Ethical Control of Unmanned Systems

Repeatable Mission Evaluation through Unmanned Systems Data Strategy

Project Update for CRUSER
Consortium for Robotics Unmanned Systems Education and Research

Don Brutzman, Curtis Blais, Terry Norbraten, and Kristen Fletcher
Naval Postgraduate School (NPS)

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Ethical Control of Unmanned Systems: Repeatable Mission Evaluation Through Unmanned Systems Data Strategy

Why / Objectives

- Ethical control of unmanned systems can be accomplished through structured mission definitions that are trusted, consistently readable, validatable, repeatable and understandable by humans and robots.
- Orders must be lawful. Unmanned systems must behave ethically and comprehensibly if they are to support manned military units effectively.
- Well-structured mission orders can be tested and trusted to give human commanders confidence that offboard systems will do what they are told to do, and further will not do what they are forbidden to do.
- Demonstrate that no technological limitations exist that prevent applying the same kind of ethical constraints on robots and unmanned vehicles that already apply to humans, in lethal and life-saving scenarios.

https://savage.nps.edu/EthicalControl

What / Deliverables

- Unmanned Systems Data Strategy is fundamental need for progress, otherwise all experiments (real or virtual) are unrepeatable, transient.
- Mission orders, metadata, track telemetry and sensor records together provide repeatable archiving of robot system testing for live-virtual-constructive (LVC) reuse, for replay live or rehearsal analysis.
- Update Mission Execution Ontology (MEO) concepts demonstrated in tests and simulation, building to perform field experimentation (FX).
- Define, simulate, and test combination of real-world goals and ethical constraints to robot mission tasks across set of canonical scenarios.
- Illustrate how human-robot teams meet moral and legal requirements if deploying unmanned systems with potential for lethal, life-saving force.

Building on Simulation, Experimentation

Principal Investigator: Don Brutzman  
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Co-Investigator: Curtis Blais  
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Team Members and Focus-Area Presentations

Curtis Blais, Co-PI
- Data modeling and formal ontology development
- Mission Execution Ontology (MEO) and C2SIM standard with NATO

Kristen Fletcher
- Legal and ethical policies, ramifications

Terry Norbraten
- Software design, development, and testing
- Data conversion using Data Format Description Language (DFDL)

Don Brutzman, PI
- Ethically constrained control of unmanned systems and robot missions by human supervisors and warfighters
- Unmanned systems data strategy and LVC interoperability architecture
Curtis Blais, Co-PI
Data Modeling and Formal Ontology Development

Mission Execution Ontology (MEO) 3.0
Motivation: Need for Stronger Semantics in Data Modeling

Improving Interoperability

Improving Enterprise Data Sharing

Improving Linking Data at Web-Scale

Stronger Semantic Representation

Improving Mission-Specific Information Sharing

Improving Automation / Autonomy
Improving Semantic Representation

• Knowledge Representation (KR) is an area of artificial intelligence (AI) research and practice focused on encoding meaning into data.

• Academia and industry now have a detailed path toward higher levels of machine understanding corresponding to human understanding.


Acronyms: Database (DB); Extensible Markup Language (XML); Resource Description Language / Schema (RDF/S); Unified Modeling Language (UML); Web Ontology Language (OWL)
Composite applications and info/knowledge-intensive processes share information at these levels.

Data models set the bar here.

Most applications do not enable data discovery and sharing.

Source: Dr. Leo Obrst, Mitre, Mills Davis, Project 10X.
Improving Interoperability

• Interoperability: “the capability of a system to automatically, without human intervention, provide services to and accept services from other systems, and to use the services so exchanged to enable the systems to work together to achieve a desired outcome” (Blais and Lacy 2004).


• Objective is to achieve conceptual and pragmatic interoperability.
Improving Interoperability: Levels of Conceptual Interoperability Model

- Level 6: Conceptual Interoperability
- Level 5: Dynamic Interoperability
- Level 4: Pragmatic Interoperability
- Level 3: Semantic Interoperability
- Level 2: Syntactic Interoperability
- Level 1: Technical Interoperability
- Level 0: No Interoperability
Semantic Web: Knowledge Representation at Web Scale

• Architects of the World Wide Web have laid out a layered set of standards to achieve the Semantic Web vision: “not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation” (Berners-Lee et al. 2001)

• Ultimate goal: achieve a **scalable trusted information infrastructure** where humans and software interact meaningfully, in a repeatable environment where expectations of quality and integrity are met.

