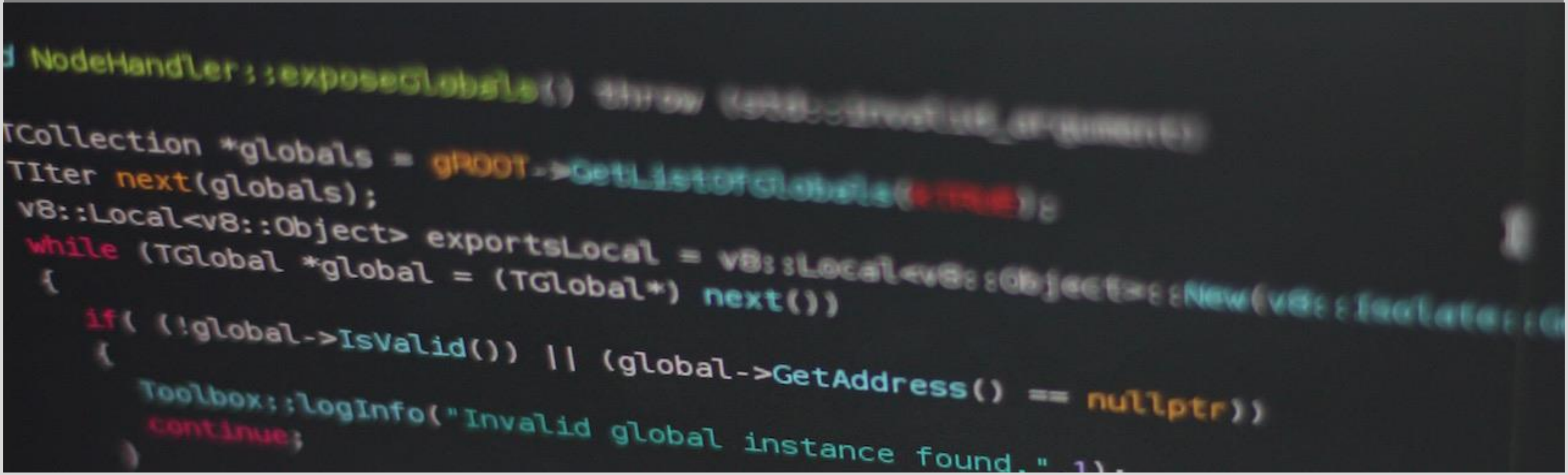
Karlsruhe Institute of Technology

rootJS – Node.js bindings for ROOT 6

PSE – Software Engineering Practice

J. Schwabe, C. Haas, T. Beffart, M. Früh, S. Rajgopal, C. Wolff

STEINBUCH CENTRE FOR COMPUTING

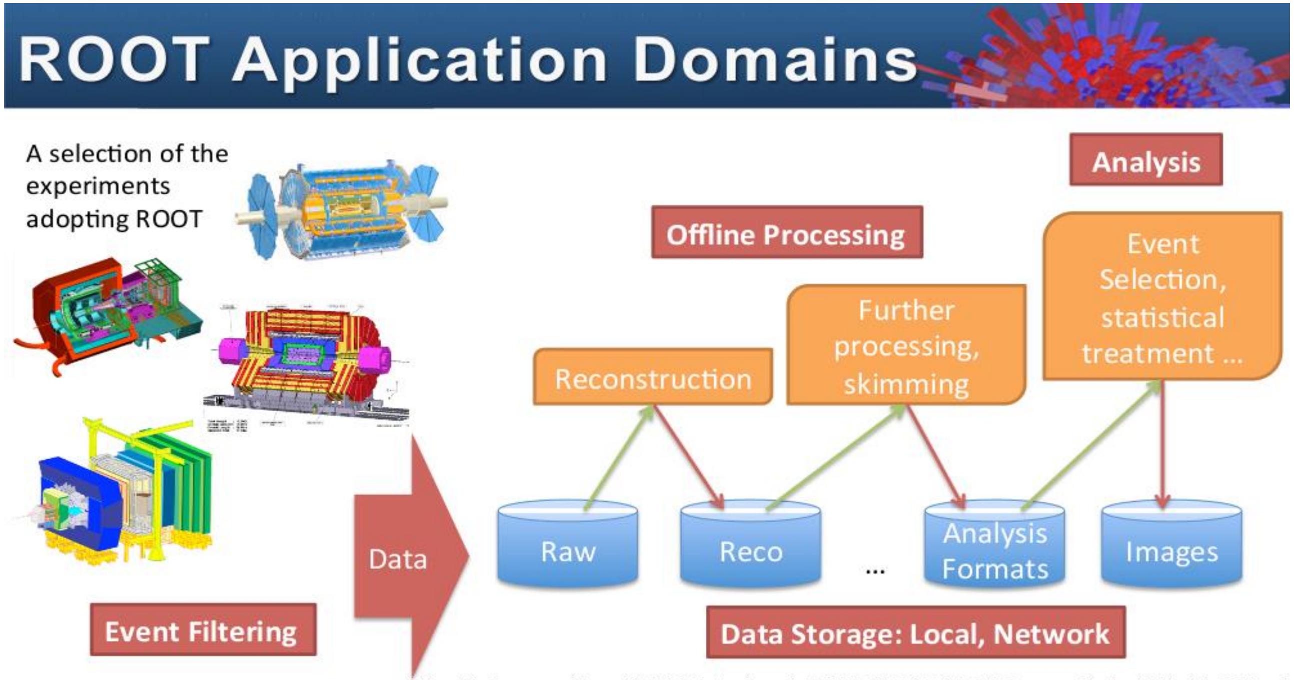


Introduction – the team

- Computer Science students 3rd semester
- Supervisor: Dr. Szuba
- Team members
    - Christoph Haas
    - Jonas Schwabe
    - Theo Beffart
    - Maximilian Früh
    - Christoph Wolff
    - Sachin Rajgopal

Introduction – ROOT

- Process and visualize large amounts of scientific data (CERN)
- Features a C++ interpreter (CLING) - i.e. used for rapid and efficient prototyping
- Persistency mechanism for C++ objects



source: https://indico.cern.ch/event/395198/attachments/791523/1084984/ROOT Summer Student Tutorial 2015.pdf

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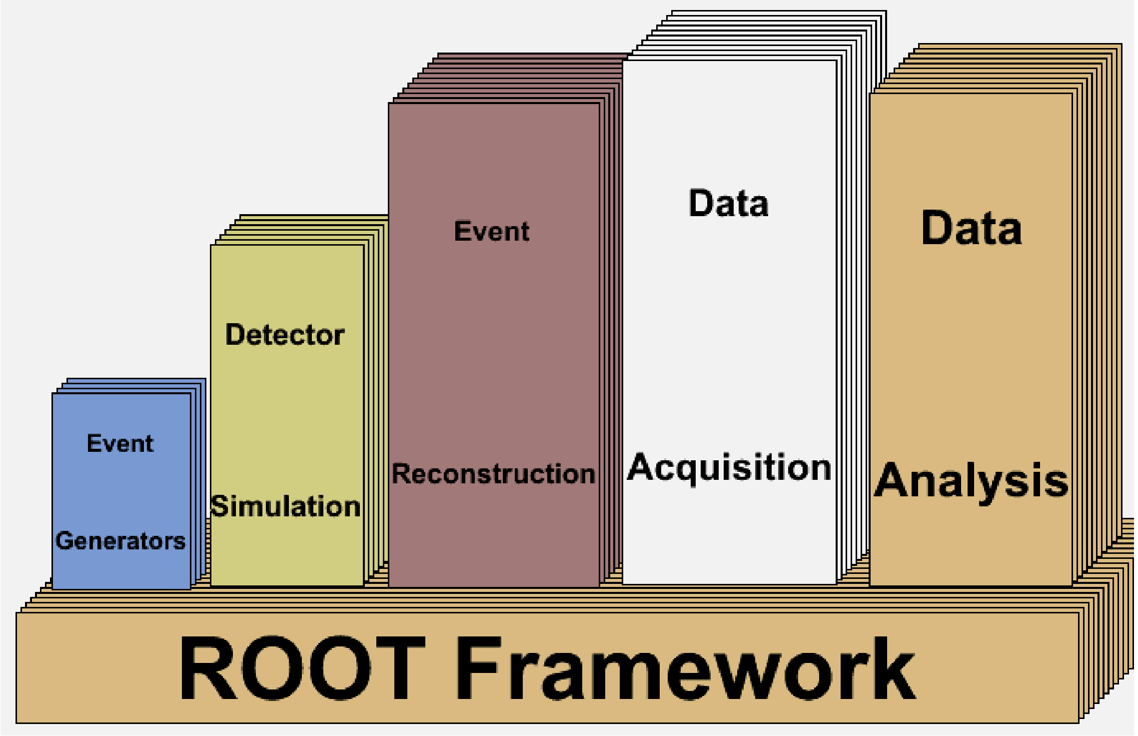


Introduction - Node.js

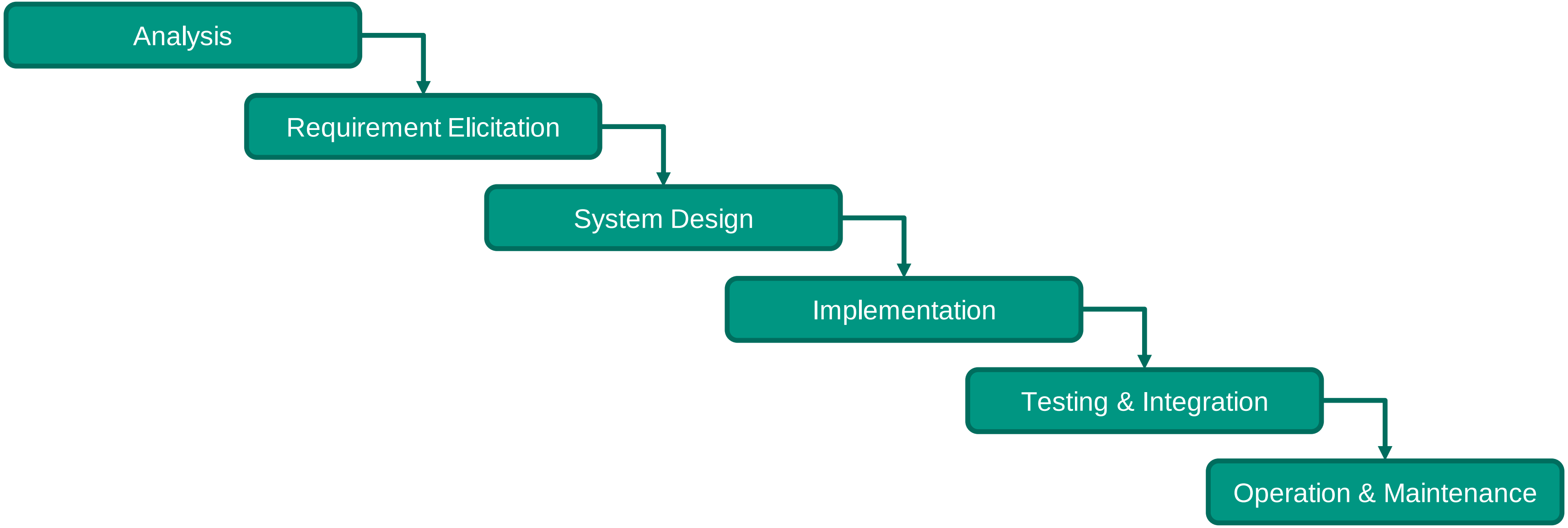
- Open source runtime environment
  - Develop server side web applications
  - Act as a stand alone web server
- Google V8 engine to execute JavaScript code
- rootJS bindings realized as native Node.js module written in C++

Introduction - rootJS

- Node.js bindings for ROOT
  - Be able to write ROOT code in Node.js programs
  - Integrate ROOT into Node.js based web applications
- System Requirements
  - Mac OS X and Linux
  - ROOT 6
  - Node.js versions
    - Stable on Node.js 4.4 (LTS)

Introduction – What is PSE?

- Praxis der Softwareentwicklung(PSE)
- Create software in a team in 5 months using object oriented software engineering
- Design: UML
- The final software: Maximum of 10k LOC, 250 hours/person
- Weekly meetings
- Development phases - waterfall model



Analysis

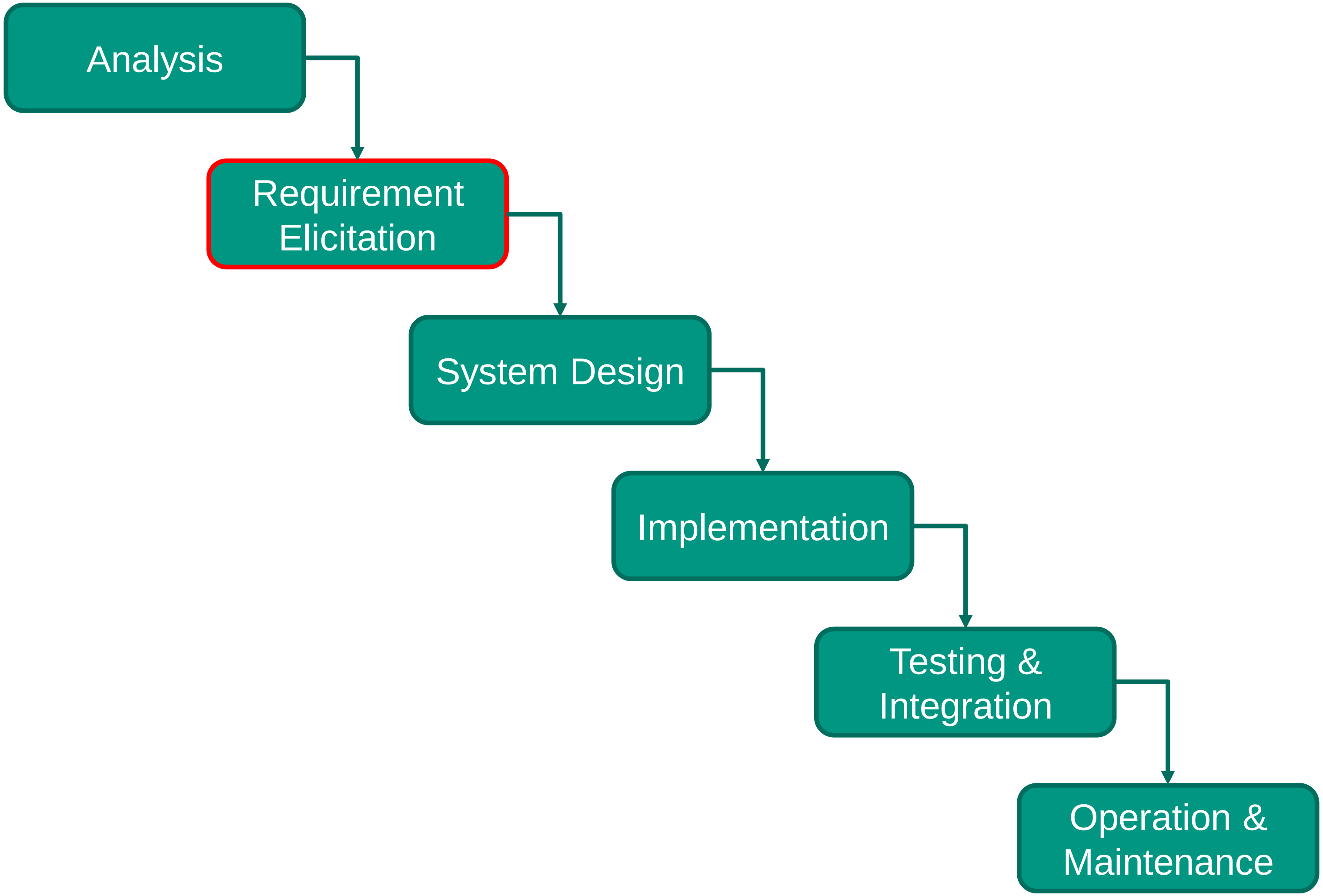
Requirement Elicitation

System Design

Implementation

Testing & Integration

Operation & Maintenance



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Phase Recap – Requirement Elicitation

- Required criteria

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- Required criteria
    - Work on Linux

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Phase Recap – Requirement Elicitation

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  - Do not extend existing ROOT functionality

Phase Recap – Requirement Elicitation

- Required criteria
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  - Accept C++ code for JIT compilation
  - Dynamically update C++ internals on changes
  - Asynchronous wrappers for common I/O operations
- Limiting criteria
  - Do not extend existing ROOT functionality
  - Do not necessarily support future ROOT versions

Phase Recap – Requirement Elicitation

- Language bindings

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- Language bindings
    - Use ROOT functions

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Phase Recap – Requirement Elicitation

- Language bindings
  - Use ROOT functions
  - Use ROOT objects
  - Use JIT compiler
- Focus on benefits provided by JavaScript
  - Asynchronous calls
  - Use in web applications

Phase Recap – Requirement Elicitation

- Usage scenario: event viewer

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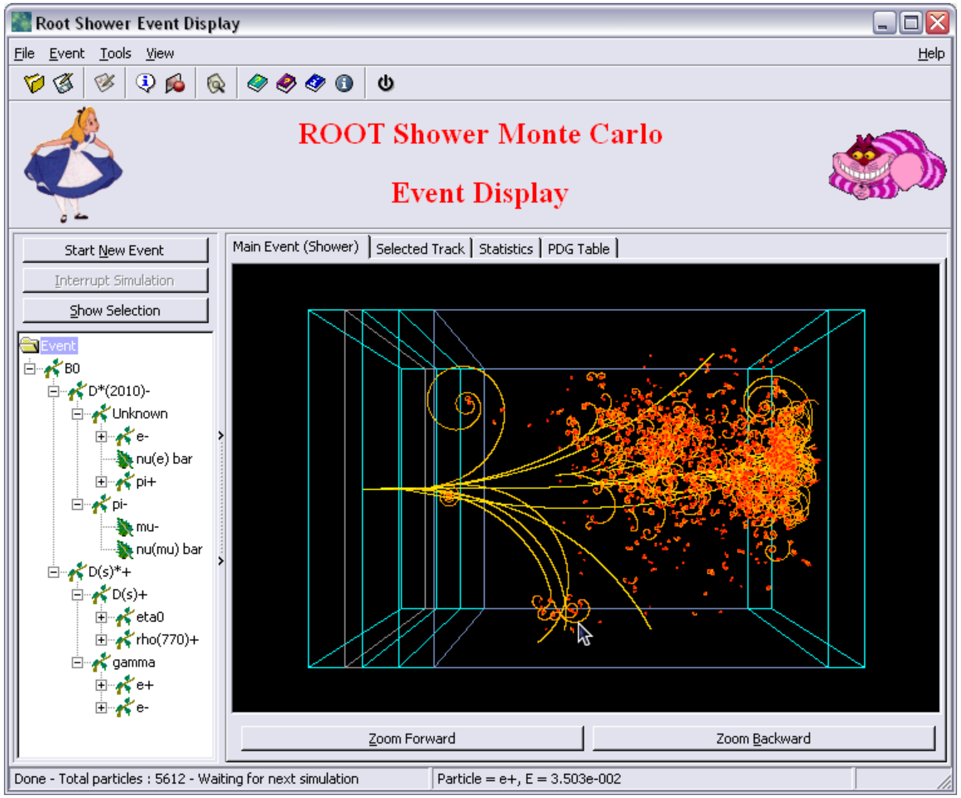

