DESIGN INTEGRITY AND OPERATIONAL SAFETY OPTIMIZATION
TECHNIQUES

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ABSTRACT
This paper discusses the concepts and methodologies employed in the Technical Integrity Framework (TIF) that is being globally adopted and proven effective for the identification and control of major accident hazards in the petrochemical and hydrocarbon (oil and gas) industries.

The TIF introduced in this paper is comprised of two consecutive pillars: First, Asset Integrity, which is the initial state for establishing technical integrity early and proactively during the design stages – by focusing efforts on identifying potential risks to process safety and setting proper controls (as process safety requirements [PSR]) to preemptively manage these risks. Risk identification and management techniques include the Hazard Effect and Management Process (HEMP). Controls to meet PSR include adopting the proper design concepts, i.e. inherently safe design, specifying performance standards and operating envelopes for the safety critical elements (SCEs). Asset Integrity, in this context, is perceived as all the design integrity assurance practices.

Process Safety is the second pillar of the TIF, where the efforts are directed toward sustaining and safeguarding the Asset Integrity standards throughout the lifecycle of the assets. The goal is to ensure operational safety, and the assurance tasks to reach this goal include HSE case development, focused asset integrity reviews, monitoring performance of SCEs, and assessment and continuous improvement of the entire TIF. Techniques to conduct these tasks efficiently will also be discussed in this paper.

Keywords: Inherently Safe Design, Design Integrity Assurance, Major Accident Hazards, Asset Integrity, Process Safety, Safety Critical Elements, Technical Integrity.

INTRODUCTION
Hydrocarbon operations are hazardous in nature, whereby the likelihood of leaks and releases of toxic and flammable substances with potential damage to life, property, environment and/or operators’ reputation vary depending on the technical integrity (TI) measures taken to ensure that assets are being designed, operated, inspected and maintained in a way such that under normal operating conditions, operational risks are tolerable and controlled at a “as low as reasonably practicable (ALARP) limit.” To achieve this essential goal, major hydrocarbon operators adopt the Technical Integrity Framework (TIF) introduced in this paper as a tool.

SAUDI ARAMCO BUSINESS CASE
Saudi Aramco has embarked upon an Accelerated Transformation Program (ATP) to achieve its strategic intent to become the world’s leading integrated energy and chemicals company.
by 2020. A key initiative in the ATP is Operational Excellence (OE). OE has 13 Enabling Elements, one of which is Asset Management. Fundamental to the globally practiced and proven successful asset management models is the Asset Integrity Management System (AIMS) that leans on TIF as a core. Figure 1 shows the association/aggregation relationship between ATP, OE, asset management, AIMS and TIF that comprise Design Integrity and Operational Integrity as two main pillars of AIMS structure.

![Fig. 1 - ATP, OE, AIMS and TIF Relationship](image)

**OE History**

Internationally, the evolution of OE began by standardizing operational procedures and work processes to mitigate the risk of catastrophic failures (Figure 2). Later, these procedures and processes became formalized as legal and regulatory mandates by governments and industries, to prevent potential major accidents that result in fatalities, injuries, property and environmental damages, and value destruction. Eventually, these systems were further enhanced to be more standardized and the focus turned to competitiveness goals. This was when OE evolved from compliance driven systems to performance driven ones, focusing on operational efficiency and value creation. Realizing the benefits of standardized and programmatic implementation of OE related procedures and processes, companies enhanced them further and expanded their scope to integrate all OE focus areas required to sustain a competitive advantage. Indeed, the evolution of a formalized OE system within Saudi Aramco followed a similar pattern [1].

Saudi Aramco’s quest for OE is not new. In fact, it started decades ago and continues to be an important part of the company’s corporate values. The OE initiative builds on Saudi Aramco’s long-standing pursuit of excellence in many areas such as safety, health and
environment (HSE). OE encompasses these Focus Areas as well as others that are of central importance to the company’s success, such as reliability, efficiency, cost and profitability in addition to several enabling elements. Figure 3 (Saudi Aramco OE model) illustrates how the OE acts as an overarching umbrella for both the Focus Areas and Enabling Elements, providing a structured approach to achieve and sustain excellence [1].

