MSIAC
Munitions Safety Information Analysis Center

Supporting Munitions Safety

RESONANT ACOUSTIC® MIXING: Qualification Challenges

Insensitive Munitions & Energetic Materials Symposium

Seville, Spain, 22-24 October 2019

Christelle COLLET
Propulsion Technology TSO
c.collet@msiac.nato.int

Matthew ANDREWS
Energetic Materials TSO
m.andrews@msiac.nato.int

Aurihona WOLFF
MSIAC Intern
a.wolff@msiac.nato.int

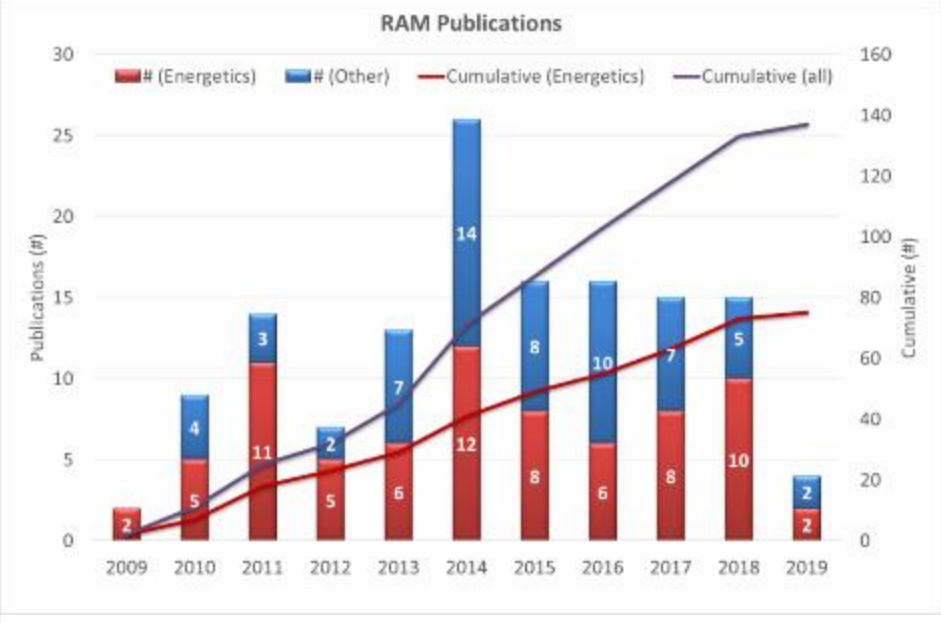
Chris HOLLANDS
DOSG, UK MoD

Outline

- Introduction
- MSIAC Technical Meetings
- Processing
  - Conventional
  - Mix In Case
- Quality & Assurance
- Qualification
- Conclusions

