

Avionics Compositional System of Systems Simulation and Modeling Tool Chain ASSIST

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Tool Expo for Model Based Embedded Systems Development

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PHYSICAL OPTICS CORPORATION BACKGROUND

- **Founded in 1985**
- **Small Business, Employee Owned**
- **Financially Strong & Profitable every year**
- **270 employees – 30 Ph.D.s, 112 Engineers**
- **Revenue – Over \$115M (2019)**
- **117,344 sq. ft. facilities, 4 buildings**
- **2020 Expansion – Additional 53,700 sq.ft., 2 buildings**
- **Over 160 issued patents – 60 technologies**
- **Strategic Advisory Board**



POC AREAS OF FOCUS

Airborne



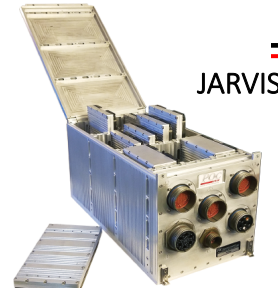
DTU
Data Transfer Unit



HDVR
High Definition Data & Video Recorder

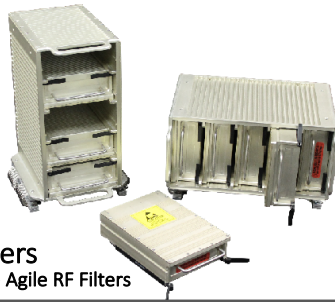


MLS - NAS
Network Attached Storage



JARVIS
Mission Computer - Distributed & Reconfigurable

RF/EW



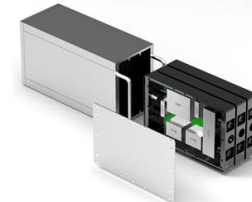
RF Filters
High Power Tunable Agile RF Filters



