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June 2022

WIAMan Biomechanics Data Management Plan Version 2.0

Compiled by Kathryn Loftis on behalf of the WIAMan Biomechanics
Product Team

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14. ABSTRACT The Warrior Injury Assessment Manikin (WIAMan) Biomechanics Product Team (BIO PT) performers, led by the Johns Hopkins University Applied Physics Laboratory (JHU/APL), are collecting an immense and diverse dataset from research conducted to support development of the WIAMan system to provide biofidelity and skeletal injury risk assessment capability for vertical loading conditions associated with underbody blast conditions. This comprehensive dataset will prove invaluable in efforts to further our understanding of human injury due to vertical loading. A robust method is required for the consistent collection and, ultimately, archive of all BIO PT performer test data such that future analysts can readily access and utilize the full wealth of data. This report describes the data structure and layout of the WIAMan Biomechanics data, including the file formats, organization, and hierarchy.					
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1. INTRODUCTION AND SUMMARY OVERVIEW

The Warrior Injury Assessment Manikin (WIAMan) Biomechanics Product Team (BIO PT) performers, led by the Johns Hopkins University Applied Physics Laboratory (JHU/APL), are collecting an immense and diverse dataset from research conducted to support development of the WIAMan to provide biofidelity and skeletal injury risk assessment capability under vertical loading conditions associated with underbody blast conditions. This comprehensive dataset will prove invaluable in efforts to further our understanding of human injury due to vertical loading. A robust method is required for the consistent collection, and ultimately, archive of all BIO PT performer test data such that future analysts can readily access and utilize the full wealth of data.

The BIO PT is recommending a data management plan to support these efforts and to prepare these data for eventual archival. Data management practices ensure consistent data collection, processing, formatting, and structure across all performer data. The scope of this document (Figure 1) provides data management guidance for BIO PT performers by detailing the requisite data delivery processes, ensuring consistent data archival.

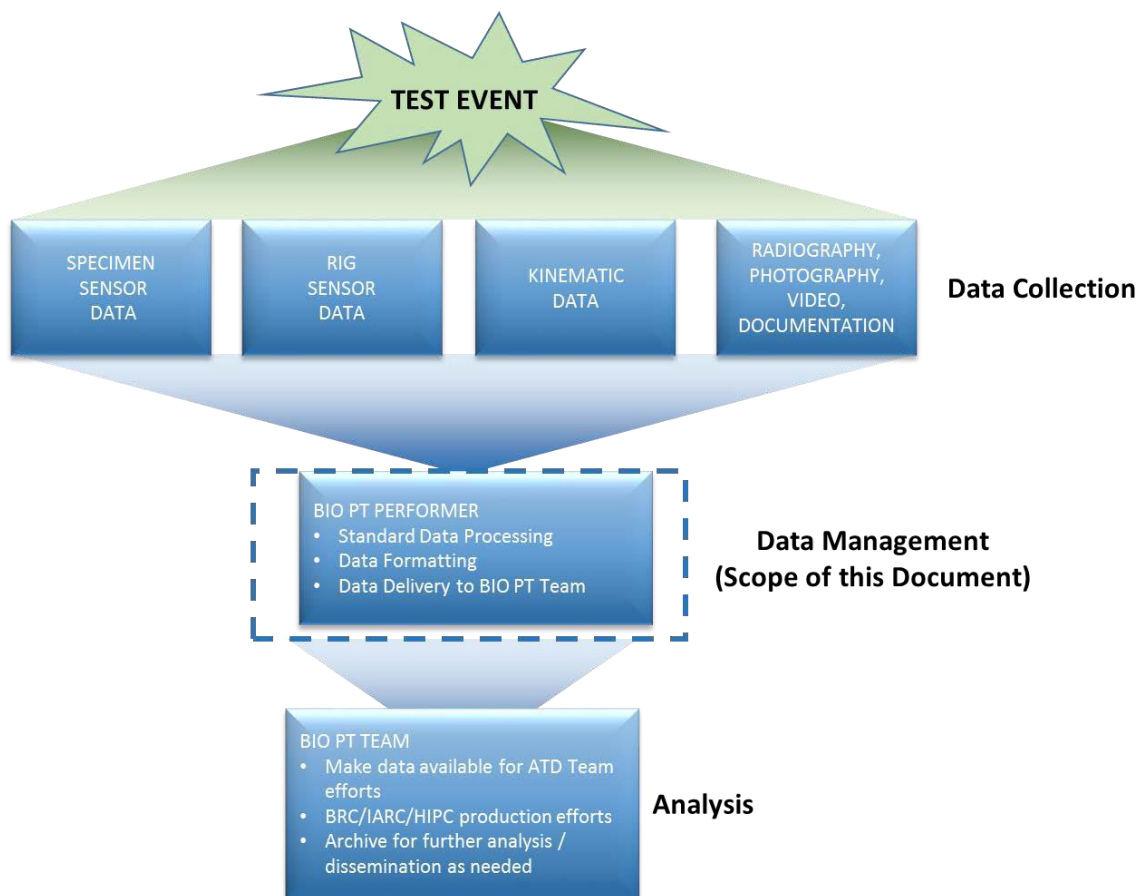


Figure 1. Data management plan overview

2. DATA MANAGEMENT GUIDANCE

This section details specific guidance and actions for data processing. Seven categories of numerical biomechanics data will be archived in the WIAMan project: binary, raw, converted, processed, calculated, scaled, and final. Additionally, imaging and documentation will be required to enhance an analyst's understanding of the test setup. It is recommended that each performer develop a batch data output pipeline to facilitate rapid and consistent data output. It is important that all data is entered per the guidance of this plan, and that the format of each table is retained to ensure efficient transfer to a final database that can be queried. Necessary descriptors that are not included in this plan must be communicated back to JHU/APL for document update and dissemination of guidance. Appendix A provides the sensor location field guidance. Allowable field descriptions are listed in Appendix B, while Appendix C provides the signal conversion guidance. Biomechanical parameters are listed in Appendix D, Integrated Text Matrix numbers are provided in Appendix E, injury designations are listed in Appendix F, and Revision History and Approvals are located in Appendix G.

2.1 Tab-Separated Value (TSV) Formatting

Most data will be TSV formatted (Section 2.6 for data formatting requests). A TSV file is a simple text format for storing data in a tabular structure to be readily parsed and logged into a database. Each line in the table is one line of the text file, with new lines designated by a carriage return and a line feed character (CR+LF, 0D + 0A in hexadecimal). Within a line, performers will separate each field from the next by a tab character (TAB, 09 in hexadecimal).

2.2 Data Categories

2.2.1 General Data Delivery Requirements

Performers will complete the following actions for all data.

- **Place in Folder Structure:** Recreate directory structure on your local computer (Section 2.7). This creates a consistent data hierarchy for ease of access, and further processing or analysis. All data must be placed into the appropriate folders within this hierarchy in order to be considered delivered. If several batches of data are delivered, recreate the full directory structure for each delivery.
- **Delivery:** Provide compressed directory structure to the JHU/APL BIO PT analysis team (Section 2.8).

2.2.2 General Numerical Data Requirements

Performers will adhere to the following requirements for each of the raw, converted, processed, calculated, scaled, and final data categories. Note that these requirements do not apply to the binary data category, which must be maintained in its native format.

- **File Naming Format:** File names will include test configuration descriptors (Section 2.3).
- **File Header and Data Format:** Each numerical data file will include a TSV header containing detailed test configuration and specific channel descriptors, followed by the numerical data (Section 2.1, Table 5).
- **Readme Format:** An overall readme file will be included for each data category submitted in both the data and kinematics subfolders where applicable.

2.2.3 Binary Data

The direct output of all data acquisition systems (DAS) in native binary format for archival and backup purposes. No modification to the binary data should be performed. Simply copy the data into the binary folder described in the hierarchy (Section 2.7) prior to data delivery. The intention is to archive the original dataset in its native format, prior to any modifications. “Binary” data refers specifically to the native output format of the following data, even if the native format is not necessarily binary.

2.2.3.1 Numerical Data Types

Numerical data being submitted will fall into the following classifications.

- Force
- Moment
- Acceleration
- Angular Rate
- Acoustic Emission
- Strain
- Kinematics
- Contact/Synchronization/Trigger channels
- Displacement (i.e., from MTS)

2.2.4 Raw Data

The output of all DAS in standard TSV format for archival and backup purposes. The intention is to complete a quick upload of data as collected during the test in a format that can be directly visualized by a user with non-proprietary applications, in contrast to proprietary formats that require the use of specialized software interfaces.

2.2.4.1 *Data Types*

The following data types should be included with raw data submission where available.

- Force
- Moment
- Acceleration
- Angular Rate
- Acoustic Emission
- Strain
- Kinematics
- Contact/Synchronization/Trigger channels
- Displacement (i.e., from MTS)

2.2.4.2 *Actions*

- **Data Synchronization Methods:** Ensure that detailed time synchronization notes are included in the documentation subfolder of the Integrated Test Matrix (ITM) level of the file hierarchy (Section 2.8). These notes should describe the triggering method and allow for complete and consistent data synchronization between separate data acquisition systems. Performers should fully capture any necessary synchronization pulses in the data window. Note that the RAW data should not necessarily be synchronized unless it was synchronized during collection. These notes are to allow future analysts to synchronize the RAW data.

