DataLab-SRD-1.02

Science Requirements Document

For the

NOAO Data Lab Project

Ken Mighell, Knut Olsen, Pat Norris, Mike Fitzpatrick, Matthew Graham, and Betty Stobie

Revised: March 4, 2015

Revision History

Date	Author	Changes / Comments	Version
	K. Olsen		0.1
11/14/14	K. Mighell & K. Olsen		0.5
11/18/14	K. Mighell	Capabilities in tabular form with new tags	0.51
11/19/14	K. Mighell	Removed references to old tags	0.52
11/20/14	K. Mighell	Added SUC tags for each capability	0.53
12/03/14	K. Mighell	Major edit with new 5-digit tags	0.6
12/04/14	K. Mighell	Added DL-SRD-21006 & 21008	0.61
12/16/14	K. Mighell	Reworded references to DES	0.62
01/16/15	K. Mighell	Added Data Lab description	0.70
01/23/15	K.Mighell & B. Stobie	Added updated acronym list	0.71
01/27/15	K.Mighell & B. Stobie	Updated acronym list, fixed typos	0.73
02/11/15	K. Mighell	Edited capability descriptions	0.80
03/02/15	K. Mighell	Final edits	0.90
03/02/15	K. Olsen	Formatting consistency with other docs	1.0
03/03/15	K. Mighell	Final edits	1.01
03/04/20	K. Mighell	Fixed Word cruft	1.02

1 Document Overview

1.1 Purpose

The overall goal of the NOAO Data Lab is to enable efficient exploration and analysis of the large datasets now being generated by instruments on NOAO's wide-field 4-m telescopes. As explained in the *NOAO Data Lab Introduction Document*, the Data Lab will support four approaches to science with large datasets:

1. *Catalog science*, for which discoveries are made purely from the catalogs
2. *Data exploration*, for which access to catalogs and pixels is needed to provide the freedom to explore
3. *User-defined custom workflows*, which will involve potentially complex analyses of catalog objects and/or pixels, requiring interfaces to user scripts and software
4. *Collaborative research*, for which the work required to make a discovery depends on the coordinated efforts of a team of people

This *Science Requirements Document* for the NOAO Data Lab lists the capabilities needed to perform the workflows described in the *Science Use Cases* Document. The SRD maintains a primary list of capabilities (see section 2.1) that will be developed as part of core NOAO Data Lab services, and a separate list of capabilities (see section 2.2) that we expect users to develop themselves to enable their science. The lists are given in tabular form, with a number of the form DL-SRD-XXXX labeling each requirement, and a second number of the form DL-SUC-XXXX that references specific workflow steps identified in the SUC.

1.2 Referenced Documents

This document may reference additional documentation identified below.

[0] Introduction Document	(Intro)
[1] Science Use Case Document	(SUC)
[2] Operational Concepts Document	(OCD)
[3] Operational Requirements Document	(ORD)
[4] System Architecture Design	SAD)
[5] Project Execution Plan	(PEP)

1.3 Key

The following keys describe when a stated capability will be implemented:

Key	Description
[Y0]	Underlying software already exists
[Y1]	To be implemented during the first year
[Y2]	To be implemented during the second year
[Y1-2]	To be implemented during both years
[YA]	Advanced Capability: might be implemented after the second year

