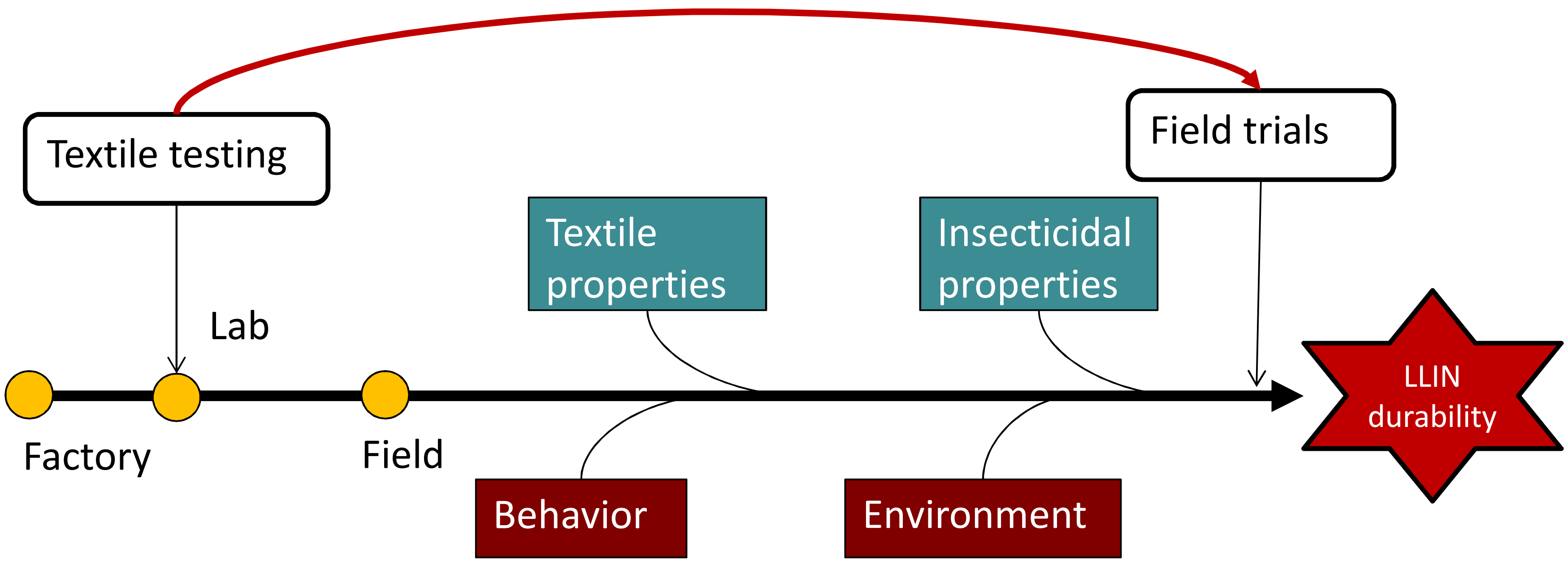
Textile Testing: Resistance to Damage (RD) and LLIN Service Life Prediction in the Field

Where are we and what next?

Stephen Russell, Albert Kilian, Amy Wheldrake

Why do we want to know?



Scope of the Study

1. Determine the **real mechanisms of damage** in LLIN field nets across different settings and geographical regions.

2. Identify a suite of **new textile test methods to assess LLIN durability** based upon the real modes of damage (*verified by comparing damage morphologies as well as correlation with field net damage data*).