WISDEM
Wideband Intelligent Spectrum

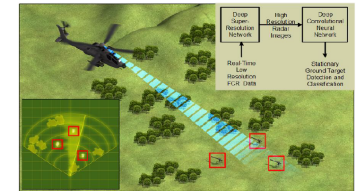


PALM
Predistortion Amplifier



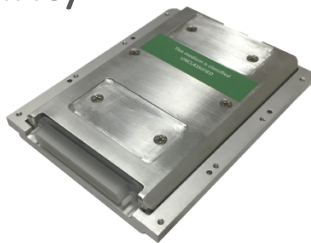
A2D
Interference Canceller

AI/Deep Learning



DEESTAC

Cyber Security

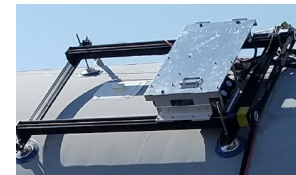


Encryption
Data - at - Rest

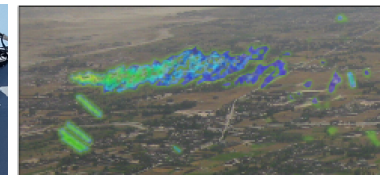


Encrypted Data

Sensor/Scanner



X-Ray
Non Destructive Corrosion Inspection



Data Fusion

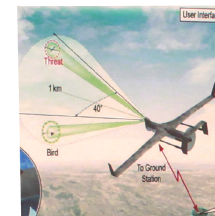
Emerging Technology



ORFOM
Orbital Fiber Optic Production Module



DREAM
Digital RF Countermeasure



ARGUS
Unmanned Surveillance

PROBLEM STATEMENT AND SOLUTION APPROACH

- ***Use of Multicore Processors in Avionics***

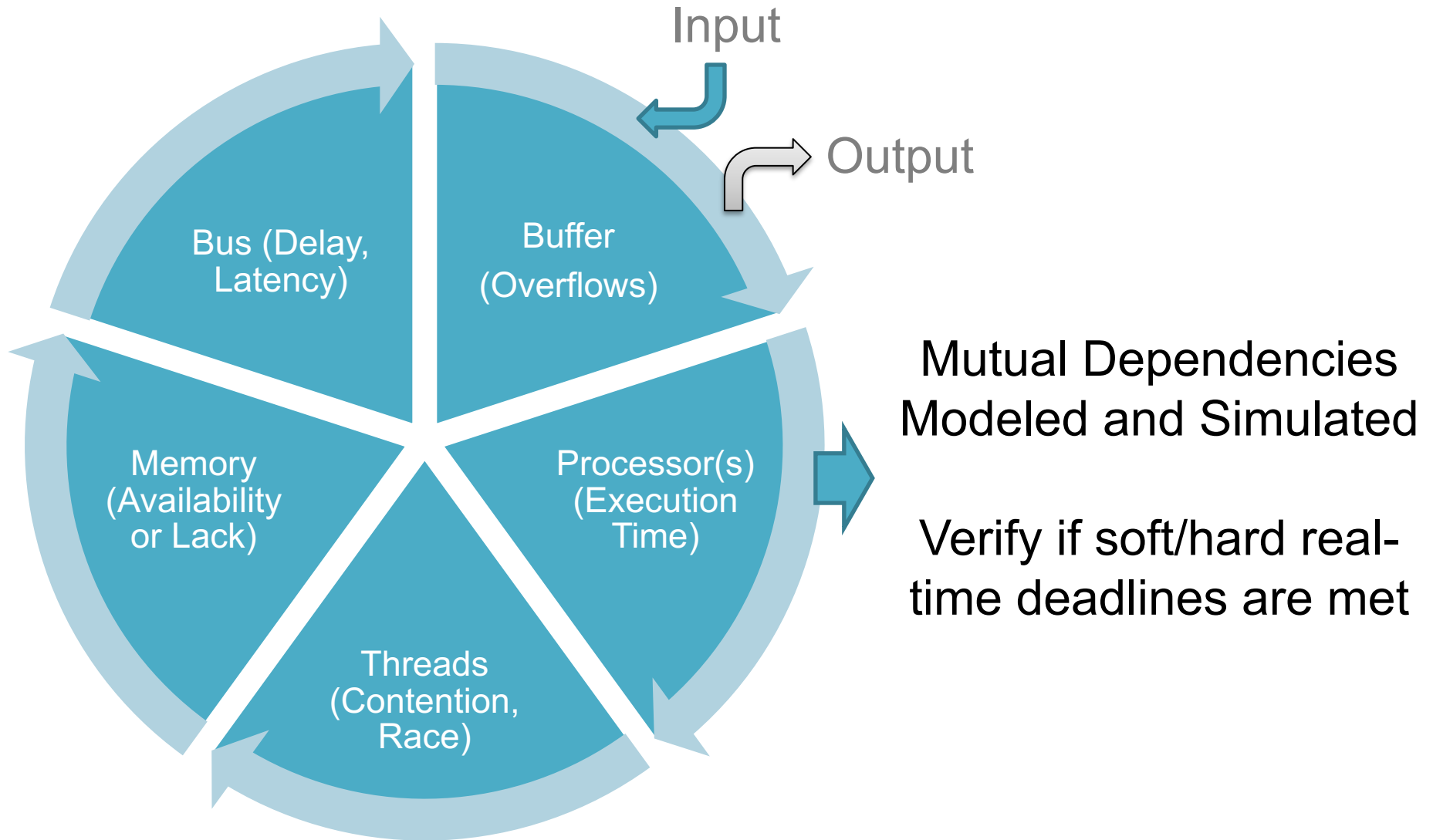
- *Difficult due to inability to verify performance during requirements, design and implementation stages*
- *Analysis of hard real-time and soft real-time requirements needed*

