Improved Blasting Results with Precise Initiation

Jonny Sjöberg

General Manager, Itasca Consultants AB

Adjunct Professor, Luleå University of Technology

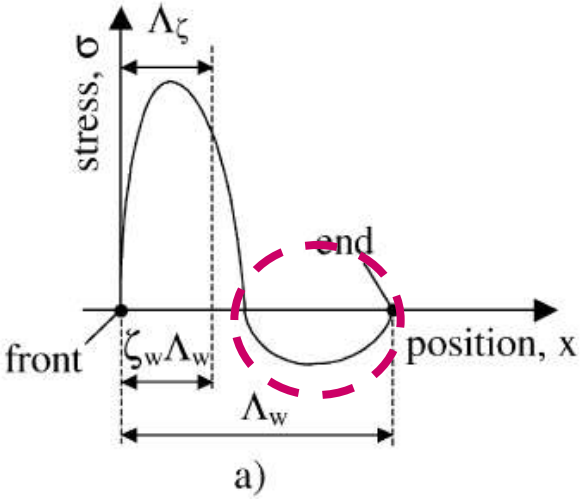
Better blasting....

- Blasting = to fragment rock into suitable dimensions

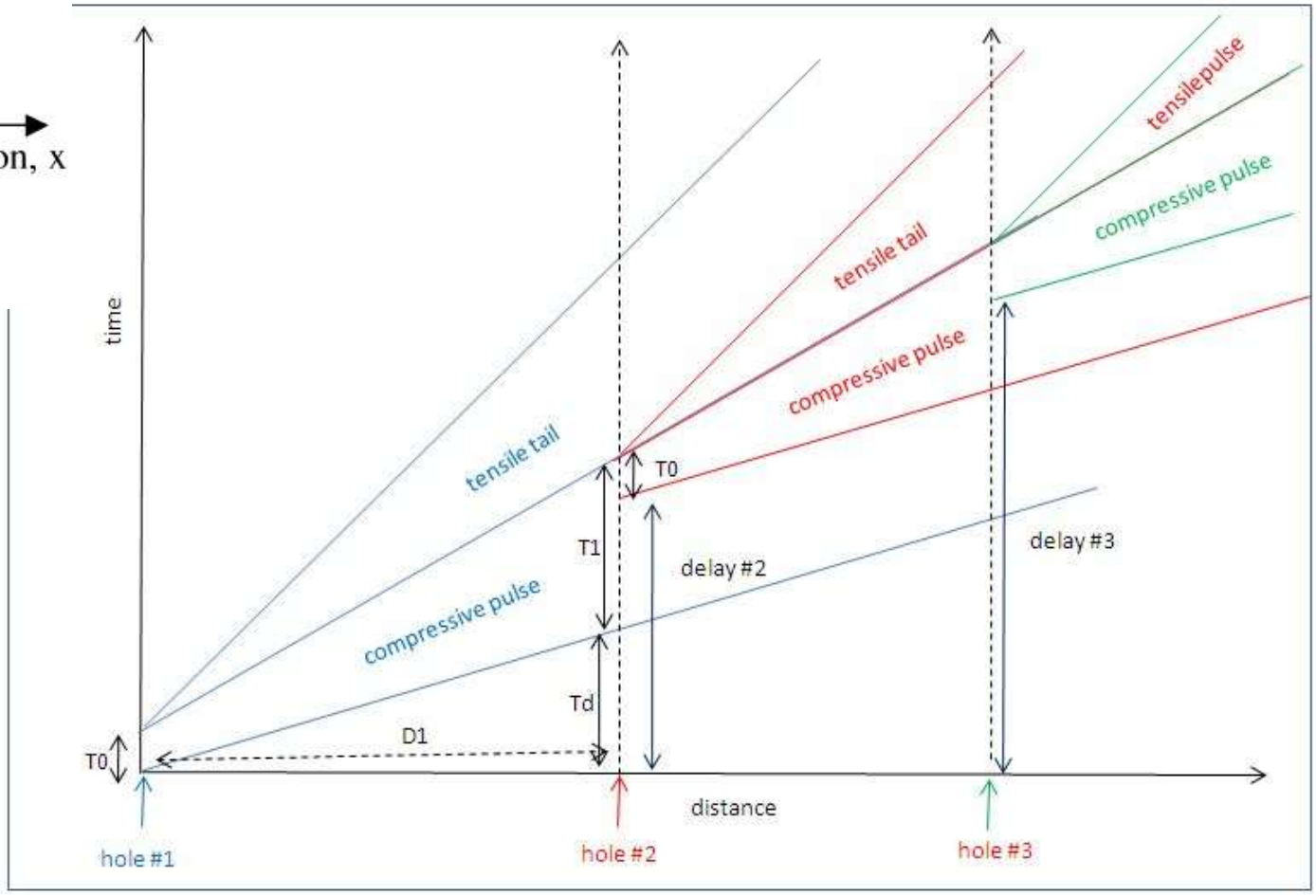
- Improved fragmentation results in:
  - Reduced costs for blasting
  - Reduced costs for transportation of blasted rock
  - Reduced emissions
  - Reductions in energy consumption during crushing & grinding
  - Improved metal recovery