2.2.5 **Converted Data**

This refers to the converted version of the previously submitted raw data. Performers will synchronize the data to a common time basis, convert to engineering units, adjust polarities as necessary and remove DC offsets. Kinematic data does not need to be included in this timeframe, but performers must fully convert kinematic data for the next stage (processed). Additionally, acoustic data does not need to be processed any further than the raw data category but will appear in the final data folder. Note that any raw data pulled through the conversion step should maintain the same channel identification number (CID) in the converted data category.

2.2.5.1 *Data Types*

The following data types should be included with the converted data submission where available.

- Force
- Moment
- Acceleration
- Angular Rate
- Strain
- Displacement (i.e., from MTS)

2.2.5.2 *Actions*

- **Synchronization:** Synchronize all data to a common time basis.
- **Conversion to Engineering Units:** Convert all signals to the preferred unit system (Section 2.6.3).
- **J211 Alignment:** Align signal polarities to their respective positive J211 axis. The header and readme should reflect these changes in the sensor axis field.
- **DC Offsets Removed:** Remove DC offsets using pre-trigger data. This is meant to remove DC artifacts and does not necessarily mean that every channel should start at zero. For instance, kinematic angle measurements do not make sense starting from zero. Technical Coordinators should be consulted for further details, as specifying preferred data processing algorithms is outside the scope of this document.
- **Error Corrections:** Section 2.6.4

2.2.6 *Processed Data*

This refers to processing the converted data including filtering, kinematic processing, and image processing. Note that any converted data pulled through the processing step should maintain the same CID in the processed data category.

2.2.6.1 *Data Types*

The following data types should be included with processed data submission where available.

- Force
- Moment
- Acceleration
- Angular Rate
- Strain

-
-
- Kinematic Tracking
 - Displacement (i.e., from MTS)

2.2.6.2 Actions

- **Kinematic Conversion:** All kinematic data must undergo all processing described in Section 2.2.5. The time basis for kinematic channels should align with the time basis for the rest of the processed data channels.
- **Filtering:** Apply filtering to numerical data (Section 2.6.1). Reference filters in header and readme filter description fields.

2.2.7 Calculated Data

The mathematically generated product of the test event that analysts will use for integration activities and creating Human Injury Probability Curves (HIPCs). This dataset builds upon the processed data and represents physically different responses. Therefore, CIDs should be unique from those used in previous data stages. Only calculated channels should be included, and performers should not carry all data through the calculation step.

2.2.7.1 Data Types

Any channels calculated from the following sensor measurements should be included in the calculated data submission where available.

- Force
- Moment
- Acceleration
- Angular Rate
- Strain
- Kinematic Tracking
- Displacement (i.e., from MTS)

2.2.7.2 Actions

- **Dynamic 6DX Acceleration Transformations:** Conduct mathematical transformations from installed sensor location to anatomically based position and alignment as described in the *WIAMan Bio PT Signal Conversion Tiger Team Recommendations for Anatomic Reference Coordinate Systems* document, including filtering methods described in Appendix D.
- **Dynamic Transformation Matrices:** Transformation information for dynamic 6DX acceleration frame transforms will be stored in TSV format according to Table 1. Static transformations do not need to be documented using this format.

Measurements should be reported with as much precision as possible for the given measurement modality (Romer arm, CT, etc.). The file consists of 13 rows and 4 columns. A separate transformation matrix file will be created for every new transformed channel and saved according to the file naming conventions in Section 2.3. This means that if three new acceleration channels are created, there will be three new transformation matrix files, even if they are identical. File naming, which handles the case of identical matrices, is documented in Section 2.3.

Table 1. Transformation Matrix Format (Consists of 13 Rows and 4 Columns)

Transformation Matrix	X	Y	Z
Measured Linear Acceleration Channels			
Measured Angular Velocity Channels			
Transformed Linear Acceleration Channels			
Transformed Angular Velocity Channels			
Measured Frame Origin (m)			
Measured Frame i (m)			
Measured Frame j (m)			
Measured Frame k (m)			
Transformed Frame Origin (m)			
Transformed Frame i (m)			
Transformed Frame j (m)			
Transformed Frame k (m)			

- **Static Transformations:** Conduct any static frame transformations necessary to align sensors with their respective J211 coordinate frame, as guided by the TCs.
- **Resultant Accelerations:** Calculate any resultant accelerations required by TCs.
- **Relative Displacements:** Calculate any relative displacements or rotations required by TCs.
- **Inertial Compensation:** Calculate any inertially compensated loads required by TCs.
- **Average Responses:** Calculate any average responses (across similar sensors, not between tests) required by TCs.

2.2.8 Scaled Data

Anthropometrically scaled dataset used to create the Biofidelity Response Corridors, or any signal scaled according to WIAMan document *W0084 PMHS Scaling Methods for Biofidelity Response Corridor Development, Version 2.5*. This dataset builds upon the calculated and processed datasets and constitutes distinctly different signals. Therefore, CIDs should be unique from those used in previous data stages. Only scaled channels should be included, and performers should not carry all data through the scaling step.

2.2.8.1 Data Types

Any channels scaled from the following sensor measurements may be included in the scaled data submission. Note that not all channels are necessarily scaled, so not all data types are required in the scaled data category.

- Force
- Moment
- Acceleration
- Angular Rate
- Strain
- Kinematic Tracking
- Displacement (i.e., from MTS)
- Calculated Channels (i.e., if scaling is applied to a calculated channel)

2.2.8.2 Actions

- **Scaling:** Scale signals based on program specifications and TC guidance (W0084 PMHS Scaling Methods for Biofidelity Response Corridor Development, Version 2.5, April 29, 2015).
- **Scale Factors:** Include a separate scale factor TSV file for every new, scaled channel (Table 2), and save according to the file naming format in Section 2.3. In this context, the original unscaled channel ID refers to the unscaled channel, the scaled channel ID refers to the scaled channel, the reference value refers to the average measurement against which the given channel is being normalized, the measured value refers to the corresponding measurement on the current specimen, and the unit gives the units of both the reference and measured values. In the case that no clear reference value exists, set the reference value to one, set the engineering units as “NA,” and include the unit-less scale factor in the measured value column. Follow Section 2.6.3 for unit descriptions. File naming for these files is documented in Section 2.3. The sensor location field should be formatted according to Appendix A.

Table 2. Scale Factor TSV Template. Each Cell Represents a Tab-Separated Field.

Sensor Location	Unscaled Channel ID	Scaled Channel ID	Reference Value	Measured Value	Engineering Units
-----------------	---------------------	-------------------	-----------------	----------------	-------------------

2.2.9 Final Data

The final data category serves as a single location where analysts can access the fully processed data for each channel, regardless of which levels of processing were or were not required for a given data channel. There will be no new data introduced with this data category.

2.2.9.1 *Data Types*

The final data category will contain a combination of the raw, converted, processed, calculated, and scaled data categories, depending on the last processing step for a particular channel.

2.2.9.2 *Actions*

- Identify the fully processed form of each physically different channel from the raw, converted, processed, calculated, and scaled datasets, including kinematics. As long as CID numbering guidance was followed from Table 3, this amounts to locating the fully processed instance of each unique CID. In this context, “fully processed” refers to the version of a given data channel that has been pulled furthest through the data categories. For example, if the same CID is present in the raw, converted, processed data categories, the data in the processed data category is considered fully processed.
- Copy the fully processed file for each distinctly different channel (unique CID) from the raw, converted, processed, calculated, and scaled datasets into the new final folder. Do not update the data category field or modify these files in any way. Note that kinematic data should be pulled into the kinematics subdirectory of the final data folder (Section 2.7 for full folder hierarchy).
- **Readme:** New overall README files (Table 8) will be created for the final data category, in both the Data and Kinematics subfolders. Note that while all channel filenames must remain unchanged, the data category field of the final readme files must be “FIN.”

2.2.10 Documentation

The other major folders are the “Imaging,” “Radiography,” and “Documentation” subfolders (Section 2.7). At the series level, the “Documentation” folder contains

presentations and reports pertaining to the overall series. At the test object level, the “Documentation” folder should contain all specimen-specific documentation. The “Radiography” folder at the test object level should contain all specimen-specific radiologic images that cover multiple tests. The “Imaging” folder at the test number level will contain images pertaining to individual tests. For all documentation, simply copy the particular supporting test documentation, specimen documentation, radiography files, and imaging into the corresponding folder described in the hierarchy (Section 2.7) prior to data delivery.

2.2.10.1 Required Documentation

- **Test Series Documentation:** The following documentation is required in the documentation subfolder at the ITM level of the hierarchy (Section 2.8). Other documentation may be freely added.
 - Test Readiness Reviews
 - Final BRC Presentations (if relevant and already generated)
 - Final HIPC Presentations (if relevant and already generated)
 - Data Synchronization Methods (Section 2.2.4.2)
- **Specimen Documentation:** The following documentation is required in the documentation subfolder at the specimen ID level of the hierarchy (Section 2.8). Other documentation may be freely added.
 - Specimen Consent
 - Serology
 - Specimen Identification
 - Documentation of Injuries
- **Radiography:** Process any radiographic images to meet the DICOM standard. The following specific images are required in the radiography subfolder at the specimen ID level of the hierarchy (Section 2.8). The “Other” subfolder within the radiography folder may be used to place any additional medical imaging not taken during a given test, as opposed to images specific to a given test number as described in the following imaging section.
 - Pre-test received CT scan
 - Pre-test instrumented CT scan
 - Post-test CT scan
- **Imaging:** Process high-speed video to synchronize with the corresponding processed sensor data and compress according to Section 2.6.5. Place videos in the appropriate IMAGING subfolder at the test number level of the data hierarchy (Section 2.7). This folder is meant to archive images (including X-rays in Digital Imaging and Communications in Medicine [DICOM] format) used to document specific tests, as opposed to the radiography folder, which is purely radiographic documentation for a single specimen and may apply to multiple tests. Pre- and

post-test still images, including X-ray images collected by performers, may be placed in the corresponding subfolder at this time. Individual video frames should not be uploaded as still images. Refer to Section 2.6.5 for photography and X-ray file formatting. The following images are required.