3. Design a means of **quantifying the resistance to damage of LLINs** to assist in providing better performing LLINs.

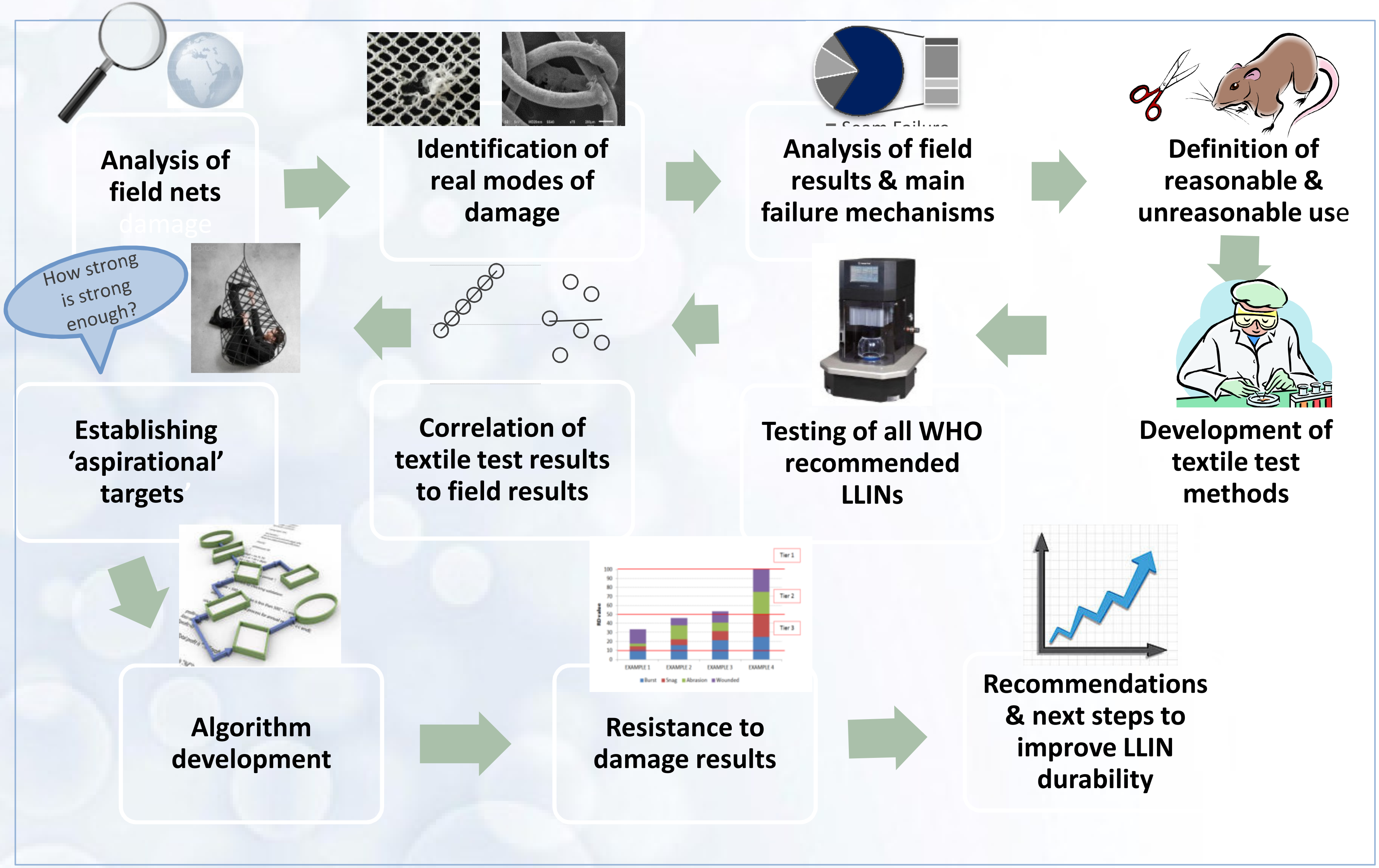
TROPICAL HEALTH

NIRI Nonwovens Innovation & Research Institute

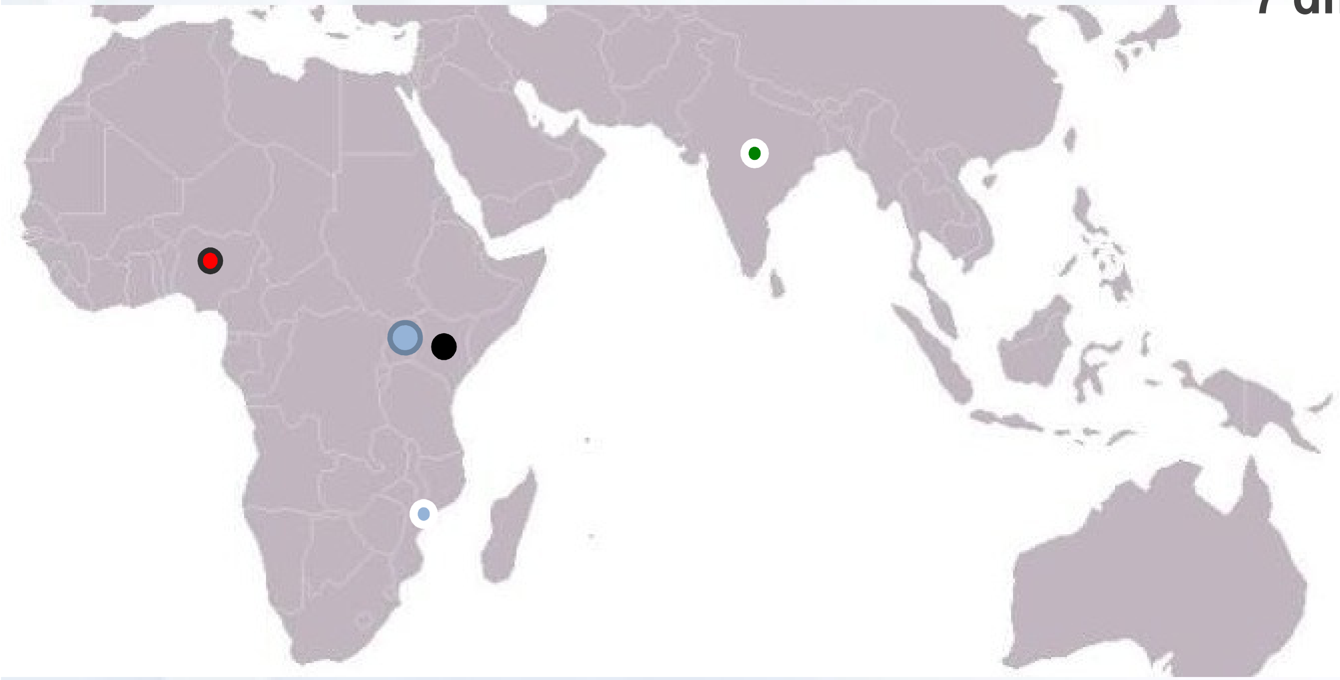
RESULTS FOR DEVELOPMENT INSTITUTE

BILL & MELINDA GATES foundation

Overview of the Approach



LLINs were Retrieved from the Field in Africa and Asia by Tropical Health LLP

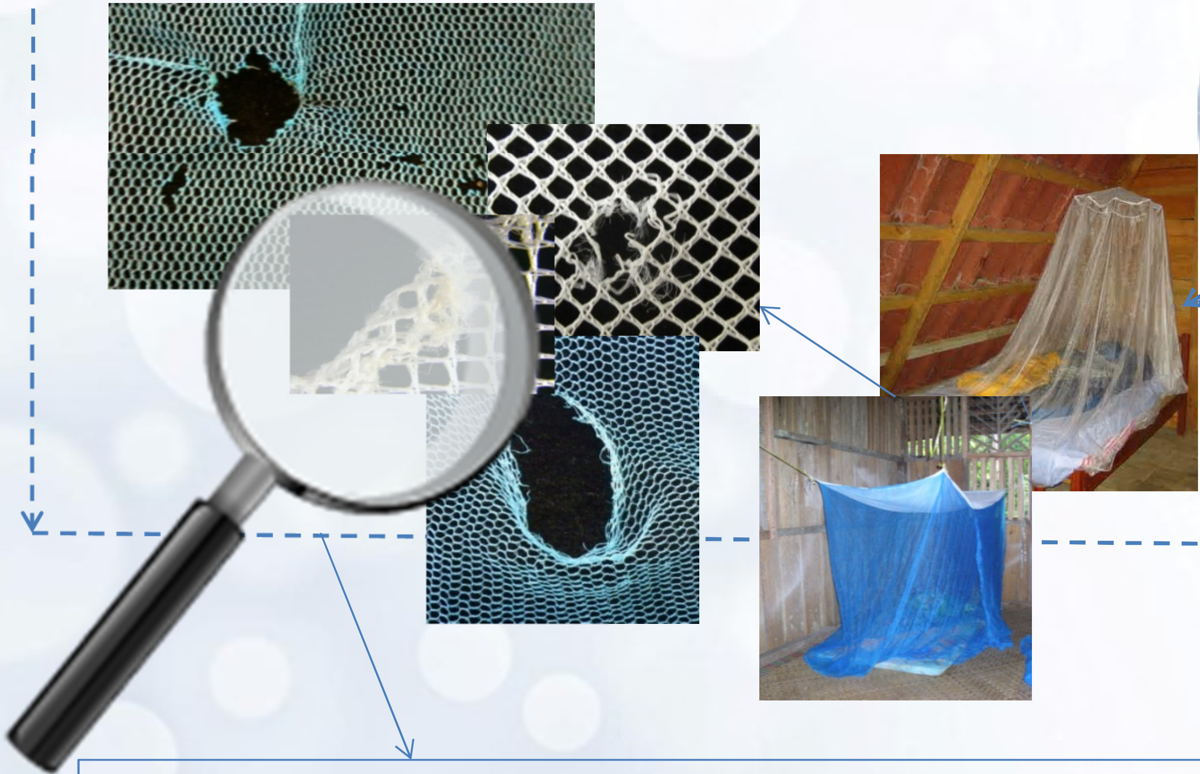


5 different countries
7 different locations

- Nigeria: NetWorks (PMI); 3 separate locations within Nigeria.
- Kenya: CDC
- Uganda: Tropical Health LLP
- Mozambique: PMI
- India: WHOPES

- **Total LLINs analysed:** n = 526.
- **Periods of use:** 12, 18 and 36 months.
- **LLINs types:** 164 PermaNet, 98 Olyset, 54 Dawaplus, 139 Duranet, 34 Interceptor, and 37 Net Protect.

Phase 1: Determine the real mechanisms of LLIN damage & hole formation



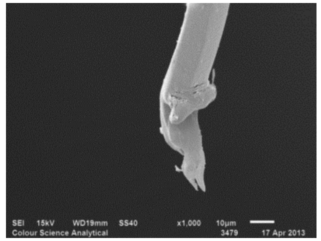
5 different countries
7 different locations

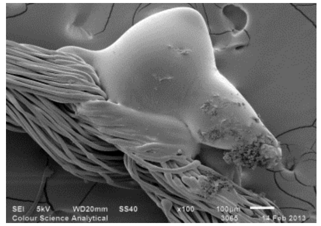
