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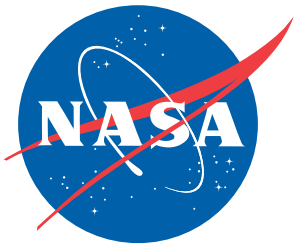

Flight Data Entry, Descent, and Landing (EDL) Repository

Elmain M. Martinez and Daniel Winterhalter
Jet Propulsion Laboratory, Pasadena, California

May 2012

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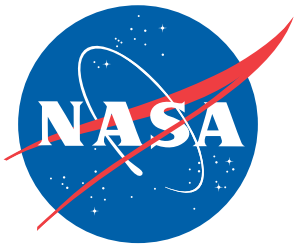

Flight Data Entry, Descent, and Landing (EDL) Repository

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National Aeronautics and
Space Administration

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May 2012

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Entry, Descent, and Landing (EDL) Repository

March 29, 2012

Report Approval and Revision History

NOTE: This document was approved at the March 29, 2012, NRB. This document was submitted to the NESC Director on April 4, 2012, for configuration control.

Approved:	*Original Signature on File*	4/10/12
	NESC Director	Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Dr. Daniel Winterhalter, Lead, JPL	3/29/2012

Table of Contents

Technical Assessment Report

1.0 Notification and Authorization 6
2.0 Signature Page 7
3.0 Team List 8
4.0 Executive Summary 9
4.1 Supporting Documentation 10
5.0 Assessment Plan 11
6.0 Problem Description and Background 13
6.1 Collection Priorities 14
7.0 Requirements Definition 17
8.0 System Design and Development Activities 17
8.1 Standards 17
8.2 Hardware Architecture 17
8.3 Software Architecture 19
8.4 EDL-R Customization 20
8.4.1 Subject Recommender Subsystem 21
8.5 Testing and Deployment 23
8.5.1 Testing 23
8.5.2 Deployment 25
9.0 Curation of the EDL-R 25
9.1 Policies and Procedures 26
10.0 Application Features 26
10.1 Main Page Overview 26
10.2 Search and Browse Methods 27
10.3 Submission Process 28
10.4 Electronic Notification 29
10.5 Most Wanted List 30
11.0 Administrative Features 30
11.1 Administrative Roles 30
11.2 User Accounts 30
11.3 Review Process 31
11.4 Statistics Generation 31
12.0 System Security 32
12.1 NASA Requirements 32
12.2 System Controls and Audits 32
12.3 EDL-R Access Controls 32
12.3.1 Authentication 33
12.3.2 Authorization 33
13.0 Operational Status 34
13.1 Maintenance and Preservation 34
13.2 Usage Statistics 35

13.3 Subject Coverage 38
13.4 Current Archive Content and Status 40
13.5 Summary of Material Pending Review 44
13.6 Summary of Material Pending Submission 45
13.7 Summary of Material to be Collected 47
13.8 Summary of Material to be Researched 49
14.0 Interaction with the EDL Community 50
14.1 Presentations 50
14.2 Links to the EDL-R 51
14.3 EDL Community Contact Information 51
15.0 Transfer of System to Sponsor 51
15.1 Transfer Agreement 52
15.2 Hand-off Plan 52
15.3 Looking Forward: Short- and Long-term Goals 52
16.0 Findings, Observations, and NESC Recommendations 55
16.1 Findings 55
16.2 Observations 55
16.3 NESC Recommendation 55
17.0 Lessons Learned 56
18.0 Definition of Terms 56
19.0 Acronyms List 57
20.0 Appendices 59

List of Figures

Figure 5.0-1. Task Phases 12
Figure 8.2-1. Hardware Layout of the EDL-R 18
Figure 8.3-1. EDL-R LAMP Stack 19
Figure 8.3-2. High Level EPrints Processing 20
Figure 8.4-1. Subject Recommender Algorithm 22
Figure 8.4-2. The EDL-R Integrated with the Subject Recommender Subsystem Integrated 23
Figure 10.1-1. EDL-R Main Page 27
Figure 13.3-1. Example of EDL-R Subject Page 39

List of Tables

Table 6.1-1. Candidate Missions 14
Table 6.1-2. Examples of EDL Subjects 15
Table 6.1-3. Examples of Contemporary EDL Missions 16
Table 8.5-1. EDL-R Release History 24
Table 10.3-1. Material Sensitivity Levels 29
Table 11.1-1. Administrative Role Definition 30
Table 11.2-1. User Classifications 31
Table 13.2-1. Number of Unique Visitors 35
Table 13.2-2. Valid and Invalid Access Attempts 35
Table 13.2-3. Top Ten Downloaded Documents 37

Table 13.2-4. Popular Operating System used to Access the EDL-R 38
Table 13.2-5. Popular Browsers used to Access the EDL-R 38
Table 13.4-1. Total Number of EPrints Records 40
Table 13.4-2. EDL-R Archive by Type of Material 41
Table 13.4-3. EDL-R Archive by Mission 41
Table 13.5-1. Material for Review by Type 44
Table 13.5-2. Material in Review per Mission 44
Table 13.6-1. Material Pending Submission 45
Table 13.7-1. Points of Contact for Material to be Collected 47
Table 13.8-1. Points of Contact for Material Research 49

Technical Assessment Report

1.0 Notification and Authorization

Dr. Daniel Winterhalter, the NASA Engineering and Safety Center (NESC) Chief Scientist at the Jet Propulsion Laboratory (JPL), requested the NESC sponsor a 3-year effort to collect entry, descent, and landing (EDL) material and to establish a NASA-wide archive to host the material electronically for secure access. The principal focus of this task was to identify EDL repository (EDL-R) material that was at risk of being lost due to damage, decay, and undocumented storage. To provide NASA-wide access to the EDL-R, a web-based digital archive was created.

Dr. Winterhalter was appointed as the assessment lead and Mr. Lloyd Keith, NESC Chief Engineer at the JPL, was appointed as the deputy lead.

Key stakeholders are NASA missions and programs that will benefit from technical and engineering material concerning EDL. During the task of collecting and analyzing EDL material, domain experts were consulted to assist the EDL-R team in identifying pertinent material. Experts aided in defining a universal set of metadata used to describe the EDL-R material.

The final report was presented to the NESC Review Board (NRB) for approval on March 29, 2012.

2.0 Signature Page

Submitted by:

Team Signature Page on File – 5/8/12

Dr. Daniel Winterhalter Date

Significant Contributors:

Ms. Elmain M. Martinez Date

Mr. Raymond L. Keith Date

Signatories declare the findings, observations, and NESC recommendations compiled in the report are factually based from data extracted from program/project documents, contractor reports, and open literature, and/or generated from independently conducted tests, analysis, and inspections.

3.0 Team List

Name	Discipline	Organization
Core Team		
Daniel Winterhalter	Project Lead, NESC Chief Scientist	JPL
Lloyd Keith	Deputy Team Lead, NESC Chief Engineer for JPL	JPL
Elmain Martinez	Lead Systems Engineer	JPL
Robert Blanchard	EDL Systems	Contractor (retired LaRC)
Prasun Desai	EDL systems	LaRC
Michael Gangl	Software	JPL
Steve Glendenning	Software	ARC
Michael Green	EDL and TPS Systems	Contractor (retired ARC)
Michael Kelly	NESC Principal Engineer	LaRC
Michael Knosp	EDL-R Editor	JPL
Laura Leybold	MTSO Program Analyst	LaRC
Richard Powell	EDL Systems	LaRC
Robert Powers	Curation, Subject Classification Development	JPL
Belinda Randolf	Software	JPL
Paul Romere	EDL Systems	Contractor (retired JSC)
Paul Seimers	EDL Systems	LaRC
Keith Shackelford	Space Shuttle Program Archive, Databases	ARC
Adrian Tinio	Software and Databases	JPL
Robert Tolson	EDL Systems	LaRC
Alan Wood	Archive	ARC
Xiaoyan Zhou	Science Support	JPL
Administrative Support		
Erin Moran	Technical Writer	LaRC/ATK
Pam Sparks	Project Coordinator	LaRC/ATK

4.0 Executive Summary

The history of NASA's flight vehicles provides a valuable, if not essential, tool for the design and development of spacecraft Entry, Descent, and Landing (EDL) systems. Although NASA missions have provided a wealth of EDL-related information, poor archiving procedures and conditions, and the lack of a common repository have led to a situation where much of the older data has been lost, or is at risk of being unusable. These are serious impediments for the EDL research and development community.

To begin to remedy this situation, the NASA Engineering and Safety Center (NESC) approved funding for the NASA EDL Data Repository (EDL-R) task. The scope of this task was to collect and preserve technical data that contributed to the research, development, and flight of EDL systems. This includes topics such as aerodynamics, computational fluid dynamics, atmospheric density and wind profiles, flight dynamics, parachute performance and testing, material science (ablators), EDL-pertinent ascent systems, and EDL-pertinent spacecraft telemetry.

The principal objectives were to:

1) Locate, collect, and analyze a prioritized set of EDL material from NASA missions.

2) Prepare and archive material.

3) Develop and deploy a NASA-wide EDL-R.

For achieving the objectives of this task, two approaches were taken: collect and archive EDL material for at-risk missions, and develop and deploy a digital library. The first approach was accomplished by identifying at-risk missions based on feedback from the EDL community. From there, the EDL-R team began contacting individuals for access to digital and hardcopy material. While the collection effort was underway, the developers began identifying requirements and performed a trade-study that led to the selection of the open-source digital archive tool EPrints (see eprints.org), which adheres to the Open Archives Initiative (OAI) (openarchives.org) and Dublin Core[1] (International Organization for Standardization (ISO) 15836:2009, dublincore.org) standards. EPrints was customized to adhere to NASA's document security requirements and was configured to capture unique EDL metadata. The first EDL-R version was deployed in 2008. Two additional releases have been deployed and collection efforts have continued in parallel.

The most heavily used EDL-R features are the search and browse options. The easiest and fastest search is "Google-like" where the user specifies a keyword search. A more detailed search can be performed using the advanced search options. Five search categories are available: EDL subject keyword, author, mission, publication date, and item type.

From the EDL-R curator's point of view and from those who submit the materials, the submission workflow will guide the user through the five categories of information to be collected: the item type (e.g., report, video, or test data), item upload and sensitivity level, item

[1] Dublin Core is a trademark of the Dublin Core Metadata Initiative Limited (USPTO 2519654).

description (e.g., title, author, and description), assigning keywords, and submitting the item for review. After this last step, the curator reviews the submission for relevance, completeness, accuracy, and works with the submitter to make any necessary corrections before releasing it for general access.

Since the first deployment in 2008, the archive size has expanded to nearly 1,500 records with many records having more than one document attached, and over 1,000 more to be submitted and reviewed. Currently, the archive is represented by 46 mission categories, more than 1,400 authors, and a broad spectrum of subjects (e.g., EDL subsystems, re-entry thermodynamics, parachute test data, aerodynamics, and ablator technology). As of this writing, there are 96 active users, which represent many NASA Centers and a variety of universities.

The consensus among users is that this task has been a beneficial effort and many have begun using the EDL-R as a resource to locate EDL material for their work. Many users feel that the EDL-R software has the potential to be used as a digital library in other domains (e.g., Planetary Protection). Although there were several interruptions due to funding limitations, the EDL-R team stayed intact and was able to produce a useful tool and built-up a valuable collection of EDL material. The EDL-R has been transferred to the Jet Propulsion Laboratory (JPL) for continued growth and maintenance on a best-effort basis. Under this new sponsorship, the EDL-R will continue to be made available to the NASA and university communities.

The findings, observations, and the NESC recommendation are discussed in Section 16.0, with the two most important aspects being: NASA should establish a practice of archiving engineering, and technical material and efforts should be made to collect EDL material from closed programs and retirees before that knowledge cannot be recovered.

4.1 Supporting Documentation

The following supporting documents provide EDL-R detailed information. To request these, go to universal resource locator (URL): http://www.nasa.gov/offices/nesc/home/index.html.

- Initial NESC Proposal
- Original EDL Repository Plan
- EDL-R Requirements
- EDL-R Trade-Study
- EDL-R User's Guide
- EDL-R Subject Classification

5.0 Assessment Plan

The original charter to this NESC assessment was:

> "The motivation for this activity stems from the lack of a common repository of EDL data from previous atmospheric flight missions to aid in the design of future EDL systems. Recent missions to Mars will provide a wealth of information; however, much of the older data has been lost or is at risk of being unusable due to poor storage conditions."

The scope of the EDL-R focused on technical data that contributed to the research, development, and flight of EDL systems. Therefore, the objectives of this assessment were:

1) Locate, collect, and analyze a prioritized set of EDL data from NASA missions.

2) Develop and deploy an EDL-R.

3) Digitize material and archive.

The task was funded intermittently over 6 years for an aggregate of about 3 years of effective work with the goal of standing up an operational repository that was to be initially populated with at-risk material.

With this focus, the EDL-R team generated a plan to meet these objectives. At the first meeting, the team revisited the objectives and established a high-level project plan and the requirements definition phase began with participation from stakeholders. These task phases are illustrated in Figure 5.0-1.

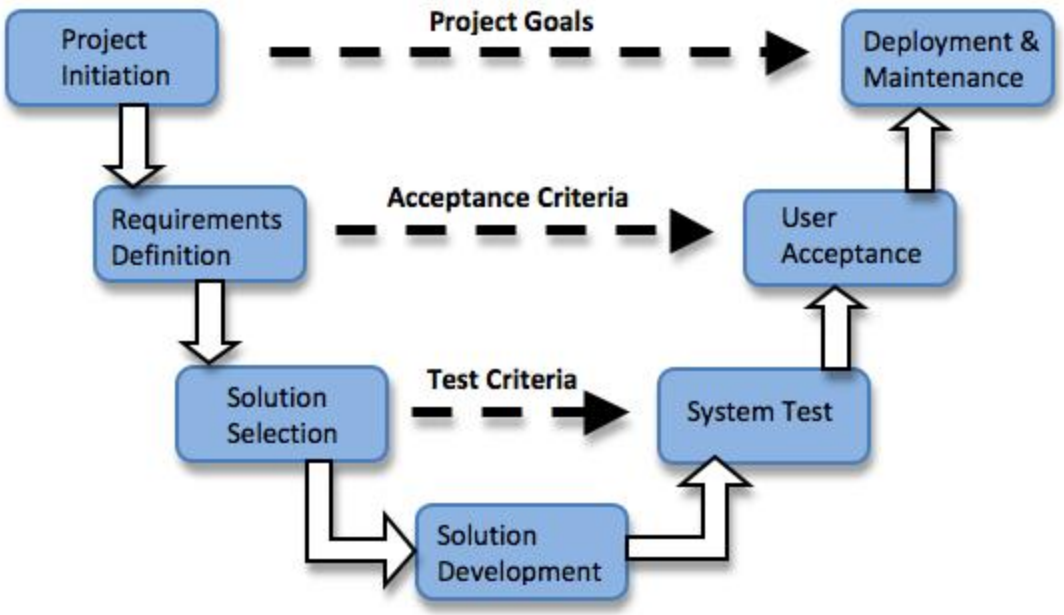

Figure 5.0-1. Task Phases

The objective of the Solution Selection phase was to identify a tool that met the requirements. To do this, a trade-study was performed to review the features of the tools available, select tools were installed for further analysis, and then a tool was selected based on an assessment from the EDL-R team and user community (see supporting documentation, *EDL-R Trade-Study*, for details). It was discovered during this phase that no single tool would meet all functional requirements and adaptation would be required on any tool that would be selected. At the conclusion of the trade-study, the EPrints open-source digital library tool was selected (see www.eprints.org).

