The LArSoft code analysis process

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June 23, 2016

General goals of the process

- Writing good code is a process.
  - Can't just sit down and “bang it out”
- With analyses, hope to improve quality and usability of code
  - Usability
    - Repeated design / usage pattens following from adherence to common principles
      - Easier to learn and use
    - Create more of a toolkit through improved design
    - Allow more sophistication through layering of algorithms
  - Quality
    - The code does what it was intended to do (from the coding point of view)
    - Good computing resource utilization
    - Maintainable: more modular, easier to test, internally well documented, …

      Particularly important – experiments long lived. Support needs to transition
  - Include full scope of code: algorithm implementations, infrastructure

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Code analysis is a strategic initiative strongly backed by SCD

Expect strong technical support to be available for an on-going program of LArSoft code analyses

General attributes / guidelines

- The analysis procedure shall:
  - Not be overly prescribed
  - Be as light-weight as possible for the situation
  - Be performed collaboratively with the code author(s)
  - Have clear objectives in each instance
  - Have adequate time and effort available for the review
  - Have adequate effort allocated in advance to implement recommendations
  - Have a written report to the authors, requesters, experiment offline coordinators, LArSoft community

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The essence of it

Want analyses to be manifestly useful to authors/experiments.

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Specific goals of each analysis

- Ensure compliance with *art* / LArSoft design principles
  - The common principles underlying the design
- Evaluate / improve code performance
  - CPU and memory
- Ensure the use of best practices in coding
  - Typically aimed at either performance or maintainability
  - The context of *art* / LArSoft is an important component of this
- Evaluate and improve high and low-level architecture
  - Class structure, data product design, interface design...
- No change to the physics output
  - NOT aimed at physics performance. Just make it do what it does now better

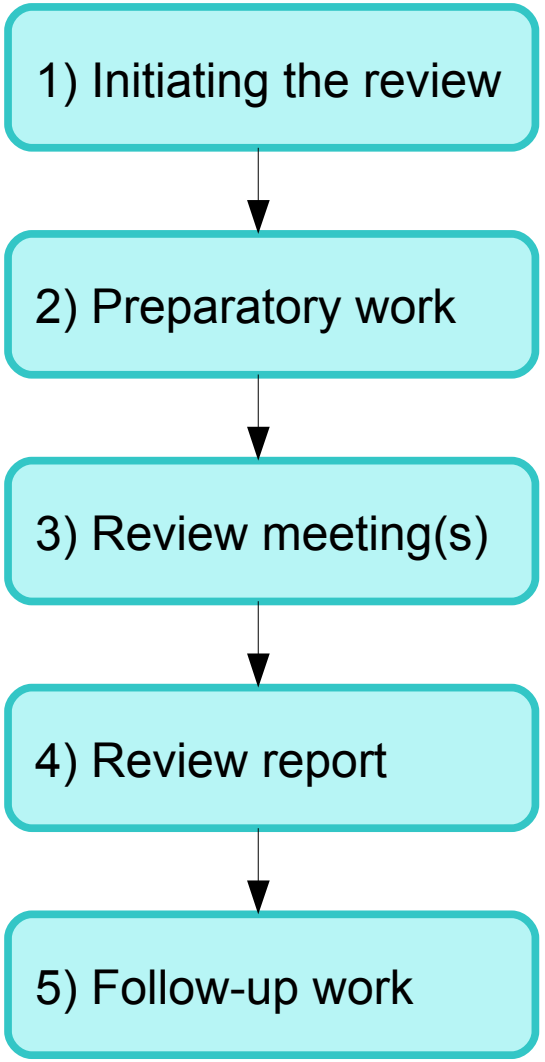
How the procedure was developed

- What we did
  - Created a committee of experts, people with experience with code reviews
  - Designed a set of guidelines based on that experience
  - Ran a trial review, keeping careful notes of issues related to the process
  - Wrote recommendations for the process
    - https://cd-docdb.fnal.gov:440/cgi-bin/ShowDocument?docid=5765
    - https://cdcvs.fnal.gov/redmine/projects/larsoft/wiki/Code_analysis_process_and_tools
- The committee
  - Software engineering experts: Chris Jones, Jim Kowalkowski, Marc Paterno
  - LArSoft domain experts: Gianluca Petrillo, Erica Snider
  - Outside domain expert: Rob Kutschke
  - Analysis trial code authors: Dorota Stefan, Robert Sulej