Done - Total particles : 5612 - Waiting for next simulation

Particle = e+, E = 3.503e-002

Phase Recap – Requirement Elicitation

- Usage scenario: event viewer
  - Visualizes experimental data
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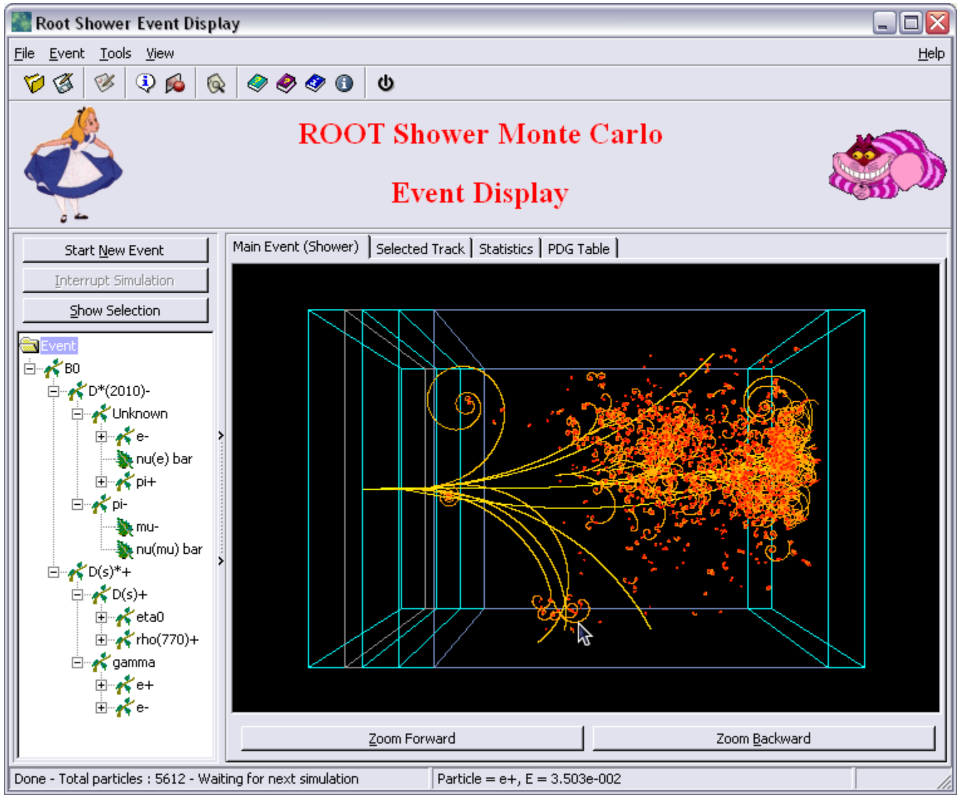

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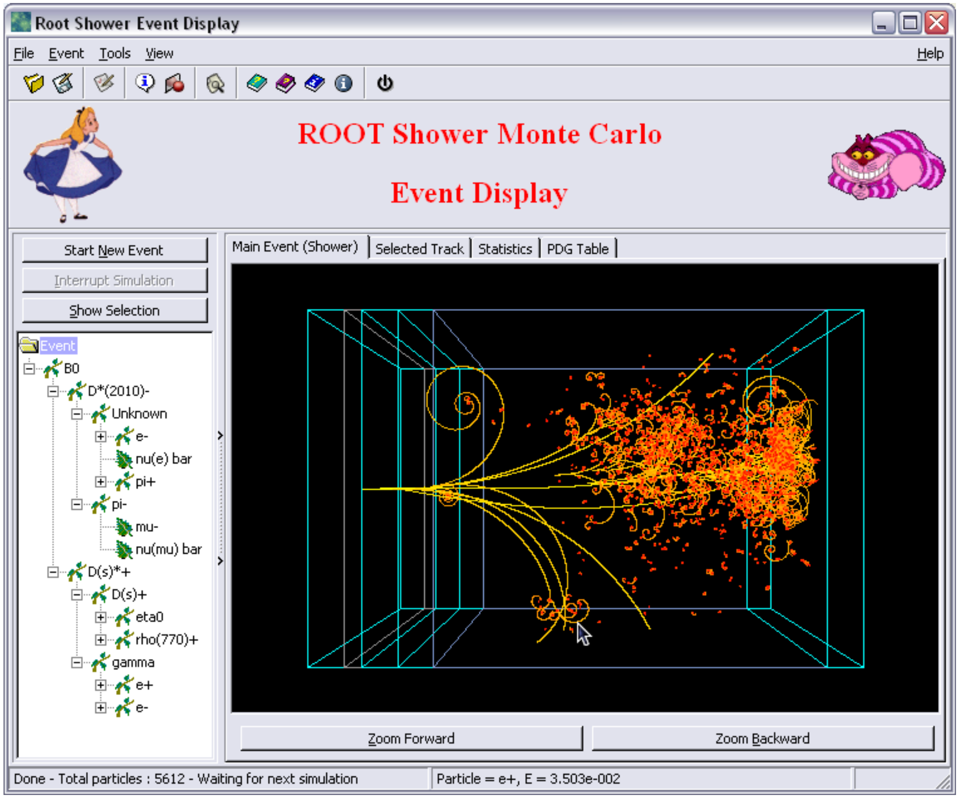

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  - Needs ROOT and dependencies installed
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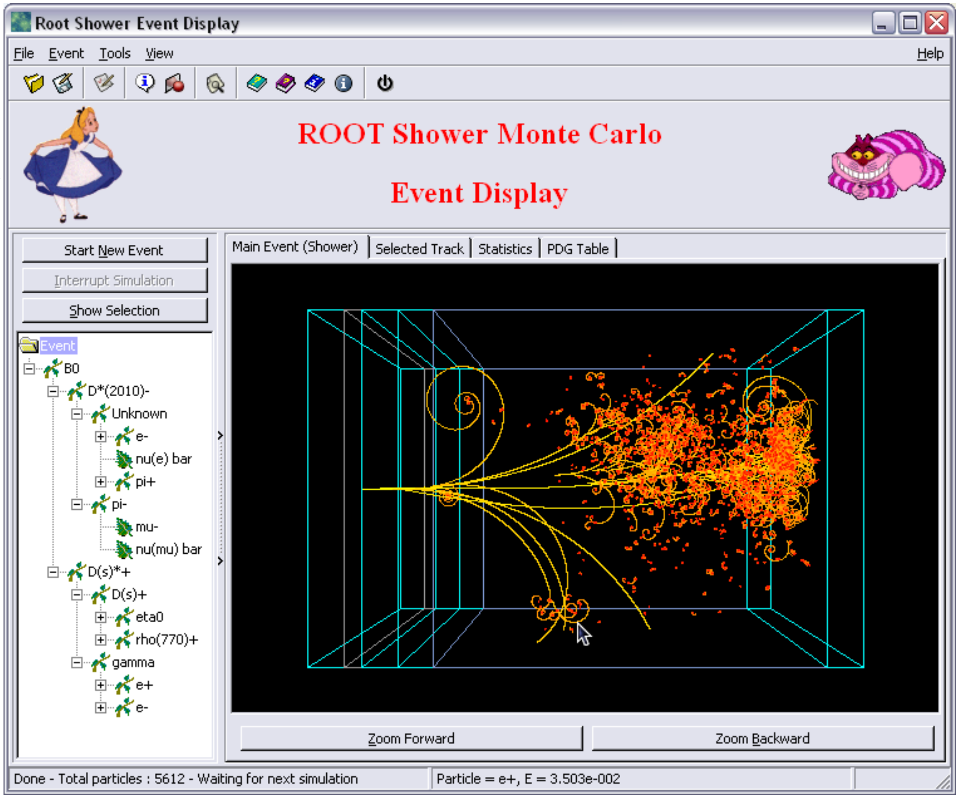

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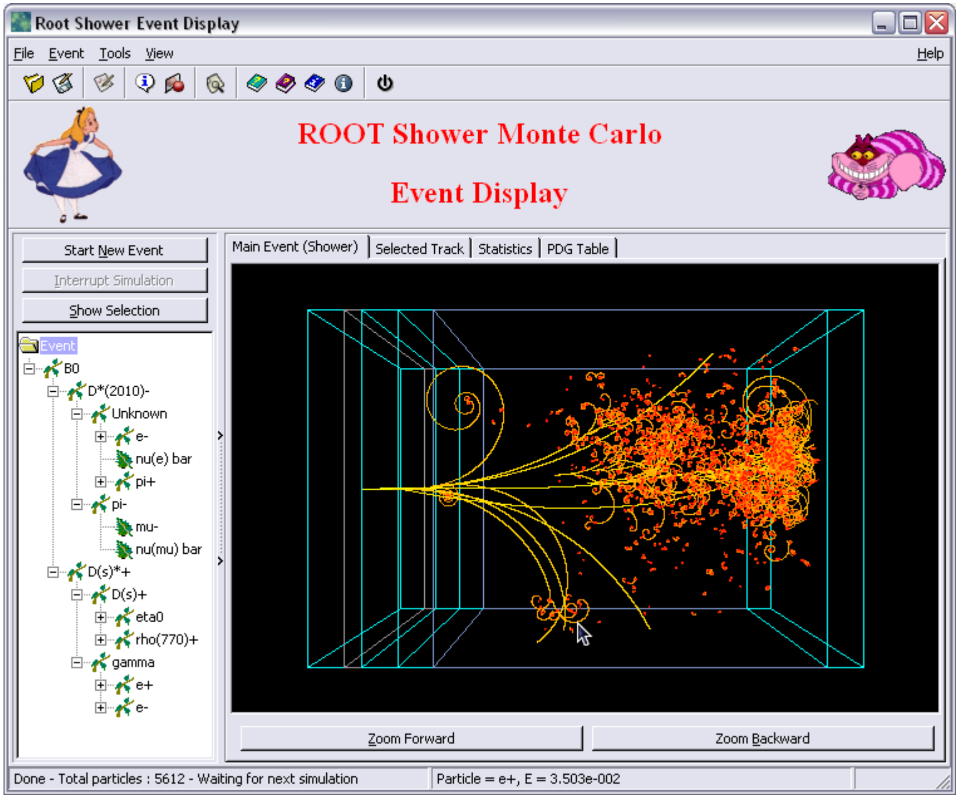
  → Limited portability



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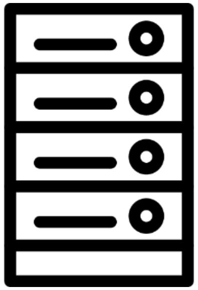

ROOT + dependencies,
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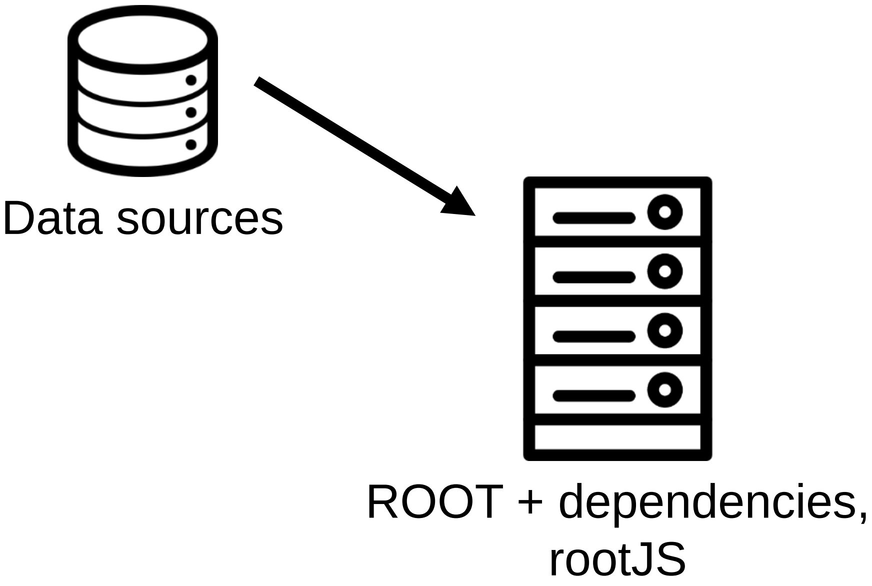

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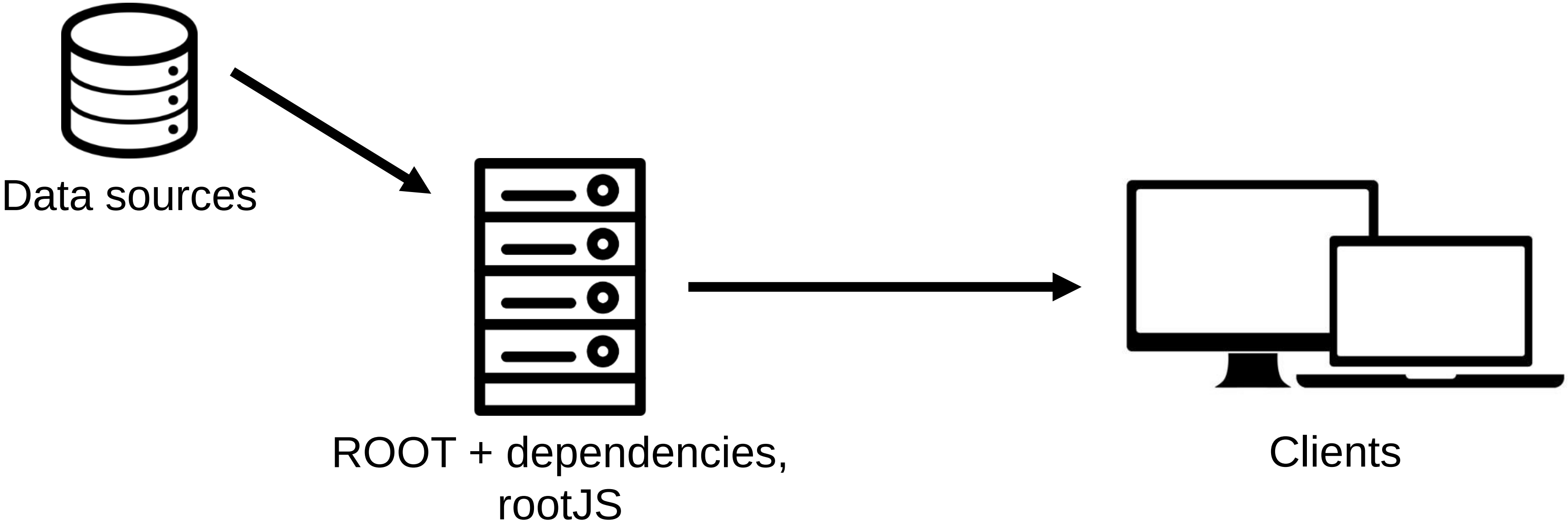

Phase Recap – Requirement Elicitation

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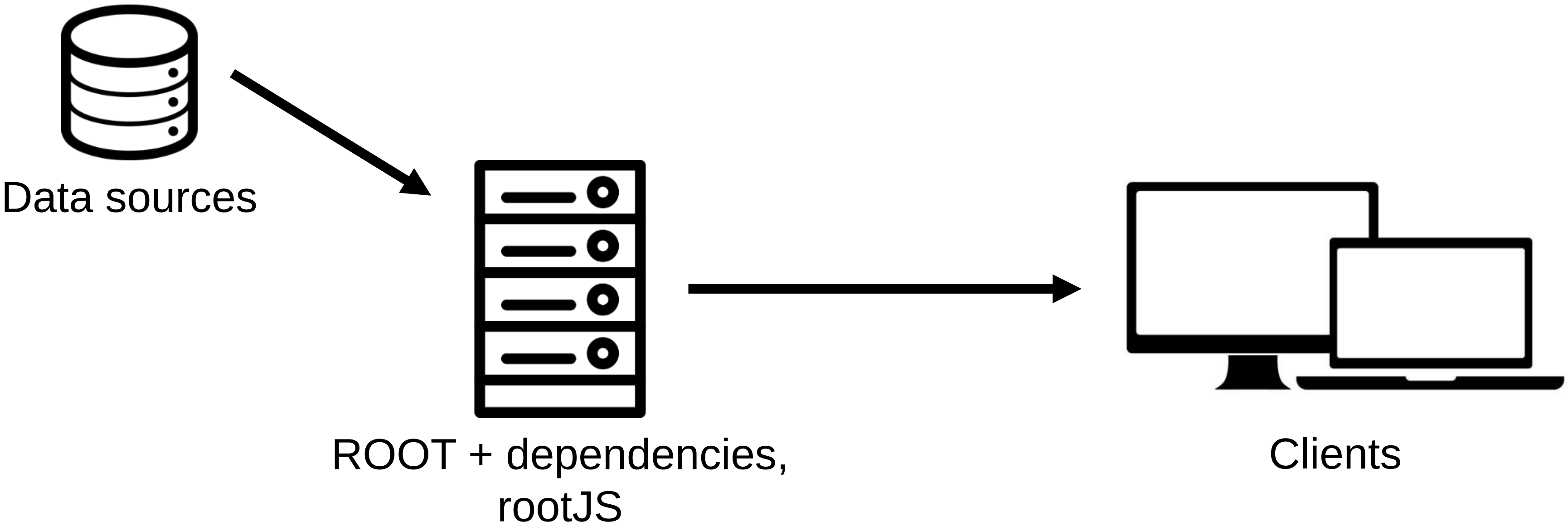
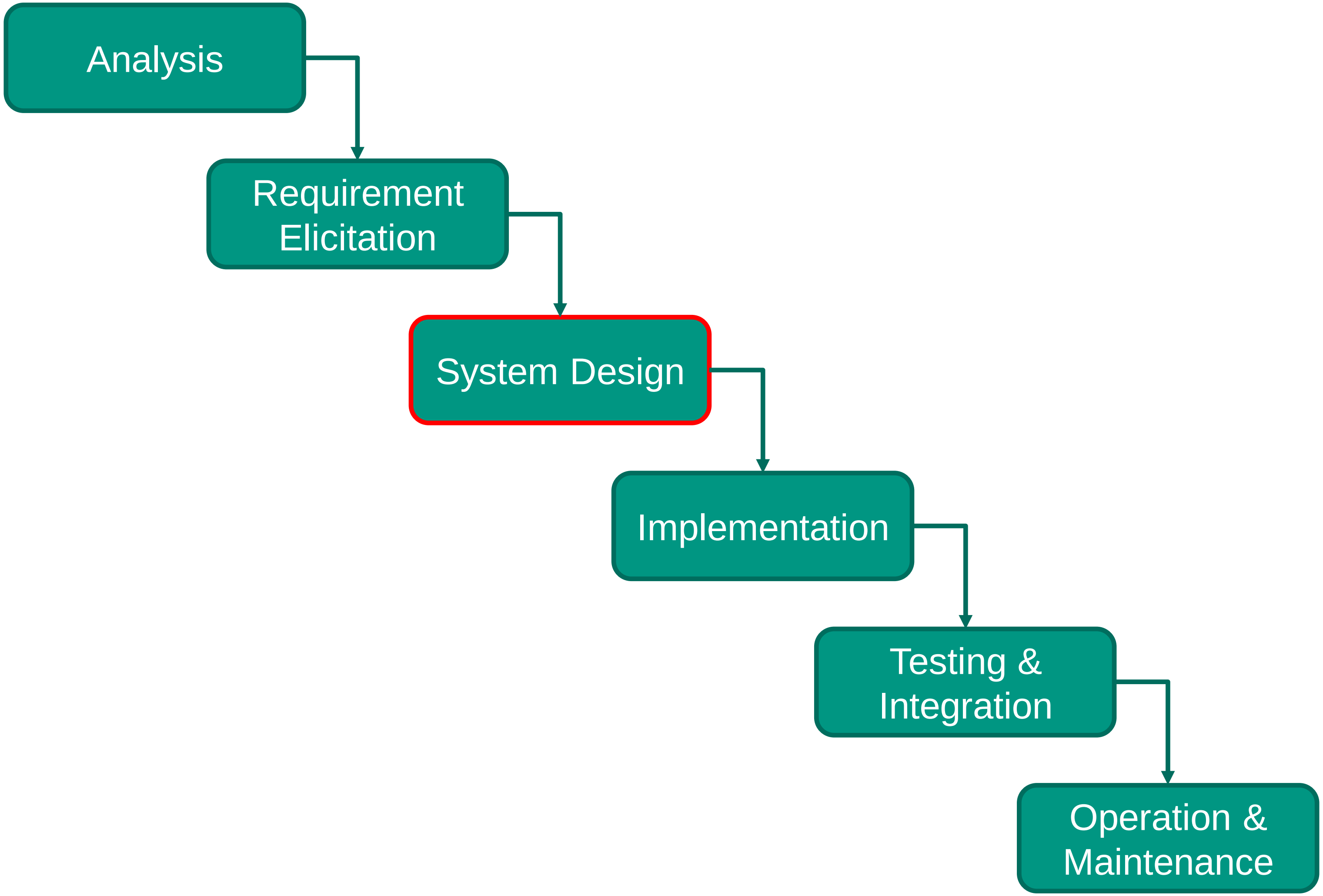


