JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

JARVIS: New Challenge Problems for Software Reverse Engineering

BSidesDC

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evm
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A Future Vision for Software Reverse Engineering

Imagine if Software RE could be faster, more effective and accessible

- You have a tool that produces meaningful, descriptive labels in your disassembly of a completely new binary
- You automatically get a well-labeled software architecture diagram with a description of each module when analyzing a new binary
- People with little or no training can be given an accurate description of a new binary produced by an automated system

Talk Outline

- What problems in software reverse engineering should we consider “solved” ?
- What are the gaps between our solved problems and our existing process?
- What problems should we work on next?
- How do we get started?

My Background – The Embedded Systems RE World

- One “device” – but many boards/processors/firmwares
- Bare metal and RTOS environments
  - Large fully-linked binaries
  - No distinction between OS/libraries/application code
  - No clearly labeled system calls for clues
  - Vulnerability analysis: Takes much longer to get to the entry point
- Dynamic analysis is rarely possible
  - Unreliable JTAG/debugger access
  - Debug fuses
  - Debug BGA balls not pulled out on the motherboard
  - Integrated cores with no physical connection (debugged in development on dev boards)

What problems in software reverse engineering should we consider “solved” ?

Solved Problems?

- Decompilation
- Function-to-function Matching
- *Combined Static & Dynamic Analysis Approaches**

**since dynamic analysis is rarely possible in my world I am not qualified to evaluate the state of the toolsets (which mostly exist in other environments)*

Decompilation

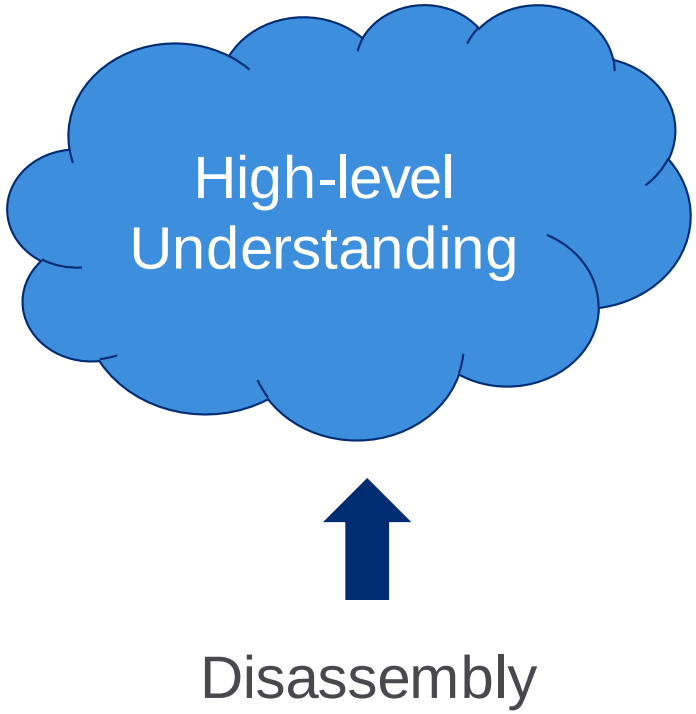
- IDA Pro,[1] GHIDRA,[2] RetDec,[3] Rellic,[4] angr-management,[5] JEB[6]
- Follow process first described by C. Cifuentes in 1994[7]
  - Syntax Analysis
  - Semantic Analysis
  - Intermediate Code Generation
    - SLEIGH/p-code (GHIDRA) [8]
    - Microcode (IDA) [9]
    - Interlude (JEB) [10]
    - LLVM IR (RetDec and Rellic) [3][4]
    - VEX (angr-management) [5]
  - Control Flow Graph Generation
  - Data Flow Analysis
  - Control Flow Analysis
  - Code Generation
- Decompilers always produce blank code!
- Incremental improvements in decompilation will not lead to fundamental changes in the speed & effectiveness of RE

