Development of the Cryogenic Target Information System

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Abstract

Part of the inertial confinement fusion research at the Laboratory for Laser Energetics (LLE) entails the production and implosion of cryogenic targets filled with deuterium or deuterium-tritium (DT). Prior to this project, the databases containing relevant data were dispersed and excessive amounts of time were required to search for simple data. This project involved the creation of a new Web-based comprehensive query that serves as the starting point of an information search. The query allows a user, for the first time, to search for information online based on a variety of target characteristics, such as ice thickness or target outcome. To complement this database, a Layer Analysis Table (an exhaustive target quality database) was also created to focus solely on the layering cycle of cryogenic targets. These new online database features are essential to LLE's future work because researchers are now able to easily connect the characteristics of cryogenic targets to the shot result. This effort has improved data management and will simplify analysis of cryogenic data.

1. Introduction

The LLE Target Fabrication Facility is used to create and assemble an assortment of targets for various experiments. There have been many methods created to prepare, inspect, and mount the targets. A spherical cryogenic target is filled with deuterium or DT at pressures up to 1000 atmospheres and cooled to 18 K, forming a uniform layer of cryogenic fusion fuel (ice) inside an outer plastic shell.[1] Cryogenic targets are denser than gas-filled targets and are able to hold fuel more efficiently. This allows them to yield more energy when they are shot and brought up to a temperature of 100 million degrees Celsius.[2]

When a target is shot, the laser ablates the plastic shell (i.e., the shell is heated and expands outwards). This process creates an opposite reaction, as defined by Newton's Law, which forces the cryogenic fuel layer to implode.[3]

The fate of a cryogenic target can be altered by a minute change in the thickness of the fuel layer or by the way it is mounted. Due to this, it has become necessary to monitor and record initial target characteristics and the shot outcome in order to make future improvements. If there is no such system, or the system to monitor these characteristics and results is too complex, then it becomes increasingly difficult to improve targets.

In this work, the Cryogenic Target Information System (CTIS) was set up in order to gather remote yet essential data from existing systems and to make it available through one database. By integrating information from all aspects of a target's life cycle (see figure 1), a comprehensive information system was created that allows for a user-friendly search feature and a manageable flow of data. The CTIS not only consolidates the existing systems into two major systems, the Target Layer Analysis Table and the All Targets Query, but it also makes necessary data available online.

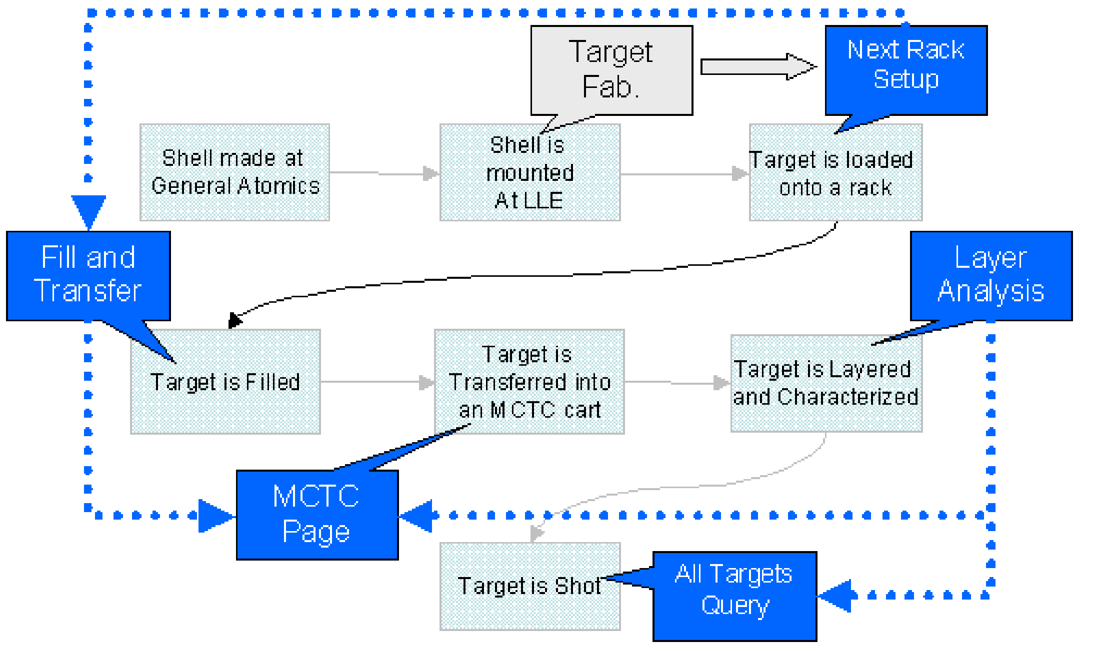


Fig. 1. Target life cycle and corresponding databases after the CTIS. The majority of these databases were consolidated and made available online.

