Methodology & Technology in the mining sector's digital transformation and DSS implementation

1) Abstract –

This paper will describe the benefits of utilizing the decision support system, DSS to support the methodology of structured decision-making in the mining environment. It will outline the layers of the mining related decision making –

a. Creation of "one truth" situational awareness utilizing existing planning, ERP, operational and monitoring agents,
b. Expressing plan verse performance across mining phases and functions compared with the actual and trends to evaluate performance.
c. Creating alternate courses of action and the implications up and downstream.

It will review the current condition were although a multitude of technologies resolve multi variable issues they do not interact in a way that assists decision makers throughout the organization in making high-quality decisions that will push the overall performance envelope.

The paper will show the benefits of integrating military methodologies to resolve multi variable complexed issues (operational, financial and other), operating in changing environments in order to meet time sensitive objectives with restricted resources. This is achieved by creating a shared situational awareness thru incorporating information from a multitude of data generating agents, creating COA, selecting the appropriate and turning it into a plan. The paper will discuss the implementation and suggest a path.

2) General –

The mining industry follows the overall digitization trend. It is manifested in multiple forms such as planning, monitoring, automation (including autonomous components such as trucks and drones)6, ERP, control and so on. The development of digitized tools derives from:

a) Grassroot problem solving innovation, SME solving issues they run into mimicking the workflow they previously used.
b) Technology companies identifying the potential market and attempting to generate revenue by incorporating their OTS products.
c) OEM attempting to improve their existing products and provide costumers additional benefit as well as create a stronger hold on the client.
d) Technology coming of age.
e) Major players in the mining industry innovation centers that fall in the categories mentioned above.

Though mining industry leadership embraced digitization, it is my opinion that by looking at the current status it's obvious that they don't lead the effort in a deliberate direction with a clear objective and compass. The visible driver is "Are we utilizing technology to its fullest?" (The CEO of a large mining outfit at projects review). Maximizing on the use of technology regardless of the driver is a beneficial to the operation, is generally a good thing and the

more of it we do, the better, but the vast amount of data generated reaches a threshold that where even if it supports the local phase in the mining value chain it doesn't materialize its full potential in contribute to the overall bottom-line.
I make the following assumptions:

a) Digitization creates vast amount of transferable data.
b) Data is used to allow for better decision making that will support better overall performance at the bottom-line.
c) Structured decision-making process sometimes fails, non-structured decision-making process sometimes succeeds.
d) Regardless of industry decision making methodology is universal and scalable.
e) Applying decision-making methodologies coupled with available and continuously emerging (deliberate and random) technologies creates a power-multiplier that opens an infinite number of opportunities.

As I am, by training, well versed in the military decision-making methodology and have successfully made the transition to management rolls in mining I find it applicable in the mining sector. The current evolution of militaries across the world differs in many aspects but all agree that decision-making process is a key to success and invest significant effort in developing methodology, tools, and the decision-makers themselves. No leadership / executive program in any of the leading companies comes close to the multi-level training military personal at the same level receive and I have yet to see a mining outfit apply decision making process and tools that come close to the ones the military apply.

3) A methodology of structured decision-making process:
   a) The decision-making methodology deals with the process that ends in a decision that allows the execution body to meats the validated objective (as objectives may and will change along the timeline) in a cost-effective way. The methodology also addresses the economics of the decision in the macro rather than the micro. Even-though time is a crucial factor timeline will change according to the circumstances.

      The methodology lays out the path from current state to achieving the objective by asserting that in order to arrive at the objective there is a need to understand as many aspects of the objective as possible such as time, cost, location and so on including a good understanding of the obstacle and opportunities along the path from our current state to the objective. This phase is referred to as Situational Awareness or SA.

   b) The decision-making methodology acknowledges and addresses limitations such as:
      I. In linear process (such as mining) any decision made at any point along the value chain carries an impact both up and downstream. The impact may either support the bottom-line (opportunity) or jeopardize it (risk).
      II. Time is a major factor in any decision made.
      III. All decisions are made based on limited (best-known) information and assessment of the situation. The threshold of what constitutes best-known

information is a part of the methodology under the topic of how much effort we take to obtain information before deciding.