Function Matching

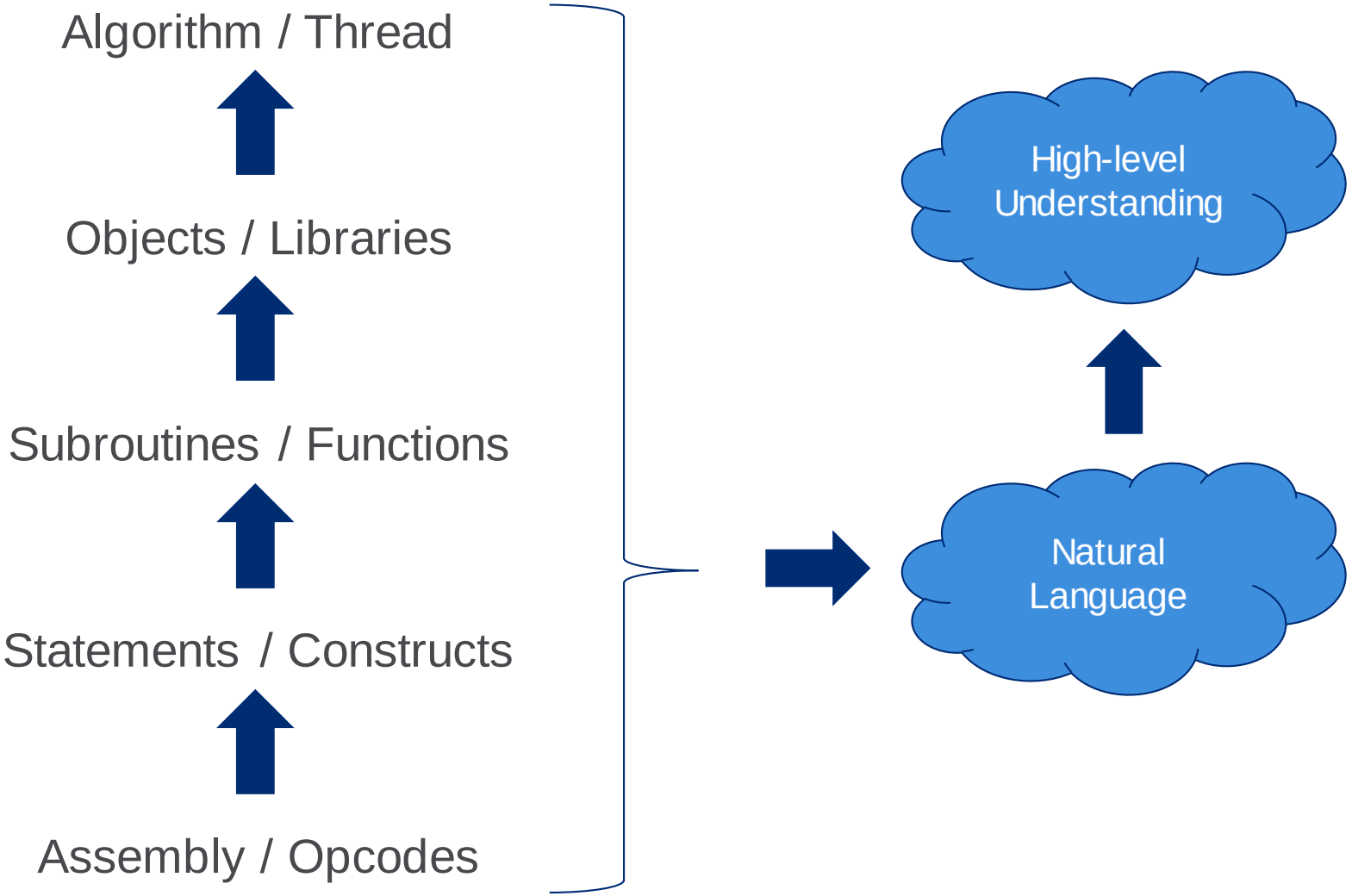
- BinDiff,[11] Diaphora,[12] GHIDRA Version Tracker[13]
- Algorithm
  - Lossy compression function at the basic block level
    - Small primes product [14]
  - Graph-based comparison function for function flow graph
    - MD Index [15][16]
    - KOKA hash [17]
  - Graph-based comparison functions for call graph
- Works fairly well in most situations where library code is pre-identified
- Incremental improvements to function matching will likewise not lead to fundamental changes in the speed & effectiveness of RE

What are the gaps between our solved problems and our existing process?

