Simulation Interoperability Standards Organization

"Simulation Interoperability & Reuse through Standards"

Repeatable Unit Testing of Distributed Interactive Simulation (DIS) Protocol Behavior Streams using Web Standards

"A Stream is a Stream"

2021-SIW-Presentation-028

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Problem Statement

- It is hard for simulation systems to interconnect, especially with partner nations and C2 systems
- Utilizing open-source Web Technology is a valuable resource that can help numerous systems regardless of data classification
- Partnerships with NATO partners are needed to improve shared understanding of mutual goals and challenges
- M&S is not relevant to active warfighting unless we can achieve interoperability between Live, Virtual and Constructive (LVC) simulations, robot telemetry, and Command and Control (C2)

Thesis Motivation: Basic Premises

- **A stream is a stream, at rest in a file or in motion over network**
  - Playback recorded manipulation of a model using PDUs
  - Stream manipulation of models using OpenDIS7 library
- **Multiple open-source codebases available, initially Java**
  - more languages to follow (JavaScript, Python, XML, JSON, etc.)
- **X3D Graphics standard allows dynamic 3D in any Web browser**
  - Record remote animation of a model using PDUs
  - Distill concise first-order linear interpolators from streams

Research Questions

- **Stability of IEEE DIS specs and capabilities of MOVES LVC Lab offer excellent new opportunities for broad interoperation**
  - Open-source codebase by Mike Bailey offers entire vocabulary
  - Curt Blais dissertation work on Rich Semantic Track (RST)
  - How can these best be adapted and applied?
- **How to promote DIS behavior streams as first-class media type?**
  - Coherent data streams for collaboration, simulation, telemetry
  - Unit testing of recorded streams for adaptable repeatability
  - Establish archivable annotated records of simulation activity

What is IEEE DIS Protocol?

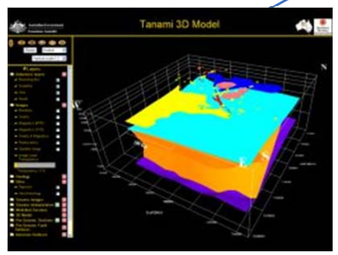
- Distributed Interactive Simulation (DIS) is an Institute of Electrical and Electronics Engineers (IEEE) standard for conducting real-time platform-level wargaming across multiple host computers and is used worldwide, especially by military organizations and other agencies.
- Wikipedia: Distributed Interactive Simulation (DIS)
- Simulation Interoperability Standards Organization (SISO): "Simulation Interoperability and Reuse through Standards“
- SISO DIS / RPR FOM Product Support Group (PSG)

What is X3D4 Graphics?

X3D Anywhere

Extensible 3D (X3D) Graphics is the royalty-free open standard for publishing, viewing, printing and archiving interactive 3D models using Web technology.

Geo Visualization

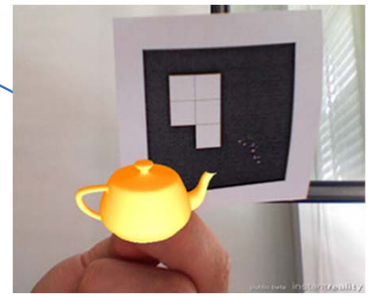


Education

Cultural Heritage

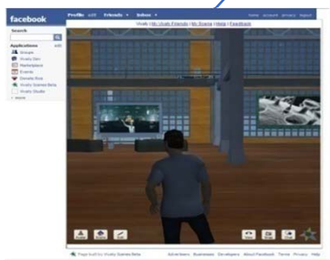
Gaming

Augmented Reality



update: X3D4

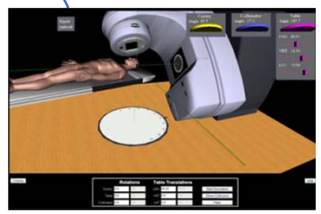
Virtual Worlds



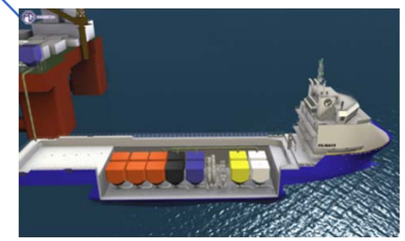
Mirror Worlds

E-commerce

Medical



Enterprise



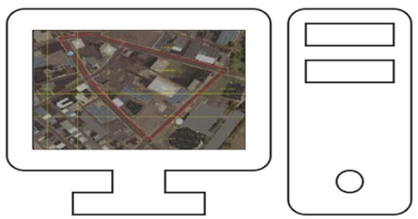
Use Case: Record in LVC Lab / Playback in X3D

Monterey
LVC Lab

Web-based
Internet

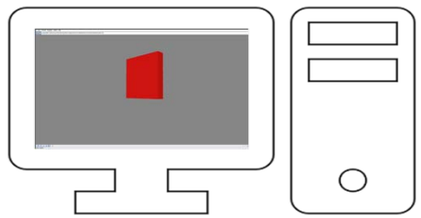
Web servers

DIS to X3D Conversion



DIS application

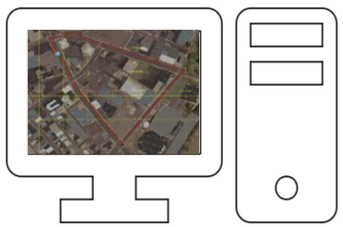
Ongoing Work



Web browser

Use Case: Long-Haul DIS for Collaboration

Monterey
LVC Lab



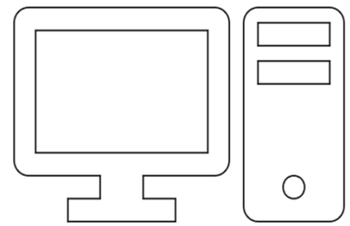
Spiders3D
Distributed
Virtual Environment