IV. The limit of resources and capacity.
V. The ability to comprehend and respond in time (by altering or not altering the plan) to changing circumstances.
VI. The human compatibility to the tasks (physical conditions, ability to operate in varying stress levels, personality, mental condition and cognitive capacity).
VII. The team's conviction and cohesiveness (as very little is done by one person alone).
VIII. The capacity of the individuals in the team to perform to the fullest of their job description and contribute to obtaining the objective.
IX. The conflict of focusing on a set mission and getting it don "come hell or high waters" verses understanding the overall picture and questioning the validity of the task and its contribution to the intent.

c) The decision-making process, is based on the following principals:
   I. That all its actions derive from a higher echelon (Policy level) objectives and intent. The intent pushed top to bottom in the form desired outcome, High level considerations and Guidelines for planning – the criteria for success.
   II. That the organization's hierarchy role is to provide its higher echelon with leverage, multiple options, alternative courses of action (COA) and best estimate of the end-result (state) - cost and consequences to all effected in the planning phase.
   III. That once events start to unfold a process of observe, orient, decide and act (OODA) loop is set in motion understanding that time & changing environment become additional factors.
   IV. That decisions are made in adherence to set principals / best practices / guidelines.
   V. That all echelons use the same protocol in transparency (the lower level will be exposed to the objectives of at least two levels up) where the key question is "how do I support the upper echelon's objectives?".
   VI. Conveying an Intent – the intent is described in the phrase "in order to" both in, why am I giving you this objective, an insight into the higher echelon's considerations and his objectives. This description precedes the objective and comes before the description of the current situation and applies to all levels.
   VII. Conveying the desired outcome (more than the objective),
   VIII. Providing guidelines for planning,

d) Although there is more than one characterization of the decision-making process, I picked the following for the benefit of this paper. The process includes the following nine steps:
   I. Triger – identification of deviation from plan (in any direction) or conditions.

II. Receive, study and understand the objective as defined by the upper echelon – the criteria for success.
III. Obtain situational Awareness
IV. Create a list of tasks to obtain success (from end to beginning)
V. Set guidelines and success criteria for the COA
VI. Create COA 1,2,3
VII. Compare and select COA
VIII. Develop the selected COA to a plan
IX. Implement the plan. This step includes the Observe, Orient, Decide Act continuous loop.

a. Decision-making steps at all levels are –
   I. Creation of "one truth", a **shared situational awareness** utilizing existing planning, ERP, operational and monitoring agents and tools. Even the lowest level decision when brought into the overall decision-making process, may yield a different outcome than a phase stand alone decision.
   II. Expressing plan verse performance across mining phases and functions compared with the actual and trends to evaluate performance.
   III. Creating alternate courses of action and the implications up and downstream.
   IV. Evaluating the options according to guidelines and taking a decision.

This process is a combination of actions taken along a timeline, both linier and circular. It includes an evaluation and action process that starts with an intent and ends with the completion of a task that is usually the start of the next task.

4) Decision support system, DSS.

Decision support systems, a system of system - from the pencil and paper to AI and machine-learning, are designed to imitate the cognitive action of decision-making. They were developed to address complexed situations that a single person is not capable of by opening collection and analyses bottlenecks in the transformation of data into insight (shared Situational awareness) driven decision. In many operations, even though a multitude of components are digitized (ERP, certain operating systems, planning tools and so on) the overall decisions are made in ether siloed or semi siloed environments, to combine local data and insights that has not reached the required level of maturity and using inadequate tools in forums that are not effective for decision making. Even if most of the data is non-biased its correlation is hand produced, hard to integrate and rarely allows simulation.

Decision Support System, DSS, are the digitized manifestation of the decision-making process. In extreme situations such as aviation and military (onboard collision avoidance systems and some air defense systems) they are full autonomous as they react to an

identified threat (according to guidelines) on their own, AI based on set rules and algorithms. More commonly, military AI is used as a recommending tool reducing the rate of human fatigue-induced errors, workload and time to push raw data to SA level. In some cases AI will recommend a preferred COA based on the shared SA. The mining industry employs some low-level autonomous functions such as autonomous trucks, drowns, QC systems and so on. In a multi-player complexed environment, DSS provide a situational awareness, identifying threats and opportunities, visualizing, assisting in constructing and selecting COA (thru simulation of different approaches rather than optimization) and assist in forming and de-bugging the selected COA into a full plan. In addition, they act as the **one** platform that **all** stakeholders interact with (feed to and from and maintain its relevance). It is an overall system of systems. Although, DSS serve central Command & Control (C&C) central functions such as strategic decision-making (just due to the nature of a digitized system), it allows decentralization of decision making by providing the tactical level with strategic considerations allowing them to support them at the local level. It achieves this without jeopardizing data integration, collaboration, transparency, the quality and integrity of the decision-making process to ensure the best decision is made at every level to support the overall intent (however it's defined).