Data sources

ROOT + dependencies, rootJS

Clients



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ROOT Data Analysis Framework

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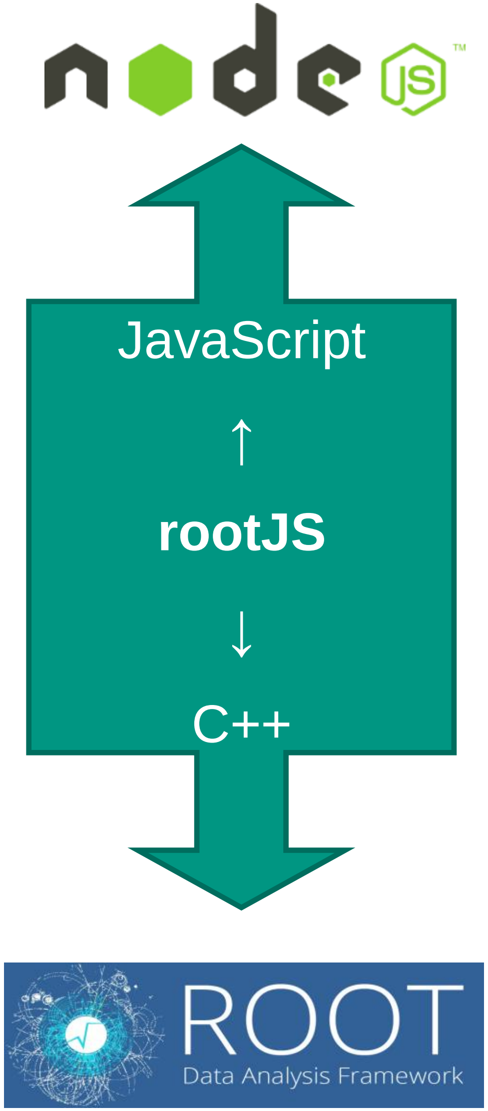

JavaScript

↑

rootJS

↓

C++

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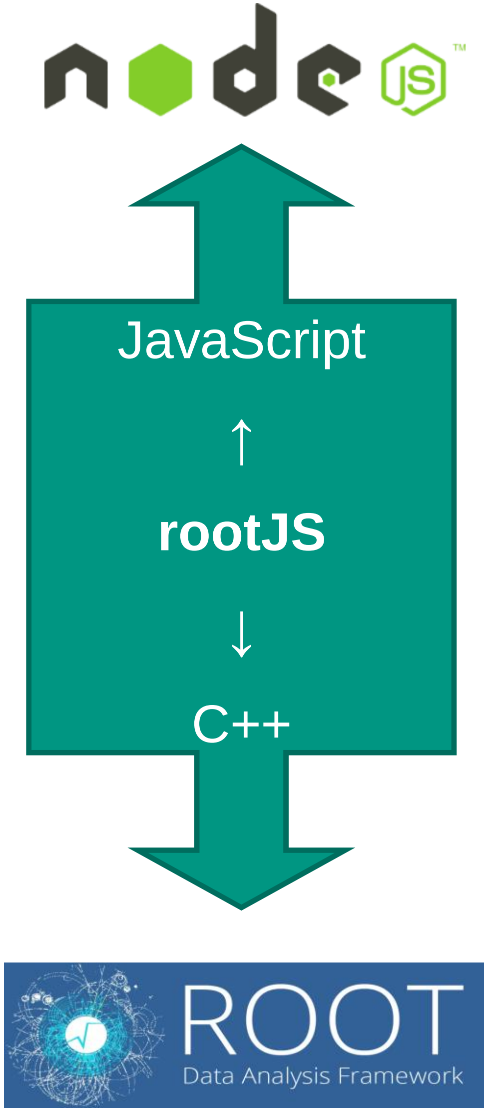

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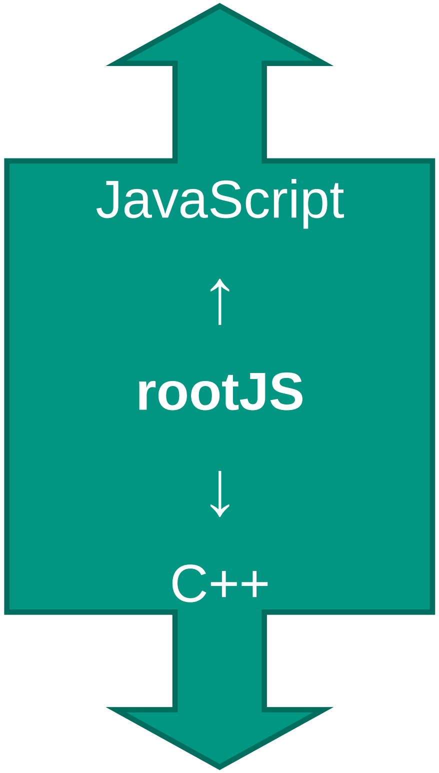

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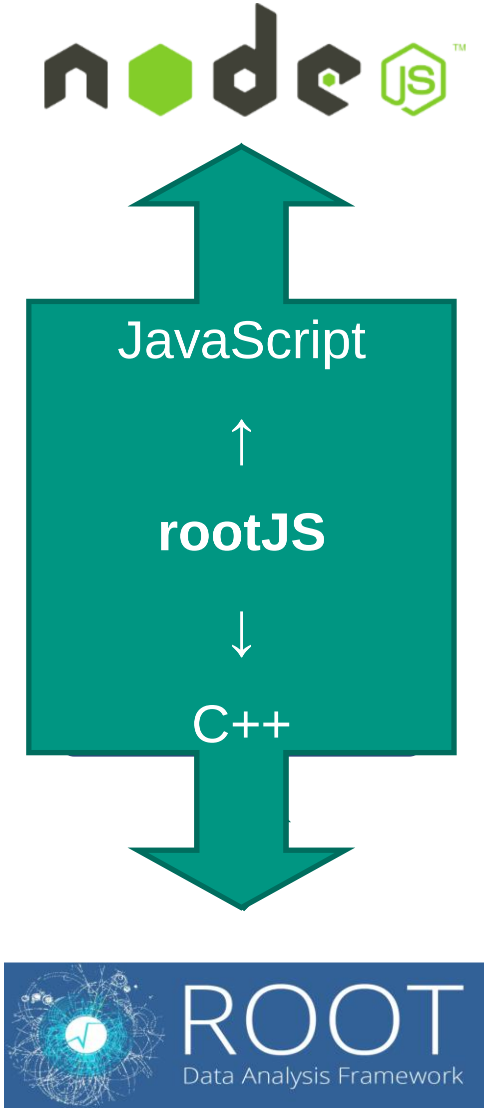

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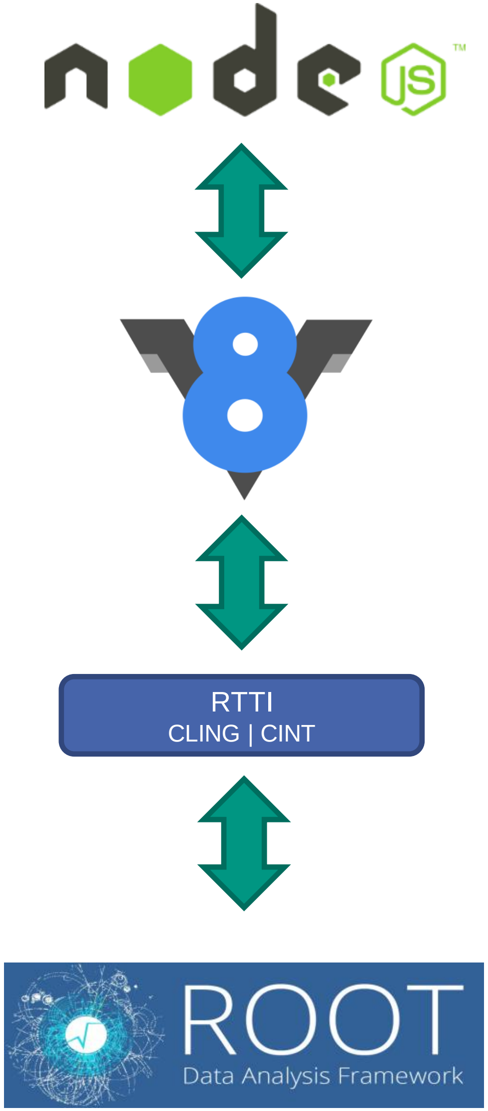

RTTI
CLING | CINT

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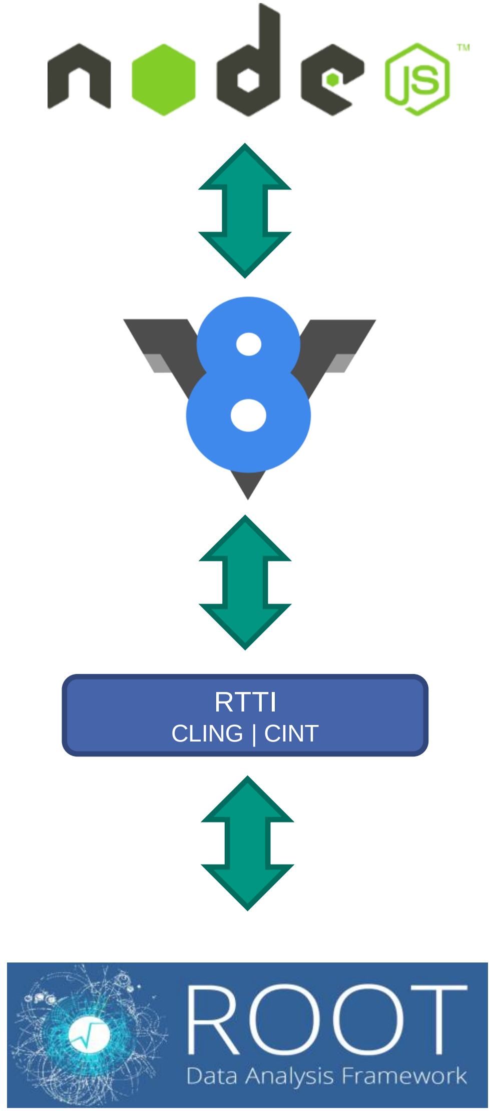

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- Environment:
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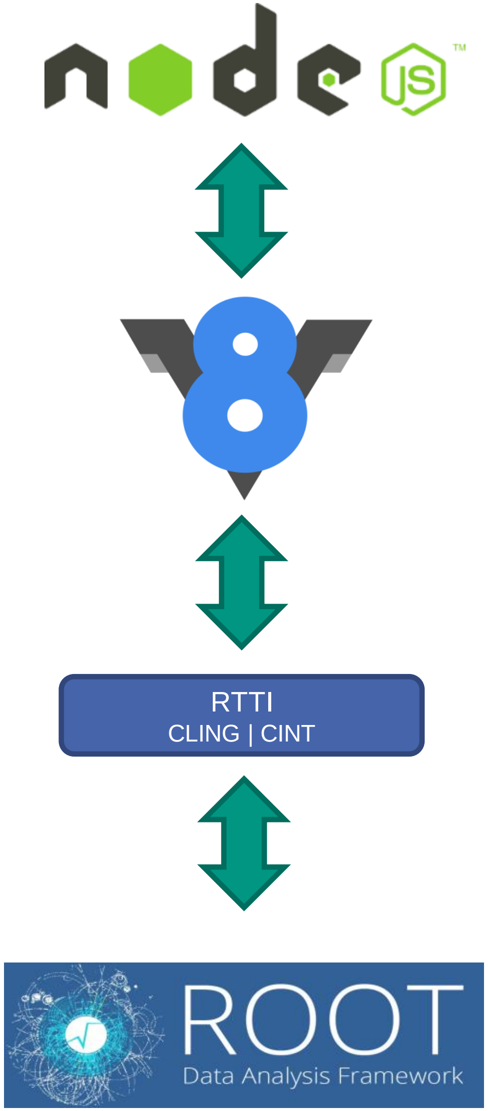
    - object exposure and callback handling
  - ROOT RTTI-interface
    - class, namespace, global and member variable information



Design – Requirements Realization

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- recursively seek & expose classes and namespaces

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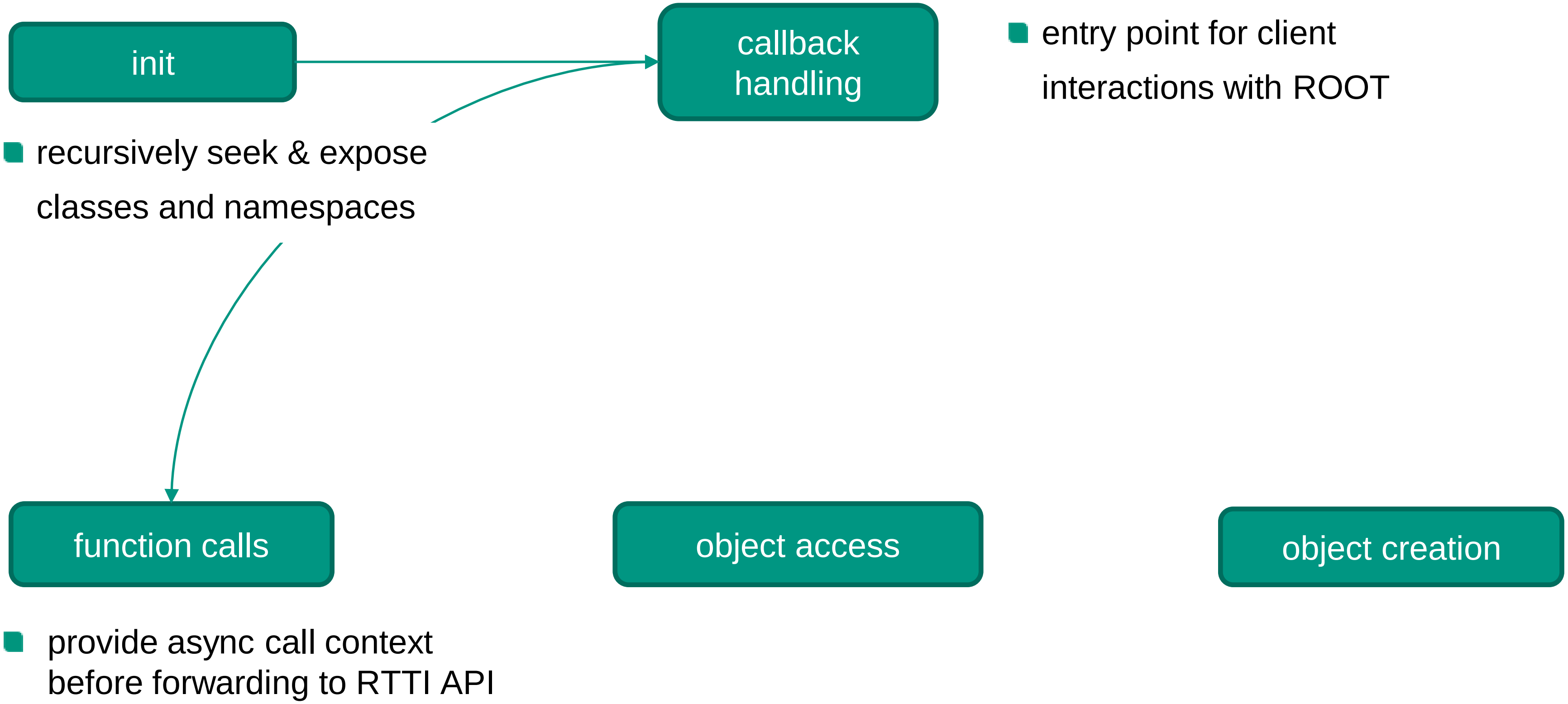

init

callback handling

- entry point for client interactions with ROOT

- recursively seek & expose classes and namespaces

function calls

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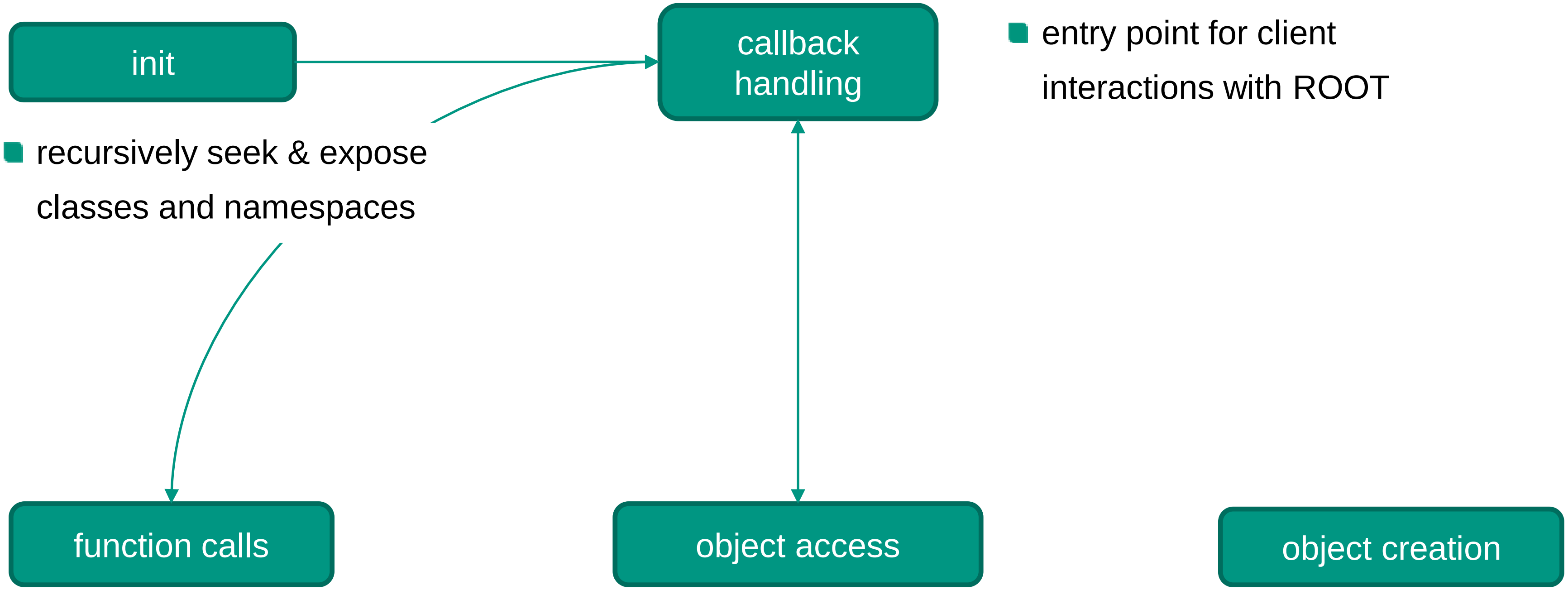
object creation

