TON Studio Tact Compiler

Security Assessment

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Project Summary

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Project Timeline

The significant events and milestones of the project are listed below.

Date	Event
September 12, 2024	Pre-project kickoff call
September 27, 2024	Status update meeting #1
October 8, 2024	Status update meeting #2
October 15, 2024	Status update meeting #3
October 21, 2024	Delivery of report draft
October 21, 2024	Report readout meeting
January 23, 2025	Delivery of final comprehensive report
January 28, 2025	Addition of fix review appendix

Executive Summary

Engagement Overview

The TON Studio engaged Trail of Bits to review the security of the Tact compiler. The Tact language is a high-level programming language for the TON virtual machine. It is compiled into FunC and bytecode that runs on the TON virtual machine.

A team of three consultants conducted the review from September 18 to October 18, 2024, for a total of eight engineer weeks of effort. Our testing efforts focused on identifying flaws that could cause incorrect semantic analysis or enable arbitrary code execution or key extraction. With full access to source code and documentation, we performed static and dynamic testing of the codebase using automated and manual processes.

Observations and Impact

The Tact compiler codebase is broken into well-defined components and is easy to navigate. However, some files include a lot of code with a complex code flow involving multiple nested control flow structures, such as the program writer component. Such a complex codebase makes it difficult to follow the data flow and understand the security properties of the project.

One medium-severity issue highlights the test suite's inefficiency in capturing logic issues. A comprehensive and efficient test suite could also discover other low- and informational-severity issues.

Recommendations

Based on the codebase maturity evaluation and findings identified during the security review, Trail of Bits recommends that the TON Studio take the following steps:

- **Remediate the findings disclosed in this report.** These findings should be addressed as part of a direct remediation or as part of any refactor that may occur when addressing other recommendations.

- **Improve and expand the test suite.** A complex system such as the Tact compiler should be thoroughly tested, considering normal usage flows as well as specific or edge cases. The fuzz test suite can also be expanded to test the compiler grammar, optimizer, and writers with well-defined invariants. A strong test suite included as part of the CI/CD pipeline will also help detect bugs earlier.

Finding Severities and Categories

The following tables provide the number of findings by severity and category.

EXPOSURE ANALYSIS

Severity	*Count*
High	0
Medium	1
Low	2
Informational	4
Undetermined	0

CATEGORY BREAKDOWN

Category	*Count*
Access Controls	1
Data Validation	6

Project Goals

The engagement was scoped to provide a security assessment of the TON Studio's Tact compiler. Specifically, we sought to answer the following non-exhaustive list of questions:

- Is it possible to generate a malicious Tact file that crashes the compiler or generates FunC code that is not compilable?
- Is it possible to alter the host's filesystem outside the current project root directory? Can a malicious project leak data from the host system?
- Is it possible to generate an incorrect or invalid program that passes syntactic and semantic checks?
- Are there bugs in the Tact compiler that could enable arbitrary code execution?
- Is it possible to write visibly correct Tact code that compiles to unexpected FunC code?
- Can the optimizer introduce bugs or change the code behavior?
- Does the compiler write correct FunC code files?

Project Targets

The engagement involved a review and testing of the following target.

Tact Compiler

Repository	https://github.com/tact-lang/tact/
Version	`0106ea14857bcf3c40dd10135243d0de96012871`
Type	TypeScript
Platform	TON

Project Coverage

This section provides an overview of the analysis coverage of the review, as determined by our high-level engagement goals. Our approaches included the following:

- Manual review and analysis of the provided grammar and semantics
- Manual review of the complete compilation flow, from Tact to FunC, from FunC to Fift, and the bag of cells representation of the output
- Manual review of the different parts of the Tact abstract syntax tree (AST) generation, analysis and optimization, and translation to FunC
- Basic automated fuzz testing of the optimizer and the FunC interpreter
- Static analysis of the compiler's TypeScript code files

Coverage Limitations

Because of the time-boxed nature of testing work, it is common to encounter coverage limitations. The following list outlines the coverage limitations of the engagement and indicates system elements that may warrant further review:

- The optimizer is not yet integrated into the main compiler code. The changes to the compiler code that are needed to add the optimizer to the data flow could affect the code generation or introduce bugs.
- The individual AST and code generation functions were reviewed and analyzed, but since the code relies on recursive traversal of structures, it was not tested with all possible edge cases.
- The FunC compiler was not part of the scope of the audit. Therefore, any bugs or unexpected behaviors that could be present in the FunC compilation were out of scope.
- Third-party libraries used as dependencies were out of scope.
- The standard library code and any other Tact files were not reviewed.