**Aims in the Saudi ARAMCO OE Model**

Asset Management was introduced as one of the 13 Enabling Elements comprising OE (Figure 3). AIMS is a major pillar of the Asset Management element, intended to help ensure that Saudi Aramco facilities are designed, constructed and inspected for safety and integrity (early at the design phase), then, after handover to operations, operated within their operating envelopes, and maintained to preserve the design standards at all times, by competent personnel who will ensure that deviations are identified, measured and timely updated.
AIMS Specific Business Needs

An AIMS is needed to facilitate the alignment of the entire organization with the corporate strategic direction. Saudi Aramco AIMS provide clear core values, mission, strategy and objectives, roles and responsibilities to associate efforts of stakeholders to work together toward one common goal of no harm to people, asset value, the environment, or company reputation by managing the TI of Saudi Aramco operations. Specific needs for AIMS include:

I. A more efficient mechanism to identify TI risks and set proper mitigation controls among SA operations;
II. Integration and enhancement of existing standards, work processes and procedures related to Asset Integrity (as a means of optimizing efforts by avoiding duplications of work and bridging the gaps that live in gray areas between disciplines);
III. New Asset Integrity specific standards, guidelines and procedures;
IV. Consistent and standardized TI assessment methodologies;
V. Greater awareness of Asset Integrity risks and skills in the mitigation of those risks;
VI. An integrity-focused competency management system;
VII. System to review and report current status of TI, tracking exceedances and ensuring that proactive corrective actions are taken to mitigate the technical integrity risks and containing their consequences at a “as low as reasonably practicable (ALARP)” limit;
VIII. A document management system for Asset Integrity related information;
IX. A software system to aid in managing Asset Integrity; and
X. A standardized mechanism to assess the efficiency and effectiveness of AIMS so that associated continuous improvement efforts can be defined and executed accordingly.

AIMS Objectives and Outcomes (High-level)

I. Creating a sustainable culture of life-cycle asset integrity management practices across the entire organization;
II. Promoting awareness and sound work environment in which all Saudi Aramco employees share commitment to asset integrity management;
III. Empowering and fully engaging the entire workforce to make the shift from a reactive to a proactive mode of lifecycle integrity management;
IV. Establishing clear TI accountabilities, roles and responsibilities;
V. Improving communication and understanding of the prevention of asset integrity degradation across the entire organization;
VI. Being vigilant and (in timely manner) intervene, making decisions on the provision of the SA desired state of ALARP;
VII. Knowing which parts of SA assets are safety/environmentally critical and operate, inspect, and maintain these critical assets accordingly;
VIII. Designing and constructing SA assets to enable sustained technical safety and integrity throughout their lifecycle;
IX. Safeguarding TI through proper operation and maintenance of SCEs;
X. Developing integrity-related standards, procedures and work processes to enable a standardized implementation of TIF by each asset owner in an corporate-aligned and consistent manner;

XI. Integrating AIMS/TIF with systems and initiatives supporting asset management (e.g., maintenance and reliability)

XII. Proactively employing leading KPIs to report TI status for SCEs across the organization;

XIII. Improvement in safety and reliability performance by managing assets in accordance with global AIMS/TIF practices;

XIV. Utilizing state-of-the-art technologies to aid in AIMS/TIF; and

XV. Playing a leading role in promoting best practices to establishing and safeguarding asset integrity in the petrochemical and hydrocarbon industries.

TECHNICAL INTEGRITY DEFINITION

The TI of an asset is achieved when: Under specified operating conditions, the risk of failure that endangers the safety of personnel, the environment, asset value, or company reputation is tolerable and controlled to be ALARP.

This definition implies that the TI practices are typically focused toward the identification of SCEs, and setting the proper controls to prevent the failures of these SCEs or to mitigate the impacts of their failures to a limit that is ALARP. A TIF is needed to govern these activities and help achieve this goal.

Technical Integrity Framework (TIF)

Typically, and as practiced by many major hydrocarbon operators, an AIMS is governed by (or depends on) a TIF that is comprised of standards and methodologies for establishing the TI during the design phase, and then, safeguarding the TI during operate phase as follows:

I. **Asset Integrity**: Efforts to establish integrity during the design phase;

II. **Process Safety**: Efforts to safeguard integrity during the operation phase, including:

   a. Maintain design integrity;
   b. Inspect and re-establish integrity; and

III. Access and improve the TI assurance processes.

**Asset Integrity (1)** and **Process Safety (2)** are the two pillars comprising the TIF, while **Assessment and Improvement (3)** are the continuous efforts exerted in identifying TI related gaps, concluding gaps and tracking gap-closure recommendations to maintain the effectiveness of the entire TIF on both system and equipment levels.