An important element for success is the data common denominator integration (source to DSS):

a. Data push intervals – it is important that the reporting intervals are relevant to the creation of the shared SA (and not necessarily what the tool currently outputs).
b. Time – calibrated time.
c. X,Y,Z location.
d. Capacity units – volume / weight / units
e. Action type – transport / transform / other
f. Action energy consumption / time unit.
g. Action value benchmark (where possible).
h. Reading accuracy.

5) Applicability of DSS to the mining industry.

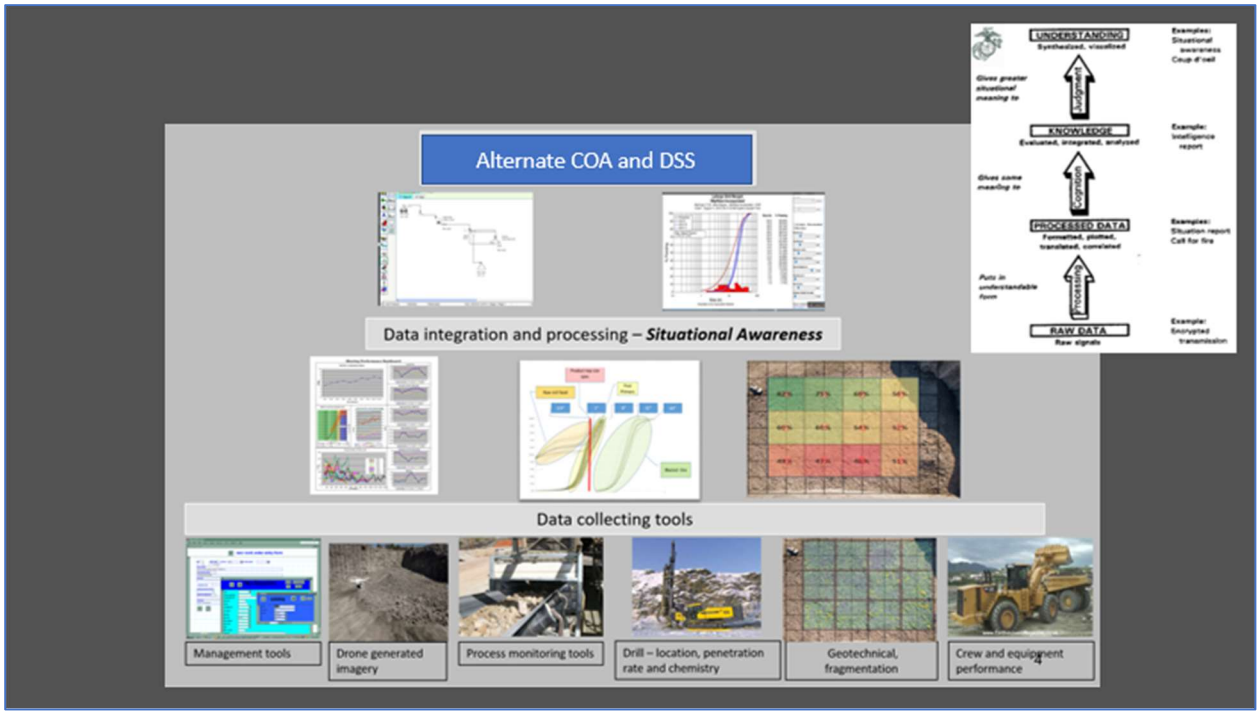
The mining industry, from pit to gate, regardless of the state of the ore at the gate (cement, gold, coal and so on) is a linear process. It is comprised of phases where resources are applied to the ore to maximize its value at the gate. Since each phase on its own carries a high level of complexity that turns it into a semi-independent unit. In most situations it is managed by and independent budget therefore becoming an entity of its own even if driven by operational and quality targets and KPI. Many seemingly low-level actions that are within that phase's operating environment have a compounding effect on upstream & downstream phases and on the gate cost (measurable by applying wave modeling