HPC

Future Work

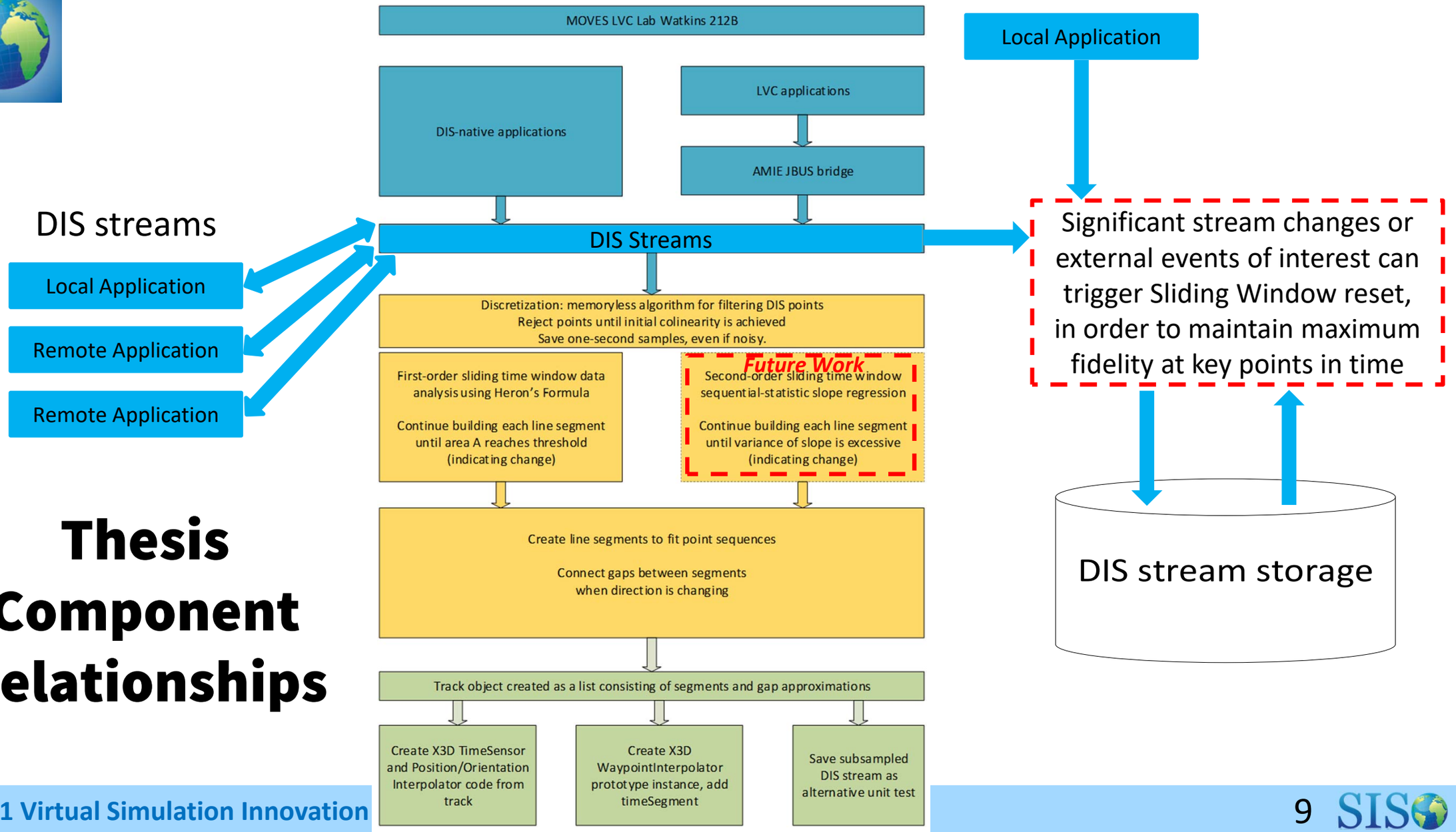
Aspirational!

- Poznan, PL
- Bydgoszcz, PL
- Germany



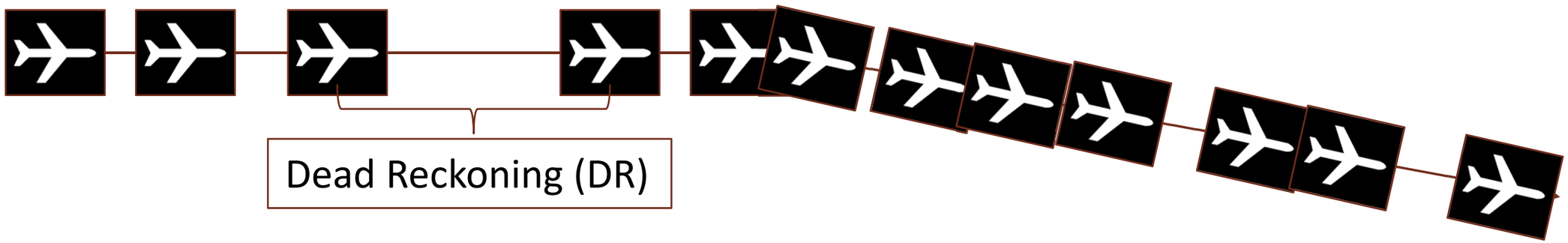
Distributed Virtual Environments
using Federated Mission
Networking (FMN) and C2SIM