Saudi Aramco TIF is neither conceptually, nor strategically different from other TIFs that are being adopted in the industry nowadays, and it is totally aligned with the following three work processes comprising the enabling element number four of the Saudi Aramco’s OE:

4.1 Design, Procurement and Construction;
4.2 Safe, Reliable, and Efficient Operations and Maintenance; and
4.3 Asset Monitoring and Continuous Improvements.
Technical Integrity Scope

An ideal AIMS with TIF should provide Operations with generic guidance to use for managing the integrity of the assets installed in their plants, including:

I. Physical integrity of wells, pipelines and facilities;
II. Inspection, maintenance, repair practices and procedures to prevent major accident hazards (MAHs);
III. Roles, responsibilities and competencies of personnel with asset integrity management roles; and
IV. Essential controlling documents.

Technical Integrity Management Process

Asset Integrity and Process Safety are inseparably linked, as both comprise the TI management process. Asset Integrity begins at the early design stages and continues until post-handover of assets to Operations, where Engineering defines integrity standards and design envelopes (based on operational safety cases). The goal is to establish TI by ensuring that assets are designed for safety and integrity as they proactively meet the PSRs.

Upon project handover to operations, process safety efforts are needed to complement the design integrity efforts, where Engineering provides Operations with guidance to safeguard the TI by means of operating SCEs within their operating envelopes, and adopting the most effective Inspection and Maintenance programs that help maintain the ALARP status for the remaining life of the assets. Figure 4 illustrates the TI management process.

![Fig. 4 -Technical Integrity (AI-PS) Management Process](image-url)
**TECHNICAL INTEGRITY STRATEGY**

Figure 5, below, illustrates a summary of a TI strategy (as typically practiced) to achieve a corporate ALARP goal in successive steps.

**Start Point**
Understand the threats to be managed

**Major Accident Hazards (MAH)**
HSE Case Management

- Develop HSE case; identify potential MAH e.g., structural failure (e.g., ship collision, mooring failure) or loss of containment (e.g., fire or explosion, toxic materials release or oil spill) and establish risk register

**Risk Assessment**

- Evaluate and prioritize the threads and escalation of events (e.g., use appropriate technique to assess risks; risk assessment is the first part of the HEMP)

**Management Strategy & Risk Reduction**

- Manage risks: Strategies include inherent safety, MAH prevention, control, mitigation, and recovery e.g. design successive berths form threats to events escalation control (second part of the HEMP)

**Selection of Safety Critical Elements (SCEs)**

- Identify SCEs (these are parts of a plant/facility, failure of which could cause a major accident, or function of which is to mitigate the impact of a major accident)

**Performance Standards’ Development**

- For all SCEs identified, specify functional goals, required performance, and acceptance criteria with Pass/Fail values.

**Technical Integrity Assurance (Tasks Management)**

- Use Performance Standards to control all tasks and efforts intended to sustain TI of SCEs (e.g., inspection, operation, maintenance, and TI reviews)

**Technical Integrity Verification**

- Independent audit of the asset integrity reviews against performance standards, conclude technical integrity status concludes for SCEs and TI barriers

**Technical Integrity (Mgt. System) Review & Update**

- Review the entire TI Management System to ensure its robustness in delivering the overall major hazard identification and mitigation controls, and then to improve as required.

Fig. 5 - Technical Integrity Strategy
The following sections will provide detailed guidance to the implementation of the TI process steps as illustrated in Figure 5.

**Major Accident Hazards (MAH) Management**

By HSE-UK definition; offshore installations (safety case) regulations 2005 that came into force on April 6, 2006[2]. Major accidents are events that have the potential to lead to multiple fatalities and/or major environmental damage and include hazards such as:

I. A release of hydrocarbons that could lead to fires or explosions;
II. A release of hazardous or toxic materials, e.g., H2S;
III. Major damage to the structural integrity of an installation, e.g. dropped objects, collision of ship, helicopter, road or rail tanker with the installation;
IV. An event involving loss of stability of the installation, e.g. failure of the mooring system;
V. An event involving major subsidence. For onshore installations, this may be either to the installation itself, or to adjacent property;
VI. Failure of diving life support systems, or detachment of a diving bell or a subsea diving chamber; and
VII. Other accidents including health issues that may lead to multiple fatalities and/or major environmental damage.

