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Standard Guide for Laboratory Informatics[1]

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1. Scope

1.1 This guide helps describe the laboratory informatics landscape and covers issues commonly encountered at all stages in the life cycle of laboratory informatics from inception to retirement. It explains the evolution of laboratory informatics tools used in today's laboratories such as Laboratory Information Management Systems (LIMS), Electronic Laboratory Notebooks (ELN), Scientific Data Management Systems (SDMS), and Chromatography Data Systems (CDS). It also covers the relationship (interactions) between these tools and the external systems in a given organization. The guide discusses supporting laboratory informatics tools and a wide variety of the issues commonly encountered at different stages in the life cycle. The sub-sections that follow describe details of scope of this document in specific areas.

1.2 *High-Level Purpose*—The purpose of this guide includes: *(1)* helping educate new users of laboratory informatics tools, *(2)* provide a standard terminology that can be used by different vendors and end users, *(3)* establish minimum requirements for laboratory informatics, *(4)* provide guidance for the specification, evaluation, cost justification, implementation, project management, training, and documentation of the systems, and *(5)* provide function checklist examples for laboratory informatics systems that can be adopted within the laboratory and integrated with the existing systems.

1.3 *Laboratory Informatics Definition*—Laboratory informatics is the specialized application of information technology aimed at optimizing laboratory operations. It is a collection of informatics tools utilized within laboratory environments to collect, store, process, analyze, report, and archive data and information from the laboratory and supporting processes. Laboratory informatics includes the integration of systems, the electronic delivery of results to customers, and the supporting systems including training and policies. Examples of laboratory informatics include: Laboratory Information Management Systems (LIMS), Electronic Laboratory Notebooks (ELNs), Chromatography Data Systems (CDS), and Scientific Data Management Systems (SDMS).

NOTE 1—Laboratory informatics scope encompasses multiple technical solutions or systems. The division between these system categories continues to soften as functionality continues to be added to each of them. LIMS were originally created to address the laboratories' need to manage laboratory operations and data, provide traceability for all laboratory samples and equipment, and ensure that laboratory procedures are followed. ELNs, on the other hand, were originally created to meet the scientists' need to document their experimental design, execution, and conclusions in an electronic format instead of in a paper notebook. SDMS was created to provide a repository of all scientific data files and results regardless of instrument type. The current definitions of each of these system categories are far more encompassing.

1.4 *Scope Considerations When Selecting and Implementing Laboratory Informatics Solutions*—Many laboratories have determined that they need to deploy multiple laboratory informatics systems to automate their laboratory process and manage their data. Selection of an informatics solution requires a detailed analysis of the laboratory's requirements rather than by choosing a product category. It is important to include representatives from Information Technology (IT) and Subject Matter Experts (SMEs), who understand the needs of the laboratory, to be involved in the selection and implementation of a laboratory informatics system to ensure that the needs of the laboratory are met and that IT can support it. Customers (internal and external) of laboratory information should also be included in the laboratory informatics solution design, to ensure there is full electronic integration between systems.

1.5 The scope of this guide covers a wide range of laboratory types, industries, and sizes. Examples of laboratory types and industries are listed in the following:

1.5.1 *General Laboratories:*

1.5.1.1 Standards (ASTM, IEEE, ISO), and

1.5.1.2 Government (EPA, FDA, JPL, NASA, NRC, USDA, FERC).

1.5.2 *Environmental:*

1.5.2.1 Environmental Monitoring.

1.5.3 *Life Science Laboratories:*

1.5.3.1 Biotechnology, and

1.5.3.2 Diagnostic.

1.5.4 *Healthcare Medical:*

1.5.4.1 Devices,

1.5.4.2 Pharmaceuticals vet/animal,

1.5.4.3 Public health, and

[1] This guide is under the jurisdiction of ASTM Committee E13 on Molecular Spectroscopy and Separation Science and is the direct responsibility of Subcommittee E13.15 on Analytical Data.

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1.5.4.4 Hospital LIS.
1.5.5 *Heavy Industry Laboratories:*
1.5.5.1 Energy and resources,
1.5.5.2 Manufacturing and construction,
1.5.5.3 Materials and chemicals, and
1.5.5.4 Transportation and shipping.
1.5.6 *Food and Beverage Laboratories:*
1.5.6.1 Agriculture,
1.5.6.2 Beverages,
1.5.6.3 Food, and
1.5.6.4 Food service and hospitality.
1.5.7 *Public Sector Laboratories:*
1.5.7.1 Law enforcement,
1.5.7.2 State and local government,
1.5.7.3 Education, and
1.5.7.4 Public utilities (water, electric, waste treatment).

1.6 *Integration*—The scope includes communication and meaningful data exchange between different laboratory informatics tools and other external systems (document management, chromatography data systems, laboratory instruments, spectroscopy data systems, Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES), Investigations/Deviations and CAPA management systems), and other integrated business systems (for example, clinical or hospital environments) provide significant business benefits to any laboratory and is discussed at a high level in this guide.

1.7 *Life Cycle Phases*—The scope of this guide is intended to provide an understanding of laboratory informatics tools' life cycle from project initiation point to retirement and absolution. This guide was designed to help newer audiences in understanding the complexity in the relationships between different laboratory informatics tools and how to plan and manage the implementation project, while seasoned users may use the different life cycles to maintain existing laboratory informatics tools. Integrating additional tool(s) to the existing one(s) in today's evolving laboratory informatics world adds constraints that need to be considered. The lifecycle discussion includes both the laboratory informatics solution lifecycle as well as the project lifecycle, which describes steps to a laboratory informatics solution.

1.7.1 The product lifecycle encompasses a specific laboratory informatics system and the expected useful life of that system before it needs to be replaced or upgraded.

1.7.2 The project lifecycle encompasses the activities to acquire, implement, operate, and eventually retire a specific laboratory informatics system.

1.8 *Audience*—This guide has been created with the needs of the following stakeholders in mind: *(1)* end users of laboratory informatics tools, *(2)* implementers of laboratory informatics tools, *(3)* quality personnel, *(4)* information technology personnel, *(5)* laboratory informatics tools vendors, *(6)* instrument vendors, *(7)* individuals who shall approve laboratory informatics tools funding, *(8)* laboratory informatics applications support specialists, and *(9)* software test/validation specialists. Information contained in this guide will benefit a broad audience of people who work or interact with a laboratory. New users can use this guide to understand the purpose and functions of the wide varieties of laboratory informatics tools as well as the interactions between these tools with external systems. The guide can also help prospective users in understanding terminology, configurations, features, design, benefits and costs of these different laboratory informatics tools. Individuals who are purchasing (a) specific tool(s) may also use this guide to identify functions that are recommended for specific laboratory environments. Research and development staff of different commercial laboratory informatics systems vendors may use the guide as a tool to evaluate, identify, and potentially improve the capabilities of their products. The vendors' sales staff may use the guide to represent functions of their laboratory informatics products to prospective customers in more generic and product neutral terms.

1.9 *Out of Scope*—This guide does not attempt to define the boundaries, as they continue to evolve, between the different types of laboratory informatics but rather focuses on the functionality that is provided by laboratory informatics as a whole.