Codebase Maturity Evaluation

Trail of Bits uses a traffic-light protocol to provide each client with a clear understanding of the areas in which its codebase is mature, immature, or underdeveloped. Deficiencies identified here often stem from root causes within the software development life cycle that should be addressed through standardization measures (e.g., the use of common libraries, functions, or frameworks) or training and awareness programs.

Category	Summary	Result
Arithmetic	The project makes minimal use of arithmetic operations for constant evaluation. We identified no issues in relation to arithmetic overflows, division by zero, or precision loss.	**Satisfactory**
Auditing	The Tact compiler emits informative log messages at appropriate places. The set of error messages is large, and the information they contain is descriptive. However, we found the use of "internal compiler errors" to be confusing; we recommend documenting when an error is meant to be an internal compiler error and what impact it has on the code. For example, if the Tact code references an undefined type, then the compiler throws an internal compiler error instead of a normal error.	**Moderate**
Complexity Management	The codebase is generally well organized, with modular components and a clear file structure. Many of the source files are short and easy to read. However, some files show several instances of code repetition. Larger modules could be refactored into several files or additional functions to improve legibility and reduce code repetition. Some patterns, such as the recursive processing of the AST nodes, are prone to errors and can be more challenging for a new collaborator to understand. Running static analysis tools on the code could also help detect and fix code smells, as mentioned in the Code Quality Findings section.	**Moderate**
Documentation	The documentation available on the project's website is	**Weak**

	targeted toward Tact developers. Other than a high-level description of the system in `CONTRIBUTING.md`, there is no specific documentation for the compiler modules and compilation stages. The code could use more comments, particularly in the bigger files and complex functions.	
Testing and Verification	The provided test suite consists of 895 unit test cases. However, given the size and complexity of the compiler codebase, it is not suitable for the project. The test suite can be improved to cover all the features, as well as more Tact code examples and edge cases, such as the ones described in the Detailed Findings section. The coverage report generation component is broken, so there is no measurable information about the test suite's efficiency.	**Weak**

Summary of Findings

The table below summarizes the findings of the review, including type and severity details.

ID	Title	Type	Severity
1	The Tact compiler does not support FunC files with .func extension	Data Validation	**Informational**
2	Circular dependencies in traits would crash the Tact compiler	Data Validation	**Medium**
3	Symbolic links can be used to bypass path restrictions	Access Controls	**Low**
4	Tact grammar does not handle Unicode correctly	Data Validation	**Low**
5	No validation of shift operator arguments	Data Validation	**Informational**
6	Incorrect use of the JavaScript map function for executing side effects	Data Validation	**Informational**
7	Ohm library limitation for nested expressions	Data Validation	**Informational**

Detailed Findings

1. The Tact compiler does not support FunC files with .func extension	
Severity: **Informational**	Difficulty: **Low**
Type: Data Validation	Finding ID: TOB-TACT-1
Target: `src/imports/resolveLibrary.ts`	

Description

The Tact language compiler considers a source file with the `.func` extension to be a Tact file and appends the `.tact` extension to the filename. As a result, importing a `.func` file throws an exception.

The Tact language documentation mentions that a `.fc` or `.func` file can be imported with the `import` keyword. However, the `resolveLibrary` function does not check for the `.func` extension while deciding whether a source file is a Tact file or a FunC file. It appends the `.tact` extension to any file imported that does not have a `.tact` or `.fc` extension. The file with the `.tact` extension appended to it does not exist, which results in a project compilation failure with an exception:

```
let importName = args.name;
const kind: "tact" | "func" = importName.endsWith(".fc") ? "func" : "tact";
if (!importName.endsWith(".tact") && !importName.endsWith(".fc")) {
    importName = importName + ".tact";
}
```

Figure 1.1: A snippet of the `resolveLibrary` function (`tact/src/imports/resolveLibrary.ts#L56–L60`)

Additionally, the exception message shows only the actual filename mentioned in the `import` statement, which does not help the developer understand the reason for the compilation failure.

