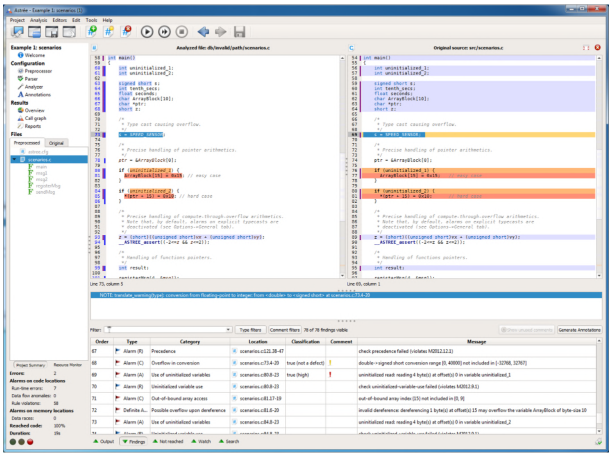
# Astrée

## Finding all Runtime Errors and Data Races in C/C++ Programs

Astrée is a parametric static analyzer designed to **prove the absence of runtime errors and data races** in software programs written in C/C++. Astrée is **parameterizable** and can be **specialized** to the program under analysis – key features to enable **high analysis precision**.



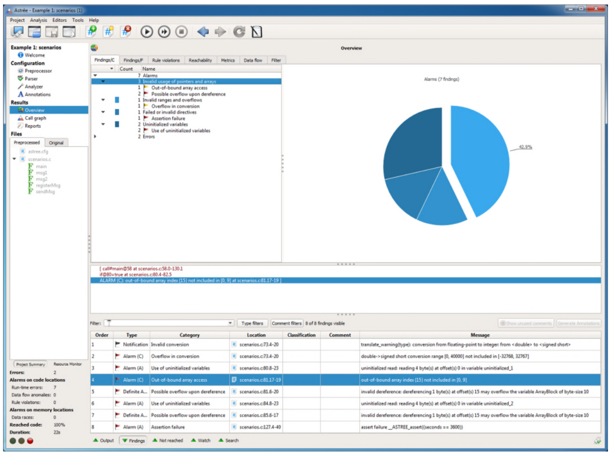
```
int main()
{
    int uninitialized_1;
    int uninitialized_2;

    signed short s;
    int tenth_secs;
    float seconds;
    char ArrayBlock[10];
    char *ptr;
    short z;

    /*
     * Type cast causing overflow.
     */
    s = SPEED_SENSOR;

    /*
     * Precise handling of pointer arithmetics.
     */
    ptr = &ArrayBlock[0];

    if (uninitialized_1) {
      ArrayBlock[15] = 0x15; // easy case
    }

    if (uninitialized_2) {
      *(ptr + 15) = 0x10; // hard case
    }

    /*
     * Precise handling of compute-through-overflow arithmetics.
     * Note that, by default, alarms on explicit typecasts are
     * deactivated (see Options->General tab).
     */
    z = (short)((unsigned short)vx + (unsigned short)vy);
    __ASTREE_assert((-2<=z && z<=2));

    /*
     * Handling of functions pointers.
     */
    int result;

    registerMsg(4, &msg1);
```

```
NOTE: translate_warning(type): conversion from floating-point to integer: from <double> to <signed short> at scenarios.c:73.4-20
```

78 of 78 findings visible

| Order | Type | Category | Location | Classification | Comment | Message |
|---|---|---|---|---|---|---|
| 67 | Alarm (R) | Precedence | scenarios.c:121.38-47 | | | check precedence failed (violates M2012.12.1) |
| 68 | Alarm (C) | Overflow in conversion | scenarios.c:73.4-20 | true (not a defect) | ! | double->signed short conversion range [0, 40000] not included in [-32768, 32767] |
| 69 | Alarm (A) | Use of uninitialized variables | scenarios.c:80.8-23 | true (high) | ! | uninitialized read: reading 4 byte(s) at offset(s) 0 in variable uninitialized_1 |
| 70 | Alarm (R) | Uninitialized variable use | scenarios.c:80.8-23 | | | check uninitialized-variable-use failed (violates M2012.9.1) |
| 71 | Alarm (C) | Out-of-bound array access | scenarios.c:81.17-19 | | | out-of-bound array index (15) not included in [0, 9] |
| 72 | Definite A... | Possible overflow upon dereference | scenarios.c:81.6-20 | | | invalid dereference: dereferencing 1 byte(s) at offset(s) 15 may overflow the variable ArrayBlock of byte-size 10 |
| 73 | Alarm (A) | Use of uninitialized variables | scenarios.c:84.8-23 | | | uninitialized read: reading 4 byte(s) at offset(s) 0 in variable uninitialized_2 |
| 74 | Alarm (R) | Uninitialized variable use | scenarios.c:84.8-23 | | | check uninitialized-variable-use failed (violates M2012.9.1) |

| | |
|---|---|
| Errors: | 2 |
| Alarms on code locations | |
| Run-time errors: | 7 |
| Data flow anomalies: | 0 |
| Rule violations: | 58 |
| Alarms on memory locations | |
| Data races: | 0 |
| Reached code: | 100% |
| Duration: | 19s |



| Count | Name |
|---|---|
| 7 | Alarms |
| 3 | Invalid usage of pointers and arrays |
| 1 | Out-of-bound array access |
| 2 | Possible overflow upon dereference |
| 1 | Invalid ranges and overflows |
| 1 | Overflow in conversion |
| 1 | Failed or invalid directives |
| 1 | Assertion failure |
| 2 | Uninitialized variables |
| 2 | Use of uninitialized variables |
| 2 | Errors |

```
[ call#main@58 at scenarios.c:58.0-130.1
if@80=true at scenarios.c:80.4-82.5
ALARM (C): out-of-bound array index (15) not included in [0, 9] at scenarios.c:81.17-19 ]
```