- High-speed video taken during test
- Any X-rays taken before/after a given test to document injury

2.2.11 Other Data

Any other numerical data that performers determine must be included for completeness, or which has been specifically requested by the TCs, may be placed into the “Other” folder designated in Table 14. It is recommended that a dedicated readme be included with each new dataset added here, so that future users will understand how to make use of these data.

2.3 File Naming

All performers will adhere to a standardized file naming convention according to the following format. Underscores should separate the following fields, and performers should not use underscores elsewhere in the filename to prevent field-parsing errors. Note, if a test falls under multiple ITM mappings in Appendix E, performers should generate a new dataset for each ITM mapping.

Data File Naming Format:

(Anatomical Region)_(Lab Name)_(Test Object)_(Vendor Specimen Identification Number)_(Test Number)_(ITM Mapping)_(Data Category)_(Channel Identification Number).tsv

Example:

WHBO_APL_PMHS_L-S122624_004_WH1a_RAW_C0001.tsv

ReadMe Naming Format:

(Anatomical Region)_(Lab Name)_(Test Object)_(Vendor Specimen Identification Number)_(Test Number)_(ITM Mapping)_(Data Category)_ReadMe.tsv

Example:

_WHBO_APL_PMHS_L-S122624_004_WH1a_RAW_ReadMe.tsv

Transformation Matrix Naming Format:

(Anatomical Region)_(Lab Name)_(Test Object)_(Vendor Specimen Identification Number)_(Test Number)_(ITM Mapping)_(Data Category)_(Channel Identification Number)_TransformationMatrix.tsv

Note, in this naming format, the channel identification number refers to the CID of the new channel being generated by this matrix. Remember, according to Section 2.3.7, there should be a unique transformation matrix file for each transformed channel.

Example:

WHBO_APL_PMHS_L-S122624_004_WH1a_CLC_C1000_TransformationMatrix.tsv

Scale Factors Naming Format:

(Anatomical Region)_(Lab Name)_(Test Object Vendor Specimen Identification Number)_(Test Number)_(ITM Mapping)_(Data Category)_(Channel Identification Number)_ScaleFactor.tsv

Note, in this naming format, the channel identification number refers to the CID of the new channel being generated by this scaling factor.

Example:

WHBO_APL_PMHS_L-S122624_004_WH1a_SCL_C2000_ScaleFactor.tsv

2.3.1 Field Definitions

Performers will supply the field values in Table 3 where applicable in the file name. If unavailable, replace given field with “NA.” Do not use underscores except as field delimiters.

Table 3. File Naming Field Conventions

Data Field	Description	Format	Example
Anatomical Region	Short text abbreviation of the anatomical region tested	Appendix B	WHBO
Lab Name	Performer abbreviation	Appendix B	APL
Test Object	Abbreviation of test article	Appendix B	PMHS
Vendor Specimen Identification Number	Vendor provided specimen identification number. For iso-lateral components, prepend 'R-' or 'L-' to designate right and left specimens	Directly copy the vendor identification number to this field after removing any restricted character per Section 2.3.1.	L-S122624
Test Number	Sequential test number for a single specimen. This number should restart at 001 when a new specimen is tested.	Consists of three digits starting at 001, padded by zeros, "###," where "#" is replaced by a numeric character	001
Integrated Test Matrix (ITM) Mapping	WIAMan ITM mapping code. If the test falls under multiple ITM, generate a new dataset for each ITM code. If the test does not fall under an ITM code, use NA.	Appendix B	LL09
Data Category	Abbreviated data category label	Appendix B	RAW
Channel Identification Number	Channel identification numbers (CIDs) are unique identifiers for physically different response data. CIDs should remain unchanged for a given channel in the raw, converted and processed data categories within a single test. Calculated and scaled channels should receive unique CIDs.	"C####," where "#" can be replaced by any numeric character	C0001

2.3.2 Restricted Characters

The characters shown in Table 4 are restricted within any file naming field. Simply delete these characters. This should only be an issue for the Vendor Specimen Identification Number. The underscore is reserved for separating fields.

Table 4. Restricted Characters for File Naming

ASCII Character	Name
/	Forward Slash
>	Greater Than
<	Less Than
:	Colon
"	Double Quote
\	Backslash
	Pipe
?	Question Mark
*	Asterisk
_	Underscore

2.4 Numerical Data Header

Each data channel will have a separate file named in accordance with Section 2.3. Each of the non-binary data files (raw, converted, processed, calculated, and scaled) will include a common structure at the head of each file as depicted in Table 5. Performers will construct the header in a two-column TSV format with the data field in the first column and values in the second column. List time series and channel data in the same two columns below the header. Each header should consist of 25 lines of information, with sensor data starting on the next line. This includes the first row “Data Field” and “Value” and the 25th row “Time (sec)” and “Value.”

Table 5. Numerical Data Header TSV Template. Each Cell Represents a Tab-Separated Field.

Data field	Value
Lab Name	
POC Name	
POC phone and email	
Test Date	
Test Time	
Test Number	
Test Rig	
Test Object	
Data Category	
Sensor Make Model Serial	
Sensor Location	
Sensor Axis	
Sensor Mount Type	
Engineering Units	
Channel Errors	
Sampling Rate (Hz)	
AA Filter Cutoff Frequency (Hz)	
Bit Resolution (Units per bit)	
Digital Filter Type/Cutoff (Hz)	
Notes	
Vendor Specimen Identification Number	
Performer Specimen Identification Number	
BP Number	
Time (sec)	

2.4.1 Field Definitions

The field values in Table 6 are a reference for populating channel headers. Include a tab between the data field and the channel data, but do not include tabs within any field, as this will result in errors during parsing. Additional header guidance is available in Appendix B, which contains the list of allowable field descriptors. Use “NA” if given field is not applicable.

Table 6. Data Header Field Descriptions

Data field	Description	Format	Example values
Lab Name	Performer abbreviation	Appendix B	APL
POC Name	Name of the test Point of Contact	None	Kyle A. Ott
POC phone and email	Applicable lab phone number, email, etc. for contacting the POC	None	Kyle.A.Ott@jhuapl.edu
Test Date	Date that the test was conducted	8 numeric characters in the form "YYYYMMDD."	20170720
Test Time	Local lab time when the test was conducted	Format is HH:MM:SS, specified in military time.	17:50:51
Test Number	Sequential test number for a single specimen. This number should restart at 001 when a new specimen is tested	Consists of three digits starting at 001, padded by zeros, "###," where "#" is replaced by a numeric character.	001
Test Rig	Short text description of test rig	Appendix B	VALTS
Test Object	Abbreviation of test article	Appendix B	PMHS
Data Category	Data category label	Appendix B	RAW
Sensor Make Model Serial	Sensor description	"[Make]_[Model]_[Serial]." Remove restricted characters per Section 2.4.2.	DTS_6DX_0066
Sensor Location	Location of the sensor in the anatomy, using body region codes from Appendix A	Appendix B	See Appendix A for guidance
Sensor Axis	Direction of the sensor axis in the J211 coordinate system	Appendix B	X
Sensor Mount Type	Type of sensor mount	Appendix B	LOFFI
Engineering Units	Engineering units depicted in Section 2.7	Section 2.7.	N
Channel Errors	Description of channel errors.	"Y-[Free text description of error]," "N," "Q-[Free text description of questionable error]"	Y- Sensor dropped out after 20ms.
Sampling Rate (Hz)	Data sampling rate in Hz	Only numeric characters.	1000000
AA Filter Cutoff Frequency (Hz)	Frequency, in Hz, content that the user may expect	Only numeric characters.	300000
Bit Resolution (Units per bit)	Resolution settings for the underlying raw experimental data in engineering units per bit.	Only numeric characters.	8
Digital Filter Type/Cutoff (Hz)	Digital filter applied and cutoff frequency in Hz	Only numeric characters.	3000
Notes	Notes or descriptions for use in supporting data analysis	None.	

Table 6. Data Header Field Descriptions

Data field	Description	Format	Example values
Vendor Specimen Identification Number	Vendor provided specimen identification number. For iso- lateral components, prepend 'R-' or 'L-' to designate right and left specimens.	Directly copy the vendor identification number to this field after removing any restricted character per Section 2.4.2.	L-S122624
Performer Specimen Identification Number	Performer provided specimen identification number	None	HS735
BP Number	Biomechanical parameter identification number. Enter "NA" if this channel does not correspond to a BP. Each BP should map to only one CID.	Appendix B	BP-1

2.4.2 Restricted Characters

The characters in Table 7 are restricted within any header field. Tab is reserved for separating values, while the carriage return and line feed are reserved to specify the end of a line.