algorithms). Many of the basic components of the DSS are embedded in the mining phases workflow already in the form of monitoring setting targets and analyses. The similarities in structural and the requirements of the military and mining disciplines can be found in:

a) Goal (financial / operational outcome) orientation.
b) Complexed working environment.
c) Multi semi-independent phase structure.
d) Multi-stakeholder solutions.
e) Linear process with major media (state of events in the military discipline ore phase change in the mining discipline) transformation rate from one phase to the other.
f) Changing conditions at any point of the process have an upstream and downstream impact.

Due to the mentioned similarities and to my experience in implementation it is, of course not possible to “copy paste” but the benefits of implementation of the DSS and the methodology brings major advantages.

As can be seen in the following the information hierarchy of the mining DSS follows the format of the military decision-making process and based on data accumulates and analyzed using digitized tools.



The main challenges in the adaptation process are overcoming the methodological gap and disseminating the intent down to the boots on the ground level.

6) Gap analyses –

The definition of gap analyses for the benefit of this paper is referred to as the gap between the implementation of decision-making methodology and the use of tools (DSS) versus siloed decision-making. It should be said that all organizations, from the smallest "mom and pop" operation to the largest international corporations, have some sort of "inhouse" methodology (from the "8 ball" to different levels of stress tests). The gap analyses should deal with the level of integration and the dissemination of a single decision-making process on a shared platform throughout the organization. It looks more at the culture of decision-making uniformity, the level of insight / shared situational awareness across the organization and the collaboration with the tools.

a. Current condition - Although a multitude of technologies resolve multi variable issues they do not interact in a way that assists decision makers throughout the organization in making high-quality decisions. Very little collaboration exists between tools operating in different phases and spheres today. In addition, those tools:
   I. Are at a different level of maturity,
   II. That outputs raw data, processed data or knowledge without considering the need to collaborate with other sources.
   III. Are not capable of becoming the "one platform".
   IV. Do not adhere to a methodology of structured decision making beyond the tactical / technical level.
   V. Some tools overlap in some aspects but have unique features as well. It is impossible to combine these tools as more often than non the developers perceive themselves as competitors and would allow integration or migration of features leaving the user with the need to choose one over the other.
   VI. Are not true Decision Support Systems.
   VII. Are entering the mining sector in a very high rate.

Partial SA generators -

It should be mentioned at this point, without mentioning names, that a multitude of partial SA generators are entering the market at this point in the fields of ERP, surveying, blasting performance, maintenance to name a few. Most of those systems are an evolution of the "grassroot" tools and are a "power multiplier" in the sense that they provide analyzed data and an extended view and limited data correlation – the corner stones of SA. They are very powerful segmented tools. However, due to their nature (purpose, architecture and narrow scope) they don't inherently poses the ability to collaborate with other platforms and meet the required criteria to be or be a part of a

true single enterprise DSS platform. In addition, they are, in most cases, attached to a single brand / product line / service provider and serve them exclusively. They do not serve their competition, therefor when changing the vendor, you lose or must change your platform. This serves as a limiting factor in more than one way,

I. After investing money in setting this system up are hesitant to change the equipment / service provider even if their performance is not at the level of the competitor.
II. The organization is used to the tool and making the change is a major event for the organization.

These factors limit the organization's options on the financial and operational levels.

b. Methodology benchmark – the gap between current typical decision making and digitized structured decision-making process is measured by a set of challenges (partial list):
   I. What is my condition? (Single platform, shared SA, integrated insight and COA creation and evaluation throughout the organization).
   II. How accurate and relevant are my operating assumptions and the shared situational awareness?
   III. What are the risks and opportunities downstream, upstream and to my phase (quantified)?
   IV. Am I aware of all the functions I am impacting?
   V. Do I have an ongoing process of evaluation, or do I evaluate when we only when we identify an abnormality?
c. Technical considerations – digitization has a very big impact in this sphere as it is responsible for physical aspect of gathering data, managing events (tactical, operational, planning and so on) and creating varying levels of shared SA. The gap is measured by:
   I. Are we tapping into all the relevant and required data sources?
   II. How much data are we able to obtain?
   III. How many activities are we able to perform digitally and how much of these activities are we able to digitize and to what level?
   IV. How many of the data sources are we able to correlate (by percentage)?
   V. Do we have a decision-making "one platform" that:
      (1) Is accessible to all?
      (2) That enables us to use the correct correlations.
      (3) That has the right logic in place.
      (4) That transforms data to insight correctly.