Introduction

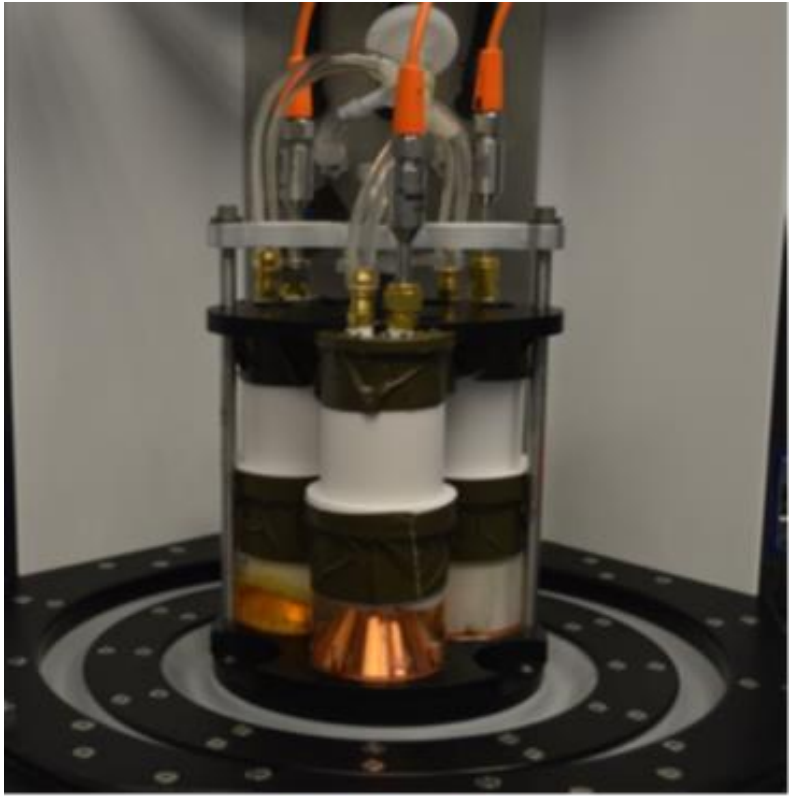
- New technologies provide access to new materials
  - E.g. for improved performance
  - Must not be done at the expense of safety
- Information required for safety assessment
  - MSIAC Limited Report: L-245
- Change in manufacturing
  - Reduced time
  - Reduced steps
- How to ensure quality through life



- Research led
- Testing feasibility of apparatus
- Full scale available

IMPORTANT

Why are we discussing this?



Nelson, 2018

- Resonant Acoustic Mixing
  - Batch
  - In-Case Mixing
  - Continuous
- AOP-7 focus on suitability of energetic material for intended role
  - No information on the process
- AOP-7
  - Change in process, manufacture or location constitutes a new materials
  - → Qualification

MSIAC Technical Meetings

Participants

- RAM users & National Authorities

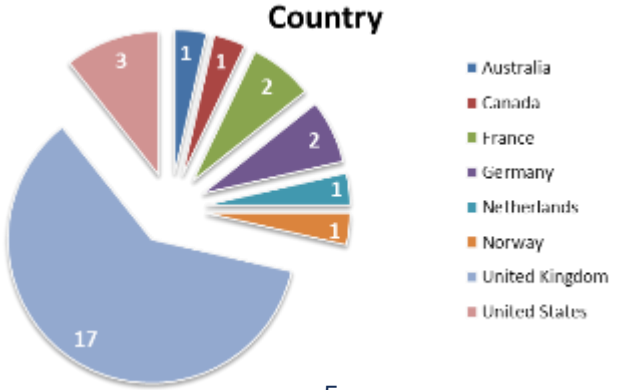
Topics for discussion

- RAM manufacturing
- Requirements for quality assurance
- Suitability of current energetic material tests in qualification
- Baseline materials for comparison
- Suitability of S3 testing for RAM produced munitions
- Cross-over to other technique

2018 IM & EM TECHNOLOGY SYMPOSIUM

INNOVATIVE INSENSITIVE MUNITION SOLUTIONS FOR ENHANCED WARFIGHTER EFFECTIVENESS

Cranfield University



Major Questions

Processing

- General
  - How to determine end of mix?
- Mix In Case
  - What is considered a batch size?
  - What will be considered lot acceptance?
- Continuous Mixing
  - What is a batch?
  - How and when to sample?
  - Acceptance criteria
- Scaling
  - Material quality
  - Safety

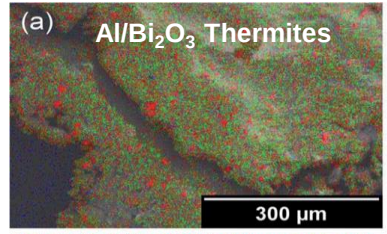
Qualification

- Material Specifications
  - Are they suitable and sufficient for RAM applications?
- Lot and batch sizes
  - Should there be a change in definition for in-case and continuous mixing?
- Current Qualification standards
  - Are they suitable and sufficient for RAM?

