L42: Flash Loans and Composability

Module F: Advanced Topics

Blockchain & Cryptocurrency Course

December 2025

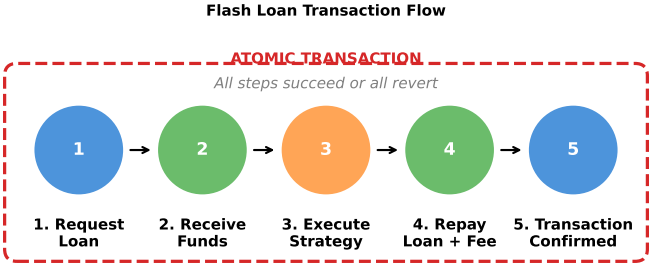
Learning Objectives

- Understand flash loan mechanics and atomicity
- Analyze legitimate flash loan use cases
- Examine flash loan attack vectors and notable exploits
- Explore DeFi composability ("money legos")
- Understand MEV and its relationship to flash loans

What is a Flash Loan?

- **Definition**: Uncollateralized loan borrowed and repaid within single transaction
- **Key Property**: *Atomicity* – loan and repayment are all-or-nothing
- **If repayment fails**: Entire transaction reverts, lender loses nothing
- **No Collateral Required**: Enabled by smart contract execution model
- **Loan Size**: Unlimited (constrained only by liquidity pool)
- **Duration**: Fraction of a second (one block)
- **Unique to DeFi**: Impossible in traditional finance

Flash Loan Transaction Flow



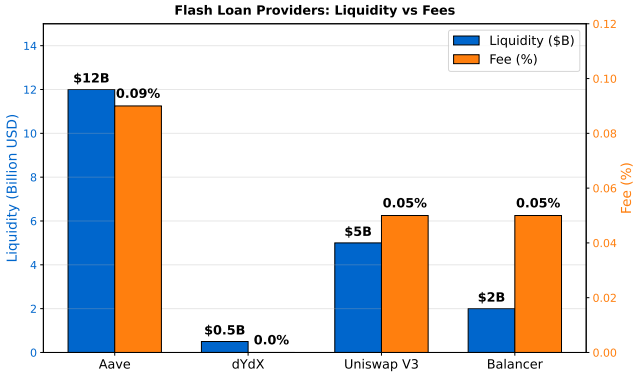
If any step fails, the entire transaction reverts – zero risk to lender

Traditional Loans vs Flash Loans

Property	Traditional Loan	Flash Loan
Collateral	Required (often ¿100%)	None
Duration	Days/months/years	Single transaction
Creditworthiness	Required (KYC)	Not required
Repayment Guarantee	Legal contracts	Smart contract atomicity
Risk to Lender	Default risk	Zero (reverts)

Paradigm Shift: Code execution guarantees replace legal enforcement

Flash Loan Providers

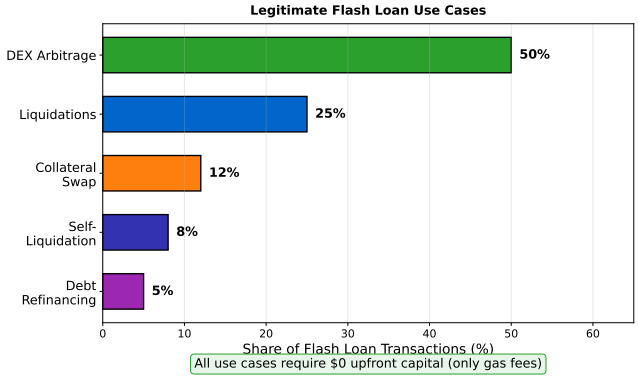


Aave is largest provider; dYdX offers free flash loans

DeFi Composability

- **Composability**: DeFi protocols are like "money legos"
- **Permissionless Integration**: Any contract can call any other contract
- **Atomic Transactions**: Multiple protocol interactions in one transaction
- **Examples of Composability**:
  1. Swap on Uniswap → Deposit into Aave → Borrow
  2. Flash loan → Liquidate → Swap collateral → Repay
  3. Borrow from Compound → Yield farm on Curve
- **Risk**: Cascading failures, expanded attack surface

Legitimate Use Cases



All use cases democratize capital-intensive strategies to anyone

Flash Loan Use Case: Arbitrage

- **Scenario**: ETH trades at $2000 on Uniswap, $2020 on SushiSwap
- **Flash Loan Arbitrage**:
  1. Borrow 1000 ETH via flash loan
  2. Buy 1000 ETH on Uniswap ($2,000,000)
  3. Sell 1000 ETH on SushiSwap ($2,020,000)
  4. Repay flash loan + fee ($2,001,000)
  5. Profit: $19,000 in one transaction
- **Capital Required**: Only gas fees ($50-$200)
- **Democratization**: Anyone can be arbitrageur, not just whales

