Workflow assessment case study in batching samples for high throughput or running consecutively in single runs in multiple sites on the BD FACSDuet™ Premium Sample Preparation System

Cambridge: David Bloxham, Fiona Cullen, Cambridge University Hospitals NHS Foundation Trust I Addenbrooke's Hospital I Cambridge Biomedical Campus I Hills Road I Cambridge I CB2 0QQ
Brescia: Marco Chiarini, Anna Galvagni, Viviana Giustini, Daniele Moratto, Duilio Brugnoni: Flow Cytometry Unit, Clinical Chemistry Laboratory, ASST Spedali Civili di Brescia, 25123 Brescia, Italy.
BD: Lori Apoll, Lucia Testolin, Nicolas Bailly, Manuele Ongari, David Sowter, and Ira Racoma: BD Biosciences, San Jose, CA 95131, U.S.

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Introduction

- Flow cytometry laboratories are increasingly integrating (semi) automated technologies into their routine workflows to meet the challenges of increasing workloads, assay complexity, limited human resources and regulatory requirements.

- The key areas in which automation can have the greatest impact are:
  - Reduction of Hands-On Time (HOT).
  - Reduction in Error Prone Tasks (EPT).
  - Process standardization and reproducibility.

- The BD FACSDuet™ Premium Sample Preparation System is a fully automated sample preparation device which integrates with the BD FACSLyric™ Flow Cytometer providing end to end sample processing including on-board sample washing and centrifugation.

Aims

- Compare fully automated sample processing with manually prewashed specimens completed on automation using:
  - Total sample processing time for both batched specimens and single specimens run consecutively.
  - Total hands-on time required during sample processing.
  - Number of error prone tasks.

Conclusions

- **BD FACSDuet™ Premium Sample Preparation System provides reproducible and predictable sample processing times.**

- **Hands-on time and error prone tasks are reduced when processes are fully (physically and digitally) automated.**

- **Sample throughput can be increased by batched sample processing.**

- **Maintaining some manual components, such as off-board pre-wash, may increase throughput but could increase variability, impact quality, and increase error prone tasks.**

Study Design and Method

Study Design
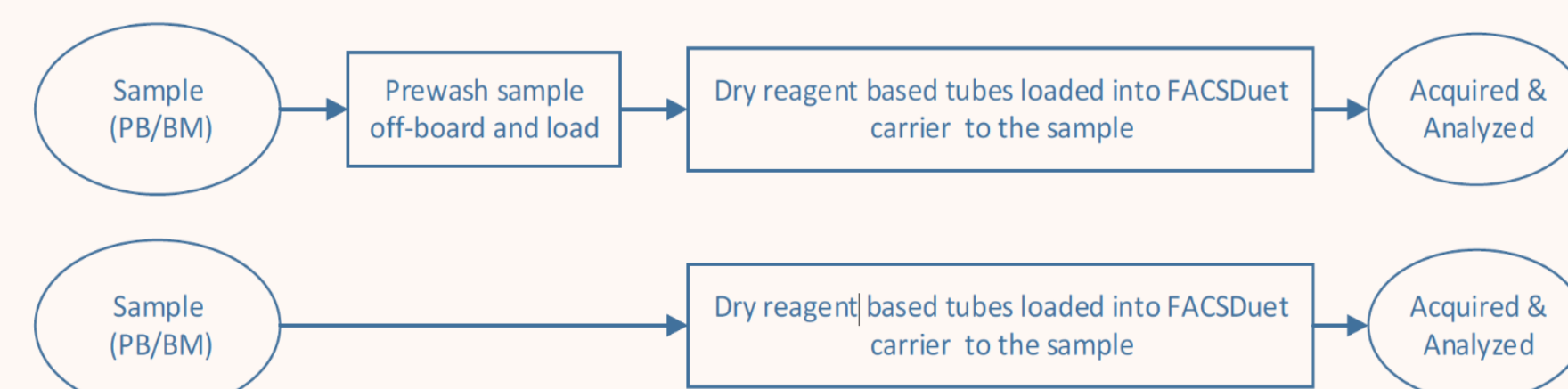
Specimen processing was completed at two sites using (a) full automation (BD FACSDuet™ Premium Sample Preparation System), inclusive of sample pre-washes, compared to (b) manual prewashing with process completed on automation (BD FACSDuet™ Premium Sample Preparation System). All manual prewash steps were matched on the automation. Total Processing Times (TPT), Hands-On Time (HOT), and number of Error Prone Tasks (EPT) were assessed on the following: (1) single specimen with two secondary tubes; (2) three consecutive worklists with a single specimen of two secondary tubes; and (3) batch of 8 specimens with 16 secondary tubes.