Experimentation - Energetics Being Processed

- Co-crystalisation
- Rocket motor propellants
- Plastic explosives
- High solids loaded PBX
  - Cast cured
  - Moulding powders
- Thermites
- Flare compositions

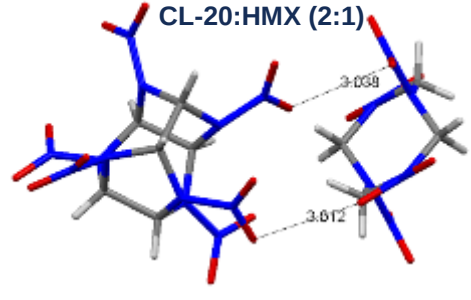
- Gun propellant still requiring safety assessments
  - Energetic liquids



Nellums, 2013

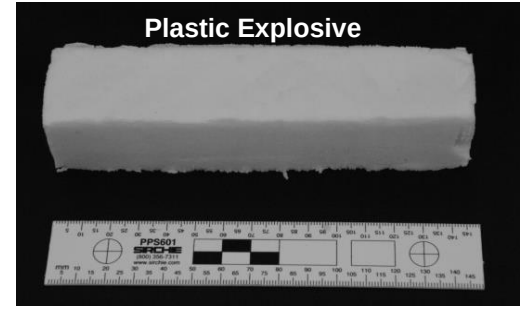
Nelson, 2018

Miklaszewski, 2018



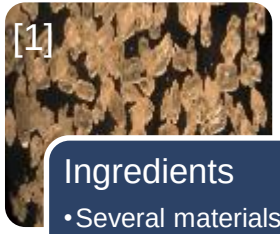
am Ende, 2015

Provatas, 2017



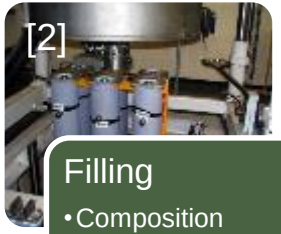
Provatas, 2017

Conventional Process

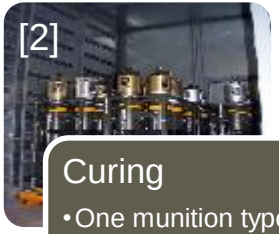


Ingredients
- Several materials
- Multiple Batches – kg/ton

Mixing
- Formulation
- Single Batch → kg/ton



Filling
- Composition
- Fills multiple items
- 1 batch → 100s lots



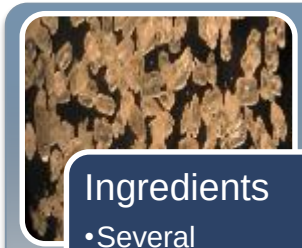
Curing
- One munition type
- 1 batch → 100s lots
- Multiple batches

Storage
- Multiple batches

- How to provide assurance
  - Material
  - Process
- Sampling throughout process
  - Extraction of material – ingredients, formulation
  - Breakdown of munition – in-service surveillance

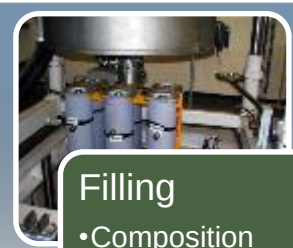
[1] Chemring, 2019, https://chemringnobel.no/produkter/base-products/nto/
[2] Eurenco, 46th Ann. Gun & Missile Sys. Conf., **2011**