- ***Solution Approach***

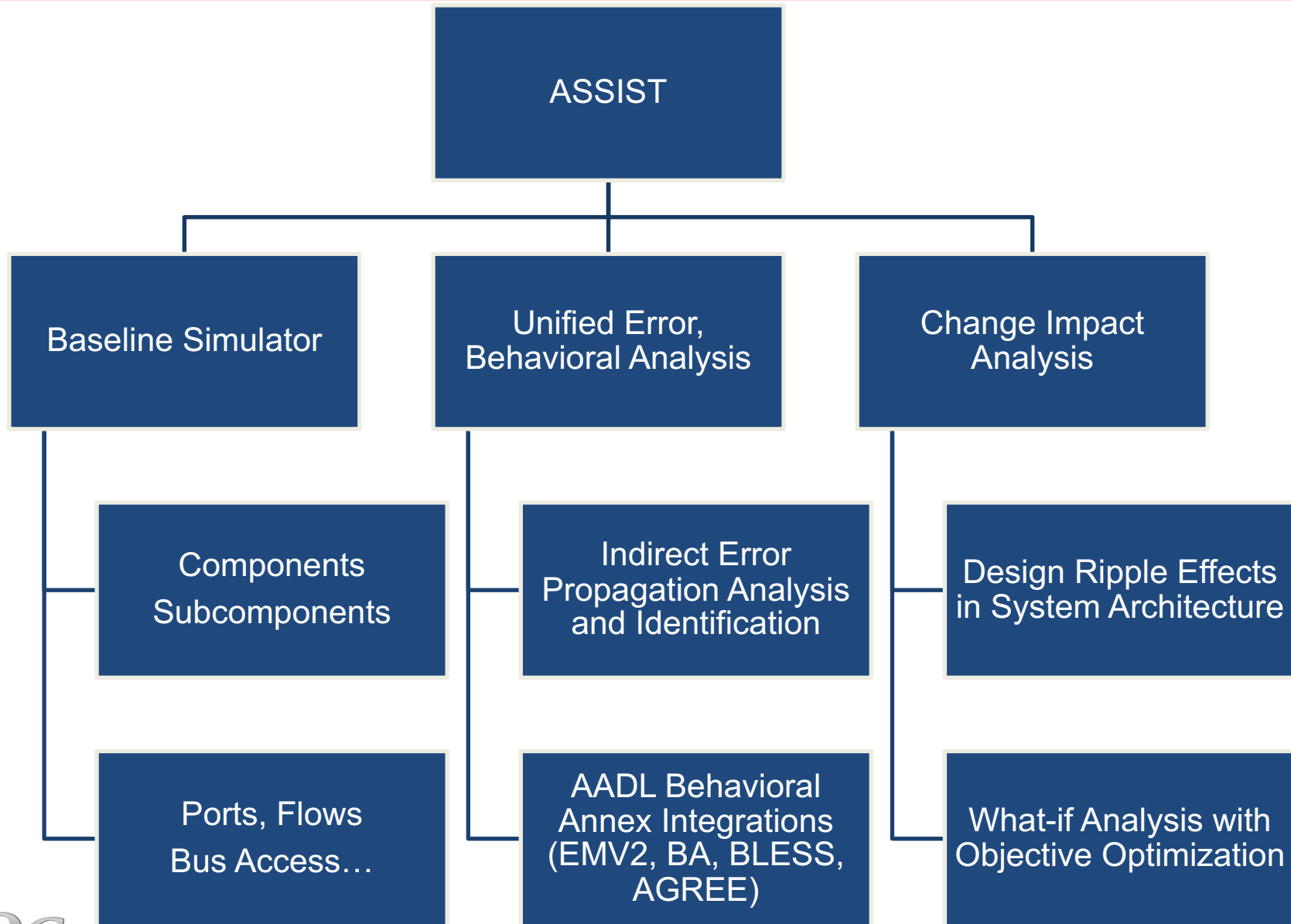
- *Rigorous specification of requirements and design using Architecture Analysis & Design Language (AADL)*
- *Input data*
 - *System design and specification in terms of AADL components*
 - *Avionics system configuration using AADL specifications*
- *Output*
 - *Model parameters from AADL specifications*
 - *Data analysis results*
 - *Positive match between specifications and designed system*
 - *Specification violations/contradictions in designed system and deficiencies*
- *Use of simulation and virtual integration to verify requirements and design*

Avionics Compositional System of Systems Simulation and Modeling Tool Chain (ASSIST)

GOAL: ANALYZE DEPENDENCIES AMONG COMPONENTS



ASSIST FEATURES



AADL COMPONENT MODELING FUNCTIONALITY

- **AADL Software Components**
 - *Thread, Process: models subprogram execution*
 - *Data: models data access latency*
 - *Subprogram: statistical model of code execution and data access times*
- **AADL Hardware Components**
 - *Processor*
 - *Scheduler: models thread preemption using priority queue*
 - *Memory: models context switching and latencies caused by cache misses*
 - *Device: models sensor and communication components*
 - *Bus: data exchange mechanism between components*
- **AADL Properties**
 - *Timing (Compute execution time, deadline), memory access*
- **Component Connections**
 - *Control, data flows*
 - *Connection features*
 - *In/Out/both, direction, ports, (a)synchronous*

