LA-UR-03-3926

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Title: Options for the Development and Testing of the Pit Disassembly and Conversion Facility Government-Furnished Design

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Submitted to: Office of Fissile Materials Disposition NA-262
June 11, 2003

Los Alamos
NATIONAL LABORATORY

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Executive Summary of Options for the Development and Testing of the Pit Disassembly and Conversion Facility Government-Furnished Design

Introduction

This document presents options and recommendations for the development and testing (D&T) of the Pit Disassembly and Conversion Facility (PDCF) government-furnished design (GFD). The options are identified by the authors, who are subject matter experts from Los Alamos National Laboratory, Westinghouse Savannah River Company, and Washington Group International (the architect / engineer of the PDCF). All options are based on evaluation of the technical maturity of the GFD equipment, outstanding data needs for the PDCF, and cost and schedule. The detailed evaluation of technical maturity for each module and its components and the corresponding data needs are appended to this document.

Methodology

Technical maturity evaluations (TMEs) involved a comprehensive and systematic comparison of the requirements, safety, and equipment maturity against program requirements including the facility design document (FDD) and the system design documents (SDDs). Each FDD function was decomposed into subfunctions defined in the SDD, which were mapped to GFD components that perform each subfunctions. In turn, the equipment elements that make up each component were defined. The components and elements in the PDCF GFD design were evaluated for technical maturity to support PDCF startup with respect to a structured set of evaluation criteria. There were four categories of evaluation criteria that were evaluated for technical maturity, each with its own structured assessment criteria. The categories were: Requirements Maturity, Process Maturity, Operational Readiness, and Equipment Maturity. The impact of failure of each element also was assessed using a structured set of criteria. From the combination of technical maturity and the impact of failure, the overall D&T need level for each element was determined (rated as high, medium or low). Also, the quality of data provided by design analysis and demonstrations to support PDCF requirements validation and verification was assessed to determine the additional data needs that must be met prior to PDCF startup. The results of the TME and data needs analysis comprise the outstanding D&T needs for the PDCF.

D&T Options

Options are presented to address the D&T needs identified by the TME and data analysis. The D&T options include a discussion of proposed testing, the ability of the options to address outstanding D&T needs, residual risk following completion of D&T, benefits of option execution, and a preliminary estimate of schedule and budget for further D&T. One recommended option is presented for each module along with additional options. Presented costs and schedule are rough order of magnitude estimates for design, cold testing and installation (where hot testing is required). Costs are those above the ARIES demonstration (approximately $15 M per year). Activity durations are the time to completion following activity approval and funding by NNSA. A high-fidelity schedule and budget will be developed as part of an integrated D&T plan.

The recommended D&T options for the eight GFD modules and manipulators are summarized in the table below.

Module	Cost	Schedule	Description
PDIS	$2 M	2 years	Hot test exact lathe and manipulator functionality
SRL	$3 M	2 years	See classified attachment
HDH	$4 M	2.5 years	Hot test essentially exact
DMO	$1 M	2.5 year	Hot test exact furnace
ICAN	$1.8 M	2.5 years	Hot test EDC, robot and welding; cold test flow loop
NDA	$1 M	1.5 years	Test with HEU & install new GRIS spectrometer
HEU	$2.2 M	2.5 years	Hot test fixture; cold test flow loop
PSF	$0.7 M	1 year	Hot test furnace; cold test crucible tilter & turntable
Manipulator	$5 M	2.5 years	Cold test for all eight modules

Disassembly: The primary D&T needs resulting from the TME and PDCF data needs for the pit disassembly module include testing of chucks, the pit orienting device (necessary to meet facility dose), the automated denesting end effector on the manipulator, and the lathe / manipulator control system. The team recommendation is to install and test the exact GFD lathe with a manipulator that can test GFD manipulator functionality. Hot testing of the exact GFD manipulator is a less desirable option due to the expense and space requirements.

Direct Metal Oxidation (DMO): The primary D&T needs for the DMO module (plutonium, HEU and auxiliary HEU) are the determination of product quality (e.g., particle size, surface area) following screw-driven calcination, measurement of the thermal profile, and testing of the bearings, the argon blower to cool the furnace and materials compatibility. The recommendation is to test plutonium characteristics using DMO-2 (an installed, nearly-exact furnace) and test the exact furnace using HEU. This recommendation is driven by cost - the cost for disposal of plutonium-contaminated HEU drives the installation of an HEU-only furnace. Hot testing of the exact GFD DMO furnace using plutonium is a less desirable option because no additional information will be gained and additional expense will be incurred.

Inner Canning: The primary D&T needs for the inner canning module include testing of the electrolytic decontamination function and swiping functions and testing of the flow loop. It is recommended that the flow loop be tested cold because there are no significant effects of radiation on the flow loop. It is recommended that electrolytic decontamination and swiping functions be hot tested using the exact equipment to be installed in LANL's plutonium facility. Hot testing of the exact GFD flow loop is a less desirable option because little information will be gained beyond cold testing and significant additional funding and space would be necessary.

Nondestructive Assay (NDA): There are two major outstanding D&T needs for the NDA system - achieving the necessary isotopics accuracy to meet the MOX specification and NDA of HEU-containing materials. The recommendation is to install a new spectrometer to meet the MOX specification accuracy requirements and testing the active neutron coincidence counter to test NDA of highly-enriched uranium (HEU).

Highly-Enriched Uranium Processing: Although it has been shown that electrolytic decontamination of HEU followed by DMO is sufficient to meet Y-12 acceptance criteria, there are outstanding D&T needs. The needs include testing of the electrolytic decontamination fixture, flow loop, dewater pot, and distillation unit. The recommendation is to hot test the fixture and dewater pot and cold test the flow loop and associated dewatering and distillation systems. The proposed hybrid allows cold testing of components that do not require hot testing in order to minimize cost.

Hydride / Dehydride (HDH): There are multiple significant outstanding D&T needs for HDH including demonstration of the reactor to meet separation requirements and demonstration of the crucible breakout station. Because verification of the reactor and crucible breakout station operability require the use of plutonium, the recommendation is to hot test the nearly-exact GFD system. Testing of the exact GFD would require significant additional time, space and funding and the differences between the nearly-exact and exact GFD are insignificant (see the gap analysis (Table 6 in the TME of hydride / dehydride section)).

Part Sanitization: Outstanding D&T needs for the part sanitization furnace include sanitization of all materials other than stainless steel and aluminum. Hot testing is recommended because of the authorization basis difficulty of cold testing beryllium. Currently, no additional equipment installations are necessary to test the part sanitization furnace. However, to address the recent conclusion of the draft FCR, design change of the part sanitization furnace may be necessary. If a significant design change is necessary, the recommendation for D&T of the furnace may be altered.

Special Recovery Line: There are a variety of outstanding data needs for the special recovery line including tritium decontamination of plutonium. See the classified addendum to this document. The recommended option for verifying that GFD can adequately decontaminate plutonium involves proof-of-principle tests.

Manipulators: The primary outstanding D&T need for the manipulators is testing of their operability. The manipulators are first generation designs and represent a high D&T need for all GFD modules. Manipulators are present in all modules to aid in material movement and reduce worker dose. Cold testing of one manipulator with the end effectors for all modules is recommended. Cold testing of all manipulators would cost significantly more than cold testing of one manipulator and therefore is not the recommended option.

Next Steps

Following NNSA selection of D&T options to pursue, two plans will be issued. First, an integrated D&T Plan will be written. This D&T Plan will detail the cost, schedule, and site for D&T of each module. Following formal acceptance of this D&T Plan, a detailed Experimental Test Plan will outline the individual tests that will be performed to address the D&T needs for the options selected by NNSA. This plan will also be submitted to NNSA for acceptance. Implementation of these two plans will follow the OFMD Quality Assurance Plan and a variety of LANL quality assurance documents, most notably NMT15-AP-147, ARIES/PDCF Design Interface and Control. The D&T Plan and the Experimental Test Plan are expected to be completed by September.

Following the TME, an independent review was completed by WSRC and INEEL. The results of this review can be found in WA-03-063 (Letter from Marggie Schwenker to Randall Erickson, June 11, 2003).

Introduction to the Options for the Development and Testing of the Pit Disassembly and Conversion Facility Government-Furnished Design

Development and testing (D&T) options for eight government-furnished design (GFD) modules (disassembly, direct metal oxidation, inner container packaging, nondestructive assay, highly-enriched uranium processing, hydride-dehydride, part sanitization, and special recovery line) are presented in this document. A ninth set of options is also presented for D&T of the GFD manipulators. The need for additional D&T is based on an evaluation of the technical maturity of the GFD equipment and outstanding data needs performed by LANL, WGI, and SRS subject matter experts. The detailed results of the technical maturity evaluation and data needs analyses are presented as appendices to this document. The D&T needs tables presented in the D&T options are summaries of the TME (high and medium D&T needs) and data needs (summary of SDD and operating needs) documents. The gap analyses, which list the differences between LANL-installed and GFD equipment, are also included (see Table 6 in each TME).

The D&T options include a high-level discussion of proposed testing, the ability of the option to address outstanding D&T needs, residual risk following D&T, and coarse schedule and budget for the work. One recommended option set is presented for each module along with additional options that have different risks and benefits. The recommended option set is based on input from LANL, WGI, and SRS subject matter experts. The costs and schedule presented are rough order of magnitude estimates for design, procurement, cold testing and plutonium-facility installation (where hot testing is required). Costs for D&T at LANL are costs above the ARIES demonstration costs ($15M per year). No costs are assigned for performing D&T upon cold or hot start-up of PDCF. Schedules are the time to completion following activity approval and funding by NNSA.

The D&T options for GFD are presented here. Other equipment to be operated at PDCF also requires D&T. It is expected that D&T options will be presented for this equipment at a later date and that a D&T plan will be authored to address these D&T needs.

Eight generic options are available for D&T of each module. The options are:

1) Use an existing, currently operable LANL design in place of GFD
2) Analytical validation
3) Cold test of GFD functionality
4) Cold test of exact GFD equipment
5) Hot test of GFD functionality
6) Hot test of exact GFD equipment
7) Test at PDCF cold start-up

8) Test at PDCF hot start-up

In general, the recommended options are a hybrid set of cold and hot test options which minimize risk and cost.

Chapter 1 - Pit Disassembly D&T Options

Introduction

The disassembly module is used to disassemble pits and cut open material containers. To date, LANL has disassembled retirement stockpile pits using manual tools and a Myford lathe modified with after-market CNC control system. The Myford lathe is a temporary installation in the LANL plutonium facility and must be removed in FY 2004 to fulfill an agreement to allow for the installation of pit certification equipment. Therefore, any work beyond 2004 will require either movement of the Myford lathe or installation of a new lathe. Data from disassemblies were used to outline the disassembly sequence and machining parameters (feed speeds, depths of cuts) for PDCF. This information resulted in the selection of the Moore parting lathe with overhead manipulator as the GFD baseline. The Myford lacks the capability to perform all operations needed for PDCF (in particular, automated tailstock movement). There is no commercially available equipment on the market that permits disassembly of pits, so the disassembly module requires several custom designed components. In summary, lathe technology is very mature but the automation of the lathe including end effectors, the alignment fixturing, and acceptable hand tooling is unproven.

Table 1 summarizes the high and medium D&T needs from the disassembly TME (see also the classified addendum to the TMEs). Table 2 lists the data needs for disassembly. Table 3 lists the costs and schedule for the D&T options. Table 4 is a summary of the SDD and component residual risks following execution of the proposed options. SDD residual risks are evaluated against process maturity and component residual risks are evaluated against equipment maturity using the TME process. Red boxes are high residual risk, yellow boxes are medium residual risk, and green boxes are low residual risk. One exception to the TME process was made to generate Table 4: for processes that do not require SNM or pits to be fully tested, boxes representing residual risk following exact cold testing were colored green even though the TME process unnecessarily regards these as medium risk.

The outstanding D&T needs for disassembly include automation of pit alignment and denesting, development of final procedures for disassembly, the development of automated denesting tools, and verification of the integrability of the lathe and manipulator control systems.

D&T Options

A) *Recommended option for pit disassembly - cold and hot test hybrid option*
Cost: $2M
Schedule: 2 years

D&T needs addressed: 1-18 (in Tables 1 and 2)
D&T needs not addressed: none
Discussion: The recommended D&T option for D&T of the disassembly module is a hybrid of cold and hot testing. The recommendation includes hot testing the exact lathe with a manipulator that is functionally equivalent to the GFD (including control system), hot testing of manual denesting tools, and hot testing of fixturing.

A1) Although all classes of pits have been manually disassembled at LANL, additional disassembly D&T is necessary to test the design of the pit chucks and to develop final automated disassembly procedures. Additional disassemblies are also necessary to support testing of other modules requiring D&T (e.g., hydride / dehydride). Therefore it is necessary to have an operational lathe through the end of D&T (estimated to be September 2005 in the IDST plan (LA-CP-02-432, September 2002)). The currently-installed Myford lathe is installed in space planned for use by the Pit Certification Program. The Myford lathe must be removed in 2004. Two options exist for re-installing the lathe capability in 2005 in the space where the LLNL bisector box currently exists - move the Myford lathe or install the exact Moore. LANL already has the Moore lathe and surrounding glovebox. The Myford lathe glovebox will not fit in the bisector box space and procurement of a new glovebox would be necessary in order to install the Myford lathe. It is therefore cheaper to install the exact Moore lathe than to re-install the Myford. In addition to the cost savings, installation of the Moore lathe results in hot testing of the exact lathe specified for PDCF, thereby increasing the technical maturity of the disassembly program and decreasing the risk to PDCF. For instance, the Moore lathe includes a programmable tailstock and a milling head on the tool post whereas the Myford does not. Because installation of the Moore lathe is necessity for continuing ARIES operations, cold testing options for the Moore lathe were not considered. The automated denesting end effector, which requires hot testing, will be tested using the existing integrated Moore lathe / non-prototypical manipulator. The ability to integrate the lathe and manipulator control systems will be tested.

A2) It is recommended that the exact manipulator and integrated lathe control system for disassembly be cold tested. The D&T options for the manipulator are discussed in a separate section below. In summary, there are no significant requirements to test the exact manipulator using plutonium or actual pits. Therefore, cold testing is sufficient to mitigate existing technical risk of the manipulator and control system.

The Moore lathe is installed in a glovebox housing a manipulator (procured prior to the start of GFD) which is different in form from that specified for PDCF but capable of the same function. It is recommended that the manipulator be installed and hot tested with the Moore lathe. Hot testing is required because denesting tests require actual pits due to the difficult-to-mock tolerances. Further, installation of the manipulator with the lathe will allow for testing of manipulator loading and unloading of fixtures on the exact lathe to be used at PDCF. Also, lathe / manipulator testing allows for testing of pit alignment using actual pits. The operability of the end effectors (e.g., pit gripper) will also be tested.

A3) As a back-up to automated denesting, manual denesting tools that meet Savannah River safety requirements will be developed. These tools will be simple tools that aid denesting and do not incorporate sharp edges.

B) *Alternate option B for pit disassembly - exact hot testing*
Cost: $6M
Schedule: 3 years
D&T needs addressed: 1-18 (in Tables 1 and 2)
D&T needs not addressed: none
Discussion: Option B involves installation and hot testing of an identical disassembly system including lathe, overhead manipulator, and end effectors. The plan would include lathe, glovebox and manipulator procurement, integration of the manipulator, lathe and glovebox, and installation and testing of the disassembly module. Manual denesting tools would also be tested. The advantage of Option B is that the exact system to be used at PDCF including the manipulator, would be tested, thereby mitigating all risks associated with disassembly. The drawback to Option B is cost and schedule.

Table 1 - High or Medium D&T needs from disassembly TME

Number	SDD Requirement	RM / Impact / D&T Need	PM / Impact / D&T Need PM	SAFT-OPS / Impact / D&T Need	EQ / Impact / D&T Need	Issues	D&T Need Level	D&T Options
1	F-2.3.1 Disassemble Uncontaminated Pits and Pu Metal Containers	Requirements in SDD under review for final approval. FDD baseline controlled. DBD internally baseline controlled. ICD internally baseline controlled.	Hot feasibility for pit demonstrated without automated handling. (see LANL DR) Container disassembly report in process.	Process logic defined and documented for normal and off-normal operations. PDCF PHA	Key functionality demonstrated on hot experimental system. (see LANL DR) Automation of material handling untested	Process feasibility demonstrated with experimental equipment. Automation of process unproven. End-to-end integration not demonstrated.	H	
2	F.2.3.1.4 Stage-In Pits or 3013 Cans	2 / L / L	9 / H / H	8 / H / H	9 / H / H	Driven by overhead manipulator. Different than the rest of the manipulators in the plant – has an X, Y, Z and a yaw axis. Should be identical to SRL.	H	Hot test
3	F.2.3.1.5 Prepare Pits or 3013 Cans for Cutting	2 / L / L	9 / H / H	8 / H / H	10 / H / H Driven by lack of alignment fixture design		H	Hot test
4	F.2.3.1.7 Cut Uncontaminated Pits for 3013	2 / L / L	9 / H / H	8 / H / H	9 / H / H Pot chuck is the big unknown	Driven by the control system and how it will interface with the lathe	H	Hot test driven by need to test lathe
5	F.2.3.1.8 Physically Separate Pieces	2 / L / L	8 / H / H	9 / H / H	8 / H / H	Driven by denesting gripper	H	Hot test
6	F.2.3.1.11 Stage-Out Pieces	2 / L / L	9 / H / H	8 / H / H	9 / H / H	Driven by overhead manipulator	H	Hot test

Number	Component	Function Addressed	RM / Impact / D&T Need Level	PM / Impact / D&T Need Level	SAFT – OPS / Impact / D&T Need Level	EQ / Impact / D&T Need Level	Issues	D&T Need Level	D&T Options
7	Overhead Manipulator	F 2.3.1.4 F 2.3.1.5 F 2.3.1.8 F 2.3.1.11	2 / L / L	9 / H / H Don't understand all issues with how gripper will interact with overhead manipulator	8 / H / H Off normal conditions not considered	9 / H / H Driven by denesting gripper	Driven by gripper issues Different than the rest of the manipulators in the plant – has an X, Y, Z and a yaw axis. Should be identical to SRL.	H	Hot test because of need to test actual parts
8	Fixture with Orientation Device	F 2.3.1.5	2 / L / L	9 / H / H	6 / H / M Know what we would do in off-normal condition	10 / H / H	If doesn't work would require to align manually, time-consuming and potentially dose intensive Don't know if alignment device will work as desired	H	Cold test
9	Lathe	F.2.3.1.7	2 / L / L	5 / H / M Demonstrated hot feasibility. Have cold system set up and ready to start testing	8 / H / H Off-normal conditions not considered	9 / H / H Driven by uncertainties of the pot chuck	Fixture and tooling development required for automated handling	H	Hot test to determine operability
10	Control System	F 2.3.1.7	2 / L / L	9 / H / H	8 / H / H	9 / H / H Driven by software concerns	Integration of automation with lathe and		Cold test
11	Manual Denesting Tools	F 2.3.1.7 F 2.3.1.8	2 / L / L	6 / M / M Hot feasibility testing. Need to improve tooling	6 / M / M	9 / M / M	Backup to the denesting gripper Needed if denesting gripper doesn't work. What are the safety concerns – how do we ensure safe use	M	Hot Test

Table 2 - Summary of data needs from disassembly data needs study

	SDD
12	Automation
13	Pit alignment
14	Denesting
	Operating parameters
15	Lathe rotation speed
16	Depth of cuts
17	Cutting tool feed rates
18	Manipulator control vacuum

Table 3 - D&T options, cost, and schedule for disassembly

Option	Description	Cost	Schedule
A	Hybrid option	$2M	2 years
B	Exact hot testing	$6M	3 years

Table 4 - Remaining risk following execution of D&T options

		Residual D&T Need Levels After Executing Option		
			Option A*	Option B
		No Further D&T	Hot & Cold Hybrid	Exact Hot
SDD Functions	F-2.3.1 Disassemble Uncontaminated Pits and Pu Metal Containers	H	M	L
	F.2.3.1.4 Stage In Pits or 3013 Cans	H	L	L
	F.2.3.1.5 Prepare Pits or 3013 Cans for Cutting	H	L	L
	F.2.3.1.7 Cut Uncontaminated Pits	H	M	L
	F.2.3.1.8 Physically Separate Pieces	H	L	L
	F.2.3.1.11 Stage Out Pieces	H	M	L
Disassembly Components	Overhead Manipulator	H	M	L
	Fixture with Orientation Device	H	L	L
	Lathe	H	L	L
	Control System	H	M	L
	Manual Denesting Tools	M	L	L
	Cost to Implement		$2 M	$6 M
	Schedule to Implement		2 yr	3 yr

*** Recommended Option**

Chapter 2 - Special Recovery Line D&T Options

See classified SRL D&T options addendum.

Chapter 3 - Hydride / Dehydride D&T Options

Introduction

The function of the Plutonium Separation System is to chemically separate plutonium from bonded pit pieces at certain rate (Mass Balances for Primary Streams Process Flow Diagrams B-PDCF-1-01-029 to meet FDD requirements R-0.0-1 and R-2.4-1). Plutonium metal produced by this process must meet the requirements given in the PDCF-MOX interface control document. The remaining bonded material must meet the requirements established by its disposal pathway. Non-plutonium pieces being sent to the sanitization module and MgO crucible pieces being sent to Aux-HEU must contain less than 100 grams of plutonium per batch of remaining metal pieces.

Based on the design to date, it is expected that the hydride-dehydride (HDH) system will include means for staging in plutonium-bearing bonded pit pieces, chemically separating plutonium in bonded pit pieces to plutonium ingots, removing pieces of crucible from the plutonium metal ingots, staging out plutonium metal ingots, non-plutonium and plutonium-contaminated crucible pieces, and recycling failed material. Means for lag storage of pit pieces is not considered a GFD item.

