GH+ Labs

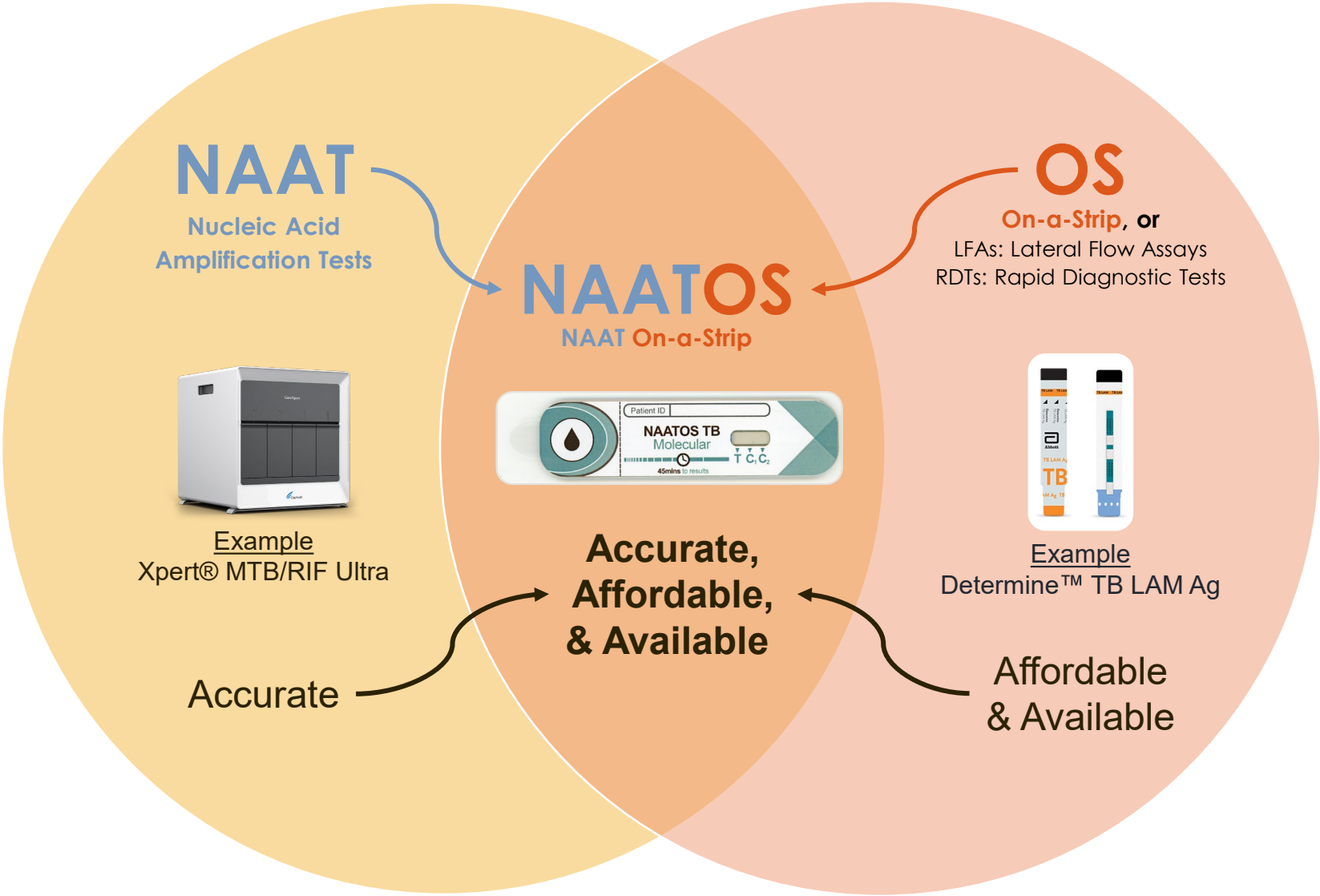
NAATOS

Nucleic Acid Amplification Test On a Strip

18 September 2025

Platform Overview

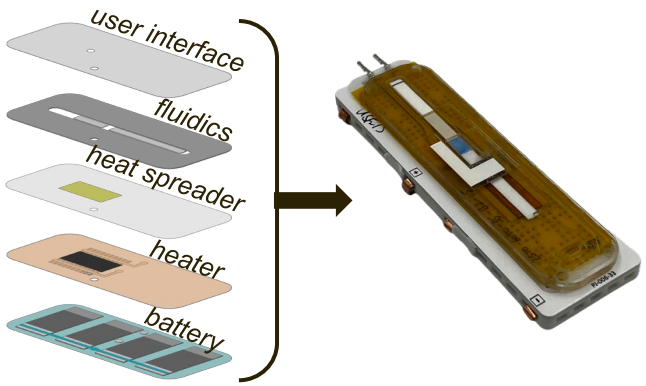
NAATOS aims to empower primary health care with essential diagnostics that are accurate, affordable, and available.



GH Labs is developing NAATOS to bring NAAT-level performance at LFA-like cost, usability, and manufacturability to PoC settings in PHC.

Past | NAATOS Prototype

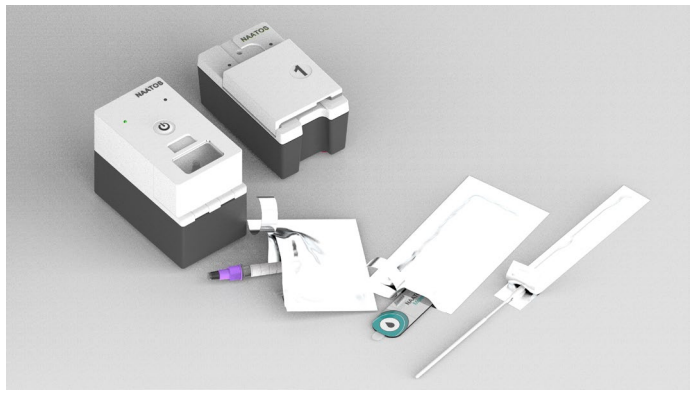
- Modular, multi-layer laminate, instrument-free, disposable POC NAAT



Concept to Functional Prototype

Present | NAATOS TB V1

- Simple, modular instruments and manufacturable $2 USD TB Dx consumables

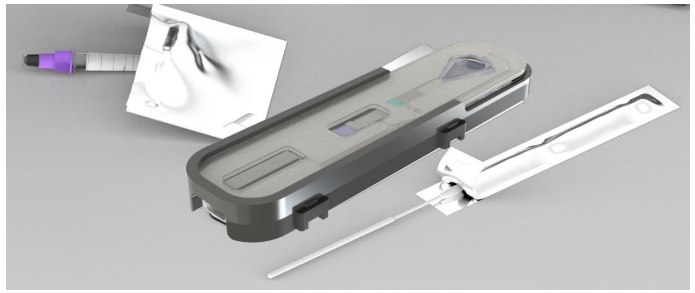


Functional Prototype to Product

- Designed as low-cost, high-sensitivity molecular aid in diagnosis for TB, which requires instrumented sample preparation of tongue swab or treated sputum specimens

Future | NAATOS V2

- Fully disposable instrument-free NAAT Dx



Modular System to Integrated Test

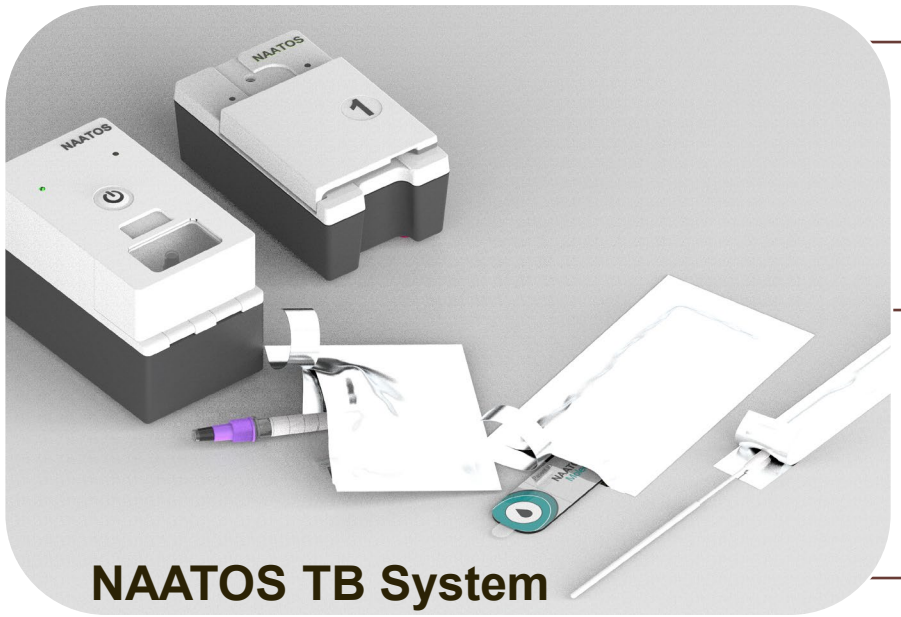
- Designed as low-cost, high-sensitivity test of swab-based or diluted blood specimens that do not require instrumented sample preparation

NAATOS TB V1
Product Overview

NAATOS TB V1 | System Overview

The NAATOS System includes two modules and a TB-specific consumable test kit.

Target: detection of *Mycobacterium tuberculosis* complex (MTBC) DNA
Sample type: dorsal tongue swab specimens or liquified sputum



NAATOS TB System

NAATOS Consumable Test Kit:

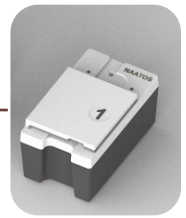
Contains all single-use consumables and test reagents required to complete testing.

- **Sample Collection Consumable** – Copan FLOQ swab (in sheath)
- **Sample Tube Consumable** – tube, lysis buffer, glass beads, internal processing control
- **Test Consumable** – TB-specific, laminate-based design

Sample Prep Module:

Module that processes the sample for NAATOS testing.

- Achieves high-efficiency lysis of TB cells for nucleic acid extraction, ensuring biosafe samples for downstream testing.



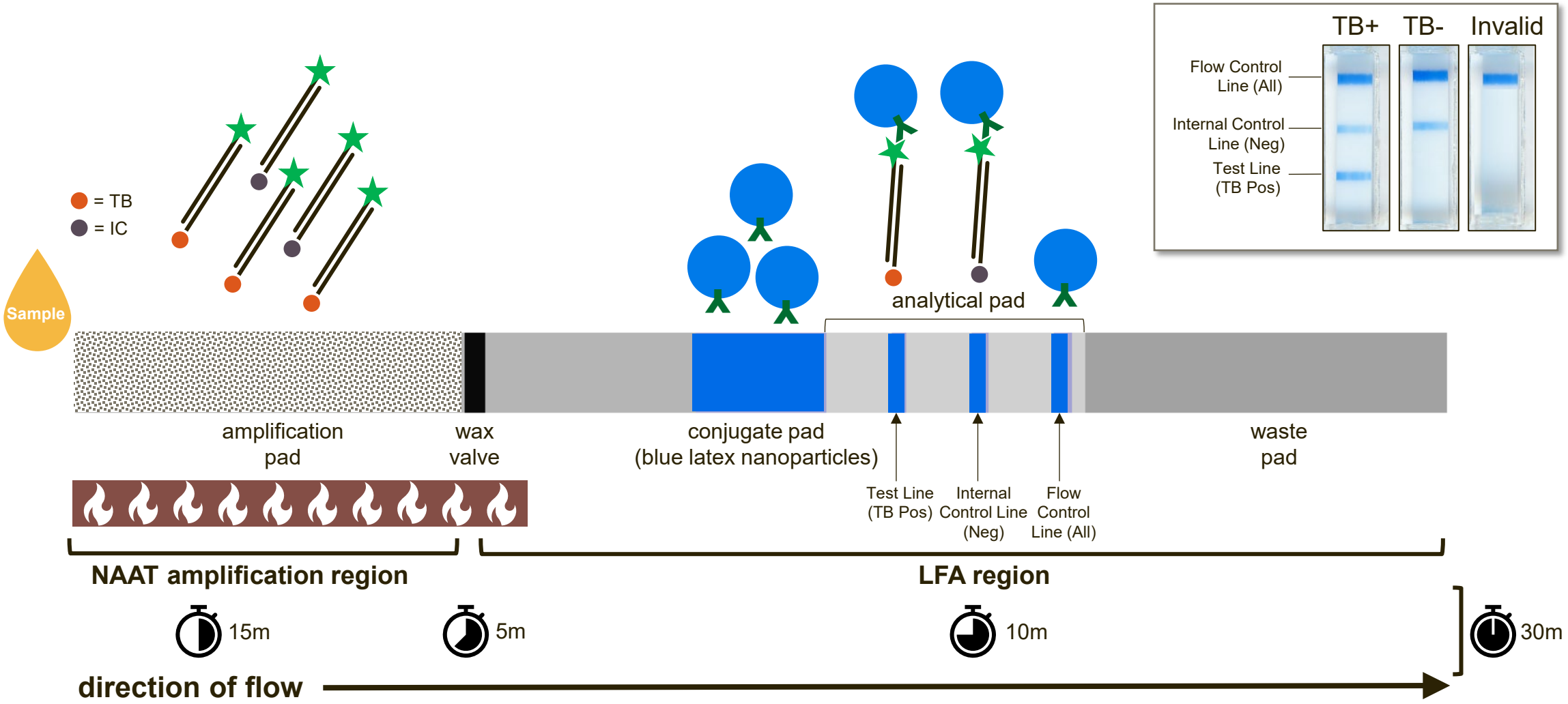
Power Module:

Module that performs NAATOS testing.

- Provides precise heating and timing steps, ensuring optimal LAMP performance and controlled reagent flow into the nitrocellulose membrane for clear visual result interpretation.

NAATOS | Core Technology and Principle of Operation

Novel design incorporates NAAT functionality into standard lateral flow assay (LFA) design



NAATOS TB V1 | Workflow Timing and Turn Around Time

Sample Preparation Module

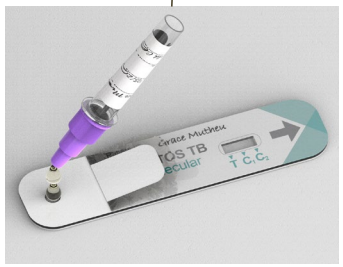
Operator to complete loading ≤ 30min

Power Module

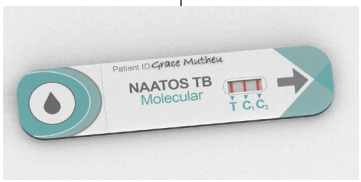
Operator to complete step ≤ 30min

Sample Loading → Sample Processing (6 min) → Device Loading → Amplification and Detection (30 min) → Visual Result Readout

Sample Preparation Tube and Cap



NAATOS TB Test Device



Total Turn Around Time ~ 36 min

NAATOS TB V1
System Overview

NAATOS TB V1 | System | Final Configuration

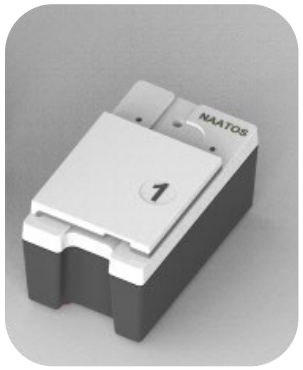
Purpose: complete design lock and confirm system readiness for use in pre-clinical pilot study

Goals for Final System Configuration	
NAATOS TB v1 Test Kit	Fully packaged, labeled Test Kit provided by DCN. All sub-assemblies from CDMO partners
Sample Prep Tube Consumable	Sample Prep Tube Consumable Mfg via CDMO fill-and-seal partner
Test Device Consumable	Completely Mfg'd and packaged by manufacturing partner w/ laminate layers provided by converter and wax valves provided by GHL
Sample Prep Module	Characterize performance of beta version (CCG)
Power Module	Characterize performance of gamma version (CCG)
Intended Use (Expand Specimen Claims)	Characterize performance of the NAATOS TB System with both tongue swab and sputum specimens to determine if the Intended Use can be expanded to include both specimen types
Preclinical Readiness	Demonstrate the NAATOS TB v1 System can meet or exceed the target clinical performance parameters of frozen retrospective samples prior to initiation of a pre-clinical field study in Q2
Improve Turn Around Time (TAT)	Demonstrate 30 min sample-to-result workflow. Characterize performance of new ThermoFisher LAMP amplification reagents at 30 min TAT
Analytical Sensitivity	Measure Analytical Sensitivity (LoD) per WHO TSS-17
Reagent Stability	Demonstrate the NAATOS TB v1 System can meet or exceed the target kitted stability parameters with accelerated aging studies
Biosafety	Conduct biosafety studies to ensure the System is completely inactivating Mtb samples

