MMS academy

The Impact of Metallurgical Accounting on your company's Balance Sheet

Presented by:

Pieter de Villiers & Wynand van Dyk

MMS Consultants

ALLEN-BRADLEY • ROCKWELL SOFTWARE

Rockwell Automation

Agenda

- Basic Principles of Metal Accounting – Dr Wynand van Dyk
- Lonmin Metal Accounting System – Pieter de Villiers

Context to the AMIRA P754 Code

- Significant increase in the requirements of Corporate Governance
- Historically, accounting for metal/commodities across processing plants not to required standard
  - Lack of knowledge & understanding of principles
    - Mass balancing
    - Sampling & Measurement
    - People – assigned to junior metallurgist
  - Equipment
    - Last minute additions (or removed)
    - Inadequate design, poor installation, maintenance & operation
  - Laboratory
    - Capacity
    - Skill levels
- Need for metal accounting to be conducted to "financial accounting" standards w.r.t. auditability & traceability

Context (continue…)

- August 2001: “Challenges in Metallurgical Accounting & Information Management” symposium, Cape Town, SAIMM
- AMIRA International proposal P754 – “Metal Accounting & Reconciliation”
- Accepted & Sponsored by 5 main sponsors:
  - Anglo American
  - Anglo Platinum
  - BHP Billiton
  - Kumba Resources
  - Rio Tinto
- August 2004: Prof. Peter Gaylard, UCT, commissioned to develop the code
- October 2005: First release of code
- Now in 3rd release (dated February 2007)

What it is not…

- The Code has not been formally adopted for internal purposes by any of the sponsors or industry associations – not binding
- The Code has not been adopted by any regulatory or legislative bodies (incl stock exchanges)
- The Code has not been incorporated into listing rules of any stock exchanges
- The Code does not constitute any form of legal standard in relation to metallurgical accounting

What it is…

- Industry benchmark/best practice for metallurgical accounting
- Living document – next revision expected H1 2008
- Document consists of two sections:
  - Code (focus of this training)
  - Guidelines document (manual)
- *"The ultimate purpose of the Code is to define the best practice for creating & reconciling process metal balances, although it does not prescribe specific valuation methods, as these will be dependent on the practices & policies of the company or operation concerned"* – *AMIRA P754: Code Guidelines Release 3 20070219*

Introduction

- Metals produced are the source of income which sustains the operation & justifies the capital expenditure
- Income is generated due to commercial transaction
  - Mass measurements
  - One or more analysis
  - Target grade and/or penalty elements
- Cost of sales impact (commercial transaction)
  - Feedstock purchases
  - Royalty payments
  - Performance payments
  - Environmental penalties
- Balance sheet impact
  - Metal inventory (asset)
- Process Improvement impact
  - "You get what you measure"

Integral part of business

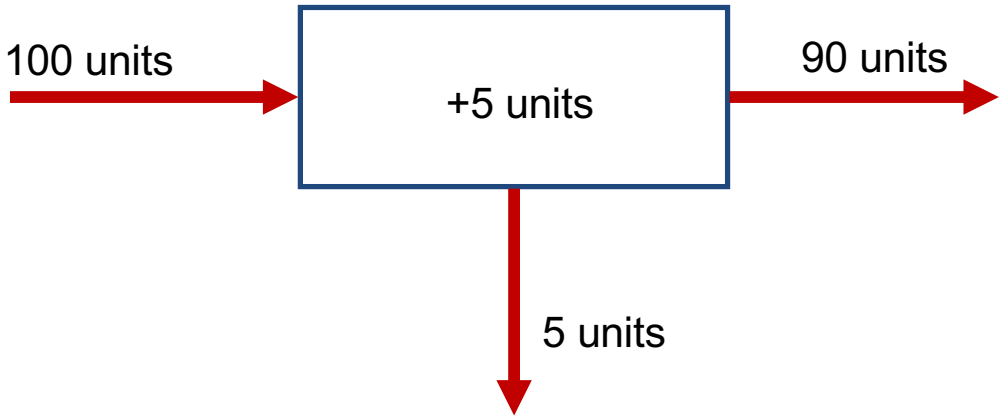
- Metallurgical accounting provides the interface between the metal recovery operations and the financial & commercial centres of the business
- Recording of information relating to flow & transfer of metals to accounting standards
  - Accuracy
  - Integrity
  - Security
  - Auditibality
    - Source data to be traced
    - Changes to data to be authorised, recorded & filed – audit trail
  - Accounting Period (typically one month)

Primary & Secondary Accounting

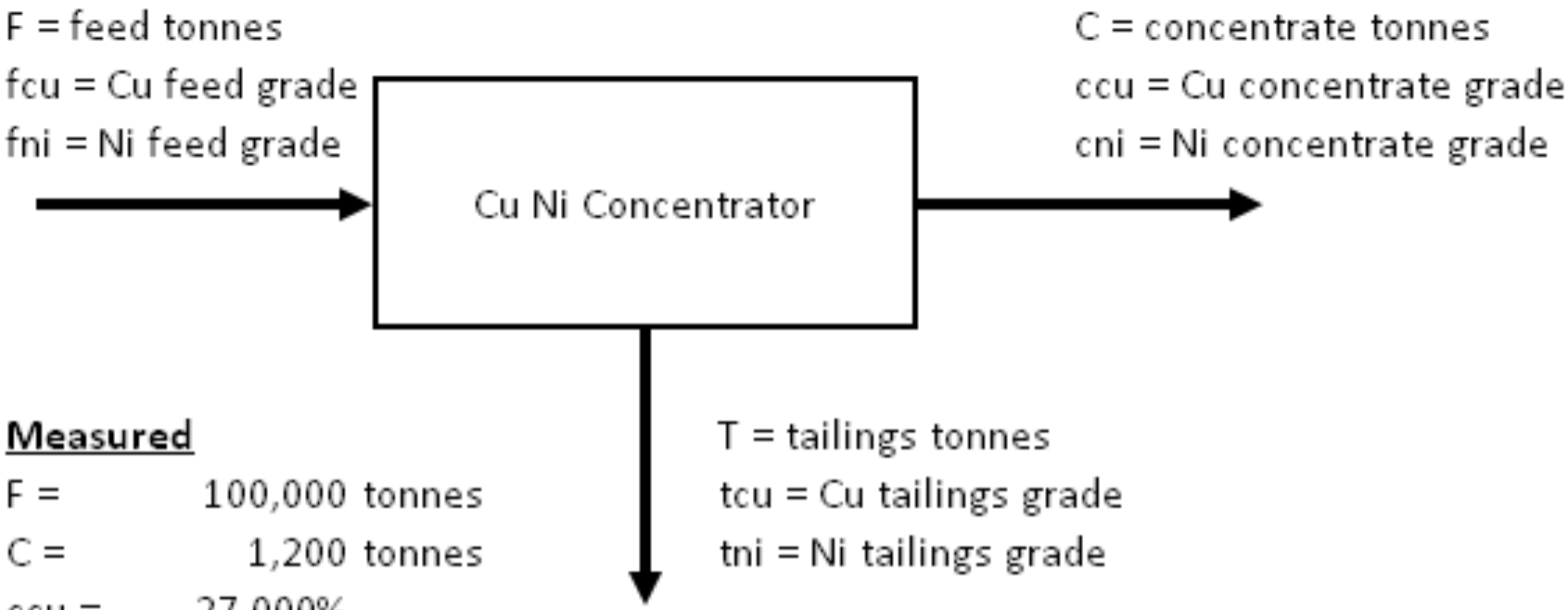
- Primary Accounting
  - Balance across an entire plant
  - Major focus of Code
  - Due to process time lags & inventory, meaningful calculations only made over longer time periods – quarter
- Secondary Accounting
  - Balance over smaller sections of plant circuit
  - Identify inventory build-up locations
  - Isolate source(s) of unaccounted losses
  - Identify measurement problems

The Basics

- Metallurgical Accounting is defined as the system whereby selected process data, including mass measurements & analysis, are collected from various sources and transformed into a coherent report format that is delivered in a timely fashion in order to meet specified reporting requirements
- A Metallurgical Balance involves the determination of the magnitude of each component across a process