2. Referenced Documents

2.1 *ASTM Standards:*[2]
E1340 Guide for Rapid Prototyping of Information Systems
E2066 Guide for Validation of Laboratory Information Management Systems

2.2 *EPA Data Standard:*[3]
40 CFR 160 Code of Regulations, 54 FR 34067, August 17, 1989

2.3 *FDA Regulation:*[4]
FDA 21 CFR Part 11 Electronic Records, Electronic Signatures Final Rule, 62 Federal Register 13464, March 20, 1997

2.4 *GAMP:*[5]
GAMP 5 Good Automated Manufacturing Practice (GAMP) Guide for Validation of Automated Systems in Pharmaceutical Manufacture, ISPE, 2008

2.5 *ICH Standard:*[6]
ICH Quality Guideline Q9 Quality Risk Management

2.6 *IEEE Standards:*[7]
IEEE 829 1998 IEEE Standard for Software Test Documentation

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.
[3] Available from United States Environmental Protection Agency (EPA), 1200 Pennsylvania Ave., NW, Washington, DC 20460, http://www.epa.gov.
[4] Available from Food and Drug Administration (FDA), 10903 New Hampshire Ave., Silver Spring, MD 20993-0002, http://www.fda.gov.
[5] Registered trademark of and available from International Society for Pharmaceutical Engineering (ISPE), 600 N. Westshore Blvd., Suite 900, Tampa, FL 33609, http://www.ispe.org.
[6] Available from International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH), ICH Secretariat, c/o IFPMA, 15 ch. Louis-Dunant, P.O. Box 195, 1211 Geneva 20, Switzerland, http://www.ich.org.
[7] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854, http://www.ieee.org.

IEEE 830 1998 IEEE Recommended Practice for Software Requirements Specifications
IEEE 1008 1987 IEEE Standard for Software Unit Testing
IEEE 1012 2004 IEEE Standard for Software Verification and Validation
IEEE 1028 1997 IEEE Standard for Software Reviews
IEEE 1063 2001 IEEE Standard for Software User Documentation

2.7 *ISO Standards:*[8]

ISO/IEC 12207 Information technology—Software life cycle processes
ISO/HL7 27932:2009 Data Exchange Standards—HL7 Clinical Document Architecture, Release 2

2.8 *NRC Standards:*[9]

FDA CFR Part 21 10 Code of Federal Regulations (CFR) Part 21.42 FR 28893, June 6, 1977
FDA CFR Part 50, Appendix B 10 Code of Federal Regulations (CFR) Part 50 Appendix B. 35 FR 10499, June 27, 1970, as amended at 36 FR 18301, Sept. 11, 1971; 40 FR 3210D, Jan. 20, 1975
FDA CFR Part 50, Appendix E 10 Code of Federal Regulations (CFR) Part 50 Appendix E. 45 FR 55410, Aug. 19, 1980, et sequentia as amended
FDA CFR Part 50, Appendix K 10 Code of Federal Regulations (CFR) Part 50 Appendix K. 21 FR 355, Jan. 19, 1956, unless otherwise noted

3. Terminology

3.1 This guide defines the majority of different terminology used in the laboratory informatics tools field. Users of this guide should request a terminology list from each vendor with a cross reference to the terms used in this guide.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *chromatography data system, CDS, n*—computer system used to acquire, analyze, store, and report information from chromatographs.

3.2.2 *cloud computing, v*—term generally used to refer to software applications that are delivered as a software service through remote hosting using the public internet (public cloud) or within the users' network environment (private cloud).

3.2.2.1 *Discussion*—Essentially, the difference between cloud computing and a traditional application deployment is that the application users are not responsible for the installation and maintenance of the computing infrastructure and application software.

3.2.3 *corrective and preventative action, CAPA, n*—CAPA applications are used to collect information, analyze information, identify and investigate product and quality problems, and take appropriate and effective corrective or preventive or both action to prevent their recurrence.

3.2.3.1 *Discussion*—Verifying or validating corrective and preventive actions, communicating corrective and preventive action activities to responsible people, providing relevant information for management review and documenting these activities are essential in dealing effectively with product and quality problems, preventing their recurrence, and preventing or minimizing device failures.[10]

3.2.4 *data exchange standardization, n*—as defined by the International Organization for Standardization (ISO) in ISO/HL7 27932, the process of agreeing on standards, which represent the common language that allows the exchange of data between disparate data systems.

3.2.4.1 *Discussion*—The goals of standardization are to achieve comparability, compatibility, and interoperability between independent systems, to ensure compatibility of data for comparative statistical purposes, and to reduce duplication of effort and redundancies. A data standard often includes data elements, data element definitions, and such agreements as formats, message structures, vocabulary. In the context of this paper, a standard is a specification or requirement and is not synonymous with a policy, procedure, guideline, framework, technique, or best practice. Adopting standards has the potential to improve interoperability and reduce costs by facilitating the ability of networked laboratories to coordinate activities during public health incidents where surge capacity may be required (for example, national response and readiness). Adopting standards may reduce the costs of LIMS implementation and vendor/developer support.

3.2.5 *electronic document management system, EDMS, n*—used to store, catalog retrieve, view, and print digital documents.

3.2.5.1 *Discussion*—Modern EDMS applications typically provide the ability to manage a document throughout its lifecycle with functions including document initiation, multiple levels of review, version controls, security and archive of historical versions of documents.

3.2.6 *electronic laboratory notebook, ELN, n*—software program designed to replace paper laboratory notebooks. Defined by CENSA (Collaborative Electronic Notebook Systems Association) as "a system to create, store, retrieve, and share fully electronic records in ways that meet all legal, regulatory, technical and scientific requirements."

3.2.6.1 *Discussion*—Laboratory notebooks in general are used by scientists, engineers, and technicians to document research, experiments, and procedures performed in a laboratory. A laboratory notebook is often maintained to be a legal document and may be used in a court of law as evidence. Similar to an inventor's notebook, the laboratory notebook is also often referred to in patent prosecution and intellectual property litigation.

3.2.7 *enterprise resource planning, ERP, n*—ERP system integrates different types of data such as inventory levels, product orders, accounting, manufacturing capacity, inspection results, and customer relationship management information from organizations within an enterprise (company) to facilitate the flow of information between various business functions across a company as well as with outside business partners.

[8] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[9] Available from U. S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pk., Rockville, MD 20852-2738, http://www.nrc.gov.

[10] For additional information, visit http://www.fda.gov/ICECI/Inspections/InspectionGuides/ucm170612.htm#page1.

3.2.8 *good automated manufacturing practice forum, GAMP Forum, n*—a volunteer group under the auspices of the International Society of Pharmaceutical Engineering (ISPE) for writing guidance for the validation of computerized systems used in the regulated portions of the pharmaceutical and allied industries. It is specifically designed to aid suppliers and users in the pharmaceutical industry.

3.2.9 *integration broker, n*—messaging application that can receive or extract data from a source system at the appropriate time, transform the data, and route the reformatted data to the target node.

3.2.9.1 *Discussion*—An integration broker application can also provide a repository for archiving, searching, and retrieving these messages.