NAATOS TB V1 | System | Manufacturing Overview

Sample Preparation Module

Power Module



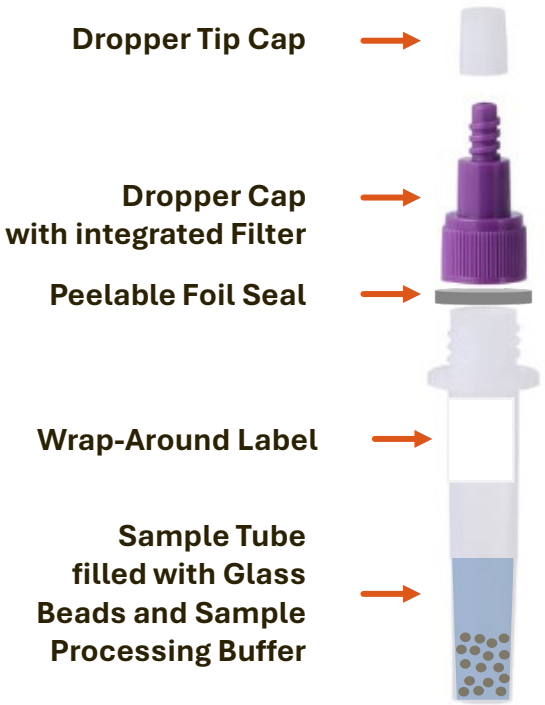
Pre-filled Sample Prep Tube + Cap

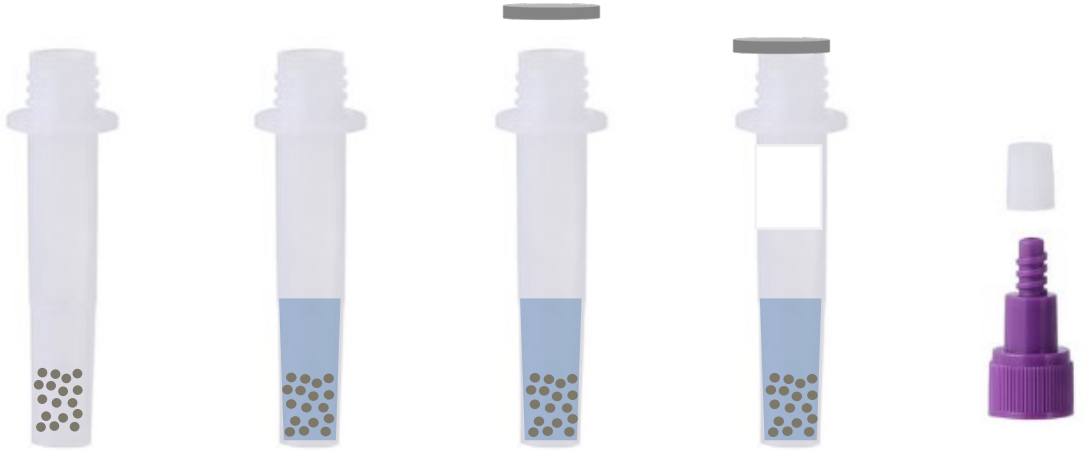
NAATOS Test Device

Manufacturer	GH Labs *(Commissioned External Design Firm for Small Batch Mfg)*	GH Labs *(Commissioned External Design Firm for Small Batch Mfg)*	GH Labs *(All processes developed in-house)*	GH Labs *(All processes developed in-house; utilize on-site fabrication shop for laminate conversion)*
Scale	N/A (Single Build)	N/A (Single Build)	R&D (400/day)	R&D (400/wk)
Drawing/CAD Available	Yes	Yes	Yes	Yes
BOM/Specifications Available	Partial	Partial	Yes	Yes
Work Instructions/ Formulation Procedures Available	No	No	Yes	Yes
Process Validated	No	No	No	No
Process Mfg Yield	Unknown	Unknown	Unknown (current estimate ≥ 99%)	Unknown (current estimate ≥ 80%)

NAATOS TB V1 | Sample Prep Tube | Components & Assembly

Sample Prep Tube Components

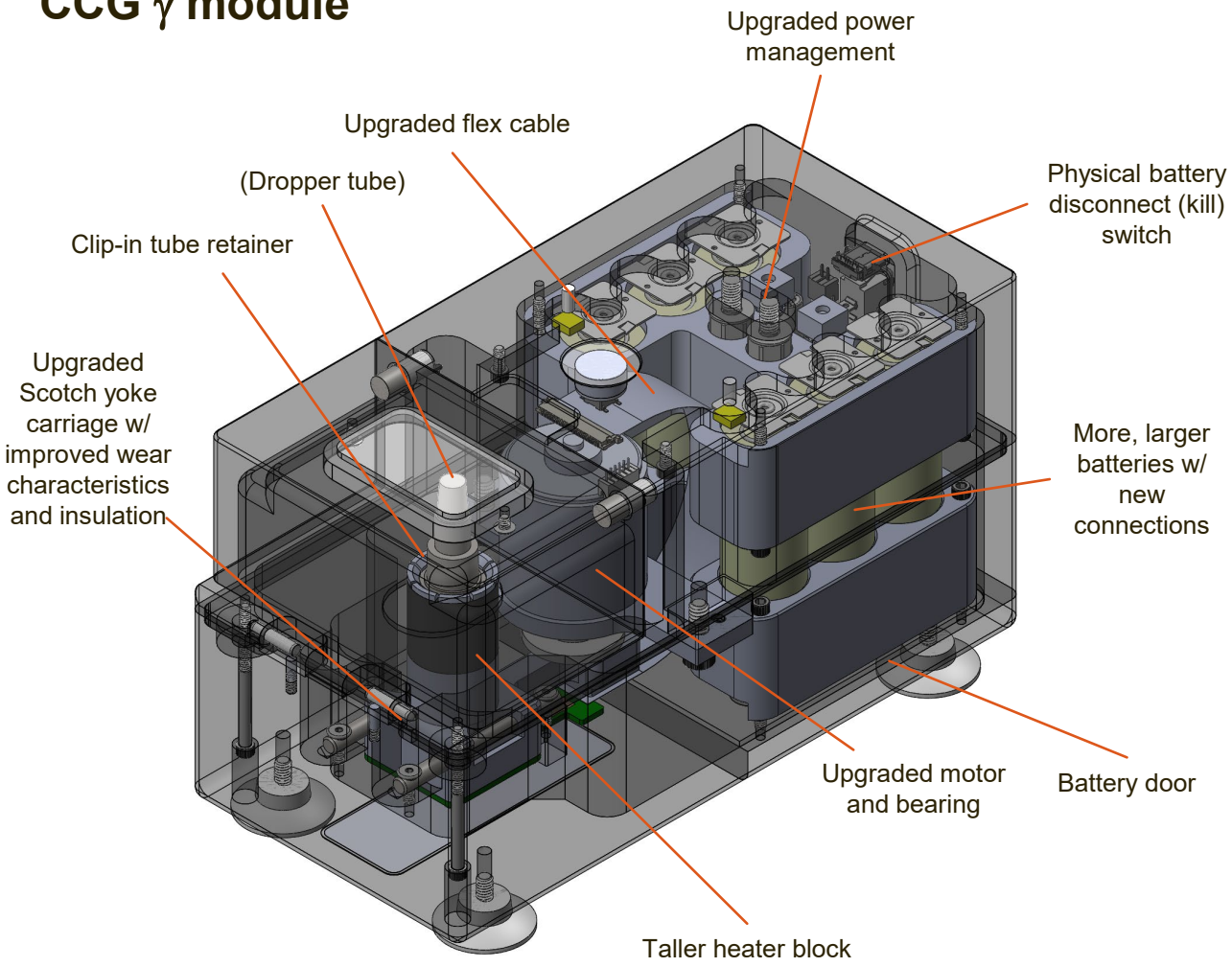




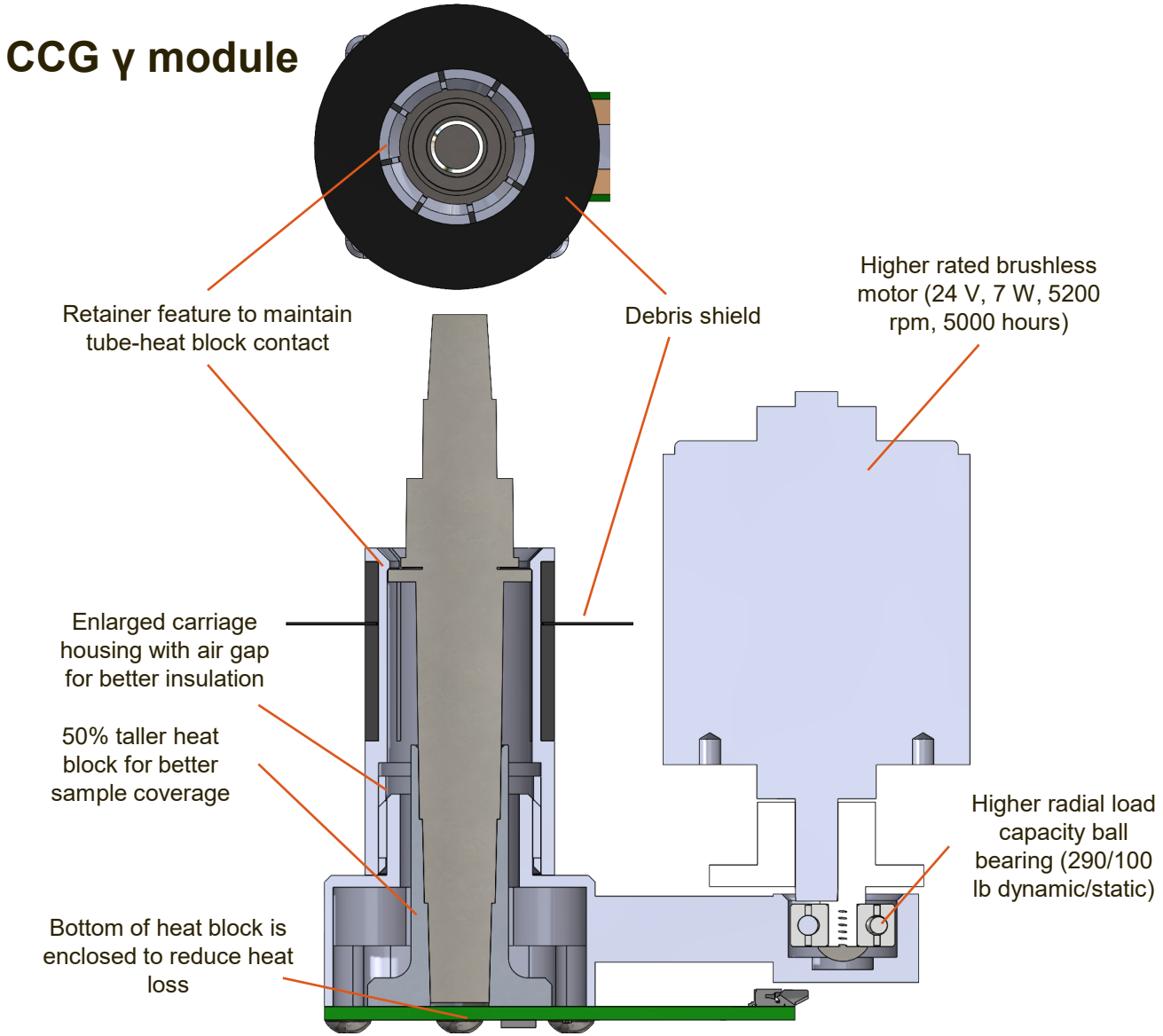
STEP	1	2	3	4	5
Process	Dispense Glass Beads into clean, dry Sample Tube	Dispense Sample Processing Buffer into	a. Manually coin precut Foil Seals b. Induction seal using carrier caps	a. Apply Label b. Kit in packages of 10 tubes/bag	Kit in packages of 10 caps/bag *(Note: Dropper Tip Cap comes attached to Dropper Cap)*
Equipment Required	Robotic Solid Dispense Head with custom calibrated powder dispense discs	XY laser guided liquid filling station	1. custom coining tool 2. custom carrier caps and racks 3. Induction Sealing Machine	None (Manual)	None (Manual)

NAATOS TB V1 | Sample Prep Module | Design Overview

CCG γ module

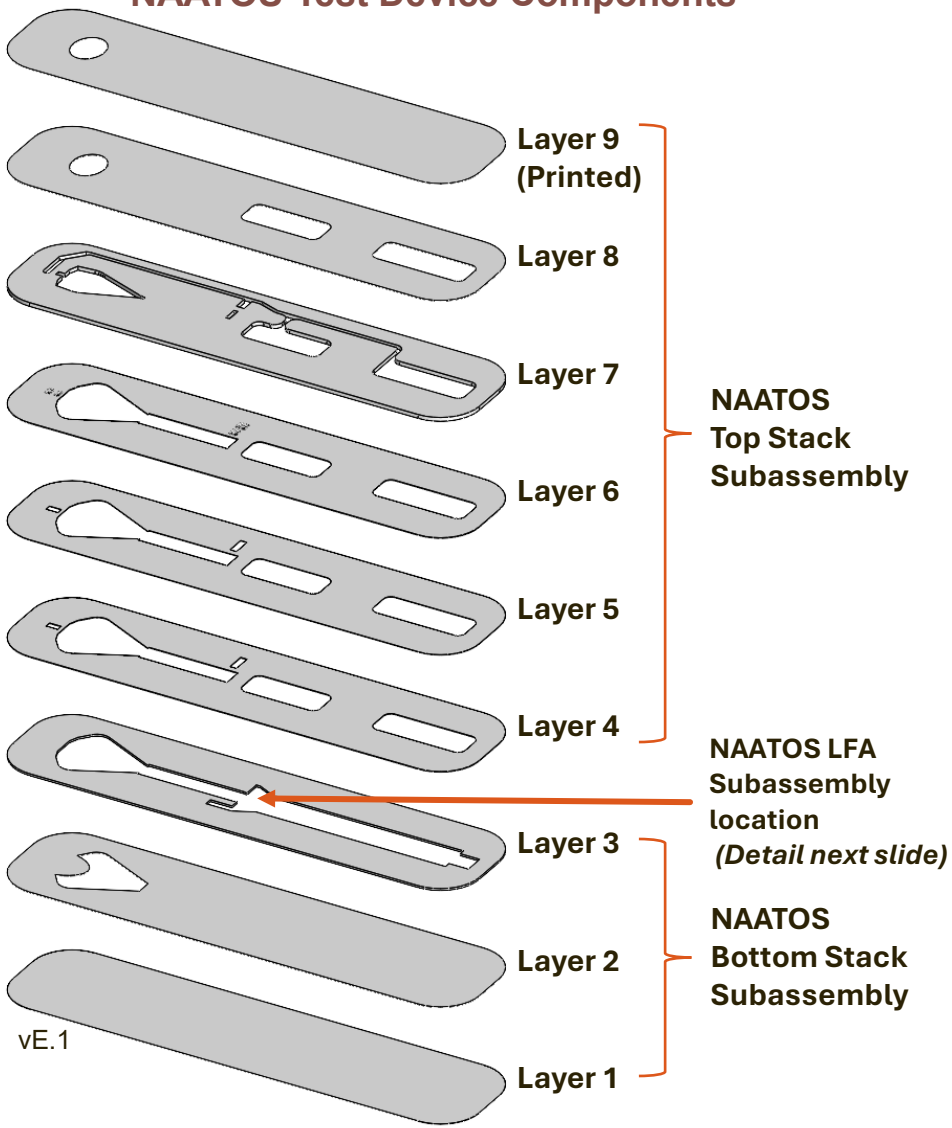


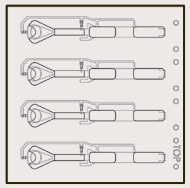
NAATOS TB V1 | Sample Prep Module Design | Tube Interface



NAATOS TB V1 | Test Consumable | Assembly

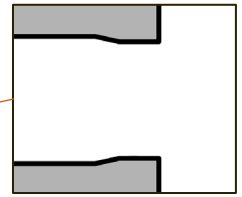
NAATOS Test Device Components



STEP	1	2	3	4	5
Process	Convert laminate layers 1- 9 into NAATOS Device 4-packs 	a. Assemble 4-pack Bottom Stack Subassemblies (Layers 1-3) b. Assemble 4-pack Top Stack Subassemblies (Layers 4-9)	NAATOS DEVICE 4-pack ASSEMBLY a. Insert LFA into Bottom Stack (Layer 3) b. Attach Top Stack c. Press and Laminate	Convert 4-packs into individual NAATOS Devices	Kit Devices a. Apply Device label and pouch labels b. Seal into Mylar bags with desiccant.
Equipment Required	Precision Laser Cutter (multiple models)	Custom alignment jigs	1. Custom alignment jigs 2. Laminator (Rolling/ Heating)	Precision Laser Cutter (multiple models)	Mylar Bag/ Heat Sealer
Environmental Control Required	No	No	RH ≤ 5%	RH ≤ 5%	RH ≤ 5%

