DESIGNING AND IMPLEMENTING INFORMATION MANAGEMENT SYSTEMS FOR LNG RECEIVING TERMINALS

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ABSTRACT

Increasing demand for and availability of liquefied natural gas (LNG) has been a driving force for building many new LNG Receiving Terminals over the last several years. Responding to this opportunity, a number of US companies are currently constructing terminals that will provide terminal services to LNG importers into the United States. These terminal services include LNG ship offloading, LNG storage, re-gasification, and natural gas send-out.

To support their business processes and operating procedures, LNG terminals require both Terminal Information Management System (TIMS) and Process Control Systems (PCS). The main role of the TIMS is to ensure operational safety and efficiency, and provide integration between the corporate management systems and terminal Process Control Systems.

Recognizing that the core business processes of LNG Receiving Terminals are unique and, thus require an innovative approach to the TIMS design and implementation, several companies have contracted Invensys Process Systems, a leading technology solutions supplier to the global LNG industry, to help address TIMS-specific requirements. Invensys has recently completed several TIMS Front-End Engineering Design (FEED) studies and is in the process of implementing TIMS for several of its customers.

The paper discusses the uniqueness of business processes stemming from an LNG Terminal's commercial model and the resulting requirement for specific interactions between Supply Chain and Operations. The paper also describes a phased approach to TIMS design and implementation that is employed by Invensys to ensure TIMS integrity and effectiveness. A typical TIMS functional architecture is presented and discussed.

INTRODUCTION

Increasing supplies of stranded natural gas reserves and favorable liquefied natural gas (LNG) economics have been driving forces for building many new LNG liquefaction plants and receiving terminals. The Global LNG trade has increased steadily by at least five percent per year since the industry began. According to leading experts (see, for instance, [1]), last year LNG comprised two to three percent of the natural gas supply in US, and projections are that it will make up to 20 percent of the global supply within 20 years. Globally, the LNG market has grown by 33 percent over the last five years and more than $4 billion has been invested in that effort, according to the International Energy Agency in Paris. Responding to the increased LNG supply, a significant number of companies are in the process of constructing LNG terminals that will provide terminal services to LNG importers, including LNG ship offloading, LNG storage, re-gasification, and natural gas sendout.

The LNG Receiving Terminal is an integral component of the LNG supply chain that lies between the gas field and the residential or industrial consumer. The primary function of the terminal is to receive LNG shipments, store the LNG in liquid form and then convert liquefied natural gas at –260°F to the gaseous state, usually, around ambient temperatures and at the conditions required by the pipelines. Many aspects of the terminal business processes and operations are unique. For example, the LNG supply chain requires a tight linkage between terminal scheduling and operating orders to facilitate ship unloading agility. The operations are cyclical and switch frequently between unloading and storage modes. The unloading mode differs significantly from the storage mode: unloading rates are very high compared to sendout rates; boil-off gas rates increase substantially during unloading creating transient conditions in the process equipment. These requirements warrant a specific approach to the design and implementation of the terminal information management and control systems.

Some of the requirements for LNG Terminal's Process Control and Operations Management Systems were described in a previous paper [2] where the emphasis was on the Operations on-line monitoring and reporting. In this paper we focus on the LNG Supply Chain's unique features and its interactions with Operations.

TIMS DESIGN CONSIDERATIONS

In the past, LNG terminals typically only served one commercial customer. The few terminals that occasionally allowed access to additional (third party) customers only did so in situations where the terminal operator substantially controlled the downstream markets and the third party users did not represent a competitive threat.

United States and European natural gas markets have become highly liquid, with commodity price transparency. As the LNG industry matures and LNG becomes a globally traded commodity, LNG terminals will be required to become more flexible and serve more customers. In some cases, these customers will be competitors. With greater flexibility, the LNG industry will be able to increase profits through strategic plays, such as intercontinental arbitrage, seasonal storage, and peaking services. The move towards third-party-use terminals require some rethinking of the business practices, as well as information system requirements.

Business models and commercial agreements have been developed to accommodate various degrees of third party use. The degree of third party use has broad ramifications on the business processes, design approach and, ultimately, information system requirements. Business models vary from a pure third party use to a mixed third party and owner use. For the third-party-use terminals, the customers are actively involved in developing the business practices for grassroots terminals and throughout the information system design and implementation. The mixed-owner model tends to result in less interaction upfront with the customers until the requirements are better defined.