3.2.10 *laboratory information system, LIS, n*—class of application software that supports clinical laboratories by helping technologists manage the quality and integrity of test samples; departmental workflow functions, result review processes, reporting of finalized results, interpretations, and diagnosis.

3.2.10.1 *Discussion*—These systems often interface with instruments and other information systems such as hospital information systems (HIS). A LIS is a highly configurable application and often includes laboratory-specific electronic medical records; direct clinician access via secure web connections; billing modules for laboratories performing commercial testing; sophisticated interface engines for routing orders and results to external systems; and on-board image archival systems for pathology images. Patient confidentiality and HIPAA requirements define unique security functionality for a LIS. The College of American Pathologists (CAP) publishes LIS product guides[11] that list current LIS in the market.

3.2.11 *laboratory execution system, LES, n*—computer system used in the laboratory at the analyst work level to aid in step enforcement for laboratory test method execution.

3.2.11.1 *Discussion*—Laboratory execution systems (LES) focus on step execution of defined laboratory test methods. The LES are typically used in quality control laboratories that have defined test methods. The functionality of LES and LIMS overlap in the areas of result entry, instrument integration and specification flagging. Deployment options include LES and LIMS systems deployed as an integrated solution, LIMS only or LES only (for limited functions).

3.2.12 *laboratory informatics, n*—term used to describe the specialized application of information technology aimed at optimizing laboratory operations and it is a collection of informatics tools utilized within laboratory environments to collect, store, process, analyze, report, and archive data and information from the laboratory and supporting processes.

3.2.12.1 *Discussion*—Laboratory informatics includes the integration of systems, the electronic delivery of results to customers, and the supporting systems including training and policies. Examples of laboratory informatics include: Laboratory Information Management Systems (LIMS), Electronic Laboratory Notebooks (ELNs), Chromatography Data Systems (CDS) and Scientific Data Management Systems (SDMS).

[11] For additional information, visit http://www.captodayonline.com/productguides/software-systems.html

3.2.13 *laboratory informatics tools configuration, n*—refers to the process of changing the functions of any of the laboratory informatics tools to match the business process used in a particular laboratory. It does not involve the use of writing software code either via a recognized software language or a language provided by the informatics application supplier. This is a GAMP 4 software category.

3.2.13.1 *Discussion*—It typically involves using an interface provided by the vendor to enter information that describes the types of samples, analytical methods, specifications, and so forth used in the laboratory.

3.2.14 *laboratory informatics tools customization, n*—refers to the process of changing the functions of any of the laboratory informatics tools to match the business process used in a particular laboratory. It involves the writing software code either via a recognized software language or a language provided by the informatics application supplier. This is a GAMP 5 software category.

3.2.14.1 *Discussion*—It typically involves adding tables, modifying table structures and writing code or programs to alter the behavior of any of the laboratory informatics tools.

3.2.15 *laboratory information management system, LIMS, n—(1)* computer application(s) software and hardware that can acquire, analyze, report, and manage data and information in the laboratory; *(2)* computer software that is used in the laboratory for the management of samples, test results, laboratory users, instruments, standards, and other laboratory functions such as invoicing, plate management, product/material stability programs, and work flow automation; and *(3)* a class of application software which handles storing and managing of information generated by laboratory processes.

3.2.15.1 *Discussion*—These systems are used to manage laboratory processes including defining master data, sample management and chain of custody, work assignment, instrument and equipment management, standard and reagent management, scheduled sample collection and testing, result entry, result review, reporting, trending and business rule enforcement. These systems interface with laboratory instruments (for example, chromatography data systems (CDS), and other information systems such enterprise resource planning (ERP), manufacturing execution systems (MES), or health care based laboratory information systems (LIS)). A LIMS is a highly flexible application, which can be configured or customized to facilitate a wide variety of laboratory workflow models.

3.2.16 *lean laboratory, n*—set of management and organizational processes derived from lean manufacturing and the Toyota Production System (TPS) and the goal of a lean laboratory is to use less effort, fewer resources, and less time to test incoming samples.

3.2.17 *mapping tools, n*—graphical data mapping, conversion, and integration applications that map data between any combination of XML, database, flat file, EDI, Excel (OOXML), XBRL, and/or web service, then transforms data or autogenerates data integration code for the execution of recurrent conversions.

3.2.18 *metadata, n—(1)* data about data and *(2)* information that describes another set of data.

3.2.18.1 *Discussion*—Metadata in any laboratory informatics tools context typically includes all data that supports a test result that is recorded in this tool. Examples include for a pH test, a pH result can be supported by metadata including what instrument was used, what is the calibration date of the instrument, what standard buffer solutions (reagents) were used to calibrate the pH probe sensor, the expiration dates for the standard solutions and the temperature of the solution at time of measurement.

3.2.19 *sample registration, n*—process of recording incoming sample information in a given laboratory informatics tool.

3.2.20 *scientific data management system, SDMS, n*—used to capture, centrally store, catalog, and manage data generated in a laboratory environment.

3.2.20.1 *Discussion*—These data are then available for reuse and integration with other laboratory informatics systems. An example of an SDMS is an electronic repository for reports from laboratory informatics systems.

3.2.21 *spectroscopic data systems, n*—computer systems used to collect, process, visualize, interpret, store, and report information from spectroscopic instruments.

4. Significance and Use

4.1 *Relevance*—This guide is intended to educate those in the intended audience on many aspects of laboratory informatics. Specifically, the guide may:

4.1.1 Help educate new users of laboratory informatics;

4.1.2 Help educate general audiences in laboratories and other organizations that use laboratory informatics;

4.1.3 Help educate instrument manufactures and producers of other commonly interfaced systems;

4.1.4 Provide standard terminology that can be used by laboratory informatics vendors and end users;

4.1.5 Establish a minimum set of requirements for primary laboratory informatics functions;

4.1.6 Provide guidance on the tasks performed and documentation created in the specification, evaluation, cost justification, implementation, project management, training, and documentation of laboratory informatics; and

4.1.7 Provide high-level guidance for the integration of laboratory informatics.

4.2 *How Used*—This guide is intended to be used by all stakeholders involved in any aspect of laboratory informatics implementation, use or maintenance.

4.2.1 It is intended to be used throughout the laboratory informatics life cycle by individuals or groups responsible for laboratory informatics including specification, build/configuration, validation, use, upgrades, retirement/decommissioning.