The EDL-R team began the Solution Development phase by implementing required security features. For example, differing user authentication levels required that the system display only those records a user was authorized to view. Further customization was required to capture unique EDL metadata to describe the various types of material and content that would be gathered. Most of the adaptations were easily made via EPrints configuration files.

System testing was performed by EDL-R team members and the intended user community. Formal system testing, conducted by the team, was performed on all EPrints features and adaptations. For User Acceptance testing, members from the EDL community were invited to exercise the various search options and submission process. The response was positive and usability suggestions were integrated before initial deployment in 2008.

6.0 Problem Description and Background

NASA has accomplished great achievements over the course of its history, with each new success building upon past efforts. This evolution of technical accomplishments and growing knowledge has allowed NASA to reach farther than before. The Mars missions in the last decade demonstrated phenomenal engineering feats and incredible discoveries. Many not closely involved with these projects, including the public, have not appreciated the complexity of the mission EDL phase, including successes and failures. As a commitment to the future, NASA needs to ensure this engineering knowledge is not lost, and should take steps to preserve the engineering and technical information from the past to enable the future.

Material can be at risk for a variety of reasons. Many of the early EDL missions took place at a time when digital storage was in its infancy and paper was the primary medium for storing information. Many of these documents have been lost to damage or placed in undocumented storage (e.g., warehouse, a file cabinet, or retiree's personal files). With the "graying" of the NASA workforce, there are many documents and test data that continue to be at risk of being lost.

The scope of this repository focuses on technical data that contributed to the research, development, and flight of EDL systems. In pursuit of this focus, the following tasks were undertaken:

- Creation of a NASA accessible EDL-R
- Acquisition of historical and current material
    - Development, test, and flight data
    - Transmitted sensor readings and telemetry from various missions
    - Software used to process EDL data
    - Reports and analyses
    - Supporting data (e.g., arc-jet testing, parachutes, etc.)
    - Bibliographic references to published papers

The project was initially funded by the NESC in mid-fiscal year 2007 and funding continued intermittently through the first half of fiscal year 2012. The first year focused on defining requirements and evaluating open-source software solutions. In 2008, the EDL-R team had a working prototype system based on a customized version of EPrints. Shortly thereafter, the EDL-R was deployed and focus shifted to collecting and archiving material.

A variety of disciplines is represented in the EDL-R that includes:

- Aerodynamics
- Thermal dynamics
- Atmospheric science
- Guidance, Navigation, and Control (GN&C)
- Thermal protections systems (TPS)

- Separation systems
- Descent and landing systems

6.1 Collection Priorities

With input from the EDL community, collection priorities were based on the drivers of: preserving material that was a risk of being lost, and to collect recent material that may be of interest to current EDL development efforts (e.g., Mars Science Laboratory (MSL) and Constellation Program (CxP) Orion Project).

As outlined in the NESC proposal, the task sought to collect EDL material from the missions shown in Table 6.1-1.

Table 6.1-1. Candidate Missions

Mission Name	Year	Mission Type	Planet
Fire2	1965	Entry	Earth
Surveyor	1966-1968	EDL	Earth
Apollo	1966-1975	EDL	Earth
RAM-C	1967	Entry	Earth
PAET	1971	Entry	Earth
Viking I and II	1975	EDL	Mars
Pioneer Venus (4 probes)	1978	EDL	Venus
Galileo	1989	Entry	Jupiter
Magellan	1989	Entry-Aerobraking	Venus
Mars Global Surveyor	1996	Entry-Aerobraking	Mars
Mars Pathfinder	1996	EDL	Mars
Huygens	2005	EDL	Titan
Mars Polar Lander	1999	EDL	Mars
Stardust	1999	EDL	Earth
Genesis	2001	EDL	Earth
Mars Odyssey	2001	Entry-Aerobraking	Mars

Mission Name	Year	Mission Type	Planet
Mars Exploration Rovers	2003	EDL	Mars
Mars Reconnaissance Orbiter	2005	Entry-Aerobraking	Mars
Space Shuttle Program	1981-2011	EDL	Earth

Once the EDL-R team was convened, the first priority was to determine which missions were deemed to have EDL material at-risk of being lost. Material for the following missions was considered high priority:

- Viking
- Galileo
- Pioneer Venus
- Stardust (Note: the mission had no agreement with NASA to archive Earth entry data)
- Mars Orbiters and Landers
- Mars Rovers
- Space Shuttle Program (SSP)

Table 6.1-2 shows examples of the types of EDL subjects that were being sought for completed missions:

Table 6.1-2. Examples of EDL Subjects

Examples of EDL Subjects
• Raw engineering flight data • Time reference data • Calibration, scale factors, etc. • Aerodynamic data • Mass properties • Software design documents • Processed or reconstructed data • EDL design, development, certification

With identifying priorities for the collection of EDL-related materials, the EDL-R team identified an initial strategy to collect this information. Key individuals were identified for each of the at-risk missions. These individuals acted as coordinators for locating and submitting the materials by identifying key community contacts that can help locate materials and by establishing a network of domain experts who could aid in the archival.

In addition to the at-risk material, the EDL-R team collected recent EDL materials, especially where the interest/need was high. For example, Apollo-era parachute studies were sought by MSL to aid in their testing. Since the SSP was retired in 2011, its EDL material was viewed as at-risk because a formal archive was not established. Fortunately, in the process of searching for at-risk material, a significant portion of the early EDL test data was found in a retiree's library. Table 6.1-3 lists topical examples that have been collected from recent missions.

Table 6.1-3. Examples of Contemporary EDL Missions

Mission (examples)	Citation Examples
Huygens Probe	• EDL Trajectory Reconstruction • Vertical Pressure Profile of Titan - Observations of the Huygens Atmospheric Structure Instrument and Pressure Profile Instrument • Parachute Characteristics of Titan Descent Modules
Mars Phoenix Lander	• Mars Phoenix Mission EDL Trajectory and Atmosphere Reconstruction • Aerodynamics for the Mars Phoenix Entry Capsule • Phoenix Mars Atmospheric Structure Experiment
MSL	• Abort determination with non-adaptive neural networks for the Mars precision landers • Real-time EDL Navigation Performance using Spacecraft to Spacecraft Radiometric Data • Surface Catalysis Experiments on Metal Surfaces in Oxygen and Carbon Monoxide Mixtures
SSP and Space Transportation Systems	• Supersonic/Hypersonic Laminar Heating Correlations for Rectangular and Impact-Induced Open and Closed Cavities • Aerodynamic Characteristics of a Vertical Takeoff Vertical Landing (Single Stage to Orbit Vehicle from M(sub infinity) = 0.1 to 10 • SSP transonic wind tunnel wall interference analysis • Subsonic lift and drag characteristics of lifting and wing-body vehicle configurations

During this assessment, the EDL-R team discovered documents and videos that were not on the priority list, but were considered highly valuable. These materials include a video from the Little Joe abort test, parachute design papers from T.W. Knacke, A. Seiff's library, Galileo Thermal Protection documents from the federal archives, and a number of documents concerning lifting-bodies (e.g., HL-10 and X-38).

7.0 Requirements Definition

A rigorous set of requirements was developed to enable an objective evaluation of potential tools to be used to host the EDL material. After reviewing the documentation on digital library tools and evaluating three in detail (see *EDL-R Trade-Study*), it became clear that no single tool would meet all requirements. In addition, a number of processes needed to be put in place concerning user accounts and document sensitivity. As a result, the EDL-R team specified additional detailed requirements across a number of topics that were added to the list of basic requirements. See *EDL-R Requirements* document for the base and adaptation requirements.

All requirements were met with the exception #4302, which was to develop a separate webpage where users could request an account. Currently, users must contact the administrator to request an account. Although not considered a high priority, having a web-based method for users to requests accounts would simplify the entire process.

8.0 System Design and Development Activities

It was established early in the assessment that the majority of funding should concentrate on the collection and preservation of EDL material. Therefore, it was desirable to keep the cost of developing a repository system to a minimum. The EDL-R team sought to design a system independent of the supporting infrastructure it was developed in since the system would be transferred to a permanent sponsor at the end of the task. These factors were the driving force behind the architectural design of the hardware and software components.

8.1 Standards

The EDL-R adheres to the OAI and Dublin Core archival standards. The OAI standard represents a model for archival systems and establishes practices for the harvesting from other repositories that are OAI-compliant. This standard requires the archives to follow the Dublin Core standard for metadata. The EDL-R allows for the possibility of sharing with the NASA Scientific and Technical Information (STI) archive. Similarly, it may be worthwhile to the new sponsor to investigate whether there are OAI archives that hold EDL material. For more information on this standard, go to URL: http://www.openarchives.org/.

The EDL-R adheres to the Dublin Core standard. This standard was adopted by ISO in 2006 with the goal of establishing a base set of metadata to be collected to describe the item being archived. The EDL-R follows the simple metadata element set, which defines 15 standard elements. To capture information unique to EDL, additional metadata elements were added. For example, “mission name” – to capture the mission that the material refers to, and “observation start/end” date – for recording the dates when data were taken. For further information on Dublin Core standard, go to URL: http://dublincore.org/documents/usageguide/.

8.2 Hardware Architecture

The EDL-R hardware is hosted in a data center that is managed by the JPL Multi-mission Image Processing Laboratory. As shown in Figure 8.2-1, the hardware consists of:

- Two Redhat Enterprise Linux 5 Servers with Dual-Core Intel® Xeon® 3060 2.4 gigahertz with 2 megabytes (MB) cache processors. Each server has 4 gigabytes (GB) memory and 80 GB of internal disk storage. One server has been assigned as the production server, while the other serves the dual purpose of being the development server and a failover backup to the production server.
- External redundant array of independent disks (RAID) system with 4.5 terabytes (TB) of usable disk space attached to production server via Small Computer System Interface (SCSI).
- External RAID system with 1.8 TB of usable disk space attached to development server via Universal Serial Bus (USB).

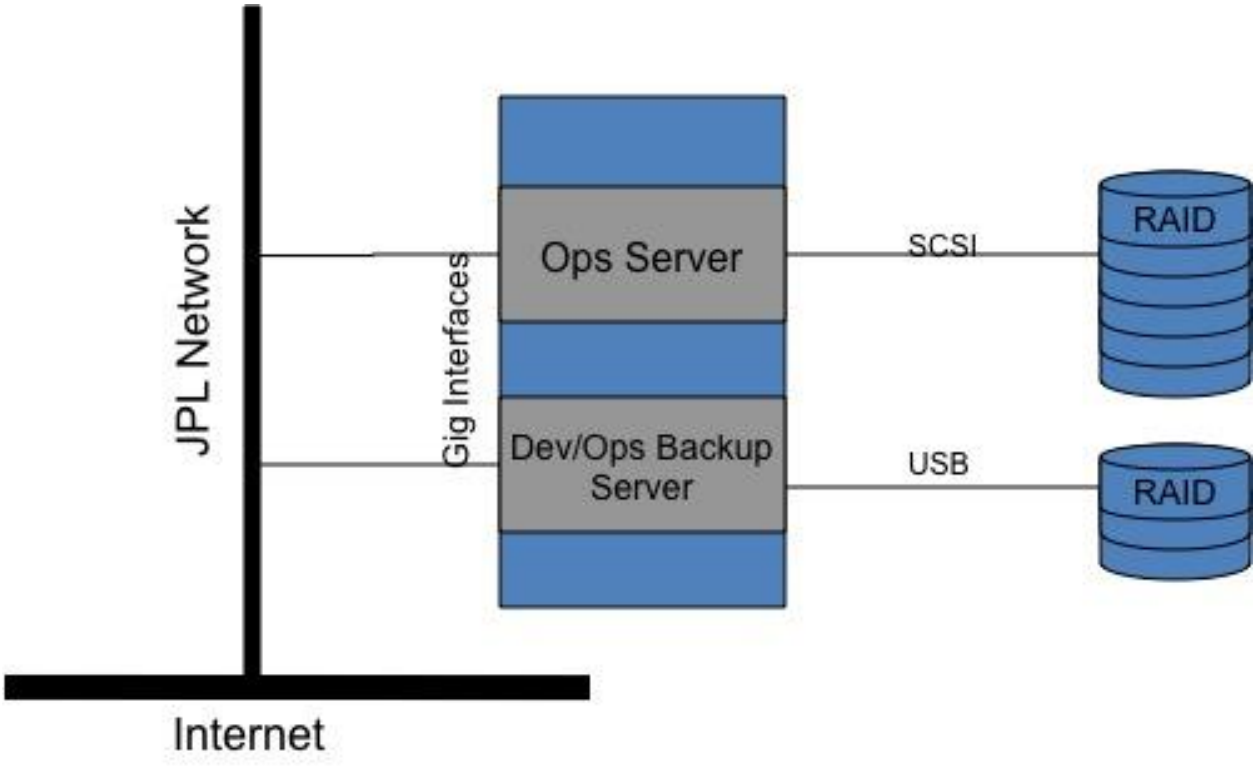

Figure 8.2-1. Hardware Layout of the EDL-R

Storage is provided by the external stand-alone RAID units, which are directly attached to the servers. This storage solution was used to remain independent of JPL's internal storage options.

To gain Internet access, the EDL-R servers are connected to the JPL internal network via GB interfaces. The JPL network, which is firewall-protected, guards against arbitrary connections originating from outside the network. Perimeter access requests have been approved to allow access to the EDL-R from outside the JPL network.

8.3 Software Architecture

The EDL-R core system uses the open-source, digital library tool EPrints. This tool is used by a number of organizations and universities as an open-source software platform for building online and web-based repository systems (http://www.eprints.org/). The design of EPrints is based on the Linux, Apache, MySQL, and PHP/Perl/Python (LAMP) software architecture, which is an acronym for a solution stack that is made up of free and open-source software. These components work in conjunction to build general-purpose web server applications.
See Figure 8.3-1.

