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MEETING REPORT

Terrestrial LiDAR Scanning Working Group for Criminal Justice Applications, First Meeting

Overview

On February 27 and 28 of 2020, The National Institute of Justice (NIJ), in partnership with the Forensic Technology Center of Excellence (FTCoE) at RTI International, convened the first meeting of the Terrestrial LiDAR Scanning (TLS) Working Group for Criminal Justice Applications. The TLS Working Group (TLSWG) will support the NIJ-FTCoE's goals of improving the practice and strengthening the impact of forensic science through rigorous technology corroboration, evaluation, and best practices dissemination. This first working group meeting was co-located with the International Association of Forensic and Security Metrology's (IAFSM) Annual International Education Conference in Nashville, Tennessee.

Light detection and ranging (LiDAR) technology is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. Terrestrial LiDAR scanning devices (also known as terrestrial laser scanning devices) acquire complex geometric data that captures a three-dimensional representation of a scene; this technology is used in criminal justice applications such as documenting a crime or crash scene. While the use of this technology is increasing in criminal justice applications, no standardized, vendor agnostic guidelines for use are currently available for end users. The goal of the working group is to develop resources that reflect consensus-based best practices to standardize and improve the use and application of TLS in crime scene documentation and reconstruction. These deliverables will help establish a minimum standard for capture, processing, analysis, visualization, presentation, and storage of TLS data in a forensic context. These resources are intended to promote uniform implementation and use of TLS technology in practice. This will ultimately improve the practitioners' ability to attain scientifically supportable conclusions from TLS data, ensure effective quality management procedures, and improve presentation of this information to stakeholders, including law enforcement, investigators, and the courts (e.g. prosecutors and defense attorneys, judges, and juries).

Objectives and Outputs of the First Meeting

The objectives of the first TLSWG meeting were to brainstorm community needs and challenges and identify work products that could help achieve these goals (see Appendix for agenda). The team focused on identifying challenges and key community needs around: 1) equipment procurement, calibration and validation; 2) data capture and relevant training; and 3) data processing, management, and reporting.

The following document provides an overview of the first meeting and intended next steps for the TLSWG. Following this meeting, the TLSWG, with support from the FTCoE, intends to develop a toolkit for successful implementation and use of TLS in criminal justice applications. This will include a guidance document for use of TLS in criminal justice applications (covering the above three focus areas); and webinar(s) to educate the justice community on the value of TLS in casework.

Participants

The TLSWG includes forensic practitioners and researchers with extensive backgrounds in crime scene documentation and reconstruction and experience in providing expert testimony on bloodstain pattern analysis and trajectory reconstruction. The working group includes representatives from federal, state, county and local systems, as well as representation from the Crime Scene Subcommittee of the National Institute of Standards and Technology (NIST) Organization of Scientific Area Committees (OSAC) and NIJ's Forensic Science Research and Development Technology Working Group.

Name	Title	Agency
Michael Russ	Sheriff's Lead Crime Scene Specialist and lead SME for the TLSWG	San Bernardino County Sheriff's Department
King Brown[1]	Crime Scene Supervisor	West Palm Beach Police Department
Hector Deleon	Crime Scene Investigator	New York Police Department
William Henningsen	Forensic Manager	Omaha Police Department Forensic Investigations Unit
Steven Jameson	Supervisor	Federal Bureau of Investigation, Operational Projects Unit
Jason Keller[2]	Forensic Graphics Specialist	Naval Criminal Investigative Service (NCIS), Office of Forensic Support
Eugene Liscio	3D Forensic Analyst and Adjunct Professor	ai2-3D Forensics, University of Toronto
Bryon O'Neil	Criminalist	Clackamas County Sheriff's Office
Prem Rachakonda	Mechanical Engineer	Dimensional Metrology Group, Sensor Science Division, Physical Measurement Lab, National Institute of Standards and Technology (NIST)
Justin Snider	Multidisciplinary Accident Investigation Teams (MAIT) Investigator	California Highway Patrol
Troy Wilson[2]	Staff Lieutenant, Crime Scene Unit Team Leader	Texas Rangers

[1] Member of NIJ's Forensic Science Research and Development Technology Working Group
[2] Members of NIST's OSAC Crime Scene Subcommittee