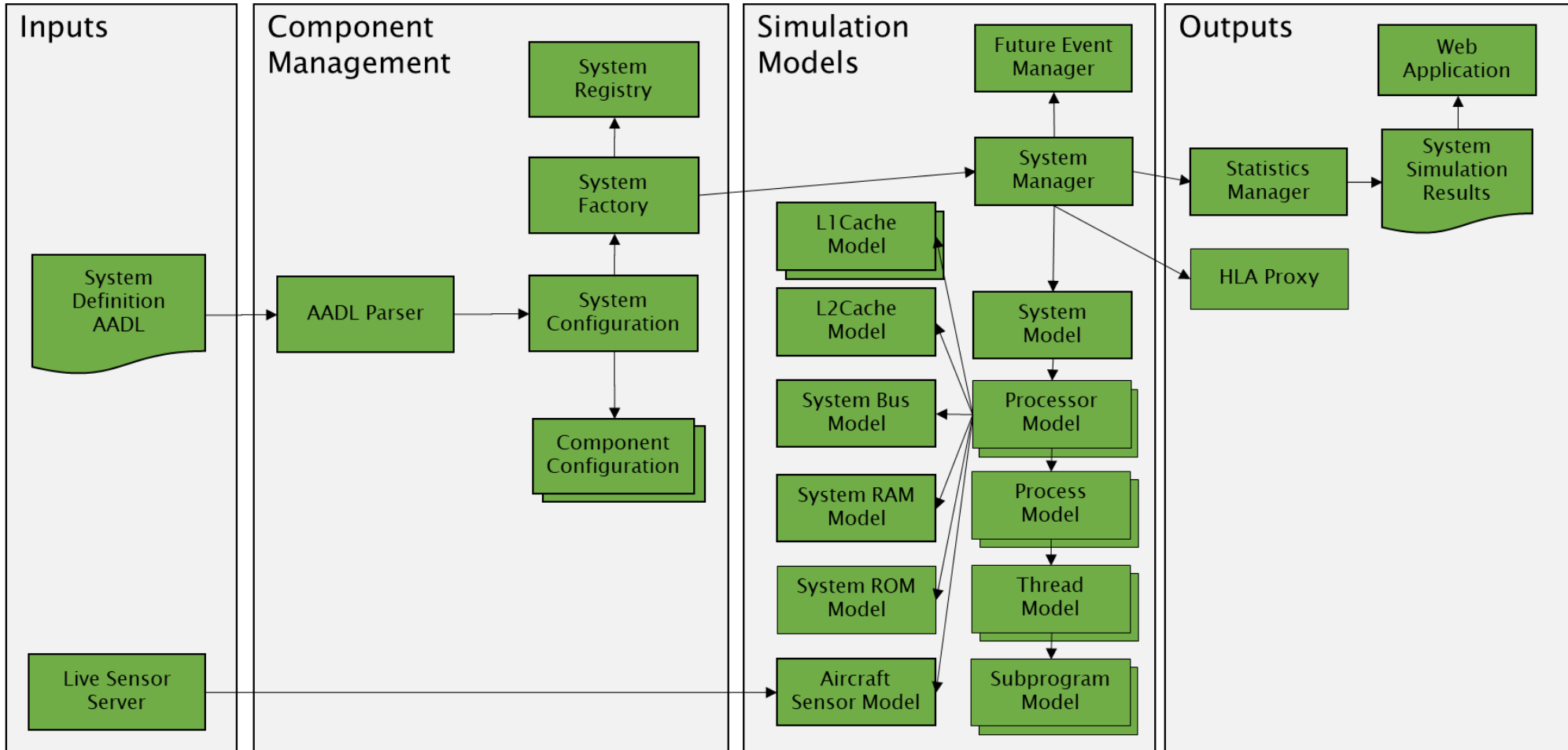
SUPPORTED AADL FEATURES

- **Package specification**
 - *Annex libraries not processed*
- **Import declaration**
- **Component Types**
 - *Software Category: Subprogram, Thread, Process*
 - *Execution Category: Memory, Processor, Bus, Device*
 - *Composite Category: System*
 - *Features*
 - *Flows*
 - *Properties*
 - *Extends*
- **Component Implementations**
 - *Subcomponents*
 - *Calls*
 - *Connections*
 - *Flows*
 - *Properties*
- **Subcomponents**
 - *Array dimensions*
 - *Refined to*
 - *Port support only*
- **Features**
 - *Direction: in, out, in out*
 - *Ports: event, data, event data*
 - *Requires*
 - *Provides*
- **Subprograms**
 - *Call sequence*
 - *Execution time*
- **Bus access connections**
- **Flow specifications**
 - *Types: source, sink, path*
- **End-to-End Flow specifications**
- **Property Sets**
- **Property Types**
 - *Basic data types, Reference, Record*

SOLUTION

- ***Avionics Compositional System of Systems Simulation and Modeling Tool Chain (ASSIST)***
- ***Analysis of hard real-time and soft real-time requirements***
 - *Aviation system of systems simulation using representative use case*
 - *Generating configuration for simulation*
 - *Verification of system against architecture model defined in AADL*
- ***Approach***
 - *Discrete event simulation of an SoS with multi-core processors*
 - *Input data: AADL specifications, external data sources*
 - *Output*
 - *SoS model characterized by parameters from AADL specifications*
 - *Data analysis results*
 - *Positive matches between specifications and designed system features*
 - *Specification violations/contradictions in designed system and deficiencies*

ASSIST HIGH LEVEL ARCHITECTURE



MULTICORE PROCESSORS IN AVIONICS

- ***ASSIST design motivated by Multicore Processor Analysis***
 - *Federal Aviation Administration Study - Assurance of Multicore Processors in Airborne Systems*
<http://www.tc.faa.gov/its/worldpac/techrpt/tc16-51.pdf>
- ***Statistics recommended by FAA and collected by ASSIST:***
 - *Core utilization (% utilized averaged over ms)*
 - *Processing time per sensor message*
 - *Processing time per thread*
 - *Cache miss (+hit) counts and miss (+hit) rates/ms*
 - *Thread execution details:*
 - *Assigned processor*
 - *State transitions (running, executing, waiting on resource, idle)*
 - *Deadline violations*
 - *Flow rates per message*