**HSE Case Definition**

An HSE case (also called a safety case) is a structured argument that presents evidence to demonstrate that a system is as safe as reasonably practicable [3]. An HSE case aim is to show that specific safety claims are met, providing proofs that the risks are identified and kept ALARP, consequently, the facility or operation in question is safe to operate since that:

I. Hazards, effects and threats have been identified;
II. Risks of hazardous events have been assessed;
III. Controls or barriers to prevent or mitigate impacts of the release of identified/assessed hazards are in place; and
IV. Emergency response and recovery plans are in place.

For operators working in Europe and overseas, developing a formal HSE case is a prerequisite for acquiring a “License-to-Operate” form from the concerned governmental safety and environmental protection agencies. That is not the case for Saudi Aramco, which is a self-regulating organization and its (indefinite) “License-to-Operate” is already granted by the government. As a result, such HSE case legislation does not currently exist.

Saudi Aramco recognizes the importance of developing an HSE case and perceives it as a pragmatic mandate necessary to protect lives, the environment, maintain competency of its employees, and reduce the risk of lost production; therefore, a corporate (operational) HSE case is being developed to demonstrate that Saudi Aramco assets are safe to operate.
HSE Case Development Process

An ultimate aim of an HSE case is to provide the proof that the risks to operational safety are identified and kept ALARP. Providing such a proof implies that the TI strategy (as illustrated in Figure 5) is conducted in full at all operating facilities of an organization. Corporate HSE case development requires that each operating facility develops its own HSE case in a way such that individual HSE cases can be compiled to produce a corporate HSE case. A typical HSE case can be developed in the following structure [3, 4]:

I. Introduction;
II. Facilities Description;
III. HSEQ Management System;
IV. Formal Safety Assessment;
V. Emergency Response;
VI. Risk Reduction Plan; and
VII. Conclusion and Statement of Fitness for Purpose.

An original HSE case should ideally be developed throughout the design, construction, and commissioning and submitted as part of the readiness for operation documentation upon project handover to Operations.

Risk Assessment

Essentially, the risk assessment process provides a careful examination and calculation of potential hazards that could result in harm to people, assets, environment or company reputation. A typical risk assessment process may include the following steps [5, 6]:

I. Identify the hazard (defined as any situation that has the potential to cause harm to people, asset, environment, or company reputation);
II. Determine the risk (using the product of "probability * consequence" formula);
III. Evaluate the risk, and then decide whether the existing precautions/controls are adequate, or whether more control measures are still needed;
IV. Keep record of your findings, and maintain weighing them against the risk control measures in place and the control measures that are required by the regulatory bodies;
V. Based on the above, implement the appropriate control strategies;
VI. Following the implementation of control strategies, keep revising risk, control strategies and make changes as necessary; and
VII. Conduct a new risk assessment following any significant changes or an incident.

Using Table 1 (Risk Assessment Matrix) [7], risk levels can be allocated based on probability and consequences may be better assessed by using the following formula: Risk = Consequence (severity of impact from an event) * Probability (likelihood of event occurring).
Table 1 - Risk Assessment Matrix

<table>
<thead>
<tr>
<th>Hazards</th>
<th>Probability (likelihood of event occurring)</th>
<th>Severity of Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>Has happened more than once per year at the Location (5)</td>
<td>Has happened at the Location or more than once per year in Company (4)</td>
</tr>
<tr>
<td>Environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reputation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Management Strategy and Risk Reduction

One of the risk management strategies that is widely practiced and is proven to be successful depends on a technical integrity barrier (TIB) to prevent or mitigate the escalation of major hazards events. Shell EP, based on their depiction of the Swiss-Cheese model, originally created their TIB (as shown in Figure 6). This model was then made publicly available by the UK Energy Institute [5, 6] (upon a publication agreement with Shell EP). As a result of this publication agreement, the TIB model became known on a global scale and was applied by many major oil and gas operators.