These functions are accomplished through the use of an overhead manipulator for material transport, a hydride-dehydride (HDH) reactor comprised of two furnaces for hydriding and dehydriding respectively, a gas delivery system (GHS) for delivering and recycling process gas, a lower reactor manipulator for removing final product from the reactor, and a crucible breakout station (CBS) for isolating the plutonium metal product from the crucible to allow for additional processing.

To date, LANL has run a limited number of hot tests on an experimental HDH system, comprised of an HDH reactor and gas delivery system, which is significantly different from GFD. These feasibility studies indicate the concept behind using HDH to chemically separate plutonium is valid. The differences between the experimental system and the GFD will not be elucidated in this document. The gap analysis presented in the TME represents the differences between the GFD HDH system and a proposed LANL HDH system install (see Option A).

There are many outstanding D&T needs (shown in Tables 1 and 2). In summary, neither the functionality of the GFD system nor the crucible breakout station is has been verified. The technical maturity of the HDH is low as compared to other GFD modules.

<u>D&T Options</u>

The options presented in this paper are the result of the TME and DA of the HDH module performed by the TME working group. Table 1 summarizes the high and medium D&T risks from the TME at the component and requirement levels. The specifics of the DA are classified, but an unclassified summary of the findings is shown in Table 2. Table 3 presents the options to be discussed in this section. The recommended option is discussed first and in greatest detail. For completeness, hot and cold testing options for the GFD prototype have also been included. Table 4 is a summary of the SDD and component residual risks following execution of the proposed options. SDD residual risks are evaluated against process maturity and component residual risks are evaluated against equipment maturity using the TME process. Red boxes are high residual risk, yellow boxes are medium residual risk, and green boxes are low residual risk. One exception to the TME process was made to generate Table 4: for processes that do not require SNM or pits to be fully tested, boxes representing residual risk following exact cold testing were colored green even though the TME process unnecessarily regards these as medium risk.

The proposed options address deficiencies in the equipment and process testing exposed by the TME and DA. Several D&T options were evaluated to mitigate the project risks identified in the TME and DA. The recommended option is a hybrid of options B and C.

A) *Recommended Option for HDH - Hot test of functionally-equivalent reactor and crucible breakout station*
Cost: $4 M
Schedule: 2.5 years

The overall integration of the automation with the entire system is not tested with Option A.

A1) HDH Reactor and associated components – Hot functionality test
Cost: $2.5 M
Schedule: 2.5 years
D&T needs addressed: 3, 4, 8, 10-12, 14, 15-16, 18-26, and 28

Discussion: Because LANL currently does not have a functioning hydride-dehydride system in PF-4, this recommendation entails the fabrication, procurement, cold acceptance testing, installation, and hot acceptance testing of a HDH furnace and associated components. Space constraints associated with PF-4 operations results in a recommendation of installing nearly exact but not identical equipment as compared to the GFD. LANL has been working on the procurement and install of a HDH reactor system based on the 90% GFD design. The differences between this system and GFD are articulated in the attached HDH gap analysis. Testing of the reactor will, by default, test the gas delivery system, the vacuum system, the reactor manipulator and the control system.

Although the technical maturity of the gas delivery system is very high because it is composed of commercial components, the integrated system is untested. In addition, the frequency of regeneration of the hydride beds has not been explored. The major equipment issues that are addressed by this option include materials compatibility, determination of the amount of remaining hydride contamination on baskets and metal pieces, impact of thermal stresses on the system particularly with respect to leak tightness, wear issues and impact of the dusty environment on motor bearings in the drive system.

A2) Crucible Breakout Station – Hot functionality test
Cost: $1.5 M
Schedule: 1.5 years
D&T needs addressed: Part of 4, 8, 13, and part of 27-28 in Tables 1 and 2

Experience indicates plutonium metal produced by HDH reactions adheres to the crucible walls unlike any other potential surrogate material. This experimental information was obtained using smaller crucibles, so the extent of adhesion needs to be determined before a final recommendation for testing the CBS can be made. The extent of adhesion can be determined by performing the hot functionality tests described in option A1. If the plutonium adheres to the larger crucibles to the same extent as seen in the experimental studies, the CBS must be hot tested to truly determine the ability of the CBS to operate under the requirements outlined in the SDD and FDD. If the separation requirement is ignored, determination of the ability of the CBS to break crucibles can be obtained with a cold test. The CBS can be tested as part of an integrated system with the HDH reactor system or separately. Hot testing at LANL, because of space constraints, would most likely require testing separate from the remainder of the system. This would result in the loss of some system integration information.

A3) Overhead Manipulator – Cold Test

It is recommended that overhead manipulator be cold tested. See the overhead manipulator D&T options section for more information.

B) *Alternative Option B - Hot test exact GFD equipment*
Cost: $6.5 M
Schedule: 3.5 years
D&T needs addressed: All in Tables 1 and 2 with the exception of interfaces with the overhead manipulator

Discussion: This option would require a space allocation, decommissioning of the existing glovebox and installation of a new, bigger glovebox capable of containing the HDH reactor and the CBS along with additional piping lines. In addition, to ensure prototypicality, procurement of the HDH system would need to wait until the design is finalized, significantly lengthening the time to installation. A new controller / interface would also be required. It is unlikely this approach would result in the collection of data unavailable by the recommended option.

C) *Alternative Option 3. Cold test exact GFD*
Cost: $2 M
Schedule: 1.5 years
D&T needs addressed: 10-14, 22, 25, and 26 in Tables 1 and 2

Discussion: This option would ensure operability of the equipment but would not give any information regarding test product characteristics (MgO and plutonium) or operational parameters associated with achieving the desired rate. Cycle times and rates, and operating temperatures and pressures would have to be based on surrogates. Given the limited amount of data available for HDH reactions, determination of operating parameters is a significant data need.

Table 1 - High or Medium D&T needs HDH TME

#	SDD Requirement / Component	RM / Impact / D&T Need	PM / Impact / D&T Need PM	SAFT-OPS / Impact / D&T Need	EQ / Impact / D&T Need	Issues	D&T Need Level	D&T Options
1	F.2.4 Chemically Separate Plutonium	2 / L / L Know what we need to do, just not how we are going to do it	9 / H / H Don't know how the overall integration will affect the process. Very little has been demonstrated.	8 / H / H Need the operational parameters defined to write the procedures that SRS needs to operate (w/o cannot operate)	9 / H / H Very little has been demonstrated HDH reactor has been hot feasibility tested.	Scores a function of the immaturity of the overhead manipulator process	H	Hot test
2	F.2.4.1 Stage In Pu-Bearing Bonded Pit Pieces	2 / L / L	9 / H / H	8 / H / H	9 / H / H	Scores a function of the immaturity of the overhead manipulator process.	H	Cold test
3	F.2.4.2 Chemically Separate Pu in Bonded Pit Pieces to Pu Ingot	2 / L / L	9 / H / H	8 / H / H	6 / M / M	Scores a function of the immaturity of the integration of gas delivery system and the immaturity of the HDH reactor. Primary issues include materials compatibility, impact of residual hydride on components, and impact of thermal stresses.	H	Hot test
4	F.2.4.3 Remove Pieces of Crucible from the Pu Metal Ingot	2 / L / L	9 / H / H	9 / H / H	9 / H / H	Scores a function of the immaturity of the crucible breakout station and the overhead manipulator processes. Issue with CBS – will the design achieve the desired sized crucible pieces?	H	Hot test
5	F.2.4.4 Stage Out Pu Metal Ingots	2 / L / L	9 / H / H	8 / H / H	9 / H / H	Scores a function of the immaturity of the overhead manipulator process.	H	Cold test
6	F.2.4.5 Stage Out Non-Plutonium	2 / L / L	9 / H / H	8 / H / H	9 / H / H	Scores a function of the immaturity of the overhead manipulator process.	H	Cold test
7	F.2.4.6 Stage Out Pu-Contaminated Crucible Pieces	2 / L / L	9 / H / H	8 / H / H	9 / H / H	Scores a function of the immaturity of the overhead manipulator process.	H	Cold test
8	F.2.4.7 Recycle Failed Material	2 / L / L	9 / H / H	8 / H / H	9 / H / H	Scores a function of the immaturity of the overhead manipulator process.	H	Hot test
9	Overhead Manipulator	2 / L / L	9 / H / H Hardware integration has not been demonstrated. Control algorithms nonexistent Drum gripper not tested.	8 / H / H Understand hazards associated. Candidate safety significant systems have been identified. PDCF PHA Operational documentation not complete	9 / H / H Piece parts require custom design Well developed technology for manipulator but not with this specific gripper and control integration	Mission critical HW/SW item used for all modules. Difference between modules is gripper chosen. Integration of Automation – will it work?	H	Cold test

10	Reactor Manipulator	2 / L / L	9 / M / M	8 / H / H PDCF PHA Operational parameters not defined	9 / M / M	Integration of Automation	M	Cold test
11	Hydride / Dehydride Reactor	2 / L /L	6 / M / M Experimental system hot demonstrated LANL logbook	8 / H / H Some operating parameters defined but need verification with actual system	6 / M / M Experimental system hot demonstrated	Large variability in operation of feasibility tests Materials compatibility (what to do about hydride contamination on basket and pieces remaining?) What types of thermal stresses will affect leak tightness, what is the impact of the cooling system?	H	Hot test to develop operation parameters
12	Gas Delivery System	2 / L / L	9 / H / H Not sure how integrated system will work	6 / H / M Process ops not defined	2 / M / L	If can't deliver gas this way, alternative is not desirable from a safety standpoint	H	Cold test
13	Crucible Breakout Station	2 / L / L	9 / L / L Specifics of the system are not well defined	9 / H / H Understand safety limits but not operation limits	9 / H / H Unclear that design will achieve desired sized crucible pieces	Integration of Automation Will it separate pieces	H	Hot test
14	Control System	2 / L / L	9 / H / H	8 / H/ H	9 / H / H	Control system is mature, algorithms are not.	H	Cold test

Table 2 - Summary of PDCF data needs for HDH

	SDD
15	Determination of separation rate / process cycle time
16	Determination of (all) product quality (separation ability)
17	Ability of CBS to perform as required
	Operating parameters
18	Verification of adequacy of initial vacuum level and rate of rise specifications
19	Min hydrogen pressure needed in reactor to achieve required rate
20	Nominal and Min upper furnace temperature
21	Nominal and Min lower furnace temperature
22	Max Min/ and Nominal Getter Heater temperatures
23	Max / Min Final Pressure in Furnace to signal end of run
24	Max / Min Drum Rotation Speed Determination
25	Glovebox Hydrogen concentration alarm set point
26	Max /Min Cooling Water Flow Rate
	T&M study
27	Remote handling times
28	Hydriding / Dehydriding times for various feed materials

Table 3 - D&T Options Summary

Option	Description	Cost	Schedule
A	Recommended Option	$4.0 M	2.5 yr
B	Hot test exact GFD PSF at LANL excluding overhead manipulator	$6.5 M	3.5 yr
C	Cold test exact GFD equipment at LANL excluding overhead manipulator	$2 M	1.5 yr

Table 4 - Remaining risk following execution of D&T options

		Residual D&T Need Levels After Executing Option			
			Option C	Option A*	Option B
		No Further D&T	Exact Cold	Hot Test Functionally Equivalent	Exact Hot
SDD Functions	F.2.4 Chemically Separate Plutonium	H	H	M	L
	F.2.4.2 Chemically Separate Pu in Bonded Pit Pieces to Pu Ingot	H	H	L	L
	F.2.4.3 Remove Pieces of Crucible from the Pu Metal Ingot	H	H	L	L
HDH Components	Hydride Dehydride Reactor		M	L	L
	Gas Delivery System	H	M	L	L
	Crucible Breakout Station	H	M	L	L
	Control System	H	M	L	L
	Cost to Implement		$2 M	$4 M	$6.5 M
	Schedule to Implement		1.5 yr	2.5 yr	3.5 yr

*** Recommended Option**

Chapter 4 - Direct Metal Oxidation D&T Options

Introduction

The direct metal oxidation module (DMO) is designed to convert the plutonium/uranium metal into plutonium/uranium oxide at a rate sufficient to meet production requirements of 25 metric tons of plutonium metal at a maximum rate of 3.5 MT/year per (FDD R-0.0-1, R-2.5-1). The system must produce plutonium oxide that meets DOE-STD-3013-2000 and the MOX acceptance criteria, and HEU that meets the Y-12 acceptance criteria. The systems must also process auxiliary HEU materials including decontamination residues containing sulfates, and stabilize these materials for storage.

LANL has demonstrated a process for the oxidation of decontaminated metal that produces Y-12 acceptable oxide. These operations have been demonstrated in static box furnaces. Very limited information is available on processing times for HEU in the GFD DMO system. The HEU DMO process needs to be tested to certify that the product meets all down stream storage requirements. The issue of materials compatibility between the furnace components and the sulfate bearing sludge needs to be addressed in the D&T.

The ARIES line at LANL has demonstrated the process of DMO of plutonium and uranium metal (LANL Demo Report LA-CP-02-449). These demonstrations, performed on non-GFD equipment, validated the oxidation process and gave bounding oxidation rates. LANL has installed an updated DMO furnace (DMO-2) in the ARIES line. This furnace is currently undergoing hot acceptance testing. Although procured prior to the completion of GFD, this furnace closely mimics the GFD in form and function (see DMO gap analysis in the DMO TME for differences between DMO-2 and GFD). The DMO module is unique in that the identical GFD equipment is to be used to process the plutonium, uranium, and auxiliary streams. LANL has acquired HEU DMO data in static box furnaces and one HEU DMO run using the DMO-1 furnace, but has no experience with the calcination of uranium or sulfate-containing sludge. LANL is planning to install the exact GFD DMO system (DMO-3) as part of the ARIES HEU upgrade. This system will be identical to the GFD in all aspects except for the overhead manipulator.

The options presented in this paper are the result of the TME and Data Needs Analysis (DA) of the DMO modules (plutonium, HEU, and Aux) performed by the TME working group. Table 1 summarizes the results of the TME at the component and requirement levels. Table 2 lists the data needs for DMO. A summary of the cost and schedule for each option is presented in Table 3. A discussion of the D&T options follows Tables 1, 2 and 3, with the recommended option discussed first and in greatest detail. For completeness, hot and cold testing options for the GFD prototype have also been included. Table 4 is a summary of the SDD and component residual risks following execution of the proposed options. SDD residual risks are evaluated against process maturity and component residual risks are evaluated against equipment maturity using the TME process. Red boxes are high residual risk, yellow boxes are medium residual risk, and green boxes are low residual risk. One exception to the TME process was made to generate Table 4: for processes that do not require SNM or pits to be fully tested, boxes representing residual risk following exact cold testing were colored green even though the TME process unnecessarily regards these as medium risk.

D&T Options

Evaluation of the DMO modules D&T options is best done by material type considering an integrated system (furnace and calciner). Evaluation of the manipulator is being done as a stand-alone options package. The proposed options address deficiencies in the equipment and process testing exposed by the TME and Data Analysis. The scope, schedule and cost for the various D&T options are presented with each option.

The TME and Data Needs analyses of the DMO system demonstrated deficiencies in both the component and process maturity. Mechanically, the GFD furnace and calciner have not been tested, although hot testing of functionally equivalent equipment (DMO-2) is underway. Given the heavy PDCF reliance on DMO processing, the gaps in mechanical maturity represent a troubling level of risk to the facility. Closure of these component level gaps can be addressed by either hot or cold testing. All three of the options presented greatly reduce the component level risk to the facility.

Hot testing is required to close the gaps identified in the process maturity. Most important to the facility is the determination of the process parameters for uranium, plutonium, and auxiliary feed streams using the GFD equipment. Further, hot testing will allow the determination of the material properties of all DMO feed streams, and address materials compatibility issues associated with sulfate calcinations.

A) *Recommended option for DMO*
Furnace and Calciner – hot test DMO-2 & DMO-3.
(Note: the furnace and calciner are integral pieces of equipment and are therefore not considered as separate components)
Cost: $1.0M
Schedule: 2.5 yr
D&T needs addressed: 3, 4, 6, and 9-17

Discussion: Selection of a recommended option for this module presents a challenge because two of the considered options have nearly equal merit. It is believed that the recommended option is the most cost effective, while still answering all relevant technical questions.

The recommended option takes advantage of the upgrades already underway in the ARIES demonstration. It is recommended that hot testing of the currently installed DMO-2 furnace be performed on plutonium metal. Hot testing of this system will yield information on product quality, operational parameters, and material compatibility issues. See the DMO gap analysis for a detailed accounting of the differences between the DMO- 2 and the GFD.

Installation of GFD prototype DMO-3 system, as part of HEU system upgrade, is also recommended. Hot testing of DMO-3 will serve two purposes. First, it will yield product quality and material compatibility data, and operational parameters for the oxidation of HEU metal and all auxiliary material. Second, installation and testing of the DMO-3 system will allow for a complete validation of the GFD DMO system under hot operating conditions. This option would cost more than the alternative that uses the same furnace to test plutonium and uranium, but would save the costs associated with the disposal of plutonium-contaminated HEU.

B) *Alternative Option B - Hot test GFD DMO functionality –Plutonium and HEU in same furnace*
Cost: \$0.5M
Schedule: 1 year
D&T needs addressed: 3, 4, 6, and 9-17

Discussion: Option B would also take advantage of the upgrades already underway in the ARIES line. As mentioned in the recommended option section, a good deal of product quality and parametric information could be gained by testing of the DMO-2 furnace that is currently installed in PF-4. See the DMO gap analysis for a listing of the differences between DMO- 2 and the GFD. A small number of HEU DMO tests could also be run on DMO-2. However, testing HEU and sludge oxidation in the plutonium-contaminated DMO-2 system would result in the generation of contaminated HEU material that must then be disposed. This option would save the cost for installation of the DMO- 3 furnace in the HEU line, but the project would incur additional costs associated with the disposal of the plutonium-contaminated HEU, and hot testing of the exact GFD DMO system would not be achieved.

C) *Alternative Option C - Hot test exact GFD equipment at LANL using plutonium and HEU in same furnace.*
Cost: \$1.5M
Schedule 2.5 yr
D&T needs addressed: 3, 4, 6, and 9-17

Discussion: This option is a subset of the recommended option, which includes installation and testing of the exact GFD DMO system. While comprehensive, it does not account for all the technical problems associated with all feed streams. Hot exact testing with plutonium could be completed in DMO-3, but this would preclude extensive HEU testing. The project would incur additional costs associated with the disposal of the plutonium-contaminated HEU.

D) *Alternative Option D - Cold test exact GFD*
Cost: $0.4M
Schedule: 0.5 years
D&T needs addressed: 9 - 11

Discussion: This option would allow the testing of the DMO equipment with surrogates. The advantages relate to cost and schedule. The disadvantages relate to lack of parametric development for HEU and auxiliary materials. Selecting either of the hot exact options would result in full cold testing prior to installation in the ARIES line and thus incorporate this option.

