

**CHRYSOS  
CORPORATION**  
Assays at the speed of light

# Chrysos™ PhotonAssay Technology

Dirk Treasure | Chief Executive Officer | Chrysos Corporation

# Chrysos PhotonAssay

---

Commercialising a best in class gold assay method:

- Fast analysis
- High accuracy and precision
- Low to zero sample preparation
- Large sample size
- Insensitive to sample matrix
- Chemical free
- Non-destructive analysis
- Application to different elements
- Improved OH&S and reduced environmental impact

# Conventional assay techniques

- Fire-assay has been the standard method for many centuries
- Existing alternatives:
  - Aqua regia digest & titration
  - Cyanidation
  - Neutron activation analysis



Turn-around time  
Usually > 24 hours



Small sample  
mass (10-50 g)



Extensive sample  
prep



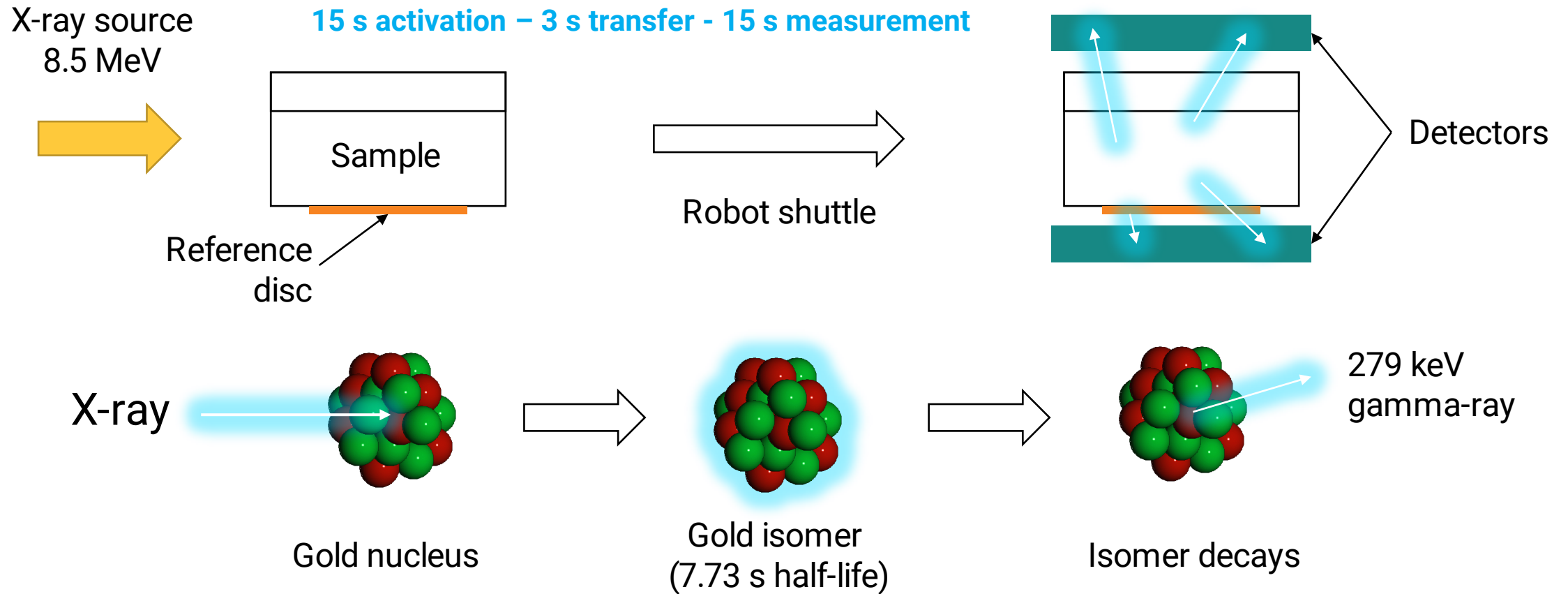
Skilled labour  
requirements



Hazardous  
process

# Technology

## Photoactivation analysis + automatic reference compensation = PhotonAssay

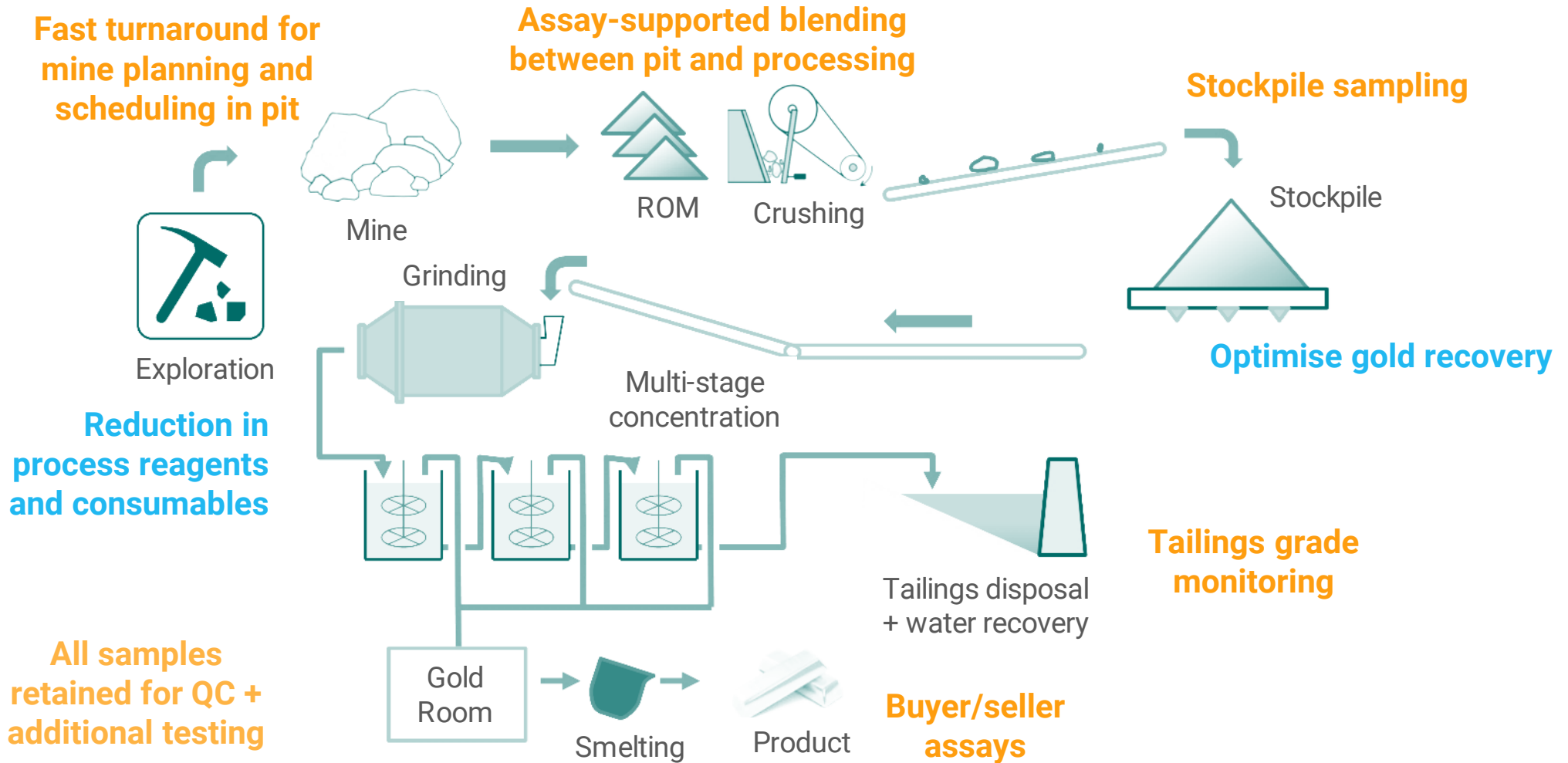


# Intrinsic performance benefits

---

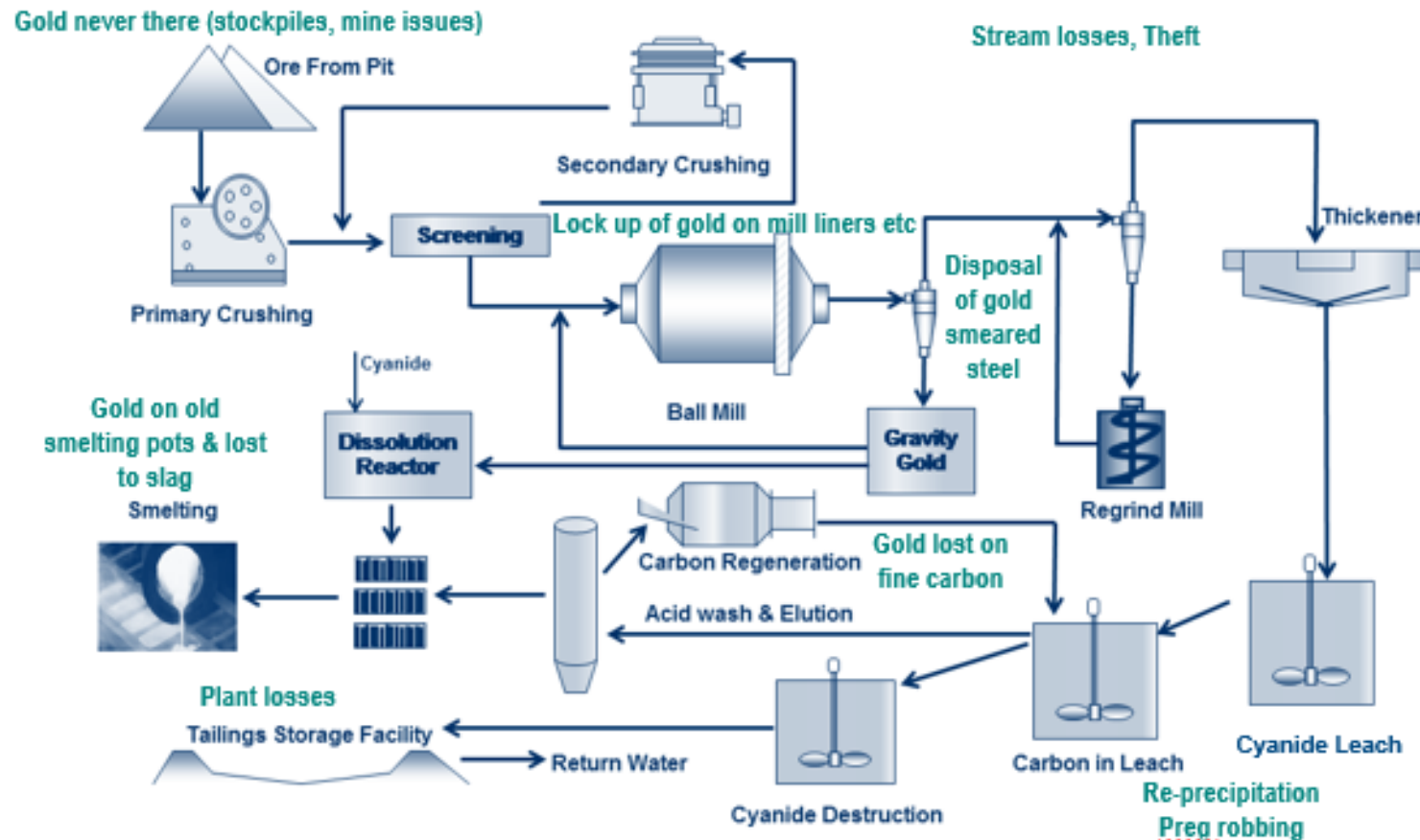
- Incident X-rays and emitted gamma-rays are very penetrating
  - True bulk analysis of large samples (typically 400-600 g)
- Insensitive to chemical form of gold and largely insensitive to physical form
- Largely insensitive to sample matrix
  - RMS matrix error < 0.2% relative for any material with atomic number  $Z \leq 30$  eg water, carbon, silicate ore, sulphide ore, Cu concentrate ...
  - Straightforward correction for other materials eg Pb concentrate
- Fully automated analysis
- Negligible residual radioactivity