Mix In Case Process

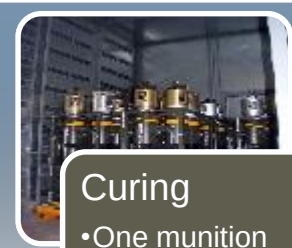


Ingredients
- Several materials
- Single batch → g/kg

Mixing
- Formulation
- Single Batch → g/kg



Filling
- Composition
- Fills single item
- 1 batch → 1 lot



Curing
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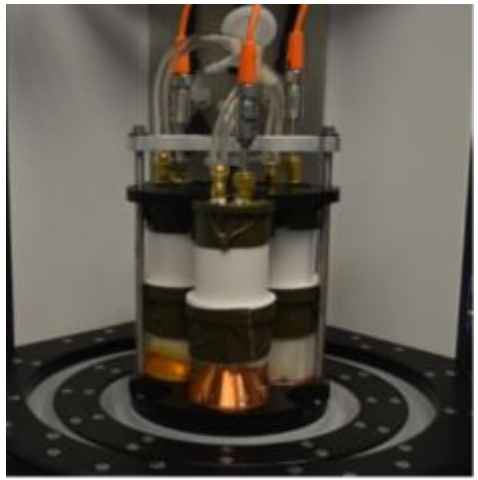
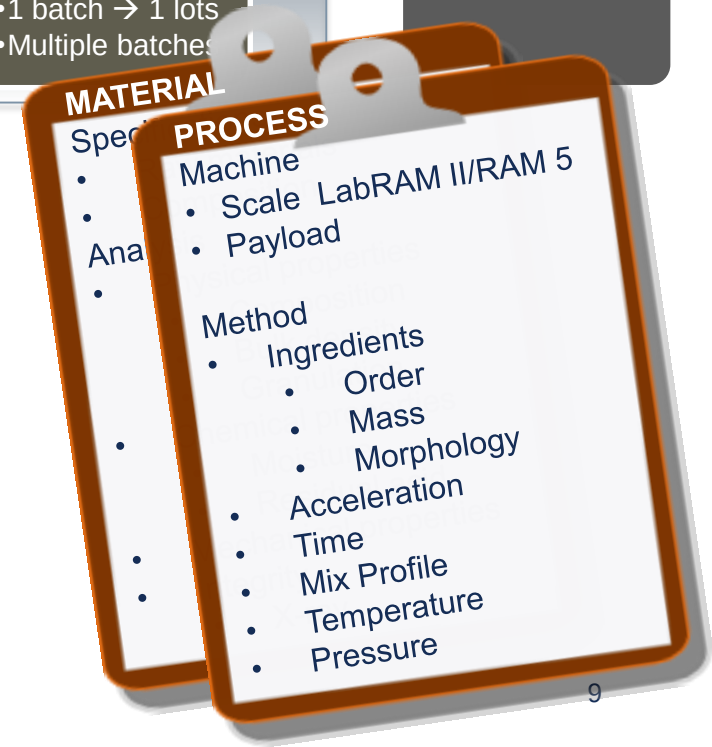
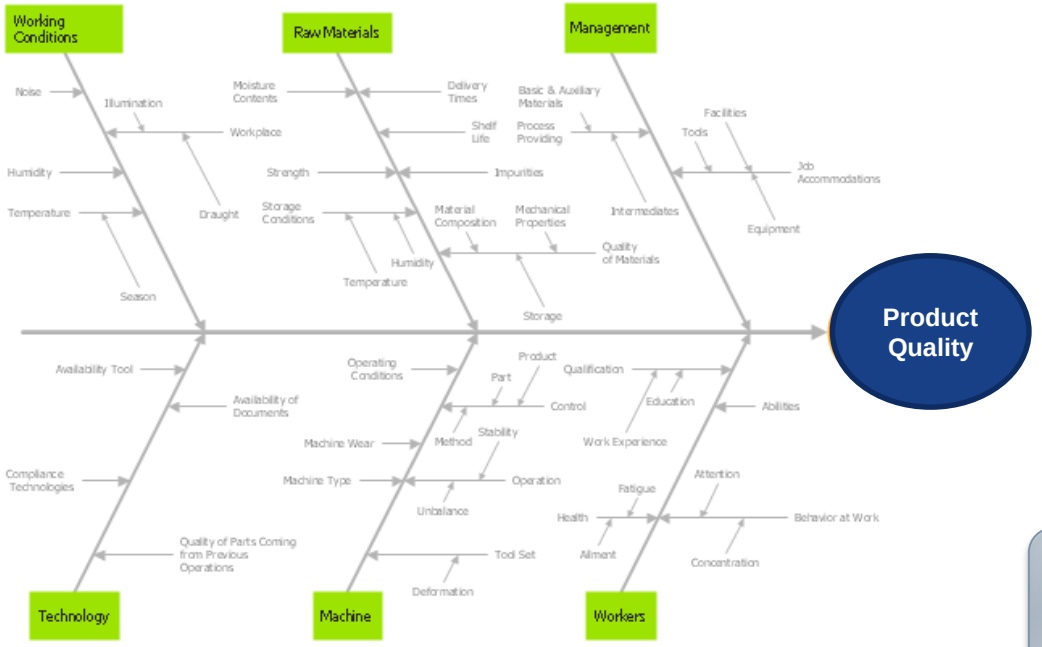


