

# **The Evolution and Current Status of Process Safety Management Metrics within DuPont**

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## **ABSTRACT**

*A broad, consistent set of PSM metrics and leading indicators is important to effectively manage process safety and prevent incidents, help ensure regulatory compliance, meet internal policies, and verify that adequate management attention and resources are allotted to meet program needs. This paper will review the development, current state and future focus areas associated with the use of process safety metrics and leading indicators within The DuPont Company as a global manufacturing organization at a site, business and corporate level. This includes a historical perspective of past metrics and their technical basis with a primary focus on incident classification and audit results, a review of recent improvements involving an expanded group of current metrics, and a general discussion of forwarding looking additional improvements. An overview of lessons learned, guidance, and challenges involving the development and use of process safety metrics and indicators within a global enterprise will also be provided.*

## **1. Background on DuPont**

DuPont is a global science based product and services company that operationally is organized around five main business platforms, each with several groupings of businesses, which serve over 200,000 customers worldwide with annual revenues of \$30 billion. Founded in 1802, the company operates at more than 175 manufacturing sites in 70 countries involving 64,000 employees.

DuPont operates many different manufacturing technologies involving both higher hazard processes and lower hazard operations (predominantly mechanical systems) which are

segmented into five global businesses as illustrated in Figure 1. Manufacturing technologies, products, and associated process safety hazards vary widely including the following examples:

- Chemical Solutions Enterprise (e.g., oleum, aniline, sodium, cyanides, methylamines,)
- Engineering polymers (polyester and acetyl resins, glass laminating products)
- Agricultural products (e.g., herbicides, fungicides, insecticides)
- Fluoroproducts (e.g., refrigerants, electronic gases, fluoropolymer solutions)
- Performance Coatings and Color technology (e.g.; automotive paints and titanium dioxide)
- Advanced Fiber Systems (e.g., Tyvek®, Sontara) and Non-Wovens (e.g., Nomex®, Kevlar®)
- Electronics, Displays, Imaging technologies (electronic polymers, circuit material, LCD's, photo)
- Pioneer Seed (corn, soybeans, alfalfa) and Solae (soy protein technology food products)
- Surfaces (Corian® and solid surface materials)

Operations is also segmented into four worldwide regions including North America, Latin America, Europe, and Asia Pacific. Internal process safety systems and standards are applied uniformly to all of the four regions and manufacturing technologies worldwide through one set of corporate policies and procedures.

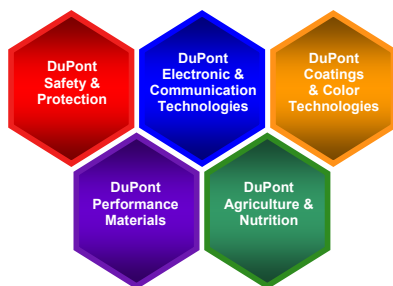


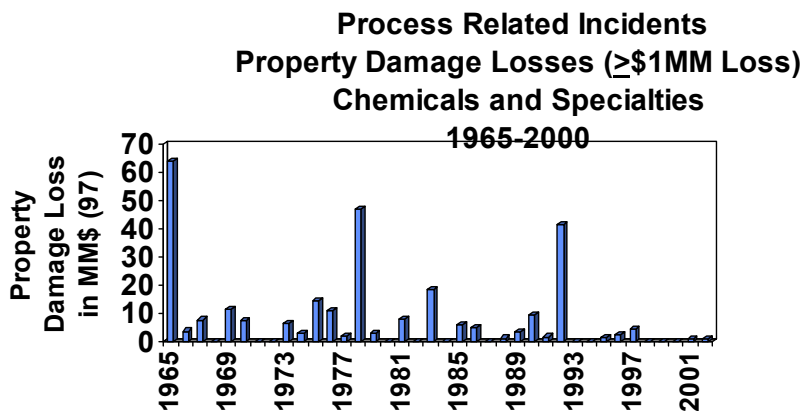
Figure 1: DuPont Global Business Platforms

The corporate structure for PSM relies on a small decentralized and matrixed global PSM competency team which has primary ownership and responsibility for internal standards, technical training, auditing, and internal initiatives. DuPont also maintains a small group of highly skilled PSM consultants within the corporate engineering group who provide complex PSM risk management support to sites and businesses such as QRA's, facility siting, project support, and complex PHA facilitation, however, the company's basic PSM model and philosophy is to develop PSM related knowledge and skills within the manufacturing site line organization and local support functions (operations, maintenance, technical, and R&D).

