diamond recovery can be considered for both brown- and green-field applications.

• Jwaneng mine will run a 12 month test programme during 2018 and 2019 using two DebTech XRT CC+ machines, treating all of the -45 mm +25 mm post scrubber material.
MARINE AUDITING AND SORTING APPLICATIONS

- XRT can provide **real-time estimates** of diamond size frequency distributions (DSFD).

- Carat measurements of **individual stones** are made using the XRT images.

- Real-time DSFD information is useful for
  - **Process diagnostics**
  - Particularly for the **marine mining** environment.

- In the **marine environment**, the sea floor is mined in well-defined sections. Rapid and accurate feedback on the DSFD for these sections is crucial for an efficient mining operation.
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MARINE AUDITING AND SORTING APPLICATIONS

• De Beers Marine, De Beers Marine Namibia and DebTech started a **collaborative test programme** in 2013.

• **DebTech’s XRT BWT1122** was installed on the DebMar Atlantic mining vessel and the **final recovery concentrate was analysed** and the carat content reported for -19mm +3DS.

• Over a one-year period, the XRT estimate of DSFD was **compared with sorthouse results** for all +3DS diamonds (0.030 ct or 1.3 mm).

• The results showed that the **XRT machine produced an accurate estimate** of total carats recovered. **Sorting** was also implemented.

![Graph showing correlation between XRT Carats and Sorthouse Carats with equation y = 0.935x and R² = 0.9651]
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DMS REPLACEMENT

• XRT technology was identified as a **lower cost alternative to DMS**.

• Studies show that this is particularly true
  - for **Green fields** applications
  - in **Coarse DMS circuits**
  - when **concentrate can bypass the recovery plant** and go straight to the sorthouse.

• It is **not presently viable for Fines DMS circuits** due to the number of sorting machines that would be required to match the DMS throughput.

• XRT also releases **Brown fields opportunities**.
DMS REPLACEMENT

- Namdeb and DebTech ran a joint **test programme in Oranjemund** from 2014 to 2016.

- The **DebTech Coarse Concentrator** was used and tested under these conditions:
  - **-32 + 6 mm alluvial gravel** in several size ranges.
  - Numerous throughput settings up to **85 tph**.
  - **Diamonds and tracers** were added to the feed.

- The test programme set out to determine:
  - **Optimal feed rate** per size fraction
  - Diamond **recovery efficiencies**
  - The **reliability and availability** of the technology
  - The **operating costs** under these conditions

*XRT Pilot plant in Oranjemund, 2014.*
DMS REPLACEMENT

• Results indicated that XRT is well suited as an alternative to Coarse DMS.

• To achieve very low yields and maintain optimal throughputs, the feed preparation is important.

• Namdeb took delivery of an XRT machine in 2016 for use in dump retreatment and for eventual re-deployment to treat Run-of-Mine material.

<table>
<thead>
<tr>
<th>Cost item</th>
<th>Normalized cost per ton</th>
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<tr>
<td></td>
<td>XRT</td>
</tr>
<tr>
<td>Electricity</td>
<td>14%</td>
</tr>
<tr>
<td>Labour</td>
<td>11%</td>
</tr>
<tr>
<td>Maintenance and consumables</td>
<td>7%</td>
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<tr>
<td>Downstream costs</td>
<td>2%</td>
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<tr>
<td>Total</td>
<td>34%</td>
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POST-DMS RECONCENTRATION

- XRT’s insensitivity to near-density material makes it an ideal reconcentration technology for high-yielding DMS circuits.

- Due to the relatively low throughputs required in this application, it would be economical to apply XRT to the Middles and Fines circuits too. However certain technical challenges remain in these size fractions.

- Venetia mine is constructing a production plant post their Coarse DMS circuit that incorporates the DebTech XRT Coarse Concentrator machine.

- Results from test work in Johannesburg have been very positive and production results are expected in early 2019.
FINE DIAMOND RECOVERY

- It would be too expensive to apply sensor based sorting (XRT or otherwise) to fines (-4mm) high throughput applications. A bulk sorting method like DMS provides a more cost-effective solution.

- The application still exists post DMS in the Recovery and Sorthouse, where x-ray luminescence and laser technology presently dominate.

- Machines like the DebTech XRT BWT1122 operate successfully on fine dry material, but presently only at low throughputs.

- Technical challenges remain for XRT Fines, notably:
  - Feed presentation – dry: fine grit and dust must be eliminated
    wet: fine wet particles adhere to all surfaces and other particles.
  - Detection: the bottom size is limited by the pixel size of the camera.
TEST FACILITY IN JOHANNESBURG

- **Samples can be processed** at the XRT Test Plant in Johannesburg.

- **The plant can become a Red Area** and link into the De Beers Security network for local or remote viewing. Personnel are Scannexed after every shift. Concentrate is hand sorted in the adjacent permanent Red Area.

- Includes a **DebTech XRT Coarse Concentrator** machine for high throughput tests

- Recovery efficiency, yield, throughput and other **performance parameters** can be determined.
CONCLUSIONS
CONCLUSIONS

• XRT technology has had a **positive and expanding impact** across the De Beers Group over the **last two decades**.

• **De Beers is pursuing XRT in several application areas** namely
  - Large diamond recovery
  - DMS replacement
  - Post DMS reconcentration
  - Sorthouse auditing and sorting
  - Recovery plant sorting

• Going forward we are **eager to unlock more value using XRT** in the areas above as well as other areas like the ultra large and fine sizes where appropriate.