Nelson, 2018

- How to provide assurance
  - Material +
  - Process
- Sampling of material
  - Single batch
- Breakdown of munition
  - Single batch



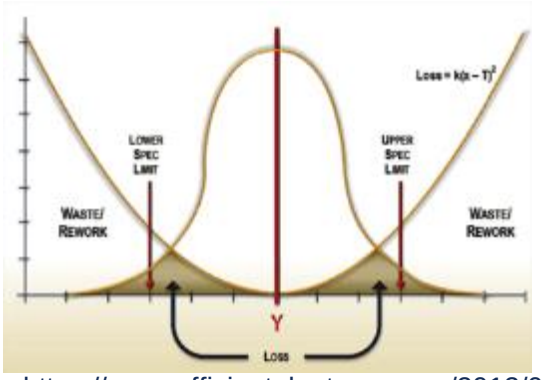
Quality

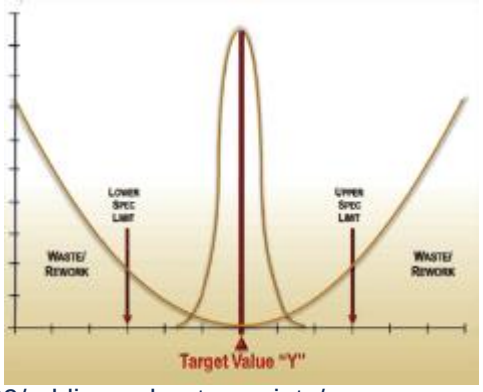


- Control required over all areas
- Technology
  - Stability
- Raw Materials
  - Tight specifications
    - Ingredients
    - Formulation
- Batch Size 1
  - Industry 4.0
- Process Control
  - E.g. Dulux
  - End to end digitalisation of the plant
  - Electronic Batch Record
    - Paperless production
    - Every step tracked & recorded
  - Remove sources of error

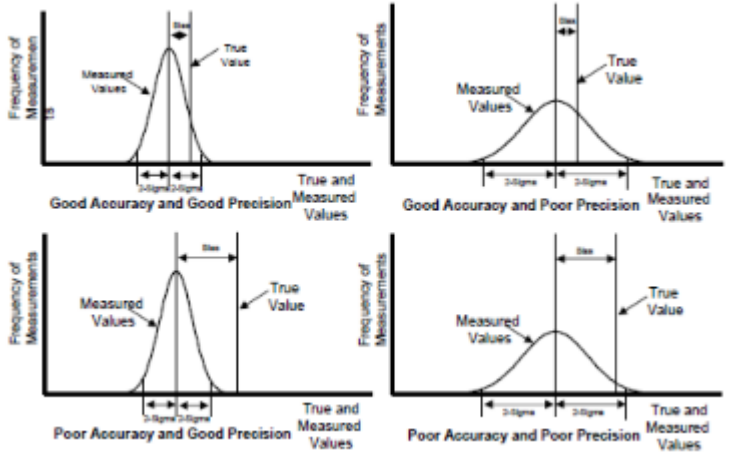
https://new.siemens.com/global/en/company/stories/industry/any-color-desired.html