Table 7. List of Restricted Characters for the Data Header

Name	Use
CR+LF	End of line
TAB	Value separation

2.5 Readme File

Performers will upload a tab-separated readme file along with each data category, for both the numerical and kinematic data (Table 8). The data included is similar to the numerical header file depicted in Table 7, but with all channel-specific information for the test listed in tab-separated rows in this single file. The readme file contains 20 header rows, along with a new row for each data file in the folder. Do not include tabs within any given field. Additional header guidance is available in Appendix B, which contains the list of allowable field descriptors. Use "NA" if given field is not applicable, or in the "Injury Outcome" field if no injury occurred.

Table 8. Readme File Format. Each Cell Represents a Tab-Delimited Field.

Lab Name												
POC Name												
POC phone and email												
Test Date												
Test Time												
Test Number												
PPE												
Target Input Condition												
Data Category												
Posture												
Camera Views												
Imaging Notes												
Injury Outcome												
Notes												
Test Rig												
Test Object												
Vendor Specimen Identification Number												
Performer Specimen Identification Number												
Actual Input Condition												
Filename of the Channel	Sensor Make Model Serial	Sensor Location	Sensor Axis	Sensor Mount Type	Engineering Units	Channel Errors	Sampling Rate (Hz)	AA Filter Cutoff Frequency (Hz)	Bit Resolution (Units per bit)	Digital Filter Type/Cutoff (Hz)	Notes	BP Number

2.5.1 Field Descriptions

Table 9 shows the README field descriptions that should be present.

Table 9. README Field Descriptions

Data Field	Description	Format	Example Values
Lab Name	Performer abbreviation	Appendix B	APL
POC Name	Name of the test Point of Contact	None	Kyle A. Ott
POC phone and email	Applicable lab phone number, email, etc. for contacting the POC	None	Kyle.A.Ott@jhuapl.edu
Test Date	Date that the test was conducted	8 numeric characters in the form "YYYYMMDD."	20170720
Test Time	Local lab time when the test was conducted.	Format is "HH:MM:SS," specified in military time.	17:50:51
Test Number	Sequential test number for a single specimen. This number should restart at 001 when a new specimen is tested.	Consists of three digits starting at 001, padded by zeros, "###," where # is replaced by a numeric character.	001
PPE	Description of PPE used	Appendix B	Boots
Target Input Condition	For majority of datasets, this will be target peak and time-to-peak velocity for each separately driven portion of rig. Modify units in the case that the input condition is not described using peak and time to peak velocity. Peaks and TTPs should always be reported as positive values.	"[Input Location]-[Peak] m/s, [TTP] s." Precision for Floor-2.0 m/s, 0.0050 s, peak and TTP should be 0.1 m/s and 0.0001 s.	Seat-2.0 m/s, 0.0060 s
Data Category	Data category label	Appendix B	RAW
Posture	Description of posture	Appendix B	90-90-90
Camera Views	Description of camera views; use as many camera descriptors as necessary	Appendix B	Right Lateral
Imaging Notes	Any relevant notes accompanying imaging	None	Image shows fracture.
Injury Outcome	Injury description where applicable. Use "NA" for PMHS tests with no injury. Only needed starting with processed data stage. Use "NA" for the raw and converted data.	Appendix F	VB FX
Test Rig	Short text description of test rig	Appendix B	VALTS
Test Object	Test object abbreviation	Appendix B	PMHS
Vendor Specimen Identification Number	Vendor provided specimen identification number. For iso-lateral components, prepend 'R-' or 'L-' to designate right and left specimens.	Directly copy the vendor identification number to this field after removing any restricted character per Section 2.3.1.	L-S122624
Performer Specimen Identification Number	Performer provided specimen identification number	None	HS735

Table 9. README Field Descriptions

Data Field	Description	Format	Example Values
Actual Input Condition	For majority of datasets, this will be actual peak and time-to-peak velocity, calculated using the Tice method, for each separately driven portion of rig Modify units in the case that the input condition is not described using peak and time to peak velocity. Peaks and TTPs should always be reported as positive values.	"[Input Location]-[Peak] m/s, [TTP] s." Precision for peak and TTP should be 0.1 m/s and 0.0001 s. May included several input locations by separating with a comma.	Floor-2.3 m/s, 0.0053 s, Seat-2.0 m/s, 0.006 s
Sensor Make Model Serial	Sensor description.	"[Make]_[Model]_[Serial]"	DTS_6DX_0066
Sensor Location	Location of the sensor in the anatomy, using body region codes from Appendix A	Appendix A	See Appendix A for guidance
Sensor Axis	Direction of the sensor axis in the J211 coordinate system	Appendix B	X
Sensor Mount Type	Type of sensor mount	Appendix B	LOFFI
Engineering Units	Engineering units	Section 2.6	N
Channel Errors	Description of channel errors. See Section 2.6.4.	"Y-[Free text description of error]," "N," "Q-[Free text description of questionable error]"	Y- Sensor dropped out after 20ms.
Sampling Rate (Hz)	Data sampling rate in Hz	Only numeric characters.	1000000
AA Filter Cutoff Frequency (Hz)	Frequency, in Hz, content that the user may expect	Only numeric characters.	300000
Bit Resolution (Units per bit)	Resolution settings for the underlying raw experimental data in engineering units per bit.	Only numeric characters.	8
Digital Filter Type/Cutoff (Hz)	Digital filter applied and cutoff frequency in Hz	Only numeric characters.	3000
Notes	Notes or descriptions for use in supporting data analysis	None.	
BP Number	Biomechanical parameter identification number. Enter "NA" if this channel does not correspond to a BP. Each BP should map to only one CID.	Appendix B	BP-1

2.5.2 Restricted Characters

The characters in Table 10 are restricted within any readme field. Tab is reserved for separating values, while the carriage return and line feed are reserved to specify the end of a line.

Table 10. List of Restricted Characters for the Readme

Name	Use
CR+LF	End of line
TAB	Value separation

2.6 Processing Guidance

In general, the aim of the DMP is to maintain consistency within the WIAMan dataset, not to recommend processing techniques. However, the following guidance is provided as a baseline, although performers may adopt other processing standards upon specific direction from the Technical Coordinators.

2.6.1 Filtering

Performers will filter according to the specifications in Table 11 to turn the converted data into processed data based upon channel type, barring further instruction from the program office. The only exception is in the calculated dataset, where performers should apply a 500-Hz low-pass phaseless four-pole Butterworth filter to angular acceleration traces in order to construct SCoTT frame transformations per TC recommendation. However, performers should still report standalone ARS channels using a 1650 Hz CFC filter. These filtering schemes are only applicable to PMHS data. ATD or simulated response data should not necessarily be filtered according to these specifications. This filtering specification does not apply to strain gage, acoustic sensor, or video image data.

Table 11. Filter Specifications

Sensor type	Filter type
Linear Acceleration	3 kHz low pass ^a
Angular Acceleration	1650 Hz low pass (CFC 1000)
Force	3 kHz low pass ^a
Moment	3 kHz low pass ^a

^a 3-kHz filters are defined as low-pass phaseless 4-pole Butterworth

2.6.2 Data Window

Performers will restrict all data channels and video to a standard data window (Table 12). Performers should upload the binary and raw numerical data as collected. Performers will not apply any time windowing or filtering prior to uploading the binary or raw datasets. Converted, processed, calculated, and scaled data channels will limit the data uploaded per the data window in Table 12. For kinematic data where frames have dropped out, include “NA” in place of the corresponding data points. Note that it is ok to include data (such as acoustics), that may not meet the minimum window due to DAS restrictions.

Table 12. Data Window Specifications

Data type	Start of window	End of window
Binary	As collected	As collected
Raw	As collected	As collected
Converted, processed, calculated, and scaled	Minimum 10 ms prior to time zero	- Body component: at least 100 ms past time zero - Whole Body: at least 400 ms past time zero - All synchronization pulses (rising and falling edges) should be captured where possible

2.6.3 Units

Use the units in Table 13 for the converted, processed, calculated, and scaled datasets, as well as in the transformation matrix and scale factor files. The binary and raw datasets will be submitted as collected.

Table 13. Unit Standards

Quantity	Unit
Mass	kg
Distance	m
Velocity	m/s
Force	N
Moment	Nm
Time	s
Acceleration	g
Voltages	mV
Acoustic Emission	mV
Angular Acceleration	deg/s/s
Angular Rate	deg/s
Angular Displacement	deg
Strain	uE

2.6.4 Error Corrections

The general guidance is to never delete data and only add. When performers discover an error through quality control check, the instructions are to place the character “Y” (for yes) or “Q” (for questionable) in the channel errors field of the readme and header, followed by a short text description (Table 9). “Y” should be used in the case that the data is likely not useful for any analysis. “Q” should be used when the data should be flagged for concern, but may still be of use. Errors are defined as uncorrectable errors such as a damaged sensor or clipped signal. For correctable errors, the performer should fix the data (such as fixing a scaling factor) when submitted to the converted data category, at which point the channel errors field should have an “N” (for no).

2.6.5 File Standards

Performers are to avoid uploading proprietary file formats as much as possible. Exceptions are standard Microsoft Office product file extensions such as .docx, .xlsx, and .pdf as instructed. Additionally, the binary data category consists of the native DAS output.

- Video files are to be converted to compressed .avi files using an H264 codec and a rate factor of 1 such that all frames are maintained, which will be sufficient for video tracking purposes.
- Any available still photography images (excluding X-ray) will be formatted into .tiff files or .jpeg files.
- Radiography images, including all CT and X-ray, will be formatted with the DICOM standard.