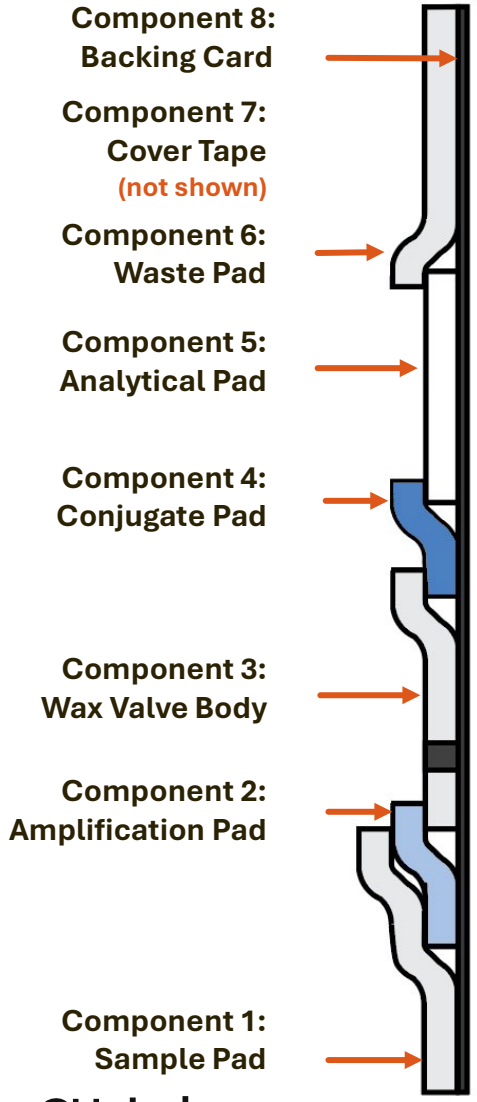
NAATOS TB V1 | Test Consumable | Components

Variable	Locked Design
Laminate Design	Version K.7 **New Features:** • Changed pinch point from triangular point to squared-off sidewall.
Material Components	Layer 1 – 0.005” Melinex 339 Layer 2 – 3M 9474LE Layer 3 – 0.020” PETG Layer 4 – 3M 9474LE Layer 5 – 0.005” Melinex 454 (clear) Layer 6 – 3M 9474LE Layer 7 – 0.040” PETG Layer 8 – 3M 9474LE Layer 9 – 0.005” Melinex 339 (custom printed)
Laminate Conversion Method	Laser cutting (SIMTG - GHL shop or LasX)
Sample Prep Tube Components	150mg glass beads + novel resin 700uL lysis buffer for Tongue Swab (600uL for Sputum) + peelable foil seal
Lysis Buffer Formulation	20 mM Tris pH 8.8 +/- 0.2 +0.003% v/v ProClin-300 (1uL/1mL = 0.1%)
Sample Prep Tube Configuration	Removable (peel off) foil seal affixed to tube via induction sealing (Thermo Scientific Easy Pierce Heat Sealing Foil, Aluminum, AB-0559)



NAATOS TB V1 | LFA Subassembly | Assembly

NAATOS Lateral Flow Assay (LFA; vertical, side-on view)



STEP	1	2	3	4	5	6
Process	Produce Sample Pad	Produce Amplification Pad	Produce Wax Valve Body	Produce Conjugate Pad	Produce Detection Strip	Produce LFA a. Assemble components 1-7 onto backing card b. Cut into LFA strips
Equipment Required	Curing Oven	1. Lyophilizer and Misc Lyophilization accessories (i.e., silicon mats, trays) 2. Dry cabinet for post-lyophilization storage	1. Custom hardware developed and manufactured by GHL 2. Curing Oven	1. Cuphorn Sonicator 2. Microvolume Spectrophotometer 3. Contact Striper/ Sprayer Dispense System 4. Dry cabinet for post-production storage	1. Contact Striper/ Sprayer Dispense System 2. Dry cabinet for post-production storage	1. Laminator 2. Guillotine Cutting Shear
Environmental Control Required	No	Formulation: cold chain Post-lyo: RH ≤ 5%	No	Post-production: RH ≤ 5%	Post-production: RH ≤ 5%	Post-production: RH ≤ 5%

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NAATOS TB V1 | LFA Subassembly | Components

Variable	Locked Design
Backing Card	Plastic Backing Card Type L-P25, 84mm x 300mm, PVC Laminate 250 µm thick (No slits/cut on these, with adhesive on entire backside of plastic backing)
Sample Pad (blocked)	Cytiva Standard 17, 20 mm
Amplification Pad (blocked, filled, lyophilized)	Cytiva Standard 17, 11 mm, cut to 180 mm (L) x 11 mm (W) strips and BSA blocked
Valve Pad (striped)	Cytiva Standard 17, 20 mm, ntreated, unblocked wax valves
Wax Valve Pad Production Method	Custom striper with Nordsen head & custom nozzle, 0.325 – 0.400 mg/mm
Conjugate Pad (blocked, filled, dried)	Ahlstrom Grade 8964, 8 mm
Detection Antibody[1]	~~FAM mAb, custom clone FAM 2A5 expressed and purified by Exon Bio, 30:1; spray rate 25.8 uL/cm~~ FITC polyclonal (BioRad 4510-7804)
Detection Nanoparticle	MagSphere Blue Latex, carboxylated, 400 nm, 10%
Conjugate formulation[2,3]	0.15% α-FAM-mAb -> 0.15% α-FITC-pAb
Stability Reagents in Detection Strip	1% Sucrose added to each line to increase stability
Analytical Pad (striped)	Sartorius CN95, 25 mm
Test Line Pattern	Asymmetric (from sample pad: 53 mm Test, 58 mm IPC, 60 mm Flow Ctrl)
Test Line Capture Proteins	• DIG mAB clone (DIG 1H7) (1 mg/mL, 1 uL/cm) • Protein A/G (1 mg/mL) • polySA (1 mg/mL)
Cover Tape	MDI Clear CT, 40 mm (transparent cover tape)
Waste Pad	Ahlstrom 270, 17 mm

Variable	Locked Design
Amplification Volume	25 µL
Oligo Design	Targets: Vm, IS1081, IS6110 (8T-linker)
Oligo Concentrations	Primer Sets: 40× Vm, 40× IS1081, 40× IS6110
LAMP Chemistry	ThermoFisher Invitrogen Lyo-ready Bst DNA Polymerase Kit (A56657)
Reaction Buffer Formulation	ThermoFisher Invitrogen 10X Bst Reaction Buffer
Bst Polymerase	ThermoFisher Invitrogen Lyo-ready Bst DNA Polymerase (40 U/µL), 6 U/reaction (previously 15.6 U/rxn on pad for NEB formulation)
Magnesium	ThermoFisher Invitrogen $MgCl_2$, 6 mM in amp pad (previously 8 mM for NEB formulation)
dNTPs	ThermoFisher Thermo Scientific 25 mM dNTP Mix
Excipient Formulation	1% (2-Hydroxypropyl)-β-cyclodextrin / 1% pullulan / 2% trehalose
Lyo Pad Batch Size	10 pads
Lyo Pad QC	QC PASS Criteria: 10 - 17 Ct (IPC)

1. Polyclonal vs monoclonal antibody to be re-evaluate
2. Casein concentration (3%, 6%) may be re-evaluated
3. Replacing Surfactant 10G with Tween20 may be re-evaluated

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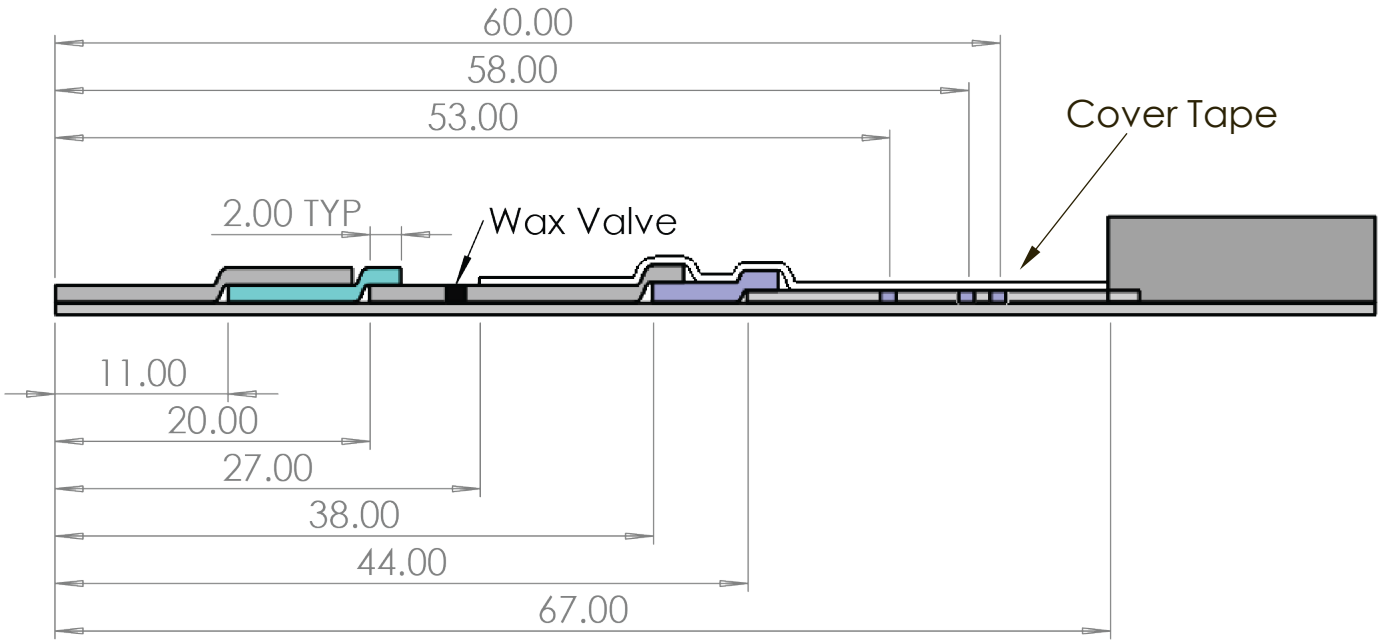
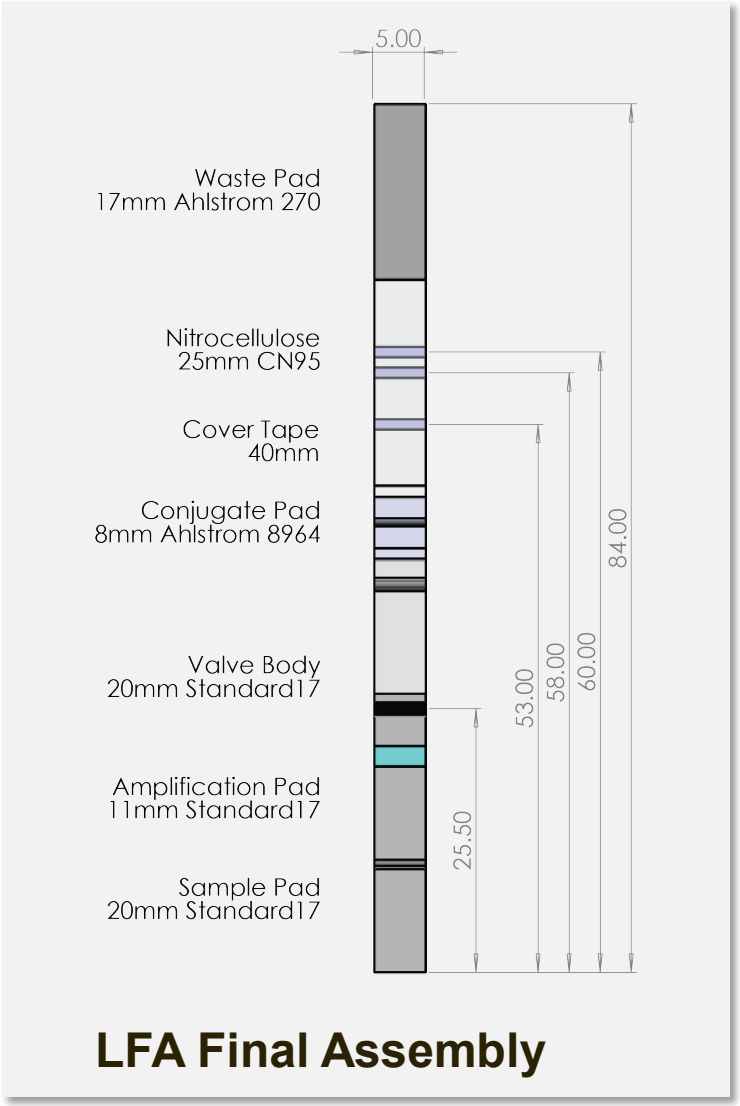
NAATOS TB V1 | LFA Subassembly | Dimensions

LFA Assembly Dimensions (with overlap specifications)





LFA Final Assembly

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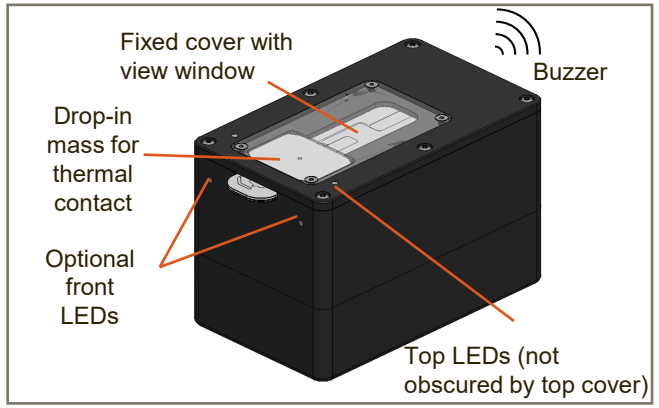
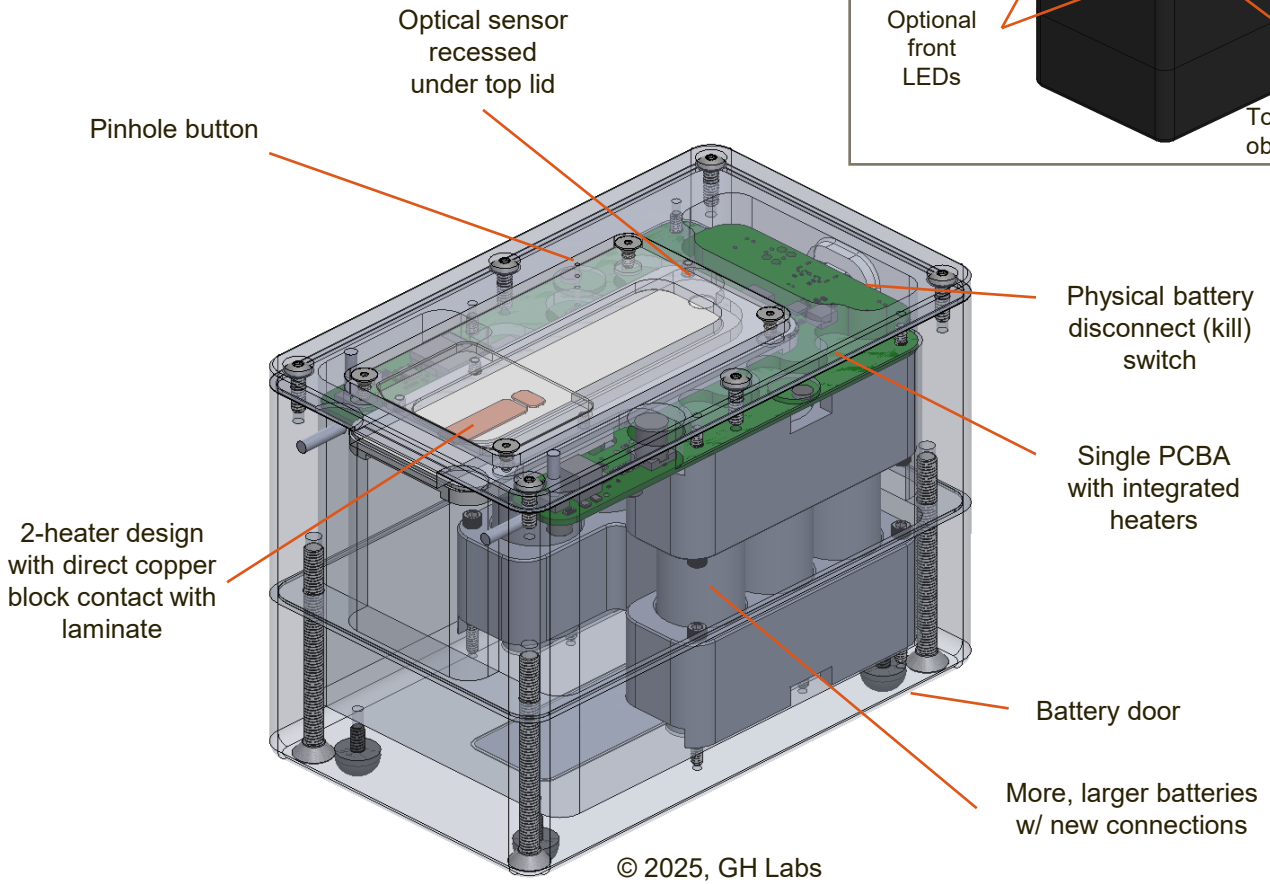
NAATOS TB V1 | Power Module Design | Overview

CCG β module





NAATOS TB V1 Pre-Clinical Readiness | Evaluation of Frozen Tongue Swab Remnants

Product Feature	Product Requirement / Study Acceptance Criteria[1,2]
Invalid/Incomplete Test Rate	≤ 3% (optimal) ≤ 5% (minimal)
Sensitivity	≥75%
Specificity	≥98%