Direct analysis of **526** retrieved nets.
41,294 individual damage sites identified and analysed.
Persistent modes of damage were identified.

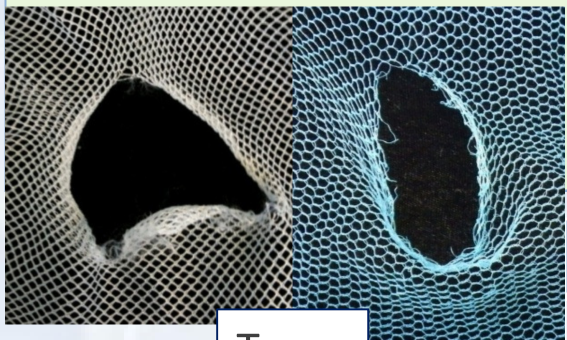
The purpose was to identify the main MODES of damage so there was no necessity to sample LLINs in every single setting.

Seven Different Mechanisms of Hole Formation

Mechanical				Thermal	Animal	Seam failure
Snag	Tear	Abrasion	Cut			
Yarn or part of a yarn pulled or plucked from the surface.	Tensile failure of yarns within the fabric plane in for example two opposing directions.	The wearing away of any part of a material by rubbing against another surface.	Yarn that is failed by slicing with a sharp object.	Polymer that is exposed to temperatures high enough to cause shrinkage, plastic flow or degradation and failure of the yarn.	Damage caused by gnawing of indigenous rodents, chewing of domestic animals or interaction with birds.	Effective breakdown of a seam due to rupture of the sewing thread or yarns in the fabric, excessive seam slippage or any combination of these.

