Pacific Northwest NATIONAL LABORATORY

PNNL-30768

Considerations on Managing Flowsheet and Technology for DFLAW Production

December 2020

Stuart T Arm

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from
the Office of Scientific and Technical
Information,
P.O. Box 62, Oak Ridge, TN 37831-0062
www.osti.gov
ph: (865) 576-8401
fox: (865) 576-5728
email: reports@osti.gov

Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
or (703) 605-6000
email: info@ntis.gov
Online ordering: http://www.ntis.gov

PNNL-30768

Considerations on Managing Flowsheet and Technology for DFLAW Production

December 2020

Stuart T Arm

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99354

Abstract

This report evaluates best practices for flowsheet and technology (F&T) management and makes recommendations for Hanford Direct Feed Low-Activity Waste (DFLAW) production operations. Establishing and practicing F&T management operations prior to hot commissioning of the Hanford Waste Treatment and Immobilization Plant is desirable to ensure focused F&T leadership and F&T capabilities and competencies are immediately ready to sustain DFLAW production operations. This study showed management of F&T is shaped by programmatic elements important to sustaining operations and leads to recommendations for managing Hanford DFLAW production operations F&T:

1. Appoint an Office of River Protection (ORP) Chief Technology Officer (CTO) for DFLAW production operations. The ORP CTO provides focus for F&T matters and coordinates and champions initiatives across the DFLAW mission.
2. Form the DFLAW Flowsheet and Technology Advisory Committee. The Committee serves to consolidate the DFLAW technical community, consisting of Hanford contractors, national laboratories, and universities, and promote their collaboration under the ORP CTO.
3. Establish a 3-5 year vision and strategy for DFLAW F&T. The Committee's first action should be to establish a vision and actionable strategy for DFLAW F&T production operations consistent with an overarching mission production strategy delineating waste processing objectives. The Committee will then be responsible for monitoring plant performance against the strategy.
4. The Committee initiates development of a DFLAW F&T Taxonomy based on the completed DFLAW design and continuously updated to account for plant modifications. The Taxonomy forms the technology baseline for DFLAW. For each DFLAW F&T element, the Taxonomy describes the flowsheet or technology and associated knowledge concerning production performance, primarily in the form of technical reports. The technical reports would initially be based on design confirmation test results, but would transition primarily to actual plant performance data after hot commissioning.
5. The Committee initiates development of a DFLAW F&T Roadmap for DFLAW production operations. With the Taxonomy including plant performace data as its basis, the Roadmap essentially implements the strategy and resolves descrepancies between actual performance and process objectives. Broadly, the Roadmap addresses what can be done to transform waste into glass "faster, cheaper, and safer." Utility should be made of an established technique such as Lean Management to systematically identify those opportunities.

Summary

Currently, the U.S. Department of Energy Office of River Protection (ORP) stores approximately 56 million gallons of radioactive and hazardous waste in 177 underground tanks at the Hanford Site. Approximately 20 million gallons of that waste is in a liquid form (supernate), approximately 10 million gallons is in the form of insoluble sludge materials, and the remainder is in a partially soluble solid form referred to as saltcake. Treatment and immobilization of the tank waste is planned, with the Hanford Waste Treatment and Immobilization Plant being the principal plant where this will be accomplished. Initially, only supernate and solubilized saltcake, collectively termed low-activity waste (LAW), will be treated and immobilized in the WTP in a Direct Feed Low-Activity Waste (DFLAW) configuration.

The start of DFLAW production operations will mark a significant event in Hanford history. Not since the 1980s, or at least a generation of engineers, will the site have experienced the sustained production operations of a multi-functional chemical process plant. An active technical authority managing DFLAW flowsheet and technology (F&T) and leading optimization initiatives was identified by Arm (2020)[1] as a key element of the culture conducive to sustaining those production operations. This report describes best practices for establishing, implementing, and maintaining technical authority for Hanford DFLAW production operations.

Arm (2020)[1] identified five programmatic elements important to sustaining operations, all of which explicitly and implicitly shape F&T management:

- **Risk management** – Identification and prioritization of F&T initiatives should be driven by an active risk management program that rigorously articulates the likelihood and consequence of DFLAW risks and opportunities and associated mitigating actions.
- **Continuous improvement** – DFLAW production operations F&T initiatives should be focused on continuously improving the rate, cost, and safety of transforming waste into glass (i.e., transforming waste into glass “faster, cheaper, and safer”). One such technique, Lean Management, is recommended for F&T management to help in identifying improvement opportunities. Evaluation of the DFLAW Lean value stream and associated Lean wastes provides for a systematic method in identifying F&T improvements. This work developed the Lean value stream and wastes to demonstrate the utility of the technique, but formal identification should be initiated by the Technical Authority.
- **Continuity of technical authority** – Recommended is an explicit technical authority over the DFLAW mission be established for DFLAW production operations. Technical authority is a concept embodying F&T leadership, management, erudition, and continuous improvement drive.
- **Stakeholder monitoring** – Hanford waste treatment production operations are influenced by complex and wide-ranging stakeholders at the federal, state, and local levels of government as well as regulators and the public. Stakeholders are not expected to influence F&T management directly, but rather indirectly through the risk management program and sustained operations strategy (below).
- **Sustained operations strategy** – An integrated Hanford waste treatment operations business plan is recommended for the site, encompassing, for example, production, processing, environmental, and legal objectives and considerations for long-lead and/or critical procurements. The strategy for achieving production operations objectives, with its near-term focus, is a primary influencer of the F&T strategy and its implementation.

[1] Arm ST. 2020. *Readiness Evaluation for Sustained Operations*. PNNL-29926, Pacific Northwest National Laboratory, Richland, Washington.

Based on the best practices described in this report, and considering the five elements important to sustained operations described above, the following recommendations are made for ORP to consider in preparing for DFLAW production operations. Recommended is that these be implemented prior to hot commissioning.

1. Appoint an ORP Chief Technology Officer (CTO) for DFLAW production operations. The ORP CTO provides focus for F&T matters, coordinates and champions initiatives across the DFLAW mission, and is the ultimate authority for all F&T matters.
2. Form the DFLAW Flowsheet and Technology Advisory Committee, chaired by the ORP CTO. The Committee is the organizational manifestation of the technical authority concept, although final authority resides with the ORP CTO. It serves to consolidate the DFLAW technical community, consisting of Hanford contractors, national laboratories, and universities, and promote their collaboration under the ORP CTO.
3. Establish the 3-5 year vision and strategy for DFLAW F&T. The Committee's first action should be to establish a vision and actionable strategy for DFLAW F&T production operations consistent with an overarching mission production strategy delineating processing objectives. The Committee will then be responsible for monitoring plant performance against the strategy.
4. The Committee initiates development of the DFLAW F&T Taxonomy based on the completed DFLAW design and continuously updated to account for plant modifications. The Taxonomy forms the F&T baseline for DFLAW and the basis to conceptualize and measure continuous improvement and issue resolution initiatives. The Taxonomy describes the DFLAW flowsheet(s) and technologies and associated knowledge concerning production performance, primarily in the form of technical reports. The technical reports would initially be based on design confirmation test results, but would transition primarily to actual plant performance data after hot commissioning.
5. The Committee initiates development of a DFLAW F&T Roadmap for DFLAW production operations. With the Taxonomy including plant performace data as its basis, the Roadmap essentially implements the strategy and resolves descrepancies between actual performance and process objectives. Broadly, the Roadmap addresses what can be done to transform waste into glass "faster, cheaper, and safer." Utility should be made of an established technique such as Lean Management to systematically identify those opportunities.

Implementing these recommendations prior to hot commissioning will ensure the F&T "toolbox" (Taxonomy and Roadmap) and leadership and management structure (ORP CTO and F&T Advisory Committee) – together manifesting the technical authority concept – is actively available for problem-solving and optimization immediately upon the start of actual waste treatment.

Acknowledgments

The work described in this report in part reflects the author's own experience of working in an operations environment and background research of public information. Additionally, however, the author acknowledges the specific input from Christopher Phillips (former chair of the Thermal Oxide Reprocessing Plant Technical Committee at Sellafield, United Kingdom); Vijay Jain, Chief Technology Officer, Savannah River Remediation LLC; Jason Vitali, Chief Technology Officer, Washington River Protection Solutions, LLC; and Anne McCartney, U.S. Department of Energy Office of River Protection.