There are other commercial agreements that affect information systems design, such as:

- Sales and Purchase Agreements (SPA), that extend beyond the terminal to a price basis hub, such as Henry Hub. These netback deals from the commodity price basis increases auditing requirements on the terminal
- Operating Balance Agreements (OBA) with downstream pipelines affects contract administration requirements
- Operating and Cooperation Agreements (OCA) among the terminal customers affects terminal scheduling and contract administration requirements
- Complex commercial relationship among the companies, in terms of customers, owners, operators, and bankers affect contract administration and terminal scheduling requirements
- Various lease and royalty agreements may also affect contract administration requirements

Business process requirements become more attenuated to accommodate third party use versus single owner operator business models. Some of the business processes impacted by third-party-use agreements are:

- Ship nominations become more important due to customer's competition for berth and storage space
- Natural gas redelivery nominations are performed in accordance with downstream pipeline nominations procedures
- Marine scheduling becomes more challenging, particularly, during weather disturbances, tidal effects, or heavy channel traffic
- Terminal scheduling becomes much more important due to the requirements to comply with the terminal use agreements and ensure equitable treatment among shippers
- Energy balance and reconciliation becomes more important in order to quickly identify losses, audit balances, and monitor ship discharge
- Customer LNG composition tracking becomes more important to ensure downstream natural gas pipeline specifications can be met for various LNG cargo qualities
- Multiple shippers sharing the same terminal require a more thorough ship monitoring and demurrage analysis

Most importantly, there is a need for a tight linkage between supply chain activities, ship unloading operations, and vaporization processes. Significant agility is needed to handle the difficult marine scheduling requirements at the terminals with multiple customers sharing the docks. These additional requirements for third-party-use terminals significantly affect TIMS design.

TIMS DESIGN AND IMPLEMENTATION APPROACH

Each TIMS project is unique due to differences in the business model, approach to business, and commercial agreements. There are, however, notable similarities among the LNG Terminals that cover the fundamental aspects of owning and operating a terminal, such as business, asset and compliance management requirements. In order to reflect terminal business processes uniqueness and ensure system integrity, Invensys utilizes a top-down, four phase approach to TIMS design and implementation:

- Business process design
- Functional design
- Detailed requirements
- Configuration design and implementation

Each phase of work is consistent with the previous phase and builds on the results of previous work. This approach preserves the terminal business processes integrity and ensures appropriate levels of automation. A brief description of each phase of work follows.

Business Process Design

Since each terminal tends to have unique requirements, it is important to begin the design with high-level workshops to identify these terminal-specific requirements. The business process design defines, at a high level, all the business processes required to operate and manage an LNG terminal business. We begin by interviewing all major stakeholder groups including management, operations, maintenance, regulatory compliance and commercial groups. We also conduct interviews with other stakeholder groups, such as customers, owners, shipping companies, agents, pilots, tug operators, pipeline dispatchers, and engineering and construction companies.

Following the interviews, we develop a business process map based on the results of the interviews and previous design experience. The following diagram on Figure 1 illustrates a high level business process map that is required to manage the LNG supply chain. The boxes in the diagram are the business process and activities. The arrows between the boxes illustrate information flow between activities. The ovals outside the boxes represent information sources, sinks and stakeholders.

In addition to supply chain management, TIMS typically includes business management, compliance management, asset management and operations management business processes