Table 1- High or Medium D&T needs from DMO TME

		RM / Impact / D&T Need	**PM / Impact / D&T Need PM**	**SAFT-OPS / Impact / D&T Need**	**EQ / Impact / D&T Need**	**Issues**	**D&T Need Level**
1	F.2.5 Oxidize Plutonium Metal	2 / L / L	9 / H / H Hot feasibility demonstrated. LANL DR No end-to-end process demonstration s.	8 / H / H Process logic defined and documented for normal and off-normal operations. Process Hazards analysis completed. Draft PDSA prepared.	9 / H / H No automation / manipulation tested. Key system functionality demonstrated on hot experimental system. LANL DR Some prototype components cold tested Cold ATR	Process feasibility demonstrated with experimental equipment Automation of process unproven. End-to-end integration not demonstrated.	H
2	F.2.5.1 Stage In Plutonium	2 / L / L	9 / H / H Automation and integration of robotics has not been tested..	8 / H / H Safety defined in PDCF PHA but little operational parameters defined	9/ H / H This is driven by the lack of operating conditions for the overhead manipulator and the doser for failed oxide material	Issue is with the weight of the basket and the height of the furnace – no alternatives exist to load furnace if manipulator does not perform as required	H
3	F.2.5.2 Convert Plutonium	2 / L / L	6 / H/ M Hot feasibility demonstrated. LANL DR Cold testing completed on some PDCF components Cold ATR.	6 / H / M LANL Experiment procedures. LANL PrHA and criticality analysis. PDCF PHA.	6 / H / M See differences as defined in Table 6.4.	Hot testing of PDCF components not complete Safety and ops parameters are immature	M

		RM / Impact / D&T Need	PM / Impact / D&T Need PM	SAFT-OPS / Impact / D&T Need	EQ / Impact / D&T Need	Issues	D&T Need Level
4	F.2.5.3 Calcine Plutonium Oxide	2 / L / L	6 / H / M Hot feasibility demonstrated. LANL DR Cold testing completed on some PDCF components Cold ATR	6 / H / M LANL Experiment procedures. LANL PrHA and criticality analysis. PDCF PHA.	8* / H / H Differences exist (Table 6.4) *would define as a 7 because was hot tested on an experimental system that wasn't close to the design	Issue is the ability of the calciner to produce and oxide with the proper product characteristics including particle size. Will the calciner introduce impurities? Is particle size an issue?	H
5	F.2.5.4 Stage Out Plutonium Oxide	2 / L / L	9 / M / M Driven by overhead manipulator but if the manipulator fails, alternatives are available	8 / H / H Safety defined in PDCF PHA but little operational parameters defined	9 / M / M Driven by lack of information regarding overhead manipulator	Automation integration not tested but if it does work, the alternative is do it by hand or with manual tools	H
6	F.2.5.5 Recycle Failed Material	2 / L /L	8 / H / H Doser Design has not been identified; Cold feasibility demonstrated Cold ATR	8 / H / H Operational procedures not developed. PDCF PHA	8/ H / H Doser not identified. Surrogate powder run on cold system Cold ATR	Holdup in Doser not measured Overhead Manipulator operation not considered in determining ratings. Covered in section F. 2.5.1	H
7	Overhead Manipulator	2 / L / L	9/H/H Hardware integration has not been demonstrated Control algorithms nonexistent Drum gripper not tested	8 / H / H Understand hazards associated. Candidate safety significant system have been identified Operational documentation not complete	9 / H / H Piece parts require custom design Well developed technology for manipulator but not with these specific grippers and control integration	Mission critical HW/SW item used for all modules. Difference between modules is gripper chosen	H

		RM / Impact / D&T Need	PM / Impact / D&T Need PM	SAFT-OPS / Impact / D&T Need	EQ / Impact / D&T Need	Issues	D&T Need Level
8	Material Transfer	2 / L / L	9 / H / H	6 / H / M	10 / M /M Not specified how going to do metal piece introduction yet	Automation and integration of robotics not tested	H
9	DMO Furnace	2 / L / L	6 / H / M Hot feasibility demonstrated. Cold testing completed on some PDCF components. Impacts of argon blower not understood. With addition of blower, cooling times from Cold ATR should be bounding.	6 / H / M LANL PrHA and criticality analysis. PDCF PHA For all range of feeds, bounding ops have been identified.	6 / H / M Some differences exist relative to PDCF design. See elements.	Impact of stresses caused by cooling water on the furnace not fully understood – may cause sealing issues. Impacts of Ar blower not understood	M
10	DMO Calciner	2 / L / L	6 / H / M Hot feasibility demonstrated. Cold testing completed on some PDCF components.	6 / H / M LANL PrHA and criticality analysis. Operating conditions are known	8* / H/ H Some differences exist relative to PDCF design. *should be a 7 because system tested is really similar to GFD	See elements for differences If Calciner doesn't work there aren't easily identified alternatives	H
11	Recycling Equipment	2 / L/ L	8 / H / H Cold feasibility demonstrated Cold ATR	8/H/H	8/H/H Conceptual design complete and demonstrated Cold ATR	Operational procedures not developed Holdup not measured	H

Table 2 - Summary of data needs from DMO data needs study

	SDD
12	Oxidation rate
13	> 99.5% oxidation
14	Material re-run
15	Particle size
	Operating parameters
16	Drum rotation speed
17	Calciner operating temperature

Table 3 - D&T Options Summary

Option	Description	Cost	Schedule
A	Recommended Option – Hot test DMO-2 and DMO-3	\$1M	2.5 y
B	Hot test GFD functionality (DMO-2)	\$0.5M	1 y
C	Hot test exact GFD on plutonium or uranium	\$1.5M	2.5 y
D	Cold test exact GFD	\$0.4M	0.5 y

Table 4 - Remaining risk following execution of D&T options

		Residual D&T Need Levels After Executing Option				
			Option D	Option B	Option A*	Option C
		No Further D&T	Exact Cold	GFD Functionality w/ Pu & HEU	Hybrid Hot	Exact Hot Pu & HEU
SDD Functions	F.2.5 Oxidize Plutonium Metal	H	M	M	L	L
	F.2.5.2 Convert Plutonium	M	M	L	L	L
	F.2.7.6 Convert & Calcine HEU & Aux Material	M	M	L	L	L
	F.2.5.3 Calcine Plutonium Oxide	M	M	L	L	L
	F.2.5.5 Recycle Failed Material	H	L	L	L	L
DMO Components	DMO Furnace	M	L	M	L	L
	DMO Calciner	H	L	M	L	L
	Recycling Equipment	H	L	L	L	L
	Cost to Implement		$0.4 M	$0.5 M	$1 M	$1.5 M
	Schedule to Implement		0.5 yr	1 yr	2.5 yr	2.5 yr

*** Recommended Option**

Chapter 5 - Inner Canning D&T Options

Introduction

The Inner Canning System (Packaging), is designed to package the plutonium and HEU / plutonium oxides into approved containers in preparation for long-term storage and transportation. The system must seal the plutonium and HEU/plutonium oxide convenience can into the 3013 inner can during normal operations and be able to open and reprocess failed cans. The decontamination stage must remove plutonium contamination from the surface of the 3013 inner container prior to transfer of the can out of the glovebox. The system must verify the can is decontaminated and does not leak.

The ARIES line at LANL has demonstrated the Packaging module with equipment that is functionally similar to the GFD (LANL Demo Report LA-CP-02-449). These demonstrations, performed with manual material transfer, validated the decontamination and welding processes and gave bounding production rates. An automated packaging system has been cold tested at LANL and the system is currently being installed in the ARIES demonstration line. This system is scheduled to become operational in the near future. Although procured prior to the completion of GFD, this system closely mimics the GFD in form and function (see packaging gap analysis for differences between automated packaging system and GFD).

The GFD flow loop is functionally similar to that used in the second ARIES demonstration. The differences are listed in the gap analysis. The main differences between the demonstrated flow loop and the GFD are component sizes and a departure from batch processing. The larger lines proposed for the GFD may make not meet the system drainage requirements. Cold testing of the ability to blow out the GFD lines are underway, but preliminary results suggest that the GFD line sizes will need to be redesigned (ESA-AET: 03-124).

D&T Options

The options presented in this paper are the result of the TME and DA of the module performed by the TME working group. Table 1 summarizes the results of the TME at the component and requirement levels. A summary of the findings of the DA study is presented in Table 2. A summary of the cost and schedule for each option is presented in Table 3. A discussion of the D&T options follows Tables 1 - 3 with the recommended option discussed first and in greatest detail. For completeness, hot and cold testing options for the GFD prototype have also been included. Table 4 is a summary of the SDD and component residual risks following execution of the proposed options. SDD residual risks are evaluated against process maturity and component residual risks are evaluated against equipment maturity using the TME process. Red boxes are high residual risk, yellow boxes are medium residual risk, and green boxes are low residual risk. One exception to the TME process was made to generate Table 4: for processes that do not require SNM or pits to be fully tested, boxes representing residual risk following exact cold testing were colored green even though the TME process unnecessarily regards these as medium risk.

The TME and Data Needs analyses of the Packaging system demonstrated deficiencies in both the component and process maturity. Mechanically, the GFD Packaging system has not been tested, although cold testing of functionally equivalent equipment has been completed and hot testing is scheduled. Given the importance of Packaging to the PDCF, the gaps in mechanical maturity represent a troubling level of risk to the facility. Closure of these component level gaps can be addressed by either hot or cold testing. All three of the options presented greatly reduce the component level risk to the facility.

Hot testing is required to close the gaps identified in the process maturity. Most important to the facility is the determination of the process parameters for decontamination and the procedural steps for obtaining a clean automated weld. In past manual tests, the weld area has been masked to prevent cross contamination, a process that is unacceptable for automated operations.

A) *Recommended Option for Packaging*
Cost: $1.8M
Schedule: 2.5 yr
D&T needs addressed: All

Overview:
This recommendation calls for continuing with the installation and hot testing of the automated packaging system currently being installed as part of the ARIES demonstration, and for cold testing of the GFD flow loop.

A1) GFD Decontamination, Robot, and Welding functions – Hot Test
Cost: $0.8M
Schedule: 2.5 years
D&T needs addressed: 1-7 and 11-13

Discussion: The automated packaging system currently being installed as part of the ARIES demonstration includes the exact GFD decontamination fixture, and a robot and welding station that are very similar to the GFD package. Extensive hot testing of the automated packaging system will drive all of the high and medium D&T needs associated with the packaging system (excluding flow loop) to acceptable levels of maturity. This includes the decontamination and welding operations which each ranked as having high D&T needs in the TME analysis.

A3) GFD Flow-loop – cold test
Cost: $1M
Schedule: 2 yr
D&T needs addressed: 1, 2, 4, 5, 11, 13, 14

Discussion: Our recommendation is to cold test the GFD flow-loop. Cold testing will provide data on the process parameters and mechanical operations of the integrated flow-loop, as well as testing of the control and safety systems (i.e. hydrogen sensors). The automated packaging flow loop is substantially different from the GFD. The differences between the GFD and automated packaging packages are listed in the gap analysis in the TME.

The purpose of the flow-loop is to transfer fluid from the process electrolyte and rinse tanks to and from the decontamination fixture, to maintain process fluids within specified pH and conductivity ranges and to distill off-spec rinse water. The flow-loop must also meet the facility hydrogen monitoring requirements. Examination of Tables 1 and 2 leads to the conclusion that the maturity of the flow-loop at the element and component level is high. The team felt that the technology required for flow-loop operations is very mature and that there were no unique components that required testing. However, the process maturity for the flow-loop functions scored as 8/H/H and the safety & ops scored as 6/H/M. These scores reflect the team's feeling that the consequences of a failed flow-loop design are very serious (the middle high), and that the operation of the integrated GFD flow-loop was not mature.

The GFD flow-loop is functionally similar to that used in the second ARIES demonstration. The differences are listed in the attached gap analysis. The main differences between the demonstrated and GFD flow-loops are component sizes, durability, and a departure from batch processing. The flow-loop proposed for the hot testing of the GFD fixture will be similar to the GFD in that it will incorporate automated valves and PLC controls but, due to space constraints, is not designed to prototype the GFD.

The TME and DA both pointed out deficiencies in the maturity of the GFD flow-loop. Other than the previously discussed bake-out operation, none of the recommended flow-loop D&T requires testing with radioactive materials. LANL has not experienced any radio-degradation in the pilot flow-loop testing. It is, however, important to vet the GFD flow-loop integrated design and develop operating parameters (flow rate, pressure, ops sequence) prior to start-up the facility. This can be done using surrogate material either at LANL or some other cold test facility.

B) *Alternative Option B - Hot test exact GFD equipment at LANL*
Cost: $5M
Schedule: 4 years
D&T needs addressed: All

Discussion: Hot testing of the exact GFD system is technically the most comprehensive option. However, the added expensive and limited technical gain of hot testing the exact GFD, rather than proceeding with the recommended option, dissuaded the team from this option. As pointed out in the gap analysis, the differences between the automated packaging system and the GFD are minimal excluding the flow loop.

C) *Alternative Option C - Cold test exact GFD*
Cost: $2.5M
Schedule: 2 years
D&T needs addressed: All, except the ability to produce acceptable cans.

Discussion: This option would allow the testing of the packaging equipment with surrogate-filled cans. Much of the testing on the nearly exact robot, decontamination system and welder is already complete. The most likely candidate for exact cold testing is the flow loop. The technical case for cold testing the exact GFD packaging system beyond the flow loop is difficult to make given the similarity between the GFD and the Pu.

Table 1 - High or Medium D&T needs from Packaging TME

		RM / Impact / D&T Need	**PM / Impact / D&T Need PM**	**SAFT-OPS / Impact / D&T Need**	**EQ / Impact / D&T Need**	**Issues**	**D&T Need Level**
1	F-2.8 Packag e Pu Oxide	2 / L / L	8 / H / H Impact of overall system integration not well studied. Impact of gripper contamination Long term reliability under continuous ops?	8 / H / H Safety defined in PDCF PHA. Some operational parameters defined.	8 / H / H Driven primarily by robotic tooling although some elements of the flow loop and fixture also rank high in this category	LANL has tested an experimental decontamination system but because there are significant equipment differences between this system and GFD.	H
2	F.2.8.1 Package plutoniu m oxide, EU/Pu oxide and other by-product in 3013 Inner Can	2 / L / L	8 / H / H Cold feasibility demonstrated Cold ATR.	8 / H / H Process logic defined and documente d for normal operations	8 / H / H Hot feasibility system tested. LANL DR Some prototypic components demonstrate d during cold testing of an experimenta l, very similar system Cold ATR	weld contamination Robotic mounting different Decontamination chamber is different Cold tested Flow loop system not GFD by use of different size piping and valves Issue with gamma detector. Reliability in continuous ops operation	H

		RM / Impact / D&T Need	PM / Impact / D&T Need PM	SAFT-OPS / Impact / D&T Need	EQ / Impact / D&T Need	Issues	D&T Need Level
3	Robotics	2 / L /L	8 / H / H Cold feasibility demonstrated Cold ATR.	8 / H / H PDCF PHA	8 /H / H Driven by robotic tooling	GFD robot on floor instead of roof. Should not affect operation In picking up a can in a potentially contaminated glovebox, will contaminates be introduced to the gripper which would affect fixed contamination found on the outer weld?	H
4	Decontamination Hardware	2 / L /L	6/ H / M Hot feasibility of all components LANL DR Cold prototype of fixture demonstrated Cold ATR..	8 / H / H PDCF PHA Some operational parameters defined	8* / H / H Experimental System. Cold Demonstrated Cold ATR.	Hot testing not started. Decontamination chamber is different from the ARIES demonstration testing.	M
5	Decontamination Flowloop	2 / L /L	8 / H / H Experimental system Cold feasibility demonstrated Cold ATR..	6 / H / M	6 / H / M Experimental System. Cold Demonstrated Cold ATR. Based on piping and controls for fluids. Will electrolyte shield the ability to test sludge?	Experimental system has many differences from the Jacobs design. Most significant differences are: piping and valve sizes are different for pressure drop, gamma detector for electrolyte loop and the evaporative container for solid waste removal.	M

		RM / Impact / D&T Need	PM / Impact / D&T Need PM	SAFT-OPS / Impact / D&T Need	EQ / Impact / D&T Need	Issues	D&T Need Level
6	Welding	2 / L /L	6 / H / M Welding process is mature but not on this exact equipment. Process assumes can is visually clean given to the welder gripper Hot feasibility demonstrated Cold ATR..	6 / H / M Process logic defined and documente d for normal operations.	5 / H / M 5 driven by housing requirement, H impact by time needed to requalify new welder in event of failure	Experimental system identical to Jacobs Assuming gripper does not introduce contaminates that interfere with weld Issue with contaminates is the weld doesn't meet 10CFR contaminate limits	M
7	Leak check Station	2 / L /L	6 / H / M Don't have a work around if the equipment doesn't work Cold feasibility demonstrated Cold ATR..	6 / H / M.	3 / M / L Exact chamber cold tested Demonstrate d Cold ATR..	Off the shelf system, modifications are only for integration.	M

Table 2 - Summary of data needs from Packaging data needs study

	SDD
11	Throughput (EDC time)
12	EDC ability to meet contamination limits
	Operating parameters
13	Throughput (EDC time)
14	Flow loop parameters

Table 3 - D&T Options Summary

Option	Description	Cost	Schedule
A	Recommended Option – hot and cold hybrid	$1.8M	2.5 yr
B	Hot Test Exact GFD	$5.0M	4 yr
C	Cold Test Exact GFD	$2.5M	2 yr

Table 4 - Remaining risk following execution of D&T options

		Residual D&T Need Levels After Executing Option			
			Option C	Option A*	Option B
		No Further D&T	Exact Cold	Hot & Cold Hybrid	Exact Hot
SDD Functions	F-2.8 Package Plutonium Oxide	H	M	L	L
	F.2.8.1 Package plutonium oxide, EU/Pu oxide and other by-product in 3013 Inner Can	H	M	L	L
	F.2.8.2 Recycle Failed 3013 Inner Cans	L	L	L	L
Inner Canning Components	Robotics	L	L	L	L
	Decontamination Hardware	M	L	L	L
	Decontamination Flow Loop	M	L	L	L
	Welder	M	M	L	L
	Radiation Monitoring Station	L	L	L	L
	Leak Check Station	M	M	M	M
	Can Opener	L	L	L	L
	Cost to Implement		$2.5 M	$1.8 M	$5 M
	Schedule to Implement		2 yr	2.5 yr	4 yr

*** Recommended Option**

Chapter 6 - Nondestructive Assay D&T Options

Introduction

The nondestructive assay (NDA) system is used to assay special nuclear materials (plutonium and uranium) prior to processing, storage and shipping. The NDA suite incorporates various instruments including a calorimeter, neutron coincidence counter (NCC), gamma ray isotopics system (GRIS), and a radiograph. The radiography station is not GFD and will be addressed in D&T options for the balance of plant. An NDA suite has been in use at LANL for 5 years. The calorimeter and NCC are identical to the GFD. The GRIS is identical to the GFD with the exception of the compumotors. The LANL equipment has been shown to be able to meet MOX requirements for NDA of plutonium oxide containers (ARIES outer containers) with the exception of accuracy using GRIS for two isotopes (^{239}Pu and ^{240}Pu). Measurement of BNFL containers, HEU material, HEU sludge from EDC and other classified components (see classified addendum to TMEs) has not been demonstrated but the equipment is expected to be capable of measuring these items. The LANL robot is different from that specified in the GFD. In summary, the NDA equipment is very mature with the exception of the robot. The SDD analysis noted that a shipper - receiver agreement between PDCF and Y-12 is necessary in order to ship HEU to Y-12 from PDCF. The agreement is being negotiated by NNSA and is outside of the scope of this document.

Table 1 summarizes the high and medium D&T needs from the NDA TME. Table 2 lists the data needs for NDA. Table 3 lists the costs and schedule for the D&T options. Table 4 is a summary of the SDD and component residual risks following execution of the proposed options. SDD residual risks are evaluated against process maturity and component residual risks are evaluated against equipment maturity using the TME process. Red boxes are high residual risk, yellow boxes are medium residual risk, and green boxes are low residual risk. One exception to the TME process was made to generate Table 4: for processes that do not require SNM or pits to be fully tested, boxes representing residual risk following exact cold testing were colored green even though the TME process unnecessarily regards these as medium risk.

The primary outstanding D&T needs for the PDCF include verification that the NDA suite can measure HEU-containing materials and that the NDA suite can achieve the accuracy necessary for MOX acceptance of plutonium oxide. The manipulator operability is also a significant D&T need.

D&T Options

A) *Recommended option for NDA -cold and hot test hybrid option*

Cost: $1M
Schedule: 1.5 years
D&T needs addressed: 1 - 9, 11, 13, and 14 (in Tables 1 and 2)
D&T needs not addressed: 10, 12, and 15 (in Tables 1 and 2)
Discussion: The recommended D&T option for the NDA module involves further testing of the integrated suite to test NDA of HEU, testing using BNFL outer containers, installation of a new spectrometer into the GRIS to increase accuracy, testing of the bar code reader, and calculations to verify lag storage and shielding requirements.

A1) The primary outstanding D&T need for the NDA module is NDA of HEU materials including oxide and sludge from HEU processing. Similar measurements have been made using different instruments, however the NDA suite has not been tested with HEU materials. Containers will be loaded with HEU materials and the necessary measurements (active neutron counting, in particular) will be performed. No additional equipment is necessary to perform the necessary HEU tests.

A2) NDA measurements of plutonium oxide are mature. The NDA suite is capable of meeting the MOX - PDCF interface control document requirements with the exception of the accuracy for two isotopes (^{239}Pu and ^{240}Pu). Installing a new spectrometer can increase the accuracy of the ^{239}Pu and ^{240}Pu measurements. A spectrometer has been ordered and it is currently planned that the spectrometer will be tested within the next year. Tests using BNFL outer containers are predicated on the DP-funded installation of an outer container welder. When the welder is installed (late CY 2003), ARIES materials will be welded into BNFL outer containers and assayed in the NDA suite.

A3) A functionally equivalent manipulator, bar code reader, and host computer have been tested at LANL. The exact manipulator, bar code reader, and host computer can all be cold tested. Manipulator testing is covered in the section on manipulator testing. The recommendation is to cold test the NDA manipulator. It is recommended that the bar code reader and host computer be cold tested because there is no influence of plutonium or pits on their operation. The recommendation is to cold test the host computer upon PDCF startup because any software tested much before PDCF startup will require updating to meet the modern operating system requirements. It is recommended that the bar code reader be tested prior to PDCF startup because bar code reading of stainless steel containers has been a significant problem throughout the DOE complex.

A4) Calculations will be performed to ensure that the lag storage is sufficient to meet the PDCF requirement. No D&T is necessary for lag storage.

A5) Interference from a co-located radiography unit is a performance concern for the NDA suite. There is no co-located radiography suite at LANL, therefore shielding requirements for the NDA suite must be assessed. If additional shielding is necessary, the NDA suite design will be changed to incorporate additional shielding.

B) *Alternate option B for NDA -exact hot testing*

Cost: $6M

Schedule: 3 years

D&T needs addressed: 1 - 9 and 11 - 15 (in Tables 1 and 2)

D&T needs not addressed: 10 (in Table 2)

Discussion: An identical NDA system including suite layout, manipulator and radiography unit can be built, installed and tested at LANL if space can be obtained. Exact hot testing addresses all of the D&T needs with the exception of establishment of a shipper - receiver agreement. The presence of sufficient lag storage would be verified by analysis. The drawback to this option is cost and schedule. The benefit is that testing of the exact system would mitigate all operability risks associated with NDA including those associated with radiography.

C) *Alternate option C for NDA -analysis only*

Cost: $0.1 M

Schedule: 1 year

D&T needs addressed: 2, 7, 9, and 14 (in Tables 1 and 2)

D&T needs not addressed: 1, 3-6, 8, 10-13, and 15 (in Tables 1 and 2)

Discussion: NDA of HEU materials has been performed at a variety of DOE sites. A study can be performed to validate the ability of the NDA suite to assay HEU materials. The presence of sufficient lag storage would be verified by analysis.