• Scalable approach indicates that single (ship + robot) solutions have potential to grow and encompass many simultaneous systems, thus improved data sharing, mission deconfliction, coordinated operations
Semantic Web Stack

Extends larger Web architecture
• All of these data languages are approved W3C standards
• Proof and unifying logic are mathematically well defined

Trusting derived (composed) statements arises from
• Encryption + digital signature confirms trusted data sources
• Formal logic is basis for deriving new information
• Wikipedia: Semantic Web Stack

Of note: this project is exercising every layer of Semantic Web stack.
Autonomous Vehicle Command Language (AVCL)

• AVCL is a command and control language for humans supervising autonomous unmanned vehicles.
  • Clarity arises from close correspondence to human naval terminology.

• Structured vocabulary defining terms and relationships for mission planning, execution, conduct, recording and replay across diverse robot types.

• Common-ground XML representations for
  • Mission agenda plans, mission scripts, and post-mission recorded telemetry results.
  • *Future work*: defining unit tests and expected results for verification and validation.

• Operators have single archivable, validatable format for robot tasking, results
  • directly convertible to and from a wide variety of different robot command languages.

https://savage.nps.edu/Savage/AuvWorkbench/AVCL/AVCL.html
## AVCL mission goals vocabulary (Davis 2015)

<table>
<thead>
<tr>
<th>AVCL mission goals</th>
<th>Define</th>
<th>Used</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attack</td>
<td>partial</td>
<td>✓</td>
<td>To conduct a type of offensive action characterized by employment of firepower and maneuver to close with and destroy an enemy.</td>
</tr>
<tr>
<td>Decontaminate</td>
<td>✓</td>
<td></td>
<td>To provide purification making an area safe by absorbing, destroying, neutralizing, making harmless, or removing chemical, biological, or nuclear contamination.</td>
</tr>
<tr>
<td>Demolish</td>
<td>✓</td>
<td></td>
<td>To destroy structures, facilities, or material by any available means.</td>
</tr>
<tr>
<td>IlluminateArea</td>
<td>✓</td>
<td></td>
<td>To provide locale lighting by searchlight or pyrotechnics.</td>
</tr>
<tr>
<td>Jam</td>
<td>✓</td>
<td></td>
<td>To deliberately radiate, re-radiate or reflect electromagnetic energy with the object of impairing the use of electronic devices or systems.</td>
</tr>
<tr>
<td>MarkTarget</td>
<td>✓ ✓</td>
<td></td>
<td>To make visible (by the use of light, infrared, laser, smoke, etc.) of an object in order to allow its identification by another object.</td>
</tr>
<tr>
<td>MonitorTransmissions</td>
<td>✓ ✓</td>
<td></td>
<td>To conduct electronic warfare support operations with a view to searching, locating, recording and analyzing radiated electromagnetic energy.</td>
</tr>
<tr>
<td>Patrol</td>
<td>✓ ✓</td>
<td></td>
<td>To gather information or carry out a security mission.</td>
</tr>
<tr>
<td>Rendezvous</td>
<td>✓</td>
<td>Partial</td>
<td>Achieve a meeting at a specified time and place.</td>
</tr>
<tr>
<td>Reposition</td>
<td>✓ ✓</td>
<td></td>
<td>To change position from one location to another.</td>
</tr>
<tr>
<td>SampleEnvironment</td>
<td>Partial</td>
<td>✓</td>
<td>Collect environmental samples for testing for chemical compounds, biological creatures, or nuclear hazards.</td>
</tr>
<tr>
<td>Search</td>
<td>✓ ✓</td>
<td></td>
<td>To look for lost or unlocated objects or persons.</td>
</tr>
</tbody>
</table>

More Goal Types Foreseen
Example AVCL mission agenda, as pseudo-code XML

<?xml version="1.0" encoding="UTF-8"?>
<UUVMission>
  <GoalSet>
    <Goal area="A" id="goal1">
      <Search nextOnSuccess="goal2" nextOnFailure="goal3"/>
    </Goal>
    <Goal area="A" id="goal2">
      <SampleEnvironment nextOnSuccess="goal3"
        nextOnFailure="recover"/>
    </Goal>
    <Goal area="B" id="goal3">
      <Search nextOnSuccess="goal4" nextOnFailure="goal4"/>
    </Goal>
    <Goal area="C" id="goal4">
      <Rendezvous nextOnSuccess="recover" nextOnFailure="recover"/>
    </Goal>
    <Goal area="recoveryPosition" id="recover">
      <Transit nextOnSuccess="missionComplete"
        nextOnFailure="missionAbort"/>
    </Goal>
  </GoalSet>
</UUVMission>

AVCL is readable by human or robot, captures logic of mission tasking

XML ensures syntactically correct, well-defined, numerically valid

Needed: semantic representation to check ethical, logical consistency
Motivating insights: converting data into logic

"The answer to your question is the response to the query."

• Jim Hendler and Dean Allemang
• Meaningfulness of an answer matches the precise meaning of a question.

"Trying to use the Semantic Web without SPARQL is like trying to use a relational database without SQL."

• Tim Berners-Lee
• Language representations are needed for query as well as for information.