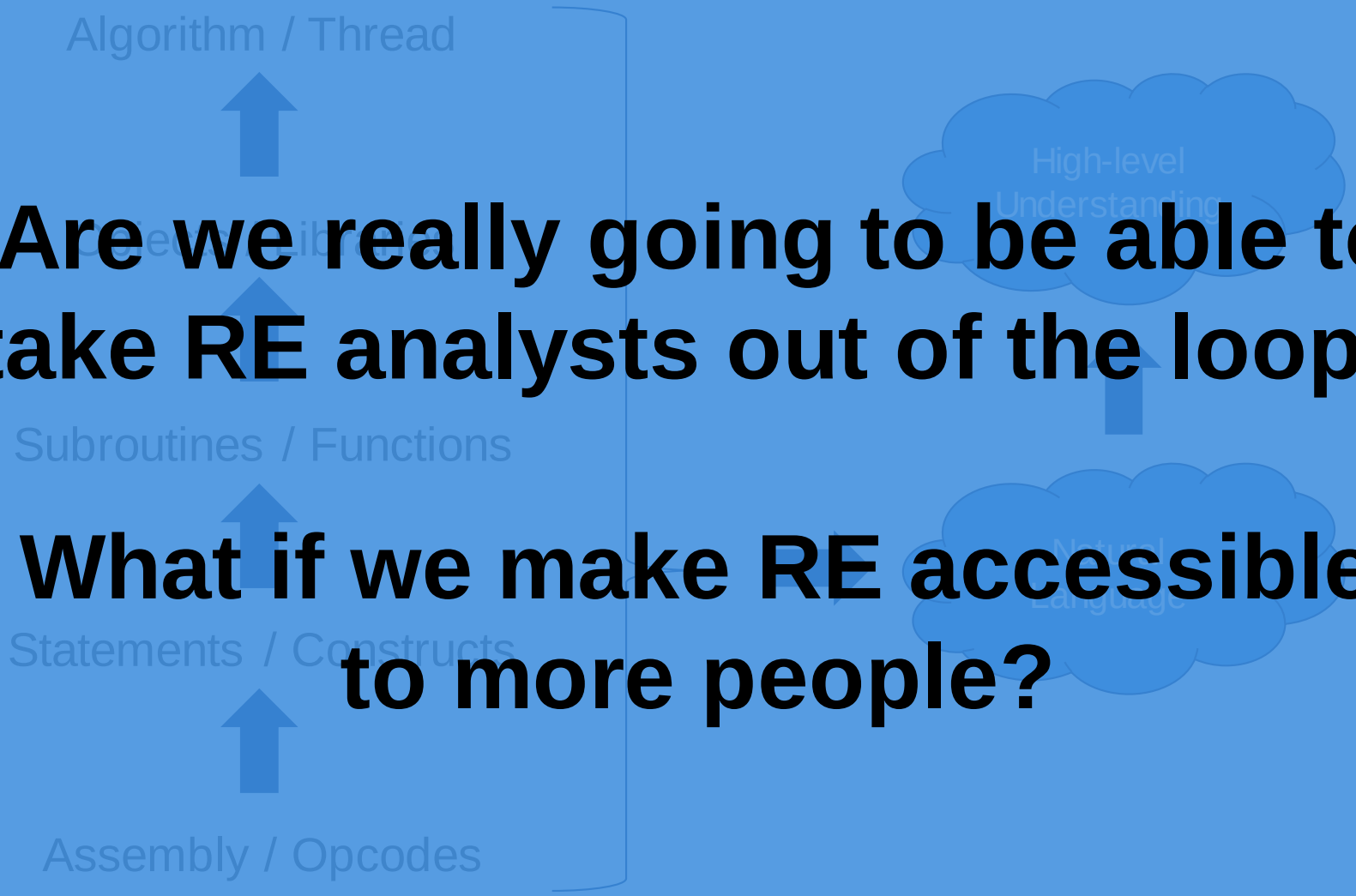
What is Software Reverse Engineering?



Software Reverse Engineering Process



Software Reverse Engineering Process



Are we really going to be able to take RE analysts out of the loop?

What if we make RE accessible to more people?

What kind of problems should we work on next?

What's Next? – Challenge Problems

- **Variable Name Prediction** – Given a blank decompiled function, output meaningful names for the variables in that function
  - Promising research from CMU, ETH Zurich using statistical machine translation (SMT) approach,[18] neural network approach,[19] probabilistic model approach[20]
  - Inspired by work recovering identifiers in obfuscated JavaScript[21]

- **Statement Commenting** – Given a blank decompiled code statement or fragment, output comments in natural language describing it
  - What is this basic block doing?
  - Existing work in code snippet tagging/labeling[22]
  - Feed in context information from function
  - Build on variable name prediction

- **Function Summarization** – Given a blank decompiled function, output comments in natural language summarizing the function
  - Language summarization is a difficult problem due to lack of datasets
  - Existing research in source code summarization[23][24] [25]
  - Needs to be built on variable name prediction, possibly statement commenting?
  - Rely on man page / documentation descriptions?