Example: Metal Balance

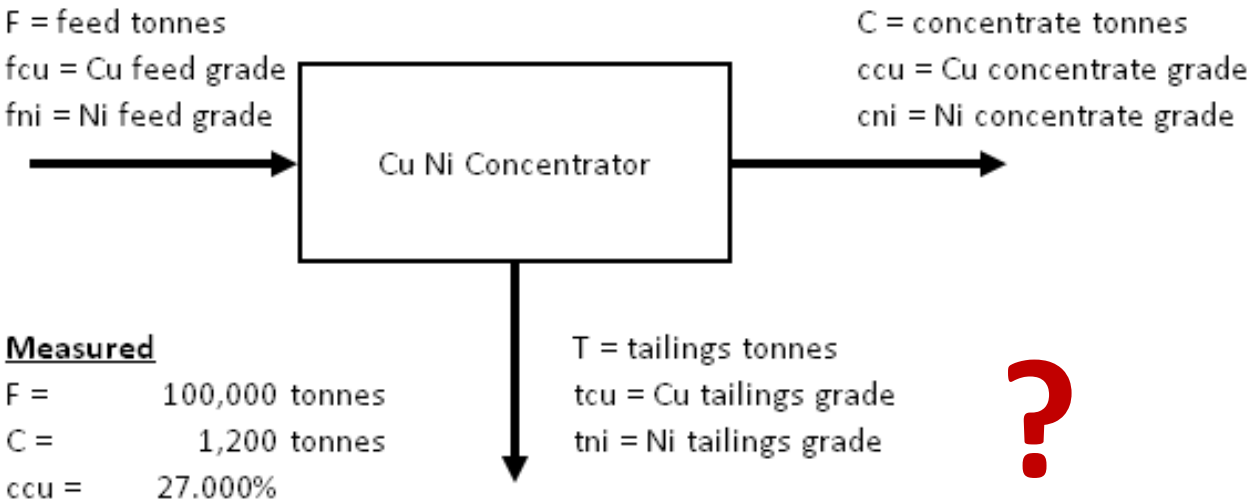


Measured

F =	100,000 tonnes
C =	1,200 tonnes
ccu =	27.000%
cni =	24.000%
tcu =	0.483%
tni =	0.416%
fcu =	0.800%
fni =	0.700%

- Cu/Ni Concentrator
- Calculate the Tails tonnage (3 ways)

Example: Which is right?



Measured

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C =	1,200	tonnes
ccu =	27.000%	
cni =	24.000%	
tcu =	0.483%	
tni =	0.416%	
fcu =	0.800%	
fni =	0.700%	

Calculate T using mass

F =	C + T	
T =	F - C	
T =	98,800	tonnes
Unacc =	0	tonnes

Calculate T using Cu grade

F.fcu =	C.ccu + T.tcu	
T =	(F.fcu - C.ccu)/tcu	
T =	98,600	tonnes
Unacc =	-200	tonnes

Calculate T using Ni grade

F.fni =	C.cni + T.tni	
T =	(F.fni - C.cni)/tni	
T =	99,100	tonnes
Unacc =	300	tonnes

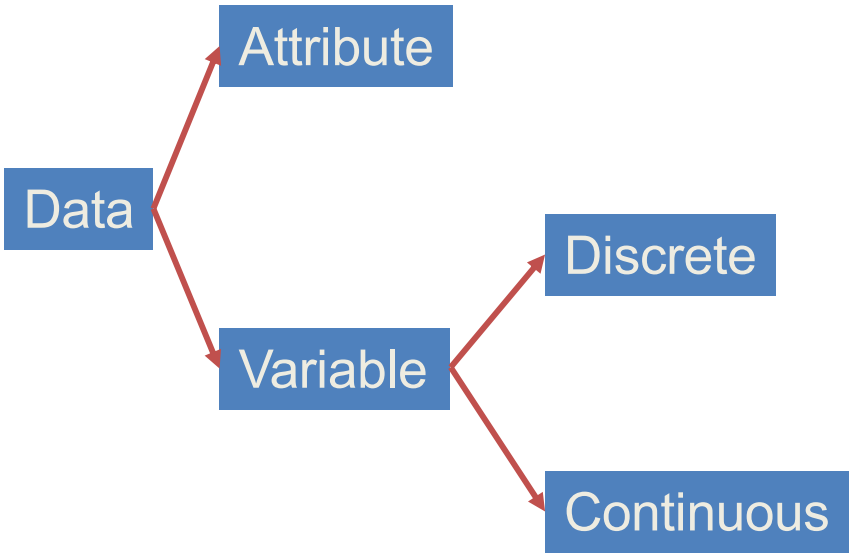
Check in-Check Out System

- *"What comes into the operation, less any internal accumulation, plus any draw down from internal stock is sufficiently similar (ie within acceptable limits in mass & analysed components) to what goes out as product(s) and reject"*
- *"what goes in is statistically similar to what comes out"*
- All streams into and out of the process or plant, for which the balance is being performed, are measured, sampled & analysed
- Check in-Check out will normally generate an imbalance due to measuring, sampling and analytical errors, or unknown losses
- Imbalance treated as an unaccounted gain or loss
- Standard procedure to be adopted for Metal Accounting

All metallurgical accounts
are wrong!

Some are just more wrong
than others…

Data Classification

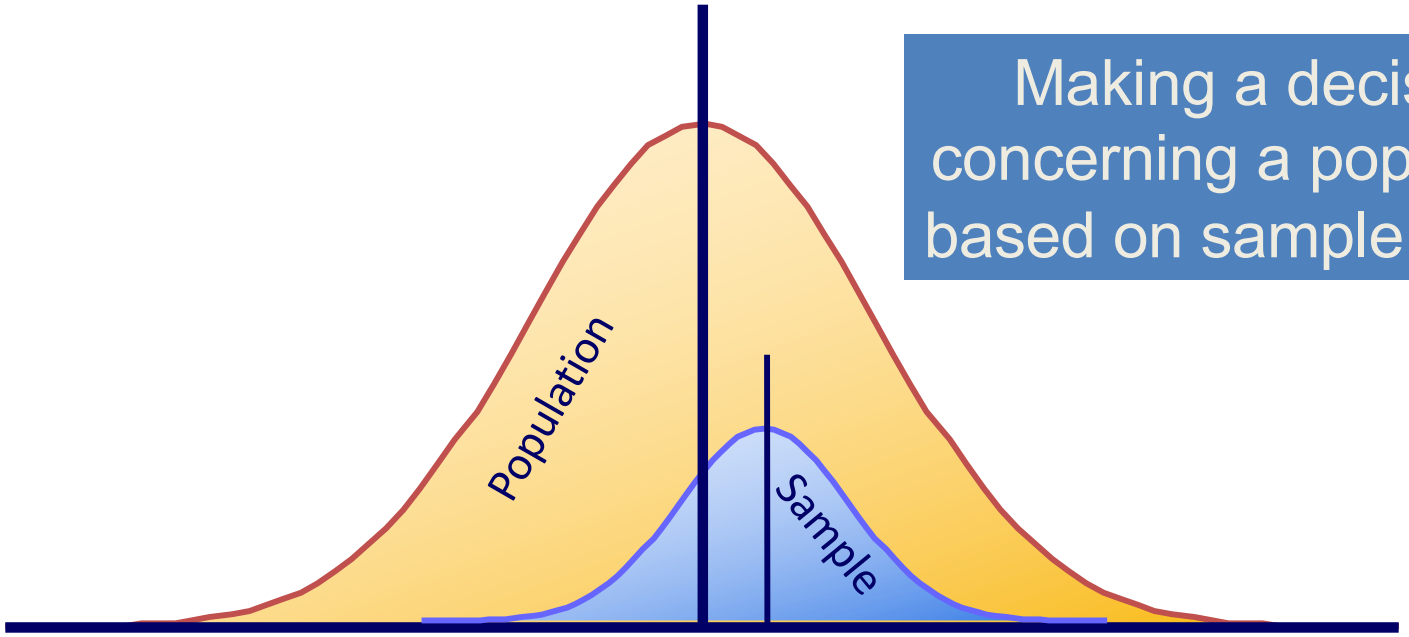


- Attribute
  - Observation process
  - Only 2 possible values (0 or 1)
  - "Do you own a dog"?
- Variable
  - Generated by measurement process
  - Discrete Variable
    - Values are countable
    - How many people here?
  - Continuous Variable
    - Any numerical value over an interval
    - How tall are you?