7) Conclusions

a. Very little was discussed in this paper about digitization itself as the technical part and the tools are evolving and finding their way into the field for the reasons we have already explained. Its what we do with the deliverables and how we utilize the digitization product that will make the big impact. The physical tools are available and functioning in many cases (from ERP, equipment monitoring, planning tools, surveying and so on).
b. Digitization is a tool serving the decision-making process. In order to maximize the benefits of this process the organization needs to adopt a methodological decision-making process and then adopt a cross organization DSS.
c. There is great benefit in low resolution local or single phase / department or even partial digitization islands to the users.
d. All digitization needs to adhere to the DSS requirements.

8) Recommendations

The overall recommendation consists of three spheres, the first, adopt a uniform decision-making methodology & process throughout the organization, the second, apply as many digitized tools at as many points of the operation and the third, integrate a DSS to enhance the decision-making methodology & process and maximize the digitized tools contribution to allow hi-quality decisions. The value of the digitized tools throughout the operation is greater than their sum if working **together** under a robust decision-making methodology and so will be their contribution. Some recommendations include:

a. Install a unified decision-making process throughout the organization top to bottom.
b. Review all local resolution tools, identify the integration points that will serve a DSS and ensure the key criteria can be exported and expressed (manipulated, correlated and visualized).
c. Ensure all future digitization ventures are capable of multi-level integration including multiple COA capability.
d. Since the integration of segmented tools is already underway leadership's main task is to initiate an organization-wide effort to apply the decision-making methodology to be followed by a DSS implementation.
e. Some tips for the implementation process:
    I. The highest management level should lead this effort as it touches the core of the organization's culture.
    II. Invite a decision-making Subject Matter Expert (SME)to join in at the road mapping level. As the military discipline has elevated this process to a science a good source for this SME profile can be found in high level officers that are graduates of Staff & Command collages (preferably armored or infantry [some of them already consulting in this sphere]). Even if they are not versed in mining operations they will be well acquainted, theoretically and hands on experience, with the level of the

operation's complexity and the correlation between the tactical, operational and strategic spheres and will be quick to adopt.

III. This type of cultural change is best implemented by the organization's leadership and not by consultants (even though the top leadership should bring some outside SME as stated in item II).

IV. The use of DSS at all levels serves the C suit as it will bring overall contribution to the bottom-line. Since at least at the beginning, lower-level management might see this more as a nuisance, as it is a cultural change, it's imperative that it reveals its benefit to them from the get-go.

V. The "mission control center" approach is not the pivotal point of the DSS, the emphasis is on creating and disseminating the SA, sharing COA and making the right decision at the right time.

VI. The available technology (C4I [Command& Control, Computing, Communication and Information]) allows this process (item V) to happen in real / near-real time and ensure the decision loop is closed in time to achieve an affective outcome supporting the bottom-line and that is the approach that should act as the goal of digitization.

VII. The DSS platform, ither of the shelf product or tailor made should be based on an independent platform that will act as a backbone of the process even if components or sub-components will change (due to commercial / financial or operational reasons).

9) Closing notes

This paper came to emphasize the importance of the relationship between technology, namely digitization, the methodology of structured decision-making. Following the military methodology for both aspects come natural to me as I possess intimate knowledge of both worlds and that of course, makes me bias and yet my extensive in mining operations leads me to believe this approach is well founded. As the military invested great efforts in dealing with the relations between methodology of war and technology it seems that a duality approach has emerged. "Let's utilize up and coming technology to support our goals & change some of our methodologies accordingly" and "lets initiate development of technologies to support our methodology". Neither appearance of the radio, the plane (prop, then jet then UAV), the nuclear submarine or aircraft carrier changed the 11 Clausewitzian principals of war (or Sen Tzu's for that matter). They did, however, make dramatic methodology changes as to how those principals are applied. All those great tools should come together under one platform, the DSS.