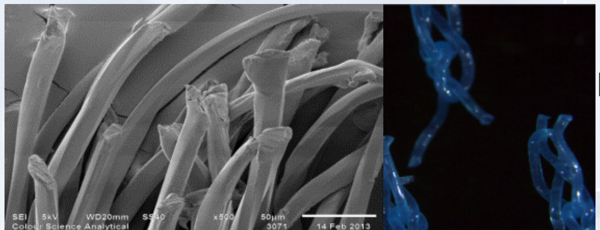

Rodent


Thermal

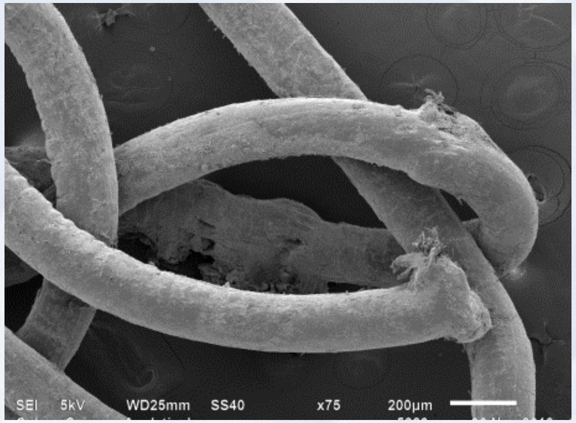
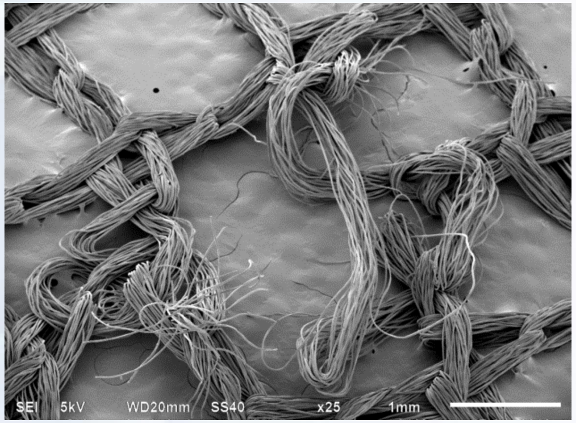
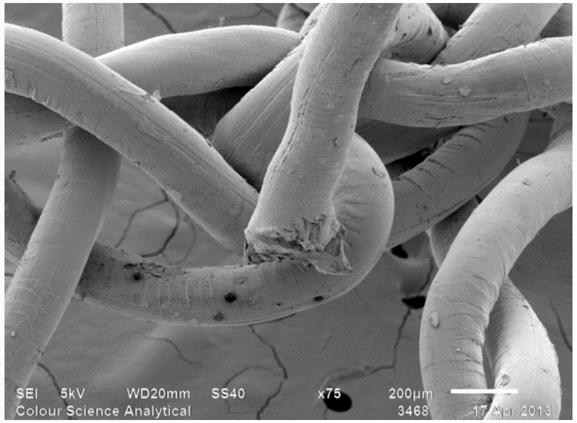

Tears

Secondary damage

Laddering	Unravelling	Tearing
Pulling out of successive knitted loops in a wale, leaving straight segments of yarns.	Following yarn failure, the broken yarns allow the loops of the knit structure to un-loop creating a larger hole.	Tensile failure of yarns within the fabric plane in for example, two opposing directions after primary damage has been initiated.

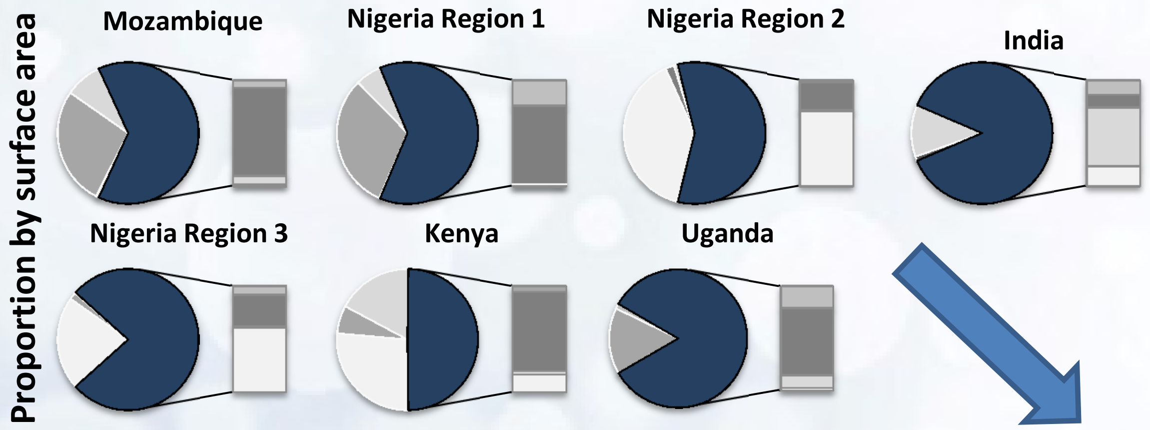

Cuts

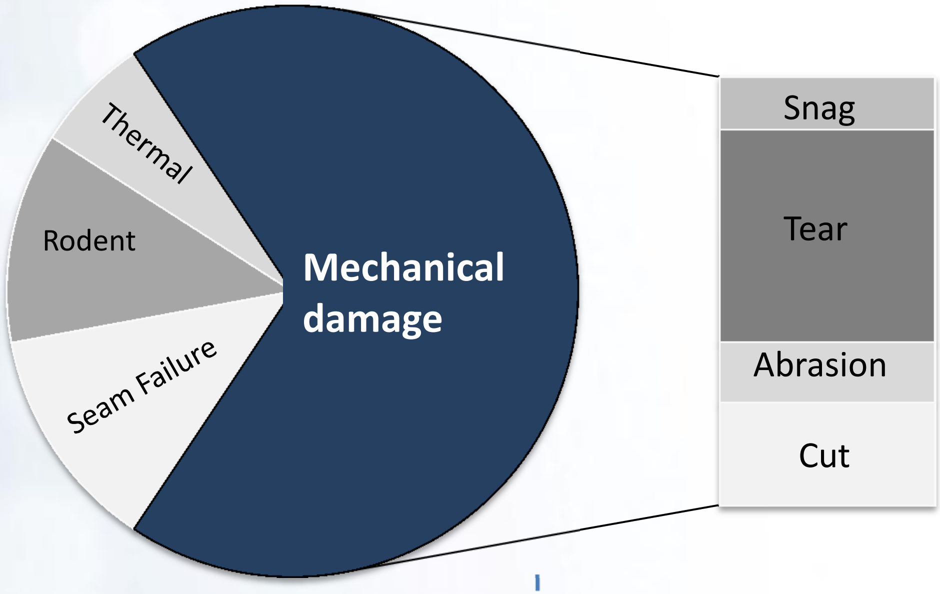
Damage Mechanisms were Consistently Encountered Regardless of Net Type, e.g. Snag Damage

Monofilament LLIN	Multifilament LLIN	Monofilament LLIN
		
		

The Same Modes of Damage were Observed across Different Geographic Settings

Phase 1 RESULTS





Mechanical damage in the form of **Snags**, **Tears**, **Abrasion** & **Cuts** consistently accounts for a large volume of the holes found in the field.