4.2.2 It is also intended to provide an example of a laboratory informatics functions checklist.

5. Laboratory Informatics Concept Model—Graphic Picture of Systems and Functionality

5.1 *Laboratory Informatics Systems Evolution*—Fig. 1 shows a timeline for the development of software products

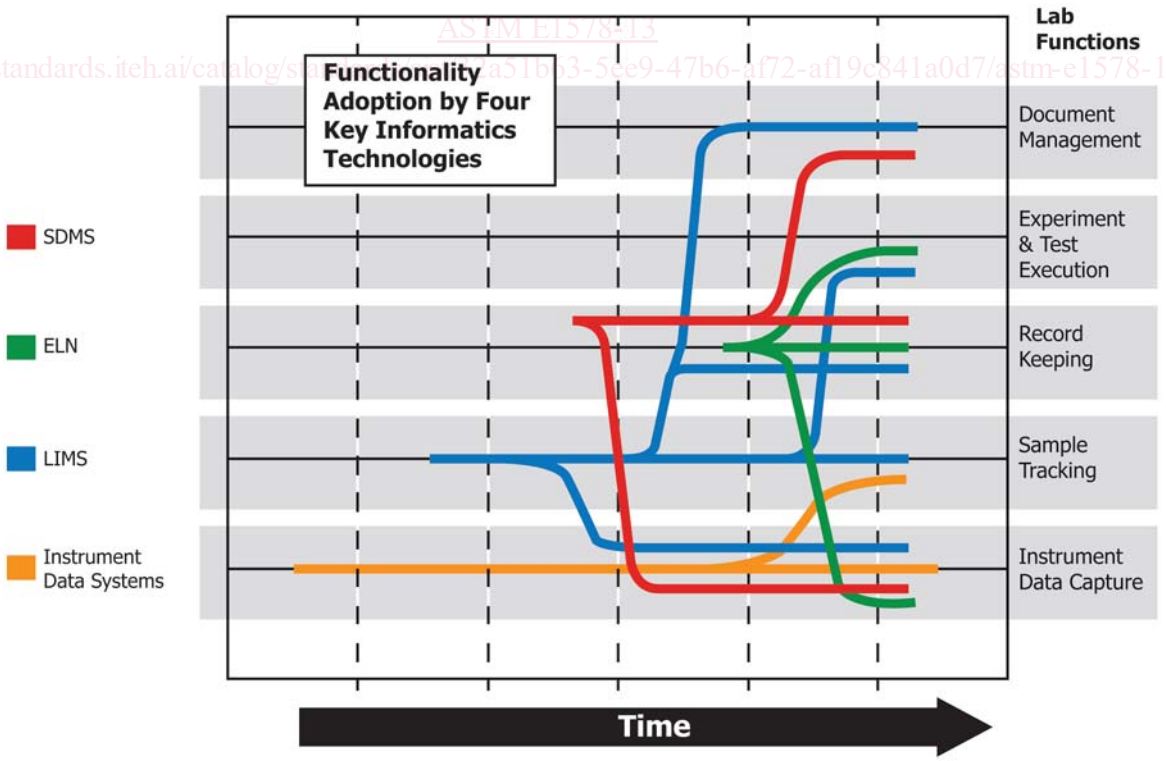

FIG. 1 Laboratory Informatics Systems Evolution

designed to meet the needs of the laboratory community. Over time additional software tools entered the laboratory and existing software products added functionality. The expanding breadth of software tools available illustrates the increased functionality and complexity of laboratory informatics solutions. The laboratory informatics solutions/tools illustrated in this figure are examples and do not imply these are the only tools available.

5.2 *Laboratory Informatics Systems Integration Concept Model*—Laboratory informatics systems, the possible overlaps between them, and their potential integration with business and enterprise computer systems both within organizations and with customers of laboratory information are illustrated in Fig. 2.

5.3 *Laboratory Informatics Functions*—Laboratory informatics core and extended functions are illustrated in Fig. 3. The figure defines:

5.3.1 Core laboratory functions are described by items listed in boxes labeled with C-x;

5.3.2 Extended laboratory functions are described by items listed in boxes labeled with E-x;

5.3.3 Functions related to system configuration, administration and validation are shown with boxes labeled with S-x; and

5.3.4 Document support functions are described in boxes labeled with D-x.

5.4 *Laboratory Informatics Systems Life Cycle Phases*—Fig. 4 defines the high-level system life cycle phases of: *(1)* initial system implementation, *(2)* system operations, and *(3)* system maintenance. Each of these primary phases is further decomposed into primary functions. The numbering scheme used matches the definitions in Fig. 3 and also ties to the requirements section located in Appendix X1.

5.5 *Laboratory Informatics Additional Functional Requirements by Laboratory Type*—All analytical laboratories require a basic work flow including sample or experiment registration, assignment of tests, entry of results, review and approval and reporting. Laboratories in various industries may require additional functionality to meet additional workflow requirements. An environmental laboratory, for example, may require tracking of sample containers, processing of samples in batches with control samples, instrument integration, multiple levels of review, and specific reporting requirements. Some laboratory informatics systems vendors gear their solutions towards a particular industry segment, while others attempt to meet the needs of many laboratory types. Fig. 5 illustrates some of the additional functions that may be required to address the needs of particular laboratory types. The functions illustrated are over and above the basic laboratory workflow and are by no means an exhaustive list, but merely examples of possible additional functionalities.

6. Laboratory Informatics Workflow and Sample Life Cycle

6.1 *Laboratory Informatics Workflow Introduction*—The laboratory informatics workflow model (see Fig. 6) provides a generic representation of the process flow in a typical analytical laboratory. The purpose of the work flow diagram is to elucidate the laboratory informatics functions and interaction points with typical laboratory work processes (that is, processing of samples, analysis, and reporting). Specific laboratory workflow requirements and test definition may vary widely from one laboratory to another, as well as from one industry to another. However, before implementing a laboratory informatics solution, care should be taken to completely define and document the unique requirements and data model for the laboratory in question. To achieve a successful deployment and use of a laboratory informatics solution, it shall be properly configured before deployment. The relatively stable information about personnel, customers, tests, reports, and the like, shall be entered into the static data. Once configured, the laboratory informatics solution is able to facilitate the sample