Supply Chain Management

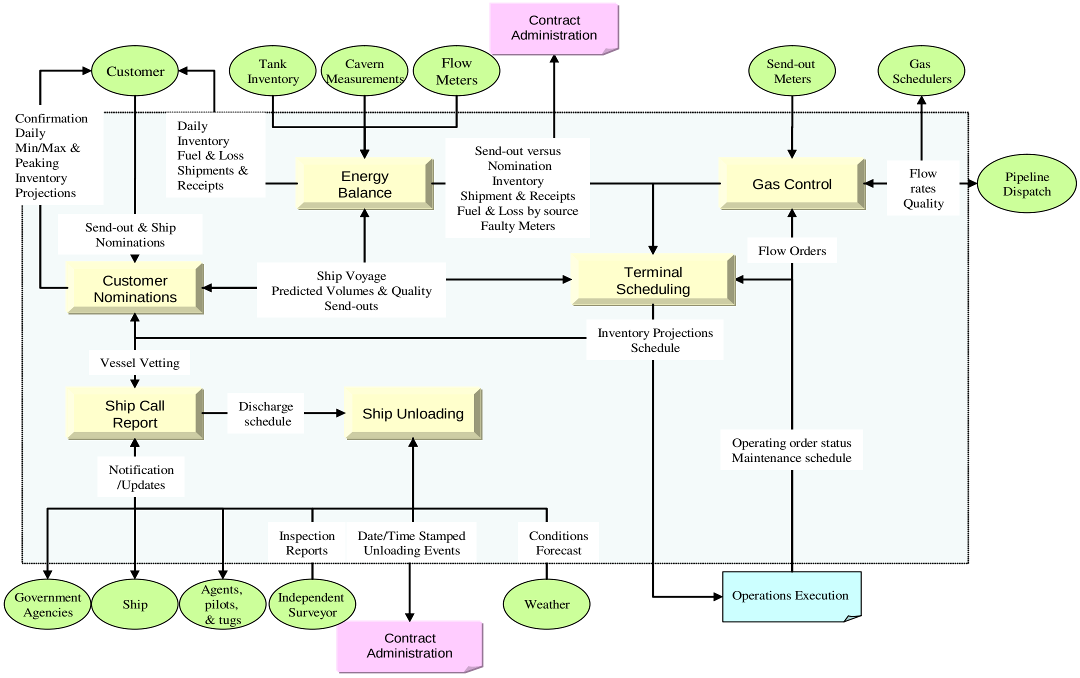

Figure 1 Supply Chain Business Process Map

Functional Design

Based on the results of the high level business process design, we develop functional design requirements for the TIMS. During functional design, we define a specific functionality required to meet the business needs and specify automation requirements for the business processes. This activity is reviewed by the business process stakeholders to ensure the business process requirements are met and the right level of automation is used for subsequent design.

At this phase, we also identify potential software vendors that can meet some or all of the automation requirements and we short-list the vendors. A budgetary estimate is developed for the remainder of the project, such that monies can be appropriated to cover the costs associated with system implementation, including software license fees, implementation and integration services, training, and ongoing software maintenance support.

Detailed Requirements

Detailed requirements drill down further into specific activities required to execute the business processes and specifies information technology requirements to automate the business process in terms of software applications and their integration, message handling, archiving, viewing and reporting results. Detailed requirements form the basis for final software selection.

The following diagram illustrates detailed design process mapping.