Continuous Variable Data

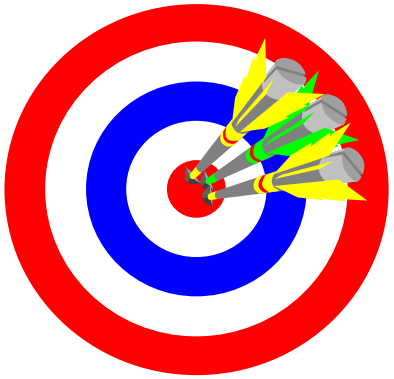
Population = The totality of items under consideration (All of the units or individual data points that exit now or will ever exist in the future)

Sample = A selection of items from a population (A selection or subset of units or individual data points drawn from the population)



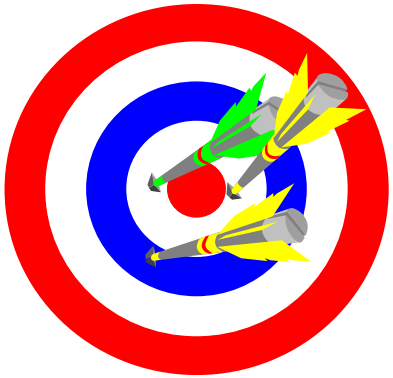
Making a decision concerning a population based on sample results