Table 1 - High or Medium D&T needs from NDA TME

#		RM / Impact / D&T Need	PM / Impact / D&T Need PM	SAFT-OPS / Impact / D&T Need	EQ / Impact / D&T Need	Issues	D&T Need Level	D&T Options
1	F.2.13 Perform NDA to Support Facility Processing	2 / L / L The requirements for PDCF NDA are dictated by compliance with DOE MC&A orders, the DOE packing standard and WIPP waste acceptance criteria.	6 / L /L Major need remaining is the determination of process parameters for measurement of HEU containing materials and the impact of the use of BNFL outer cans	8 / H / H* Driven by calorimeter / robot manipuilator issures * M by consensus	6 / H / M Driven by robot. Other technology is fairly mature.	Radiography may impact equipment operability (including electrical interference). Not yet demonstrated for HEU containing materials. No measurements done on BNFL cans.	M	Hot test
2	F.2.13.2 Perform NDA on Product 3013 Cans	2 / L / L The requirements for PDCF NDA are dictated by compliance with DOE MC&A orders, the DOE packing standard and WIPP waste acceptance criteria	6 / H / M A similar NDA system has been demonstrated as a part of the ARIES process. Impact is driven by lack of alternative to calorimetry	8 / H / H* Driven by calorimeter and robot manipulator. * By process this is an H, by consensus this is an M	6/ H / M The ARIES NDA system differs only in layout and robot control interface. High EQ value driven by robot manipulator, other equipment very mature.	The individual NDA instruments will be identical with those used in ARIES, however, their numbers will be increased. The robot, storage areas, and input output systems will be different than ARIES. Some materials have not been evaluated yet using calorimetery	H* * M by consensus	Hot test

#	Component	Function Addressed	RM / Impact / D&T Need Level	PM / Impact / D&T Need Level	SAFT – OPS / Impact / D&T Need Level	EQ / Impact / D&T Need Level	Issues	D&T Need Level	D&T Options
3	Robot Manipulator and Bay Support (includes Gripper)	*NDA SDD R.2.13.2.B* Containers must be moved between NDA functions	2 / L / L All parameter values are specified, little or no change in requirements are expected ***PDR NDA*** ***NDA 90%***	6 / H / M Hot feasibility demonstrated with ARIES NDA robot. Small scale of ARIES demo inappropriate for PDCF ***ARIES-NDA*** ***ARIES Demo Report***	6 / H / M Process logic has been defined and documented for normal and off-normal conditions. ARIES robot operational data used to define operation conditions and possible recovery modes. ***ARIES-NDA*** ***ARIES Demo Report***	6 / H / M Experimental System hot tested. ***PDR NDA*** ***NDA 90%***	If manipulator fails, can't make dose limit	M	Cold test
4	Calorimeter	Quantitative measurement of Pu product materials ***DOE 474.1-1A*** ***PDCF MC&A***	2 / L / L Description complete and applicability of the calorimeter are understood. ***PDR NDA*** ***NDA 90%***	2 / H / L Performance of calorimeter with radioactive materials well understood. ***ARIES-NDA*** ***ARIES Demo Report***	6 / H / M LANL procedures ***DOE 474.1-1A*** ***PDCF MC&A***	1 / H / L ARIES experimental system hot demonstrated ***ARIES-NDA*** ***ARIES Demo Report***	Shown can meet MOX ICD requirements Need to develop PDCF procedures. Never demonstrated on BNFL outer cans	M	Paper Documentation

Table 2 - Summary of data needs from NDA data needs study

	SDD
5	PDCF host computer testing
6	PDCF manipulator
7	HEU NDA
8	Radiography shielding calc
9	Verify lag storage design
10	Formal agreement between Y-12 & PDCF necessary
11	Bar code reader
12	Radiography - can deflection
	Operating parameters
13	Bar code reader
14	HEU NDA
15	Radiography - can deflection

Table 3 - D&T options, cost, and schedule for NDA

Option	Description	Cost	Schedule
A	Hybrid testing option	$1 M	1.5 years
B	Exact hot testing	$6 M	3 years
C	Analysis	$0.1 M	1 year

Table 4 - Remaining risk following execution of D&T options

		Residual D&T Need Levels After Executing Option			
			Option C	Option A*	Option B
		No Further D&T	Analysis Only	Hybrid Hot & Cold	Exact Hot
SDD Functions	F.2.13 Perform NDA to Support Facility Processing	M	M	M	M
	F.2.13.2 Perform NDA on Product 3013 Cans	M	M	L	L
Nondestructive Assay Components	Robot Manipulator and Bay Support (includes Gripper)	M	M	M	L
	Calorimeter	M	M	L	L
	Gamma Ray Isotopics	L	L	L	L
	Neutron Coincidence Counter	L	L	L	L
	Cost to Implement		$0.1 M	$1 M	$6 M
	Schedule to Implement		1 yr	1.5 yr	3 yr

*** Recommended Option**

Chapter 7 - Highly Enriched Uranium Processing D&T Options

Introduction

The function of Uranium Processing & Staging System (UP&SS) is to convert highly-enriched uranium (HEU) metal to uranium oxide that will meet Y-12 plant acceptance criteria for plutonium contamination. HEU hemishells arrive at UP&SS from either pit disassembly or the special recovery line. After receipt at UP&SS, the HEU hemishells are weighed. The HEU hemishells are then subjected to an electrolytic decontamination process that has been demonstrated yield material meeting the Y-12 plant acceptance criteria for HEU. This process requires three electrolytic decontamination cycles, followed by the oxidation of the resulting decontaminated HEU in a furnace at elevated temperatures. The resultant HEU oxide product is milled and blended for homogenization prior to sampling, placed into cans that are sealed by crimping the lid, and sent to inner canning. A sample analysis of the oxide is used to insure compliance with receiver (Y-12 Plant) requirements. The ARIES HEU Decontamination and Conversion (D&C) process has demonstrated the ability of the proposed process to generate Y-12 acceptable material (see classified addendum to TMEs and LANL Demo Report LA-CP-02-449). Demonstrations of the D&C module, performed with all manual instrumentation and material transfer, validated the decontamination and oxidation processes and supported the development of bounding production rates. Although the functional requirements for direct metal oxidation (DMO) and auxiliary oxidation (Aux-DMO) are associated with the UP&SS module in the FDD, the D&T options for these functions are integrated with the Pu DMO discussion in Chapter 2, *Direct Metal Oxidation D&T Options*.

D&T Options

The options presented in this paper are the result of the TME and data needs analysis (DA) of the UP & SS module performed by the TME working group. Table 1 summarizes the results of the TME at the component and requirement levels. The specifics of the HEU data needs analysis are classified, but an unclassified summary of the findings is shown in Table 2. A high level approximation of the cost and schedule for each option is presented in Table 3. Following Tables 1-3, a discussion of the D&T options, with the recommended option discussed first and in greatest detail, is presented. For completeness, hot and cold testing options for the GFD prototype have been included along with the recommended option. Table 4 is a summary of the SDD and component level residual risks following execution of the proposed options. SDD residual risks are evaluated against process maturity and component residual risks are evaluated against equipment maturity using the TME process. Red boxes represent high residual risk, yellow boxes medium residual risk, and green boxes low residual risk. One exception to the TME process was made to generate Table 4: for processes that do not require SNM or pits to be fully tested, boxes representing residual risk following exact cold testing were colored green even though the TME process unnecessarily regards these as medium risk.

The TME and DA for the UP&SS system demonstrated deficiencies in both the component and process maturity of this system. Mechanically, the GFD fixture and flow-loop have not been tested, although cold testing of the GFD fixture is underway. These gaps in mechanical maturity represent a troubling level of risk to the facility. Since HEU processing is a low dose operation, hot testing is not required in order to close the component maturity gaps. All three of the options presented greatly reduce the component level risk to the facility.

Hot testing is required, however, to close the gaps identified in the process maturity. Most important to the facility is the formal qualification of the HEU decontamination parameters. Formal qualification of the decontamination process will allow shells to be directly transferred from the decontamination to metal preparation stations without smearing. Process qualification will also address the distillation requirement, and may lead to the elimination of distillation from the GFD design. The amount and material characteristics of the process sludge, and the consumable requirements of the system will also be determined.

A) *UP&SS - Recommended Options – Hot and Cold Test Hybrid.*
Cost: $2.2M
Schedule: 2.5 yr to completion of all hot and cold D&T
D&T needs addressed: All, except those associated with DMO.

Overview:
The recommended D&T option comprises the set of two hot tests and a cold integrated flow-loop test. Hot testing of the GFD decontamination fixture assembly with an associated non-GFD flow-loop is recommended. The flow-loop, while not an exact copy of the GFD due to size constraints, will be similar to the GFD in that it will include automated valves and PLC control. The second recommended hot test involves testing of the GFD dewater pot bake-out function, apart from the recommended integrated cold testing of the entire GFD flow-loop. Testing of the back-out function of the dewatering system will generate important data on the characteristics of the HEU material produced in this system, as well as data on processing times. The back out function is the only flow-loop related sub-system that requires hot testing. Cold testing of the GFD flow-loop with integrated distillation and dewatering systems is also recommended. Cold testing of the flow-loop will yield data on component functionality and integration, and also allow development of the system control algorithm.

A1) GFD Decontamination Fixture – hot test
Cost: $1M
Schedule: 2.5 yr

D&T needs addressed: 1, 2, 5, 6, 18, 21-24

Discussion: The first and second ARIES demonstrations have been run with non-prototypic decontamination fixtures. The decontamination fixture (MOD 4) used in the second ARIES demonstration was designed for manual operation. The MOD 4 fixture requires rotation for draining, manual opening and closing, does not have any features to prevent cross-contamination of material, and does not allow for selective decontamination of the inner or outer hemishell surfaces. Hot acceptance testing of a GFD test fixture (MOD 6) is underway. The MOD 6 requires manual closure and was designed to aid in the ongoing development of the GFD fixture by testing the dip-tube and electrical isolation functions. It does not allow testing of the GFD closure mechanisms or contamination isolation function. In support of the GFD effort, cold tests are currently being conducted on a prototype decontamination fixture. This prototype fixture is scheduled to be cold tested through 2003, with hot installation as part of the HEU upgrade scheduled for 2004.

Hot testing of the GFD fixture will necessitate installation of a flow-loop to supply the fixture will process fluids and gases. Due to space constraints in PF-4, this flow-loop will be much smaller than the GFD, but will retain many of the essential functions. Flow-loop operations will be automated and PLC controlled, and all flow rates to and from the fixture will mimic those expected in the GFD.

A2) Dewatering System – bake-out pot hot test.
Cost: 0.2M
Schedule: 1.0yr.
D&T needs addressed: 5, 17

Discussion: The recommendation is to hot test only the GFD dewater pot with actual process sludge under the GFD evaporation conditions. This will allow for the evaluation of the sludge mechanical and physical characteristics, but will not require the hot installation of the entire dewatering system. Cold testing of the GFD dewatering system, discussed in A3, should be sufficient to evaluate the overall system performance and to establish the operating parameters.

The TME analysis ranks the D&T need level for the flow-loop dewatering system as high in the process maturity, the safety/ops, and equipment categories. The primary reason for these high ratings is the lack of experience with the evaporation component of the dewatering system. LANL currently uses a UF loop similar to the GFD to concentrate the uranium sludge into slurry, and then uses vacuum filtration and oven heating to complete the sludge drying process. In order to limit hands-on operations, the GFD replaces the vacuum filtration and oven heating with the dewater pot. The principle concerns with the GFD system relate to the material characteristics of the dried sludge.

A3) GFD Flow-loop – cold test
Cost: \$1M
Schedule: 2 yr
D&T needs addressed: 1, 2, 5, 7, 8, 14-17, 19, 20, and 24.

Discussion: Our recommendation is to cold test the GFD flow-loop. Cold testing will provide data on the process parameters and mechanical operations of the integrated flow-loop, as well as testing of the control and safety systems (i.e. hydrogen sensors). The distillation and dewatering operations of the UP&SS system are integral to the operation of the GFD flow-loop and will be demonstrated in the recommended cold test.

The purpose of the UP&SS flow-loop is to transfer fluid from the process electrolyte and rinse tanks to and from the decontamination fixture, to maintain process fluids within specified pH and conductivity ranges, to distill off-spec rinse water, and to dewater process sludge for transfer to the Auxiliary DMO module. The flow-loop must also meet the facility hydrogen monitoring requirements. Examination of Tables 1 and 2 leads to the conclusion that the maturity of the flow-loop at the element and component level is high. The team felt that the technology required for flow-loop operations is very mature and that there were no unique components that required testing. However, the process maturity for the flow-loop functions scored as 8/H/H and the safety & ops scored as 6/H/M. These scores reflect the team's feeling that the consequences of a failed flow-loop design are very serious (the middle high), and that the operation of the integrated GFD flow-loop was not mature.

The GFD flow-loop is functionally similar to that used in the second ARIES demonstration. The differences are listed in the attached gap analysis. The main differences between the demonstrated and GFD flow-loops are component sizes, durability, and a departure from batch processing. The flow-loop proposed for the hot testing of the GFD fixture will be similar to the GFD in that it will incorporate automated valves and PLC controls but, due to space constraints, is not designed to prototype the GFD.

The TME and DA both pointed out deficiencies in the maturity of the GFD flow-loop. Other than the previously discussed bake-out operation, none of the recommended flow-loop D&T requires testing with radioactive materials. LANL has not experienced any radio-degradation in the pilot flow-loop testing. It is, however, important to vet the GFD flow-loop integrated design and develop operating parameters (flow rate, pressure, ops sequence) prior to start-up the facility. This can be done using surrogate material either at LANL or some other cold test facility.

B) Alternative Option B - Hot test exact GFD equipment at LANL
Cost: $5M
Schedule: 4 yr.
D&T needs addressed: All, except those associated with DMO.

Discussion: This option would allow for the most comprehensive testing of the GFD. LANL is currently scheduled to hot test the GFD fixture, but not to hot test any of the GFD flow-loop components. Given that there are no radiation related issues associated with the operation of the flow-loop, hot testing of the entire GFD UP&SS is difficult to justify technically. Space, schedule, and budget constraints may also argue against a complete system hot test.

C) Alternative Option C - Cold test exact GFD.
Cost: $1.6M
Schedule: 2 yr
D&T needs addressed: 1, 2, 5, 7, 8, 14-17, 19, 20, and 24

Discussion: This option is most applicable to the GFD flow-loop, including distillation and dewatering systems. Hot testing of the flow-loop may be cost and schedule prohibited, and cold testing could generate much of the needed data. Preliminary results of LANL cold tests on the GFD line sizes indicate that the GFD may be driven by drainage requirements to a smaller overall flow-loop, more closely resembling the current LANL design (ESA-AET: 03-124). Cold testing of the distillation and dewatering systems is technically defensible. Cold testing of the fixture is currently underway and is yielding valuable information about the mechanical functioning of this component.

Table 1 - High or Medium D&T needs from the HEU TME *

		RM / Impact / D&T Need Level	PM / Impact / D&T Need Level	SAFT – OPS / Impact / D&T Need Level	EQ / Impact / D&T Need Level	D&T Need Level
1	F.2.7 Process Uranium Pieces	2/L/L	9/H/H		Equipment requirement s undefined	H
2	F.2.7.3 Decontaminate HEU Hemishells	2 / L / L	9 / H / H	8 / H / H	9 / H / H	H
3	F.2.7.6 Convert Uranium Pieces, EU/Pu pieces and crucibles and Main HEU fluid sludge to oxide R.2.7.6.A At least 99 percent **{HOLD}** of uranium shall be converted to U3O8.	2 / L / L This may be a bad requireme nt with respect to sludge	10 / H / H	6 / H / M	6 / M / M	H
4	F.2.7.6.1 Oxidize/Calcine Decontaminated Uranium Pieces	2 / L / L	10 / H / H	6 / H / M	6 / M / M	H
5	Decon Flow Loop	2/L/L	8*/H/H	6 / M / M	6 / L / L	H
6	Decon Fixture	2/L/L	6/H/M	8/H/H	8*/H/H	H
7	Off-line solution dewatering	2/L/L	9/M/H	8/M/H	9/M/H	H
8	Distillation	2/L/L	8/M/H	8/M/H	8 /M / H	H
9	DMO Furnace	2/L/L	2/L/L	8*/M/H	6/M/M	H
10	Calciner	2/L/L	8*/H/H	2/L/L	6/M/M	H

Table 2 - Summary of data needs from HEU data needs study

	SDD
11	O/M determination
12	Blend batch uniformity
13	Oxide recycle
	Operating parameters
14	Pressure drop
15	Electrolyte flow rate
16	CIP
17	Dewater pot
18	Electrode I / V
19	EDF operating T
20	Purge air P
	T&M study
21	Change upper EDF assembly
22	Change lower EDF assembly
23	Unlock & open EDF assembly
24	Run EDC process
25	Evacuate furnace
26	Oxidize metal
27	Calcine oxide

Table 3 D&T Options Summary

Option	**Description**	**Cost**	**Schedule**
A	Recommended Option – hot and cold hybrid	\$2.2M	2.5 yr
B	Hot Test Exact GFD	\$5.0M	4 yr
C	Cold Test Exact GFD	\$1.6M	2 yr

Table 4 - Remaining risk following execution of D&T options

		Residual D&T Need Levels After Executing Option			
			Option C	Option A*	Option B
		No Further D&T	Exact Cold	Hot & Cold Hybrid	Exact Hot
SDD Functions	F.2.7 Process Uranium Pieces	H	H	M	L
	F.2.7.3 Decontaminate Uranium Hemishells	H	M	M	L
HEU Processing Components	Decon Flow Loop	M	M	M	L
	EDC Fixture	H	M	M	L
	Off-line Solution Dewatering	H	M	M	L
	Distillation	H	M	M	L
	Cost to Implement		$1.6 M	$2.2 M	$5 M
	Schedule to Implement		2 yr	2.5 yr	4 yr

*** Recommended Option**

Chapter 8 - Part Sanitization D&T Options

Introduction

The part sanitization module is designed to melt non-SNM components in a part sanitization furnace (PSF) to destroy all classified characteristics (FDD R-2.9-1) at a rate sufficient to meet maximum throughput in Mass Balances for Primary Streams for PFDs (U), B-PDCF-1-01-029, FDD R-0.0-1and R-2.9-2. The system must produce sanitized waste that meets the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC).

The PSF system will include a means for staging in components and loading the furnace, a PSF to melt the components, and a means to stage out metal ingots and crucibles. Means for segregating materials by type, lag storage of non-SNM components, verification of component destruction, and recording of component destruction are non-GFD items and were not evaluated here.

Material movement is accomplished through the use of an overhead manipulator for material transport, a crucible turntable to load crucibles into an RF induction furnace where parts are melted, and a crucible tilter that allows the finished product be removed from the crucible so it can be placed in the final storage container by the overhead manipulator. Each of the components can operate independently.

The ARIES project at LANL has demonstrated the process of sanitizing stainless steel and aluminum shapes (John J. Park, et. al., "Results of Cold Acceptance Tests for the Parts Sanitization Furnace", Los Alamos National Laboratory Report, LA-UR-01-3568) in a functionally equivalent PSF. These demonstrations validate the melting process and gave bounding production rates for the GFD PSF. The LANL PSF has been installed into the plutonium production line. This furnace is scheduled to become operational in the near future. Although procured prior to the completion of GFD, this furnace closely mimics the GFD in form and function (see the PSF gap analysis, for differences between the PSF and GFD).

A hazards analysis by WGI has suggested that the GFD may require some redesign to address explosion hazards. The extent of this redesign, if any, is unclear at this time.

The primary outstanding needs for the part sanitization furnace include developing process parameters for sanitization of beryllium and vanadium, and assessing the functionality of the crucible tilter and turntable.

D&T Options

The options presented below result from the TME and DA of the PSF module performed by the TME working group. Table 1 summarizes high and medium D&T risks from the TME at the component and requirement levels. A summary of the DA is shown in Table 2. Table 3 summarizes the D&T Options discussed in this section. The recommended option is discussed first and in greatest detail. For completeness, several alternative options are also presented. The proposed options address deficiencies in the equipment and process testing exposed by the TME and DA. Several D&T options were evaluated to mitigate the project risks identified in the TME and DA. Table 4 is a summary of the SDD and component residual risks following execution of the proposed options. SDD residual risks are evaluated against process maturity and component residual risks are evaluated against equipment maturity using the TME process. Red boxes are high residual risk, yellow boxes are medium residual risk, and green boxes are low residual risk. One exception to the TME process was made to generate Table 4: for processes that do not require SNM or pits to be fully tested, boxes representing residual risk following exact cold testing were colored green even though the TME process unnecessarily regards these as medium risk.

The D&T options presented for the PSF assume that the steam explosion safety issue will be resolved without a major redesign. If the issue requires a major redesign of the furnace such that the furnace currently installed in the ARIES line differs significantly from the GFD design, these options will need to be revisited.

A) *Recommended option for PSF - Cold and hot test hybrid*
Cost: $0.7M
Schedule: 1 year
D&T needs addressed: 3-10 & 13-19

Overview: The recommended option does not address the overall integration of the system including integration with the automation system. Without the automation, D&T need 1 cannot be sufficiently addressed. Also, the impact of the differences between the LANL PSF and the GFD PSF would not be evaluated. All of the aforementioned D&T needs could be addressed at PDCF start-up.

The only remaining D&T need not addressed is 12, which is an administrative need and is independent of GFD equipment. D&T needs 2, 5, 6 and 11 are addressed in the overhead manipulator D&T options section.

A1) Furnace and Vacuum System – hot test GFD functionality on system currently installed in ARIES line
Cost: $0.3M
Schedule: 1 year
D&T needs addressed: 4, 8, 9-10, and 13-19 in Tables 1 and 2
Discussion: The recommended option takes advantage of the upgrades already underway in the ARIES line. Parametric information and product quality information can be obtained by testing of the PSF that is currently installed in PF-4. See the PSF gap analysis for detailed accounting of the differences between the LANL PSF and the GFD PSF.

The recommended option addresses the majority of the major issues identified in the TME and DA including impact of beryllium particulates on the vacuum and filtration systems, impact of beryllium plating on coil performance, ability to adequately melt all feed materials, gripper functionality and overall operating parameters and procedure development.

A2) Crucible Turntable and Crucible Tilter – Cold test exact
Cost: $0.4M
Schedule: 1 yr
D&T needs addressed: 3, 5, and 7 in Table 1

Discussion: The crucible turntable and tilter are purely mechanical items that do not require pits or SNM to test their functionality. Therefore, the recommendation is to cold test these items to avoid the cost and schedule impacts associated with hot testing.

