

Lightgrep™ - Fast Search for Forensics

Lightgrep for EnCase[[1]](#footnote-2) provides you with new options for search in a familiar environment: Keywords that are compatible with Perl; filters for search terms to help you find the real information you're looking for faster; text extraction for Office 2007 and similar document formats.

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# Getting Help

* We’re here to help, and we want you to be successful using Lightgrep! If you have any comments, questions, or need to report a bug, please email us at [info@lightboxtechnologies.com](mailto:info@lightboxtechnologies.com).

# Minimum Requirements

* EnCase Forensic or Enterprise version 6.16.2 (32-bit or 64-bit) or greater
* Windows XP SP3, Windows 7 (32-bit or 64-bit) – the application has not been tested with Windows Vista.
* 4 GB of RAM preferred minimum
* Microsoft .Net Framework 3.5 SP1 is required for Excel output

# Known Issues

* BETA 1: The beta test is only being offered in a 64-bit version, which requires your Windows installation to be 64-bit. EnCase can be either 32-bit or 64-bit.
* BETA 1: Only one instance of Lightgrep can be running at any given time. This means that multiple searches with Lightgrep cannot be run at the same time, even if using different instances of EnCase. You will receive a warning if trying to start a second instance of Lightgrep search. Due to this limitation within the beta, you may notice a slight delay when starting the script to check for running instances. This limitation will not be present in the 1.0 release.
* BETA 1: Selecting the UTF-8 encoding will only search for ASCII characters. This limitation will not be present in the final release.
* BETA 1: Selecting the UTF-16 LE encoding will only search for the UTF-16 equivalent of ASCII characters. For example, for the expression “abc” Lightgrep will search for “\x00a\x00b\x00c”. This limitation will not be present in the final release.
* BETA 1: Attempting to use characters that can only be represented by UTF-8 or UTF-16 will result in a validation error. Full UTF-8 and UTF-16 support will be available in the final release.
* BETA 1: Canceling the script waits until the current entry is fully searched to complete. Thus, if searching a device with very large unallocated space, it may take a long time to cancel.
* BETA 1, v1.0: Not compatible with EnCase version 7.
* If you have an extremely large number of search hits, the search hits file in the Output Folder can grow fairly large. The file will likely reach 4 GB in size after approximately 150 million hits, depending on the keywords you’re using. If the Output Folder is on a FAT32 drive or similar which has a relatively small file size limitation, the search may fail. We suggest that you always use NTFS for the Output Folder file system.

# Limitations and General Information

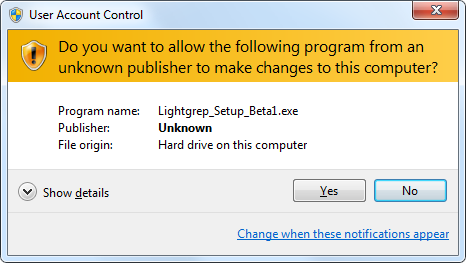
* We are unable to output search results to the EnCase “Search Hits” tab, because this is not allowed by the EnScript API. Only EnCase’s built-in search functionality can save search hits to this location. Because of this limitation in the EnCase product, we save search hits to the “Bookmarks” tab. It should be noted that Search Hits in EnCase are simply Bookmarks which contain references to the keyword that was searched for, so you’re not missing any data that would otherwise be present in the EnCase search hits results.
* Sweeping Bookmarks in EnCase v6 have a limit of 16,384 bytes. Although Lightgrep does not have a technical limit on the length of search hits, the limit within EnCase presents a practical limitation when the desired output format is an EnCase Bookmark.
* We filter a few entries by default before searching. Spcifically, any entries with a Physical Size of 0 bytes is filtered out; there’s no reason to search these because they have no content. Also, we filter out the NTFS bad cluster map file using the following criteria: file name in EnCase entry view is "$BadClus·$Bad" and the entry description contains both “Internal” and “Stream”.
* Entries without a starting extent cannot be bookmarked. These usually are files containing Invalid Cluster in the Description field, although some files marked as Internal, such as the streams $UsnJrnl·$J and $BadClus·$Bad, also fall into this category.
* While Lightgrep is able to search files flagged as Overwritten, bookmarks containing hits may point to the overwriting file, not to the overwritten entry that you originally selected. This is a limitation of the bookmarking function in EnCase v6.
* The “Lightgrep Output Folder” location cannot be set to a protected location in Windows Vista or Windows 7. Protected locations include, but may not be limited to, those locations represented by the following Windows environment variables: *SystemRoot*, *ProgramFiles(x86)*, *ProgramW6432* (e.g. C:\Windows, C:\Program Files, C:\Program Files (x86)). Lightgrep for EnCase will attempt to automatically identify if you are trying to save output to one of these locations and ask you to correct it.
* Lightgrep stores settings in two files: *Lightgrep Search.ini* and *Lightgrep Search.xml*. The .ini file stores simple options that have been selected in the GUI; the .xml file stores Entities and Keywords. The .xml file uses approximately 75 MB of space per 100,000 keywords.
* Lightgrep uses a constant and relatively small amount of memory while searching, but can require more memory up front while parsing the keyword list depending on the number of keywords. 4 GB of RAM with no other applications running should allow you to parse and search approximately 100,000 fixed string keywords. A minimum of 8 GB of RAM is required to parse and search 1 million fixed string keywords, and more could be required if using GREP expressions. When searching 1 million or more keywords, it can take several minutes before the search begins while the search engine parses the list of keywords.
* The first time you run a search, you may be presented with an alert from your firewall. Lightgrep uses a local network socket to communicate with EnCase. You should Allow Access for lightgrep.exe if prompted to insure there aren’t any problems with searching as shown in Figure 1 below.



