Metaplex Core Program Audit Report *(V-1.0.0)*

– Mad Shield

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1. Introduction

Metaplex engaged Mad Shield to audit the MPL Core program which is a new initiative to introduce a more simple, intuitive NFT standard interface on the Solana blockchain. The audit included an initial full analysis of the core functionality of the library spanning approximately ~2 weeks over the time period between April 1st to April 15th.

This audit report presents the findings from our comprehensive security analysis of the program. In summary, our audit yielded 5 vulnerabilities within the Metaplex Core program: 2 categorized as Critical, 1 Medium-severity, and 2 Low-severity. Additionally, we reported an Informational finding focused on the central authority validation unit in the program to recommend additional separation of duties and continuous incremental testing and auditing of this particular segment of the business logic.

We communicated all our findings with proper mitigations through private channels to the Metaplex developer team. **We are glad to confirm that all the vulnerabilities disclosed here have since been addressed and resolved accordingly and/or are being hawked closely.** This document outlines the audit procedure, the assessment methodology, key findings and suggestions to further improve the program.

1.1 Overview

The MPL-Core program is designed to serve as a foundational component within the Metaplex ecosystem, facilitating various functionalities centered around NFTs and token management on the Solana blockchain and to improve upon the original mpl-token-metadata program.

A critical transformation in this upgrade is the removal of the SPL-Token program and associated accounts, which simplifies the underlying architecture significantly against original design which was heavily reliant on multiple Program Derived Addresses (PDAs) from the mint account such as metadata and master editions.

Additionally, Metaplex Core introduces a plugin system, an enhancement that replaces the diverse functionalities previously scattered across various accounts in mpl-token-metadata. This allows for extensible development and integration, where specific functionalities can be incorporated as needed through these plugins.

This modular approach not only simplifies the account management by consolidating functionalities into a single account but also enhances the program's flexibility, adaptability to meet diverse use cases and reduces the complexity that makes the system more efficient and less error-prone.

For more information on the Core program and plugins, please visit the official documentation [1]

2. Scope and Objectives

The primary objectives of the audit are defined as:

- Minimizing the possible presence of any critical vulnerabilities in the program. This would include detailed examination of the code and edge case scrutinization to find as many vulnerabilities.

- 2-way communication during the audit process. This included for Mad Shield to reach a perfect understanding of the design of Token Metadata and the goals of the Raydium team.

- Provide clear and thorough explanations of all vulnerabilities discovered during the process with potential suggestions and recommendations for fixes and code improvements.

- Clear attention to the documentation of the vulnerabilities with an eventual publication of a comprehensive audit report to the public audience for all stakeholders to understand the security status of the programs.

Metaplex has delivered these programs to Mad Shield at the following Github repositories.

Repository URL	https://github.com/metaplex-foundation/mpl-core/
Commit (start of audit)	cd53660fd2652836e07c4299611dc40fca96d8fd
Commit (end of audit)	fa3c7f7f4675e2bceea64ca51dae2d32b8c6efe8

3. Methodology

After the initial request from Metaplex to review we did a quick read-through of the code to evaluate the scope of the work and recognize early potential footguns.

The standard supports the same features as the original mpl-token-metadata program, however, reshaped through the plugin structure. Regardless, it was straight-forward for us to assume invariants that the program must follow and potential pitfalls that it must avoid.

We applied a targeted testing approach using our in-house developed testing suite to scrutinize scenario use cases drawn from previous audits of the mpl-token-metadata. This suite specifically focuses on vulnerabilities such as account substitutions and authority counterfeiting, the prevalent Solana security bugs. We also targeted the test cases toward specific coreNFT functionalities such as plugin access violations and account resizing.

During our tests, we discovered several vulnerabilities, notably SHIELD_MC_01, where a collection authority, surprisingly non-existent on the asset, was still able to alter plugin data such as Attributes. This highlighted a major oversight in authority validation mechanisms. Another significant finding was SHIELD_MC_04, which involved the problematic scenario of nested collection features potentially misleading on-chain data and indexers about the true size of a collection, compromising data integrity.