From Shell’s standpoint, risk assessment is the process of evaluating and prioritizing the threads, escalation of events, and the consequent management strategy and risk reduction strategies that include inherent safety, prevention, control, mitigation and recovery measures. These practices/tasks are typically conducted early at the design stage (to establish technical integrity) and termed as HEMP.

During the operation stage, focused asset integrity reviews (FAIRs) must be conducted to reevaluate the effectiveness of the original HEMP. Conducting FAIR during operations may lead to identifying more SCEs or SCE components and more importantly: FAIR during operations help determine whether the original risk mitigations that are initially taken during the design are sufficient to maintain the design integrity and preserve the ALARP status.

If FAIR revealed overlooked risks or insufficient controls to mitigate the consequences of identified risks, then HEMP is required to preserve the ALARP status. In such a manner, updating the Safety Case/Risk Register is a must.

HEMP

The Hazard and Effects Management Process (HEMP) is an essential process that addresses the effective control of major accident hazards (MAHs) and risks identified in HSE cases.
HEMP also underpins the data and information input requirements for various types of integrity assessments to managing potential hazards and effects of operational activities at the organization.

The technique to carryout HEMP must be chosen carefully to suite the process safety requirements and associated risk scenarios, accordingly. HEMP techniques include: Failure mode and effects analysis (FMEA), system safety and operability (SAFOP) studies, hazard identification (HAZID), hazards analysis (HAZAN), hazards and operability (HAZOP), task risk assessment (TRA), quantitative risk assessment (QRA), etc. Typically, HEMP process involves four steps [5, 6]:

I. Identify – Potential HSE hazards and effects of hydrocarbon processing operations and associated activities;

II. Assess – Rank the HSE risks of hydrocarbon processing operations and associated activities;

III. Control – Using appropriate risk control identification technique(s), develop effective risk control plan(s) to mitigate the identified risks; and

IV. Recover – Ensure that there is an efficient plan in place to recover from the release of a hazard (should the control measures that have been set fail to deliver its prevention/mitigation function).

The HEMP process should be documented to generate records on the identification of the major hazards (to people and the environment, assessment of the related risks), and the measures taken to control these risks and to recover in case these measures fail to preserve the ALARP status. These records will eventually form a significant part of a corporate HSE case.

Selection of Safety Critical Elements (SCEs)

An SCE is defined as a system, equipment, or a component, failure of which can result in a major accident, or function of which is to manage the escalation of events during a major accident. The selection and management of SCEs and their verification is driven by the Safety Case) Regulations 2005 and associated guides [2, 3, 4, 5]. Key questions to identify SCEs are:

I. Do the system/equipment prevent or limit the effect of a major accident?

II. Would a failure of the system/equipment cause or contribute substantially to a major accident?

If the answer to one of the two questions above is yes, then the system; equipment; structure; or element in question is expected to be safety/environmentally critical where installed.

To help answer the above two questions is a structured way, Table 2 provides an example of a selection of a SCE within the SIB, using specific risk identifiers.
Table 2 - A tool to identify SCEs based on generic HSE risk identifiers.

<table>
<thead>
<tr>
<th>Barrier/Serial Number</th>
<th>Description of SCE</th>
<th>Safety and/or Environmentally Critical Components</th>
<th>HSE Hazard Identifiers (Tick risk identifiers as they apply)</th>
<th>Clarification of the Basis of Selection (HSE Hazards) and Functional Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI-001</td>
<td>Sub-sea Structures</td>
<td>Subsea Foundation (including Piles &amp; Pile Guides)</td>
<td>+</td>
<td>Basis of Selection: An element with components, a failure of any could cause structural damage, instability of the installation and/or loss of containment.</td>
</tr>
</tbody>
</table>
|                       |                    | Primary Jacket and Substructures               | +                                                                 | Functional Goals:  
  - Provide and maintain structural integrity under all expected actions through service life.  
  - Provide sufficient robustness to maintain availability of critical systems during MAH. |
|                       |                    | Cathodic Protection                             | +                                                                 |                                                                  |
|                       |                    | Secondary Jacket Bracing and Installation Systems| +                                                                 |                                                                  |
|                       |                    | Riser Guides and Protection                    | +                                                                 |                                                                  |
|                       |                    | Conductors and Conductor Guides                | +                                                                 |                                                                  |
|                       |                    | Collaisons and Caisson Supports                | +                                                                 |                                                                  |
|                       |                    | GS Inlet Strainers                             | +                                                                 |                                                                  |

Once identified, SCE can be grouped into barriers based on their function (role) in preventing or mitigating the consequences of a major accident. Each barrier may consist of one or more SCE, which in turn can be broken down into SCE components as illustrated in Figure 6.