Exploit Scenario

Alice creates a Tact project and tries to import an old FunC source file named `old.func` in her Tact file named `main.tact`. The project compilation fails with the exception, `Could not resolve import "./old.func" in main.tact`. Alice sees that the `old.func` file exists and cannot understand why the compilation is failing.

Recommendations

Short term, update the `resolveLibrary` function to consider `.func` files as FunC source files.

Long term, expand the unit test cases to test all the edge cases.

2. Circular dependencies in traits would crash the Tact compiler

Severity: **Medium**	Difficulty: **Low**
Type: Data Validation	Finding ID: TOB-TACT-2
Target: `src/types/resolveDescriptors.ts`	

Description

The contract and traits dependency resolver crashes the compiler when there are circular dependencies in traits.

The `processType` function in the `resolveDescriptors` function checks whether there are any circular dependencies in traits inherited by a contract by keeping track of intermediate traits in the `processing` variable:

```
function processType(name: string) {
    // Check if processed
    if (processed.has(name)) {
        return;
    }
    if (processing.has(name)) {
        throwCompilationError(
            `Circular dependency detected for type "${name}"`,
            types.get(name)!.ast.loc,
        );
    }
    processing.has(name);

    // Process dependencies first
    const dependencies = Array.from(types.values()).filter((v) =>
        v.traits.find((v2) => v2.name === name),
    );
    for (const d of dependencies) {
        processType(d.name);
    }

    // Copy traits
    copyTraits(types.get(name)!);

    // Mark as processed
    processed.add(name);
    processing.delete(name);
}
```

Figure 2.1: The `processType` function
(`tact/src/types/resolveDescriptors.ts#L1773–L1800`)

However, as shown in the highlighted line in figure 2.1, the trait being processed is not added to the `processing` list, and because of this, the `processType` function keeps calling itself recursively indefinitely if there are circular dependencies in the traits, and the Tact compiler eventually crashes with the `Maximum call stack size exceeded` error.

Exploit Scenario

Alice pushes the following Tact code to her remote Git repository, and it crashes her CI/CD pipeline:

```
trait A with B {}
trait B with A {}

contract Test with A {}
```

Figure 2.2: A contract with a circular trait dependency

Recommendations

Short term, replace the highlighted line in figure 2.1 with the `processing.add(name)` statement to track intermediate traits correctly and detect circular dependencies.

Long term, improve the test suite to include test cases for all the errors thrown by the compiler.

3. Symbolic links can be used to bypass path restrictions	
Severity: **Low**	Difficulty: **Low**
Type: Access Controls	Finding ID: TOB-TACT-3
Target: `src/vfs/createNodeFileSystem.ts`	

Description

The filesystem functions that read and write files do not check for symbolic links. This makes it possible for a user with the right permissions to import files outside the current root path or overwrite arbitrary files.

When the `readFile` and `writeFile` functions are defined in `createNodeFileSystem.ts`, the default flags are used for `fs.readFileSync` and `fs.writeFileSync` calls. This means that when a file is read, the file will be opened, or an exception will be thrown if it does not exist. When a file is written to, the default "`w`" flag creates the file if it does not exist or opens and truncates the existing file.