1. WHO **Target product profile for tuberculosis diagnosis and detection of drug resistance.** 14 August 2024 (https://www.who.int/publications/i/item/9789240097698)
2. NAATOS TB v1 PRD and MRD

NAATOS TB Performance | Frozen Clinical Remnant Tongue Swabs

- Dry Tongue Swabs (120 total) collected from patients with signs and symptoms of TB and banked frozen.
- Sample set collected in 4 geographies: Uganda (Qty 60), South Africa (Qty 18), Vietnam (Qty 24), Philippines (Qty 18)
- Uganda samples were previously heat inactivated and frozen prior to testing
- South Africa, Vietnam, and Philippines samples were not heat inactivated, previously frozen

NAATOS TB Kit Details	
Lot	2025-06-12 RG 130:01328 – 130:01343
Device	K.7 (100% Inspection)
Conjugate	α-FITC pAb
Detect	1% Sucrose NC

TB Prevalence	41.7%
Remnant Specimens Tested	**120**
Total External QC Runs	12
Total NAATOS Runs	132
Resolved Specimen Tests	**115**
Total Invalid Runs	5
Total Invalid Rate	**3.8% (5/132)**
Total Aborted/Incomplete Runs	0
Total Abort Rate	**0% (0/132)**
Sensitivity	**69.6% CI_{95} (54.2 – 82.3)**
Specificity	**100% CI_{95} (94.8 – 100.0)**

2x2 table

	Disease Present	Disease Absent	
Test Positive:	32	0	32
Test Negative:	14	69	83
	46	69	

Options

If the ratio of cases in the Disease Present and Disease Absent groups does not reflect the disease prevalence, enter:

disease prevalence (%): 41.7

Results

Sensitivity	69.565%	54.245% to 82.257%
Specificity	100.000%	94.794% to 100.000%
AUC	0.848	0.769 to 0.908
Positive Likelihood Ratio		
Negative Likelihood Ratio	0.304	0.197 to 0.471
Disease prevalence	41.700%	
Positive Predictive Value	100.000%	89.112% to 100.000%
Negative Predictive Value	82.123%	74.796% to 87.671%
Accuracy	87.309%	79.812% to 92.785%

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NAATOS TB Performance | Performance by Geography

K.7

South Africa, Vietnam and Philippines
UCSF Biobank (Cohort 2) Samples Only

	Disease Present	Disease Absent	
Test Positive	7	0	7
Test Negative	7	45	52
	14	45	59
TB Prevalence	25.0% (15/60)		
Invalid	1.7% (1/60)		
Sensitivity	**50.0%**	**CI_{95} (23.0 – 77.0)**	
Specificity	**100%**	**CI_{95} (92.1 – 100.0)**	

K.7

GHL Biobank
Uganda Samples Only

	Disease Present	Disease Absent	
Test Positive	25	0	25
Test Negative	7	24	31
	32	24	56
TB Prevalence	58.3% (35/60)		
Invalid	6.7% (4/60)		
Sensitivity	**78.1%**	**CI_{95} (60.0 – 90.7)**	
Specificity	**100%**	**CI_{95} (85.8 – 100.0)**	

K.7

All Samples Combined

	Disease Present	Disease Absent	
Test Positive	32	0	32
Test Negative	14	69	83
	46	69	115
TB Prevalence	41.7% (50/120)		
Invalid	4.2% (5/120)		
Sensitivity	**69.6%**	**CI_{95} (54.2 – 82.3)**	
Specificity	**100%**	**CI_{95} (94.8 – 100.0)**	

Frozen Specimen Testing Conclusions:

- Cumulatively the Sensitivity of 69.6% is shy of the product requirement (≥ 75%) . However, the Uganda cohort resulted in significantly higher sensitivity (78.1%) than the samples collected in other geographies which has been seen in other studies.
- The overall Invalid Rate (4.2%) met the product requirement (≤ 5%).
- Specificity was exceptional at 100% and exceeded the product requirement (≥ 98%).
- This is the configuration of devices that was sent to a hospital in Uganda where GHL is initiating a pilot study on freshly collected tongue swabs with the R2D2 SMART4TB Grant.

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NAATOS TB Performance | Positive Results Striated by Cepheid Xpert MTB/RIF Ultra Category

		NAATOS TB Test Results (All Sites Combined| Round 3)				
Xpert SemiQuant Category	**Samples Tested (#)**	**TB Detected (TP)**	**TB Not Detected (FN)**	**INVALID (No Result)**	**NAATOSTB Detected/ Total Resolved**	**NAATOS TB % Detected**
HIGH	15	14	0	1	14/14	100.0%
MEDIUM	12	11	1	0	11/12	91.7%
LOW	13	5	6	2	5/11	45.5%
VERY LOW	8	2	6	0	2/8	25.0%
TRACE	0	N/A	N/A	N/A	N/A	N/A
UNKNOWN	2	0	1	1	0/1	0.0%
TOTAL	**50**	**32**	**14**	**4**	**32/46**	**69.6%**

Pre-Clinical Field Evaluation Pilot Study | Timeline

Key
- Completed
- Planned

2025

Q1	Q2	Q3	Q4

Pre-Clinical Readiness Studies

Pilot Study SOP Development, Review and Approvals

GH+ Labs

R2D2 TB Network

SMART4TB Consortium

Pilot Study Site Training

Pre-Clinical Readiness Technical Review

NAATOS v1 Field Evaluation Pilot Study

GOALS:
1) First field testing of NAATOS v1 with clinical tongue swab specimen
2) Establish single point estimate of diagnostic accuracy (Sens/Spec) vs mixed clinical reference

SCOPE:
-Enroll and Test ~30 positive samples (expected enrollment 150 patients (approx. 15/week for 10-12-weeks), prevalence 20-30%) vs mixed reference (GeneXpert + MGIT Culture)
-Tongue Swab Specimen Only

Estimated Enrollment Start Date: Jul 21
Estimated Completion Date: Oct 13

LOCATION:
WALIMU ((Mulago Hospital, Kampala)

walimu
Quality Health Care For Everyone

Pilot Study Outcome Review
Target Date: Oct 20

GHL Closure Nov 1

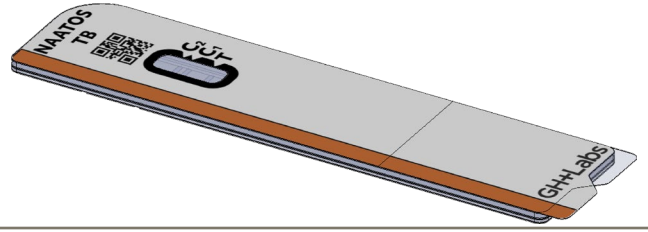
NAATOS TB V1
Analytical Sensitivity (LoD)

Modifications to NAATOS TB Workflow to Accommodate Sputum

1 Collect Tongue Swab, transfer directly into NAATOS Sample Prep Tube and perform NAATOS Sample Prep

NAATOS Sample Prep Tube
(700 uL lysis reagent)

2 Load NAATOS TB Test Device and Initiate Testing



1 Perform Sample Pre-Treatment

20 min

+

Sputum
500 uL

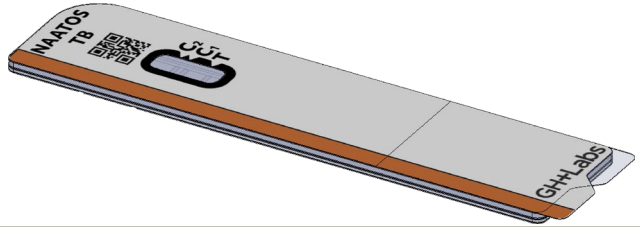
Liquification Reagent
3 drops

2 Transfer liquified sputum and perform NAATOS Sample Prep

Liquified Sputum
100 uL

NAATOS Sample Prep Tube
(600 uL lysis reagent)

3 Load NAATOS TB Test Device and Initiate Testing



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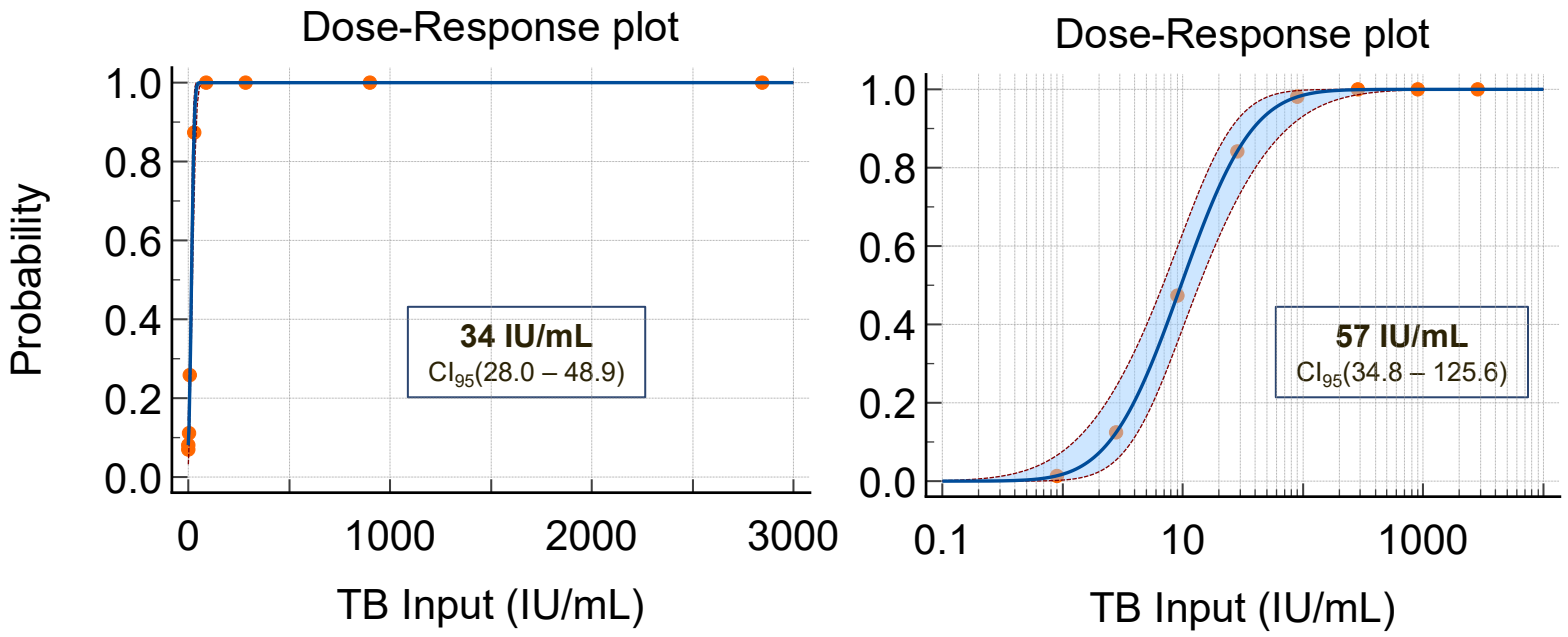
Analytical Sensitivity (LoD) | NAATOS TB Tongue Swab

Dilution	Dose (IU/mL Sample[1])	Total Replicates[2]	NAATOS TB Detected	Response (% Detected)
-1	2,844.0	24	24	100%
-2	898.7	24	24	100%
-3	284.0	24	24	100%
-4	89.7	24	24	100%
Confirmatory	**40**	**20**	**20**	**100%**
-5	28.4	24	20	83.3%
-6	9.0	24	9	37.5%
-7	2.8	24	5	20.8%
-8	0.9	24	0	0%
NTC[3]	0	24	0	0%
INVALID Rate			11/247	4.5%

1. Testing Conducted according to WHO TSS-17 using NIBSC *Mycobacterium tuberculosis* (H37Rv) WHO reference standard (20-152)
2. Testing conducted in 3 rounds with 3 unique serial dilutions over multiple testing days and multiple lots of NAATOS TB Test Devices. Each round consisting of 8 replicates.
3. Negative datapoints included in Probit fit.
4. Tongue swabs collected from healthy donors and pooled.

NAATOS TB v1 Test Device
(Pooled Tongue Swab Matrix[4])



- **Confirmatory LoD Completed at 40 IU/mL (40 genomes/mL) with 100% agreement (20/20)**

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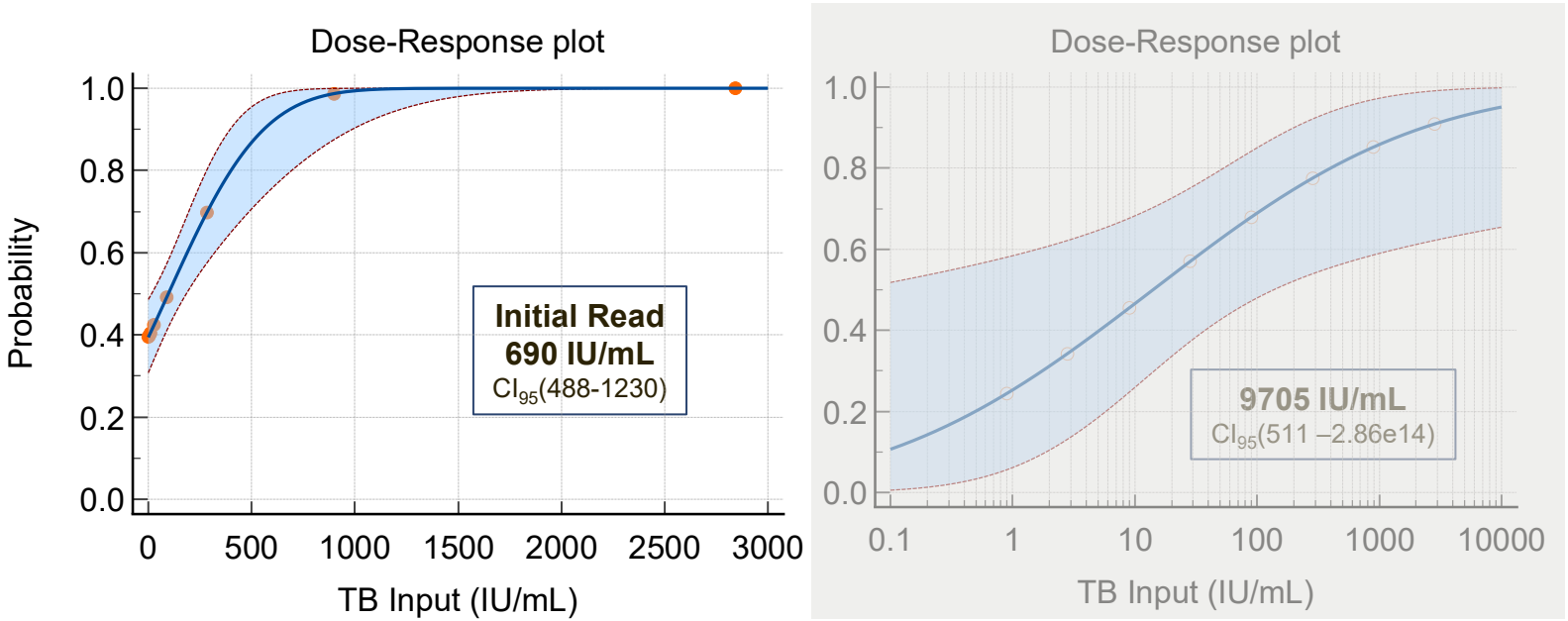
Analytical Sensitivity (LoD) | NAATOS TB Sputum (Initial Read)

Dilution	[FINAL] IU/mL Sample[1]	Total Replicates[2]	NAATOS TB Detected	Response (% Detected)
-1	2,844.0	24	24	100.0%
-2	898.7	24	24	100.0%
-3	284.0	24	15	62.5%
-4	89.7	24	11	45.8%
-5	28.4	24	16	66.7%
-6	9.0	24	5	20.8%
-7	2.8	24	11	45.8%
-8	0.9	24	9	37.5%
NTC[3]	0	24	5	20.8%
INVALID Rate			13/229	5.7%

1. Testing Conducted according to WHO TSS-17 using NIBSC *Mycobacterium tuberculosis* (H37Rv) WHO reference standard
2. Testing conducted in 3 rounds with 3 unique serial dilutions over multiple testing days and multiple lots of NAATOS TB Test Devices. Each round consisting of 8 replicates.
3. Negative datapoints not included in Probit fit.
4. Normal Human Pooled Sputum (Sera Care, Material No. 0375-0002)

NAATOS TB v1 Test Device (Pooled Sputum[4])



- ***LFA clearance on devices run with Sputum was poor at the 30 min read point defined in the Product's Package Insert. For this analytical study we read at 30min (this slide) and then allowed the devices to reach equilibrium with 24hr room temperature incubation and read the next day (i.e., Day 2). This is NOT the Intended Use, therefore optimization for sputum is required. Confirmatory LoD was conducted from 'Day 2' read Probit (Slide 27) and completed at 240 IU/mL.***