Our review also covered the asset account creation process, where we found that the current implementation inadequately addressed scenarios where the target keypair already held a SOL balance described in SHIELD_MC_05.

Additionally, our consistency checks on programmable NFT specifications revealed that the implementation of the `allow_list` was insufficient as captured under SHIELD_MC_02 opening up the possibility for marketplaces/programs to avoid creator `rule_sets`.

Finally, we corroborate in SHIELD_MC_GR_01 that the program is in a nascent stage of development and relies heavily on specific assumptions in critical validation functions. In addition, the absence of some functionalities yet to be enabled by Metaplex is to be carefully evaluated before release.

4. Findings & Recommendations

Our severity classification system adheres to the criteria outlined here.

Severity Level	Exploitability	Potential Impact	Examples
Critical	Low to moderate difficulty, 3rd-party attacker	Irreparable financial harm	Direct theft of funds, permanent freezing of tokens/NFTs
High	High difficulty, external attacker or specific user interactions	Recoverable financial harm	Temporary freezing of assets
Medium	Unexpected behavior, potential for misuse	Limited to no financial harm, non-critical disruption	Escalation of non-sensitive privilege, program malfunctions, inefficient execution
Low	Implementation variance, uncommon scenarios	Zero financial implications, minor inconvenience	Program crashes in rare situations, parameter adjustments by authorized entities
Informational	N/A	Recommendations for improvement	Design enhancements, best practices, usability suggestions

In the following, we enumerate some of the findings and issues we discovered and explain their implications and corresponding resolutions.

Finding	Description	Severity Level
SHIELD_MC_01 [RESOLVED]	Collection Authority Overreach	*Critical*
SHIELD_MC_02 [RESOLVED]	Faulty Allow-List Logic	*Critical*
SHIELD_MC_03 [RESOLVED]	Incomplete Collection Authority Check Allowing Arbitrary Collection Size Modification	*Medium*
SHIELD_MC_04 [HAWKED]	Possibility Of Nested Collections	*Low*
SHIELD_MC_05 [HAWKED]	Asset Creation Fails If Account Is Pre Topped Up With Any Amount of SOL	*Low*
SHIELD_MC_GR_01 [ACKNOWLEDGED]	On the extra dependence on the validate_asset_permissions function	*Informational*

1. **SHIELD_MC_01 - Collection Authority Overreach *[Critical]***

The collection authority feature may override attributes on ccNFTs without an assigned collection by merely specifying a collection. This bypasses the intended security checks and is a clear breach of the intended authority over the ccNFT where a non-existent collection authority can override the plugin details for a token that does not have a collection authority set. This is due to the incomplete collection check in the `validate_asset_permission` function.

```
if let UpdateAuthority::Collection(collection_address: Pubkey) = deserialized_asset.update_authority {
    if collection.is_none() {
        return Err(MplCoreError::MissingCollection.into());
    } else if collection.unwrap().key != &collection_address {
        return Err(MplCoreError::InvalidCollection.into());
    }
}
```

Recommended Fix

Add a validation check to ensure that the collection account is non-existent if the asset does not belong to a collection returning an error upon asset deserialization.

The patch commit: [b5c6d97f]

2. **SHIELD_MC_02 – Faulty Allow-List Logic [Critical]**

The logic implemented to manage allow lists is incorrectly formulated. Specifically, the allow list should verify that both the destination and owner of the core NFT are controlled by the current program. However, the existing checks treat these conditions as mutually exclusive rather than concurrent requirements.

The condition also does not account for PDAs that are not owned i.e. assigned to the target program being allowed/disallowed yielding a discrepancy ƒrom the original mpl-token-metadata program.

```
RuleSet::ProgramAllowList(allow_list: &Vec<Pubkey>) => {
    if allow_list.contains(ctx.authority_info.owner)
        || allow_list.contains(new_owner.owner)
    {      blockiosaurus, 2 months ago • Making authority a single field instead of a ve…
        Ok(ValidationResult::Pass)
    } else {
        solana_program::msg!("Royalties: Rejected");
        Ok(ValidationResult::Rejected)
    }
}
```

The Metaplex team acknowledged that they are aware of this issue, however, they will take a stealth approach, monitoring on-chain transactions especially those of marketplaces to observe any potential ruleset violations as a fix involves account

creation for the owner accounts proven to complicate interactions in the case of the mpl-token-metadata program.