Figure

# Setup & Installation

Run Lightgrep\_Setup\_Beta2.exe and, if User Account Control is enabled on Windows Vista or Windows 7, you will see a dialog asking for approval to run the installer. Select Yes to continue.

****

The Welcome dialog notes the version of Lightgrep Search for EnCase that you are installing. Click Next on the Welcome dialog to proceed.

****

Please read the License Agreement, select “I accept the agreement,” and click Next to continue. If you do not accept the agreement, you cannot continue with installation.

****

Choose the location to install the Lightgrep executable. The installer should choose the best location for you. Click Next to continue.

****

Select the location of your EnCase 6 directory. The installer will copy the Lightgrep\_Search EnPack and EnLicense into the appropriate EnScript and License folders based on this selection.

****

Choose the Start Menu folder to place Lightgrep shortcuts in. The installer will create shortcuts for the Lightgrep End User License Agreement (EULA), User Manual, and Uninstall application.

****

On the Ready to Install dialog, the installer will show you the destination locations you previously selected. Confirm these selections by clicking Install.

****

After installation is complete, an informational message is presented. Click Next.

****

The installation is complete! Leave the box checked to open the Lightgrep Search for EnCase user manual, and click Finish to complete the installer.

****

Run Lightgrep Search for EnCase by opening EnCase and navigating to the EnScript pane, usually in the lower right hand corner of EnCase. Expand the Lightgrep folder and double-click on Lightgrep\_Search to run the application.

****

## File Locations

Several files are installed with Lightgrep Search for EnCase. *Lightgrep\_Search.EnPack* is the EnScript application code that allows Lightgrep to integrate with EnCase. It is installed in the *[EnCase6]\EnScript\Lightgrep* folder.



*Lightgrep\_Search.EnLicense* is the EnCase license file, which links Lightgrep Search to your dongle ID(s) and also contains the expiration date, unique to your account. This file is placed in the *[EnCase6]\License* folder.



The main *Lightgrep* folder is typically placed under *Program Files* and, at the top level, contains the EULA, user manual, and the uninstall application.

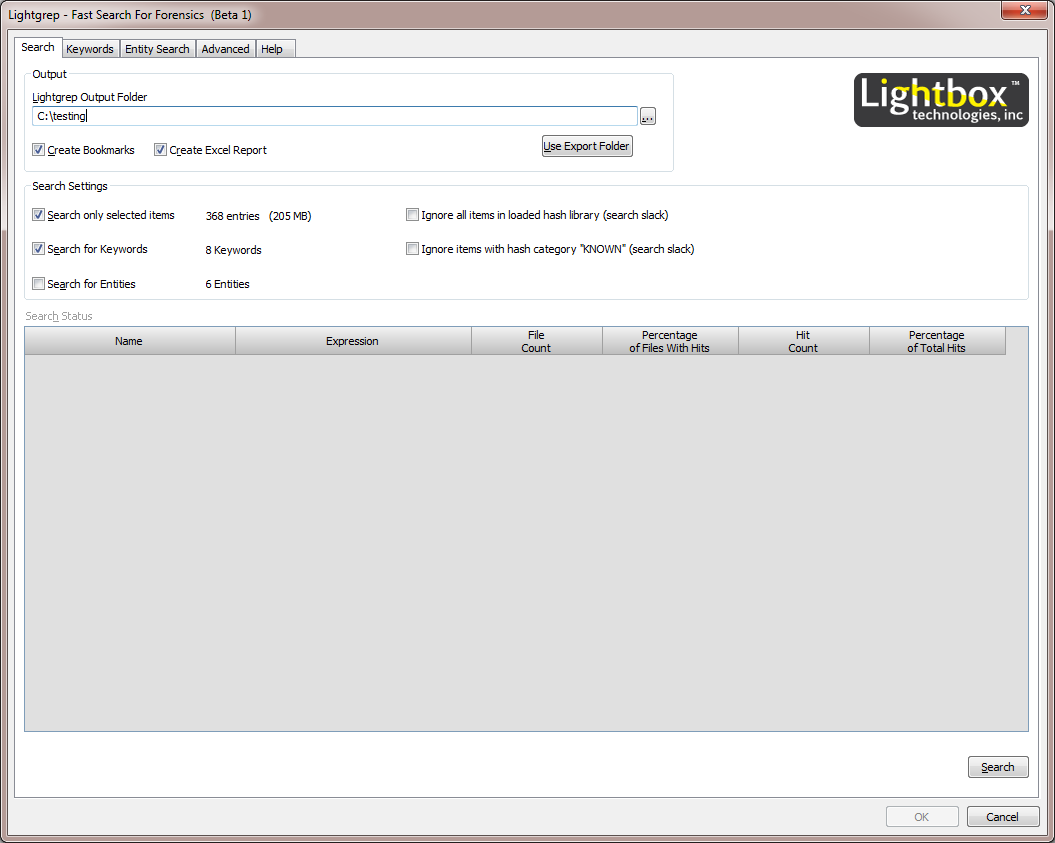


Finally, the *bin* folder, located under the *Lightgrep* folder, contains the Lightgrep executable, the excelutil helper application to create Microsoft Excel output, and a Microsoft library file, which is also required for Excel output.