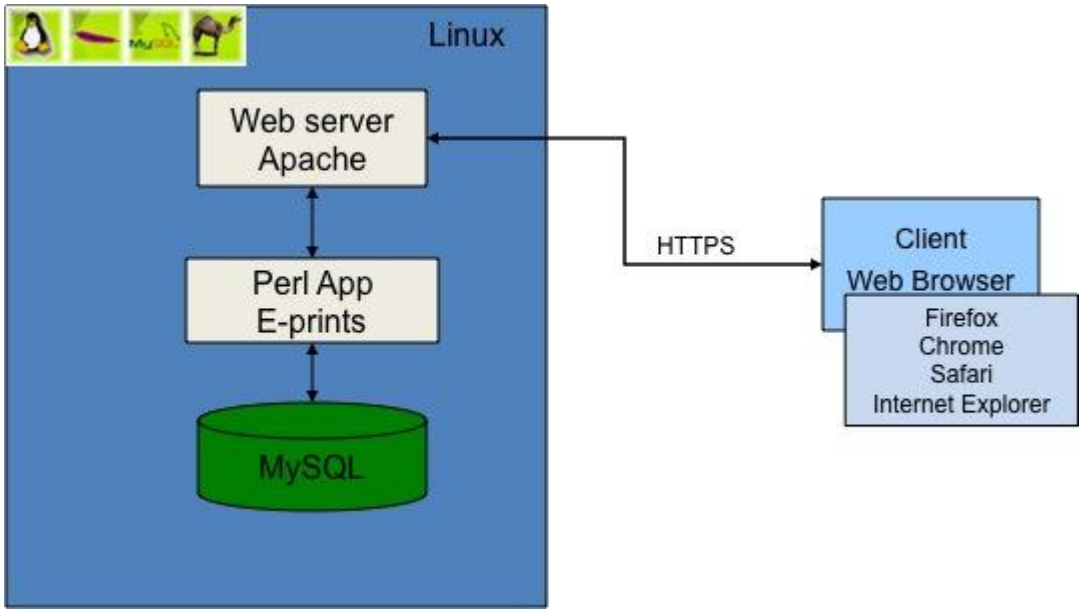

Figure 8.3-1. EDL-R LAMP Stack

Linux provides the secure operating system environment where the components run and execute. Apache provides the web server environment for the EPrints web application. MySQL provides the relational database back-end to store metadata information. Finally, Perl is the source code language that implements the logic and integrates the other components together to provide the functionalities for the EDL-R. Figure 8.3-2 depicts the high level processing that occurs for each EPrints request.

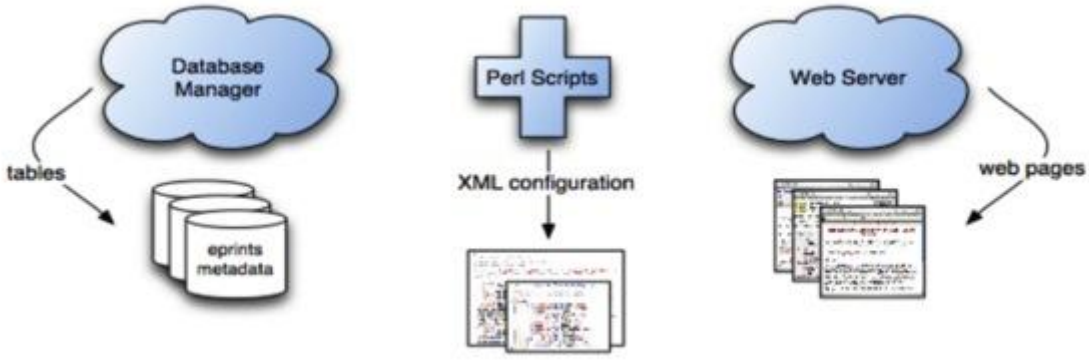

Figure 8.3-2. High Level EPrints Processing

When a request is made to the EPrints system, the various Perl programs query data from the MySQL database manager to retrieve EPrints metadata. With the use of EXtensible Markup Language (XML) configurations and the data retrieved from the database, the Perl programs generate the "views" or the web pages, which are served to the user by the web server.

8.4 EDL-R Customization

The EPrints system is made up of two main components: the core archiving software component and the site-specific component. The core archive component provides the general functionalities required for an archive. The site-specific component provides details about what is stored in the archive, how it is presented, and how it can be made accessible to the users. The EPrints system is a fully functional repository system. However, to meet the specific needs of the EDL-R, the core archive component and the site-specific component of EPrints required modification.

The following is a list of the major EPrints customizations to meet the EDL-R requirements:

1. Authentication and Authorization
    a. Modified EPrints to prevent "dark data" (i.e., International Traffic in Arms Regulation (ITAR), and Sensitive But Unclassified (SBU)) from being shown to unauthorized users. Dark data, in this context, is any piece of information that gives evidence of sensitive information to unauthorized users. EPrints was modified so that browse views, citation pages, and search results only contain information that the user is authorized to access.
2. Security
    a. The EPrints was modified to enforce NASA requirements on the use of password strength and aging.
    b. Virus scanning was added for every document uploaded.
    c. Utilized the secure socket layer (SSL) for encrypted connections, which ensures secure communication between the client and server.

d. Configured to be a login-only repository, which requires a user to be logged-in to perform any operation.

3. Workflow
    a. Added a "Curator Only" sensitivity level, which prevents the document and the associated EPrints record from going to the live repository.
4. Interface
    a. Modified the submission Details page to include EDL-related metadata.
    b. Added batch upload via Excel® spreadsheet.
    c. Updated the Subject tree to reflect the EDL disciplines.
    d. Modified Subject Selection interface to perform bulk subject selections. This allows the user to select multiple subject keywords with fewer mouse clicks. This improves the general usability of the subject selection interface and performance as this method requires less interaction from the server when selecting multiple subjects.
    e. Implemented a Subject Recommender Subsystem that preselects subject keywords based on the material's title and description.
5. Miscellaneous
    a. Implemented a capability to edit, manage, and post a list of "Most Wanted" materials.
    b. Integrated the statistics gathering packages to collect data and provide graphical reports on which material is being accessed, how much it is being accessed, and who is accessing the data.

8.4.1 Subject Recommender Subsystem

The EDL-R employs a multi-step submission workflow. One such step is to specify bibliographic type of metadata (e.g., title, description, and author) to describe the material. Another is to assign the appropriate subjects from a predefined subject list. The Subject Recommender Subsystem attempts to augment the subject assignment step by automatically classifying the material based on the title and description. The Subject Recommender Subsystem utilizes a Naïve Bayes document classifier.

The Naïve Bayes is a machine-learning-based classifier and is a statistical method that has been successfully applied to automatic document classification. This method is based on Bayes' theorem for computing the conditional probability that a given document belongs to a category. The machine-learning (ML) algorithm is divided into two main phases: learning and classification. The learning phase is an inductive process that automatically builds a classifier or a model by observing the characteristics of a set of documents that have previously been

manually classified by a domain expert. This type of learning process is known as supervised learning since it is supervised by the predefined categories of the training data that belong to each category. The classification phase then uses the model built in the learning phase to classify new documents. Figure 8.4-1 illustrates this process.

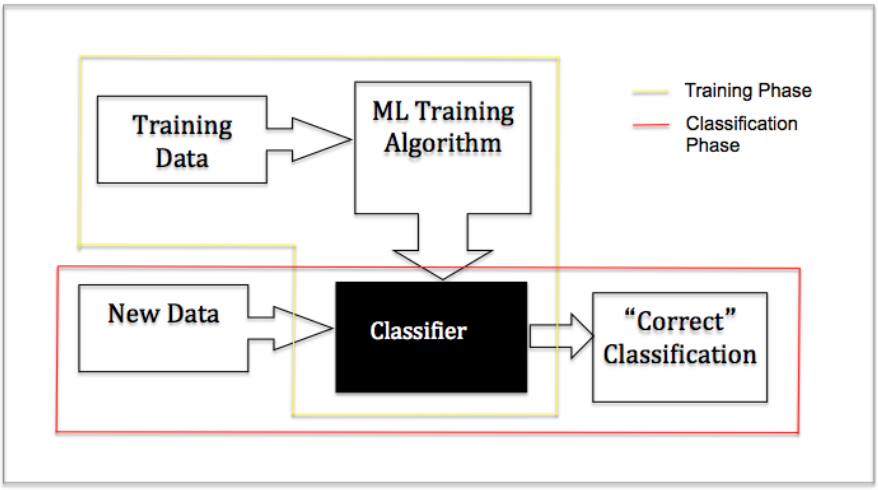

Figure 8.4-1. Subject Recommender Algorithm

Supervised learning approach. The ML algorithm receives training data as input to generate a black box model that is used to classify new data.

Other methods for automatic document classifications were considered (e.g., the use of neural networks and support vector machines). Ultimately, the Naïve Bayes method was selected because it provided fast training and classification time with reliable classification accuracy.

Since the EDL-R/EPrints is a software system that is written in the Perl programming language, choosing a machine-learning package written in Perl to implement the Subject Recommender Subsystem made the integration easier. The machine-learning package used was the AI::Categorizer package, which is a Perl framework for automatic text categorization. It consists of a collection of Perl modules that implement common categorization tasks and a set of defined relationships among those modules. It provided an implementation for the Naïve Bayes classifier and the flexibility to use different classifier implementations (e.g., support vector machines (SVM) and other classifiers).

Following the model of supervised ML methods, the Subject Recommender Subsystem is composed of three main modules: learner, classifier, and a preprocessor. The learner module is responsible for taking in the training documents and building a model. The classifier module uses the model built by the learner module to classify incoming documents. The preprocessor module consists of utilities to convert the documents into feature vectors with the appropriate format for the Naïve Bayes classifier. The classifier and preprocessor modules are integrated into the EDL-R software. The learner module sits outside of the EDL-R software and can be

treated as a separate process. Figure 8.4-2 shows the high-level EDL-R architecture with the integrated Subject Recommender Subsystem.

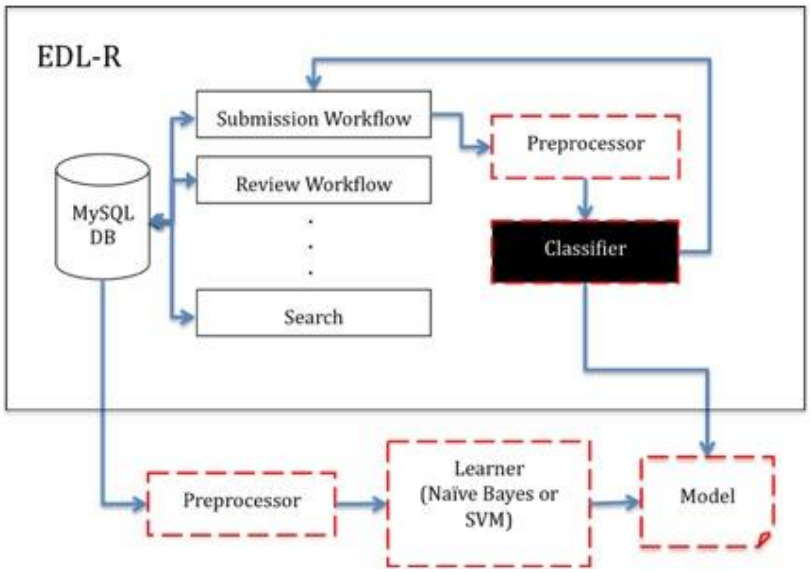

Figure 8.4-2. The EDL-R Integrated with the Subject Recommender Subsystem Integrated *Subject Recommender Subsystem components in red/dashed boxes.*

8.5 Testing and Deployment

8.5.1 Testing

A test plan was prepared for each of the three deployed releases. Each plan defined the deliverables and described test cases for new features and bug fixes. Table 8.5-1 describes the schedule of releases.

Table 8.5-1. EDL-R Release History

Release #	Date	Description
1	April 2008	This was the first version that was used to begin archiving material.
2	August 2009	This release contained a number of improvements suggested by the team: the addition of Browse by Mission, additional Advanced Search fields, additional controlled keywords, URL verifier, and a virus checker for uploaded files. The team conducted the User Acceptance test with this release.
3	December 2009	Last major EDL-R release. The Subject Recommender Subsystem and statistics packages for monitoring usage were added. More controlled keywords and a new feature to import data in other formats were added. Documentation was updated for the user and curator.

For the three system tests, EDL-R team members were recruited to exercise the test cases. This proved helpful in getting alternate perspectives on how features should work and it allowed team members to verify bug fixes and explore new system features.

As summarized in Table 8.5-1, the second release included the User Acceptance test. For this test, the EDL-R team prepared test scenarios for the two most popular features: search and material submission. Users were invited to comment on the organization of the main page, to peruse the documentation on the site (e.g., frequently asked questions (FAQs)) and to provide recommendations for improvement.

The following is a summary of the feedback provided by the EDL community:

- NASA requirement password rules were strict.
- Main page organization was favorable.
- Navigation issues with the Most Wanted List were identified that resulted in a fix.
- Confusion on the Advanced Search field terminology prompted improvements to the in-line documentation.
- Document batch upload worked as expected.
- Confusion on whether delimiters should be used to separate words in the uncontrolled keyword field, which prompted clarification in the in-line documentation.

8.5.2 Deployment

There are two EDL-R deployed systems: operational and development. As the name implies, the development system is used primarily for developing capabilities, bug fixes, and systems tests. Towards the end of each release cycle, the development system is frozen so that official testing can proceed without the developer introducing new changes to the system.

The successful completion of formal testing marks the start of the deployment of the new release to the production server. The deployment of the EDL-R software involves three major phases: release, installation, and activation. The release phase involves committing new and modified code to Subversion, the project's version control system. A new release is tagged with a release label or identifier when committed to Subversion. Installation involves syncing the operational system with the newly committed EDL-R release from Subversion. After this step, the operational system software is upgraded to the latest version. Part of the installation phase includes loading any new or modified database tables, stored procedures, or triggers, modifying host specific configurations, and installing EDL-R/EPrints web server configuration. The activation phase involves restarting the Apache web server to see the updated release.

9.0 Curation of the EDL-R

The person responsible for managing and expanding the EDL-R collection is referred to as the *curator*. This person is required to be familiar with digital library practices, metadata standards, and trends in technology that define widely used file formats. Ultimately, the curator's role is to ensure that material stored in the EDL-R is technically relevant and preserved for current and future NASA EDL missions.

The curator performs many different functions, such as researcher, site administrator, user support, and marketing. To perform operational tasks, the curator is assigned EDL-R administrator permissions, grants privileges to create and manage user accounts, submits records, makes changes to live records, and generates usage statistics. In addition to this, the curator is responsible for:

- Actively seeking EDL material from public and NASA sources.
- Reviewing material for appropriate release approvals and sensitivity restrictions.
- Providing assistance to submitters and users seeking material.
- Verifying that all URL references continue to be valid.
- Preservation activities, such as file format migration.
- Coordinating software and system upgrades.
- Reporting status to management.
- Promoting the EDL-R via NASA channels and relevant meetings/conferences.

9.1 Policies and Procedures

Policies and procedures have been implemented for the use, operation, and management of the EDL-R. In addition to the NASA security and Information Technology (IT) policies, key policies concerning access and archival under which the EDL-R operates include:

- Material is only available to NASA representatives (i.e., civil servant or contractor) and affiliates (See Table 10.3-1 for a definition of user classifications).
- Create a reference to material located in copyrighted and public archives (e.g., American Institute of Aeronautics and Astronautics, Planetary Data System instead of storing a copy). However, highly-relevant public material may be duplicated for convenience purposes.
- Periodically transfer unique material to STI, per their request.
- Submitters and owners of material can request that documents be withdrawn.

Detailed procedures, in the form of User's Guides, have been defined to aid the user and the curator. Only the former is available on the EDL-R.

10.0 Application Features

The following sections highlight some of EDL-R's main features.

10.1 Main Page Overview

The main page is the starting point for all EDL-R functions: documentation, Search, Browse, Most Wanted List edits, Submission workflow, and access to a user's Profile. Figure 10.1-1 is an example of the main page.

Figure 10.1-1. EDL-R Main Page

The main page has three major sections. The left-hand side contains general information (e.g., policies, a user's guide, and contact information), a link to initiate a submission and instructions on how to submit via e-mail, and website statistics. The middle section contains links to the various search methods: Browse, Simple, and Advanced search. The bottom of this section has links to the Most Wanted List. The right-hand side lists two sections: one listing the most recently added items and another that contains a list of other EDL-related web sites.