Thesis Component Relationships

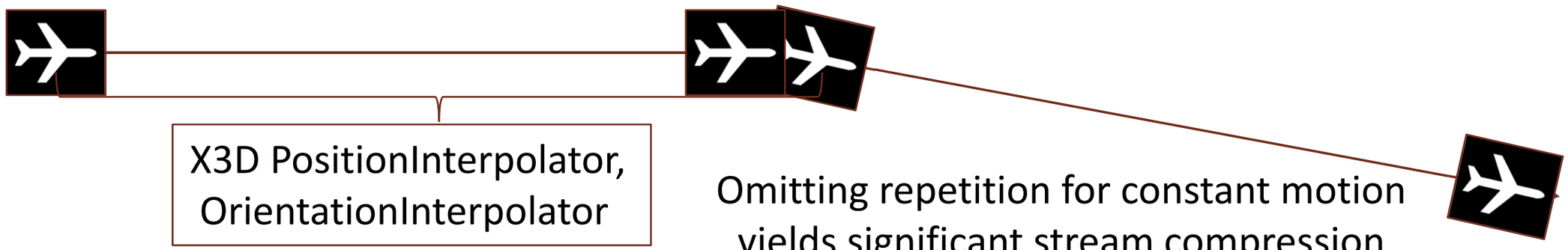


Test Scenario for Playback Compression

Raw DIS PDU Data from Simulation or Live Streaming:



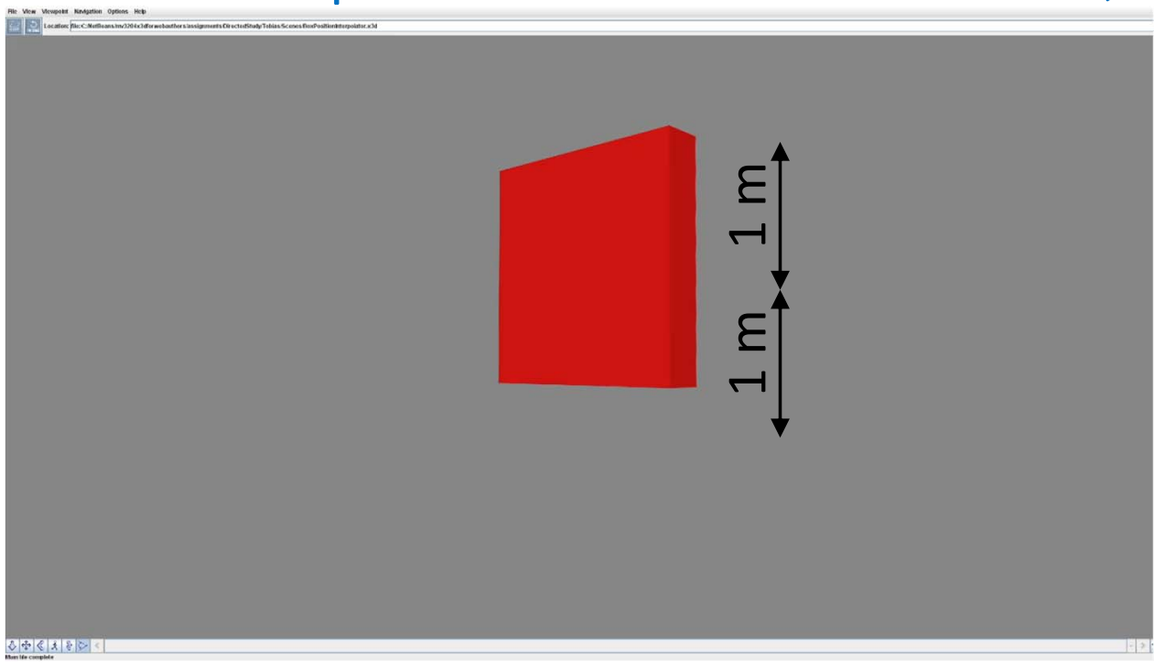
Sliding Window Interpolator for X3D Animation Playback:



Omitting repetition for constant motion yields significant stream compression for chosen degree of fidelity

Completed research implementation

Generating X3D PositionInterpolator from DIS Stream (Example)



<TimeSensor DEF='BoxTimeInterval' cycleInterval='1' loop = 'true'/>

<PositionInterpolator DEF='Entity' key = '0.0 0.25 0.5 0.75 1.0 ' keyValue = '0 0 0 0 1 0 0 2 0 0 1 0 0 0 0' />

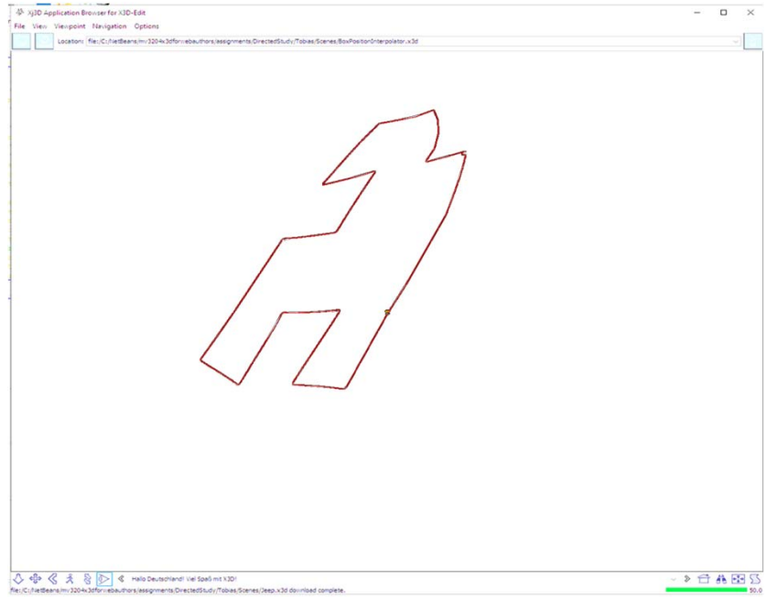
(Similarly for OrientationInterpolator)