"The proof of the pudding is in the eating."

• Wiktionary
• Confidence in results requires testing.
Mission Execution Ontology (MEO) Development

- Define MEO from concepts, properties, relationships using Protégé tool.
- Create full set of canonical missions in AVCL (XML).
- Determine exemplar mappings for AVCL primitives to Turtle for RDF/OWL.
- Write conversion stylesheet AvclToMEO.xslt for full expressiveness.
- Convert all AVCL missions to corresponding triples.
- Confirm AVCL MEO, missions validate satisfactorily using Protégé, ARQ.
- Automate build process as suite of repeatable unit-test queries (log).
- SPARQL queries to test AVCL mission representations in Turtle.
- Write SPARQL metaqueries to test, document MEO ontology relationships.
- Continuing work: Adding Shapes Constraint Language (SHACL) statements for mission validation.
- Continuing work: Ontology linking (mission specification, mission data stream, ethics, policies, provenance) for query and automated reasoning.
Description Logic (DL) Rules provide basis for Mission Execution Ontology (MEO)

<table>
<thead>
<tr>
<th>Rules</th>
<th>Description Logic Equations</th>
<th>Plain-language description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Mission ⊑ ∀startsWith.Goal ∩ =1startsWith.Goal</td>
<td>A Mission can only start with a Goal and must start with exactly one Goal</td>
</tr>
<tr>
<td>M2</td>
<td>Mission ⊑ ∀includes.Goal ∩ ≥1includes.Goal</td>
<td>A Mission can only include Goals and must include one of more Goals</td>
</tr>
<tr>
<td>M3</td>
<td>Mission ⊑ ∀hasConstraint.Constraint</td>
<td>A Mission can only be constrained by Constraints</td>
</tr>
<tr>
<td>M4</td>
<td>startsWith ⊑ includes</td>
<td>A Mission must include the Goal that it starts with</td>
</tr>
<tr>
<td>M5</td>
<td>Mission ⊑ ∀performableBy.Vehicle</td>
<td>A Mission can only be performed by a Vehicle</td>
</tr>
<tr>
<td>M6</td>
<td>Cannot be expressed in DL</td>
<td>A Mission cannot be performable by a Vehicle unless that Vehicle has the ability to identify all Constraints associated with that mission</td>
</tr>
<tr>
<td>M7</td>
<td>Cannot be expressed in DL</td>
<td>A Mission cannot be performable by a Vehicle unless that Vehicle has the capability to accomplish all Goals included in that Mission</td>
</tr>
</tbody>
</table>

Excerpted from full Mission Execution Ontology Decision Logic Tables

Original author: Duane Davis
Model updated by Curtis Blais in collaboration with Raytheon engineers through NPS-Raytheon CRADA
Mission Execution Ontology (MEO) source implemented, tested using Protégé tool
Mission Execution Ontology (MEO) for Ethical Control of Unmanned Systems in Surrogate Scenarios

• Autonomous Vehicle Command Language (AVCL) for Missions.
  • Declarative XML, years of NPS research.

• Multiple Mission Representations.
  • Imperative commands (orders/waypoints/etc.).
  • Declarative commands (mission goals).
  • Mission results (order log, telemetry etc.).
  • Mission metadata for parameters, settings.
  • Lisp and Prolog examples (Bob McGhee, NPS).

• Autonomous Unmanned Vehicle (AUV) Workbench Simulation and Visualization Support
  • Recently restored, debug testing commenced.
  • AVCL 2.1 is prior published version, centered on syntactic validation, solo robot operations.
  • AVCL 3.0 is new working version for testing range of multi-participant missions.

• Mission Execution Ontology (MEO) for Semantic Validation
  • Semantic Web framework of rules, relationships for ethical validation.
  • Initial examples in IEEE JOE paper.
  • Retested using current Protégé, Jena tools.

• Sailor Overboard and Other Missions
  • Hand-crafted triples using Turtle syntax.
  • Beginning to build unit testing framework.
  • Confirming correlation of AVCL information model to existing MEO ontology.
  • Automatic conversion of AVCL missions to match, thus accelerating multiple-mission testing on diverse systems.
  • Visualization, reporting via AUV Workbench can aid understanding, mission planning and further progress.
Example Mission Validation using Protégé Tool
Ethical Control of Unmanned Systems in a Surrogate Scenario: Sailor Overboard Mission defined using the MEO Ontology

Current work is designing, building and testing a set of exemplar missions
SPARQL Protocol and RDF Query Language

• “SPARQL is an RDF query language — that is, a semantic query language for databases — able to retrieve and manipulate data stored in Resource Description Framework (RDF) format.” -- Wikipedia

• Standardized as World Wide Web (W3C) Recommendation
  • Open-source implementations that we use include Apache ARQ and Protégé tool.