Acronyms and Abbreviations

AM	Assistant Manager
Committee	DFLAW Flowsheet and Technology Advisory Committee
CTO	Chief Technology Officer
DFLAW	Direct Feed Low-Activity Waste
DOE	U.S. Department of Energy
DST	double-shell tank
F&T	flowsheet and technology
GFC	glass forming chemical
IDF	Integrated Disposal Facility
ILAW	immobilized low-activity waste
LAW	low-activity waste
NASA	National Aeronautics and Space Administration
ORP	Office of River Protection
RPP	River Protection Project
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
SST	single-shell tank
THORP	Thermal Oxide Reprocessing Plant
TSCR	Tank Side Cesium Removal
WRPS	Washington River Protection Solutions
WTP	Waste Treatment and Immobilization Plant

Contents

Figures

Tables

1.0 Introduction

1.1 Background

Currently, the U.S. Department of Energy (DOE) stores approximately 56 million gallons of radioactive and hazardous waste in 177 underground tanks at the Hanford Site. Approximately 20 million gallons of that waste is in a liquid form (supernate), approximately 10 million gallons is in the form of insoluble sludge materials, and the remainder is in a partially soluble solid form referred to as saltcake. Treatment and immobilization of the tank waste is planned, with the Hanford Waste Treatment and Immobilization Plant (WTP) being the principal plant where this will be accomplished. Initially, only supernate and solubilized saltcake, collectively termed low-activity waste (LAW), will be treated and immobilized in the WTP in a Direct Feed Low-Activity Waste (DFLAW) configuration.

The WTP LAW Facility combines hazardous low-level liquid wastes with glass formers to subsequently create a stable waste form suitable for shallow land disposal in a high-temperature melter. The project includes engineering, procurement, construction, and commissioning scope to complete the LAW Facility and selected other WTP facilities such as the Laboratory, Effluent Management Facility, and Balance of Facilities. The DFLAW configuration also requires a LAW feed treatment and delivery system provided by the tank farm contractor.

The tank farm contractor manages the Hanford Site tank waste and tank farms cleanup, including interfaces between the tank farms, WTP, and other Hanford Site contractors providing infrastructure support. The tank farm contractor has responsibility for the delivery of compliant feed to the WTP, managing secondary wastes, and transportation of immobilized low-activity waste (ILAW) containers to the Integrated Disposal Facility (IDF) on the Hanford Site. Another contractor manages the preparations and ultimate operations of the IDF, the low level/mixed waste disposal site for ILAW and secondary solid wastes from DFLAW production operations.

1.2 Purpose and Need

Historically, flowsheet and technology (F&T) initiatives associated with Hanford tank waste treatment and immobilization have been nearly all directed at underpinning the design of facilities. These initiatives are directed at defining and understanding F&T performance with a view to informing and confirming design. With startup of DFLAW facilities perhaps as little as 2 years into the future, that philosophy needs to transition to one appropriate to production operations. Important here is to philosophically differentiate between “production operations” and solely “operations.” Production involves a product while operations does not necessarily. Specific to Hanford, the site has not engaged in production activities since production of plutonium (the product) was terminated several decades ago. However, the Hanford Site today does “operate,” i.e., tank waste is retrieved from single-shell tanks (SSTs) into double-shell tanks (DSTs) and is concentrated by evaporation, but there is no “product.” With DFLAW startup, though, the site again becomes focused on production, with glass as a product in this case.

While current design-driven approaches and individual philosophy would naturally evolve and adapt to the prevailing production circumstances, that laissez-faire approach will more likely lead to misapplication or inefficient application of F&T budget. However, the DFLAW community has opportunity to deliberately define and implement a new philosophy and strategy for managing F&T toward optimizing DFLAW production operations.

As described in this report, the philosophy aims to manage F&T to the benefit of production operations instead of design confirmation. Here it is important for the technological community to accept what is implemented and its performance upon startup as the baseline for optimizing the F&T to the benefit of production. Conceptually, as the F&T philosophy pivots from design confirmation to production improvement, there is a concomitant change in focus from the process to the product. That pivotal focus has fundamental implications for all stages of F&T activities, from their proposal to final reporting.

In summary, the purpose of this report is to promote a deliberate philosophy and strategy for pursuing DFLAW F&T improvements toward optimizing production operations.

1.3 Scope

As described for its purpose, this report is principally concerned with pursuing DFLAW F&T improvements toward optimizing production operations. F&T initiatives will also be driven by immediate production challenges that may not be resolved by operational workarounds. These initiatives require a short turnaround, are specific in nature, and can lead to sub-optimal solutions given limited time available. This report does not explicitly cover the management of such initiatives, although implementation of the recommendations will ensure the capabilities and competencies are available to pursue them as the need arises.

This report establishes best practices for F&T management in the context of the five programmatic elements important to sustained production operations identified by Arm (2020):

- Risk management
- Sustained operations strategy
- Continuous improvement
- Continuity of design and technical authorities
- Stakeholder monitoring

F&T management is described in its relationship to risk management (section 2.0), sustained operations strategy (section 3.0) and continuous improvement (section 4.0). Sections 5.0 and 6.0 describe the technical authority concept and its implementation in terms of organizational and F&T planning dimensions. Stakeholder monitoring is not specifically addressed but is considered in terms of risk management and operations strategy. However, important to note that the programmatic elements should not be individually considered in isolation; there are strong interdependencies that make the more holisitic approach also adopted in this report valuable. Finally, recommendations specific to implementating the technical authority for DFLAW production operations are established in section 7.0.

2.0 Improving Production Operations in the Context of Risk and Opportunity

Consistent with the programmatic elements identified by Arm (2020) as important to sustaining DFLAW production operations, F&T initiatives ideally should be driven by the results of a rigorous program managing production risks and opportunities. The risk management program will be managed as a distinct activity separate from F&T management but shaping it. Risks and opportunities will often be associated with actions that are intended to contribute toward mitigating risk and realizing opportunity. Such actions should include those directed toward F&T initiatives.

Consider risk as it pertains to production operations and F&T. From a technical perspective, a significant source of production operations risk will be associated with uncertainties in waste feed composition and technology performance. A generic mitigating action will be to improve upon the robustness of flowsheets, technologies, and control strategies toward the uncertainties. Put another way, the breadth of an production operations envelope should be commensurate with the significance of the associated technical uncertainties. An ongoing desire to expand production operations envelopes is, therefore, envisioned. Nevertheless, as shown in the context of continuous improvement in section 4.0, this risk can also be considered an opportunity in the context of production. Accounting for compositional uncertainties from a product perspective, for example, will inevitably mean some compromise of the operational performance of a technology, leading to inefficiency. Arguably, aside from definitive gaps that terminate and/or prohibit production, compromises would be made to ensure continued production operations to account for risks. This phenomenon leads to inefficiencies that are actually opportunities for improvement.

3.0 Alignment of Flowsheet and Technology Objectives and the River Protection Project Mission

The objectives for F&T must be aligned with the mission of the River Protection Project (RPP), which is to *safely, efficiently*, and *effectively* treat tank waste and close Hanford tanks. The three elements of the mission (*safety, efficiency,* and *effectiveness*) form the metrics against which alignment of the F&T objectives with the mission is measured. Arm (2020) identified the need for a strategic business plan as important for sustaining production operations. In that context, the three mission elements, at the highest level, are primarily focused on how the sustained operations business plan influences F&T strategy.

Specifically:

- The *safety* element of the mission will transcend the project's phases since F&T will be directed at either obtaining data to incorporate safety into design or improving safety during production operations.
- The element of *effectiveness* is considered related to satisfying mission requirements; examples include glass product requirements and feed acceptance criteria. F&T initiatives related to effectiveness are more relevant to the design confirmation phase of the mission as systems are designed with the intention of best satisfying production operations requirements.
- Only during production operations, however, are the design intentions tested in practice. As described above, design deficiencies manifest themselves as inefficiencies during production operations. Therefore, the F&T objective during production operations is more aligned to the *efficiency* element and directed toward processing waste into glass "safer, faster, and cheaper."

4.0 Alignment of Flowsheet and Technology with Production Continuous Improvement

One of the programmatic elements identified by Arm (2020) as important to sustaining DFLAW production operations is a commitment to continuous improvement. A systematic and historically powerful tool intended to improve production is Lean Management. Lean Management concepts are developed here to demonstrate a structure for identifying and managing F&T improvement opportunities. First, however, the scope of F&T continuous improvement for production operations is discussed.