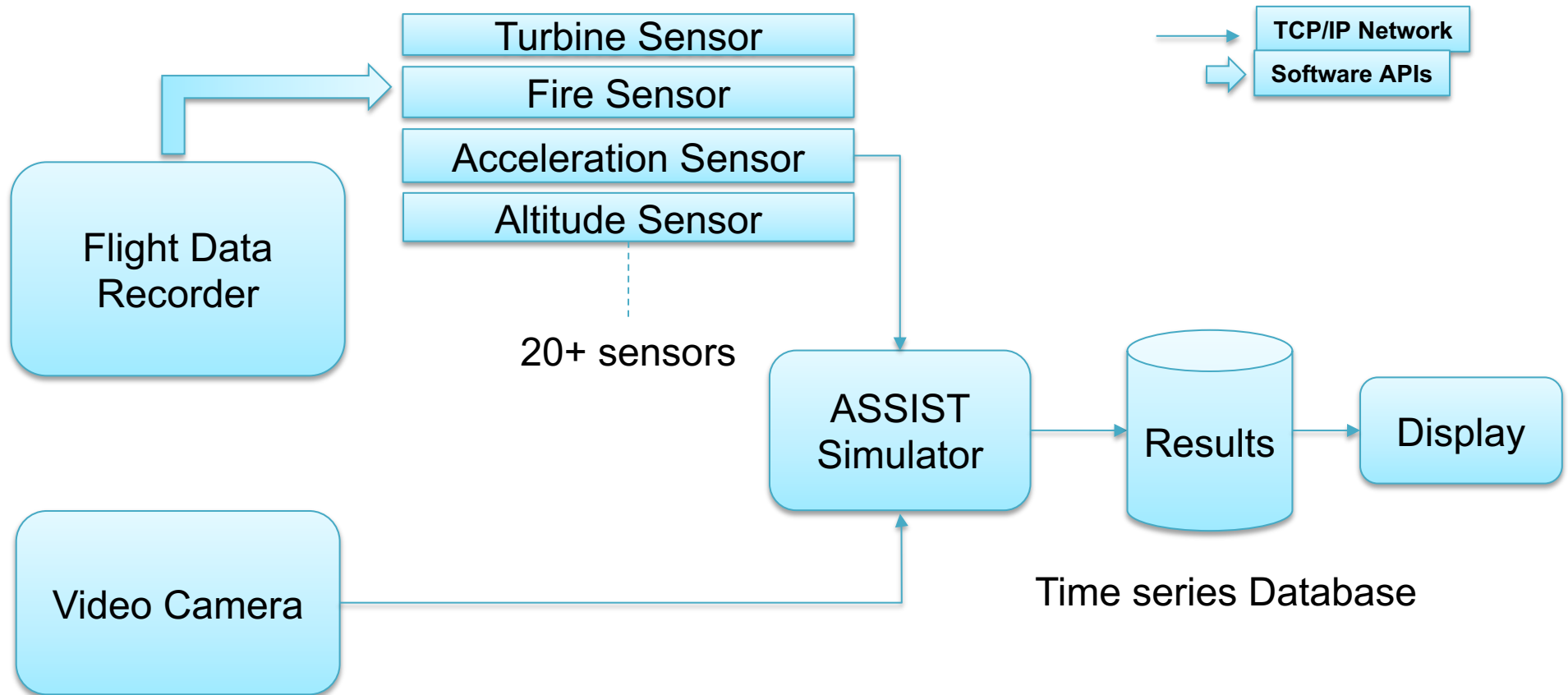
DEMONSTRATION SCENARIO (AADL MEETING OCT 2019, WASHINGTON DC)

- ***Virtual Integration via ASSIST Simulation featuring Hardware In the Loop (HWIL)***
- ***Hardware: POC's flight data recorder***
 - *Current input sensors: turbine, fire, acceleration, altitude*
 - *(Modified) system design includes:*
 - *Multi-Core CPU, RAM, Caches, Bus*
 - *An additional video sensor (live feed)*
- ***Software: Data processing framework***
 - *Threads, processes, subprograms to record data from sensors*
- ***Scenario #1:***
 - *Flight Data Recorder (FDR) simulation using a **dual** core system*
 - *Simulate feeds from sensors (timing, message-size, order of message arrival modeled)*
 - *Additional messages from video: data-size, timing*
- ***Scenario #2***
 - *Perform joint FDR+video simulation using a **quad** core system*

CHALLENGES IN SYSTEM IMPLEMENTATION

- ***Mismatch in simulation rate and data-arrival rate***
 - *Require tradeoff between simulation times and modeling fidelity*
- ***Running multiple simulations simultaneously not possible on a dedicated laptop***
- ***Modeling large systems will require platforms with high computational capabilities***
- ***Ease of software distribution among stakeholders for evaluation during Capstone event***
- ***Computing Approach Scalable with Size and Complexity of Simulations Is Needed***