The only access control check performed in both cases verifies that the file's location is inside the current root path for the compilation. This check is passed when a symbolic link is placed inside the root path, and since the link destination is not verified, any file could be read or written to.

```
export function createNodeFileSystem(
    root: string,
    readonly: boolean = true,
): VirtualFileSystem {
    let normalizedRoot = path.normalize(root);
    if (!normalizedRoot.endsWith(path.sep)) {
        normalizedRoot += path.sep;
    }
    return {
        root: normalizedRoot,
        exists(filePath: string): boolean {
            if (!filePath.startsWith(normalizedRoot)) {
                throw new Error(
                    `Path '${filePath}' is outside of the root directory
'${normalizedRoot}'`,
                );
            }
            return fs.existsSync(filePath);
        },
        resolve(...filePath) {
            return path.normalize(path.resolve(normalizedRoot, ...filePath));
```

```
        },
        readFile(filePath) {
            if (!filePath.startsWith(normalizedRoot)) {
                throw new Error(
                    `Path '${filePath}' is outside of the root directory
'${normalizedRoot}'`,
                );
            }
            return fs.readFileSync(filePath);
        },
        writeFile(filePath, content) {
            if (readonly) {
                throw new Error("File system is readonly");
            }
            if (!filePath.startsWith(normalizedRoot)) {
                throw new Error(
                    `Path '${filePath}' is outside of the root directory
'${normalizedRoot}'`,
                );
            }

            mkdirp.sync(path.dirname(filePath));
            fs.writeFileSync(filePath, content);
        },
    };
}
```

Figure 3.1: The `createNodeFileSystem` function
(`tact/src/vfs/createNodeFileSystem.ts#L6–L49`)

Exploit Scenario

Bob distributes a malicious Tact project in GitHub, where one of the output files is a symbolic link to `~/.ssh/id_ed25519`. When Alice compiles this project, her default-named SSH private keys are overwritten.

Recommendations

Short term, either add a check for symbolic links that ensures their target paths are within the project root directory when opening files, or completely disallow symbolic links.

Long term, improve the filesystem test suite to include test cases for all platform-specific behavior and exceptional cases mentioned in the Node.js documentation.

4. Tact grammar does not handle Unicode correctly

Severity: **Low**	Difficulty: **Low**
Type: Data Validation	Finding ID: TOB-TACT-4
Target: `src/grammar/grammar.ohm`	

Description

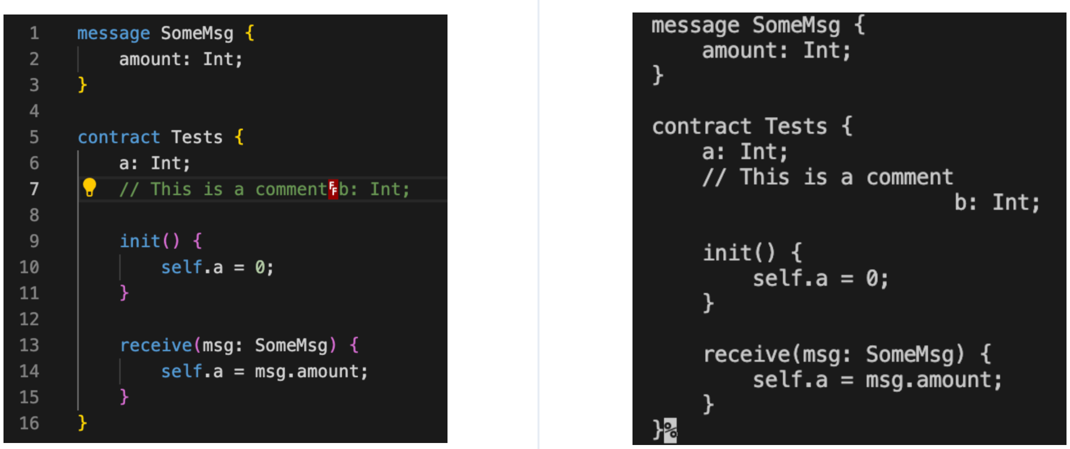
Unicode is a complex encoding standard. Some control characters, such as all the newline character alternatives, are not correctly handled in the Tact grammar. Additionally, it is possible to alter the source code visualization using Unicode right-to-left and left-to-right overrides, causing users and developers to be unaware of potentially dangerous code.

The Tact grammar defines several line terminators: CR (`\u000D`), LF (`\u000A`), LS (`\u2028`), and PS (`\u2029`).

```
    lineTerminator = "\n" | "\r" | "\u2028" | "\u2029"
```

Figure 4.1: The `lineTerminator` definition, lacking some mandatory breaks (`tact/src/grammar/grammar.ohm#L406`)

However, Unicode Standard Annex #14 also defines FF (`\u000C`) and VT (`\u000B`) as mandatory breaks. Some editors (such as Visual Studio Code; figure 4.2a) show the control characters, but some might not (such as a terminal; figure 4.2b), which can be misleading for the user or developer.



a) b)

Figure 4.2: An example of code that displays differently depending on the editor used

The same misleading behavior can be reproduced using right-to-left (`\u202E`) and left-to-right (`\u202D`) overrides. Exploiting these text direction changes makes it easier for malicious developers to hide unexpected behavior in clear sight.