Analysis & Results

- **Hands-On Time (HOT) and Error Prone Tasks are greatly reduced using the BD FACSDuet™ Premium Sample Preparation System for fully automated sample processing**
  - HOT was significantly lower (1.5% to 5.6% of TPT) compared to samples prewashed prior to completion on automation (4.6% to 12.7% of TPT).
  - Assuming the use of an integrated laboratory information system, fully automated sample processing reduces the number of tasks by 64.5% and reduces the Error Prone Tasks by 50%
  - Error Prone Tasks could be further reduced with the use of barcoded reagents on the BD FACSDuet™ Premium Sample Preparation System.

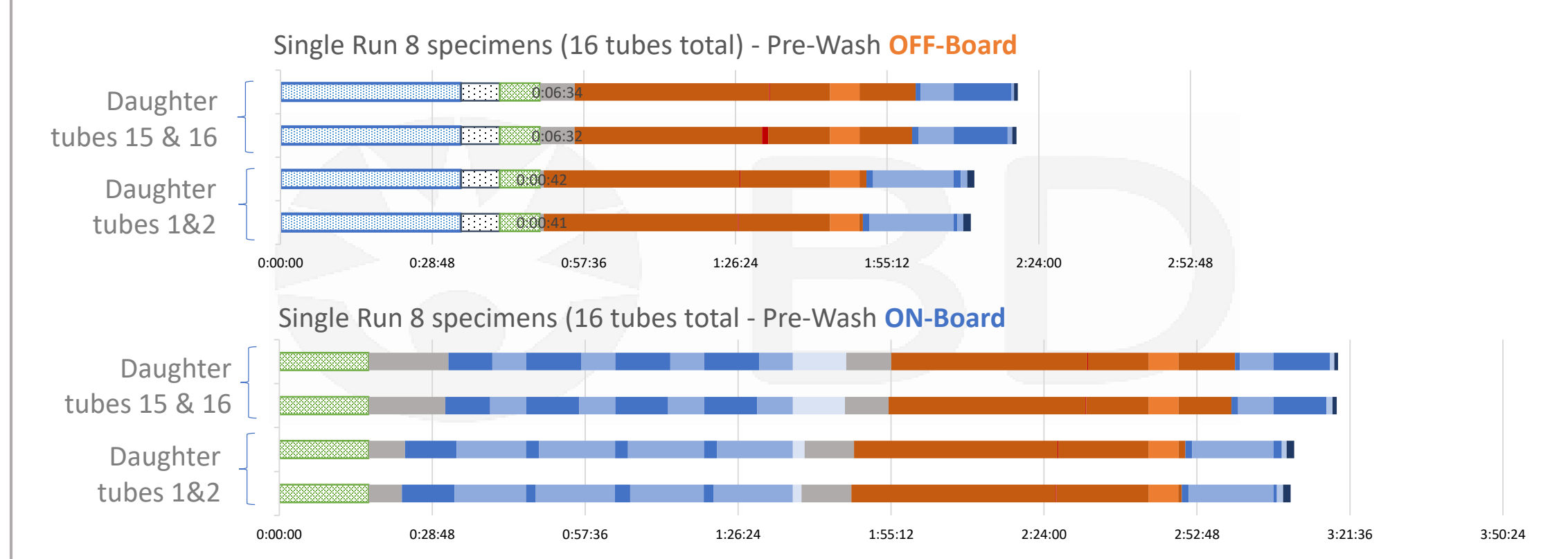| Condition tested	Tasks (Site1)	Error Prone (Site1)	%ERR
1 Sample OFF-Board prewash	31	4	12.9%
1 Sample ON-Board prewash	11	2	18.2%
Reduction with ON-Board prewash	64.5%	50.0%	