10.2 Search and Browse Methods

The EDL-R provides a number of search and browse methods for the identification and retrieval of relevant materials. The *Quick* and *Simple* search capabilities allow keyword searching of the following fields:

- Submission title
- Item description
- Author name(s)

- Publication date
- Uncontrolled (subject) keywords
- Submission content

Quick search provides an intuitive "Google-like" search box at the top of each page with the results sorted by title, while Simple search give users the added flexibility of sorting results by year, author's name, or title.

Advanced search allows the user to build a targeted search by specifying a variety of different criteria. This search combines the criteria using the AND Boolean operator. The search criteria can be saved for re-use.

The browse options are integrated into the user interface. Browsing can be done by *Year*, *Subject*, *Author*, *Mission*, or document *Type*. The browse by *Subject* provides a good way to peruse the various topics covered in the EDL-R. Alternatively, browsing by *Mission* or *Author* is a fast way to navigate down to a level where browsing can be done at the citation level.

Underneath the Quick and Simple tools is the Apache open-source Lucene search engine (http://lucene.apache.org/). One of the main features of this engine is its full-featured text indexing. This allows any uploaded document that is formatted as .txt, .pdf, or .doc to have keywords indexed. This greatly improves the search experience and compliments the searchable metadata stored with each EDL-R record.

10.3 Submission Process

Registered users can submit material into the EDL-R by entering information into web-based forms. The process is divided into five distinct stages: *Type, Upload, Details, Subjects,* and *Deposit*. Related to this, each user has a work area where submissions-in-progress can be stored until they are completed and ready for submission.

The *Type* stage involves selecting the type or kind of material that is being added to the repository. The customized item types that are available to choose from in the EDL-R includes book, book section, dataset/data, model/simulation, presentation, publication, report, review, study, teaching material, and test results. There is also an *Other* item type that can be selected for material that does not fit into any of the 11 distinct item types. A description is provided for each of the item types to help the depositor select the appropriate type.

The next step in the submission workflow is the *Upload* stage. In this stage, the depositor is presented with an interface to upload the material to the system. It is also in this stage that the depositor specifies the format and the sensitivity level. The EDL-R has a list of formats that include various image, video, and application formats that are natively recognized. However, any formats are accepted. The sensitivity level specifies who has access to the material once it is in the repository. There are six customized sensitivity levels: *Public, Copyright, NASA-Sensitive, ITAR, NASA-Sensitive ITAR,* and *Curator-Only,* as shown in Table 10.3-1.

Table 10.3-1. Material Sensitivity Levels

Sensitivity Level	Description
Public	The item is publicly available (i.e., can be found via Internet search or public archives). Material is accessible by all registered users.
Copyright	Used when an item is copyrighted. If the document is uploaded, then a letter of permission is required. Material is accessible by all registered users.
NASA-Sensitive	Used to describe SBU material; appropriate marking language must be included. Material is only accessible to NASA employees and NASA contractors.
ITAR	Used to indicate that the uploaded document is ITAR-restricted; appropriate marking language must be included. Material is only accessible to United States (U.S.) persons.
NASA-Sensitive ITAR	An item is NASA-sensitive and ITAR-restricted; appropriate marking language must be included. Material is only accessible to NASA employees who are U.S. persons.
Curator-Only	Used to hold material for investigative purposes or until permission for release has been given. Only the Editor/Reviewer/Admin can see these submissions.

The bibliographic information about the material (e.g., title, author, and publisher) is specified in the *Details* stage. This step in the workflow has been customized to capture EDL information that will help preserve the material and will provide a rich set of search criteria. Some fields are required and if not filled-in will generate a warning at the top of the page. The system will not allow a submission to be deposited if any required fields are blank.

The *Subjects* stage involves selecting the subjects or keywords that are most appropriate to the material being submitted. In this stage, a predefined subject tree is presented from which the user can choose any number of keywords that best describe the material. An *Uncontrolled Keyword* text field is provided for free-form words or phrases that are not found in the subject tree.

The final step in the submission workflow is to submit the material to the repository. This is performed in the *Deposit* stage. When the user clicks on the Deposit button, they are acknowledging that the necessary steps have been taken to vet the material for appropriateness and distribution, and that any required marking language has been added.

10.4 Electronic Notification

The EDL-R has a feature that informs registered users when new material has been added to the repository. A user can set up a notification by saving search criteria and then indicating how often the search should be automatically run. Users are notified of new items via e-mail.

10.5 Most Wanted List

The Most Wanted list is where a user can create a public request for material on a particular EDL subject or for a specific document. Since the postings in the Most Wanted list are located on the login page, any person that goes to the EDL-R can see this list. An e-mail contact link is provided to facilitate direct correspondence.

Only a registered user can create a Most Wanted request. A link on the main page allows the user to create a posting. However, only the EDL-R administrator can remove a posting.

11.0 Administrative Features

11.1 Administrative Roles

The EDL-R has three administrative roles (Table 11.1-1), which provide access to increasing levels of control of the archive content and site administration.

Table 11.1-1. Administrative Role Definition

Administrative Roles	Access
Reviewer	Can view submissions that are in Review. However, a Reviewer cannot release submissions from Review to the live repository.
Editor	Has Reviewer privileges. In addition, an Editor can move submissions from Review to the live repository and vice-versa reject submissions, edit submissions that are in Review and live repository, and delete submissions.
Administrator	Has Editor privileges, and has access to all administrative functions on the webpage, history logs, detailed statistics, and user accounts.

11.2 User Accounts

Since the EDL-R is a NASA tool, access is based on the requestor's affiliation with a NASA EDL-related task/mission and citizenship. The site is not available to the public or offered for commercial use.

When an account is created, a user type must be specified. This sets the user's authorization level that controls the types of sensitive material that can be accessed since the site contains SBU and ITAR material. Table 11.2-1 shows the user types, definitions, and level of access.

Table 11.2-1. User Classifications

User Type	Definition	Access
Non-U.S. Affiliate	A foreign person who is not a NASA representative (i.e., civil or contractor), but collaborates with NASA.	Public material.
U.S. Affiliate	A U.S. person who is not a NASA representative, but collaborates with NASA.	ITAR and public material.
Non-U.S. NASA Employee	A foreign person who is a NASA representative.	NASA SBU and public material.
U.S. NASA Representative	A U.S. person who is a NASA representative.	NASA SBU, ITAR, and public material.
Reviewer	An authorized U.S. NASA representative who can review and release submissions.	NASA SBU, ITAR, and public material.
Editor	An authorized U.S. NASA representative who can edit released submissions and has Reviewer privileges.	NASA SBU, ITAR, and public material.
Administrator	An authorized U.S. NASA representative who has access to the entire website content and can create/change/delete user accounts.	NASA SBU, ITAR, and public material.

11.3 Review Process

Deposited materials are reviewed before being released to the community. Once a submission has been deposited it is held in a temporary review area where the Reviewer or Editor evaluates the metadata for completeness and accuracy, condition of the submitted material (e.g., quality of scanned documents), and the appropriateness of the material being submitted.

After the material has been reviewed, the Editor has three courses of action. If the submission does not pass the review process, then the Editor will return the item to the depositor with a description of what needs to be corrected, or delete the item if it is not relevant. Both of these actions will generate an e-mail message to the depositor explaining the issue and actions to be taken. When the submission passes the review process, then the Editor can release it to the operational system where it becomes available to users.

11.4 Statistics Generation

Two plug-in statistics packages have been configured to track EDL-R usage. The IRStats tool comes with EPrints and it provides a number of reporting options that are generated in real-time (e.g., downloads, unique visitors, top ten downloads, and a comma-separated values file) that can be used for further analysis. The AWStats package is an open-source log analyzer that reports on various web site usage statistics (e.g., number of visits, visit duration, host Internet Protocol

(IP) addresses, most viewed pages, and browsers used). These tools provide an in-depth view of the historical usage.

12.0 System Security

12.1 NASA Requirements

The EDL-R adheres to the guiding NASA security requirements defined in:

- NASA Procedural Requirement: 2810.1, NASA Information Security Policy
- NASA Procedural Requirement: 2810.1, Security of Information Technology
- NASA Procedural Requirement: 1600.1, NASA Security Program Procedural Requirements
- NASA Interim Directive: 5.24 Sensitive But Unclassified (SBU) Controlled Information, NID 1600-55

Links to these and the related applicable documents are located at http://www.nasa.gov/offices/ocio/itsecurity/index.html.

These documents describe the rules and practices to ensure the integrity and confidentiality of equipment and data. The following sections describe the steps taken to meet these requirements.

12.2 System Controls and Audits

The EDL-R hardware is physically secured in an access-controlled computer room. Access to this room is limited to the system and hardware administrators. The health and safety of the systems are constantly monitored and any incidents are reported to the administrators.

The JPL IT Security performs random scans on the operational and development servers. These scans are performed to identify software vulnerabilities and security weak points. The system administrators are notified of the scan results, especially when security violations have been identified. For each identified violation, a Security Problem Log ticket is issued, which the administrator must address. The scan results are assessed by the JPL IT Security and a full system audit is performed if the scans consistently reveal security violations. The audits are intended to assess how well the systems comply with the security policy with regard to hardware criticality and data sensitivity. These reports are gathered and reviewed by the JPL IT Security.

Access to the machines is controlled on two levels: machine logins are restricted to the developers and administrators, and system directories and files are controlled by access-control lists that are managed by the system administrators.

12.3 EDL-R Access Controls

Access to the EDL-R is controlled by a user's authentication and authorization. The authentication process is enforced by a login, which requires a valid user name and password. The authentication process is accomplished by verifying that the user is affiliated with NASA and verifying their U.S. citizenship. This is done using NASA's employee directory and may

involve contacting the requestor's supervisor to confirm affiliation and citizenship. With this information, the EDL-R administrator can determine the user's authorization (classification) level (see Table 11.2-1 for a list of user classifications). The following sections describe how EDL-R authentication and authorization are implemented.

12.3.1 Authentication

Authentication consists of a valid user name and password. To implement this, the default EPrints configuration had to be changed from open access to password-only access. The password-only configuration uses the SSL for all interactions, including login. These alterations required the definition of a comprehensive rule set for the passwords (including length and special characters), including keyboard patterns, and dictionary-based checking.

With these password requirements, a custom aging component was built into the existing repository and database. The aging script can be configured for any variable amount of days, and sends reminder e-mails regarding password expiration 1 and 2 weeks prior to expiration. Once a password expires, only a repository administrator has the ability to reset it. Users can request a reset by clicking the Contact the Curator e-mail link on the login page.

12.3.2 Authorization

The EDL-R authorization policy is similar to that used by NASA STI (i.e., a specific user authorization level is set at the time a user account is created and this controls what the user is allowed to see and do). To control access to the various types of material, the EDL-R established a policy to only display information that the user is authorized to see. Implementing this policy required a new capability to be implemented in EPrints to filter the browse list and search results based on a user's authorization level. For example, the EDL-R will intercept search results before being displayed to the user and determines if the sensitivity of the document maps to the user authorization level. If any documents do not match, then they are removed from the results. If access is granted, then the result is passed to the screen processor for display. This same methodology is used for the saved searches that users can use to find or store information that has been previously searched. Because users can search via other users' saved searches, this is needed to be a dynamic filter completed in real time. If a user attempts to access a document via the EDL-R search URL and it does not match his/her authorization level, then an "access denied" message is displayed.

Browse pages are different because they are not generated dynamically like search results. Instead, the browse contents are created once per day for each user type. This means each user type has its own browse page that it will be authenticated against. This policy means that a user can only see information they are authorized to see; there are no hints or clues that are displayed to suggest that other documents exist. To capture attempts to circumvent these controls (e.g., typing in a URL directly into the address bar of a browser), the EDL-R performs authentication in the background for all requests to browse pages, giving a 403 forbidden error when a user attempts to access an unauthorized access browse page.

From the administrator's perspective, the EDL-R has authorization levels for submissions and system management. Each type of EDL-R administrator (e.g., Editor, Reviewer, and Administrator) has a specific role that limits the types of changes that can be performed on a submission depending on where the submission is in the workflow process. The highest level of access is reserved for the Administrator. In addition to being able to modify a submission at any step in the workflow process, the Administrator can modify the system settings and subject tree, view system status and submission histories, and create user accounts.

For the next major EPrints upgrade, a goal is to interface with the NASA Lightweight Directory Access Protocol (LDAP) for authentication and authorization. This would eliminate the need for a separate password checking and aging component because all of the information is stored and retrieved in a central location.

13.0 Operational Status

13.1 Maintenance and Preservation

Maintaining the EDL-R archive encompasses two aspects: system maintenance and material preservation. System maintenance involves the periodic installation of operating system/database upgrades and patches. The scope includes expenses related to hardware replenishment. For this, it is suggested the servers be replenished every five years to avoid hardware failures due to age and to take advantage of higher performance machines. Since the EDL-R servers were purchased in 2007 they are due for replenishment in 2012.

EPrints upgrades are less frequent since this requires porting customized software (e.g., password checking and aging). EDL-R is currently on EPrints version 3.01, but should be upgraded to version 3.3.7 to take advantage of a number of bug fixes and new features. For a list of features per version, go to URL: http://wiki.eprints.org/w/New_Features_in_EPrints_3.1.

Material preservation is a more challenging aspect of maintenance. The preservation strategy is based not only on archival standards, but also by paying close attention to technology changes and the file formats needed by the EDL community. File format changes could mean the lack of support for a particular file format or the increasing popularity of a new format. Fortunately, major shifts in file format usage are infrequent. However, when format changes occur, tools will need to be employed to search the EDL-R database/file system for old formats, then migrate these formats to the new format, and save the migrated file in the EDL-R record with the old format. Once the popularity of the old format has waned sufficiently, then the old format can be removed. There may be a few cases where the migration path may be uncertain, and better conversion processes may evolve over time. It is important to keep the original format until migration processes are stable and robust.

Another preservation activity is maintaining changes to the metadata (e.g., document sensitivity-level changes). Government policies and procedures for marking and handling of government information are evolving and, in some cases, becoming more open. It is important that the materials in the EDL-R be reviewed on a periodic basis to meet current requirements. The

curator will need to review all ITAR records for changes to the sensitivity level and marking language.

Because the EDL archive adheres to archival interface standards defined by the OIA, all material can be copied to an alternate archive that complies with the same standard. This flexibility allows all material and metadata to be moved to an alternate archival system, whether it is a successor to the EDL-R or an improved archival tool.

13.2 Usage Statistics

This section describes various usage aspects. The system tracks the IP address of each visitor/user who accesses the EDL-R, including the login page. Table 13.2-1 provides the number of unique visitors (i.e., unique IP addresses) and the total number of visits per year.

Table 13.2-1. Number of Unique Visitors

Year	Unique Visitors	Number of Visits
2009	147	557
2010	469	1525
2011	353	721
2012	63	147

Table 13.2-2 lists valid and invalid access attempts in the month of January 2012. The Valid Attempts category lists users who have EDL-R accounts and Invalid Attempts represent login failures. The Location column lists the city of origin based on the IP address.