Hole enlargement is an issue in LLINs after initial damage is incurred.

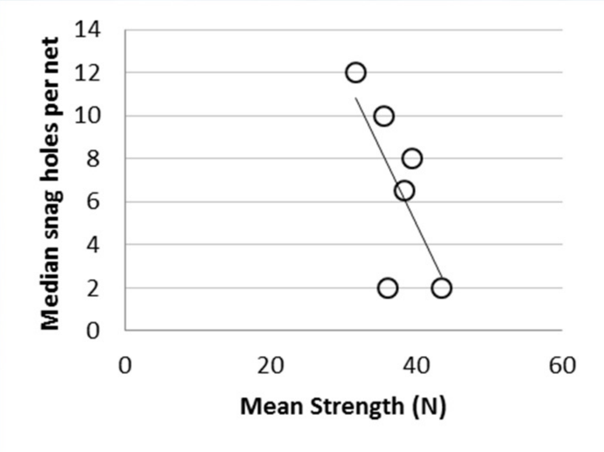
Phase 2 Development of Textile Testing Methods using all WHOPES recommended LLINs

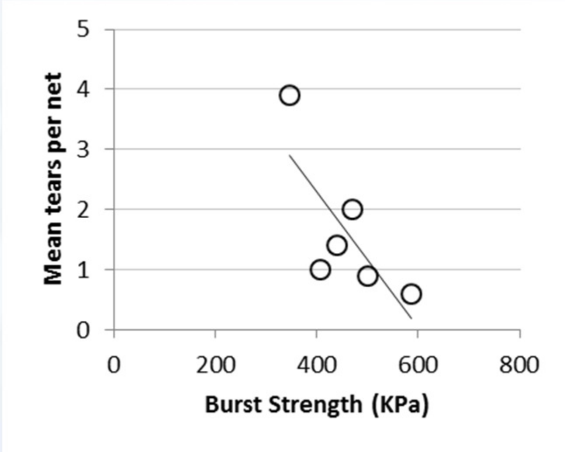
Identify test methods that:

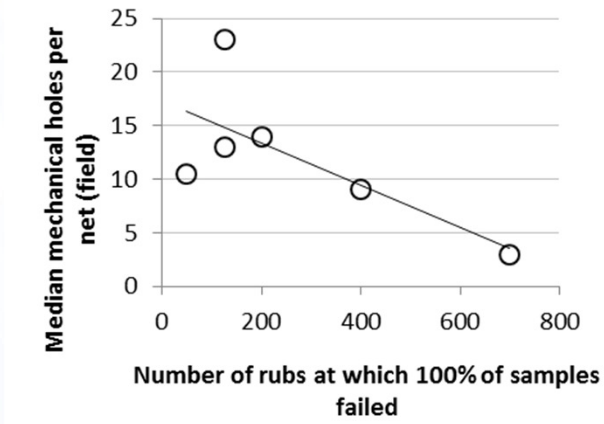
1. Reflect actual damage found in the field (Phase 1 results).
2. Produce accurate and reproducible results with LLINs.
3. Can easily be performed by existing testing labs.
4. Reflect damage mechanisms incurred as a result of "reasonable use" confirmed by correlating lab test data with field hole damage data.

Snag test	Tear (Bursting Strength)	Abrasion resistance	Hole Propagation
Adapted from BS 15598:2008	ISO 13938-2 (1999)	Adapted from ISO 12947:1998	Adapted from BS 3424-38:1998
Force to break yarn perpendicular to the surface	Pressure to burst	Number of cycles to yarn break during flat abrasion	Increase in hole size following an initial yarn break & behaviour

Phase 2 Correlation between test and field results (Kenya)







How strong is strong enough ?

Textile Test Data

Fitness for Purpose = Quality

- The primary consideration in the design of all consumer products.
- How is the product supposed to be used ? What specific real-life usage conditions must it withstand ? Essential vs. desirable features ? End cost ?

Repeated snagging on wooden edges or other protuberances; repeated pulling and stretching, repeated abrasion on wooden or hard ground

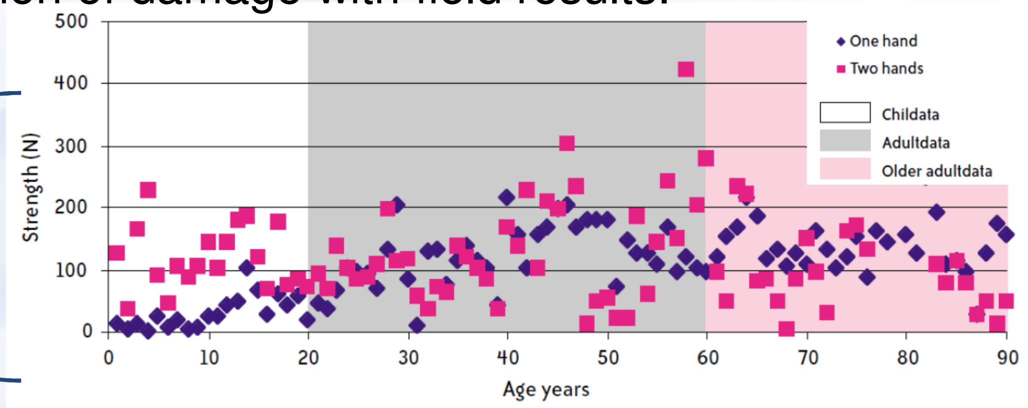
Estimating Real-Life Forces

Set aspirational targets

What forces will a human generate during reasonable use of a LLIN ?