Background and hypothesis

- Electronic blasting caps enable achieving wave superposition in rock blasting
- Frag-mentation is improved in areas between blast holes where the tensile waves meet, overlap and interact (Rossmanith (2002)
- Practical experiences show that improved fragmentation, throw, swell-ing, and diggability, can be achieved through this
- Quantitative computational models that describe this phenomenon are lacking


Λζ
stress, σ
end
front
ζwΛw
position, x
Λw

a)


time
tensile tail
compressive pulse
tensile tail
compressive pulse
tensile pulse
compressive pulse
T0
T1
delay #2
delay #3
Td
D1
T0
distance
hole #1
hole #2
hole #3

Project objectives

- Achieve a better frag-mentation, throw and other results from blast in quarries and mines
- Study the exten-sion of Rossmanith's concept to a three-dimensional geometry by identifying the rock vol-umes within a blast where the wave interaction from neighboring blast holes may create additional damage

Project approach

- Develop a methodology for dynamic numerical (computer) simulations of blasting
- Full-scale field tests using electronic blasting caps
- Numerical analysis of laboratory (model scale) tests and full-scale field tests

Project organization

- **Participants**
  - **Luleå University of Technology and Swebrec**
    Laboratory tests, monitoring, computer modeling
  - **Boliden Mineral AB**
    Full-scale field tests
  - **LKAB**
    Field test data, applications
  - **Engineering Research AB (ERAB)**
    Computer modeling
  - **Itasca Consultants AB**
    Project management

Project actitivities

- **Re-start of project – new project leader, new resources:**
  - Project start: Feb 1, 2011
  - Project end: Dec 31, 2012
- **On-going activities:**
  - Computer simulations
  - Field tests

Computer simulation of blasting

- **Challenges:**
  - Representative material model for rock (DIANE material)
  - Replicate rock response to large pressure (GPa) and subsequent damage
  - Material model for the explosives
  - High resolution of numerical model