Key Terminology

artificial common reference object –also called "targets," are objects strategically placed in the scan area to serve as reference points between scan positions to enable registration.

calibration—"set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards."
(ASTM E2544-11a (2019): Standard Terminology for Three-Dimensional (3D) Imaging Systems)

hash algorithms—"use complex mathematics to create a value that is typically represented as a string of hexadecimal characteristics (called a hash) on a given set of data. If the data changes, so will the hash." (SWGDE Position on the Use of MD5 and SHA1 Hash Algorithms in Digital and Multimedia Forensics)

hash function—"a function that maps a bit string of arbitrary length to a fixed length bit string. The function is expected to have the following three properties: 1) collision resistance, 2) preimage resistance, and 3) second preimage resistance." (NIST Recommendations for Applications Using Approved Hash Algorithms)

known distance artifact – also called an "artifact," are items with a known size that are introduced into the scan area to allow for an accuracy check of the individual scan data.

light detection and ranging (LiDAR)—a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. (FTCoE Landscape Study on 3D Crime Scene Scanning Devices)

NIST traceable artifact—an object that is metrologically traceable to NIST's practical realization of the SI unit of length, the meter (NIST website) and is used as a known distance artifact.

point cloud—"a collection of data points in 3D space (frequently in the hundreds of thousands), for example as obtained using a 3D imaging system." (ASTM E2544-11a)

range—"the distance, in units of length, between a point in space and an origin fixed to the 3D imaging system that is measuring that point." (ASTM E2544-11a)

range resolution—"the smallest change in range that causes a perceptible change in the corresponding range measurement indication." (ASTM E2544-11a)

registration—"the process of determining and applying to two or more datasets the transformations that locate each dataset in a common coordinate system so that the datasets are aligned relative to each other." (ASTM E2544-11a)

total station—a surveying instrument that uses a theodolite with an electronic distance meter to read slope distances from the instrument to a particular point. (FTCoE Landscape Study on 3D Crime Scene Scanning Devices)

terrestrial LiDAR scanner (also known as terrestrial laser scanner)—a method for surveying tasks that acquires complex geometric data where each point is determined by the position (X, Y, Z) and the intensity (i) of the returning signal. (FTCoE Landscape Study on 3D Crime Scene Scanning Devices)

Important Discussion Points

During this initial TLSWG meeting, the team discussed community challenges and needs related to three main themes concerning proper use of TLS:

1. Equipment procurement, calibration, and validation
2. Data capture and relevant training; and
3. Data processing, management, and reporting.

The following section provides an overview of these challenges and needs.

1. Equipment Procurement, Calibration, and Validation

Challenges

- **Agencies must invest in multiple pieces of equipment for successful TLS implementation and use.** Agencies need equipment besides a scanner to use TLS successfully: tripods, reference targets, NIST traceable standards, and other hardware and software elements add operation costs to TLS and may be difficult to justify purchasing in an organization.
- **No current "calibration check" in the field exists.** Currently, there is a lack of an in-field method to perform a "calibration check" for TLS. Performance tests or "function tests" can be made against a known artifact or NIST traceable artifact, but these are not adequate to assess the current state of the instrument's calibration.
    - It is difficult to perform a thorough field test to assess whether the TLS instrument is operating within established tolerances, especially in situations where it may have been damaged in transport, dropped, or subjected to extreme temperatures.
    - There is a need to enhance device durability: most instruments have IP54 rating[3], but vendors need to improve ruggedization-related qualities (e.g., their shock rating) to improve adoption and use in the field.
    - Calibration is an accredited discipline and a key part of instrument maintenance. Agencies and end users need to send away their scanners through shipping companies to have them calibrated, which may undo the calibration that the company has performed. This also leads to downtime. These calibrated instruments could be compared to other instruments to determine whether additional devices are operating within the functional parameters.
    - Accredited calibration cycles prescribed by manufacturers are typically set for industries that engage in constant use of TLS units in surveying, Building Information Modeling (BIM) or Engineering. Accredited calibrations are also a significant expense. Forensic deployments of TLS units are typically much less frequent and much smaller in scope.
- **Product offerings are difficult to compare.** It may be difficult to compare specs for instrument accuracy, resolution, speed, and other key metrics across vendor offerings. The NIJ FTCoE's Landscape Study of 3D Scanning Devices directly compares specs of product offerings of key TLS vendors.
- **It is difficult to calculate return on investment (ROI).** Some organizations have conducted cost studies that show it may be easy to calculate ROI for crash scene reconstruction but difficult for crime scene reconstruction. There is very minimal guidance to measure ROI because of the following reasons:
    - While rooted in science, the impact of a point cloud presentation can be difficult to convey to a trier of fact.