4.1 The Scope of Production Flowsheet and Technology Continuous Improvement

The National Institute of Standards and Technology has provided a definition of manufacturing (synonymous with production) research and development broadly adapted here for DFLAW production operations. Production innovation is fostered by research and development of flowsheets and technologies that are aimed at improving DFLAW production, cost, and safety. Broadly speaking, production-related research and development encompasses improvements in existing methods or processes, or wholly new processes, machines, or systems, as developed in Table 4.1. The National Institute of Standards and Technology's definition of manufacturing research and development, then, provides the contextual scope of this work.

Table 4.1. The Scope of Production Research and Development

Area	Specific Description
Process technologies and flowsheets that improve the production process	• Fundamental improvements in existing processes or flowsheets that deliver substantial productivity, quality, or environmental benefits • Development of new flowsheets and processes, including new materials, coatings, methods, and practices associated with these processes
Mechanical technologies that improve production equipment and systems	• Improvements in technologies that create increased capability (such as accuracy or repeatability), increased capacity (through productivity improvements or cost reduction), or increased environmental efficiency (safety, energy efficiency, environmental impact) • New apparatus and equipment for production, including additive and subtractive manufacturing, deformation and molding, assembly and test
Systems level technologies for innovation in the manufacturing enterprise	• Advances in controls, sensors, networks, and other information technologies that improve quality and productivity • Innovation in extended enterprise functions critical to production, such as quality systems, resource management, supply chain integration, and distribution, scheduling, and tracking • Technologies that advance integrated and collaborative product and process development, including computer-aided and expert systems for design, tolerancing, process and materials selection, life-cycle cost estimation, rapid prototyping, and tooling
Environment or societal level technologies that improve workforce abilities and manufacturing competitiveness	• Technologies improving workforce health and safety, such as human factors and ergonomics • Technologies that improve workforce manufacturing skills and technical excellence, such as educational systems incorporating improved manufacturing knowledge and instructional methods

4.2 Lean Management Concepts

The remainder of section 4.0 is devoted to brief overview of the Lean Management concept and its application to DFLAW production operations. Doing so serves two objectives:

- Demonstrate the utility of an approach like Lean Management to systematically identify F&T improvement opportunities.
- Demonstrate and encourage promoting one important characteristic of an F&T program oriented toward production operations distinct from design confirmation.

One description of Lean Management comes from Koenigsaecker (2013), which was used as the source material for this report. Lean Management techniques are exemplified by the Toyota Production System and focus on amplifying the activities that directly add value, as recognized by the customer, to raw material to make a product and relentlessly pursuing to diminish those that do not. Lean Management is essentially about continuously improving production operations in four areas:

- Quality improvement – The goal is zero defects, not only in reference to the final product but at every step.

- Delivery, lead time, or "flow" time improvement – An important step in the Lean process is definition of the value stream. The value stream is the series of activities by which value is progressively added to raw material to create the product, i.e., raw material is transformed into a valuable product. This improvement area is focused on reducing the time needed to generate the product, i.e., how can we produce faster?
- Cost or productivity improvement – This improvement area is focused on reducing the activity needed (and thereby cost) to generate the product, i.e., how can we produce cheaper?
- Human development – Human development is generally manifested through group activities to work through the Lean process. Some elements described in this report are best performed by groups for that reason as well as to reflect the broad viewpoint, but are developed here by the author for illustrative purposes in defining the F&T improvement philosophy focused on production optimization.

Activities not considered part of the value stream are defined as waste and candidates to be considered for minimization and, ultimately, elimination. Elimination may not be achievable but should be considered the goal, which, in reality, is approached asymptotically with diminishing returns. Lean waste can be broadly considered in seven categories, which are each related to the waste areas described above, as shown in Table 4.2.

Table 4.2. Definition of Waste Categories

Waste Category	Waste Area(s)	Description
Overproduction	Productivity	Generating or acquiring more than is needed to satisfy value expectations
Over-processing	Productivity and flow time improvement	Transformational activity not needed to satisfy value expectations
Production of defects	Quality improvement	Failure to satisfy quality control criteria
Movement or transport	Productivity and flow time improvement	Moving any item from one place to another
Inventory	Productivity	Storage of overproduced items
Waiting time	Productivity and flow time improvement	Time lapse between transformational activities
Unnecessary motion	Productivity and flow time improvement	Performance of non-value-added and non-transformational activity

4.3 Defining the DFLAW Value Stream

The DFLAW value stream is defined by first considering the RPP mission: to safely, efficiently, and effectively treat tank waste and close Hanford tanks. Tank waste is currently stored as saltcake (precipitated salt) and sludge in SSTs and as saltcake, sludge, and liquid in DSTs. The waste in the SSTs poses the greater threat to the environment because of their single containment, which in some cases has failed. Therefore, the environmental threat is reduced as waste is retrieved from SSTs into DSTs. The DSTs essentially serve to consolidate and characterize tank waste for treatment, stabilization, and disposal because of their superior integrity and design for storing hazardous material. Nonetheless, both SSTs and DSTs need to be closed, and so waste requires retrieval, treatment, stabilization, and ultimate disposal.

In the language of Lean, tank waste (the raw material) is transformed into a stabilized waste form suitable for disposal (the product). Furthermore, for purposes of defining the value stream, calling out the hazardous and radioactive constituents from the tank waste is necessary because only they are important for environmental protection. For brevity, however, the text refers to “tank waste.” Therefore, the RPP’s value stream for tank waste can be described by Figure 4.1.

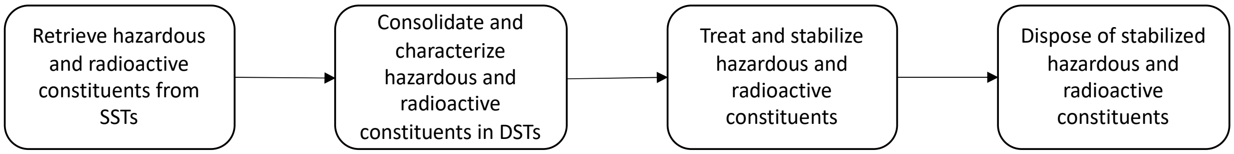

Figure 4.1. River Protection Project Value Stream for Tank Waste

There are two key unique characteristics of DFLAW:

- Tank waste stabilization occurs in the WTP LAW Facility, specifically in a glass matrix since vitrification is the stabilization technology deployed in WTP.
- Disposal of the glass product occurs in the IDF.

Therefore, the tank waste and glass product need to satisfy the feed requirements for WTP delineated by the RPP (2015) and IDF provided by Borlaug (2019), respectively. Consideration of these feed requirements means that a significant volume of liquid tank waste can be selected and staged for stabilization and disposal without the need for any pretreatment except separation of insoluble particulate and cesium-137. Pretreatment of the liquid tank waste will occur in the Tank Side Cesium Removal (TSCR) system. The specific DFLAW value stream for tank waste can be described by the flow diagram in Figure 4.2.

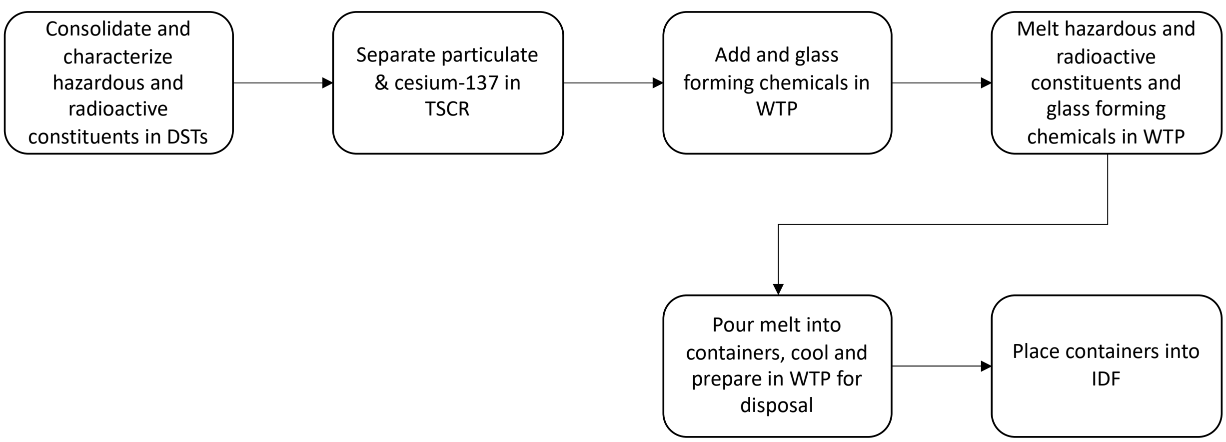

Figure 4.2. DFLAW Value Stream for Tank Waste

Each of these steps represents a progressive transformation of tank waste into a product of value. Thus far, no mention has been made of what constitutes “value.” Typically, value is associated with the price a customer would pay for the product. At Hanford, Congress pays for the transformation of tank waste into glass, but arguably that could equally be transformation into any form (e.g., grout). Nonetheless, product acceptability is defined by the environmental permits promulgated by the Washington State Department of Ecology in their role as regulator. Arguably, though, Congress expects a product compliant with regulations and so could be considered the "customer." In any case, defining the customer is perhaps unnecessary because the value stream architecture for DFLAW is what defines the product.