2. Existing databases

Numerous independent databases were in use throughout LLE for each part of the target life cycle. Once a target was received and mounted, the Target Fabrication Database served as a source of information regarding the mount format, shell thickness, and shell material type. As a target was shifted into a rack and filled, the Fill and Transfer Database was used to collect the temperature, moles of gas, ice thickness, and cart number. When the target was layered, there was no single system used to monitor the process. Correct layering of a target is crucial, as a faulty layer often leads to a lost target or an unsuccessful shot. An example of a DT target with a good uniformity is given in figure 2. The shell smoothness and ice thickness must be as close to uniform as possible in order to allow for a high energy yield.

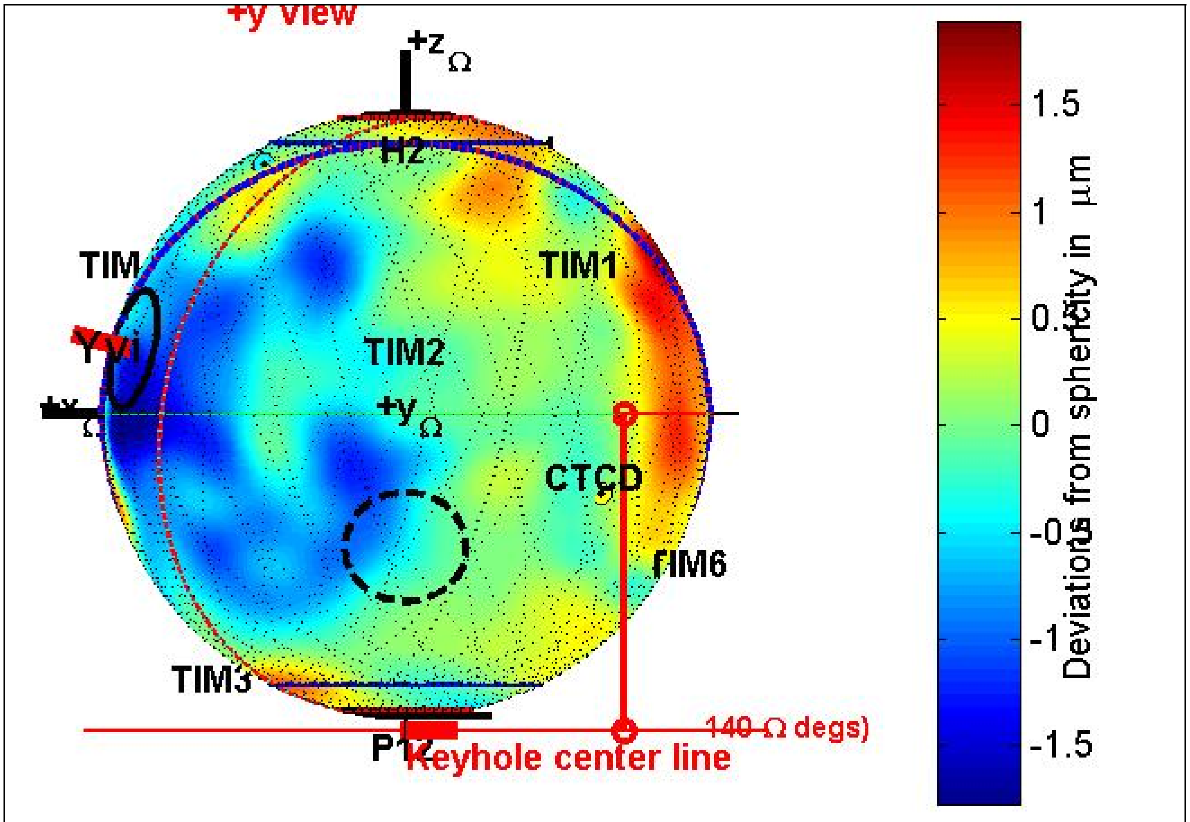


Fig. 2. Three-dimensional picture of a cryogenic DT target indicating the deviations from sphericity of the ice layer thickness. The minute deviations in ice thickness can cause problems when the target is shot by the laser.