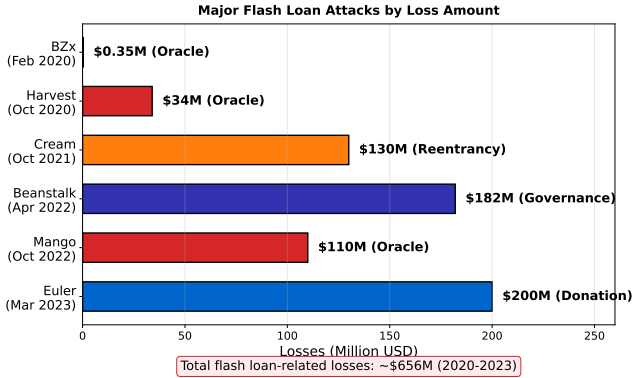
Flash Loan Use Case: Collateral Swap

- **Problem**: User has debt collateralized with Asset A, wants Asset B
- **Flash Loan Solution**:
  1. Borrow Asset A via flash loan
  2. Repay existing debt
  3. Withdraw original collateral
  4. Deposit new collateral (Asset B)
  5. Borrow Asset A again
  6. Repay flash loan
- **Result**: Collateral swapped atomically, zero liquidation risk
- **Fee**: Only flash loan fee (0.05-0.09%)

Flash Loan Attacks: Overview

- **Dark Side**: Flash loans enable large-scale attacks with zero capital
- **Attack Pattern**:
  1. Borrow massive amount via flash loan
  2. Manipulate protocol state (price oracle, governance)
  3. Exploit manipulation for profit
  4. Repay flash loan
- **Impact**: $500M+ stolen via flash loan attacks (2020-2023)
- **Key Insight**: Flash loans amplify existing vulnerabilities

Major Flash Loan Attacks



Oracle manipulation is most common attack vector

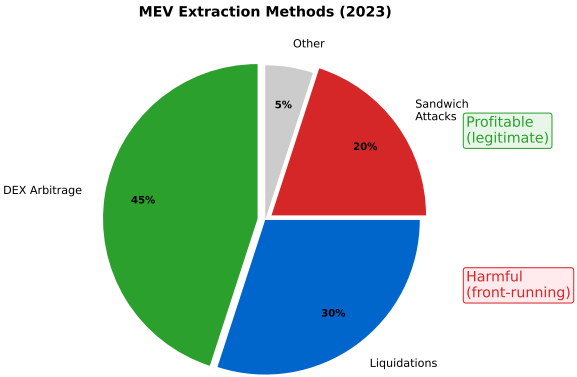
Attack Example: Oracle Manipulation

- **Vulnerable Protocol**: Uses single DEX price as oracle
- **Attack Steps**:
  1. Borrow 10,000 ETH via flash loan
  2. Buy all TOKEN on Uniswap (10x price increase)
  3. Protocol oracle reads inflated price
  4. Borrow stablecoins using overvalued TOKEN
  5. Sell TOKEN back (price normalizes)
  6. Repay flash loan + keep stablecoins
- **Real Example**: Harvest Finance ($34M stolen)
- **Mitigation**: Use TWAP or Chainlink oracles

Defense Mechanisms

1. **Decentralized Oracles**: Use Chainlink (not single DEX)
2. **Time-Weighted Average Price (TWAP)**: Average over blocks
3. **Reentrancy Guards**: Prevent recursive contract calls
4. **Governance Delays**: Timelock on parameter changes
5. **Vote Locking**: Require tokens locked before voting
6. **Circuit Breakers**: Pause if anomalous activity detected

MEV and Flash Loans



Flash loans amplify both legitimate arbitrage and harmful MEV extraction

MEV Extraction Techniques

- **MEV (Maximal Extractable Value)**: Profit from transaction ordering
- **Flash Loans + MEV**: Amplify arbitrage and liquidation profits
- **Techniques**:
  - **Front-running**: Place transaction before victim's
  - **Back-running**: Place transaction after victim's
  - **Sandwich Attacks**: Front-run + back-run
- **Flashbots**: Democratize MEV extraction, reduce gas wars
- **MEV Volume**: $600M+ extracted in 2023

Economic Impact

Positive Effects

- Democratize arbitrage
- Increase market efficiency
- Enable capital-efficient refinancing
- Liquidation bots improve protocol health

Negative Effects

- Enable zero-capital attacks
- Amplify protocol vulnerabilities
- MEV extraction harms users
- Governance manipulation risk

Net Assessment: Powerful tool that magnifies both good and bad protocol design

Flash Loans and Regulation

- **Legal Gray Area**: No clear regulatory framework
- **Key Questions**:
  - Are flash loan attacks theft or code exploitation?
  - Is the protocol or attacker liable?
  - Code is law vs legal enforcement
- **Precedent**: Mango Markets attacker arrested (Oct 2022)
  - Charged with market manipulation, not flash loan use
- **Protocol Responsibility**: Bug bounties, audits, insurance

Summary

Key Takeaways:

- Flash loans: Uncollateralized loans repaid in single atomic transaction
- Enabled by smart contract atomicity: Revert on failure = zero lender risk
- Use cases: Arbitrage, collateral swaps, self-liquidation, refinancing
- Composability: DeFi protocols as interoperable building blocks
- Attacks: Oracle manipulation, governance takeover ($500M+ stolen)
- Flash loans amplify existing protocol vulnerabilities (not root cause)
- Defenses: Decentralized oracles, TWAP, vote locking, circuit breakers

Questions for Reflection

1. Why can flash loans exist in DeFi but not in traditional finance?
2. How do flash loans democratize arbitrage opportunities?
3. What makes oracle manipulation the most common attack vector?
4. Should flash loan attackers be prosecuted if they exploit code bugs?
5. How can protocols defend against flash loan governance attacks?