The proposed DFLAW value stream is now further discussed. Liquid tank waste is consolidated as a feed campaign in a DST where it is characterized to show it satisfies requirements for further processing in TSCR and WTP. Treatment occurs in TSCR, where cesium-137 and particulate are separated to satisfy acceptance limits for subsequent stabilization. In actuality, the treated tank waste is then staged in several locations before glass forming chemicals (GFCs) are added to it in the WTP. These interim staging activities, which include characterization in the WTP ostensibly required to determine the types and quantities of GFCs needed, are not considered value-added. Staging in itself represents an inventory Lean waste, and characterization is performed prior to acceptance at TSCR and is an overproduction Lean waste. The value addition of this characterization activity is probably a matter for group discussion. Determination of what constitutes value-added GFCs would also benefit from group discussion. There is very little silicon in LAW, and this element obviously needs to be added to make glass. Other GFCs improve glass durability, and these need to be considered with reference to the IDF waste acceptance criteria. Still others are added to optimize glass physical properties and melter performance. These are unlikely to be value-added in the Lean sense, but discussion is still needed.

Tank waste is transformed into glass by melting it with the GFCs at high temperature in a melter. Notably, treatment and management of the offgas and effluents from the melter do not add value to the product and so are not considered in the value stream. To satisfy acceptance criteria for IDF, the molten glass is poured into containers, cooled, and prepared (primarily enclosure) for placement into the disposal facility.

Value stream analyses of the DFLAW flowsheet were performed in December 2014 (Spires et al. 2016) and May 2016 (Arm et al. 2016). These analyses focused on the flowsheet in terms of material flow between facilities rather than the flow related to additive value to facilitate flowsheet maturation. The analyses were also performed in the context of design confirmation as the prevailing nature of the project at the time. The teams identified initial and target flowsheets that accepted some non-value streams to be inherent to the flowsheet that satisfied the purposes of the time. However, a generic value flowchart purely focused on value progression, as illustrated in this discussion, sharpens the differentiation between value and waste streams.

4.4 Defining DFLAW Lean Wastes

Anything that doesn't increase the product's value in the eye of the customer or, alternatively, directly contribute toward transformation of raw material into product, must be considered waste. For DFLAW, raw materials are conceptually tank waste and GFCs while the product is glass. DFLAW activities can all be considered as Lean waste or value-added. Lean waste activities reduce productivity because they contribute to the cost of production without adding value. They can also increase flow time if the activity disrupts the value stream.

Minimizing Lean waste to transform tank waste into glass safer, faster, and cheaper is the objective of F&T management during DFLAW production operations. Within this philosophy, what are considered F&T gaps from the standpoint of design confirmation become production operations limitations or risks that deleteriously would or could impact productivity and flow time. By way of example, consider the current gap related to iodine-129 management. The current gap is in knowing the performance of individual offgas system unit operations in separating iodine from the melter offgas. There is a risk that the iodine-129 concentration in the effluent sentenced to the Effluent Treatment Facility exceeds its acceptance criteria. In the design confirmation phase, the chemistry of iodine is being evaluated in attempting to determine if a flowsheet adjustment (possibly including a new unit operation) is required to affect its separation from the effluent. Note that the focus is on the process. Now consider the scenario whereby the risk is realized during production because the determination could not be made with sufficient certainty for its acceptance by project and program managers prior to hot commissioning. The required action within the current permit and flowsheet construct might be to recycle the effluent to the melter to incorporate the iodine-129 into glass (product focus) not already incorporated in the first pass. Doing so, however, deleteriously impacts productivity and flow time because less tank waste can be transformed in the same time given the effluent contains constituents other than tank waste.

Given the foregoing definitions of Lean waste types and the DFLAW value stream, Table 4.3 describes some examples of DFLAW Lean wastes for each type. Many of the examples are self-evident wastes by their description (secondary wastes). Others, such as transportation of ILAW containers, are less obvious and become evident by considering the value stream in particular.

Table 4.3. Examples of DFLAW Lean Wastes

Lean Waste Type	Summary Description	Example DFLAW Wastes
Overproduction	Generating or acquiring more than is needed to satisfy value expectations	• Generation of cesium-loaded ion exchange columns from TSCR • Generation of any DFLAW by-product (i.e., "secondary waste," that is liquid effluent, offgas, failed equipment, and other solid waste) • Compromising waste loading in product to account for compositional and technology performance uncertainties
Over-processing	Transformational activity not needed to satisfy value expectations	• Treatment for hazardous and radioactive tank waste constituents in DFLAW by-products • Stabilization of non-hazardous and non-radioactive tank waste constituents • Concentration and recycle of melter offgas system liquid effluent • Duplicated characterization of tank or secondary wastes
Producing defects	Failure to satisfy quality control criteria	• Analytical quality control failures during feed characterization and process control
Movement or transport	Moving any item from one place to another	• Transport of ILAW containers from WTP to IDF • Pumping of LAW feed to TSCR and from there to WTP
Inventory	Storage of overproduced items	• Storage of loaded ion exchange columns from TSCR • Short term storage of secondary wastes • Any "staging" of LAW
Waiting time	Time lapse between transformational activities	• Switching loaded and fresh ion exchange columns in TSCR (putting TSCR offline) • Replacing bubblers in the melter (making the melter offline)
Unnecessary motion	Performance of non-value-added and non-transformational activity	• Any decontamination activity

4.5 DFLAW Lean Metrics

Metrics are needed to understand the significance of a Lean waste. The previous discussion showed that productivity and flow time should be the main areas of focus for improving the context of DFLAW production operations optimization.

The traditional measure or metric for productivity is cost per unit of product, with cost largely driven by human resources, raw material, and equipment. Theoretically, each F&T initiative could be associated with a reduction in the cost of stabilizing a unit measure of tank waste into glass. However, the cost metric is probably too complex to be of practical application for understanding the benefits of F&T initiatives. Instead, the total process time needed to transform and disposition a campaign of tank waste into product and by-products is proposed since there is a direct relationship between time and cost. Consider secondary liquid effluent as an example by-product. Processing of the secondary liquid effluent arising from a campaign must be complete within the time needed to process the LAW campaign to avoid it becoming a bottleneck. Therefore, the total process time then conceptually becomes double the campaign process time. Processing of other by-products (secondary waste) must then be considered in like manner. Actual DFLAW performance will inform the total process time. However, an initial baseline value can be derived from design bases and risks for preliminary purposes in determining the benefits of competing F&T initiatives.

The flow time is the time needed to transform tank waste into glass and disposition it. Again, actual DFLAW performance will inform the total process time. The flow time currently baselined for design purposes for a campaign of tank waste includes down time for changing out TSCR ion exchange columns, staging, and other Lean waste activities.

Thinking in terms of DFLAW flow time and productivity pivots DFLAW F&T initiatives from primarily design confirmation (in the broad sense) to aiming to minimize the seven Lean wastes in Table 4.2 and transforming tank waste into glass safer, faster, and cheaper. Existing plans and programs can be transitioned from their emphasis on design confirmation to production optimization and their scope commensurately adjusted. A strategy for F&T management can be conceived to provide overall direction. It is recommended that the strategy and implementing plans are recommended to be managed by a DFLAW Flowsheet and Technology Advisory Committee, which would provide overall direction to DFLAW production operations F&T management. The Committee’s model charter is described in section 6.0, but is prefaced by discussion of alternate F&T strategic planning process and management approaches directed toward DFLAW production operations in section 5.0.