## 2. PSM Metrics – The Early Stages (pre- 1990)

Prior to 1990, DuPont's principle data collection and process safety metrics focused on serious process safety incidents, fatalities and lost workday injury cases, and large (financial) property losses due to fires, explosions, and toxic releases. Figure 2 provides a limited example of these summary data. Use of this approach originated in the late 1960's as a result of a major incident which occurred at the DuPont Louisville Works involving twelve fatalities and approximately

\$50 million in damages as a result of a series of explosions which started in a compressor handling mono vinyl acetylene.



PSM2

Figure 2: Property Damage Losses due to PSM Incidents (1965-2000)  
(Source: Arthur F. Burk, DuPont)

### 3. PSM Metrics – Decade of the 1990's

DuPont's initial set of PSM incident metrics from earlier years expanded significantly in the 1990's as a result of two significant program improvements which included:

- 1) Development and implementation of a global second (2<sup>nd</sup>) party process safety auditing program which tracked audit results based on cumulative scores as well as individual scores for each PSM element commencing in 1992.
- 2) Development and implementation of a global PSM internal incident classification and reporting process for significant and moderate severity events commencing in 1995.

More information on both of these internal practices will be discussed in Section 3 of this paper. These initial data enabled a broad review of annual serious incident performance, as well as a summary and basic trend analysis of audit results. These data were initially collected using paper reports and collated manually. Figure 3 provides an example of a chart tracking the number of significant incidents versus an annual summary of audit score averages.

These summary data were reviewed annually with senior operations leadership and were analyzed in more detail to identify improvement opportunities, need for additional training, and enhancements to existing internal policies and requirements.

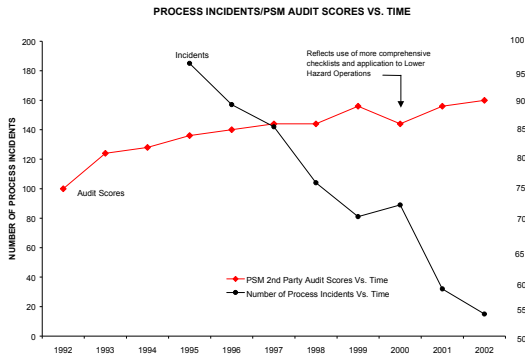


Figure 1: PSM incidents versus 2<sup>nd</sup> party audit score averages 1992- 2002  
(Source: Arthur F. Burk, DuPont)

#### 4. PSM Metrics – 2000 to present

Within the past seven years, DuPont has expanded the internal focus and capabilities to track a more extensive set of process safety metrics and program performance indicators. Each of these indicators will be described in more detail in the following sections.

##### 4.1 Process Safety Incidents

DuPont currently utilizes a detailed PSM incident classification and reporting policy based on incident severity which provides an ongoing lagging metric for year over year PSM incident performance. The incident classification process requires sites to evaluate and score all PSM incidents on a standardized scale of 10- 230 points; the final score determines relative severity and internal reporting and communication requirements.

The current scoring architecture includes an evaluation and summation of ten (10) components for each incident. These components include the following:

- Type of event and material released (flammability, combustibility, toxicity)
- Actual quantity (size) of release
- Potential quantity (size) of release
- Degree of control by site during incident
- Involvement and functionality of lines of defense/layers of protection
- Actual on site impact (injuries, emergency response, evacuation)
- Potential on site impact
- Actual off site impact (injuries, shelter in place, agency reporting, media attention)
- Potential off site impact
- Actual monetary loss associated with the incident

Each incident is evaluated and scored by the site line organization and the final score dictates overall classification as described below. There are also “automatic” classification triggers for specific Category A events (e.g., a fatality, multiple lost work day injury cases, off-site impact, or total costs exceeding \$1 million are automatic Category A events regardless of score)

Classification	Description	Internal Reporting
Category A PSM incident (130 points or more)	The most significant class of PSM incident which typically involves major on-site and/or off-site impacts	Corporate reporting to the CEO and corporate SHE organization within 24 hours of classification
Category B PSM incident (75-125 points)	A moderate to high severity PSM incident which typically has a significant on-site impact	Corporate reporting to the SHE organization within 72 hours of classification
Category C PSM incident (70 points or less)	A low to moderate severity PSM incident or near miss which has limited or no impact on site and is used primarily for trend analysis	Reporting into a global electronic incident tracking database after the formal investigation is complete.