- provide async call context before forwarding to RTTI API

Design – Requirements Realization



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- direct access to C++ objects in memory via corresponding proxy object

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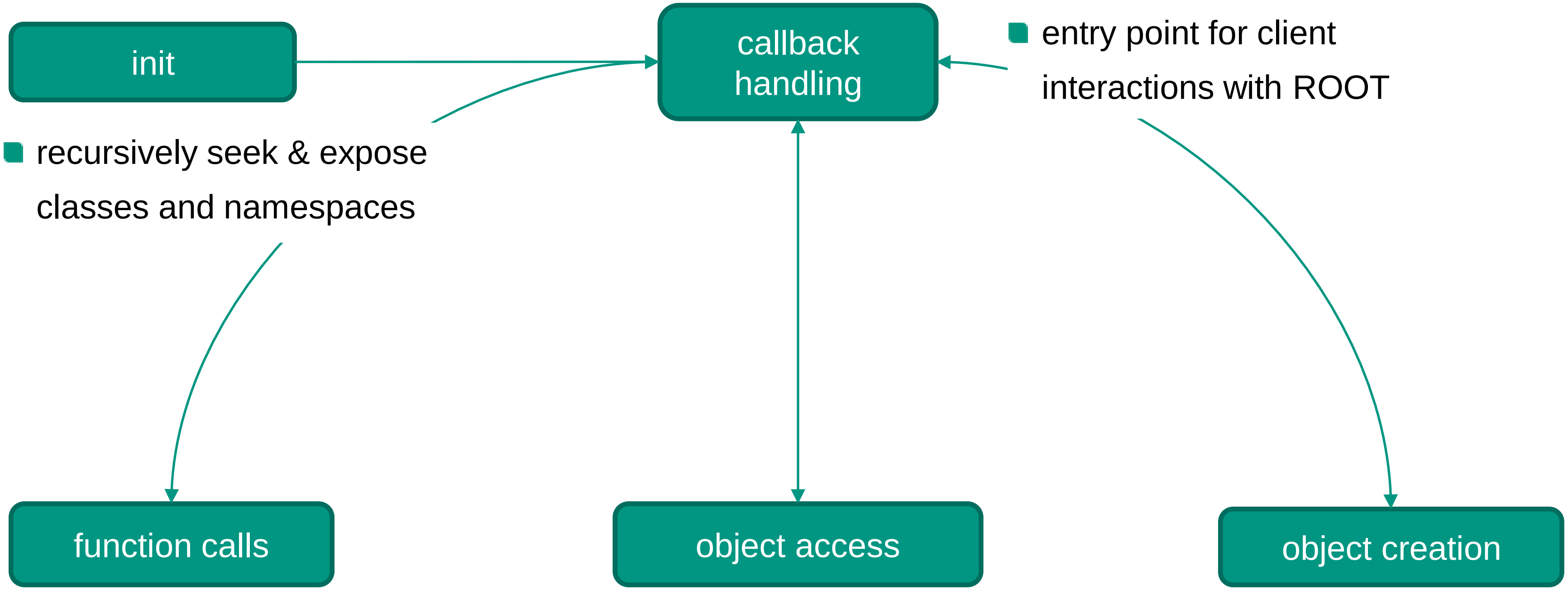

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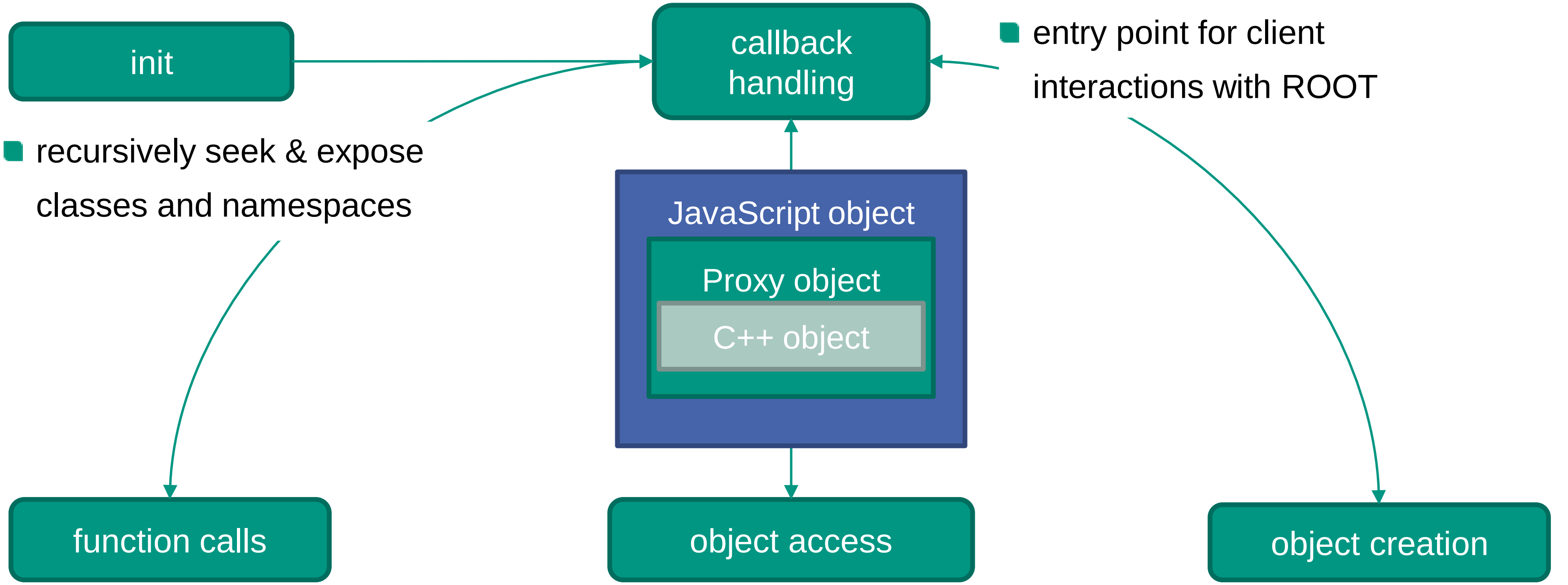

init

callback handling

- entry point for client interactions with ROOT

- recursively seek & expose classes and namespaces

JavaScript object

Proxy object

C++ object

function calls

object access

object creation

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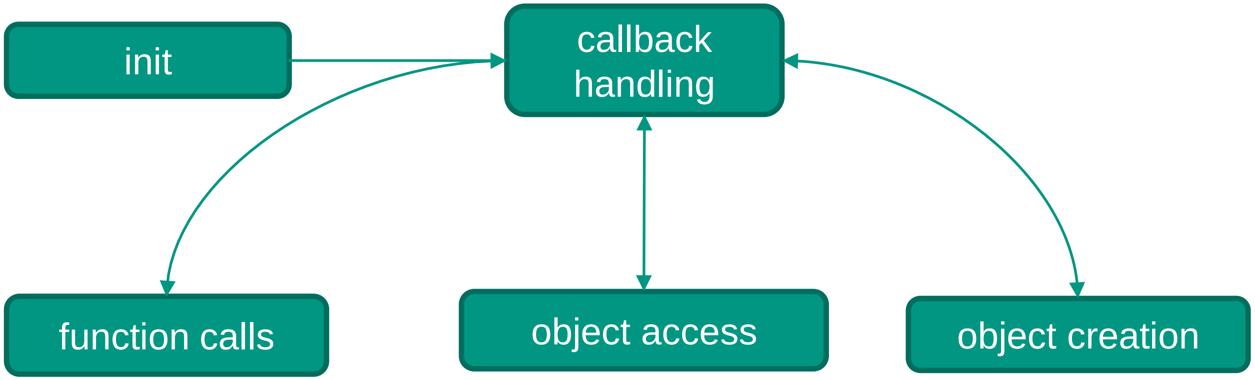
Design – Architecture Concept



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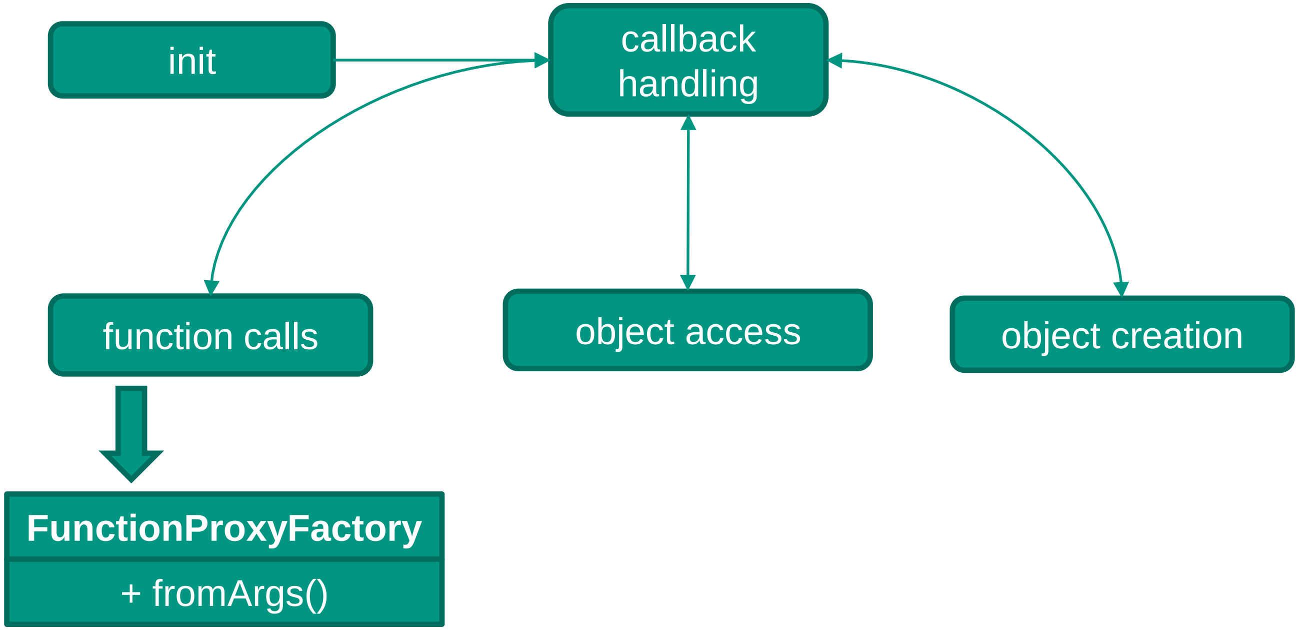
Design – Architecture Concept



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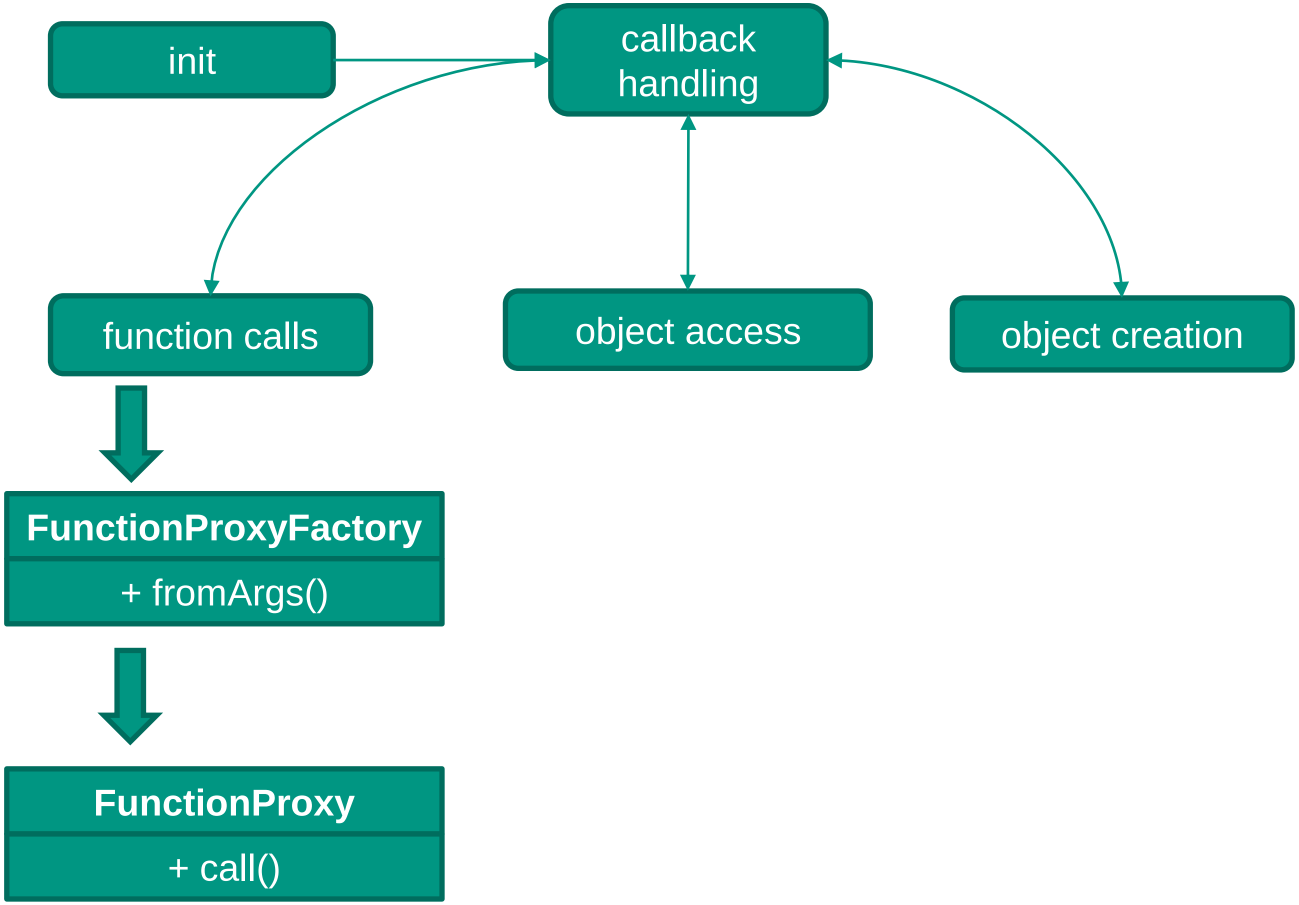
FunctionProxyFactory

+ fromArgs()

Design – Architecture Concept



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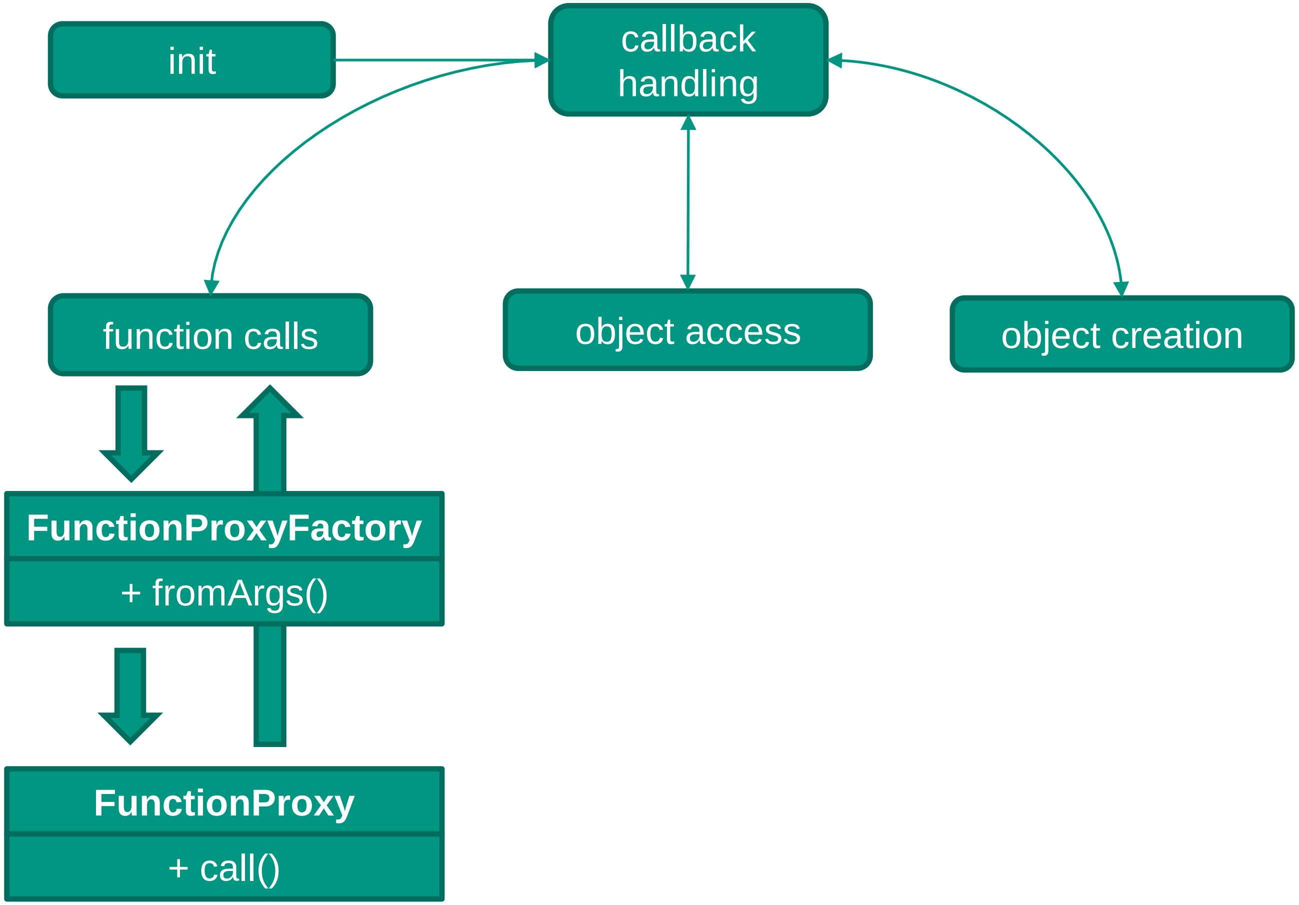