Table 13.2-2. Valid and Invalid Access Attempts

Valid Attempts	IP Address	Location
	137.78...	Pasadena, CA
	205.201...	Bayfield, CO
	75.3...	Chicago, IL
	98.166...	Yorktown, VA
	70.186...	Hayes, VA
	98.234...	San Jose, CA

Valid Attempts	IP Address	Location
	198.116...	Halethorpe, MD
	128.149..	Huntsville, AL
	166.250...	Cerritos, CA
	98.112...	Sylmar, CA
Invalid Attempts	**IP Address**	**Location**
	209.85...	Council Bluffs, IA
	74.125...	Atlanta, GE
	146.165...	Newport News, VA
	66.102...	Groningen, Netherlands
	98.112...	San Fernando, CA
	59.92...	Madras, Tamil Nadu, India

Table 13.2-3 lists the top ten documents that have been downloaded over the course of the EDL-R task and the number of times each was downloaded.

Table 13.2-3. Top Ten Downloaded Documents

Top Ten Downloaded Documents	Number of Downloads
Pamadi, Bandu N. and Covell, Peter F. and Powell, Richard W. and Schoenenberger, Mark and Graves, Claude A. and Cerimeli, Christopher J. and Romere, Paul O. (2005) A Brief Analysis of Apollo Command Module Dynamic Stability. [Presentation] (Unpublished)	9
Sengupta, Anita (2008) Supersonic Unconstrained DGB Parachute in GRC 10x10 Wind Tunnel. [Test Results]	8
Ertle, Ivan D. and Morse, Mary Louise and Bays, Jean Kennahan and Brooks, Courtney G. (1978) The Apollo Spacecraft - A Chronology - Volumes I - IV. [Report]	8
Sengupta, Anita Mars Science Lab. Parachute Test data: Excel File for GRC Subscale Unconstrained Parachute Load Cell Data (axial load only). [Data]	7
Seiff, Alvin and Blanchard, Robert C. (2009) Comparative Atmosphere Structure Experiment (Pioneer Venus). [Other]	6
Catling, David Phoenix Mars Atmospheric Structure Experiment (ASE). [Data]	5
Achtermann, E., and Kapp, R., and Lehra, H. (1986) Parachute Characteristics of Titan Descent Modules; Planetary Probe; Final Report. [Report]	5
UNSPECIFIED (1976) Pioneer Venus Large and Small Probe Data Book. [Report]	5
Manning, R. (2005) Landing on Mars. [Presentation] (Unpublished)	5
Wercinski, Paul, Stardust Entry Observation "DIM" (Wercinski). [Data]	5

Table 13.2-4 shows the popular operating systems (OS) that visitors used when visiting the site in 2011.

Table 13.2-4. Popular Operating Systems used to Access the EDL-R

Operating System	Percentage
Windows XP	82.2
Windows 2008	8.9
Mac OS X	6.6
Windows NT	1.9
Unknown	0.3

Similarly, Table 13.2-5 lists the most popular browsers used to access the EDL-R in 2011.

Table 13.2-5. Popular Browsers used to Access the EDL-R

Browser	Percentage
Internet Explorer®	84.6
Firefox®	12.2
Safari®	2.8
Google Chrome	0.4
Netscape®	0.1

13.3 Subject Coverage

The penultimate step in the submission workflow is where multiple subject terms are selected to describe the item(s) being submitted. Figure 13.3-1 is an example of this page where search terms have been selected to describe a document concerning subsonic parachutes.

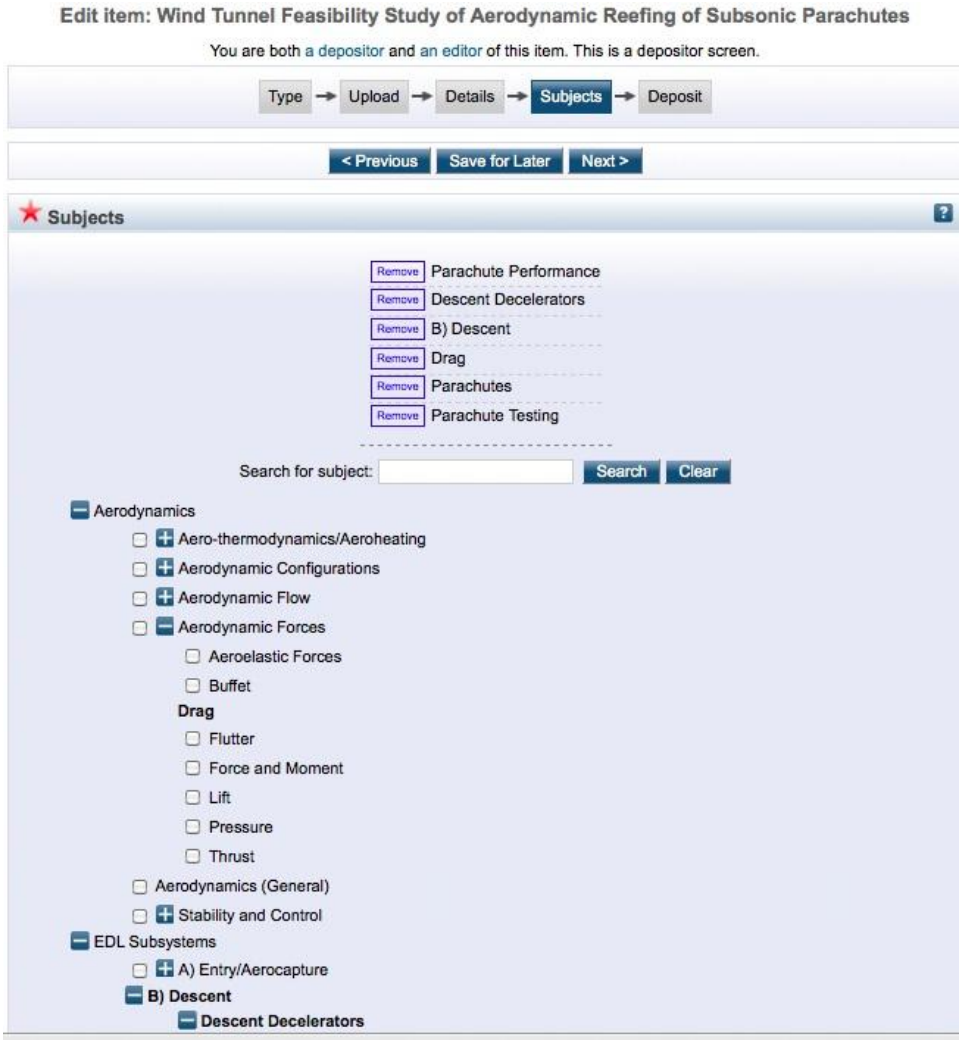

Figure 13.3-1. Example of EDL-R Subject Page

The subject tree is organized hierarchically with four levels and over 200 keywords. The user can expand or close a level by toggling the +/- icons next to the keywords. If a keyword is in bold font, then it indicates that it has been selected, as in the case of Drag and Descent in the example. What is not shown is the uncontrolled keyword field at the bottom of the page, which contains terms: reefing, porosity distribution, and squidding. The purpose of this field is to allow the user to specify keywords that were not found in the hierarchical list.

As mentioned, the controlled subject keywords are defined in a four-level, hierarchical subject classification tree. The *EDL-R Subject Classification* document (see supporting documentation*)* defines the list of subject terms by which submissions can be indexed and then retrieved via the various EDL-R search and browse methods. This document outlines a structured subject classification for the EDL discipline, which has the major classifications of:

- Aerodynamics
- EDL Subsystems
- Mission Phase
- Other Technical Topics
- Project Lifecycle
- Systems Engineering
- Testing

This classification scheme provides a broad subject structure for topics that are likely to occur in any large repository, while providing a framework for covering in more detail the technical areas unique to EDL.

Terms for the controlled subject classification were drawn from multiple sources. Much of the terminology was based on terms from the *NASA Scope and Subject Category Guide*, the *NASA Thesaurus*, and from work breakdown structure terminology. Additions and refinement of the subject terms and classification was conducted iteratively with input from a number of EDL-R experts and team members.

In addition to the controlled subject classification, the EDL-R allows the user to specify free-text uncontrolled keywords to be assigned to particular documents. These terms supplement the subject access to documents provided by the classification. In addition to providing enhanced keyword search retrieval, the uncontrolled keywords can be used by the curator to evaluate patterns of new terms/topics that are being entered into the repository (i.e., terms that might be appropriate additions to the controlled subject classification).

13.4 Current Archive Content and Status

This section describes the EDL-R archive content as of January 31, 2012. Table 13.4-1 lists the number of live records that have been released, the number of records that are waiting to be reviewed, the number of records in user's work area, and the total number of records.

Table 13.4-1. Total Number of EPrints Records

EPrints Records	Number of Records
Live Records	1,491
Records Under Review	649
Records in Managed Deposits (User work areas)	192
Total Number of Records	2,332

The types of EDL-R material consist mostly of reports and publications. The archive contains a number of records showing scientific data as shown in Table 13.4-2.

Table 13.4-2. EDL-R Archive by Type of Material

Type of Material (Number of Records)
Book (8)
Book Section (2)
Data (35)
External Repository Reference (6)
Model/Simulation (0)
Other (41)
Presentation (54)
Publication (262)
Report (934)
Review (6)
Study (45)
Teaching Material (2)
Test Results (99)

Note that some EPrints records can contain more than one type of document. For example, scientific data are often accompanied by documentation describing the data.

The missions with the dominant number of records are the SSP and Apollo, as shown in the alphabetical listing in Table 13.4-3.

Table 13.4-3. EDL-R Archive by Mission

Mission Name (Number of Records)
Apollo Missions (437)
Assured Crew Return Vehicle (1)
Beagle 2 (1)
Buran Project (1)
Constellation (1)
Crew Exploration Vehicle (2)
Fire (16)
Galileo (1)
Galileo Probe (7)
Gemini Missions (32)
Human exploration of Mars (2)
Huygens Probe (8)
Japanese Orbital Reentry Experiment (1)
Lunar Landers (1)
Magellan (26)
Mariner 10 (1)
Mariner 5 (1)
Mars 4 Orbiter (4)

Mission Name (Number of Records)
Mars 5 Orbiter (4)
Mars 6 Lander (6)
Mars 7 Lander (5)
Mars Exploration Rover (1)
Mars Exploration Rovers Missions A and B (1)
Mars Global Surveyor (1)
Mars Pathfinder (2)
Mars Phoenix Lander (4)
Mars Reconnaissance Orbiter (1)
Mars Science Laboratory (13)
Mars Surveyor (2)
Mercury (19)
Multiple (5)
Non-specific (66)
Pioneer Venus (73)
Planetary Atmospheric Entry Test (PAET) (2)
Probe/Lander (1)
SHARP (1)
SSP (515)
Stardust (18)
Surveyor (2)
Transport Spacecraft (1)
Unknown (0)
Unspecified (216)
Venera (2)
Venera 10 (1)
Venera 9 (1)
Viking (22)
X-33 (1)
X-37 (1)
X-38 (1)

As indicated in Table 13.4-3, some archived material applies to more than one mission (Multiple) and some are generic to any mission (Non-specific). There is the category of Unspecified, which is intended to capture material that is relevant to the EDL discipline (e.g., simulations and models).

The following is a listing of the number of items archived in the Aerodynamics subject category:

- Aerodynamics (1058)
  - Aero-thermodynamics/Aeroheating (447)
    - Ablative heating (35)
  - Aerodynamic Configurations (668)
    - Blunt Body (232)
    - Wing Body (429)
  - Aerodynamic Flow (726)
    - Hypersonic (314)
    - Laminar Flow (46)
    - Rarefied-Flow (18)
    - Subsonic (193)
    - Supersonic (231)
    - Transitional Flow (9)
    - Transonic (215)
    - Turbulent Flow (28)
  - Aerodynamic Forces (503)
    - Aeroelastic Forces (8)
    - Buffet (2)
    - Drag (323)
    - Flutter (3)
    - Force and Moment (289)
    - Lift (298)
    - Pressure (159)
    - Thrust (34)
  - Aerodynamics (General) (584)
  - Stability and Control (328)
    - Control Surfaces (207)

For the current listing of EDL-R subjects and the associated number of records, select the Browse→Browse by Subject option on the EDL-R webpage.

Over the course of this task, a variety of material has been archived. For example, the SSP DataMan collection of wind tunnel test reports was submitted and a number of documents on various EDL topics are in the process of being submitted. Much of retirees' personal collection of Mercury, Gemini, Apollo, and SSP documents along with multiple NASA technical note documents, technical memorandums, X-series technical memorandums (i.e., X denotes older designation given to the technical memorandums numbering scheme (e.g., 1970s)), and contractor reports have been archived. Contacts continue to be pursued towards locating information related to HL-10, HL-20, X-34, X-38, various other lifting body vehicles, and the CxP Orion parachute subsystem.

13.5 Summary of Material Pending Review

On January 31, 2012, there were 649 submissions awaiting the review process. Table 13.5-1 shows the majority of these submissions were technical reports.

Table 13.5-1. Material for Review by Type

Item Type	Count in Review
Book	2
Book Section	6
Data	36
Model/Simulation	2
Presentation	8
Publication	16
Report	571
Study	4
Test Results	2
Other	2
Total	649

In terms of subjects, the vast majority of the materials pending review concern the SSP (i.e., 486 records, 75 percent) wind tunnel test DataMan documents. Table 13.5-2 shows the number of records pending review per mission:

Table 13.5-2. Material in Review per Mission

Mission Name	Count in Review
Apollo Missions	52
Galileo Probe	20
Magellan	15
Mars Exploration Rover	3
MSL	3

Mission Name	Count in Review
MISR	4
Mars ISRU	1
Mercury	1
PAET	1
Pioneer Venus	6
SSP	486
Stardust	29
Unspecified	11
Viking	2
Other	15
Total	649

13.6 Summary of Material Pending Submission

Table 13.6-1 show items in the possession of the curator, but have not been submitted to the EDL-R. The majority of these items are in a digital format. However, the EDL-R team has a number of boxes containing hardcopy that will need to be scanned if the digital version cannot be found.

Table 13.6-1. Material Pending Submission

Description	Format	Status
Stardust CT scan data.	Digital	Pending Review
CxP Orion drop test.	Digital	Pending Submission
T. Knacke parachute papers.	Digital	Pending Submission
Northrop-Apollo parachute documents.	Digital	Pending Submission
SSP Ascent/Descent BET data.	Digital	Collection started by EDL-R Curator
Apollo Landing Test, Crew Couch videos.	Digital	Pending Submission

Description	Format	Status
NASA command module drop test.	Digital	Pending Submission
Infrared Sensing Aeroheating Flight Experiment (ISAFE) data; performed on SSP flight 96.	Digital	Uploading started
Huygens EDL documents.	Digital	Uploading started
X-38 drop test videos and documentation, includes parachute data.	Digital	In process of sending to JPL
HL-10, HL-20, X-33, X-24, X-38, ASSET, Lifting Bodies reports, and data books from personal library, JSC retiree.	Digital and Hardcopy	Sent to JPL for uploading
Hypersonic Thermodynamic Infrared Measurements, HYTHIRM.	Digital, Hardcopy, and digital image frames	Process started (publications) awaiting data processing completion
Gemini EDL material from Ft. Worth Federal Records Center.	Digital	Pending Submission
Mercury EDL material from Ft. Worth Federal Records Center	Digital	Uploading started
Apollo Pad abort stills and Little Joe launch abort video.	Digital	Sent to JPL for uploading
Apollo impact test, landing simulation, parachute qualification video.	Digital	Pending Submission
Apollo land landing damage analysis images.	Digital	Pending Submission
Personal Library, JSC employee working on Orion.	Digital	Uploading started
Personal library, JPL employee. Various documents on parachute design.	Hardcopy	Pending Submission

Description	Format	Status
Personal library, JSC employee. Various reports and presentations on EDL designs and tests - primarily for Apollo and SSP.	Digital	Uploading started
Personal Library, JSC retiree. Various documents related to EDL.	Digital and Hardcopy	Partially completed only
Personal Library, Langley retiree. Various documents related to EDL.		Pending Submission
Personal Library, JPL employee working on MSL.	Hardcopy	Pending Submission

13.7 Summary of Material to be Collected

Table 13.7-1 lists material that has been identified, but not collected for submission.