• We use SPARQL to express queries against AVCL missions in RDF/OWL (Turtle syntax) together with Mission Execution Ontology (MEO).

• Results reveal interesting properties about missions that are otherwise difficult to determine. Inferences can also be combined and correlated.

• Goal is to express in-depth mission-related queries that determine
  • Whether all logical mission prerequisites and constraints are satisfied, and
  • Whether tactical policies and Rules of Engagement (ROE) are met.
Perform Mission Execution Ontology metaquery MissionExecutionOntologyQuery_01.rq to produce output file MissionExecutionOntologyQuery_01.rq.txt:

PREFIX :  <https://www.nps.edu/ontologies/MissionExecutionOntology/missions#>
PREFIex meo: <https://www.nps.edu/ontologies/MissionExecutionOntology#>
PREFIex owl: <http://www.w3.org/2002/07/owl#>
PREFIex rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIex rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIex xml: <http://www.w3.org/XML/1998/namespace>
PREFIex xsd: <http://www.w3.org/2001/XMLSchema#>

# @base <https://www.nps.edu/ontologies/MissionExecutionOntology/missions>

# MissionExecutionOntologyQuery_01.rq Metaquery to list all properties with corresponding domains and ranges in Mission Execution Ontology.

'--------------------'

SELECT distinct ?property ?domain ?range WHERE
{
?property rdfs:range ?range .
}
ORDER by ASC(?property) # alphabetize
<table>
<thead>
<tr>
<th>property</th>
<th>domain</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>meo:appliesTo</td>
<td>meo:Constraint</td>
<td>_:b0</td>
</tr>
<tr>
<td>meo:canFulfill</td>
<td>meo:VehicleFeature</td>
<td>meo:GoalRequirement</td>
</tr>
<tr>
<td>meo:canIdentify</td>
<td>meo:Vehicle</td>
<td>meo:Constraint</td>
</tr>
<tr>
<td>meo:canMeet</td>
<td>meo:Vehicle</td>
<td>meo:Goal</td>
</tr>
<tr>
<td>meo:canPerform</td>
<td>meo:Vehicle</td>
<td>meo:Mission</td>
</tr>
<tr>
<td>meo:canTest</td>
<td>meo:VehicleFeature</td>
<td>meo:Constraint</td>
</tr>
<tr>
<td>meo:hasConstraint</td>
<td>meo:Mission</td>
<td>meo:Constraint</td>
</tr>
<tr>
<td>meo:hasEndCondition</td>
<td>meo:Goal</td>
<td>meo:EndCondition</td>
</tr>
<tr>
<td>meo:hasFeature</td>
<td>meo:Vehicle</td>
<td>meo:VehicleFeature</td>
</tr>
<tr>
<td>meo:hasNext</td>
<td>meo:Goal</td>
<td>meo:Goal</td>
</tr>
<tr>
<td>meo:hasNextOnFail</td>
<td>meo:Goal</td>
<td></td>
</tr>
<tr>
<td>meo:hasNextOnSucceed</td>
<td>meo:Goal</td>
<td></td>
</tr>
<tr>
<td>meo:hasNextOnViolate</td>
<td>meo:Goal</td>
<td></td>
</tr>
<tr>
<td>meo:includes</td>
<td>meo:Mission</td>
<td></td>
</tr>
<tr>
<td>meo:isFollowedBy</td>
<td>meo:Goal</td>
<td></td>
</tr>
<tr>
<td>meo:isPerformableBy</td>
<td>meo:Mission</td>
<td></td>
</tr>
<tr>
<td>meo:meetsRequirement</td>
<td>meo:Vehicle</td>
<td>meo:GoalRequirement</td>
</tr>
<tr>
<td>meo:requires</td>
<td>meo:Goal</td>
<td>meo:GoalRequirement</td>
</tr>
<tr>
<td>meo:startsWith</td>
<td>meo:Mission</td>
<td>meo:Goal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Confirm MEO via self-centered SPARQL metaquery response

MissionExecutionOntologyQuery_01.rq.txt
The Rich Semantic Track model formalizes the semantics and pragmatics of track data for broad application, including potential for improving data interchange and processing for unmanned systems.
Coalition Interoperability: C2SIM Standard

• Only international standard for information interchange across C2 systems, simulation systems, and robotic and autonomous systems (RAS)
  • Plans, orders, and reports
  • Being adopted as NATO Standardization Agreement (STANAG)
  • Identified standard for the NATO Federated Mission Networking initiative