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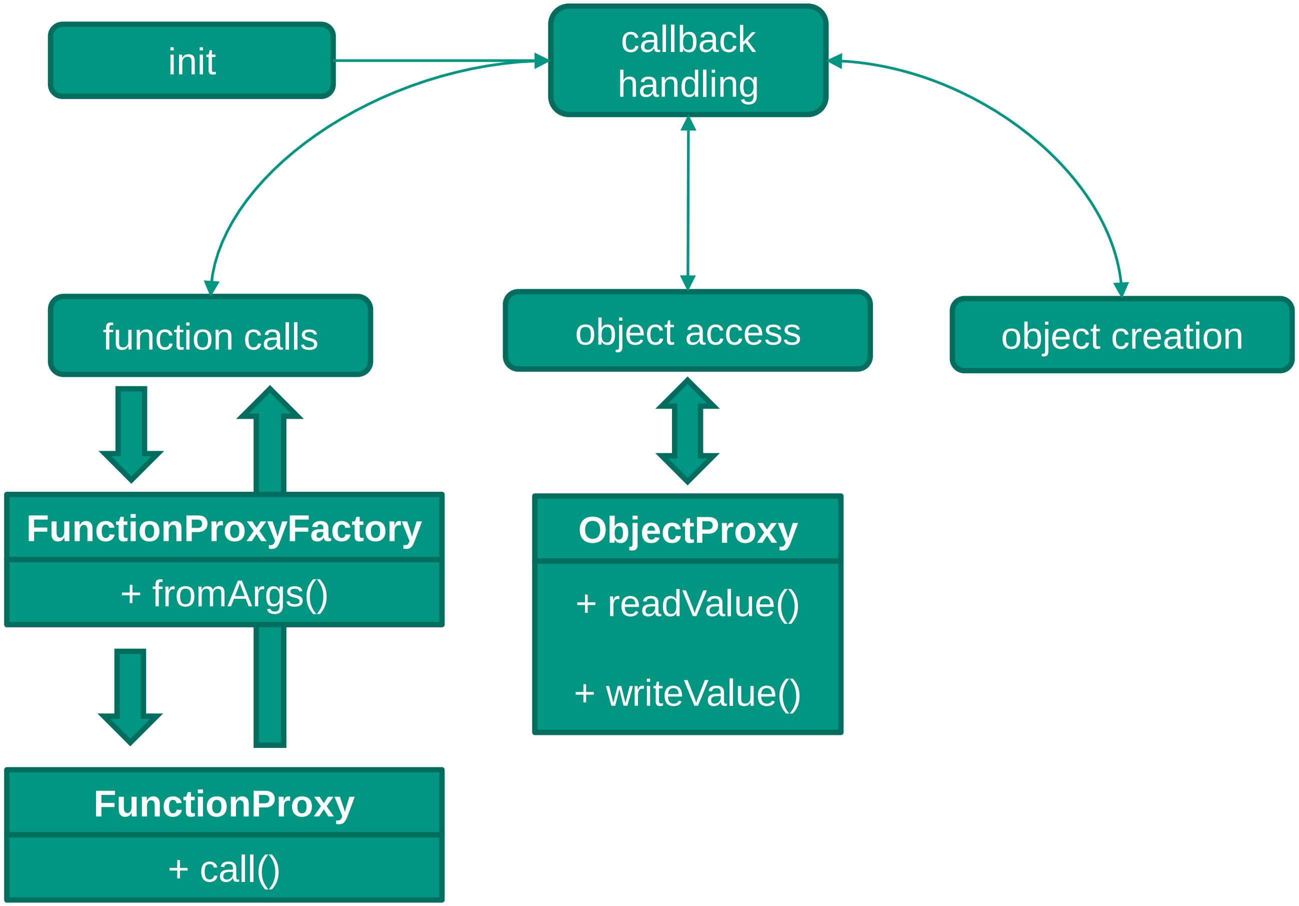

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ObjectProxy

+ readValue()

+ writeValue()

FunctionProxy

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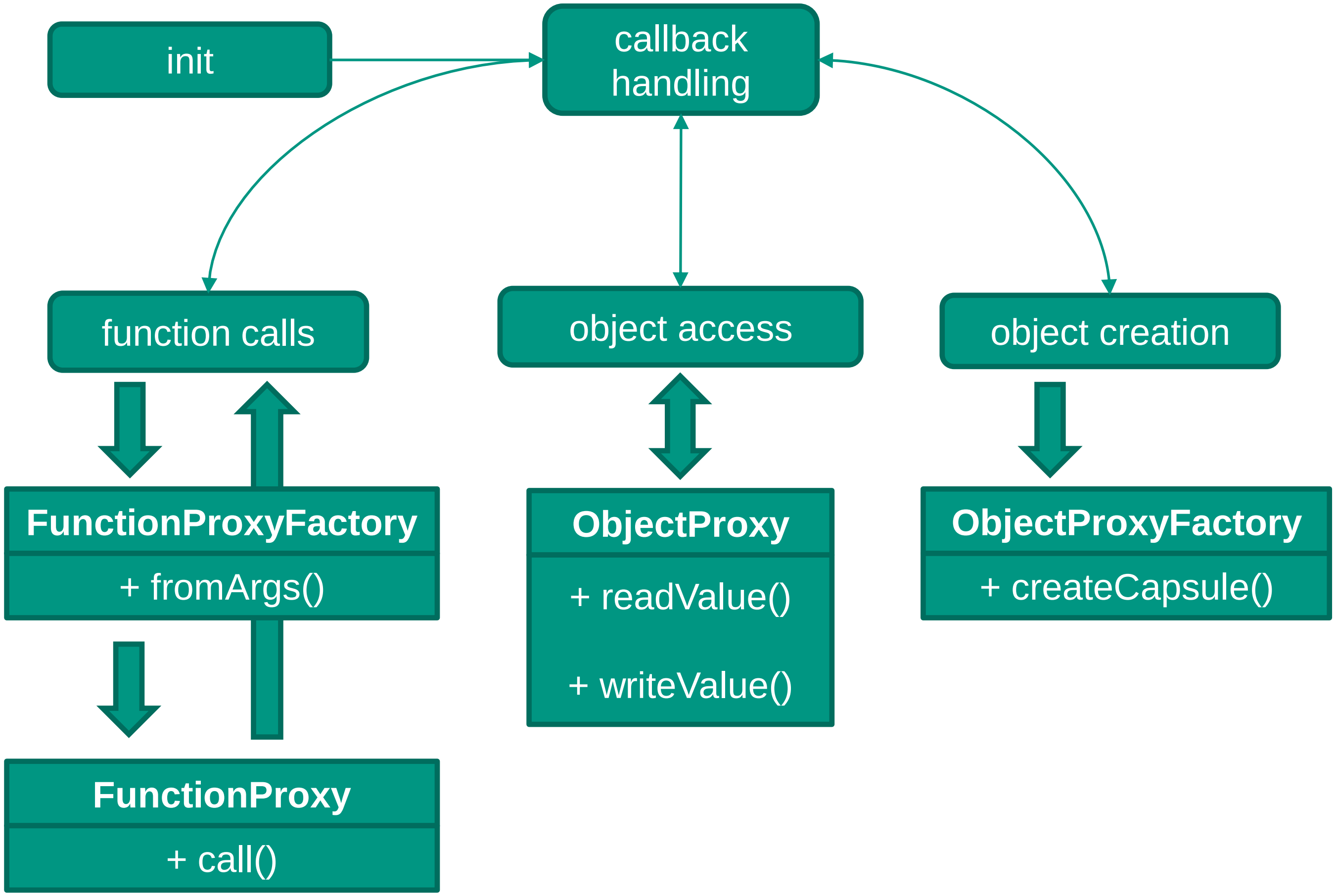

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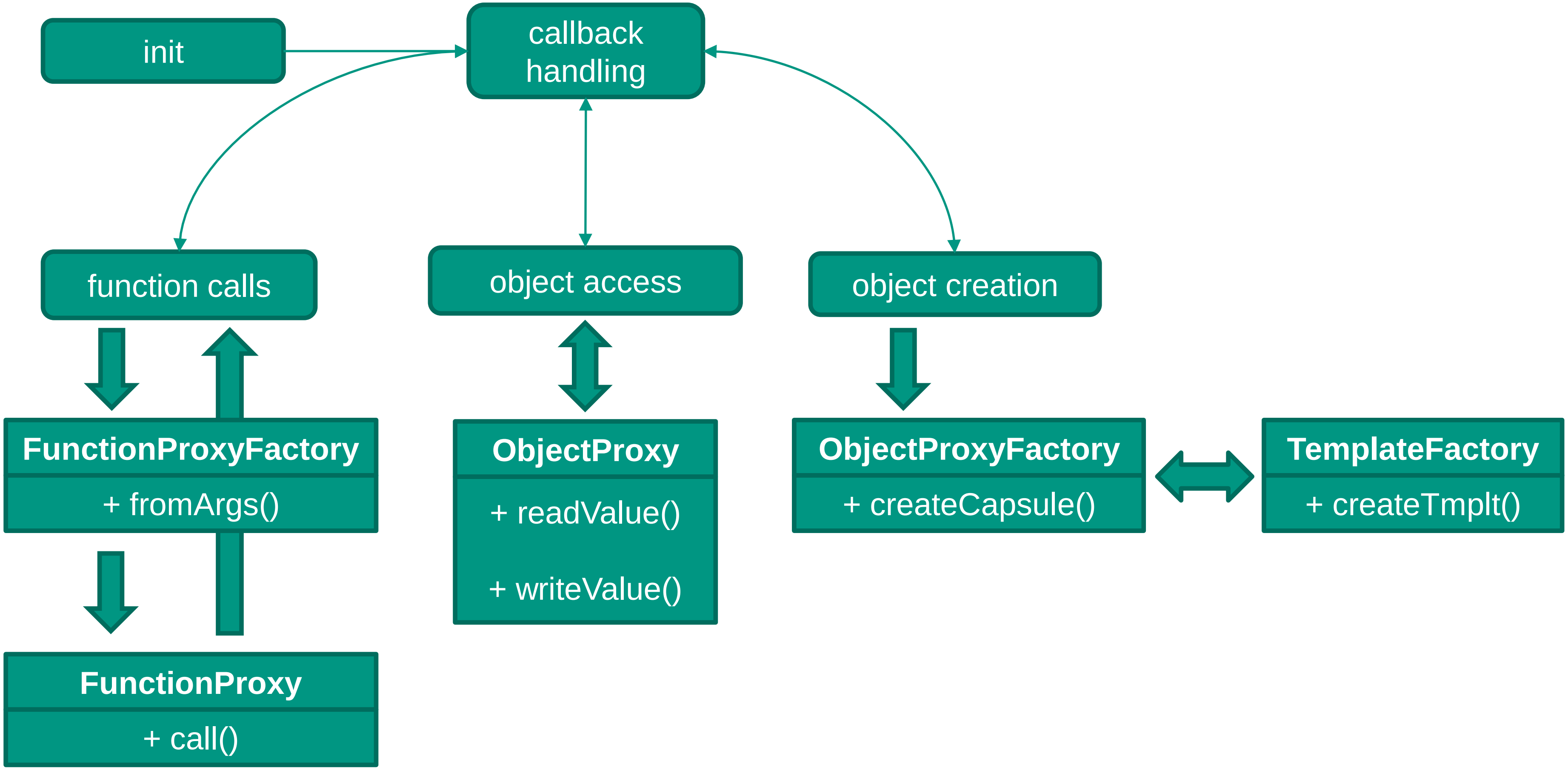

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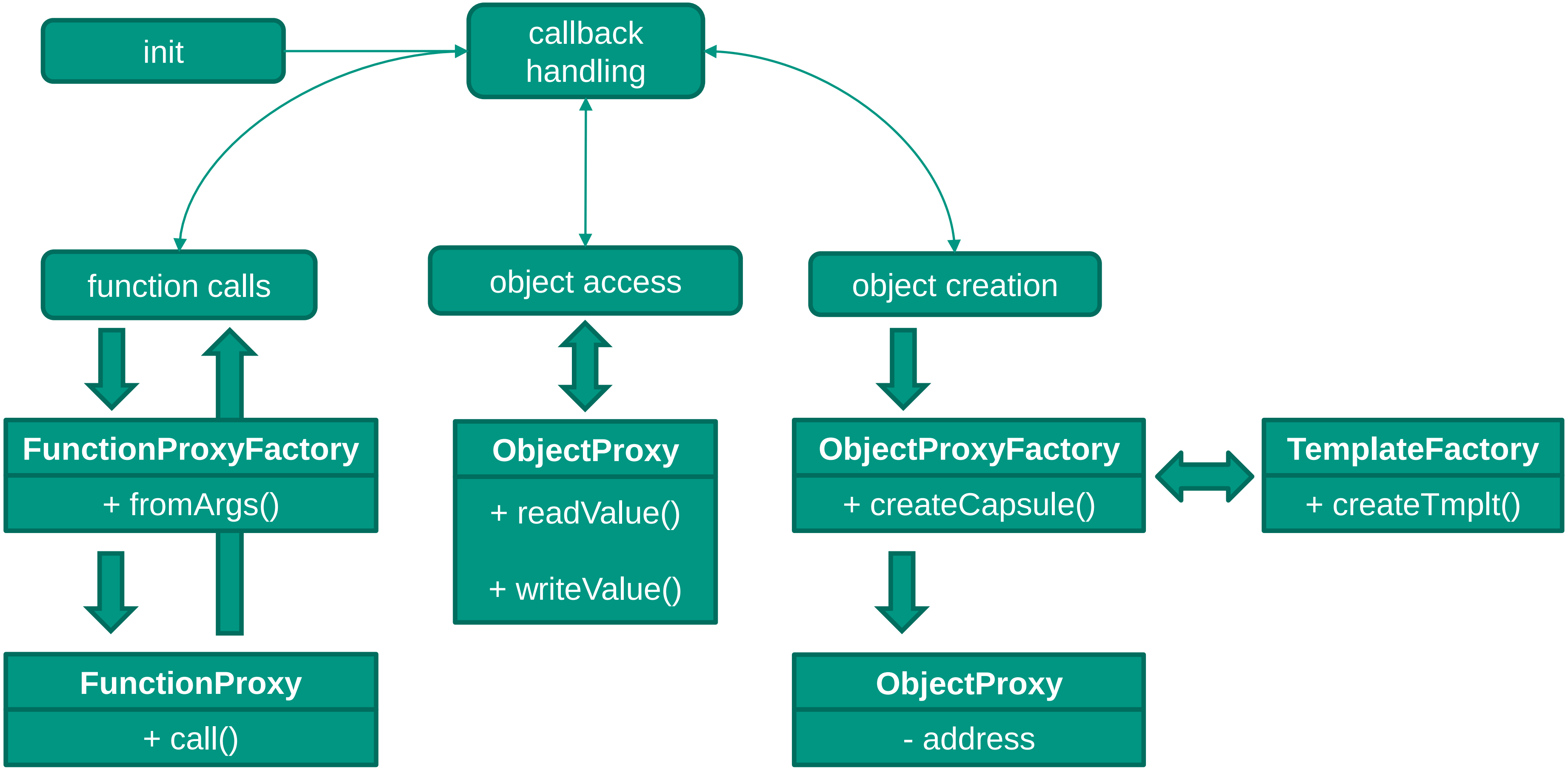

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FunctionProxyFactory

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ObjectProxy

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ObjectProxyFactory

+ createCapsule()

TemplateFactory

+ createTmplt()

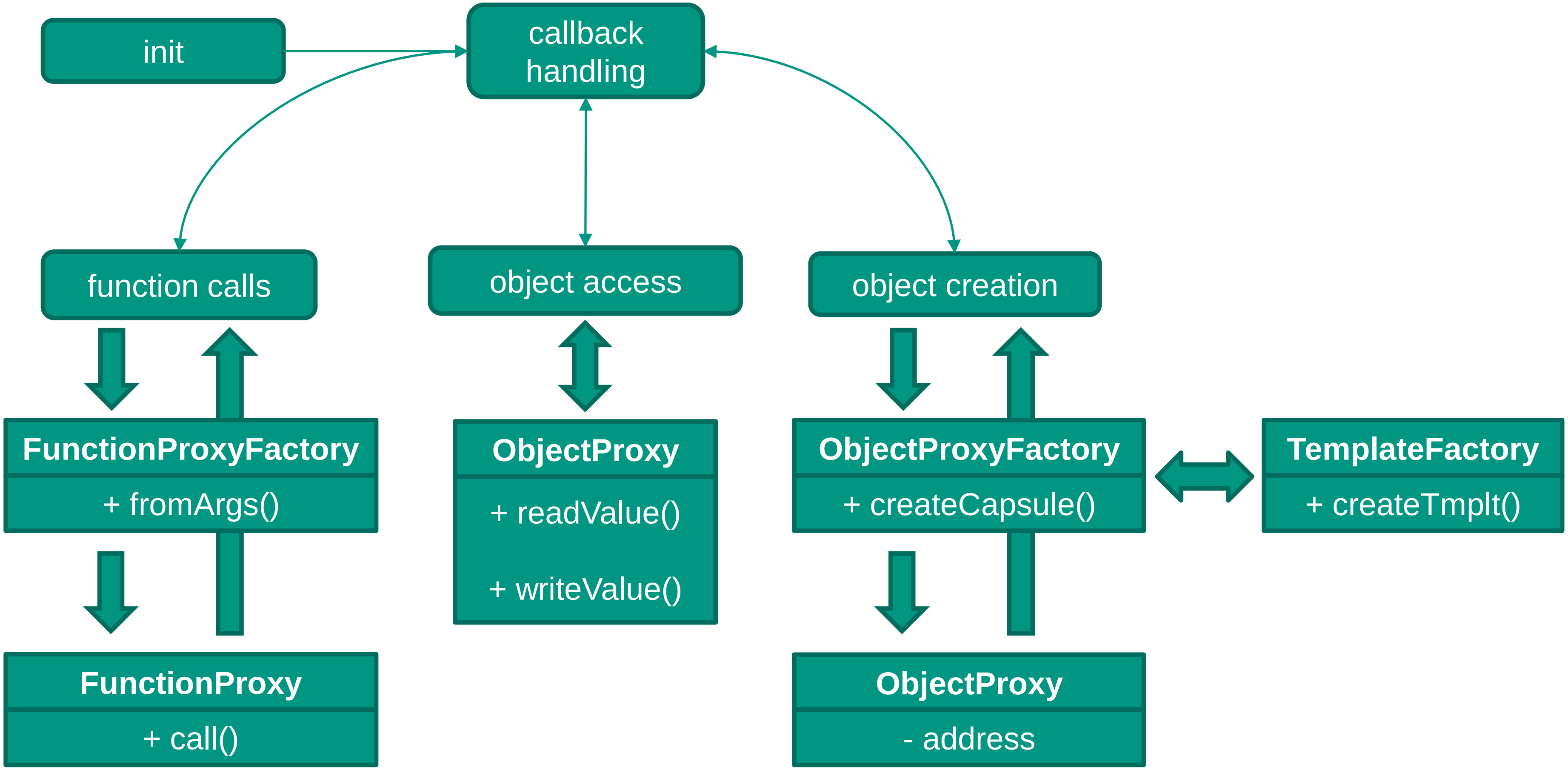
FunctionProxy

+ call()