2.7 File Structure

We instruct performers to package all data in a consistent hierarchical structure prior to submission. Table 14 shows the proposed directory structure. Performers can coordinate with the Bio PT Technical Coordinators and add as needed to capture or sort additional test information. Sensor data refers to any data derived from force, moment, acceleration, angular rate, acoustic, strain, or MTS measurements. Folder names within the <> should be populated according to the file name field descriptions described above, including the restricted characters list (Section 2.3).

Table 14. File Hierarchy

<Lab Name>\	
<Anatomical Region>\	
<ITM Mapping>\	
Documentation\	
	[TRR, Final Presentations, Reports, Data Synchronization Methods, Notes]
<Test Object>\	
<Vendor Specimen Identification Number>\	
Documentation\	
	[Specimen consent, serology, specimen identification, autopsy reports]
Radiography\	
PreTest-received\	
	[Radiography Files]
PreTest-instrumentation\	
	[Radiography Files]
PostTest\	
	[Radiography Files]
Other\	
	[Radiography Files]
<Test Number>\	
Imaging\	
Video\	
	[Video Files]
Still Images\	
PreTest\	
PostTest\	
Other\	
Binary\	
Data\	
	[Native DAS data]
Kinematics\	
	[Native kinematic data]
Raw\	
Data\	
	[ReadMe.tsv files]
	[Sensor Data]
Kinematics\	
	[ReadMe.tsv files]
	[Kinematic Data]
Converted\	
Data\	
	[ReadMe.tsv files]
	[Sensor Data]
Processed\	

Table 14. File Hierarchy

	Data\	
		[ReadMe.tsv files]
		[Sensor Data]
	Kinematics\	
		[ReadMe.tsv files]
		[Kinematic Data]
Calculated\		
	Data\	
		[ReadMe.tsv files]
		[Sensor Data]
		[Transform Matrix .tsv Files]
	Kinematics\	
		[ReadMe.tsv files]
		[Kinematic Data]
Scaled\		
	Data\	
		[ReadMe.tsv files]
		[ScaleFactors.tsv files]
		[Numerical Data]
	Kinematics\	
		[ReadMe.tsv file]
		[Kinematic Data]
Final\		
	Data\	
		[ReadMe.tsv files]
		[Numerical Data]
	Kinematics\	
		[ReadMe.tsv files]
		[Kinematic Data]
Other\		
	[Other Data]	

2.8 Data Delivery

All datasets shall be delivered to JHU/APL for aggregation and transmission to the Government while under the overarching agreement. After that, data shall be delivered to DAC for aggregation and storage. Each individual organization will be held responsible for the quality of their data. A quality assurance check will be performed by JHU/APL, and corrections to the data may be requested to confirm compliance with the specifications outlined in this document. JHU/APL will provide instructions on methods and timing of data transmission such that the Government requirements are achieved. Data may be uploaded in a .zip file to limit transfer size, but all folder levels should be included, starting with the lab name.

3. CONCLUSION

This WIAMan Biomechanics DMP establishes the data standards for all data collected within the Biomechanics PMHS experimental testing program. Once the data is collected by the government, it will be verified that it abides by this DMP so that it can be stored for future reference and research purposes.

4. REFERENCES

WIAMan Team. (2015, May 21). *Signal conversion tiger team recommendations for anatomic reference coordinate systems, revision 0.6.*

WIAMan Team. (2015, April 29). *W0084 PMHS scaling methods for biofidelity response corridor development, version 2.5.*

Appendix A – Sensor Location Field Guidance

The following table gives guidance for describing the location of sensors, which is a required field for numerical data headers and the readme files. The general format should be:

(Anatomical Region)_(Descriptor 1)_ (Optional Descriptor 2)_(Optional Descriptor 3)

Table A-1. Sensor Location

Anatomical region	Descriptor (Maximum of 3)
This will be the first part of every sensor location	A minimum of 1 and maximum of 3 descriptors should be used following the location to define where on the anatomy or rig the sensor is mounted
Head	Left
Sternum	Right
Thorax	Center (rig only)
C# (Cervical Spine)	Medial
T# (Thoracic Spine)	Lateral
L# (Lumbar Spine)	Anterior
Rib#	Posterior
Manubrium	Distal
Sacrum	Proximal
Pubictubercle	Inferior
ASIS (anterior superior iliac spine)	Superior
AIIS (anterior inferior iliac spine)	
SPR (superior pubic ramus)	
IPR (inferior pubic ramus)	
Ilium	
Ischium	
Acetabulum	
Femoralneck	
Femur	
Knee	
Tibia	
Fibula	
Phalangesmediae#	
Phalangesproximale#	
Metatarsals#	
Navicular	
Cuboid	
Talus	
Calcaneus	
Floor	
ShoulderBelt	
LapBelt	
IW (iliac wing)	
Seatpan	
Seatback	
Scapula	
Boot	

Note: If redundant sensors, or rosettes, use indexes, i.e., Floor_Center_1,2,etc.

Appendix B – List of Allowable Field Descriptors

Any necessary test descriptor not included in this plan is to be relayed back to APL for document update and dissemination of guidance. Make sure to refer to Tables 3, 6, and 9 for additional formatting guidance.

Table B-1. List of Allowable Field Descriptors

Data field	Field descriptors
Lab Name	"APL," "WSU," "UVA," "MCW," "ARL," "DUK," "UMT"
Anatomical Region	"WHBO," "PELV," "LLEG," "CERV," "LUMB," "HEAD," "HEADN," "FEMUR"
Data Category	"RAW," "CON," "PRO," "CLC," "SCL," or "FIN"
PPE ^a	WHBO: "No," "Helmet," "Light," "Medium," "Boots" PELV: "No" LLEG: "No," "Boots" CERV: "No" LUMB: "No" HEAD: "No," "Helmet," HEADN: "No," "Helmet," FEMUR: "No"
Posture ^b	WHBO: "90/90/90," "30/60/90," "LoweredSeat," "Acute," "####/####/####" (where order is Hip/Knee/Ankle) PELV: "Nominal," "Anterior Tilt," "Posterior Tilt," "28 deg," "40 deg," "58 deg," "####" LLEG: "90/90/90," "30/60/90," "####/####/####," (where order is Hip/Knee/Ankle) CERV: "Nominal," "Flexed," "Extended," "Pre-Flexed," "Pre-Extended" LUMB: "Nominal," "Flexed," "Extended," "Pre-Flexed," "Pre-Extended" HEAD: "Nominal," "Flexed," "Extended," "Pre-Flexed," "Pre-Extended" HEADN: "Nominal," "Flexed," "Extended," "Pre-Flexed," "Pre-Extended" FEMUR: "Nominal"
Camera Views ^a	"Left," "Right," "Oblique," "Medial," "Lateral," "Frontal," "Anterior," "Posterior," "Distal," "Proximal," "Overhead," "Inferior," "Superior"
Sensor Location	See Appendix A for guidance
Sensor Axis	"X," "Y," "Z," "R," "NA"
Sensor Mount Type	"Rigid," "Contact," "Screwed," "Clamped," "Weave," "Fixed," "Sticker," "Glued," "LOFFI," "Epoxied," "Internal," "Tied," "Taped," "BOBKAT"
Test Rig	"Telemachus," "Odyssey," "Sisyphus," "VALTS," "ALF," "Vertac," "Vertac-1," "Vertac-2," "Sled," "Piston Compression," "MTS," "Drop," "Pendulum," "Blast"
Test Objects	"PMHS"
Injury Outcome	Appendix F
Engineering Units	Section 2.6.3
Integrated Test Matrix (ITM)	
Mapping	Appendix E
BP Number	Appendix D
Sensor Location	Appendix A

^a Multiple descriptors may be combined in comma separated lists

^b Replace # with any numeric character

Appendix C – Signal Conversion Tiger Team

Final Recommendation

Follow the rigid body transformation recommended by SCoTT WG:

Rigid Body Transformation to Local Bone Coordinate System

After aligning the measured sensor data to the local bone coordinate system a rigid body translation to the desired location of interest can be performed using the rigid body dynamics equation as described by Equation 1 (Rudd et al. 2006).

$$a_{\text{origin}} = a_{\text{sensor}} - \alpha_{\text{bone}} \times r_{\text{bone}} - \omega_{\text{bone}} \times (\omega_{\text{bone}} \times r_{\text{bone}}) \quad [1]$$

For each components in the equation:

1. a_{sensor} = 3 kHz filtered linear accelerometer data
 2. ω_{bone} = 1650 Hz filtered angular rate sensor data
 3. α_{bone} = Result from the two steps below
 - a) Filter raw angular rate sensor data at 500Hz
 - b) Time differentiated the 500Hz filtered data
 4. Execute transformation equation [1] using data from step 1, 2, 3
-

Figure C-1. Summary of the WIAMan Bio PT Signal Conversion Tiger Team Recommendations for Anatomic Reference Coordinate Systems, Rev 0.6, May 21, 2015 document. Note that the citation of Rudd et al. is a specific application of well-understood planar kinematic equations, outlined in texts such as Mechanics for Engineers by Hibbeler et al.

Appendix D – Biomechanical Parameters List

The following Biomechanical Parameters (BP) list was copied from the WIAMan Master BP Listing on May 18, 2018. The ITM Ref. BP# from this table should be used for the BP Number field in the data headers and readme files. Use NA when a BP does not correspond to a given channel. Each BP should have no more than one corresponding CID.