2 Capabilities

2.1 NOAO Data Lab Core Capabilities

DL-SRD-2100	**[Y1] Access to SQL catalogs**	Used by all SUCs
DL-SRD-21000	DL must provide access to SQL catalogs with command line tools for experienced users.	
DL-SRD-21002	DL must provide access to SQL catalogs with Web-based tools for intermediate and novice users.	
DL-SRD-21004	DL must provide the capability to create table joins of DL-based SQL catalogs.	
DL-SRD-21006	DL must provide asynchronous state-full access to DL-based SQL catalogs.	
DL-SRD-21008	DL must provide synchronous access to DL-based SQL catalogs.	
DL-SRD-2105	**[Y1] User database storage (local & remote)**	Used by all SUCs
DL-SRD-21050	DL must be able to use databases on the user's desktop computer (local storage).	
DL-SRD-21055	DL must be able to use databases at the DL (remote storage). *User storage requirements at the DL may range from a few gigabytes to many terabytes.*	
DL-SRD-2110	**[Y1-2] Light curve data generation from catalogs**	DL-SUC-4140 DL-SUC-4215 DL-SUC-4315
DL-SRD-21100	The DL must provide the means to generate light curve data from multi-epoch flux/magnitude measurements in SQL catalogs served by the DL. *The Bulge catalog (SUC 4.2) will provide light curve data during the first year of operation.* *In the future, the DES catalog could provide light curve data. Those light curves will improve with time as the survey progresses (especially in the DES supernova fields).*	
DL-SRD-2115	**[Y1] Virtual Storage (VOSpace) Service** *DL will provide a Virtual Storage Service that will be an access point for the DL distributed storage network. This service will provide seamless integration of access to data resources and will enable collaborative sharing of data and data products.*	Used by all SUCs
DL-SRD-21150	DL must provide means for users to store results of SQL database queries near the computational resources serving the major SQL catalogs at the DL. *With results stored near to the hardware serving the catalogs, DL users will have quicker response times since results will not need to be transmitted over the Internet to their desktop computers.*	
DL-SRD-21151	DL must provide means for users to create their own data objects (files) in the DL distributed storage network.	
DL-SRD-21152	DL must provide means for users to delete their own data objects in the DL distributed storage network.	

DL-SRD-21153	DL must provide means for users to upload data objects from local (desktop) to remote storage.	
DL-SRD-21154	DL must provide means for users to download data objects from remote to local storage.	
DL-SRD-21155	DL must provide means for users to manipulate metadata of their own data objects.	
DL-SRD-21156	DL must provide means for users to set access privileges of their own data objects.	
DL-SRD-21157	DL must provide means for users to access the content of data objects within the DL distributed storage network.	
DL-SRD-2120	**[Y0] IVOA registry searches**	
DL-SRD-21200	DL must provide means for users to search (cone-searches) for observations (images/fluxes) obtained at different wavelengths. IVOA registry searches for Spectral Energy Distributions (galaxies and stars). *The underlying software already exists.*	DL-SUC-3320
DL-SRD-21205	DL must provide means for users to search for Spectral Energy Distributions (galaxies and stars). *The underlying software already exists.*	
DL-SRD-2125	**[Y0] Access to external image surveys**	
DL-SRD-21250	DL must provide means for users to access significant ground-based optical/near-infrared image surveys (e.g. DSS, 2MASS, ESO Vista Hemisphere Survey). *The underlying software already exists.*	DL-SUC-3310
DL-SRD-2130	**[Y2] Galactic Extinction/Reddening Service**	
DL-SRD-21300	DL must provide means for users to get extinction and reddening values due to Galactic dust as a function of position on the sky. *This is an Advanced Capability. This capability could be used by researchers working with large DECam surveys of the Galaxy and the Magellanic Clouds (e.g., SUC 4.2: the Bulge Survey; SUC 3.1: the SMASH Survey). An existing Website (Galactic Dust Reddening and Extinction: http://irsa.ipac.caltech.edu/applications/DUST) at the NASA/IPAC Infrared Science Archive serves Galactic extinction and reddening values based on Schlegel, Finkbeiner, & Davis (1998, ApJ, 500, 525) and Schlafly & Finkbeiner (2011, ApJ, 737, 103).*	DL-SUC-3105 DL-SUC-3230 DL-SUC-5105
DL-SRD-2135	**[Y2] Magellanic Clouds Extinction Service**	
DL-SRD-21350	DL must provide means for users to get extinction due to dust in the Magellanic Clouds as a function of position on the sky. *This is an Advanced Capability. This capability could be used by researchers working with large DECam surveys of the Magellanic Clouds (e.g., SUC 3.1: the SMASH Survey). An existing Website (Magellanic Clouds Extinction Values: http://dc.zah.uni-heidelberg.de/mcextinct/q/cone/form) provides extinction values due to the Magellanic Clouds based on Haschke, Grebel, & Duffau (2011, AJ, 141, 158).*	DL-SUC-3105 DL-SUC-5105
DL-SRD-2140	**[Y1-2] Color-Magnitude & Hess Diagram plotting tool**	
DL-SRD-21400	DL must provide a plotting tool which can be used to create	Used by