Autogenerate X3D Code

- Generating PositionInterpolator and OrientationInterpolator from DIS Stream

DIS Converter

DIS stream



- **X3D TimeSensor and X3D PositionInterpolator are distilled from raw DIS streams and saved as XML.**
- **Looking ahead: can we build libraries of recorded behaviors for playback?**

Goal: Physics-Based Compression (kinematics)

<TimeSensor DEF='PduStreamClock' cycleInterval='114.735954' loop = 'true'/>
<PositionInterpolator DEF='Entity' key = '0 0.024 0.025 0.026 0.027 0.028 0.029 0.03 0.031 0.032 0.033 0.034 0.035 0.036 0.038 0.039 0.041 0.041 0.043 0.043 0.044 0.046 0.046 0.048 0.049 0.05 0.051 0.052 0.053 0.055 0.056 0.058 0.059 0.063 0.067 0.071 0.077 0.078 0.084 0.086 0.092 0.102 0.105 0.116 0.118 0.12 0.13 0.167 0.172 0.19 0.19 0.255 0.32 0.346 0.385 0.39 0.435 0.452 0.454 0.456 0.468 0.475 0.517 0.518 0.52 0.522 0.522 0.523 0.525 0.525 0.527 0.528 0.528 0.53 0.53 0.533 0.534 0.535 0.536 0.537 0.538 0.539 0.54 0.541 0.542 0.544 0.545 0.546 0.547 0.548 0.549 0.558 0.564 0.569 0.578 0.62 0.625 0.641 0.642 0.657 0.673 0.673 0.713 0.713 0.714 0.735 0.735 0.751 0.751 0.767 0.767 0.782 0.782 0.814 0.844 0.844 0.867 0.896 0.903 0.905 0.912 0.925 0.927 0.931 0.932 0.946 0.949 0.954 0.974 0.975 0.992 0.993 0.996 0.997 0.998 0.999 1 '
keyValue = ' 0 0 0 0.007 0.003 0.018 0.014 0.005 0.038 0.038 0.014 0.103 0.054 0.019 0.146 0.097 0.029 0.257 0.123 0.034 0.323 0.187 0.04 0.481 0.225 0.041 0.57 0.267 0.039 0.668 0.363 0.025 0.882 0.418 0.012 1 0.542 -0.031 1.252 0.611 -0.062 1.388 0.851 -0.204 1.82 0.941 -0.271 1.971 1.137 -0.438 2.278 1.243 -0.54 2.432 1.469 -0.785 2.734 1.589 -0.93 2.88 1.712 -1.091 3.021 1.968 -1.459 3.278 2.099 -1.667 3.391 2.414 -2.229 3.606 2.497 -2.394 3.647 2.643 -2.703 3.702 2.766 -2.984 3.728 2.867 -3.231 3.732 2.948 -3.445 3.723 3.063 -3.772 3.685 3.137 -3.996 3.645 3.278 -4.473 3.518 3.321 -4.638 3.461 3.595 -5.773 3.014 3.916 -7.104 2.49 4.219 -8.345 2 4.958 -11.234 0.839 5.114 -11.855 0.502 5.967 -15.285 -0.773 6.135 -15.975 -1.046 7.162 -20.299 -2.74 9.053 -28.241 -5.855 9.703 -30.95 -6.92 11.988 -40.467 -10.664 12.316 -41.831 -11.199 12.712 -43.466 -11.[illegible] 14.[illegible] -219 [illegible] -34 [illegible] 2[illegible] -29 [illegible] 44 [illegible] -105.[illegible] -35[illegible] 95 [illegible] -1[illegible] 205 -35.828 41.954 -161.927 -56.738 56.241 -218.71 -77.67 62.154 -242.195 -86.33 70.611 -275.[illegible] -98 [illegible] 1.6[illegible] -20.164 [illegible] 36 -32[illegible] 06 [illegible] 114 [illegible] 37 [illegible] 33.6[illegible] -329.408 [illegible] 8.23[illegible] 35[illegible] 52 -329[illegible] 08 [illegible] 18.419 83.841 -330.27 -118.551 84.369 -332.426 -119.338 84.686 -333.702 -119.806 86.533 -341.037 -122.511 86.585 -341.244 -122.587 86.68 -341.675 -[illegible] 86.732 -341.975 -122.940 86.753 -342.13 -123.044 86.771 -342.287 -123.153 86.795 -342.607 -123.408 86.798 -342.768 -123.554 86.786 -343.083 -123.888 86.769 -343.235 -124.075 86.744 -343.382 -124.276 86.667 -343.651 -124.721 86.613 -343.769 -124.963 86.384 -344.039 -125.768 86.173 -344.123 -126.35 86.05 -344.131 -126.65 85.915 -344.114 -126.954 85.61 -343.996 -127.563 85.442 -343.892 -127.862 85.079 -343.589 -128.431 84.887 -343.389 -128.695 84.689 -343.156 -128.939 84.285 -342.592 -129.354 83.698 -341.537 -129.729 83.541 -341.195 -129.771 83.258 -340.481 -129.753 83.024 -339.737 -129.59 82.93 -339.365 -129.452 82.803 -338.751 -129.162 81.527 -332.9 -126.538 80.538 -328.282 -124.478 79.585 -323.714 -122.453 77.938 -315.823 -118.956 70.493 -280.143 -103.141 69.562 -275.759 -101.188 66.427 -261.386 -94.736 66.409 -261.297 -94.693 63.715 -248.042 -88.276 61.468 -235.099 -81.099 61.455 -235.014 -81.048 56.336 -202.176 -61.466 56.321 -202.089 -61.418 56.055 -200.997 -60.996 49.848 -182.231 -57.608 49.818 -182.136 -57.587 45.452 -168.162 -54.456 45.424 -168.067 -54.431 41.326 -154.152 -50.719 41.3 -154.059 -50.691 37.436 -140.376 -46.647 37.411 -140.284 -46.618 29.742 -112.301 -37.795 22.739 -85.889 -28.905 22.715 -85.796 -28.872 17.387 -65.111 -21.586 10.823 -39.611 -12.606 9.204 -33.307 -10.387 8.692 -31.298 -9.683 7.324 -25.919 -7.797 5.175 -17.47 -4.835 5.054 -17.001 -4.67 4.784 -15.961 -4.302 4.717 -15.702 -4.211 4.081 -13.254 -3.346 3.954 -12.779 -3.176 3.691 -11.814 -2.829 2.769 -8.431 -1.611 2.7 -8.176 -1.52 1.899 -5.184 -0.45 1.841 -4.966 -0.372 1.745 -4.577 -0.214 1.681 -4.267 -0.058 1.654 -4.118 0.027 1.615 -3.807 0.228 1.601 -3.648 0.345 ' />