Figure 4.3 shows an example of a contract that can show different operations depending on the editor used. This is a visualization issue; the compiler is unaffected, and the generated FunC code follows the correct logic.

```
message SomeMsg {
    amount: Int;
    fee: Int;
}

contract Tests {
    amount_minus_fee: Int;
    init() {
        self.amount_minus_fee = 0;
    }

    receive(msg: SomeMsg) {
        let x = msg.amount;
        let y = msg.fee;
        self.amount_minus_fee = /*amount[U+202E]/*eef*/y - x/*
        [U+202D]/*all done!*/;
    }
}
```

a)

```
message SomeMsg {
    amount: Int;
    fee: Int;
}

contract Tests {
    amount_minus_fee: Int;
    init() {
        self.amount_minus_fee = 0;
    }

    receive(msg: SomeMsg) {
        let x = msg.amount;
        let y = msg.fee;
        self.amount_minus_fee = /*amount*/x - y/*fee*/
        /*all done!*/;
    }
}
```

b)

Figure 4.3: An example of code exploiting right-to-left override and left-to-right override control characters

Exploit Scenario

Bob wants to deploy a malicious contract that intentionally miscalculates fees to steal jettons from the contract users. To gain people's trust, he makes a blog post showing the contract code and explaining how it works. Since web browsers can understand and process Unicode strings, the code shown is not what is actually compiled, and people can still download and verify that the output bag of cells matches Bob's.

Recommendations

Short term, follow Unicode Technical Standard #55 ("Unicode Source Code Handling") and ensure that all problematic cases are handled correctly.

Long term, improve the test suite to include test cases for Unicode ambiguities.

5. No validation of shift operator arguments	
Severity: **Informational**	Difficulty: **Low**
Type: Data Validation	Finding ID: TOB-TACT-5
Target: `src/types/resolveExpression.ts`	

Description

The Tact compiler does not validate that the shift operator argument is less than 257. The FunC compiler throws an error for the use of an invalid shift operator argument.

The Tact compiler resolves all the types and ensures that the operands of all the operators are of the correct type. However, it does not check the bounds of the operand values, so it could miss some trivial bugs that would then be caught by the FunC compiler or only at runtime.

```
get fun hello1(src: Int): Int {
    return src << 34605176784551 & 32769;
}
```

Figure 5.1: A sample function with an invalid shift operator argument

Recommendations

Short term, implement a bounds check for shift operator arguments to ensure that the operation does not result in an unexpected value.

Long term, consider having the compiler catch trivial runtime errors to improve the developer experience and security of the codebase.

6. Incorrect use of the JavaScript map function for executing side effects

Severity: **Informational**	Difficulty: **Low**
Type: Data Validation	Finding ID: TOB-TACT-6
Target: `src/grammar/rename.ts`	

Description

The `renameModuleItems` function of the `rename.ts` file sorts the attributes in the AST for Tact functions, traits, and contracts with the `map` JavaScript function, which does not update the objects in place.

The `renameModuleItems` function of the `rename.ts` file is used to canonicalize the Tact code item names for comparison of two code files. The comparison function expects the `renameModuleItems` function to return a sorted array of items with sorted attributes for each item object:

```
public renameModuleItems(items: AstModuleItem[]): AstModuleItem[] {
    // Give new names to module-level elements.
    let renamedItems = items.map((item) => this.changeItemName(item));

    if (this.sort) {
        renamedItems.map((item) => this.sortAttributes(item));
    }

    // Apply renaming to the contents of these elements.
    renamedItems = renamedItems.map((item) =>
        this.renameModuleItemContents(item),
    );

    return this.sort ? this.sortModuleItems(renamedItems) : renamedItems;
}
```

Figure 6.1: The `renameModuleItems` function in the `rename.ts` file
(`tact/src/grammar/rename.ts#L114–L128`)

However, as shown in the highlighted line in figure 5.1, the returned value of the `map` function call is not stored in the `renamedItems` variable, which discards any updates made to the `renamedItems` array items, resulting in unsorted attributes in the code items. These unsorted attributes could cause the comparator to return false negatives for the same code and could allow users to pass the plagiarism test by changing the order of attributes in the code.