Prior to the CTIS, the ice thickness, mount type, layer quality, image analysis, and shell smoothness data was available to very few people. The final stage that a target passed through was the shot process. The data at this stage was collected and maintained individually as a stand-alone file. The shot number, energy yield amount, layer measurements, and shot quality data were stored in this file.

The existing databases were functional and contained a massive amount of data. However, this information was often inaccessible to researchers due to the way in which it was stored. It was exceedingly difficult to navigate through the scattered systems in order to find data that connected initial target characteristics with the shot result.

3. Formation of the Cryogenic Target Information System

To solve this problem, a two-step process had to be followed. Initially, the existing systems were renovated and edited. Crucial information that was scattered throughout these systems was consolidated. A search engine or main page was then added in order to make searching easier. A main page is the primary place for starting a search by means of Target ID, Target Characteristics, Fill Number, or Target Fate. The two systems that have been created are currently being used by LLE scientists and engineers throughout the lab on a daily basis.

3.1 Target Layer Analysis Table

In order to make important layering data available, a new table was developed that allowed users to search for targets based on many characteristics. The Layer Analysis Table (see figure 3) allows targets to be sorted based upon the dates that they were layered and makes it simple to compile statistics. In order to create this table, data had to be translated into an offline Access table based upon a target's ID.

OMEGA_CRYO_TARGET_LAYER : Table

CTL_FILES_USED	CTL_TARGET_ID	CTL_LAYER_DATE	CTL_RMS	CTL_SHELI	CTL_ICE
1x19885(1,2,4,5,7:25);1y19886(1:14,16:21,23:25)	CRYO-2033-418	4/20/2005 9:57:43 AM	3.7234	0.32885	98.6979
1x19974(1:25);1y19975(1:25)	CRYO-2035-388	5/19/2005 8:13:01 AM	1372.802	0.31846	11451.8
1x20460(1:25);1y20461(1:25)	CRYO-2040-532	1/6/2006 9:31:20 AM	7.9461	0.2644	96.882
1x20468(1:25);1y20469(1:25)	CRYO-2040-532	1/9/2006 2:11:57 PM	8.182	0.27354	96.2826
1x20478(1:25);1y20479(1:25)	CRYO-2040-532	1/10/2006 12:07:58 PM	5.8089	0.22418	96.268
1x20503(1:25);1y20504(1:25)	CRYO-2038-536	1/17/2006 6:46:55 AM	7.1301	0.43303	96.0728
1x20540(1:25);1y20539(1:25)	CRYO-2040-495	2/8/2006 2:11:43 PM	3.4938	0.3482	93.4747
1x20551(1:25);1y20552(1:25)	CRYO-2040-495	2/9/2006 1:38:52 PM	4.053	0.3477	93.4794
1x20561(1:25);1y20560(1:25)	CRYO-2040-495	2/10/2006 6:08:14 AM	4.0461	0.35488	93.4383
1x20590(1:25);1y20591(1:25)	CRYO-2081-581	3/2/2006 9:44:49 AM	7.6931	0.26549	97.6428
1x20601(1:25);1y20600(1:25)	CRYO-2080-582	3/3/2006 7:04:48 AM	4.6593	1.4777	95.9618
1x20605(1:20,22:26);1y20604(1:25)	CRYO-2080-582	3/6/2006 5:59:07 AM	4.1652	0.3519	95.7148
1x20613(1:25);1y20614(1:25)	CRYO-2080-582	3/7/2006 7:18:34 AM	4.2931	0.31041	95.1915
1x20618(1:25);1y20619(1:25)	CRYO-2085-600	3/9/2006 6:34:52 AM	3.9534	0.18384	95.035
1x20652(1:25);1y20653(1:25)	CRYO-2085-600	3/10/2006 9:55:32 AM	3.8013	0.41233	94.8712
1x20659(1:25);1y20660(1:25)	CRYO-2085-600	3/13/2006 6:35:05 AM	4.5652	0.19327	94.805
1x20725(1:25);1y20726(1:25)	CRYO-2036-546	5/16/2006 6:18:14 AM	3.0259	0.38908	95.3254
1x20727(1:25);1y20728(1:25)	CRYO-2036-546	5/16/2006 1:13:47 PM	2.571	0.34433	95.3385
1x20733(1:16);1y20734(1:21)	CRYO-2036-546	5/17/2006 11:30:22 AM	3.9387	0.34709	95.1467
1x20737(1:25);1y20738(1:25)	CRYO-2036-546	5/17/2006 5:23:09 PM	2.5272	0.34213	95.6633
1x20742(3:11,13:22);1y20741(1,2,4,5,9:11,13:15,18:25)	CRYO-2036-546	5/18/2006 6:39:41 AM	5.1975	0.36165	94.9047

Fig. 3. The Layer Analysis Table. This is automatically updated with each layer analysis

Every time a layer for a target is analyzed, this table is automatically updated. This table contains information such as ice smoothness values, ice thickness values, and numerous other data. In order to make this table effective, query features were created so that a user can filter necessary data. The completed table is available online for easy access (see figure 4).