• Published April 2020 by the Simulation Interoperability Standards Organization (SISO)
  • C2SIM Core Ontology and Standard Military Extension
  • C2SIM Land Operations Extension
  • C2SIM Guide
IEEE P7000-series Standards Projects

https://ethicsinaction.ieee.org

- P7000 Model Process for Addressing Ethical Concerns during System Design
- P7001 Transparency of Autonomous Systems
- P7002 Data Privacy Process
- P7003 Algorithmic Bias Considerations
- P7004 Standard on Child and Student Data Governance
- P7005 Standard on Employee Data Governance
- P7006 Standard on Personal Data AI Agent Working Group
- P7007 Ontological Standard for Ethically driven Robotics and Automation Systems
- P7008 Standard for Ethically Driven Nudging for Robotic, Intelligent and Autonomous Systems
- P7009 Standard for Fail-Safe Design of Autonomous, Semi-Autonomous Systems
- P7010 Well-being metrics Standard for Ethical Artificial Intelligence and Autonomous Systems
- P7011 Stadard for the Porcess of Identifying and Rating the Trustworthiness of News Sources
- P7012 Standard for Machine Readable Personal Privacy Terms
- P7014 Standard for Ethical Considerations in Emulated Empathy in Autonomous and Intelligent Systems
IEEE Standards Project P7007 for Ontological Standard for Ethically driven Robotics and Automation Systems

- IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems.
  - [https://ethicsinaction.ieee.org](https://ethicsinaction.ieee.org) includes large document providing broad rationale.
  - Includes 15 separate working groups in IEEE Standards Association (IEEE-SA).

  - “IEEE P7007 Standards Project for Ontological Standard for Ethically driven Robotics and Automation Systems establishes a set of ontologies with different abstraction levels that contain concepts, definitions and axioms that are necessary to establish ethically driven methodologies for the design of Robots and Automation Systems.”
  - [http://standards.ieee.org/develop/project/7007.html](http://standards.ieee.org/develop/project/7007.html)
  - Must be IEEE member, observe patent-policy requirements to participate in working group.
  - “Not the intent to specify required ethical behaviors, but rather to formalize a vocabulary of terms, concepts, and relationships that can be used to enable unambiguous discussion among [...] communities regarding what it means for autonomous systems to exhibit ethical behaviors.”
  - Excellent forum with rich references, worth observation and participation.

- Active work: align several Ethical Control terms, concepts, use cases with P7007.
Kristen Fletcher
Legal and Ethical Policies

PROJECTS

SCENARIOS
2021:

**Ethical Control of Unmanned Systems: Repeatable Mission Evaluation Through Unmanned Systems Data Strategy for UMAA/RAIL**
Brutzman, Blais, Fletcher / CRUSER

**Priority Legal and Policy Issues of Unmanned Systems**
Fletcher, Hahn, Lesse, DeCocco / CRUSER

**Formation, Implementation, and Verification of Requirements for Human-Autonomy Teaming**
Van Bossuyt, Weger, Semmens, Fletcher, Mesmer, Tenhundfeld, Jones / CRUSER

**TTCP AI Strategic Challenge: Law/Ethics Theme Team**
Fletcher, Choinski, Palmer, international partners / OSD OUSD R-E

2022:

**Advancing Clarity: Analysis of UxS Legal Questions**
Fletcher, Hahn, Lesse / CRUSER

**Interactive Synthetic Environment (ISE) to Evaluate Zero-Carbon UAS Launch Platforms in the Arctic**
Dew, Balogh, Fitzpatrick, Fletcher, Lesse / CRUSER

**TTCP AI Strategic Challenge: Law/Ethics Theme Team**
Fletcher, Palmer, international partners / OSD OUSD R-E
SCENARIOS

WHAT ARE THE LEGAL REQUIREMENTS FOR AS/UxS TO OPERATE IN INTERNATIONAL WATERS AND EEZS?

WHAT ARE THE LEGAL CONSIDERATIONS FOR AS/UxS IN THE U.S. IN AREAS OF OVERLAPPING JURISDICTIONS?
Scenario 1
Scenario 2

- Protected Areas:
  - National Marine Sanctuary
  - State Marine Conservation Areas
  - State Marine Reserves

- Federal Laws
  - Clean Water Act
  - Laws related to:
    - Discharges
    - Marine Debris
    - Hazardous Waste
• Rapidly-evolving technology challenges the law: law and policy will often lag behind.

• Applicable laws may differ depending on the operating environment and level of autonomy.

• The need to understand the environmental and climate considerations for these systems is increasing.

(CRUSER Advancing Legal Clarity Project)

Kristen Fletcher, Energy Academic Group: kristen.fletcher@nps.edu
(added) Observations: Ethics, Law and Data

• Conceptual Interoperability is straightforward for humans to measure: “does it make sense?”

• **We are not** asking robots to make ethical decisions – illegal, not possible. **We are** enabling systems support for ethical human decision making.

• “Answer to question” = “response to query” means we all have to get beyond curious syntax to shared terminology and understanding of results, otherwise (like it or not) your overall system design must be insufficient.