This issue cannot be exploited because of the use of the `Array.sort` function in the `sortAttributes` function in the `sort.ts` file. The `Array.sort` function sorts the array in place; therefore, the `renamedItems` array items have sorted attributes.

Recommendations

Short term, replace the `map` function with the `forEach` function.

Long term, refactor the codebase to use non-mutating methods to avoid unexpected side effects and confusion.

7. Ohm library limitation for nested expressions

Severity: **Informational**	Difficulty: **Low**
Type: Data Validation	Finding ID: TOB-TACT-7
Target: `src/grammar/grammar.ohm`	

Description

The Tact compiler uses the Ohm parsing toolkit to implement the source code parser. The Ohm library uses recursion to parse nested items in expressions and throws a `RangeError: Maximum call stack size exceeded` error for deeply nested expressions. For example, the expression shown in the following image throws the error and crashes the compiler:

```
((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((((
((((((((((((((((1)))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))
)))))))))))))))))))))))))))))))))
```

Figure 7.1: An example expression that would cause a compiler error

The above expression is a valid Tact code expression and should be parsed correctly. However, because of the limitations of the Ohm library, the Tact compiler does not support it.

Recommendations

Short term, document the limitations of the Ohm library for deeply nested expressions.

A. Vulnerability Categories

The following tables describe the vulnerability categories, severity levels, and difficulty levels used in this document.

Vulnerability Categories	
Category	**Description**
Access Controls	Insufficient authorization or assessment of rights
Auditing and Logging	Insufficient auditing of actions or logging of problems
Authentication	Improper identification of users
Configuration	Misconfigured servers, devices, or software components
Cryptography	A breach of system confidentiality or integrity
Data Exposure	Exposure of sensitive information
Data Validation	Improper reliance on the structure or values of data
Denial of Service	A system failure with an availability impact
Error Reporting	Insecure or insufficient reporting of error conditions
Patching	Use of an outdated software package or library
Session Management	Improper identification of authenticated users
Testing	Insufficient test methodology or test coverage
Timing	Race conditions or other order-of-operations flaws
Undefined Behavior	Undefined behavior triggered within the system

Severity Levels	
Severity	**Description**
Informational	The issue does not pose an immediate risk but is relevant to security best practices.
Undetermined	The extent of the risk was not determined during this engagement.
Low	The risk is small or is not one the client has indicated is important.
Medium	User information is at risk; exploitation could pose reputational, legal, or moderate financial risks.
High	The flaw could affect numerous users and have serious reputational, legal, or financial implications.

Difficulty Levels	
Difficulty	**Description**
Undetermined	The difficulty of exploitation was not determined during this engagement.
Low	The flaw is well known; public tools for its exploitation exist or can be scripted.
Medium	An attacker must write an exploit or will need in-depth knowledge of the system.
High	An attacker must have privileged access to the system, may need to know complex technical details, or must discover other weaknesses to exploit this issue.

B. Code Maturity Categories

The following tables describe the code maturity categories and rating criteria used in this document.

Code Maturity Categories	
Category	**Description**
Arithmetic	The proper use of mathematical operations and semantics
Auditing	The use of event auditing and logging to support monitoring
Complexity Management	The presence of clear structures designed to manage system complexity, including the separation of system logic into clearly defined functions
Documentation	The presence of comprehensive and readable codebase documentation
Testing and Verification	The presence of robust testing procedures (e.g., unit tests, integration tests, and verification methods) and sufficient test coverage

Rating Criteria	
Rating	**Description**
Strong	No issues were found, and the system exceeds industry standards.
Satisfactory	Minor issues were found, but the system is compliant with best practices.
Moderate	Some issues that may affect system safety were found.
Weak	Many issues that affect system safety were found.
Missing	A required component is missing, significantly affecting system safety.
Not Applicable	The category is not applicable to this review.
Not Considered	The category was not considered in this review.
Further Investigation Required	Further investigation is required to reach a meaningful conclusion.