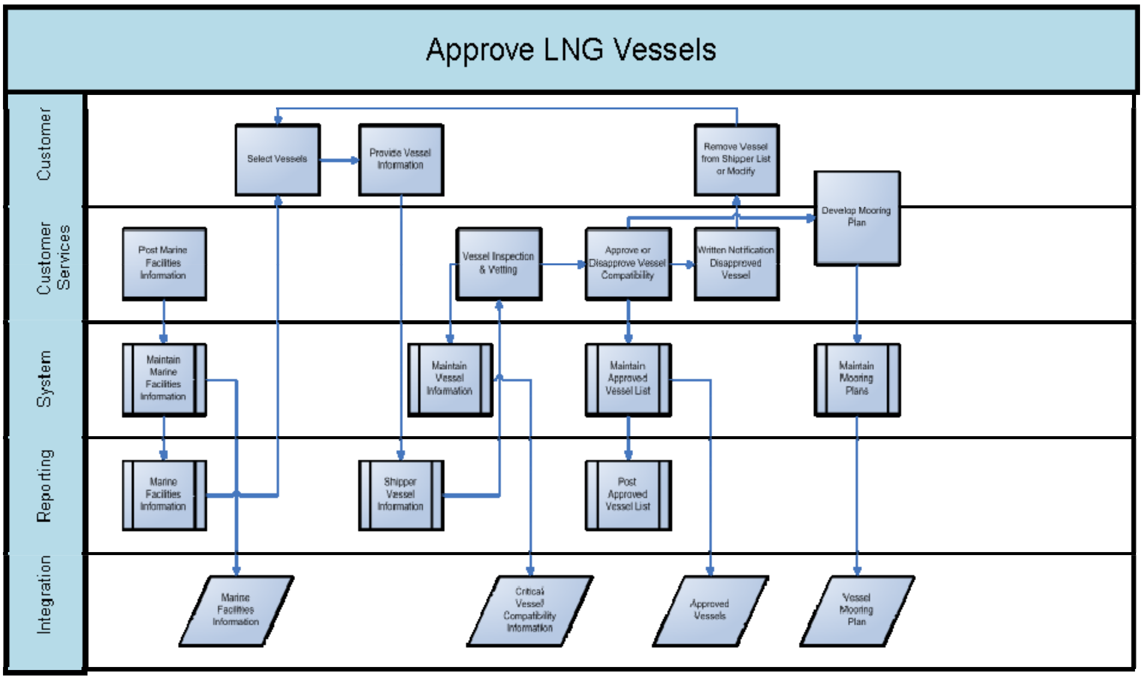

Figure 2 Typical Detail Requirements Mapping

Detailed requirements are tabulated in a compliance matrix such that software vendors can specify compliance with the requirements. The completed compliance matrix forms the foundation of their commercial proposal. After final software selection is made, integration requirements among applications are detailed.

Configuration Design and Implementation

Based on the detailed requirements design, the software vendors develop a configuration document, which provides all the specificity that an application engineer needs to design and configure the software to meet the business requirements. The application vendor conducts design workshops with the end users in order to ensure the system meets the user needs prior to developing the configuration design. During these workshops, the vendor exposes the users to best practices and obtains input into the proper application of these best practices.

The configuration design document also details the integration requirements and defines how the application will implement the integration requirements. For the case of custom application development, the design includes use cases, screen and report design mock-ups. During configuration design, the testing procedures are developed and approved by the stakeholders, and hardware requirements detailed.

Implementation consists of loading the selected software in the development environment and configuring it as defined in the configuration design document. After the software is configured, a full factory acceptance test is conducted to identify and correct problems prior to moving the software into the production environment.

For grass roots LNG terminals, it is particularly important to test the entire system prior to placing it into production due to the high level of integration among the software applications. Integration testing is performed with all the applications installed to validate automation requirements across the major business processes. User training is conducted prior to placing the system into production. The system is placed into production and readied for cargo receipt. Once the system is fully operational, a performance audit is conducted to certify the system meets its business process and system performance requirements.

Typical Implementation Schedule

The overall TIMS schedule is illustrated in the figure below.

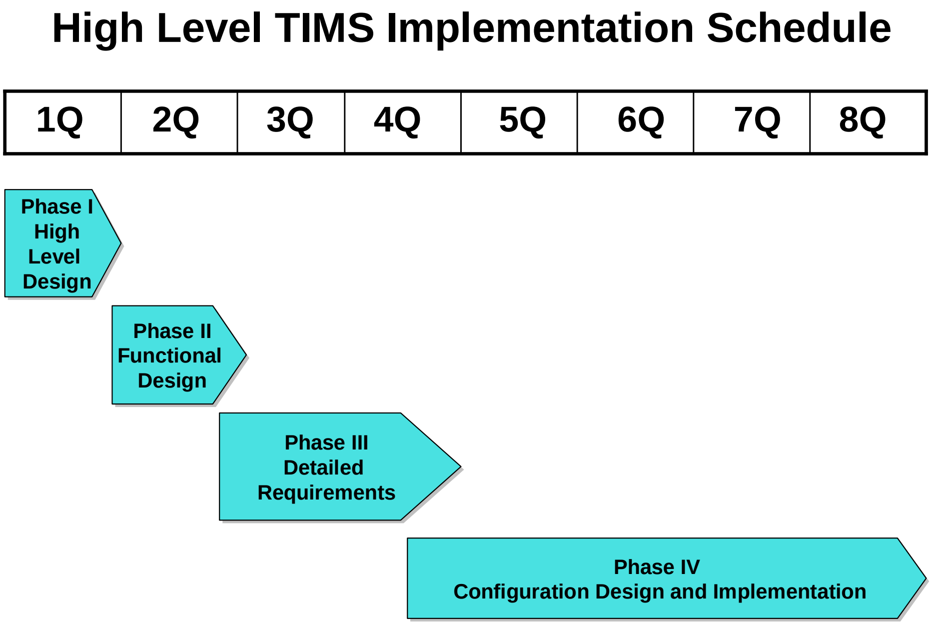

Figure 3 Typical TIMS Implementation Schedule

From start to finish, the TIMS project requires 18 to 24 months to complete. TIMS should be fully operational prior to receiving the first cool down LNG cargo.