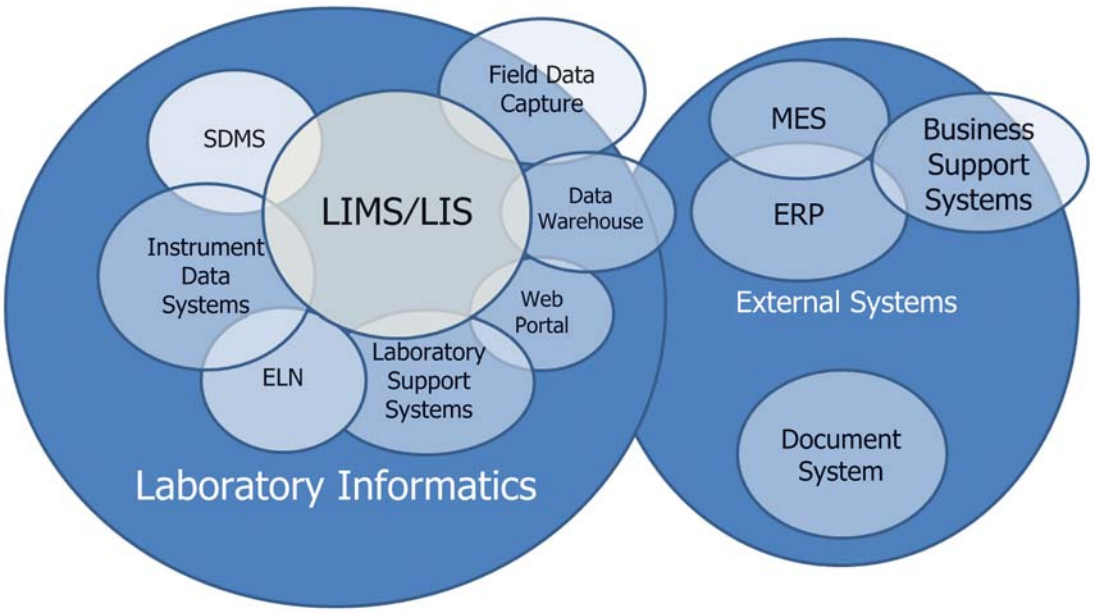

FIG. 2 Laboratory Informatics Systems Integration Concept Model

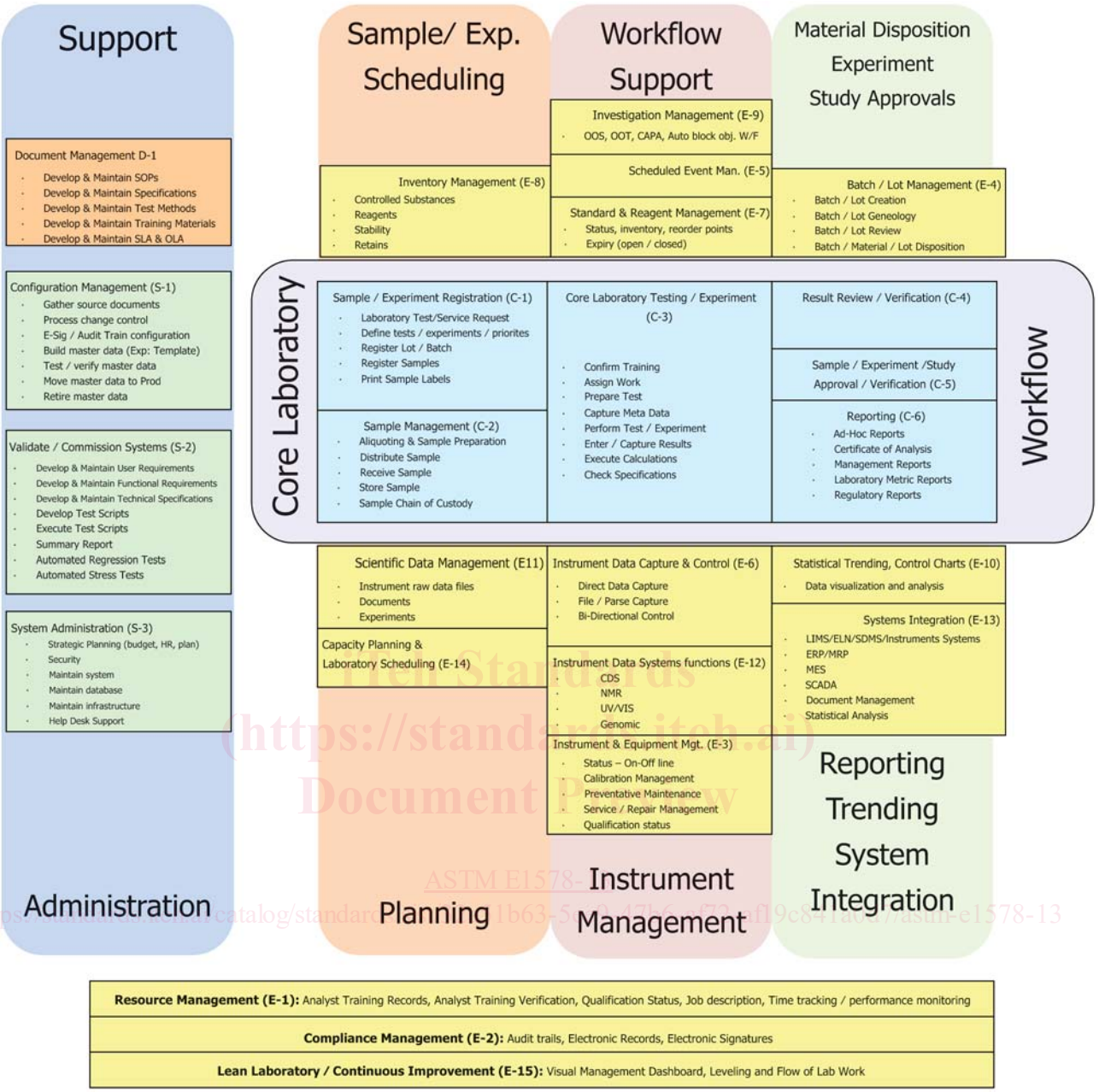

FIG. 3 Laboratory Informatics Functions

lifecycle process. The boundaries of the laboratory informatics solution should be established during the data model design phase.

6.2 *Laboratory Informatics Data Model*—Defining the correct data model for the laboratory is essential to a successful laboratory informatics implementation and deployment. Many laboratories opt for data models that are procedure centric (that is, test methods are defined from approved external procedures and SOPs) where the requestor selects the appropriate laboratory informatics methods based on a knowledge of which procedures are appropriate for the sample in question. This model relies on the experience of the user and has great flexibility for the R&D laboratory or laboratories where a wide variety of samples are submitted. Other models are sample or product specific (that is, a suite of "approved" tests are bundled together and typically always applied to one sample type), as is typically the case for a QA laboratory in charge of product release. This model removes the dependency upon the requestor to select the appropriate tests when submitting the sample for analysis and improve compliance to testing plans.

6.2.1 *Types of Data*—The technology used by a laboratory informatics solution varies with each vendor and platform. However, laboratory informatics databases are typically divided into two broad areas: *(1)* static data where descriptive information is defined (for example, users, locations, profiles, tests, calculations, specifications, and related information;