[3] Devices with an Ingress Protection (IP) 54 rating have limited protection from dust and water spray from any direction.

  - It is hard to quantify the costs saved by civil liability cases.
  - The true value of the instrument is being able to capture data in ways that were previously impossible, which is difficult to assign a price value.

Needs

- A protocol to perform a "in-field calibration test" in an operational environment to determine whether the instrument is operating within established tolerances.
- Better guidance on the cadence of official calibration for forensic TLS units.
- Insight on the true cost of implementing TLS for criminal justice applications. This includes training and equipment costs.
- Improved artifacts like trajectory rods and other products that can be easily captured in scan data.
- Guidance on developing and using artifacts in practice.
- A model procurement guide or list with emphasis on specific types of computers (e.g., gaming computers with upgraded processor/memory/video card capabilities) and appropriate data storage devices.

2. Data Capture and Relevant Training

Challenges

- **No standardized procedures currently exist.** Scanning procedures vary based on application, and there is no standardized guidance on the parameters (e.g., resolution, quality, cut-off distance) used.
- **Data capture is difficult in certain situations and environments**. It is difficult to capture data on shiny or reflective surfaces, or if there is accumulated snow in the area.
- **More training is needed for practitioners and the court systems.**
  - Many agencies do not have specific training for investigators and practitioners for providing TLS-related testimony.
  - Training is needed for judges, prosecutors and defense attorneys. Prosecutors and defense attorneys may not understand the science and accuracy behind the algorithms and technology used to produce these scans, and judges may deem these data inadmissible depending on their experience with this technology.
- **Agencies often lack consistency between role descriptions.** Roles of "operators", "analysts" and "technologists" in this field have no standardization and vary widely across agencies.

Needs

- Need to balance workforce of trained TLS operators to be few enough so that each operator gains adequate experience using the instrument, but enough that multiple staff can review scan quality and provide feedback.
- Need for improved education for TLS operators:
  - Curriculum standards for training operators,
  - Vendor-agnostic certification standard for TLS operators
- Need for a 101-style webinar to inform investigators, jurors, prosecutors, defense attorneys and judges about TLS, which also provides practitioners with the language to easily explain the technology's value within a court of law.
- Need for research on nondestructive methods to address reflective surfaces in scans (e.g., chrome features on cars, windows).

- Need for vendor agnostic forensic and security metrology forums to continue regular discussion and collaboration between regional agencies.
    - IAFSM members could leverage regional working groups in a way that could encourage cooperative scene collaboration and sharing of case studies.
    - Regional meetings can be used as a mechanism to test and research together and to validate procedures and techniques.
- Need for regionally held training opportunities that address specific skill levels.
- Need to define/name positions and identify their functions/skill sets (i.e., operator, technologist, analyst).
- Need for agencies who are looking to adopt this technology to have standard language that articulates the need for and value of the technology.

3. Data Processing, Management, and Reporting

Challenges

- **Data storage methods vary between agencies.** There is little guidance on the most appropriate methods to store data physically (i.e., what medium the content is burned onto, like an archive quality optical disk). Inconsistency in storage methods may limit the ability of agencies to collaborate (for example, agencies may not have the same kind of optical disk reader).
- **Data integrity must be maintained and verified.** Traditional methods of verifying data integrity involve using cryptographic hash functions after the scan is performed. It does not guarantee data integrity because this method is manual. Manufacturers need to incorporate automated methods of creating hash values and verification to ensure data integrity and inhibit tampering.
- **Data access by other criminal justice stakeholders can be limited.** Prosecutors, defense attorneys and practitioners in other agencies who want access to the data must download proprietary software to view it. This makes it difficult for agencies using different scanners to collaborate.
- **Data authentication is paramount.** Presenting high-quality and useful data requires data visibility management by filtering, layering and minimizing extraneous noise, (e.g. hiding passing cars out of the scans on a crash scene); however, this process may not be well understood by courts or practitioners.
- **Difficulty of data transfer and aggregation.** TLS manufacturers do not use a common format for the raw data. This creates issues when transferring data sets (e.g., for peer review) or combining data sets captured on devices from different manufacturers. While the data can be saved in an e57 file format for sharing, it is unknown if this affects the data quality of the scans.