• Rules followed by warfighters, peace officer, responsible individuals are all based on **The Law**. Thus we can now strive for consistency with [LOAC](#), etc.

• **TRUST** is the top of the semantic chain... bridging to next section:

  In God We Trust. All Others Bring Data!  
  
  *W. Edwards Deming*
Terry Norbraten
Software Design, Development, and Testing

Real-World Mission Execution

Virtual-World Mission Playback
The process of capturing wirelessly networked KLV Local Set data transmitted from an unmanned aerial system (UAS) to visualizing that data in 3D using Open Source, Open Standards technology.
PCAPNG File

Filter for udp.port==4040

Marked up filtered PCAPNG (Hex Text) (Parse)

Extract KLV (UDP payload) (Hex Text)

Parse, visualize KLV (Hex Text) as marked up XML

PCAPNG File

Filter for udp.port==4040

Marked up filtered PCAPNG (Hex Text) (Parse)

Extract KLV (UDP payload) (Hex Text)

Parse, visualize KLV (Hex Text) as marked up XML

{Wireshark/tshark}

{Wireshark/tshark}

{pcapng.dfdl.xsd}

{ExtractPcapngDataValues.xslt}

{klv.dfdl.xsd}

{DFDL extract KLV Hex}

Decode KLV (Hex Binary)

Generate DIS PDU Tracks

Save/Replay DIS PDU streams

Visualize 3D Scene (Playback)

LVC

{Harder KLV Java}

{OpenDIS7 Java}

{OpenDIS}

{X3D, Spiders3D}

{Plan, Analyze, Train, Archive}

Java parse KLV telemetry track into DIS

In-memory DOM objects

The top right + lower left blocks might be replaced by DIS Schema with DFDL for KLV, as a general pattern for DIS DFDL parsing of any telemetry track values, leapfrog for future telemetry patterns. End result remains DIS XML in either case.

Decode KLV (Decimal)

{West Ridge Systems jMisb}
The top right + lower left blocks might be replaced by DIS Schema with DFDL for KLV, as a general pattern for DIS DFDL parsing of any telemetry track values, leapfrog for future telemetry patterns. End result remains DIS XML in either case.

The Blais approach would be KLV XML -> XSLT -> RST XML.
The top right + lower left blocks might be replaced by DIS Schema with DFDL for KLV, as a general pattern for DIS DFDL parsing of any telemetry track values, leapfrog for future telemetry patterns. End result remains DIS XML in either case.

The Blais approach would be KLV XML -> XSLT -> RST XML
DFDL decorated XML Schema for PCAPNG

```xml
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" version="1.1"
xmlns:dfdl="http://www.ofg.org/dfdl/dfdl-1.0/"
xmlns:fn="http://www.w3.org/2005/xpath-functions"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="http://www.ofg.org/dfdl/dfdl-1.0/extension1
 http://www.ofg.org/dfdl/dfdl-1.0/extension2
 http://www.ofg.org/dfdl/dfdl-1.0/extension3">

<xs:import namespace="urn:dynamicEndianBinary"
 schemaLocation="binaryDynamicEndianBinary.dfdl.xsd"/>

<xs:import namespace="urn:ethernet"
 schemaLocation="ethernetIP.dfdl.xsd"/>

<xs:annotation>
  <xs:appinfo source="http://www.ofg.org/dfdl/">
    <dfdl:format ref="ob:binaryDynamicEndian" byteOrder="littleEndian"/>
  </xs:appinfo>
</xs:annotation>

<xs:defineVariable name="valueLen" type="xs:int" dfdlx:direction="unparseOnly"/>

</xs:schema>

Since this is a DFDL schema for a concrete file format, we have a root global element. All other elements are declared as local element declarations and so will have unqualified names.

<xs:element name="PCAPNG" type="tns:PCAPNG"/>

<xs:complexType name="PCAPNG">
  <xs:sequence>
    <xs:element name="SectionHeader">
      <xs:complexType>
        <xs:sequence>
          <xs:element name="Block">
            <xs:complexType>
              <xs:sequence>
                <xs:element name="type" type="xs:hexBinary" dfdl:lengthKind="explicit"
                dfdl:length="4" dfdl:lengthUnits="bytes"/>
              </xs:sequence>
            </xs:complexType>
          </xs:element>
        </xs:sequence>
      </xs:complexType>
    </xs:element>
  </xs:sequence>
</xs:complexType>
```

---

Diagnostic to see what BlockType # really is

```xml
<xs:appinfo source="http://www.ofg.org/dfdl/">
  <dfdl:assert message="{( fn:concat(\'Block Type # was not 0x00000000A.
        test\') }" eq xs:hexBinary("00000000A") )"/>
</xs:appinfo>
```
PCAPNG File

Filter for udp.port==4040

Marked up filtered PCAPNG (Hex Text) (Parse)

Extract KLV (UDP payload) (Hex Text)

Parse, visualize KLV (Hex Text) as marked up XML

Save/Replay DIS PDU streams

Visualize 3D Scene (Playback)

LVC

Onboard Robot

Network

Ground Station

Software Format

KLV Format

Software Format

Metadata Encoder

Metadata Decoder

Time Position Sensor Angles Etc.