Precision & Accuracy of sample results

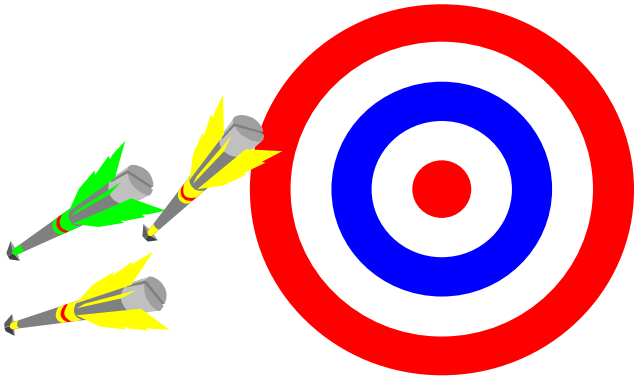


Accurate and Precise

Precise but not Accurate

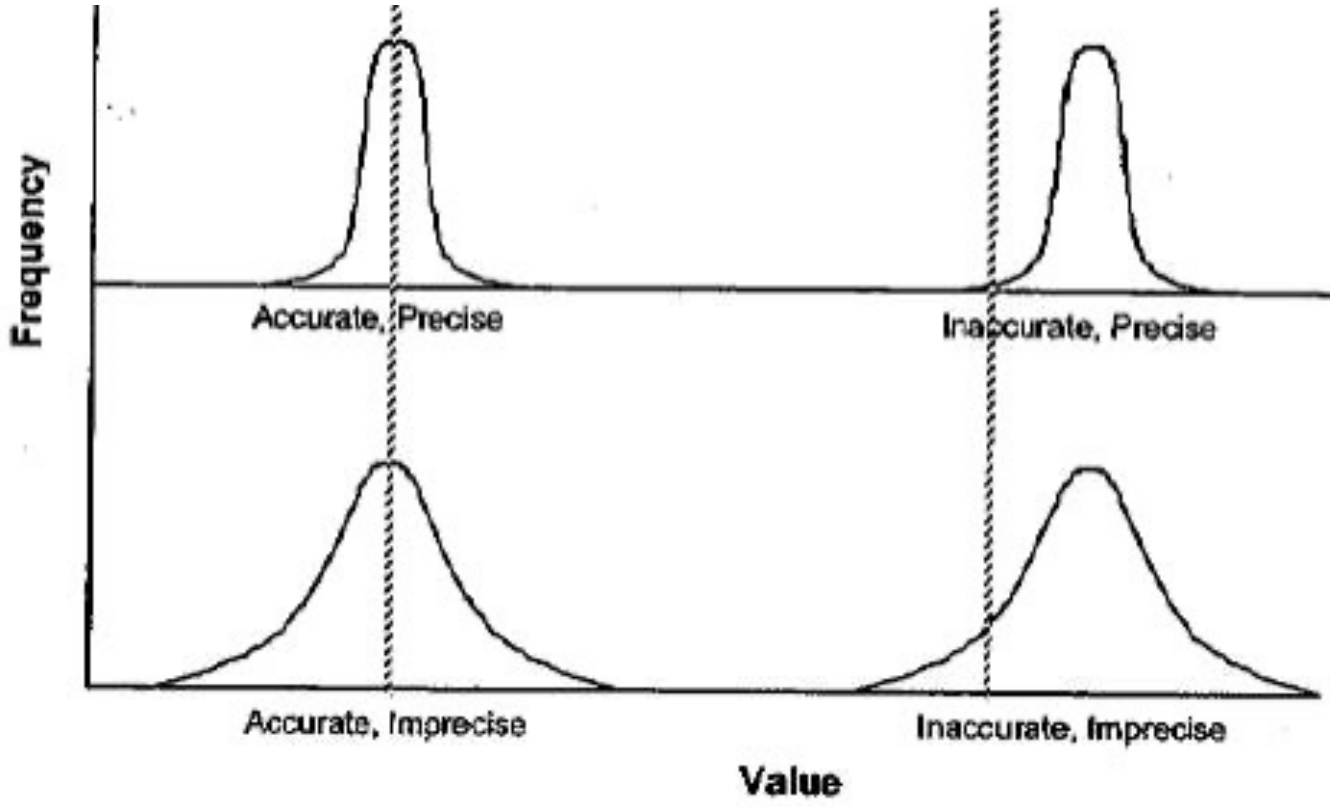


Accurate but not Precise



Not Accurate Not Precise

Precision & Accuracy

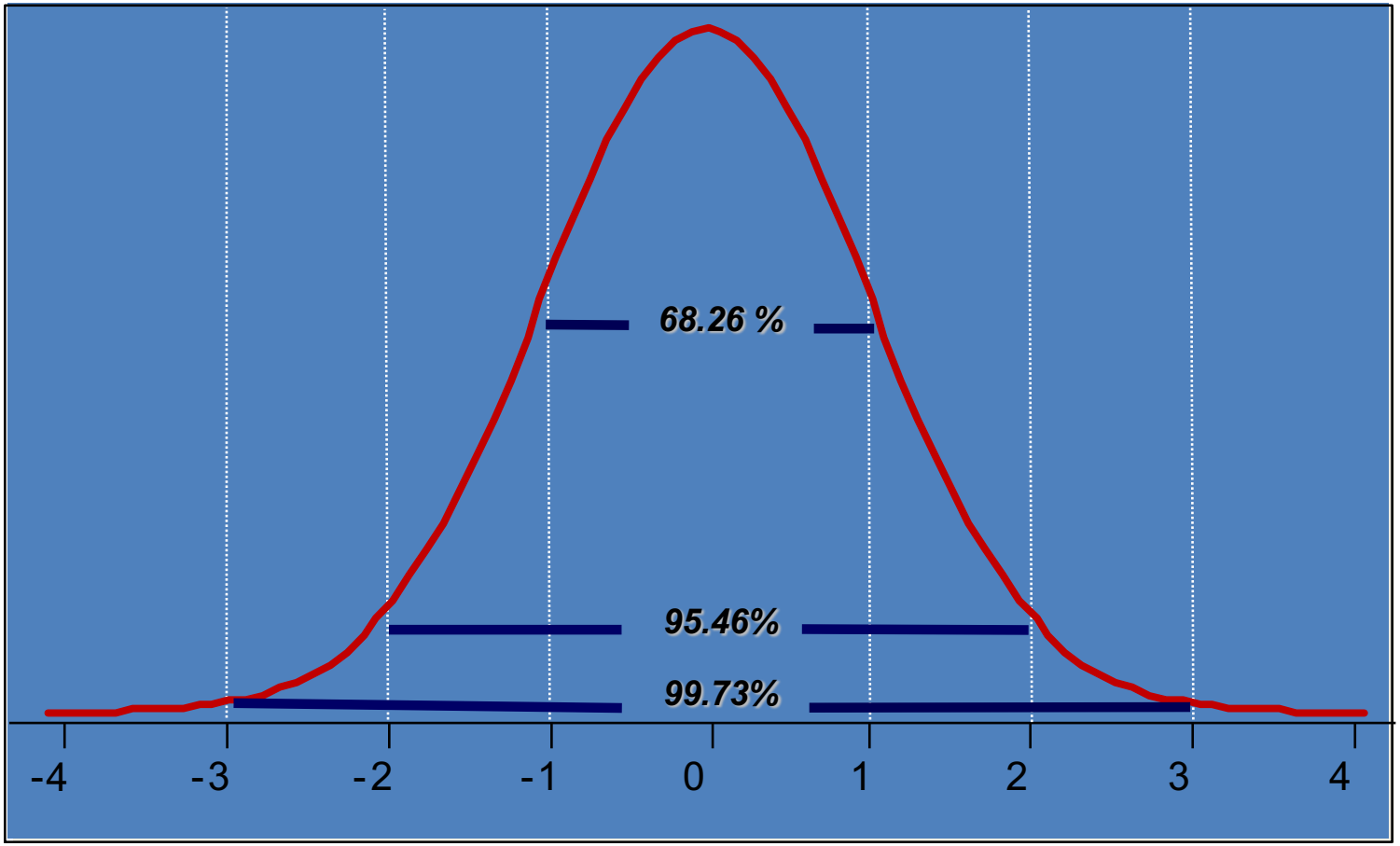


- **Precision** (reproducibility) is a measure of the spread. Poor precision implies uncertainty and thus reduced confidence
- **Accuracy** is a measure of deviation from a target. Inaccurate data implies bias

Types of Error

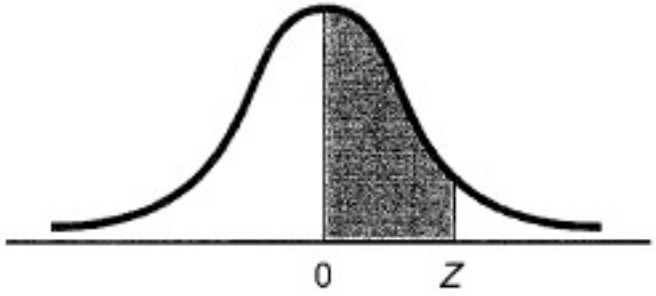
- Random Errors (Precision)
  - Natural fluctuations in the measurement process
    - Vibration & instrument noise
    - Temperature
    - Tolerances of equipment
  - Average tend to zero over time – increase sampling
- Systematic Errors (Accuracy)
  - Bias – consistently higher/lower than actual
  - Increasing number of measurements will not reduce average to zero
  - Sometimes known
    - K-factor in weightometers
    - Assay correction factors
- Illegitimate (Spurious) Errors
  - Usually caused by people
    - Incorrect readings
    - Accidental swapping of samples

Normal Curve Properties



Normal distribution tables

The Standardized Normal Distribution

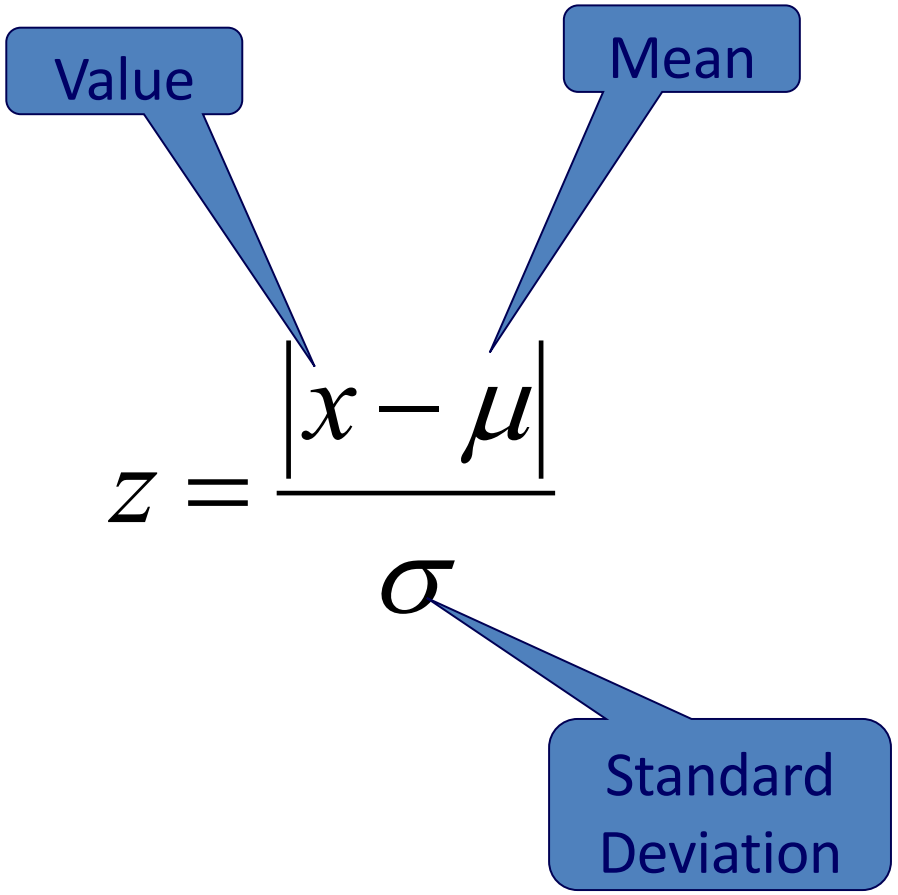


Entry represents area under the standardized normal distribution from the mean to Z

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2518	.2549
0.7	.2580	.2612	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389

What about real life?

- Tables of the Normal Distribution are presented in standardised for, which has μ = 0 and σ = 1.
- Z is called the standard normal deviate
- Think of it as the number of SDEV "units"
- From the transformation it is possible to determine the probability of obtaining a value of more (or less) than *x*.



Example: Identify Spurious Errors

- Historically, a smelter produces matte with μ = 5200g/t and σ = 270g/t. No process changes, but a matte sample with grade of 6100g/t is reported – do you accept?

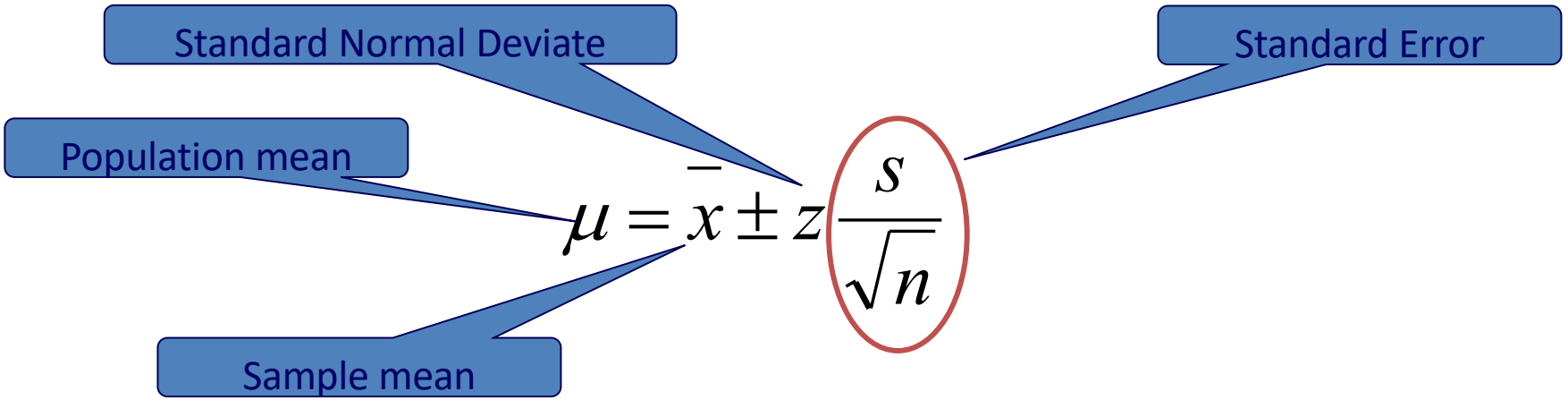
$$z = \frac{|x - \mu|}{\sigma}$$

$$z = \frac{|6100 - 5200|}{270} = 3.33$$

- From the tables: If z=3.33, then area = 0.49957
- Probability = 0.5-0.49957 = 0.00043 (looking for value >)
- From the tables, the probability of encountering a value of 6100g/t or more is 0.00043, or 0.04% (1 chance in 2300, or once in 6.3 years)
- Because of the symmetry of the normal distribution, a value of 4300g/t or less (z=-3.33) would have the same low probability of occurring.