The impact of this table has been substantial. Now, the whole organization has access to the same data in real time. Decisions based on layer quality are now more objective because they are data based. Reports can be quickly assembled and the layer process development has been made more efficient.

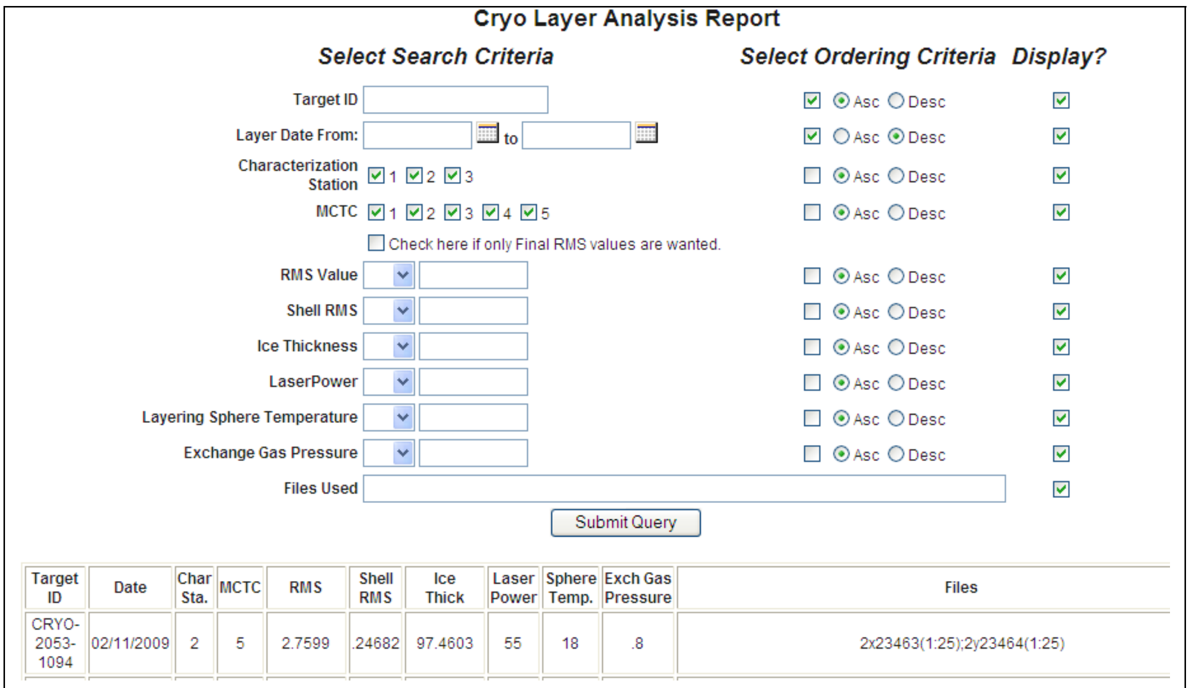
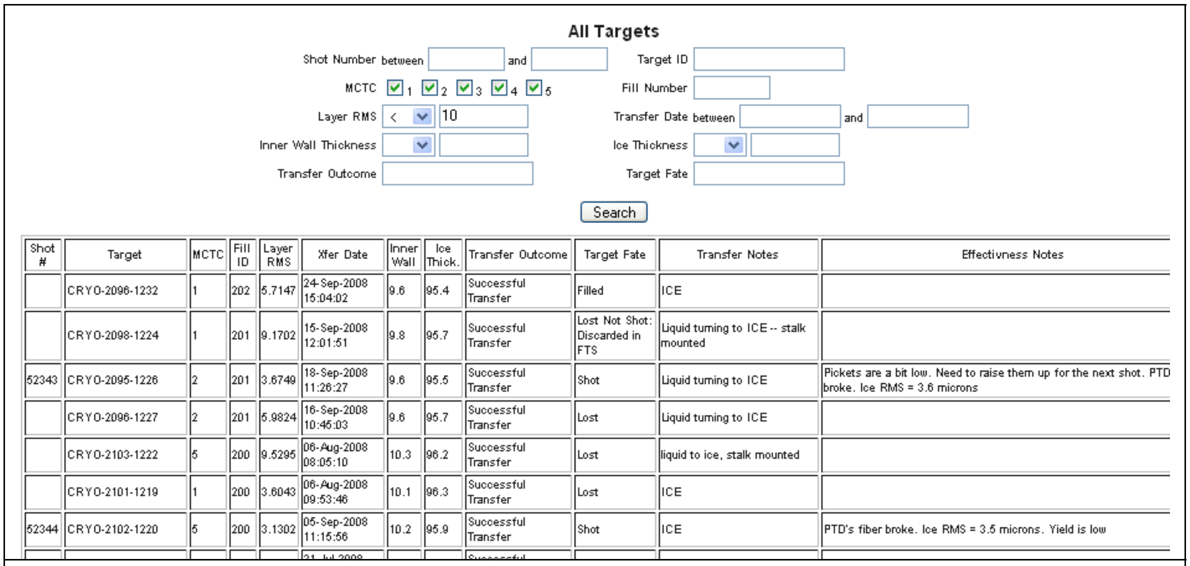