![Swiss Cheese Model as Depicted by Shell E&P](image-url)
Performance Standards Development

A performance standard is a statement of the performance required of a SCE, which is used as a basis for managing a hazard of a major accident. A performance standard should state the overall goals of the SCE. The goals will be aligned with the role that the SCE has in preventing or mitigating (control) the unlikely consequences of a major accident. From the goals, detailed performance criteria can be developed.

Performance standards can be split into two distinct areas [2, 3, 4, 5]:

I. Performance standards for use in ensuring the initial suitability of SCEs during design, construction and commissioning; and

II. Performance standards for use in ensuring the ongoing suitability of SCEs (by conducting operational inspection, maintenance and testing) during the operational phase. For each identified SCEs, the performance standards must detail the following:

   a) The goal of the SCE;
   b) The functional performance requirement for the following FARSI criteria:
      - Functionality: What must the SCE achieve to fulfill the goals?
      - Availability: When would the SCE be required to function?
      - Reliability: What is the minimum allowable failure rate of the SCE?
      - Survivability: Will it work as required when called upon, and if not, what are the contingencies to be invoked if the SCE fails to deliver its function?
      - Interactions (or Dependencies): Which other systems are required to work for the SCE to deliver its function and meet acceptance criteria as specified in the performance standard?

III. The detailed pass/fail acceptance criteria, against which the SCE will be measured and its TI will be rated and recorded. This value should be specific and measurable, and should reflect the outcome of the MAH assessment in the HSE case.

IV. The referential normative and informative standards, from which the acceptance criteria were derived.

V. Each performance standard requirement should specify a set of contingency actions that are to be invoked if a SCE fails its pass/fail criteria. The contingency actions should be clear and specific and are the means for managing the additional risk caused by the SCE failure. As a minimum they should specify the essential measures to be implemented following detection of a failure.

Each functional requirement in terms of the above categories should be linked to one or more assurance tasks. An assurance task is an activity carried out by the operator to confirm that the SCE meets, or will deliver its required function as in the performance standard.

Technical Integrity Assurance Task Management

As explained earlier: TI must be established during the early Design Phase, and safeguarded during the Operational Phase.

During design stages, each installation will require an installation specific review with input from the assets and HSE experts, where the technical authorities for each discipline will
determine the exact scope of SCEs for each installation and their appropriate performance standards, which are typically developed for each SCE once identified.

Design concepts and reviews should be based on the operational HSE case, which are the assessment of major accidents and the understanding of the role that each potential SCE has in the prevention or mitigation of the consequences of these MAHs. The outcome of this process should be an installation register of SCEs and a suite of performance standards for each element identified as a safety/environmentally critical.

During operations, asset integrity reviews are must to assure that SCEs still preserve the ALARP status that was established during design. Current status reports (CSRs) with specific performance standards and minimum acceptance criteria are used for the review of the integrity of all SCEs to determine whether [4, 5]:

I. Technical integrity is demonstrated
II. Technical integrity is demonstrated but recommendations for improvement are identified, or
III. Technical integrity is NOT demonstrated.

When TI is demonstrated with improvement recommendation, or when the TI is not demonstrated, the asset manager concerned (in collaboration with the support organizations) must implement the gap-closure recommendations or set the proper controls to reinstate the ALARP status as intended/established during the design stage.

Technical Integrity Verification
Technical integrity status reported by asset managers on all TI reviews conducted at their operating facilities should ideally be analyzed and – if required – verified through independent audit by an internal or external third party.

TI System Review and Update
Technical integrity management requires that each operating facility develop and implement a TI Review and Update Plan to provide objective evidence that key integrity activities are being performed effectively. The plan shall ideally cover a period of five years with the first year in detail. For better management over TI, the review plan must be updated annually and adjusted – when required – based on changes to either assets or risks. The rationale is to ensure that the TI management system is delivering the overall major hazards identification and mitigation controls, and then continually improves as required.