C. Code Quality Findings

The following findings are not associated with any specific vulnerabilities. However, addressing them will enhance code readability and may prevent the introduction of vulnerabilities in the future.

- **One of the project's dependencies has a known vulnerability.** Running `npx yarn audit` on the repository shows that the `ajv-cli` package used for validating the linting schema depends on a vulnerable version of the `fast-json-patch` package.
- **The TypeScript compiler can be configured to be stricter.** The `tsconfig.json` configuration file does not enforce several options to increase the generated code's robustness and reliability. An example of a stricter `tsconfig.json` file can be found in the "recommendations for `TSConfig` bases" repository. The strictest configuration should be used, and all errors and warnings that arise from the process must be addressed.
- **There are several instances of unused variables and function parameters.** Compiling Tact code with the stricter rule set reveals several cases of unused variables in the following files:
  - `src/abi/global.ts`
  - `src/abi/map.ts`
  - `src/bindings/typescript/serializers.ts`
  - `src/bindings/typescript/writeStruct.ts`
  - `src/generator/writers/writeAccessors.ts`
  - `src/generator/writers/writeContract.ts`
  - `src/generator/writers/writeSerialization.ts`
  - `src/types/resolveDescriptors.ts`
  - `src/types/resolveExpression.ts`
- **Some built-in Ohm rules are redefined in the grammar.** The `letterAscii`, `letterAsciiUC`, and `letterAsciiLC` rules are equivalent to the built-in `letter`, `upper`, and `lower` rules, respectively.
- **There are unused and duplicated rules in the Tact grammar.** The `letterDigitUnderscore` rule is unused and is equivalent to the `typeIdPart` and `idPart` rules.

- **There is a misleading error message in the Tact grammar.** The `checkVariableName` function is used to validate several attribute names in `grammar.ts`. If the validation fails, the error message mentions "variable name" regardless of the origin of the error. This can be confusing for users.

- **The return type of the `buildFieldDescription` function does not explicitly indicate all fields.** The `FieldDescription` struct returned by the function lacks an explicit `index` key, and the order of the returned fields does not match the definition.

- **The division functions do not check a precondition; instead, they rely on the caller.** As mentioned in the comments for the `divFloor` and `modFloor` functions, they do not check for cases when the divisor is zero. This is not an issue in the current state of the codebase, but it can introduce issues in the future if a developer adds a new use case where the divisor is not checked.

- **The `buildConstantDescription` function does not run its struct field count before traversing the struct.** When passed a struct, it loops over all fields before checking for the existence of at least one field. This check should be performed before the iterations.

D. Fix Review Results

When undertaking a fix review, Trail of Bits reviews the fixes implemented for issues identified in the original report. This work involves a review of specific areas of the source code and system configuration, not comprehensive analysis of the system.

From January 2 to January 3, 2025, Trail of Bits reviewed the fixes and mitigations implemented by the TON Studio team for the issues identified in this report. We reviewed each fix to determine its effectiveness in resolving the associated issue.

Several of the fixes also improve the test suite, adding cases with the mentioned exploit scenarios and new examples. The Unicode character handling was not changed; however, the team plans on changing the Unicode support for Tact in the long term. The Ohm library nesting limit (TOB-TACT-7) was not solved, as it is outside of the TON Studio codebase, but the Tact compiler documentation was updated to reflect the issue. Finally, TOB-TACT-5 requires a better solution for the general case; however, the proposed solution works for the cases in which the bit shift operand is constant or can be calculated as a constant.

In summary, of the seven issues described in this report, TON Studio has resolved four issues, has partially resolved one issue, and has not resolved the remaining two issues. For additional information, please see the Detailed Fix Review Results below.