Table D-1 Master BP Listing

Body Region	Measurement Objective	Measured Biomechanical Parameters/Channel	Whole Body	Component	ITM Ref. BP #
Head	Head Kinematics	Head Accel Z	x	x	BP-1
		Head Accel X			BP-1-X
		Head Accel Y			BP-1-Y
		Head Accel Z			BP-1-Z
Head	Head Kinematics	Head Accel Resultant	x	x	BP-2
		Head Rotation X-ARS			BP-3-X
		Head Rotation Y-ARS			BP-3-Y
		Head Rotation Z-ARS			BP-3-Z
Head	Head Kinematics	Head rotation Relative to T1 (XZ Plane)	x	x	BP-3
		Motion of Head X			BP-4-X
		Motion of Head Z			BP-4-Z
Head	Head Kinematics	Head rotation Relative to T1 (YZ Plane)	x	x	BP-4
Head	Head Kinematics	Head rotation Relative to Torso (XY Plane)	x	x	BP-5
Head	Head Kinematics	Head Rotation Relative to Pelvis (XZ Plane)	x		BP-6
Neck	Forces/Moments Transmitted between Head and Neck	Upper Neck Forces FZ		x	BP-7-U
Neck	Forces/Moments Transmitted between Head and Neck	Lower Neck Forces FZ		x	BP-7-L
Neck	Forces/Moments Transmitted between Head and Neck	Lower Neck Forces FX		x	BP-8-L
Neck	Forces/Moments Transmitted between Head and Neck	Upper Neck Forces FX		x	BP-8-U
Neck	Forces/Moments Transmitted between Head and Neck	Lower Neck Moments MY		x	BP-9-L
Neck	Forces/Moments Transmitted between Head and Neck	Upper Neck Moments MY		x	BP-9-U
Neck	Neck Kinematics and Curvature	C3 Spinal Accel Z			BP-10
Neck	Neck Kinematics and Curvature	C3 Spinal Rotation (ARS)			BP-11
Neck	Neck Kinematics and Curvature	C3 Motion (Video)		x	BP-12
Neck	Neck Kinematics and Curvature	C5 Spinal Accel Z			BP-13
Neck	Neck Kinematics and Curvature	C5 Spinal Rotation (ARS)			BP-14
Neck	Neck Kinematics and Curvature	C5 Motion (video)		x	BP-15
		Spinal Compression-Head- T1-X			BP-16-1-X
		Spinal Compression-Head- T1-Z			BP-16-1-Z
		Spinal Compression-T1-T5-X			BP-16-2-X
		Spinal Compression-T1-T5-Z			BP-16-2-Z
		Spinal Compression-T5-T8-X			BP-16-3-X
		Spinal Compression-T5-T8-Z			BP-16-3-Z
		Spinal Compression-T8-T12- X			BP-16-4-X
		Spinal Compression-T8-T12- Z			BP-16-4-Z
		Spinal Compression-T12-S1- X			BP-16-5-X
		Spinal Compression-T12-S1- Z			BP-16-5-Z
Neck		Neck X Deformation (OC relative to T1 displacement X)	x	x	BP-16X
Neck	Spine Stiffness	Neck Z Deformation (OC relative to T1 displacement Z)	x	x	BP-16Z
Neck		Cervical Spinal Compression (OC to T1 distance change)	x	x	BP-16
Shoulder	Shoulder Kinematics	Motion of Shoulder (video)	x		BP-17
		Motion of Shoulder Y			BP-17-Y
		Motion of Shoulder Z			BP-17-Z

Table D-1 Master BP Listing

Body Region	Measurement Objective	Measured Biomechanical Parameters/Channel	Whole Body	Component	ITM Ref. BP #
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T1 Linear Accel X,Z	x	x	BP-18
		T1 Spinal Accel X			BP-18-X
		T1 Spinal Accel Z			BP-18-Z
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T1 Rotation (ARS) Y	x	x	BP-19
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T1 Motion (video) XZ plane		x	BP-20
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T4 Linear Accel X,Z	x	x	BP-21
		T5 Spinal Accel X			BP-21-X
		T5 Spinal Accel Z			BP-21-Z
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T5 Motion (video) XZ plane		x	BP-23
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T12 Linear Accel X,Z	x	x	BP-24
		T12 Spinal Accel X			BP-24-X
		T12 Spinal Accel Z			BP-24-Z
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T12 Rotation (ARS) Y	x	x	BP-25
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T12 Motion (video) XZ plane		x	BP-26
Thoracic Spine	Forces/Moments Transmitted along Thoracic Spine	Thoracic Spine Forces FZ		x	BP-27
Thoracic Spine	Forces/Moments Transmitted along Thoracic Spine	Thoracic Spine Forces FX		x	BP-28
Thoracic Spine	Forces/Moments Transmitted along Thoracic Spine	Thoracic Spine Moments MY		x	BP-29
Lumbar Spine	Forces/Moments Acting on Lumbar Spine	Lower Lumbar Spine Forces FZ at L5/S1		x	BP-30-L
Lumbar Spine	Forces/Moments Acting on Lumbar Spine	Upper Lumbar Spine Forces FZ at T12/L1		x	BP-30-U
Lumbar Spine	Forces/Moments Acting on Lumbar Spine	Lower Lumbar Spine Forces FX at L5/S1		x	BP-31-L
Lumbar Spine	Forces/Moments Acting on Lumbar Spine	Upper Lumbar Spine Forces FX at T12/L1		x	BP-31-U
Lumbar Spine	Forces/Moments Acting on Lumbar Spine	Lower Lumbar Spine Moments MY at L5/S1		x	BP-32-L
Lumbar Spine	Forces/Moments Acting on Lumbar Spine	Upper Lumbar Spine Moments MY at T12/L1		x	BP-32-U
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L1 Linear Accel X,Z		x	BP-33
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L1 Rotation (ARS) Y		x	BP-34
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L1 Motion (video) XZ plane		x	BP-35
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L3 Linear Accel X,Z		x	BP-36
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L3 Rotation (ARS) Y		x	BP-37
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L3 Motion (video) XZ plane		x	BP-38
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L5 LinearAccel X,Z		x	BP-39
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L5 Rotation (ARS) Y		x	BP-40
Lumbar Spine	Lumbar Spine Kinematics and Curvature	L5 Motion (video) XZ plane		x	BP-41
Pelvis	Pelvis Kinematics	Pelvis Accel Z at Sacrum	x	x	BP-42
		Pelvis Accel X			BP-42-X
		Pelvis Accel Y			BP-42-Y
		Pelvis Accel Z			BP-42-Z

Table D-1 Master BP Listing

Body Region	Measurement Objective	Measured Biomechanical Parameters/Channel	Whole Body	Component	ITM Ref. BP #
Pelvis	Pelvis Kinematics	Pelvis Accel Resultant at Sacrum - X,Y,Z	x	x	BP-43
		Pelvis Rotation X-ARS			BP-44-X
		Pelvis Rotation Y-ARS			BP-44-Y
		Pelvis Rotation Z-ARS			BP-44-Z
Pelvis	Force transmitted from seat to pelvis. Ischial Tuberosity Forces FZ	Pelvis to seat (impact plate) contact force Fz	x	x	BP-45
Pelvis	Force transmitted from pelvis to spine. Sacro-Iliac Forces FZ	Forces FZ measured at sacrum		x	BP-46
		Distal Femur Accel X			BP-47-X
		Distal Femur Accel Z			BP-47-Z
Femur	Forces in Upper Leg	Femur Forces FX	Strain Gages (optional)	Load Cell	BP-48
		Motion of Knee X			BP-49-X
		Motion of Knee Y			BP-49-Y-L
		Motion of Knee Y			BP-49-Y-R
		Motion of Knee Z			BP-49-Z
		Distal Tibia Accel X			BP-50-X
		Distal Tibia Accel Z			BP-50-Z
Tibia	Lower Leg Kinematics	Tibia Linear Accel Z	x	x	BP-51z
Tibia	Forces in Lower Leg	Upper Tibia Forces FZ	Strain Gages (optional)	Load Cell	BP-51
Tibia	Forces in Lower Leg	Upper Tibia Forces FX	Strain Gages (optional)	Load Cell	BP-52
		Foot Accel Z			BP-53
Foot/Ankle	Forces in Lower Leg	Motion of Feet Heel X (video)		x	BP-54x
Foot/Ankle	Forces in Lower Leg	Ankle Angle Change Y (video)		x	BP-54y
Foot/Ankle	Forces in Lower Leg	Motion of Feet Heel Z (video)	x	x	BP-54z
Foot/Ankle	Ankle Stiffness	Ankle Compression Z (video)		x	BP-55
Flesh	Flesh Properties	Compression of Pelvis Flesh		x	BP-56
Flesh	Flesh Properties	Compression of Heel Flesh		x	BP-57
Lumbar	Overall spine compression	Overall spine compression from T12 to S1		x	BP-58
Lumbar Spine	Overall Stiffness and Response of Lumbar Spine	Relative Lumbar Spine Rotation between T12/L1 and L5/S1 - X,Y,Z		x	BP-59
Pelvis	Overall Stiffness and Response of Pelvis	Relative displacement bet. sacrum and seat (impactor) - X,Y,Z		x	BP-60
Pelvis	Overall Stiffness and Response of Pelvis	Relative rotation bet. Sacrum and seat (impactor plate) - X,Y,Z		x	BP-61
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T8 Spinal Accel X			BP-62-X
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T8 Spinal Accel Z			BP-62-Z
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T8 Spinal Rotation Y-ARS			BP-63
Thoracic Spine	Thoracic Spine Kinematics and Curvature	T8 Motion (video) XZ plane		x	BP-64
Head	Roof Contact Force	Head Impact Force FZ	x	x	BP-65
Head	Head Comp. Stiffness	Head Deformation Z (Isolated Head)		x	BP-66
		Distal Femur Rotation Y-ARS			BP-67
		Distal Tibia Rotation Y-ARS			BP-68
Lumbar	Spine kinematics	Velocity measured at S1 level		x	BP-69
Pelvis	Moments acting on pelvis	Moment-Y at L5/S1 Joint		x	BP-70
Leg	Bending moment at upper tibia	My measured at knee potting		x	BP-71
Pelvis	Pelvis Kinematics	Pelvis rotational velocity measured at pubic symphysis		x	BP-72
Pelvis	Pelvis Kinematics	Pelvis rotation measured at pubic symphysis		x	BP-73