The Phase I, High Level Design, typically takes about one quarter to complete. During this time, 30 to 50 interviews are conducted with the various stakeholder groups and several workshops are conducted to develop a common vision on the design.

Phase II, Functional Design, builds on the high-level requirements work in Phase I and takes about one quarter to complete. The implementation strategy defines the timing critical applications implementation to prepare for the transition from construction to operations and eventual start-up and requires considerable interaction with the engineering and construction contractor.

The Phase III deliverable is a "Detailed Requirements Document," which is specific enough to obtain fixed price quotes from systems integrators or software vendors and requires one to two quarters to complete.

Phase IV, Configuration Design and Implementation, typically requires five to six quarters to complete and should be done in waves that are aligned with the construction schedule. Prior to terminal start-up, the TIMS system should be fully tested, data populated into the system and personnel trained in its use. Phase IV sometimes can commence prior to the detailed requirements completion.

TIMS FUNCTIONALITY OVERVIEW

A typical TIMS functional architecture is presented on Figure 4. For completeness, the figure also includes Terminal PCS.

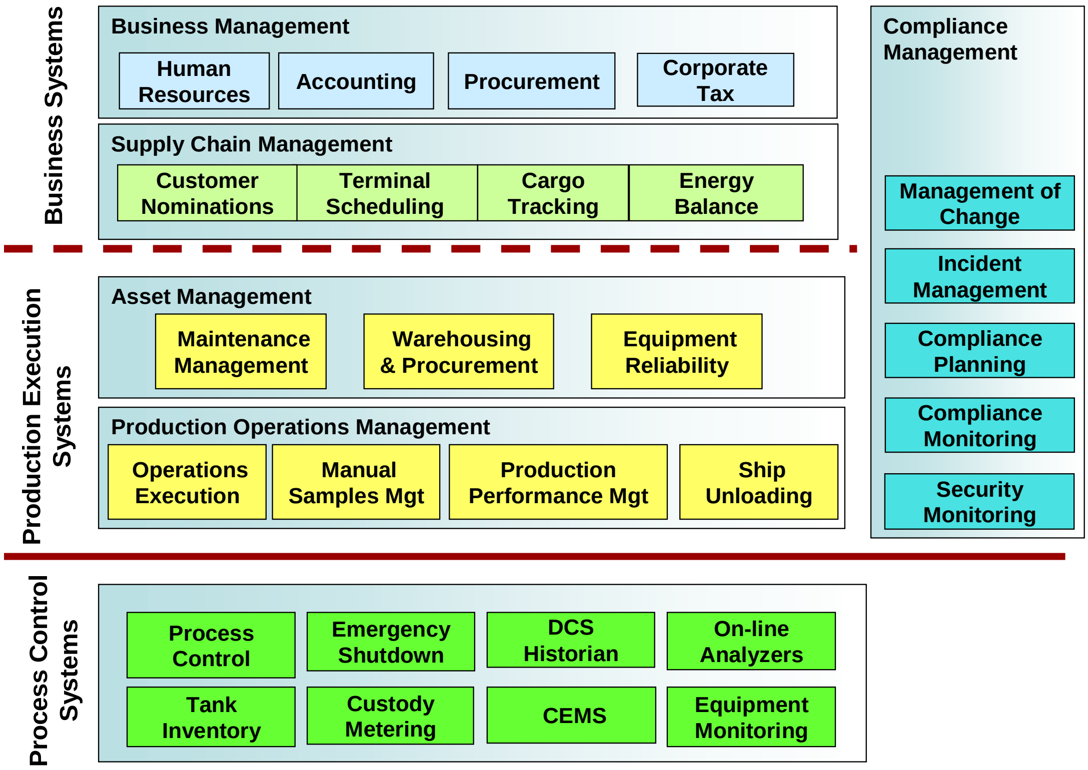

Figure 4. Typical Terminal Functional Architecture (PCS and TIMS)

TIMS includes two hierarchical levels: Business Systems (Supply Chain Management and Business Management) and Production Execution Systems (Operations Management and Asset Management). The Compliance Management System is shown separately because it spreads over the both hierarchical levels – it includes transactional activities as well as execution activities. In order to achieve safety and high efficiency, all these systems must work in concert, i.e. their business processes and corresponding applications must have coordinated business targets, schedules and information interactions.