Tasks and Error Proneness
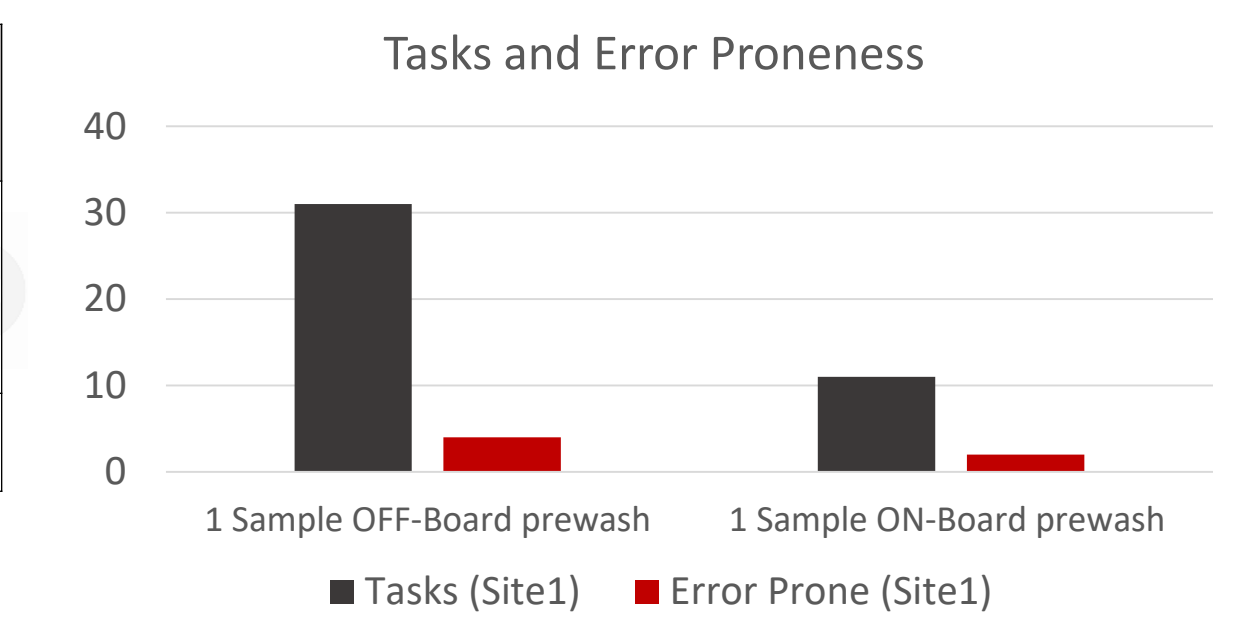
The total number of **tasks** and **error prone tasks** was determined for both sample handling procedures.