Needs

- Need for guidance on methods to document processing of scans into exhibits to show the progression from original raw data to final product.
- Need for a better understanding of how each type of software is registering scans (i.e., what error range is acceptable). This could be addressed in the form of technical validation or software study.
- Need for guidance on viable long-term storage options for scan data (both physical and cloud/network storage options)
- Need for methods to share data between different scanner software products offered by scanner vendors and other software providers (i.e., interoperability). For example, leveraging the e57 file format or automatically saving the file in different file formats.
- Need for a forensic data copy tool that automatically produces hash values before copying and verifying.

- Need for manufacturer involvement to incorporate data integrity methods (e.g., hash functions) into their software.
- Need for best practices for target-based registration.

Miscellaneous/Other Interesting Insights

- Although a value proposition of the TLS technology is that it saves time for investigators at the crime scene, practitioners often end up taking more scans; however, more data gets captured.
- At least two operators and two analysts need to be trained for TLS operations to accommodate for technical review.
    - It should be noted that other agencies can be leveraged for technical review—regional conferences can help establish relationships between agencies that can promote this collaboration. However, evidence sharing processes must take into consideration methods that are compliant with governmental standards (such as the Criminal Justice Information Services requirements).
    - Because of the nature of using TLS instruments (e.g., in homicides or officer-involved shootings), agencies may consider training multiple individuals to mitigate challenges. However, a smaller number of trained operators means that each has more opportunities and time using the scanner.
    - Bringing in both drone and photography experts to audit TLS operator classes could be a helpful approach to ensuring common knowledge and improved collaboration between the teams.
- To provide value, TLS must optimize the following:
    - Time to train,
    - Time to response,
    - Time on target
    - Ease of operation, and
    - Time processing to a universally accessible deliverable.

Proposed Work Products: Leveraging IAFSM Foundational Work to Create a TLS Implementation Toolkit

Based on the two-day discussion, the TLSWG agreed on two key work products that could be developed into a TLS use toolkit to be housed on the FTCoE website. These deliverables would be created in collaboration with the IAFSM.

1) A guidance document for use of TLS for criminal justice applications; and
2) A webinar to educate justice partners on the value of TLS in casework.

Deliverable 1: Guidance Document for Use of TLS for Criminal Justice Applications

In 2015, the IAFSM began drafting a set of best practice guidelines for uniform TLS use in criminal justice applications. The team had built a skeleton outline for categories that they would include in a best practices document, and the TLSWG used this skeleton as a starting point to brainstorm what should be included in a guidance document for appropriate TLS use in criminal justice applications.

Although this could be packaged as one large guidance document, there could be multiple resources nested within the document that could be pulled out as tools in a toolkit. These include checklists, sample procedures, and other helpful resources for agencies.

The TLSWG divided this document by the three themes outlined above, with a designated point person for each section.

Equipment Procurement, Calibration, and Validation
What follows is a list of draft guidance document content for the procurement, calibration and validation of equipment.

- *Necessary Equipment*
    - Checklist of equipment including minimum performance standards.
    - Hardware requirements for TLS:
        - Scanner
        - Tripod/platform tripod/elevated tripod and associated mounting hardware
        - Floor mount
        - Reference targets
        - Laptop
        - Marking material
        - Spray/powder materials to accurately depict reflective/glass materials (e.g., cheap spray deodorant, dry shampoo, fingerprint powder, baby powder)
        - Markers, highlighter, and tape
        - Necessary forms, methods to record major steps and notes (paper or electronic note taking)
    - Software requirements for TLS:
        - Products used to clean scans and draw
        - Registration software
        - Software that enables universal transfer of data (free viewer or accessibility in multiple file formats)
        - Software with traceability (because of the need to understand challenges of testifying to audit trails)
        - Software products that help maintain data integrity (e.g., hashing)
    - Consult with examples from TSLWG SME setup
    - Tips and tricks for maintenance that may not be in typical product manuals (e.g., how to prevent tripod and other equipment contamination in biohazard scenes)
- *Calibration, Validation, and Quality Control*
    - Description of how an agency should keep records of calibration (e.g., attaching to case files)
    - Steps for an accurate in-field calibration check that may be used to assess whether the instrument can be used and when to perform this check (e.g., if the instrument is dropped)
    - List of metrics to use for checking quality (i.e., targets)
    - Standard procedure/checklist for a quality assurance or technical review (which may be considered a peer review)
    - How artifacts can be used in scans as an in-field performance test or Reference Measurement Protocol similar to other methods of Forensic Mapping (e.g. Total Station use of a backsight)
    - Checklist for completeness of data/internal review