- Review of human testing studies (children & adults).
- Destructive testing of WHOPES-recommended LLINs using real human subjects.
- Correlation of damage with field results.

Maximum pulling strength using underhand grip



Aspirational Performance Targets	**Durability Test Parameters**			
	Snag Strength	Tear (Burst) Resistance	Abrasion Resistance	Hole Enlargement

Development of a Single "Resistance to Damage" Value

Minimum Entry Requirements

	Safety Parameters		Durability Test Parameters			
	Thermal stability Pass/Fail	Seam strength *Pass/Fail*	Snag strength (N)	Bursting strength (kPa)	Abrasion resistance (number of rubs)	Hole enlargement (mm)
Minimum Requirement	Pass	Pass	20	250	N/A	N/A

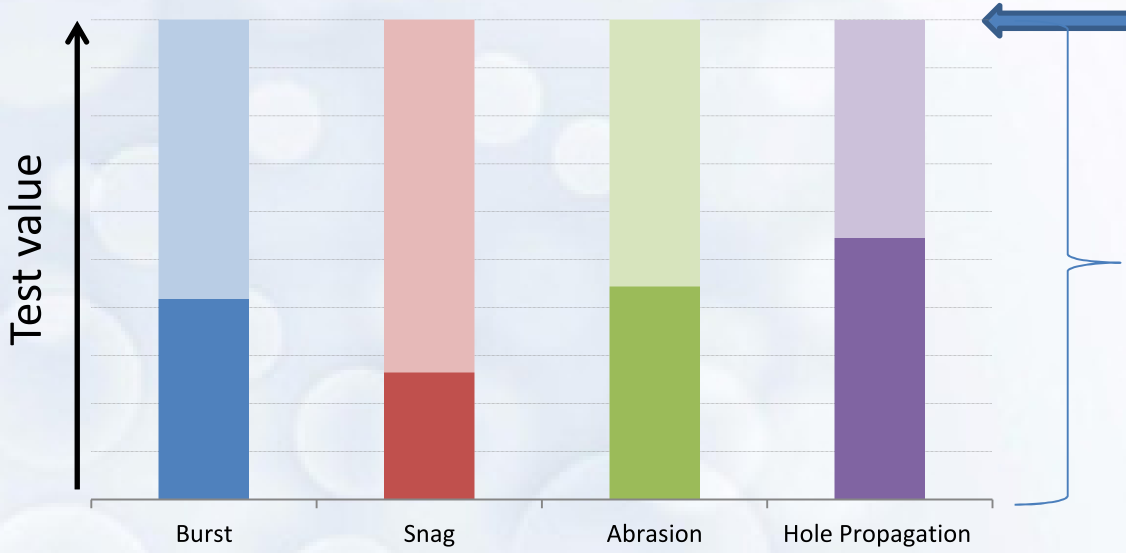
Determination of Resistance to Damage Value

Algorithm 1

Algorithm 2

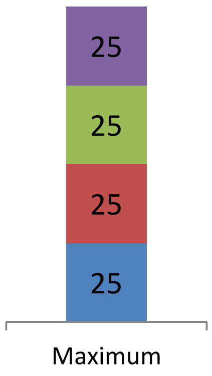
Calculation of Resistance to Damage (RD)

- Quantitative performance ranges were established for each durability parameter: bursting strength, snag strength, abrasion resistance and hole enlargement based on the aspirational targets.
- A composite Resistance to Damage (RD) value was calculated based on the magnitude of each of the four durability parameter test values.
- Two different algorithms were developed, both producing comparable Resistance to Damage results.

