sLASh – a simple LAS reader library in a single header file

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European Lidar Map Forum, 2013

Danish Ministry of the Environment
Danish Geodata Agency

Outline

1. **What?**
   - What is it
   - What does it look like?
2. **Why?**
   - Do we need yet another LAS library?
   - But why a header library?
3. **How? – Design and Usage**
   - Setting and influences
   - Overall Design
4. **(Un)conclusion**
5. **DVD bonus material – digitally remastered director's cut**

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What is it

- sLASh – `slash.h` – reads **LAS** files
- Header library, written in plain C
- Permissive license (ISC/OpenBSD)
- Very compact

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```
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   1346  slash.h

awk -f lines_of_code.awk  slash.h|wc -l
    577
```

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    577
```

- Data type definitions and self tests ≈200 lines
- Core library functionality **<400 lines**
- Binary **< 7 kB** (gcc, Win64).

What does it look like?

```c
#include "slash.h"

int main (int argc, char **argv) {
    LAS *h;
    double x, y, z;

    h = las_open (argv[1], "rb");
    while  (las_read (h))  {
        x = las_x (h);
        y = las_y (h);
        z = las_z (h);
        printf ("%f %f %f\n", x, y, z);
    }

    las_close (h);
    return 0;
}
```

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A relevant question...

LASlib

libLAS

But... **Do we really need another LAS library?**

Do we really need another LAS library?

- **We** may not need it
- but **I did** need it

Long story short...

Do we really need another LAS library?

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Long story short...

- Needed to patch some slightly erroneous LAS 1.0 files
- Just a small extra effort to turn the code into a library.

But why a *header* library?

Recently, we did some experiments packaging small re-usable software components as *header-only libraries*

- Including

  ASTA
  : Accumulation of STAtistics

  stack
  : Template library in plain C

  comquat
  : COMplex numbers and QUATernions

- Obvious idea to package the LAS reader in the style of ASTA, stack and comquat.

Helios

The entire package of libraries was named after 3 elements

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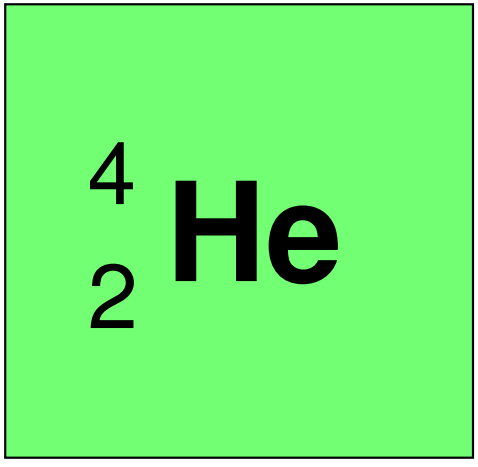
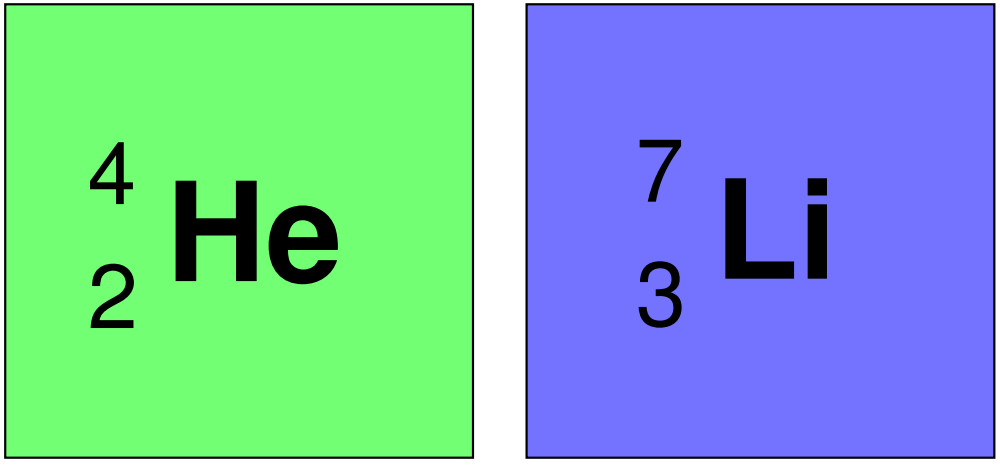


Header

Helios

The entire package of libraries was named after 3 elements



Header Libraries

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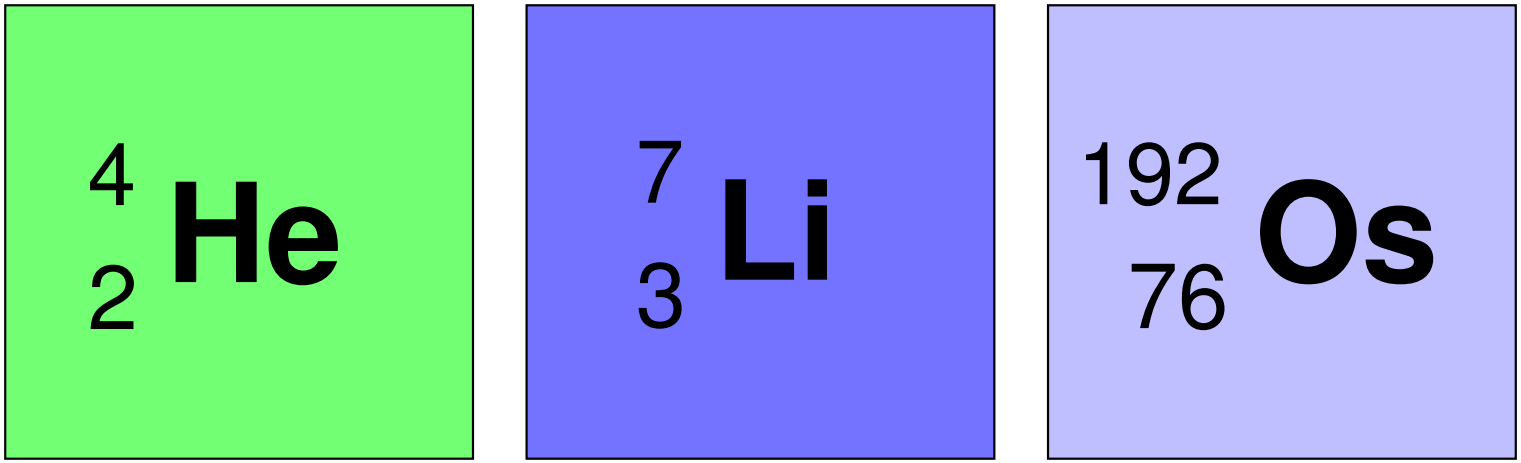
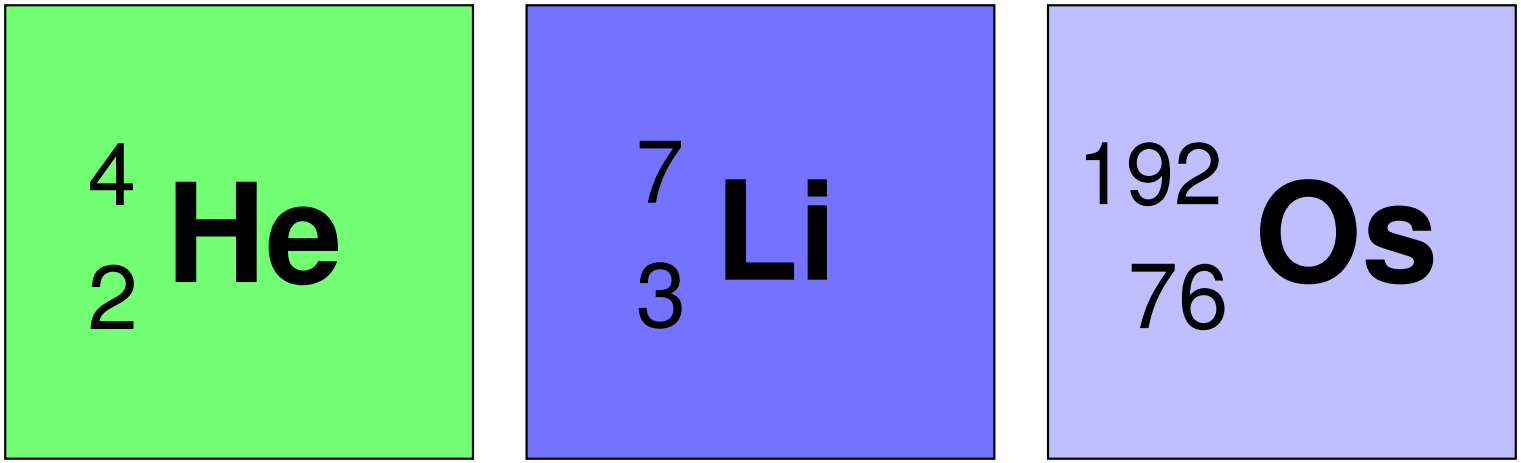


Header Libraries on Steroids

Helios

The entire package of libraries was named after 3 elements



Header Libraries on Steroids

It may be *perceived* as *dense and brittle*, but it's *lightweight* and it *keeps you sane* **:-)**

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Our typical software tool setup

LAS processing

LAStools, libLAS, OPALS, TerraSolid

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Core functionality/library implementation

C (with Python bindings)

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Python/PyQt

Our typical software tool setup

LAS processing
: LAStools, libLAS, OPALS, TerraSolid

Core functionality/library implementation
: C (with Python bindings)

Graphical User Interfaces
: Python/PyQt

Production automatization
: Python, bash, Windows **cmd.exe**

The LAS format

The sLASh design is necessarily shaped by the main structures defined in the LAS format specification:

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: Georeferencing, generic user defined metadata

Fixed Length Records
: The actual LiDAR point data

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: e.g. Waveform data

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: Georeferencing, generic user defined metadata

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: The actual LiDAR point data

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Five versions (LAS 1.0–1.4), 11 fixed record formats (0–10)

$\Longrightarrow$ Probably not as simple as it could be. . .

Design principles

Less is more

You cannot do everything in 400 lines

Worse is better

Go for simple implementations. Don’t get smart unless necessary: smart means brittle

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Avoid the 2nd system syndrome

Plan ahead but *keep it simple, stupid* (KISS)

Avoid creeping featurism

"you're not gonna need it".

Overall Design

Data types

LAS, NRGB, Waveform Descriptor, LAS record, VLR

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las_open, las_seek, las_read, las_close

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las_header_display, las_record_display, las_vlr_display

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: LAS, NRGB, Waveform Descriptor, LAS record, VLR

File access API
: las_open, las_seek, las_read, las_close

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Printing and formatting API
: las_header_display, las_record_display, las_vlr_display

Plumbing
: Record structure LUTs, big endian/little endian, WIN32 large file support.

Back to page 1...

```c
#include "slash.h"

int main (int argc, char **argv) {
    LAS *h;
    double x, y, z;

    h = las_open (argv[1], "rb");
    while  (las_read (h))  {
        x = las_x (h);
        y = las_y (h);
        z = las_z (h);
        printf ("%f %f %f\n", x, y, z);
    }

    las_close (h);
    return 0;
}
```

Features

sLASh will happily. . .

Features

sLASh will happily...

- Access LAS files

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sLASh will happily. . .

- Access LAS files
- Read variable length records
- Read fixed length records
- Access/interpret fields and flags of the fixed length records.

Un-features

sLASh will only reluctantly (or not at all)...

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- Interpret variable length records
- Read compressed **LAZ** files
- Write LAS files

Un-features

sLASh will only reluctantly (or not at all)...

- Interpret variable length records
- Read compressed **LAZ** files
- Write LAS files
- Make coffee
- Provide kitchen sink access
- Read mail
- Emit tweets.

Where to use?

The Use Cases. . .

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- Probably mostly for lovers of the C language

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Where to use?

The Use Cases. . .

- Probably mostly for lovers of the C language
- Quick-and-dirty hacks
- When stream mode reading is sufficient (e.g. building inventories, collecting statistics. . .)
- Memory constrained (e.g. embedded) systems

Where to use? (2)

The Useless Cases...

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- When writing LAS files are important

Where to use? (2)

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- When writing LAS files are important
- When you need on-the-fly reprojection

Where to use? (2)

The Useless Cases...

- When writing LAS files are important
- When you need on-the-fly reprojection
- When you need spatial indexing (.lax files)
- When you need LAS compression (.laz files)

Where to use? (3)

In brief:

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- Use LAStools/LASlib/libLAS for the heavy lifting

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- only consider sLASh when filling in where you need specialized functionality

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In brief:

- Use LAStools/LASlib/libLAS for the heavy lifting
- only consider sLASh when filling in where you need specialized functionality
- . . . and have fun!

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Summary

- Try sLASh
- It's compact
- It's fast
- It's fun
- It's available from http://bitbucket.org/busstop/helios
- a.k.a. **http://goo.gl/zsi8qz**
- Get it while it's hot!

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lasinfo in 8 lines

```
#include "slash.h"
int main (int argc, char **argv) {
    LAS *h;
    h = las_open (argv[1], "rb");
    las_header_display (stdout, h);
    las_close (h);
    return 0;
}
```

lasinfo in 8 lines

```c
#include "slash.h"
int main (int argc, char **argv) {
    LAS *h;
    h = las_open (argv[1], "rb");
    las_header_display (stdout, h);
    las_close (h);
    return 0;
}
```

Or even shorter:

```c
#include "slash.h"
int main (int argc, char **argv) {
    return las_header_display (stdout,
                    las_open (argv[1], "rb"));
}
```

It's compact

```
> gcc -Os -o slashinfo -I../include slashinfo.c
> strip --strip-all slashinfo.exe
> dir

2013-10-31  13:17                20.992 slashinfo.exe
```

It’s tiny

```
> gcc -Os -x c -c -o slash.o slash.h
> strip --strip-all slash.o
> dir slash.o

2013-11-01  05:48                 6.660 slash.o
```

A LAS reader library in 6.5 kB!

It's fast

```
Read 392826 points.

(bla bla bla...)

********** timings for sLASh **********
Min:  0.0644 s
Max:  0.0657 s
Mean: 0.0650 s

.
```

Python bindings and timings by Simon L. Kokkendorf

It's fast

```
Read 392826 points.

(bla bla bla...)

********** timings for libLAS **********
Min:  8.4942 s
Max:  8.5881 s
Mean: 8.5480 s

(8.548 / 0.065 = 131.5)
```

Python bindings and timings by Simon L. Kokkendorf

What does it look like?

```c
#include "slash.h"

int main (int argc, char **argv) {
    LAS *h;
    double x, y, z;

    h = las_open (argv[1], "rb");
    while  (las_read (h))  {
        x = las_x (h);
        y = las_y (h);
        z = las_z (h);
        printf ("%f %f %f\n", x, y, z);
    }

    las_close (h);
    return 0;
}
```

. . . compared to LASlib

```
#include "lasreader.hpp"
#include "laswriter.hpp"

int main(int argc, char *argv[]) {
  LASreadOpener lasreadopener;
  lasreadopener.set_file_name("original.las");
  LASreader* lasreader = lasreadopener.open();

  LASwriteOpener laswriteopener;
  laswriteopener.set_file_name("compressed.laz");
  LASwriter* laswriter = laswriteopener.open(&lasreader->header);

  while (lasreader->read_point())
      laswriter->write_point(&lasreader->point);

  laswriter->close();
  delete laswriter;
  lasreader->close();
  delete lasreader;
  return 0;
}
```

Data types

```
struct lasheader;
typedef struct lasheader LAS;

struct las_nrgb;
typedef struct las_nrgb    LAS_NRGB;

struct las_wf_desc;
typedef struct las_wf_desc LAS_WAVEFORM_DESCRIPTOR;

struct lasrecord;
typedef struct lasrecord LAS_RECORD;

struct lasvlr;
typedef struct lasvlr    LAS_VLR;
```

Main API

```
LAS   *las_open (const char *filename, const char *mode);

void   las_close (LAS *h);

int    las_seek (LAS *h, size_t pos, int whence);

size_t las_read (LAS *h);
```

Record access API

```
double        las_x (const LAS *h);
double        las_y (const LAS *h);
double        las_z (const LAS *h);
double        las_gps_time (const LAS *h);
double        las_intensity (const LAS *h);

unsigned int las_class (const LAS *h);
unsigned int las_class_flags (const LAS *h);
unsigned int las_flag_synthetic (const LAS *h);
unsigned int las_flag_key_point (const LAS *h);
unsigned int las_flag_withheld (const LAS *h);
unsigned int las_flag_overlap (const LAS *h);

unsigned int las_return_number (const LAS *h);
unsigned int las_number_of_returns (const LAS *h);
unsigned long long las_record_number (const LAS *h);

double        las_scan_angle_rank (const LAS *h);
int           las_point_source_id (const LAS *h);
int           las_scanner_channel (const LAS *h);
unsigned int las_scan_direction (const LAS *h);
unsigned int las_edge_of_flight_line (const LAS *h);

LAS_WAVEFORM_DESCRIPTOR las_waveform_descriptor (const LAS *h);
LAS_NRGB las_colour (const LAS *h);
```

Variable length records API

```
LAS_VLR *las_vlr_read (LAS *h, int type) ;
void las_vlr_free (LAS_VLR *self) ;
```

Printing and formatting API

```
struct tm yd2dmy(int y, int d) ;
void las_record_display (FILE *f, const LAS *h);
void las_header_display (FILE *f, const LAS *h);
void las_vlr_display (LAS_VLR *self, FILE *stream);
void las_vlr_display_all (LAS *h, FILE *stream);
```

Low level portability functions

```
void memcpy_swapping (void *dest, const void *src, size_t offset
long long get_signed_16 (const void *buf, size_t offset);
long long get_signed_32 (const void *buf, size_t offset);
long long get_signed_64 (const void *buf, size_t offset);
unsigned long long get_unsigned_16 (const void *buf, size_t offs
unsigned long long get_unsigned_32 (const void *buf, size_t offs
unsigned long long get_unsigned_64 (const void *buf, size_t offs
float get_float (const void *buf, size_t offset);
double get_double (const void *buf, size_t offset);
```

LAS (1)

```
/* LAS file header straightforwardly implemented from the LAS 1.0--1.4 specs */
struct lasheader {
    char                    signature[8];     /* LASF */
    unsigned short          file_source_id;
    unsigned short          global_encoding;

    unsigned long           project_id_1;
    unsigned short          project_id_2;
    unsigned short          project_id_3;
    unsigned char           project_id_4[8];

    unsigned char           version_major;
    unsigned char           version_minor;

    char                    system_id[32];
    char                    generated_by[32];

    unsigned short          file_creation_day_of_year;
    unsigned short          file_creation_year;

    unsigned short          header_size;
    unsigned long           offset_to_point_data;
    unsigned long           number_of_variable_length_records;

    unsigned char           point_data_format;
    unsigned short          point_data_record_length;
    unsigned long long      number_of_point_records;
    unsigned long long      number_of_points_by_return[15];
```

LAS (2)

```
    double                      x_scale;
    double                      y_scale;
    double                      z_scale;
    double                      x_offset;
    double                      y_offset;
    double                      z_offset;

    double                      x_max;
    double                      x_min;
    double                      y_max;
    double                      y_min;
    double                      z_max;
    double                      z_min;

    unsigned long long          offset_to_waveform_data_packet_record;
    unsigned long long          start_of_extended_vlrs;
    unsigned long long          number_of_extended_vlrs;

    /* additional fields for internal use by sLASh */
    size_t  next_record;
    FILE   *f;
    char mode[256];
    size_t class_histogram[256];

    /* number of decimals recommended (computed from scale factors by las_open)*/
    int nx, ny, nz;
    unsigned char raw[8192];
    unsigned char record[1024];
};
```

Colour and Waveforms

```
/* Colour information - types 2, 3, 5, 7 (rgb),
                            and 8, 10 (nrgb)  */
struct las_nrgb {double n, r, g, b;};


/* Waveform information - types 4, 5, 9, 10 */
struct las_wf_desc {
    unsigned char      descriptor_index;
    float              return_point_location;
    float              x_t, y_t, z_t;
    unsigned long long offset_to_data;
    unsigned long long packet_size;
};
```

LAS record – in preparation for writing

```
struct lasrecord {
    /* The common (unpacked) subset for all record types */
    double x, y, z;
    double intensity;

    /* Flags and narrow data fields from bytes 14-15 */
    unsigned int return_number, number_of_returns;
    unsigned int scanner_channel, scan_direction, edge_of_flight_line;
    /* Classification flags (overlap: types 6-10 only) */
    unsigned int synthetic, key_point, withheld, overlap;

    unsigned int classification; /* "class" is reserved under C++, hence "classificat

    double scan_angle;
    unsigned char user_data;
    unsigned int  point_source_id;

    /* Record types 0 and 2 omits the GPS time */
    double gps_time;

    /* Colour information - types 2, 3, 5, 7 (rgb), and 8, 10 (nrgb) */
    LAS_NRGB colour;

    /* Waveform information - types 4, 5, 9, 10*/
    LAS_WAVEFORM_DESCRIPTOR waveform;
};
```

Variable length records

```
struct lasvlr {
    unsigned long long reserved;
    char user_id[16];
    unsigned long long record_id;
    unsigned long long payload_size;
    char description[32];
    /* -------------------- */
    fpos_t pos;
    int type; /* vlr: 0, evlr: 1 */
    unsigned char *payload;
};
```