Table D-1 Master BP Listing

Body Region	Measurement Objective	Measured Biomechanical Parameters/Channel	Whole Body	Component	ITM Ref. BP #
Pelvis	Pelvis test rig kinematics	Ballast mass acceleration		x	BP-74
Pelvis	Pelvis test rig kinematics	Seat platen acceleration		x	BP-75
Pelvis	Pelvis Kinematics	Pelvis iliac wing acceleration	x	x	BP-76
Pelvis	Pelvis Kinematics	Pelvis iliac wing displacement		x	BP-77
Whole Body	Seat Pan Loading	Seat Load at Ischium	x		BP-78
Whole Body	Seat Pan Loading	Seat Load at Thigh	x		BP-79
Whole Body	Seat Pan Loading	Seat Load at Sacrum	x		BP-80
Whole Body	Pelvis Kinematics	Pubic Ramus Accel X	x		BP-81-X
Whole Body	Pelvis Kinematics	Pubic Ramus Accel Y	x		BP-81-Y
Whole Body	Pelvis Kinematics	Pubic Ramus Accel Z	x		BP-81-Z
Whole Body	Pelvis Kinematics	Pubic Ramus Rotation X- ARS	x		BP-82-X
Whole Body	Pelvis Kinematics	Pubic Ramus Rotation Y- ARS	x		BP-82-Y
Whole Body	Pelvis Kinematics	Pubic Ramus Rotation Z- ARS	x		BP-82-Z
Whole Body	Seat Pan Loading	Seat Load at Ischium+Thigh	x		BP-83
Whole Body	Pelvis Kinematics	Floor Velocity Z			BP-101-F
		Seat Velocity Z			BP-102-S
		Knee Z-Velocity			BP-103
		Pelvis Z-Velocity (S1)			BP-104
		Lower Neck Z-Velocity (T1)			BP-105
		Roof Z-Velocity			BP-106
Pelvis	Pelvis Kinematics	Pelvis iliac wing rotation ARS	x	x	BP-107
Foot/Ankle	Forces in Lower Leg	Foot Force-Toe	x		BP-108
Foot/Ankle	Forces in Lower Leg	Foot Force-Heel	x		BP-109
Foot/Ankle	Forces in Lower Leg	Foot Force-Total	x		BP-110

Appendix E – Integrated Test Matrix (ITM) Codes

The following Integrated Test Matrix (ITM) list was derived from historic or planned test series as of May 18, 2018. The appropriate BRC or INJURY test series from this table should be used for the ITM field in all file names.

Table E-1. Master ITM List

	BRC Test Series		Injury Test Series			BRC Test Series		Injury Test Series	
Head	HN01	HN06	HN-H01	HN-H06	Lumbar	LS01	LS-B03	LS-H01	LS-H03
	HN02	HN07	HN-H02	HN-H07		LS02	LS-B04	LS-H01a	LS-H04
	HN03		HN-H03	HN-H08		LS07		LS-H01b	LS-H05
	HN-B04		HN-H04	HN-H09				LS-H01c	LS-H06
	HN-B05		HN-H05					LS-H02	LS-H07
Pelvis	PV01		PV-H01	PV-H03	Thigh			UL-H01	UL-H07
	PV02		PV-H01a	PV-H04				UL-H02	UL-H08
	PV04		PV-H01b	PV-H04a				UL-H03	UL-H09
	PV05		PV-H02	PV-H04b				UL-H04	UL-H10
	PV06		PV-H02a	PV-H05				UL-H05	UL-H11
	PV11		PV-H02b	PV-H06				UL-H06	
	PV12		PV-H02c						
Lower Extremity	LL01		LL-H01	FA-H01	Whole Body	WH01	WH07	WS01	
	LL02		LL-H02	FA-H01a		WH01a	WH07a	WS02	
	LL03		LL-H03	FA-H01b		WH01b	WH07b	WS03	
	LL04		LL-H03a	FA-H01c		WH02	WH08	WS04	
	LL01/03/04		LL-H03b	FA-H02		WH02a	WH08a	WS05	
	LL08		LL-H04	FA-H02a		WH02b	WH08b	WS06	
	LL09		LL-H04a	FA-H03		WH03	WH09	WS07	
	LL11		LL-H04b	FA-H03a		WH03a	WH09a	WS08	
	LL12		LL-H05	FA-H03b		WH03b	WH09b	WS09	
	LL-B05		LL-H06	FA-H03c		WH04	WH10	WS10	
	LL-B10		LL-H07	FA-H04		WH04a	WH10a	WS11	
	LL-B15		LL-H08	FA-H04a		WH04b	WH10b	WS12	
	LL-B16		LL-H09	FA-H04b		WH05	WH11	WS13	
	LL-B17		LL-H10	FA-H04c		WH05a	WH11a	WS14	
	LL-B18		LL-H11a	FA-H05		WH05b	WH11b	WS15	
	LL-B19		LL-H11b	FA-H06		WH06	WH12		
	LL-B18-B19		LL-H12a	FA-H07		WH06a	WH12a		
			LL-H12b			WH06b	WH12b		

Appendix F – Injury Designations

The following injury designation list was compiled on May 22, 2018. It is possible that more injury bins are added. Always use “NA” to designate no injury in the readme “Injury Outcome” field. Otherwise, copy the “Injury Description” from the list in Table F-1.

Table F-1. Injury Designations

	Injury Description	Detailed Description
HEAD NECK INJURIES	C1/C2 STABLE	C1/C2 STABLE - Stable C1 or C2 fractures
	C1/C2 UNSTABLE	C1/C2 UNSTABLE - Unstable C1 or C2 fractures with ligament tear
	POST VERT SINGLE	POST VERT SINGLE - Single part fracture of pedicle, lamina, facet, transverse, or sp. Process
	POST VERT MULTI	POST VERT MULTI - Multi-part fracture of pedicle, lamina, facet, transverse, or sp. Process; fracture with anterior ligament/disc rupture
	VB FX	VB FX - Simple vertebral body fracture (wedge), no canal compromise
	MULTI VB FX	MULTI VB FX - Multipart VB fracture (burst or wedge) with or without canal compromise, or with posterior ligament rupture
	VB + POST (NO CANAL)	VB + POST (NO CANAL)- Fracture of VB & Posterior vertebra at same level with no canal compromise
	VB+POST+CANAL	VB+POST+CANAL - Fracture of VB & Posterior vertebra at same level with canal compromise or anterior soft tissue rupture
	MULTI LEVEL	MULTI LEVEL - Vertebral body fracture (multiple spinal levels)
	Other - JOINT DISRUPTION	Other Injuries - JOINT DISRUPTION OR LIGAMENTOUS INJURY
	Other - BASILIAR FX	Other Injuries - BASILIAR SKULL FX
LUMBAR INJURIES	Other - VB FX	Other Injuries - describe
	POST VERT FX	VB Fx (simple fx; no canal compromise)
	MULTIPART	Posterior vertebra fx (simple fx; no canal compromise)
	MULTI LEVEL MINOR	VB and/or Posterior vertebra (MULTIPART or comminuted fx with or without canal compromise)
	MULTI LEVEL SEVERE	Multi Level Minor (two levels with minor vertebral body fxs)
	Other - ISO LIGAMENT	Multi Level Severe (three or more levels with any vertebral fx w/ or w/o canal compromise, or two or more levels with anterior and posterior vertebral fx)
	Other -	Isolated Ligament Damage (Minor or Severe; no bony fx)
PELVIS	Other -	Other Injuries - describe
	PELVIS RING STABLE - 61.A1 - Avulsions	PELVIS RING STABLE - 61.A1 - Avulsions 61.A1.1 - ASIS, PSIS, Spinous Avulsion 61.A1.2 - Iliac Crest Avulsion 61.A1.3 - Ischial Tuberosity Avulsion