5.0 Planning and Managing Flowsheet and Technology Improvements

Several approaches can be used to manage improvements to F&T in a general sense, as discussed in sections 5.1 and 5.2. Section 5.3 compares the current F&T management approaches at the Hanford and Savannah River Sites. Sections 5.4 and 5.5 discuss the F&T strategic planning process in the context of the DFLAW mission. These discussions serve as the basis for recommendations to the DFLAW mission identified in section 7.0.

5.1 Technology Roadmaps and their Use

Technology roadmaps are one tool for managing and planning F&T. Technology roadmaps have an ongoing utility at the Hanford Site and the RPP. For example, the most recent the Technology and Innovation Roadmap (Reid et al. 2020) provides a compendium of technology development and maturation opportunities and needs related to the RPP mission, though it does not cover WTP or DFLAW production operations.

Galvin (2004) has provided a very broad definition for the purpose of technology roadmaps in providing an "extended look at the future from the collective knowledge and imagination of the groups and individuals." The author further explains a roadmap becoming the "inventory of possibilities for a particular field" and as a means to "communicate in a convincing and coordinated way with colleagues within business and government policymakers."

Yet, while "roadmapping" has become somewhat of a cliché tool, some more fundamental definitions will help in identifying the appropriate tool for communicating improvements to F&T to optimize production. Phaal et al. (2004) addressed some of these fundamental questions. To them, "technology" is applied knowledge focusing on an organization's "know-how." Technology management is then the "effective identification, selection, acquisition, development, exploitation and protection of technologies needed to achieve, maintain [and grow] a market position and business performance in accordance with the company's objectives." For the DFLAW program, market and business performance arguably relate to the competitive environment of appropriating federal funds for the RPP to successfully complete its mission to safely, efficiently, and effectively treat tank waste and close Hanford tanks.

Phaal et al. (2004) identify eight types of technology roadmaps based on their intended purpose. Of these, roadmaps for integration planning would serve as the best template for a plan describing F&T improvements to optimize DFLAW production. This type of roadmap would focus on how F&T improvements would combine into the DFLAW product or system with less focus on any strategic milestones. The integration planning roadmap type describes the technology flow, showing how it matures through test and demonstration systems before insertion into the flowsheet or plant.

Probert et al. (2003) discuss the relationships between technology, product, and market layers with an emphasis on commercial markets for products. For the DFLAW program, the market layer would include the external drivers for F&T management, including cost (as it relates to federal funding), strategic objectives, and environmental constraints, for example. The product layer includes not only the DFLAW product (glass) requirements, but also program risks, opportunities, and process performance, for example. Whereas technology represents the "know-how," product and market layers represent the "know-what" (i.e., the tangible) and "know-why" (i.e., the purpose), respectively. Therefore, technology not yet applied in DFLAW production may be driven toward incorporation into a tangible and so influence DFLAW purpose and strategy. This is technology push. Development of the enhanced waste glass formulations is an example of technology push in the DFLAW program. Usually, however, it is

DFLAW purposes and requirements that drive the need for a particular tangible, which incorporates newly matured technology. One example of market pull in the DFLAW program was the decision to switch to crystalline silicotitanate for cesium ion exchange in TSCR based on cost and DST space management drivers. Both technology push and market pull, then, have their place in a DFLAW F&T management plan.

5.2 Other Flowsheet and Technology Planning Tools

The National Aeronautics and Space Administration (NASA) has historically been a leader in the development of technology roadmaps and technology management. Most recently, however, NASA has moved away from using roadmaps to manage technology at the strategic level since they were found to be disregarded by potential users. Instead, this year NASA (2020) published their Technology Taxonomy, which provides a description and classification of their technology portfolio. Additionally, a strategic framework has been established as described by Earle et al. (2018). Roadmaps are then an option for technology planning at the tactical level but are not proscribed.

The goal of NASA's strategic framework is to deliver a high-performing space technology portfolio; delivering technologies in the near term that directly address customer needs (market pull in the roadmap discussion above) while identifying and maturing immature technologies that address future anticipated customer needs and transform the industry (technology push). The framework identifies strategic trends, what are termed *mega-driver*s, derived from community dialogue that have driven, are driving, and will drive the space program. These mega-drivers lead to the identification of strategic thrusts or visions for the future. The framework goes onto identifying the outcomes, or achievements, necessary to realize the visions. Finally, the products and capabilities, or technical challenges, are identified for the outcomes to be realized. Complementary to the strategic framework is NASA's (2020) Technology Taxonomy. NASA considers the Technology Taxonomy key to their ability to manage and communicate their technology portfolio by providing a structure articulating the diverse technologies relevant to the NASA mission.

The physical nature of NASA's mission is obviously very different from that of DFLAW. DFLAW is centered on a fixed plant, WTP, which has at best moderate flexibility to accommodate new or enhanced hardware. TSCR has a modular character, which has greater flexibility. Nonetheless, a technology taxonomy could be valuable in providing an overview of the technologies important to DFLAW.

5.3 Flowsheet and Technology Management at Hanford, Savannah River, and Sellafield Sites

This section evaluates the differences in how the Hanford Site and Savannah River Site (SRS) manage technology. Interestingly, two different management approaches are represented at these two DOE sites, which have similar missions for the Office of Environmental Management.

Both sites' contractors have a Chief Technology Officer (CTO) who, at the highest level, acts as the champion and point of contact for technology. There is no CTO position in either DOE local office at Hanford and SRS, but a senior engineering staff member is assigned responsibility for overseeing technology. Another commonality evident from both sites is that technology is managed under the engineering umbrella. At SRS, technology resides within the contractor's individual projects and facilities engineering functions while the contractor's CTO's organization at Hanford is under the purview of the contractor's chief engineer. This characteristic is also evident within the respective local DOE offices.

The SRS CTO has neither staff nor budget for progressing technology. Instead, technology maturation is budgeted and managed by the project or facility and the CTO coordinates and integrates those activities at a site level. Technology activities at SRS are described in a report prepared by Savannah River Remediation (2017). Savannah River Remediation's technology program uses the expertise and experience of the workforce to develop potential technology ideas that can increase processing rates, decrease costs, and increase safety. These ideas are described in the blueprint, typically on single pages that summarize the issue and potential approach to resolution. The program also uses senior engineering management in a Technology Oversight Committee to evaluate and prioritize the technology development proposals to maximize DOE's return on investment.

Nearly all of SRS's technology activities are undertaken by Savannah River National Laboratory (SRNL). This single source for technology helps in managing resources as emerging issues arise in the facilities that require nearer term attention. One advantage of the devolved nature of technology management at SRS is that technology improvements are inherently championed by the projects and facilities for implementation; i.e., there is ownership by the projects and facilities. On the other hand, however, technology maturation is a more likely candidate for deferral when project and facility budgets are reduced. Additionally, technology ideas put forward by the projects and facilities tend to be of nearer term time horizon and more focused on incremental improvement to technology familiar to the generator.

In contrast, the Hanford CTO has an organization within the tank farms contractor's engineering function focused on maturing technology for the projects and facilities. Nonetheless, projects and facilities undertake some specific near-term activities, depending on need and budget availability. Technology ideas are generated both by the project and the facility subject matter experts and by the CTO's organization, with input from the national laboratories. Ideas generated by the CTO's organization can be more than incremental improvements, but face the challenge of becoming accepted by the projects and facilities for which they are intended.

The RPP Integrated Flowsheet is managed by an organizational element in Washington River Protection Solutions (WRPS) consistent with a plan described by WRPS (2019). Interfaces between plants and capabilities are the primary focus of the RPP Integrated Flowsheet program, and a Technical Advisory Committee provides advisory oversight. The Technical Advisory Committee is chartered to include participation from process engineering and technology managers from the DFLAW contractors and from Pacific Northwest National Laboratory and SRNL. The national laboratories provide for technical defensibility and continuity of scientific expertise.

A common theme at Hanford and SRS is that technology is overseen and managed with significant input from engineering organizations as the drivers for technology improvement and needs. Priorities for technology at both sites are driven by consensus, largely by engineering participants as the primary customers. The tank farms contractor's CTO organization at Hanford provides for a longer temporal viewpoint beyond the immediate needs of projects and facilities. However, the lack of a similar organization at SRS is not necessarily significant because the longer term perspective is demonstrably provided to an extent by the engineering organizations in the operating facilities. In contrast, DFLAW facility organizations are overwhelmingly sighted on the near-term objective of startup, which one would expect to change to something similar to the SRS approach as they attain a steady state production status.