Specification





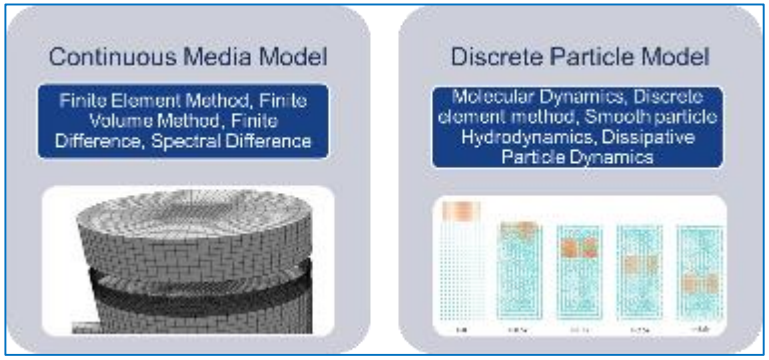
https://www.efficientplantmag.com/2012/09/adding-value-to-society/



Ref: ISA 2010

- Tightening material specification
  - Ingredients
  - Formulation
- Process specification
- Robustness of the process to deviation
- Accuracy
  - The closeness of agreement between a test result and the accepted reference value
- Precision
  - The closeness of agreement between independent test results obtained under stipulated conditions

Fundamental & Applied Research



A Model of Modern Science

SIMULATION
Computational Model

SUGGEST EXPERIMENTS
DATA ACQUISITION

VALIDATE MODELS
PROVIDE DATA

PROVIDE MODELS
INTERPRET RESULTS

EXPERIMENTS
Physical Models

SUGGEST THORIES

TEST THEORIES

SUGGEST EXPERIMENTS

INTERPRET RESULTS

THEORY
Conceptual Models

Mixing	Solid-Solid	Solid-Liquid	Liquid-Liquid/Gas
Dominant phenomenon	Particle-Particle Collisions	Acoustic streaming	Faraday Instabilities
Important parameters to establish a mixing regime	- Acceleration - Fill ratio, aspect ratio - Vacuum/pressure	- Acceleration - Fill ratio - Viscosity - Order of introduction - Aspect ratio - Vacuum	- Acceleration - Fill ratio
Scale-up parameters (for the same power input and acceleration)	- Height of the bed - Transducer Area - Number of Acoustic - Transducers; - Density - Elasticity; -Pressure	- Partial Vacuum	No data

Experimentation – Different Approaches

Two categories of tests:

1) Tests on the how **the apparatus** mixes

- Macro & micromixing
  - Beam line experiments [Jubb, 2018]
  - RAM provides a more homogeneous mix [Beckel, 2018] [Nelson, 2018]
  - Apparatus to monitor mixing progress [Jubb, 2018]
- Scale up
- Vessel and mixing parameters
- These tests are needed to
  - Build models,
  - Test theory and
  - Run simulations