Uncompressed

<TimeSensor DEF='PduStreamClock' cycleInterval='114.735954' loop = 'true'/>
<PositionInterpolator DEF='Entity' key = '0 0.035 0.036 0.044 0.046 0.055 0.056 0.071 0.077 0.116 0.118 0.167 0.172 0.255 0.32 0.385 0.39 0.435 0.454 0.517 0.518 0.527 0.528 0.535 0.536 0.54 0.541 0.544 0.545 0.548 0.549 0.569 0.578 0.62 0.641 0.713 0.713 0.735 0.735 0.767 0.767 0.814 0.844 0.896 0.903 0.946 0.949 0.992 0.993 0.996 0.997 0.998 0.999 1 '
keyValue = ' 0 0 0 0.542 -0.031 1.252 0.611 -0.062 1.388 1.71[illegible] 1.0[illegible] 3.021 1.968 -1.459 3.278 3.063 -3.772 3.685 3.137 -3.996 3.645 4.219 -8.345 2 [illegible] 958 -11.234 0.839 11.988 -40.467 -10.664 12.316 -41.831 -11.199 22.634 -84.441 -27.754 23.69 -88.782 -29.444 41.95[illegible] 161.927 [illegible] 6.[illegible] 8 5[illegible] 4 [illegible] 1[illegible] 1 -[illegible] 6[illegible] 70[illegible] 1 2[illegible] 6.7[illegible] -9[illegible] 714 [illegible] .697 -[illegible] 0.[illegible] 4 -[illegible] 0.[illegible] 1 81.364 -320.067 -114.837 83.752 -329.908 -118.419 86.533 -341.037 -122.511 86.585 -341.244 -122.587 86.786 -[illegible] 3.083 -[illegible] 3.88 [illegible] 8[illegible] 769 [illegible] 343 [illegible] 35[illegible] 24.[illegible] 5 [illegible] 5.05[illegible] 44.131 -1[illegible] 65 [illegible] 1[illegible] 344.11[illegible] -126[illegible] 54 84.887 -343.389 -128.695 84.689 -343.156 -128.939 83.698 -341.537 -129.729 83.541 -341.195 -129.771 82.93 -33[illegible] -12[illegible] 82[illegible] 03 [illegible] 38.[illegible] 1 -[illegible] 2 7[illegible] 585 -[illegible] 14[illegible] 2.43[illegible] 7.93[illegible] 8.82[illegible] 1[illegible] 956 70.493 -280.143 -103.141 66.427 -261.386 -94.736 56.336 -202.176 -61.466 56.321 -202.089 -61.418 49.848 -182.231 -57.608 49.818 -182.136 -57.587 41.326 -154.152 -50.719 41.3 -154.059 -50.691 29.742 -112.301 -37.795 22.739 -85.889 -28.905 10.823 -39.611 -12.606 9.204 -33.307 -10.387 4.081 -13.254 -3.346 3.954 -12.779 -3.176 1.899 -5.184 -0.45 1.841 -4.966 -0.372 1.745 -4.577 -0.214 1.681 -4.267 -0.058 1.654 -4.118 0.027 1.615 -3.807 0.228 1.601 -3.648 0.345 ' />

Compressed

Goal: Parsability/Readability with Compression

BASE64:

536 bytes

```
!Begin!Beginning of DIS capture file, Pdusave3.dislog.
AAAAABnRSPQ=,BwAFAwAAAAAAAAAAAAAAAAAAAAAAAAAAAA==
AAAAAB/m8kg=,BwAGAwAAAAAAAAAAAAAAAAAAAAAAAAAAAA==
AAAAACXtWVw=,BwAHAwAAAAAAAAAAAAAAAAAAAAAAAAAAAA==
AAAAACvzmWA=,BwAIAwAAAAAAAAAAAAAAAAAAAAAA
AAAAADH7KVQ=,BwAJAwAAAAAAAAAAAAAAAAAAAAAAAAAAAA==
AAAAADgffug=,BwAKAwAAAAAAAAAAAAAAAAAAAAAAAAAA==
AAAAAD5FCqQ=,BwALBQAAAAAAAAAAAAAAAAAAAAAAAAAAAA==
AAAAAERbrfg=,BwAMBQAAAAAAAAAAAAAAAAAAAAAAAAAAAA==
!End!End of DIS capture file, Pdusave3.dislog.
```