Another point of reference for operating production plant is the Thermal Oxide Reprocessing Plant (THORP) at Sellafield in the United Kingdom. THORP reprocessed used nuclear fuel from a commercial nuclear power plant to produce fissile material product for recycle. THORP started with two technical committees, once commissioning was completed and production operations began, covering the two main processing areas of the plant. Ultimately, the two committees were merged to become the Reprocessing Plant Technical Committee. The committees had membership from the THORP technical, operations, and safety groups with design participation in the early years of operations. The customer perspective was provided by representatives from the commercial department. The committees considered all technical aspects of THORP’s operations: (1) product quality, operational deviations, operational efficiency, off-normal operations, and “near misses,” and what could be learned from them: (2) cold chemical feed qualities and effects on operations: (3) flowsheet performance and maintenance; (4) proposed flowsheet modifications and their likely effects; and (5) formal approval of all operational flowsheets. Some safety issues were also considered, but THORP had a separate safety committee, which, as well as considering any safety deviations, also had to formally approve all proposed plant and flowsheet modifications.

Together, the Hanford, SRS, and Sellafield (THORP) sites provide a spectrum in technology and flowsheet management and the role of technologists. On THORP, F&T was explicitly managed by a technical committee with direct participation of technologists, while it is apparently driven more by engineering functions alone at SRS with technologists (a role largely represented by SRNL) fulfilling purely provider rather than instigator roles. Hanford sits somewhat in the middle, with technologists embedded in the CTO and flowsheet organizations and providing some input for at least flowsheet management in technical defensibility and scientific advice.

5.4 Considerations for a DFLAW Production Technology Strategic Plan

As explained by Gaynor (1996), “strategy” is the first step toward implementation of objectives; it is separate from planning, which responds to what specifically should be done. Additionally, a strategy is a living document that should be amenable to frequent review and should be considered as a “paragraph on a sheet of paper.”

A strategy for F&T, then, is important in providing overall direction and prioritization to F&T initiatives. Important here is alignment of F&T with the production strategy for its benefit to be explicitly articulated. Arm (2020) identified integrated business planning as important for sustaining operations, and the result of that exercise would be an integrated production plan for the RPP mission. While a technology roadmap and/or taxonomy provides a description of the F&T portfolio, the strategy is the first step in describing how the portfolio is implemented to meet strategic objectives. For example, NASA has developed a strategic framework for its Space Technology Mission Directorate using a process described by Earle et al. (2018).

As described by Earle et al. (2018), NASA’s strategic planning for technology starts with understanding current space policy and the NASA strategic plan before proceeding to a dialogue with stakeholders to ground the exercise in their needs and trends. This understanding drives a strategic response, essentially a vision, that is decomposed into strategic thrusts that focus on major lines of investment. Each thrust area then has a set of objectives, or outcomes, that prioritize investment. The NASA process is not unlike the approach undertaken by WRPS in developing their Technology and Innovation Roadmap in the extensive dialogue with stakeholders to understand their needs and trends. Different, however, at Hanford is the lack of a current explicit vision and strategy for F&T aligned with the overarching mission of the DOE Office of River Protection (ORP).

Concluding, then, that an F&T vision and strategy is needed for the DFLAW program, Szakonyi (1996) has described the preconditions for their development:

1. Perception that a strategy can solve a problem – For the DFLAW program, the problem is: How should we manage F&T to sustain DFLAW production operations? Such a question recognizes technical authority as a key element for sustaining operations consistent with Arm (2020).

2. Commitment from F&T managers to devote their time to developing a F&T strategy – This is arguably a question more of identifying individuals with a strategic and technical dispositional nexus to lead the development. Such individuals can listen to the DFLAW F&T community to consolidate and articulate any already implied strategy and apply the thought leadership toward developing a strategy for the future.
3. Linking F&T strategic planning with F&T operations – This precondition relates to ensuring the strategy is used to prioritize and coordinate F&T projects. A strategy of some form is always at least implied when F&T projects are prioritized, for example in Reid et al. (2020).
4. Linking F&T strategic planning with product or process marketing – This precondition may not appear immediately relevant to the DFLAW program, but Szakonyi (1996) directs it toward understanding economic, regulatory, demographic, and social trends and opportunities. Therefore, the precondition distills to ensuring the strategic planning exercise is aligned with stakeholders, and in doing so links technical authority to stakeholder monitoring, which Arm (2020) identified important to sustaining operations.
5. Active support from senior management – To gain this support, an F&T organization must be able to explain the benefits of continuously improving F&T in language senior management can comprehend and articulate themselves. For the DFLAW program, transforming waste into glass faster, cheaper, and safer is one such high-level articulation of DFLAW F&T strategy.
6. One or more previous efforts to develop an F&T strategy – Essentially, this precondition is a commitment to continuously improving the F&T strategy in serving the needs of the mission.
7. Concrete efforts that produce tangible results on their own – The strategic planning exercise consists of contributing tasks that by themselves produce tangible results. For example, consolidating F&T elements into a taxonomy like that of NASA (2020) by itself provides the foundation for their improvement by laying out the baseline. However, it also contributes to the strategy development. Another example is group analysis of the strengths, weaknesses, opportunities, and threats (SWOT) associated with an F&T area. These analyses by themselves produce tangible results by enlightening staff to the strategic dimension of their individual contributions, but also serve to underpin the strategy itself.

The foregoing discussion leads into the framework for developing an F&T strategic plan articulated in the next section.

5.5 DFLAW Production F&T Strategic Planning Framework

Without considering the five elements important to sustaining production operations identified by Arm (2020), one could conclude that a “do-nothing” strategy for F&T is perfectly acceptable. F&T activity then becomes purely reactive in single issue management and responding to problems. However, recognizing the five elements means F&T management becomes proactive and an intrinsic and necessary piece of the DFLAW program. Furthermore, the DFLAW program is naturally F&T intensive by being about transforming waste into glass. Therefore, the natural outcome of a “do-nothing” strategy for F&T is DFLAW production operations become unsustainable. A “do-something” strategy for DFLAW F&T is, then, a prerequisite for sustaining production operations.

The five elements important to sustaining production operations described by Arm (2020) form the principal tenants or framework of any DFLAW F&T strategy. As already stated, DFLAW is an F&T-intensive program that transforms tank waste into glass, which is subsequently dispositioned. To sustain production operations, DFLAW F&T needs to meet the following conditions:

- F&T must be continuously improved so the transformation is accomplished progressively faster, cheaper, and safer.
- Improvements should be prioritized by considering programmatic and risk and opportunity analyses.
- Improvements should be informed by stakeholder values and priorities.
- Improvements should inform and should be driven by production targets that contribute toward accomplishing RPP mission objectives.
- Improvements must be managed and directed by an established technical authority and guided by the design authority.

A prerequisite to any strategy is a vision, and together they form a mission. The following example demonstrates the utility of the framework, but is considered sufficiently realistic that it could be adopted or at least implied. For DFLAW in the 3-5 year window after startup based on Mauws (2020), the vision is arguably to create sufficient space in the DST system to enable completion of retrieval of waste in the SSTs in A and AX farms compliant with Consent Decree milestones. The five tenants executed as programs will all contribute to a strategy to realize that vision:

- Focus primarily on improvements transforming waste into glass faster.
- A risk and opportunity program identifies the most effective initiatives.
- Compliance with Consent Decree milestones is a value associated with several important stakeholders and builds goodwill and trust as well as associated legal compliance. Monitoring stakeholder attitudes and input is key to managing expectations for F&T improvements.
- A production plan identifies the targets for the F&T improvements.
- A technical authority promotes the role of F&T improvements in mission success and manages integration of the initiatives.

6.0 DFLAW Flowsheet and Technology Advisory Committee

This section presents a draft conceptual charter for the DFLAW Flowsheet and Technology Advisory Committee (the Committee). Establishing the Committee is recommended for the DFLAW program given its complexity, the highly inter-related nature of its constituent facilities and projects, and its high dependence on one of a kind technologies and flowsheet. The current Hanford Flowsheet Technology Advisory Committee and tank farms contractor CTO organization are discussed in section 5.3. The former committee could be assimilated into the DFLAW Flowsheet and Technology Advisory Committee. The tank farms contractor CTO would have a role but would not be wholly assimilated given the individual and organization have technology responsibilities outside the scope of DFLAW production operations (e.g., waste retrievals and tank farm operations).