	Color-Magnitude and Hess Diagram plots. These plots will enable the graphical analysis of data samples of possibly millions of stars. The plotting tool will provide efficient plotting of millions of data values resulting from SQL queries of DL-based catalogs. *This plotting tool should have the option of displaying contour overlays; when used in regions of high count densities in the plots, the plotting time (size of the plot in bytes) could be greatly reduced.* *Year1: Mark Taylor's topcat Java application could be used.* *Year2: A more sophisticated (publication-grade) application will be developed.*	SUC 3.1 SUC 3.2 SUC 4.2 SUC 5.1
DL-SRD-2145	**[Y1-2] Variable resolution display tool for remote users**	
DL-SRD-21450	DL must provide an interactive plotting/visualization/ analysis tool with variable resolution for remote users in order to improve the user interaction experience. *It is impractical to display large images consisting of many hundreds of megabytes (e.g., all the observations of a single DECam observation) at full resolution over the Internet. A global view of such large images can be displayed at low resolution while full-resolution imagery of small regions can be quickly served.* *Year1: DL could implement this using CDS's Aladin (Lite) viewer application* *Year2: A more sophisticated application will be developed.*	Used by all SUCs
DL-SRD-2150	**[Y2] Phase-folded light curves**	
DL-SRD-21500	DL must provide the means to produce phase-folded light curves for a given period value from light curve data.	DL-SUC-4150 DL-SUC-4215 DL-SUC-4315
DL-SRD-2155	**[Y1] Create animations/movies of variable objects**	
DL-SRD-21550	DL must provide the means to create animations/movies of observations of variable objects (e.g., RR Lyrae stars, supernova, etc.). *This capability could be used by researchers working with synoptic curves (e.g., SUC 4.2: the Bulge Survey). These animations may be based on images served by the Image Cutout Service.*	DL-SUC-4145 DL-SUC-4205 DL-SUC-4300
DL-SRD-2160	**[Y1-2] Image Cutout Service** *DL will provide a general Image Cutout Service that will serve DL-based images. This service will allow the comparison of DECam observations to other surveys.* *Year1: The image data will initially come from the NOAO Science Archive (NSA).* *Year2: Additional image data could come from DECam Legacy Survey (DECaLS) images or stacked DES images.*	Used by all SUCs except 3.1
DL-SRD-21600	DL must provide a general asynchronous state-full Image Cutout Service that will serve subimages (image cutouts) of images based at the DL.	
DL-SRD-21601	The Image Cutout Service must be able to be run in a synchronous mode.	
DL-SRD-21602	The Image Cutout Service must be capable of delivering small	