Table 1: DuPont process safety incident classification and reporting criteria

All Category A and B incidents are currently included as business and site performance metrics. Higher level Category C incidents (50-70 points) have historically been used primarily for trend analysis in order to identify additional leveraged improvement opportunities across the corporation (for example, revisions to internal standards and guidance, additional technical training, improved or leveraged tools, etc)

Commencing in June 2004, DuPont initiated use of an existing electronic database for recordable injury and illness statistics to report and capture process safety incidents. This database was not specifically designed to manage PSM incident elements, however it did enable expanded trend analysis for a larger data set of events where the type of incident can be sorted based on the following attributes:

- Type of incident (fire, explosion, loss of containment, etc)
- Status of process at time of incident (start-up, normal, shutdown, etc)
- Element(s) of PSM involved which need strengthening
- Element(s) of Operational Discipline involved which need strengthening
- General types of process equipment involved
- Costs associated with the incident

Figure 4 below provides a historical trend on the number of significant process safety incidents within DuPont (Category A and B incidents) for the previous twelve years.

In addition to incidents, DuPont also maintains an annual process safety Total Recordable Rate (TRR) metric which includes a frequency rate for all recordable injuries caused directly by process safety sources such as chemical exposures, burns, and similar events. These data are a small subset of the total recordable injury rates for all types of injuries and illnesses across the company and it includes data for both employees and contractors on a global basis.

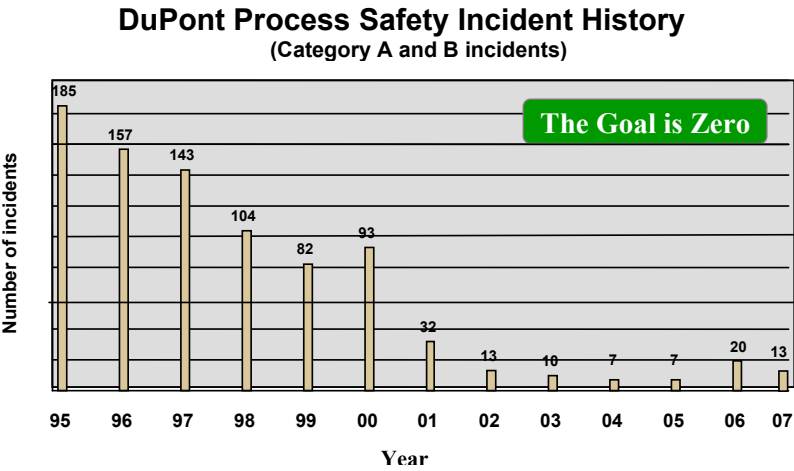


Figure 4: Twelve year global incident trend (Category A and B PSM incidents)

4.2 Process Safety Audits

DuPont has developed and maintains a global second (2<sup>nd</sup>) party PSM auditing process to periodically evaluate PSM systems and performance at all manufacturing locations. A standard set of audit attributes (protocols and checklists) are utilized based on internal requirements and standards. The audit checklist contains approximately 300 questions across fifteen PSM elements. DuPont conducts approximately seventy-five (75) 2<sup>nd</sup> party PSM audits each year across all four regions. A 2<sup>nd</sup> party audit is defined as a formal independent review conducted by trained DuPont personnel who are not assigned to the site subject to the audit using established protocols. 2<sup>nd</sup> party audits are scheduled by each operating region and tracked using an internal scheduling database. A typical audit involves 4 ½ days with a minimum of two experienced auditors. Completed audit reports and all individual audit recommendations are generated and entered into a central database using commercial software for tracking, closure, semi-annual reporting, and trend analysis (data mining).

Each 2<sup>nd</sup> party PSM audit is scored by the audit team on a scale of 0-100%. This generates a composite score for the entire audit, as well as individual scores for each of the fifteen PSM elements. PSM audit scores are collected and compiled within each region and summarized for trend analysis to identify further broad based improvement areas. Figure 5 provides an example of PSM audit scores in the North America region for the past three years across all process safety elements. The audit process includes all existing higher hazard and lower hazard manufacturing locations, including recent acquisitions and joint ventures where DuPont has a majority ownership.