Through our work, Invensys has defined five overarching, end-to-end business processes that collectively encompass all aspects of the LNG terminal business. These are generally classified as:

- ***Supply Chain Management*** - this business process objective is to deliver reliable, transparent and timely information in one easy to use, role-based, secure portal to manage across the LNG supply chain

- ***Operations Management*** - the primary objective is to empower operations personnel with easy to use production information access, operating instructions, and alerts in order to execute the terminal schedule in the most efficient way
- ***Asset Management*** - the primary objective is to empower maintenance personnel with easy access to equipment information, maintenance order information, and alerts to ensure equipment's high availability and align maintenance work with the terminal schedule
- ***Compliance Management*** **–** this business process is designed to ensure constituency information needs and reporting requirements are met, with a focus on regulatory requirements.
- ***Business Management*** - provides the ability to achieve a balanced approach to meeting stakeholder needs and ensuring alignment of the business processes to those needs

Functions of the three latter business processes, Asset Management, Compliance Management and Business Management are fairly typical of a process plant with the exception of specific requirements to manage LNG Terminal's various contractual agreements and capital structures.

Asset Management business process begins with an approved maintenance schedule and budget that are coordinated with overall terminal schedule and budget. It ends with an executed maintenance schedule and replenished spare parts that are necessary to maintain equipment high availability.

Compliance Management is driven by a regulatory requirement or constituency issues that require planning and execution tracking; it ends with an executed plan or regulatory requirement being met. Typical activities include incident reporting, compliance planning and monitoring, and Management of Change (MOC)

Business Management process begins with an annual plan and budget and ends with reporting results relative to the plan and budget. Typical activities include business planning, financial accounting, human resources, contract administration, cost & capital accounting, and performance management and reporting.

The uniqueness of an LNG Terminal's business processes and TIMS functionality stem from unique supply chain's commercial model and tight interactions between Supply Chain and Operations. These business processes are described in more detail in the following sub-sections on Supply Chain and Operations Management.

SUPPLY CHAIN MANAGEMENT

The business process begins with an Annual "Customer LNG Receipt Schedule" and ends with meeting daily send-out commitments on a physical basis. On a financial basis the process ends with a paid invoice by the customer to LNG Terminal. The business process objectives are:

- Ensure the LNG terminal's full contribution to the customer's LNG supply chain
- Meet receipts and send-out delivery commitments with timely reporting of receipts and send-outs.

- Manage terminal services while meeting natural gas send-out specifications
- Quickly respond to schedule changes due to unplanned events
- Manage supply costs, including demurrage and losses

  The primary activities included in this process are:

- Customer nominations
- Terminal scheduling
- Cargo tracking
- Energy balances

Other supply chain activities may include contract administration, mooring and piloting, and demurrage claims management.

Customer Nominations

Customer nomination is the primary supply chain customer-facing activity. This application coordinates all ship and natural gas redelivery nominations and confirmations with the customer. Based on the terms in the contract, nominations can be for the ship only, or for both ships and natural gas redeliveries. Customer nominations manage the creation of the Annual Delivery Program which are customer specific and defined in the terminal use agreements. Once the annual program is developed, typically there are rolling three month updates to the annual program. The monthly updates, once accepted, take precedence over the annual program. During the annual and monthly nomination cycles, the customer nominations are displayed, and in some cases available ship unloading windows are also displayed.

On a daily basis, records are published to the customers that contain basis information such that the customer can nominate the next day natural gas redeliveries. For an unplanned event, such as a weather disturbance or ship delays, the customer nomination application receives and manages any customer requests to change ship arrival dates. All notifications, nominations, and confirmations are tracked for commercial purposes in the application. This application is tightly integrated with terminal scheduling. Embedded in the application are checks to ensure the customer is in compliance within their contractual limits.

Terminal Scheduling

A critical activity, terminal scheduling integrates customer nomination with operations to produce a feasible schedule that meets the customer needs. Terminal scheduling determines schedule feasibility, analyzes various alternatives, and develops the best feasible terminal schedule. Once the schedule is developed, key parameters are passed from the schedule to the Operations Execution and Ship Unloading applications for execution.