	images ("postage stamps" with ~100 pixels) with position orientation metadata from DL-based images.	
DL-SRD-21603	The Image Cutout Service should be capable of delivering large images (millions of pixels covering possibly more than one deg^2) with position orientation metadata from DL-based images. *This is an Advanced Capability.*	
DL-SRD-21604	The Image Cutout Service must be able to serve large numbers of image cutouts as part of large asynchronous batch jobs.	
DL-SRD-21605	The Image Cutout Service must serve images in a format suitable for the creation of animations/movies of variable objects (see DL-SRD-21550).	
DL-SRD-2165	**[Y1-2] Task automation tools**	
DL-SRD-21650	DL must provide task automation tools to enable computation workloads (tasks) to be spread over many cores and/or machines. *These speedups will be achieved with the identical processing of long lists of different images/spectra (spreading the workload over many cores) – not the parallelization of computational algorithms by the DL.*	Used by all SUCs except 3.1 & 5.2
DL-SRD-2170	**[Y1-YA] Positional Cross-Match Service** *DL will provide a discovery tool to allow DL users with SQL tables of objects with positions to be cross-matched with objects in DL-based SQL catalogs.*	DL-SUC-3315
DL-SRD-21700	DL must provide an asynchronous state-full Positional Cross-Match Service (PCMS) that will enable a DL user to cross-match objects with positions in a custom database with SQL catalogs served by the DL (e.g., SUC 3.1: the SMASH catalog; SUC 4.2: the Bulge catalog).	
DL-SRD-21702	The PCMS must be able to be run in a synchronous mode.	
DL-SRD-21704	The PCMS must be able to process large number of object positions as part of large asynchronous batch jobs.	
DL-SRD-21706	The PCMS must provide access to external robust IVOA-standards-compliant positional cross-match services (e.g., CDS's VisieR).	
DL-SRD-2175	**[YA] Period-finding (Periodogram) Service** *DL may provide a Period-finding (Periodogram) Service that will estimate the period(s) of an object with variable flux. The Compute Service may be required if a large number of objects (light curves) need to be analyze.*	DL-SUC-4150 DL-SUC-4210 DL-SUC-4310
DL-SRD-21750	The DL should provide an asynchronous state-full Period-finding (Periodogram) Service that will return the period(s) of time series data. *This is an Advanced Capability. The most probable peaks of the periods correspond to the best estimates of the period(s) of the variable object.*	
DL-SRD-21752	The Period-finding Service should be able to be run in a synchronous mode.	
DL-SRD-21754	The Period-finding Service should be able to analyze large numbers of light curves as part of large asynchronous batch jobs.	

DL-SRD-21756	The Period-finding should be able to process light curves that were generated by DL-SRD-21100.	
DL-SRD-2180	**[Y1-YA] Stellar photometry codes**	
DL-SRD-21800	DL must provide users with at least one executable binary of a standard stellar photometry code (e.g., SExtractor, Dophot, DAOPHOT, etc.) for inclusion in user-designed photometric pipelines.	DL-SUC-5115
DL-SRD-2185	**[Y1-YA] Statistical time series analysis tools**	DL-SUC-4150 DL-SUC-4200 DL-SUC-4300
DL-SRD-21850	DL must provide time series (light curve) statistical analysis tools that determine if the flux of an object varies in time for a given level of statistical significance.	
DL-SRD-21855	The statistical time series analysis tools should be able to determine the statistical nature of a variable object: periodic, aperiodic (semiregular), random (stochastic), or transient.	
DL-SRD-2190	**[YA] Compute Service**	
DL-SRD-21900	The DL should provide an asynchronous state-full Compute Service that would do data-parallel calculations (e.g., in a few hours or days instead of weeks or months). *These calculations may include intensive interactions with DL-based catalogs. If insufficient computational power is available at the DL for the required task, then the user could possibly use an instance of the DL deployed at the NCSA or with Amazon Web (Cloud) Services.*	Used by large batch jobs of: SUC 3.2 SUC 3.3 SUC 4.1 SUC 5.1

2.2 User-provided Science Capabilities

DL-SRD-2200	**[YA] User tools to determine crowding factor**	
DL-SRD-22000	DL should provide the means to enable user-defined database tools to determine crowding factor (nearest neighbor distances, N-point correlations, etc.)	DL-SUC-4205
DL-SRD-2205	**[YA] Database of theoretical isochrones**	
DL-SRD-22050	DL should provide at least on set of theoretical stellar isochrones transformed to the SDSS (DECam) filter set. *The isochrones should range logarithmically in time from 10 million years to 14 billion years and span metallicities from very metal poor to super-solar.*	DL-SUC-5125
DL-SRD-2210	**[YA] Registration of large/complex images**	
DL-SRD-22100	DL should provide resources to enable the spatial register/cross-match large/complex images observed with different filters, exposure times, rotation angles, etc.	DL-SUC-3315
DL-SRD-2215	**[YA] Capture interactive results**	Used by all SUCs except 3.3 & 4.3
DL-SRD-22150	DL should provide resources to enable the capture of interactive results for reproducibility and sharing within collaborations. *This is an Advanced Capability. Note: the capture of interactive results of an entire workflow chain is dependent on the ability of every tool in that workflow chain being capable of capturing interactive results.*	