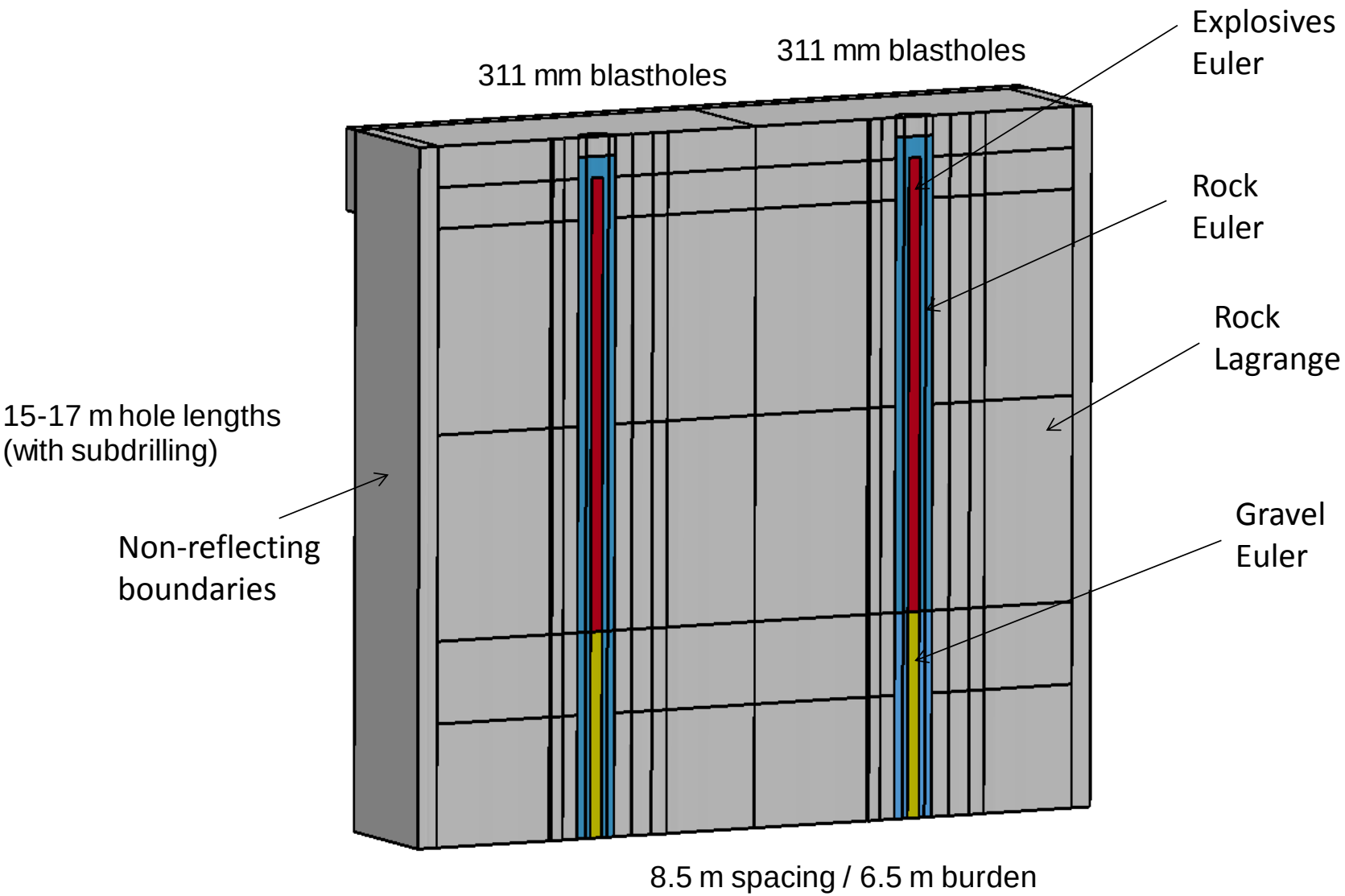
This is at – or beyond – the current state-of-the-art!

Computer simulation of blasting

- **Evaluation of computer codes and choice of approach**
  - *LS-DYNA* computer code
  - Euler and Lagrange element formulation (in combination)
  - Method for interpretating fragmentation based on calculated damage (yield)
  - Different constitutive models (including the *RHT* model)

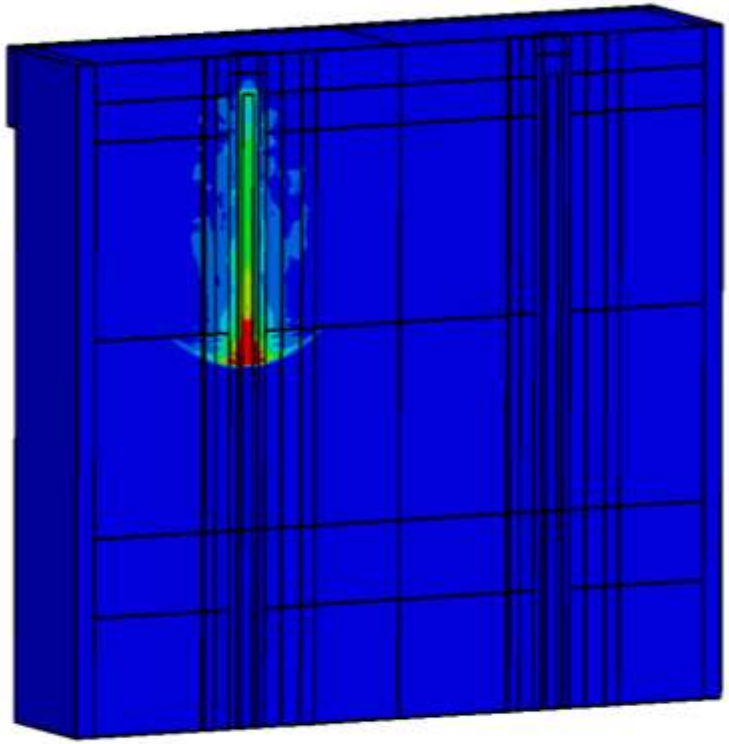
Model of subset of Aitik bench blast:

4 blastholes; 20 million elements; 50-60 mm resolution

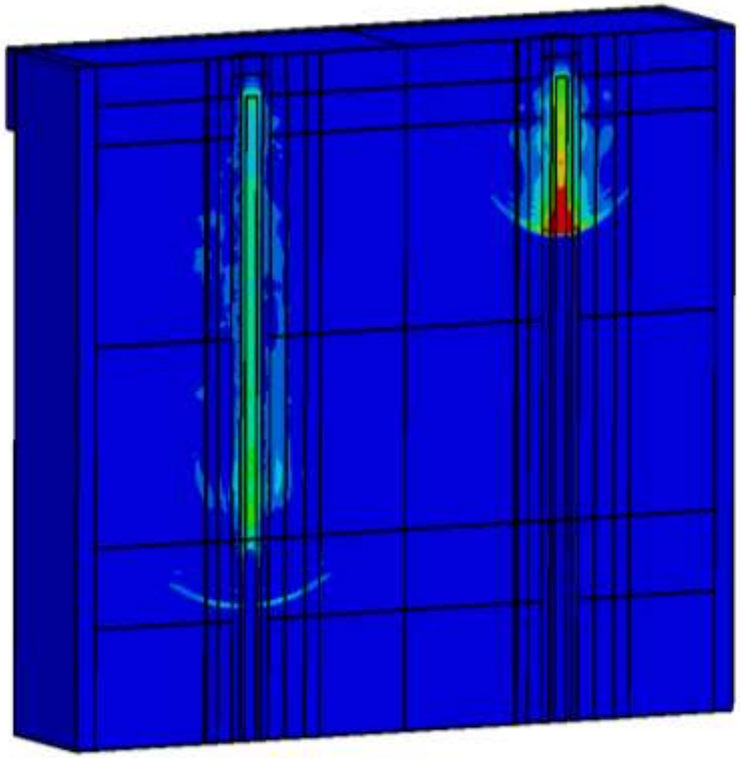

311 mm blastholes
311 mm blastholes
Explosives
Euler
Rock
Euler
Rock
Lagrange
15-17 m hole lengths
(with subdrilling)
Non-reflecting
boundaries
Gravel
Euler
8.5 m spacing / 6.5 m burden

Calculated pressures

Initiation of first hole



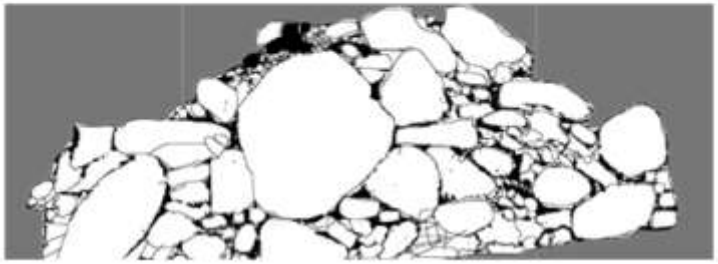
Initiation of second hole

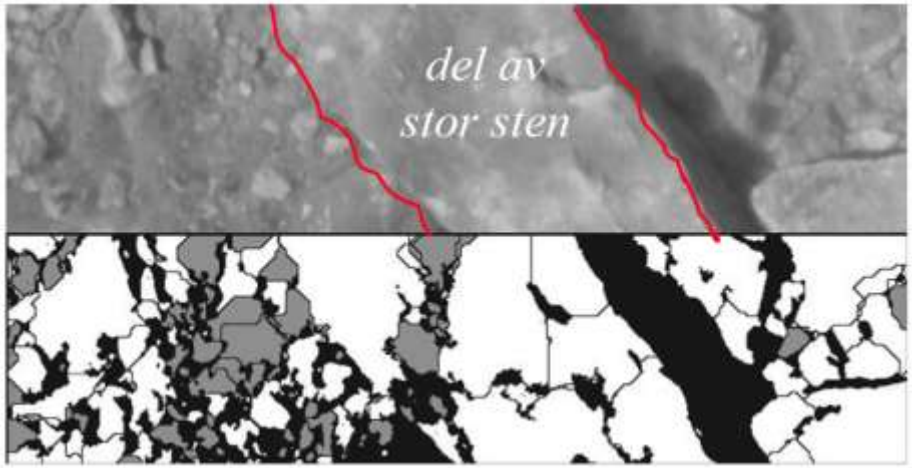


Full-scale tests at the Aitik open pit

- Reference blasts to determine wave characteristics, etc
- Reference blasts to determine "normal" fragmentation
- Test blasts with different designs
- Follow-up of fragmentation, swell, energy consumption, etc.