DEMONSTRATION SETUP



DEMONSTRATION RESULTS

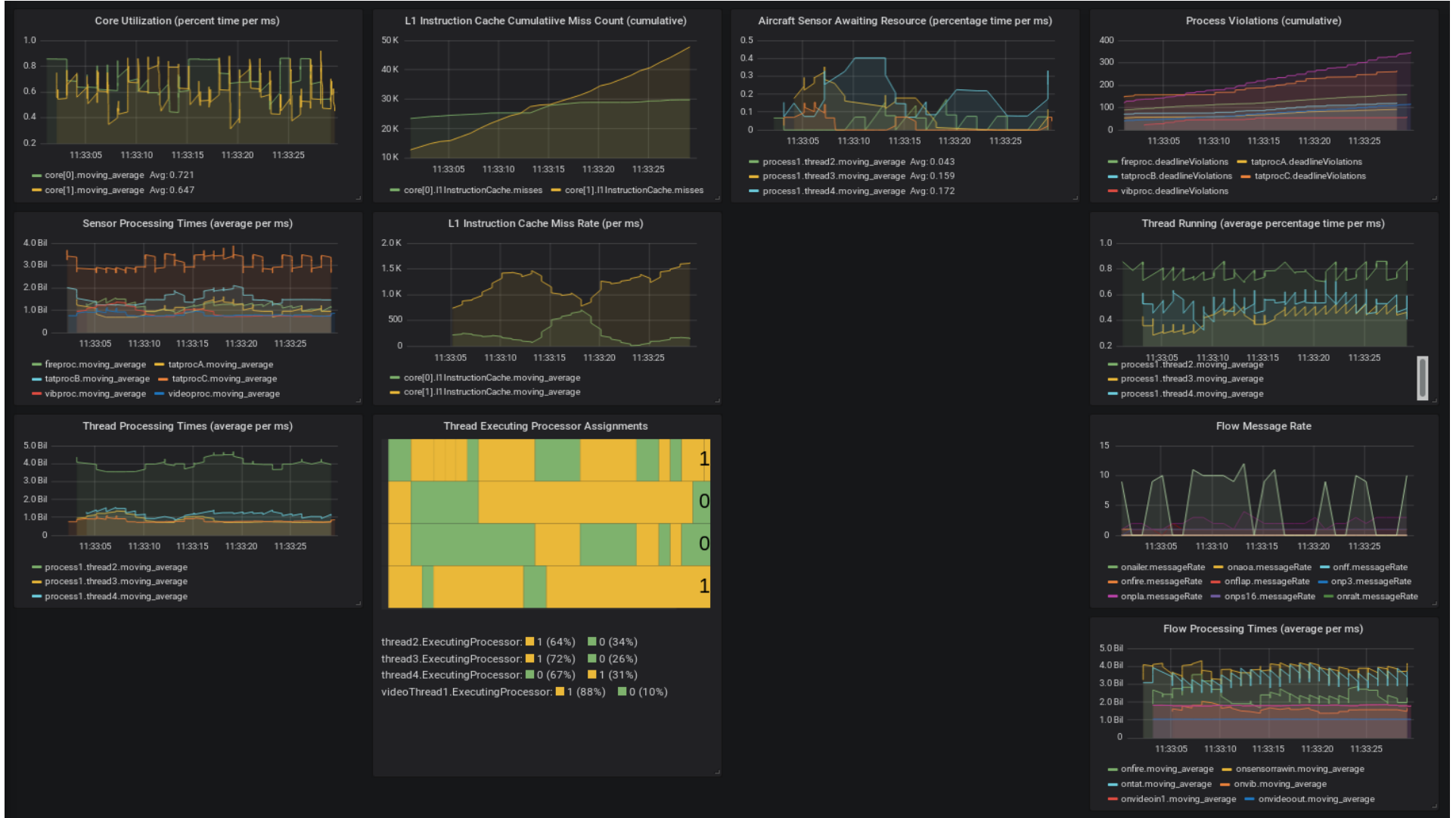
- **Dual Core:**

- *Without video camera: no violations, normal/expected operating behavior*
- *Adding a video camera:*
 - *CPUs are unable to process additional data.*
 - *Limited computation capabilities result in deadline violations and increased processing time for all critical sensor tasks.*