# Applications of rapid turn-around assay



# Optimise Gold Recovery

- Studies indicate ~35% of gold lost to tailings is avoidable
  - Industry feedback is an expectation of 1-3% improvement in recovery



# Reduction in Consumables

- Overuse of reagents
  - Overdosing to ensure maximum recovery
  - Overgrinding to ensure liberation
  - Operating the process plant retrospectively on old data
- Industry feedback is 3-5% reduction
  - Reagent costs are ~A\$3/t of ore (S&P Global Database)
  - Equivalent to A\$1.5m for a project with:
    - 250 kozpa
    - 1g/t gold grade
    - 75% gold recovery

Reagent costs are around \$3/t of ore processed

Reagents	Usage g/t	Input cost \$/t reagent	Unit operating cost \$/t ore
Cyanide	750	2,450	1.84
Lime	1,500	150	0.23
Hydrochloric Acid	300	1,000	0.30
Carbon	200	3,000	0.60
Caustic	75	1,500	0.11
Other (eg O <sub>2</sub> )			0.21
<b>Total</b>			<b>3.28</b>
<b>Weighted average as per S&amp;P Global mining model database</b>			<b>3.02</b>



# Commercial unit – PA1408X

---

- Improve precision more than two-fold at low grade
- Containerised system, designed for deployment in a commercial assay laboratory environment
- Radiation safety and licensing
- Fully automated sample handling
- Automatic calibration, data analysis and reporting
- 24/7 operation with high availability
  - target >95% outside scheduled maintenance
- Automated QA/QC

# PA1408X – Perth Installation



# PA1408X – Perth Installation



# PA1408X – sample prep and loading

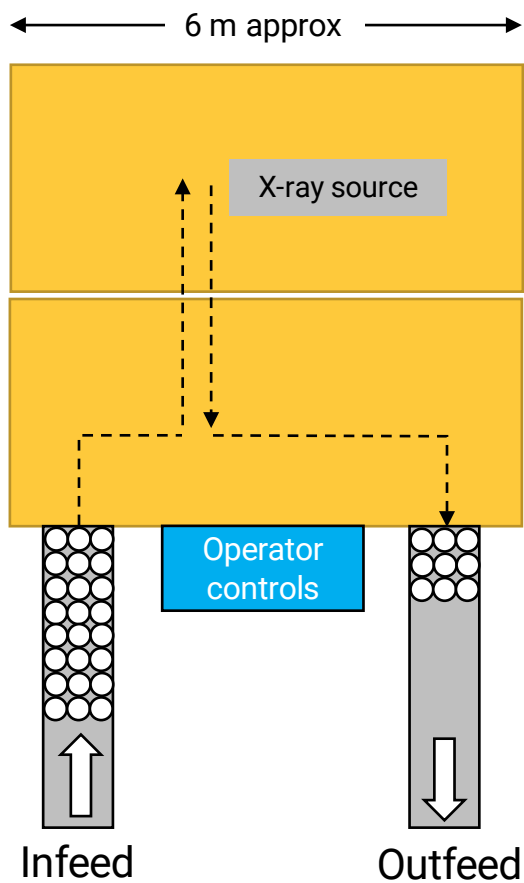


*Coarse or pulverised material in samples jars*



*Sample jars loaded onto automatic conveyor*

# Safety and operator requirements



- Fully automated sample handling. Operator loads and unloads samples from outside unit
- Electronic X-ray source: no power, no radiation
- Equipment packaged as 'black box'. No operator access during routine use
- Radiation levels, interlocks etc in compliance with state and national regulations
- Samples can be safely handled, stored or disposed of after analysis
- Minimal opportunities for human error