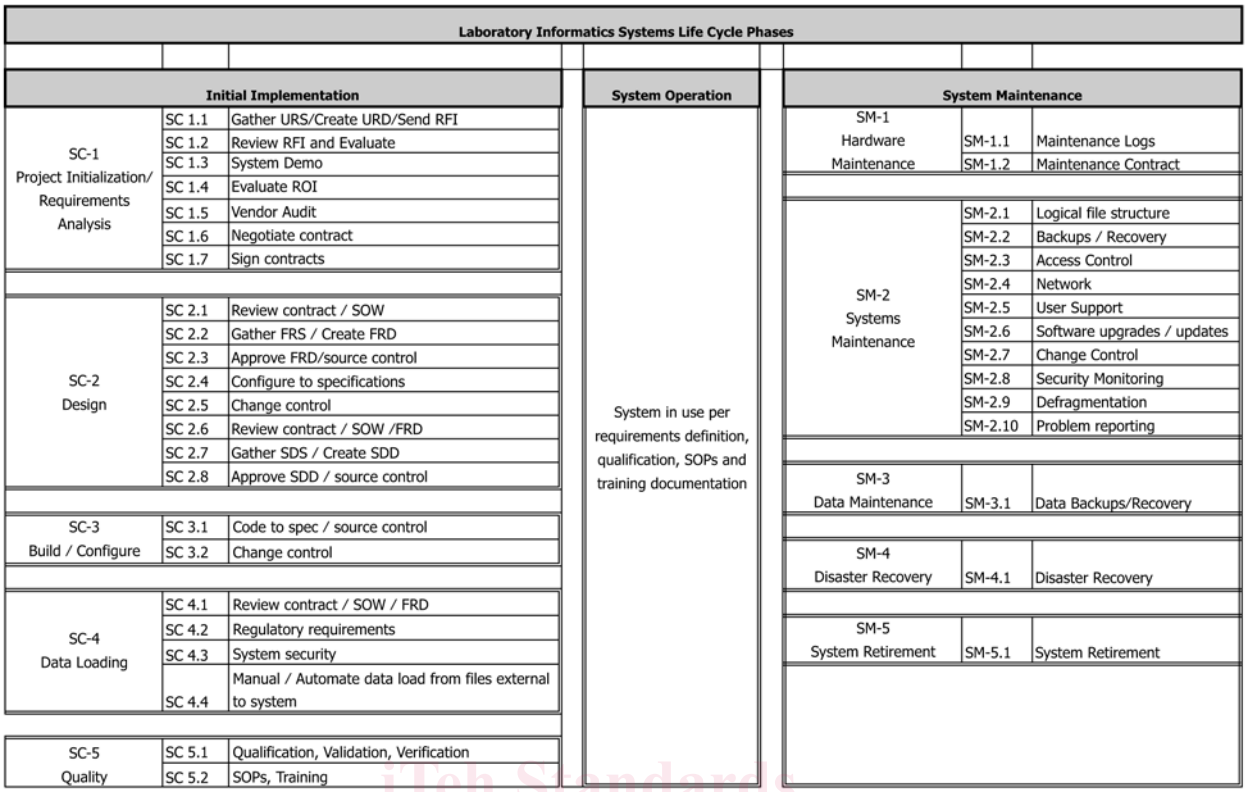

FIG. 4 Laboratory Informatics Systems Life Cycle Phases

commonly found in "look up/reference/dictionary" tables) and *(2)* dynamic data where sample and result/determination information is stored as samples are logged and results are entered. The terms static and dynamic represent a general characterization of laboratory informatics data, reflecting the frequency of change. The laboratory informatics implementation team shall assess the current laboratory information organization and workflow in order to match the two database areas (static and dynamic) to the information/data collected, generated or required by the laboratory in order to conduct their laboratory processes, whether that be in processing samples or in general laboratory experiments.

6.2.2 *Statuses*—Laboratory informatics solutions are generally capable of maintaining information on the status of various items, for example, but not limited to: experiments, samples, individual tests/determinations, comparison of results to specifications, verification of results, approval of samples/orders, workflows, and much more. Status values provide the insight with the laboratory informatics solution to track the item's progress in its workflow (that is, active, complete, reviewed, and so forth) and may provide context on the evaluated result (that is, pass/fail). Other status information may be updated as each laboratory informatics transaction takes place. Individual functions/workflows may be configured to have an associated status value. Examples of sample/order statuses include, but are not limited to (and should be reflective of the laboratory's unique workflow): unavailable, available, received in the laboratory, testing in progress, suspended, complete, approved, and rejected. Examples of test/determination statuses include: available, active, complete, approved, out of specification.

6.2.3 *Data Load and Migration*—A laboratory informatics solution is capable of maintaining information for a broad range of business and laboratory data required for the effective operation of the laboratory. Laboratory informatics contains data that not only reflects the current operation state of the laboratory but also historical information on past performance and events. When implementing a laboratory informatics solution in a previously manual environment or replacing an outdated electronic version, it shall be determined how much and of what type (if any) historical data should be carried forward (that is, loaded, "migrated," or re-entered) into the new laboratory informatics solution to provide the base configuration. Static data are generally always loaded into the laboratory informatics solution as part of the deployment lifecycle. The decision on how to deal with historical dynamic data should be evaluated on the basis of risk. Appropriate strategies for dealing with this data include migration, preservation and archival. In cases in which a new solution is replacing an existing laboratory informatics solution, it may be possible to migrate data from the source laboratory informatics solution to the new target deployment. Migration of data needs to be carefully analyzed and planned. The plan should include processes to verify that the data are successfully migrated to the new database.

6.3 *Sample Management and Life Cycle:*

Additional Functions Required by Laboratory Types		Laboratory Functional Area					
		Sample / Experiment Management	**Lab Testing**	**Review, Verification Approval**	**System Integration**	**Reporting and Trending**	**Other Functions**
Laboratory Type	**General Laboratories**	Chain of custody	Batch Processing of Samples including QA		ELN, SDMS, instrument integration	Electronic Reporting of QC Results	
	Environmental	Container management, Chain of custody, regulatory compliance - significant auxiliary data	Batch Processing of Samples including QA	Multiple levels of review and approval	GIS integration	Electronic Reporting of QC Results by batch	Method QA/QC, Calculation validation, electronic data delivery
	Public Health Sector- (clinical microbiology and chemical)	Chain of custody, electronic test ordering, Emergency response, public health surveillance	Batch Processing of Samples including QA, agent regulations	Multiple levels of review and approval, CLIA certification	Emphasis on surveillance at multiple state and federal levels	Electronic Reporting multiple data formats, vocabulary, and secure transport	Clinical and non-clinical, sample centric and patient centric
	Life Sciences	Controlled substances Stability samples	Uniformity Calculations Product Specifications	Multiple levels of review and approval	ERP integration	SPC and Process variability analysis	Instrument maintenance and calibration tracking
	Food and Beverage	Lot geneology	Product Specifications		MES and ERP integration	SPC and Process variability analysis	Exception Reporting
	Heavy Industry	Automatic scheduling, Lot Management	Product Specifications		Process Control / PM integration	SPC and Process variability analysis	
	R&D	Experiment sharing	Method versioning		ELN, SDMS, instrument integration	Experiment Conclusions, Technical Reports	Expanded Search capability
	Medical Laboratory	Embedded LIS Standalone LIS Niche LIS Patient centric			interface engines to external systems	Unique functions Diagnostic and Surveillance	electronic medical records; direct clinician access, billing modules

FIG. 5 Laboratory Informatics Additional Functional Requirements by Laboratory Type

6.3.1 *Sample Registration*—Sample registration may precede or follow physical sample collection. The laboratory informatics sample registration function should be a simple, straightforward process with an intuitive and efficient user interface. The initiation of a request for testing/sampling generally starts the sample workflow process. Sample requests may include manual forms, electronic forms, phone requests, web requests, process-driven requests, time or calendar-based requests, ad-hoc requests, and system-generated requests. Information obtained from the sample request should include biographical, client, requested test(s), and safety information. Some laboratory informatics solutions allow the laboratory to pre-log or post-log samples or the client to pre-log samples through a web portal.