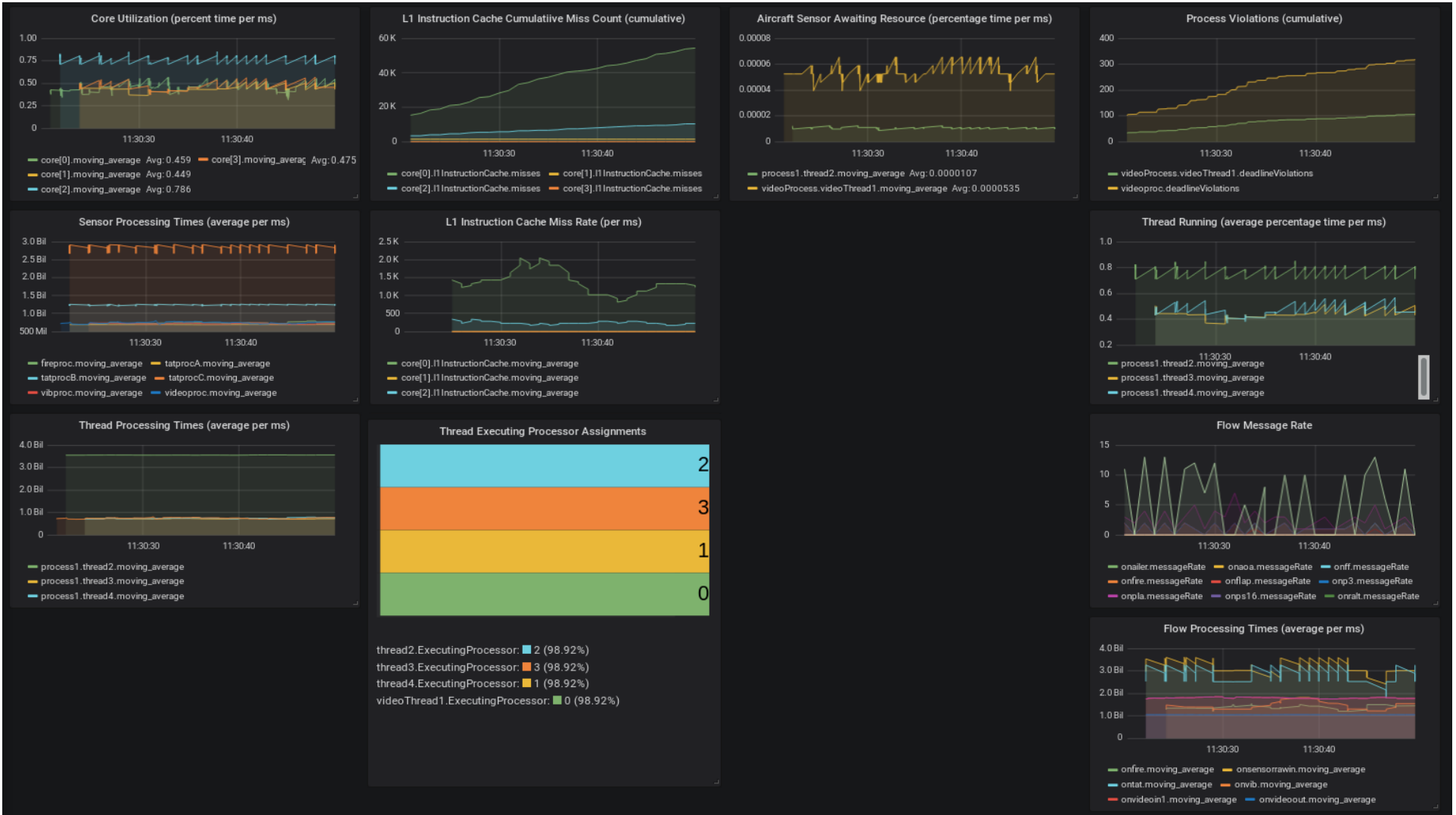
- **Quad Core:**

- *Without video camera: no violations, normal/expected operating behavior*
- *Adding a video camera:*
 - *Data rate is still too high for any single CPU to handle*
 - **However**, *additional cores are available so the critical sensor processing tasks are not affected*

RESULTS – DUAL CORE



RESULTS – QUAD CORE

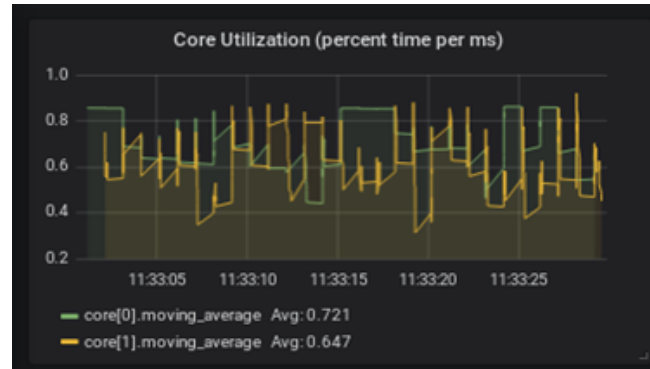


COMPARATIVE ANALYSIS

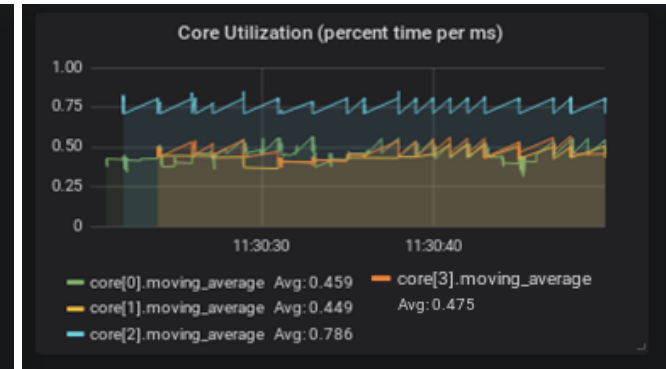
Processor Core Utilization

- Dual Core: 72% / 64%
- Quad Core: 45% / 44% / 78% / 47% (additional headroom) ✓