B) *Alternative option B - Hot test exact GFD PSF at LANL*
Cost: $3M
Schedule: 2.5 yr
D&T needs addressed: 3-5, 7-11, and 13-19 in Tables 1 and 2

Discussion: Option B would address everything that does not interface with the overhead manipulator. Depending on the resolution of the steam explosion issue this may become the recommended option. The primary reason it is not the recommended option now is because testing an exact system buys little over the testing the functionally-equivalent system described above.

C) *Alternative Options C - Cold test exact GFD equipment at LANL*
Cost: $1M
Schedule 1 yr
D&T needs addressed: 3-5, 7-11, and 13-19 in Tables 1 and 2

Discussion: This option is a subset of the recommended option in which the crucible tilter and crucible turntable are cold tested. The difference is that the exact GFD PSF is only cold tested. While this option would allow for a comprehensive, integrated systems test, it would not allow for resolution of all the technical issues associated with the different feed streams.

Table 1 - High or Medium D&T needs from the PSF TME

#	SDD requirement	RM / Impact / D&T Need Level	PM / Impact / D&T Need Level	SAFT – OPS / Impact / D&T Need Level	EQ / Impact / D&T Need Level	Issues	D&T Need Level	D&T Options
1	F.2.9 Sanitize Non-SNM	2 / L / L	9 / H / H	10 / H / H	9 / H / H Driven primarily by gripper issues	Only SS, Al, and Ni have been cold tested.	H	Hot test experimental system with all predicted feed metals.
2	F.2.9.1 Stage-In Components	2 / L / L	9 / H / H Driven by overhead manipulator and gripper issues	8 / H / H Recovery from cracked or broken crucible not addressed	9 / H / H Design concepts exist for all equipment	Automation and integrations of robotics.	H	Cold test
3	F.2.9.4 Load Furnace with Crucible	2 / L / L	9 / H / H Not demonstrated	8 / H / H	9 / H / H Design concepts exist for all equipment	Automation and integrations of robotics.	H	Cold test
4	F.2.9.5 Melt Non-SNM Components	2 / L / L	9 / H / H Not demonstrated to melt all materials	10 / H / H See bell jar in Table 4	10 / H / H Steam explosion issue not resolved yet. Experimental system. Cold demonstrated on some material types	Only SS, Al, and Ni have been cold tested.	H	Hot test experimental system with all predicted feed metals.
5	F.2.9.8 Stage-Out Metal Ingots and Spent Crucibles	2 / L / L	9 / M / M Driven by crucible tilter	6 / M / M	9 / M / M	Automation and integrations of robotics.	M	Cold test
6	Overhead Manipulator	2 / L / L	9 / H / H Hardware integration has not been demonstrated Control algorithms nonexistent Gripper concept may be flawed – may push too hard and break?	8 / H / H Understand hazards associated. Candidate safety significant system have been identified Operational documentation not complete	9 / H / H Piece parts require custom design Well developed technology for manipulator but not with these specific grippers and control integration	Mission critical HW/SW item used for all modules. Difference between modules is gripper chosen Integration of automation – will it work?	H	Cold test
78	Crucible Tilter	2 / L / L	9 / M / M Entire integration not tested	6 / M / M PDCF PHA	9 /M/M Driven by piston table	Cost of waste drums if system doesn't work drives impact to M	M	Cold test
8	Bell Jar Furnace	2 / L / L	9 / H / H Cold tested with Al, SS, Ni, Cold ATR V, Be has not been tested; off-gas filter not tested for Be. Potential for Be plating not evaluated	10 /H / H Steam explosion issue not resolved. Operating parameters not defined for all materials	8 / H / H Some differences exist relative to PDCF design		H	Cold test* *Includes Be if had a cold facility to run tests otherwise would need to be a hot test.

Table 2 - Summary of PDCF data needs for PSF

#	SDD
9	Process parameters for all but Al and SS
10	Alloying V with other materials
11	Manipulator & gripper
12	Develop PDCF - WIPP WAC agreement
	Operating parameters
13	Induction Coil Water Flow Rate, Temperature, Amperage, Voltage, and Frequency
14	Base Plate Water Flow Rate and Temperature, and Base Plate Temperature
15	Bell Jar Water Flow Rate and Temperature, Bell Jar Temperature and Pressure
16	Heat Station Water Flow Rate, Temperature and Resistivity and Heat Station Volts
17	Power Supply Parameters
18	Temperature of the Melt
19	Temperature of the Crucible

Table 3 - D&T Options Summary

Option	Description	Cost	Schedule
A	Recommended Option	$0.7 M	1 yr
B	Hot test exact GFD PSF at LANL excluding overhead manipulator	$3.0 M	2.5 yr
C	Cold test exact GFD equipment at LANL excluding overhead manipulator	$1.0 M	1 year

Table 4 - Remaining risk following execution of D&T options

		Residual D&T Need Levels After Executing Option			
			Option C	Option A*	Option B
		No Further D&T	Exact Cold	Hot & Cold Hybrid	Exact Hot
SDD Functions	F.2.9 Sanitize Non-SNM	H	H	M	L
	F.2.9.5 Melt Non-SNM Components	H	H	L	
Part Sanitization Components	Crucible Tilter	M	M	M	L
	Bell Jar Furnace	M	M	M	L
	Cost to Implement		\$1 M	\$0.7 M	\$3 M
	Schedule to Implement		1 yr	1 yr	2.5 yr

*** Recommended Option**

Chapter 9 - Manipulator D&T Options

Introduction

Overhead manipulator is a generic term to describe the systems that will grip and move objects for the various modules. There are two types of manipulators in the PDCF facility – one that goes into the glovebox line and one that operates the NDA system.

The only function of the 3-axis NDA manipulator is to move an object from one defined location to another defined location. The objects to be moved include product oxide cans (3013 and Y-12 style), standards cans, check source cans, top and bottom neutron counter plugs, and calorimeter baffles. Each object is equipped with a lifting knob. During each move, the manipulator may be commanded to move the object past the bar code reader mounted on the cross gantry of the manipulator before placing the object in the new location. The manipulator is equipped with a sensitive force feedback transducer, which will provide collision and positioning feedback. The manipulator is interlocked with the E-stop system to prevent injury and equipment damage.

The glovebox manipulators have been modified to seal all the rails and components from dust and to meet glovebox size requirements. These manipulators will use one of three standard robot versions: the 3-axis thin mast version, the 4 axis thin mast version or the 5-axis square mast version (Table 1). The 4-axis thin mast version includes a tool rotate axis referred to as the yaw. The 5-axis square mast version includes a tool rotate axis and a mast rotate axis. The 5-axis version also has the capability to operate a vacuum gripper. The generic manipulator has four overall dimensions that vary to accommodate different glovebox sizes and configurations. The robots will work in conjunction with a variety of end effectors (i.e. grippers) to grip and move objects within the glovebox (Table 1).

Universally, the function of the grippers and overhead manipulators in conjunction with the overall integration of automation with the modules represented the highest TME need for every module (Table 2).

NDA had a lower D&T Need because it is located outside the glovebox and the current NDA system used in the ARIES line has a different robot that performs the function of the GFD manipulator.

The manipulator designs have never been tested. Given the extensive hardware and software requirements and the number of manipulators to be installed in the PDCF, testing of the manipulators is a high priority. The D&T needs include software development, testing the accuracy, precision, and reproducibility of object placement and testing the efficacy of the end effectors for the various modules. Table 3 summarizes the D&T options for the overhead manipulator. Table 4 is a summary of the SDD and component residual risks following execution of the proposed options. SDD residual risks are evaluated against process maturity and component residual risks are evaluated against equipment maturity using the TME process. Red boxes are high residual risk, yellow boxes are medium residual risk, and green boxes are low residual risk. One exception to the TME process was made to generate Table 4: for processes that do not require SNM or pits to be fully tested, boxes representing residual risk following exact cold testing were colored green even though the TME process unnecessarily regards these as medium risk.

D&T Options

The options presented in this paper are the result of the TME and DA of each module performed by the TME working group. Table 2 summarizes the results of the TMEs. The DA for most modules identified the need to test the integration of automation but did not specifically address data needs associated with overhead manipulator operation.

A) *Recommended option for Overhead Manipulator - Cold test one manipulator with end effectors for all modules*
Hot test functionality of automation with disassembly; Cold test one exact manipulator for other modules. Cold test includes testing of the all modules gripper functionality with exact grippers
Cost: $5 M
Schedule: 2.5 year
D&T needs addressed: 1-6 in Table 1

Discussion: This option takes advantage of the fact that the prototypic Moore lathe proposed to be installed for disassembly (see Disassembly D&T Options) is already interfaced with a non-GFD manipulator. The functionality test is necessary to test the denesting gripper and prove that overall automation of the disassembly operations is feasible. Denesting cannot be adequately tested with a cold system – real pits are required. Other gripper functions are not plutonium dependent and can be cold tested. This option recommends cold testing only one manipulator, the 5-axis manipulator. Testing of the 5-axis manipulator bounds the 3- and 4-axis manipulators. Calculations / modeling will be performed once the glovebox layouts are finalized to ensure that the manipulator can reach all required areas. This option does not allow for the testing of the functionality of all robot combinations. It would also not allow for the testing of end effectors in a hot environment, but there are no significant effects of radiation or pits other than with denesting (discussed above).

The lathe control system requires integration of the lathe controller with the overhead manipulator. The recommended option is to test the lathe controller with the overhead manipulator. A lathe is not necessary for the testing because a test bed that mimics the lathe can be used in place of an actual lathe.

B) *Alternative Option B - Hot test exact GFD Overhead Manipulator*
Cost: $20 M
Schedule: 5 years
D&T needs addressed: 1-6 in Table 1

Discussion: This option would require the testing of 4 separate manipulators: NDA, 3-, 4, and 5-axis manipulator with associated grippers. It would also require the acquisition of a large amount of space to accommodate the installation of a new, larger glovebox(es). Depending on how the manipulators are interfaced with the equipment, it might require the procurement and installation of additional GFD equipment. This test would provide all the operability information for each robot and would provide information regarding automation integration with the remainder of the modules.

C) *Alternative Option C – Cold test exact GFD Overhead Manipulator.*
Cost: $10 M
Schedule 3 year
D&T needs addressed: 1-6 in Table 1

Discussion: This option would require the testing of 4 separate manipulators: NDA, 3-, 4-, and 5- axis manipulator with associated grippers. This option would allow for the collection of all relevant information with the exception of overall integration of automation with the modules and specific information regarding the use of the denesting gripper.

Table 1 - Overhead manipulators located in the glovebox line

Description	Type of Manipulator	Grippers Used
DMO Manipulator	4-Axis, Thin Mast	Drum/Lid Gripper Milk-Bottle Gripper Heater-Panel Gripper
HDH Manipulator	3-Axis, Thin Mast	Lid/Lid Gripper Heater-Panel Gripper HDH Crucible Gripper
SAN Manipulator	3-Axis, Thin Mast	SAN Crucible Gripper SAN Disposal Gripper
PITD Manipulator	5-Axis, Square Mast	Pit Gripper Lathe Tool Gripper Inner Hemishell Gripper Universal Vacuum Gripper Pot Chuck Gripper PITD Gripper
SRL Disassembly Manipulator	5-Axis, Square Mast	Pit Gripper Lathe Tool Gripper Inner Hemishell Gripper Universal Vacuum Gripper Pot Chuck Gripper Furnace Loading Gripper
SRL Exit Manipulator	5-Axis, Square Mast	Universal Vacuum Gripper SRL Crucible Gripper Furnace Loading Gripper

Table 2- High or Medium D&T needs from each TME

#	Manipulator	RM / Impact / D&T Need Level	PM / Impact / D&T Need Level	SAFT – OPS / Impact / D&T Need Level	EQ / Impact / D&T Need Level	Issues	D&T Need Leve l	D&T Options
1	Overhead Manipulator for Disassembly	2 / L / L	9 / H / H Don't understand all issues with how gripper will interact with overhead manipulator	8 / H / H Off normal conditions not considered	9 / H / H Driven by denesting gripper	Driven by gripper issues Different than the rest of the manipulators in the plant – has an X, Y, Z and a yaw axis. Should be identical to SRL	H	Hot test because of need to test actual parts. Driven by denesting gripper.
2	Overhead Manipulator for DMO	2 / L / L	9/H/H Hardware integration has not been demonstrated Control algorithms nonexistent Drum gripper not tested	8 / H / H Understand hazards associated. Candidate safety significant system have been identified Operational documentation not complete	9 / H / H Piece parts require custom design Well developed technology for manipulator but not with these specific grippers and control integration	Mission critical HW/SW item used for all modules. Difference between modules is gripper chosen	H	Cold test
3	Robotics for Packaging	2 / L /L	8 / H / H Cold feasibility demonstrated Cold ATR.	8 / H / H PDCF PHA	8 /H / H Driven by robotic tooling	Jacobs design has cold robot on the floor of the glovebox instead of the roof. Should not affect operation In picking up a can in a potentially contaminated glovebox, will contaminates be introduced to the gripper which would affect fixed contamination found on the outer weld?	H	Hot Test
4	Overhead Manipulator for PSF	2 / L / L	9 / H / H Hardware integration has not been demonstrated Control algorithms nonexistent Gripper concept may be flawed – may push too hard and break?	8 / H / H Understand hazards associated. Candidate safety significant system have been identified Operational documentation not complete	9 / H / H Piece parts require custom design Well developed technology for manipulator but not with these specific grippers and control integration	Mission critical HW/SW item used for all modules. Difference between modules is gripper chosen Integration of automation – will it work?	H	Cold test

#	Manipulator	RM / Impact / D&T Need Level	PM / Impact / D&T Need Level	SAFT – OPS / Impact / D&T Need Level	EQ / Impact / D&T Need Level	Issues	D&T Need Level	D&T Options
5	Overhead Manipulator for HDH	2 / L / L	9 / H / H Hardware integration has not been demonstrated. Control algorithms nonexistent Drum gripper not tested.	8 / H / H Understand hazards associated. Candidate safety significant systems have been identified. PDCF PHA Operational documentation not complete	9 / H / H Piece parts require custom design Well developed technology for manipulator but not with this specific gripper and control integration	Mission critical HW/SW item used for all modules. Difference between modules is gripper chosen. Integration of Automation – will it work?	H	Cold test
6	Robot Manipulator for NDA	2 / L / L All parameter values are specified, little or no change in requirements are expected *PDR NDA* *NDA 90%*	6 / H / M Hot feasibility demonstrated with ARIES NDA robot. Small scale of ARIES demo inappropriate for PDCF *ARIES-NDA* *LANL DR*	6 / H / M Process logic has been defined and documented for normal and off-normal conditions. ARIES robot operational data used to define operation conditions and possible recovery modes. *ARIES-NDA* *LANL DR*	6 / H / M Experimental System hot tested. *PDR NDA* *NDA 90%*	If manipulator fails, can't make dose limit	M	Cold test

Table 3 - D&T Options Summary

Option	Description	Cost	Schedule
A	Recommended Option – hot test functionality in disassembly plus cold test exact	\$5 M	2.5 yr
B	Hot test exact GFD	\$20 M	5 yr
C	Cold test exact GFD	\$10 M	3 yr

Table 4 - Remaining risk following execution of D&T options

	Residual D&T Need Levels After Executing Option			
		Option A*	Option C	Option B
	No Further D&T	One O.M. w/ All End Effectors	Exact Cold Test All O.M.	Exact Hot Test All O.M.
DMO Manipulator				
NDA Manipulator				
HDH Manipulator				
SAN Manipulator				
PITD Manipulator				
SRL Disassembly Manipulator				
SRL Exit Manipulator				
Cost to Implement		$5 M	$10 M	$20 M
Schedule to Implement		2.5 yr	3 yr	5 yr

*** Recommended Option**

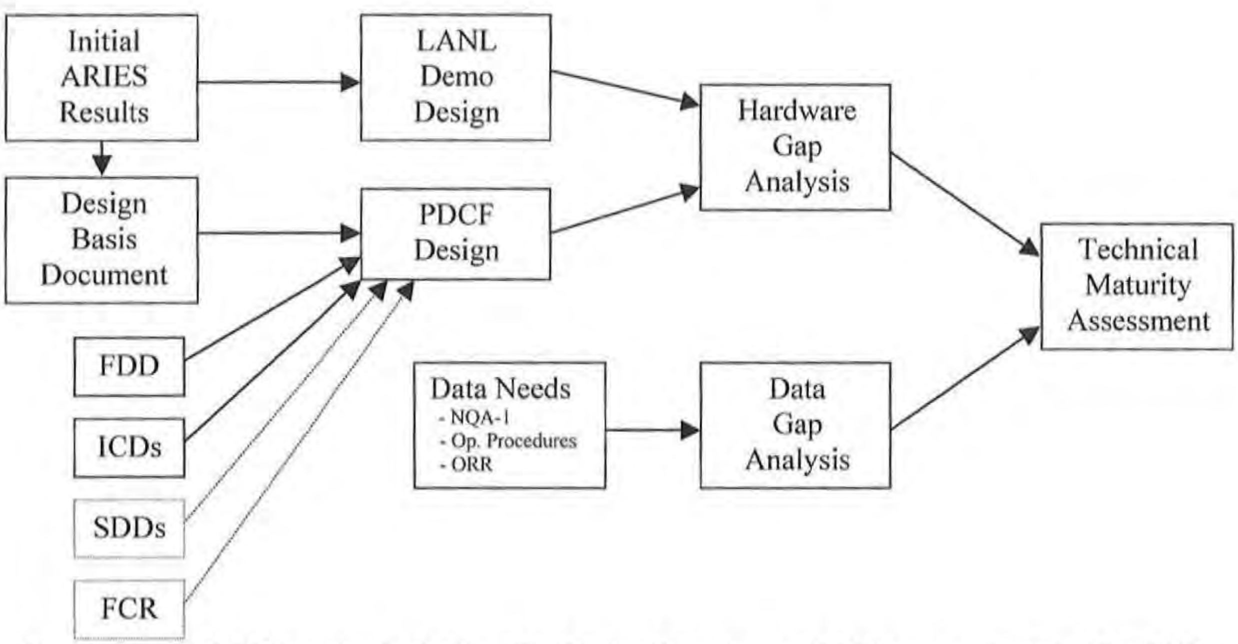
Appendix A - Technical Maturity Evaluations

See also the classified attachment to this document for additional discussions of various modules.

Introduction to the Technical Maturity Process

Development and testing recommendations for the Government Furnished Design (GFD) were developed for the Pit Disassembly and Conversion Facility (PDCF) for FY 04 and beyond planning to support successful startup of PDCF. These recommendations were developed using a systematic, structured technical maturity assessment to evaluate the results and data developed from the Advanced Recovery and Integrated Extraction System (ARIES) demonstrations and available technical data against the Pit Disassembly and Conversion Facility (PDCF) design requirements and process systems. It is anticipated that the evaluation will be updated annually until PDCF startup. Figure 1 (below) illustrates the information that was used the technical maturity evaluation. A dotted line indicates that a document was a draft document at the time of the evaluation.

Figure 1. Technical Maturity Evaluation Inputs



Each top-level GFD function in the Facility Design Description (FDD) was evaluated. The FDD functions evaluated were:

- F-2.3 Disassemble Pits and Material PreparationF-2.4 Chemically Separate Plutonium
- F-2.5 Oxidize Plutonium Metal F-2.7 Process Uranium Parts
- F-2 .8 Package Plutonium Oxide F-2.9 Sanitize Non-SNM
- F-2.13 Perform NDA to Support Facility

Each FDD function was hierarchically decomposed into subfunctions defined in the SDD, which are mapped to GFD components that perform each subfunctions. In turn, the elements that make up each component are defined. The decomposition steps are shown in the left-hand side of Figure 2. Continuing with the process flow shown in Figure 2 at the bottom right-hand side, the elements in the PDCF GFD design are evaluated for technical maturity to support PDCF startup with respect to a structured set of evaluation criteria. There are four categories evaluated for technical maturity, each with its own structured assessment criteria. The categories are: Requirements Maturity, Process Maturity, Operational Readiness, and Equipment Maturity. At the element level, only Equipment Maturity is applicable. All four criteria are applicable to the component, subfunction, and function levels. Issues that cause technical maturity to be inadequate are captured as part of the evaluation. The impact of failure for each element also was assessed using a structured set of criteria. From the combination of technical maturity and the impact of failure, the overall D&T Need Level for each element was determined.

The information at the element level was rolled up to the component level as depicted in the right-hand side of Figure 2 to provide a summary evaluation and to develop D&T Need Levels for each Component. The roll-up process was repeated at the subfunction, and function levels as shown in Figure 2.

Also, the quality of data provided by design analysis and demonstrations to support PDCF requirements validation and verification was assessed to determine the additional data needs that must be met prior to PDCF startup.

The total collection of D&T Need Levels, issues, and data needs were integrated for each major function to provide D&T options that were appropriate to D&T Need Level. These options were developed into a set of D&T recommendations with ROM cost information and associated implementation schedules.

The Technical Maturity Evaluation contains 5 tables for each of the functions evaluated using this process as shown in Table 1. In addition to the technical maturity and data needs evaluations, the tables contain references to source material and additional explanations that support the evaluation conclusions.