Table 13.7-1. Points of Contact for Material to be Collected

Description	Point-of-Contact
Lifting bodies, e.g., X-38, HL-10, HL-20 reports, test data, videos, and databases.	Ricardo (Koki) Machin, JSC Christopher Cerimele, JSC Jay Lebeau, JSC Paul Romere, JSC retired
CxP Orion EDL designs, test data, and associated documentation.	Phil Robinson, JSC Jay Lebeau, JSC
Mars Global Surveyor data	Robert H. Tolson, NIA Robert C. Blanchard, NIA
HYTHIRM	Thomas J. Horvath, LaRC Robert C. Blanchard, NIA
Galileo Probe reports.	Robert C. Blanchard, NIA
X-38 drop tests and parachute videos and data from JSC.	Richardo (Koki) Machin, JSC Christopher Cerimele, JSC Jay Lebeau, JSC
Apollo parachute test video with voice-over dubs from JSC.	Tim Fisher, JSC

Description	Point-of-Contact
Apollo Little Joe Launch Abort Test Video and Pad Abort Stills.	Tuan Truong, JSC
Odyssey data.	Robert H. Tolson, NIA Robert C. Blanchard, NIA
Aero database for 70 degree half-cone forebody (using MER and Phoenix data).	Robert C. Blanchard, NIA
Pioneer Venus documents, for example: "Final report on Investigation Of The Probe Buffeting Problem at Low Subsonic Mach Numbers," by Vincent U. Muirhead, Principal Investigator, The University of Kansas, July 1975. Large Probe Pressure Vessel Aerodynamics, Hughes Final report HS507/Pioneer Venus, Oct., 1976; prepared by T.W. Oswald. Pioneer Venus Deceleration Module Final Design Review, Hughes Subcontract 08-737440-L72, by General electric Company, Entry, and Environmental Systems Division, final data report, Pioneer Venus Static and dynamic transonic wind tunnel tests by S.A. Weinberg, July 11, 1975.	Robert C. Blanchard, NIA
Magellan data and documents.	Robert H. Tolson, NIA Robert C. Blanchard, NIA
Aerobraking papers.	Public sources
Phoenix EDL; George Washington University final report.	Robert C. Blanchard, NIA
SSP Orbiter Experiments (OEX): HiRAP, OARE, SUMS, SEADS, SILTS.	Robert C. Blanchard, NIA
Crew Exploration Vehicle Program, Thermal Protection System (in Windchill), JSC.	Jay Lebeau, JSC
Parachute data from Crew Exploration Vehicle (CEV) Parachute Assembly Subsystem (CPAS) and Orion.	Richardo (Koki) Machin, JSC Howard Hu, JSC
MLAS project large parachute test data (NESC).	John Baker, JPL
Huygens's EDL collection.	Dr. Jean-Pierre Leberton, ESA
Mars Exploration Rover EDL material.	Mission Project Office, JPL

13.8 Summary of Material to be Researched

Table 13.8-1 lists other subject areas that may have valuable material to archive, but further research is required.

Table 13.8-1. Points of Contact for Material Research

Description	Point-of-Contact
All EDL material related to the Crew Exploration Vehicle/Orion - JSC	Phil Robinson, JSC Jay Lebeau, JSC
MSFC-led Space Transportation Programs, including Reusable Launch Vehicle (RLV) Programs: X-33, X-34, X-37, NGLT, TSTO*, and Orbital Space Plane (OSP)*, and associated technologies programs: RLV and NGLT *MSFC-funded studies	Paul Romere, JSC retired Michael J. Green, ARC retired X-34, Henri J. Fuhrmann, Orbital Sciences Dale Andrews, MSFC retired
Ames documentation on Thermal Protection Systems for some of the MSFC-led Space Transportation Programs. (Over 100 boxes, stored in Building N-229).	Michael J. Green, ARC retired
X-38 data and databooks - JSC	Jay Lebeau, JSC
Personal library (JPL employee)	EDL-R Curator; pending JPL Limited Release
Personal Library (Retired JSC employee)	Paul Romere, JSC retired
NASA Langley parachute material	Juan Cruz, LaRC
LCROS data and analyst's notebook	Data is publicly available from pds.nasa.gov and Notebook is at http://an.rsl.wustl.edu/lcross/lcrossbrowser/
Pioneer Venus Large Probe heatshield data	Jim Garvin, GSFC Gary Allen, ARC

Description	Point-of-Contact
Huygens Probe material - ESA	Contains links to data and documentation: http://www.sciops.esa.int/index.php?project=PSA&page=huygens
Mars Exploration Rovers EDL material	Data is publicly available from pds.nasa.gov and Notebook is at http://an.rsl.wustl.edu/mer/ For project documents, contact John Callas, MER Project Manager, JPL
Viking reprocessed data	James E. Tillman, University of Washington
Mars Pathfinder	Data is publicly available from pds.nasa.gov and other technical documentation located at JPL
Mars Phoenix	Data is publicly available from pds.nasa.gov and Notebook is at http://an.rsl.wustl.edu/phx/solbrowser/default.aspx
SSP Wind tunnel data Access Tool (SWAT), JSC	Accessible with IDMAX password. URL is web-eg3.nasa.gov/swat. Post on EDL-R main page

14.0 Interaction with the EDL Community

During this assessment, the EDL-R team took the initiative to engage the EDL community. The following paragraphs describe some of the key interactions.

In 2008, the team prepared a paper, poster, and demonstration for the International Planetary Probe Workshop, held in Atlanta, Georgia. The purpose of the paper, entitled "Rescuing EDL Data," was to introduce the community to this newly established archive and to describe the various search and subscription features (see Appendix A). The poster illustrated the submission workflow and the review processes, provided greater detail on the search options, and described the security features. The poster session and demonstration were well attended with lots of interest and enthusiasm for the EDL-R.

In 2009, EDL-R team members attended the CxP Orion/MSL Workshop where engineers discussed various EDL issues from both missions. The facilitator of the meeting was Mr. Daniel Murri, NASA Technical Fellow for Flight Mechanics, who allocated time to present an EDL-R overview and demonstration.

14.1 Presentations

The EDL-R team presented several presentations on EDL-R to three types of audiences: those who were interested in a similar archive system, potential EDL-R users, and providers of EDL material. On more than one occasion, the team was invited to give a presentation to multiple NASA facilities and groups on the EDL-R and its features. One group in particular was the

Entry Systems Division at the Ames Research Center (ARC), who looked for a way to archive the large number of boxes and cabinets filled with thermal protection papers. Although the EDL-R was considered as a solution, the group made the decision to use their existing document management tool with future plans to move appropriate documents into the EDL-R. A presentation was given to JPL's Planetary Protection group, who were looking for a tool to archive test data from various missions. In this case, they were looking to run their own version of the EDL-R; however, they were never able to secure funding for a sample archive. Presentations were given at various NASA Centers to groups who were interested in using and providing material, including: JSC's Crew Exploration Vehicle Parachute Subsystem group and interested personnel from Langley Research Center's (LaRC) Atmospheric Flight and Entry Systems Branch, JPL's Spacecraft and Mechanical Engineering group, and NASA's Mars Program Office.

In the team's quest for "at-risk" material, presentations were given to organizations outlining specific subjects of interest. Audiences included the JSC-CPAS (CEV Parachute Assembly System) group, LaRC's Atmospheric Flight and Entry Systems Branch, JSC and ARC's library archives, and LaRC's Records Office.

14.2 Links to the EDL-R

To increase the visibility of the EDL-R within NASA and the EDL community, the team researched NASA websites where a link to the EDL-R could be posted. Two years ago, the EDL-R team contacted the NASA Technical Fellow who manages the Flight Mechanics webpage on the NASA Engineering Network (NEN).[2] He agreed to provide a link to the EDL-R, which is listed under the "Links" heading (https://nen.nasa.gov/web/fm/links). The team also inquired about providing a link on the Aerosciences webpage that is on the same parent site.

14.3 EDL Community Contact Information

During this assessment and the involvement with persons in the EDL community, the EDL-R team compiled a contact list from across NASA who have worked on or are currently working on EDL projects. See Appendix B for a listing.

15.0 Transfer of System to Sponsor

After numerous inquiries for sponsorship of the EDL-R, the Office of the Chief Engineer at JPL agreed to accept the responsibility. Since the curator, developers, and hardware are located at JPL, this makes the transfer much easier (e.g., minimal training) and inexpensive (e.g., no shipping and installation costs, or travel expenses).

[2] https://nen.nasa.gov/web/nen/community/technical

15.1 Transfer Agreement

The terms of the transfer are primarily driven by concerns of the EDL-R team. The terms address the continued collection and archive of material, and long-term access. The sponsor agrees to:

1. Provide funding to train a new curator.
2. Significantly reduce the backlog of material within the next year.
3. Keep the EDL community informed about the EDL-R and encourage usage.
4. Actively seek material from other NASA Centers, federal archives, and retirees based on the available funding.
5. At a minimum, provide funding for back-ups, security patches, and any other tasks/expenses that are needed to keep the site available to users.
6. Find an alternate sponsor (e.g., NASA STI) should funding cease to be available.

15.2 Hand-off Plan

Specific sections of this document have been written to aid in the transition to JPL, including:

- The state of the archive, material pending collection, and potential leads are detailed in Section 13.0.
- Recommendations on software improvements and hardware replenishment are provided in Section 15.3.
- A partial list of names in the EDL community is listed Appendix A.

In addition to this, presentations, meeting minutes, and other relevant documentation are provided on a DVD.

As part of the hand-off plan, JPL took the initiative to train a new curator before the NESC assessment was completed to ensure adequate familiarization with the task history, curation processes, and EDL-R team members. Doing this in parallel with the systems already residing at JPL allowed the hand-off to be straightforward.

Once the collection activities were completed for this task, only two tasks remained to be fulfilled in the final phase. The penultimate close-out milestone was the hand-off to JPL, which occurred on February 29, 2012. This transition marked the end of this NESC task and the beginning of a renewed focus on collecting EDL material from recent and current missions. The final milestone will be the final report presentation to the NRB, which occurred in mid-March 2012.

15.3 Looking Forward: Short- and Long-term Goals

The primary priority of this task was to collect and archive older technical and engineering materials that were at risk of being lost. The secondary priority was to collect and archive

material from recent missions (i.e., 1990s to present). For the future goals of the EDL-R, the EDL-R team suggested that the JPL sponsor continue to support and contribute to the NASA EDL community by providing a NASA-wide resource to aid engineers in the design of future EDL systems so that they can continue to acquire and archive older and current technical/engineering material.

For the short-term, the EDL-R team recommended that the JPL sponsor continue to collect at-risk material. The collection efforts of this task, while successful, found that a lot of older material still remains in archives at various NASA Centers and in employees' personal files. To this end, the EDL-R team has attempted to document what is known to be available with points-of-contact that can help narrow the search effort (see Sections 12.7 and 12.8). In reviewing the depth of material on some older missions represented in the EDL-R, the EDL-R team identified the following that should have their collections expanded:

- Surveyor
- RAM-C
- PAET
- GLL Probe

Other short-term goals that the EDL-R team recommends are to:

1. Archive and release highly valuable material as soon as possible, e.g., Knacke parachute material.
2. Expand the collection for underrepresented missions.
3. Continue to seek material from retirees, NASA libraries, NASA Center records/archives, and Federal archives.
4. Improve the user experience in downloading multi-gigabyte collections.
5. Increase visibility to external search engines to promote visibility.
6. Establish a domain expert support network drawing from the EDL community.
7. Identify and implement ways to inform NASA and the EDL community about this resource.
8. Replenish the servers.

Long-term goals for the EDL-R have already been mentioned in this report, including the below additional recommendations:

1. Establish working relationships to support material flow into the EDL-R. Relationships with current missions, NASA Center libraries/records, professors, retirees, and NASA historians are vitally important to the continued expansion of the EDL-R since the majority of leads and valuable material come directly from them. To make the archival process easier for currently NASA employees and retirees, the EDL-R team recommends

that the curator offer to organize and digitize hardcopy material, and to offer a DVD of the digitized documents along with the return of the original hardcopy.

2. Collect EDL material from current missions. Recent missions, such as MSL and CEV/Orion, have extensive libraries on EDL, including valuable Apollo-era material. Since these designs will likely be referenced by future missions, the EDL-R team strongly recommends that the curator establish a good relationship with engineers and document librarians working on these missions to ensure that their engineering and technical material is archived.
3. Create and maintain a list of material to periodically send to STI. At the start of the task, the EDL-R team spoke with lead members of STI about the purpose of the EDL-R. While supportive, they asked that material be provided that was not in their archives. Not all material in the EDL-R qualifies to be in STI, such as the Stardust data and videos, but any NASA documents that are not found in STI should be periodically exported and sent to STI.
4. Update the subject keyword list. To keep the controlled subject list up to date, the curator should periodically review the set of uncontrolled subject keywords to identify recurring words that should be added to the controlled subject list. The EDL-R team also suggested that the curator run the learning component of the Subject Recommender over the entire archive to ensure that a meaningful set of recommended subject keywords are strongly related to what is being archived.
5. Keep track of newly published papers and authors. Doing this has two benefits: new material is added to the EDL-R and potential new users can be identified.
6. Make improvements to the EDL-R that promotes content and encourages new users. One suggestion is to create an e-mail list of registered users (perhaps by user type) and unregistered users, where registered users would get announcements on recently added NASA material and unregistered users would receive announcements on valuable public material. It has been suggested to post a bibliography of public material on the login page so that unregistered users, such as students, can also make use of this resource.
7. Monitor the file format evolution to determine when to migrate old versions. This issue concerns activities related to preservation. To keep the EDL-R content usable, it is recommended that the curator periodically refresh a list of archived file formats to track those that are fading from use and those that are becoming more popular.
8. Upgrade to the most recent version of EPrints. The EDL-R team recommends upgrading to the current release for two reasons: 1) upgrading will become more difficult as additional versions are released; and 2) the EDL-R may be able to take advantage of new features to replace custom software. For example, edit locking which locks records to reduce the risk of multiple people editing the same record at the same time, plug-in based issue tracking system to replace the custom-developed URL verifier tool, improve

privilege handling that allows more fine-grained control to what a user is allowed to do, and improve workflow and document management.