# Performance on CRMs

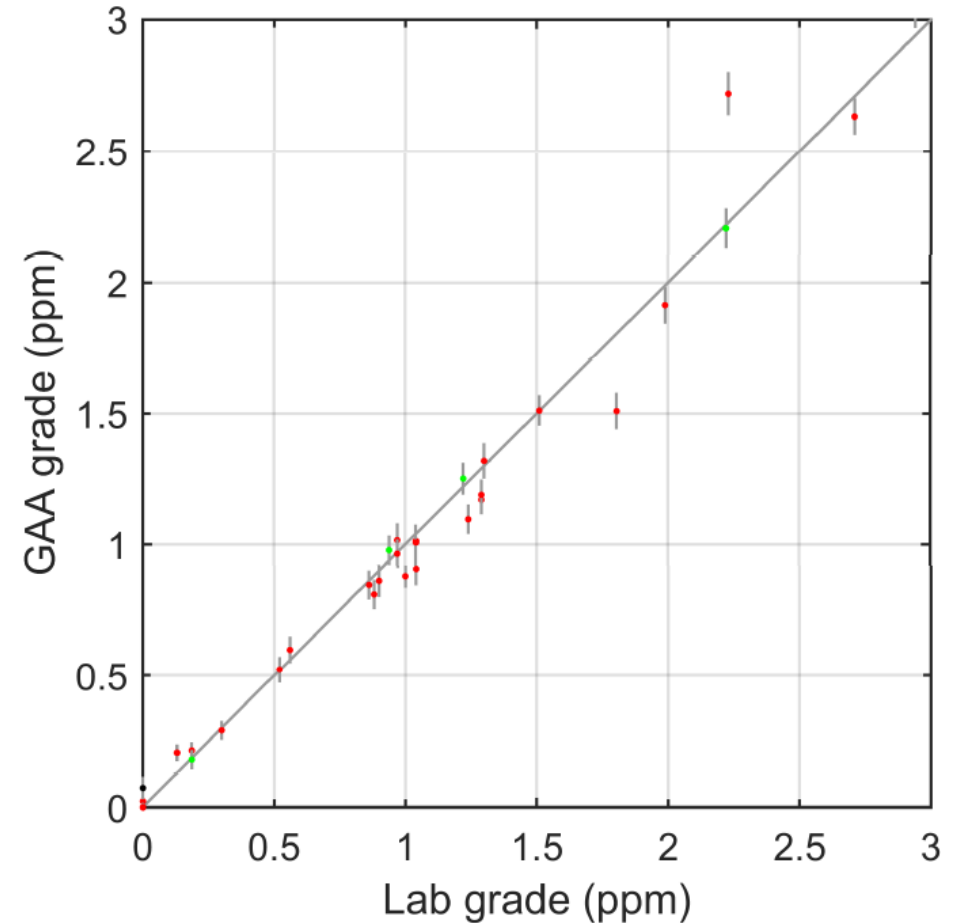
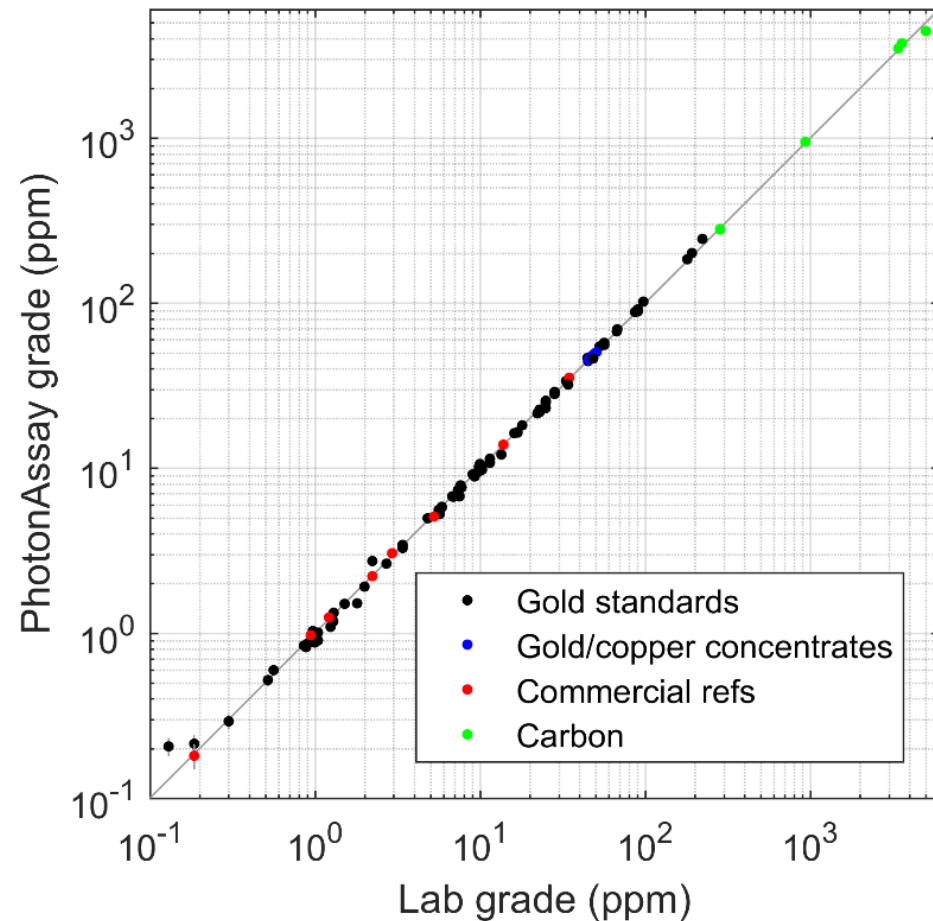
Parameter	PhotonAssay	Fire assay <sup>†</sup>	Aqua regia <sup>†</sup>
Throughput	72 samples/h*		
Det. limit (3 $\sigma$ )	30 ppb*	1 ppb (ICP finish) 10 ppb (AAS finish) 3 ppm (gravimetric)	1-20 ppb, depending on finish
Accuracy @ 0.1 ppm	20% (0.02 ppm)	10-12%	15%
Accuracy @ 1 ppm	3-4%	3-4%	4-6%
Accuracy @ >10 ppm	<1.5%	2.5-3.5%	4-6%