What's Next? – Challenge Problems

- **Library/Object Organization ("CodeCut")** – Given a fully linked binary with no symbols, locate the boundaries between the original object files – or the boundaries between related sections of code.
  - Preliminary solution using a function affinity metric and a weighted cut graph approach[26]
  - Source code available for IDA Pro[27]

- **Library Summarization** – Given an identified set of related decompiled functions, output a name or labels describing it
  - Extension of function-level summarization work
  - Extension of code snippet tagging work

- **Foundational NLP Work**
  - asm2vec[28]
  - code2vec[29]

How do we get started?

Assembled Labeled Library for Static Analysis Research (ALLSTAR)

- NLP research will require a large (publicly available) database of:
  Open Source Code → Compile Artifacts → Binaries (with Symbols)

- There is a TON of open source code
- There is a TON of firmware out there

- But….there are ZERO debugging symbols

  (ok almost zero)

- And *ideally* it would be cross-architecture…(so we avoid overtraining on x86)

ALLSTAR Build Process

- Uses Debian “jessie” distribution
- Try to remove packages that are documentation, debug, data-only, Python, Java, etc. – leaves over 32,000 packages
- Build for all Debian architectures (x86, amd64, ARM, PPC, MIPS, s390x) using Dockcross (Docker containers with cross compilers)
- Fairly simple technical details:
  - CFLAGS: -g -fdump-final-insns -fdump-tree-gimple
  - CXXFLAGS: -g -fdump-final-insns -fdump-tree-gimple -fdump-class-hierarchy
  - DEB_BUILD_OPTIONS: nostrip debug
  - Build with ‘debuild’ setting architecture
- Takes 5 to 6 weeks (?) to build, 35-55 packages per hour

ALLSTAR Stats*

- 1.1 TB total storage
- Binaries:

- i386, MIPS and PPC numbers reflect Debian packages that properly conform to cross-arch build spec
- ARM and s390x lower due to Dockcross' cross compiler (uses a sysroot)
- ~20K cross-platform binaries is still a nice dataset

*projected, build currently in process

Debian vs. Github

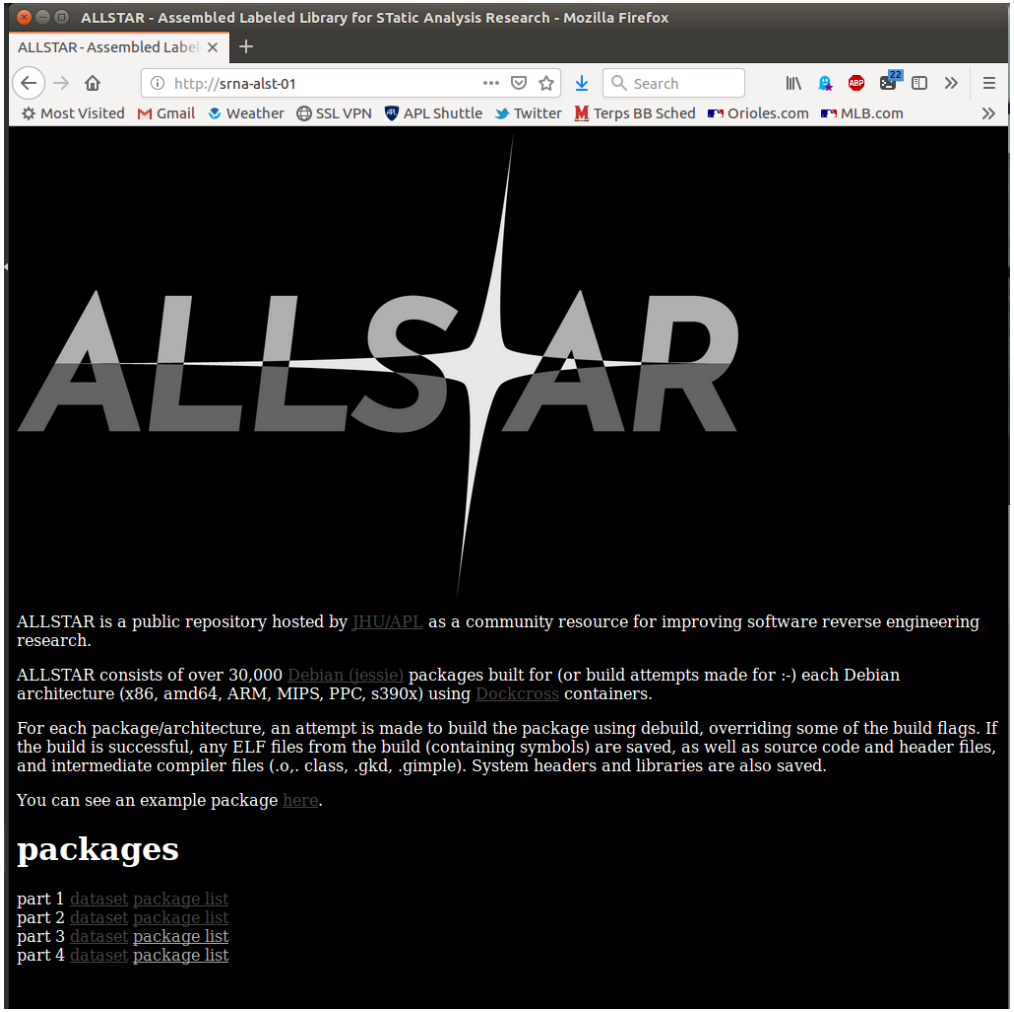
~32K packages (mostly C/C++)	~400K packages in C [18]
Structured build process (debuild)	Build by trying “configure” and “make”
Packages build cross-architecture (theoretically, if they follow spec)	Less likely to build for non-amd64
Less duplication	More duplication (up to 70%![30])
GPL or similar open licensing	Licensing unclear / non-obvious
More serious/polished code?	A bit more random code?