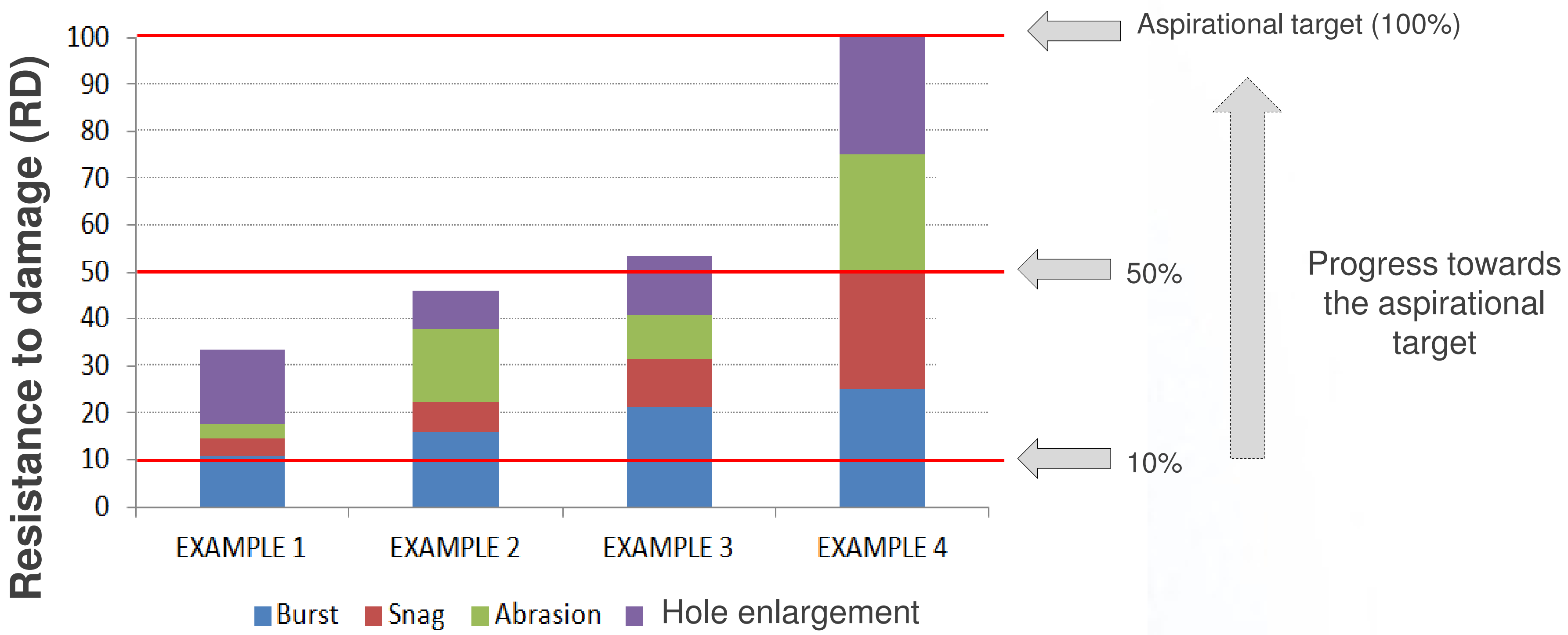


Aspirational performance level = 100%

Textile test values from the lab are each expressed as a percentage of the aspirational value.



The Resistance to Damage (RD) value has been established to quantify the mechanical robustness of LLINs

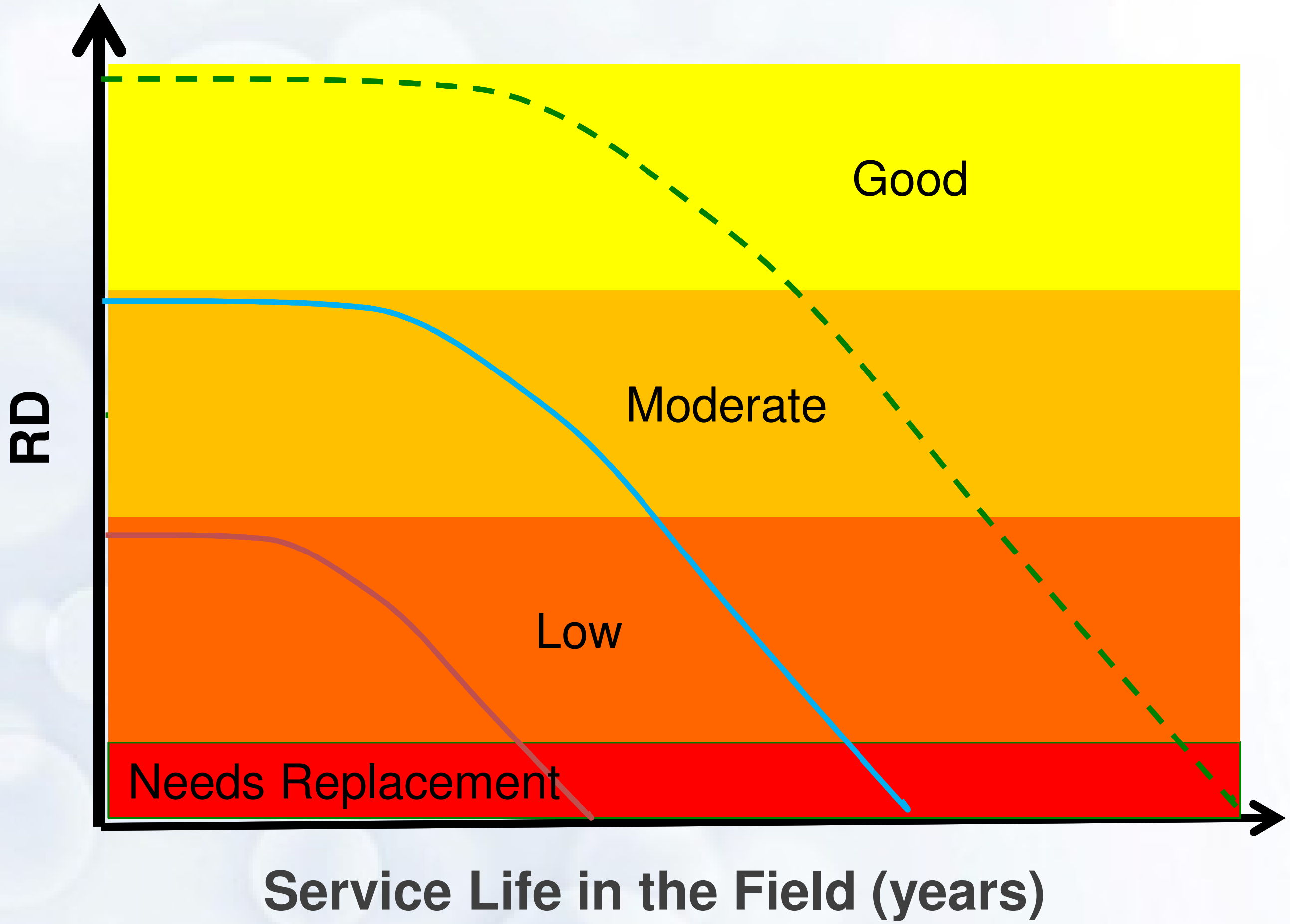


Outstanding Issues

- Validation of reliability of test methods across textile labs (started)
- Is this the best combination of tests?
- Is this the right way to weigh the different aspects of mechanical damage?
- How can we use the RD metric to inform procurement and drive innovation?
- Is there a sufficient correlation between RD and actual resistance to mechanical damage in the field?
- How much more Bang for the Buck?