Dual Core

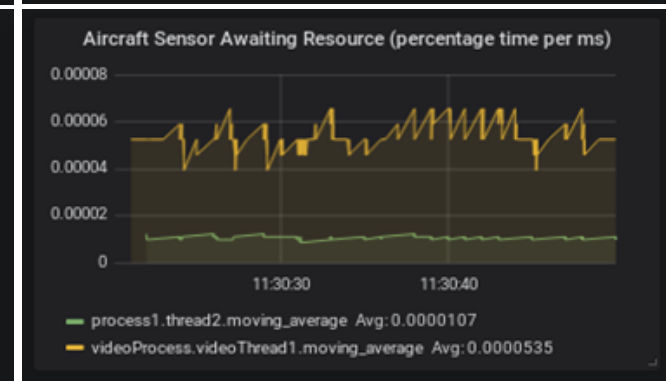
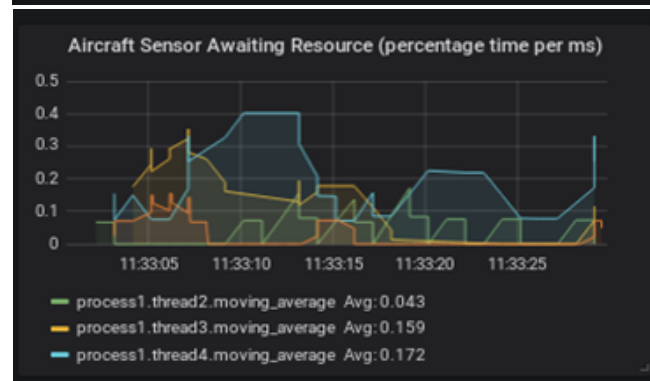


Quad Core



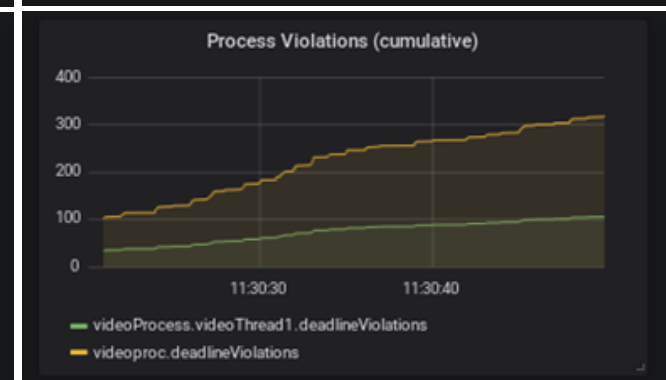
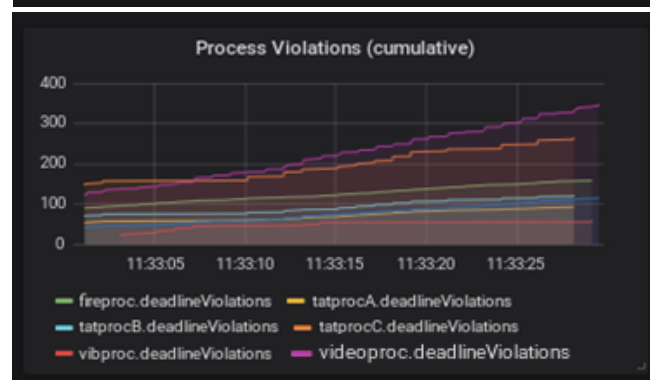
Thread Preemption Latency

- Dual Core: ~15-20 instances preemption exceeds 10%
- Quad Core: 0 instances preemption exceeds 10% ✓



Processing Deadline Violations

- Dual Core: 4 critical threads 100's violations
- Quad Core: only non-critical video thread ✓



NEXT STEPS

- **ARINC 653**
 - *Virtual Processor Partitioning*
- **Additional Summary Statistics**
- **AADL Features**
 - *Parameters*
 - *Access to peripherals*
 - *Programming languages*
- **GUI Improvements**
 - *Improve interface to add files and simulate. Most of the technical work is done – just need to clean it up.*
 - *Improve GUI for comparing and contrasting variations in SoS AADL models*
- **Cloud Infrastructure – deploy as cluster on Amazon**
 - *Currently working on deploying on Kubernetes*