The terminal schedulers collect schedule baseline information from various information sources to establish the current state of the terminal operations. The most current ship and gas redelivery nominations are imported into the application and analyzed to ensure feasibility of ship unloading, storage, and redelivery capability. The scheduling application also is used to evaluate the impact of terminal services unavailability, weather disturbances, or ship delays.

Cargo Tracking

Cargo tracking coordinates and tracks LNG cargoes from the time of the annual LNG Receipt schedule until the ship's cargo is discharged and the ship is sailing. The activity ensures compliance with the terminal use agreement terms with respect to ship nominations, scheduling, and discharge. Cargo tracking is used to manage ship departure notices throughout the voyage, capture cargo information, manage channel transits from the sea buoy to the dock, collect cargo unloading information, and ship positions throughout channel transit. Cargo tracking collects all information associated with a cargo life cycle, such as nominations, notifications, cargo quality, and ship discharge events and performance.

Energy Balance

The energy balance application provides reconciled, auditable information for the purposes of managing inventory and custody transfers and identifies sources of unreported losses and meter errors. Energy balance receives information from all the flow meters, tank inventory levels, and ship discharge reports to develop reconciled gross heating value energy balances. The energy balance performs the following functions:

- Provides capability for near real time monitoring of terminal inventory of volume, mass and calorific basis
- Develops reconciled energy balances based on redundant measurements for various energy envelopes including ship to LNG tank, LNG tank to vaporizer, and vaporizer to custody meters
- Reviews balance inquiries and make adjustments as necessary to historical balances
- Identifies faulty meters and real sources of losses
- Performs various ad hoc analysis such as ship discharges, process performance, and tank compositions

The energy balance manages prior period adjustments for the purposes of custody transfers. It forms the basis of daily inventory positions and tank compositions, sendout custody transfers, fuel usage monitoring and ship discharge validations.

OPERATIONS MANAGEMENT

Operations Management begins with an approved terminal schedule and ends with an executed daily schedule. The business process objectives are:

- Meet receipts and send-out delivery commitments and timely unloading of ships
- Provide safe, flexible operations to comply with terminal schedule
- Ensure high level of operational readiness and efficiency

- Communicate terminal status and condition
- Control operating costs

The primary activities included in Operations Management are:

- Operations execution
- Sample records management
- Ship unloading
- Production performance

The high-level business flow diagram depicting information flows, as well as business process activities is illustrated below on Figure 5.

Operations Execution

This activity provides operations personnel with visibility into critical information to empower the operations. It complements PCS capabilities by automating and expanding the traditional shift logbook functions.

Operations Manager receives the daily terminal schedule and create daily targets and operating orders. Operators receive daily operating targets and operating orders from the logbook. As work is progressed, the operators update the order status and enter comments into the logbook.