\* Throughput/sensitivity can be traded

† Ideal performance, homogenous materials, outliers excluded

# Fire assay comparison

- High correlation for samples run in test work at full scale <0.9% discrepancy



# PA1408X – factory testing

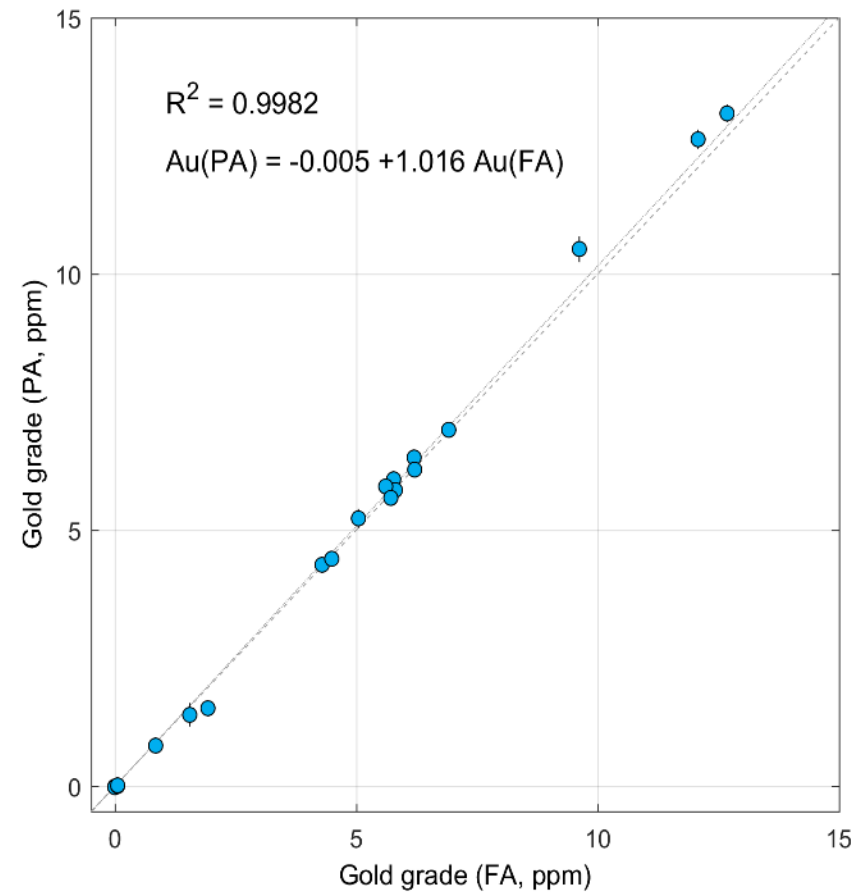
---

- Samples received from multiple operations and companies in:
  - North America
  - Central America
  - Africa
  - Australia
- Diverse ore and material types
  - Gold, Copper/gold, polymetallic, ore, process pulps, carbon, resin
- Certified reference materials provided or purchased from:
  - OREAS, Rocklabs, Gannet Holdings, AMIS and RRM
- Approximately 1600 sample splits in total



# Performance on client materials

- Example: 22 samples received from Peruvian gold operation
- 1-3 kg of each sample received; sampled to exhaustion into PA jars
- Samples provided blind; client subsequently provided FA data (4 repeats)



# QA/QC and operation protocols

---

- Plan to mimic conventional fire-assay QA/QC protocol
  - ~10% of processed samples will comprise
    - Certified reference materials and blanks
    - Repeat samples
    - Client-supplied CRMs and repeats (supplied blind)
- Reference disc directly ties each assay back to CRM suite
- As method is non-destructive, QA/QC samples can be reused
  - Automated charting and report generation
- System operation is fully automated (loading/unloading samples and pressing 'start' button)
  - Low-skill operators overseen by qualified personnel

# Validation program (started mid-April)

---

## Instrument performance

- Detection limits
- Linearity
- Automatic calibration process
- Repeatability
- Total measurement uncertainty
- Approx 10,000 samples

## Sample handling

- Sampling methodology
- Sensitivity to crush/grind size
- Establish QA/QC protocols
- Operator protocols
- Comparison back to fire-assay

Validation

NATA (ISO17025)

JORC

# Moisture

---

- PhotonAssay can easily measure wet materials, but by default reports grade in as-received basis
  - Initial measurements performed on dry materials
- Chrysos is currently testing a novel on-line moisture measurement method
- This would allow dry-basis reporting for wet samples, slurries etc without pre-drying