The Purpose is to link RD to Service Life in the Field

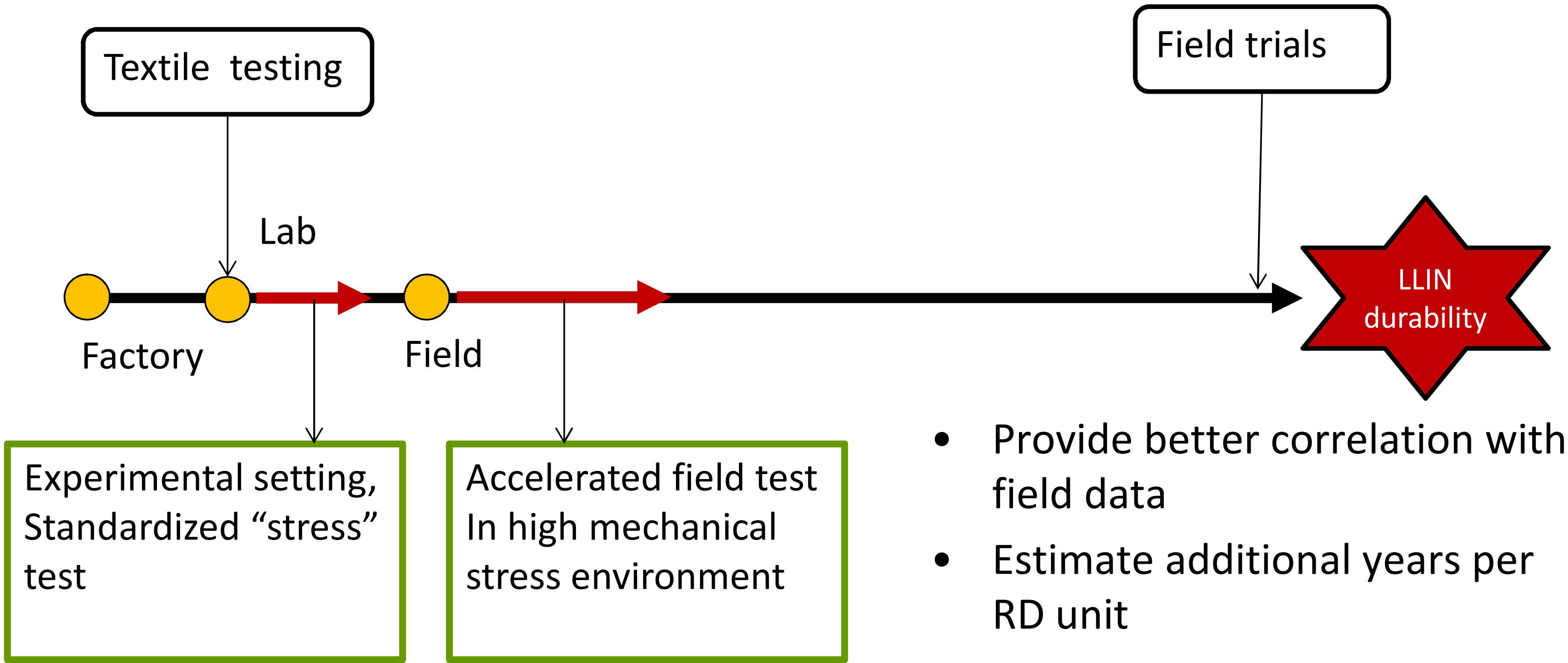
Higher RD nets should last longer, but how much longer ?



Damage accumulation curve will depend on RD and behavioral factors.

Need for accelerated Field Testing

- Field trials take at least 3-4 years
- Behavioral factors will "dilute" correlation with RD
- Not able to include promising new prototypes



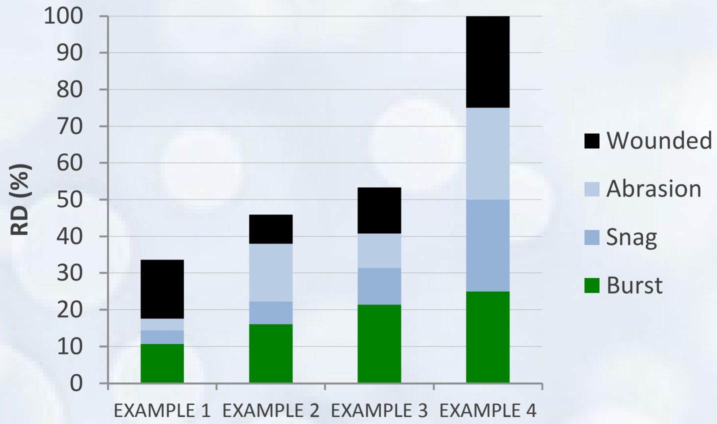
- Provide better correlation with field data
- Estimate additional years per RD unit
- Reduce time to ~18 months

Service Life in the Field can be Estimated based on Initial RD values

The two data sets can be used to calculate LLIN service life:

- The RD value (determined in the lab).
- Damage accumulation curve (determined from normal wear & tear in the field).

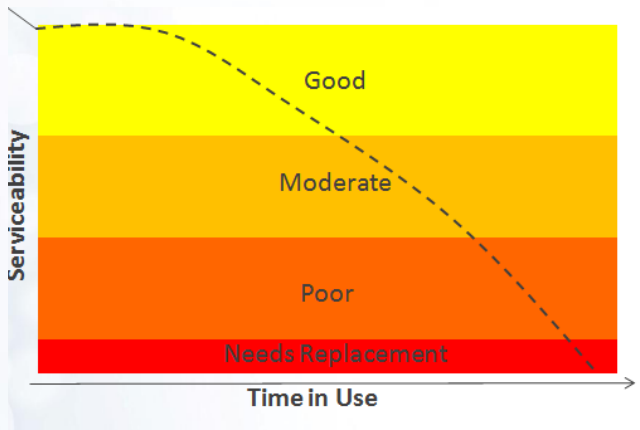
RD Value



NET A

&

Damage Accumulation Curve obtained from the field



NET A

What Next?

- Do we have enough evidence to continue with RD approach? Is there alternative?
- Can we start using it while still working to improve?
- Develop study designs for “stress testing” and accelerated field testing and carry out as operations research
- Provide evidence of link between RD value and actual resistance to mechanical damage in the field
- Collect “routine” monitoring data in a starndardized fashion and include textile testing for damage mechanisms in some studies