Figure 2. Technical Maturity Evaluation Process

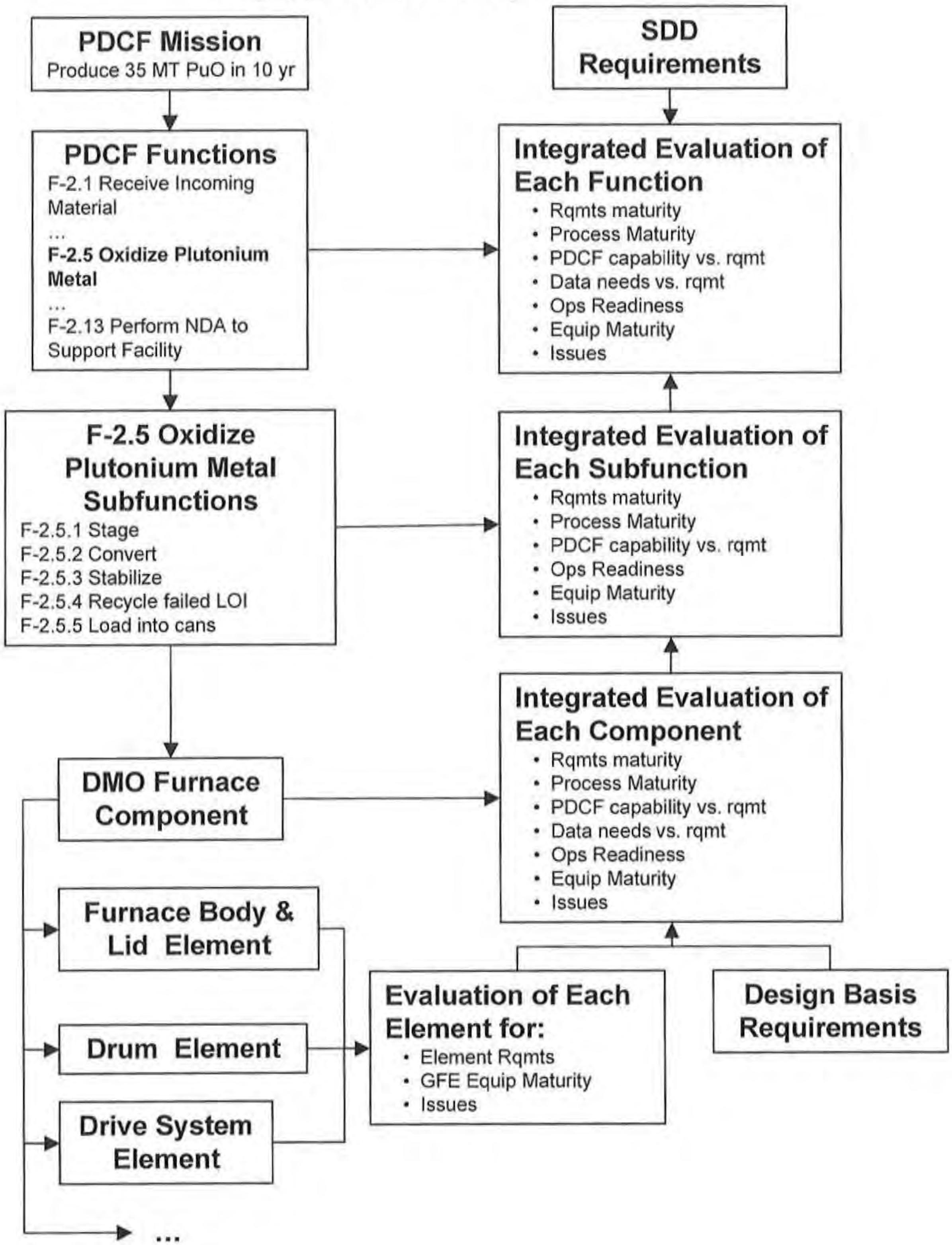


Table 1 - Summary of Technical Maturity Data Provided for Each Function

Table No.	Description
1	Summary Evaluation of Function and Subfunction as defined in the SDD
2	Evaluation of the Functional Requirement as defined in the SDD for the Function
3	Mapping of the Functions and Subfunctions to PDCF Components
4	Component and Element Evaluation Summaries
5	Component Requirements as found in the PDCF GFD Design Basis Document, LA-CP-0498

The above table lists the 5 tables that compose the TME of each module. Table 1 in each TME is a summary table that rolls up the element and component evaluations and compares their maturity against the SDD. Table 2 includes SDD requirements, an evaluation of the requirement maturity and a discussion of the ability of the GFD to meet the SDD requirement. Table 3 includes the high-level SDD requirements, the components in the GFD that are used to meet the requirement and the equipment elements that form each component (i.e., subcomponents). Table 4 is an evaluation of both the element equipment maturities and the component maturity with respect to equipment maturity, process maturity, safety / operations maturity, and equipment maturity. Table 5 includes design basis requirements, an evaluation of the requirements maturity and a discussion of the ability of the GFD to meet the design basis requirement.

The technical maturity scales in Table 2 are applied at different levels within the evaluation. The Hardware Equipment Maturity (EQ) is applied directly only at the element evaluation level. At other levels, summary statements are made about the combined EQ of lower levels, but no direct evaluation is made. Requirements Maturity (RM), Process Maturity (PM), and Operational Readiness (OPS) are directly evaluated at the component, subfunction, and function levels. Hardware Equipment Maturity (EQ) and Process Maturity (PM) are used in determining the D&T Need Level as described below for the application of Table 4.

Table 2 - Technical Maturity Evaluation Scales

LEVEL	REQUIREMENTS MATURITY (RM)	PROCESS MATURITY (PM)	HARDWARE EQUIPMENT MATURITY (EQ)	OPERATIONAL READINESS (OPS)
10	Mission objectives not quantified or baselined *(volatility in mission)*	No currently identified solutions meet requirements	Equipment requirements not yet defined	Operating parameters, safety limits not defined
9		Design concept / technology application formulated	New design. Conceptual design completed.	
8	System concept formulated, but flow sheet description (process inputs, outputs, volumes, and rates is incomplete and/or driving component performance parameters (e.g., storage duration, LOI) are not identified (*volatility in system concept)*	Cold feasibility demonstrated	Experimental system. Cold demonstrated.	Process logic defined and documented for normal operations
7				
6	Flow sheet description complete and applicability of this component understood. Performance parameters are identified, but most parameter values are not quantified (*volatility in key requirements*)	Hot feasibility demonstrated	Experimental system. Hot demonstrated.	Process logic defined and documented for normal and off-normal operations
5		End-to-end design (flow sheet) complete	Commercially equipment available. Requires modification.	

LEVEL	REQUIREMENTS MATURITY (RM)	PROCESS MATURITY (PM)	HARDWARE EQUIPMENT MATURITY (EQ)	OPERATIONAL READINESS (OPS)
4	Flow sheet description and impact on this component understood. Most driving performance parameter values for component have "first pass" values or the supporting analysis is incomplete (*volatility in minor requirements)*	Cold prototype demonstrated	Integrated end-to-end equipment designs completed.	Draft procedures and safety documents complete
3	All parameter values which drive the component selection have been resolved and supporting analysis is complete (*little to no change in requirements expected)*		Cold prototype demonstrated.	
2	Detailed design parameters and operational requirements are established. As necessary, requirement and parameter values have been validated by models of appropriate fidelity. Specification is under formal configuration control (*changes in requirements cause contract changes)*	Hot prototype demonstrated	Commercially available equipment.	Procedures and safety documents approved
1	Verification test procedures written to demonstrate that component satisfies requirements *(component test plan complete)*		Hot prototype demonstrated.	
0	Design verification procedures complete and results are acceptable (*requirements are verified)*	Process integrated into operations	Equipment in use processing the given material.	Procedures in use in facility operating at capacity and within safety envelope

The impact level in Table 3 is assessed at each level of evaluation (element, component, subfunction, and function). The impacts are those that would occur if the LANL D&T to date were concluded, and the item (element, component, subfunction, or function) has no further D&T effort applied to it until it is integrated into PDCF. The impact level is used in determining the D&T Need Level as described below for the application of Table 3.

Table 3 - Impact Evaluation Scales

LEVEL	Impact
High	The failure of the item or system to perform as required is a "show stopper" for the overall system. No alternative designs have been identified. A thorough investigation of alternative concepts or technologies would be required to meet operational requirements. Cost will significantly exceed budget with consequences to interfacing efforts.
Moderate	The failure of the item or system will degrade the overall system performance below system specifications/requirements. Design alternatives have only been demonstrated in a laboratory environment. A significant amount of testing and investment is required before the operational capability can be achieved. Cost will exceed budget and development schedule slips will affect major milestones such as hot startup at PDCF.
Low	The failure of the item or system may degrade the overall system performance. Alternative solutions are available that are readily implemented by the operator. Minor investments and/or schedule slips are required to meet operational requirements.

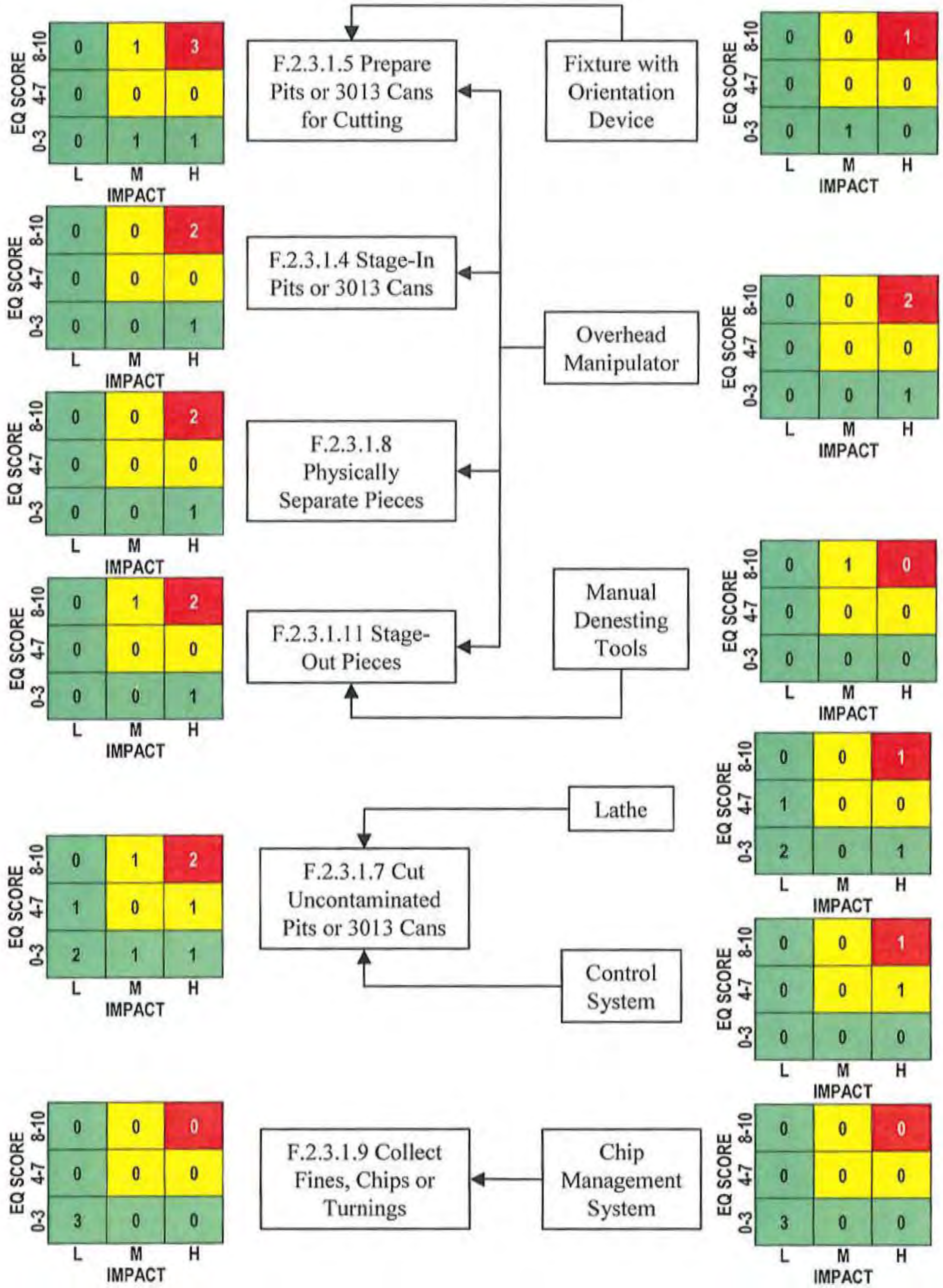
The D&T Need Level in Table 4 is assessed at each level of evaluation (element, component, subfunction, and function). For all assessment levels, the column (Low, Moderate, or High) in Table 4 is determined from application of Table 3 as described above. At the element level, the row is selected using the Hardware Equipment Maturity level (EQ) assessed by applying Table 2 at the element level. For all other levels (component, subfunction, and function), the row is selected for each Maturity level evaluated.

Table 4 - D&T Need Level Matrix

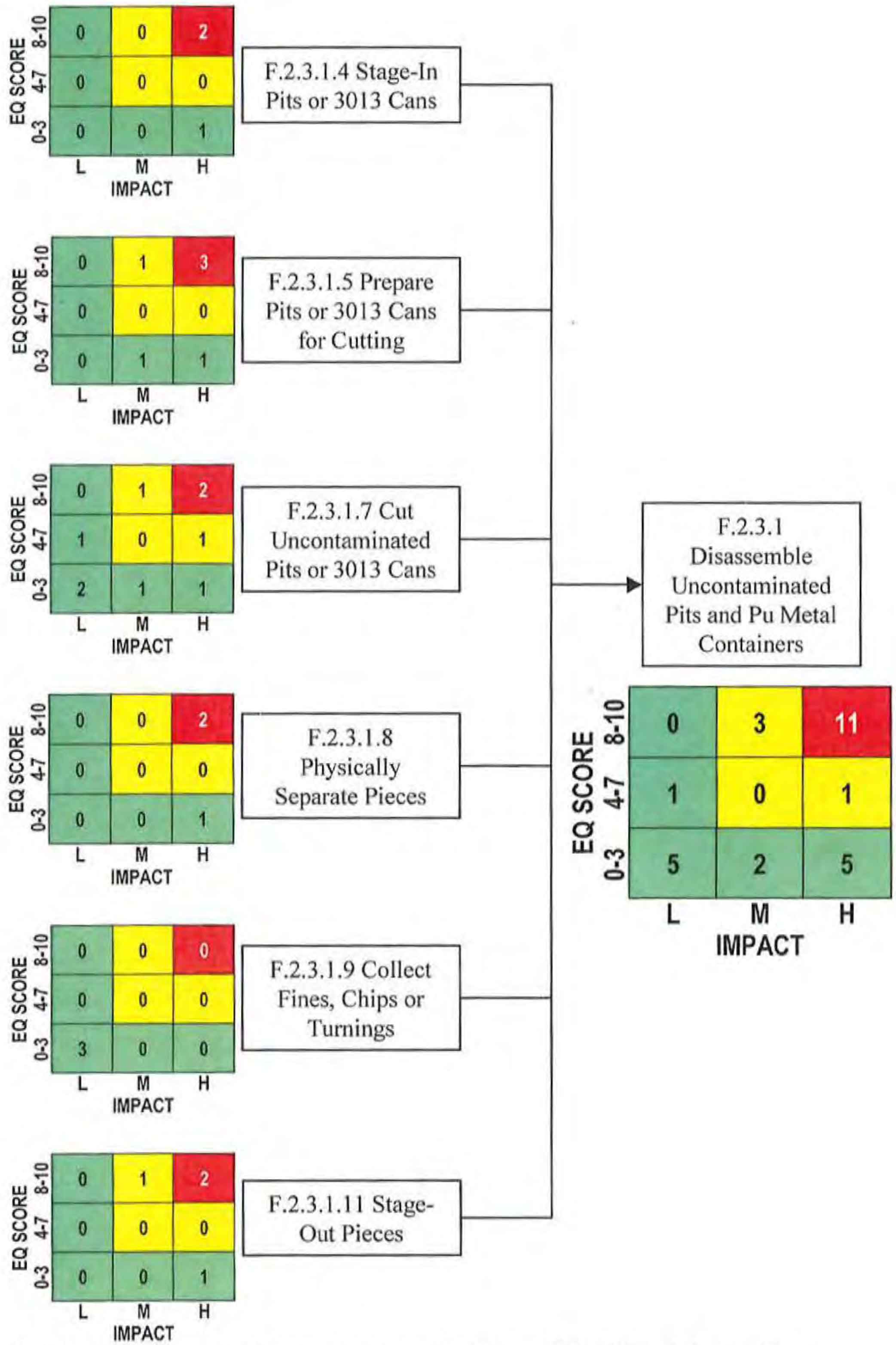
	Impact Level		
Technical Maturity Level	Low	Moderate	High
8 - 10	Low D&T Need Level (L)	Moderate D&T Need Level (M)	High D&T Need Level (H)
4 - 7	Low D&T Need Level (L)	Moderate D&T Need Level (M)	Moderate D&T Need Level (M)
0 - 3	Low D&T Need Level (L)	Low D&T Need Level (L)	Low D&T Need Level (L)

The TMEs are summarized graphically on the following pages. The graphical roll-up starts with a count of the number of elements in each grid of the 3x3 D&T Need Matrix for a given component. For a subfunction, the grid is populated by adding all of the grids together for the contributing elements. For each function, the contributing subfunction grids are added together.

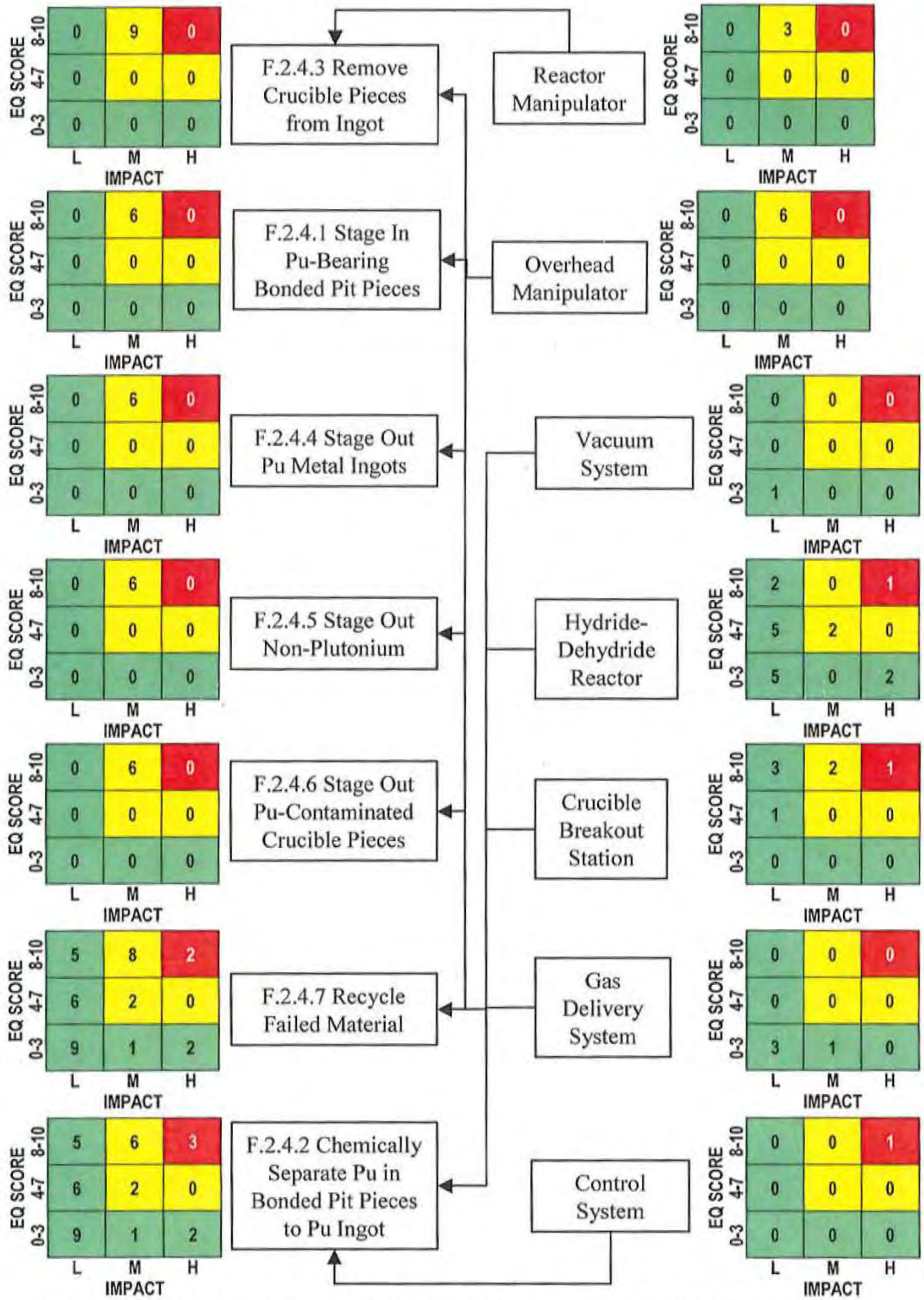
The final summary shows the resulting grids for the 7 unclassified functions that were evaluated. It gives an idea of the relative equipment maturity across functions. If an element such as the overhead manipulator contributes to multiple subfunctions within a function it is counted multiple times. This results in a large number in a grid, which is an indication of a greater overall integration complexity for that function.