Suitable for MIME email attachments

Plain Text:

781 bytes

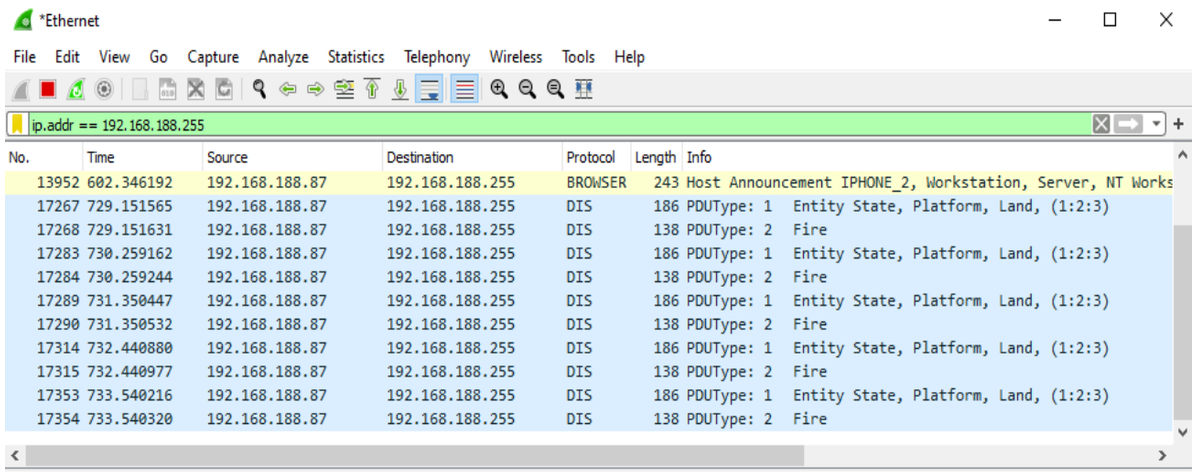
```
!Begin!Beginning of DIS capture file, Pdusave4.dislog. [PDU Header],[PDU Stream]
[0,0,0,0,25,-31,0,0],[7,0,5,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
[0,0,0,0,32,5,-36,88],[7,0,6,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
[0,0,0,0,38,43,-73,96],[7,0,7,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
[0,0,0,0,44,49,-50,-60],[7,0,8,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
[0,0,0,0,50,56,113,56],[7,0,9,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
[0,0,0,0,56,62,-116,32],[7,0,10,3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
[0,0,0,0,62,69,-56,124],[7,0,11,5,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
[0,0,0,0,68,93,94,-56],[7,0,12,5,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
!End!End of DIS capture file, Pdusave4.dislog.
```

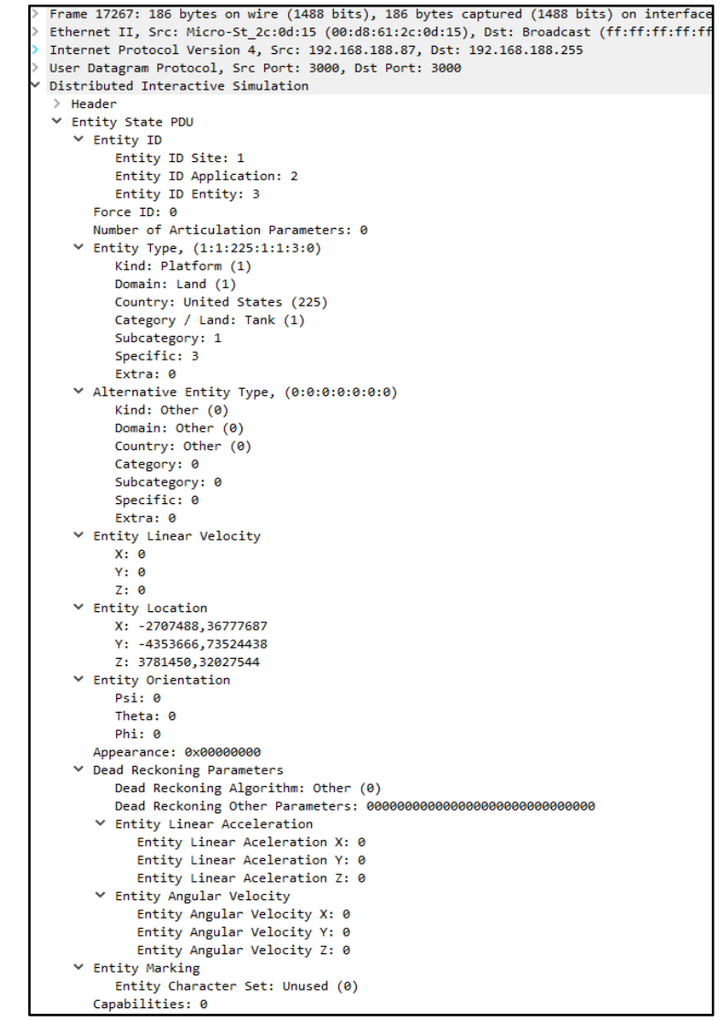
Suitable for debugging

Software archives include round-trip testing with version-control diffs for consistency checking