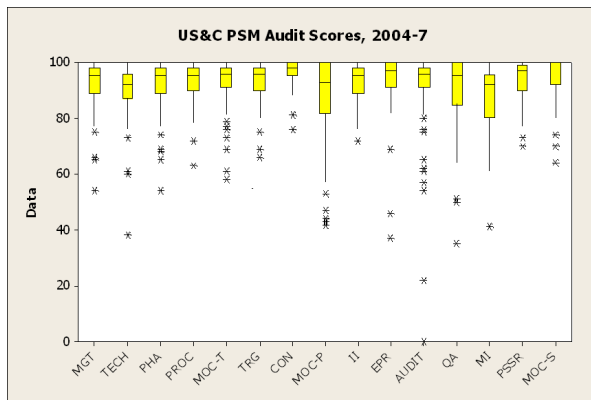


Figure 5 – PSM 2<sup>nd</sup> party audit scores in US and Canada Region  
(Source: James A. Klein, DuPont NA PSM Consultant)

#### 4.3 Site Based and Corporate Quarterly PSM Metrics

In late 2006, DuPont adopted a revised internal policy involving the collection and reporting of a series of standard PSM metrics every quarter for each of the 175 global manufacturing locations. This includes reporting on the following indicators:

- Number of Category A/B/C PSM incidents
- Number of open and overdue first party PSM Audit recommendations
- Number of open and overdue second party PSM Audit recommendations
- Number of scheduled, open, and overdue cyclic PHA's
- Number of open and overdue PHA recommendations
- Number of open and overdue PSM incident recommendations
- Number of overdue Operating Procedure revisions (three year schedule)
- Number of overdue Mechanical Integrity tests and inspections (psm critical equipment)
- Total number of PSM action items with approved extensions by site leadership

These metrics are reported by each site at the end of each quarter and posted in a central database where they are displayed within the DuPont PSM intranet website. Nine data elements are entered into an excel spreadsheet by each operating unit and site, and may be sorted, summed, and displayed at the enterprise, business platform, business unit, regional, and site level. DuPont currently does not maintain a global integrated tracking system for these data, so individual sites are expected to implement local electronic or manual data management systems to track and generate these metrics as part of the site PSM management system.

A key input to these data involves creating a standard set of definitions for each metric which is important to help ensure consistency and provide guidance to all site personnel. These definitions have been developed, communicated to all sites, and are also posted on the internal DuPont PSM website.

Figure 6 illustrates the format and content for the global PSM metrics spreadsheet which is used to generate quarterly status reports. Data may be sorted by site, business, platform and region. Quarterly and annual trend analysis (figure 7) may also be generated to assess aggregate data (open and overdue items) across various entities within the organization.

4Q 2007 Process Safety Management Performance Metrics																				
Color code	Required for H&P's, recommended for L&H's per S2A, Section 5.5	PSM Incidents Year to Date			# Incident Investigation Back		# BESAs		# PSHA Back		# for P&P PSM Audit Back		# for P&P PSM Audit Back		# Operating Procedures on 3y review revision		# M&I tests and inspections for PSM's equipment		# PSM's and action items with approved extensions based on S2A, Section 5.5.1 and Table 2	
Color code	Required for both H&P's and L&H's per S2A, Section 5.5	A	B	C	Open	Overdue	Sat'd	Open	Overdue	Open	Overdue	Open	Overdue	Open	Overdue	Open	Overdue	Platform metric	Platform metric	
Region Business Platform																				
EMEA Region Total																				
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70	EMEA																			
71	EMEA																			
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Figure 6: DuPont Global Quarterly PSM Metrics Reporting Spreadsheet

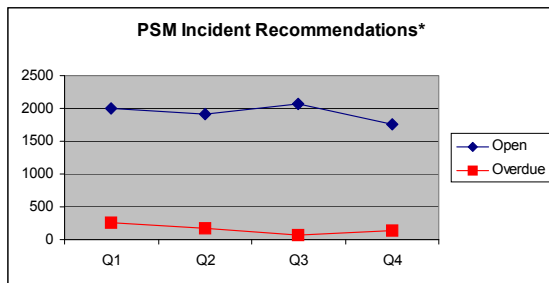


Figure 7: Example of Global Tracking for PSM Incident Recommendations

In addition to these nine quarterly metrics which are reported globally, additional process safety metrics are required within each site for tracking and reporting at the local level only and are reviewed during 2<sup>nd</sup> party PSM audits. These metrics include the following:

- Personnel (operations and mechanical) skill based refresher training/re-qualifications
- Open and overdue MOC- Technology recommendations and trials
- Open and overdue PSSR recommendations
- Status of MOC – Personnel 90-day competency demonstrations
- Number of open corrective actions or work orders from completed MI tests/inspections
- Open and overdue emergency response drill critique recommendations



#### 4.4 Global PSM Critical Operating Tasks

DuPont maintains a global PSM competency team comprised of key PSM related resources from central functions as well as each of the four operating regions. This team has overall accountability for internal PSM standards, training and development, auditing, and PSM managing systems. The team develops and publishes a set of formal critical operating tasks each year which are periodically reviewed with senior leadership. A final report on the results and accomplishments involving formal goals and objectives is distributed at year end.

Certain critical operating tasks may also lend themselves to a set of one-time indicators or “sub-metrics” which demonstrate completion of a broad based but specific objective. For example, this may include updating of site wide facility siting studies, leadership PSM visits to plant sites, or enhancements involving design reviews and analysis of safety instrumented systems for existing processes as part of cyclic process hazards analyses. These completed goals and objectives activities may also be considered as non routine performance indicators and reported with other traditional metrics for a give time period.

#### 4.5 PSM Related Internal Standards

DuPont has developed and maintains a series of detailed internal standards and policies which provide general and prescriptive requirements for process safety at all sites. Currently, there are twelve (12) specific PSM standards involving technology, facilities or personnel. These PSM standards are periodically reviewed and revised based on internal or external key learnings, or at a minimum every five years. Tracking the progress and updating of these standards is also considered a PSM program performance indicator.

#### 4.6 Changes in Key PSM Personnel

DuPont maintains a decentralized and matrixed approach involving technical personnel who lead and develop PSM related programs and provide risk management subject matter expertise and consultations. These groups include the following:

- A global PSM competency team involving fifteen (15) individuals representing regions, business platforms, and key technical or leveraged functions.
- Eight (8) technology sub-teams who provide guidance on various PSM elements such as PHA's, mechanical integrity, incident investigation, etc which have responsibility for internal technical training, standards, new strategies, and “best practices”.
- Twenty-two(22) highly toxic material technology teams that are comprised of a leader and site representatives who handle or manufacture highly toxic materials such as chlorine, phosgene, oleum, anhydrous HF, titanium tetrachloride, etc
- A small group of highly skilled and trained process safety consultants and subject matter experts within DuPont Engineering including the process safety and fire group, explosions hazards laboratory, safety instrumented systems competency, and reliability engineering resources.

In all, the sixty-plus leaders and members of these PSM technical teams comprise the core of DuPont's internal process safety and risk management structure and delivery system, including some of the most experienced resources in the corporation beyond those assigned to individual

plant locations. DuPont tracks turnover and transitions across this group of key roles as a higher level metric in order to analyze long term trends in experience and capabilities (e.g., individuals with less than 2 years, 2-5 years, and greater than 5 years of experience in current process safety related roles)

#### 4.7 Third Party PSM Related Assessments

DuPont receives PSM inputs and evaluations from two external third party sources in addition to internal evaluations and metrics. This includes an annual third party audit of our internal second party audit program and an external third party review of the Responsible Care Management System (RCMS) as part of the company's public commitment and membership in the American Chemistry Council. These reviews, while not specifically focused on metrics and performance indicators, do provide an annual independent analysis of corporate and regional performance against internal standards and procedures.

The third party review of Safety Health and Environmental audit programs is conducted each year and includes an analysis of corporate process safety auditing results, a periodic review of each region and key business audit performance and reports, and 3<sup>rd</sup> party participation on a small number of representative second party audits. The third party auditor evaluates internal audit systems and performance against ten key audit system elements and provides a numerical measure for each item listed below.