ObjectProxy

- address

Design – Architecture Concept



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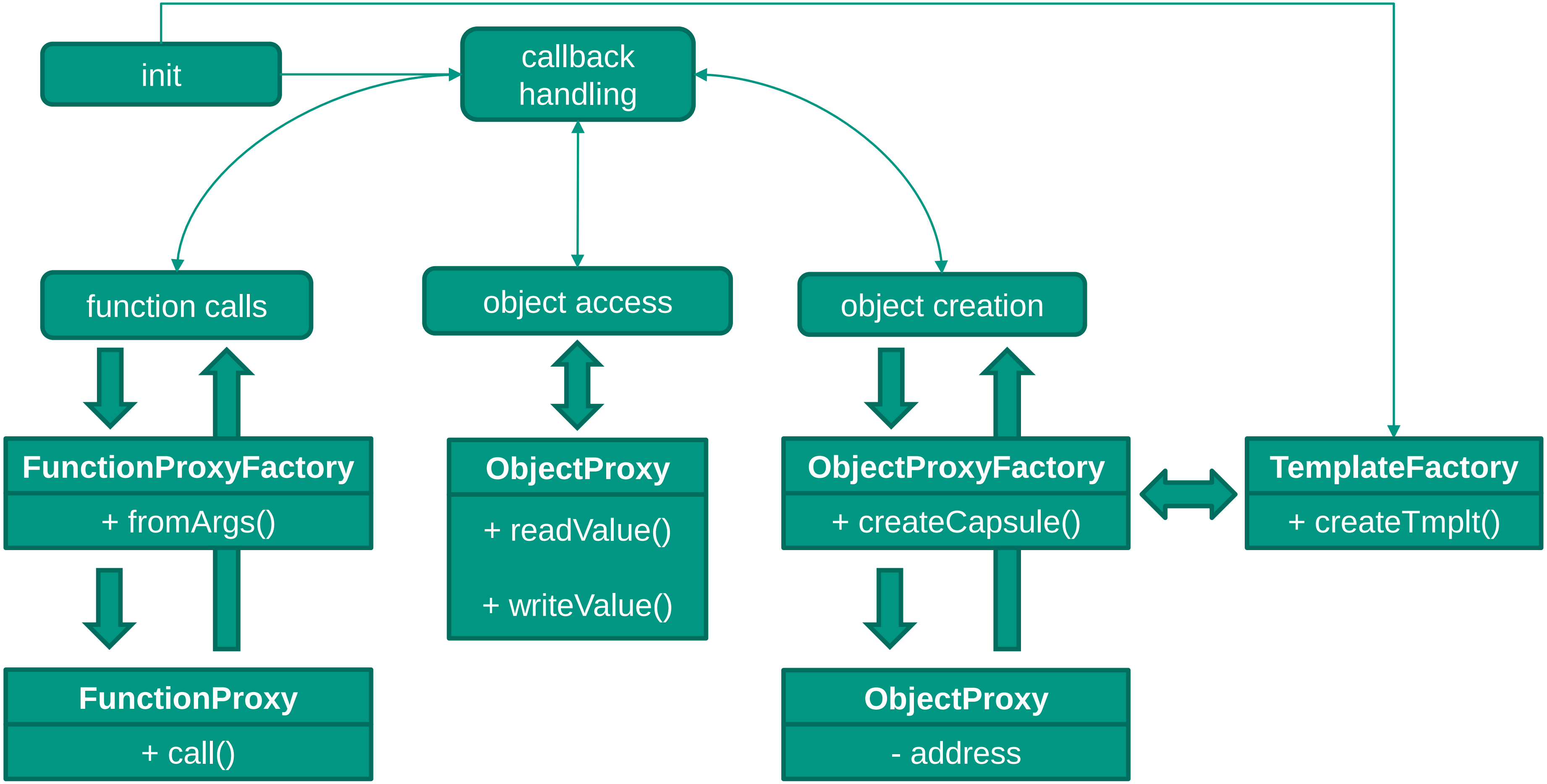

Design – Core Architecture

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NodeHandler

+ exposeROOT()

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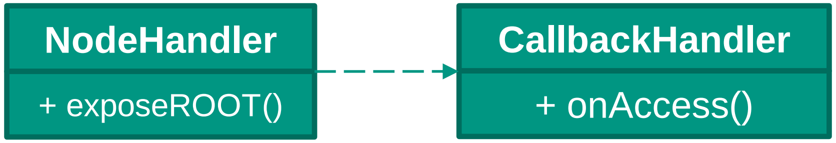

NodeHandler

+ exposeROOT()

CallbackHandler

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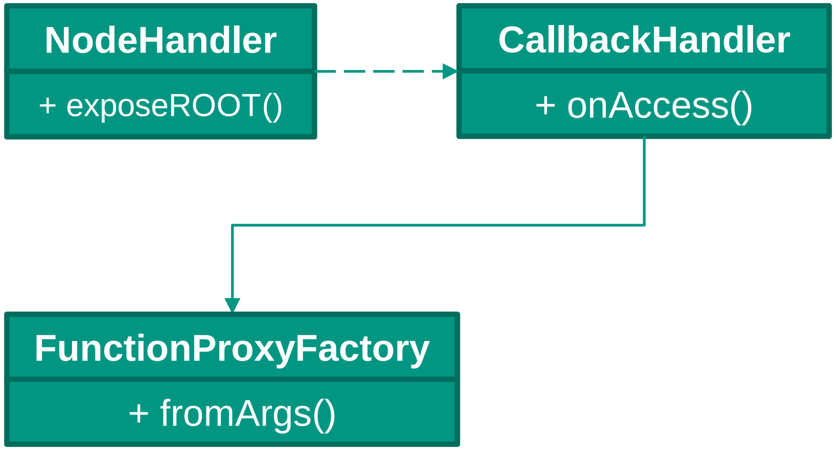
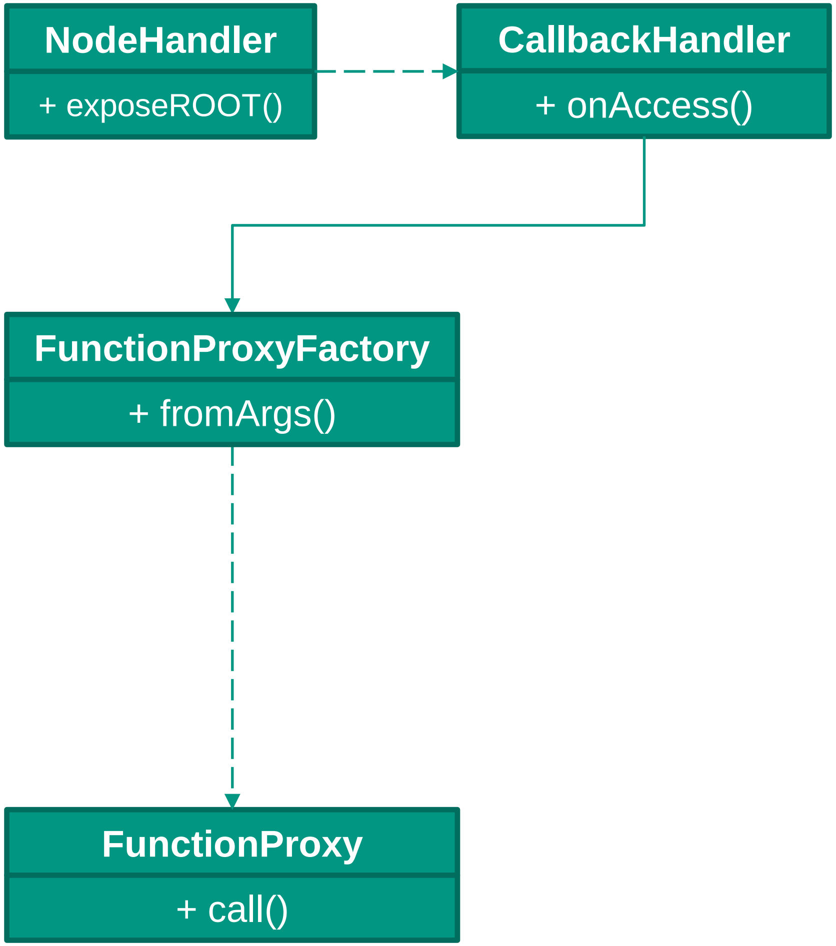


Design – Core Architecture



NodeHandler

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CallbackHandler

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FunctionProxyFactory

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FunctionProxy

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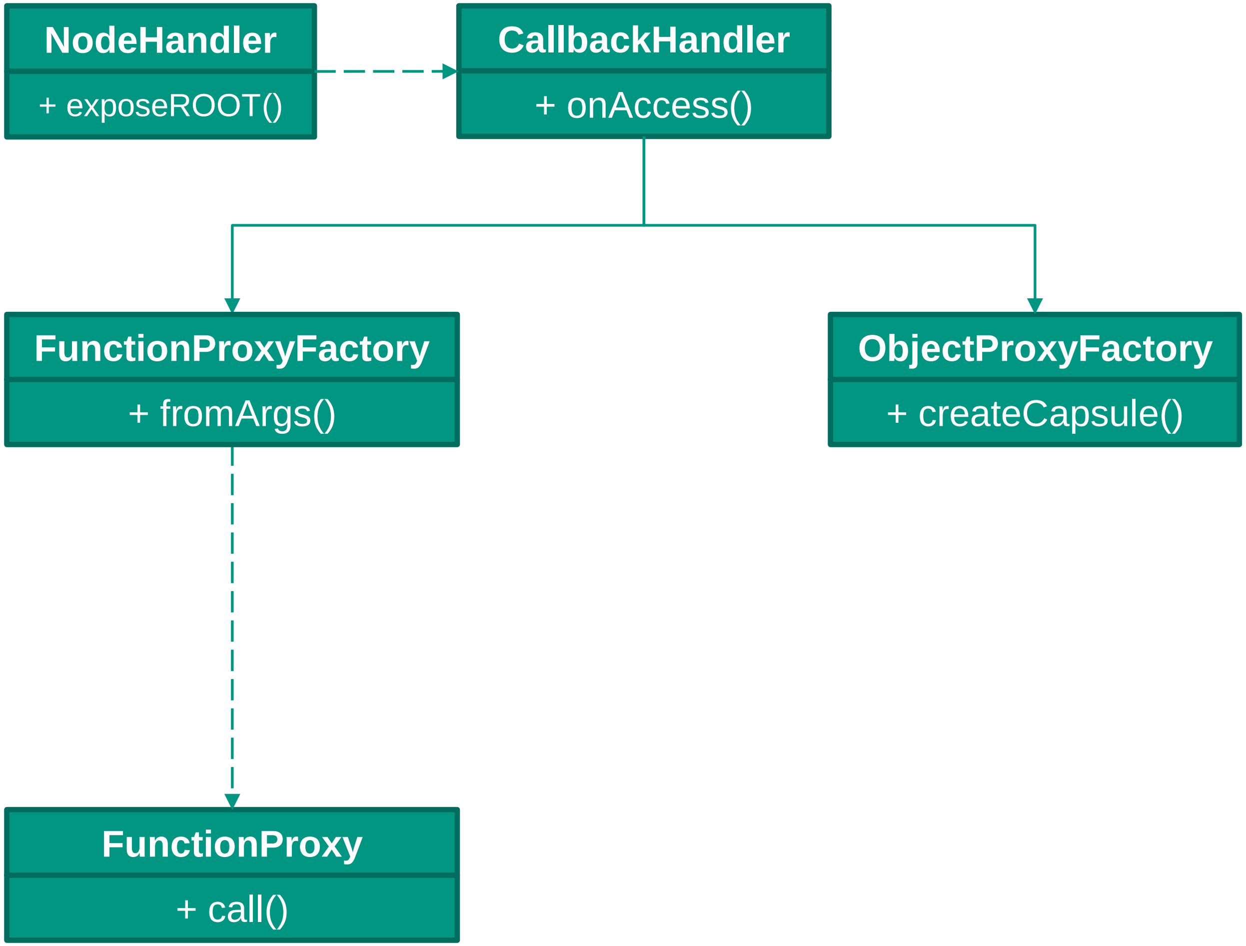

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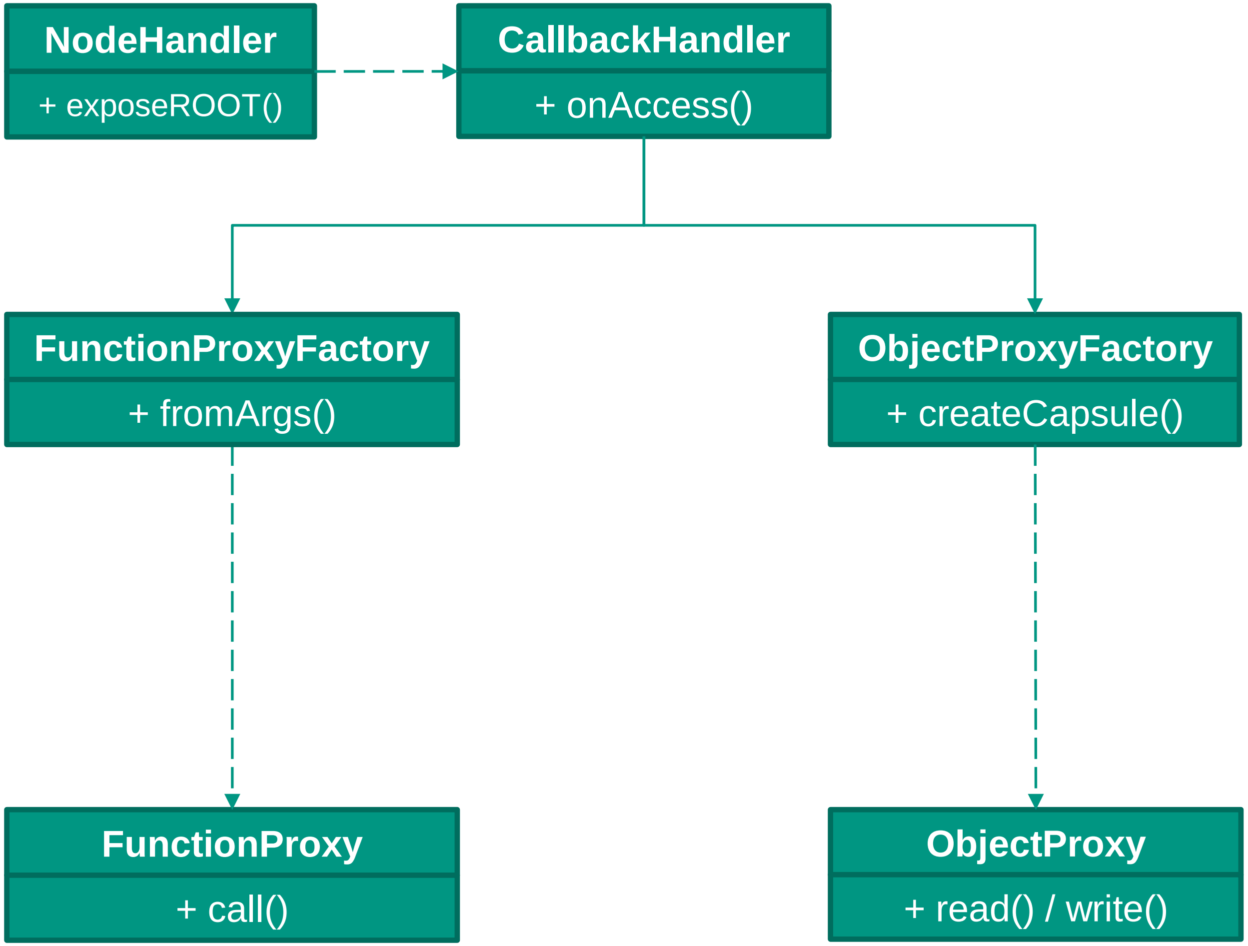

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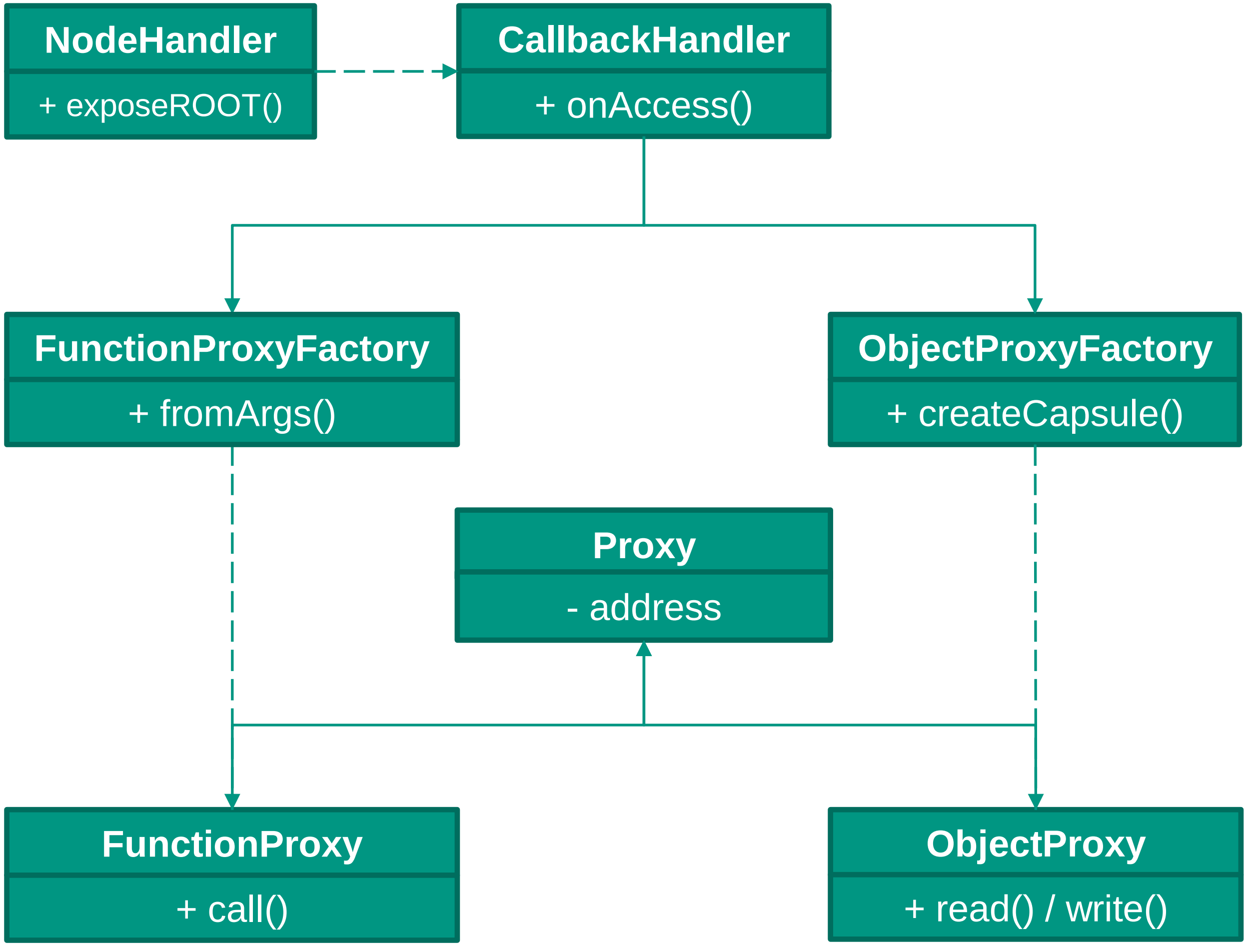