Confidence Interval

When dealing with *large* samples of data:



The true value of μ is said to lie between $\left(\bar{x} - zs/\sqrt{n}\right)$ and $\left(\bar{x} + zs/\sqrt{n}\right)$

with a degree of confidence given by the probability level of z (from tables).

These are called the confidence limits for the sample mean.

Example: Confidence Interval

- The mining & geology department carry out Ten PGM (4E) assays on a sample of Opencast Merensky, with the following results:
- 3.26, 3.19, 2.85, 2.99, 2.95, 3.31, 3.15, 3.02, 3.08, 2.91 g/t
- Calculate the mean, standard deviation, standard error, variance and 2 sided 95% confidence intervals (use z).

$$\bar{x} = 3.071 g/t$$

$$s = 0.153 g/t$$

$$n = 10$$

$$s_{\bar{x}} = s/\sqrt{n} = 0.153/\sqrt{10} = 0.518$$

$$@95\% = 0.11 g/t$$

95% confident that the grade is between 2.961 & 3.181 g/t

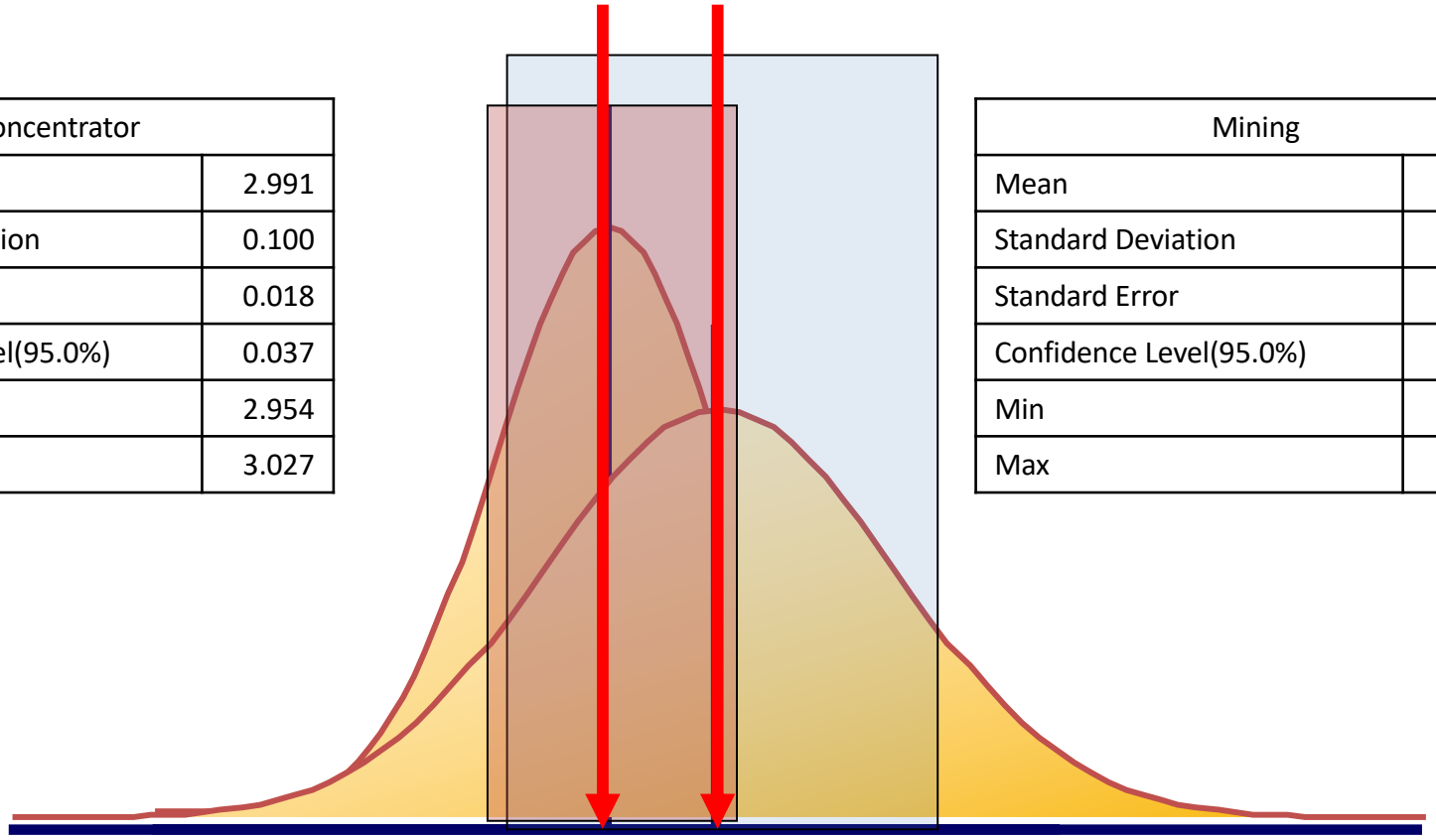
Example continue

- At month-end, the concentrator reports that based on 31 samples, the headgrade = 2.99 g/t with a standard deviation of 0.1 g/t. Mining disagrees strongly & insist to declare a headgrade of 3.07g/t. Who is right?

Who is right?

Concentrators Mining

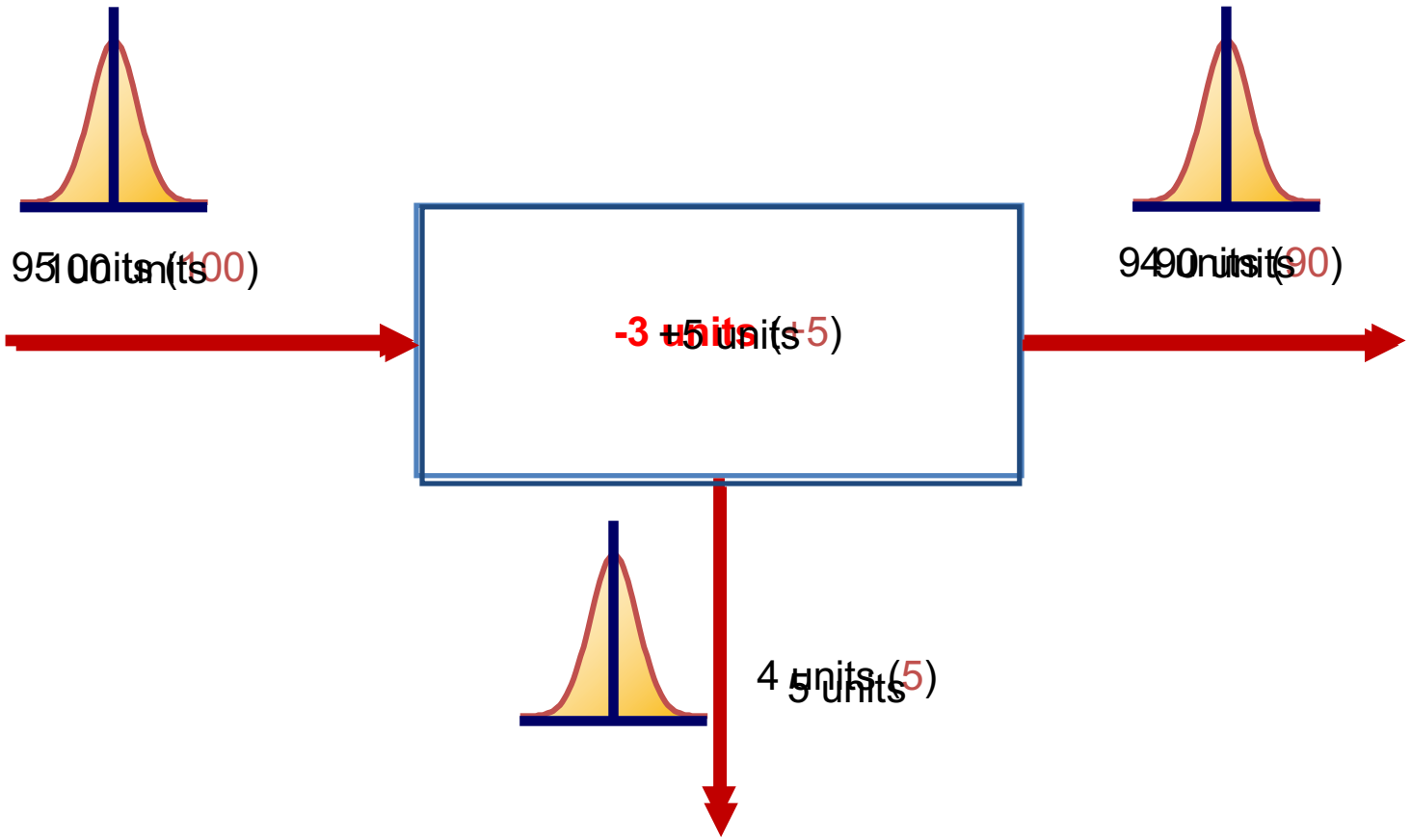
Concentrator	
Mean	2.991
Standard Deviation	0.100
Standard Error	0.018
Confidence Level(95.0%)	0.037
Min	2.954
Max	3.027