Participants / roles

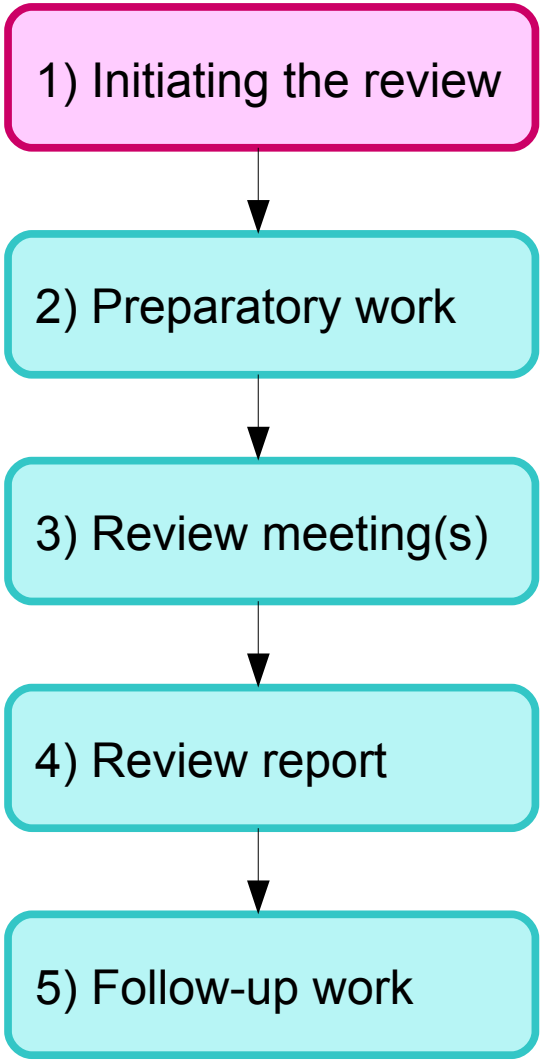
- Each review will involve the following parties
  - Code authors
  - Two software engineering experts
  - An additional problem domain expert
    - e.g., someone from LArSoft team, SCD reconstruction group, additional experiment members
  - Additional experts considered to be necessary or useful
  - Also, observers with no official role are welcome
- The following roles will be assigned
  - Review leader, who will facilitate the process
    - Should be one of the experts
  - Scribe, who will record important conclusions or points of discussion
    - Should not be the review leader