Recommended Fix

Update the allow list verification logic to require both the destination and owner of the core NFT to be owned by the current program simultaneously.

The second issue is on the Hawk Deck and no actions are taken until further notice.

The patch commit: fa3c7f7f

3. **SHIELD_MC_03 – Incomplete Collection Authority Check allows Arbitrary Collection Size Modification [Medium]**

   Due to the incomplete collection authority check in the `validate_asset_permission` function (as described in SHIELD_MC_01), an attacker can arbitrarily change the size of a collection.

   This is possible because the current implementation does not verify if the asset being burned is truly part of the collection, allowing an attacker to manipulate the collection size without proper authorization.

   Recommended Fix

   The fix for SHIELD_MC_01 will also remove the possibility for exploit in the `burn` instruction, however, to avoid the excessive dependency on the `validate_asset_permission` that exhibits a single point of failure behavior (elaborated more extensively in SHIELD_MC_GR_01), we recommend adding checks on the asset's update authority similar to the `create` instruction.

   The patch commit – b5c6d97

4. **SHIELD_MC_04 – Possibility Of Nested Collections [Low]**

   It is possible to assign a collection as the update authority of another collection, creating nested collections which could complicate the authority hierarchy and meddle with the collection sizing and indexers.

   Recommended Fix

   Introduce constraints to prevent a collection from being its own update authority or that of another collection.

   The patch status – *Hawked*

5. **SHIELD_MC_05 – Asset Creation Fails If Account Is Pre Topped Up With Any Amount of SOL [Low]**

   The create_account function used in the code snippet is a system call provided by the Solana runtime, which creates a new account and allocates space and transfers some enough SOL to the account to be rent-exempt. However, this function fails if the account has a balance greater than zero.

   This could cause a DoS attack especially if the function is invoked to initialize a PDA from another contract if an attacker tops up the account with a non-zero SOL balance.

   Recommended Fix

   This implementation seems to be an active design decision to prevent users from using their wallets and other addresses with spendable SOL balance as MPL Core accounts.

   However, To mitigate the DoS risk, it is recommended to use the `create_or_allocate_account_raw` routine provided in the mpl-utils crate. This function does check if there is a non-zero balance present and will use the alternative account creation mechanism using the allocate and assign instructions from the system program.

   The patch status – *Hawked*

4. General Recommendations

In this section, we provide general recommendations and informational issues that we found during the process of the audit.

1. **SHIELD_MC_GR_01 – On The Extra Dependence On The validate_asset_permissions Function**

   The consolidation of authority checking into the `validate_asset_permissions` function presents both strengths and risks. While this centralization simplifies the management of permissions and aligns with Rust's design philosophy by providing a clear, singular point of validation, it introduces a significant risk as a single point of failure.

   The absence of certain functionalities, such as burning, transferring, and plugin management for compressed assets, introduces yet another additional layer of complexity and potential risk. It is crucial that these incomplete features do not compromise the overall security and functionality of the Core program. Therefore, we suggest:

   - **Incremental Deployment –** As new functionalities are developed and ready for release, they should be deployed incrementally with thorough beta testing and limited user exposure until fully vetted. This allows for controlled observation of the features' behavior under real conditions without risking the entire platform.
   - **Perpetual Testing and Monitoring –** Ongoing testing and real-time monitoring of the system should be implemented to quickly detect and respond to any issues arising from newly introduced features. This includes automated systems to monitor the behavior of these features in live environments to ensure they perform as intended and do not introduce vulnerabilities.

5. Conclusion

The MPL-Core program exhibits a robust framework with numerous innovative features. However, the vulnerabilities identified need to be addressed to ensure the program can operate securely and efficiently within the Metaplex ecosystem. Our recommendations aim to assist the development team in enhancing the program's security posture and operational stability.

References

[1] Metaplex Developer Hub – https://developers.metaplex.com/core/