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Proxy

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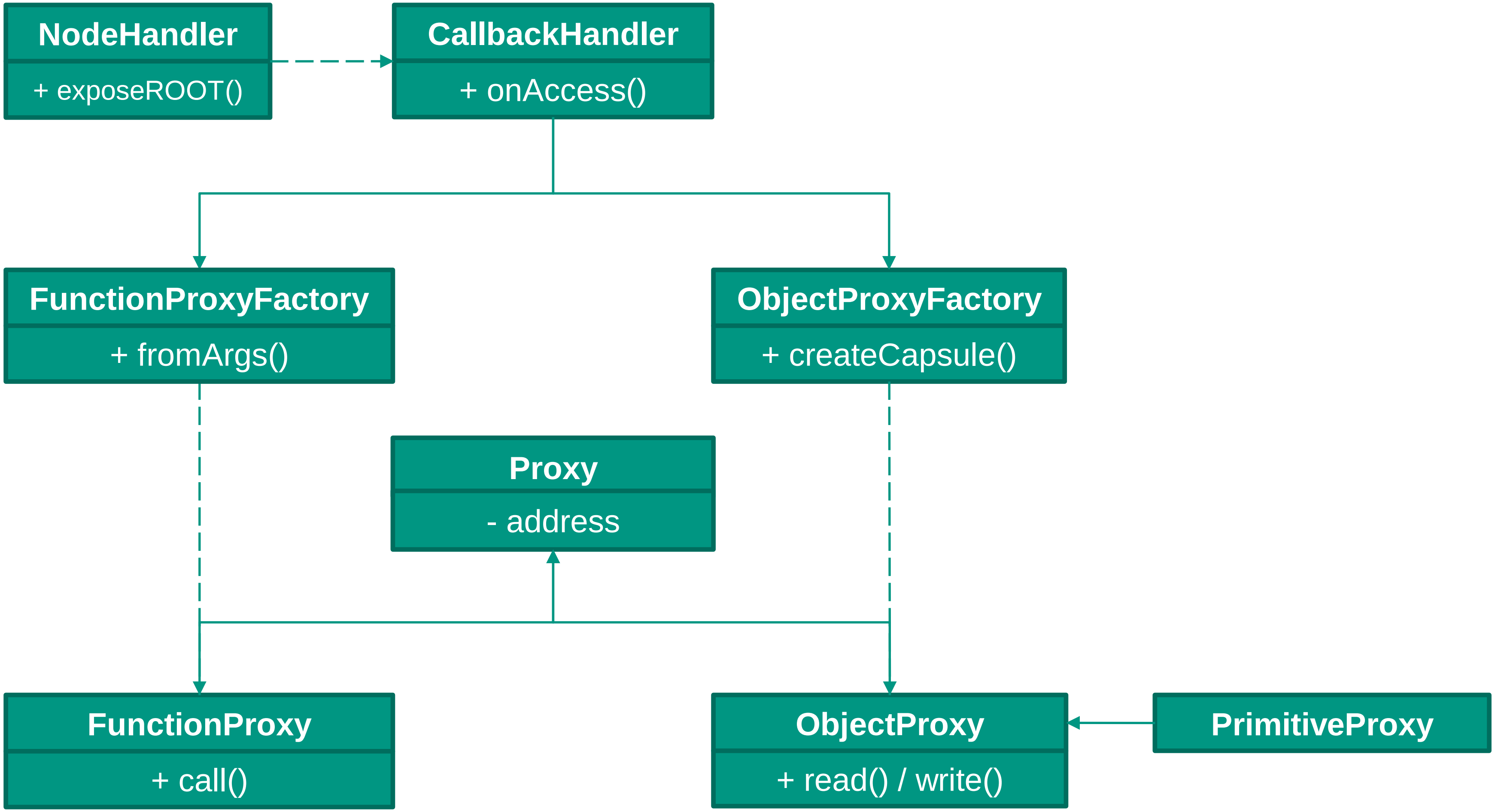

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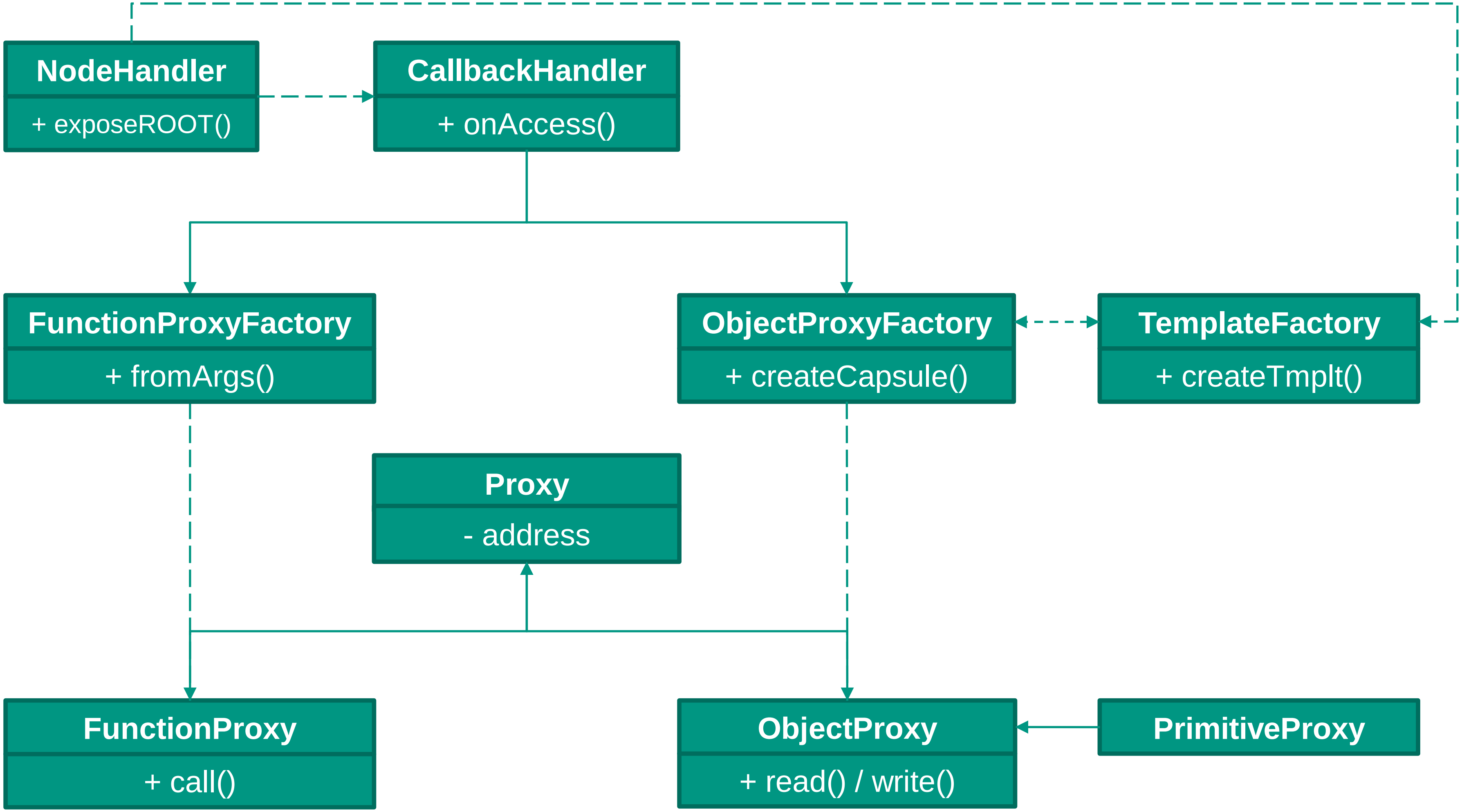

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ObjectProxyFactory

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TemplateFactory

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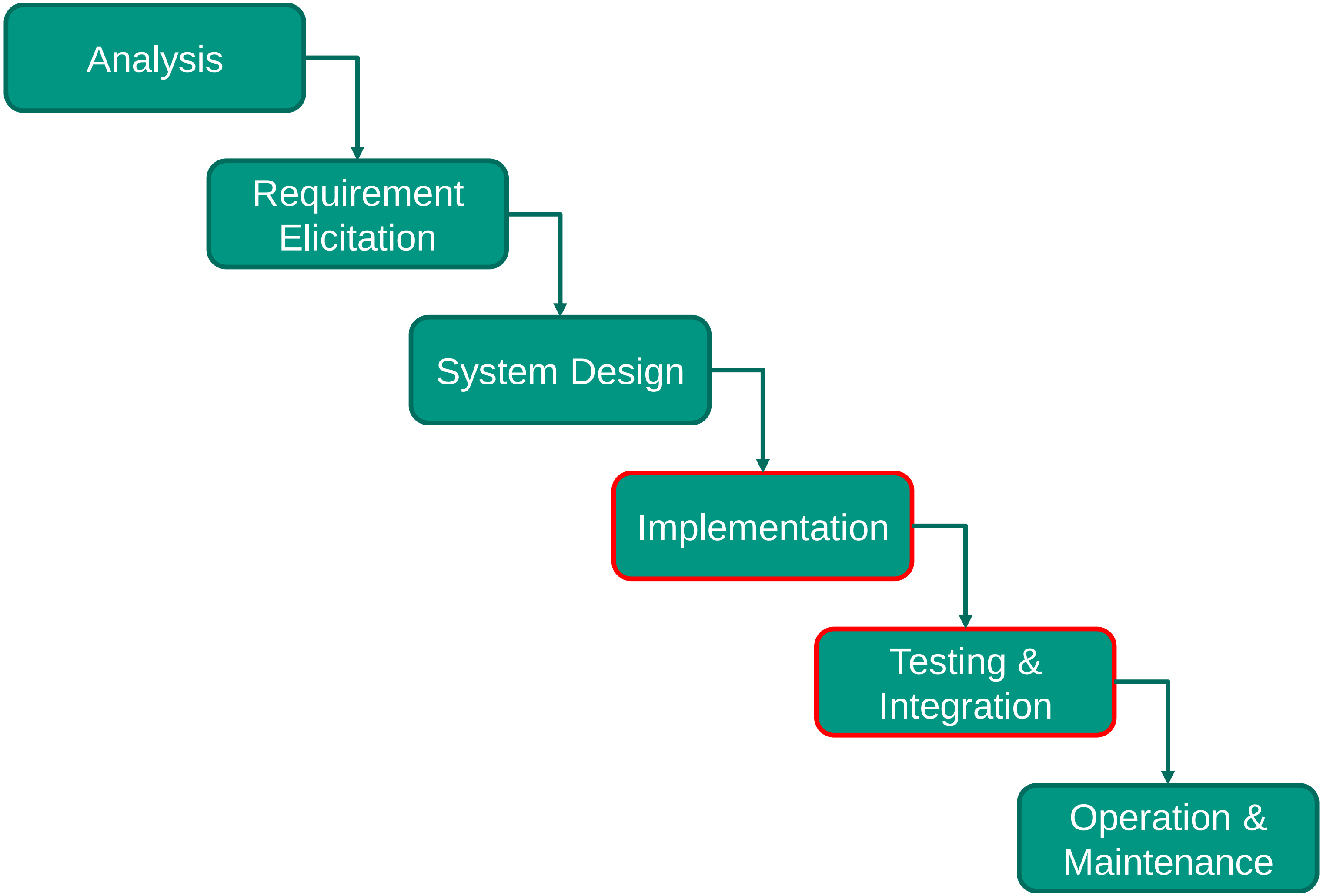

Analysis

Requirement Elicitation

System Design

Implementation

Testing & Integration

Operation & Maintenance

Implementation – Principles

Implementation – Principles

- Test driven development
  - Tests for features
  - Test for encountered bugs
  - Tests rely on ROOT behaviour

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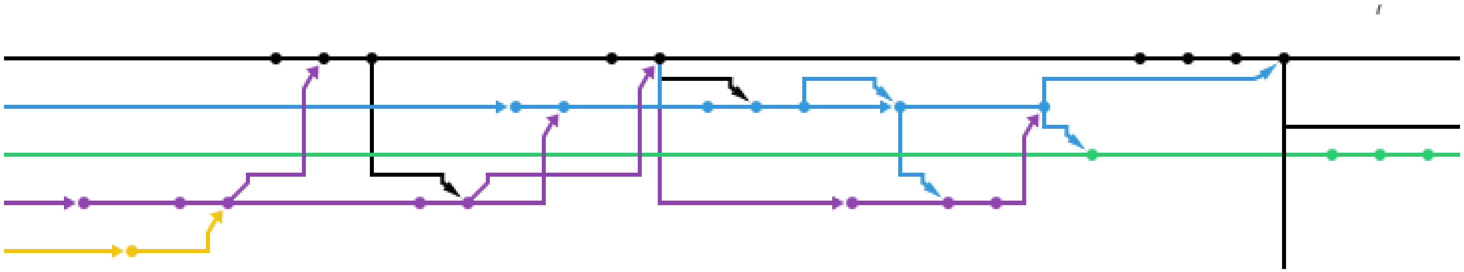
- Test driven development
    - Tests for features
    - Test for encountered bugs
    - Tests rely on ROOT behaviour
- Stable master branch
    - Features / bug fixes on separate branches



Implementation – Our Setup

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  - https://github.com/rootjs

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  - https://github.com/rootjs
- Continuous integration via Jenkins http://jnugh.de:8080/
  - Integration tests
  - Code coverage
  - Doxygen documentation on http://rootjsdocs.jnugh.de/annotated.html

Implementation – Our Setup

- Why GitHub?

Implementation – Our Setup

- Why GitHub?
  - Open source
  - Everyone knows how to use it
  - Always available

Implementation – Our Setup

- Why Jenkins?

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  - Originally wanted TravisCI
    - Building ROOT times out

Implementation – Our Setup

- Why Jenkins?
  - Originally wanted TravisCI
    - Building ROOT times out
  - On our own system timeouts don‘t matter
    - Jenkins also gets the job done

Implementation – Our Workflow

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- New features are developed in separate branches
  - Pull requests are only merged if all tests pass
  - Pull requests tagged “help wanted“ are discussed during weekly meeting

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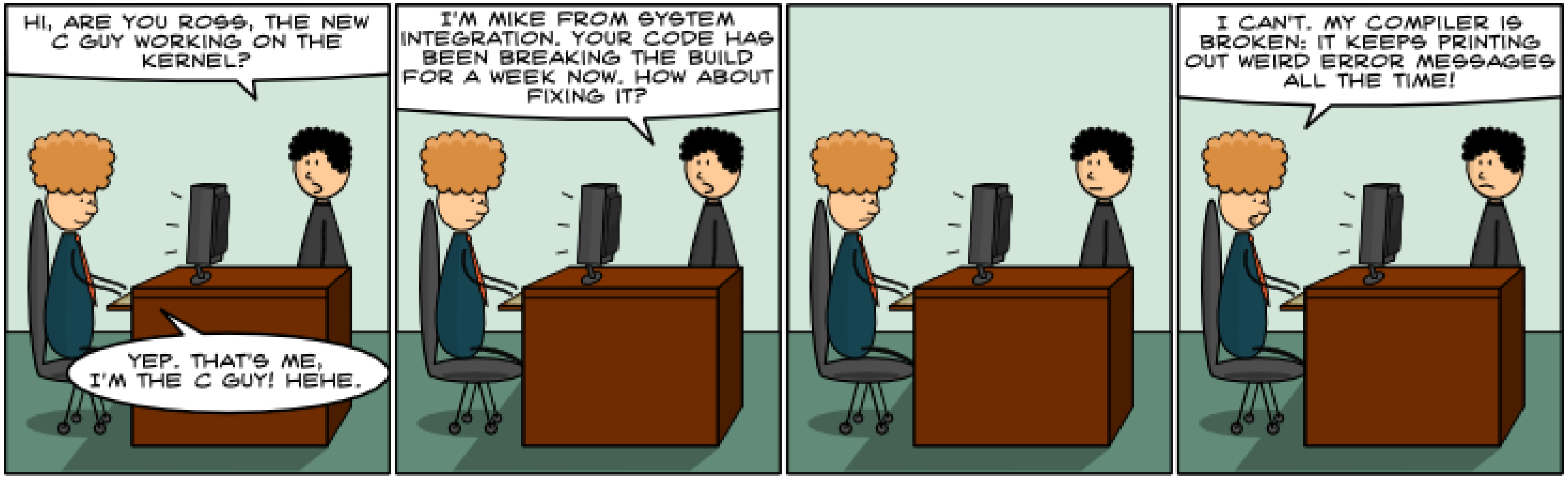
  - Pull requests are only merged if all tests pass
  - Pull requests tagged “help wanted“ are discussed during weekly meeting
- Easch bug in the issue tracker is assigned a new branch containing a test for that bug
  - Bug is fixed in that branch
  - When all tests pass it can be merged



#66: "THE PRICE OF CONTINUOUS INTEGRATION" - BY SALVATORE IOVENE, NOV. 10TH, 2008 HTTP://WWW.GEEKHEROCOMIC.COM/

Implementation – Testing

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- ~4000 lines of code with 77% line coverage
    - Missing lines are error handling or seldom used argument types (eg. ushort)

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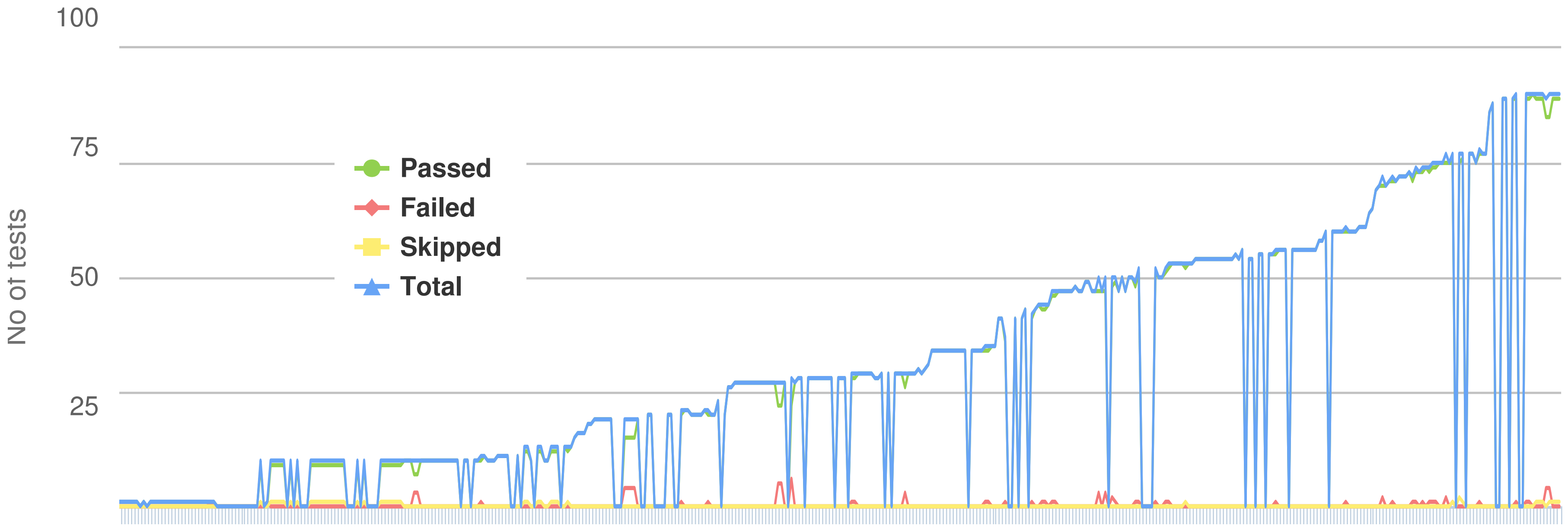
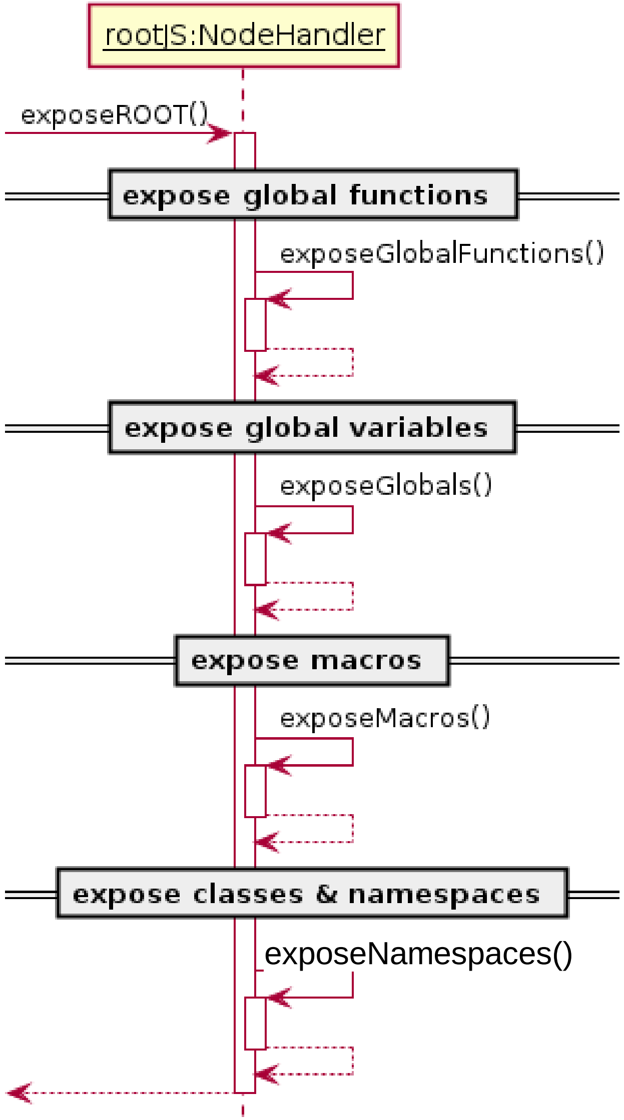
  - Missing lines are error handling or seldom used argument types (eg. ushort)
- 89 tests used in continous integration at the end of implementation