8 of 8 findings visible

| Order | Type | Category | Location | Classification | Comment | Message |
|---|---|---|---|---|---|---|
| 1 | Notification | Invalid conversion | scenarios.c:73.4-20 | | | translate_warning(type): conversion from floating-point to integer: from <double> to <signed short> |
| 2 | Alarm (C) | Overflow in conversion | scenarios.c:73.4-20 | | | double->signed short conversion range [0, 40000] not included in [-32768, 32767] |
| 3 | Alarm (A) | Use of uninitialized variables | scenarios.c:80.8-23 | | | uninitialized read: reading 4 byte(s) at offset(s) 0 in variable uninitialized_1 |
| 4 | Alarm (C) | Out-of-bound array access | scenarios.c:81.17-19 | | | out-of-bound array index (15) not included in [0, 9] |
| 5 | Definite A... | Possible overflow upon dereference | scenarios.c:81.6-20 | | | invalid dereference: dereferencing 1 byte(s) at offset(s) 15 may overflow the variable ArrayBlock of byte-size 10 |
| 6 | Alarm (A) | Use of uninitialized variables | scenarios.c:84.8-23 | | | uninitialized read: reading 4 byte(s) at offset(s) 0 in variable uninitialized_2 |
| 7 | Definite A... | Possible overflow upon dereference | scenarios.c:85.6-17 | | | invalid dereference: dereferencing 1 byte(s) at offset(s) 15 may overflow the variable ArrayBlock of byte-size 10 |
| 8 | Alarm (A) | Assertion failure | scenarios.c:127.4-40 | | | assert failure __ASTREE_assert((seconds == 3600)) |

| | |
|---|---|
| Errors: | 2 |
| Alarms on code locations | |
| Run-time errors: | 7 |
| Data flow anomalies: | 0 |
| Rule violations: | 0 |
| Alarms on memory locations | |
| Data races: | 0 |
| Reached code: | 100% |
| Duration: | 22s |

Astrée is developed and distributed by AbsInt, under license from the CNRS/ENS. It has been successfully used on safety-critical software projects from various industry sectors, including aerospace, automotive, and nuclear energy.

### The Challenge:

Runtime errors and data races can provoke erroneous program behavior and may even cause the software to crash. Software testing can be used to detect errors, but not to prove their absence, since usually no complete test coverage is possible. Static analysis based on Abstract Interpretation can be used to **prove the absence of runtime errors and data races**. A small number of false alarms is important to enable an **efficient verification process**.

### Examples for Errors detected by Astrée:

- Out-of-bound array accesses
- Erroneous pointer manipulations and dereferencing (NULL, uninitialized, dangling, misaligned, … pointers)
- Integer and floating-point divisions by zero
- Integer and floating-point arithmetic overflows
- Read accesses to uninitialized variables
- Violations of user-specified assertions
- Pure virtual function calls
- Memory leaks
- Data races between concurrent threads
- Inconsistent locking and deadlocks

Astrée also reports accesses to shared variables, non-terminating loops, and unreachable code. It includes **RuleChecker** for reporting violations of coding guidelines to prevent potential safety and security risks, newly supporting the novel **MISRA C++:2023 Draft.** New

### Key Features of Astrée:

- Astrée is **sound**: If the analysis does not detect any errors, the absence of runtime errors has been proven. Control and data coverage is 100%.
- Astrée is **precise**: Its state-of-the-art analysis engine enables very low false alarm rates.
- Astrée is **scalable**: Projects with more than 10 million lines of code have successfully been analyzed.
- False alarms can be safely eliminated by tuning the precision to the software under analysis.
- Astrée can be **seamlessly integrated** in existing CI and development environments; plugins for **Jenkins**, **Eclipse**, **µVision** and **dSPACE TargetLink** are available.
- Astrée automatically takes the **OS configuration** of ARINC653, OSEK, and AUTOSAR projects into account, including the mapping of processes to cores, their resources and their priorities.
- Advanced **taint analysis** supporting detection of **SPECTRE** vulnerabilities, and supporting user-defined **cybersecurity analyses**.
- Astrée supports sound **data and control coupling** analysis / **software component interference** analysis. New
- Interactive **visualizations** of **call graph** and **C++ class graph** help **program review and understanding**. New
- A Qualification Support Kit is available, providing support for automatic **tool qualification** up to the highest criticality levels.

AbsInt

AbsInt Angewandte Informatik GmbH    Science Park 1    D-66123 Saarbrücken    Germany
phone: +49 681 383 60 0    fax: +49 681 383 60 20    info@absint.com    www.absint.com