Future Work:
Compressed DIS (C-DIS) Encoding

Additional parsing tool: Wireshark (setup help)





Independent second checks are helpful with widely used open-source protocol decoder and networking-analysis tool

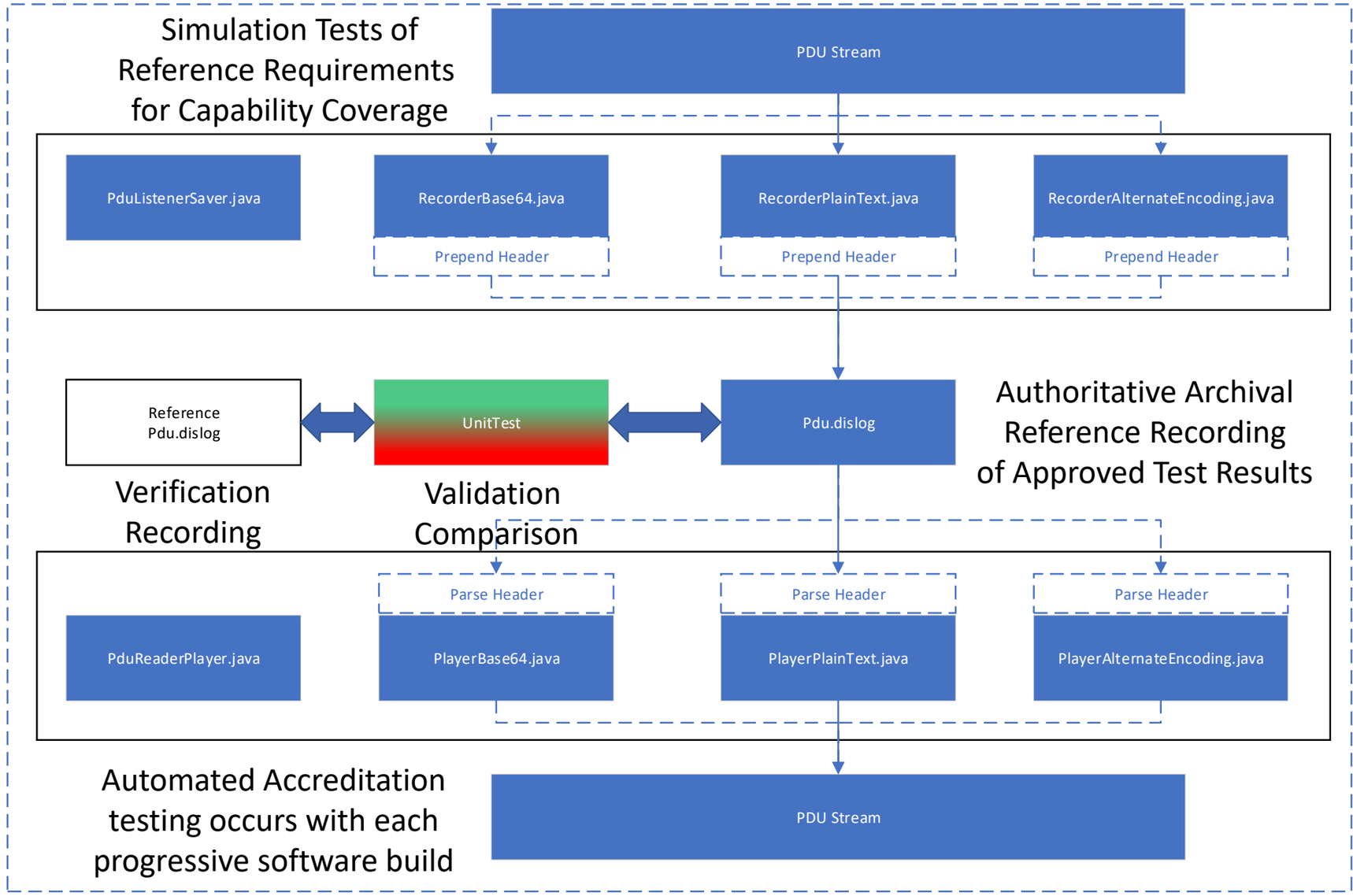
www.wireshark.org (DIS support)