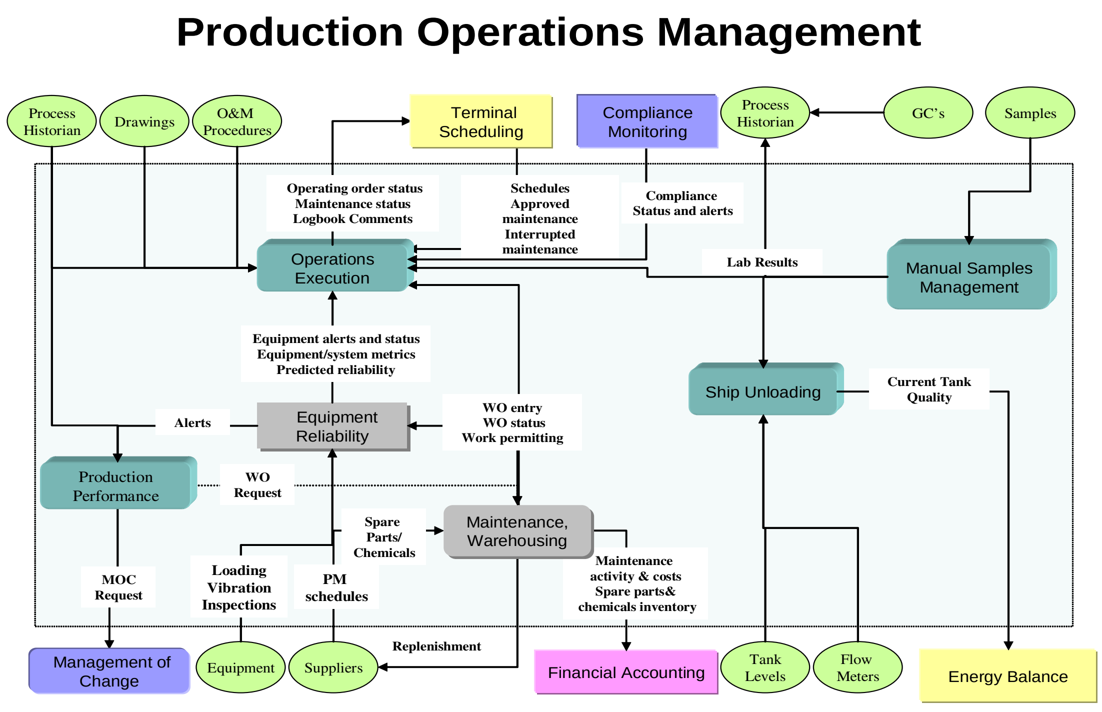

Figure 5. Production Operations Business Process Map

Operations personnel also have visibility into technical information, such as equipment drawings, Process & Instrumentation Diagrams (P&ID's), control system conditions and alerts, and operating and maintenance procedures. Operations management has access to the logbook from remote locations to assess current operations and maintenance status and issues.

Typical functions of the activity are:

- Translate schedule into daily operating targets and orders
- Approve operating and ship unloading orders
- Execute operating orders
- Update operating order status
- Monitor equipment, sendout and compliance alerts
- Enter logbook comments required during operating orders execution
- Update work order status and inspection prior to placing in equipment in service
- Enter remote readings and observations
- Monitor inspection rounds and routine tasks

Operations Execution assists in managing the scheduled operating tasks performed by operations personnel. The activity provides necessary tools to communicate the tasks to the operators and log execution results to ensure timely actions and to collect information for operations performance analysis.

Sample Records Management

Sample Records Management provides the capability to electronically manage records of manually collected samples. The scope of this activity typically includes gas sample records from the unloaded ships and environmental sample records (air and water).

Sample Records Management functions include:

- Manage sample retention storage as specified in terminal use agreements
- Record sample retention requests and issue samples as specified in terminal use agreements
- Monitor sample container retention aging
- Return sample containers to use after storage
- Record environmental sample quality results
- Historize sample records

Sample Records Management is specific to LNG Terminals due to special conditions stated in Terminal Use Agreements (TUA) for gas samples handling and dispute resolution. The activity also helps effectively managing sample containers and third-party lab results.

Ship Unloading

The objective of the activity is to enable proper management of ship unloading operations by automating the operating tasks and user-system interactions. This activity is critical for LNG Terminals since it generates custody transfer data and actual unloading time log that are used by Supply Chain to calculate customer storage positions and demurrage charges are collected and generated by this activity. Ship unloading is an important integration point with the Supply Chain activities. Integration is achieved in both directions: 1) From Supply Chain to Operations - through terminal scheduling, which coordinates ship unloading operations with vaporization operations and passes the unloading targets to operations, and 2) From Operations to Supply Chain – through reporting of actual ship unloading results.

The Ship Unloading functions are:

- Translate daily schedule into daily unloading targets and orders
- Generate Ship Unloading Report
- Generate Ship Unloading Time Log Report
- Capture key ship unloading timestamps and events

Ship Unloading provides necessary tools for managing the scheduled ship unloading tasks performed by operations personnel. The activity complements Process Control Systems by communicating the tasks to the operators and reporting execution results to Supply Chain activities.

Production Performance

This activity provides operations personnel and process engineers with information required to monitor production performance so that they can diagnose and fix process problems in a timely fashion.

The main functions are:

- Analyze process performance and calculate process efficiency
- Identify root causes of process under-performance or equipment failures
- Set thresholds for process alerts
- Modify operational procedures and process conditions as necessary

All the above functions use real-time production data stored in the Plant Historian, which is considered typically as a part of the activity. Production Performance Management monitors production processes and provides operations personnel with analytical data leading to further performance improvements.

CONCLUSION

The unique business processes and resulting operating agility and information requirements of a modern LNG receiving terminal warrant a specific approach to the design and implementation of the terminal information and control systems. This approach must address both general and terminal-specific conditions. To this end, a phased, top-down design and implementation approach as been found to produce the desired results.

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