The Blais approach would be KLV XML -> XSLT -> RST XML

The top right + lower left blocks might be replaced by DIS Schema with DFDL for KLV, as a general pattern for DIS DFDL parsing of any telemetry track values, leapfrog for future telemetry patterns. End result remains DIS XML in either case.
DFDL Decorated XML Schema for KLV
PCAPNG File

Filter for udp.port==4040

Marked up filtered PCAPNG (Hex Text) (Parse)

Extract KLV (UDP payload) (Hex Text)

Parse, visualize KLV (Hex Text) as marked up XML

Extract KLV DataValues.xslt

Save/Replay DIS PDU streams

Visualize 3D Scene (Playback)

LVC

Onboard Robot

Network

Ground Station

Software Format

KLV Format

Software Format

Metadata Encoder

Metadata Decoder

Time Position Sensor Angles Etc.

Time Tag 1

Time Tag 2

Metadata

The Blais approach would be KLV XML -> XSLT -> RST XML

The top right + lower left blocks might be replaced by DIS Schema with DFDL for KLV, as a general pattern for DIS DFDL parsing of any telemetry track values, leapfrog for future telemetry patterns. End result remains DIS XML in either case.

{Wireshark/tshark}

{Wireshark/tshark}

{pcapng.dfdl.xsd}

{klv.dfdl.xsd}

{ExtractPcapngDataValues.xslt}

{klv.dfdl.xsd}

{DFDL extract KLV Hex}

Decode KLV (Hex Binary)

Generate DIS PDU Tracks

{OpenDIS7 Java}

{OpenDIS}

{X3D, Spiders3D}

{Plan, Analyze, Train, Archive}

In-memory DOM objects

Java parse KLV telemetry track into DIS

Decode KLV (Decimal)

{Harder KLV Java}

{West Ridge Systems jMisb}

{Wireshark/tshark}

{Wireshark/tshark}

{pcapng.dfdl.xsd}
PCAPNG File

Filter for udp.port==4040

Marked up filtered PCAPNG (Hex Text)

Extract KLV (UDP payload) (Hex Text)

Parse, visualize KLV (Hex Text) as marked up XML

Extract Pcapng DataValues.xslt

Parse, visualize KLV (Hex Text) as marked up XML

{ExtractPcapng DataValues.xslt}

{klv.dfdl.xsd}

Decide KLV (Hex Binary)

Generate DIS PDU Tracks

Save/Replay DIS PDU streams

Visualize 3D Scene (Playback)

{klv.dfdl.xsd}

{klv.dfdl.xsd}

The Blais approach would be KLV XML -> XSLT -> RST XML

The top right + lower left blocks might be replaced by DIS Schema with DFDL for KLV, as a general pattern for DIS DFDL parsing of any telemetry track values, leapfrog for future telemetry patterns. End result remains DIS XML in either case.
Saved DIS PDU Capture
PCAPNG File

Filter for udp.port==4040

Marked up filtered PCAPNG (Hex Text) (Parse)

Extract KLV (UDP payload) (Hex Text)

Parse, visualize KLV (Hex Text) as marked up XML

Save/Replay DIS PDU streams

Visualize 3D Scene (Playback)

LVC

The top right + lower left blocks might be replaced by DIS Schema with DFDL for KLV, as a general pattern for DIS DFDL parsing of any telemetry track values, leapfrog for future telemetry patterns. End result remains DIS XML in either case.

{Wireshark/tshark}

{Wireshark/tshark}

{pcapng.dfdl.xsd}

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{Harder KLV Java}

{OpenDIS7 Java}

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{X3D, Spiders3D}

{Plan, Analyze, Train, Archive}

{DFDL extract KLV Hex}

Decode KLV (Hex Binary)

Generate DIS PDU Tracks

Save/Replay DIS PDU streams

Visualize 3D Scene (Playback)

LVC

The Blais approach would be KLV XML -> XSLT -> RST XML

{West Ridge Systems jMisb}

{DFDL extract KLV Hex}

Decode KLV (Decimal)

{Harder KLV Java}

{OpenDIS7 Java}

{OpenDIS}

{X3D, Spiders3D}

{Plan, Analyze, Train, Archive}

The top right + lower left blocks might be replaced by DIS Schema with DFDL for KLV, as a general pattern for DIS DFDL parsing of any telemetry track values, leapfrog for future telemetry patterns. End result remains DIS XML in either case.
It works 
Open-Source, Open-Standards Technology Used