16.0 Findings, Observations, and NESC Recommendations

16.1 Findings

The following findings were identified by the EDL-R team based on their experience with this task:

F-1. EDL material was located in a variety of locations from institutional files to private collections. The EDL-R team discovered many caches of EDL data and have leads on many more sources.

F-2. The most effective method of obtaining EDL material and supporting information is through face-to-face meetings. People were busy and getting them to focus on archiving documents was always a lower priority. On more than one occasion, the EDL-R team found that sitting down with the person is the best way to get their attention. Projects of this nature should plan for a travel budget.

F-3. The time and effort to collect EDL material can be far less than the submission and review time. After a few dozen submissions, the EDL-R team reduced the submission time to around 15 minutes. However, the review effort can take days if the document(s) are not publicly available. In cases where the document is either sensitive or so old it has no markings, it could take days or weeks before it is released.

16.2 Observations

The EDL-R team identified the following observations that could have an impact on future archival initiatives and the engineers who seek older, technical information:

O-1. It becomes exponentially more difficult to recover EDL data as the time from project completion increases. There is a large volume of existing EDL-related data and, as time passes, it is becoming much harder to locate and completely correlate. As people retire or move to new projects, the data may be passed to remaining team members or even be taken home and stored as data that is too important to lose. Eventually, the space that the data occupies is needed and the files are thrown away.

O-2. Many of the current projects are relying on the old data, and when they "push the edges of the envelope" on their designs, access to the old data is required to ensure their assumptions are still valid.

16.3 NESC Recommendations

The following recommendations were identified by the EDL-R team:

R-1. NASA should establish a technical documents archive policy for each mission similar to the required scientific archive. ***(F-1, F-2, O-1, and O-2)***

R-2. NASA should consider how to fund efforts to collect EDL material from closed programs and retirees before that knowledge cannot be recovered. (***F-1, F-2, and O-1)***

17.0 Lessons Learned

Lessons learned from the development of the EDL-R point to several areas of interest. The task of locating documentation and data for archiving needs to proceed as the result of many decisions, the least of which being what information qualifies as archival candidates. Those considered for EDL-R were initially limited to EDL; however, it soon became apparent that information related to launch and ascent were equally important archival candidates. The candidate archival items were expanded to include formal and informal reports, memorandums, presentations, events, flight and ground test data, analyses, drawings, and decisions, which shaped the direction of the program of interest.

To further enhance the presence of EDL-R, all NASA Centers and associated contractors must be made aware of the archive facility and the importance of transferring candidate information to the EDL-R. If it does not become a natural concept of archiving, the importation and retrieval usage will only decrease due to not being aware of the facility, or a lack of dedicated funding and manpower on the part of NASA Centers and contractors to pursue active archiving.

As a result of the efforts in place to define and implement EDL-R, any archival undertaking should adhere to standard IT practices to control access and protect content. Archival standards should be followed so that future application upgrades or database migrations can be easily accommodated. Once the concept of archiving has been set, it must be a dedicated and fully funded effort, both in dollars and manpower, to assure that the maintenance and system availability remains in place for the extended future.

18.0 Definition of Terms

Corrective Actions	Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.
E-print	Also refers to the open-source tool, EPrints.
Finding	A relevant factual conclusion and/or issue that is within the assessment scope and that the team has rigorously based on data from their independent analyses, tests, inspections, and/or reviews of technical documentation.
Lessons Learned	Knowledge, understanding, or conclusive insight gained by experience that may benefit other current or future NASA programs and projects. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure.

Observation	A noteworthy fact, issue, and/or risk, which may not be directly within the assessment scope, but could generate a separate issue or concern if not addressed. Alternatively, an observation can be a positive acknowledgement of a Center/Program/Project/Organization's operational structure, tools, and/or support provided.
Problem	The subject of the independent technical assessment.
Proximate Cause	The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome.
Recommendation	A proposed measurable stakeholder action directly supported by specific Finding(s) and/or Observation(s) that will correct or mitigate an identified issue or risk.
Root Cause	One of multiple factors (events, conditions, or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated or modified, would have prevented the undesired outcome. Typically, multiple root causes contribute to an undesired outcome.
Supporting Narrative	A paragraph, or section, in an NESC final report that provides the detailed explanation of a succinctly worded finding or observation. For example, the logical deduction that led to a finding or observation; descriptions of assumptions, exceptions, clarifications, and boundary conditions. Avoid squeezing all of this information into a finding or observation.

19.0 Acronyms List

ACL	Access Control List
ARC	Ames Research Center
ASE	Atmospheric Structure Experiment
ATK	Alliant Techsystems
BET	Best Estimated Trajectory
CEV	Crew Exploration Vehicle
CPAS	CEV Parachute Assembly System
CxP	Constellation Program
DB	Database
EDL	entry descent and landing
EDL-R	entry descent and landing repository
FAQs	frequently asked questions
GB	gigabyte

GN&C	Guidance, Navigation, and Control
ISO	International Organization for Standardization
IT	Information Technology
ITAR	International Traffic in Arms Regulations
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LAMP	Linux, Apache, MySQL, and Perl
LaRC	Langley Research Center
LCROS	Lunar CRater Observation and Sensing Satellite
LDAP	Lightweight Directory Access Protocol
MB	megabyte
ML	Machine Learning
MSL	Mars Science Laboratory
MTSO	Management Technical Support Office
NEN	NASA Engineering Network
NESC	NASA Engineering and Safety Center
NIA	National Institute of Aerospace
NRB	NESC Review Board
OAI	Open Archives Initiative
OS	Operating System
OSP	Orbital Space Plane
PAET	Planetary Atmosphere Experiments Test
RAID	Redundant Array of Independent Disks
RAM-C	Radio Attenuation Measurement Flight C
RLV	Reusable Launch Vehicle
SBU	Sensitive But Unclassified
SCSI	Small Computer System Interface
SSL	Secure Socket Layer
SSP	Space Shuttle Program
STI	Scientific and Technical Information (NASA)
SVM	support vector machines
SWAT	SSP Wind tunnel data Access Tool
TB	Terabyte
U.S.	United States
URL	Universal Resource Locator
USB	Universal Serial Bus
V&V	Validation and Verification
XML	EXtensible Markup Language

20.0 Appendices

A. Rescuing EDL Data

B. EDL Community Contacts

Appendix A. Rescuing EDL Data

(Paper published in the International Planetary Probe Workshop, 2008)

Rescuing EDL Data

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ABSTRACT

After 50 years of spaceflight a tremendous amount of information has been written and published about the Entry, Descent, and Landing (EDL) discipline. While there are holdings, with individuals and partial collections at various NASA web sites, there is no central repository or portal for this critical information. This paper will discuss a new initiative for archiving and preserving technical EDL material, which aims to provide a single resource for archiving and preserving EDL material from recent missions as well as older data that are at risk of being lost.

Background information will be presented establishing the rationale and charter for the Repository along with a description of the scope and intended users.

Key features of the web-based EDL-R will be presented, including:

- a standards-oriented open-source solution
- security measures
- various retrieval methods
- submission and review processes
- subscription and automatic notification

Lastly, plans for future capabilities, expanded repository content, and maintenance will be described.

Introduction

After 50 years of spaceflight a tremendous amount of information has been written and published about the Entry, Descent, and Landing (EDL) discipline. While there are holdings with individuals and partial collections at various NASA web sites, there is no central repository or portal for this critical information. The lack of a centralized collection was the impetus for members in the EDL community to request that the NASA Engineering and Safety Center (NESC) fund a task to develop a digital EDL archive (https://edlr.jpl.nasa.gov).

The content of the EDL repository (EDL-R) focuses on technical and engineering data that contributed to the research, development, test, and flight of EDL systems. Some examples are:

- Development and test data
- Transmitted sensor readings & telemetry from various missions
- Software used to process EDL data
- Reports and analysis
- Bibliographic references to published papers

A variety of disciplines are represented:

- Aerodynamics
- Propulsion & decelerators
- Guidance & control
- Thermal Protections Systems
- Separation systems

Of keen interest is older material, such as Viking parachute and EDL data, which has already proven useful to the EDL design of the Mars Science Laboratory mission. This kind of material is "at risk" of being lost, and it is the highest priority for the content development of the repository. Materials can be at risk for a variety of reasons. Many of the early EDL missions took place in a time when information systems were not in wide use, and paper was the medium for storing information. Combine this with the "graying" of the NASA workforce, many of the pioneers' in the EDL community are, or have, retired, and there are many documents and test data that are vulnerable to being lost.

The EDL-R Team has identified a number of "at risk" missions and types of data that are to be given a priority for collection, as shown in Table 1.

Table 1. Examples of High Risk Materials

Missions (examples)	Types of Information (examples)
• Viking I&II (1976) • Pioneer Venus (1978) • Galileo [entry and descent] (1989) • Project Fire [Heatshield testing] (1962) • Magellan [aero-braking data] (1989) • Early planetary atmospheric entry tests • Apollo (1961-1972) • Gemini (1965-1966) • Mercury (1959-1963)	• Raw engineering flight data • Time reference data • Calibration, scale factors, etc. • Aerodynamic data base • Mass properties (detailed) • Software design documents • Process or reconstructed data

Along with identifying priorities for the collection of EDL related materials, the team has identified an initial strategy to collect this information. Key individuals have been identified for each of the at risk missions. These individuals will act as coordinators for the location of materials. They will identify key community contacts and network to identify, collect, and possibly interpret these materials. If necessary, an informal peer review process will be set up to evaluate the materials for accuracy and appropriateness for the repository.

Along with at-risk data, the Repository is also collecting contemporary EDL-R materials especially where the interest/need for the data is high. Included in the current ingest plan is Stardust Entry Observation EDL and shuttle EDL. Shuttle EDL material is viewed as at-risk because the program will be retired in two years and there is currently no archive plan. Fortunately, in the process of searching for some of the high-risk data, a significant portion of the early Columbia EDL test data was found in a private holding and that data has been transferred to the EDL-R for use. The capture of *all* shuttle data is beyond the scope of this activity and even the archival of shuttle EDL data would be a monumental effort extending beyond the scope of the EDL-R development phase. For this reason, proposals for capturing all shuttle EDL data are being planned.

Tool Selection

An open-source solution was sought to reduce development time and to take advantage of existing digital library practices and standards, such as the Open Archives Initiative (OAI) and the Dublin Core Metadata Initiative (DCMI). At the completion of a trade study, which reviewed and tested similar open-source, web-based digital library solutions, EPrints was selected. This tool was developed at the School of Electronics and Computer Science, University of Southampton, UK (see www.eprints.org) and is used by universities, libraries, and businesses worldwide,

One of the main benefits of open-source software is absence of copyright restrictions. This flexibility has allowed the team to customize the EDL-R to meet the specific needs and constraints of the user community. For example, it has been customized to support encryption, user authorization and authentication, additional browse options, as well as a number of other added capabilities that will be described in this paper.

Search & Retrieval Methods

The EDL-R database provides a number of distinct search and browse methods for the identification and retrieval of relevant materials. A "Quick Search" and a "Simple Search" capability both allow easy keyword searching of the following fields:

- document content
- title
- description
- individual authors
- date
- uncontrolled keywords
- subjects

"Quick Search" provides an intuitive "Google-like" search box at the top of each page, while "Simple Search" give uses the added flexibility of sorting results by year, author's name, or by title. The "Advanced Search" function allows the user to build a targeted search by specifying a variety of different criteria, which are represented in the database. This search combines the criteria using the Boolean operator AND. The search criteria used in all searches can be saved for later re-use.

Browse capabilities are well integrated into the user interface. Browsing can be done by *Year*, *Subject*, *Author*, or document *Type*. The browse by *Subject* provides a good way to find all the documents in the repository on a specific topic. The hierarchical nature of the subject access provides the user with a rich way to explore the repository. In the future, an option to browse by Mission will be added.

Submission Process

Registered users can submit material into the EDL-R by entering information into web-base forms. The process is divided into 5 distinct stages: *Type, Upload, Details, Subjects,* and *Deposit* stage.

The *Type* stage involves selecting the type of material that is being added to the repository. The customized item types that are available to choose from in the EDL-R includes book, book section, dataset/data, model/simulation, presentation, publication, report, review, study, teaching material, and test results. In addition, there is also an *Other* item type that can be selected for

material that does not fit into any of the 11 distinct item types. A description is provided for each of the item types to help the depositor select the appropriate type.

The next step in the submission workflow is the *Upload* stage. In this stage, the depositor is presented with an interface to upload the material to the system. It is also in this stage that the depositor specifies the format and the sensitivity level of the material. The EDL-R has a list of formats that include various image, video, and application formats that are natively recognized by the system. However, any and all formats are accepted. The sensitivity level specifies who has access to the material once it is in the repository. There are five customized sensitivity levels: *None, Copyright, NASA-sensitive, ITAR, and NASA-sensitive ITAR.* All users can access materials with a *None* or *Copyright* level. *NASA-sensitive* materials are only accessible by NASA employees, *ITAR* materials are only accessible by U.S. persons, and *NASA-sensitive ITAR* materials are only accessible by U.S. persons who are also NASA employees.

The bibliographic information about the material, such as title, author, and publisher, is specified in the *Details* stage of the workflow. This step in the workflow has been customized to capture information that will help preserve the material and will provide a rich set of search criteria. Because there are several fields to be filled out some fields are pre-filled with default values. Other fields have an auto-completion feature where matching options are presented as the depositor types in a value. Some fields are mandatory and will prevent the material from being deposited if a value is not supplied. Specifying as much information as possible in this stage makes the material more easily searchable.

The *Subjects* stage involves selecting the subjects or keywords that are most appropriate to the material being submitted. In this stage, a predefined subject tree is presented from which the depositor can choose. Multiple subject keywords can be selected. Aside from the predefined subject tree, the depositor may also specify *Uncontrolled Keywords*. Uncontrolled keywords are free-form words or phrases that describe the material.

All the work has been done to upload and describe the material being submitted. The final step in the submission workflow is to deposit the material to the repository. This is performed in the *Deposit* stage. The depositor is presented with legal language regarding any rules and regulations with submitting material in the EDL-R. It is implied that by depositing the material, the depositor is in agreement set forth by the terms of the legal language.

Review Process

Deposited materials are reviewed before being released to the community. Once a submission has been deposited it is held in a temporary review area where the curator or editor can review the completeness and accuracy of the metadata. The curator's review process may include checking the submission for metadata completeness and accuracy, condition of the submitted material (e.g., quality of scanned documents), and the appropriateness of the material being submitted.

After the material has been reviewed, the curator has three courses of action. If the submission does not pass the review process, the curator may "return" the item to the depositor so that any inadequacies can be corrected, or the curator may decide to simply destroy the item. Both of these actions will generate a notification e-mail message to the depositor. If the submission passes the review process, the curator can approve it. It is only after the curator approves the submission that it goes into the live repository where it becomes available.

Special Features

Automatic Notification

Users can be notified of new material through the use of the *Save Search* capability. When search criteria are saved using any of the three search mechanisms (Quick, Simple and Advance search) it can also be configured to send an e-mail notification listing new material that matches the search criteria. The frequency of e-mail notifications can be set to daily, weekly, monthly, or never.