6.3.1.1 *Store/Retrieve Sample*—An often overlooked benefit of utilizing a laboratory informatics solution is the ability to manage inventories for reference samples, laboratories reagents, standards, QC samples, time-based samples (shelf-life stability), and laboratory equipment/instruments, in addition to normal samples. Inventory functions may provide critical business information with respect to resource and consumables management as well. This could include such

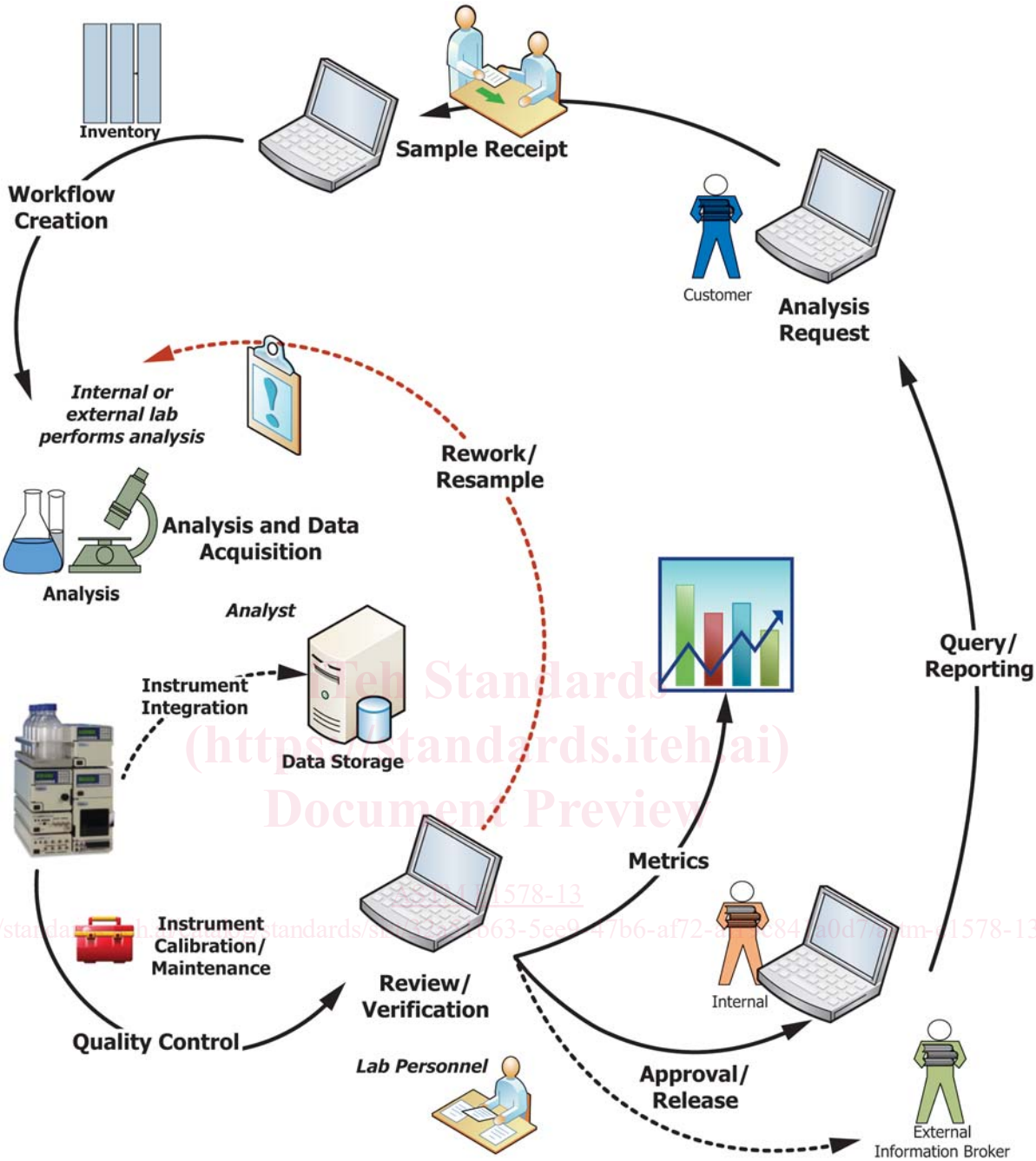

FIG. 6 Laboratory Informatics Workflow Model

information as expiration dates, vendor information, restock quantities, as well as, in the case of instruments; calibration status, maintenance history, and so forth.

6.3.2 *Sample Identification*—The laboratory informatics solution should assign a unique number to each sample registered (that is, submitted for testing). The unique number can be a system generated sequential integer or a user-defined sequence. Multiple samples, submitted together for registration should be logically "linked" in the laboratory informatics solution (for example, all samples for a particular lot). The system will normally provide functionality to capture descriptive information about the sample(s) such as who submitted the sample(s), costs, sample description, and what tests are to be performed on the sample. Other information may also be important, such as the priority of the tests, what level of accuracy and precision of testing needed, what hazards the sample might present to the laboratory personnel, what approximate levels of components are expected, and what should be done with the sample when analysis is complete.

6.3.2.1 A confirmation report is often issued (sometimes emailed) to assure requestors that the system accepted the sample request and may accompany the physical samples as they are delivered to the testing laboratory. Often, laboratory informatics solution statuses are updated for the sample/order

and may be used to record the fact that an order was made (for keeping operational metrics) and when it was made so the system can track the time intervals for the remaining steps of the process. This will also allow laboratory management to determine turnaround time, sample status and various overdue conditions.

6.3.3 *Sample Collection*—Sample collection may be a manual, automated, or robotic process. The sample collection logistics may become more efficient by having the laboratory informatics solution print collection lists and generate labels (for example, bar codes) for the sample containers. Sample collection can precede or follow sample registration as defined by the laboratory's workflow. The laboratory informatics solution can provide information on how to collect samples, specific sample plans, container and preservation requirements, safety [Material Safety Data Sheets (MSDS)] information, sample storage requirements, and sample routing information. Chain of custody for samples is often tracked by the laboratory informatics solution, generally for location and status information. Chain-of-custody may be required to provide documented evidence of control and traceability of sample containers and their contents. Examples of situations where chain-of-custody requirements may be required include handling of controlled substances, pieces of evidence (forensic) supporting legal court cases, or radioactive materials. It is important to note, that this functionality may not have all legal chain of custody requirements for specified sample types as defined by governmental or law enforcement agencies. The implementation team should review these requirements carefully during the planning/implementation phase.

6.3.4 *Sample Receipt*—The physical receipt of samples in the laboratory may be recorded in the system and may also include initial sample checking and labeling. Sample orders or groups of samples may be reviewed against customer or project sampling requirements. Additional information such as the number of samples received and the arrival time may be recorded and the status of samples may be updated for the sample/order from logged to received. Where collection lists are used, a "missed sample" report should be used to indicate those samples that were not received as expected.

6.3.4.1 The laboratory informatics solution may be configured to specify the aliquot requirements for a sample based on the tests to be performed on it. Upon sample receipt, any issues, such as an unexpected color or physical state, may be noted and recorded within the sample record. The laboratory informatics solution should be flexible enough to allow preliminary sample treatment, such as addition of a preservative, to be performed and documented.

6.3.5 *Sample Distribution*—Distribution processes often include important laboratory informatics solution functions such as work lists, resource allocation, sample routing and custody.

6.3.5.1 The laboratory informatics solution should provide a listing of all the tests that shall be performed, the amount of material required, and where samples are to be sent. The date and time of sample distribution is important since it designates when the sample becomes available to the various laboratory workstations for analysis. Sample status may be updated to indicate samples are available for analysis at this time as well.