- Explicit Top Management Support
- Program and Auditor Independence
- Appropriate audit team staffing
- Defined Audit Program objectives and Scope
- Adequate program resources
- Audit Frequency based on Risk
- Appropriate Audit process
- Documentation of Audit findings
- Resolution of Corrective actions
- Appropriate Quality Assurance Measures

Table 2 provides a sample schedule for 3<sup>rd</sup> party audit reviews across each operating region and business. The results of 3<sup>rd</sup> party Audit program reviews are reviewed with DuPont executive leadership and posted on the DuPont internet for public access and review each year.

Region or Business	2004	2005	2006	2007	2008	2009
<b>US/Canada</b>	✓		✓			✓
<b>Europe</b>		✓		✓		
<b>Asia Pacific</b>	✓		✓			✓
<b>Latin America</b>		✓			✓	
<b>Pioneer</b>	✓		✓			✓
<b>Solae</b>		✓			✓	
<b>Oversight Audits</b>	6	6	6	4	6	6

Table 2: Schedule for 3<sup>rd</sup> Party Reviews - DuPont SHE Audit Programs (Source: Larry Cahill, ERM)

## 5. Key Points and Limitations with Metrics

A combination of real time, broad based leading and lagging PSM metrics is critical to measure the overall “health” and functionality of the process safety risk management program on an ongoing basis both in a general or macro level within the corporation and with enough specificity within sites and regions to enable targeted improvement actions.

As a first step, senior leadership must establish clear expectations and ground rules for metrics, including timely and accurate reporting, and the development of processes to ensure routine leadership review of metrics and performance indicators, both to recognize and celebrate strong performance and accomplishments as well as institute interventions, where necessary.

In a large enterprise, the approach to measure performance needs to be consistent over time yet flexible enough to address organization changes and updated process safety policies that occur (restructuring, acquisitions and divestitures, new plant site construction, new requirements, etc)

Metrics data collection and reporting systems should be as simple and easy to use as possible so that sites and businesses can access and update the data quickly and focus on the status of PSM improvements rather than expend resources on data entry and statistical compilations; use of an easily accessible and “transparent” information technology data collection and analysis system enhances the use of PSM metrics significantly.

Metrics do have specific limitations which must be recognized across the organization and are better addressed as part of a thorough site based process safety audit. These include:

- 1) Metrics cannot measure the specific quality of risk management work activities and decision making (for example, one can track timely completion of incident investigation reports and closure of recommendations, but this alone does not help ensure the overall quality and completeness of the investigation recommendations and the supporting root cause failure analysis).
- 2) Metrics do not measure or guarantee the quality and completeness of actions taken to address recommendations or other improvement actions to achieve closure. Actions to achieve closure based on locally assigned targets must be balanced and not take precedence over achieving the intended risk reduction or mitigation outcomes.
- 3) Metrics alone cannot provide an absolute assurance of preventing high consequence, low probability catastrophic events (explosions, fires, or uncontrolled chemical reactions).

## 6. Summary

Dr. Edward Deming emphasized many concepts in his works involving the “seven deadly diseases of management”, including the philosophy that one cannot run a company on visible figures (data) alone since some things that are important can’t be measured. This has validity to process safety in terms of core values, commitment, and the intrinsic behaviors of individuals, from the operator and mechanic on the shop floor handling hydrogen cyanide, through senior operations and business management. While it is exceedingly difficult to measure certain intangibles, DuPont’s

current set of PSM metrics have been and will continue to evolve over time to serve as a suite of indicators on the internal “state of PSM” associated with all hazardous manufacturing processes.

Current PSM metrics provide a global picture on status, performance, and progress over time for sites, businesses, regions, and the corporation. Table 3 summarizes each of these current metrics.