6.1 Roles and Accountabilities

The Committee's primary role is in assisting the DOE Assistant Manager's (AM's) leadership team in fulfilling their responsibilities for technical oversight of DFLAW production operations.

The Committee is accountable to the DOE AM responsible for the DFLAW program or its production operations.

The Committee is chartered to provide continuity and consistency in its technical expert assistance and integrated knowledge management between DOE, technology providers, and the plant engineering organizations to facilitate the optimization of production operations. To fulfill its role, the Committee must be actively engaged in plant operations with active interest in the results from analyzing plant performance and reliability data.

6.2 Responsibilities and Authorities

To assist the DOE AM's leadership team, specific responsibilities and authorities of the Committee include the following:

- Establish and maintain a strategy for F&T consistent with the DFLAW sustained operations business plan identified in Arm (2020) and as prepared by others.
- Initiate, review, and approve the DFLAW Flowsheet and Technology Roadmap for Production Improvement and any other products of the Committee.
- Initiate actions targeted to address emerging shortfalls in F&T performance and reliability.
- Review the following on a regular basis with other program functions (e.g., risk management, plant engineering, and production planning):
  - The current state of F&T performance and reliability as measured through the appropriate key metrics and goals previously established in the F&T strategy
  - Actions and risks associated with any emerging shortfalls in F&T performance and reliability for inclusion in the DFLAW Flowsheet and Technology Roadmap for Production Improvement or immediate attention depending on need
  - Ongoing and proposed F&T improvement programs, emphasizing results as measured against goals
  - The DFLAW Program Risk and Opportunity Register and status associated with F&T mitigating actions

- Periodically review the processes established for F&T improvement and reliability, and change control.
- Review as judged needed by the Chair any proposed changes to the organizational structures that could significantly impact the management and/or responsibilities for F&T optimization, performance, or reliability.

In discharging its responsibilities, the Committee will transparently integrate the knowledge and experience of its participating organizations with DFLAW production operations optimization its single objective.

6.3 Structure and Operations

The Committee is chartered to provide continuity and consistency of technical expert assistance to the DOE AM's leadership team and integrated knowledge management. To fulfill these roles, the Committee is structured to facilitate participation of subject matter experts in specific functional areas of the DFLAW program. As shown as a draft concept in Figure 6.1, there are five potential subcommittees of the Committee covering the main functional areas of the DFLAW program: Waste Feed Delivery, Melter Feed and Vitrification, Offgas Treatment, Secondary Waste Treatment, Glass and Waste Disposal. The Committee integrates and coordinates the work of the subcommittees and also assumes ownership of any functional area not covered if the need arises.

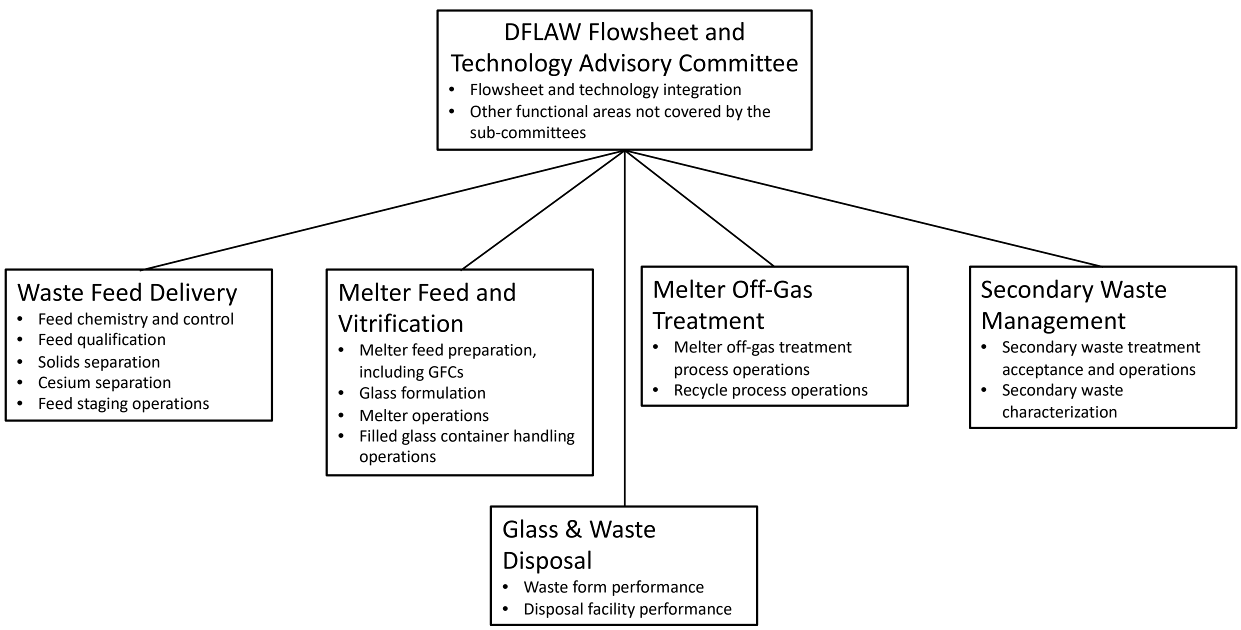

Figure 6.1. Structure of the DFLAW Technical Advisory Committee

The Committee and subcommittees are chaired by DOE staff. The DOE AM appoints the Committee chair, who then appoints subcommittee chairs. Subcommittee chairs appoints the subcommittee members with concurrence from the Committee chair. The Committee chair serves as the point of contact to the DOE AM and the subcommittee chairs and is the ORP CTO.

The (sub)Committee shall meet in person or telephonically with such frequency (but no less than quarterly) and at such times and places as may be determined by the (sub)Committee chair, with further actions to be taken by unanimous written consent when deemed necessary or desirable by the (sub)Committee or its chair. The chair, with input from other members of the (sub)Committee and, where appropriate, the DOE AM leadership team, shall set the agendas for (sub)Committee meetings. The (sub)Committee may request that any subject matter experts or manager attend any meeting of the (sub)Committee to provide such pertinent information or guidance as the (sub)Committee requests. The (sub)Committee shall maintain minutes or other records of its meetings.

The (sub)Committee secretaries are appointed from the participants and are responsible for preparation and control of the minutes or other records, tracking completion of actions, and implementing determinations of the Chair.

The Committee shall give regular reports to the DOE AM leadership team on its meetings and other such matters as required by this Charter or as the DOE AM leadership team shall periodically specify. Reports to the DOE AM leadership team may take the form of oral reports by the chair of the Committee or any other member of the Committee designated by the Committee to give such report. Individual subcommittees may make special reports at the request of the Committee chair or DOE AM.

6.4 Committee Participants

The Committee is chartered to provide continuity and consistency of technical expert assistance to the DOE AM leadership team and integrated knowledge management. To fulfill this role, Committee participants should be the recognized equivalents of DFLAW Flowsheet and Technology Program managers and plant engineering managers.

The subcommittees should include individuals with F&T management experience, but who are also cognizant of the specific flowsheet or technologies in the scope of the (sub)Committee. Engineering participants will be responsible for the plant encompassed by the scope of the subcommittee.

The (sub)Committee chair is responsible for appointing their (sub)Committee’s participants. However, at minimum, the Committee and subcommittees should include at least one individual from the following organizations (unless declined by the organization):

- Pacific Northwest National Laboratory
- Savannah River National Laboratory
- Atkins Nuclear or Vitreous State Laboratory
- Hanford tank farms (engineering and/or F&T management)
- Hanford Waste Treatment and Immobilization Plant (plant engineering and/or F&T management)

7.0 Recommendations for Managing DFLAW Production Flowsheet and Technology

As already described here and by Arm (2020), an active technical authority is a foundational element to a sustained operations culture and especially so for the F&T-intensive DFLAW mission. Therefore, and on the basis of the foregoing discussion, the following recommendations are made for ORP to consider in preparing for DFLAW sustained production operations.