CHALLENGES
Execution of the TIF described in this paper is not an easy task; the challenges encountered during the development, execution, and rollout of TIF (as the core of AIMS) can be summarized as follows:

I. A paradigm shift toward TI is a quite challenging chore, especially when people who are assigned to develop and implement TIF – from scratch – are gathered from different backgrounds. TIF would then be a new area to them in terms of concepts and strategies; different from what they used to do and believe works for them;
II. Gray areas between TIF specific tasks and other asset management tasks (practiced under different programs adopted by cross-functional departments), such as Reliability, Maintenance, Inspection, and Non-Technical Safety;

III. Streamlining cross-functional departments to work together toward the corporate asset management goals is difficult to achieve without management commitment and leadership directions to the execution of the entire asset management (as an integrated system that require clear mission and vision, setting SMART goals, proper planning, clear definition of roles and responsibilities and optimum unitization of all resources available to achieve the corporate asset management goals);

IV. TIF concepts and strategies are difficult to comprehend prior to involvement in a (discipline oriented) progressive task-based development program, including on-the-job-training;

V. An AIMS/TIF package includes a unique policy statement, performance standards, and guides that need to be encapsulated into (or streamlined with) the existing standards/document management system before it can be enforced as corporate requirements/mandates;

VI. Since the scope of AIMS/TIF is wide and ranging from wells, pipelines and facilities (both offshore and onshore), acquiring the technical expertise required to cover all disciplines is not easy; technical safety subject matter experts (SMEs) in some of the critical disciplines are rare in the job market;

VII. Execution of AIMS/TIF consumes budget and resources; furthermore, it requires a stable management that is prepared for what it takes to promote and execute it right (with full patience and even on stages);

VIII. Utilization of software applications to aid in the execution of AIMS/TIF may not be possible due to software security precautions. For instance, utilizing SAP to the inspection and maintenance of the SCEs requires data entry, modification, verification and perhaps integration with external tools. These activities may be restricted for data security considerations;

IX. In some cultural contexts, establishing effective/robust risk registers may be difficult as the major accident hazards are not appropriately investigated and transparently reported to allow the lesson learning process to be completed, measured and monitored to identify where interventions are needed;

X. Identifying and reporting large amount of risks and gap-closure recommendations (out of TI reviews) may not be perceived as healthy signs and good ways of identifying hazards as a preliminary step towards establishing a safer work environment;

XI. The asset management legislators and standardization bodies provide only WHAT their expectations are and rarely do they provide guidance to HOW to meet these expectations, leaving the strategies and techniques for the operators to set based on their accumulative knowledge and expertise, and when these are not exist and up to a certain level, the chances of executing a robust AIMS/TIF would then be quite low;

XII. For inexperienced operators, hiring third parties to verify the effectiveness of AIMS/TIF that they have produced may result in losing their ingenuity to those third parties who possibly manipulate the operators’ (owners’) efforts/products to their own advantages;

XIII. Return on investment (ROI) in AIMS/TIF is not tangible enough to provide a radical business case justification (unless the management is convinced beforehand
that having a robust system to manage major accident hazards worthwhile the money, time and resources invested in it).

RESULTS AND RECOMMENDATIONS

Despite the challenges facing the execution of AIMS and its TIF, a number of top major oil and gas operators have managed to execute it and then use its outcomes (listed above) as a proof to demonstrate that the content of their safety case will achieve the "safe operation and environmental protection" targets stated in their corporate principles as a social responsibility. Accordingly, AIMS/TIF (as a system to manage MAH) is recommended for chemical, petrochemical and hydrocarbon operators who are committed to operational safety and environmental protection as well as those who are interested in applying for a “License to Operate,” or planning for obtaining an “ISO-55000 Certification.”

CONCLUSION

In this paper, a Technical Integrity Framework that comprises Asset Integrity and Process Safety assurance methodologies was presented. Techniques for the identification of safety/environmentally critical elements, management of major accident hazards, and development of HSE cases were explained in this paper and recommended to chemical, petrochemical, and oil and gas companies as structured processes that are rooted in science and proven effective in the management of operational safety risks at these industries.

REFERENCES