Metric	Elements	Type
PSM Incidents	<ul style="list-style-type: none"><li>• Type (severity) – Category A/B/C incidents and annual trends</li><li>• Elements of PSM and Operational Discipline involved which need Strengthening</li><li>• Other incident factors (type of event, equipment, substances, costs)</li><li>• PSM related injury rates (annual Total Recordable Rate)</li></ul>	Lagging
2 <sup>nd</sup> Party PSM Auditing	<ul style="list-style-type: none"><li>• Audits completed versus scheduled (%)</li><li>• Audit reports finalized and issued per internal timelines</li><li>• Audit scores for each PSM element</li><li>• Types of audit findings and trends (data mining)</li><li>• Status of audit recommendations(open and overdue)</li><li>• Special focus audits -Highly Toxic Materials handling</li><li>• 3<sup>rd</sup> party annual review results</li></ul>	Leading
Site, Business, Regional PSM metrics	<ul style="list-style-type: none"><li>• Quarterly reporting of PSM metrics on nine key elements for all sites, businesses and regions (open, overdue and extended action items)</li></ul>	Leading
Annual PSM Critical Operating Tasks	<ul style="list-style-type: none"><li>• Review, analysis and reporting results of annual Global and Regional PSM Competency Critical Operating Tasks</li></ul>	Leading
Update/Revisions to global PSM Standards	<ul style="list-style-type: none"><li>• Status of updates/revision to global PSM related internal standards and policies</li></ul>	Leading
Changes within Key PSM Personnel	<ul style="list-style-type: none"><li>• Changes and experience levels of “top 60” PSM resources (central function, PSM competency team, regions and platforms)</li></ul>	Leading

Table 3: Summary of Current PSM Metrics across DuPont

DuPont’s PSM leadership model as described in Figure 8 highlights the foundational role that leadership must provide and maintain to achieve strong and consistent results, including establishing a culture of “the goal is zero”, strong operational discipline(OD), adequate resources, and setting accountabilities for performance. This approach, in concert with DuPont’s process safety model involving fourteen technical elements, provides a strong framework for managing PSM on a day-to-day basis at all global sites. The performance metrics above complement these technical elements and provides ongoing leading and lagging indicators to demonstrate the overall quality of implementation in a visible and sustainable manner.

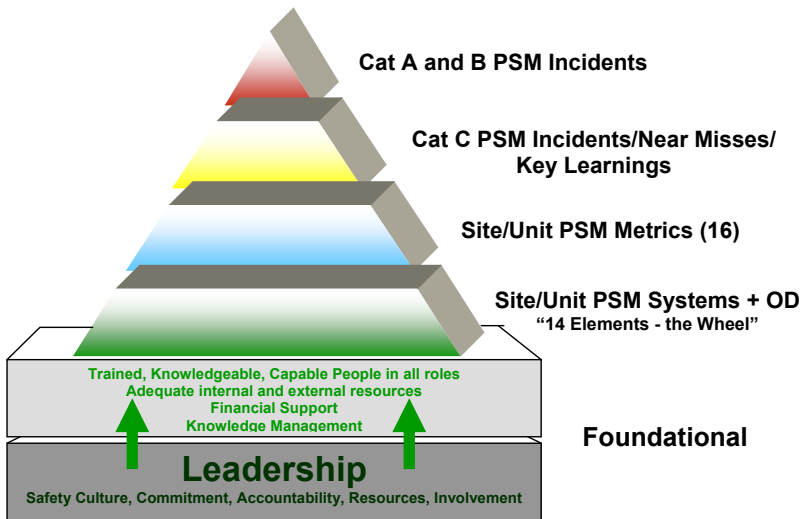


Figure 8: DuPont PSM Leadership and Performance Model

## 7. Future Focus areas involving process safety metrics and performance

Development, collection, and use of PSM leading and lagging metrics should be an evolving and dynamic process over time as organizations, systems, and stakeholder expectations change. Collection of metrics and review of performance trends must be used to strengthen the existing programs and ultimately ensure that high quality risk management decisions are maintained within each business and across each generation of operations personnel at all levels. Additional areas of consideration involving process safety metrics and performance indicators within DuPont include the following areas:

- Development of broad based metrics with focus on training and development to monitor PSM skills and capabilities across various manufacturing and technical organizations (a measure of “organizational capacity” and resourcing to maintain high quality PSM performance).
- Consideration of improved measures to assess Operational Discipline (OD) and Felt Leadership.
- Full integration of PSM metrics and results (both leading and lagging) into annual HR performance review cycles for line management.
- Development and use of a global integrated web-based central data collection and management system for PSM and SHE activities, including workflow management tools for process safety elements.

- Completion of annual reviews on the “State of PSM” within each of the five major business platforms to analyze performance indicators and results by senior operations and business management.
- Designing and conducting additional voice of the customer and PSM perception surveys to solicit further areas of improvement and focus.