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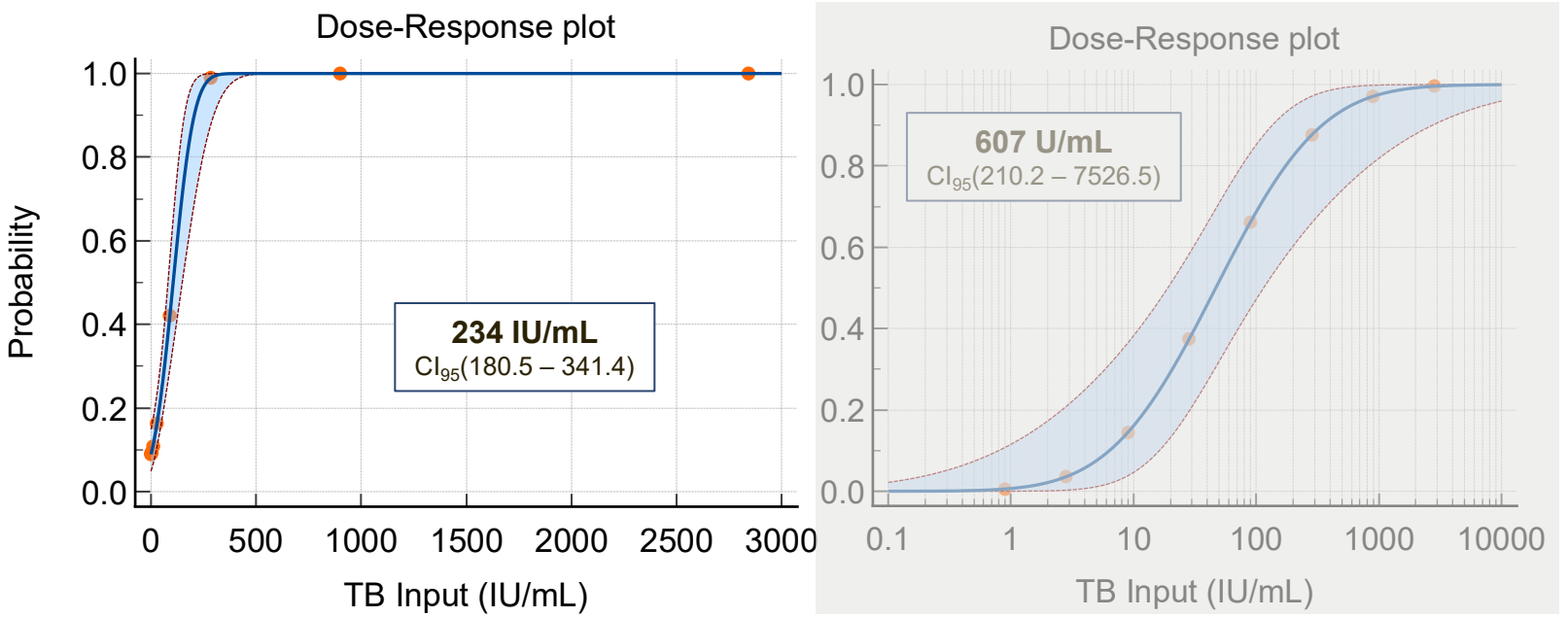
Analytical Sensitivity (LoD) | NAATOS TB Sputum (Day 2 Read)

Dilution	[FINAL] IU/mL Sample[1]	Total Replicates[2]	NAATOS TB Detected[3]	Response (% Detected)
-1	2,844.0	24	24	100.0%
-2	898.7	24	24	100.0%
-3	284.0	24	23	95.8%
Confirmatory	**250**	**20**	**20**	**100.0%**
-4	89.7	24	13	54.2%
-5	28.4	24	7	29.2%
-6	9.0	24	1	4.2%
-7	2.8	24	4	16.7%
-8	0.9	24	0	0.0%
NTC[4]	0	24	0	0.0%
INVALID Rate			13/229	5.7%

1. Testing Conducted according to WHO TSS-17 using NIBSC *Mycobacterium tuberculosis* (H37Rv) WHO reference standard
2. Testing conducted in 3 rounds with 3 unique serial dilutions over multiple testing days and multiple lots of NAATOS TB Test Devices. Each round consisting of 8 replicates.
3. Due to differences in flow properties caused by sputum, the NAATOS TB devices were read after 24hr development (i.e., Day 2) to allow the system to reach equilibrium.
3. Negative datapoints included in Probit fit.
4. Normal Human Pooled Sputum (Sera Care, Material No. 0375-0002)

NAATOS TB v1 Test Device (Pooled Sputum[5])



- **Confirmatory LoD Completed at 250 IU/mL (250 genomes/mL) with 100% agreement (20/20)**

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Competitive Analysis | POC TB Tests

	GHL NAATOS TB v1	PlusLife TB[1]	Cepheid Xpert MTB/RIF Ultra	Cepheid Xpert MTB/RIF
Tongue Swab	**40 genomes/mL**	50 CFU/mL	32.4 – 110.9 CFU/mL[2]	N/A
Sputum	**250 genomes/mL *(unoptimized)***	50 CFU/mL	16 CFU/mL[6]	600 CFU/mL[5] 131 CFU/mL[4] 114 CFU/mL[6]
TTR	36 min	30 min	65min NEG[3] 77min POS[3]	< 2hr
Target Gene	IS6110, IS1081	*gyrB*, IS6110	*rpoB*, IS6110, IS1081	*rpoB*

1. Pluslife Product Info Site (https://www.pluslife.com/productinfo/1268173.html).
2. Preprint. medRxiv. 2024;2024.06.20.24309244. Published 2024 Jun 22. doi:10.1101/2024.06.20.24309244
3. Xpert MTB/RIF Ultra Reference Sheet (https://cepheid.widen.net/view/pdf/aultksfkwg/Cepheid-Xpert-MTB-RIF-Ultra-GPM-Reference-Sheet-CE-IVD-3340-English.pdf)
4. Source*: J Clin Microbiol*. 2010;48(1):229-237. doi:10.1128/JCM.01463-09
5. Cepheid MTB/RIF Package Insert (https://web-support.cepheid.com/Package%20Insert%20Files/Xpert-MTB-RIF-ENGLISH-Package-Insert-301-1404-Rev-G.pdf). Claims analytical sensitivity of 600 CFU/mL for *Mycobacterium tuberculosis* (H37Rv).
6. WHO Knowledge Sharing Platform. Rapid diagnostics for tuberculosis infection (Module 3, Section 2.1) https://tbksp.who.int/en/node/1649

Note: 1 CFU/mL ≥ 1 genome/mL. For a conservative conversion estimate of genomes/mL to CFU/mL use a ratio of 1:1.

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NAATOS TB V1
Analytical Specificity

Target 3 Results: Assay Robustness (Inclusivity/Exclusivity Results)

		Strain QC Testing and Characterization					NAATOS % Agreement			
	Microorganism	16S rRNA qPCR (1 ng/µL)	rpoB qPCR (1 ng/µL)	rpoB ddPCR (0.1 ng/µL)	IS6110 LAMP (~1x10^6 genomes)	IS1081 LAMP (~1x10^6 genomes)	~1x10^6 genomes	0.5X LOD	2X LOD	5X LOD
M. tuberculosis complex (MTBC)	*Mycobacterium africanum* FI10067	+	+	+	+	+	nd	0% (0/3)	100% (3/3)	nd
	Mycobacterium bovis 95-1315	+	+	+	+	+	nd	67% (2/3)	100% (3/3)	nd
	Mycobacterium bovis BGC	+	+	+	+	+	nd	100% (3/3)	100% (3/3)	nd
	Mycobacterium canettii NLA000017120	+	+	+	+	+	nd	0% (0/3)	100% (3/3)	nd
	Mycobacterium caprae NLA000201913	+	+	+	+	+	100% (3/3)	33% (1/3)	0% (0/2**)	100% (3/3)
	Mycobacterium tuberculosis HN878	+	+	+	+	+	nd	100% (3/3)	100% (3/3)	nd
	Mycobacterium tuberculosis H37Ra	+	+	+	+	+	nd	100% (3/3)	100% (2/2**)	nd
Non-tuberculous mycobacteria (NTM)	*Mycobacterium abscessus MC1518*	+	- *	-	-	-	100% (0/3)	nd	nd	nd
	Mycobacterium avium 2285 Rough	+	- *	-	-	-	100% (0/3)	nd	nd	nd
	Mycobacterium leprae NHDP-63	+	-	nd	-	-	100% (0/3)	nd	nd	nd
	Mycobacterium smegmatis mc(2)155	+	- *	-	-	-	100% (0/3)	nd	nd	nd
	Mycobacterium ulcerans S4018	+	- *	-	-	-	100% (0/3)	nd	nd	nd
Oral microbiome	*Acinetobacter baumannii* H72721	+	-	N/A	-	-	100% (0/3)	nd	nd	nd
	Actinomyces odontolyticus F0309	+	-	N/A	-	-	100% (0/3)	nd	nd	nd
	Capnocytophaga sp. Oral Taxon 329 F0087	+	-	N/A	-	-	100% (0/3)	nd	nd	nd
	Fusobacterium periodonticum 1_A_54/D10	+	-	N/A	-	-	100% (0/3)	nd	nd	nd
	Klebsiella pneumoniae Isolate 2	+	-	N/A	-	-	100% (0/3)	nd	nd	nd
	Neisseria sp., Oral Taxon 014 F0314	+	-	N/A	-	-	100% (0/3)	nd	nd	nd

* rpoB curve not as steep as MTC but generated Ct values above threshold; tested using ddPCR using the same primers/probe set and were confirmed negative for Mtb rpoB.
** Dataset contained a single (1) device failure.
nd, no data or not determined

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NAATOS TB V1
Reagent Stability Study (Accelerated Aging)

NAATOS TB V1 | Reagent Stability Test Plan | Overview

Start

End

Conservative Model (Aging Factor 1.8)		WEEK 1		WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 8	WEEK 12	WEEK 14	WEEK 16	WEEK 20	WEEK 21	WEEK 23	WEEK 27	WEEK 28
		Day 0	Day 4													
Accelerated Timepoint* (Ambient 22°C)	**Storage Temp:** 55°C	Day 0 (Mar 19)	30 day (Mar 23)	60 day (day 9) (Mar 28)	3 mo (day 13) (Apr 1)		6 mo (day 26) (Apr 14)	12 mo (day 52*) (May 9)	←	**DEVICES FAIL**	**24 mo (day 105) (Jul 2)** →	30 mo (day 130*) (Jul 28) -> Component		**36 mo (day 157*) (Aug 22)** -> Component		
Accelerated Timepoint* (Ambient 22°C)	**Storage Temp:** 45°C					3 mo (day 23) (Apr 11)		6 mo (day 47) (May 5)		**12mo (day 94*) (Jun 20)** -> Component						**24mo (day 189) (Sep 24)**
Real-time (Ambient 22°C)	**Storage Temp:** 22°C														**6 mo (Sep 19)**	
Total Device Runs (20 POS + 4 NEG/Timepoint)		**24**	**24**	**24**	**24**	**24**	**24**	**48**	**24**	**24**	**24**		**TBD**	**24**	**24**	**TBD**

Incubator 1	Incubator 2	Incubator 3
22°C	45°C	55°C
48 Devices	96 Devices (Kitted)	240 Devices (Kitted)
48 Tubes	96 Tubes (Foil Sealed)	240 Tubes (Foil Sealed)
N/A	Conjugate Pad (1-2 strips) Amp/Collector Pad (1-2 strips) Wax Valve (1-2 strips) NC (1-2 strips) Lysis buffer (10 mL)	Conjugate Pad (2-3 strips) Amp/Collector Pad (2-3 strips) Wax Valve (2-3 strips) NC (2-3 strips) Lysis buffer (10 mL)

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NAATOS TB V1 | Kitted Assembly | Accelerated Stability (55°C) Results

Accelerated Aging Study Conservative Model (Aging Factor 1.8)	WEEK 1		WEEK 2	WEEK 3	WEEK 5	WEEK 8	WEEK 14
	T0 (Day 0)	T1 (Day 4)	T2 (Day 9)	T3 (Day 13)	T5 (Day 26)	T6 (Day 54)	T6 (Day 100)
Storage of Product: Ambient (22°C) **Accelerated Storage Condition:** 55°C	Day 0 (Mar 19)	30 day (Mar 23)	60 day (Mar 28)	3 mo (Apr 1)	6 mo (Apr 14)	12 mo (May 12[a])	~24 mo (Jun 27[d])
Total Runs	26	32	29	29	27	31	24
Invalid Runs	2	7	7	6	3	9	16
Incomplete (Abort) Runs	0	3	0	0	1	1	0
Total Invalid Rate (Includes Incomplete Runs)	**7.7% (2/26)**	**31.3% (10/32)**	**24.1% (7/29)**	**20.7% (6/29)**	**14.8% (4/27)**	**32.3% (10/31)**	**66.7%** (16/24)
Valve Failure Rate	11.5% (3/26)	18.8% (6/32)	17.2% (5/29)	13.8% (4/29)	7.4% (2/27)	12.9% (4/31)	0.0% (0/24)
Condensation Rate	30.8% (8/26)	25.0% (8/32)	20.7% (6/29)	3.4% (1/29)	14.8% (4/27)	22.6% (7/31)	8.3% (2/24)
Percent Agreement	**91.7% (22/24)**	**100.0% (22/22)**	**95.5% (21/22)**	**95.7% (22/23)**	**95.7% (22/23)**	**90.5% (19/21[b,c])**	**62.5% (5/8[e])**
Observations						• **Sample Prep Tubes Fail:** Volume Loss • **Devices Near Failure:** Weak Signal	• **Device Failure: Weak/No signal, invalid rate above 50%.**

a. Shifted test date 2-days due to resource availability
b. Observed significant decrease in signal strength and quality at 12mo aging timepoint.
c. Sample Prep tube volume below the minimum volume required for testing at 12mo timepoint. Sample Prep Tube failure point at 55°C.
d. Shifted test date 5-days to complete within allotted time.
e. NAATOS TB Test Device Failure point at 55°C.

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NAATOS TB V1 | Component Stability | Accelerated Aging (55°C, 30mo)

Accelerated Aging Study Conservative Model (Aging Factor 1.8)	**Day 133**			
Storage of Product: Ambient (22°C) **Accelerated Storage Condition:** 55°C	30 mo (July 29)			
Test Variable	Conjugate Pad	Detect Pad (Nitrocellulose)	Amplification Pad	Wax Valve
Total Runs	24[b,c]	24[b,c]	24[b,c]	24[b,c]
Invalid Runs	0	0	0	0
Total Invalid Rate (Includes Incomplete Runs)	**0% (0/24)**	**0% (0/24)**	**0% (0/24)**	**0% (0/24)**
Percent Agreement	**100% (24/24)**	**100% (24/24)**	**95.8% (23/24)**	**100% (24/24)**
Visual Inspection	**Clean (No NSB), Strong signal**	**Clean (No NSB), Strong signal**	**Some weak TB lines, patchy (all lines)**	**Clean (No NSB), Strong signal**

a. Shifted test date 1-day due to resource availability.
b. Twenty (20) replicates at 10 genomes Mtb/reaction. Sample Prep buffer spiked with genomic DNA.
c. Four(4) negative replicates. Sample Prep buffer only.

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NAATOS TB V1 | Kitted Assembly | Accelerated Stability (45°C) Results

Accelerated Aging Study Conservative Model (Aging Factor 1.8)	WEEK 1 T0 (Day 0)	WEEK 4 T1 (Day 23)	WEEK 8 T2 (Day 47)	WEEK 14 T3 (Day 92)	WEEK 28 T5 (Day 189)
Storage of Product: Ambient (22°C) **Accelerated Storage Condition:** 45°C	Day 0 (Mar 19)	3 mo (Apr 11)	6 mo (May 5)	12 mo (Jun 18[b])	*24mo* *(Sep 24)* *(Device Dependent)*
Total Runs	26	24[a]	27	26	
Invalid Runs	2	2	3	3	
Incomplete (Abort) Runs	0	0	0	0	
Total Invalid Rate (Includes Incomplete Runs)	**7.7% (2/26)**	**8.3% (2/24)**	**11.1% (3/27)**	**11.5% (3/26)**	
Valve Failure Rate	11.5% (3/26)	16.7% (4/24)	11.1% (3/27)	11.5% (3/26)	
Condensation Rate	30.8% (8/26)	12.5% (3/24)	14.8% (4/27)	7.7% (2/26)	
Percent Agreement	**91.7% (22/24)**	**100.0% (22/22)**	**100.0% (24/24)**	**95.7% (22/23)**	

a. Dataset contains twelve (12) additional runs with known user loading error that were removed from analysis.
b. Shifted test date 2-days due to resource availability.

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NAATOS TB V1 | Component Stability | Accelerated Aging (45°C, 12mo)

Accelerated Aging Study Conservative Model (Aging Factor 1.8)	**WEEK 14**			
	T3 (Day 92)			
Storage of Product: Ambient (22°C) **Accelerated Storage Condition:** 45°C	12 mo (Jun 18[a])			
Test Variable	Conjugate Pad	Detect Pad (Nitrocellulose)	Amplification Pad	Wax Valve
Total Runs	24[b,c]	24[b,c]	24[b,c]	24[b,c]
Invalid Runs	0	0	1	1
Total Invalid Rate (Includes Incomplete Runs)	**0% (0/24)**	**0% (0/24)**	**4.2% (1/24)**	**4.2% (1/24)**
Percent Agreement	**100% (24/24)**	**100% (24/24)**	**100.0% (23/23)**	**100.0% (23/23)**
Visual Inspection	**Clean (No NSB), Strong signal**	**Clean (No NSB), Strong signal**	**Clean (No NSB), Strong signal**	**Clean (No NSB), Strong signal**

a. Shifted test date 2-days due to resource availability.
b. Twenty (20) replicates at 10 genomes Mtb/reaction. Sample Prep buffer spiked with genomic DNA.
c. Four(4) negative replicates. Sample Prep buffer only.