• Wireshark
• PCAPNG
• ST 0601.17
• SMPTE ST 336
• Apache Daffodil
• OpenDIS7 Java
• Harder KLV
• West Ridge Systems jMisb

• X3D Graphics
• Xj3D
• XML (Schema, XSLT)
• OpenJDK
• Apache NetBeans IDE
Robodata & RobodataCUI Code Repositories

• Robodata including PCAPNG transformation: https://gitlab.nps.edu/Savage/robodata

• RobodataCUI including KLV transformation: https://gitlab.nps.edu/SavageDefense/robodatadefense
(added) Check Questions

• No prior knowledge of this robot? Standards, bits, go? YES
• Peeling computer-science onion: unlike other flow diagrams, your boxes aren’t programs but rather refined data? YES
• You modified community’s pcap Packet Capture mappings written for Data Format Description Language (DFDL), added next-generation PCAPng support and posted back? YES
• If you can handle this robot, are we ready for any other? YES

The Purpose of Computing is Insight, Not Numbers

Richard W. Hamming
Don Brutzman
Synopsis: Ethical Control of Unmanned Systems

• **Project Motivation**: ethically constrained control of unmanned systems and robot missions by human supervisors and warfighters.

• **Precept**: well-structured mission orders can be syntactically and semantically validated to give human commanders confidence that offboard systems
  - will *do* what they are *told to do*, and further
  - will *not do* what they are *forbidden to do*.

• **Project Goal**: apply Semantic Web ontology to scenario goals and constraints for logical validation that human-approved mission orders for robots are semantically coherent, precise, unambiguous, and without internal contradictions.

• **Long-term Objective**: demonstrate that no technological limitations exist that prevent applying the same kind of ethical constraints on robots and unmanned vehicles that already apply to human beings.

Paraphrase: can qualified robots correctly follow human orders?
Data Strategy for Unmanned Systems

Problem Statement
- **What are you trying to do?** Continuing creation of Data Strategy for Unmanned Systems Field Experimentation, Simulation and Analysis.
- **What is your approach?** A data plus metadata pipeline for any robot mission definition and telemetry has been demonstrated for all technical components. This project will prepare end-to-end exemplars from CRUSER FX and produce a transition plan for mainstream adoption of best practices in NPS experimentation.

Impact
- **What contribution does this work make to your field?** Integrating multiple open-source libraries utilizing multiple open-data standards for comprehensive robot data collection.
- **What is the warfighting impact?** NPS FX is a microcosm matching test range capabilities at Fleet activities. Collaborative connections that are repeatable over time benefit all parties.
- **How will you measure success?** Reuse and adaptation of robot data for live-virtual-constructive (LVC) analysis.

Transition
- **Who cares?** This work directly reflects operational testing TESTDEVOPS and PMS 406 UMAA/RAIL. Multiple NPS collaboration partners include robot developers, armed services, and coalition forces. Mutual support for NPS/USNA research and education keeps all efforts grounded and relevant.
- **What are specific sources of continued support and collaboration?** Multiple candidates identified aligning NPS transformation with all key players, now and longitudinally into the future.

Robodata Workflow: Collection and storage of data enables recording, replay, smoothing and visualization of robot tracks.
We Want All Your Data!

• Huge amounts of data gets collected by CRUSER experimenters
• Huge amounts of data gets saved and ignored, remaining unused
• This is not uncommon

• What if everything was saved, structured, annotated with metadata?
• What if analysis, replay, re-use, Live Virtual Constructive (LVC) were easy?
• What if all student/faculty/partner products were archivable?
• What if best practices influenced DoD and DTIC, all for the better?
NPS Field Experimentation (FX) as DoD Test Range

• JIFX at Camp Roberts quarterly
• New Sea Land Air Military Robotics (SLAMR) by NPS is possible even more frequently
• Connect via TENA infrastructure for Distributed Interactive Simulation (DIS) and NATO C2/SIM repeatability and mashups
• Open or CUI access

• Outcome: NPS “looks like” a DoD Test Range with best practices for TestDevOps
• Consider annual focus on Test + Evaluation with COTF and other testing commands

National Academies' report, November 2021


Where must we all go next

• Massive testing of unmanned hardware + software ability to follow both orders and constraints in physically realistic virtual environments: TestDevOps for learning-improvement cycles.

• **Influence and impact operations**: certify real-world capabilities via field experimentation (FX), confirmed by Big Data analysis, defense test range exercises, wargames and theses.

• Human warfighters and mission commanders (not just engineers) review and approve unmanned systems as... **qualified**.

• New normal will be **human + machine teaming** together; future must mainstream all capabilities in acquisition and deployment.

• **Welcome to the future** – the horizon is here!
Acknowledgements

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• Collaborative design efforts with numerous skilled engineers and scientists is gratefully acknowledged. Further activity is welcome.
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