Conduct of the analysis



Each analysis has five basic steps

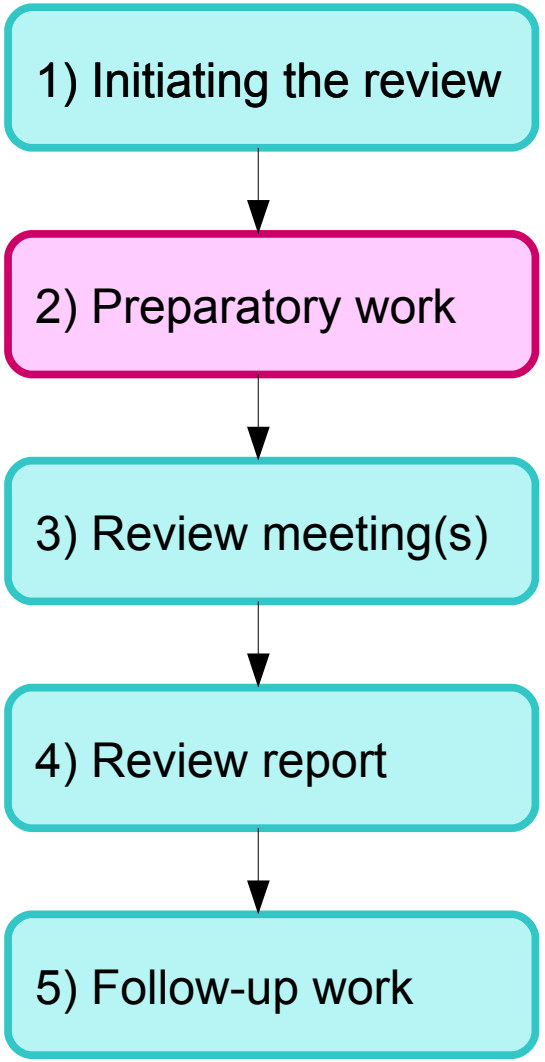
Conduct of the analysis



Initiating an analysis

- Basically anyone can request a review.
  - The code authors
  - An experiment representative
  - Core LArSoft team
  - The result of some future policy (e.g., for each “pull request” equivalent)
- Several types of analyses are possible
  - General design, class structure, interfaces
  - Computing performance, resource bottlenecks
  - Compliance with coding or C++ practices
- At the time of the request
  - Agree on type and scope of the review, the charge to the analysis team, objectives and any metrics needed to assess “success”

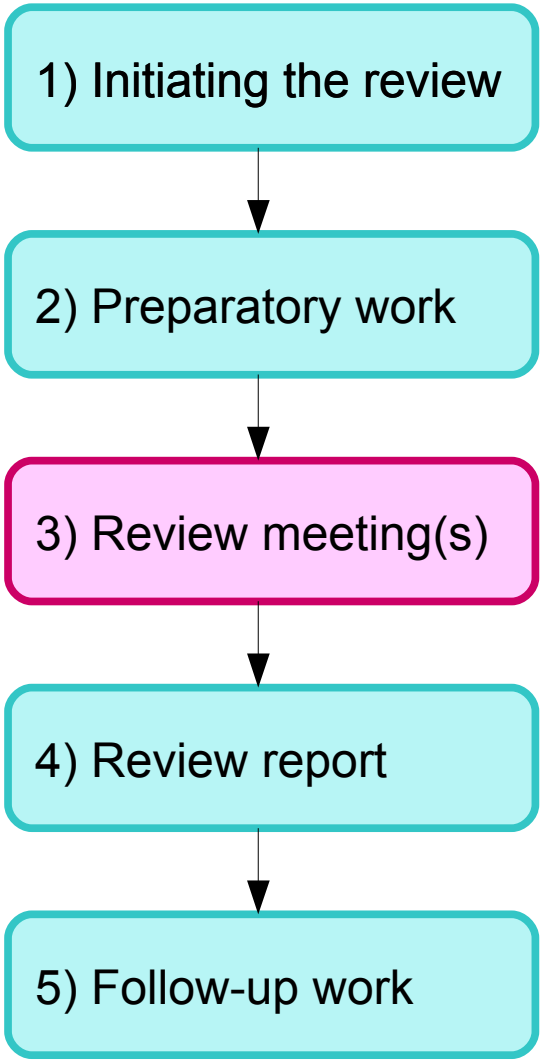
Conduct of the analysis



Preparatory work

- Prerequisites
  - Assemble analysis team
  - Agreements with people who will implement the agreed upon changes
- To make meetings as productive as possible
  - Common work areas for building, profiling
  - Obtain test fcl and input data
  - A set of tests to validate changes
  - Gather viewing aids: diagrams, repository clones
  - Generate reports from static analysis tool
  - Generate preliminary time and memory profiles
  - Preview of the code by the analysis team