Mining	
Mean	3.071
Standard Deviation	0.153
Standard Error	0.049
Confidence Level(95.0%)	0.110
Min	2.961
Max	3.181

BOTH ARE RIGHT!

The “not so” - Basics



Code of Practice

- In the examples, we have seen issues related to:
  - Settlement
  - Negative Stock
  - Impact of Error
  - Accuracy & Precision
  - Confidence intervals
  - Data that needs to change
  - Commercial transaction risk
- Each has a direct impact on the financial statements of an organisation
- Requirement for accounting standards in metal accounting
- Code of Practise was commissioned

10 Principles (shortened)

1. Accurate & Precise Measurements
2. Data Management
3. Procedures
4. Audits & Risk Management
5. Reporting
6. Governance
7. Data validation, reconciliation & metal balance
8. Propagation of variance – Accuracies
9. Stock & Unaccounted losses/gains
10. Quality & Continuous Improvement

Principle 1:
Accurate & Precise Measurements

The metal accounting system must be based on
accurate and precise measurements
of mass & metal content.

To calculate metal content

$$Metal_t = Mass_t \times \%solids_t \times Assay_t$$

- $Metal_t$ = metal content over time period (t)
- $Mass_t$ = Gross mass of solids and water over time period (t)
- $\%solids_t$ = average % solids of the stream with $Mass_t$ over time period (t)
- $Assay_t$ = average metal assay of the stream with $Mass_t$ over time period (t)

Require:

- Accurate & precise measurement of the cumulative gross mass over time period *t*
- Sampling system to extract a representative sample from the main stream over the time period *t*
- Accurate & precise sample preparation system to determine the % solids in the sample
- Sample splitting system in order to prepare a representative sample for the chemical analysis
- Chemical analysis system which is accurate and precise

Identify possible sources of errors

Identify possible sources of errors

Identify possible sources of errors

Identify possible sources of errors

Identify possible sources of errors

Identify possible sources of errors

Audit System

Metal Accounting System Audit: Amira P754

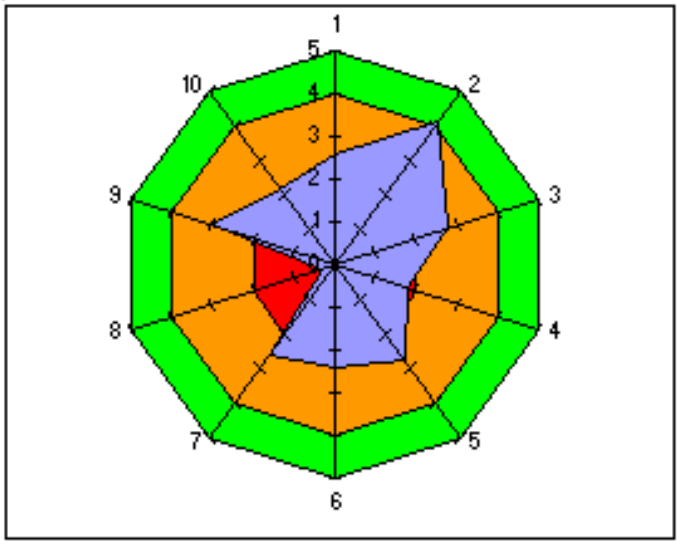
Client: **xxxx**
Division: **Division yyy**

Date: **2008-03-10**

Audit Team: Wynand van Dyk — Team Lead
Pieter de Villiers — Team Member

Division score sheet

Principle	Description	Score
1	Accurate & Precise Measurements	2.61
2	Data Management	4.12
3	Procedures	2.75
4	Audits & Risk Management	1.75
5	Reporting	2.74
6	Governance	2.44
7	Data Validation, reconciliation & metal balance	2.63
8	Propagation of Variance - Accuracies	0.29
9	Stock & Unaccounted Losses/Gains	3.00
10	Quality & Continuous Improvement	2.19
	Average Score	**2.45**



Notes to Scoring System:

0	No evidence of requirement
1	Some evidence of requirement, but mostly non-compliant
2	Some areas starting to comply with requirement - some major findings exist
3	Most areas comply with requirement - some **major** findings still exist
4	Most areas comply with requirement - some **minor** findings
5	All areas complying with requirement - clear benchmark

The detail…

Metal Accounting Audit System

Principle 3: Procedures

Definition:

The accounting procedures must be well documented and user friendly for easy application by plant personnel, to avoid the system becoming dependent on one person. The procedures must incorporate controls and audit trails. Calculation procedures must comply with the requirements set out in the Code; they must be consistent at all times and must include clear rules for handling data.

Ref	No	Question	Finding	Score/5
1.8.2.1	1	Weighing, sampling & analytical procedures must be drawn up in line with **international standard procedures** (eg ISO 9002)		1.00
1.8.2.5	2	**Sample preparation** procedures must be in place to avoid the risk of sample contamination		4.00
1.8.2.5	3	Clear **sample handling procedures** must be in place to avoid a sample being inadvertently substituted for another		3.00
1.8.2.6	4	Procedures exist for **stock estimation**		5.00
1.8.2.7	5	Standard calculation procedures must be defined for **metal recoveries**, based on full Check In-Check Out system		5.00
1.8.2.8	6	Procedures for **reviewing data**, in order to eliminate illegitimate or biased entries from the metal accounting database must be established		3.00
1.8.3	7	Defined procedures in place to **deal with real losses of unknown nature** (theft, dust etc)		1.00

CEO Requirements

Principles of System

- Common across the business in South Africa and London
- Web based and accessible from any internal web location
- Architecture that allows for easy storage, search and retrieval of information.
  - Common data warehouse
  - One version of the truth
  - Single point entry of data
- Quality control at source
  - Eliminate spreadsheets as repository
  - Eliminate data re-entry and manipulation