DL-SRD-2220	**[YA] Poisson-based Matched-Filter Service**	
DL-SRD-22200	DL should provide resources to enable the identification of unique stellar populations in complex stellar fields contaminated by multiple external stellar populations in the Milky Way or other Local Group galaxies [e.g., the analysis of DECam observations of the Carina dwarf spheroidal galaxy by McMonigal et al. (2014, MNRAS, 444, 3139)].	DL-SUC-3130 DL-SUC-3200
DL-SRD-2225	**[YA] Estimate reddening of RR Lyraes from light curves**	
DL-SRD-22250	DL should provide resources to enable analysis tools to estimate reddening of individual RR Lyrae stars based on time series observations.	DL-SUC-4220
DL-SRD-2230	**[YA] User-defined analysis tools**	
DL-SRD-22300	DL should provide resources to enable user-defined analysis tools (code, scripts, templates, etc.).	Used by all SUCs
DL-SRD-2235	**[YA] High-order Polynomial Background Fitting**	
DL-SRD-22350	DL should provide resources to enable high-order polynomial background fitting in complex star fields.	DL-SUC-3205
DL-SRD-2240	**[YA] Digital image filters for feature/object detection**	
DL-SRD-22400	DL should provide digital filters for feature recognition/ object detection in images. *This capability could be used to detect faint low surface brightness dwarf galaxies seen only in the diffuse light of bright red giant branch stars.*	DL-SUC-3215 DL-SUC-5215
DL-SRD-2245	**[YA] Variable Object Classification Service**	
DL-SRD-22450	DL should provide resources to determine what type of variable is an object based on its light curve. *Is the variable object an RR Lyrae star? A delta Scuti star? A Cepheid variable? This service could potentially be implemented very efficiently using state-of-the-art template-fitting techniques. This is an Advanced Capability.*	DL-SUC-4150 DL-SUC-4210 DL-SUC-4310
DL-SRD-2250	**[YA] Galaxy Morphology Analysis Service**	
DL-SRD-22500	DL should provide resources to determine to enable galaxy morphology analysis codes like Galfit, Galphot, etc. to analyze large (many pixel) galaxy images.	DL-SUC-5210
DL-SRD-22505	DL should provide resources to enable morphological analysis of galaxy blob images (with a small number of pixels). *This could be done using various statistical tests like the Gini coefficient, M_{20}, concentration, asymmetry, and clumpiness (Lotz, Primack, & Madau et al. 2004, AJ, 128, 163).*	DL-SUC-5210
DL-SRD-2255	**[YA] Single-Galaxy Photometric Redshift**	
DL-SRD-22550	DL should provide resources to enable the determination of photometric redshifts of a galaxy from multiband observations using Spectral Energy Distribution (SED) template libraries.	DL-SUC-3325
DL-SRD-2260	**[YA] Interactive User-Defined Plotting/Visualization Tools**	
DL-SRD-22600	DL should provide resources to enable the graphical user interface tools developed by users to enhance the visualization or understanding of complex images or	Used by all SUCs

	databases.	
DL-SRD-2265	**[YA] Astrometry for large images**	
DL-SRD-22650	DL should provide resources to enable the development of tools for the computation of astrometric solutions of large astronomical images that may be distorted due to imager optics.	DL-SUC-3200
DL-SRD-2270	**[YA] Extended object/non-point-source detection**	
DL-SRD-22700	DL should provide resources to enable the development of image analysis tools for the detection of astrophysical objects that are not point sources.	DL-SUC-5210