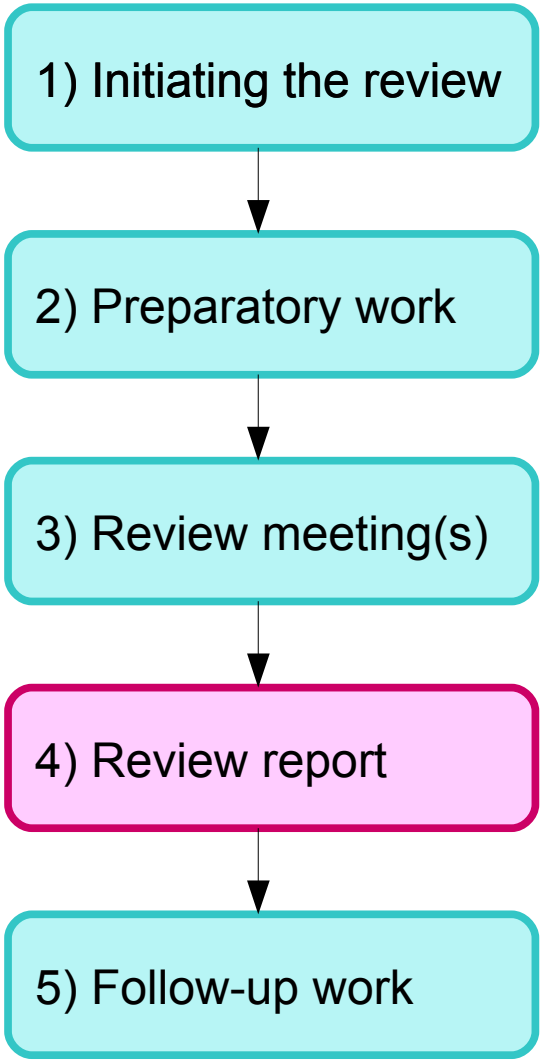
Conduct of the analysis



Review meetings

- No pre-defined structure or format
- The following considered useful
  - Agreement on how to allocate time
  - Overview presentation or discussion by authors
    - Introduction to major concepts and abstractions
  - Discussion of targets of opportunity
    - e.g., “While we were in there, we noticed that 90% of the time was spent here...”
- Sessions should last about four hours
  - Number of sessions depends on the analysis

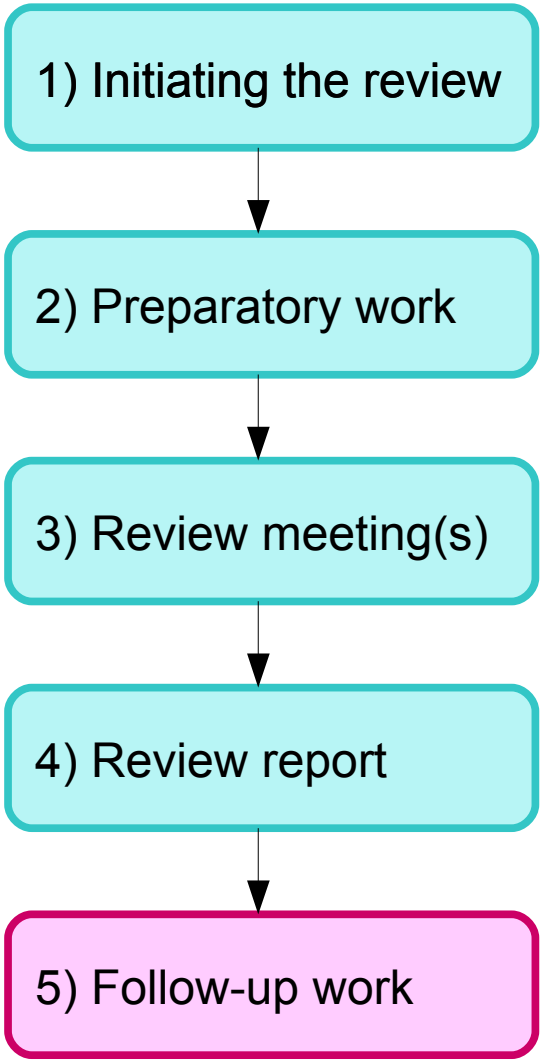
Conduct of the analysis



Review report

- Should include
  - Recommended
    - changes
    - items for more investigation, thought, discussion
    - conclusions regarding targets of opportunity
  - Additional items worthy of note
  - Before / after metrics, when they exist
  - Comments on the process
- Should be co-authored by all involved
  - Need only be long enough to specify problems and solutions