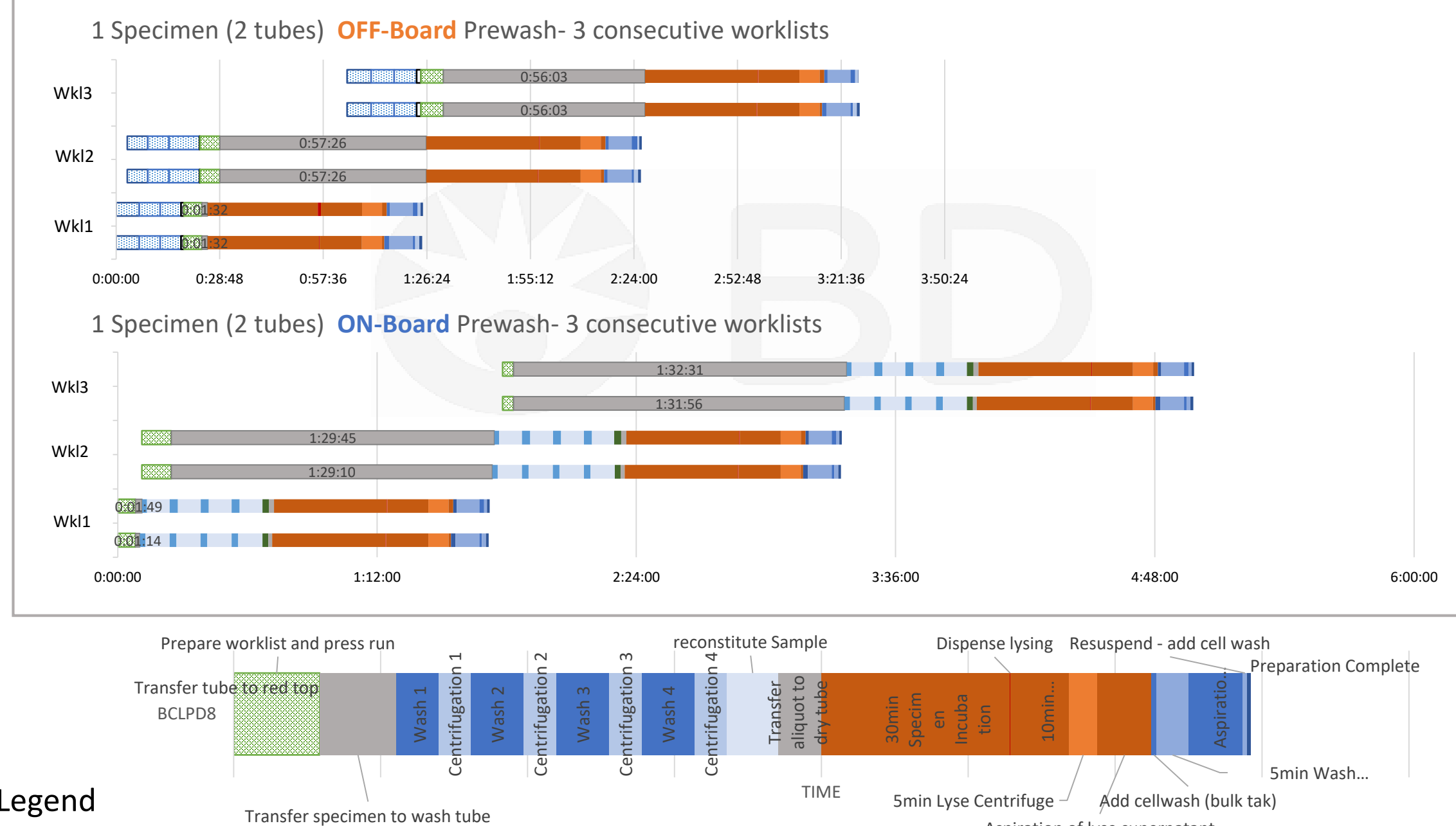
8 Specimen Worklists – 16 tubes; Samples were prepared in a single worklist; one worklist with pre-wash OFF-Board and one worklist with prewash ON-Board