Appendix I: Vocabulary / Acronyms Used

AAS	(American Astronomical Society)
ADASS	(Astronomical Data Analysis Software and Systems) conference
ADQL	(Astronomical Data Query Language) An SQL-like language which includes astronomical facilities to query a database.
AGN	(Active Galactic Nucleus)
API	(Application Programming Interface) The documentation of the interface to a software library or tool.
ASCII	(American Standard Code for Information Interchange) A character-encoding scheme based on the English alphabet where 128 specific characters are encoded into 7-bit binary integers.
ASV	(ASCII Space Values)
AURA	(Association of Universities for Research in Astronomy)
CADC	(Canadian Astronomy Data Centre)
CDS	Centre de Données astronomiques de Strasbourg
CMD	(Color Magnitude Diagram)
CSV	(Comma Separated Values)
CTIO	(Cerro Tololo Inter-American Observatory)
DAL	(Data Access Layer) The VO protocols that define how VO applications access data resources.
Datalink	VO protocol for associating complex astronomical data
DECaLS	DECam Legacy Survey
DECam	(Dark Energy Camera) A 520 megapixel digital camera on the Blanco 4-m telescope at CTIO.
DES	(Dark Energy Survey) a survey to prove the origin of the accelerating Universe and help uncover the nature of dark energy by measuring the 14 billion-year history of cosmic expansion with high precision over five years beginning in summer 2013.
DESI	(Dark Energy Spectroscopic Instrument) An instrument to measure the effect of dark energy on the expansion of the universe by obtaining optical spectra for tens of millions of galaxies and quasars (beginning 2018).
DESDM	(Dark Energy Survey Data Management) Project that developed and operates the DESDM system at NCSA.
DL	(Data Lab)
DAOPHOT	Package for crowded field stellar photometry.
Docker	An open platform for developers and system administrators to build, ship, and run distributed applications.
DoPHOT	CCD PSF fitting photometry program.
DS9	SAOimage DS9, an astronomical imaging and data visualization application.
DSS	(Digitized Sky Survey)
ESO	(European Southern Observatory)
FITS	(Flexible Image Transport System) An open standard defining a digital file format for storage, transmission, and processing of astronomical (and other scientific) data.
FTP	(File Transfer Protocol) A standard network protocol used to transfer computer files from one host to another host over a TCP-based network.

FUSE	(FileSystem in User Space) An operating system mechanism that lets non-priviledged users to create their own file systems.
GAVO	(German Astrophysical Virtual Observatory)
GMS	(Group Management Services)
GPFS	(General Parallel File System) A high-performance clustered file system developed by IBM
Hess diagram	Plots the relative density of the occurrence of stars at different color-magnitude positions of Hertzsprung-Russell diagram for a given galaxy.
HSB	(High Surface Brightness)
HST	(Hubble Space Telescope)
HTTP	(HyperText Transfer Protocol) An application protocol for distributed, collaborative, hypermedia information systems.
IDL	(Interactive Data Language) A programming language used for data visualization and analysis.
IPAC	(Infrared Processing and Analysis Center)
IRAF	(Image Reduction and Analysis Facility) NOAO image reduction/analysis and visualization software system.
IVOA	(International Virtual Observatory Alliance) The international VO community responsible for developing VO standards.
JIRA	A commercial tool for software teams to plan, build, and track projects.
JPEG	(Joint Photographic Experts Group) Lossy compression for digital images
LDAP	(Lightweight Directory Access Protocol) An industry standard application protocol for accessing and maintaining distributed directory information services over an Internet Protocol (IP) network.
LSB	(Low Surface Brightness)
LMC	(Large Magellanic Clouds)
LSST	(Large Synoptic Survey Telescope)
MAST	(Mikulski Archive for Space Telescopes)
MPC	(Minor Planet Center)
MCs	(Magellanic Clouds)
MySQL	Popular open source database.
MyDB	A read-write database available to users for saving results from queries of read-only databases. This is similar to the SDSS *MyDB* concept..
NASA	(National Aeronautics and Space Administration)
NCSA	(National Center for Supercomputing Applications)
NHPPS	(NOAO High-Performance Pipeline System) An event-driven, multi-process executor system developed to manage pipeline applications in a coarse-grained, distributed processing environment.
NOAO	(National Optical Astronomy Observatory)
NSA	(NOAO Science Archive)
NSSDC	(NOAO System Science and Data Center)
OCD	(Operational Concept Document)
ORD	(Operational Requirements Document)
OS	(Operating System)
PCMS	(Positional Cross-Match Service)
PNG	(Portable Network Graphics) Raster graphics file format that supports lossless data compression.
PSF	(Point Spread Function)
QServ	The LSST database management system.