Conduct of the analysis



Follow-up work

- Scope defined by code authors / experiments in consultation with Core LArSoft team
  - Create prioritized task list
- To facilitate implementation
  - Define milestones in LArSoft issue tracker that describe overall targets
  - Enter work tasks into LArSoft issue tracker
    - Each task should be under a milestone
    - Experiments may choose to track tasks also
  - Reports on the progress toward these milestones
    - e.g., at experiment / LArSoft meetings
- Document lessons learned
  - Make this list available to LArSoft community
  - A brief report presented when of broad interest

A recent example: the PMA analysis

- Analyzed Pattern Matching Algorithm code
  - Authors Dorota Stefan and Robert Sulej
  - Analysis team: Chris Jones, Jim Kowalkowski, Rob Kutschke, Marc Paterno, Gianluca Petrillo, Erica Snider
- Focused on
  - High-level design
  - Computing performance (authors priority)
  - Low-level coding practices

  and
  - the analysis process

A recent example: the PMA analysis

- About a week in advance
  - Prepared shared repositories on GitHub
  - The team read and commented on the code
  - Identified testing fcl and data
- The meetings
  - Three hours on one day, two hours the next
    - Each meeting focused more narrowly on particular topics
  - Ran memory and CPU profiling using `igprof` (+ `valgrind`, but was less useful)
  - Quickly identified performance issue with use of TVector in a tight loop
    - Change resulted in factor of 2 in CPU speed (profiling reported 10—20%)
    - A second suggestion led to another 30% improvement, for a total factor of 3
  - Identified various possible structural and low-level improvements

A recent example: the PMA analysis

- The report
  - Everyone met a third time for about one hour to write the report
  - Recommended changes, further consideration in five areas
    - Design / architecture
    - LArSoft coding guidelines
    - *art* coding guidelines
    - C++ coding practices
    - Code management

    for three groups to implement
    - Code authors
    - LArSoft team
    - *art* team
  - Report is here: https://cd-docdb.fnal.gov:440/cgi-bin/ShowDocument?docid=5766

A recent example: the PMA analysis

- Created first “lessons learned” list

From the report

- Keeping transient data as module state between events can significantly and unnecessarily increase the memory footprint of modules.
- TObject memory and CPU overheads can have a significant impact on overall performance in some cases. Care should be exercised when choosing to use TObjects sub-classes.
- IgProf was much more convenient that Callgrind for profiling work.
- Cloning the repository and using local tools was faster for looking at large amounts of code.
- The GitHub repository was very convenient for commenting.
  - *For structural reviews, the GitHub commenting was not very useful.*
  - *For code conformance and best practices comments, the GitHub commenting was very useful.*
- The search facilities in git itself (e.g. git grep) are useful in looking at code. The git history facilities are also useful.

The authors' description of the experience

Summary

- instructive and for sure helpful for the further PMA development; a lot of collaborative work with experts
- otherwise never have time to look at our own code
- reasonable amount of recommendations, should be feasible to implement in parallel with other developments

- as of today: code x3 faster

- such reviews are required by DUNE!
- LArTPC reconstruction is still huge R&D effort, but it looks like we are moving towards well organised, high-quality software culture

5

Important tools for analyses

- Collaborative
  - GitHub.com
    - Used for annotating code, chats between analysis team members
- Performance profilers
  - IgProf (http://igprof.org)
  - Valgrind (http://valgrind.org)
- Static code analyzers
  - Clang static analyzer (http:clang-analyzer.llvm.org)
    - Used by CMS, works at Fermilab
- Class structure diagramming
  - No general tools available that works well

    (Just used, so just used what team was familiar with)

Summary / conclusions

- LArSoft hopes to create a culture that seeks code analysis
  - Assist non-expert code authors in writing expertly crafted code
  - More time to think about physics
- Had good experience with the first analysis
  - Tangible improvements: 3x faster
  - Design improvements: create independent algorithmic components
  - Authors are happy!
  - Experiment, LArSoft team, computing providers all happy at the outcome
- Will take the next steps here, today
  - Thank you Mike Wallbank (EM shower reconstruction) and Bruce Baller (clustering) for volunteering their code!!

The end