Condition tested	TPT (Site1)	HOT (Site1)	%HOT (Site1)	TPT (Site2)	HOT (Site2)	TPT Difference - between sites	Site1 OFF-board: Increase throughput
8 Samples OFF-board prewash	2:17:09	0:17:26	12.7%	2:49:26	0:56:53	23.5%	42.2%
8 Samples ON-board prewash	3:15:03	0:10:56	5.6%	3:10:49	0:10:45	-2.2%	

Single Run 8 specimens (16 tubes total) - Pre-Wash OFF-Board

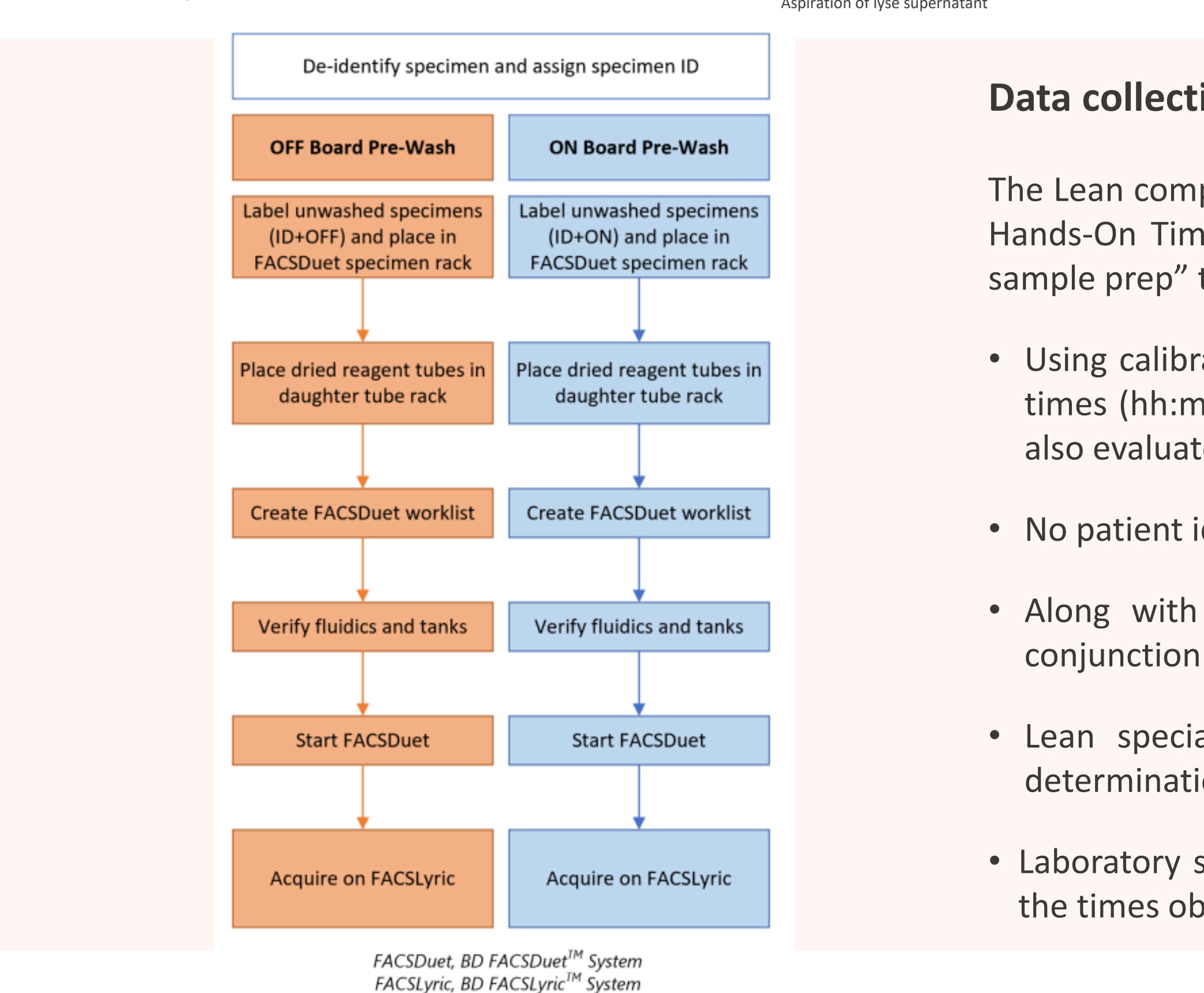**Single Run 8 specimens (16 tubes total) - Pre-Wash ON-Board**

Single Specimen Worklists – 2 tubes each; Samples were prepared in three consecutive worklists; one condition with pre-wash OFF-Board and one with prewash ON-Board