# Search Tab

The Lightgrep Search Tab as shown in presents the main program options that should be reviewed before performing a search, and also provides an area to display ongoing output about search statistics.



Figure

## Options

### Lightgrep Output Folder

The folder specified here will be used both as a temporary folder location and as the output location for Lightgrep search results. Generally speaking, less than 10 megabytes of space is used by temporary files from the application, depending on the number and size of keywords. The size of results files can vary greatly depending on the number of hits found.

### Create Bookmarks

This option will create sweeping bookmarks of all search hits in the current EnCase Case. The output is very similar to EnCase search hits. Search hits will be organized into the same folder structure as present in the Keywords tree (see ). If you have a folder named “Financial” containing 5 keywords, you will also have a bookmarks folder named “Financial” which will contain one folder for each of the 5 keywords that have hits.

### Create Excel Report

This option will create an Excel 2007 format overview report, containing statistics about the results of the search. The Microsoft .NET Framework 3.5 SP1 is required for output. It is not required to have Microsoft Excel installed in order to produce the report.

### Use Export Folder

This button sets the Lightgrep Output Folder to the current Case Export Folder.

### Search only selected items

This option determines whether all Entries or only selected (blue checked) Entries will be searched. Note that Records are not searched directly, but their content can be searched by selecting the appropriate Entries. Information about the number and size of selected Entries is displayed for reference.

### Search for Keywords

When this is selected, Lightgrep will search for the keywords selected in the Keywords tab. See .

### Search for Entities

When this option is selected, Lightgrep will search for entities using the options on the Entity Search tab. Keyword hit results will be restricted based on each entity’s filter code. See the Entity Search tab description for further information.

### Ignore all items in loaded hash library (search slack)

This option will prevent searching of any item that is present in the currently loaded hash library. To learn more about loading hash sets into the active hash library, please consult the EnCase Help file sections named “Hash Sets” and “Rebuilding a Hash Library.” Slack space will always be searched regardless of this setting. Selecting this item disables the following option.

### Ignore items with hash category ‘KNOWN’ (search slack)

This option will prevent searching of any item with a hash category of ‘KNOWN’ (case insensitive) that is present in the currently loaded hash library. To learn more about loading hash sets into the active hash library, please consult the EnCase Help file sections named “Hash Sets” and “Rebuilding a Hash Library.” Slack space will always be searched regardless of this setting. This item will be disabled if the preceding option is selected.

### Search Status

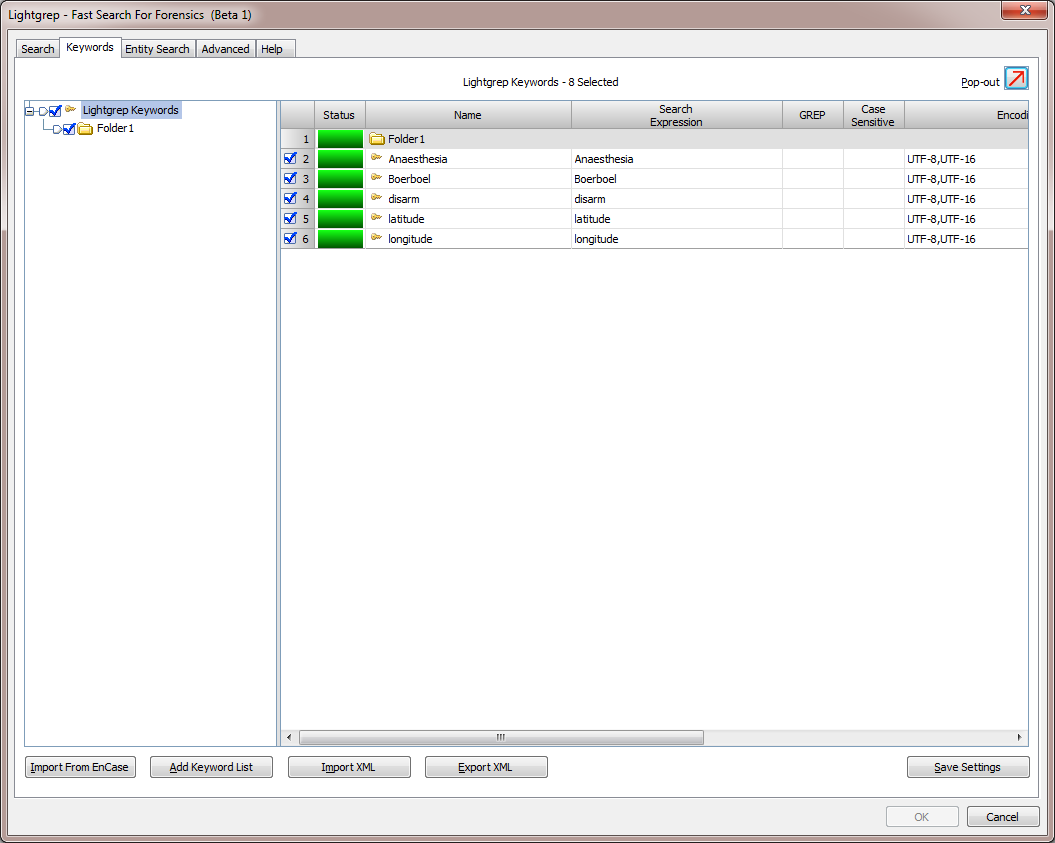
The Search Status window displays statistics about the currently running search. You will see the keyword name, search expression, a count of how many files have hits for each keyword, the percentage of files with hits, the total count of hits produced by that keyword, and the percentage of total hits related to that keyword.

### Search (Button)

The Search button starts the search using all previously selected criteria.

# Keywords

Lightgrep keywords are a little different from EnCase keywords. For one, Lightgrep keywords are PCRE compatible. Lightgrep supports more operators, longer repetition, and longer search hits. Unfortunately this means we can't use EnCase keywords, so you won't see your EnCase keywords here automatically. Supported keyword syntax is discussed in the section .



Figure

## Options

### Import From EnCase

Clicking this button will open the *Import Keywords from EnCase* dialog as shown in . The leftmost tree pane shows folders in both Global Keywords and Case Keywords from EnCase. Use this pane and the pane on the right to select (blue-check) the keywords you would like to import.

The right tree pane shows Lightgrep Keywords folders. The folder selected (highlighted) here will receive the imported keywords.



Figure

At the bottom of the dialog, a checkbox labeled “Retain folder structure when importing” allows you to keep the imported keywords organized as they were in EnCase. The folders named “\*\*GLOBAL KEYWORDS\*\*” and “\*\*CASE KEYWORDS\*\*” are not retained, and are displayed only for informational purposes. In the example from , the root of Lightgrep Keywords is selected on the right; this will produce folders as shown below in .



Figure

When done, click the OK button and the EnCase keywords will be imported and converted into Lightgrep Keywords. A summary of the import will be presented as in .



Figure

### Add Keyword List

Clicking this button will open the *Add Keywords from List or File* dialog as shown in . By default, the “List” option is selected. Copy and Paste a list of keywords, one per line to import. Then, select the proper options for the keywords. The right tree pane shows Lightgrep Keywords folders. The folder selected (highlighted) here will receive the imported keywords.



Figure

If you select the “File” option, they will be presented with a path selection box. Choose the path to a text file containing keywords, one per line. Then, select the proper options for the keywords. The right tree pane shows Lightgrep Keywords folders. The folder selected (highlighted) here will receive the imported keywords.



Figure

### Import / Export XML

These options allow you to export selected keyword folders to an XML file for later import or for import on another installation of Lightgrep for EnCase. Once exported, you can click the “Import XML” button and import the exported keywords to the folder of their choosing.

### Save Settings

Clicking the “Save Settings” button will save all changed options, including Keywords and Entities, to the script’s storage files. After clicking “Save Settings,” the saved settings will be available the next time you run the script even if you cancel the dialog without running a search.

### Keyword Tree

The Keyword Tree as shown in gives a familiar interface to view, organize, edit, and delete keywords. Keywords can be organized into folders on the left (tree) side of the interface just as any other dialog within EnCase. The heading / title directly above the keyword tree shows how many keywords are currently selected. **Only keywords which are blue checked will be searched by Lightgrep.**

### Editing Keywords

You can create a new keyword by right-clicking anywhere in the tree and selecting “New” from the context menu or edit an existing keyword either by right-clicking on the keyword and selecting “Edit” or by double clicking on the keyword. Upon creating a new keyword or opening one to edit, you will be presented with the *Edit Keyword* dialog as shown below in . The fields in the keyword dialog are:

* Search Expression – the fixed string or GREP pattern to search for
* Name – familiar representation of the keyword
* GREP – search using regular expression pattern matching (see )
* Case Sensitive – only search for the exact case shown in the expression (i.e. “test” will not hit on “Test” or “teSt” if this is selected)
* Encodings – blue check the desired encodings to search for
* Supported Patterns – displays supported syntax for GREP patterns
* Sample Keyword Hits – displays sample strings that the expression could hit on, or an error message if invalid; these are not necessarily representative of data that may be present in the currently open Case



Figure

## Supported Pattern Syntax

### Individual Bytes

***b*** where ***b*** is any literal byte except **0x00** and metacharacters

**\a** **0x07**, bell

**\e** **0x1B**, escape

**\f** **0x0C**, form feed

**\n** **0x0A**, new line

**\r** **0x0D**, carriage return

**\t** **0x09**, horizontal tab

**\*o*** **0*o***, where *o* is an octal digit

**\*oo*** **0*oo***, where each *o* is an octal digit

**\*ooo*** **0*ooo***, where each *o* is an octal digit, less than or equal to 0377

**\x*hh*** **0x*hh***, where each h is a hexadecimal digit

**\c** ***c***, where c is any character not listed above

### Metacharacters

Outside of character class specifications, the following characters have special meanings: \, |, (, ), ?, +, \*, ., [. To specify a literal backslash, pipe, left parenthesis, right parenthesis, question mark, plus, asterisk, period, or left square bracket, escape it with a backslash. Additionally, literal left curly braces ({) must be escaped outside of character class specifications if they could otherwise be interpreted as the start of ranged quantifiers, but need not be escaped otherwise.

### Character Classes

[*ccspec*] matches any byte in *ccspec*  
[^*ccspec*] matches any byte not in *ccspec*

Where *ccspec* is one or more of the following:

* a byte,
* a byte escape,
* a range formed by bytes or byte escapes, or
* a named character class (except .).

### Character Class Metacharacters

* The right square bracket ] must be escaped inside character class specifications unless it is the first member.
* The hyphen - forms ranges inside character class specifications using the characters immediately preceding and following it, except when - is the first or last character in the class specification or if the previous character is already part of a range, in which case - stands for itself.
* A literal \ must always be escaped.
* All other characters stand for themselves.

### Named Character Classes

**.** equivalent to **[0x00-0xFF]**  
**\d** equivalent to **[0-9]**  
**\D** equivalent to **[^0-9]**  
**\s** equivalent to **[\t\n\f\r]**  
**\S** equivalent to **[^\t\n\f\r]**  
**\w** equivalent to **[0-9A-Za-z\_]**  
**\W** equivalent to **[^0-9A-Za-z\_]**

### Repetition

***S*\*** equivalent to***S*{0,}*****S*+** equivalent to***S*{1,}*****S*?** equivalent to ***S*{0,1}*****S*{*n*,}** equivalent to***S*{*n*,*M*} *S*{*n*,*m*}** matches at least ***n*** and at most ***m*** repetitions of ***S***, greedily***S*\*?** equivalent to***S*{0,}?*****S*+?** equivalent to***S*{1,}?*****S*??** equivalent to***S*{0,1}? *S*{*n*,}?** equivalent to***S*{*n*,*M*}?*****S*{*n*,*m*}?** matches at least *n* and at most *m* repetitions of *S*, reluctantly

Where ***S*** is an atomic pattern, 0 ≤ ***n*** ≤ ***m***, and ***M*** is a largish integer which presently depends on the size of the memory available on the machine where Lightgrep is run. An ***M*** value of 10,000,000 can be searched successfully with less than 24 GB of RAM, though startup time will be extremely slow.

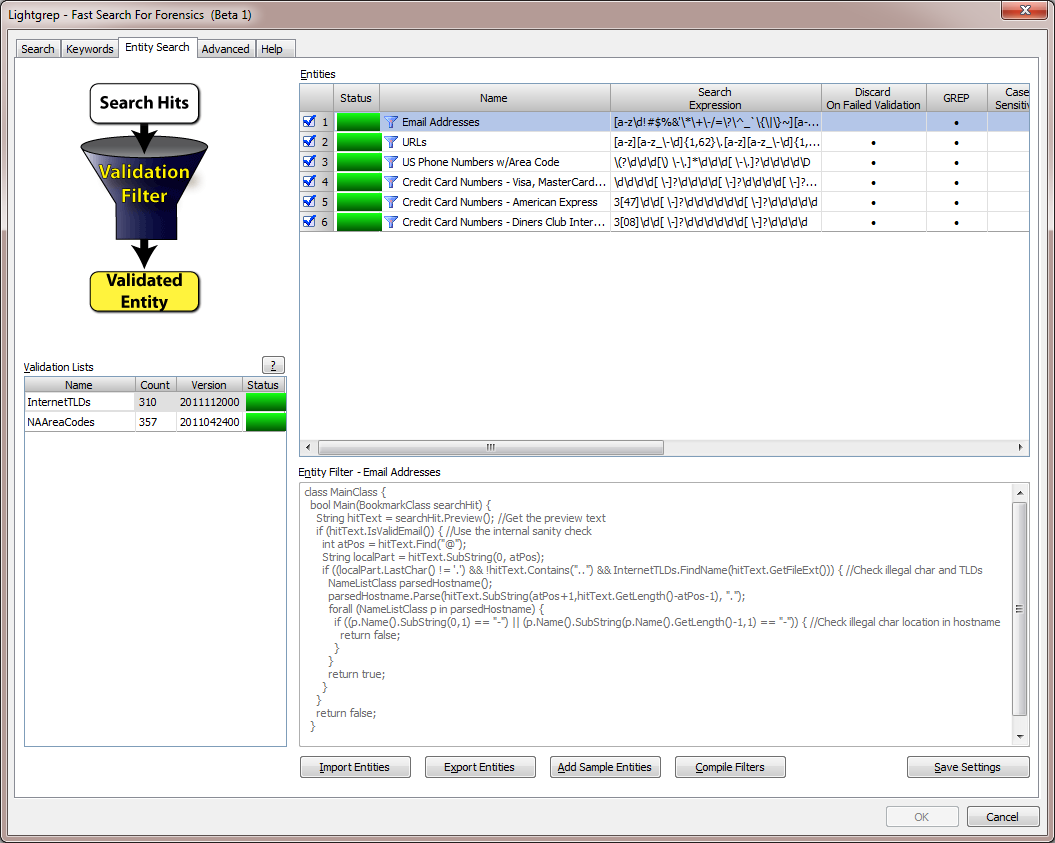
### Conjunction, Alternation, Grouping

***ST*** matches something matching ***S*** followed by something matching ***T******S*|*T*** matches ***S*** or ***T***, preferring matches for ***S***  
**(*S*)** equivalent to ***S***, but is atomic

Individual bytes, character classes, and groups are atomic.

# Entity Search

Entity search looks for GREP keywords and then uses filters to verify the results as shown in . The default filters compare Email addresses and URLs to the list of approved top-level domains to insure validity; check US phone numbers for valid area codes; and compare credit card numbers using Luhn's algorithm. If "Discard On Failed Validation" is selected, the search hit will be ignored completely if the filter returns false, otherwise it will be noted in the bookmark comment. Be aware that filtering search hits for entities can take some time, if the filter code is involved and there are lots of hits. The productivity gain from reducing false positives, however, is well worth the slightly extended filtering time.



Figure

## Options

### Entities

Entities use the same expression rules as regular Lightgrep keywords. You can add new entities, edit and delete existing entities in the same manner as keywords using right click controls.

### Entity Filter

This read-only text box displays the filter code for the currently selected Entity. You must edit the Entity in order to change the filter code.

### Validation Lists

Validation Lists are NameListClass objects (see the EnScript Help within EnCase for an example of working with NameListClass types) that are pre-populated with useful lists of information. For example, the 'InternetTLDs' list is a NameListClass containing every IANA approved top level domain, such as com, edu, uk, etc. The list count and version (a string typically representing the date of the most recent update) are displayed. Double-click on a Validation List name to view its contents.

Validation Lists can be used as NameListClass objects directly in the Main() function of entity filters without initialization:

NameListClass comDomain = InternetTLDs.FindName("com");

Validation Lists are local to the Main() function; they cannot be used outside of Main() without being passed into other functions.

Current Sources:

InternetTLDs  
List of valid Internet top level domains, maintained by IANA (com, edu, uk, etc)  
http://data.iana.org/TLD/tlds-alpha-by-domain.txt

NAAreaCodes  
List of active North American area codes, maintained by the North American Numbering Plan Administration  
http://www.nationalnanpa.com/nas/public/npasInServiceByNumberReport.do?method=displayNpasInServiceByNumberReport"

### Import / Export Entities

These options allow you to export entities to an XML file for later import or for import on another installation of Lightgrep for EnCase. Once exported, you can click the “Import Entities” button and import the exported items.

### Add Sample Entities

Clicking this button will allow you to add the sample entities shown in . Sample entities are provided as a starting pointing and demonstration of the power of entity filtering.

### Compile Filters

This button will compile all filters in any blue checked entity. If a filter fails to compile, you will see an error message that describes which entity filter could not be compiled.

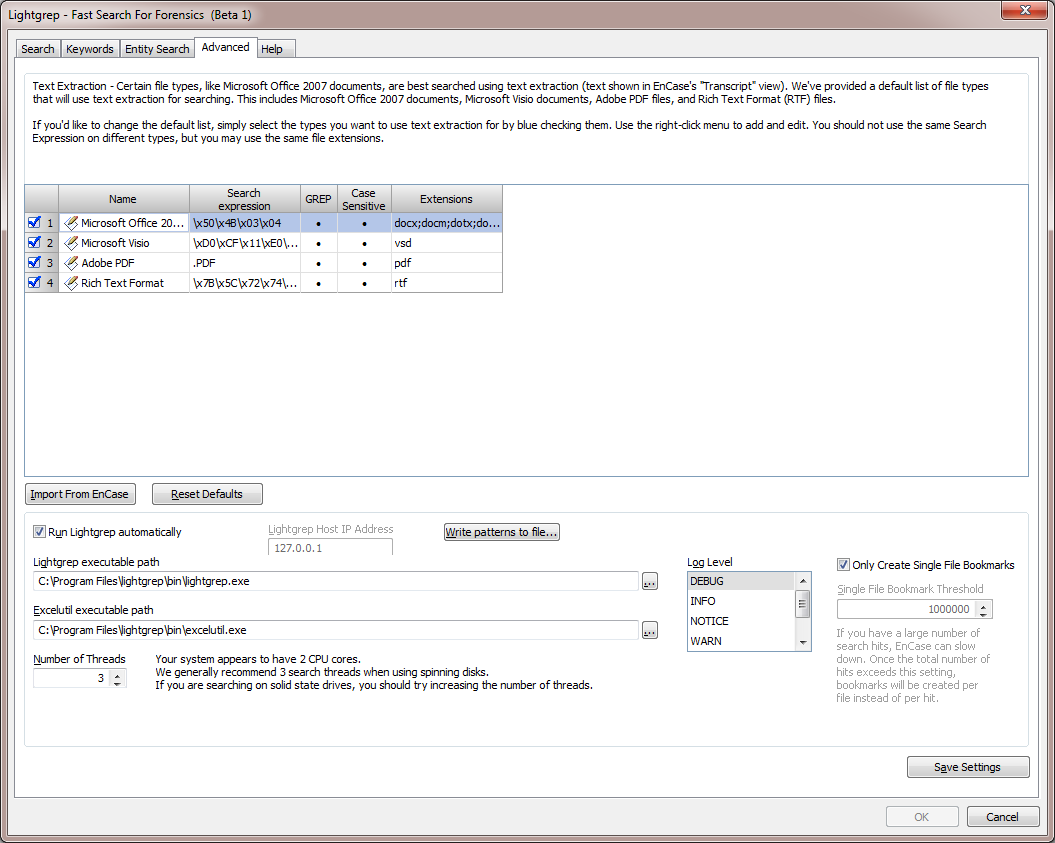
### Save Settings

Clicking the “Save Settings” button will save all changed options, including Keywords and Entities, to the script’s storage files. After clicking “Save Settings,” the saved settings will be available the next time you run the script even if you cancel the dialog without running a search.

# Advanced Tab

Text Extraction - Certain file types, like Microsoft Office 2007 documents, are best searched using text extraction (text shown in EnCase's "Transcript" view). We've provided a default list of file types that will be used text extraction for searching. This includes Microsoft Office 2007 documents, Microsoft Visio documents, Adobe PDF files, and Rich Text Format (RTF) files.

If you'd like to change the default list, simply select the types you want to use text extraction for by blue checking them. You should not use the same Search Expression on different types, but you may use the same file extensions.



Figure

## Options

### File Signature List

The File Signature List, as shown in the top portion of , contains a list of file types that will be used to identify files for text extraction. This list contains standard EnCase file signatures. You can add or edit file signatures just as you would in EnCase.

During a search, any file types selected here will have text extracted using EnCase’s Oracle Outside-In technology. Lightgrep will search the extracted text for keywords instead of the binary content of the file. It will also search binary file slack of any files identified for text extraction, so you don’t have to worry about missing anything.

If you deselect any types, you will receive a warning: “You have deselected one or more file types. Any file type that is not selected will be searched using standard native content instead of extracted text.”

### Import From EnCase

Clicking this button will open the *Import File Signatures from EnCase* dialog as shown in . The dialog shows the standard EnCase File Signatures list. Use this window to select (blue-check) the file signatures you would like to import. When done, click the OK button and they will be imported into Lightgrep.



Figure

### Reset Defaults

Clicking on the Reset Defaults button will remove any custom file signatures that have been created or imported from EnCase and replace them with the default values as shown in .

### Run Lightgrep automatically

This setting should always be checked when performing searches. You should only change this option at the instruction of Lightbox Technologies support for the purposes of debugging.

### Lightgrep executable path

The path to lightgrep.exe on the examiner system. The Lightgrep search executable is run using this path. Usually *C:\Program Files\lightgrep\bin\lightgrep.exe*.

### Excelutil executable path

The path to excelutil.exe on the examiner system. The excelutil executable is run using this path to output the Excel report. Usually *C:\Program Files\lightgrep\bin\excelutil.exe*.

### Number of Threads

The script will attempt to auto-detect how many cores you have on your box. Regardless of the number of cores, we generally recommend 3 search threads when using spinning / magnetic hard disks. If you are searching on solid state drives, and have more than 2 cores, you can try increasing the number of threads.

### Log Level

This represents the level of detail provided in the EnCase Console log. Usually this should be set to WARN. Setting this to DEBUG will cause an extremely large number of log events to be written to the Console.

### Only Create Single File Bookmark s

Selecting this option will cause bookmarks to be created per file instead of per hit. If selected, the “Single File Bookmark Threshold” will be disabled.

### Single File Bookmark Threshold

If you have a large number of search hits, EnCase can slow down significantly. Once the total number of hits exceeds this setting, bookmarks will be created per file instead of per hit. The default value is *3,000,000*.

### Save Settings

Clicking the “Save Settings” button will save all changed options, including Keywords and Entities, to the script’s storage files. After clicking “Save Settings,” the saved settings will be available the next time you run the script even if you cancel the dialog without running a search.

# Starting a Search

Once you click the “Search” button on the main Search tab, the search process will begin. The first thing you will see in the bottom status bar is “Initial filtering” as shown in .



Figure

The “Initial filtering” process consists of several phases:

* Writing out the selected keyword and entity expressions to the file *keywords.txt*
* Filtering out entries with a physical size of 0 and also files which are completely sparse
* Sorting the entries selected for search so as to maintain consistently high usage of the tool’s multithreading capabilities
* Checking each individual entry to determine if it should be searched using extracted text (transcript)
* Writing the list of entries to be searched to the file *EntryList.txt*

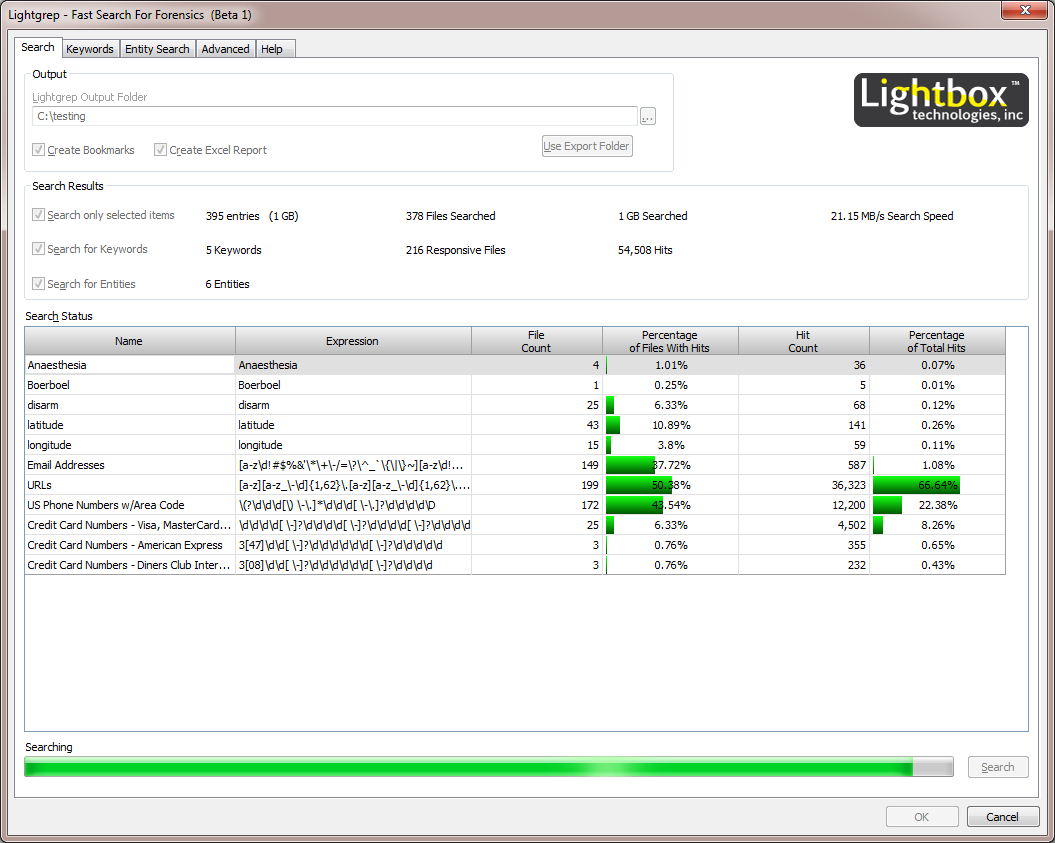
This process can take anywhere from a few seconds to a few minutes, depending on how many entries are selected, and which options you choose.

Clicking the “Cancel” button at any time during the search will cause the entire search to be aborted.

# Monitoring Search Progress

Once the search begins, you can monitor the progress of the search through the main Search tab as shown in . The following fields will be displayed during a search:

* Keyword or Entity name
* Search Expression
* File Count – the number of files which are responsive to each keyword
* Percentage of Files With Hits – of the total files searched, what percentage contained hits for each keyword
* Hit Count – the number of search hits produced by each keyword (before entity filtering)
* Percentage of Total Hits – of the total search hits found for all keywords, what percentage of hits were produced by each keyword



Figure

# Reviewing Output

The “OK” button is enabled when the search completes. Clicking “OK” will save sweeping bookmarks containing the search hit results. If “Create Excel Report” was selected, the Excel overview will also be created. Clicking “Cancel” will end the search without saving bookmarks or the Excel report.



Figure

## Bookmark Output

Once the bookmarks have saved, you can review them just as you would other search hits. shows example bookmark output from the URLs entity search.



Figure

When reviewing search hits, the folders for Entities will contain a comment noting how many hits failed entity filtering, and whether they were discarded.



Figure

## Excel Output

The Excel report provides an overview of results by displaying charts of the top ten keywords by number of hits and file size.

|  |  |
| --- | --- |
|  |  |

A keyword frequency report shows all keywords that were searched, and the resulting hit statistics. These results are identical to those in the Search Status box which are displayed during the search.



The DataCategories tab shows all file extensions for search hits, with the number of files and size of files represented by each file extension. Files with no extension are denoted by the asterisk (\*).



The Excel report worksheets are protected so you don’t accidentally alter the data. If you wish to edit the report, simply go to the Review tab in the Office Ribbon as shown in , and click “Unprotect Sheet.” No password is needed.



Figure

1. EnCase® is a registered trademark of Guidance Software, Inc. [↑](#footnote-ref-2)