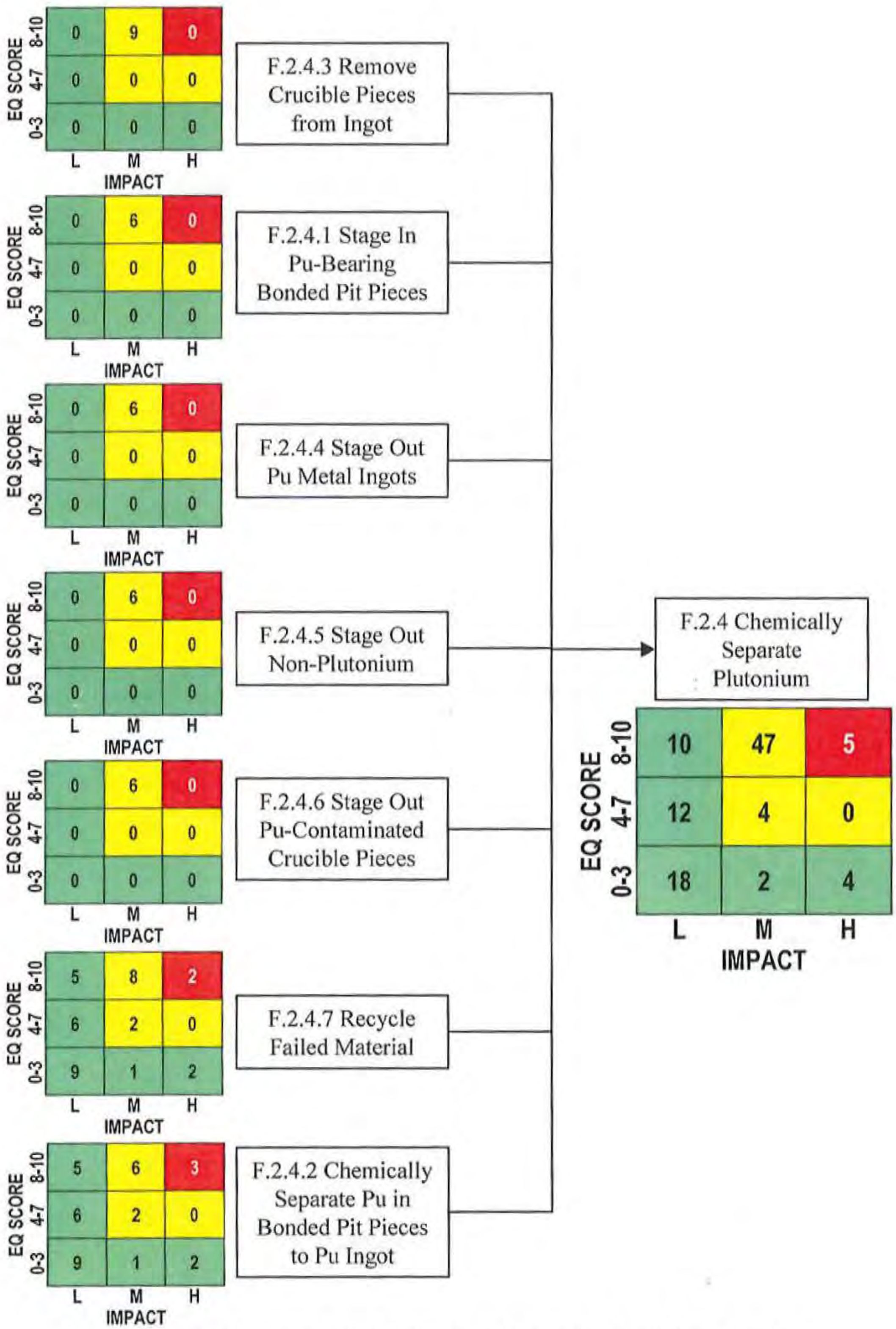
F-2.3.1 Disassemble Uncontaminated Pits and Pu Metal Containers Component and Subfunction Equipment D&T Needs



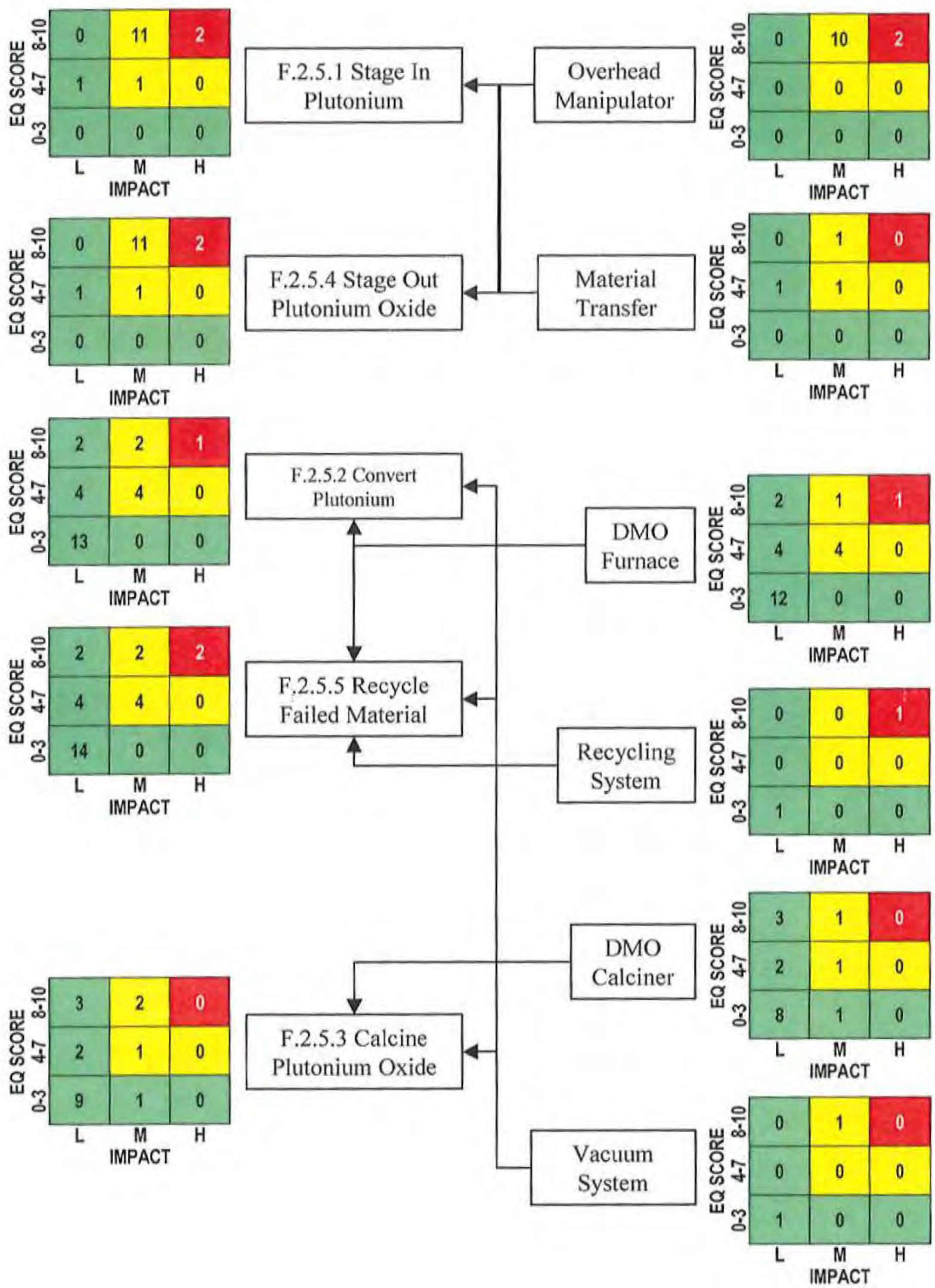
F-2.3.1 Disassemble Uncontaminated Pits and Pu Metal Containers Function and Subfunction Equipment D&T Needs



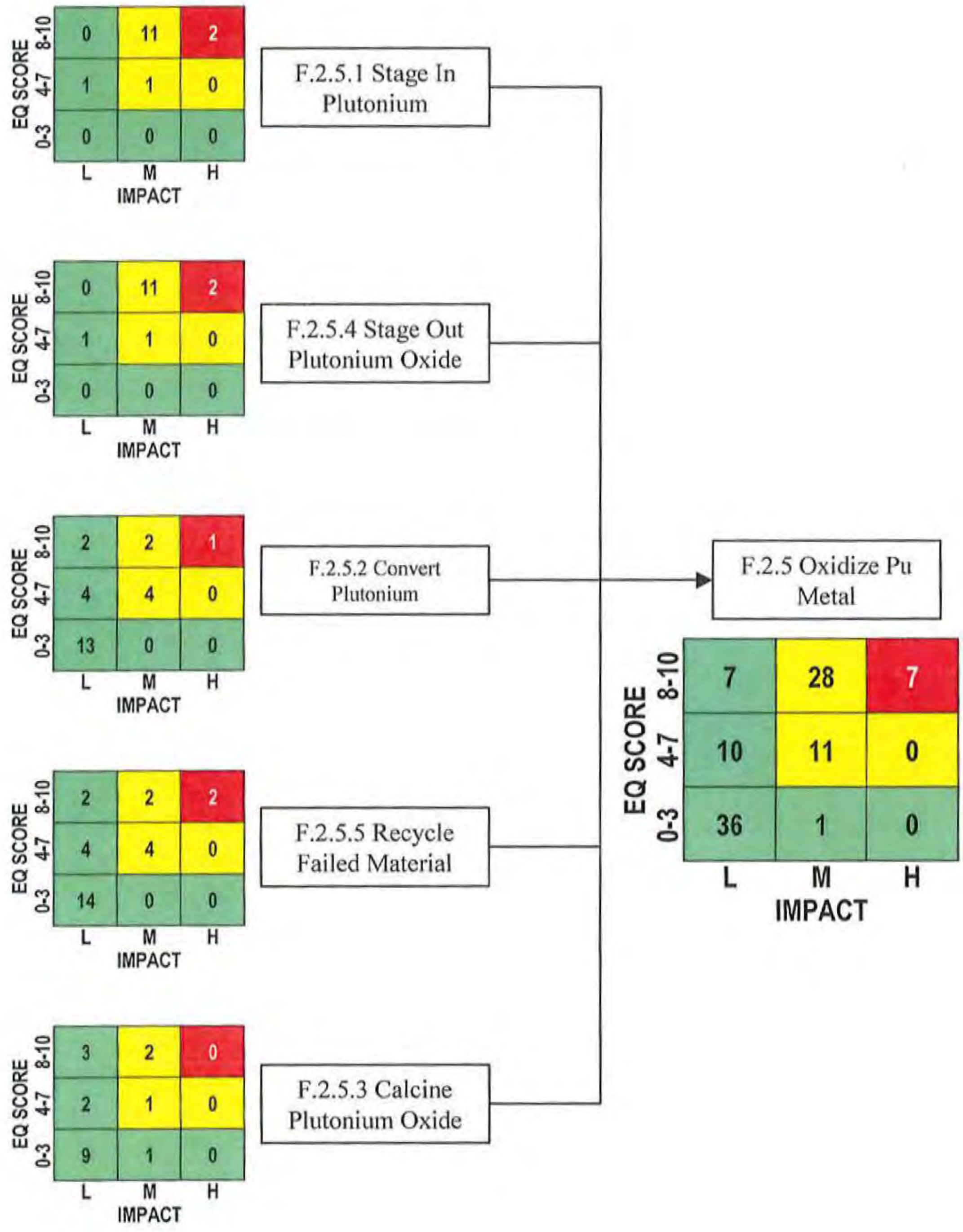
F.2.4 Chemically Separate Plutonium Component and Subfunction Equipment D&T Needs



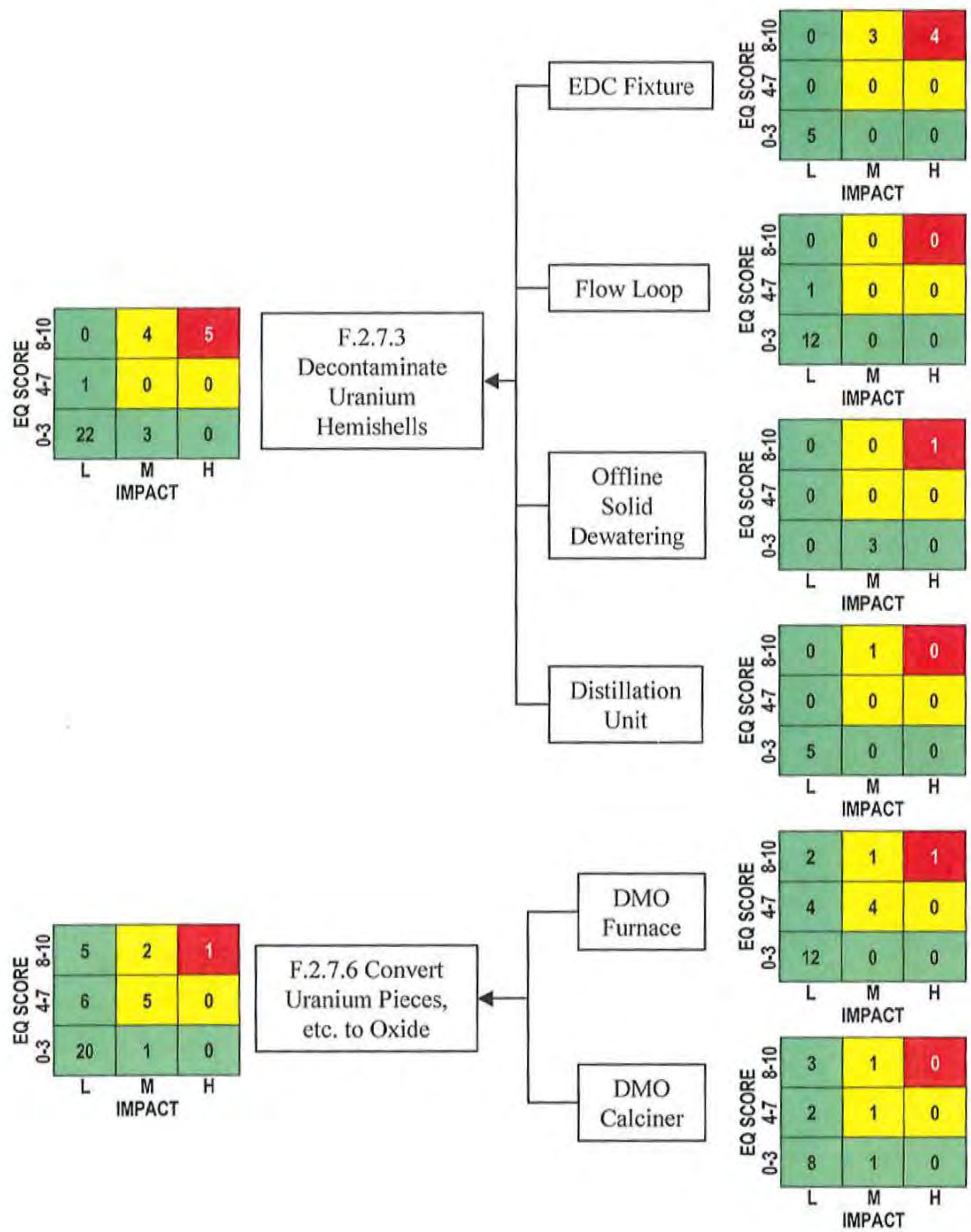
F.2.4 Chemically Separate Plutonium Function and Subfunction Equipment D&T Needs



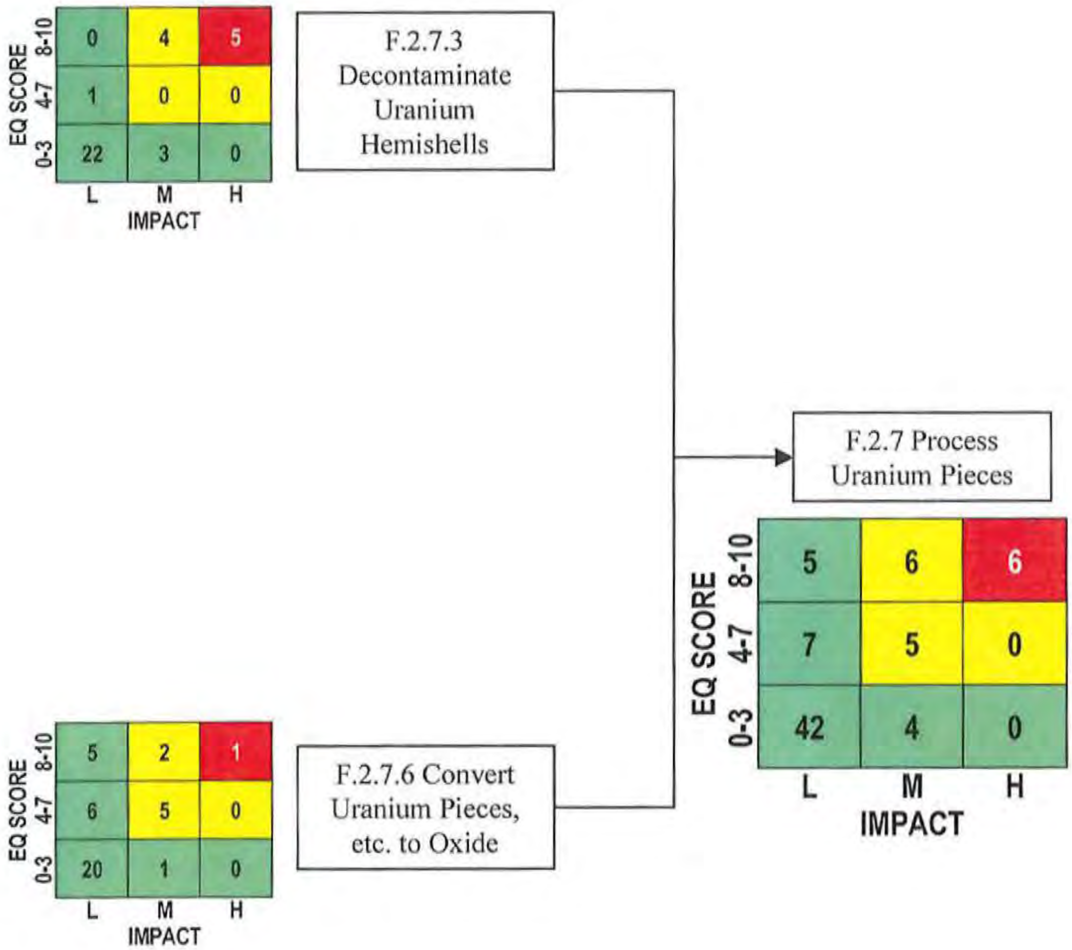
F-2.5 Oxidize Pu Metal Component and Subfunction Equipment D&T Needs



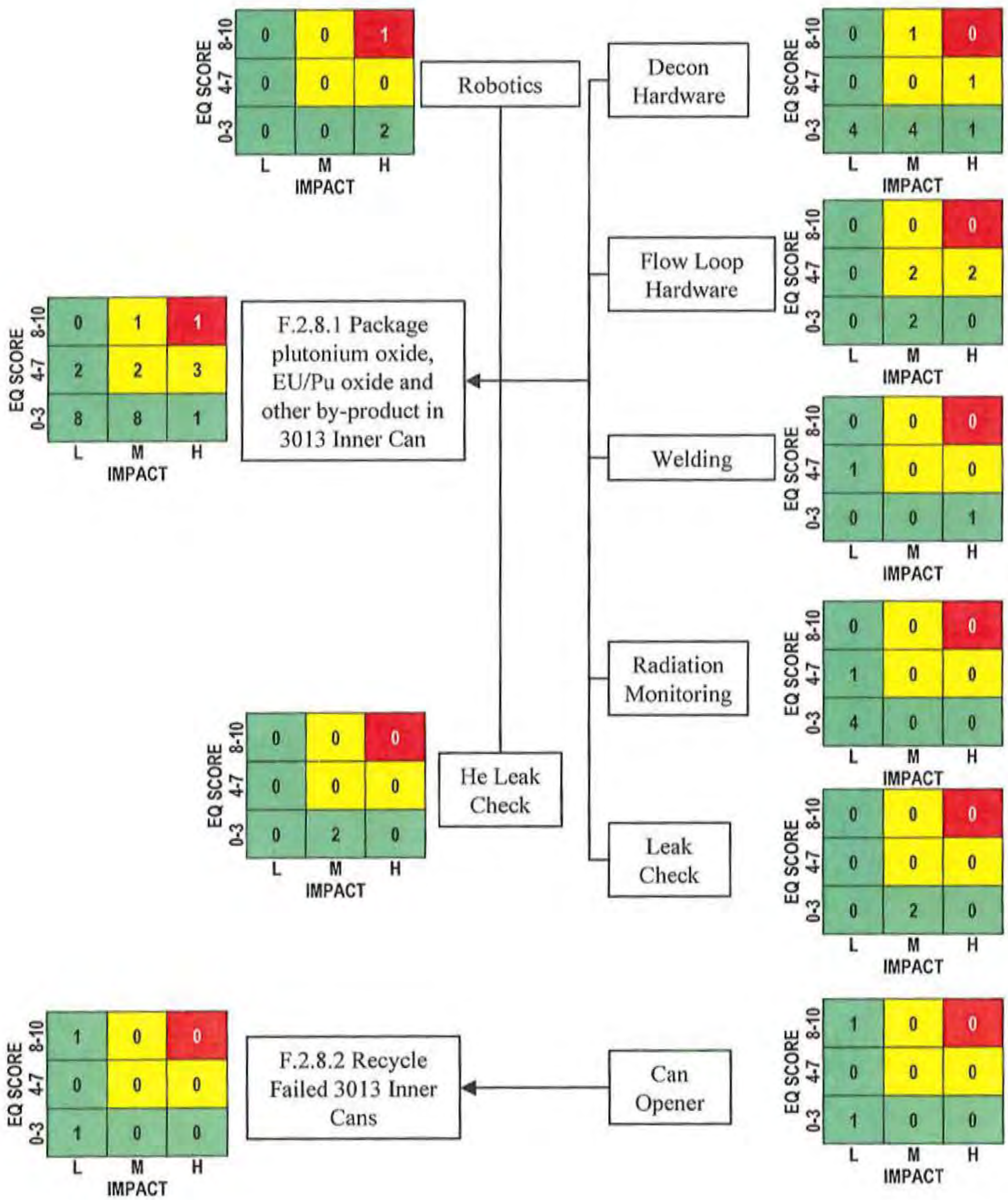
F-2.5 Oxidize Pu Metal Function and Subfunction Equipment D&T Needs