Challenges in measuring fragmentation





Full-scale tests at the Aitik open pit

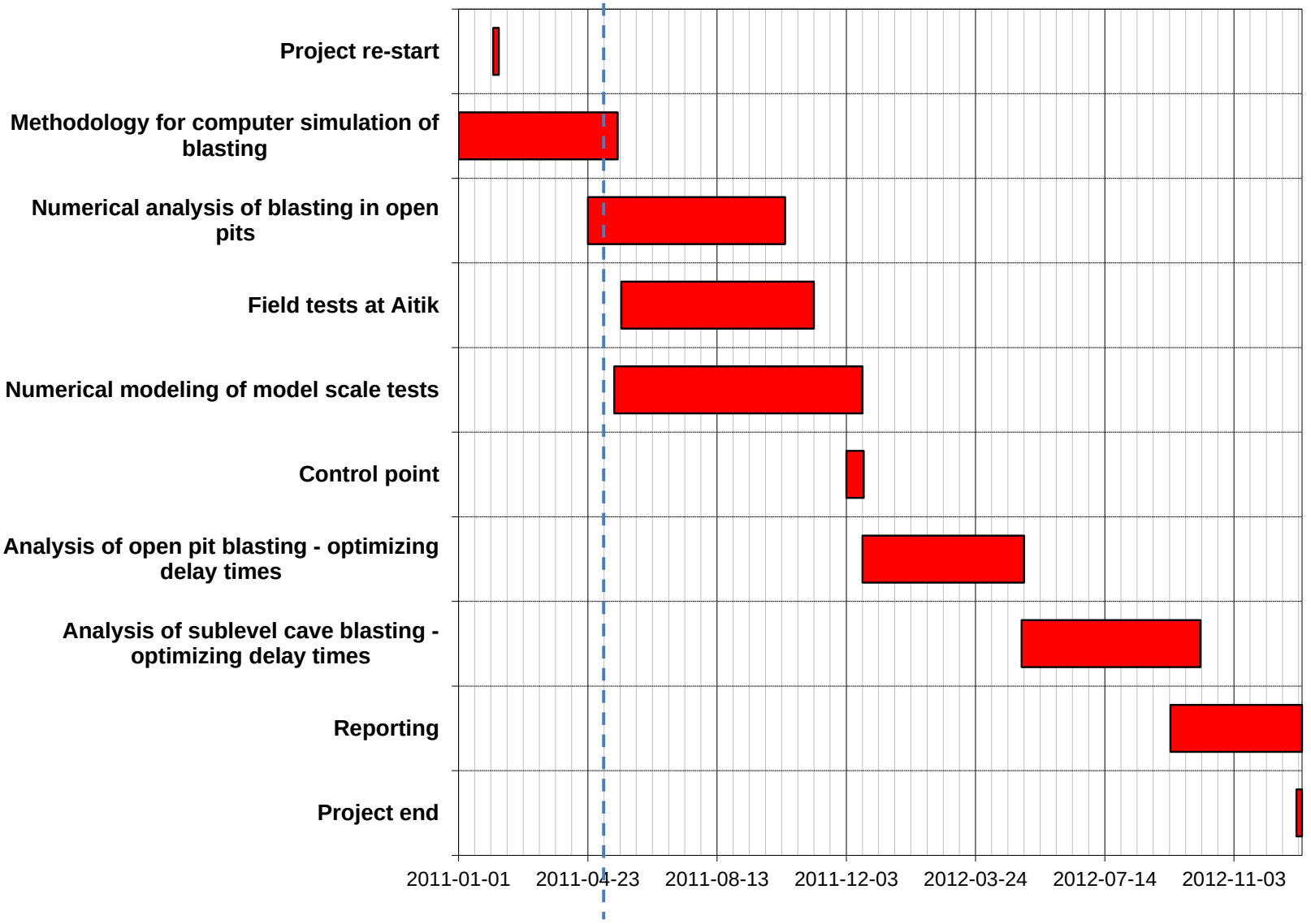
- How to measure fragmentation?
  - Improved image processing systems (commercially available today) to be tested
  - Indirectly via energy consumption
  - Sieving is more reliable but impossible in practice

The way forward…

- Computer simulations
  - Methodology tested and initial simulations: April – Oct, 2011
  - Simulations of model scale tests: May – Dec, 2011

- Field tests at Aitik: May – Oct, 2011

- Open pit blast optimization – 2012
- Sublevel cave blast optimization -- 2012


Project re-start
Methodology for computer simulation of blasting
Numerical analysis of blasting in open pits
Field tests at Aitik
Numerical modeling of model scale tests
Control point
Analysis of open pit blasting - optimizing delay times
Analysis of sublevel cave blasting - optimizing delay times
Reporting
Project end
2011-01-01
2011-04-23
2011-08-13
2011-12-03
2012-03-24
2012-07-14
2012-11-03