1. Appoint an ORP CTO for DFLAW production operations. The ORP CTO provides focus for F&T matters, coordinates and champions initiatives across the DFLAW mission, and is the ultimate authority for all F&T matters. The ORP CTO is the leadership manifestation of the technical authority concept.
2. Form the DFLAW Flowsheet and Technology Advisory Committee chaired by the ORP CTO. The Committee is the organizational manifestation of the technical authority concept, although final authority resides with the ORP CTO. It serves to consolidate the DFLAW technical community consisting of Hanford contractors, national laboratories, and universities and promote their collaboration under the ORP CTO.
3. Establish the 3-5 year vision and strategy for DFLAW F&T. The Committee's first action should be to establish a vision and actionable strategy for DFLAW F&T production operations consistent with an overarching mission production strategy delineating waste processing objectives. The Committee will then be responsible for monitoring plant performance against the strategy.
4. The Committee initiates development of the DFLAW F&T Taxonomy based on the completed DFLAW design. The taxonomy forms the F&T baseline for DFLAW and the basis to conceptualize and measure continuous improvement initiatives. The taxonomy describes the DFLAW flowsheet(s) and technologies and associated knowledge concerning production performance, primarily in the form of technical reports. The technical reports would initially be based on design confirmation test results, but would transition primarily to actual plant performance data after hot commissioning.
5. The Committee initiates development of a DFLAW F&T Roadmap for DFLAW production operations. With the Taxonomy including plant performace data as its basis, the Roadmap essentially implements the strategy and resolves descrepancies between actual performance and process objectives. Broadly, the Roadmap addresses what can be done to transform waste into glass "faster, cheaper, and safer." Utility should be made of an established technique such as Lean Management to systematically identify those opportunities

A typical of first-of-a-kind chemical process plant, the WTP will undergo cold commissioning with a relatively narrow scope. As described in Oakes and Matejek (2020), cold commissioning of the WTP is focused on the Environmental Performance Demonstration Test using simulated waste unrepresentative of DFLAW feed in terms of the concentrations of key constituents (sodium and sulfate). The cold commissioning approach does not include demonstrating plant performance across a broad range of DFLAW feed compositions. Therefore, the plant performance with respect to feed variability will only become apparent upon processing actual tank waste, when response to plant inefficiencies will be more urgent and complex. Implementing these recommendations prior to hot commissioning will ensure the F&T "toolbox" (Taxonomy and Roadmap) and leadership and management structure (ORP CTO and F&T Advisory Committee), together manifesting the technical authority concept, are actively available for problem-solving and optimization immediately upon the start of actual waste treatment.

8.0 Conclusions

Active F&T management is important to sustaining production operations and more so for F&T-intensive production exemplified by the DFLAW mission. The work reflected by this report demonstrates that a best practice for F&T management is identifiable from F&T-intensive commercial and government enterprises. Management of F&T is shaped by the five programmatic elements important to sustained production operations identified by Arm (2020):

- **Risk management** – Identification and prioritization of F&T initiatives should be driven by an active risk management program that rigorously articulates the likelihood and consequence of DFLAW risks and opportunities and associated mitigating actions.
- **Continuous improvement** – F&T initiatives for DFLAW production operations should be focused on continuously improving the rate of transforming waste into glass, the cost, and safety (transforming waste into glass “faster, cheaper, and safer”). One such technique recommended for F&T management to help in identifying improvement opportunities is Lean Management.
- **Continuity of technical authority** – Recommended for DFLAW production operations is establishing an explicit technical authority over the DFLAW mission. Technical authority is a concept embodying F&T leadership, management, erudition, and continuous improvement drive.
- **Stakeholder monitoring** – Hanford waste treatment operations are influenced by complex and wide-ranging stakeholders at federal, state, and local levels of government and regulators and the public. Stakeholders are not expected to directly influence F&T management, but indirectly through the risk management program and sustained operations strategy (below).
- **Sustained operations strategy** – An integrated Hanford waste treatment operations business plan is recommended for the Hanford Site, encompassing, for example, production, environmental, and legal objectives and considerations for long-lead and/or critical procurements. The strategy for achieving production operations objectives, with its near-term focus, is a primary influencer of the F&T strategy and its implementation.

Implementing the technical authority concept prior to hot commissioning is desirable to ensure focused F&T leadership and the F&T “toolbox” are immediately ready to sustain DFLAW production operations starting with hot commissioning. Implemetation is accomplished by following through on five specific recommendations:

1. Appoint an ORP CTO for DFLAW production operations.
2. Form the DFLAW Flowsheet and Technology Advisory Committee chaired by the ORP CTO.
3. Establish the 3-5 year vision and strategy for DFLAW F&T.
4. Develop the DFLAW F&T Taxonomy.
5. Develop the DFLAW F&T Roadmap for DFLAW production operations. Utility should be made of an established technique such as Lean Management to systematically identify F&T improvement opportunities.

9.0 References

Arm ST, RH Davis, RM Russell, D McCabe, JG Reynolds, J Vienna, RF Gimpel, DR Reinemann, TL Waldo, RL Hanson, MA Servin, PA Empey, PA Benson, ML Hendrickson, and JD Belsher. 2016. *Value Stream Analysis #2: Direct Feed Low Activity Waste Flowsheet*. RPP-RPT-59450, Washington River Protection Solutions, LLC, Richland, Washington.

Arm ST. 2020. *Readiness Evaluation for Sustained Operations*. PNNL-29926, Pacific Northwest National Laboratory, Richland, Washington.

Borlaug WA. 2019. *Waste Acceptance Criteria for the Integrated Disposal Facility*. IDF-00002, CH2M Hill Plateau Remediation Company, Richland Washington.

Earle KD, MJ Carrier, WM Cirillo, ML Grande, CA Jones, EL Judd, JJ Klovstad, AC Owens, DM Reeves, and MA Stafford. 2018. *Strategic Framework for NASA's Space Technology Mission Directorate*. 2018 AIAA SPACE and Astronautics Forum and Exposition, 17-19 September 2018, Orlando, Florida.

Galvin R. 2004. "Roadmapping – A Practitioner's Update." *Technological Forecasting and Social Change* 71:101-103.

Gaynor GH. 1996. "Management of Technology: Description, Scope and Implications." In GH Gaynor (Ed.), *Handbook of Technology Management,* pp. 1.3-1.31. McGraw Hill.

Koenigsaecker G. 2013. *Leading the Lean Enterprise Transformation*. CRC Press.

Mauws RC. 2020. *Multi-Year Operating Plan (MYOP)*. RPP-PLAN-63778, Rev. 3, Washington River Protection Solutions, LLC, Richland, Washington.

NASA. 2020. *NASA Technology Taxonomy*. National Aeronautics and Space Administration, Washington, D.C.

Oakes LC and WM Matejek. 2020. *DFLAW Commissioning Plan*. 24590-WTP-PL-RACT-CG-0001, Rev. 2, Bechtel National, Inc., Richland, Washington.

Phaal R, CJP Farrukh, and DR Probert. 2004. "Technology Roadmapping – A Planning Framework for Evolution and Revolution." *Technological Forecasting and Social Change* 71, 5-26.

Probert DR, CJP Farrukh, and R Phaal. 2003. "Technology Roadmapping – Developing a Practical Approach for Linking Resources to Strategic Goals." *Proceedings of the Institute of Mechanical Engineers* 217:1183-1195.

Reid DJ, TA Wooley, RM Yanochko, and PD James. 2020. *Technology and Innovation Roadmap*. RPP-PLAN-43988, Rev. 5, Washington River Protection Solutions, LLC, Richland, Washington.

RPP. 2015. *Interface Control Document for Direct LAW Feed*. 24590-WTP-ICD-MG-01-030, River Protection Project, Bechtel National, Inc., Richland, Washington.

Savannah River Remediation. 2017. *Liquid Waste Project Technology Development and Support Optimization Blueprint*. SRR-CWDA-2017-00066, Savannah River Remediation LLC, Aitken, South Carolina.

Spires RH, ST Arm, RM Russell, M Mills, D Blumenkranz, JG Reynolds, ME Stone, MS Fountain, MR Thorson, DR Reinemann, LT Nirider, BD Taki, PA Benson, TL Waldo, BN Gallaher, and DT Herman. 2016. *Value Stream Analysis #1: Direct Feed Low Activity Waste Flowsheet*. RPP-RPT-59449, Washington River Protection Solutions, LLC, Richland, Washington.

Szakonyi R. 1996. “The Process of Developing an R&D Strategy.” In GH Gaynor (Ed.), *Handbook of Technology Management,* pp. 14.1-14.9. McGraw Hill.

WRPS. 2019. *River Protection Project Integrated Flowsheet Configuration Management Plan*. TFC-PLN-139, Washington River Protection Solutions, LLC, Richland, Washington.

PNNL-30768

Pacific Northwest
National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov