

# GoPro GPMF-parser Vulnerabilities

Oct 17, 2020 • Christian Reitter

ID: CVE-2020-16158, CVE-2020-16160, CVE-2020-16161, CVE-2020-16159

As part of my fuzzing research [into C parsers](#), I took a look at the open source GoPro [GPMF-parser](#) project. The GPMF-parser software decodes custom telemetry metadata from GoPro camera video recordings. Multimedia file parsers are notoriously difficult to write safely in C, so I expected some memory security issues and saw this as a good exercise for fuzzing.

Ultimately, this analysis led to ~25 bug reports, most of them communicated confidentially to the vendor over the course of a long disclosure process due to security implications. After coordination with the vendor, I requested four CVEs in July to track several issues with a direct impact.

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## Consulting

*I'm a freelance Security Consultant and currently available for new projects. If you are looking for assistance to secure your projects or organization, [contact me](#).*

## Technical Background

The [GPMF-parser documentation](#) gives some insight into the design of the GPMF format. Action cameras store multiple telemetry datasets within the main video container alongside the compressed video and audio, apparently for performance reasons. On the technical side, this is done via the GPMF key-length-value structure and custom extensible markers such as FourCC.

In practice, the decoding of GPMF data from existing video files involves

1. GPMF data extraction from the video container (*not core functionality, but implemented for MP4*)
2. GPMF data parsing via the GPMF-parser library (*core functionality*)

The library ships with a standalone demo program to do this processing on MP4 file inputs.

## Summary

The discovered issues are presented in a condensed format due to the raw number of bugs.

Please note that the security issues are treated differently depending on their code origin. Although there are existing CVEs from 2018 and 2019 for memory issues in the MP4 parsing section (*that were discovered by other researchers, see [CVE-2018-18699](#), [CVE-2019-15148](#)*), GoPro indicated during the disclosure process that the MP4 parsing code is not actually in-scope.

I would probably not have researched/reported the related issues in depth if this fact would have been documented more explicitly.

Issues within the example program (marked “demo”) were also treated as out-of-scope and are listed here for completeness.

## Product Overview

| Project     | Source                 | Fix   | References        |
|-------------|------------------------|---|-------------------|
| GPMF-parser | <a href="#">GitHub</a> | <a href="#">release 2.0</a> , <a href="#">release 2.0.2</a> | <a href="#">?</a> |

It is not documented which other internal or external projects use the GPMF-parser library.

## Main Security Issues

| ID | CVE                            | Description                               | Potential Impact  | Location                    | CWE     | POC                  |
|----|--------------------------------|---|---|-----------------------------|---------|----------------------|
| 1  | <a href="#">CVE-2020-16158</a> | Stack-buffer-overflow out of bounds write | Crash (with stack protection)<br>potentially arbitrary code execution | <a href="#">core</a>        | CWE-787 | <a href="#">file</a> |
| 17 | <a href="#">CVE-2020-16160</a> | Division by zero                          | DOS via crash (confirmed)   | <a href="#">core</a>        | CWE-369 | <a href="#">file</a> |
| 18 | <a href="#">CVE-2020-16161</a> | Division by zero                          | DOS via crash (confirmed)   | <a href="#">core</a> (1, 2) | CWE-369 | <a href="#">file</a> |
| 21 | <a href="#">CVE-2020-16159</a> | Heap out of bounds read                   | crash (confirmed) or information disclosure                           | <a href="#">core</a>        | CWE-125 | <a href="#">file</a> |

## Potential or Out-Of-Scope Security Issues

| ID | Description  | Potential Impact                        | Location             | POC     |
|----|--|---|----------------------|---------|
| 2  | Stack-use-after-scope                              | unclear, not well defined               | core                 | file    |
| 3  | Heap-buffer-overflow out of bounds read            | information disclosure                  | demo print           | see #2  |
| 4  | Large memory allocation                            | DOS via resource exhaustion             | MP4 parser           | file    |
| 5  | Large memory allocation                            | DOS via resource exhaustion             | MP4 parser           | file    |
| 6  | Large memory allocation                            | DOS via resource exhaustion             | MP4 parser           | -       |
| 7  | Null pointer read → segfault                       | DOS via crash                           | MP4 parser           | file    |
| 8  | Heap out of bounds read                            | information disclosure                  | MP4 parser           | file    |
| 9  | Division by zero                                   | DOS via crash                           | MP4 parser           | file    |
| 10 | Heap out of bounds read                            | information disclosure                  | MP4 parser           | file    |
| 11 | Heap out of bounds read                            | DOS via crash, information disclosure?  | MP4 parser           | file    |
| 12 | Division by zero ( <i>difficult to reproduce</i> ) | potential DOS via crash                 | MP4 parser           | -       |
| 13 | Long-running loops                                 | Partial DOS via CPU resource exhaustion | MP4 parser (1, 2, 3) | file    |
| 14 | Heap out of bounds read                            | Potentially information disclosure      | core                 | file    |
| 15 | Heap out of bounds read                            | Potentially information disclosure      | core                 | file    |
| 16 | Stack out of bounds write                          | DOS via crash or worse                  | demo                 | file    |
| 19 | Heap out of bounds read                            | information disclosure                  | core                 | see #18 |
| 20 | Heap out of bounds read                            | information disclosure                  | core (1, 2, 3)       | file    |

### Mainly Functional Issues:

| ID    | Description          | Potential Impact    | Location   |
|-------|----------------------|---------------------|------------|
| GH101 | memory resource leak | resource exhaustion | MP4 parser |
| GH102 | undefined behavior   | unspecified         | MP4 parser |
| GH103 | memory resource leak | resource exhaustion | MP4 parser |
| GH104 | memory resource leak | resource exhaustion | core       |

## Selection of Discovered Issues

### CVE-2020-16158

The `GPMF_ExpandComplexTYPE()` function allows multiple 1 byte stack out of bounds writes behind the `dst` buffer. The outer `while()` loop has some bounds checks but manipulates the relevant counters within the loop without additional checks.

Relevant code (simplified):

```
uint32_t GPMF_ExpandComplexTYPE(char *src, uint32_t srcsize, char *dst, uint32_t *dstsize)
{
    uint32_t i = 0, k = 0, count = 0;

    while (i < srcsize && k < *dstsize)
    {
        // [...], new count value is calculated here
        uint32_t l;
        for (l = 1; l < count; l++)
        {
            dst[k] = src[i - l];
            k++;
        }

        // [...]
        i++;
        k++;
    }
}
```

*GPMF\_parser.c*

As you can see, the limits imposed via the `while (i < srcsize && k < *dstsize)` condition are ineffective since `k` is increased locally based on other values. The assignment `dst[k] = src[i - l]` is therefore reachable with larger than intended `k` values.

Consider the following problematic run of `GPMF_ExpandComplexTYPE()` on a target buffer `dst` with a size of 64 bytes:

```
(gdb) print *dstsize
$7 = 64
```

Here is the memory view of the destination buffer plus following 32 bytes of memory, captured at the start of the function:

(x86\_64, no stack canary)

```
(gdb) x/96xb dst
0x7fffffffcd0: 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00
0x7fffffffcd8: 0x78 0xd0 0xff 0xff 0xff 0x7f 0x00 0x00
```

Here is the same memory region after exiting the `while()` loop with a problematic input:

In this particular case the memory is clobbered with a single `0x0f` value that is taken from `src[i - 1]`.

If the target binary is compiled without stack canaries, the vulnerability may allow an attacker to perform changes to the program flow via manipulation of adjacent memory regions behind `dst`. The changes are constrained by the nature of the out of bounds write, but a carefully crafted input might still leverage this bug to do something interesting on certain systems or architectures. In that case, the integrity and confidentiality properties of the target program will be impacted as well, although the overall attack complexity might be high or some user interaction might be involved.

The `GPMF_Decompress()` function includes a problematic division that can lead to a division by zero issue if `type` is not detected. This is possible since `GPMF_SizeOfType()` can return zero.

GPMF\_parser.c

The impact is a denial of service through the crash, represented by the following sanitizer warning:

```
==20022==ERROR: AddressSanitizer: FPE on unknown address
```

The `GPMF.ScaledData()` function includes a problematic modulo operation that can lead to division by zero issue if `inputtypeelements` is zero:

GPMF parser.c

The same issue is also present at a [second location](#) in the code.

The impact is a denial of service through the crash, represented by the following sanitizer warning:

```
==20022==ERROR: AddressSanitizer: FPE on unknown address
```

`GPMF_ScaledData()` calls macros to read and convert input data into specific types.

This can lead to a heap out of bounds read and following Segmentation fault in the `MACRO_BSWAP_CAST_UNSIGNED_SCALE` handling when operating on the end of `ms->buffer`:

The main observed impact of this is a denial of service via the seqfault.

Depending on the usage of the GPMF-parser library, it might be possible to avoid the segfault and leverage this for some sort of information disclosure via uninitialized heap memory.

## POC

Crafted example inputs for the individual issues were provided to the vendor and are linked in the bug summary overview at the beginning of the article.

To reproduce:

- Compile an older version of the GPMF-parser demo application
  - Optionally add appropriate sanitizers such as `-fsanitize=address` and other compile flags for error detection
- Run the example program against the `poc_issue*.mp4` file
- Use special compile-time and run-time flags such as `-fsanitize-recover=address, ASAN_OPTIONS=halt_on_error=0` to proceed beyond the initial errors on inputs that trigger multiple issues

## Disclosure

The disclosure process for these bugs was long and exhausting.

One of the reasons for this is my decision to fuzz the GPMF parsing code “all the way” through the MP4 file parsing interface. While this allowed me to present MP4-based POCs that directly worked as input for the unmodified demo application (better reproducibility for the developers), it also doubled the number of bugs that I had to analyze, report and patch away. Additionally, many bugs happened on similar inputs, which increased the complexity of preparing useful reports due to overlapping crashes.

Another major factor is the perceived unfamiliarity of the vendor with the requested type of coordinated disclosure for their open source code. For example, there is insufficient public documentation regarding disclosure contacts, guidelines and processes. A lot of back and forth via email was required to coordinate the relevant aspects, and this was not always successful.

The main patch release (2.0) was released around a month after the disclosure to the vendor. While this is not a bad response time for a likely nonessential vendor project, 9 of the 21 confidentially reported issues were missed during patching. The vendor quickly followed up with another release (2.0.2) a few days after I reported this.

To my knowledge, no public credit has been given for the 21 vulnerability reports despite a number of code changes and two security releases, which is disappointing.

## Partial Timeline

Note: this timeline excludes confidential data points and related information.

| Date                     | information  |
|--------------------------|--|
| 2020-06-20               | Initial communication to developer address and request for security contact                |
| 2020-06-23               | Request to 2nd developer address   |
| 2020-06-25               | <a href="#">GitHub issue</a> to ask for official security contact                          |
| 2020-06-25               | Initial email communication with GoPro security  |
| 2020-07-10 to 2020-07-14 | Public GitHub bug issues GH101 to GH104  |
| 2020-07-11 to 2020-07-15 | Confidential coordinated disclosure of issues #1 to #21 with POCs                          |
| 2020-07-15               | Shared fuzzing corpus with GoPro for testing   |
| 2020-07-23               | GoPro agrees to proposed CVE request process   |
| 2020-07-27               | GoPro acknowledges proposed CVE descriptions   |
| 2020-07-28               | Request of CVEs from MITRE   |
| 2020-07-30               | MITRE assigns CVEs   |
| 2020-08-20               | GPMF-parser 2.0.0 is released with security fixes  |
| 2020-08-22               | Note to GoPro about incomplete fixes for issues #3, #4, #7, #8, #15, #16, #19, #20 and #21 |
| 2020-08-27               | GPMF-parser 2.0.2 is released with security fixes  |
| 2020-08-28               | GoPro requests deadline extension to 6th October (accepted)                                |
| 2020-10-06               | Disclosure deadline  |
| 2020-10-17               | Publication of this blog article   |

**Christian Reitter**

Information security and other interests.