Data Capture and Relevant Training

What follows is a list of draft guidance document content for data capture and training.

- *Personnel Training, Experience, and Qualifications*
  - Use of a combined written/practical competence examination for scanner certification, similar to other forensic discipline requirements
    - Established Performance Period including periodic proficiency testing
    - Re-testing when there are significant software changes and updates
  - Need for local agency-trained and certified trainers/instructors, not just vendor trainers
    - Provide language to justify investing in certifying instructors within your agency, rather than relying solely on the vendor trainers
  - Minimum curriculum requirements for vendor- and organization-based training
  - The importance of field-testing experience and a list of approaches a trainee may take to gain more experience (e.g., taking a scanner out and practicing one time per quarter)
  - Need for a field-accessible resource (like a template) that serves as a step-by-step technical guide for using a scanner, which can be provided as a hard copy or on an online platform, like SharePoint
  - Identify the difference between capabilities and skill sets of an operator, analyst, and technologist: what qualifies you for each role (e.g., what type of analysis, expertise in recording, testimony, ability to interpret the work of others)
- *Data Capture*
  - Guidance around what data quality is needed for specific applications (i.e., common accuracy and precision standards)
    - Guidance around point resolution suggested for crime scene vs. bloodstain vs. trajectory vs. crash, and other applications
    - Identifying what may be considered high resolution, high quality, or range to surface
    - Appropriate environmental range standards
    - Example of how to calculate the right point resolution for a given set of field conditions
    - What cut-off distance should be used when capturing the scene and how this relates to the measurement method of a given TLS
  - Data collection: consider the following when capturing data at the scene
    - Scan where it matters most, prioritize when there are environmental issues that may hinder scanner use or compromise scene (e.g., snow)
    - Make sure evidence is clearly marked
    - "Order of operations" guidance for use of TLS with other instruments, such as the total station
    - How to secure scenes in a way that facilitates TLS scanning (e.g., two perimeters)
    - Field notes to include site sketch and other documentation
    - Developing a scan plan: what to include (e.g., scanner positions, settings, crew, locations of the scans, target locations)
    - Documented annotations of aerial images and evacuation plans to establish context
  - Reference measurements
    - Incorporation of a NIST traceable standard or other known distance artifact
    - Incorporation of standards useful to the instrument, such as ASTM E3125-17 (Standard Test Method for Evaluating the Point-to-Point Distance Measurement Performance of Spherical Coordinate 3D Imaging Systems in the Medium Range), ASTM 2544-11a

(Standard Terminology for Three-Dimensional (3D) Imaging Systems) and ISO 17123-9-2018 (Optics and Optical Instruments- Field Procedures for Testing Geodetic and Survey Instruments-Part 9: Terrestrial Laser Scanners).

- Guidance on types of artifacts to use for scans—ideas for 3D printed materials, other types of materials for reference measurements (e.g., tape on trajectory rods, how to go about getting a NIST traceable certificate for objects)
- Guidance around incorporating reference measurement depending on scene (e.g., testing in middle of capable range of scanner)
- Guidance around use of laser range finder and targets
- When to add an artifact in scans or show reference measurements from some sort of traceable standard (e.g., should they be visible in more than one scan position)

Data Processing, Management, and Reporting
What follows is a list of draft guidance document content for processing, management and reporting of data.