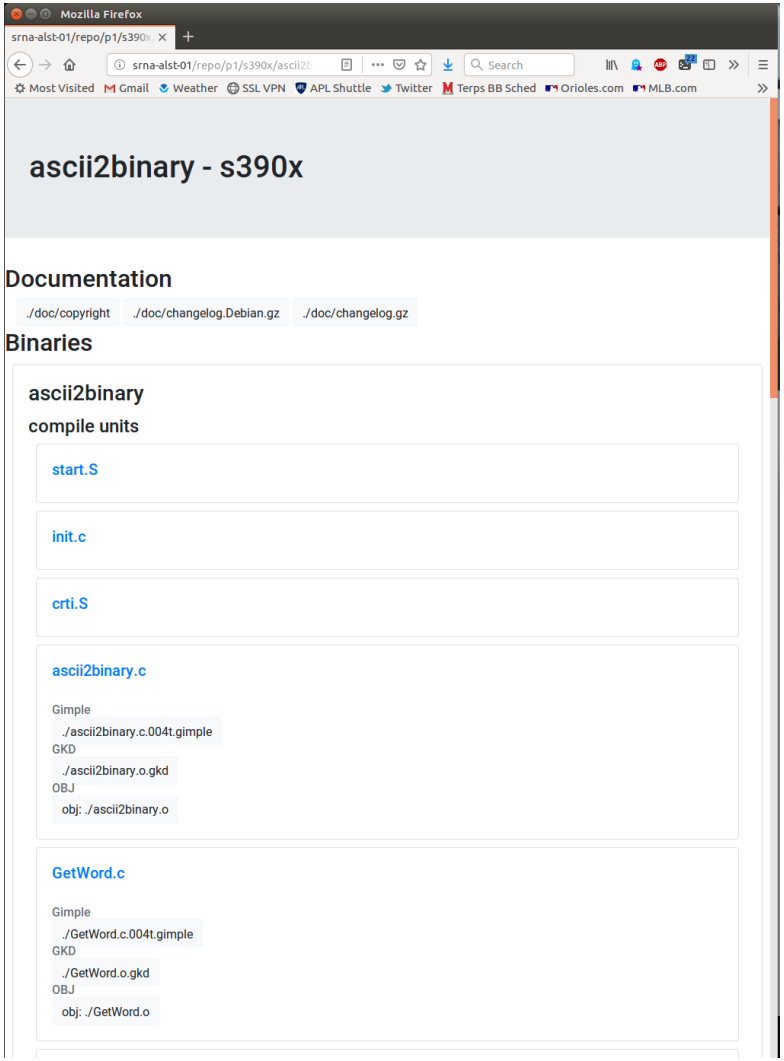
What's in ALLSTAR? A Single Data Record

- Binary (fully linked ELF, either runnable or .so)
  - Source file
    - Header files
    - GIMPLE file (like an abstract syntax tree)
    - .class file (if C++)
    - gkd file (final internal representation in RTL)
    - Object file
  - Man page
  - Symbols (in binary) – can be used to produce a .map file
  - Any system library dependencies

- Package Documentation
- HTML index for browsing
- JSON index for code parsing

ALLSTAR – Browser Interface





Building on ALLSTAR

- Open source / publish by end of 2019
- 2 internal research projects for FY20 planned
- Hope to see a lot of research building on ALLSTAR in the future

JOHNS HOPKINS

APPLIED PHYSICS LABORATORY

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Questions?

evm

@evm_sec

evm.ftw@gmail.com

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