# Other elements

1 1.008 <b>H</b> Hydrogen																	2 4.003 <b>He</b> Helium																
3 6.941 <b>Li</b> Lithium	4 9.012 <b>Be</b> Beryllium																	5 10.811 <b>B</b> Boron	6 12.011 <b>C</b> Carbon	7 14.007 <b>N</b> Nitrogen	8 15.999 <b>O</b> Oxygen	9 18.998 <b>F</b> Fluorine	10 20.180 <b>Ne</b> Neon										
11 22.990 <b>Na</b> Sodium	12 24.305 <b>Mg</b> Magnesium																	13 26.982 <b>Al</b> Aluminium	14 28.086 <b>Si</b> Silicon	15 30.974 <b>P</b> Phosphorus	16 32.065 <b>S</b> Sulphur	17 35.453 <b>Cl</b> Chlorine	18 39.948 <b>Ar</b> Argon										
19 39.098 <b>K</b> Potassium	20 40.078 <b>Ca</b> Calcium	21 44.956 <b>Sc</b> Scandium	22 47.867 <b>Ti</b> Titanium	23 50.941 <b>V</b> Vanadium	24 51.996 <b>Cr</b> Chromium	25 54.938 <b>Mn</b> Manganese	26 55.845 <b>Fe</b> Iron	27 58.933 <b>Co</b> Cobalt	28 58.693 <b>Ni</b> Nickel	29 63.546 <b>Cu</b> Copper	30 65.409 <b>Zn</b> Zinc	31 69.723 <b>Ga</b> Gallium	32 72.640 <b>Ge</b> Germanium	33 74.922 <b>As</b> Arsenic	34 78.960 <b>Se</b> Selenium	35 79.904 <b>Br</b> Bromine	36 83.798 <b>Kr</b> Krypton																
37 85.468 <b>Rb</b> Rubidium	38 87.620 <b>Sr</b> Strontium	39 88.906 <b>Y</b> Yttrium	40 91.224 <b>Zr</b> Zirconium	41 92.906 <b>Nb</b> Niobium	42 95.940 <b>Mo</b> Molybdenum	43 [98] <b>Tc</b> Technetium	44 101.070 <b>Ru</b> Ruthenium	45 102.906 <b>Rh</b> Rhodium	46 106.420 <b>Pd</b> Palladium	47 107.868 <b>Ag</b> Silver	48 112.411 <b>Cd</b> Cadmium	49 114.818 <b>In</b> Indium	50 118.710 <b>Sn</b> Tin	51 121.760 <b>Sb</b> Antimony	52 127.600 <b>Te</b> Tellurium	53 126.904 <b>I</b> Iodine	54 131.293 <b>Xe</b> Xenon																
55 132.905 <b>Cs</b> Cesium	56 137.327 <b>Ba</b> Barium																	72 178.490 <b>Hf</b> Hafnium	73 180.948 <b>Ta</b> Tantalum	74 183.840 <b>W</b> Tungsten	75 186.207 <b>Re</b> Rhenium	76 190.230 <b>Os</b> Osmium	77 192.217 <b>Ir</b> Iridium	78 195.078 <b>Pt</b> Platinum	79 196.967 <b>Au</b> Gold	80 200.590 <b>Hg</b> Mercury	81 204.383 <b>Tl</b> Thallium	82 207.200 <b>Pb</b> Lead	83 208.980 <b>Bi</b> Bismuth	84 [209] <b>Po</b> Polonium	85 [210] <b>At</b> Astatine	86 [222] <b>Rn</b> Radon	
87 [223] <b>Fr</b> Francium	88 [226] <b>Ra</b> Radium																	57 138.905 <b>La</b> Lanthanum	58 140.116 <b>Ce</b> Cerium	59 140.908 <b>Pr</b> Praseodymium	60 144.240 <b>Nd</b> Neodymium	61 [145] <b>Pm</b> Promethium	62 150.360 <b>Sm</b> Samarium	63 151.964 <b>Eu</b> Europium	64 157.250 <b>Gd</b> Gadolinium	65 158.925 <b>Tb</b> Terbium	66 162.500 <b>Dy</b> Dysprosium	67 164.930 <b>Ho</b> Holmium	68 167.259 <b>Er</b> Erbium	69 168.934 <b>Tm</b> Thulium	70 173.040 <b>Yb</b> Ytterbium	71 174.967 <b>Lu</b> Lutetium	
																		89 [227] <b>Ac</b> Actinium	90 232.038 <b>Th</b> Thorium	91 231.036 <b>Pa</b> Protactinium	92 238.029 <b>U</b> Uranium	93 [237] <b>Np</b> Neptunium											

Fully demonstrated  
 Experimental validation  
 Sensitivity measurements  
 Theoretically accessible

Det. limit ( $3\sigma$ ) : Ag (~4-5ppm), Cu (~0.02%), Pb (~0.02%)

# Summary

---

- PhotonAssay provides accurate gold analysis and is insensitive to chemical or physical form of the sample
- Rapid, non-destructive true bulk analysis of large samples
- PA1480X unit designed for convenient deployment and operation in commercial or mine-site laboratories
- Roll out of five additional units planned for 2019
  - Units two & three for Kalgoorlie with Ausdrill (<1m samples pa capacity)
- Release of ruggedized 'mine-site' unit planned for 2020
- Fee-per-sample lease model

Dirk Treasure

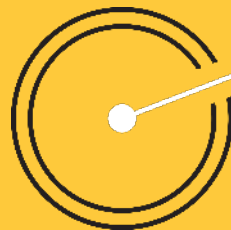
Chief Executive Officer

**T** +61 (0) 8 8303 8430

**E** [Dirk.Treasure@chrysos.com.au](mailto:Dirk.Treasure@chrysos.com.au)

**W** [chrysos.com.au](http://chrysos.com.au)

# Thank you



**CHRYSOS  
CORPORATION**