EBIT Requirements

Practical Issues

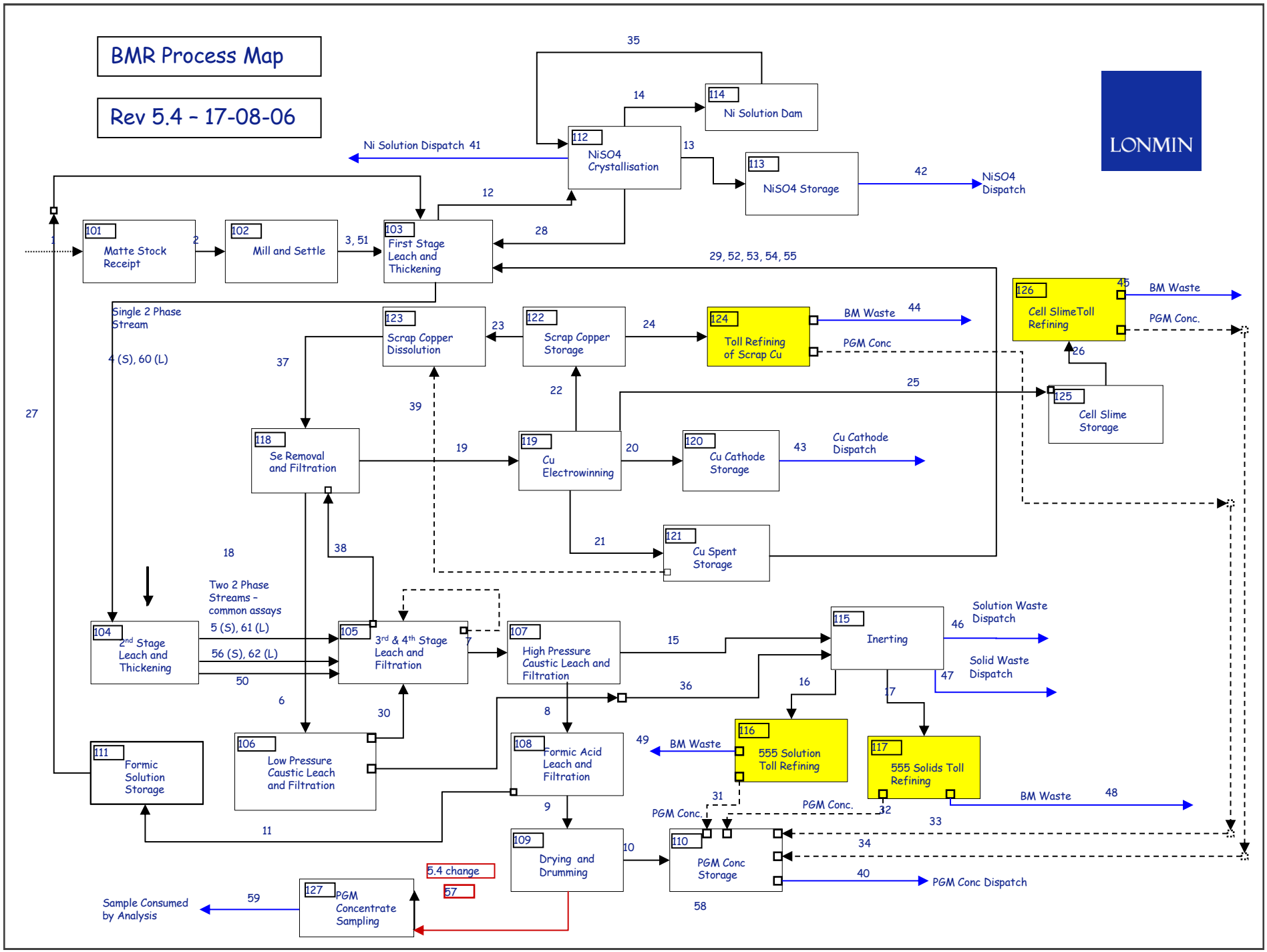
- Deal with various material types such as ore, dry solids, slurries, filter cakes, concentrate and final metal, including salts and ingots
- Capable of adding a new stream (inputs & outputs) at any point within the value chain to cater for new acquisitions and tolling properties

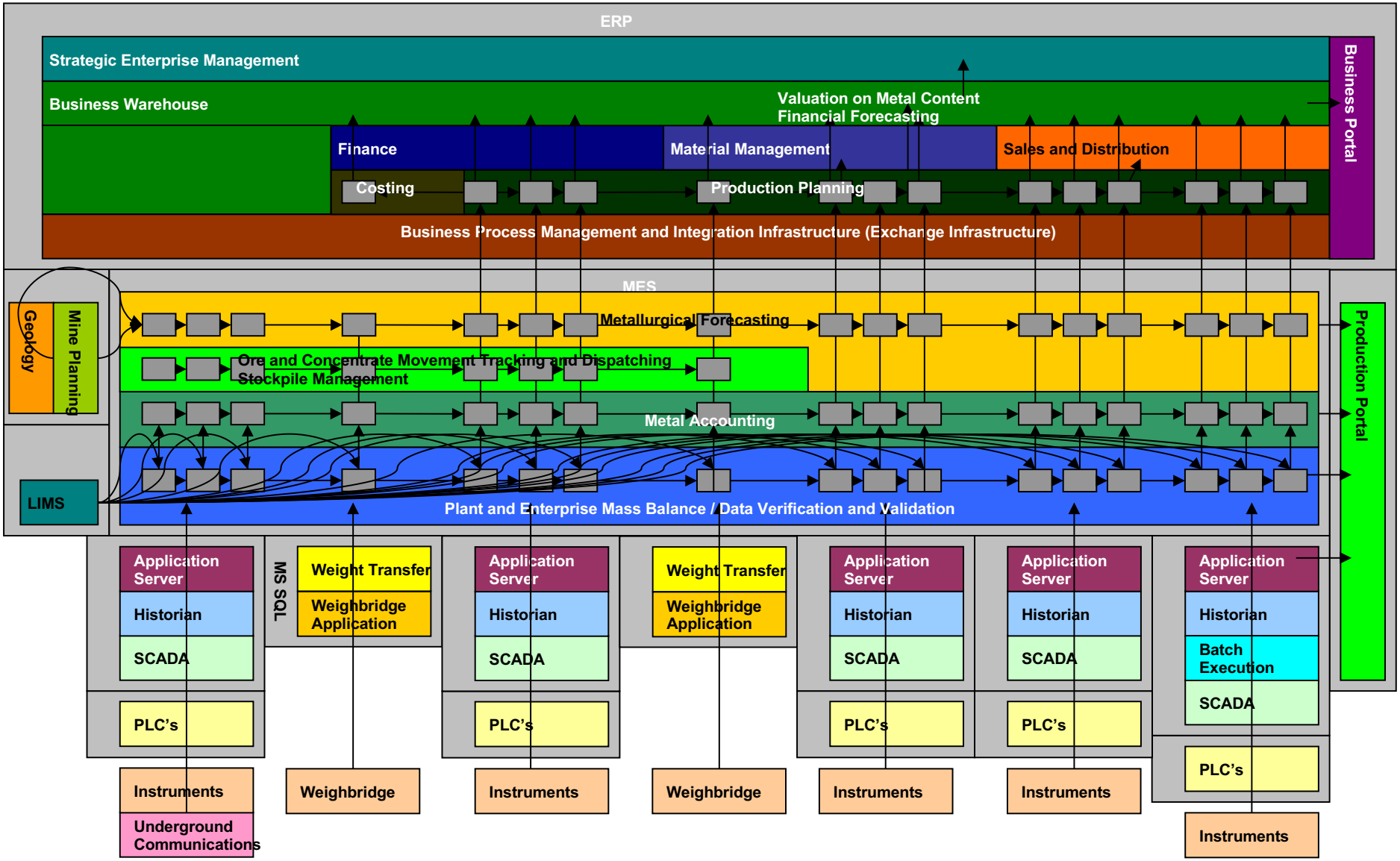
Metal Accounting

- Deal with transactional data from material movements such as tankers, concentrate, pure metals etc.