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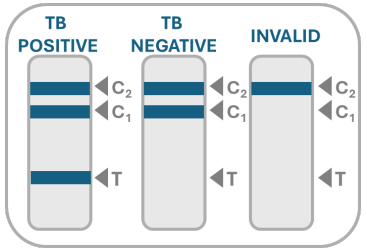
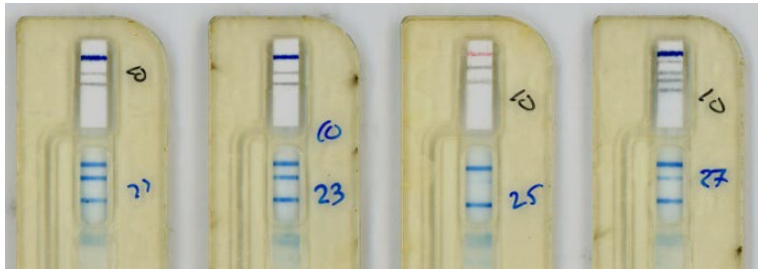
NAATOS TB V1 | Accelerated Aging | Device Images

Interpretation Legend



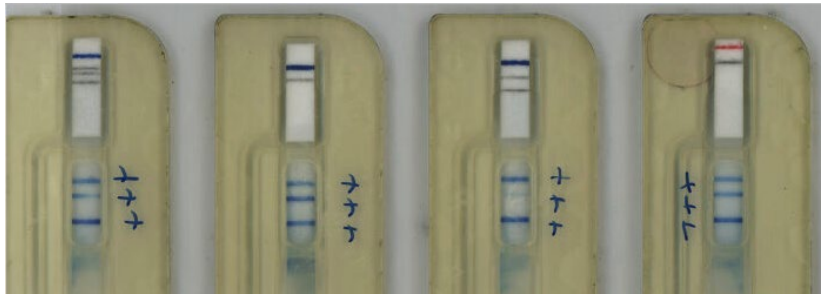
Baseline (Day 0)

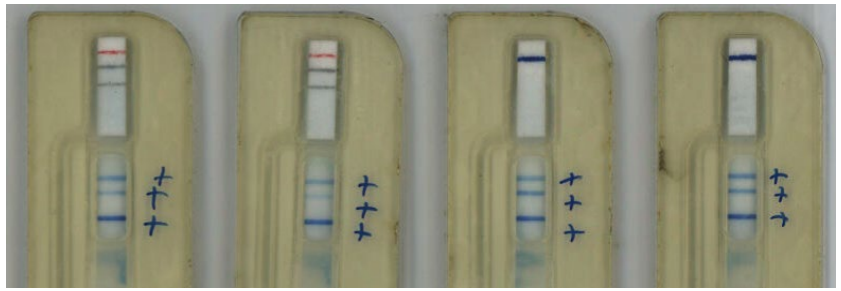


55°C

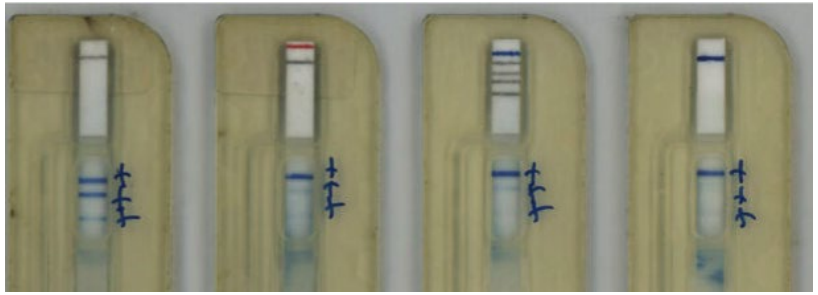
45°C

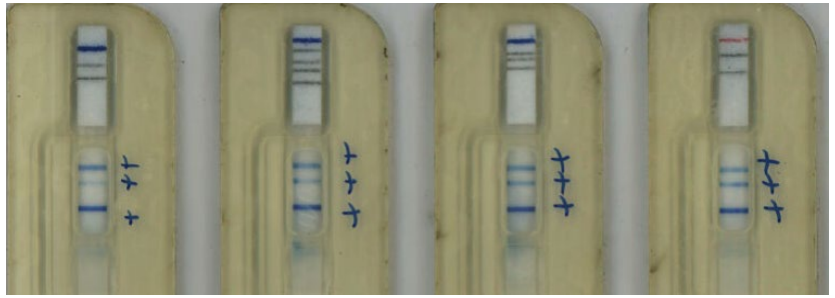
Accelerated Aging (6mo)



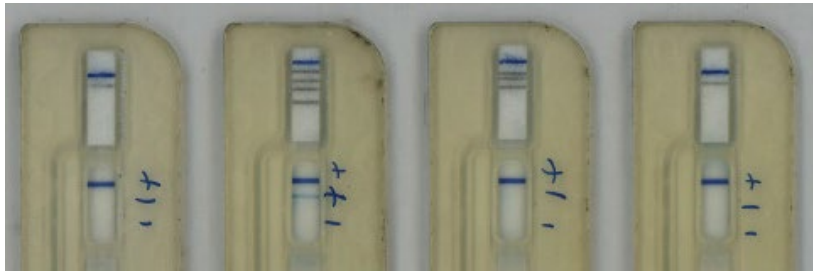


Accelerated Aging (12mo)





Accelerated Aging (24mo)



Pending

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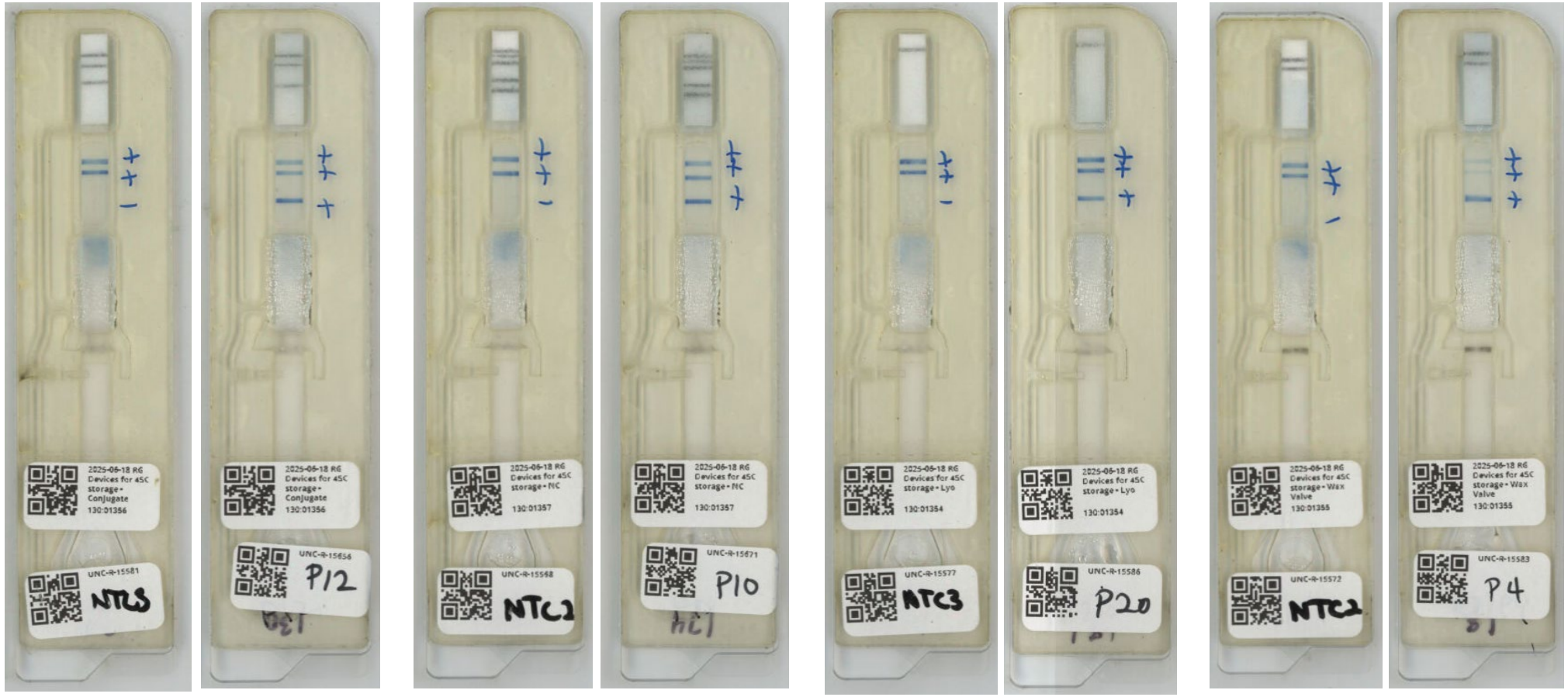
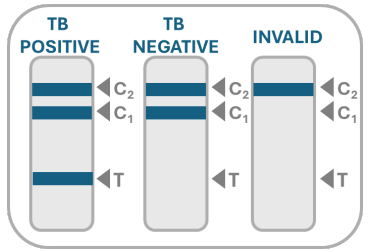
NAATOS TB V1 | Component Stability | Accelerated Aging (45°C, 12mo)

Conjugate Pad[a]		Detect Pad (Nitrocellulose)[a]		Amplification Pad[a]		Wax Valve[a]	
NEG	POS	NEG	POS	NEG	POS	NEG	POS



Interpretation Legend



a. K.7 Test devices with α-FITC polyclonal antibody conjugate.

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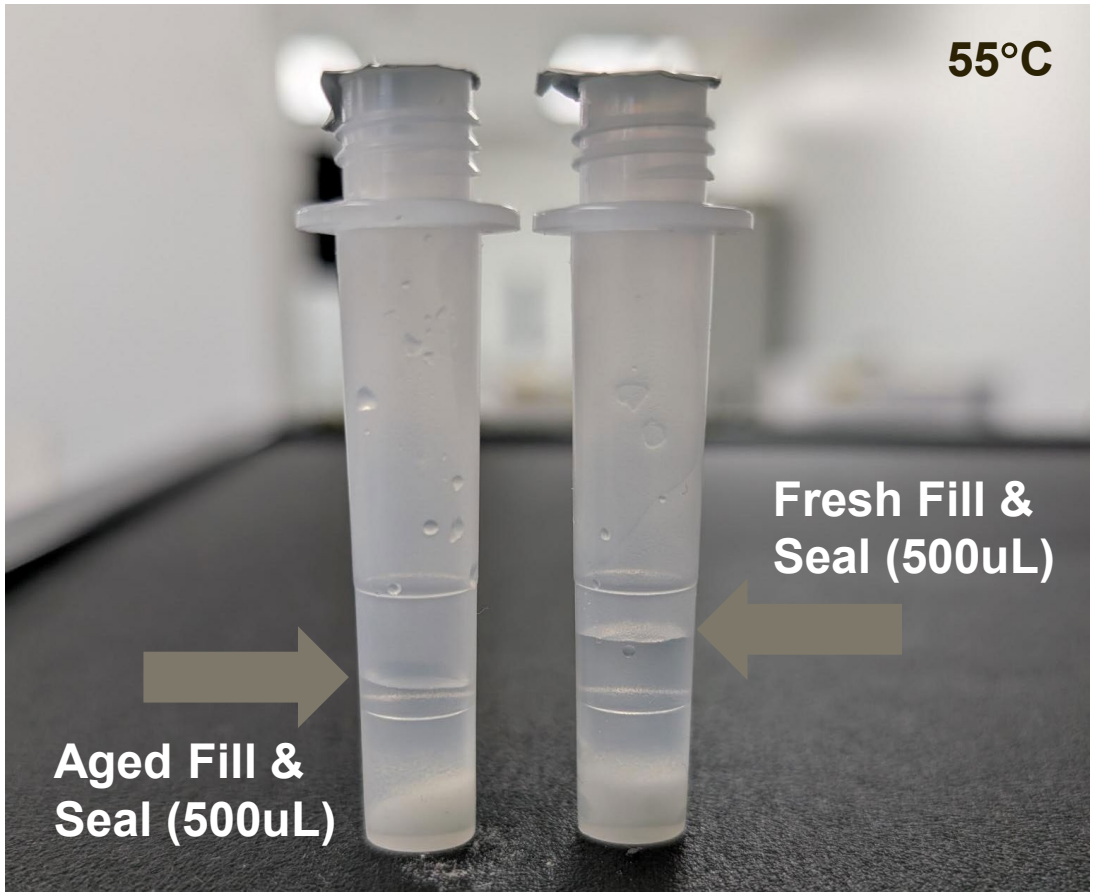
NAATOS TB V1 | Accelerated Aging | Accelerated (55°C)

Sample Prep Tubes fail at 6 months due to volume loss

Accelerated Aging (6 mo)



- All tube seals can withstand a hand squeeze tests at time of production, but evaporation is still escaping somewhere through foil seal or directly through tube.
- Process and/or materials require further optimization for this to be ‘product ready’.
- During reagent stability study the team visually inspected to ensure sufficient loading volume.
- After the 6mo 55°C timepoint (8 weeks) the Sample Prep Tubes were unusable due to insufficient volume. Aged buffer (stored in bulk) was used for remaining accelerated aging tests.
- *Note: To improve the usability and product robustness we also moved from 500uL to 700uL.*

NAATOS TB V1 | Stability Study | Original Component Results

- Blanks showed little change over time
- No changes due to high temp conjugate pads
- *Progressively lower signals for high temp 0% sucrose membranes over time*
- *The presence of 1% sucrose protected membranes from damage at high temp conditions*

					Average Peak Value by Week				
Format	Sample	% Membrane Sucrose	Membrane Temp	Conjugate Pad Temp	0	1	2	4	8
Dipsticks	Blnk	0	25	25	0.6	0.0	0.0	0.6	0.0
				55		0.1	1.1	0.0	
			55	25		0.3	0.0	0.7	0.1
		1	25	25	0.8	0.0	1.0	0.9	0.0
				55		0.1	0.7	0.4	
			55	25		0.0	0.4	0.6	0.4
	Low	0	25	25	14.6	12.6	14.3	13.7	13.4
				55		11.2	13.9	14.0	
			55	25		7.0	8.0	5.3	4.1
		1	25	25	14.3	11.4	13.6	15.1	14.8
				55		12.4	14.9	13.7	
			55	25		15.0	13.0	11.7	15.8
	Mid	0	25	25	41.5	44.3	43.3	43.6	34.6
				55		40.8	45.7	42.2	
			55	25		25.8	28.5	20.8	16.5
		1	25	25	42.8	41.9	43.3	45.3	38.7
				55		43.5	46.5	47.1	
			55	25		45.4	45.2	46.8	41.3
E.1 Devices	Blnk	0	25	25	0.6		0.5	0.7	
			55	55		2.1	1.8	0.0	
		1	25	25	0.6		0.8	0.7	
			55	55		1.5	0.5	0.0	
	Low	0	25	25	19.2		10.3	11.3	
			55	55		8.9	9.6	9.1	
		1	25	25	16.1		7.5	13.8	
			55	55		13.3	12.7	13.9	

NAATOS TB V1 | Stability Study | Conclusions

- Accelerated aging studies were initiated on fully kitted (i.e., individual packaged, mylar bag sealed with desiccant pouch) NAATOS TB v1 Test Devices and Sample Prep Tubes at both 45°C and 55°C accelerated aging conditions.

- Both conditions are monitored with functional testing at intervals to approximate up to 24 months ambient (22°C) storage with a conservative aging factor (1.8).

- Product degradation was observed in fully kitted NAATOS TB v1 Test Devices under accelerated aging at 55°C by an approximated 12-month aging (Week 8) with total degradation and complete failure at the 24-month aging timepoint (Week 14). The root cause of failure at 55°C is unknown and currently under investigation.

- The NAATOS TB v1 Sample Prep Tubes failed stability testing at 55°C at the 12-month aging (Week 8) timepoint due to loss of volume. The Sample Prep tube manufacturing process and packaging needs additional development work and further stability testing.

- All fully kitted NAATOS TB v1 Test Devices and all raw material components aged at 45°C have demonstrated accelerated stability up to 12 months without any degradations. The 45°C accelerated aging study is ongoing with the final 24-month timepoint scheduled for late September.