- *Process Methodology/Reporting*
    - Stepwise methods (at a high level) for processing data, including record of workflow, stepwise outputs, and example products for court.
    - Guidance around when/what/and how to use various filters and layers to minimize views of noise and extraneous data while still maintaining audit trail and admissibility of the dataset
    - Boilerplate language to describe what TLS is and how it is used, for an audience like jurors
    - Technical review (peer review) procedure, understanding how deep the analysis should be and what checks should be in place
- *Data Management*
    - Guidance around creating hash checks: at what point should hash checking technology be used and what types of algorithms should be used for hash checks
    - Ensuring that redundant storage of some kind is used—guidance around digital retention system and hard copies of media (e.g., blu-rays, DVDs)
    - Suggestions for spanning software that can help stitch scans/data that are divided over more than one disc
- *Reporting and Disclosure*
    - Legal standards for reporting are country dependent but could include a case citation list that is being aggregated by IAFSM
    - Guidance on capturing an accurate record of the process to capture and process data
    - What types of data are typically necessary for these investigations
        - Calibration reports (i.e., date, time, environmental conditions)
        - Registration reports
    - Recommended actions for trial preparation (e.g., review case data)

Deliverable 2: Webinar to Educate the Justice Community on the Value of TLS in Casework

This webinar, or a series of webinars, aims to address challenges faced because prosecutors often do not understand how these instruments work and may be hesitant to use these data in casework. Although TLS operators may be well-trained on using the technology, they may feel less comfortable explaining how the technology works to laypeople. This limits the ability of courts to understand the value and quality of data gathered through TLS. The working group will convene a panel of TLS experts and 2-3 stakeholders from the legal community who has used TLS data in casework to help succinctly convey how TLS works and why it is important. The team will leverage content from the IAFSM basic laser scanner certification course and previous NIST work to communicate scientific concepts to prosecutors' defense attorney and judges. The FTCoE will support the planning, dissemination, and execution for this webinar.

Next Steps

Through this initial working group meeting, the team has successfully identified challenges in TLS use in criminal justice applications and potential work products that could address needs of the community. The group will form subcommittees to address the three sections of the guidance document. The working group will work closely with the FTCoE to plan, disseminate, and execute the deliverables. The working group also plans to coordinate efforts with NIST's OSAC, specifically the Crime Scene Investigation subcommittee, so that the OSAC may build on our efforts to pursue the development of standards for TLS.

APPENDIX: Agenda

Terrestrial LiDAR Scanning (TLS) for Criminal Justice Applications Working Group, Nashville, TN

Opryland Hotel, Pennington Room

DAY 1: Thursday, February 27, 2020
1:30–6:00 pm

1:30–1:45 pm	Welcoming Remarks	**Mike Russ** Sheriff's Lead Crime Scene Specialist, San Bernardino County Sheriff's Office
1:45–2:30 pm	Discussion #1: Goals & Objectives of TLS Working Group	**Lance Miller** Senior Criminal Justice Technology Advisor RTI International/FTCoE **Mike Russ**
2:30–3:00 pm	Discussion #2: Overview of TLS Technology Needs	**Mike Russ** **Group**
3:00–3:15 pm	Break	
3:15–4:30 pm	Discussion #3: Performance Standards Relevant to TLS	**Lance Miller**
4:30–6:00 pm	Discussion #4: Technology & Operational Issues for TLS	**Group**
6:00 pm	Adjourn	

Terrestrial LiDAR Scanning (TLS) for Criminal Justice Applications Working Group, Nashville, TN

Opryland Hotel, Pennington Room

DAY 2, Friday, February 28, 2020
8:30 am–3:00 pm

8:30–8:45 am	Recap of Yesterday's Discussions	**Lance Miller**
8:45–9:45 am	Discussion #4 (cont'd): Technology & Operational Issues for TLS	**Group**
9:45–10:15 am	Discussion #5: Identification of Barriers to TLS Technology Adoption and Use	**Group**
10:15–10:30 am	Break	
10:30–11:45 am	Discussion #5 (cont'd)	**Group**
11:45 am–1:00 pm	Lunch (on your own)	
1:00–2:30 pm	Discussion #6: Path Forward—Development of Action Item & Task List	**Lance Miller** **Mike Russ**
2:30–3:00 pm	Wrap-up and Closing Comments Discussion of Schedule/Next Meeting	**Group**
3:00 pm	Adjourn	