V V & A Possible via Test Streams

Verification

Validation

Accreditation

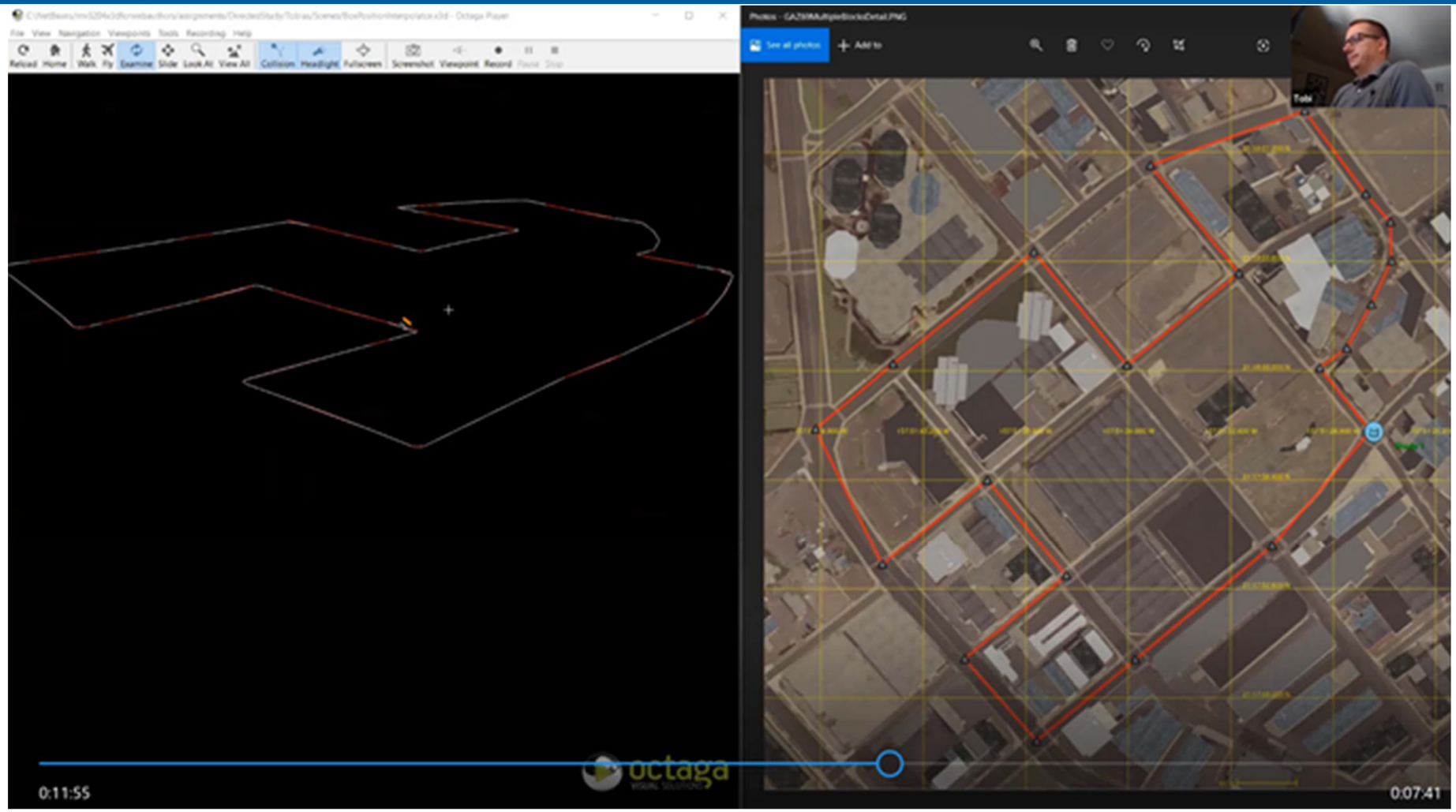


Suitable for lifecycle V V + A through archival repeatability against DevSecOps test suite

Way Ahead and Future Work

- **Further test Java implementation, then create Python, JavaScript**
- **Expand X3D capture/conversion/replay code for multiple entities**
  - Further optimization coding of Sliding Window Algorithm
- **Assess Spiders3D with JavaScript Virtual Environment Web Server**
- **Collaborate on distributed LVC models and simulations**
  - Take advantage, test campus-wide Multicast capability
  - Test with #Xj3D Java-based X3D browser
  - Explore possible HPC network connection to Germany, Poland
  - Consider NATO C2SIM and CWIX 2021 participation
- **Continue Experimentation and Unit Testing!**

Thesis, presentation and video demonstration online



Asset Availability

- **OpenDIS7 Java**
  - https://github.com/open-dis/open-dis7-java
  - https://github.com/open-dis/open-dis7-source-generator
- **MOVES MV3500 course Network Simulation**
  - https://gitlab.nps.edu/Savage/NetworkedGraphicsMV3500/-/blob/master/README.md (with Brennenstuhl thesis assets)
- **Extensible 3D (X3D) Graphics International Standard**
  - https://www.web3D.org/what-x3d
- **SPIDERS3D Naval Virtual Environment**
  - https://gitlab.nps.edu/Savage/Spiders3dPublic/-/blob/master/README.md

Tobias Brennenstuhl Thesis Availability

REPEATABLE UNIT TESTING OF DISTRIBUTED INTERACTIVE SIMULATION (DIS) PROTOCOL BEHAVIOR STREAMS USING WEB STANDARDS, Tobias Brennenstuhl, Masters Thesis, NPS, June 2020, https://calhoun.nps.edu/handle/10945/65436

Abstract. The IEEE Distributed Interactive Simulation (DIS) protocol is used for high-fidelity real-time information sharing among simulations and trainers across the entire international Modeling and Simulation (M&S) community. If archivally saved and replayed, DIS streams have the potential to become a valuable source of Big Data. The availability of archived prerecorded behavior streams for replay, adaptation, and analysis can benefit an immense variety of application areas. The computer science principle "a stream is a stream" indicates that data in motion is equivalent to data at rest. This characteristic can enable powerful capabilities for DIS. This thesis presents prototypes to demonstrate how various forms of repeatability are key to gaining improved benefits from DIS stream analysis. Unit testing of DIS behavior streams allows confirmation of both repeatability and correctness when testing all manner of applications, exercises, simulations, and training sessions. A related use case is automated after-action review (AAR) from recorded DIS streams. This thesis also shows how a DIS stream is converted into autogenerated code that can animate an X3D Graphics model. Many obstacles were overcome during this work, and so various best practices are provided. Of note is that unit testing might even become a contract requirement for incrementally developing and stably maintaining Live Virtual Constructive (LVC) code bases. Recent progress includes autogeneration of all SISO enumerations as Java classes and development of a complete type-safe XML Schema for a DIS-XML encoding as well. This progress provides many opportunities for future work including C-DIS and DISv8 activity.

Questions and contributions always welcome!

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SISO
Simulation Interoperability
Standards Organization
"Simulation Interoperability & Reuse through Standards"
QUESTIONS