Table F-1. Injury Designations

	Injury Description	Detailed Description
	PELVIS RING STABLE - 61.A2	PELVIS RING STABLE - 61.A2 61.A2.1 - Iliac Wing Fragment(s) 61.A2.2 - Unilateral fx of anterior arch 61.A2.3 - Bilateral fx of anterior arch
	PELVIS RING STABLE 61.A3 - Transverse Sacral;	PELVIS RING STABLE 61.A3 - Transverse Sacral; coccyx 61.A3.1 - Trnasverse Sacrococcygeal dislocation - coccyx 61.A3.2 - Transverse Sacral Fx; undisplaced 61.A3.3 - Transverse Sacral fx; displaced
	PELVIS RING UNSTABLE - Unilateral	PELVIS RING UNSTABLE - Unilateral - SI alone or Sacral fx; Denis zone 1 (ala) - Sacral fx; Denis zone 2 (foramina) - Sacral fx; Denis zone 3 (central sacral canal)
	PELVIS RING UNSTABLE - Bilateral	PELVIS RING UNSTABLE - Bilateral - SI alone or Sacral fx; Denis zone 1 (ala) - Sacral fx; Denis zone 2 (foramina) - Sacral fx; Denis zone 3 (central sacral canal)
	ACETABULUM FX - Partial	Acetabulum fracture (single column partial articular, transverse partial articular)
	ACETABULUM FX - Comminuted	Acetabulum fracture (comminuted complete articular, transverse open, transverse comminuted open)
	Other - L4 or L5 VB fx	Other - L4 or L5 VB fx
	Other - Sacrum H or U FX	Other - Sacrum H-Style or U-Style fx (vertical and transverse)
	Other - Ligament Avulsions	Other - Soft Tissue - Ligament Avulsions
FEMUR	Other -	Other Injuries - describe
	FEMUR SHAFT - OTA 32-A	Femur shaft fracture (simple; OTA Type 32-A; Winquist I)
	FEMUR SHAFT - OTA 32-B	Femur shaft fracture (wedge; OTA Type 32-B; Winquist II/III)
	FEMUR SHAFT - OTA 32-C	Femur shaft fracture (complex; OTA Type 32-C; Winquist IV)

Table F-1. Injury Designations

	Injury Description	Detailed Description
	Other -	Other Injuries – describe
LOWER LEG INJURIES	MID TIBIA FX - OTA 42-A	Diaphyseal tibia fracture (simple; OTA Type 42-A; Winquist I)
	MID TIBIA FX - OTA 42-B	Diaphyseal Midshaft tibia fracture (wedge; OTA Type 42-B; Winquist II/III); Fibula Fracture (communitied wedge)
	MID TIBIA FX - OTA 43-C	Diaphyseal tibia fracture (complex; OTA Type 42-C; Winquist IV)
	OPEN - MID TIBIA FX - OTA 42-1	OPEN Diaphyseal tibia fracture (simple; OTA Type 42-A; Winquist I)
	OPEN - MID TIBIA FX - OTA 42-B	OPEN Diaphyseal Midshaft tibia fracture (wedge; OTA Type 42-B; Winquist II/III); Fibula Fracture (communitied wedge)
	OPEN - MID TIBIA FX - OTA 43-C	OPEN Diaphyseal tibia fracture (complex; OTA Type 42-C; Winquist IV)
	PROX TIBIA FX - OTA 41-A	Proximal tibia fracture (extra-articular; OTA Type 41-A)
	PROX TIBIA FX - OTA 41-B	Proximal tibia fracture (partial articular; OTA Type 41-B)
	PROX TIBIA FX - OTA 41-C	Proximal tibia fracture (complete articular; OTA Type 41-C)
	DIST TIBIA FX - OTA 43-A	Distal tibia fracture (extra-articular; OTA Type 43-A)
	Other -	Other Injuries - describe
FOOT ANKLE INJURIES	TARSAL FX	Tarsal bone fracture (navicular, cuboid, and cuneiforms)
	TALUS FX SIMPLE	Talus fracture (fx non-displaced or simple displacement; Hawkins Type-I, II)
	TALUS FX DISPLACED	Talus fracture (fx with displacement and dislocation; Hawkins Type-III, IV)
	CALCANEUS FX SIMPLE	Calcaneus fracture (simple, 1 articular surface simple, Sanders Type-I, II)
	CALCANEUS FX SEVERE	Calcaneus fracture (comminuted crush, comminuted, Sanders Type-III, Type-IV)
	DIST TIBIA FX - OTA 43-B	Distal tibia fracture (partial articular; simple pilon; OTA Type 43-B)
	DIST TIBIA FX - OTA 43-C	Distal tibia fracture (complete articular; comminuted pilon; OTA Type 43-C)
	MALLEOLAR FX - OTA 44-A	Malleolar fibula fracture (simple uni or bi infrasyndesmotoc; OTA Type 44-A)
	MALLEOLAR FX - OTA 44-b	Malleolar Distal fibula fracture (trans-syndesmotoc; OTA Type 44-B)
	Other -	Other Injuries - describe

Appendix G – Revision History and Approvals

Revision History

Rev#	Date	Description of Change	Lead	Collaborators
1.0	2013-07-109	Initial release	Huyssoon	JHU/APL: Merkle, D'Angelo, Kleinberger, Ott USAARL: Vasquez, McEntire
1.1	2013-10-15	Updated with comments from V1.0, significant modifications to: File Naming Data Header Folder Structure	Huyssoon	PMO: Coates JHU/APL: Merkle, D'Angelo, Kleinberger, Ott, Dooley USAARL: McEntire, Rooks MCW: Schlick, Humm Duke: Schmidt, Bass
1.2	2013-11-08	Modifications to File Naming, RAW data guidance, and Notification instructions	Huyssoon	PMO: Coates JHU/APL: Merkle, D'Angelo, Kleinberger, Ott, Dooley USAARL: McEntire, Rooks MCW: Schlick, Humm Duke: Schmidt, Bass
1.2.1	2013-11-25	Final Edits	D'Angelo	Huyssoon
1.3	2015-06-30	Data Structure Tiger Team (DSTT) updates: File Naming Folder Structure Header Information	Dooley	JHU/APL: Dooley UVA: Alai WSU/USC: Sherman, Greb, Abubakr UMTRI: Miller OSU: Kang WFU: Marcus, Birkenbach
1.4	2017-07-02	Updated to clarify and remove redundancy	Pyles	JHU/APL: Pyles, Kuo, Demetropoulos UMTRI: Miller
.0	2018-06-07	Updated to include new guidance from WEO and BioPT working groups - Specimen ID tracking - Input condition tracking - BP tracking - Binary data folder - Final data folder - Other data folder - Folder hierarchy and naming update - CID clarifications - Transformation matrix documentation - Scale factor documentation - Appendix for allowable field descriptors, including BP and ITM - Video standard specifications - Test Number clarifications - Formatting for field descriptors - Restricted character lists - Required imaging and documentation - Detailed explanation of data categories - Miscellaneous clarifications	Pyles	JHU/APL: Pyles, Demetropoulos, Voo, Zhang, Conner, Carneal WIAMan EO: Bilodeau, Loftis, Alai UVA: Spratley MCW: Schlick WSU: Sherman Duke: Bass UMTRI: Miller

Approvals

Approver	Signature	Approval Date	Group Represented
C. Carneal	Catherine M Carneal Digitally signed by Catherine M Carneal Date: 2018.06.19 12:37:26 -04'00'	19 June 18	JHU/APL
F. Hughes	HUGHES.FRED ERICK.JAMES.I V.1186542408 Digitally signed by HUGHES.FREDERICK.JAMES.IV.1186542408 Date: 2018.06.19 13:21:25 -04'00'	19 June 18	WIAMan Engineering Office
S. Snead	SNEAD.STEPHANIE.LEIGH.1229656771 Digitally signed by SNEAD.STEPHANIE.LEIGH.1229656771 Date: 2018.06.19 13:36:41 -04'00'	19 June 18	SLAD Warfighter Survivability

LIST OF ACRONYMS

AA	Anti-Aliasing
AIIS	Anterior Inferior Iliac Spine
ARS	Angular Rate Sensor
ASIS	Anterior Superior Iliac Spine
ATD	Anthropomorphic Test Dummy
APL	Johns Hopkins Applied Physics Laboratory
ARL	Army Research Laboratory
BIO PT	Biomechanics Product Team
BP	Biomechanical Parameter
BRC	Biofidelity Response Corridor
CERV	Cervical Spine
CFC	Channel Frequency Class
CID	Channel Identification
CLC	Calculated Data Category
CON	Converted Data Category
CR	Carriage Return
DAC	DEVCOM Analysis Center
DAS	Data Acquisition System
DC	Direct Current
DEVCOM	U.S. Army Combat Capabilities Development Command
DICOM	Digital Imaging and Communications in Medicine
DSTT	Data Structure Tiger Team
DUK	Duke University
FIN	Final Data Category
Fx	Fracture
HEADN	Head Neck
HIII	Hybrid III
HIPC	Human Injury Probability Curve

ID	Identification
IPR	Inferior Pubic Ramus
ITM	Integrated Test Matrix
IW	Iliac Wing
JHU/APL	Johns Hopkins University Applied Physics Laboratory
LF	Line Feed
LLEG	Lower Leg
LUMB	Lumbar Spine
MCW	Medical College of Wisconsin
NA	Not Available
OSU	Ohio State University
PELV	Pelvis
PMHS	Post-Mortem Human Surrogate
PMO	Program Management Office
POC	Point of Contact
PPE	Personal Protective Equipment
PRO	Processed Data Category
RAW	Raw Data Category
SCL	Scaled Data Category
SCoTT	Signal Conversion Tiger Team
SLAD	Survivability Lethality Assessment Directorate
SPR	Superior Pubic Ramus
TD2	Tech Demonstrator 2
TRR	Test Readiness Review
TSV	Tab-Separated Values
TTP	Time to Peak
UMTRI	University of Michigan Transportation Research Institute
USAARL	United States of America Army Research Laboratory
USC	University of Southern California

UVA	University of Virginia
VALTS	Vertically Accelerated Load Transfer System
WFU	Wake Forest University
WHBO	Whole Body
WIAMan	Warrior Injury Assessment Manikin
WSU	Wayne State University

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