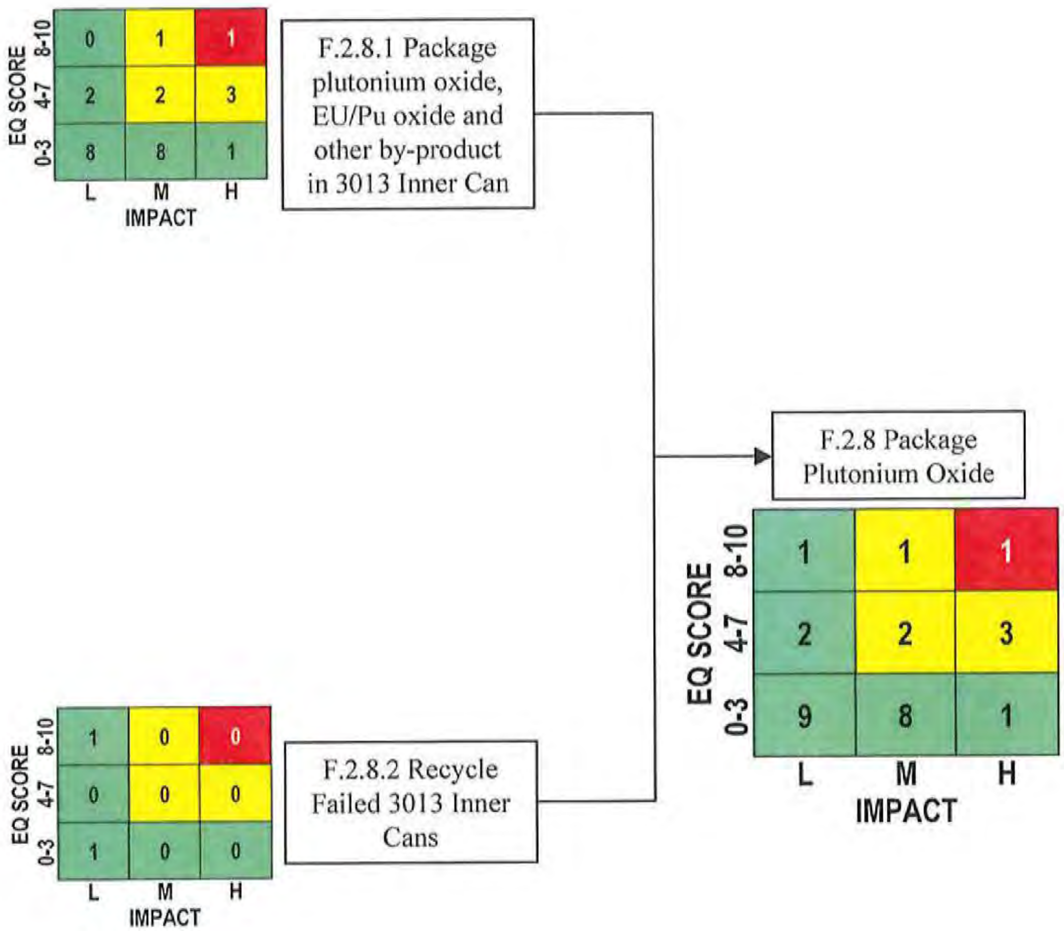
F-2.7 Process Uranium Pieces Component and Subfunction Equipment D&T Needs



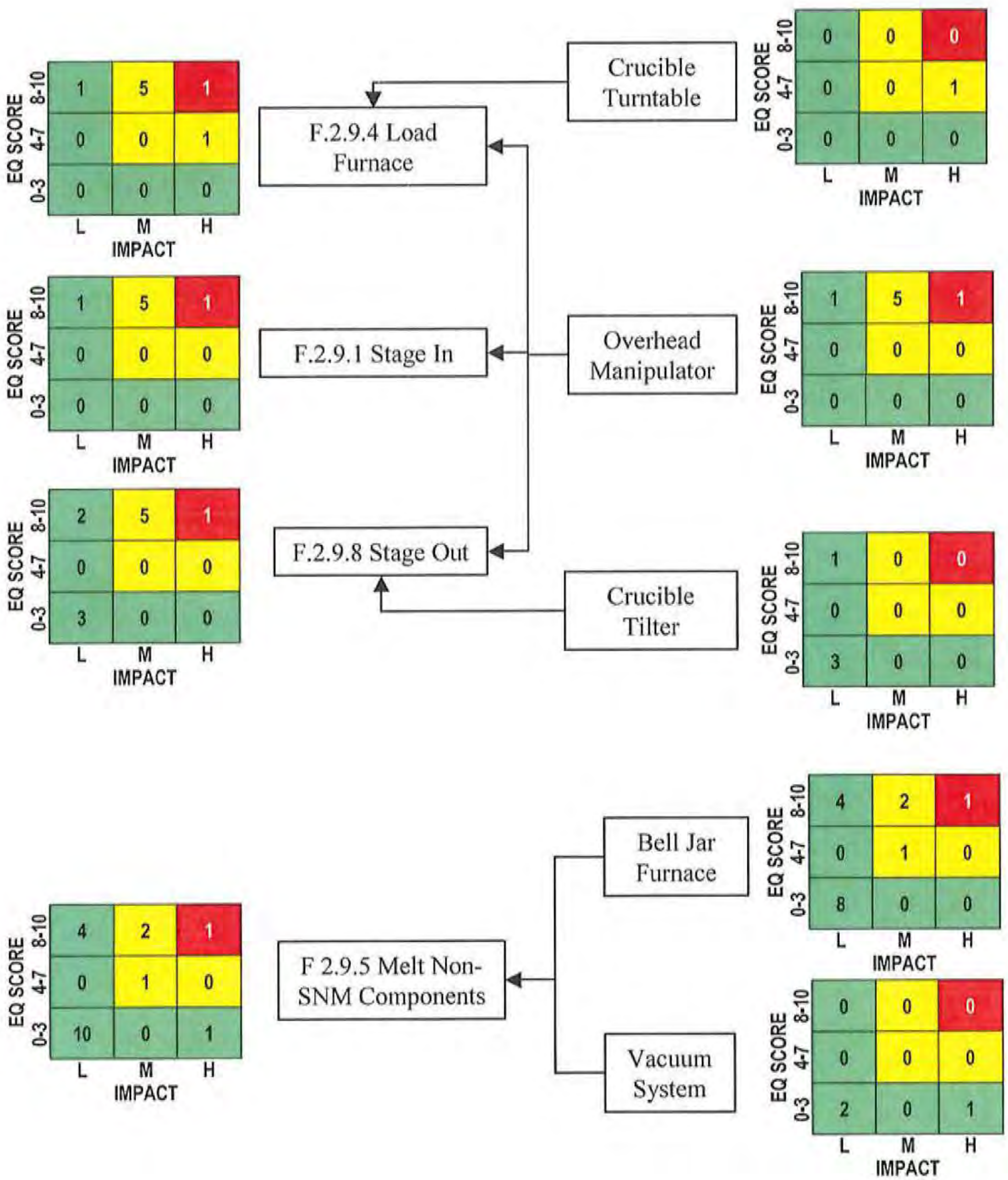
F-2.7 Process Uranium Pieces Function and Subfunction Equipment D&T Needs



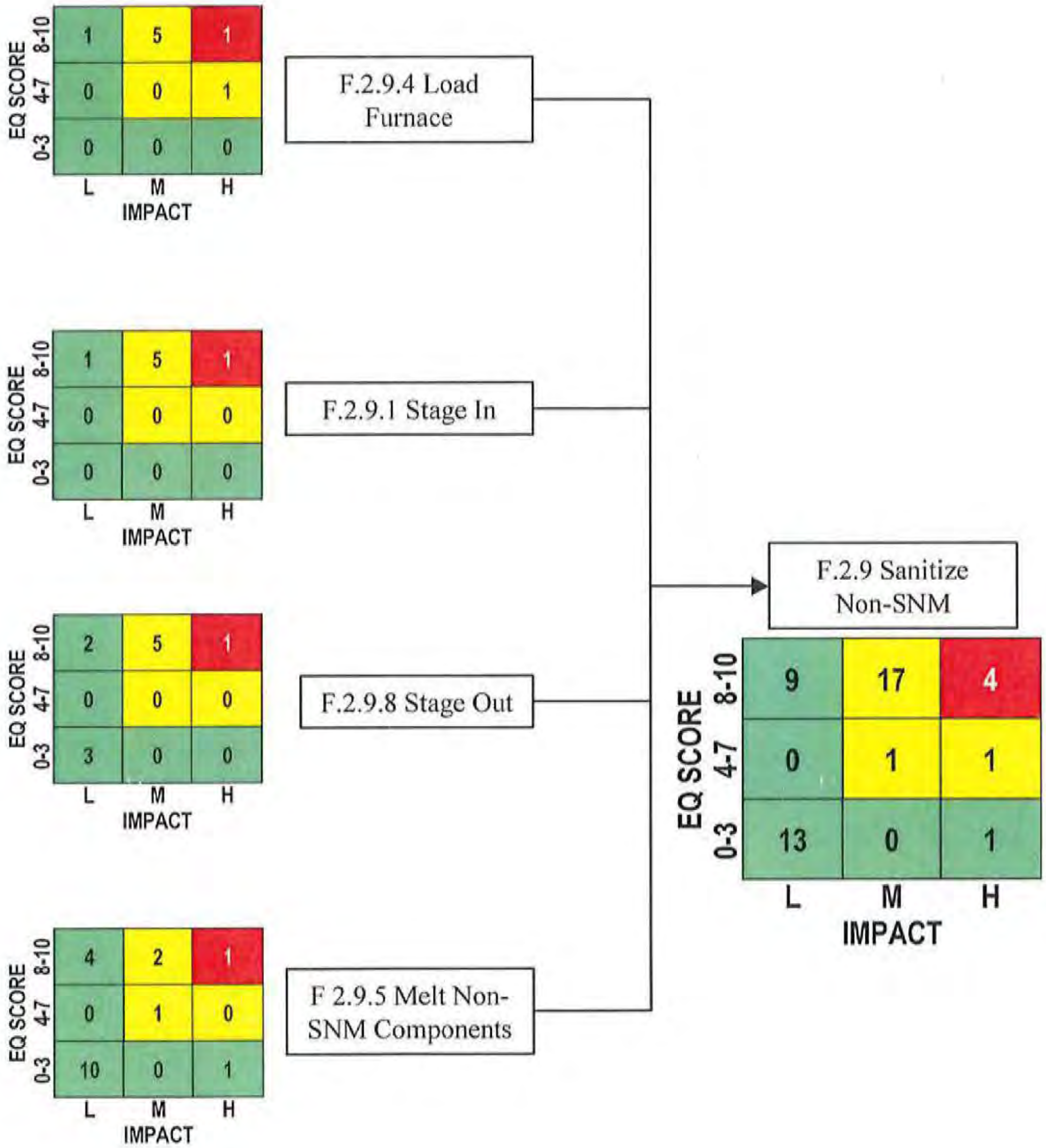
F-2.8 Package Plutonium Oxide Component and Subfunction Equipment D&T Needs



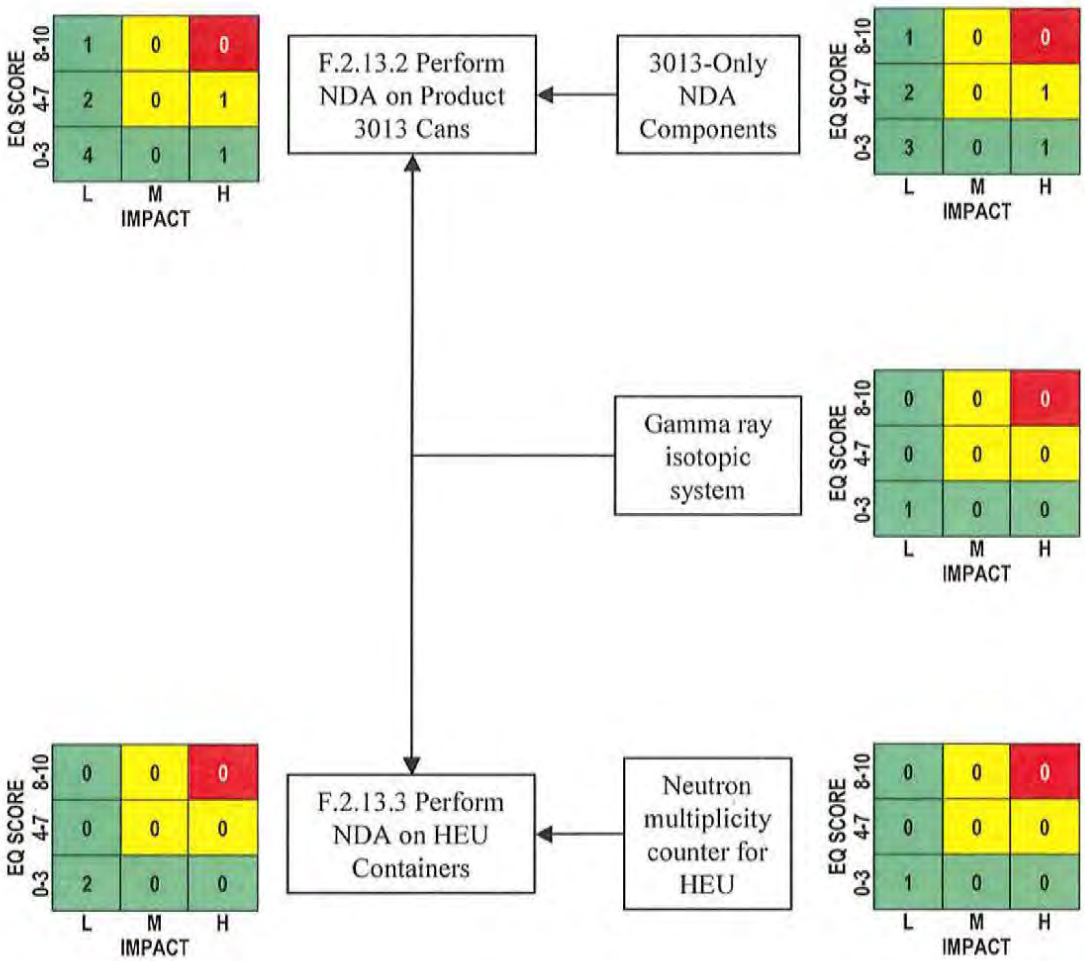
F-2.8 Package Plutonium Oxide Function and Subfunction Equipment D&T Needs



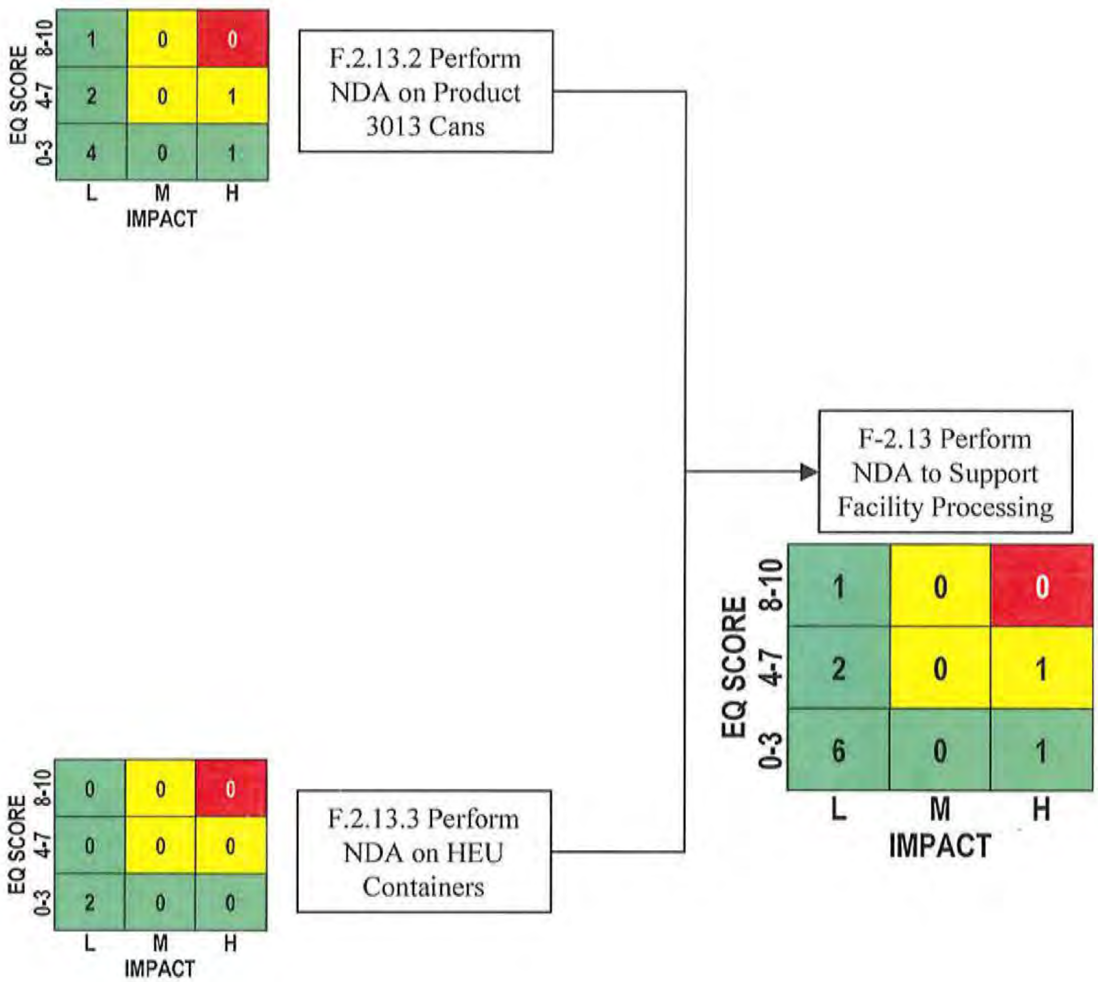
F-2.9 Sanitize Non-SNM Component and Subfunction Equipment D&T Needs



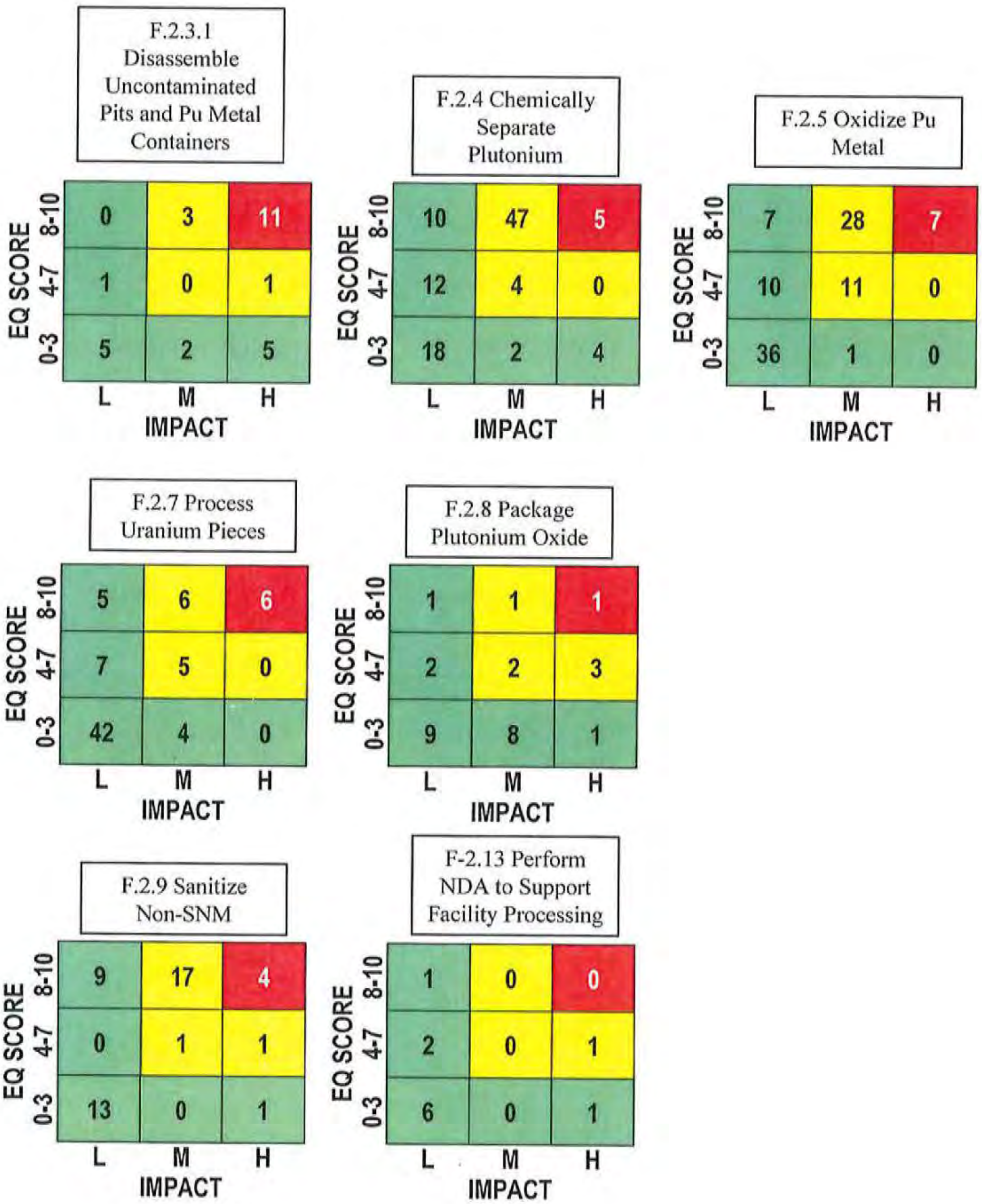
F-2.9 Sanitize Non-SNM Function and Subfunction Equipment D&T Needs



F-2.13 Perform NDA to Support Facility Processing Component and Subfunction Equipment D&T Needs



F-2.13 Perform NDA to Support Facility Processing Function and Subfunction Equipment D&T Needs



PDCF Function Equipment D&T Needs