“Intelligence”

- Capable of doing real time mass balancing for smoothed multiple components
- Must have modeling and probability capabilities (P numbers)


BMR Process Map
Rev 5.4 – 17-08-06
LONMIN
101 Matte Stock Receipt
102 Mill and Settle
103 First Stage Leach and Thickening
104 2nd Stage Leach and Thickening
105 3rd & 4th Stage Leach and Filtration
106 Low Pressure Caustic Leach and Filtration
107 High Pressure Caustic Leach and Filtration
108 Formic Acid Leach and Filtration
109 Drying and Drumming
110 PGM Conc Storage
111 Formic Solution Storage
112 NiSO4 Crystallisation
113 NiSO4 Storage
114 Ni Solution Dam
115 Inerting
116 555 Solution Toll Refining
117 555 Solids Toll Refining
118 Se Removal and Filtration
119 Cu Electrowinning
120 Cu Cathode Storage
121 Cu Spent Storage
122 Scrap Copper Storage
123 Scrap Copper Dissolution
124 Toll Refining of Scrap Cu
125 Cell Slime Storage
126 Cell SlimeToll Refining
127 PGM Concentrate Sampling
Ni Solution Dispatch 41
NiSO4 Dispatch
Single 2 Phase Stream
4 (S), 60 (L)
Two 2 Phase Streams – common assays
5 (S), 61 (L)
56 (S), 62 (L)
50
29, 52, 53, 54, 55
BM Waste
PGM Conc.
PGM Conc
Cu Cathode Dispatch
Solution Waste Dispatch
Solid Waste Dispatch
BM Waste
PGM Conc.
PGM Conc.
PGM Conc Dispatch
5.4 change
Sample Consumed by Analysis

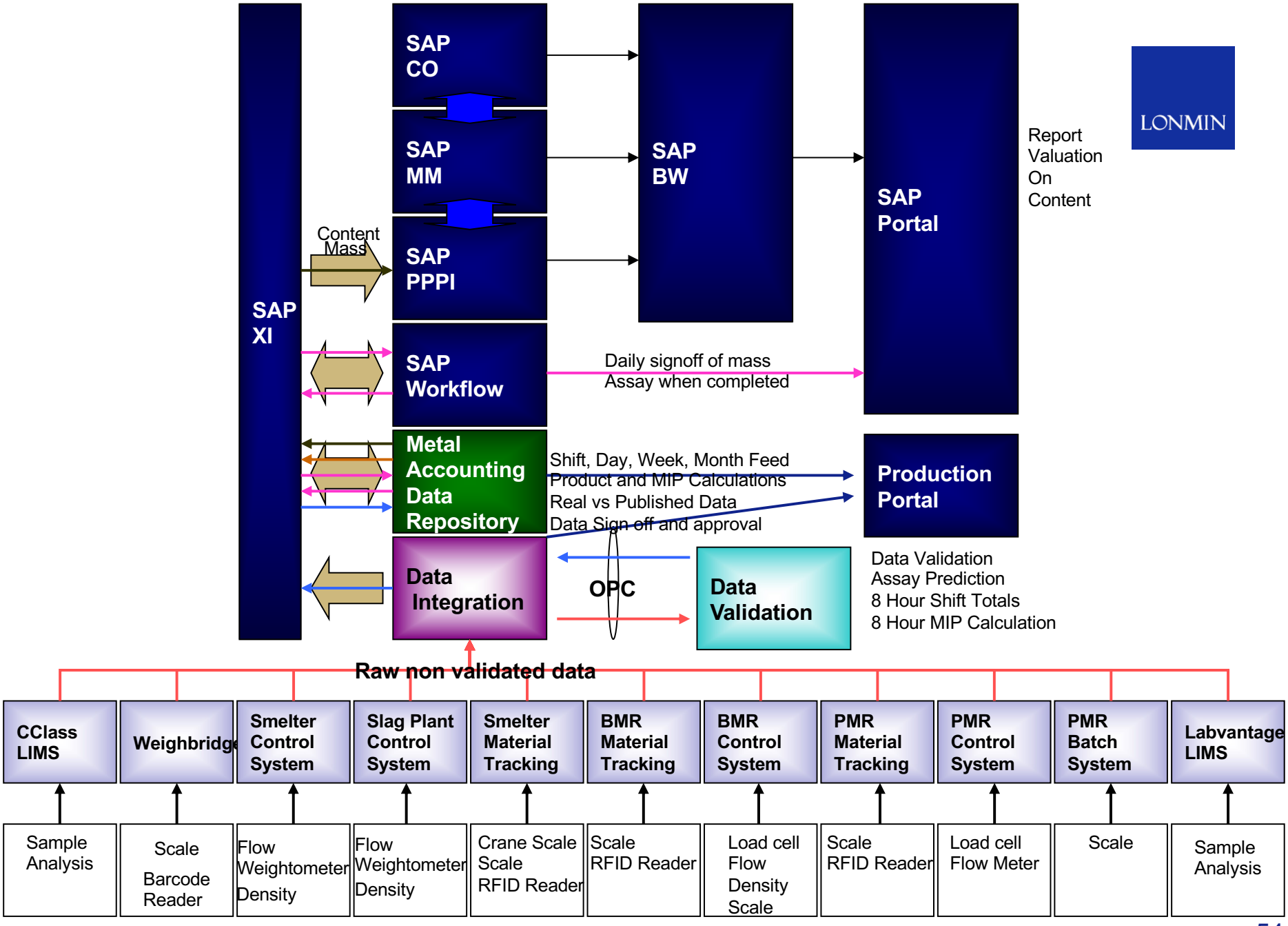

ERP
Strategic Enterprise Management
Business Warehouse
Valuation on Metal Content
Financial Forecasting
Business Portal
Finance
Material Management
Sales and Distribution
Costing
Production Planning
Business Process Management and Integration Infrastructure (Exchange Infrastructure)
MES
Geology
Mine Planning
Metallurgical Forecasting
Ore and Concentrate Movement Tracking and Dispatching
Stockpile Management
Metal Accounting
LIMS
Plant and Enterprise Mass Balance / Data Verification and Validation
Production Portal
Application Server
Historian
SCADA
PLC's
MS SQL
Weight Transfer
Weighbridge Application
Batch Execution
Instruments
Underground Communications
Weighbridge
Mine
Ore TPT
Concentrators
Concentrate TPT
Smelter
BMR
PMR

Options

- Bespoke application
  - “+” Can be developed to fit exact business requirement
  - “-” Duration for implementation
  - “-” Reliance on Developers and their relevant skill level
  - “-” Not necessary aligned with Metal Accounting Best Practice or Industry Standard
  - “-” Support and Maintenance Costly
- New MES product
  - “+” Can also be configured and developed to fit exact business requirement
  - “+” Maintenance and support from single Vendor
  - “+” Aligned with international MES (Not Mining) standards
  - “-” Duration of Implementation
  - “-” Reliance on MES (not Mining) Consultants and their relevant skill and experience
  - “-” Have to develop ad-on functionality to support Metal Accounting Standards
  - “-” Additional development not standard and becomes a maintenance and support risk

Option Selected

- Best of Breed integrated with existing applications using Service Orientated Architecture (SOA)
  - “+” Aligned with Metal accounting and Industry Standards
  - “+” Incorporates Metal Accounting best practices
  - “+” Short Implementation Duration
  - “+” Use SOA standards for Integration
  - “+” Standard based Integration with existing plant and other applications
  - “-” Multi Product Multi Vendor environment introduce the following challenges:
  - “-” Implementation Methodology – Forced to use Iterative rather than Waterfall implementation methodology
  - “-” Integration both Technical as well as Project Teams
  - “-” Support and Maintenance – Multi Products


SAP CO
SAP MM
SAP PPPI
SAP BW
SAP Portal
Report Valuation On Content
LONMIN
SAP XI
Content Mass
SAP Workflow
Daily signoff of mass Assay when completed
Metal Accounting Data Repository
Shift, Day, Week, Month Feed
Product and MIP Calculations
Real vs Published Data
Data Sign off and approval
Production Portal
Data Integration
OPC
Data Validation
Data Validation
Assay Prediction
8 Hour Shift Totals
8 Hour MIP Calculation
Raw non validated data
CClass LIMS
Weighbridge
Smelter Control System
Slag Plant Control System
Smelter Material Tracking
BMR Material Tracking
BMR Control System
PMR Material Tracking
PMR Control System
PMR Batch System
Labvantage LIMS
Sample Analysis
Scale
Barcode Reader
Flow
Weightometer
Density
Flow
Weightometer
Density
Crane Scale
Scale
RFID Reader
Scale
RFID Reader
Load cell
Flow
Density
Scale
Scale
RFID Reader
Load cell
Flow Meter
Scale
Sample Analysis

Key Success Factors

- Backing from CEO
  - Create the burning platform
  - Who owns this process?
- SOA route
  - “Best of breed” integrated into solution
- Organisational Maturity
  - People
  - Mindset change – key instrument going down = no production!
- IT infrastructure
  - Dual redundancy
  - Understanding of “real time” concept
- Unique project management approach
  - IT route (management by committee)
  - Committed to outcome – rates based