NAATOS TB V1 Biosafety Study

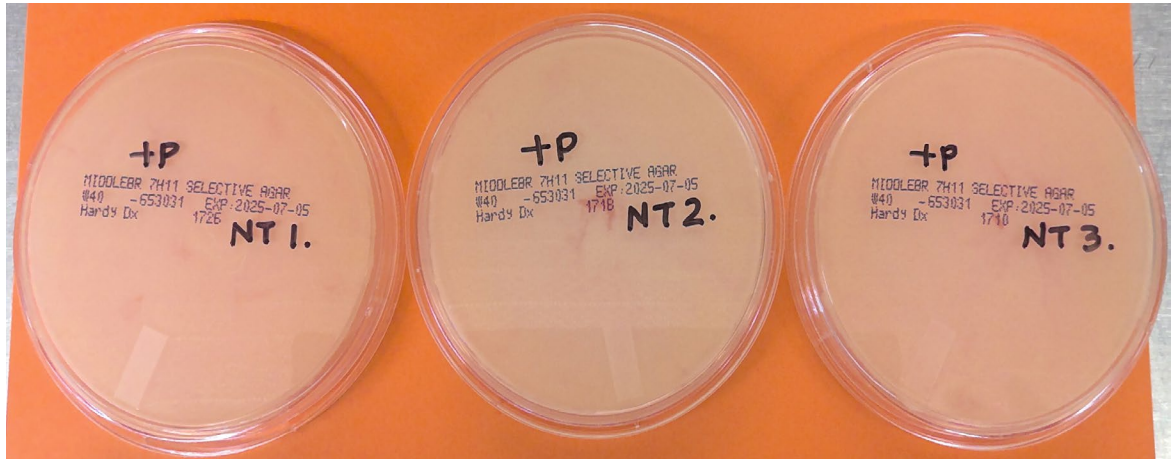
NAATOS TB V1 | Biosafety Results | 8 weeks

- A biosafety study was conducted to ensure the NAATOS Sample Prep Module gamma version and buffer system can completely lyse Mtb cells.
- For this experiment, test samples were contrived at very high concentrations of Mtb (5.0e8 cells/mL) from freshly cultured cells.
- The contrived samples were processed in the NAATOS Sample Prep Module and plated on culture plates.
- Six (6) modules were evaluated in the study.
- Growth was monitored for 8 weeks.

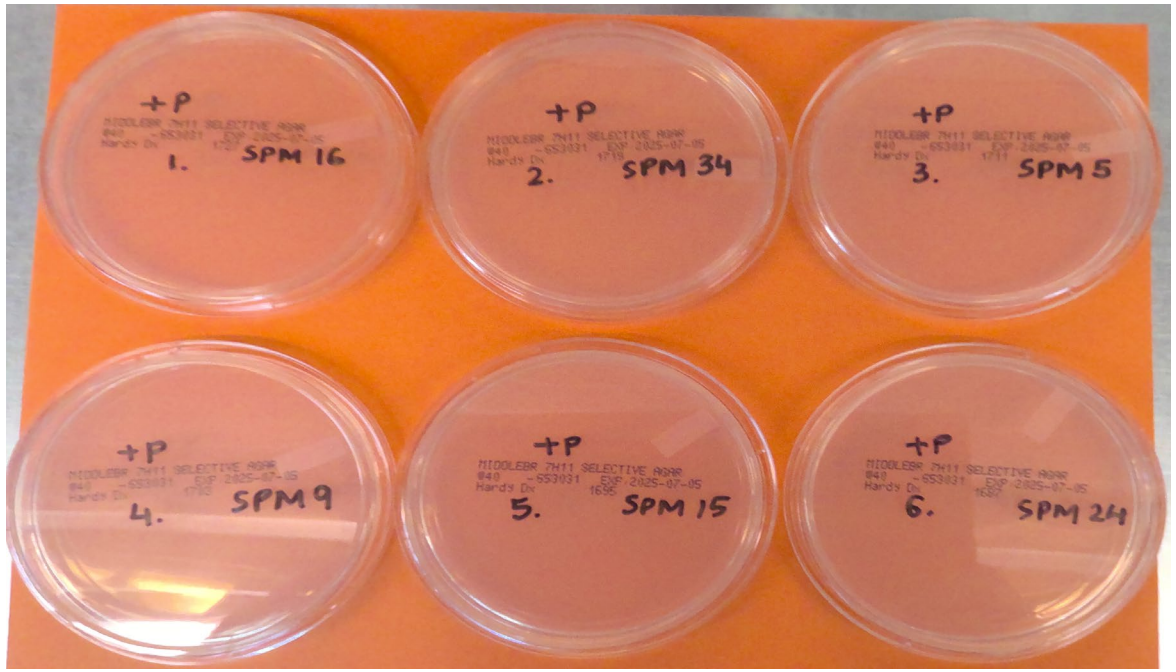
Outcomes:

- Plates with untreated samples had robust Mtb growth.
- Samples processed on the NAATOS Sample Prep Module (γ) had no growth at 8 weeks indicating no viable Mtb cells present after processing on the NAATOS Sample Prep Module.

No Treatment Controls (Mtb H37Ra)



Mtb H37Ra Samples (5.0e8cells/mL) Processed on NAATOS Sample Prep Module



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NAATOS TB V1
Final Configuration Testing Takeaways and Learnings

NAATOS TB V1 | Outcomes

Complete design lock and confirm System readiness for use in pre-clinical pilot study.

Development Goals		Outcomes
NAATOS TB v1 Test Kit	Fully packaged, labeled Test Kit provided by DCN. All sub-assemblies from CDMO partners	Manufacturing goals for the product were not yet met.
Sample Prep Tube Consumable	Sample Prep Tube Consumable Mfg via CDMO fill-and-seal partner	GHL team manually produced all Sample Prep Tubes used.
Test Device Consumable	Completely Mfg'd and packaged by manufacturing partner w/ laminate layers provided by converter and wax valves provided by GHL	GHL team manually produced all Test Device Consumables used in the study. Some component were provided by a partners.
Sample Prep Module	Characterize performance of beta version (CCG)	Goal met; Activities Completed
Power Module	Characterize performance of gamma version (CCG)	Goal met; Activities Completed
Intended Use (Expand Specimen Claims)	Characterize performance of the NAATOS TB System with both tongue swab and sputum specimens to determine if the Intended Use can be expanded to include both specimen types	Goal met; Activities Completed
Preclinical Readiness	Demonstrate the NAATOS TB v1 System can meet or exceed the target clinical performance parameters of frozen retrospective samples prior to initiation of a pre-clinical field study in Q2	Goal met; Activities Completed Preclinical Pilot Study Initiated
Improve Turn Around Time (TAT)	Demonstrate 30 min sample-to-result workflow. Characterize performance of new ThermoFisher LAMP amplification reagents at 30 min TAT	Goal met; Activities Completed
Analytical Sensitivity	Measure Analytical Sensitivity (LoD) per WHO TSS-17	Goal met; Activities Completed
Reagent Stability	Demonstrate the NAATOS TB v1 System can meet or exceed the target kitted stability parameters with accelerated aging studies	In progress. Goal (24mo stability) was not met at accelerated temps of 55°C and root cause under investigation. Studies are ongoing at lower temp.
Biosafety	Conduct biosafety studies to ensure the System is completely inactivating Mtb samples	Goal met; Activities Completed

NAATOS TB V1 | Test Consumable | Learnings

	Indicator	Learnings	Path to Scale	Risks	Solution(s) / Mitigation(s)
Laminate Design and Production	• Invalid/Device Failure Rates >5% • Condensation Phenomenon	• Fluidic valving in the NAATOS device is tightly linked to a channel tolerance in Layer 3 of the consumable. • This tolerance is critical for consumable performance, but hard to control via the current production method (i.e., Laser cutting). • Channel width over specification (i.e., too wide) = premature valve failure. • Channel width under specification (i.e., too narrow) = stalled flow.	Undefined. Rotary die cutting and high-speed laser cutting have both been investigated, but not with K.7 or in-line LFA integration.	• Poor product Performance • Product Assembly Complexity • Production cost • Laminate layer sourcing	Alternative consumable designs (e.g., non-laminate, molded cartridge) that are more amenable to manufacturing at scale.
Consumable Feature: Vents	• Invalid / Device Failure Rates >5%, specifically Invalids caused by stalled flow	• The current air vents are constructed from laser cut pores integrated into a laminate layer • Vents can be overloaded with sample if device is overfilled or handled improperly, leading to blocked vents and stalled flow.	Undefined. In-line hydrophobic material inlays were investigated and may work at scale, but the integration of hydrophobic filters increases layer count, assembly complexity, cost, and did not completely relieve occasional fluid blockages.	• Poor product Performance • Product Assembly Complexity • Production cost	Further development, to evaluate alternative valving concepts in laminate (e.g., Porex membranes). Alternative consumable designs.
Consumable Feature: Wax Valve	• Invalid/Device Failure Rates >5% • Condensation Phenomenon	• Fluidic valving in the NAATOS device requires tight coupling of the wax valve to the pinch point in Layer 3 of the consumable. • The wax valve to Layer 3 coupling requires the dimensions of both the wax valve and pinch point to be tightly controlled and precise manual alignment by the assembler.	Undefined. Wax valve production process require wax deposition onto a glass fiber substrate with highly customized production equipment and is not well-controlled. Assembly of the wax valve into the laminate channel requires precise, manual placement. Path to scale this process is unclear. is not well-controlled.	• Poor product Performance • Critical reagent (Freeman wax) is a sole-source proprietary blend • Highly complex assembly, not amenable to automation • Production cost	Alternative wax valve designs, that 1) do not require wax deposition onto a glass fiber substrate, and 2) do not require Freeman wax for performance should be considered. Alternative consumable designs that enable automated (e.g., pick and place) LFA placement should be considered.

NAATOS TB V1 | Product/Kit | Learnings

	Indicator	Learnings	Path to Scale	Risks	Solution/ Mitigation
Sputum	Poor analytical LoD	Preliminary LoD measurement performed with sputum result in LoDs that are 6-20X higher that tongue swab.	Undefined. Optimization of formulations for sputum have not been performed	• Poor product performance • Regulatory risk to a tongue-swab only product	Optimize the assay (e.g., sample input volume, dried reagents, buffers, etc.) for this sample type to achieve performance similar to tongue swabs.
Sample Prep Tube	• Accelerated stability failed after 8wks of storage at 55C due to evaporation, suggesting this format might have poor long-term stability.	• Current tube Material is very soft and deforms under fill and seal conditions. • Once deformed it cannot be capped. • Current materials may not be suitable for 2yr room temperature storage in target environments without redesigned packaging.	Undefined. Higher-heat material is desirable during sample prep heating, but flexible material is desirable during transfer of lysate to test consumable Due to the combination of 1) small tube diameter and 2) soft tube material, the current "Fill-and-Seal" process requires operators to manually emboss each foil seal with a coining cap to produce a sealing ridge before induction sealing. This process is manual, time-consuming and may be difficult to scale.	• Poor product performance • Poor Shelf-life • Cost and Complexity to manufacture	Alternative tube Alternative sealing foil material Secondary storage (e.g., pouch) Process optimization

NAATOS TB V1 | Modules | Learnings

	Indicator	Learnings	Path to Scale	Risks	Solution/ Mitigation
Sample Prep Module	• Large size/weight of module due to suboptimal battery configuration	• Tube holder/retainer feature is not user friendly • Performance of gamma module is fantastic, but device is bulky, nosier than the alpha unit, and tends to 'dance' across the table if feet aren't well adhered	• Optimize power/battery system to minimize cost/size/weight • Optimize low-power-modes while device is in standby • Injection molded housing to reduce cost • Adding ambient temperature sensor to better control temperature at extreme ends of ambient.	High cost	Further development • Redesign power/battery system • Redesign housing • Redesign tube holder/retainer • Optimize firmware
Power Module	Inoperable device due to: • File system corruption (1 unit) • Optical sensor failure (1 unit) NAATOS Device failure due to device out of calibration (1 unit).	• File system is not necessary for product	• Optimize power/battery system to minimize cost/size/weight • Optimize low-power-modes while device is in standby • Injection molded housing to reduce cost • Adding ambient temperature sensor to better control temperature at extreme ends of ambient.	High cost	Further development • Redesign power/battery system • Redesign housing • Optimize firmware

NAATOS TB V1 | Final Development Status at GHL

Phase 20

Critical Subassemblies	Specifications Finalized (i.e., Design Locked)	Production Process Defined (Prototype Scale)	Quality Testing/ Inspection Procedure(s) Finalized	Tolerance(s)/ Acceptance Criteria Finalized	Production Process Finalized (Pilot Mfg Scale)
NAATOS TB Test Device					
Laminate					
Wax Valve					
Lyophilized Amplification Pad					
Lateral Flow (Detection) Strip					
Sample Prep Tube					
Sample Prep Module					
Power Module					

Key: Complete; Near Complete *(Would Benefit from Further Optimization)*; Work In Progress; Not Started *(Uses Common and/or Well-Known Processes)*; Not Started/Unknown

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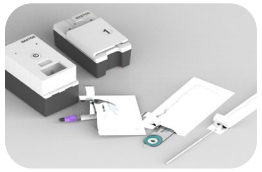
NAATOS V2
Product Overview

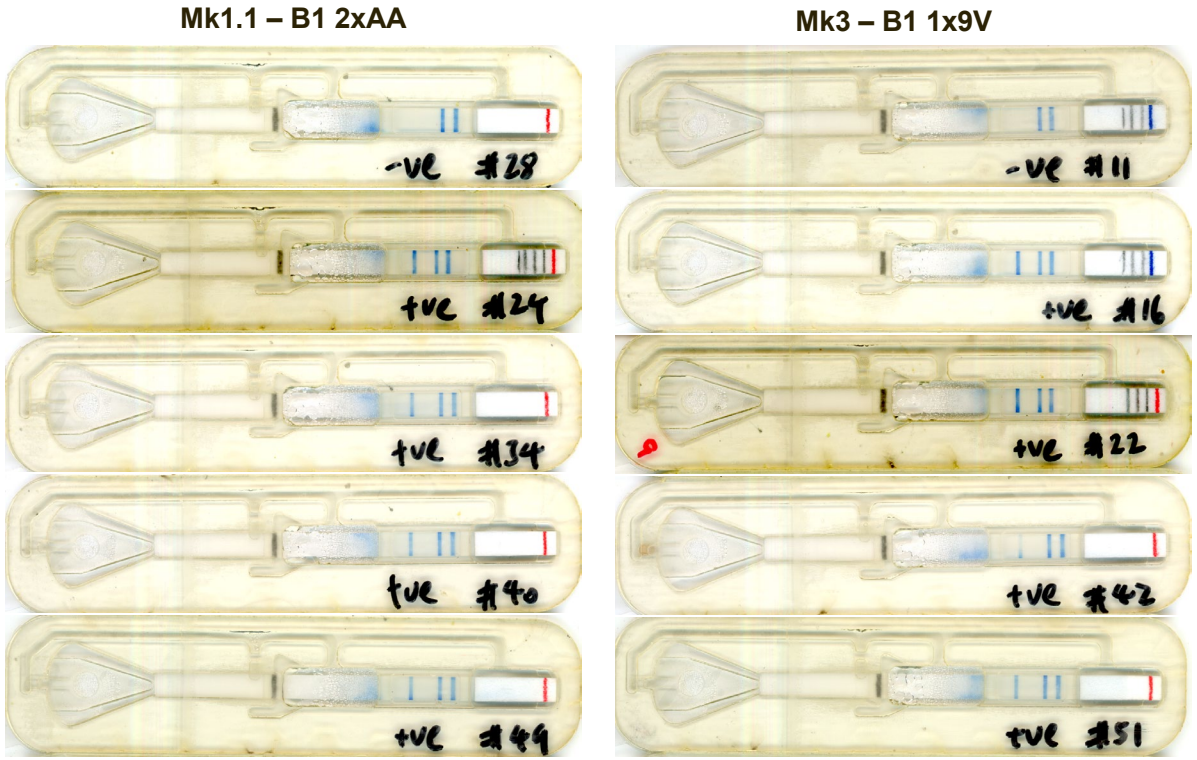
Key product differences v2 vs. v1

Requirement	v1 	v2 
Usability – Indications: must visually communicate progress and completion of system processes.	Visual indications on power module	Visual progress onboard
Usability – Portability: must be a hand transportable product that weighs less than < 1 kg.	System includes 2 modules and a TB-specific consumable test kit	System includes one (or no, depending on target analyte) modules and a disease-specific consumable test kit
Compatibility with health infrastructure – Mains power time: must require no more than 8 hours of mains power per day.	The modules take no longer than 6 hours to charge to full capacity	No mains power required. Uses commodity alkaline batteries or USB-C providing 1.5A
Conformity with clinical workflows – User interactions: must not require more than 3 user interactions after collecting the specimen and before recording the result.	3 user interactions after sample preparation.	No instrument required after sample preparation
Scalability to support patient throughput – Daily throughput, Random access: must be able to support a daily throughput of 10-25 tests per 6-hour day. must offer random access capability to run parallel analyses of tests.	Depended on instrumentation – power module configuration	Independent of instrumentation, throughput proportional to availability of test consumables (up to limit of sample prep module, depending on target analyte)

Battery powered PCBs support LAMP in NAATOS laminates

2xAA or 1x9V provide sufficient energy for amplification & valve actuation

- **Setup:**
  - Test performed on five Mk1.1 and six Mk3 devices
  - Batteries:
    - Mk1.1: 9V (Amazon)
    - Mk3: 2x AA (Amazon or Kirkland)
- **Results:**
  - Success rate: 42/46 (91.3%)*
    - 2 PCBs had higher than designed resistance leading to running under temp.
  - Valve opened within the 5 min heating period: 40/46 (87%)
    - Valves that opened late resulted from battery variability (Amazon Basics = Bad)



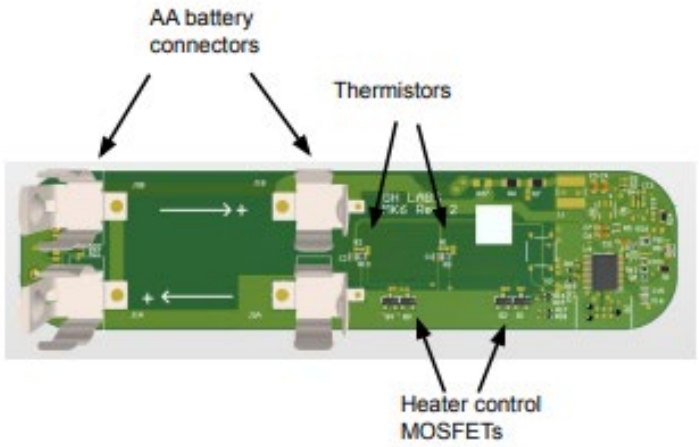
NAATOS V2
System Overview

NAATOS V2 | Product Concepts | Key Components

Bringing NAAT level performance on-a-strip at LFA-like cost, usability, and manufacturability to PHC.