Fig. 4. Graphical user interface for the new Target Layer Analysis Table. A target's layer history is displayed based on user input

3.2 All Targets Query

In order to connect all of the existing databases and to display shot outcomes, the All Targets Query was created. This query also serves as the primary place for starting a search. The All Targets Query allows a user to search for multiple targets based on fields such as the target transfer result, shot number, and target fate. It then gathers information from the existing databases and automatically generates a report showing all of the targets that meet the search criteria (see figure 5). The query was created so that any user can find specific information about any target. An essential component of the query was the ability to allow a user to bring up a list of targets that meet specified input characteristics.

The All Targets Query has reduced the time required to produce target production statistics by a substantial amount. It has led to standardizing terminology for target outcomes and has made data searches more effective.



Shot #	Target	MCTC	Fill ID	Layer RMS	Xfer Date	Inner Wall	Ice Thick.	Transfer Outcome	Target Fate	Transfer Notes	Effectivness Notes
	CRYO-2096-1232	1	202	5.7147	24-Sep-2008 15:04:02	9.6	95.4	Successful Transfer	Filled	ICE	
	CRYO-2098-1224	1	201	9.1702	15-Sep-2008 12:01:51	9.8	95.7	Successful Transfer	Lost Not Shot: Discarded in FTS	Liquid turning to ICE -- stalk mounted	
52343	CRYO-2095-1226	2	201	3.6749	18-Sep-2008 11:26:27	9.6	95.5	Successful Transfer	Shot	Liquid turning to ICE	Pickets are a bit low. Need to raise them up for the next shot. PTD broke. Ice RMS = 3.6 microns
	CRYO-2096-1227	2	201	5.9824	16-Sep-2008 10:45:03	9.6	95.7	Successful Transfer	Lost	Liquid turning to ICE	
	CRYO-2103-1222	5	200	9.5295	06-Aug-2008 08:05:10	10.3	96.2	Successful Transfer	Lost	liquid to ice, stalk mounted	
	CRYO-2101-1219	1	200	3.6043	06-Aug-2008 09:53:46	10.1	96.3	Successful Transfer	Lost	ICE	
52344	CRYO-2102-1220	5	200	3.1302	05-Sep-2008 11:15:56	10.2	95.9	Successful Transfer	Shot	ICE	PTD's fiber broke. Ice RMS = 3.5 microns. Yield is low

Fig. 5. All Targets Query Page. A table of all targets that meet the criteria selected by the user is automatically generated

4. Further Improvements

A dynamic system such as the CTIS will always require changes in order to meet current demands. One such addition that could not be developed to completion was a graphing utility that functioned alongside the Layer Analysis Table. The purpose of this was to enhance the ability of the table to prepare statistics by graphing data onto a plot as well as displaying it in the current online table. Other changes include modifying the data fields that are searchable. One such modification could allow for a target search based on the type of fuel a target was filled with, such as deuterium or DT. The ultimate goal of this system is to consolidate all of the existing data systems further into a universal query.

5. Acknowledgements

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6. References

1. Duffy, Tim, and R. Janezic, Cryogenic Target Handling System Operations Manual Rev. A, 1-2, 2004

2. Emmett, J., J. Nuckolls, and L. Wood, *Fusion Power by Laser Implosion,* Scientific American, 24-37, June 1974.

3. Gresh, Lois. *Inertial Confinement Fusion: An Introduction*, University of Rochester Laboratory for Laser Energetics, 23, 2009.