Implementation – Talking to Node: NodeHandler



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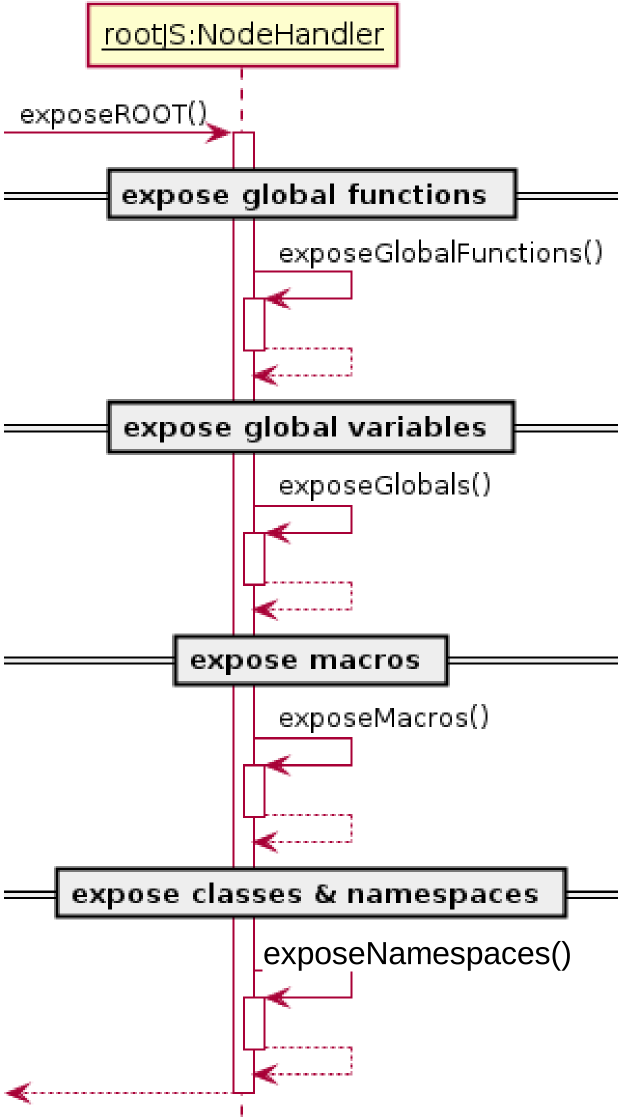
- V8 provides an exports
  - Expose everything using `Set` on that object



Implementation – Talking to Node: NodeHandler

- V8 provides an exports
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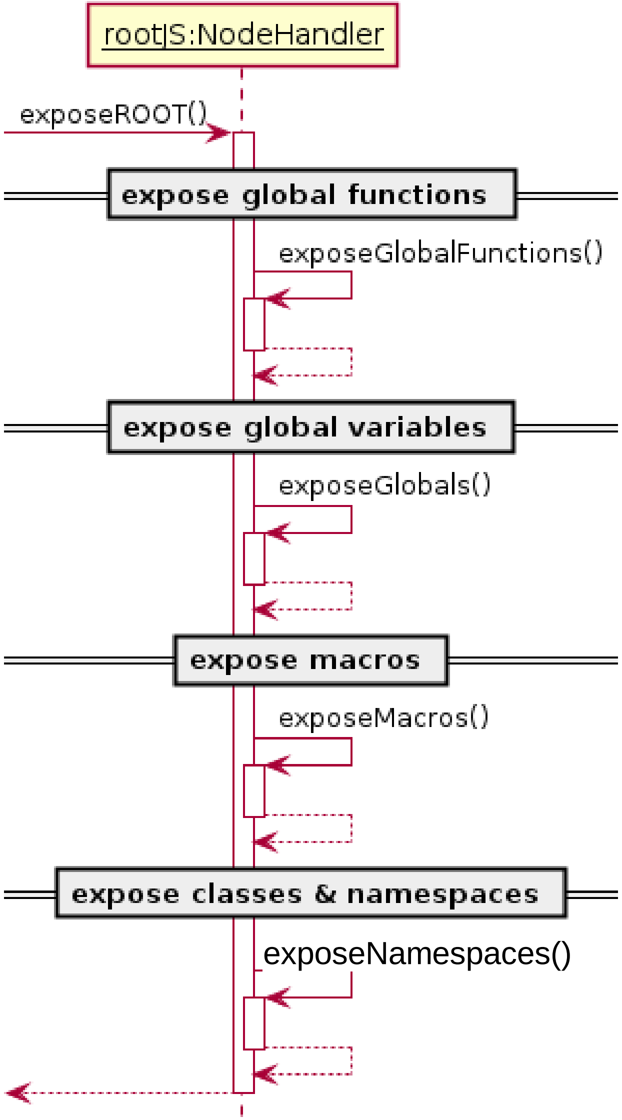
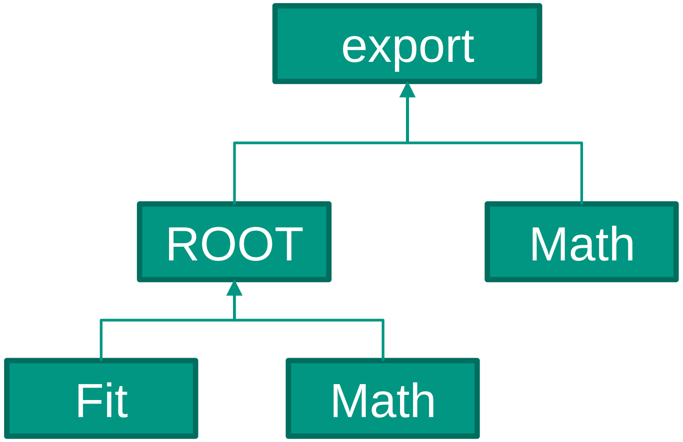
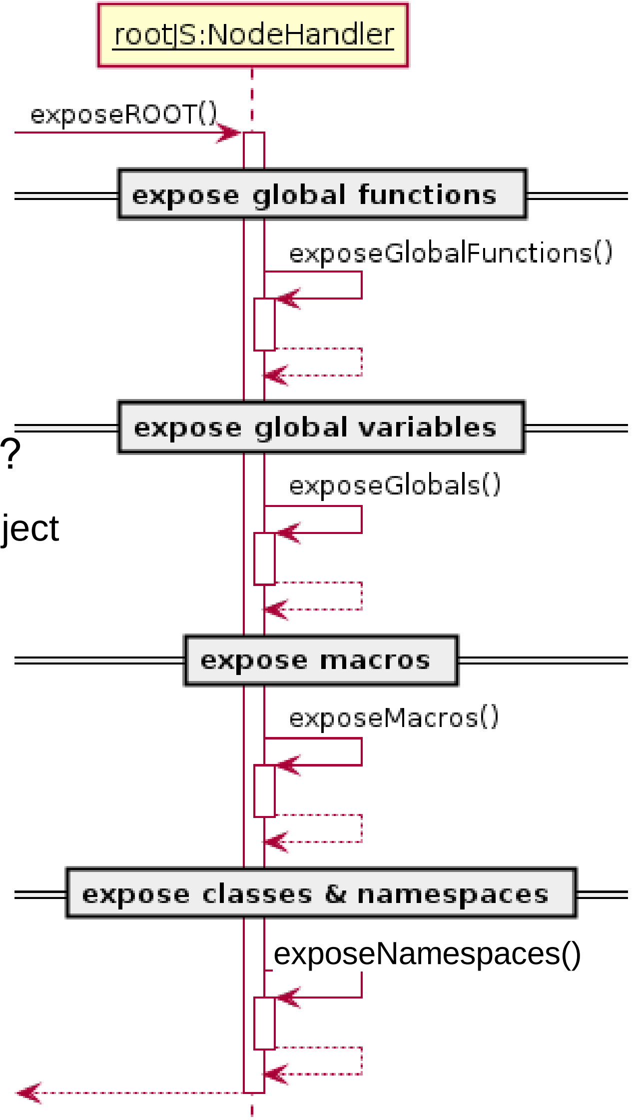


Implementation – Talking to Node: NodeHandler

- V8 provides an exports
  - Expose everything using `Set` on that object
- Use ROOT‘s GetListofGLobals, gClassTable etc.
  - Iterate those lists and create Templates/Proxies
  - Set them as properties in the exports object
- How do we make sure ROOT‘s namepaces are preserved?
  - Each namespace gets a template which is `Set` to the export object
  - Classes are `Set` in their respective namespace‘s object





Implementation – Talking to Node: Callbacks

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- Each exposed function is associated with a static method in the CallbackHandler
  - Functions “know“ whether they are static, a constructor...
  - Can handle them accordingly

Implementation – Factories

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- Factories create wrapper proxies for ROOT objects, primitive data and functions
  - Invoked whenever a constructor is called
  - Invoked whenever a function is called for the first time

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  - Invoked whenever a constructor is called
  - Invoked whenever a function is called for the first time
- Template factory creates function templates for classes and namespaces
  - Iterates the class/namespace‘s ListOfPublicDataMembers etc.
  - Creates proxies for those and `Set`s them as properties in the v8 template it is creating

Implementation – Proxies

…

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  - Or pointer pointers?
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→ Normalize memory address by referencing/derefencing until it is a `void**`

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  - Objects are always passed by address
- Creation of buffer and call of function are separated to support async calling

Implementation – FunctionProxy

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- What was hard:
  - Very little documentation for cling API
  - Had to guess how to use some of the functionality
  - PyROOT was a helpful reference

Implementation – FunctionProxy

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  - Very little documentation for cling API
  - Had to guess how to use some of the functionality
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- What we didn‘t think of:
  - Overloaded methods that support different types of floating point numbers
    - If number fits into type, overloaded version is selected
    - Problem because for example
      - First variant uses float
      - We have a small number
      - Number has many decimal places

Implementation – Asynchronous Calls

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  - Planned to use ROOT‘s TThread

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- V8 does not work in a multithreaded environment
  - Interactions with node need to be done from main thread

Implementation – Asynchronous Calls → libuv

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- Libuv‘s message passing between async workers and v8

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- Libuv‘s message passing between async workers and v8
- We use libuv because it integrates great with node
    - No need to wait for threads actively
    - Handled by signals → non-blocking & no waste of CPU time

Implementation – ObjectProxyBuilder

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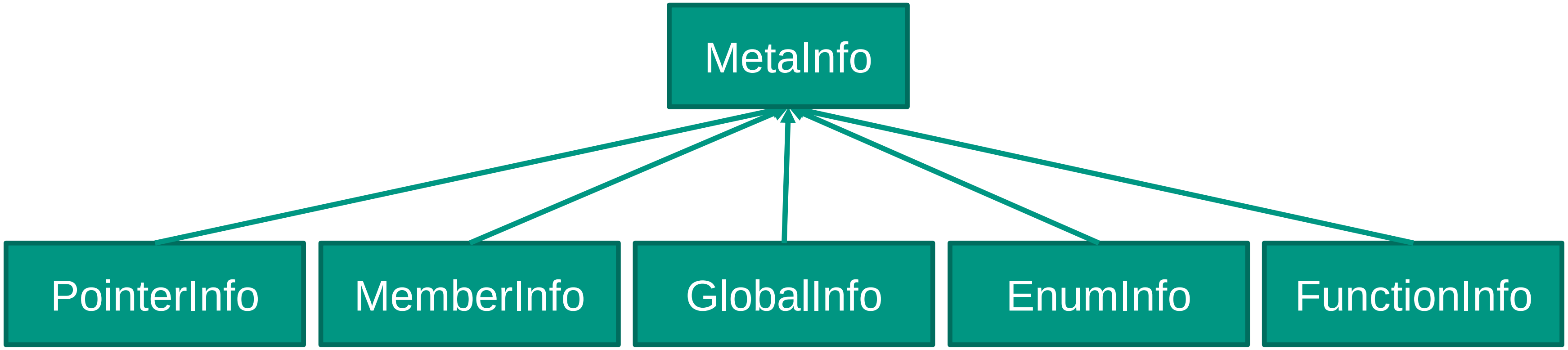
→ ObjectProxyBuilder contains meta data to be used in the main thread

Implementation – Differences between Proxies


MetaInfo

PointerInfo

MemberInfo

GlobalInfo

EnumInfo

FunctionInfo

Implementation – Differences between Proxies

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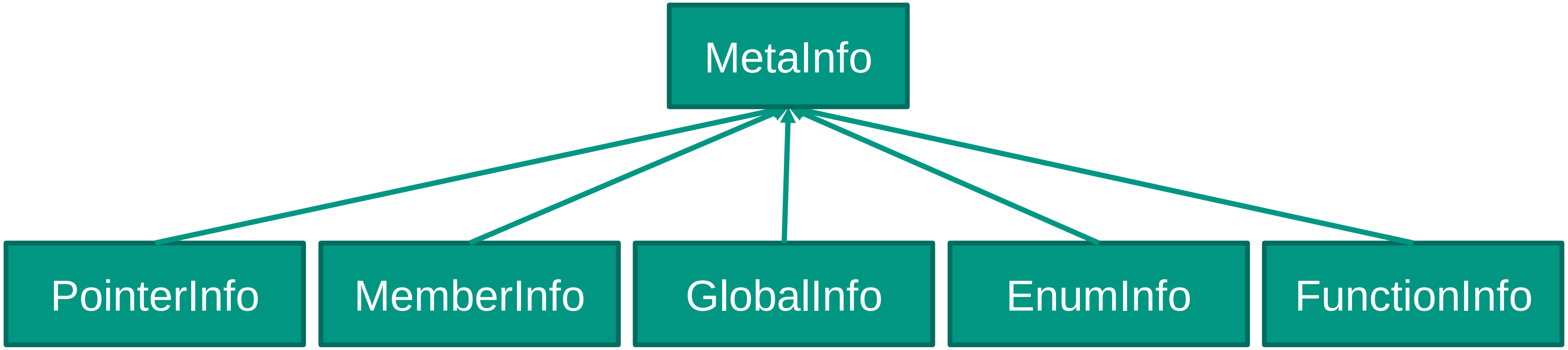
  - Want to have unified interface for all Proxies



Implementation – Differences between Proxies

- Interfaces of ROOT classes we have to wrap in a proxy are incosistent
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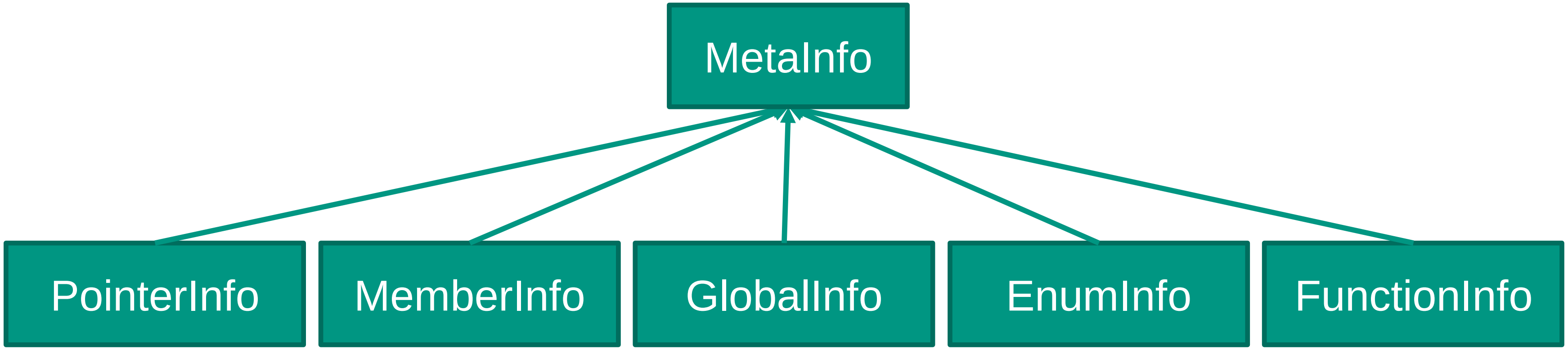
- Another layer of indirection saves the day:
  - MetaInfo encapsulates differences
  - Each Proxy instance has a MetaInfo object associated that contains the needed implementations



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- gSystem can load additional shared libraries
  - We have to updae our bindings whenever new classes are added
- Provide an additional function `loadlibrary()` and `refreshExports()`
  - Loads a library and updates or just updates repsectively
  - Simply reexecutes exposure process
    - Traverses gClassTable etc and adds any new classes, globals ..
    - Fast because v8 properties are stored in a hashtable
  - Allows for library loading during runtime and even creation of new global variables

LIVE DEMONSTRATION

Project Review

- Features

Project Review

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  - Fulfills all required criteria

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  - Use function pointer as return value
  - Encapsulation of anonymous types

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  - It went really well
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    - Especially considering most of us didn't know any or very little C++ or JavaScript

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    - Especially considering most of us didn't know any or very little C++ or JavaScript
- What could be improved?
  - Time management
    - Often difficult because of university/work commitments
  - Task management
    - Difficult at first to coordinate who does what
    - Got better towards the end with Github issues

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- What we learned

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    - Git is awesome!

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Project Review

- What we learned
  - Git is awesome!
  - LaTeX has a steep learning curve
  - Testing is effective!
  - A lot about the Google v8 engine
  - Old projects may have a somewhat chaotic code base

Questions?

- Find rootJS on github: https://github.com/rootjs

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