6.3.6 *Work Assignment*—Once samples arrive in the laboratory, the work shall be scheduled and allocated against available resources, people, and/or equipment. Resource availability and management may be handled through the laboratory informatics solution, if configured to capture this information. By utilizing the laboratory informatics solution appropriately, resources may be forecast, allocated, and tracked to improve the overall efficiency of the laboratory. The laboratory informatics solution may also be configured, in some instances, to group automatically samples into runs or sequences and schedule work (tests) for each sample/order, as well as be configured to allow authorized users to perform these functions manually.

6.3.7 *Disposal of Samples*—The proper documentation of sample disposal following analysis is an important responsibility of the laboratory. The laboratory informatics solution may be used to track final sample disposition.

6.4 *Analysis:*

6.4.1 *Sample Preparation*—Most samples require some preparation before analysis. The laboratory informatics solution may be configured to provide sample preparation directions for these preliminary processing and sample preparation steps, however this information may also be available in the form of standard operating procedures, technical documents, or work instructions stored externally to the laboratory informatics solution. In addition, it may be configured to capture who and when the sample preparation was completed.

6.4.2 *Sample Analysis*—Analysis activities will vary from laboratory to laboratory. Depending upon the laboratory's requirements and data model, much of the information gathered during this phase, other than the actual result data, may be recorded in a hardcopy laboratory notebook, or captured within another laboratory informatics solution as sample or method attributes. In general however, the analysis phase contains the following subparts:

6.4.3 *Perform Test*—Test results/determinations are the main output of the analysis process. Intermediate and final test results for the samples, standards and their associated QC samples may be reported out in hard copy, electronic formats, or both. In addition, the measurement process may produce values for additional internal blanks, standards, and instrument self-checks. The definition of what is the laboratory's "raw data" and what needs to be retained for legal evidence may be defined differently for each client or agency involved and should be a fundamental part of the data model design process.

6.4.3.1 *Re-Test Loop*—Retests can be initiated at multiple points in the laboratory informatics solution workflow. A re-test is defined as one or more additional determinations on the original sample/order container. These retests would normally be ordered if a given test was suspected to fail for reasons that may include failed quality control parameters, instrument malfunction or technical judgment. The laboratory informatics solution should document each retest along with an appropriate justification.

6.4.3.2 *Re-Sample Loop*—Re-samples can also be initiated at multiple points in the laboratory informatics solution workflow. A re-sample is defined as one or more additional samples. The laboratory informatics solution needs to establish forward

and backward links to samples that are added by way of the re-sample loop. These re-samples would normally be ordered if a given sample was suspected to fail for reasons that may include where insufficient sample was available for a retest, technician judgment that the original sample was not appropriate for the test performed, or to confirm a test failure.

6.4.4 *Data Capture*—The results of the analysis should be captured within the laboratory informatics solution. While this may be a manual process, the true power of laboratory informatics lies in automating data transfer. This can involve automated capture of instrument data files, printable reports, data from simple devices, and automatic extraction of information from one part of the laboratory informatics implementation and transfer into another one. The amount and type of supporting data to include with the result data, should be carefully evaluated and defined during the data model design. When a test result/determination is captured, the statuses of the sample/order and result determination should be updated. The associated date/time records should also be captured so that they can keep statistics of work accomplished and track the progress of each test order. The laboratory informatics solution should have electronic audit trails that record biographical information about each transaction.

6.4.4.1 Direct instrument integration with the laboratory informatics solution is critical to fully realizing the business benefits of the solution. In cases in which instruments are bidirectionally interfaced to laboratory informatics solutions, the sequence of unknown samples and control standards may be transferred to the instrument to streamline instrument setup before analysis. The sequence should include information such as sample ID, analyst ID, analysis date/time, and/or other pertinent information.

6.5 *Analysis Review:*

6.5.1 *Test Result Review and Interpretation*—A laboratory should require that each test result undergo one or more levels of documented review and interpretation. The laboratory informatics solution can be configured to document at multiple levels of review. The original sample result would typically be reviewed and interpreted by the primary analyst for any anomalies associated with the performance of the test method. This review can be documented in the laboratory informatics solution. Laboratories often require that results be reviewed by a second qualified person (this is industry specific and dependent on regulatory requirements) to ensure that the tests were properly executed, documented, entered, and interpreted.

6.5.1.1 To help in this process, the laboratory informatics solution may indicate the unusual or out-of-range results as flagged for further evaluation. If normal values are known for the substance being tested, they can be displayed. Results outside of normal can be highlighted or displayed separately for closer review. The laboratory informatics solution can enforce laboratory SOPs that require the reviewer to be a different person from the tester. Corrections or changes to laboratory informatics solution data made during the verification step should be audit trailed and require authorization with change comment. Audit trails should contain original data and all changes to the result record including date/time of change, who made the change, and the reason for the change. Electronic signatures may be used to confirm changes in status to the laboratory informatics solution records if the regulations or guidelines require this. Management may need to know when results are verified—another milestone in the progress of a test/sample/order. Not all laboratory informatics solution implementations require audit trails. The laboratory informatics solution implementation team needs to determine whether audit trails are important, what information should be audited, and whether reasons for changes should be recorded during the data model design phase.

6.6 *Sample Disposition:*

6.6.1 A laboratory generally requires that samples undergo a documented review/approval process to disposition the sample to indicate that it has been evaluated against established criteria. The laboratory informatics solution can be configured to document the review/approval process. Since the laboratory exists to generate information for the parent/client organization, the laboratory may organize and configure results to make interpretation and decision-making easier. Analysis is frequently done to confirm quality or properties of a material. In this case, material specifications may be entered into the laboratory informatics solution so that results can be checked against acceptable values to determine whether the sample meets/does not meet specifications. Electronic signatures may be used to document the sample review/approval process and update the sample status in the laboratory informatics solution records. In addition, certain industries/regulations prohibit final sample approval by the analyst who performed the test. Restrictions of this nature need to be identified during the implementation design phase so that the laboratory informatics solution configuration will support the constraint.

6.6.2 The output of the review/approval process is verified data and may be in the form of data reports, Certificates of Analysis (COA), or direct process control actions. Often, the interpretation function coincides with the reporting process. In many laboratory informatics solutions, data are interpreted in a reported format either in electronic or paper forms.

6.6.3 Result data itself can undergo a separate evaluation and disposition process from the sample. In some industries and research organizations, the pass/fail status (or approved/rejected, that is, multiple terminology exists) of an individual result data point is captured, yet the overall sample is approved because the science generating the result value is sound. This is a key element that the implementation team needs to incorporate into the data model design.

6.7 *Reporting:*

6.7.1 Following verification, data reported to the customer may include test results (including quality control data), auxiliary data such as sample demographics, and accompanying pass through data and is not “generated” by the laboratory, other data necessary for data evaluation such as sample characteristics such pH or temperature. This can take a variety of forms, including hardcopy reports, electronic data deliverables, and web-based systems. The report generators within a given laboratory informatics solution need to be flexible to accommodate the different reporting needs of individual clients. The laboratory informatics solution vendors provide basic formats for the most common hardcopy and