ID	Title	Severity	Status
1	The Tact compiler does not support FunC files with .func extension	Informational	Resolved
2	Circular dependencies in traits would crash the Tact compiler	Medium	Resolved
3	Symbolic links can be used to bypass path restrictions	Low	Resolved
4	Tact grammar does not handle Unicode correctly	Low	Unresolved
5	No validation of shift operator arguments	Informational	Partially Resolved
6	Incorrect use of the JavaScript map function for executing side effects	Informational	Resolved

7	Ohm library limitation for nested expressions	Informational	Unresolved

Detailed Fix Review Results

TOB-TACT-1: The Tact compiler does not support FunC files with .func extension
Resolved in commit `abe8746`. The `.func` extension was added to the filename check, and a new test case was added to ensure that `.func` type files are imported correctly.

TOB-TACT-2: Circular dependencies in traits would crash the Tact compiler
Resolved in commit `d12cf94`. The current trait is now added to the processing list, and the circular dependency is now detected. A new test case was added to check for circular dependencies.

TOB-TACT-3: Symbolic links can be used to bypass path restrictions
Resolved in commit `40a6342`. A new function to check filepaths for symbolic links and disallow them was added to `createNodeFilesystem.ts`. All read and write file accesses in the `createNodeFileSystem` function are now validated. Additionally, test files and test cases were added to check for symbolic link imports.

TOB-TACT-4: Tact grammar does not handle Unicode correctly
Unresolved. No changes were made to the project to address this issue.

The client provided the following context for this finding's fix status:

> *We acknowledge possible Unicode exploits via text editors and most likely our long term goal will be ban Unicode from Tact source code except comments and string literals.*

TOB-TACT-5: No validation of shift operator arguments
Partially resolved in commit `32dbaa8`. The implemented fix works only for constant expressions, without variables. However, the team stated that proper constant propagation static analysis will be included in the next Tact release. Tests were also added for constant bit shifts.

TOB-TACT-6: Incorrect use of the JavaScript map function for executing side effects
Resolved in commit `00bf680`. The `renameModuleItems` function was refactored to fix the issue, and now the `renamedItems` map is correctly sorted when the flag is set.

TOB-TACT-7: Ohm library limitation for nested expressions
Unresolved. As this is a limitation in the Ohm library, it has not been resolved. However, the team documented the issue in the Expressions section of Tact main documentation.

E. Fix Review Status Categories

The following table describes the statuses used to indicate whether an issue has been sufficiently addressed.

Fix Status	
Status	**Description**
Undetermined	The status of the issue was not determined during this engagement.
Unresolved	The issue persists and has not been resolved.
Partially Resolved	The issue persists but has been partially resolved.
Resolved	The issue has been sufficiently resolved.

About Trail of Bits

Founded in 2012 and headquartered in New York, Trail of Bits provides technical security assessment and advisory services to some of the world's most targeted organizations. We combine high-end security research with a real-world attacker mentality to reduce risk and fortify code. With 100+ employees around the globe, we've helped secure critical software elements that support billions of end users, including Kubernetes and the Linux kernel.

We maintain an exhaustive list of publications at https://github.com/trailofbits/publications, with links to papers, presentations, public audit reports, and podcast appearances.

In recent years, Trail of Bits consultants have showcased cutting-edge research through presentations at CanSecWest, HCSS, Devcon, Empire Hacking, GrrCon, LangSec, NorthSec, the O'Reilly Security Conference, PyCon, REcon, Security BSides, and SummerCon.

We specialize in software testing and code review projects, supporting client organizations in the technology, defense, and finance industries, as well as government entities. Notable clients include HashiCorp, Google, Microsoft, Western Digital, and Zoom.

Trail of Bits also operates a center of excellence with regard to blockchain security. Notable projects include audits of Algorand, Bitcoin SV, Chainlink, Compound, Ethereum 2.0, MakerDAO, Matic, Uniswap, Web3, and Zcash.

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Security assessment projects are time-boxed and often reliant on information that may be provided by a client, its affiliates, or its partners. As a result, the findings documented in this report should not be considered a comprehensive list of security issues, flaws, or defects in the target system or codebase.

Trail of Bits uses automated testing techniques to rapidly test the controls and security properties of software. These techniques augment our manual security review work, but each has its limitations: for example, a tool may not generate a random edge case that violates a property or may not fully complete its analysis during the allotted time. Their use is also limited by the time and resource constraints of a project.