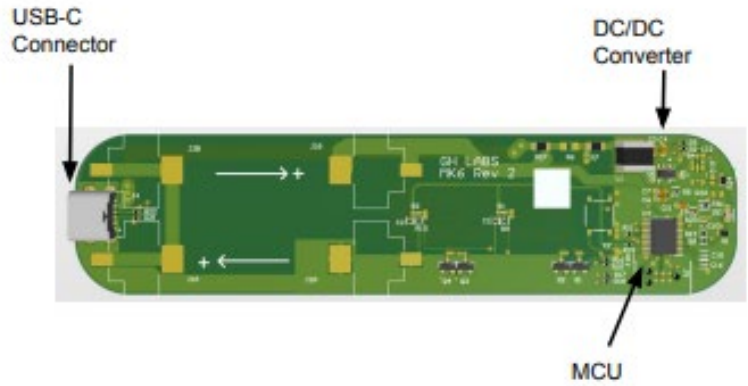
Powered by batteries

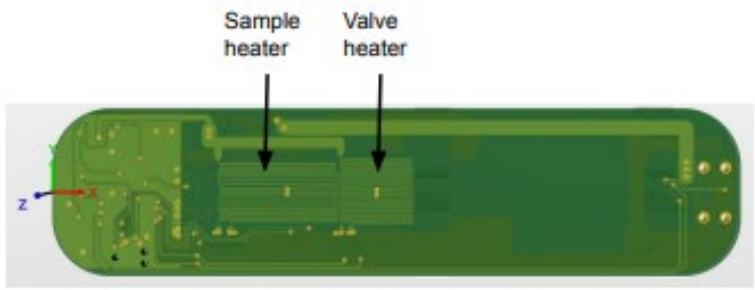
- Onboard Power – Alkaline Batteries



Powered by USB-C

- Onboard Power – USB-C





NAATOS V2 | Product Concepts | BOM comparison

Bringing NAAT level performance on-a-strip at LFA-like cost, usability, and manufacturability to PHC.

Powered by batteries

- Onboard Power – Alkaline Batteries

• Core Electronics	$0.22
• MCU, thermistors, heater control	
• Printed Circuit Board (PCB)	$0.16
• Power	
• AA Batteries (2)	$0.16
• AA battery clips (4)	$0.20
• PCBA Manufacturing / Test	$0.08
Total PCBA Cost Estimate (@ 10k build quantity)	$0.82

Powered by USB-C

- External Power – USB-C

• Core Electronics	$0.22
• MCU, thermistors, heater control	
• Printed Circuit Board (PCB)	$0.16
• Power	
• USB-C connector	$0.013
• DC/DC converter circuit	$0.05
• PCBA Manufacturing / Test	$0.08
Total PCBA Cost Estimate (@ 10k build quantity)	$0.52

NAATOS V2 | Electronics | Detailed BOM Cost Estimates

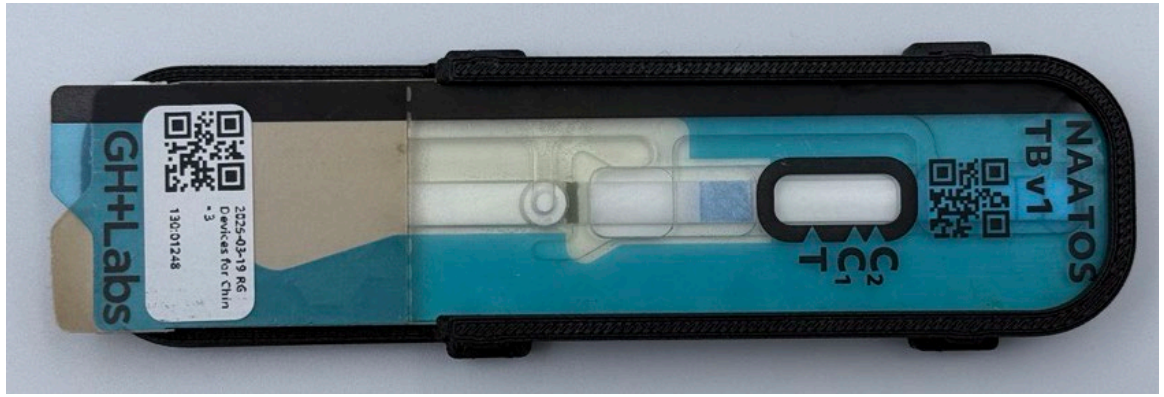
Description	Qty MK6C	Qty MK6AA			Unit Price	MK6C (USB) Subtotal	MK6AA (Batt) Subtotal
Ferrite Bead, 470Ω @ 100MHz, 0603	1	1	FH风华	CBW160808U471T	$0.00200	0.002	0.002
Cap, Ceramic, 0.001uF, 16V, X7R, 0402	2	2	微容(VIIYONG)	V102J0402C0G500NBT	$0.00200	0.004	0.004
Cap, Ceramic 100nF, 10V, X7R, 0402	4	4	Samsung	CL05B104KP5NNNC	$0.00055	0.002194286	0.002194286
Cap, Ceramic 10uF, 10V, X7R, 0402	5	3	三环	TCC0603X5R106M160CT	$0.00480	0.024	0.0144
Res, 100kΩ, 1%, 0402	4	3	VO翔胜	SCR0402F100K	$0.00200	0.008	0.006
MOSFET, N-CH, SOT-23	4	4	HXY Mosfet	DMG2302	$0.00857	0.034285714	0.034285714
Thermistor, NTC, 100k, 1%, 4250k, 0402	2	2	顺络(Sunlord)	SDNT1005X104F4250FTF	$0.00634	0.012685714	0.012685714
IC, DC-DC, SOT23-5	1	0	TI	TLV62569DBVR	$0.03000	0.03	0
IC, MCU, ARM Cortex M0+, TSSOP-20	1	1	Puya Semiconductor	PY32F003F18P6TU	$0.13000	0.13	0.13
Res, 0Ω, 1%, 0805	2	2	VO翔胜	SCR0805F0R	$0.00069	0.001371429	0.001371429
Res, 0Ω, 1%, 0603	1	1	VO翔胜	SCR0603J0R	$0.00026	0.000264	0.000264
Res, 1KΩ, 1%, 0603	1	1	VO翔胜	SCR0603F1K	$0.00034	0.000339429	0.000339429
Res, 5.1KΩ, 1%, 0402	2	2	VO翔胜	SCR0402F5K1	$0.00020	0.0004	0.0004
Res, 10KΩ, 1%, 0402	8	7	VO翔胜	SCR0402F10K	$0.00020	0.0016	0.0014
Res, 316KΩ, 1%, 0402	1	0	VO翔胜	SCR0402F316K	$0.00020	0.0002	0
Ind, 2.2uH, 3.95A, 17 mohm DCR, shielded	1	0	CENKER(岑科)	CKCS5040-2.2uH/M	$0.01886	0.018857143	0
LED, Red, side mount	1	1	HLS		$0.00257	0.002571429	0.002571429
USB-C Connector, power only	1	0	XTJ	TYPE C 6P 四脚插	$0.01234	0.012342857	0
Battery terminals, SMT	0	4			0.05	0	0.2
Battery, AA, Alkaline	0	2			0.07	0	0.14
PCB, 120 x 29 mm, 2 layer, 5 mil min trace width	1	1			0.16	0.16	0.16
			Total electronics BOM			**0.445112**	**0.711912**

NAATOS V2 | Power | Alkaline vs. USB-C

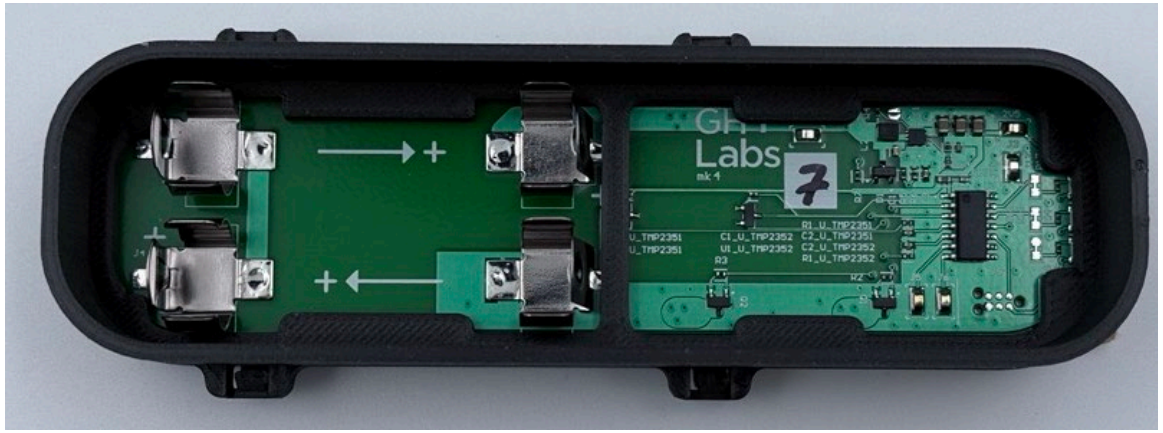
Bringing NAAT level performance on-a-strip at LFA-like cost, usability, and manufacturability to PHC.

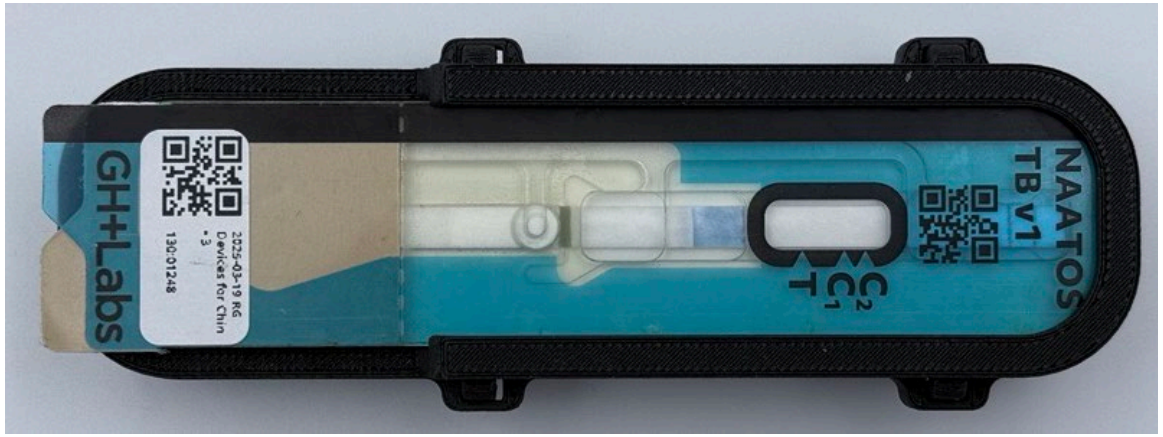
Criteria	*Alkaline Batteries*	*USB-C*
Development Simplicity	Simple, with established battery technology.	Simplifies device by removing internal power design.
Availability	✓ Alkaline batteries are widely available and easily replaceable in most markets	✗ USB-C is common, but only certain devices/cables provide the required amperage (1.5A)
Initial Cost	Moderate cost; alkaline batteries are low-cost	Lower cost components on-board, but requires re-usable externals (power bank, or mains adapter)
Scalability	Scalable for remote and low-infrastructure settings	Scalable for remote and low-infrastructure settings when paired with rechargeable power bank
Portability	Highly portable, all requirements met on-board	Portable when paired with portable power source
Instrumentation	✓ No dependency on other devices for power	✗ Dependent on other devices for power
User Familiarity	Users are familiar with batteries.	Users are familiar with connecting devices via USB-C.
Infrastructure Dependency	✓ On-board batteries increase shipping weight/dimensions	✗ Requires either mains power + charger or power bank
Operational Complexity	Low complexity; device operable out of package	Higher complexity as individual devices must be connected to power to start test
Environmental Sustainability	✗ High environmental impact due to disposable battery waste	✓ More sustainable by avoiding battery waste
Risk of User Error	Risk that user neglects to activate battery connection	Risk that user neglects to connect power
Cost Over Lifecycle	Slightly higher per test cost due to batteries	Amortized cost of charger/cable or power bank
Power Reliability	Must source batteries from quality vendor to reduce variability Battery power can fluctuate based on ambient temperature	Mains power subject to surges/outages. Power bank requires recharging
Device Complexity	Low complexity	Low complexity
Durability	Risk of corrosion or leakage from batteries.	Risk of damage to power connections
Time-to-Result	Equivalent	Equivalent

NAATOS V2 | MK6C (USB) + J-series demo unit pictures



NAATOS V2 | MK4 (AA) + J-series demo unit pictures



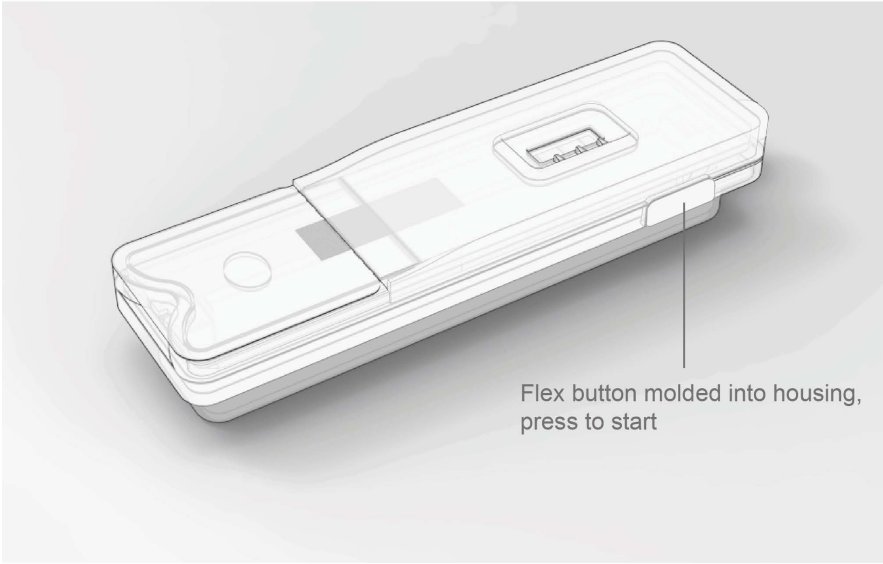


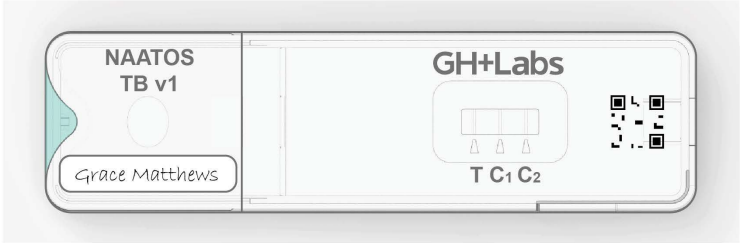
Note:
Bottom is opened for demo purpose. A battery cover with pull tab can be added.

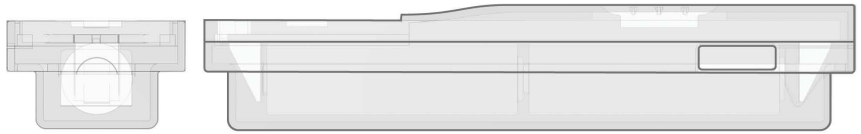
NAATOS V2 | Positive test result video

NAATOS V2 | Next steps and potential future work

- **Next steps:**
  - Continued refinement of circuit design for performance/cost
  - Pivot to molded fluidics
  - Finalize a proposed housing
  - Stage gate to demonstrate equivalence with V1







References

- Technical Files
  - https://github.com/Global-Health-Labs/NAATOS
- Help Pages
  - https://global-health-labs.github.io/NAATOS/