R	A programming language and software environment for statistical computing and graphics.
RDBMS	(Relational DataBase Management System) A DBMS that represents data using a relational database.
Relational database	A database that stores data in a structure consisting of one or more tables (aka relations) of rows and columns, which may be interconnected.
ReST	(Representational State Transfer) An approach to web services that uses the standard HTTP GET and POST protocols.
SAD	(System Architecture Design) document
SAMP	(Simple Applications Messaging Protocol) A VO protocol for desktop messaging.
SCS	(Simple Cone Search)
SDM	(Science Data Management) group
SDSS	(Sloan Digital Sky Survey)
SED	(Spectral Energy Distribution) Plot of brightness of flux density versus frequency or wavelength.
SExtractor	A program that builds a catalogue of objects from an astronomical image.
SIA/SIAP	(Simple Image Access Protocol) A VO protocol that supports queries for images available in a given data collection near a given position on the sky.
SMASH	(Survey of the MAgellanic Stellar History) PI: Nidever
SMC	(Small Magellanic Cloud)
SN	(Super Nova)
SQL	(Structured Query Language) The standard language used to communicate with RDBMS's.
SQLite	A software library that implement a self-contained, serverless, zero-configuration, transactional SQL database engine.
SRD	(Science Requirements Document)
SSh	Secure Shell
SSA	(Simple Spectral Access) A VO protocol for spectral query/retrieval.
SSO	(Single Sign-On)
SUC	(Science Use Case) document
SVC	An abbreviation for a Web service.
SWIG	(Simplified Wrapper and Interface Generator) An open source software tool used to connect C or C# programs or libraries with scripting languages.
TAP	(Table Access Protocol) A VO protocol for querying remote databases.
TB	(Tera Bytes) 10^{12} bytes or 1,000,000,000,000 bytes (base 10)
TiB	(Tebibyte) 2^{40} bytes or 1,099,511,627,776 bytes (base 2)
TCP	(Transmission Control Protocol) One of the core protocols of the Internet protocol suite, commonly referred to as TCP/IP.
TSV	(Tab-Separated Values) A simple file format often used to move tabular data between computer programs that support the format, e.g., transferring information from a database program to a spreadsheet.
URI	(Uniform Resource Identifier) An address standard for a resource available on the Internet.
URL	(Uniform Resource Locator) The global address of documents and other Resources on the World Wide Web. The address contains 2 parts: specification of the protocol to be used in accessing the resource and its network location.
UWS	(Universal Worker Service) pattern defines how to manage asynchronous

	execution of jobs on a service.
VAO	(Virtual Astronomical Observatory) The US VO project.
VM	(Virtual Machine)
VO	(Virtual Observatory)
VOSI	(VO Support Interfaces) The minimum interface that a SOAP or REST-based web service requires for compatibility with the IVOA.
VOSpace	The IVOA interface to distributed storage that specifies how VO agents and applications can use network attached data stores to persist and exchange data in a standard way.
XML	(eXtensible Markup Language)
2MASS-PSC	(2 Micron All Sky Survey – Point Source Catalog)