2) Tests on the **produced materials**

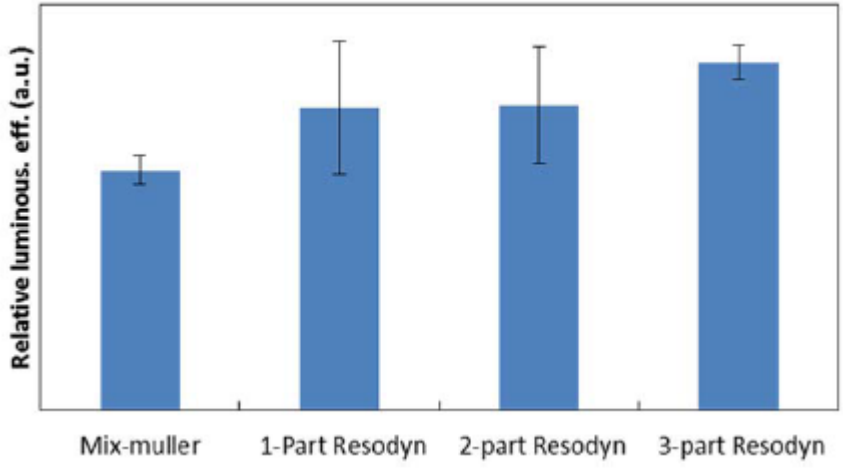
- Similar density can be found [Zebregs, 2018] and less voids are observed with the RAM,
- Similar safety properties are observed in terms of impact, friction and ESD [Beckel, 2016]
- Similar performance can be seen with RAM [Jubb, 2018]
- Similar sensitivity of the final product [Komansechek, 2018]

Qualification

- Existing material – RA mixed
  - Meets material and performance specifications
  - Passes AOP-7 tests
  - Compared against conventional mixed
- Process
  - Batch or Mix In Case?
- National Authority
  - Decision on qualification

"If it looks like a duck and walks like a duck, perhaps it is a duck"

- Existing material – RA mixed
  - Exceeds performance specification
  - Passes AOP-7 tests
  - Compared against conventional mixed
- Process
- National Authority



Miklaszewski, 2018

Qualification

- Ensure that knowledge exists in both industry and government
  - Intelligent customers
- RAM processed materials
  - Awareness of co-crystal formation
  - Shortened mixing time
  - Chemical reactions still need to take place
  - Understand impact on mechanical properties
  - Alter formulations to achieve required properties
- Testing of Energetic Materials
  - No initial change expected for current materials
  - Possibly for very viscous materials
- Overall qualification
  - Potential to reduce time
- Concerns
  - Rate of change of RAM affecting qualification
  - RAM standard – steady state of technology maturity

Conclusion

- Current testing for energetic materials is considered suitable
- No change for batch processing
- In case mixing still requires consideration for through-life support
- Batch Size 1 is possible if the whole process is controlled and documented

- Knowledge of the process needed in both government and industry
- Greater understanding of the whole process is required to provide assurance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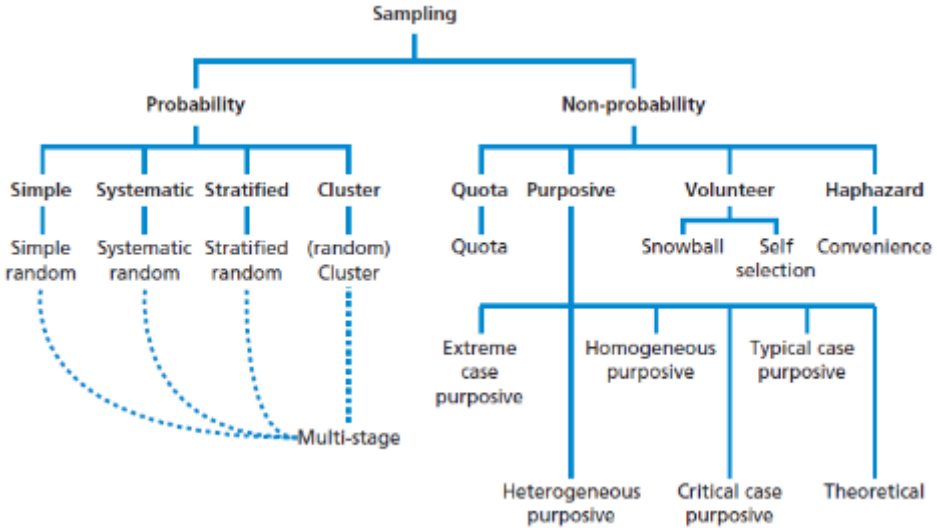
Sampling



https://research-methodology.net/sampling-in-primary-data-collection/