Most Wanted List

A unique feature of the EDL-R is the 'Most Wanted' list, which serves as a classified ad for rare and sought-after EDL material. Since it is located on the login page permissions are not required to view it, however, registered users can add to it. As material is located and submitted to the EDL-R, the curator will remove the request from the list.

System Security

Developing a secure repository to store and serve entry, descent and landing data presents some interesting challenges. These issues range from user account creation and password expiration to ITAR rules and regulations. In order to best understand these issues and their complexity, it is important to understand the assumptions and conditions under which the EDL-R will be used.

One key determination that was made early on in the planning process regards the type of information that can be stored in the repository. The EDL-R will house public, copyright, and Sensitive But Unclassified (SBU) information, but no classified material shall be kept in the EDL-R. This excludes discrete and classified information, new technology, intellectual property, patents, competitive information, budgets, and proposals. This decision creates different security requirements, often more lax, than a repository that allows these more sensitive information types.

Another assumption that was made affecting the design had to do with the metadata for each entry. Due to the sensitivity of some data, no metadata will be displayed to users who do not have access to the document. This change affected how search, browse, and other parts of the system were to be modified.

To best understand the modifications and tailoring done to the EDL-R, understanding data sensitivity and user roles is paramount. Modification to the EPrints software has dealt directly with one, two, or both of these components. Users have been separated into distinct groups

based on their affiliation with NASA or not, and their status as a U.S. person. There are two other roles that are more administrative in function, one being an actual administrator who can modify accounts and change passwords, and others are reviewers charged with making sure that the material submitted has adequate metadata associated with it.

User accounts are created via a separate site, where potential users fill out a form containing their work and project information, along with some points of contact for verification purposes. Once verified, the account is created and given access depending on the outcome of their background check.

Understanding user roles and accounts is only one of the two key components to the repository. This user role can be mapped to document sensitivity levels in what can be best described as an access control list (ACL). The document sensitivity levels relate to the SBU classifications NASA uses, including ITAR and NASA Sensitive markings. These markings will originate from the author's center when the document goes through review.

These markings are included with the digital files during the upload process, and verified by the editors of the repository. From this point on, this mapping is used to allow or disallow access to the document by various users in the repository. For example, if a link to a document is shared between users, one having access to the document and the other not, an access denied message will be issued to the user who does not have access when visiting the link. This is done by authentication mechanisms that map the sensitivity level and the user role, determining access.

Once the decision to make metadata invisible to users without document access was made, there were two major areas that needed to be modified: Browsing and Searching. Both are very similar in what needed to be accomplished, but how the two are achieved is very different. Search results in the default configuration are all shown to the user regardless of their sensitivity level. The EDL-R now filters out search results that are not accessible by the user. It does this by intercepting the results before being displayed to the user, and then determining if the sensitivity of the document maps to the user role via an ACL. If it does not, it is removed from the listing of results; if access is granted then the result is passed along to the screen processor for display. This same methodology is used for the saved searches that users can use to find or store information that they've searched on before. Because users can search via other users' saved searches, this needed to be a dynamic filter, done in real time.

Unlike the search features, the browse feature, also known a view, is generated statically at some predetermined interval. Because the repository serves static pages, the EDL-R cannot dynamically filter out these lists. The solution to this is to dynamically allow or disallow access to the browse pages. Before this authorization is given, the browse pages are created on a per user type basis. This means each user type has its own browse page that will authenticate against.

The browse pages are created very similarly to the search results, whereby a user role is used to filter out documents, which are inaccessible to that role. From this, static HTML pages are created and stored on the web server and are accessed through links found on the site.

These links are dynamically created when the user logs in, so all links pointing to static browse pages point to the one associated with their user role. To avoid typing an alternate URL directly into the address bar of a browser, the EDL-R also does authentication in the background for all requests to these browse pages, giving a 403 (forbidden) error when a user attempts an unauthorized access to a browse page.

The default system configuration is a completely open access, unencrypted system, meaning no password or user account is needed to access documents stored in the repository. The EDL-R uses password only access over secure socket layer (SSL). These alterations required a comprehensive rule set for the passwords (including length and special characters), and future plans of more robust password checking, including keyboard patterns and dictionary based checking. Along with these password requirements, a custom aging component built on top of the existing repository and database.

The aging component can be easily modified for any variable amount of days, and sends reminder emails regarding password expiration 1 and 2 weeks prior to expiration. This reminds a user to change his or her password before expiration, which can be done through their EDL-R profile. Once a password expires, only a repository administrator has the ability to reset it.

While a lot of work has been done to the repository thus far, there are plans for future developments. One addition to be made will be anti-virus checking to all incoming files. While this does not affect the repository directly, the EDL-R should not disseminate information to users that contain virus, exploits, or other malicious code.

Other plans include interfacing with the NASA LDAP for authentication and authorization. This would eliminate the need for a separate password checking and aging component because all of the information is stored and retrieved in a central location.

Maintenance & Preservation

Maintaining the EDL archive encompasses two aspects: regular hardware and software maintenance, and preservation of the material stored in the archive. The former is fairly straight forward up until the time technology surpasses the current architecture. Because the EDL archive adheres to archival interface standards defined by the OAI, all material can essentially be copied to an alternate archive that complies with the same standard. This flexibility will allow all material to be moved to an improved archival system.

Preservation of the material may be more challenging aspect of maintenance. The preservation strategy is based not only on the open source software and standards but also by paying close attention to technology changes and the file formats needed by the EDL community. In addition, practical considerations have been implemented and planned for, such as off-site frequent mirrors of the site, planned media and software migration as media decays, and software becomes obsolete.

Closing

The next delivery of the EDL-R is scheduled for the summer of 2008 and it has a number of additional capabilities planned to improve security and ease of use:

- On-line Account Request form
- Automatic virus checking
- Batch submissions
- User interface for updating the Most Wanted List
- Improved Subject selection
- NASA branding
- FAQ and on-line Help

As the development of this tool continues, a number of challenges lie ahead:

- ensuring the security of sensitive material
- incorporating all of shuttle EDL data
- continuing search to preserve rare and at-risk material
- securing a post development home and sustained funding

Looking further down the road, it is our hope that NASA continues to archive valuable information and considers expanding this repository to include EDL material from other countries that are committed to space exploration, perhaps by means of a federated archive.

Ames, JPL, and Langley collaborate on this task, which is funded by the NASA Engineering and Safety Center. The development of the EDL-R has been guided by the keen interest and dedication of these members of the EDL community: Prasun Desai, Dick Powell, Bob Blanchard, Bob Tolson, Paul Seimers, and Paul Romere. We would also like to give our appreciation and thanks to Daniel Winterhalter and Lloyd Keith for their direction and insightful leadership.

Appendix B. EDL Community Contacts

Name	Contact Information
Chen, Allen	Organization: JPL Title: MSL EDL Systems Engineering Team (Flight Dynamics Lead, Chief of Staff) Discipline: Systems Engineering
Barth, Andy	Organization: Lockheed Martin Discipline: Entry GN&C
Queen, Eric	Organization: LaRC Title: Research Engineer Discipline: GN&C and Simulation
Kipp, Devin	Organization: JPL Title: MSL EDL Systems Engineer & Terrain Interaction Lead
Olejniczak, Joseph	Organization: ARC Discipline: Aerosciences
Edquist, Karl	Organization: LaRC, Atmospheric Flight and Entry Systems Branch Title: MSL Aerothermal Lead Discipline: Aerodynamics/Aerothermodynamics
French, Richard	Organization: JPL Title: EDL Systems Engineering/Orion TPS V&V Discipline: EDL system engineering
Adams, Douglas	Organization: JPL Title: MSL Parachute Cognizant Engineer, Phoenix EDL Mechanical Systems Engineer Discipline: EDL Simulations, Vehicle Dynamics, and Structural Dynamics
O'Donnell, Jim	Organization: NESC GN&C TDT/GSFC Attitude Control Systems Engineering Branch Title: Core Member/Branch Head Discipline: GN&C
Reuther, James	Organization: ARC (MS 230-2) Title: Project Manager, CEV Thermal Protection System

Name	Contact Information
Wright, Michael	Organization: ARC Title: Senior Research Scientist Discipline: Aerothermodynamics and Thermal Protection Systems
Sell, Steve	Organization: JPL Title: MSL EDL Powered Flight Lead
Mendeck, Gavin	Organization: JSC, Mission Operations Directorate Title: MSL Entry Guidance, CEV GNC/Ops Integrator Discipline: Entry Guidance, Mission Operations
Kramer-White, Julie	Organization: JSC Title: Orion Chief Engineer
Rivellini, Tom	Organization: JPL Title: Mechanical Systems Lead for MSL EDL Hardware, Supervisor of EDL and Mechanical systems Group Discipline: Mechanical Engineering
Shidner, Jeremy	Organization: MSL, LaRC, Atmospheric Flight and Entry Systems Branch Title: Research Engineer Discipline: Flight Mechanics Modeling and Simulation
Fremaux, Charles M. (Mike)	Organization: LaRC/RTD/Flight Dynamic Branch Title: Branch Head Discipline: Flight Dynamics and Control
Jackson, Bruce	Organization: LaRC Title: Sr. Research Engineer Discipline: Handling Qualities/GNC
Baird, Darren	Organization: JSC Title: GN&C Engineer Discipline: Entry Guidance
Beck, Robin	Organization: ARC Title: NESC Passive Thermal TDT member, MSL TPS Cognizant Engineer, Principal Technologist for ETDP TPS Technology Development Project Discipline: Ablative Materials

Name	Contact Information
Powell, Richard (Dick)	Organization: AMA/LaRC Title: Senior Research Engineer Discipline: Flight Mechanics
Chen, George	Organization: JPL Title: EDL Systems Engineering and Advanced Technology Group Supervisor Discipline: EDL Systems Engineering, GN&C, Spacecraft Systems Engineering
Prakash, Ravi	Organization: JPL Title: Orion TPS Task Lead Discipline: EDL Systems
Sengupta, Anita	Organization: JPL Title: Senior Systems Engineer Discipline: Decelerators and Aerodynamics
Salerno, Chris	Organization: Lockheed Martin Discipline: Orion Mission Analysis
Desai, Prasun	Organization: LaRC Title: Senior Systems Engineer Discipline: EDL Systems
Tigges, Michael	Organization: JSC Title: SSM Entry Guidance Discipline: Guidance
Engelund, Walter	Organization: LaRC Title: Head, Atmospheric Flight and Entry Systems Branch Discipline: Aerodynamics, Systems Engineering
Kim, Sungwan	Organization: LaRC Title: Orion LaRC GN&C Team Deputy Lead Discipline: GN&C
Hoelscher, Brian	Organization: JSC Title: Subsystem Manager - Orion Entry Flight Control Discipline: flight control and entry simulation
Machin, Ricardo (Koki)	Organization: JSC, Aerosciences Branch

Name	Contact Information
Rea, Jeremy	Organization: JSC Title: Orion Entry Performance Subsystem Manager Discipline: Orion Entry Flight Dynamics and GN&C
Mueller, Eric	Organization: NESC Flight Mechanics TDT (org code is AFT at ARC) Title: Aerospace engineer Discipline: GNC, spacecraft handling qualities
Morris, Aaron	Organization: JSC, Engineering Support Contract Group Title: CPAS Engineering Group Lead Discipline: Orion Parachutes
Westhelle, Carlos H	Organization: JSC - Aeroscience and Flight Mechanics Division Title: JSC Tech. Lead for Mars EDL Systems Analysis Study, Flight Mechanics TDT extended member Discipline: Aerocapture Guidance, Mission Design and Analysis
Venkatapathy, Ethiraj	Organization: ARC/CEV TPS Insight-Oversight Team Title: Chief Technologist, Space Technology Division/TPS Integration Technologist Discipline: Aerothermal/TPS
Rickman, Steve	Organization: NESC Title: NASA Technical Fellow for Passive Thermal Discipline: Passive Thermal
Stachowiak, Susan	Organization: JSC Title: Aerospace Engineer Discipline: Orion Entry Flight Control, MSL Entry Guidance
Nguyen, Luat	Organization: Flight Projects Directorate, LaRC Title: Director, Flight Projects Directorate Discipline: Flight Mechanics
Beaty, James R. (Jim)	Organization: LaRC, Systems Analysis & Concepts Directorate Discipline: Flight Mechanics, GN&C, Simulation & Modeling
Hughes, Mike	Organization: LM Title: Orion GN&C Lead Systems Engineer Discipline: GN&C

Name	Contact Information
Calhoun, Philip	Organization: GSFC Title: Aerospace Engineer Discipline: Guidance, Navigation, and Control
Gay, Robert	Organization: JSC EG6 Title: Orion EDL Navigation Subsystem Manager/Orion Nav System Team Member Discipline: Navigation/Modeling and Simulation
Cerimele, Chris	Organization: JSC CxP SE&I and Engineering Directorate Title: Constellation Level II Flight Performance Systems Integration Group Lead Flight Mechanics and Trajectory Design Branch Chief Discipline: Flight Mechanics
Zang, Thomas A.	Organization: LaRC Title: Chief Technologist, Systems Analysis and Concepts Directorate Discipline: Systems Analysis
Putnam, Zachary	Organization: Draper Laboratory, Orion GN&C Entry Mode Team Title: none Discipline: Entry Guidance
Murri, Daniel	Organization: NESC Title: NASA Technical Fellow for Flight Mechanics Discipline: Flight Mechanics
Manning, Robert	Organization: JPL Title: MSL Chief Engineer Discipline: EDL
Steltzner, Adam	Organization: JPL Title: MSL EDL Phase Lead Discipline: EDL
Blanchard, Robert	Organization: Retired Discipline: EDL
Romere, Paul	Organization: JSC Retired Discipline: SSP EDL
Green, Michael	Organization: Retired Discipline: EDL

Name	Contact Information
Tolson, Robert	Organization: Retired Discipline: EDL
Desai, Prasun	Organization: LaRC Discipline: EDL, Aerospace Flight Systems
St. Vaughn, Josh	Organization: JPL Title: Manager, Spacecraft Mechanical Engineering Discipline: Spacecraft Mechanical Engineering

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
01- 05 - 2012	Technical Memorandum	July 2006 - March 2012

4. TITLE AND SUBTITLE
Flight Data Entry, Descent, and Landing (EDL) Repository

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Martinez, Elmain M.; Winterhalter, Daniel

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
869021.05.01.01.02

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, VA 23681-2199

8. PERFORMING ORGANIZATION REPORT NUMBER
L-20146 NESC-RP-06-066

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSOR/MONITOR'S ACRONYM(S)
NASA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
NASA/TM-2012-217574

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 16- Space Transportation and Safety
Availability: NASA CASI (443) 757-5802

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Dr. Daniel Winterhalter, NASA Engineering and Safety Center Chief Engineer at the Jet Propulsion Laboratory, requested the NASA Engineering and Safety Center sponsor a 3-year effort to collect entry, descent, and landing material and to establish a NASA-wide archive to serve the material. The principle focus of this task was to identify entry, descent, and landing repository material that was at risk of being permanently lost due to damage, decay, and undocumented storage. To provide NASA-wide access to this material, a web-based digital archive was created. This document contains the outcome of the effort.

15. SUBJECT TERMS
NASA Engineering and Safety Center; EDL repository; digital archive

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			STI Help Desk (email: help@sti.nasa.gov)
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