Condition tested	TPT (Site1)	HOT (Site1)	%HOT (Site1)	TPT (Site2)	HOT (Site2)	TPT Difference - between sites	Site1 OFF-board: Increase throughput
Sample 1 OFF-board prewash (Worklist 1)	1:36:47	0:07:56	8.2%	1:46:07	0:17:16	9.6%	34.6%
Sample 2 OFF-board prewash (Worklist 2)	2:38:17	0:07:11	4.6%	2:39:21	0:26:55	2.0%	
Sample 3 OFF-board prewash (Worklist 3)	2:31:23	0:09:21	6.2%	2:37:55	0:15:29	4.3%	
Sample 1 ON-board prewash (Worklist 1)	1:55:34	0:04:56	4.3%	1:54:49	0:04:29	-0.6%	
Sample 2 ON-board prewash (Worklist 2)	3:20:25	0:07:56	4.0%	3:20:01	0:04:19	-0.2%	
Sample 3 ON-board prewash (Worklist 3)	3:23:45	0:02:59	1.5%	3:31:17	0:01:41	3.7%	

1 Specimen (2 tubes) OFF-Board Prewash- 3 consecutive worklists

1 Specimen (2 tubes) ON-Board Prewash- 3 consecutive worklists

Legend

Fully automated processing provides more predictable Total Process Times (TPT)

- Lower variation in TPT was observed across both sites (0.2% to 3.7% variation) when compared to specimens prewashed prior to completion on automation (2.0% to 23.5% variation).
- Fewer manual interventions removes delays associated with human resource availability
- TPTs may be further impacted by variability of sample quality/cellularity impacting on acquisition time affecting throughput (data not included).

Batched sample processing increases sample throughput

- When using fully automated processes, TPT observed for batched 8 specimens (16 tubes) was 37.8% faster than TPT for 3 consecutive worklists with 3 single specimens (6 tubes). While the number of tubes differ between the two scenarios, this comparison is helpful in assessing the value of batching specimens to increase throughput and could be used in tandem with consecutive worklists depending on sample arrival into the laboratory.

- Samples run in consecutive worklists may be inaccessible during the time between loading and start of stain in some run scenarios (those that include washing steps), precluding their use in other laboratory processes.

Fully Automated Runs	TPT (Site1)	Batching time gain
8 Samples (1 worklist)	3:15:03	37.8%
Sample 1-3 (3 worklists)	5:13:34	

- Prewashing specimens prior completion on automation may increase throughput by 34.6% to 42.2%. The impact of delayed time to processing on specimen quality requires further assessment.

Variability between sites reflects the 'real world' challenges faced by flow cytometry laboratories

- Less predictable TPTs and increased HOT when processing manually prewashed samples were observed on both sites which may be impacted by:
  - Availability of staff due to conflicting pressures (assisting others, answering telephone calls/queries etc.)
  - Laboratory layout and access to shared equipment (centrifuges, pipettes)
  - Variations in sample processing (choice of method of supernatant removal for example)

Please note: TPT, HOT and Error Prone Tasks are highly dependent on the method used for preparation, etc., meaning that these data may not be representative of what other labs may achieve. However, if the exportable preparation protocol option on the BD FACSDuet™ Premium Sample Preparation System is used, the automated portion of the preparation can be standardized within labs and across collaborating labs.

Data collection

The Lean component of this study used timers, paper logging, and video to capture the Total Process Time (TPT), Hands-On Time (HOT), and Error Prone Tasks (EPT) for time and motion. The time captured is from "Start of sample prep" to "ready for acquisition".

- Using calibrated timers, video equipment was aligned with the instrumentation to ensure accuracy of record times (hh:mm:ss) for each step in the process to capture Total Process Time and Hands-On Time. Steps were also evaluated as to whether they were considered error prone.

- No patient identification was captured in documentation or by video equipment.

- Along with video equipment for tracking processes, paper records were made during the process in conjunction with the sites SOP.

- Lean specialists with a background in flow cytometry are crucial in identifying all steps and in the determination of error prone steps or deviations from SOP's that may lead to bias in the results.

- Laboratory staff performed tasks uninterrupted by the lean specialist to ensure there were no disruptions in the times observed or distractions from the SOPs.

FACSDuet, BD FACSDuet™ System
FACSLyric, BD FACSLyric™ System